

Glacier National Park: Restoration Monitoring Report

2015

By: Jennifer Asebrook and Jennifer Hintz

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I. INTRODUCTION

The Revegetation Monitoring Program, established in 1991, is designed to provide a systematic framework for describing a site prior to disturbance and for monitoring the success of seeded and planted species after revegetation. The goals of the monitoring program (Kurth and Potter, 1991) are to:

- (1) Develop revegetation techniques based on collected information;
- (2) Set feasible expected levels of success for revegetation and set reasonable time frames in which to expect those levels;
- (3) Establish appropriate site-specific goals for projects;
- (4) Determine the degree to which a project meets predetermined goals or expected levels of success;
- (5) Determine cause and effect relationships from revegetation treatments;
- (6) Determine spatial requirements for specific environments;
- (7) Identify sensitive areas where impacts must be avoided because revegetation is too costly or impossible;
- (8) Identify needs and methods for remedial work at a site; and
- (9) Reduce time and money spent on revegetation.

Based on these goals, four levels of monitoring have been established to document the success of revegetation projects. These levels range from a simple, quick assessment of a site (Level I) to complex experiments that test revegetation techniques (Level IV). Table 1 summarizes the main variables that are monitored within each level.

Table 1. Levels of Monitoring

Monitoring Level	Variables monitored
Level I	• soil erosion • estimated canopy cover of (1) mature, pole, sapling, and seedling trees; (2) tall, medium, and low shrubs; (3) native and exotic grasses; and (4) native and exotic forbs • ground cover description (% soil, rock, gravel, litter, moss/lichen, wood, and basal vegetation) • disturbance history • evidence of animal use
Level II	• data from Level I • species list of at least the dominant native and exotic species and their respective canopy covers • description of planted and seeded material (estimated density, mean height, phenology, vigor)
Level III	• data from Level II • permanent transects and microplots established to monitor the number of species, and their respective canopy covers, densities, and mean heights • permanent circular plots established to monitor height, width, vigor and damage of planted shrubs and trees
Level IV	• experiment using replicate and control plots to evaluate revegetation techniques

In addition, a site analysis procedure has been designed to collect information on revegetation sites prior to disturbance. Site analysis data includes information on:

- Parent material (weathered mineral or organic material from which the soil develops)
- Slope shape and aspect;
- Soil surface status and soil texture analysis
- Ground cover description (% soil, rock, gravel, litter, moss/lichen, down wood and basal vegetation)
- Estimated canopy cover of (1) mature, pole, sapling, and seedling trees; (2) tall, medium, and low shrubs; (3) native and exotic grasses; and (4) native and exotic forbs
- Species list of at least the dominant exotic and native species and their respective canopy covers
- Evidence of animal use
- Disturbance history
- List of species or cultural resources of special concern

- Recommendations for revegetation (target plant community, site preparation, use of plant or soil salvage, use restrictions and safety considerations)

Revegetation areas are listed in Table 2. The monitoring report for the appropriate year should be referenced for further information.

Table 2. Monitoring projects to date

LOCATION	Monitoring Level	Monitoring Dates
303-B: Lake McDonald segment of GTSR	Level III	1992, 1993, 1994, 1996, 2001, 2011
303-B Road shoulders	Level II	1993, 1994, 1995, 1998
303-C: St. Mary segment of GTSR	Level II	1993, 1994, 1995, 1998, 2003, 2013
303-C Road shoulders	Level II	1994, 1995, 1998, 2003
Two Dog Flats	Level IV	1993, 1995, 1997, 2002
303-D: Rising Sun segment of GTSR	Site Analysis, Level IV	1993-1997, 1999, 2004, 2005, 2015
303-D: Road shoulders	Level II	1996, 1997
303-E: Logan Pass and Oberlin Bend	Site Analysis, Level IV	1993, 1996, 1997, 1998, 1999, 2001, 2006, 2011
303-E: Logan Pass Seeding/ Planting Plots	Site Analysis, Level IV	1997, 1998, 1999, 2000, 2008
303-F: McDonald Creek segment of GTSR	Site Analysis, Level II	1994, 2000, 2001, 2002, 2009
303-F: Avalanche Campground & Picnic Area	Site Analysis	1995, 1996
Phase VI: West Tunnel to Haystack section of GTSR	Site Analysis, Level II	2007, 2010, 2011, 2012, 2013, 2015
Phase VII: Avalanche to West Tunnel section of GTSR	Site Analysis	2004, 2010, 2013, 2014
Phase VIII: Big Bend to Logan Pass section of GTSR	Site Analysis	2010
Phase IX: Haystack to Big Bend section of GTSR	Site Analysis	2010
Phase XI: Logan Pass to Siyeh Bend section of GTSR	Site Analysis, Level II	2010, 2013, 2014
Phase XII: Siyeh Bend to Rising Sun section of GTSR	Site Analysis	2010
Apgar Transit Center	Site Analysis, Levels II & IV	2006, 2007, 2008, 2009, 2010, 2012
Bowman Creek Campground	Level II	1993, 1998
Camas Road - Revegetation	Site Analysis, Level II	1995, 2000, 2002, 2003, 2008
Camas Road - Hydromulch	Level II	2004, 2005, 2007, 2009, 2014
Granite Park Chalet	Site Analysis	1994
Grinnell Point Picnic Area	Site Analysis	2010
Herbicide / Revegetation Experimental Plots	Level IV	2008, 2009, 2010, 2012
Hidden Lake Social Trails	Level II	2003, 2005, 2010
Lake McDonald Lodge dorm site	Site Analysis, Level II	2007, 2009, 2010, 2011, 2014
Logan Pass Comfort Station	Level II	1993
Polebridge Bridge	Level II	1993, 1998
Polebridge Ranger Station	Level II	1993, 1998
River Campground	Level II	1993, 1998
Sperry Chalet	Site Analysis	1996
St. Mary housing area	Level II	1993
St. Mary Visitor Center	Site Analysis, Level II	2006, 2010, 2011, 2013, 2015
Swiftcurrent Apartments	Level II	1993
Three Bears Lake	Level II	1993, 2000
Two Medicine housing area	Site Analysis	1994
West Glacier Bike Path	Level II	2005, 2007, 2009, 2014
West Glacier Entrance Station	Level II	2009, 2010, 2011, 2013

The objectives of this report are to document the results of the 2015 season. The report includes: (1) data from four revegetation projects (303-D, St. Mary Visitor Center, and Phases VI and XII of the GTSR reconstruction); (2) results from whitebark and limber pine restoration projects; (3) results from whitebark and limber pine plus tree monitoring; and (4) overall recommendations for the monitoring program, including a schedule for future monitoring. All road projects are based on and are evaluated against the following revegetation goals and objectives (Lange, 1988; Lapp, 1994):

Overall goal: Within 5 years following construction, a vegetative cover of native plants will be established that will potentially blend with the adjacent plant communities, is ecologically compatible with the surrounding community, and is consistent with maintenance and safety requirements. Within 20 years following construction, the color and structure of the vegetation will blend into the adjacent plant community and diversity of native species will resemble the plant community prior to disturbance.

- Objectives:
- (1) Preserve genetic integrity of native floral populations.
 - (2) Provide for optimum survival of plant material by using species collected at or near the disturbed site.
 - (3) Quickly provide plant cover to stabilize soil and prevent erosion.
 - (4) Keep coverage of exotic plants low in cut and fill slopes, and prevent invasion into undisturbed vegetation.
 - (5) Restore aesthetic value of vegetation within disturbed area that blends in with adjacent undisturbed plant communities.
 - (6) Use roadside vegetation that will not be a long-term food attraction to wildlife.
 - (7) Select appropriate vegetation for cut slopes, ditches, and a turf shoulder that is low maintenance, durable, safe, and able to stand up under heavy visitor foot and automobile traffic.
 - (8) Provide opportunity for research and technology transfer.

II. 303-D: RISING SUN SEGMENT OF GOING-TO-THE-SUN ROAD

A. BACKGROUND AND PURPOSE

Road reconstruction on the 303-D section of the Going-to-the-Sun Road (GTSR) occurred during the summer and fall of 1994. Initial revegetation of the road slopes, including seeding grasses and forbs and planting woody material, was conducted in October of 1994 on landtypes 26-C (mixed conifer/aspen; silt loam soil) and 26-L-S (steeper slopes of mixed conifer/aspen; clay loam soil). Additional planting of woody material continued during the spring and fall of 1995 and spring of 1996. Road shoulders were seeded and hydromulched in the fall of 1995.

Monitoring of 303-D from 1995 to 1997 had three objectives. In addition to assessing the success of revegetation, a second monitoring goal was to also examine the benefit of fertilizers on both seeded herbaceous material and planted woody material that had not previously been documented for roadside revegetation projects in the park. A Level IV experiment was designed for 303-D to meet the following objectives: (1) to determine if broadcasting 3-15-0 NuLife raw bone meal as a root growth stimulant, not historically used in revegetation projects, increases the germination, survival, and growth of seeded grasses and forbs; (2) to determine if 13-13-13 Osmocote fertilizer, historically used in revegetation projects, is necessary for the survival and growth of planted trees and shrubs; and (3) to document the canopy cover (%) of seeded/planted species, other native species that naturally regenerate, and exotic plants. Results of these experiments can be found in Revegetation Monitoring Reports from 1995 to 1997 (Asebrook et. al., 1995; Asebrook et. al., 1996; Asebrook and Lamb, 1997)

Monitoring of 303-D from 1999 to 2005 focused on vegetation change over time and the survival and growth of planted woody material independent of treatment. Monitoring objectives for 303-D during this time included: (1) documenting the canopy cover (%) of seeded/planted species, other native species that naturally regenerate, and exotic plants overall and by landtype; (2) documenting the density (#/m²) of seeded species overall and by landtype; (3) assessing the survival and growth of planted trees and shrubs overall and by landtype; and (4) determining if specific goals and objectives (Table 3) for 303-D were met. These monitoring results can be found in Revegetation Monitoring Reports from 1999 and 2005 (Asebrook and Brenneman, 1999; Asebrook et. al., 2005).

As logistics of the woody plant material study became too numerous, that portion of the monitoring protocol was discontinued after 2005. Current monitoring objectives for 2015 include: (1) documenting the canopy cover (%) of seeded/planted species, other native species that naturally regenerate, and exotic plants overall and by landtype; and (2) determining if specific twenty-year goals and objectives (Table 3) for 303-D were met.

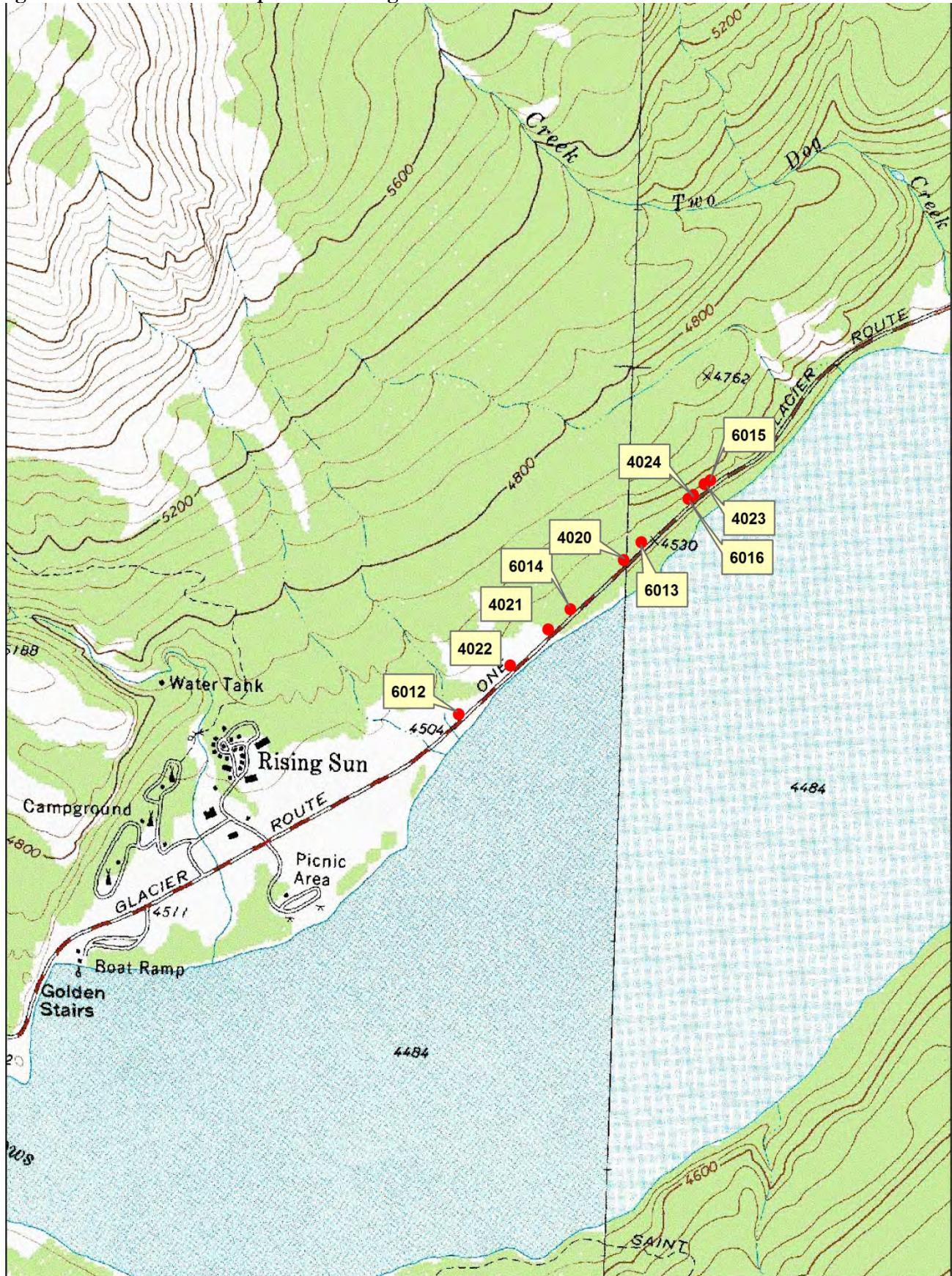
Roadside plant community prior to disturbance: From site analysis data collected in 1993, a mix of lifeforms dominated the plant community on the non-steep portions of this roadside prior to construction. Shrub cover averaged 10% to 30% and was dominated by *Symphoricarpos albus*, *Amelanchier alnifolia*, and *Rosa woodsii*. Native forb cover averaged 20% to 30% and was dominated by *Aster conspicuus*, *Aster laevis*, *Chamerion angustifolium*, *Fragaria virginiana*, *Geranium viscosissimum*, *Lupinus sericeus*, *Monarda fistulosa*, *Maianthemum* spp., and *Solidago canadensis*. Native grass cover was low with scattered *Carex* spp., *Elymus glaucus*, and *Stipa nelsonii* predominating. Due to historic disturbances of the road corridor, non-native grasses and forbs were also present. Exotic grass cover was high in certain areas with *Phleum pratense* and *Poa pratensis* averaging 30% cover. Exotic forb cover was lower, averaging 5% to 10%, and included *Centaurea maculosa*, *Cirsium arvense*, *Medicago lupulina*, *Melilotus officinale*, *Prunella vulgaris*, and *Trifolium pratense*.

B. METHODS

1. Assessing success of revegetation and vegetation change over time

In 1995, replicate 100 m² macroplots were randomly located within each landtype. Six 20m x 5m macroplots were established on landtype 26-C and four 14m x 7m macroplots were established on landtype 26-L-S (Figure 1).

Figure 1. 303-D: Location Map of Monitoring Plots



Plot numbers for each landtype are as follows:

<u>Landtype</u>	<u>Plot number</u>
26-C	SM946012
	SM944022
	SM944021
	SM946014
	SM944020
	SM946013
26-L-S	SM946016
	SM944024
	SM944023
	SM946015

In conjunction with the fertilizer experiment that was assessed from 1995-1997, half of the plots on each landtype received a broadcast treatment of bone meal at the recommended rate of 1 lb./100 ft², while the remaining half of the plots, as well as the rest of the roadside, were not fertilized to serve as controls (Asebrook and Lamb, 1997).

A number of monitoring strategies were evaluated in 1995 to determine the most accurate and efficient methodology to assess the success of revegetation (Asebrook et. al. 1995, Asebrook et. al. 1996). Based on these results, 24 50cm x 50cm microplots were sampled on the 6 plots on landtype 26-C and 21 50cm x 50cm microplots were sampled on the 4 plots on landtype 26-L-S. Three line transects, stratified lengthwise within each plot, were randomly located. Seven or eight microplot locations, depending on the landtype, were then randomly selected along each transect. All transect and microplot locations have been re-randomized each year to ensure independent samples. Canopy cover of each species and density of each seeded species were recorded for each microplot. Ocular estimates of canopy cover were made for species not captured in the microplots. Nested frequency monitoring, conducted in 1995 and 1996, was discontinued on all plots in 1997 due to lack of pertinent information. Additionally, density estimates for seeded species were discontinued after 2004 because it is likely that current density numbers no longer reflect seeding efforts implemented ten years ago.

Currently, mean canopy cover of each lifeform and mean canopy cover of each species are calculated and statistical comparisons between years are conducted. Due to the diminished effect of fertilizer application over time, statistical comparisons between fertilized and unfertilized plots were discontinued in 1999.

2. Shrub plots: Assessing shrub and tree survival and growth

It should be noted that one hundred nine 1.8m radius (10m² or 0.001 hectare) circular shrub plots were also established along the roadside in the 303-D project area. These plots, installed from 1994-1996, were aimed not only to assess survival and growth of woody material, but to also track the benefits of fertilizing planted woody material. Survival data and height and width measurements were collected from these plots in 1995, 1997, 1999, and 2005. Only assessments of survival were conducted in 1996.

Monitoring of all shrub plots, however, was discontinued after 2005. Various natural and human impacts, such as soil slumping, game trails, game browse, frost heaves, varying planting techniques, and burial of shrubs when replanting, made it impossible to control whether plants in the fertilized and unfertilized plots were treated the same. Tags and shrub plot locators also became difficult to find adding a tremendous amount of experimental “noise” to this project. Assessments of fertilizer influence on planted woody material were discontinued in 1999 and assessments of survival and growth were discontinued after 2005. Please refer to the 2005 Restoration Monitoring Report for methodologies of this project and for the ten-year data assessment from 1995-2005.

C. ***RESULTS AND DISCUSSION***

1. Current Status of Revegetation Objectives and Seeded Species

1a. Meeting Twenty Year Revegetation Objectives

The twenty year objectives for the 303-D section of the GTSR have been mostly achieved (Tables 3 and 4). Although ten-year native cover objectives were not met, native cover at year twenty on both landtypes generally met the 50% desired native cover objective. Native cover significantly increased on both landtypes since 2004 with the steep plots having 49.6% native cover, meeting the objective, and the non-steep plots having 44.4% native cover, almost meeting the objective. Increases in native trees, shrubs, and forbs were the main source of this increase in native cover.

Table 3. 303-D: Percentage of Vegetation Cover in for Landtypes 26-C and 26-L-S, 1999-2015

Year	Overall	Native	Exotic*
1999 Landtype 26-C	49.5	34.5	15 (2.0)
2004 Landtype 26-C	40.9	24.3	16.6 (1.4)
2015 Landtype 26-C	69.0	44.4	24.6 (3.7)
1999 Landtype 26-L-S	32.6	26.9	5.7(0.8)
2004 Landtype 26-L-S	40.2	27.9	12.3(1.9)
2015 Landtype 26-L-S	59.3	49.6	9.7 (2.1)

*bracketed numbers (#) represent percent of noxious cover

Exotic cover for the steep landtype was well under the set tolerance level for noxious (<5%) and other weeds (<20%) (Tables 3 and 4). Actually decreasing in cover since 2004, exotic cover on steep plots at year twenty was 9.7% while noxious weed cover was only 2.1%, meeting both objectives. Noxious weed cover on the non-steep plots, at 3.7%, also met the twenty year objective, although the exotic cover on this landtype, at 24.6%, is just higher than the desired twenty year condition of 20%. Two Priority 2B noxious species - *Centaurea maculosa* and *Cirsium arvense* - were observed on both landtypes, however, neither species, singularly or combined, exceeded 5 percent in cover (Tables 3 and 5). *Bromus tectorum*, a Priority 3 weed but not on the Montana noxious weed list, is also present on both landtypes.

Overall native vegetation cover continues to exceed exotic cover for both landtypes (Table 3). During the first three years of monitoring, exotic species cover fluctuated and the ratio of native to exotic species varied between macroplots. However, this year's monitoring determined that eight out of the ten macroplots maintained higher native cover than exotic cover. Typically, native trees, shrubs, and forbs had the largest increases in cover, while exotic cover actually decreased on a few plots. At the very least, the increases in native cover are generally outpacing any increases in exotic cover, resulting in predominantly native plants along this stretch of roadside, our ultimate objective.

In 1999, Asebrook and Brenneman discussed the possibility of modifying objectives to reflect more attainable goals (Table 4). They were concerned that maintaining a target objective of 50 percent native cover after five years may be unrealistic and suggested lowering it to 30 percent. Subsequent revegetation monitoring supported this modification. Although five year objectives were modified, ten and twenty year objectives remained unchanged.

1b. Status of Seeded Species

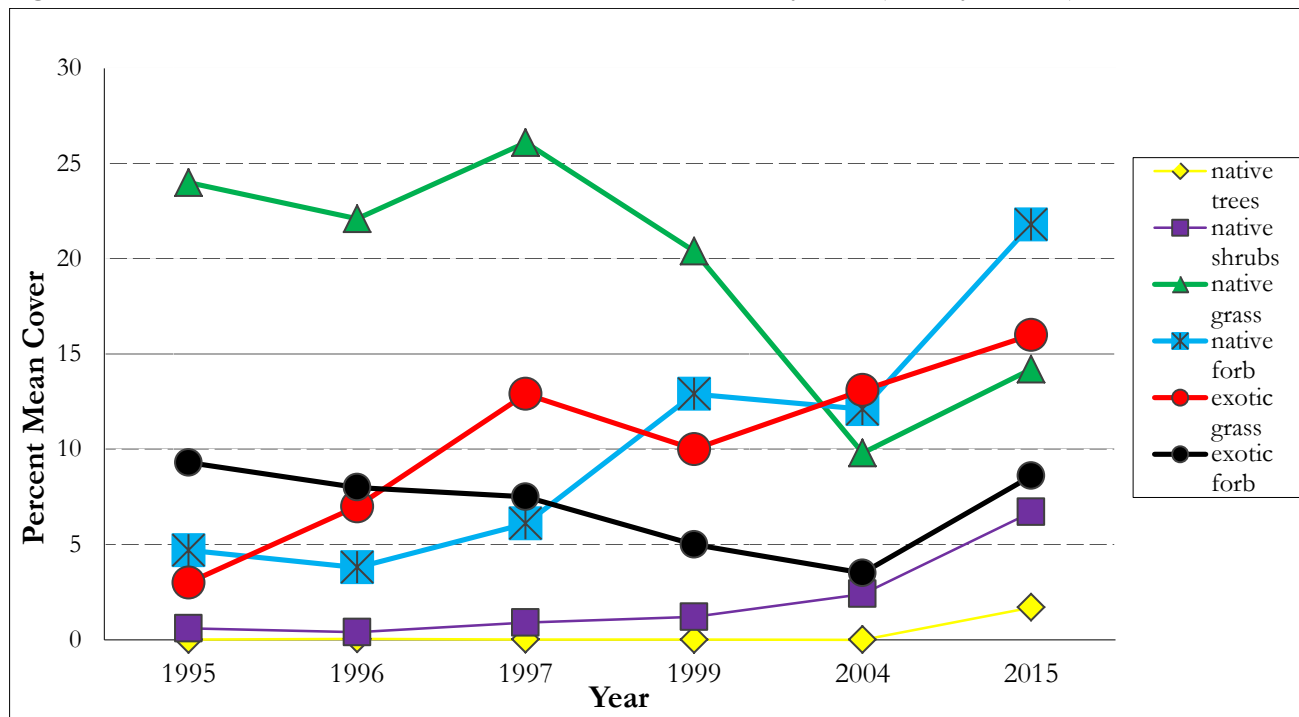
While the number of seeded species observed within the macroplots declined from year five to year ten, more seeded species were detected in year twenty. On non-steep plots, 6 out of 6 seeded grasses were observed, similar to 2004. In terms of seeded forbs, 15 out of 22 forb species were observed, compared to only 11 forb species observed in 2004 (Table 5). Similarly on steep plots, 6 out of 6 seeded grasses were observed, similar to 2004. 14 out of 22 seeded forbs were observed this year, compared to 7 forb species observed in 2004. For the first time on this project, seeded native forbs have higher cover than seeded native grasses on the non-steep slopes and equal cover on the steep slopes. Similar to other projects, seral grasses, such as *Bromus carinatus* and *Elymus glaucus* have continued to decline. As stated in previous reports, despite excellent early establishment, these seral grasses are short-lived perennials that have weak stand longevity, decreasing in cover three to ten years after initial seeding (Asebrook et. al. 2001; Asebrook et. al. 2003). These grasses were virtually gone by year twenty. Other more persistent grasses such as *Elymus spicatus* and *Festuca idahoensis* steadily increased over the first ten years and have generally maintained their cover at year twenty after seeding. Of the 14 seeded native forbs observed, *Achillea millefolium*, *Lupinus sericeus*, *Penstemon confertus*, *Potentilla gracilis*, and *Solidago canadensis* have more than 1% cover throughout the project. The remaining seeded forbs have trace cover, although some of them are slowly increasing in certain areas.

2. Current Status of Vegetation Cover by Landtype

2a. Non-steep plots (26C): species trends

Native plant cover continues to dominate on non-steep plots after twenty years (Table 3 and Figure 2). After decreasing in cover from year five to year ten, overall native cover nearly doubled from year ten to year twenty due to significant increases in shrubs, native grasses, and particularly native forbs. At the same time, exotic forbs significantly increased in cover and exotic grasses maintained their cover for an 8% increase in overall exotic cover. Native forbs experienced the greatest increase in cover from year ten to year twenty while trees exhibited the smallest increase in cover over the same time period. The percentage of native cover relative to the overall vegetation cover has risen from 59% in 2004 to 64% in 2015. After a decline in the diversity of native species from 1999 to 2004, diversity increased in the number of native species observed from 2004 to 2015.

Figure 2. 303-D: Overall Mean Comparison of Lifeform Cover by Year (Landtype 26-C)



Trees and Shrubs: While tree cover remains the lowest lifeform on the non-steep slopes, trees did show a notable increase in cover from 0% in year ten to 1.7% in year twenty (Table 5 and Figure 2). Trees were actually detected within microplots for the first time since the onset of monitoring. Despite mortality of planted trees early on, surviving trees and trees that have naturally recruited to the project area have finally increased in size to provide notable vegetation cover. Plot 6013 had the biggest increase in tree cover (Table 6 and Figure 3), significantly increasing in cover from 0% in 2004 to 9.8% this year. Overall, *Pinus contorta* increased in cover on all plots combined from 0% at year ten to 1.1% at year twenty. *Pseudotsuga menziesii* increased in cover on all plots combined from 0% to 0.5% over the same time period (Table 5).

Overall shrub cover significantly increased for the first time since the project began from 2.4% in year ten to 6.7% in year twenty (Table 5 and Figure 2). Similar to tree cover above and observed on other road projects, this result confirms that it often takes twenty years to see significant structural change with planted woody plants. Shrub cover significantly increased on plots 4020, 4022 and 6014 and slightly increased on plot 6013 (Table 6 and Figure 4). Shrub cover on these 4 plots ranges between 9.2% and 11.3%. Shrub cover, however, remains less than 1% on plots 4021 and 6012, although both plots had no shrub cover ten years ago. Increase in shrub cover across this landtype can be attributed to small increases in cover of several planted shrub species, including *Amelanchier alnifolia*, *Mahonia repens*, *Symphoricarpos albus*, and *Salix bebbiana*. With all plot data averaged together, these shrubs range in cover from 0.2% to 4.2%. Currently, *S. albus* has the highest and most consistent shrub cover on the non-steep slopes. *Rosa woodsii*, another planted shrub, remains with approximately 1% cover, similar to 2004.

Figure 3. 303-D: Tree Cover, 1996-2015

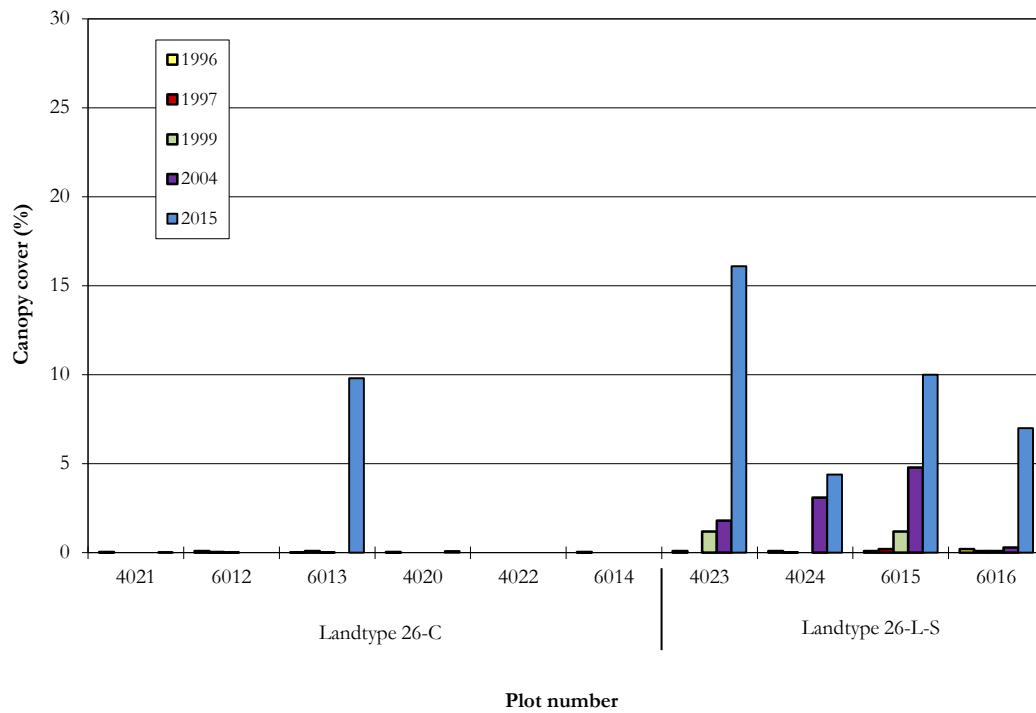
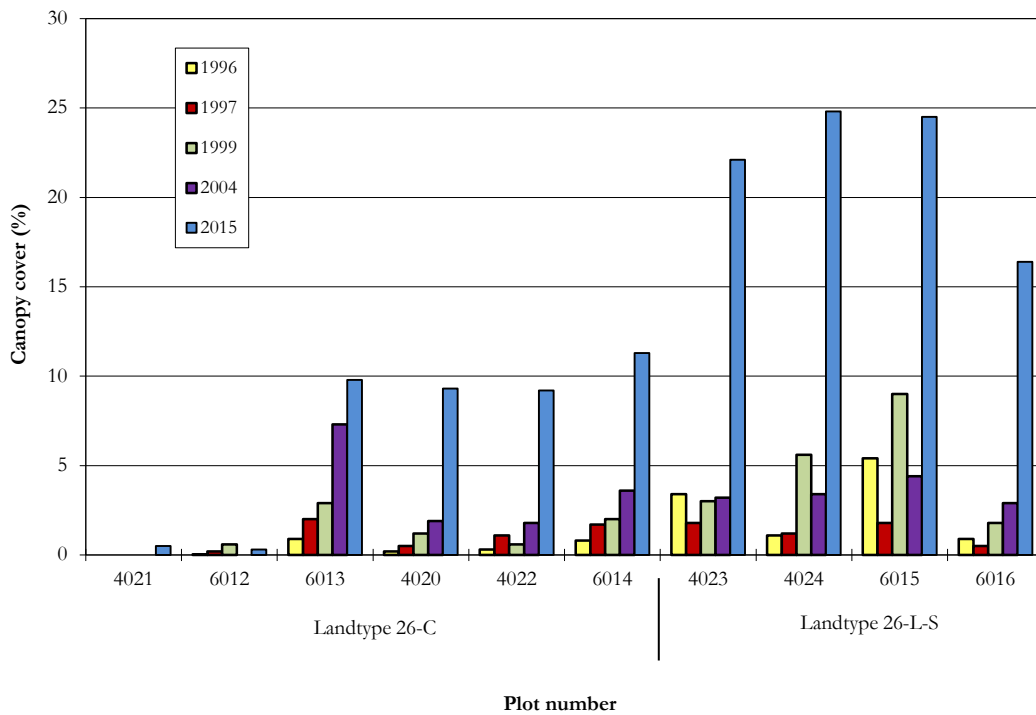


Figure 4. 303-D: Shrub Cover, 1996-2015



While woody material finally increased in cover twenty years after planting, it is important to note that Asebrook and Brenneman (1999) determined that survival and growth of woody material on this landtype had been negatively affected by various natural and anthropogenic impacts early on in the project. Frost-heaving, animal trampling, erosion, and road maintenance have been some of the impacts that have affected these plants over time. It was also observed soon after planting that competition from well-established grasses may also have been out-competing several shrubs for resources. Many of the dominant grasses on non-steep 303-D plots are native grasses that were seeded.

Other monitoring projects have observed a correlation between high grass on seeded plots and low shrub cover, particularly through year ten after planting. In a ten year monitoring study of roadside revegetation plots (303-B), Asebrook et. al. (2001) found higher percentages of shrub cover on unseeded plots compared to seeded plots. This trend was also observed after ten years of monitoring on nearby 303-C plots (Asebrook et. al. 2003). It has been recommended in other revegetation monitoring reports to leave a 'well' of unseeded area around each shrub or tree in an attempt to lessen the thick cover of various native nurse grasses that can crowd woody plants.

It does appear, however, that if trees and shrubs can survive to year ten, they generally continue to grow at an accelerated rate from year ten to year twenty and are not as impacted by competition with surrounding herbaceous vegetation. To date, tree and shrub covers on three roadside projects (303-B, 303-C, and 303-D) have increased two to four fold from year ten to year twenty. Twenty-year tree covers on seeded, non-steep slopes range from 6.2% on 303-B (Asebrook et. al. 2011), 5.5% on 303-C (Asebrook and Hintz 2013), and 1.7% on this project. Twenty-year shrub covers on seeded, non-steep slopes range from 15.8% on 303-B, 16.0% on 303-C, and 6.7% on this project. These lifeforms will only continue to increase over the next ten to twenty year, hopefully approaching pre-disturbance levels along this roadside.

Native Grasses: While native grasses have been on a steady decline since year three after planting, native grass cover significantly increased from 9.8% at year ten to 14.2% at year twenty (Table 5 and Figure 2). Native grass cover significantly increased on 3 out of the 6 plots (4022, 6012, 6013) and slightly increased on 1 plot (4020) (Table 6 and Figure 5). As a result, native grasses had the highest lifeform cover on plot 4022 and co-dominated by vegetation on plot 6012. At the same time, native grass cover significantly decreased on 1 plot (4021) and decreased slightly on 1 plot (6014).

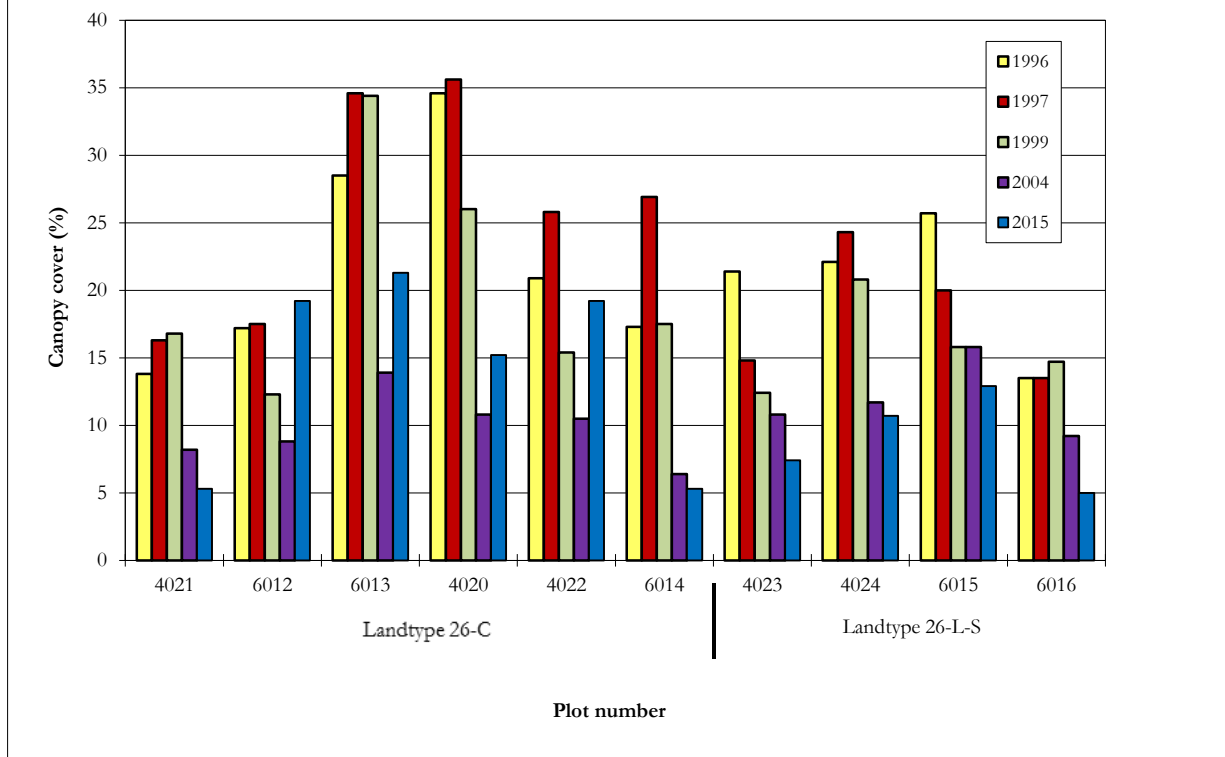
Despite the overall increase, the only two native grass species to significantly change in cover since year ten were *Bromus carinatus* that significantly decreased in cover from 0.7% to 0.03% and *Elymus glaucus* that significantly decreased in cover from 1.1% to 0.03% over the past 10 years (Table 5). This trend is typical of these two seral species and has been observed across many roadside projects twenty years after replanting (Asebrook and Hintz 2011, Asebrook et. al. 2013). While *E. glaucus* can sometimes maintain low cover over time, in general, it appears that these two grasses will no longer occur as part of this roadside vegetation.

While established at the beginning of the project, the overall increase in native grasses is actually due to increases of slower growing, later seral species that have taken twenty years to show appreciable growth. Although increases are not statistically significant, seeded *Festuca idahoensis* has finally increased from 2.9% in 2004 to 5.3% in 2015. Naturally regenerating sedge species *Carex geyeri* and *Carex hoodii* also increased from less than 1% cover at year ten to 3-4% cover at year twenty. Naturally regenerating *Carex petasata* increased from 0% to 0.3% cover as well, resulting in over 7% cover from native sedges. While other established seeded grasses have declined slightly over the past ten years on this landtype, *Elymus spicatus* still remains with a notable 1.6% cover, while *Stipa nelsonii* has 0.2% cover and *Koeleria macrantha* has 0.02% cover averaged over all non-steep plots.

In a previous west-side road project (303-B), seeded versus non-seeded plots have also been compared for vegetation cover over a twenty year time period (Asebrook et. al. 2011). While early seral species such as *Bromus carinatus* and *Elymus glaucus* were equally successful in the early years of this project, later seral grasses were still not established in many roadside areas by year twenty with overall native grass cover continuing to decline as the early seral grasses decreased. As a result, seeded plots had 4% overall native grass cover, much lower than on 303-D and not much higher than on the non-seeded plots that had 2.4% overall native grass cover. Clearly, later seral grasses and naturally regenerating grasses were not able to establish on 303-B as they have on 303-D.

Data collected on nearby 303-C plots, however, is following similar patterns to 303-D. Similar to this project, native grass on 303-C peaked at year three, declined in cover through year ten as seral grasses began to decrease, and then more than doubled in cover from 6% at year ten to 13.9% at year twenty (Asebrook and Hintz 2013). Later seral grass species and naturally recruiting sedges are now dominant native grasses on both 303-D and 303-C, both of which now have similar native grass cover twenty years after replanting.

Figure 5. 303-D: Native Grass Cover, 1996-2015

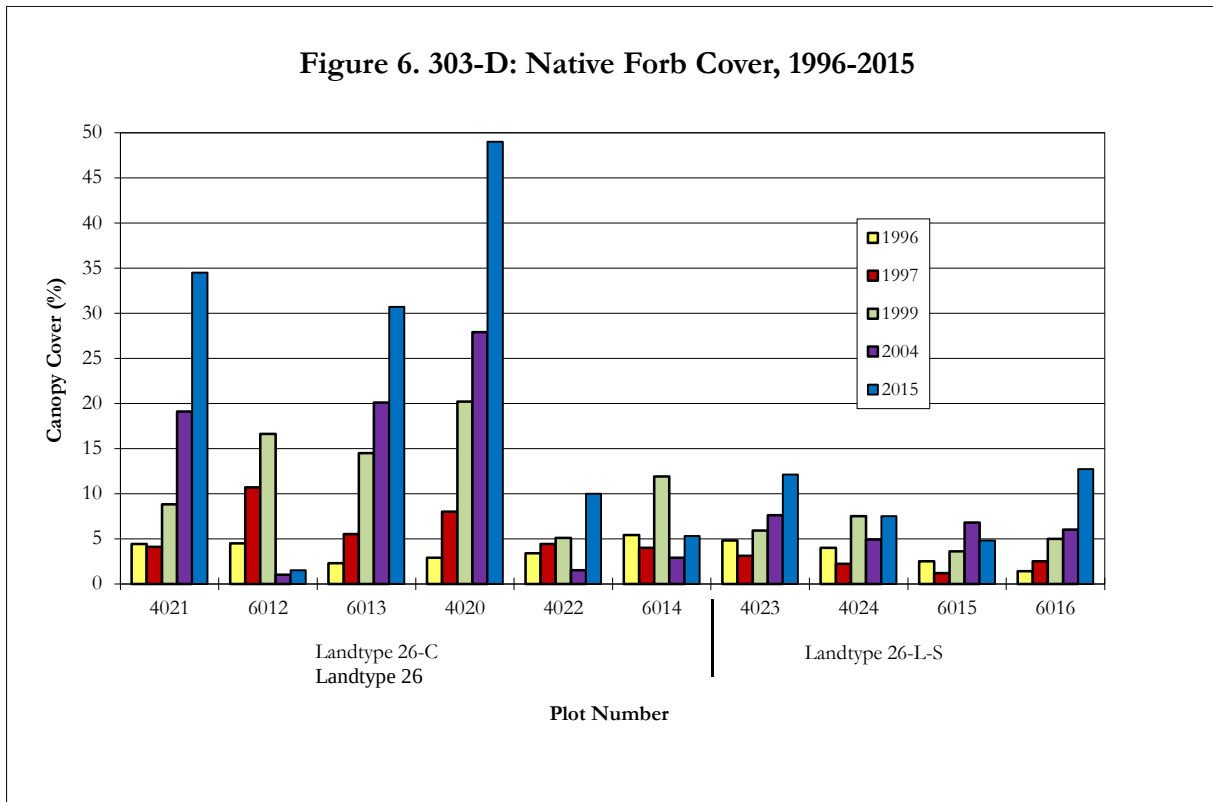


Native Forbs: After experiencing significant increases during the first five years, overall native forbs did not change in cover from year five to year ten (Table 5 and Figure 2). Native forbs, however, significantly increased again in cover from year ten to year twenty, almost doubling in cover in that time frame (Table 5 and Figure 2). Overall native forb cover significantly increased from 12.1% to 21.8% over the last decade, due to the fact that native forbs significantly increased in cover on 4 of the 6 plots (4020, 4021, 4022, 6013) (Table 6 and Figure 6). Native forb cover also increased on the remaining 2 plots (6012, 6014), although these results are not statistically significant. As a result, overall native forbs had the highest lifeform cover of all lifeforms (Table 5 and Figure 2) and native forbs had the highest lifeform cover on 3 of the 6 plots (4020, 4021, 6013).

Native forb cover remains highly variable between microplots, ranging from 1.5% to 49% (Table 6). Variability can be attributed to inconsistent cover of individual species, including seeded, planted, and naturally regenerating species. Interestingly, no seeded species significantly increased in cover from year ten to year twenty. Several species had notable increases in cover, but these were not statistically significant increases. These include seeded species *Penstemon confertus* that increased from 2.2% to 3.7% cover, *Lupinus sericeus* that increased from 0.6% to 1.3% cover, and *Heuchera cylindrica* that increased from 0.02% to 0.1% cover. Other seeded species that have notable cover, specifically 1-2% cover, but that did not change since 2004 include *Achillea millefolium*, *Potentilla gracilis*, and *Solidago canadensis*. Finally, seeded species *Anaphalis margaritacea*, *Polemonium pulcherrimum*, *Potentilla glandulosa*, and *Potentilla hippiana* have low but consistent cover across the project. *Anemone multifida*, *Erigeron compositus*, *Eriogonum umbellatum*, *Gaillardia aristata*, and *Heracleum sphondylium* were only observed with trace cover in a few locations on this landtype. Seeded species *Eriogonum flavum*, *Gentiana affinis*, *Oxytropis splendens*, *Oxytropis campestris*, and *Penstemon albertinus* have been observed with trace amounts in the past but are no longer present within the project area. *Hedysarum boreale* and *Hedysarum sulphurescens* have never been observed on the project.

Fragaria virginiana appears to be the only native forb species that was planted within this roadside restoration area. This stoloniferous species significantly increased in cover from 0.2% in 2004 to 2.5% in 2015. Several naturally regenerating species also increased in cover. Most notably, *Lomatium triternatum* increased from 0.05% in 2004 to 4.9% in 2015. This species now has the highest cover of any native forb on the project, followed by planted *F. virginiana* and seeded *L. sericeus* and *P. confertus*. Other naturally regenerating species that have had notable increases in cover over the past ten years or remain with consistent cover include *Aster laevis*, *Campanula*

Figure 6. 303-D: Native Forb Cover, 1996-2015



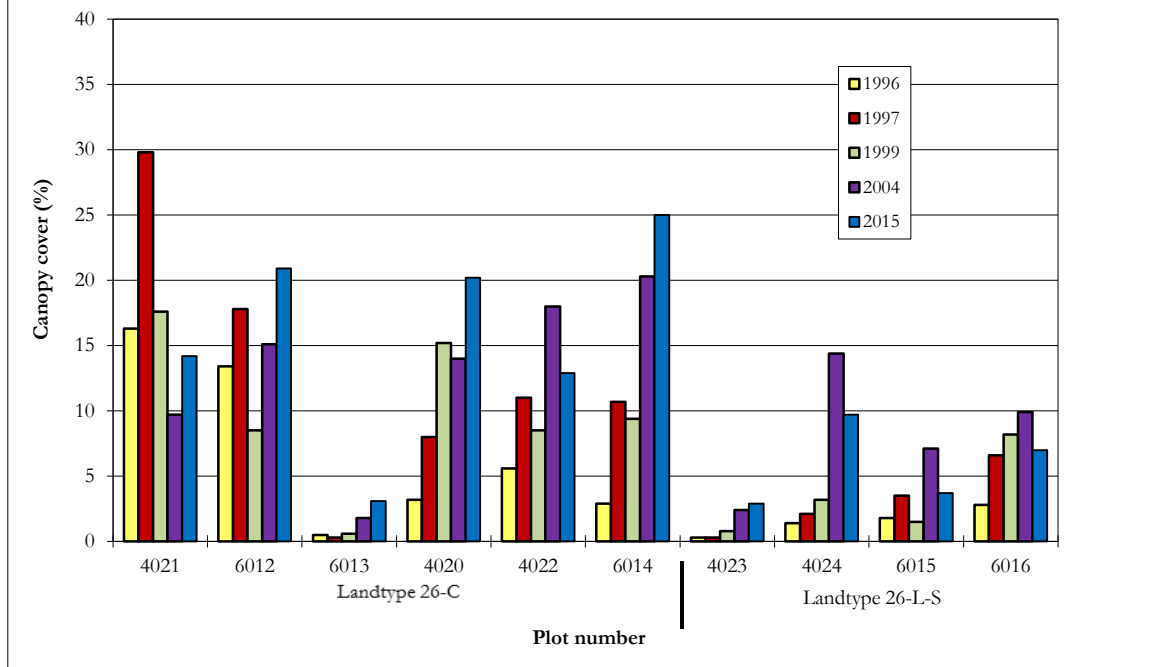
rotundifolia, *Erigeron speciosus*, *Geranium viscosissimum*, *Iliamna rivularis*, *Lathyrus ochroleucus*, *Osmorhiza occidentalis* and *Vicia americana*. Each of these species has 0.4% to 1.6% cover. Despite the on-going threat of spotted knapweed on this roadside, it appears that less herbicide is being applied to these restored areas in the last few years. Perhaps less herbicide application is allowing these species in the aster and pea families to recover, as many of these species were on the decline ten years ago.

Similar to 303-D, native forbs increased in cover from year ten to year twenty on several other road revegetation projects. On 303-B on the west side of the park, native forbs increased from 4.5% at year ten to 8% at year twenty on seeded plots (Asebrook et. al. 2011). While the trend of increasing native forbs is similar, native forb are clearly becoming better established on 303-D with an overall average of 21.8% cover on non-steep seeded roadsides. On 303-C, overall native forb cover reached 35.5% on non-steep slopes at year twenty (Asebrook and Hintz 2013), indicating even greater success of native forbs on this project. Successful native forb species are now similar between 303-C and 303-D, although 303-C had a much higher cover of naturally regenerating *Equisetum arvense*.

Exotic Grasses: While exotic grasses significantly increased in cover on “non-steep” plots from year five to year ten, exotic grasses only slightly increased in cover from year ten to year twenty (Table 5, Figure 2). While these results are not statistically significant, exotic grasses increased from 13.1% in 2004 to 16.0% in 2015. Exotic grasses only significantly increased on 1 plot (4020), although they slightly increased on 4 of the 6 plots (4021, 6012, 6013, 6014) (Table 6 and Figure 7). Exotic grasses slightly decreased on 1 plot (4022). Despite these increases, exotic grasses only had the highest lifeform cover on 1 plot (6014) and only co-dominated the vegetation with native grasses on 1 plot (6012). These are the only two plots on the entire project, including steep slopes, where exotic species dominate or co-dominate the vegetation.

Cover of exotic grasses typically ranged from 13-20%, although one plot had only 3.1% cover of exotic grass and one plot had 25% cover of exotic grass (Table 6). Currently, *Poa pratensis* is the most dominant exotic grass on the project with an overall average cover of 6.5%, up from 4.1% in 2004. This cover is now higher than cover of *Phleum pratense* that had the highest exotic grass cover ten years ago (Table 5). No exotic grasses significantly increased or decreased over the past ten years, although several species did have notable increases. *Poa compressa* increased considerably from 1.6% cover in 2004 to 5.1% cover in 2015, although most of this cover was due to increases on plots 4022 and 6012. *P. pratensis*, *Bromus secalinus*, and *Elymus repens* also increased slightly across the project.

Figure 7. 303-D: Exotic Grass Cover, 1996-2015



Interestingly, *Bromus tectorum* decreased slightly from 2.2% in 2004 to 1.0% in 2015. This aggressive annual grass was only found on one of the six non-steep plots, although it comprised 6.2% cover on plot 6014. The first reason for this decrease may have to do with the fact that in years past, *Bromus secalinus* was lumped together with *B. tectorum*, as these two weedy annuals are difficult to tell apart without seed heads. *B. secalinus* had 0.2% average cover across all plots this year, comprising some of the cover that was attributed to *B. tectorum* in the past. Second, it could also be that treatment of this exotic grass is becoming effective. Hand-pulling, chemical control, and interspersing of competitive native plants have all been shown to reduce *B. tectorum* populations. Weed crews have been hand-pulling and spraying this grass periodically along this roadside, possibly decreasing its cover. Similarly, *Phleum pratense* continued to decrease in cover from 5.2% in 2004 to 2.3% in 2015. No active control of this grass has been occurring, however, it turns out *P. pratense* is only considered an intermediate competitor (FEIS 2011). Now that woody material and native herbaceous species are on the rise, *P. pratense* appears to finally be out-competed by native plants.

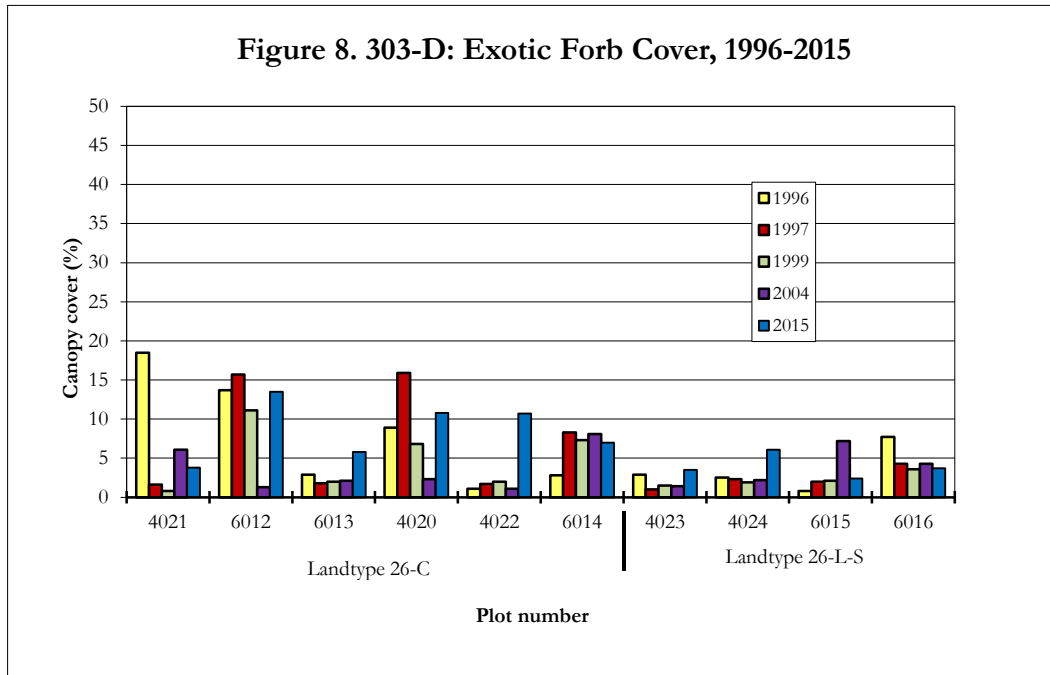
The persistence of exotic grasses into the twentieth year of monitoring is similar to trends observed on other roadside revegetation projects (Asebrook et. al. 2011, Asebrook et. al. 2013). Exotic grasses continued to increase between years ten and twenty on 303-B on the west side of the park, although exotic grass cover was estimated at only 8% at year twenty on seeded plots, relatively lower than the 16% average exotic cover on 303-D. Conversely, exotic grass cover on nearby 303-C became extremely high three to five years after replanting, reaching cover of 53.3% by year five on non-steep plots. While exotic grass cover on these plots has declined slightly to 44.5% by year twenty, exotic grass cover remains significantly higher on this roadside project than any other in the park. Overall, while exotic grasses tend to persist on roadside revegetation projects and generally increase between years ten and twenty, their overall cover can be highly variable. High cover of native herbaceous species early on in the project and later increases in woody native cover appear to be the most important influences in keeping exotic grasses in check.

Exotic Forbs: While exotic forb cover on non-steep 303-D plots steadily declined from year two to year ten after planting, overall exotic forb cover significantly increased from year ten to year twenty (Table 5, Figure 2). Cover significantly increased from 3.5% in 2004 to 8.6% in 2015. This is due to the fact that exotic forbs significantly increased on 4 of the 6 non-steep plots (4020, 4022, 6012, 6013). Exotic forbs decreased slightly on the remaining 2 plots (4021, 6014).

Cover between macroplots was relatively variable, ranging from 3.8% to 13.5% (Table 6). The good news

is that despite an increase in cover, exotic forbs are not the highest lifeform on any plot. Since 1999, exotic forbs have maintained the lowest average cover on non-steep plots for any lifeform with the exception of trees and shrubs. Currently, almost all of the exotic forb cover is comprised from 5 species; *Centaurea maculosa*, a Priority 2B noxious weed, has the highest cover at 3.4%, followed by *Abyssum alyssoides*, *Taraxacum officinale*, *Tragopogon dubius*, and *Medicago lupulina* that each have 1-2% cover. While *A. alyssoides*, *T. officinale*, and *T. dubius* have steadily been increasing in cover over time, cover of *C. maculosa* and *M. lupulina* has increased and decreased over time in response to herbicide application on these roadsides. Over the past 3 years, these roadsides have not had consistent herbicide application as they have in the past. As a result, exotic forb species in both the Asteraceae and Fabaceae families, including *C. maculosa*, *T. dubius*, *T. officinale*, *M. lupulina*, and noxious weed *Cirsium arvense*, have increased in cover. It is recommended that this project be a priority for spot spraying in 2016, likely reducing the covers of several of these species in the future.

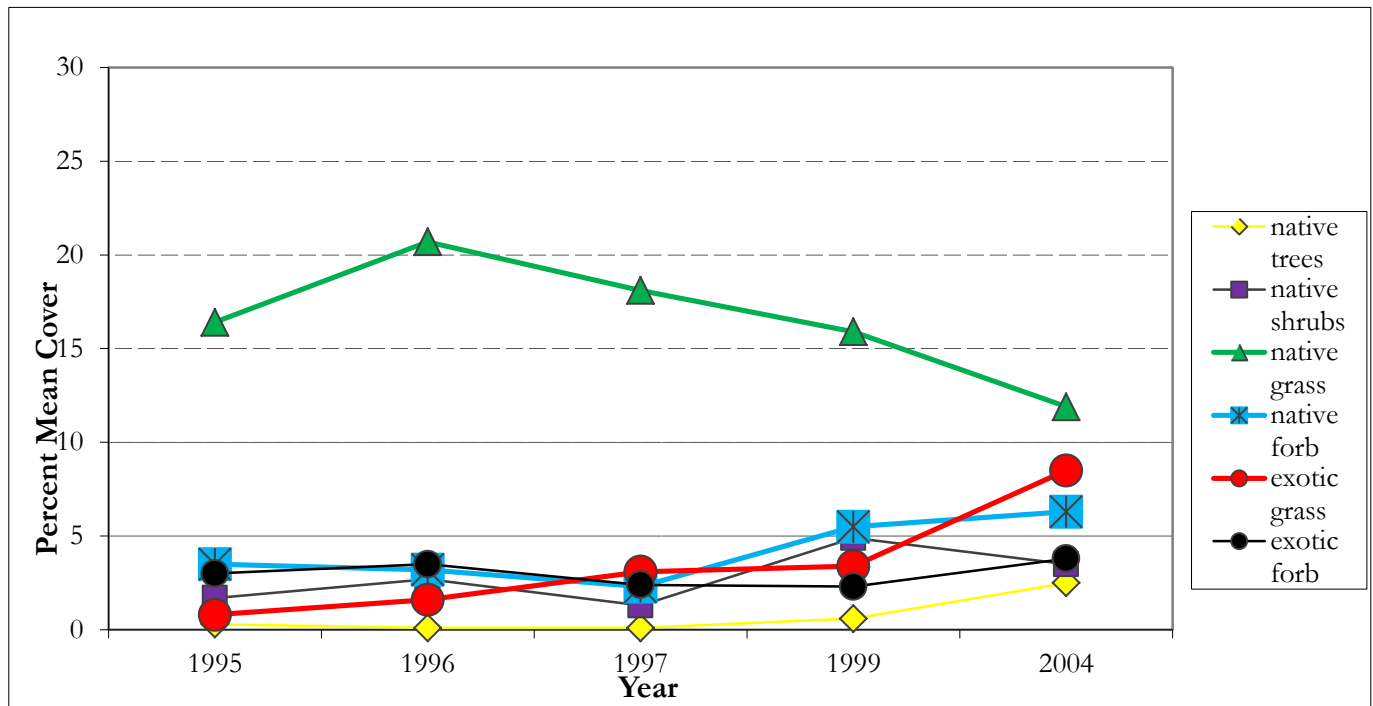
Overall, exotic forb cover on non-steep plots has remained low over the last twenty years and is probably more related to herbicide treatments than from direct competition from native species. Interestingly, average exotic forb cover is unbelievably similar on 3 low elevation road projects at year twenty. Average exotic forb cover was 8.6% cover on 303-D, compared to 7.7% exotic forb cover on non-steep plots of nearby 303-C (Asebrook and Hintz 2013) and 6.7% exotic forb cover on seeded plots of 303-B (Asebrook et. al. 2011). It is an excellent trend that, in general, native forb cover continues to increase dramatically from year ten to year twenty on all roadside projects, while exotic forb cover remains lower, despite small increases. Active control and increases from several native lifeforms are likely keeping exotic forbs from dominating these road sides.



2b. Steep plots (26-L-S): species trends

As with non-steep plots, native vegetation continues to dominate steep plots after twenty years (Table 3 and Figure 9). After remaining the about the same from year five to year ten after replanting, like non-steep plots, overall native cover nearly doubled from year ten to year twenty due primarily to significant increases in trees and shrubs. While native grasses and forbs have not notably changed over the past ten years, woody plant material has nearly tripled on these steep road sides. At the same time, overall exotic grass cover decreased slightly and exotic forbs remained with the same low cover, resulting in lower overall exotic cover in year twenty than in year ten. Native species currently make up 84% of the overall vegetation cover, up from 70 percent in 2004, with native shrubs experiencing the greatest increase in cover from year ten to year twenty. Similar to the non-steep plots, after a decline in the diversity of native species from 1999 to 2004, diversity increased in the number of native species observed on steep plots from 2004 to 2015.

Figure 9. 303-D: Overall Mean Comparison of Lifeform Cover By Year (Landtype 26-L-S)



Trees and Shrubs: The change in woody plant cover was the most dramatic change on this steep landtype at year twenty after replanting. Overall tree cover, which had slowly increased from year five to year ten, increased significantly from 2.5% in 2004 to 9.4% in 2015 (Table 5, Figures 3 and 9). Significant increases in tree cover were observed on 3 of the 4 steep plots (4023, 6015, 6016)(Table 7). Tree cover increased 5-14% on these plots with tree cover now the second highest lifeform on plot 4023. Tree cover also increased slightly on plot 4024 by 1.3%. All increases in tree cover are due to *Pinus contorta* that significantly increased from 2.4% cover in 2004 to 6.9% cover in 2015 over all steep plots and *Pseudotsuga menziesii* that significantly increased from 0.1% cover in 2004 to 2.2% cover in 2015 (Table 5). Similar to other roadside projects, it appears to take a minimum of twenty years for planted and naturally regenerating trees to provide structural change to these areas.

Earlier reports speculated that lower overall vegetation cover on this landtype, combined with low exotic cover, decreased competition for the trees and increased their potential for survival (Asebrook and Brenneman 2004). This trend was observed on 303-B when comparing seeded and unseeded plots: woody material on unseeded plots had higher survival and growth than seeded plots without competition from high herbaceous cover (Asebrook et. al. 2011). But this trend has not been observed in all road projects. Tree cover on steep plots on nearby 303-C, for instance, remained at 0.6% twenty years after planting (Asebrook and Hintz 2013). This area also had low overall vegetation cover and low exotic cover early on during the project and remains with much lower overall vegetative cover than non-steep plots at year twenty. Under similar conditions, trees have not survived and grown on 303-C where they continue to thrive on 303-D. This variation is likely due to different planting strategies, soil textures, nutrient availability and natural and anthropogenic impacts. It appears that revegetation efforts on steep 303-D plots have been able to minimize these impacts and variables more than other areas along the east-side road corridor.

The most dramatic change on these steep plots, however, has been the change in shrub cover from year ten to year twenty. After significantly decreasing by over 1% from year five to year ten, shrub cover significantly increased from 3.5% cover in 2004 to 21.9% cover in 2015 (Figures 4 and 9; Table 5). Shrub cover significantly increased on all 4 plots (Table 7) by 13-21%, resulting in shrubs having the highest lifeform cover on all 4 steep plots. Overall, 5 shrub species significantly increased in cover over the last ten years (Table 7): *Arctostaphylos uva-ursi* increased from 0.5% to 9.9% cover, *Amelanchier alnifolia* increased from 0.5% to 4.2% cover, *Mahonia repens* increased from 0.6% to 2.6% cover, *Shepherdia canadensis* increased from 0.01% to 1.1% cover, and *Symphoricarpos albus* increased from 1.9% to 3.9% cover. Currently, *A. uva-ursi* has the highest average shrub cover across all steep plots. Shrub cover is now over 15% higher on steep plots than non-steep plots on this project (Table 5).

Shrub cover trends observed on steep 303-D plots are similar to those observed on other roadside projects at year twenty. On nearby steep 303-C plots, shrub cover increased over 10% on one steep landtype and

nearly 20% on the other steep landtype, resulting in 11-20.5% shrub cover at year twenty, (Asebrook and Hintz 2013), similar to 303-D. Similarly on 303-B, shrub cover reached approximately 15% cover on seeded plots and approximately 25% on unseeded plots. As described above, it may be that lower overall vegetation cover and lower exotic cover, particularly early on in the project, benefits shrubs in the long run. All roadside areas that typically had less herbaceous cover, and thus less competition with woody material, resulted in higher shrub cover at this later date. As suggested in past reports, it is still recommended to have active weed control in these areas and maintain a 'well' around each planted shrub or tree that is not seeded to lessen the thick cover of various nurse grasses that can crowd woody plants. This appears to be the best strategy if a shrub component is the desired end result of revegetation.

Native Grasses: Unlike non-steep plots, native grasses on steep plots decreased slightly over the last ten years. Overall native grass cover fell from 11.9% to 9% (Table 5, Figure 9) with native grass cover slightly declining on all 4 plots (Table 7, Figure 5). Native grass cover on these plots peaked in 1996 and has been declining ever since. Seeded grasses that significantly decreased in cover include *Bromus carinatus*, *Elymus glaucus*, *Festuca idahoensis*, and *Koeleria macrantha* (Table 5). While it is expected, as explained above, that seral grasses like *E. glaucus* and *B. carinatus* decrease over time, it is uncertain why grasses like *F. idahoensis* decreased on this landtype. This grass species did appear brown and dried at the time of monitoring so it may be that it was stressed during this unseasonably warm summer. Interesting, however, the opposite trend is occurring on non-steep slopes with this grass species.

Some later seral, seeded native grasses have persisted into year twenty and continue to maintain their cover. *Elymus spicatus*, the most dominant native grass on these steeper slopes, maintained its cover at 5.7%, similar to 2004. *Stipa nelsonii*, another seeded grass, has also maintained a consistent, low cover on this landtype. *Carex hoodii* and *Carex geyeri*, naturally regenerating species, now have the second and third highest native grass cover, increasing slightly since 2004 to 1.0% and 1.8% cover. Despite these increases, it appears that, unlike the non-steep plots, increases by persistent native grasses are not completely offsetting losses due to seral species (Figures 5 and 9). Species such as *Elymus trachycaulus* ssp. *trachycaulus* and *Elymus trachycaulus* ssp. *subsecundus* are no longer present in this area and no other seeded grasses are dramatically increasing in cover to fill in the gaps behind the decline in seral grasses. While it is not well understood, it is possible that the dramatic increase in woody material is preventing herbaceous grasses from spreading.

Interestingly, the steep plots on nearby 303-C had a very different trend with native grasses at year twenty. While native grass cover did decline at year ten after seeding, more persistent grasses like *Elymus spicatus* did significantly increase in cover from year ten to year twenty on 303-C, resulting in 35.8% native grass cover (Asebrook and Hintz 2013). At the same time, total woody cover of shrubs and trees on 303-C was only approximately 12%, a third of total woody cover on 303-D at year twenty. As stated, perhaps the dominance of woody material is influential on the overall cover of herbaceous grasses.

Native Forbs: Native forb cover on steep plots is currently at 9.3% percent, a 3% increase since 2004 (Table 5, Figure 9). Although not significant overall, this increase is due to a significant increase of 5-6% native forb cover on 2 of the 4 plots (4023, 6016) and a slight increase of 2.5% native forb cover on 1 plot (4024). (Table 7, Figure 6). Native forbs slightly decreased by 2% on one plot (6015). While cover for this lifeform remains relatively variable, ranging from 4.8% to 12.7% across all steep plots (Table 7), overall native forb cover remains higher than both exotic forb and grass cover and is on par with overall native grass and tree cover on this landtype.

Similar to non-steep plots, very few seeded forb species significantly increased in cover from year ten to year twenty. The only seeded native forb species to significantly increase was *Penstemon confertus* that increased from 0.8% to 2.8% cover over the past ten years. This species now has the highest cover of any seeded native forb. Seeded forb species *Lupinus sericeus* also increased slightly in cover from 0.5% to 1.2% but these results are not significant. While few other seeded forb species have notable cover, the good news is that the diversity of seeded forb species is higher than ten years ago and several species are increasing slowly over time. Seeded forbs with low but consistent cover include *Achillea millefolium*, *Anemone multifida*, *Gaillardia aristata*, *Hedysarum sulphurescens*, *Penstemon albertinus*, *Polemonium pulcherrimum*, *Potentilla glandulosa*, *Potentilla hippiana*, and *Solidago canadensis*. *Erigeron compositus* and *Heuchera cylindrica* and were only observed with trace cover in a few locations on this landtype. Seeded species *Anaphalis margaritacea*, *Hedysarum boreale*, and *Oxytropis campestris* have been observed with trace amounts in the past but are no longer present within the project area. Finally, *Eriogonum flavum*, *Eriogonum umbellatum*, *Gentiana affinis*, *Heracleum sphondylium*, and *Oxytropis splendens* have never been observed on the steep slopes of this project.

As on non-steep plots, *Fragaria virginiana* appears to be the only native forb species that was planted within these steep roadside areas. This stoloniferous species significantly increased in cover from 0.5% in 2004 to 2.4% in 2015. Several naturally regenerating species also increased in cover, contributing to increases in native forb cover. Most notably and similar to non-steep plots, *Lomatium triternatum* significantly increased in cover from 0% in 2004 to 0.3% in 2015. Despite this increase, this species remains much lower in cover than on the non-steep plots. Other naturally regenerating species that have had notable increases in cover over the past ten years or remain with consistent cover include *Aster laevis* and *Osmorhiza occidentalis*.

The slow and steady increase of native forbs on the steep plots of 303-D are actually doing quite well in comparison to other roadside revegetation projects. While native forb cover is much lower than on the non-steep areas of this project, overall native forb cover is higher than the nearby steep plots of 303-C that had 6.8% native forb cover by year twenty, and slightly higher than the native forb cover on seeded 303-B plots that had 8% cover at year twenty. It is possible within the next ten years that native forbs will continue to increase over time.

Exotic Grasses: Unlike non-steep plots, exotic grass cover on steep plots decreased slightly over the last ten years (Table 5, Figure 9). It is this decrease that is primarily responsible for the overall decrease in exotic cover on steep plots (Table 3). Currently overall exotic grass cover averages 5.8% percent, down 2.7% from 2004. Exotic grasses significantly decreased on 2 of the 4 plots (6015, 6016) by 2-4%, while slightly decreasing on 1 plot (4024) and maintaining the same cover on the last plot (4023) (Table 7, Figure 7). Surprisingly, significant decreases were observed for *Bromus tectorum* and *Poa pratensis* on this landtype. The dominant exotic grasses on these steep slopes are currently *Phleum pratense*, which has the highest exotic grass cover at 4.1%, and *Poa compressa*, which has 0.9% cover. Neither of these exotic grasses significantly changed in cover since 2004.

The trend of decreasing exotic grasses on these steeper slopes is a positive one and perhaps a sign that native species are truly able to compete with non-native plants in this location. Like the decline in native grasses, perhaps the dramatic increase in woody plant cover is also causing exotic grasses to decline. This trend of declining exotic grasses is not occurring on adjacent non-steep plots and did not occur on nearby 303-C steep plots at year twenty, both of which had lower overall woody cover (Asebrook and Hintz 2013).

Exotic Forbs: Exotic forb cover on steep plots remained basically the same as in 2004, estimated at 3.9% compared to 3.8% ten years ago (Table 5 and Figure 9). This result is due to the fact that while exotic forbs significantly increased on 2 plots (4023, 4024) by 2-4%, exotic forbs also significantly decreased on one plot (6015) by 5% (Table 7, Figure 8). Exotic forb cover remained the same on plot 6016. A great trend is that exotic forbs had the lowest lifeform cover on 3 out of the 4 plots (4024, 6015, 6016).

The only exotic forb to significantly change since 2004 was *Tragopogon dubius* that increased from 0.02% cover to 0.7% cover over the last ten years (Table 5). Due to the fact that these roadside areas have not been as actively sprayed for noxious weeds as they have been in the past, it is not surprising that noxious weed *Centaurea maculosa* also slightly increased in cover from 1.4% in 2004 to 2.1% in 2015. Many of the observed spotted knapweed were extremely large as if they had been present for some time. Other exotic forb species with consistent but low cover include *Taraxacum officinale*, *Medicago lupulina*, *Melilotus officinale*, and *Alyssum alyssoides*.

Interestingly, cover of *Cirsium arvense*, the other noxious weed within the project, declined from 0.5% to trace amounts from year ten to year twenty. While there are patches of this weed on this roadside, it does not appear to be increasing. Other exotic forb species to decline include *Verbascum thapsus* that now has only 0.2% cover and *Trifolium hybridum* which is no longer present on the project. It is important to note that *V. thapsus* actually tripled its overall cover from 1999 to 2004. As this weed requires bare ground to colonize, it appears that overall increases in vegetation cover on these slopes are finally preventing this non-native forb from further increase. Other studies have noted that if there is no available bare ground nearby, populations of *V. thapsus* tend to die off because their seeds do not have long ranged dispersal mechanisms.

Overall, cover for this lifeform on 303-D remains very low. This is similar to several other twenty year results for roadside projects (Asebrook et al. 2011, Asebrook et al. 2013). Exotic forb cover at twenty years has even remained as low as 1.8% on nearby, steep 303-C plots. Surely, herbicide application over this time period that has targeted certain non-native forbs has kept exotic forbs in check on these roadside communities. By year twenty, it appears that established native vegetation is also partially responsible for preventing the increase of exotic forbs in these areas.

D. CONCLUSIONS AND RECOMMENDATIONS

Native species continue to dominate 303-D plots and twenty year objectives for restoration along this section of the GTSR have mostly been achieved. Native cover at year twenty on both landtypes generally met the 50% desired native cover objective due to significant increases of native plants since 2004. All areas meet the objectives for noxious weed cover and only non-steep plots were slightly over the desired twenty year condition of 20% exotic cover. Steep plots met this objective. Overall, monitoring indicates that overall native vegetation cover continues to exceed exotic cover for both landtypes, our ultimate objective.

Woody plants, including trees and particularly shrubs, experienced the most change over the past ten years. On non-steep plots, trees were actually detected within microplots for the first time since the onset of monitoring, increasing from 0% to 1.7%, while shrubs tripled in cover. Increases of woody material on steep plots were even more dramatic. Tree cover tripled on steep plots and shrub cover increased by nearly seven-fold. Shrubs now have the highest lifeform cover on all 4 steep plots, a dramatic change from ten years ago. Similar to other road projects, these results confirm that it often takes twenty years to see significant structural change with planted woody plants.

While grasses changed dramatically from year five to year ten after planting, both native and exotic grasses did not undergo as much change from year ten to year twenty. Native grasses on non-steep plots have finally begun to increase again after reaching their peak cover three years after planting. They remain the second highest native lifeform after native forbs on the non-steep plots. Native grasses on steep plots continue to slightly decline since their peak two years after planting. Trees, native forbs, and native grasses now all have equal cover on steep plots that are dominated by shrubs. Patterns of native grass cover are generally following trends observed on other road projects by year twenty. Native grasses tend to peak by year two or three with high germination and growth of seral grasses such as *Elymus glaucus* and *Bromus carinatus*, decline in cover through year ten as seral grasses began to decrease, and then increase, sometimes significantly, from year ten to year twenty. Later seral grass species like *Elymus spicatus* and *Festuca idahoensis* and naturally recruiting sedges are now dominant native grasses on this project with expectations that they will persist into the future.

Similarly, exotic grass cover did not change dramatically from year ten to year twenty after planting. On non-steep plots, this maintained exotic grass cover allowed increasing native forbs to become the dominant lifeform on these slopes, unlike 2004 when exotic grasses were the dominant lifeform. Exotic grasses only had the highest lifeform cover on 1 non-steep plot and only co-dominated the vegetation with native grasses on 1 non-steep plot. These are the only two plots on the entire project, including steep slopes, where exotic species dominate or co-dominate the vegetation. At the same time, exotic grasses decreased on the steep plots. The trend of decreasing exotic grasses on these steeper slopes is a positive one and perhaps a sign that native species are truly able to compete with non-native plants in this location. Like the decline in native grasses, it is speculated that perhaps the dramatic increase in woody plant cover is also causing exotic grasses to decline. This trend of declining exotic grasses is not occurring on adjacent non-steep plots and did not occur on nearby 303-C steep plots at year twenty, both of which had lower overall woody cover. *Phleum pratense* and *Poa compressa* dominate steep plots while *Poa pratensis* dominates the non-steep plots. *Bromus tectorum*, an aggressive annual, has declined across the project, perhaps in response to active control over the past several years.

Forbs, on the other hand, are on the rise, particularly native forbs. On non-steep slopes, native forbs nearly doubled in cover, becoming the dominant lifeform in these areas. The most successful native forb species include seeded and planted species, such as *Penstemon confertus*, *Lupinus sericeus*, *Fragaria virginiana*, *Potentilla gracilis*, and *Solidago canadensis*, but also includes naturally regenerating species like *Lomatium triternatum*, *Aster laevis*, *Osmorhiza occidentalis*, and *Iliamna rivularis*. Despite the on-going threat of spotted knapweed and other exotic forbs on this roadside, it appears that less herbicide has been applied to these restored areas in the last few years. Perhaps less herbicide application is allowing these species in the aster and pea families to recover, as many of these species were on the decline ten years ago. It appears that native diversity is also on rise, perhaps another by-product of less herbicide application in these areas.

Less herbicide treatment on these road areas may be the cause of increased exotic forb cover on the non-steep plots. Over the past 3 years, these roadsides have not had consistent herbicide application as they have in the past. As a result, exotic forb species in both the Asteraceae and Fabaceae families, including noxious weeds *Cenaturea maculosa* and *Cirsium arvense*, *Tragopogon dubius*, *Taraxacum officinale*, and *Medicago lupulina*, have increased in cover. Some of the *C. maculosa* was very large, indicating that it had not been controlled for some time. While less

herbicide may be positively impacting native forbs, it is important to control exotic forbs on these roads, particularly noxious weeds. If careful herbicide spot application occurred on several of these weed species, it is likely that their covers would be reduced without negatively impacting native forb cover.

Overall, information collected during the first twenty years of monitoring on 303-D and other projects has provided numerous suggestions to assist with revegetation and management strategies used on roadside revegetation projects. A few big picture recommendations that we have learned over the years include the following:

- Identify and use the most effective native species: With 20 years of monitoring data for several roadside projects, we currently have a good list of native grass and forb species that are effective to use as revegetation species (see section VIII of this report). We have a good idea of what to plant and what to seed and the appropriate seed rate to use in order to have a particular native species become a dominant feature on the roadside. We are still experimenting with the correct seed rates for early seral grasses and late seral grasses to find the appropriate mix for effective short-term and long-term grass cover.
- High diversity of seeded species does not always translate to more cover or higher diversity of plants: Over the years, we have found that it is better to reduce the number of species used in a restoration seed mix to fewer species that each have more seed, if possible. Species with low seed rates are not often observed on restoration projects and typically if those species do in fact germinate, they are often later out-competed or negatively impacted by herbicide. Seed selection should concentrate on species not typically impacted by herbicides and that have shown to persist over the long-term. Naturally regenerating grasses and forbs often increase the diversity of these roadside areas in the long run.
- Planting woody shrubs and trees in high densities is a successful restoration tactic but takes 20 years for structural change: All roadside projects are finally showing great increases in planted woody cover at year 20. If trees and shrubs can survive to this point, they finally begin to significantly grow to add structure, shade, and notable cover to these roadsides. These woody plants will become much more effective competitors against exotic plants as they continue to increase, reducing the need for herbicide and general weed control. Many of these areas will begin to blend more naturally with the adjacent forest as these roadsides return to being dominated by trees and shrubs.
- Protect planted woody material by leaving a well around the plant that does not get seeded: Several projects have shown that if seeding is too aggressive around a planted shrub or tree, the shrub or tree may die or significantly die back due to competition with high herbaceous cover. It is recommended again, as in past reports, to leave a well around each planted tree or shrub that is not seeded. Higher survival of planted woody material will only allow the increase of trees and shrubs to happen sooner.
- Continue to control non-native and noxious weeds: It should be a priority to control noxious weeds *Centaurea maculosa* and *Cirsium arvense* on these roadsides next year. The spotted knapweed is getting quite large, distributing a large amount of seed into the seed bank. Canada thistle remains isolated and could easily be controlled. Hand-pulling and/or spraying of *Bromus tectorum* should also continue as it appears that this is effectively controlling this aggressive exotic grass.
- Use herbicide to control noxious weeds but be careful to protect native forbs: All herbicide application should be done carefully as to not negatively impact native forb populations. With less herbicide used on these roadsides over the past several years, some native forbs have been able to recover and even increase. If careful spot herbicide application was done, exotic forb species could be controlled while protecting important native forb species.

If possible, these plots should be read again at year 30 in 2024. With continued increases of native lifeforms, particularly trees, shrubs, and native forbs, it is important to document the long-term outcome of this restoration project. Changes to monitor include growth of woody species, the persistence and/or trend of native forbs and grasses, the persistence of exotic grasses, the impacts of control on exotic forbs, and whether any new exotic species are being introduced.

Table 4. 303-D: Original and Modified Revegetation Objectives

Original Objectives	Year 1	Year 2	Year 5	Year 10	Year 20
Surface soil stability	X				
Native species cover					
25%	X				
35%		X			
50%			X	X	X
Noxious weed cover (under herbicide use plan)					
< 10%	X	X	X		
< 5%				X	X
Other exotic species cover (under herbicide use plan)					
< 30%	X	X			
< 20%			X	X	X
Species composition and diversity					
restore 75% of target restoration native community					X
Survival of containerized material					
80%	X				
70%		X	X		
Significant growth ($p>0.05$) of nursery stock			X	X	X

Modified Objectives	Year 1	Year 2	Year 5	Year 10	Year 20
Surface soil stability	X				
Native species cover					
20%	X				
25%		X			
30%			X		
50%				X	X
Noxious weed cover (under herbicide use plan)					
< 10%	X	X	X		
< 5%				X	X
Other exotic species cover (under herbicide use plan)					
< 30%	X	X			
< 20%			X	X	X
Species composition and diversity					
restore 75% of target restoration native community					X
Survival of containerized material					
80%	X				
70%		X	X		
Significant growth ($p>0.05$) of nursery stock			X	X	X

Table 5. 303-D: Comparison of Mean Canopy Cover (%) Estimates ($\pm$ std. dev.) Over Time Independent of Treatment for Lifeform.

b indicates that 1996 and 1997 numbers are significantly different on each plot at the 90% confidence level.

c indicates that 1997 and 1999 numbers are significantly different on each plot at the 90% confidence level.

d indicates that 1999 and 2004 numbers are significantly different on each plot at the 90% confidence level.

f indicates that 2004 and 2015 numbers are significantly different on each plot at the 90% confidence level.



green cells indicate significant difference between non-consecutive years (90% confidence level).

	Seed Rate (seeds/m ²)	Landtype 26-C					Landtype 26-L-S				
		1996	1997	1999	2004	2015	1996	1997	1999	2004	2015
LIFEFORM											
Tree		0.04 ± 0.03	0.02 ± 0.03	0.01 ±0.01	0	1.7 ± 3.7	0.1 ± 0.4	0.1 ± 0.07 ^c	0.6 ± 0.5 ^{cd}	2.5 ± 1.6 ^{d,f}	9.4 ± 4.4 ^f
Shrub		0.4 ± 0.3	0.9 ± 0.7	1.2 ± 0.9	2.4 ± 2.3 ^f	6.7 ± 4.5 ^f	2.7 ± 1.6 ^b	1.3 ± 0.5 ^{b,c}	4.9 ± 2.5 ^c	3.5 ± 0.6 ^f	21.9 ± 3.4 ^f
Native grass		22.1 ± 6.7	26.1 ± 6.9	20.4 ± 7.0 ^d	9.8 ± 2.2 ^{df}	14.2 ± 6.6 ^f	20.7 ± 4.0	18.1 ± 3.8	15.9 ± 2.7 ^d	11.9 ± 2.4 ^d	9.0 ± 3.0
Native forb		3.8 ± 1.0 ^b	6.1 ± 2.3 ^{b,c}	12.9 ± 4.6 ^c	12.1 ± 9.9 ^f	21.8 ± 7.4 ^f	3.2 ± 1.2	2.3 ± 0.6 ^c	5.5 ± 1.3 ^c	6.3 ± 1.0	9.3 ± 3.3
Exotic grass		7.0 ±5.4 ^b	12.9 ± 8.5 ^b	10.0 ± 5.0	13.1 ± 5.6	16.0 ± 7.1	1.6 ± 0.8 ^b	3.1 ± 2.1 ^b	3.4 ± 2.6 ^d	8.5 ± 4.4 ^d	5.8 ± 2.7
Exotic forb		8.0 ± 5.9	7.5 ± 5.8	5.0 ± 3.4	3.5 ± 2.4 ^f	8.6 ± 3.3 ^f	3.5 ± 2.3	2.4 ± 1.1	2.3 ± 0.7	3.8 ± 2.2	3.9 ± 1.4
SEEDED GRASSES											
<i>Bromus carinatus</i>	258.2	7.5 ± 1.8 ^b	9.7 ± 2.4 ^{b,c}	2.9 ± 0.8 ^{cd}	0.7 ± 0.4 ^{df}	0.03 ± 0.05 ^f	4.7 ± 1.1	3.7 ± 1.4 ^c	2.2 ± 0.6 ^{cd}	0.6 ± 0.3 ^{df}	0.05 ± 0.05 ^f
<i>Elymus glaucus</i>	247.5	10.1 ± 4.6	11.4 ± 6.4	9.5 ± 4.7 ^d	1.1 ± 1.0 ^{df}	0.03 ± 0.05 ^f	10.4 ± 3.7	9.5 ± 3.4 ^c	6.3 ± 1.8 ^{cd}	1.1 ± 0.4 ^{df}	0.05 ± 0.05 ^f
<i>Elymus spicatus</i>	43.0	0.9 ± 0.3	1.0 ± 0.5 ^c	1.7 ± 0.6 ^{cd}	2.7 ± 1.2 ^d	1.6 ± 1.5	0.8 ± 0.4	0.8 ± 0.3 ^c	1.6 ± 0.5 ^{cd}	6.0 ± 2.4 ^d	5.7 ± 3.7
<i>Festuca idahoensis</i>	86.1	1.2 ± 0.5 ^b	1.9 ± 0.5 ^b	2.0 ± 0.7	2.9 ± 1.2	5.3 ± 4.1	0.5 ± 0.3	0.5 ± 0.2	0.6 ± 0.4 ^d	1.3 ± 0.6 ^{d,f}	0.4 ± 0.2 ^f
<i>Koeleria macrantha</i>	86.1	0.3 ± 0.2	0.4 ± 0.2	0.4 ± 0.4	0.3 ± 0.4	0.02 ± 0.04	0.2 ± 0.1	0.1 ± 0.06	0.2 ± 0.2 ^d	0.5 ± 0.2 ^{d,f}	0.05 ± 0.03 ^f
<i>Stipa nelsonii</i>	32.3	0.07 ± 0.05	0.1 ± 0.02	0.2 ± 0.2	0.1 ± 0.1	0.2 ± 0.5	0	0.03 ± 0.02	0.04 ± 0.04	0	0.05 ± 0.05
SEEDED FORBS											
<i>Achillea millefolium</i>	12.9	0.6 ± 0.5	0.6 ± 0.4	1.0 ± 1.3	1.5 ± 2.4	1.0 ± 1.5	0.1 ± 0.2	0.2 ± 0.1 ^c	0.5 ± 0.3 ^c	0.5 ± 0.5	0.2 ± 0.2
<i>Anaphalis margaritacea</i>	1.4	0	0	0	0	0.1 ± 0.2	0	0.06 ± 0.1	0	0	0
<i>Anemone multifida</i>	19.8	0.02 ± 0.02	0.03 ± 0.06	0.02 ± 0.05	0	0.01 ± 0.03	0	0	0	0	0.1 ± 0.1
<i>Erigeron compositus</i>	3.3	0.02 ± 0.02	0.003 ± 0.01	0.01 ± 0.02	0.02 ± 0.05	0.01 ± 0.02	0	0	0	0	0.01 ± 0.02
<i>Eriogonum flavum</i>	1.4	0	0.003 ± 0.01	0	0	0	0	0	0	0	0
<i>Eriogonum umbellatum</i>	2.6	0	0.01 ± 0.02	0	0	0.04 ± 0.08	0	0	0	0	0
<i>Gaillardia aristata</i>	1.9	0.02 ± 0.03	0.04 ± 0.1	0.02 ± 0.05	0.3 ± 0.5	0.03 ± 0.06	0.01 ± 0.01	0.02 ± 0.02	0	0	0.1 ± 0.1
<i>Gentiana affinis</i>	trace	0.003 ±0.01	0.003 ± 0.01	0	0	0	0	0	0	0	0
<i>Hedysarum boreale</i>	0.1	0	0	0	0	0	0.1 ± 0.2	0	0	0	0
<i>Hedysarum sulphurescens</i>	0.1	0	0	0	0	0	0	0	0.1 ± 0.1	0	0.3 ± 0.4
<i>Heracleum sphondylium</i>	1.7	0	0.02 ±0.05	0.1 ± 0.3	0	0.02 ± 0.04	0	0	0	0	0
<i>Heuchera cylindrica</i>	86.1	0.02 ± 0.02	0.01 ± 0.02	0.01 ± 0.02	0.02 ± 0.05	0.1 ± 0.1	0.01 ± 0.01	0	0.02 ± 0.04	0	0.03 ± 0.04
<i>Lupinus sericeus</i>	1.6	0.1 ± 0.2	0.2 ± 0.5 ^c	1.1 ± 2.5 ^c	0.6 ± 1.0	1.3 ± 2.6	0.6 ± 0.6	0.3 ± 0.3	0.5 ± 0.6	0.5 ± 0.5	1.2 ± 0.8
<i>Oxytropis campestris</i>	0.03	0	0.02 ± 0.05	0	0.02 ± 0.5	0	0	0.01 ±0.01	0	0	0
<i>Oxytropis splendens</i>	0.03	0.06 ± 0.1	0.1 ± 0.3	0	0	0	0	0	0	0	0
<i>Penstemon confertus</i> / <i>hyalli</i> / <i>procerus</i> #	91.4	1.3 ± 0.7	1.6 ± 0.7 ^c	3.5 ± 1.8 ^c	2.2 ± 1.8	3.7 ± 4.6	1.0 ± 0.9	0.5 ± 0.3 ^c	1.4 ± 0.8 ^c	0.8 ± 0.3 ^f	2.8 ± 1.7 ^f
<i>Penstemon albertinus</i>	1.7	0	0.1 ± 0.2	0.1 ± 0.2	0	0	0	0.03 ± 0.04	0.08 ± 0.04 ^d	0 ^d	0.1 ± 0.04
<i>Polemonium pulcherrimum</i>	86.1	0.2 ± 0.3	0.4 ± 0.5	0.4 ± 0.4	0.2 ± 0.3	0.5 ± 0.7	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.2	0.1 ± 0.1	0.1 ± 0.1
<i>Potentilla glandulosa</i>	8.0	0.2 ± 0.2	0.2 ± 0.2	0.3 ± 0.3	0.2 ± 0.4	0.1 ± 0.06	0.02 ± 0.02	0.03 ± 0.04	0.05 ± 0.1	0.01 ± 0.02	0.1 ± 0.04
<i>Potentilla gracilis</i>	24.7	0.2 ± 0.2	0.3 ± 0.3 ^c	1.1 ± 1.5 ^c	1.6 ± 2.6	1.3 ± 1.6	0.1 ± 0.1	0.07 ± 0.04	0.2 ± 0.2	0.5 ± 0.5	0.3 ± 0.2
<i>Potentilla hippiana</i>	7.4	0.003 ±0.01	0.02 ± 0.03	0.02 ± 0.05	0	0.1 ± 0.1	0	0	0	0	0.1 ± 0.1
<i>Solidago canadensis</i>	?	0.1 ± 0.2	0.06 ± 0.1	0.3 ± 0.4	0.9 ± 1.6	1.1 ± 1.0	0.01 ± 0.01	0.07 ± 0.1	0.2 ± 0.2	0.05 ± 0.08	0.2 ± 0.3

Table 5. cont. 303-D: Comparison of Mean Canopy Cover (%) Estimates ($\pm$ std. dev.) Over Time Independent of Treatment for Lifeform.

	Seed Rate (seeds/m ²)	Landtype 26-C					Landtype 26-L-S				
		1996	1997	1999	2004	2015	1996	1997	1999	2004	2015
SELECT NATIVE SPECIES											
<i>Amelanchier alnifolia</i>		0.01 ± 0.02	0.04 ± 0.04	0.1 ± 0.2	0.2 ± 0.2	1.0 ± 1.2	1.0 ± 1.0	0.5 ± 0.2	1.3 ± 1.0	0.5 ± 0.7 ^f	4.2 ± 3.2 ^f
<i>Arctostaphylos uva-ursi</i>		0	0.01 ± 0.03	0	0	0	0.01 ± 0.02	0.05 ± 0.04	0.05 ± 0.03 ^d	0.5 ± 0.3 ^{d,f}	9.9 ± 2.2 ^f
<i>Aster laevis</i>		0.1 ± 0.1	0.2 ± 0.1 ^c	1.1 ± 1.2 ^c	0.9 ± 1.7	1.6 ± 3.3	0.05 ± 0.05	0.4 ± 0.5	0.1 ± 0.1	0.4 ± 0.4	0.5 ± 0.3
<i>Campanula rotundifolia</i>		0.2 ± 0.2	0.2 ± 0.1	0.3 ± 0.2	0.4 ± 0.4	0.5 ± 0.3	0.04 ± 0.04	0.2 ± 0.3	0.1 ± 0.1	0.1 ± 0.2	0.1 ± 0.1
<i>Carex</i> spp.		2.1 ± 3.3	2.9 ± 4.1 ^c	0.3 ± 0.5 ^c	0.1 ± 0.1	0.07 ± 0.2	0	0	0	0	0
<i>Carex boodii</i>		-	-	0.9 ± 1.5	0.7 ± 1.0	3.2 ± 4.9	0.1 ± 0.2	0.1 ± 0.2	0.1 ± 0.2	0.4 ± 0.7	1.0 ± 1.5
<i>Carex petasata</i>		-	-	0.2 ± 0.2	0	0.3 ± 0.3	0	0	0	0	0
<i>Carex geyeri</i>		-	-	2.3 ± 3.8	1.1 ± 1.9	3.7 ± 5.1	3.4 ± 2.1	4.4 ± 2.4	4.6 ± 3.0 ^d	1.7 ± 1.0 ^d	1.8 ± 1.4
<i>Chamerion angustifolium</i>		0.01 ± 0.01	0	0	0.02 ± 0.05	0.03 ± 0.07	0.3 ± 0.4	0.03 ± 0.03	0.01 ± 0.01	0	0
<i>Elymus trachycaulus v. subsecundus</i>		0.01 ± 0.01	0.03 ± 0.04	0.06 ± 0.1	0.03 ± 0.06	0	0.01 ± 0.01	0.01 ± 0.02	0	0	0.04 ± 0.04
<i>Elymus trachycaulus v. trachycaulus</i>		0.01 ± 0.01	0.01 ± 0.01	0.04 ± 0.03	0.01 ± 0.02	0.02 ± 0.02	0.3 ± 0.2	0.4 ± 0.4	0.4 ± 0.4	0.5 ± 0.4	0
<i>Erigeron speciosus</i>		0	0 ^c	0.3 ± 0.4 ^c	0.2 ± 0.5	0.4 ± 0.8	0	0	0.3 ± 0.4	0	0
<i>Fragaria virginiana</i>		0.06 ± 0.06 ^b	0.4 ± 0.7 ^b	0.2 ± 0.4	0.2 ± 0.3 ^f	2.5 ± 3.3 ^f	0.01 ± 0.01	0.1 ± 0.04	0.1 ± 0.1 ^d	0.5 ± 0.4 ^{d,f}	2.4 ± 1.5 ^f
<i>Geranium viscosissimum</i>		0	0	0.06 ± 0.07	0.2 ± 0.2	0.5 ± 0.8	0	0	0	0	0
<i>Iliamna rivularis</i>		0.1 ± 0.1	0.4 ± 0.7	0.6 ± 1.2	0.3 ± 0.4	1.1 ± 1.6	0.01 ± 0.02	0.04 ± 0.06	0.4 ± 0.6	0	0
<i>Lathyrus ochroleucus</i>		0.06 ± 0.1	0.3 ± 0.4	0.7 ± 0.7	0.5 ± 0.8	0.8 ± 1.3	0.07 ± 0.06	0.05 ± 0.05	0.2 ± 0.2	0.1 ± 0.1	0.05 ± 0.05
<i>Lomatium triternatum</i>		0	0	0.04 ± 0.07	0.05 ± 0.1	4.9 ± 7.5	0	0	0	0 ^f	0.3 ± 0.2 ^f
<i>Mahonia repens</i>		0.01 ± 0.02	0.01 ± 0.02	0.01 ± 0.02	0	0.2 ± 0.4	0.1 ± 0.1	0.1 ± 0.1	0.4 ± 0.3	0.6 ± 0.1 ^f	2.6 ± 1.6 ^f
<i>Osmorhiza occidentalis</i>		0	0	0.1 ± 0.2	0.1 ± 0.2	1.0 ± 2.2	0	0	0	0.05 ± 0.1	0.4 ± 0.6
<i>Pinus contorta</i>		0	0.02 ± 0.05	0.003 ± 0.01	0	1.1 ± 2.5	0.07 ± 0.02	0.05 ± 0.1	0.6 ± 0.6 ^d	2.4 ± 1.7 ^{d,f}	6.9 ± 4.3 ^f
<i>Polygonum douglasii</i>		0.6 ± 0.7	0.5 ± 0.4	0.3 ± 0.2	0.2 ± 0.1 ^f	0 ^f	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.1	0
<i>Pseudotsuga menziesii</i>		0.02 ± 0.02	0.01 ± 0.02	0	0	0.5 ± 1.2	0.05 ± 0.07	0.02 ± 0.02	0.01 ± 0.01	0.1 ± 0.1 ^f	2.2 ± 1.2 ^f
<i>Rosa woodsii</i>		0.1 ± 0.3	0.3 ± 0.4	0.3 ± 0.5	0.8 ± 1.7	0.9 ± 1.1	0	0.01 ± 0.02	0.2 ± 0.4	0.06 ± 0.1	0.03 ± 0.04
<i>Salix bebbiana</i>		0	0	0.07 ± 0.2	0	0.6 ± 0.7	0	0	0	0	0
<i>Shepherdia canadensis</i>		0	0	0	0	0	0.03 ± 0.04	0	0	0.01 ± 0.02 ^f	1.1 ± 0.8 ^f
<i>Symphoricarpos albus</i>		0.2 ± 0.3	0.6 ± 0.6	0.7 ± 0.6	1.4 ± 1.2	4.2 ± 3.7	1.5 ± 1.0	0.7 ± 0.3 ^c	2.9 ± 1.9 ^c	1.9 ± 0.1 ^f	3.9 ± 1.6 ^f
<i>Vicia americana</i>		0.2 ± 0.2 ^b	0.6 ± 0.4 ^b	1.2 ± 1.1	0.5 ± 0.8	0.2 ± 0.4	0.3 ± 0.2	0.1 ± 0.03 ^c	0.5 ± 0.3 ^c	0.2 ± 0.2	0.02 ± 0.04
SELECT EXOTIC SPECIES											
<i>Agrostis stolonifera</i>		0.1 ± 0.1	0.2 ± 0.4	0.06 ± 0.1	0.06 ± 0.1	0.04 ± 0.07	0.1 ± 0.2	0.2 ± 0.2	0.3 ± 0.3	0.02 ± 0.03	0.01 ± 0.02
<i>Alyssum alyssoides</i>		0.01 ± 0.03	0.01 ± 0.01 ^c	0.1 ± 0.1 ^c	0.4 ± 0.7 ^f	1.7 ± 1.8 ^f	0.1 ± 0.1	0.01 ± 0.01	0.1 ± 0.1	0.5 ± 0.5	0.3 ± 0.3
<i>Bromus secalinus</i>		0	0	0.01 ± 0.02	0	0.2 ± 0.5	0	0	0.1 ± 0.1	0	0.1 ± 0.1
<i>Bromus tectorum</i>		0.06 ± 0.1	0.06 ± 0.1	0.05 ± 0.1	2.2 ± 4.9	1.0 ± 2.3	0.02 ± 0.02	0.01 ± 0.02	0.02 ± 0.03 ^d	0.4 ± 0.3 ^{d,f}	0.1 ± 0.1 ^f
<i>Centaurea maculosa</i>		3.0 ± 4.9	1.1 ± 2.0	1.9 ± 2.1	1.4 ± 1.5	3.4 ± 3.8	0.2 ± 0.2	0.3 ± 0.2	0.7 ± 0.6	1.4 ± 1.6	2.1 ± 0.7
<i>Cerastium fontanum</i>		0.1 ± 0.2	0.3 ± 0.4	0.07 ± 0.1	0.003±0.01	0.02 ± 0.05	0.01 ± 0.01	0.02 ± 0.03	0	0	0
<i>Chenopodium album</i>		0.3 ± 0.2	0.3 ± 0.2 ^c	0.1 ± 0.1 ^{cd}	0.02 ± 0.02 ^d	0	0.2 ± 0.2	0.1 ± 0.1 ^c	0.05 ± 0.02 ^c	0.02 ± 0.03	0
<i>Cirsium arvense</i>		0.03 ± 0.03	0.1 ± 0.1	0.05 ± 0.1	0.03 ± 0.08	0.3 ± 0.6	0.2 ± 0.2	0.6 ± 0.5 ^c	0.1 ± 0.1 ^c	0.5 ± 0.8	0.03 ± 0.04
<i>Elymus repens</i>		0	0	0.1 ± 0.2	0	0.9 ± 2.0	0	0	0	0	0
<i>Medicago lupulina</i>		1.7 ± 1.5	2.3 ± 2.8	1.1 ± 1.6 ^d	0.03 ± 0.06 ^d	0.8 ± 1.5	1.1 ± 0.5 ^b	0.2 ± 0.2 ^b	0.3 ± 0.3	0.1 ± 0.1	0.2 ± 0.1
<i>Melilotus officianale</i>		0.7 ± 1.0	0.2 ± 0.3	0.004 ± 0.01	0	0	0.2 ± 0.3	0	0.01 ± 0.01	0	0.1 ± 0.1
<i>Pbleum pratense</i>		4.5 ± 4.6	8.1 ± 6.7	6.0 ± 2.9	5.2 ± 3.8	2.3 ± 0.8	0.7 ± 0.6	1.1 ± 0.9	1.4 ± 1.0 ^d	3.8 ± 1.3 ^d	4.1 ± 1.6
<i>Poa compressa</i>		0.5 ± 0.4	0.8 ± 0.9	1.2 ± 1.0	1.6 ± 1.5	5.1 ± 6.5	0.1 ± 0.1	0.1 ± 0.1	0.4 ± 0.3	1.2 ± 1.1	0.9 ± 0.9
<i>Poa pratensis</i>		1.9 ± 1.2 ^b	4.2 ± 3.5 ^b	2.9 ± 2.5	4.1 ± 3.2	6.5 ± 6.8	0.8 ± 0.5 ^b	1.8 ± 1.6 ^b	1.5 ± 1.4	3.2 ± 2.3 ^f	0.8 ± 0.8 ^f
<i>Taraxacum officinale</i>		0.06 ± 0.1 ^b	0.3 ± 0.3 ^b	0.3 ± 0.5	0.4 ± 0.7	1.2 ± 1.1	0.02 ± 0.02	0.03 ± 0.03 ^c	0.1 ± 0.04 ^c	0.1 ± 0.2	0.2 ± 0.1
<i>Tragopogon dubius</i>		0	0.02 ± 0.03	0.07 ± 0.1	0.3 ± 0.4	1.0 ± 0.9	0	0	0.01 ± 0.02	0.02 ± 0.04 ^f	0.7 ± 0.3 ^f
<i>Trifolium hybridum</i>		1.6 ± 2.8	3.0 ± 5.5	1.2 ± 1.7 ^d	0.1 ± 0.1 ^d	0.07 ± 0.2	1.3 ± 1.8	1.0 ± 1.4	0.6 ± 0.9	0	0
<i>Verbascum thapsus</i>		0.4 ± 0.5	0.7 ± 0.6	0.4 ± 0.6	0.6 ± 1.2	0.1 ± 0.1	0.1 ± 0.2	0.1 ± 0.1 ^c	0.4 ± 0.2 ^c	1.2 ± 1.9	0.2 ± 0.4

Penstemon spp. seed rate includes 88.2 seeds/m² of Penstemon confertus/Iyalli, 3.2 seeds/m² of Penstemon procerus, and 1.7 seeds/m² of Penstemon albertinus.

Table 6. 303-D: Lifeform Canopy Cover ($\pm$ std. dev.) and Ground Cover (%) by Plot on Landtype 26-C, 1996-2015.

b indicates that 1996 and 1997 numbers are significantly different on each plot at the 90% confidence level.

c indicates that 1997 and 1999 numbers are significantly different on each plot at the 90% confidence level.

d indicates that 1999 and 2004 numbers are significantly different on each plot at the 90% confidence level.

f indicates that 2004 and 2015 numbers are significantly different on each plot at the 90% confidence level.

	4020					4021					4022				
	1996	1997	1999	2004	2015	1996	1997	1999	2004	2015	1996	1997	1999	2004	2015
LIFEFORM CANOPY COVER (%)															
Tree	0.04 $\pm$ 0.1	0	0	0	0.1 $\pm$ 0.1	0.04 $\pm$ 0.1	0	0	0	0.01 $\pm$ 0.04	0	0	0	0	0
Shrub	0.2 $\pm$ 0.5	0.5 $\pm$ 1.1	1.2 $\pm$ 3.3	1.9 $\pm$ 2.4 ^f	9.3 $\pm$ 13.5 ^f	0	0	0	0	0.5 $\pm$ 1.5	0.3 $\pm$ 0.5	1.1 $\pm$ 2.4	0.6 $\pm$ 1.0	1.8 $\pm$ 4.9 ^f	9.2 $\pm$ 19.6 ^f
Native grass	34.6 $\pm$ 15.4	35.6 $\pm$ 18.1 ^c	26.0 $\pm$ 16.3 ^{c,d}	10.8 $\pm$ 6.7 ^d	15.2 $\pm$ 12.8	13.8 $\pm$ 7.2	16.3 $\pm$ 10.6	16.8 $\pm$ 7.4 ^d	8.2 $\pm$ 6.5 ^{d,f}	5.3 $\pm$ 4.4 ^f	20.9 $\pm$ 12.1	25.8 $\pm$ 11.0 ^c	15.4 $\pm$ 6.5 ^{c,d}	10.5 $\pm$ 8.6 ^{d,f}	19.2 $\pm$ 19.4 ^f
Native forb	2.9 $\pm$ 3.8 ^b	8.0 $\pm$ 7.7 ^{b,c}	20.2 $\pm$ 12.2 ^{c,d}	27.9 $\pm$ 10.6 ^{d,f}	49.0 $\pm$ 20.5 ^f	4.4 $\pm$ 2.9	4.1 $\pm$ 2.9 ^c	8.8 $\pm$ 6.0 ^{c,d}	19.1 $\pm$ 11.8 ^{d,f}	34.5 $\pm$ 15.5 ^f	3.4 $\pm$ 6.8	4.4 $\pm$ 4.3	5.1 $\pm$ 4.8 ^d	1.5 $\pm$ 2.7 ^{d,f}	10.0 $\pm$ 10.1 ^f
Exotic grass	3.2 $\pm$ 3.1 ^b	8.0 $\pm$ 7.4 ^{b,c}	15.2 $\pm$ 8.1 ^c	14.0 $\pm$ 6.6 ^c	20.2 $\pm$ 13.9 ^f	16.3 $\pm$ 6.8 ^b	29.8 $\pm$ 10.6 ^{b,c}	17.6 $\pm$ 5.4 ^{c,d}	9.7 $\pm$ 5.5 ^d	14.2 $\pm$ 16.1	5.6 $\pm$ 6.4 ^b	11.0 $\pm$ 8.1 ^b	8.5 $\pm$ 4.0 ^d	18.0 $\pm$ 8.6 ^{d,f}	12.9 $\pm$ 9.6 ^f
Exotic forb	8.9 $\pm$ 10.6 ^b	15.9 $\pm$ 16.1 ^{b,c}	6.8 $\pm$ 7.7 ^{c,d}	2.3 $\pm$ 1.8 ^{d,f}	10.8 $\pm$ 10.2 ^f	18.5 $\pm$ 6.7 ^b	1.6 $\pm$ 1.3 ^b	0.8 $\pm$ 2.3 ^d	6.1 $\pm$ 6.8 ^d	3.8 $\pm$ 4.1	1.1 $\pm$ 1.1	1.7 $\pm$ 2.7	2.0 $\pm$ 2.8	1.1 $\pm$ 2.2 ^f	10.7 $\pm$ 8.9 ^f
GROUND COVER (%)															
Basal vegetation	3	4	5	2	5	3	5	5	2	4	3	4	5	3	4
Litter	66	78	88	95	89	63	74	87	94	60	30	59	74	85	72
Moss	1	2	1	1	1	1	4	3	2	28	6	1	3	1	3
Bare soil	14	1	<1	<1	<1	21	5	1	<1	5	36	13	6	3	10
Gravel	3	5	1	<1	<1	5	6	1	<1	1	15	14	4	2	6
Rock	9	8	3	2	3	5	7	3	2	2	7	6	5	4	6
Wood	4	3	2	<1	2	<1	<1	<1	<1	0	4	2	3	2	1
Other	0	0	0	0	0	<1	<1	<1	0	0	0	<1	<1	0	0

	6012					6013					6014				
	1996	1997	1999	2004	2015	1996	1997	1999	2004	2015	1996	1997	1999	2004	2015
LIFEFORM CANOPY COVER (%)															
Tree	0.1 $\pm$ 0.2	0.04 $\pm$ 0.1	0.02 $\pm$ 0.1	0	0	0.02 $\pm$ 0.1	0.1 $\pm$ 0.6	0.02 $\pm$ 0.1	0 ^f	9.8 $\pm$ 25.7 ^f	0.04 $\pm$ 0.1	0	0	0	0
Shrub	0.04 $\pm$ 0.1	0.2 $\pm$ 0.6	0.6 $\pm$ 2.2	0	0.3 $\pm$ 1.6	0.9 $\pm$ 3.0	2.0 $\pm$ 3.0	2.9 $\pm$ 4.1 ^d	7.3 $\pm$ 11.3 ^d	9.8 $\pm$ 9.9	0.8 $\pm$ 1.2	1.7 $\pm$ 4.1	2.0 $\pm$ 4.2	3.6 $\pm$ 14.9 ^f	11.3 $\pm$ 20.1 ^f
Native grass	17.2 $\pm$ 9.5	17.5 $\pm$ 12.2 ^c	12.3 $\pm$ 5.8 ^{c,d}	8.8 $\pm$ 4.3 ^{d,f}	19.2 $\pm$ 10.4 ^f	28.5 $\pm$ 14.6 ^b	34.6 $\pm$ 9.5 ^b	34.4 $\pm$ 7.8 ^d	13.9 $\pm$ 6.7 ^{d,f}	21.3 $\pm$ 12.5 ^f	17.3 $\pm$ 11.8 ^b	26.9 $\pm$ 11.4 ^{b,c}	17.5 $\pm$ 10.4 ^{c,d}	6.4 $\pm$ 8.4 ^d	5.3 $\pm$ 5.9
Native forb	4.5 $\pm$ 2.7 ^b	10.7 $\pm$ 5.7 ^{b,c}	16.6 $\pm$ 7.2 ^{c,d}	1.0 $\pm$ 2.1 ^d	1.5 $\pm$ 2.1	2.3 $\pm$ 2.3 ^b	5.5 $\pm$ 6.1 ^{b,c}	14.5 $\pm$ 17.3 ^{c,d}	20.1 $\pm$ 12.4 ^{d,f}	30.7 $\pm$ 16.0 ^f	5.4 $\pm$ 5.6	4.0 $\pm$ 2.3 ^c	11.9 $\pm$ 10.7 ^{c,d}	2.9 $\pm$ 3.0 ^d	5.3 $\pm$ 10.2
Exotic grass	13.4 $\pm$ 11.1	17.8 $\pm$ 11.4 ^c	8.5 $\pm$ 4.6 ^{c,d}	15.1 $\pm$ 8.0 ^d	20.9 $\pm$ 16.4	0.5 $\pm$ 2.0	0.3 $\pm$ 0.3	0.6 $\pm$ 0.9 ^d	1.8 $\pm$ 2.1 ^d	3.1 $\pm$ 3.6	2.9 $\pm$ 3.4 ^b	10.7 $\pm$ 10.1 ^b	9.4 $\pm$ 7.9 ^d	20.3 $\pm$ 11.5 ^d	25.0 $\pm$ 17.8
Exotic forb	13.7 $\pm$ 7.0	15.7 $\pm$ 14.6	11.1 $\pm$ 6.7 ^d	1.3 $\pm$ 1.8 ^{d,f}	13.5 $\pm$ 20.6 ^f	2.9 $\pm$ 6.1	1.8 $\pm$ 2.2	2.0 $\pm$ 3.1	2.1 $\pm$ 2.5 ^f	5.8 $\pm$ 6.9 ^f	2.8 $\pm$ 3.7 ^b	8.3 $\pm$ 10.1 ^b	7.3 $\pm$ 8.5	8.1 $\pm$ 13.4	7.0 $\pm$ 7.7
GROUND COVER (%)															
Basal vegetation	3	4	6	2	5	3	4	7	2	5	3	4	5	1	3
Litter	41	60	80	88	69	25	68	74	87	71	25	57	72	76	53
Moss	3	2	3	4	20	8	1	5	3	5	2	2	2	7	10
Bare soil	16	5	2	1	1	38	6	3	2	6	50	14	9	5	22
Gravel	19	15	1	1	1	13	12	4	2	6	14	15	5	4	9
Rock	18	13	8	6	4	8	7	6	4	7	5	4	4	4	2
Wood	<1	0	<1	0	0	2	2	1	1	0	2	5	2	1	1
Other	0	0	<1	0	0	0	<1	<1	0	0	0	0	<1	0	0

Table 7. 303-D: Lifeform Canopy Cover ($\pm$ std. dev.) and Ground Cover (%) by Plot on Landtype 26-L-S, 1996-2015.

b indicates that 1996 and 1997 numbers are significantly different on each plot at the 90% confidence level.

c indicates that 1997 and 1999 numbers are significantly different on each plot at the 90% confidence level.

d indicates that 1999 and 2004 numbers are significantly different on each plot at the 90% confidence level.

f indicates that 2004 and 2015 numbers are significantly different on each plot at the 90% confidence level.

	4023					4024				
	1996	1997	1999	2004	2015	1996	1997	1999	2004	2015
LIFEFORM CANOPY COVER (%)										
Tree	0.1 $\pm$ 0.3	0	1.2 $\pm$ 5.3	1.8 $\pm$ 7.4 ^f	16.1 $\pm$ 32.3 ^f	0.1 $\pm$ 0.4	0.02 $\pm$ 0.1	0	3.1 $\pm$ 13.8	4.4 $\pm$ 10.6
Shrub	3.4 $\pm$ 5.9	1.8 $\pm$ 3.7	3.0 $\pm$ 5.3	3.2 $\pm$ 4.5 ^f	22.1 $\pm$ 26.4 ^f	1.1 $\pm$ 1.5	1.2 $\pm$ 2.9 ^c	5.6 $\pm$ 10.8 ^c	3.4 $\pm$ 5.4 ^f	24.8 $\pm$ 26.8 ^f
Native grass	21.4 $\pm$ 11.6 ^b	14.8 $\pm$ 5.7 ^b	12.4 $\pm$ 5.4	10.8 $\pm$ 7.3	7.4 $\pm$ 7.1	22.1 $\pm$ 12.2	24.3 $\pm$ 9.9	20.8 $\pm$ 8.3 ^d	11.7 $\pm$ 7.7 ^d	10.7 $\pm$ 12.8
Native forb	4.8 $\pm$ 6.8	3.1 $\pm$ 4.2 ^c	5.9 $\pm$ 4.5 ^c	7.6 $\pm$ 7.9 ^f	12.1 $\pm$ 10.7 ^f	4.0 $\pm$ 4.1 ^b	2.2 $\pm$ 3.3 ^{b,c}	7.5 $\pm$ 9.0 ^c	4.9 $\pm$ 7.3	7.5 $\pm$ 7.9
Exotic grass	0.3 $\pm$ 1.1	0.3 $\pm$ 0.5 ^c	0.8 $\pm$ 1.1 ^{c,d}	2.4 $\pm$ 2.5 ^d	2.9 $\pm$ 4.4	1.4 $\pm$ 2.8	2.1 $\pm$ 3.2	3.2 $\pm$ 1.8 ^d	14.4 $\pm$ 11.3 ^d	9.7 $\pm$ 7.4
Exotic forb	2.9 $\pm$ 4.9 ^b	1.0 $\pm$ 2.3 ^b	1.5 $\pm$ 2.4	1.4 $\pm$ 1.8 ^f	3.5 $\pm$ 3.8 ^f	2.5 $\pm$ 2.4	2.3 $\pm$ 4.5	1.9 $\pm$ 1.8	2.2 $\pm$ 3.0 ^f	6.1 $\pm$ 6.8 ^f
GROUND COVER (%)										
Basal vegetation	3	2	3	2	3	3	3	4	3	3
Litter	15	28	45	33	47	18	39	57	70	65
Moss	<1	1	4	3	6	<1	1	2	9	5
Bare soil	46	25	18	41	17	54	25	15	10	13
Gravel	26	33	18	15	18	14	22	13	5	9
Rock	6	7	8	6	4	7	9	6	4	2
Wood	2	4	4	2	4	3	1	3	1	3
Other	0	0	0	0	0	0	0	0	0	0

	6015					6016				
	1996	1997	1999	2004	2015	1996	1997	1999	2004	2015
LIFEFORM CANOPY COVER (%)										
Tree	0.1 $\pm$ 0.4	0.2 $\pm$ 0.7	1.2 $\pm$ 5.3	4.8 $\pm$ 19.2 ^f	10.0 $\pm$ 21.4 ^f	0.2 $\pm$ 0.6	0.1 $\pm$ 0.2	0.1 $\pm$ 0.6	0.3 $\pm$ 1.3 ^f	7.0 $\pm$ 14.6 ^f
Shrub	5.4 $\pm$ 7.1 ^b	1.8 $\pm$ 3.2 ^{b,c}	9.0 $\pm$ 14.4 ^{c,d}	4.4 $\pm$ 7.2 ^{d,f}	24.5 $\pm$ 24.6 ^f	0.9 $\pm$ 1.6	0.5 $\pm$ 0.6 ^c	1.8 $\pm$ 3.1 ^c	2.9 $\pm$ 4.3 ^f	16.4 $\pm$ 30.9 ^f
Native grass	25.7 $\pm$ 13.5	20.0 $\pm$ 14.3	15.8 $\pm$ 8.3	15.8 $\pm$ 15.0	12.9 $\pm$ 15.3	13.5 $\pm$ 11.6	13.5 $\pm$ 10.2	14.7 $\pm$ 7.1 ^d	9.2 $\pm$ 6.3 ^{d,f}	5.0 $\pm$ 5.4 ^f
Native forb	2.5 $\pm$ 5.5	1.2 $\pm$ 1.7 ^c	3.6 $\pm$ 5.8 ^c	6.8 $\pm$ 7.0	4.8 $\pm$ 7.9	1.4 $\pm$ 1.4	2.5 $\pm$ 5.3 ^c	5.0 $\pm$ 5.9 ^c	6.0 $\pm$ 8.0 ^f	12.7 $\pm$ 17.4 ^f
Exotic grass	1.8 $\pm$ 6.3	3.5 $\pm$ 7.3	1.5 $\pm$ 3.2 ^d	7.1 $\pm$ 7.2 ^{d,f}	3.7 $\pm$ 4.3 ^f	2.8 $\pm$ 4.3 ^b	6.6 $\pm$ 8.4 ^b	8.2 $\pm$ 7.4	9.9 $\pm$ 6.3 ^f	7.0 $\pm$ 4.9 ^f
Exotic forb	0.8 $\pm$ 2.3	2.0 $\pm$ 3.4	2.1 $\pm$ 2.7 ^d	7.2 $\pm$ 14.5 ^{d,f}	2.4 $\pm$ 3.4 ^f	7.7 $\pm$ 8.2	4.3 $\pm$ 6.6	3.6 $\pm$ 5.3	4.3 $\pm$ 8.8	3.7 $\pm$ 5.9
GROUND COVER (%)										
Basal vegetation	3	3	4	2	3	2	3	4	2	3
Litter	13	28	57	53	46	11	37	59	71	72
Moss	<1	<1	1	2	1	<1	1	2	8	3
Bare soil	54	28	18	26	19	55	25	12	5	8
Gravel	21	30	11	10	23	22	28	12	5	9
Rock	7	9	8	6	6	7	6	6	5	4
Wood	2	1	1	2	3	2	3	5	4	1
Other	0	0	<1	<1	0	0	<1	0	0	0

III. PHASE VI MONITORING: GOING-TO-THE-SUN ROAD

A. BACKGROUND AND PURPOSE

In July 2007, a 10-year rehabilitation project for the Going to the Sun Road (GTSR) was initiated, funded by Federal Highway dollars. Phase VI of the project, including the roadside from West Tunnel to Haystack Creek, began in 2007 and continued into 2008. Construction during this phase included installation of retaining walls, culverts and drains, as well as base stabilization. Additionally, a day-use and vista area was created across from the “Road Camp” area on the south side of the road. Elevation for this phase of the GTSR Rehabilitation Project ranges from approximately 4,400 feet to 5,230 feet.

A species list was created for this segment of road in 2007 which directed seed collection. Disturbance created from construction of this phase was revegetated in June 2010. Five roadside sites or turnouts, estimated at 18,732 ft², in phase VI were planted, seeded, and provided with fencing to deter trampling. Several of these sites were planted with significant plant material and were only lightly seeded with a forb, shrub, and grass mix (Table 8). Others had less planted material and were seeded more heavily with the same seed mix. In all turnout areas that were seeded, the soil was scarified and seeds were hand raked into the ground. All roadside edges that were disturbed throughout phase VI, totaling at 87,120 ft², were then hydroseeded with the same seed mix.

In 2012, the turnout at mile 26.25, east of Alder Creek (containing plot 2), was planted with supplemental material (Table 9) due to the fact that visitors were climbing over the guardrail and trampling the revegetation to take photographs on a large platform rock that was purposefully put here. The area was also seeded using the remaining seed mix from phase VI (Table 8). In 2013, the same turnout was determined to be too small and was enlarged for visitor safety, resulting in a smaller revegetation area and reduced the size of plot 2. Fortunately, the bare, trampled areas of this plot were incorporated into the parking surface of the turnout, resulting in no bare areas in the plot and no need for further revegetation. All turnouts now have either guardrail fences or barrier rocks to prevent people from walking on the revegetated area.

Table 8. GTSR Phase VI: List of seeded species and their seed rates

Species	Grams of seeds	Seeds/ft ²	Acc. #
Forbs/Shrubs			
<i>Achillea millefolium</i>	73g	5 seeds/ft ²	9054522, 9054562, 9057899, 9076137
<i>Chamerion angustifolium</i>	28g	5 seeds/ft ²	9087363, 9082171
<i>Eurybia conspicua</i>	138g	5 seeds/ft ²	9081946, 9087433
<i>Fragaria spp.</i>	1.2g	trace/ft ²	09-002
<i>Geum macrophyllum</i>	261g	5 seeds/ft ²	9087654
<i>Monarda fistulosa</i>	6.11g	0.2 seeds/ft ²	9088010, 9088080
<i>Penstemon confertus</i>	39.0g	4 seeds/ft ²	9057993
<i>Penstemon hyalii</i>	29.78g	0.3 seeds/ft ²	9063300, 9057994
<i>Solidago canadensis</i>	32.5g	5 seeds/ft ²	9081611
<i>Spiraea betulifolia</i>	26.8g	0.8 seeds/ft ²	9078402
Grass/Sedge:			
<i>Carex pachystachya</i>	532g	seed weight estimated at 4900 seeds/g 30 seeds/ft ²	9078645
<i>Carex rossii</i>	119g	seed weight estimated at 2500 seeds/g 3.41 seeds/ft ²	9088095
<i>Elymus glaucus</i>	5866g	20 seeds/ft ²	9087927
<i>Elymus trachycaulus</i>	5462g	20 seeds/ft ²	cultivar Revenue
<i>Bromus carinatus</i>	9469g	20 seeds/ft ²	cultivar Garnet
<i>Festuca occidentalis</i>	1136g	10 seeds/ft ²	cultivar

Table 9. GTSR Phase VI: Plants Added to Turnout Areas, 2012.

Species	Number of plants
<i>Betula papyifera</i>	10
<i>Populus balsamifera</i>	10
<i>Arctostaphylos uva-ursi</i>	10
<i>Cornus sericea</i>	15
<i>Holodiscus discolor</i>	7
<i>Paxistima myrsinites</i>	7
<i>Rubus parviflorus</i>	10
<i>Salix scouleriana</i>	14
<i>Spiraea betulifolia</i>	7
<i>Symphoricarpos albus</i>	10
<i>Anaphalis margaritacea</i>	7
<i>Eurybia conspicua</i>	21
<i>Fragaria virginiana</i>	1
<i>Maianthemum stellatum</i>	10
<i>Penstemon confertus</i>	35
<i>Solidago canadensis</i>	21
<i>Symphytotrichum laeve</i>	10
<i>Carex pachystachya</i>	21
Total plants	226

B. METHODS

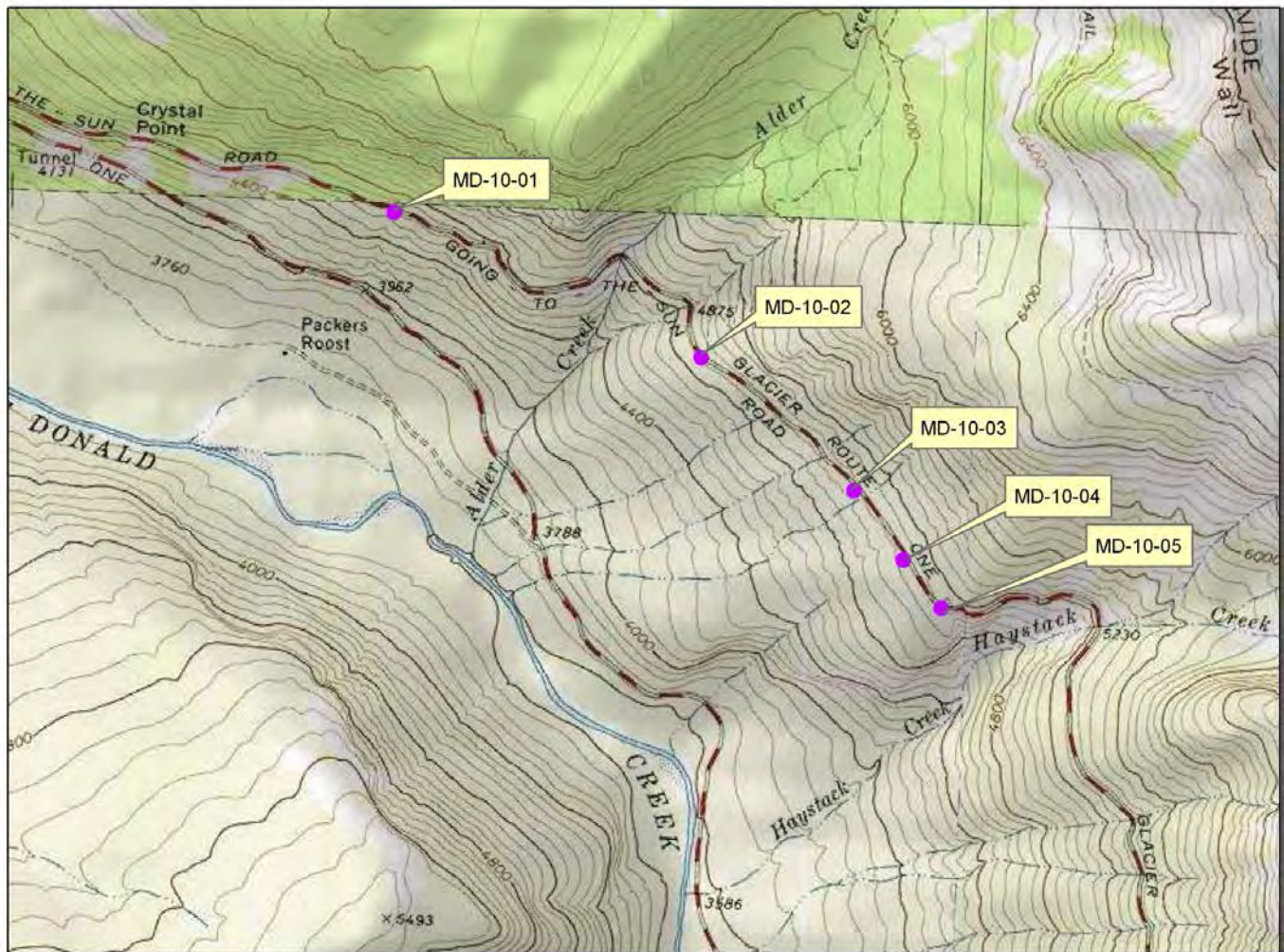
Five monitoring plots were established in September 2010, one at each site that was planted with nursery stock (Figure 10). Due to the narrow width of reseeded roadside on the remaining portion of the project, no additional plots were established to track reseeded road edge areas. Plots are not permanently marked and the size and shape of plots were determined by site parameters (Table 10). Most plots are located behind wood fencing and vary in width.

Plots were evaluated using Level II protocol. All plants within plots were identified to species and given ocular cover estimates. All plots have been monitored in 2011, 2012, 2013 and 2015 at years 1, 2, 3 and 5 after restoration.

Table 10. GTSR Phase VI: Plot Dimensions and Locations.

Plot Number	Plot dimensions	UTM N	UTM E
MD-10-01	24 m x 2 m	5403348	295945
MD-10-02	35 m x 3 m	5402887	296917
MD-10-03	50 m x 2 m	5402469	297398
MD-10-04	25 m x 4 m	5402249	297553
MD-10-05	18 m x 3 m	5402096	297673

Figure 10. GTSR Phase VI: Location of Plots



C. RESULTS

Cover of native species, as well as overall cover in plots, was relatively high at five years post planting. In 2015, average vegetative cover across plots was 74%, increasing by 22% over the course of the last two years. This was almost exclusively due to increases in native cover. Overall native species cover increased by 20%, while exotic cover increased only 2% over the past two years (Figure 11). Overall exotic cover remained low at 7%. Low exotic species cover can be attributed to diligent weeding by the revegetation and monitoring crews, as well as a consistent regime of roadside herbicide application.

Trends among lifeforms continued to be encouraging. All native lifeforms increased in average cover over the past three monitoring events (Figure 12). After a slight decline of both exotic forbs and exotic grasses from 2011 to 2012, both have increased slightly each monitoring event since 2012. Exotic plants have, on average, increased at a lower rate than native species, however. Native grasses have shown the greatest increase of all lifeforms since the last monitoring event, increasing by 7% since 2013 (Figure 12). Up until this monitoring event, the largest increase in lifeform cover had been from native forbs. Native forbs continue to show good progress, increasing by 6% since 2013, and have remained the lifeform with the highest cover as a whole in this project. Native tree and shrub cover increased by 3% and 4%, respectively, since 2013.

Seeded material had begun to establish by 2011 and most species have continued to increase through 2015. *Elymus glaucus* and *Solidago canadensis* were the most successful seeded species, increasing in cover in most plots (Table

13). *Bromus carinatus*, *Elymus trachycaulus*, *Carex* spp., *Achillea millefolium* and *Geum macrophyllum* have also been successful seeded species.

Figure 11. GTSR Phase VI: Percent Native vs. Exotic Cover for All Plots, 2010-2015.

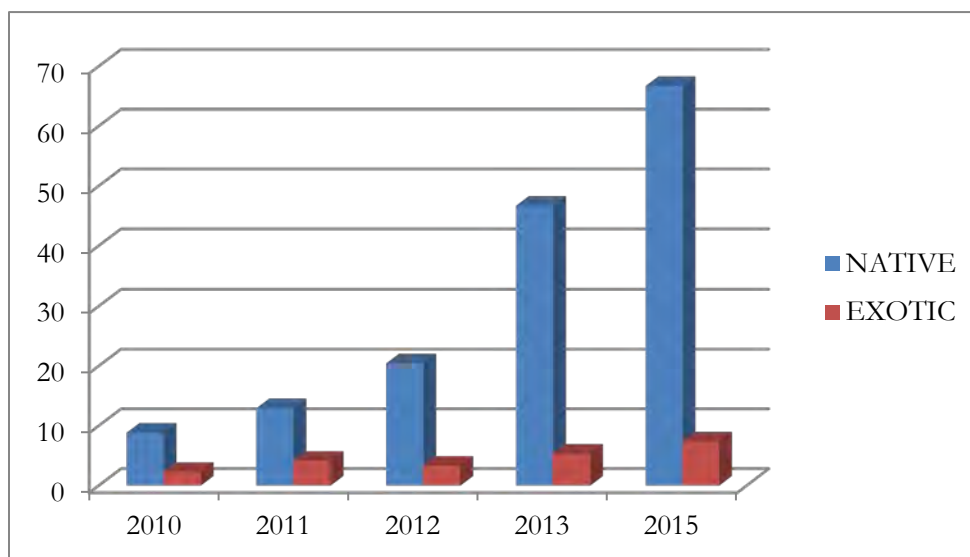


Figure 12. GTSR Phase VI: Percent Ocular Cover of Lifeforms for All Plots, 2010-2015.

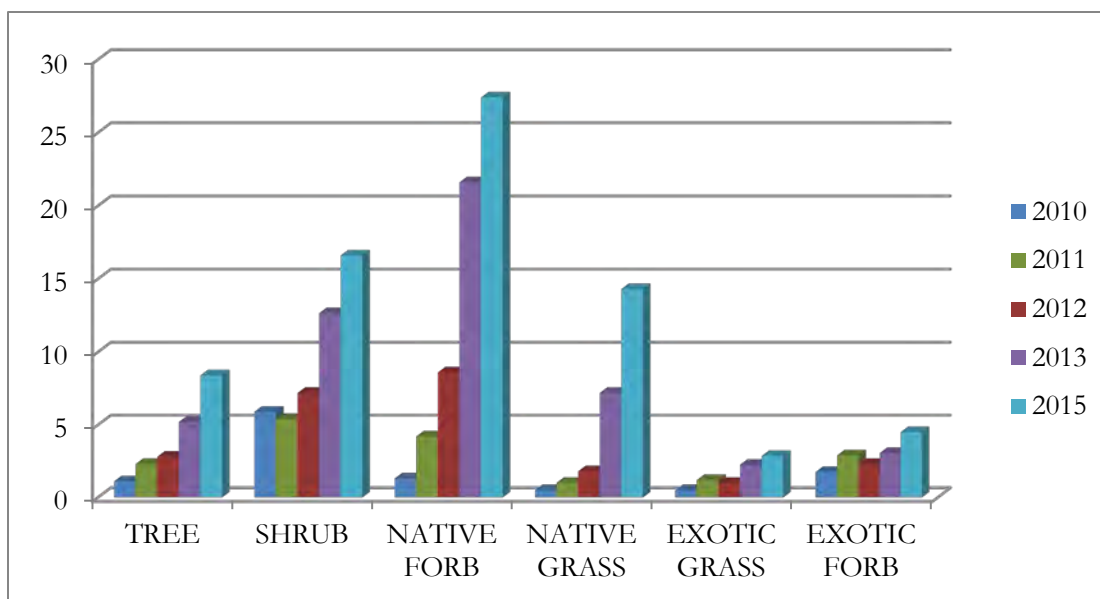


Table 11. GTSR Phase VI: Percent Ocular Cover of Lifeforms for All Plots, 2010 – 2015.

MD-10-01					
	2010	2011	2012	2013	2015
<i>TREE</i>	0.5	3	1	1	2
<i>SHRUB</i>	14	15	11	11	11
<i>NATIVE FORB</i>	0.5	1	1	2	2
<i>NATIVE GRASS</i>	0.5	0.5	0.5	1	0.5
<i>EXOTIC GRASS</i>	0.5	1	0.5	0.75	0.75
<i>EXOTIC FORB</i>	1	0.5	0.5	1	1
TOTAL COVER	17	21	14.5	16.75	17.25
MD-10-02					
	2010	2011	2012	2013	2015
<i>TREE</i>	0	0	1	2	3
<i>SHRUB</i>	0.5	1	5	12	13
<i>NATIVE FORB</i>	1	3	3	27	34
<i>NATIVE GRASS</i>	0.5	1	1	4	11
<i>EXOTIC GRASS</i>	0.5	1	1	1.25	2.25
<i>EXOTIC FORB</i>	3	8	4	1	5
TOTAL COVER	5.5	14	15	47.25	68.25
MD-10-03					
	2010	2011	2012	2013	2015
<i>TREE</i>	0.5	0.5	2	3	10
<i>SHRUB</i>	9	5	11	16	25
<i>NATIVE FORB</i>	1	5	10	23	33
<i>NATIVE GRASS</i>	0.5	1	3	12	22
<i>EXOTIC GRASS</i>	0.5	1	2	2.25	3
<i>EXOTIC FORB</i>	0.75	2	3	3	4
TOTAL COVER	12.25	14.5	31	59.25	97
MD-10-04					
	2010	2011	2012	2013	2015
<i>TREE</i>	2.5	3	5	15	21
<i>SHRUB</i>	4	3	4	14.25	15
<i>NATIVE FORB</i>	2	5	9	29	32
<i>NATIVE GRASS</i>	0.5	2	0.5	7	18
<i>EXOTIC GRASS</i>	0.5	2	0.5	5	7
<i>EXOTIC FORB</i>	1	3	3	9	12
TOTAL COVER	10.5	18	22	79.25	105
MD-10-05					
	2010	2011	2012	2013	2015
<i>TREE</i>	2	5	5	5	6
<i>SHRUB</i>	2	3	5	10	19
<i>NATIVE FORB</i>	2	7	20	27	36
<i>NATIVE GRASS</i>	0.5	0.5	4	12	20
<i>EXOTIC GRASS</i>	0.5	1	1	2	1.25
<i>EXOTIC FORB</i>	3	1	1	1.25	0.5
TOTAL COVER	10	17.5	36	57.25	82.75

Table 12. GTSR Phase VI: Average Percent Ocular Cover of Lifeforms for All Plots, 2010 – 2015.

	2010	2011	2012	2013	2015
<i>TREE</i>	1.1	2.3	2.8	5.2	8.4
<i>SHRUB</i>	5.9	5.4	7.2	12.65	16.6
<i>NATIVE FORB</i>	1.3	4.2	8.6	21.6	27.4
<i>NATIVE GRASS</i>	0.5	1	1.8	7.2	14.3
<i>EXOTIC GRASS</i>	0.5	1.2	1	2.25	2.85
<i>EXOTIC FORB</i>	1.75	2.9	2.3	3.05	4.5
OVERALL AVERAGE	11.05	17	23.7	51.95	74.05

It should be noted that at least the edges of all plots had been recently mowed at the time of monitoring in 2015. Species in these mowed areas were difficult to ID and some areas were inundated with gravel. Additionally, most areas had also been sprayed with herbicide. Subsequently, species that had been previously reported for this project and were missing in 2015 could have been eliminated by mowing, buried by gravel, killed by herbicide, or rendered unidentifiable by mowing, especially in the case of grasses. Other species may have died back due to natural causes.

Trees: Tree cover exhibited the largest increase since the start of the project, increasing from 5% cover in 2013 to 8% cover in 2015. Continuing the trend in the past, this increase was mostly due to increases in cover of *Populus balsamifera*, much of which was planted. This species increased in cover in four plots and was present with 10% to 20% cover in two areas. *Abies lasiocarpa*, *Betula papyrifera*, *Picea engelmannii* and *Pseudotsuga menziesii* remained relatively stable in the plots where they were planted, although there was one dead tree of unknown species in plot 5. *Picea engelmannii* disappeared from plot 1 where it had been present with trace cover since 2012.

Shrubs: Shrub cover, estimated at 17%, continued to have the second highest cover of all the lifeforms behind native forbs. Shrub cover increased by 4% since 2013. Most plots remained relatively stable in shrub cover, although plots 3 and 5 exhibited notable increases. The increase in shrub cover in plot 3 was mainly due to a 6% rise in the cover of *Cornus sericea*, while the increase in plot 5 was largely due to a 5% increase of *Rosa woodsii*, both planted species. *Cornus sericea* is one of the most successful planted species in the project. Smaller increases of several other species also contributed to the overall rise of shrub cover in these plots.

Native forbs: Native forb cover remained the most successful lifeform overall in this project with 27% average cover (Figure 12). Cover increased by 6% since 2013 and native forbs continue to dominate the vegetation, similar to the last several years. All plots except plot 1 saw an increase in native forbs since 2013. Plot 1 is a less vegetated plot, consisting mostly of shrubs, and had only 2% native forb cover. Native forbs in all other plots, however, increased more substantially from 3 to 9%.

Most seeded and planted species continued to do well in this project. *Solidago canadensis* was the most successful native forb species this year, increasing by 3% to 5% in three plots for a total of 8% to 12% cover. This species, which was both seeded and planted in this project, reproduces by rhizomes after becoming established and can therefore increase quickly. It may also experience less incidental loss to herbicide drift compared to other native species, since this species tends to form obvious clumps that maintain clear boundaries from targeted weeds. *Symphytotrichum laeve*, a planted species, increased in cover by 2% to 3% in two plots. It was noted that in several areas, this species had been mowed and would likely have been much more successful had mowing not occurred. *Monarda fistulosa*, a seeded species, had not established very well in this project until this year when it increased in cover in all plots by an average of 1%. *Iliamna rivularis*, a planted species, increased in cover by 1% to 2% in two plots, while at the same time decreased by 1% in two plots.

Other seeded and planted species have generally maintained their cover. Both species of *Fragaria*, which were seeded and planted, maintained and increased in cover by 1% in several plots. Covers of *Penstemon confertus* and *Penstemon hyallii*, which were both seeded and planted, remained constant in most plots, although did increase slightly in one plot. In the past, *Achillea millefolium* typically had one of the highest native forb covers. In the last two years, however, this species remained relatively constant in cover in most plots and decreased by 5% in plot 4. This is potentially due to herbicide application along road edges, as Milestone is typically used that commonly targets species in the aster family. Mowing of roadside edges may also be preventing this species from increasing. Seeded *Geum macrophyllum* also maintained trace to 1% cover in most plots, but did decrease by 2% in plot 5. *Chamerion angustifolium* mostly retained trace cover where it was seeded.

The highest cover observed for a single native forb species was 18% for *Artemisia ludoviciana*, a naturally regenerating species. A few other seeded species, including *A. millefolium* and *F. virginiana*, also had notable covers that range from 5% to 10%. At five years after planting, a few native forb species continued to recruit to plots and contribute cover, including *Heracleum sphondylium*, *Anaphalis margaritacea*, *Castilleja miniata* and *Equisetum arvense*. Overall, native forb diversity remains high, contributing to the high overall native forb cover that continues to increase.

Native grasses: While native grasses only increased slightly the first few years, average native grass cover has been increasing at a much higher rate since 2012 (Figure 12). This reiterates the importance of planting material initially to establish some ground cover, while seeding species to more gradually increase native diversity. Native grasses continue to be the lifeform with the third highest cover, although native grasses had the highest growth rate of all lifeforms since 2013. Average cover of native grasses has doubled since 2013 and now averages 14% across plots. The largest increases came from *Elymus glaucus* which increased in three of the five plots by 5-6%. *Carex* species, which have only been present with less than 1% cover prior to 2015, increased in four of the plots by 3-4%. This underscores the potential importance of sedge species over time in restoration areas. It should be noted that several species of sedge were present in most plots but were lumped together due to difficulty in identifying them to species. Sedge plants had either not matured to a point where they had seed heads, or had been mowed and were not identifiable to species. *Bromus carinatus* also increased in two of the plots by 1-2%, while *Elymus trachycaulus* increased in one plot by 4%. Currently the species that has the highest cover of any native grass is *E. glaucus* with 15% cover in one plot and 12% in two other plots. There continues to be little natural regeneration of other native grass species, reiterating the importance of seeding native grasses along this road corridor.

Exotic grasses: Average cover of exotic grasses remains low on this project at 3%, continuing to be the lowest cover of all lifeforms on the project. Additionally, exotic grasses have increased at the slowest rate of any lifeform since 2013, with an increase of less than 1%. Diligent weeding has facilitated this trend, which is extremely important as rhizomatous non-native grasses have a great capacity to spread rapidly. Exotic grasses increased slightly in three of the five plots, but actually decreased slightly or remained the same in the other two plots. The increases are due mostly to small increases of *Agrostis stolonifera*, *Phleum pratense*, and *Poa pratensis* instead of an increase in the diversity of non-native grasses that are naturally recruiting to the planted areas. *Bromus tectorum*, likely brought in on construction equipment, continues to be a threat to this area. *B. tectorum* remains in three of the five plots, but with only trace cover due to diligent hand pulling. With the overall low cover, attempts should continue to control all exotic grass species.

Exotic forbs: Exotic forb cover remains a low 3% and continues to be the second lowest lifeform cover in project. While there has been a steady increase in exotic forbs over time, it has remained low at 1%. Three of the five plots had 1% to 4% increases in exotic forb cover, while cover in one plot remained the same and cover in one plot decreased slightly. *Medicago lupulina* and *Melilotus officinale* continued to be the species that increased the most, although these species only increased in cover in one plot by 3% and 2%, respectively. While there continues to be a relatively high diversity of exotic forb species within the project, covers of most species remain low. Herbicide application in concert with hand pulling likely is keeping many of these species at bay.

Noxious weeds are present in all plots. Although most noxious weeds only have trace cover, *Cirsium arvense* and *Cynoglossum officinale* are present with 1% cover in plot 3, while *Hypericum perforatum* and *Leucanthemum vulgare* are present with 1% cover in plot 4. Hand pulling and herbicide application have been helpful reducing these weeds, although several species have returned to plots after removal. For example, plot 1 had no noxious weed cover in 2012 after *Centaurea stoebe*, *H. perforatum*, and *L. vulgare* were removed through hand pulling, but *C. stoebe* and *L. vulgare* returned in 2015. Additionally, some noxious weeds are recruiting to new areas, as seen on plot 3 with the introduction of *H. perforatum*. While all of these noxious weed species are threats to the success of this project, *L. vulgare* is the most ubiquitous as it is present in all plots. *Hypericum perforatum* is also of concern due to its constant and increasing presence along the GTSR corridor. *Linaria vulgaris* is another serious threat to this area, even though it was only found in one plot in 2015. This species is on the rise park-wide and proves extremely difficult to control. Hand pulling is not very effective due to its deep roots and rhizomatous nature and the Park has not found a safe, effective herbicide to control this noxious weed. Herbicide application and hand pulling should continue wherever possible, however, to reduce overall noxious weed cover in this area.

D. CONCLUSIONS AND RECOMMENDATIONS

Survival of planted material has continued to be high five years after planting. With increases of vegetation in all plots, most roadside areas within this project are quite aesthetically pleasing to visitors. Most planted trees are surviving and are showing growth, most notably *Populus balsamifera*. Shrubs, although not the dominant lifeform in

monitoring plots, are showing high survival as well as some growth. *Cornus sericea* and *Rosa woodsii* had notable increases in cover. Most planted native forbs are surviving and many are increasing in cover.

Seeded species, some of which were also planted, are largely the dominant plants within the project, clearly indicating the importance of seeding along these upper road sections. Seeded species increased dramatically over the past year, greatly increasing both the native forb and native grass cover. Several seeded species are slow to establish, but by the third year after planting begin to greatly contribute to overall vegetative cover. Seeded and/or planted forbs *Solidago canadensis*, *Achillea millefolium* and *Symphyotrichum laeve* have the most consistently high cover across all plots, although *Geum macrophyllum*, *Fragaria virginiana*, *Penstemon confertus*, *Fragaria vesca*, *Iliamna rivularis*, *Monarda fistulosa*, and *Penstemon lyallii* each have notable cover on several plots. A few seeded species, such as *I. rivularis*, have taken up to five years to establish in some areas. This continues to illustrate the importance of planted species for initial ground cover as well as seeding a variety of species to more gradually increase cover and diversity. *Elymus glaucus*, *Elymus trachycaulus* and *Bromus carinatus* continue to be successful seeded native grasses with fairly consistent high cover. *Carex* species have emerged as important native grasses after having little more than trace cover prior to five years post planting. Sedges can be important components of restoration projects but may require patience when seeded due to slower germination and growth. Two species that were seeded still have not yet been identified in monitoring plots; these include *Carex rossii* and *Festuca occidentalis*.

Although exotic species cover is still not high at this time, it may become problematic over time if these areas are not consistently weeded and sprayed. While most species of exotic forbs and grasses have very low cover, a few species are slowly increasing. These include exotic grasses *Phleum pratense* and *Poa pratensis* and exotic forbs *Medicago lupulina* and *Melilotus officinale*. Additionally, although not captured in monitoring plots, *Phalaris arundinacea* was observed growing on the roadside within the phase VI revegetation area. This extremely aggressive grass has not been historically present in many areas of the park but since the intensification of road rehabilitation in the last several years, it has been observed in several places including small patches at Logan Pass and larger patches along the Packer's Roost Road. It is highly recommended to eradicate this grass when observed since it is known to rapidly overtake sensitive areas such as wetlands.

Montana Priority 2B Noxious Weeds *Centaurea stoebe* (*Centaurea maculosa*), *Cirsium arvense*, *Cynoglossum officinale*, *Hypericum perforatum*, *Leucanthemum vulgare* and *Linnaea vulgaris* were all found in at least one plot and several species were found in two to five plots. While none of these species have more than 1% cover at this time, some species have increased in cover or spread to new plots since the last monitoring event. The spread of weeds across this project should be closely monitored. Herbicide application should continue in this area to reduce noxious weeds. Frequent hand pulling of exotic species is also recommended to enhance native species survival.

Plots should be read again in 2020 at year 10 after planting and in 2030 at year 20 after planting. Several road projects have now been monitored twenty years after planting documenting valuable information concerning long-term success of seeded and planted material. This long-term monitoring data continues to improve restoration strategies throughout the park and on the GTSR.

Table 13. GTSR Phase VI: Ocular Canopy Cover of all Species by Plot, 2010-2015.

Species:	MD-10-01						MD-10-02						MD-10-03						MD-10-04						MD-10-05						
	source	2010	2011	2012	2013	2015 ³	source	2010	2011	2012	2013	2015 ³	source	2010	2011	2012	2013	2015 ³	source	2010	2011	2012	2013	2015 ³	source	2010	2011	2012	2013	2015 ³	
TREE	planted?	T	3	1	1	2	planted?	0	0	1-	2	3	planted?	T	T	2	3	10	planted?	2+	3	5	15	21	planted?	2	5	5	5	6	
Abies lasiocarpa	p																			T	T	T	T	T+					T		
Betula papyrifera	p						p							T	T	T	T	T												T	
Picea engelmannii				T	T																						2	5	5	5	4
Populus balsamifera	p	T	3	1	1	2	p			1-	2	3		T	T	1+	3	10		2	3	5	15	20			T	T	T	2	
Pseudotsuga menziesii	p		T	T	T	T														T	T	T	T	T+							
SHRUB	planted?	14	15	11	11	11	planted?	T	1	5	12	13	planted?	9	5	11	16	25	planted?	4	3	4	14+	15	planted?	2	3	5	10	19	
Acer glabrum		T+	1+	1	1	1+					T	T ¹					T	T	p		T	T	T	T		T	T	1	1	2	
Alnus viridis										T+	1	1+		T			T	T+													
Amelanchier alnifolia		T	1	0.5	0.5	1													p												
Arctostaphylos uva-ursi	p	2-	1+	1	1	1	p	T	T	T			p	3-	1	T+	T+	1	p					T ¹			T	T	T	1	
Cornus sericea	p	5	4	3	3	2+	p			1+	3-	2		3	T	1.5	4	10	p	1	1	1	5	5	p	1	1	1+	3	3	
Dasiphora floribunda				T	T ¹													T				T	T					T	T	T	
Holodiscus discolor	p		T	T	T	T ¹				T	T																				
Mahonia repens	p						p	T	T				p	T	T	1-	T+	T								T	T	T+	1	1+	
Paxistima myrsinites	p						p			T				T	T	T	T	T								T	T	T+	T	1	
Prunus virginiana	p						p							T	T	1-	T+	T+													
Ribes viscosissimum		T	T			T ¹		T					p						p												
Rosa woodsii	p						p							2 (other Rosa sp?)		3	5	8+	10					T		p	T+	1	2	3	8
Rosa sp.				T																									T+	T	
Rubus idaeus		T+	1	1	1	1		T	T	1	2	3		T	T	T	T	T	p	T			T	1	1						1
Rubus parviflorus		T+	T+	0.5	0.5	1-	p					T		T	1	0.5	1	1	p	T			T	T	T						
Salix sp.	p	5									T	T							p	2-											
Salix boothii (?)	p																		p		1	2+	7	8							
Salix commutata (?)	p									T	T	1-																			
Salix pseudomonticola	p		3	1	0.5	T													p												
Salix scouleriana	p		T	T	0.5	T				T								T	p												
Salix sitchensis	p		T	T	T	T												T	p												
Sambucus racemosa	r						r	T (regen)	1	2	5	6					T	1									T			1	1
Shepherdia canadensis						T																									
Sorbus scopulina (on edge, not reveg.)																					T	T	T	T							
Spiraea betulifolia	p/s	T	2	1	1-	1-	p/s	T	T	T	T		p/s	T+	T	1-	1	1	p/s	T	T	T	T	T	p/s	T	T	T+	T+	1+	
Symphoricarpos albus		1	1	1	2	2	p			T	T+							T		T+	1	T	1+	1		T	T	T	T+	T+	
NATIVE FORB		T	1	1	2	2		1	3	3	27	34		1	5	10	23	33		2	5	9	29	32		2	7	20	27	36	
Achillea millefolium	s	T	T	T	T+	T	s	T	T	T	1+	1+	s	T	4	4+	5	5	s	T+	3	5	10	5	s	1-	5	6	7	8	
Actaea rubra											out																	T	T	T	
Agoseris aurantiaca																								T (out?)							
Anaphalis margaritacea			T	T	T			T	T	T					T	T	T					T	T+	T+			T	T	1	3	
Angelica arguta											T					T	T	1			T	T	1	1							
Antennaria bonellii	p						p	T	T	T			p	T		T	T								p	T	T	T	T	T	
Antennaria racemosa																		T													
Antennaria rosea									T	T		T+			T	T	T	T										T	T	T	T
Aquilegia flavescens																						T	T	T		T	T	T	T	T	
Arabis drummondii															T	T	T	T				T	T	T							
Arabis hirsuta			T																												
Arabis holboellii									T																						
Artemisia ludoviciana				T	T	T ¹		T	1	1	17	18				T	T	T	T		T	T	1-	2	3				T	T	T

Table 13, continued: GTSR Phase VI: Ocular Canopy Cover of all Species by Plot, 2010-2015.

Species:	MD-10-01						MD-10-02						MD-10-03						MD-10-04						MD-10-05						
	source	2010	2011	2012	2013	2015	source	2010	2011	2012	2013	2015	source	2010	2011	2012	2013	2015	source	2010	2011	2012	2013	2015	source	2010	2011	2012	2013	2015	
NATIVE FORB cont'd																															
Artemisia micbeauxiana																													T	T	
Aster sp.	p	T																													
Brickellia grandiflora																T	T	T											T	T+	T+
Campanula rotundifolia																		T			T	T									
Cardamine pensylvanica								T						T							T										
Castilleja miniata		T		T	T	T ¹					T	T						T			T	T	1	3					T	T	T
Chamerion angustifolium	s	T		T	T		s						s	T			T	T	T	s			T	T	T	s	T	T	T+	1	T
Cirsium hookerianum																T	T	T			T	T	T	T+	T+						
Conyza canadensis																								T					T	T	T
Convolvulus arvensis																							T								
Cryptantha (?) - annual																													T		
Draba nemerosa																													T		T
Epilobium brachycarpum				T		T				T	T	T				T	T	T					T	T							T
Epilobium brachycarpum (wide leaves)			T			T			T			T			T	T	T				T	T	T	T	T			T	T	T	T+
Epilobium sp.								T													T				T						
Equisetum arvense																															1
Erigeron strigosus																														T	
Eurybia conspicua (Aster conspicuus)	s										T	T					T	T						T					T	T	T
Fragaria vesca	s			T	T	T	s	T		T	T	T	p/s	T	T	T	1	2	p/s	T	T	T	1	1+	s				T	T	1
Fragaria virginiana	p/s	T	T	T	T	T	s	T	T	T	T	T+	p/s	T		T	1	2-	p/s	1	T	T	2	2	s	T	T	1+	5	5	
Galium triernatum																	T														
Geranium bicknellii								T																							
Geum macrophyllum	s	T	T	T	T	T	s	T	T	T	T	T	s	T	T	T+	T+	T	s	T	T	T+	1	1-	s		1	5	6	4	
Gnaphalium macounii								T																							
Heracleum sphondylium																T		T						1							1
Illiamna rivularis	p			T	T		p	T	T	T	1-	T	p			T	T	2-	p	T	T	T	1	1+	p	T	T	1	1	T	
Maianthemum stellatum		T	T	T	1	1-			T	T							T	T	p												
Minuartia rossii																		T	T					T	T						
Minuartia sp.																															
Monarda fistulosa	s		T			T	s	T	T	T+	T ¹	1	s		T	T	T	1-	s		T	T	T	1+	s		T	T	T+	1	
Osmorhiza berteroi																															
Oxyria digyna																													T	T	
Penstemon albertinus								T				T	T																		
Penstemon confertus	p/s	T	T	T	T	T	p/s	T	T	T	T+	T	p/s	T	T	T	1-	1	p/s	T	T	T	T+	T	p/s	T	T	3	3	4	
Penstemon ellipticus								T																							
Penstemon lyallii	p/s	T	T	T	T+	T	s			T	T+	T+	p/s	T	T	T	1+	1+	p/s	T	T	T	T	1+	s		T	T	T+	1+	
Phacelia hastata								T		T	T	T+		T			T	T		T		T	T	T					1	2	2
Phacelia sericea																													T	T	
Plagiobothrys scouleri		T																												T	
Polygonum achoreum									T	T																					
Polygonum douglasii											T				T	T							T								
Potentilla arguta						T ¹						T				T	T	T					T	T	T						
Ranunculus uncinatus												T						T													T
Sibbaldia procumbens																								T	T						
Solidago canadensis	p/s	T	T	T	T	T	p/s	T	T	T+	7	10	s	T	T	2-	7	12	s	T	T	1-	4	8	p/s				T	T	T+
Solidago multiradiata			T			T																									
Symphyotrichum laeae (Aster laevis)	p	T	T+	T	T+	T+	p	T	T	T	T+	2	p	T	T	1+	6	6 ⁴		T	T	T+	5	5		T		1	1-	4	
Urtica dioica														T	T	T	T	T			T	T	T	T		T	T	T	T	T	
Viola spp.																					T			T ¹							

Table 13, continued: GTSR Phase VI: Ocular Canopy Cover of all Species by Plot, 2010-2015.

Species:	MD-10-01						MD-10-02						MD-10-03						MD-10-04						MD-10-05						
		2010	2011	2012	2013	2015		2010	2011	2012	2013	2015		2010	2011	2012	2013	2015		2010	2011	2012	2013	2015		2010	2011	2012	2013	2015	
NATIVE GRASS	seeded?	T	T	T	1	T	seeded?	T	1	1	4	11	seeded?	T	1	3	12	22	seeded?	T	2-	T	7	18	seeded?	T	T		4	12	20
Agrostis scabra			T		T										T	T		T				T	T							T	T
Bromus carinatus	s	T		T	T	T	s	T	T	T	T	T	s	T		T	1	3	s	T	T		1	2	s		T	1	3	3	
Carex sp.*	s				T	T	s	T		T	T	3	s				T	4 ⁵	s	T			T	2	s	T		T	1	4	
Carex athrostachya									T		T+	2				T	T	T													
Carex deveyana																					T		T	T							
Carex pachystachya	s						s						s		T	T	1		s		T		T	2	s						
Carex petasata (?)																	T														
Deschampsia elongata																													T		T+
Elymus glaucus	s		T	T	T+	T	s		T	T	T	T	s		T	2	10	15	s		1		6	12	s		T	3	7	12	
Elymus trachycaulus v. trachycaulus	s	T	T	T	T		s		T	T	4-	8	s			T	T	T	s						s		T	T	1	1	
Festuca campestris					T ¹																										
Festuca sp.						T																									
Hordeum jubatum																T	T	T													
Poa alpina																							T	T							
Poa interior																														T	
Trisetum cernuum (?)		T												T						T							T	T		T	
EXOTIC GRASS		T	1	T	1-	1-		T	1	1	1+	2+		T	1	2	2+	3		T	2	T	5	7		T	1	1	2	1+	
Agrostis stolonifera			T	T	T	T			T	T	T	T			T	T+	1	1			T		1	1+				T+	1-		
Bromus secalinus (?)			T	T						T	T	T						T				T (P)									
Bromus tectorum			T	T						T	T	T	T			T	T	T			T	T (P)	T	T				T	T	T+	
Elymus repens										T	T	T+	1+		T		T	T	T+												
Lolium perenne																						T		T							
Panicum capillare								T (P)																							
Phalaris arundinacea																															T ⁶
Phleum pratense										T	T	T+	1			T	T	T+	1+		T	T		2	2			T			
Poa annua				T (P)							T				T		T										T		T	T	
Poa compressa		T	1	T	1-	1-		T	T	T	T (P)	T			T		T	T+			T			2	2			T	T	1	1
Poa pratensis			T	T	T	T			T	T	T	T				T	T+	T			T	T		T	1			T	T	T	T+
unknwn grass											T						T				T							T			
EXOTIC FORB		1	T	T	1	1		3	8	4	1	5		T+	2	3	3	4		1	3	3	9	12		3	1	1	1+	T+	
Achillea nobilis										T								T				T	T	T	T				T	T	
Amaranthus graecizans																					T (P)										
Arenaria serpyllifolia								T			T (P)	T										T	T (P)					T (P)			
Artemisia absinthium																							T (P)								
Cardamine oligosperma															T								T (P)								
Capsella bursa-pastoris		T			T			T (P)	T		T (P)				T	T					T (P)	T	T (P)				2-	T	T	T	
Centaurea stoebe (Centaurea maculosa)						T		T		T	T (P)	T (P)	T																		
Cerastium fontanum				T								T					T	T				T	T	T							
Chaenorrhinum minus								T			T	T (P)				T	T	T													
Chenopodium album											T (P)				T (P)	T	T				T (P)	T					T (P)	T	T	T	
Chenopodium sp.															T (P)																
Cirsium arvense								T	T	T	T	T			T	T	T+	1-	1-					T			T (P)		T	T	T
Cirsium vulgare								T	T															dead			T		T		
Cynoglossum officinale								T	T		T (P)	T (P)			T	T	T	T	1-		T (P)	T	T (P)	T	T (P)		T (P)	T	T (P)	T	T
Descurainia sophia																					T (P)						T (P)				
Erodium cicutarium								T	T	T					T (P)												T (P)				
Filago arvensis																						T						T (P)			
Gnaphalium palustris																															
Hypericum perforatum		T (P)	T	T (P)				T (P)	T	T (P)	T	T						T				T	T (P)	T	1						
Lactuca serriola																T						T (P)	T	T				T (P)			
Lamium amplexicaule																						T (P)					T (P)		T	T	
Leucanthemum vulgare				T	T (P)							T (P)	T						T (P)			T (P)		1				T			
Linaria vulgaris																T	T	T	T												

Table 13, continued: GTSR Phase VI: Ocular Canopy Cover of all Species by Plot, 2010-2015.

Species:	MD-10-01						MD-10-02						MD-10-03						MD-10-04						MD-10-05					
		2010	2011	2012	2013	2015		2010	2011	2012	2013	2015		2010	2011	2012	2013	2015		2010	2011	2012	2013	2015		2010	2011	2012	2013	2015
EXOTIC FORB cont'd																														
<i>Matricaria matricarioides</i>																														
<i>Medicago lupulina</i>		T (P)	T	T	T+ (P)	T+		T (P)	T	T (P)	T	3				T	T	T		T (P)	1	1	5	5		T (P)	T	T	T	T
<i>Melilotus alba</i>																	1	2												
<i>Melilotus officinalis</i>		T+ (P)		T	T (P)	T+			T	T (P)	T	2								T	T		3	3			T			
<i>Melilotus sp.</i>								T (P)																						
<i>Mustard sp.</i>									T																					
<i>Myosotis arvensis</i>								T																						
<i>Myosotis stricta</i>																											T	T		
<i>Plantago major</i>									T	T	T	T			T	T	T	T		T	T	T+	T+	T				T	T	T
<i>Polygonum aviculare</i>								T (P)		T (P)	T (P)			T (P)						T (P)		T				T (P)				
<i>Polygonum convolvulus</i>								T (P)	T	T (P)										T (P)		T				T (P)				
<i>Potentilla argentea</i>														T																
<i>Potentilla norvegica</i>								T	T	T (P)	T (P)	T						T										T (P)		
<i>Prunella vulgaris</i>									T		T	T			T		T	T		T	T	T	T	1						
<i>Rumex acetosella</i>									T	T	T	T				T	T	T												
<i>Rumex crispus</i>														T	T	T	T	T			T	T	T	T+		T (P)	T	T+	1	T
<i>Rumex sp.</i>								T	T																					
<i>Silene latifolia</i>											T						T	T		T	T	T	T	T+			T	T		
<i>Sisymbrium altissimum</i>								T (P)	T	T					T					T (P)	T					T+ (P)				
<i>Sonchus arvensis</i>																							T							
<i>Spergularia rubra</i>				T												T						T								
<i>Taraxacum officinale</i>		T (P)		T		T								T	T	T	T	T			T	T	T	T+		T (P)		T	T	T
<i>Thlaspi arvense</i>								T		T (P)										T (P)	T	T	T				T (P)	T	T	T
<i>Tragopogon dubius</i>								T																						T (P)
<i>Trifolium agrarium</i>		T (P)	T		T (P)	T		T	T		T	T+						T												T
<i>Trifolium hybridum</i>						T														T	T	T	T					T		
<i>Trifolium pratense</i>			T	T	T			T			T	T				T	T	T			T	1	1-	1-				T		
<i>Trifolium repens</i>																	T												T	
<i>Verbascum thapsus</i>		T (P)	T	T				2	4	T (P)		T					T	T		T (P)	T		T	T		T (P)	T		T	T
<i>Veronica arvensis</i>														T													T	T	T	
<i>Veronica peregrina</i>														T																
<i>Veronica serpyllifolia</i>								T	T	T	T	T			T	T	T	T		T	T		T							

(P) = Pulled some or all

red text = noxious weed species

p = planted s = seeded

*Carex phaeocephala and C. praticola are in plot 2

¹ = on road edge

Plot became smaller - turnout reworked and vegetation removed

² = very small but density is good

³ = Edge of plots was mowed in 2015; also sprayed in spots

⁴ = a lot has been mowed around rocks

⁵ = mostly Carex pachystachya; some Carex some without heads

⁶ = most was sprayed here

IV. PHASE XII MONITORING: GOING-TO-THE-SUN ROAD

A. BACKGROUND AND PURPOSE

In July 2007, an 8 to 10-year rehabilitation project for the Going to the Sun Road (GTSR) was initiated, funded by Federal Highway dollars. Phase XII of the project, which included the road section from Siyeh Bend to Rose Creek, began in 2013 and was completed in 2015. Construction during this phase rehabilitated an 11 mile stretch of road, including rock wall work, upgrades to selected turnouts and transit stops, resurfacing, and drainage. In addition to road rehabilitation, Phase XII also included the replacement of the Rose Creek Bridge. Revegetation of this project included planting and seeding native plants within turnouts, as well as seeding road shoulders with native species. Multiple turnouts with parking islands required replanting, as did a relatively narrow swath of road shoulder along both sides of the GTSR. Elevation for this phase of the GTSR Rehabilitation Project ranges from approximately 4,500 to 5,500 feet.

The adjacent vegetation consists of *Pinus contorta*, *Populus balsamifera*, *Abies lasiocarpa*, *Acer glabrum*, *Holodiscus discolor*, *Mahonia repens*, *Rubus parviflorus*, *Penstemon confertus*, *Achillea millefolium*, and *Pseudoroegneria spicata*. This project is located in a montane to subalpine environment and is snow covered, frigid and wind blasted for up to nine months of the year. Soils are relatively shallow, gravelly loams. Several areas have been greatly impacted by construction activities, including a few high visitor use areas. Additionally, sections of Phase XII were burned in the Reynolds Creek fire of 2015, furthering the need for restoration in certain places. Several non-native invasive plants such as oxeye daisy (*Leucanthemum vulgare*) and spotted knapweed (*Centaurea stoebe*) are growing throughout the area.

A species list was created for this segment of road in 2010 which directed seed collection. Disturbance created from construction of this phase was revegetated in 2015. The restoration goal is to blend the existing vegetation around these turnouts with the new plantings. Restoration objectives aim:

- To plant the created islands and areas along pathways at various turnouts along the road.
- To install plant materials to blend the disturbance into the adjacent undisturbed area.
- To seed the planted areas and road shoulders with native seed.
- To provide soil stabilization and cover to the disturbed soil that will inhibit weed invasion.
- To provide photo-documentation before and after revegetation.
- To sign and fence off revegetation work to inform visitor of work done and need to stay off areas.

In 2015, 2,923 forbs, shrubs, trees, sedges and grasses were planted in four turnouts between the Siyeh Bend and Rose Creek (Figure 13; Tables 15, 16, 17). 2,383.37g of native seed was also seeded within these turnouts (Table 14). In addition, 13,545.4g of native seed was seeded along 11 miles of road shoulder on both sides of the road (Table 14). With the exception of one turnout, all planting areas were protected either by rocks or wooden guard rails. The one location that was not is the turnout at Grizzly Point where the majority of the area was bermed to create picnic spots at the east end of the turnout. All plants were watered in well. Seedlings were also sprayed with Wiltpruf which coats the needles and leaves diminishing desiccation from wind and sun.

In all locations, all non-native plants were attempted to be pulled and bagged with special attention to pull noxious weeds *Leucanthemum vulgare*, *Hypericum perforatum*, and *Centaurea stoebe*.

B. METHODS

Given the small areas of revegetation within this project that focused on turnout edges, no formal monitoring plots were established for this project. Instead, several photomonitoring points were established and a species list was created for each planting area with notes on the overall success/cover of each species. Photographs were taken in 2015, the same year the turnouts were planted.

Figure 13. GTSR Phase XII: Location of Planting and Monitoring Areas



Table 14. GTSR Phase XII: Seeded species list for turnouts and road shoulders

Species	Grams for Road Shoulders	Grams for Turnouts
NATIVE SHRUBS		
<i>Holodiscus discolor</i>		8.44
NATIVE FORBS		
<i>Achillea millefolium</i>		11.04
<i>Anaphalis margaritacea</i>		17.43
<i>Antennaria</i> spp.		5.34
<i>Aquilegia flavescens</i>	10.84	
<i>Aster</i> spp.		8
<i>Chamerion angustifolium</i>	31	5.8
<i>Erigeron</i> spp.		11.46
<i>Fragaria virginiana</i>		0.55
<i>Galium boreale</i>		5.22
<i>Geum macrophyllum</i>	17	
<i>Heracleum sphondylium</i>	966.15	53
<i>Monarda fistulosa</i>		0.49
<i>Penstemon confertus</i>	2	
<i>Penstemon lyallii</i>		7.84
<i>Senecio pseudolaurens</i>		5
<i>Senecio triangularis</i>		2.62
<i>Solidago canadensis</i>	51.4	
NATIVE GRASSES		
<i>Carex geyeri</i>		1.14
<i>Elymus trachycaulus</i>	5,951	1,110
<i>Elymus glaucus</i>	6,386	1,130
TOTAL SEED WEIGHT	13,545.4g	2,383.37g

C. RESULTS AND RECOMMENDATIONS

Planting areas 1, 2, 3, and 4 were revegetated with native plant material and seed. A species list and species observations were recorded for these areas.

Planting Area 1: Grizzly Point turnout

The Grizzly Point turnout was the largest area that required revegetation. Overall, dirt in this area was built into a series of circular berms that defined 2 to 3 picnic areas for visitors. As non-native species quickly dominated these berms after they were created, the revegetation crew hand-pulled several bags of weeds prior to planting. These included noxious weeds *Centaurea stoebe*, *Leucanthemum vulgare*, and *Hypericum perforatum*. Some areas were weeded better than others; the eastern portion of the turnout had a higher cover of weed species, requiring that this turnout will need additional hand-pulling of weeds in the future.

Overall, however, the planting at this turnout looked in good condition soon after it was planted and seeded. No evidence of the seeded material could be observed but all planted material looked in good shape except for a few plants that appeared wilted. In general, the vegetation at this turnout had high diversity and was planted densely, providing good cover and an appropriate landscaped look. Seven photopoints were taken at this turnout.

Table 15. GTSR Phase XII: Species Present at Planting Area 1: Grizzly Point Turnout

Native Species Present	Planted?	Notes 2015	# planted	container
NATIVE TREE				
<i>Acer glabrum</i>	p	Low cover	10	1 gal.
<i>Picea engelmannii</i>	p	Low cover	6	1 gal.
<i>Populus balsamifera</i>	p	Low cover	9	1 gal.
NATIVE SHRUB				
<i>Amelanchier alnifolia</i>	p	DID NOT OBSERVE	16	cones
<i>Cornus sericeus</i>	p	High cover	31	1 gal.
<i>Dasiphora floribunda</i>	p	Low cover	44	1 gal.
<i>Holodiscus discolor</i>	p	Low cover	40	cones
<i>Mahonia repens</i>	p	Moderate cover	187	D-cells
<i>Paxistima myrsinites</i>	p	Low cover	17	1 gal.
<i>Ribes spp.</i>	p	Low cover	8	cones
<i>Rosa woodsii</i>	p	Low cover	10	1 gal.
<i>Rubus parviflorus</i>	p	Moderate cover	86	1 gal./D-cells
<i>Sorbus scopulina</i>	p	DID NOT OBSERVE	5	1 gal.
<i>Spiraea betulifolia</i>	p	High cover	68	1 gal.
<i>Symphoricarpos albus</i>	p	Moderate cover	69	1 gal.
NATIVE FORBS				
<i>Achillea millefolium</i>	p	Moderate cover	89	cones
<i>Anaphalis margaritacea</i>	p	Low cover	98	cones
<i>Castilleja miniata</i>		Low cover		
<i>Collomia linearis</i>		Low cover		
<i>Erigeron speciosus</i>	p	DID NOT OBSERVE	37	cones
<i>Eurybia conspicua</i>	p	Low cover	126	cones
<i>Fragaria virginiana</i>	p	Moderate-high cover	2	flats
<i>Galium boreale</i>	p	Low cover	50	cones
<i>Heuchera cylindrica</i>		Low cover		
<i>Iliamna rivularis</i>		Low cover		
<i>Osmorhiza occidentalis</i>		Low cover		
<i>Penstemon albertinus</i>	p	DID NOT OBSERVE	98	cones
<i>Penstemon confertus</i>	p	Moderate cover	196	cones
<i>Phacelia sericea</i>		Low cover		
<i>Polemonium pulcherrimum</i>	p	Low cover	35	cones
<i>Polygonum douglasii</i>		Low cover		
<i>Potentilla spp.</i>	p	DID NOT OBSERVE	20	cones
<i>Symphyotrichum laeve</i>	p	Low cover	90	cones
<i>Thalictrum occidentale</i>		Low cover		
<i>Viola adunca</i>		Low cover		
NATIVE GRASSES				
<i>Carex pachystachya</i>	p	Low cover	52	cones
<i>Elymus trachycaulus ssp. trachycaulus</i>	p	Low cover	60	cones
<i>Festuca occidentalis</i>		Low cover		
<i>Pseudoroegneria spicata</i>		Low cover		
TOTAL PLANTED			1,559	
Exotic Species Present				
EXOTIC FORBS				
<i>Alyssum alyssoides</i>		Low+ cover		
<i>Arabis glabra?</i>		Low cover		
<i>Arenaria serpyllifolia</i>		Low cover		
<i>Cerastium fontanum</i>		Low cover – pulled some		
<i>Glechoma hederacea</i>		Low cover		
<i>Medicago lupulina</i>		Low cover – pulled some		

<i>Melilotus officinale</i>		Moderate cover
<i>Plantago major</i>		Low cover
<i>Taraxacum officinale</i>		Moderate cover
<i>Trifolium hybridum</i>		Moderate cover
EXOTIC GRASSES		
<i>Agrostis stolonifera</i>		Low cover
<i>Phleum pratense</i>		Low cover
<i>Poa compressa</i>		Moderate cover – pulled some
<i>Poa pratensis</i>		Moderate cover – pulled some

Planting Areas 2 & 3: St. Mary Falls Turnouts west and east

Most of the planted material in this area was planted in planting area 2, or the St. Mary Falls turnout west. A large parking lot island was densely planted and generally had a moderate diversity of plants. This area had an appropriate landscaped look. Edges of the turnout were also planted with a variety of shrubs and forbs. These plants also appeared in good condition, although planting was not quite as dense. Hand-pulling of the few weeds present within the planting areas should continue and additional native plants should be considered if vegetation does not fill in along the turnout edges. Two photopoints were taken at this turnout.

Fewer plants were planted in planting area 3, or the St. Mary Falls turnout east. This area had a very small parking lot island that was appropriately planted with shrubs and forbs, but several areas behind the rock barrier edge of the turnout were quite barren. In addition, there is a fair amount of existing vegetation behind the rock barrier that is dominated by non-native plants, including mats of *Phleum pratense*, *Poa pratensis*, and noxious weed *Centaurea stoebe*. It is recommended that targeted weed control be implemented for this area with follow up planting and seeding of native shrubs, forbs, and grasses. A fair amount of plant material may be necessary for the area behind the rock barrier once non-native plants are removed. The same plants used to plant this turnout this year could be used for additional planting, particularly *Heuchera cylindrica*, *Penstemon confertus*, and *Galium boreale* that naturally occur as large mats of vegetation behind the rock barrier.

Table 16. GTSR Phase XII: Species Present at Planting Areas 2 & 3: St. Mary Falls Turnouts west & east

Native Species Present	Planted?	West turnout 2015	East turnout 2015	# planted	container
NATIVE SHRUB					
<i>Dasiphora floribunda</i>	p	High cover	Moderate cover in A; low cover in B	130	1 gal.
<i>Holodiscus discolor</i>	p	Low cover	Did not observe	14	cones
<i>Mahonia repens</i>	p	Moderate+ cover	Moderate cover in A; low cover in B	200	D-cells
<i>Ribes spp.</i>		Low cover			
<i>Rosa woodsii</i>		Low cover			
<i>Rubus parviflorus</i>		Low cover			
<i>Spiraea betulifolia</i>			Low cover in B		
<i>Symphoricarpos albus</i>	p	High cover	Did not observe	32	1 gal.
NATIVE FORBS					
<i>Achillea millefolium</i>	p	Low cover	Did not observe	21	cones
<i>Anaphalis margaritacea</i>	p	Low cover	Did not observe	21	cones
<i>Anemone multifida</i>	p	Low cover	Did not observe	6	cones
<i>Antennaria howellii</i>	p	Moderate cover	Did not observe	32	cones
<i>Corydalis spp.</i>		Low cover			
<i>Eriogonum umbellatum</i>	p	Low cover	Did not observe	11	cones
<i>Fragaria vesca</i>		Low cover			
<i>Gaillardia aristata</i>	p	Did not observe	Did not observe	32	cones
<i>Galium boreale</i>			Low cover in B		
<i>Geranium viscosissimum</i>	p	Low cover		9	cones

<i>Heuchera cylindrica</i>			Moderate cover in B		
<i>Penstemon albertinus</i>	p	Low cover	Did not observe	21	cones
<i>Penstemon confertus</i>	p	Low cover	Did not observe	32	cones
<i>Phacelia sericea</i>	p	Low cover	Low cover in B	20	cones
<i>Polemonium pulcherrimum</i>	p	Low cover	Low cover in B	18	cones
<i>Potentilla gracilis</i>			Moderate cover in B		
<i>Xerophyllum tenax</i>			Low cover		
NATIVE GRASSES					
<i>Carex geyeri</i>	p	Low cover	Did not observe	2	cones
<i>Danthonia intermedia</i>	p	Did not observe	Did not observe	2	cones
<i>Elymus trachycaulus??</i>		Low cover			
<i>Festuca campestris</i>	p	Did not observe	Did not observe	9	cones
<i>Festuca idahoensis</i>	p	Low cover	Did not observe	11	cones
<i>Koeleria macrantha</i>	p	Did not observe	Did not observe	24	cones
<i>Pseudoroegneria spicata</i>	p	Low cover	Did not observe	35	cones
TOTAL PLANTED				682	
Exotic Species Present		West turnout 2015		East turnout 2015	
EXOTIC FORBS					
<i>Arabis glabra?</i>		Low cover			
<i>Arenaria serpyllifolia</i>					
<i>Capsella bursa-pastoris</i>				Low cover in B	
<i>Centaurea stoebe</i>		Low cover		High cover in B – some pulled	
<i>Cerastium fontanum</i>				Low cover in B	
<i>Convolvulus arvensis</i>				Moderate cover in B	
<i>Glechoma hederacea</i>		Low cover			
<i>Leucanthemum vulgare</i>		Low cover - pulled			
<i>Melilotus officinale</i>		Low cover			
<i>Plantago lanceolata</i>				Low cover in B	
<i>Plantago major</i>				Low cover in B	
<i>Polygonum aviculare</i>		Low cover - pulled			
<i>Prunella vulgaris</i>		Low cover - pulled			
<i>Taraxacum officinale</i>				Low cover in A & B	
<i>Trifolium hybridum</i>				Low cover in B	
EXOTIC GRASSES					
<i>Phleum pratense</i>		Low cover		Low cover in A (pulled); High cover in B – in mats	
<i>Poa compressa</i>		Low cover – pulled some			
<i>Poa pratensis</i>		Low cover – pulled some		Low cover in A (some pulled); High cover in B – in mats	

A = small island B = behind rock barrier

Planting Area 4: Wild Goose Island Turnout

The two planting areas at this turnout looked in good condition soon after they were planted and seeded. No evidence of the seeded material could be observed but all planted material looked in good shape except for *Anaphalis margaritacea* which appeared wilted. In general, the vegetation at this turnout had moderately high diversity and was planted densely, providing good cover and an appropriate landscaped look. Hand-pulling of the few weeds present within planting areas should continue. Two photopoints were taken at this location.

While it is not likely that the two planted areas will require additional plant material, it should be noted that the area just to the east of the turnout is dominated by noxious and other weeds and should be addressed. A high amount of *Centaurea stoebe* is present here, along with high cover of *Lactuca serriola*, *Tragopogon dubius*, and *Verbascum thapsus*. Other areas were barren and appeared in need of plant material. It is recommended that targeted weed control

be implemented for this area with follow up planting and seeding of native shrubs, forbs, and grasses. The same plants used to plant this turnout this year could be used for additional planting.

Table 17. GTSR Phase XII: Species Present at Planting Area 4: Wild Goose Island Turnout

Native Species Present	Planted?	Notes 2015	# planted	container
NATIVE TREE				
<i>Acer glabrum</i>	p	Low cover on B	1	4" pot
NATIVE SHRUB				
<i>Amelanchier alnifolia</i>	p	DID NOT OBSERVE	8	cones
<i>Cornus sericeus</i>	p	Moderate cover on B	15	1 gal.
<i>Dasiphora floribunda</i>	p	High cover on A	35	1 gal.
<i>Holodiscus discolor</i>	p	DID NOT OBSERVE	4	cones
<i>Mahonia repens</i>	p	High cover on A	200	D-cells
<i>Rosa woodsii</i>	p	DID NOT OBSERVE	5	1 gal.
<i>Rubus parviflorus</i>	p	Low+ cover on B	37	1 gal.
<i>Spiraea betulifolia</i>	p	Moderate cover on A & B	31	1 gal.
<i>Symphoricarpos albus</i>	p	Moderate cover on B	34	1 gal.
NATIVE FORBS				
<i>Achillea millefolium</i>	p	Low cover on A	35	cones
<i>Anaphalis margaritacea</i>	p	Moderate cover on A; does not look that great	35	cones
<i>Antennaria bonellii</i>	p	Moderate cover on A	32	cones
<i>Eurybia conspicua</i> (SYMLAE??)	p	DID NOT OBSERVE	50	cones
<i>Fragaria virginiana</i>	p	Low cover on A & B	1	flat
<i>Galium boreale</i>	p	Low cover on A	25	cones
<i>Heuchera cylindrica</i>	p	Moderate cover on A	35	cones
<i>Penstemon confertus</i>	p	Low cover on A	49	cones
<i>Polemonium pulcherrimum</i>		Low cover on A		
<i>Symphyotrichum laeve</i>		Low cover on A		
NATIVE GRASSES				
<i>Festuca idahoensis</i>	p	Low cover on A	25	cones
<i>Pseudoroegneria spicata</i>	p	Low cover on A	25	cones
TOTAL PLANTS			682	
Exotic Species Present				
EXOTIC FORBS				
<i>Centaurea stoebe</i>		Low-moderate on B		
<i>Glechoma hederacea</i>		Low cover on A		
<i>Melilotus officinale</i>		Low cover on A		
<i>Prunella vulgaris</i>		Low cover on A		
EXOTIC GRASSES				
<i>Phleum pratense</i>		Low cover on A		
<i>Poa compressa</i>		Low cover on A		
<i>Poa pratensis</i>		Low cover on A		

A = island B = behind wooden fence

Figure 14. GTSR Phase XII: Photopoints 2015



Grizzly Point photo 1 (planting area 1) – 2015



Grizzly Point photo 2 (planting area 1) – 2015



Grizzly Point photo 3 (planting area 1) – 2015



Grizzly Point photo 4 (planting area 1) - 2015



Grizzly Point photo 5 (planting area 1) – 2015



Grizzly Point photo 6 (planting area 1) – 2015



Grizzly Point photo 7 (planting area 1) - 2015



Planting Area 2 (St. Mary Falls TO west) photo 1 – 2015



Planting Area 2 (St. Mary Falls TO west) photo 2 – 2015



Wild Goose Island turnout photo 1 (planting area 4) – 2015



Wild Goose Island turnout photo 2 (planting area 4) - 2015



Planting Area 3 (St. Mary Falls TO east) photo 1 – 2015



Planting Area 3 (St. Mary Falls TO east) photo 2 – 2015



Planting Area 3 (St. Mary Falls TO east) photo 3 – 2015

V. ST. MARY VISITOR CENTER MONITORING

A. BACKGROUND AND PURPOSE

Construction surrounding the St. Mary Visitor Center coincided with creation of the park's transit system, which provides shuttle service across the Going-to-the-Sun Road. The parking lot around the St. Mary Visitor Center was renovated while accommodating a new transit stop and was completed in 2008.

Parking lot islands and bare areas surrounding the visitor center were initially planted in the spring and fall of 2008. A total of 3,582 plants were planted in June and September in the various islands in the parking lot (Revegetation Crew Completion Report 2008; Table 20). These areas did not have supplement seed. Bark mulch was used to cover the soil for moisture retention, however, most of this mulch was blown away throughout the winter of 2008-2009. Many plants did not survive the winter due to root exposure when topsoil was blown away along with the mulch. The perimeter of the parking lot and visitor center were also hydroseeded in the fall of 2008. A total of 1.5 acres were hydroseeded in the St. Mary Visitor Center area (Table 19). Weeds recruited due to both the open habitat on parking lot islands and also because much of the hydroseed didn't germinate until the fall of 2009.

To compensate plant losses, additional plants were added to all of the islands in 2009. During May, June, August and September, 1,514 additional forbs, shrubs and grasses were planted in the islands around the St. Mary Visitor Center (Table 20). The islands were also weeded extensively on multiple occasions. *Cirsium arvense*, *Bromus tectorum*, *Polygonum convolvulus*, *Centaurea stoebe*, *Kochia scoparia*, *Thlaspi arvense*, and *Linaria vulgaris* were the most common weeds found growing in the planting areas (Revegetation Crew Completion Report 2009). Weeds were also prolific in the hydroseeded area and some of these were pulled as well.

Supplemental plant material was again added in 2010. In May and June, 767 forbs, shrubs, and grasses were added to parking lot islands of St. Mary Visitor Center (Table 20). Additional work to the area is recommended in the future with several islands still in need of more plant material. Non-native grasses continue to dominate areas, particularly those that have previously been mowed, and it is suggested that non-native grasses be removed or a barrier be placed between these areas and planted areas (Revegetation Crew Completion Report 2010).

B. METHODS

In August 2010, six monitoring plots were established at the St. Mary Visitor Center (Figure 15). Plots are not permanently marked and the size and shape of plots were determined by site parameters (Table 18). Three plots are located in parking lot islands, each encompassing the entire island. Two plots are located adjacent to the parking lot with dimensions for each measuring 20m x 5m. One plot is located adjacent to the visitor center. This plot is triangular in shape to avoid the pre-construction presence of *Elymus repens* adjacent to the plot.

Plots were evaluated using Level II monitoring protocol. All species within plots were identified and given ocular cover estimates. Ground cover was also estimated within plots.

Table 18. St. Mary Visitor Center: Dimensions and Location of Monitoring Plots

Plot Number	Plot dimensions	UTM N	UTM E
SM-10-01	entire island	5402152	320821
SM-10-02	20 m x 5 m	5402141	320800
SM-10-03	20 m x 5 m	5402189	320812
SM-10-04	entire island	5402189	320778
SM-10-05	triangle	5402266	320725
SM-10-06	entire island	5402329	320711

Figure 15. St. Mary Visitor Center: Location of Plots



Table 19. St. Mary Visitor Center: Seeding Prescription for Areas Adjacent to Parking Lot

Seeds per ft ²	Lifeform	Species:	Weight:
15	grass	<i>Festuca idahoensis</i>	930 g
20	grass	<i>Festuca campestris</i>	2.5 kg
5	grass	<i>Koeleria macrantha</i>	63.7 g
10	grass	<i>Juncus balticus</i>	no seed weight
5	grass	<i>Elymus trachycaulus ssp. subsecundus</i>	1.024 kg
5	grass	<i>Bromus carinatus</i>	1.776 kg
5	grass	<i>Elymus smithii</i>	1.38 kg
5	grass	<i>Carex aurea</i>	no seed weight
5	grass	<i>Carex obtusata</i>	no seed weight
5	grass	<i>Carex filifolia</i>	no seed weight
10	forb	<i>Achillea millefolium</i>	110 g
5	forb	<i>Dasiphora floribunda</i>	104 g
5	forb	<i>Fragaria virginiana</i>	160 g
10	forb	<i>Geum triflorum</i>	451 g
5	forb	<i>Anemone multifida</i>	389 g
5	forb	<i>Heuchera cylindrica</i>	21 g
5	forb	<i>Penstemon confertus</i>	55 g
10	forb	<i>Potentilla gracilis</i>	204 g
10	forb	<i>Solidago sp.</i>	50 g

80 total seeds of grass per square foot; 65 total seeds of forb per square foot

Table 20. St. Mary Visitor Center: Species Planted in Islands within Parking Lot

Shrubs	2008	2009	2010
	<i>Arctostaphylos uva-ursi</i>	<i>Arctostaphylos uva-ursi</i>	<i>Amelanchier alnifolia</i>
	<i>Mabonia repens</i>	<i>Dasiphora floribunda</i>	<i>Arctostaphylos uva-ursi</i>
	<i>Paxistima myrsinites</i>	<i>Mabonia repens</i>	<i>Mabonia repens</i>
	<i>Spiraea betulifolia</i>	<i>Paxistima myrsinites</i>	<i>Paxistima myrsinites</i>
	<i>Symphoricarpos albus</i>	<i>Rosa woodsii</i>	
		<i>Rubus parviflorus</i>	
		<i>Spiraea betulifolia</i>	
		<i>Symphoricarpos albus</i>	
Grasses/Sedges	<i>Danthonia intermedia</i>	<i>Carex microptera</i>	<i>Carex pachystachya</i>
	<i>Festuca idahoensis</i>	<i>Koeleria macrantha</i>	<i>Carex petasata</i>
	<i>Koeleria macrantha</i>		<i>Festuca idahoensis</i>
Forbs	<i>Anaphalis margaritacea</i>	<i>Anemone multifida</i>	<i>Anaphalis margaritacea</i>
	<i>Anemone multifida</i>	<i>Artemisia ludoviciana</i>	<i>Artemisia frigida</i>
	<i>Antennaria sp.</i>	<i>Fragaria sp.</i>	<i>Fragaria sp.</i>
	<i>Aster/Erigeron mix</i>	<i>Gaillardia aristata</i>	<i>Gaillardia aristata</i>
	<i>Aquilegia flavescens</i>	<i>Geum triflorum</i>	<i>Gaillardia aristata</i>
	<i>Erigeron speciosus</i>	<i>Hedysarum boreale</i>	<i>Geum triflorum</i>
	<i>Eriogonum umbellatum</i>	<i>Gaillardia aristata</i>	<i>Heuchera cylindrica</i>
	<i>Fragaria vesca</i>	<i>Fragaria sp.</i>	<i>Penstemon confertus</i>
	<i>Gaillardia aristata</i>	<i>Lupinus sericeus</i>	<i>Phacelia sericea</i>
	<i>Geranium viscosissimum</i>	<i>Polemonium pulcherrimum</i>	<i>Polemonium pulcherrimum</i>
	<i>Geum triflorum</i>		<i>Potentilla hippiana</i>
	<i>Heuchera cylindrica</i>		
	<i>Oxytropis splendens</i>		
	<i>Penstemon albertinus</i>		
	<i>Penstemon confertus</i>		
	<i>Polemonium pulcherrimum</i>		
	<i>Potentilla gracilis</i>		
	<i>Potentilla sp.</i>		

C. RESULTS

Five year results show that while there has been a steady increase in both native and exotic cover, the largest increase over the course of the last four years has been in the cover of exotic species (Figure 16). An initial dip in exotic cover was seen the first year after planting, but exotic cover has steadily increased since then, resulting in equal native and exotic cover in 2015. Prior to this, average native cover had been higher than exotic cover. The increase in exotic cover over the last several years has mainly been due to an increase in exotic grass cover. Rates of increase varied among plots that are located on the edge of the parking lot and plots located within islands of the parking lot. While native cover did increase in both edge and island plots, it was at a lower rate than the increase seen in exotic species cover (Figure 17). Exotic cover increased at a higher rate on edge plots than on island plots, again mostly due to increases in exotic grass cover.

Figure 16: St. Mary Visitor Center: Overall % Native and Exotic Cover, 2010-2015.

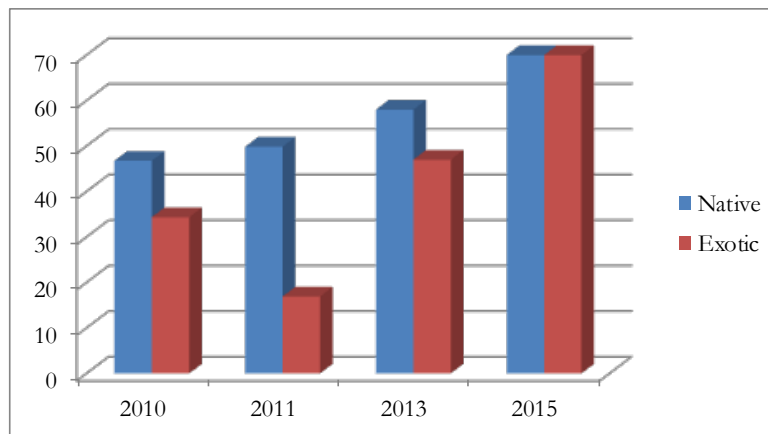
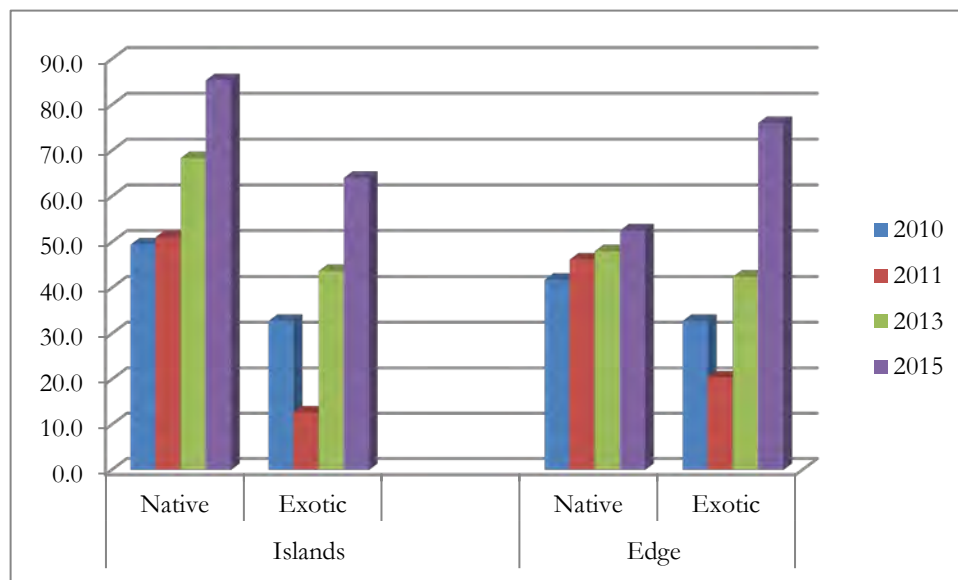


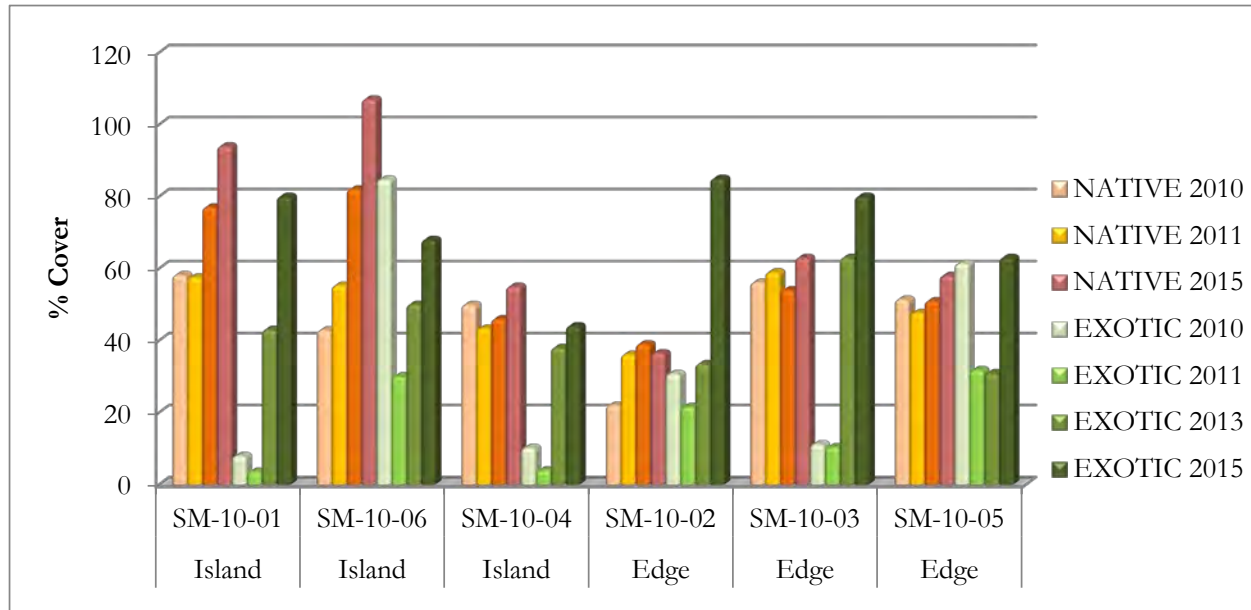
Figure 17: St. Mary Visitor Center: % Native and Exotic Cover in Island and Edge Plots, 2010-2015.



Results of individual plots have varied widely in the five years of monitoring. Overall, the island plots have tended to have higher overall native cover with native lifeforms continuing to increase greatly over the last few years. This has largely been due to two plots, SM-10-01 and SM-10-06, where native cover has continued to

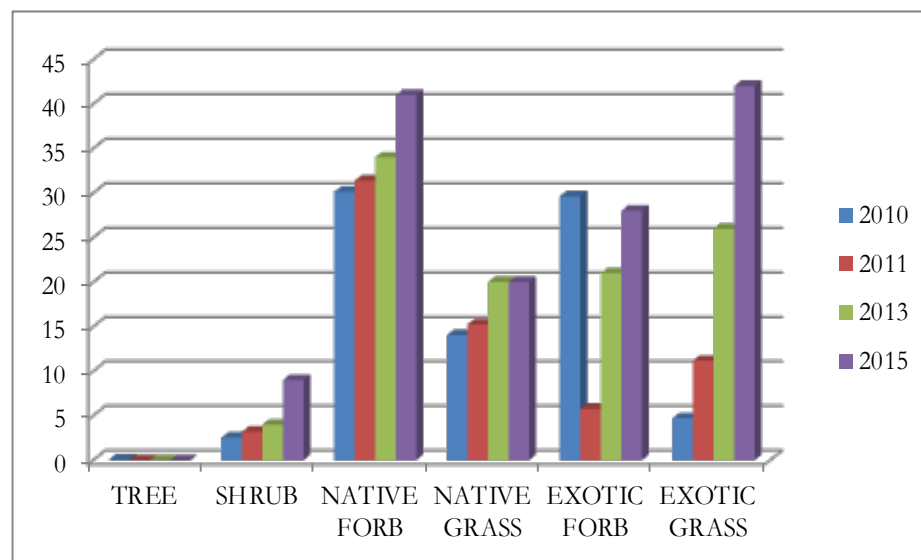
increase at a relatively fast pace over time (Figure 18). Increases in exotic cover in all plots have resulted in exotic cover of 44-85% across all plots. At three years after planting, five of the six plots had higher native cover than exotic cover. By five years after planting, only three plots, specifically the island plots, had higher native cover than exotic cover.

Figure 18: St. Mary Visitor Center: % Native and Exotic Cover by Plot, 2010-2015.



Overall, most lifeforms have increased in cover from year three to year five after replanting (Figure 19). As mentioned earlier, the largest increase in lifeform cover came from exotic grasses which increased by 16% across all plots. Native forbs and exotic grasses now co-dominate this project area, whereas native forbs were the clear dominants three years prior. Both native and exotic forbs increased by 7%, shrubs increased by 5%, and native grass cover remained essentially the same since 2013.

Figure 19. St. Mary Visitor Center: Overall Percent Cover of Lifeforms, 2010-2015.



Lifeform composition also varied among plots (Figure 20). In general, native forb cover was highest in planted island plots, while both native and exotic grass cover was higher in seeded edge plots. In 2013, exotic forb

cover was higher in the island plots. Two years later, this trend was mostly reversed, and exotic forb cover was mostly higher in edge plots (Figures 20 and 21). This fluctuation is mostly due to inconsistent changes in cover in *Medicago lupulina* and *Melilotus officinale* in different areas. Shrub cover has been slowly increasing across all plots, but was higher in island plots where more shrub material was planted.

Figure 20. St. Mary Visitor Center: Percent Cover of Lifeforms by Plot, 2015.

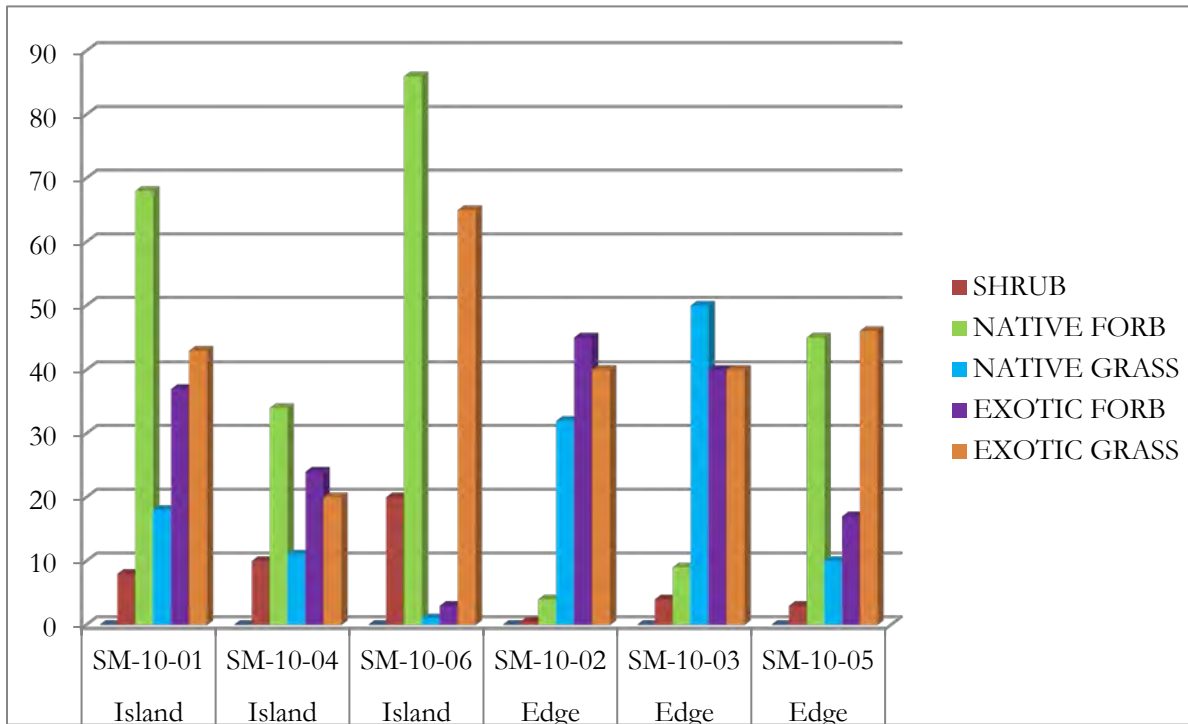
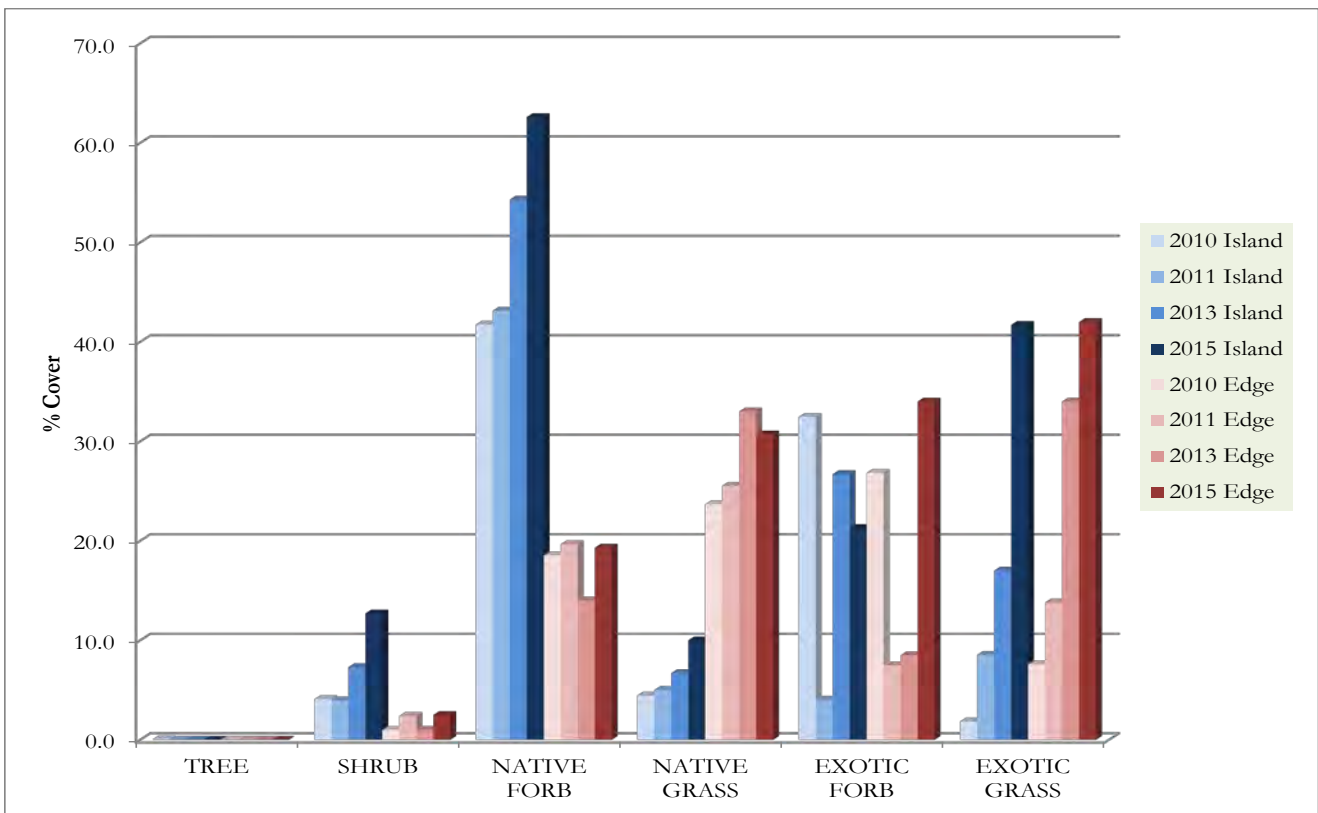


Figure 21. St. Mary Visitor Center: Average Lifeform Cover for Island and Edge areas, 2010-2015.



a. Native forbs

Native forbs are the dominant lifeform on all island plots. While native forb cover remained constant in one edge plot and increased in the other two edge plots, this lifeform did not dominate any edge plots. In plot 5, however, the cover of native forbs nearly equaled exotic grasses, the dominant life form, due to the large increase in *Solidago canadensis*.

Native forb cover has increased in all plots since 2013, except in plot 2 where it remained the same. In this edge plot, covers of some species, like *Achillea millefolium* and other species in the aster family, have actually decreased, potentially due to herbicide spraying. In general, cover of native forbs remains higher in island plots than in edge plots (Figure 21), as would be expected since nursery stock was planted in these plots between 2008 and 2010. *Artemisia ludoviciana* continued to have the highest cover of almost all native forbs with 9 to 36% cover in island plots where it was planted (Table 21). However, cover of this species has not changed much over the last two years. Seeded forb *Solidago canadensis*, on the other hand, has been increasing dramatically in some areas, reaching 20 to 30% cover in two plots. This is largely the reason why plot 6, an edge plot near the entrance to the Visitor's Center, supports a higher native plant component than the other edge plots which contain no *S. canadensis*. *Solidago multiradiata*, also likely seeded, has also increased on two plots by 3-6%. This non-rhizomatous species hasn't colonized to the same extent as *S. canadensis*, a strongly rhizomatous species.

Other planted native forbs that are present in island plots with constant or increasing cover include *Erigeron speciosus*, *Antennaria howellii*, *Geranium viscosissimum*, *Geum triflorum*, *Heuchera cylindrica*, *Polemonium pulcherrimum*, *Potentilla gracilis* and *Potentilla hippiana*. A few species showed mixed results, increasing or remaining the same in cover in some plots while decreasing in others. These include seeded or planted species *Achillea millefolium*, *Fragaria vesca*, *Gaillardia aristata*, *Penstemon confertus* and *Potentilla arguta*, and recruited species *Equisetum laevigatum*. These mixed results may be due to an interaction of inconsistent herbicide application across sites and a year of warm, dry conditions. A few recruited native forbs have slightly increased in several plots, such as *Chamerion angustifolium*, *Eurybia conspicua* and *Lithospermum ruderales*, and are contributing to the overall success of native forbs in the project.

b. Native grasses

Overall, native grass cover has remained relatively stable over the past two years (Figures 19 and 21). However, trends vary across plots. Native grasses are doing relatively well in two of the three island plots, despite the fact that these areas were merely planted with grasses and not seeded. Cover ranges from 11 to 18% in these plots and was stable in island plot SM-10-06 where cover remained at only 1%. Native grass increases in island plots were mainly due to *Elymus trachycaulus* var. *trachycaulus*, which increased by 6% in plot 1 and by 2% in plot 4. Smaller 1 to 2% increases of *Achnatherum nelsonii*, *Koeleria macrantha*, and *Festuca idahoensis* also contributed to the overall increase of native grasses on these plots. The fact that native grasses have not become well established on plot 6 may be due to the very high native forb and exotic grass cover on this plot that may be outcompeting them.

Overall, similar to past years, native grass cover is higher on the seeded edge plots with 10 to 50% cover (Figure 21). This is as expected since the edge areas were seeded with a higher amount of grass seed while island plots were merely planted with a few grass species and not hydroseeded at all. However, cover of native grasses in edge plots actually decreased in two of the three plots over the past two years, while increasing only slightly in the third plot. These decreases are likely due to a combination of factors, such as seasonal die-back exacerbated by a warm dry summer. It was noted in at least one instance that *Koeleria macrantha* was dried up and the cover may have been higher earlier in the season. In plot 5, cover of this species decreased by 6%. Additionally, several other native grass species disappeared from that plot. While these species were present with only trace cover previously, it contributed to the overall decline of native grass cover in this plot and certainly to a decrease in diversity. A 9% decrease in *E. trachycaulus* var. *trachycaulus* in plot 2 was the major contributor to the overall decrease in native grasses in that plot. While there could be a factor of mis-identifying *E. trachycaulus* var. *trachycaulus* for *Elymus repens* in the past, especially when seed heads are not present, this did not account for the totality of the change and likely this result reflects some real change. It is uncertain what is causing these decreases in certain native grass, although recent drought conditions and increased competition from exotic grasses may be causing their decline.

Individual species showed a fair amount of variation in success from plot to plot. *Festuca idahoensis* increased on all plots except plot 6, where it remained constant at trace cover. *Bromus carinatus*, thought to be a nurse grass which dies back over time as new species establish, has indeed disappeared from three plots. However, this species appeared for the first time in plot 1 suggesting that seed can lie dormant in soil and germinate years later. *Carex pachystachya* disappeared from plot 5 but increased slightly in cover in plot 6. *Achnatherum nelsonii*, *Elymus trachycaulus* var. *trachycaulus* and *Koeleria macrantha* also increased in cover in some plots while decreasing in others.

c. *Exotic Forbs*

Exotic forb cover increased substantially on all edge plots, while it decreased or stayed the same in the island plots. Overall, exotic forb cover is now higher on edge plots than island plots, completely reversing the trend from the last monitoring event. In 2013, the biggest increases in exotic forb cover occurred on island plots, where exotic forb cover became higher, on average, than on edge plots (Figure 21). In 2015, the most dramatic increases in exotic forb cover were on edge plots 2 and 3 that had 45% and 16% increases in cover, respectively.

Almost all of this increase in cover was due to the dramatic increase of *Medicago lupulina* on plot 2 from 0 to 35% and the increase of *Melilotus officinale* on plots 2 and 3, increasing by 8% and 12%. As seen in other restoration projects, these species can have large changes in cover depending on disturbance and precipitation levels. Interestingly, *M. officinale* actually decreased in all island plots, potentially from hand pulling or spraying in these areas. Mostly as a result of this, exotic forb cover decreased or stayed the same in the islands plots. This entire area had been actively weeded for the last several years and has been sprayed with herbicide at various times. Likely not all areas are weeded at the same time or sprayed at the same rate, which is potentially why some species gain ground in some areas and decline in other nearby areas.

Several noxious weed species persist across this project with a few increasing in cover in certain areas. *Centaurea stoebe* reappeared after being eradicated from plot 3 and increased from 1 to 3% cover in plot 1. This species was present in four of the six plots. *Cirsium arvense* is also now present with trace cover in five plots, up from three plots in 2013. Although *Linaria vulgaris* was only found in one plot, its cover increased from trace to 3% in plot 6 in the past two years. Species that once had high cover but have declined over time to trace or zero amounts include *Capsella bursa-pastoris*, *Polygonum aviculare* and *Sisymbrium altissimum*, which had 50% cover in plot 6 at the start of the project in 2010. Most of these species tend to colonize disturbed areas and then decrease over time as other vegetation becomes established.

d. *Exotic Grasses*

Exotic grasses increased in all plots over the past two years, most often dramatically, and continue to be the largest threat to the success of this project. Although exotic grass cover increased by only 1% in plot 3, cover in all other plots increased by 7% to 27%. Plot 5, directly adjacent to the visitor center, and plot 6, the island furthest north, both developed significant cover of *Elymus repens* in 2011. *E. repens* continues to increase in these two plots, where it now accounts for 40% and 60% cover. Cover of *E. repens* has also increased in plots 1 and 2, comprising 35% and 25% cover in these plots (Table 21). In addition, *Bromus inermis* has increased in four of the five plots as well, perhaps even outcompeting *E. repens* in plot 3, the only plot where *E. repens* saw a decline in cover. The result is that all plots exhibited a fairly dramatic increase in exotic grass cover since 2011. These rhizomatous grasses are aggressive and have the potential to take over revegetated areas. Interestingly, *Poa pratensis*, also a rhizomatous grass with similar potential, has not increased greatly across this project, as was predicted that it may. Most plots have 5% or less cover of this species with the exception of plot 3, where it has remained steady at 20% cover since 2013. Perhaps competition from the other rhizomatous grasses has kept this grass from increasing. Also of note, *Bromus tectorum* was found in 4 of the 6 plots. While this annual grass only has trace cover, it also has the potential to increase in cover quickly.

While there did not appear to be any trend in clarifying why certain areas have more exotic grass cover than others earlier in the project, most plots have now been heavily colonized by rhizomatous exotic grasses. Overall diversity of exotic grasses is remaining about the same.

e. *Shrubs and Trees*

Shrub cover is not a large component in most plots, however, where shrubs have been planted they are generally increasing in cover. Shrub cover on plot 6, the island plot closest to the exit of the north parking lot, is now at a notable 20%. All three island plots where shrubs were planted had increases in shrub cover from 2013 to 2015 by 2% to 11%. *Rosa woodsii* is perhaps the most successful of all shrub species on the project, increasing on four plots and reaching 8% cover on plot 6. *Symphoricarpos albus* also increased by 6% on plot 6, reaching 10% cover on that plot, as well as slightly increasing on two other plots. Several species, including *Arctostaphylos uva-ursi* and *Dasiphora floribunda*, had small increases in cover on at least one plot. Shrub cover on island plots ranges between 8% and 20%, becoming a more notable lifeform in these areas. Conversely, all three edge plots currently have 4% cover or less, due mostly to the low amount of shrub planted in these areas. Plot 2 continues to have only

trace shrub cover, although plot 3 has increased to 4% cover with a 3% increase in *R. woodsii* and plot 5 increased to 3% cover with a 1% increase in both *R. woodsii* and *S. albus*.

There continues to be no tree cover on any of the plots.

D. CONCLUSIONS AND RECOMMENDATIONS

Earlier in the project, wind had been the biggest challenge to restoration success. Most of the bark mulch that was applied around plantings in 2008 was dispersed by wind, scouring the soil and exposing plant roots. Exotic species were also given the opportunity to invade exposed soil. Since establishing early in the project, exotic species have competed with planted native species for space. Fortunately, most of the exotic forb species that are becoming established and dominant on the project are species that generally exhibit cyclical populations due to precipitation levels and disturbance. For instance, various clover and pea species appear to have extremely high cover one year and are gone the next based on spring rain patterns and how much other vegetation they have to compete with. These species are likely not long-term threats to this project. Several species, however, can be perennially aggressive and need to be controlled. A few noxious weeds that are present, including *Centaurea stoebe*, *Cirsium arvense*, and *Linaria vulgaris*, will need to be controlled with herbicide and/or hand pulling. *Linaria dalmatica* has been eliminated from the project due to consistent hand pulling, but has been found recently in the surrounding area.

Weedy grasses are the biggest threat to the project. *Elymus repens* appears to be the largest challenge to this area, evidenced by its continued increases in cover from 2011 to 2015. It was present in high covers prior to restoration and persists in areas that were not revegetated that are adjacent to restoration areas. This grass can be extremely aggressive and may need to be controlled from surrounding areas in order to protect the area as a whole. *Bromus tectorum*, an annual species which was present in 4 of 6 plots, appears to be controlled somewhat by hand pulling as it disappeared from 2 plots since 2011 after being weeded. Hand pulling should continue for this species. Rhizomatous perennial grasses will be more difficult to hand pull, including *Bromus inermis* and *Poa pratensis*. While edge areas will be more difficult to control for rhizomatous weedy grasses due to their abundance, it may be manageable, however, to hand pull these grasses from parking lot islands, particularly in the spring when the soil is wet. Finally, the control efforts of weeding and spraying over the past 5 years are showing a desired effect on certain exotic forbs. At a minimum, hand weeding of all exotic species is needed annually to keep these weeds from increasing.

Despite these setbacks, substantial additional planting within the first 3 years of the project and diligent annual weeding over the past 5 years have allowed natives to establish and increase over time in most areas. Native forbs are performing best in parking lot islands where they were planted, while native grasses have higher covers along edges where they were seeded. However, native grasses are beginning to be outcompeted in edge areas where exotic grasses are aggressively invading. Without keeping exotic grasses in check, they show the potential to overtake this project.

These plots should be monitored in 2020, ten years after restoration.

Codes for Table X:

* s = seeded (adjacent to parking lot only, not in islands)

* p = planted in islands

red text = Montana noxious weed species

1 = direct seeded into ground after scarification, cold moist stratification and inoculation with root-slurry

2 = starting to shrivel in areas, may be getting outcompeted

3 = much of this has died back

4 = some dying back

5 = on edge of plot

Table 21. St. Mary Visitor's Center: Ocular Percent Cover for all Species by Plot, 2010-2015.

		Island				Edge				Edge				Island				Edge				Island			
		SM-10-01				SM-10-02				SM-10-03				SM-10-04				SM-10-05				SM-10-06			
		2010	2011	2013	2015	2010	2011	2013	2015	2010	2011	2013	2015	2010	2011	2013	2015	2010	2011	2013	2015	2010	2011	2013	2015
	source*	0.25m ² ≈1%																0.65m ² ≈ 1%				0.25m ² ≈1%			
GROUND COVER																									
Bare soil		40		24	15	40	40	20	10	35		10	12	15		20	20	64		15	15	30		5	9
Gravel		3		25	25	52	50	20	20	3		3	3	10		10	10	20		10	15	5		5	5
Rock		3		1	1	T	T	T	T	2		2	2			2	2	1		2	2	3		3	3
Litter		51		40	49	5	7	55	60	57		80	78	70		60	58	10		68	63	58		77	71
Basal vegetation		3		10	10	3	3	5	10	3		5	5	5		8	10	5		5	5	4		10	12
TREE		0	0	0	0	0	0	0	0	0	0	0	0	T	0	0	0	0	0	0	0	0	0	0	0
Populus balsamifera														T											
SHRUB		3	3	6	8	T	T+	1	T+	1	1	1	4	5	3	7	10	2	6	1	3	4+	5+	9	20
Arctostaphylos uva-ursi	p	T	T	1	1+									1	T	2	3	T	T			1-	1-	T	T+
Dasiphora floribunda	p			T					T	T	T	T	T+	T		T	T	T	T	T	T		T	T	1
Mahonia repens					T							T					T		T						
Rosa woodsii	p	2	2	2	3	T	T+	1-	T+	1-	T+	1	4	3	3	3	4+	T	T	T	1	1+	2	3	8
Spiraea betulifolia	p	T	T	T	T									T		1	1					1	1	2	1-
Symphoricarpos albus	p	1	1	3	3	T	T	T	T					T	T	1	1+	1	5	1	2	1+	1+	4	10
NATIVE FORB		53	49	62	68	6	9	4	4	12	10	4	9	35	33	29	34	33	37	34	45	35	46	72	86
Achillea millefolium	s	T	T	1	1	5	8	3	1	10	8	1	1	T		T	T+	1	1	2	3	2	1	2	5
Androsace septentrionalis						T					T														
Anemone multifida	s & p	T	T	T+	T+				T	T	T	T	T	T+	T	T+	T	T	T	T	T	T	T	T	
Antennaria bowellii	p?	4	4	5 ²	5 ²									3	3	4	4								
Arabis glabra						T																			
Aquilegia flavescens	p																					1-	1	2	T
Arabis sp.												T										T			
Arnica sororia	p																	T	T	T			T		
Artemisia frigida	p							T						T		T									
Artemisia ludoviciana	p	20	20	25	26								T	7	7	7+	9					15	23	35	36
Artemisia michauxiana	p?																	1	1	1+	2				
Astragalus sp.					T																				
Chamerion angustifolium		1	1	3	3					T		T	T	2	1	T	T+				T	1-	1	4	6+
Conyza canadensis														T									T		
Epilobium brachycarpum		T												T											
Equisetum laevigatum															T			1	3	1	3	1-	2	5	2
Equisetum variegatum		T	T	T	T																				
Erigeron caespitosus									T																
Erigeron speciosus	p	2+	2	4	5									2	2	2	3			T	T	T	T	T	T+
Eriogonum flavum	p?					T	T	T	T														T	T	T
Eriogonum umbellatum																									
Eurybia conspicua																		5	1	1	2		T	T	T
Fragaria vesca	p															T	T			T	T	T	2	3	T
Fragaria virginiana	p	3	2	4	5					T	T	T	T	3	2	1	1	2	2	3	3	3	2	1	1
Gaillardia aristata	p	10	10	12	14	T	T	1-	T+	T	T	T	T	8	8	7	5	1	1+	T	T+	5	3	3	3
Galium boreale	p					T	T	T	T			T	T	T					T						
Geranium viscosissimum	p	T	T	T	T+							T ⁵	T									1-	1	2-	2
Geum triflorum	s & p	1	T	1	1									T	T	T	T	T	T	T	T	1-	T	1	2

Table 21, continued: St. Mary Visitor's Center: Ocular Percent Cover for all Species by Plot, 2010-2015.

		Island				Edge				Edge				Island				Edge				Island				
		SM-10-01				SM-10-02				SM-10-03				SM-10-04				SM-10-05				SM-10-06				
	source*	2010	2011	2013	2015	2010	2011	2013	2015	2010	2011	2013	2015	2010	2011	2013	2015	2010	2011	2013	2015	2010	2011	2013	2015	
NATIVE FORB, con't																										
										T																
										T	T										T		T+	T		
	p?				1									T	T	T+	T									
	s & p	1	1	2	3									2	2	3-	3-	T	T	T	T	1+	2	2	4	
					T											T	T						T	1-		
	s ¹	T	T	T	T		T		T					T	T	T	T	T	T	T	T+					
																					T					
										1	T	T	T											T	T	
		1	1	T	T+	T	T	T	T			T	T	T			T	T+								
	p					T	T	T	T	T	T	T	T	1	1	T	1+		T							
	p	T				T			T		T							T								
	s & p	1	1	1	1	T	T	T	T		T+	T	T	1	T	T	T+	1	T	T	T	1+	3	3	T	
	p																T	T	T	T	T					
	p	1	1	2	2									3	3	2-	2-	1	T+	T	1	T	T+	T	1	
						T				1																
						T	T												4	T						
		6	6	2 ³	1	T	T	T	T		T	T	T	1			T	1						T	T+	T+
	s & p	1	T	1 ⁴	1		T	T	T	T	T	T	T	2	1	T	1			T	T			T	T+	
	p							T	T		T	T	T	T	T	T	1+							T	T	T
														T												
	s?	T	T	T+	1		T							T	T	T	1-	20	22	25	30	2	3	8	20	
	s?			T	T			T	T+	T	T	2	8			T	T					T	T	T	3	
					1						T		T	T	T	2	1									
									T							T	T									
NATIVE GRASS		3	3	9	18	15	25	34	32	41	46	49	50	7	8	10	11	15	4	16	10	3-	3	1	1	
	s?		T	1+	2	3	5	8	5	35	30	30	30			T		T	1	1	1			1	T	
																				T			T	T	T	
	s				T		T			T	T	T				T										
	p																	T	T	T		1	1+	T	1	
	p	T	T	T	T																	T+	T			
						T		1	T																	
											T															
			T	2	8	6	8	10	1		10	10	10	3	4	5	7						T		T	
					T				T	T							T									
	s & p	1	1	3	4	2	2	10	12	1		3	4	1	1	1	1+					T	T	T	T	
											T															
										T											T		T	T		
	s & p	2	2	3	4	3	10	5	5	5	6	6	6	3	3	4	3	15	3	15	9	1	1	T	T	
											T										T	T				
											T															
								T					T ¹													
EXOTIC FORB		5	3	37	37	24	12	T	45	2+	T	24	40	6	3	34	24	49	8	1	17	82	7	9	3	
				T	T	T	T		T		T		T		T	T	T	1	T				T		T	
		T				T			T	T				T			T	T								
																						1			T	
		3		T		3	T			T				2	T			5	T	T		20	T			

Table 21, continued: St. Mary Visitor's Center: Ocular Percent Cover for all Species by Plot, 2010-2015.

	source*	Island				Edge				Edge				Island				Edge				Island			
		SM-10-01				SM-10-02				SM-10-03				SM-10-04				SM-10-05				SM-10-06			
		2010	2011	2013	2015	2010	2011	2013	2015	2010	2011	2013	2015	2010	2011	2013	2015	2010	2011	2013	2015	2010	2011	2013	2015
EXOTIC FORB, con't																									
<i>Centaurea stoebe</i>				3	1+	T	T+	T	T+	1-			2			T	T			T					
<i>Chenopodium album</i>		1	T			T	T			T				1	T	T		T				T+	T		
<i>Chenopodium sp.</i>																						T			
<i>Cirsium arvense</i>									T	T	T	T	T+	T	T	T	T	T+	3	T	T+		T		T
<i>Cirsium vulgare</i>									T														T		T+
<i>Convolvulus arvensis</i>																			T						
<i>Descurainia sophia</i>		T	T			T								1					T			T	T		
<i>Erodium cicutarium</i>		T	T			T				T															
<i>Filago arvensis</i>		T				T	T			T	T			T								T	T		
<i>Gnaphalium palustre</i>										T															
<i>Lactuca serriola</i>						T	T							T	T							T			
<i>Lappula squarrosa</i>																							T		
<i>Linaria dalmatika</i>																							T		
<i>Linaria vulgaris</i>																						T	T+	T+	3
<i>Matricaria matricarioides</i>																			T						
<i>Medicago lupulina</i>		T	T	4	20	15	10		35					T	T	1	9	T	T	T	T	1	T	T	
<i>Melilotus alba</i>										T		1	2												
<i>Melilotus officinale</i>			T	30	14	2	T		8	T+	T	23	35		T	33	15	10	2	T	15	8	3	8	
<i>Polygonum aviculare</i>		T	T			2	T											30	2		T+	3	T		
<i>Polygonum convulvulus</i>				T(P)		T								T				T				T	T		
<i>Potentilla argentea</i>																							T		
<i>Potentilla norvegica</i>																							T		
<i>Salsola pestifer</i>										T															
<i>Silene latifolia</i>						T		T																T+	
<i>Sisymbrium altissimum</i>		1	T			1-	T			T+				1	T			1	T			50	2		
<i>Taraxacum officinale</i>		T	T	T	1	T	T		T						T	T	T	1	T	T	T				
<i>Thlaspi arvense</i>		T	T															T				T			
<i>Tragopogon dubius</i>			T		T		T	T	1			T	T				T							T	T
<i>Verbana bracteata</i>						T	T+	T	T	1-		T						T							
<i>Verbascum thapsus</i>										T		T		T											
<i>Veronica peregrinus</i>		T																							
EXOTIC GRASS		1	1	6	43	6	9	33	40	5	9	39	40	4	2	4	20	12	23	30	46	T	22	41	65
<i>Avena sativa</i>																		T							
<i>Bromus tectorum</i>		T	T	T	T	T	T	T	T	T	T			T	T	T	T	T	T	T	T	T	T		
<i>Bromus inermis</i>						1	2	6	10	T	T	5	12	1	1	2	5								3
<i>Elymus repens</i>		T	T	4	35	2	5	20	25	1	1	10	2	2	1	1	12	10	20	25	40	T	20	40	60
<i>Lolium multiflorum</i>										1	1														
<i>Phleum pratense</i>					2	2	1	1	T+	T	T	2	4	T		1	1			T	T		T	T	T
<i>Poa compressa</i>			T	1	4	T	T	5	4	1	2	2	2				T		1	T	1		T	T	T
<i>Poa pratensis</i>		1-	1	1	2	T	T	1	1	2	5	20	20	T		T	2	1	2	5	5	T	1+	1	2
<i>Setaria glauca</i>										T															

VI. WHITEBARK AND LIMBER PINE RESTORATION PROJECT

A. INTRODUCTION

Whitebark pine (*Pinus albicaulis*), is a long-lived, slow-growing mid to high-elevation five-needled pine tree. In Glacier National Park, this species is found on the east and west sides of the Continental Divide, although it is more abundant on the east side. Whitebark pine is considered a keystone species because of the important role it plays in the ecosystem. It is a hardy subalpine conifer that tolerates poor soils, steep slopes, windy exposures, and tree-line environments (Arno and Hoff 1990). This species provides valuable cover, shelter and nesting opportunities for many wildlife species. The grizzly bear and Clark's nutcracker rely on their seed for food. These trees also influence vegetation patterns by pioneering dry, exposed sites where no other tree species can grow. Because they establish on windy ridges and have broad crowns, they accumulate and retain snow which lengthens the snow melt period.

Another five-needled pine, limber pine (*Pinus flexilis*), is also considered to be a keystone species. This tree is found only on the east side of the Continental Divide in the park, mostly along the eastern margin of the Park. Glacier National Park has many fewer limber pine stands than whitebark pine stands as limber pine is more abundant on the Flathead Indian Reservation to the east of the Park. Small to medium in size, it often grows on rocky ridges and its form is frequently irregular. At the lower tree line it mixes with other conifers. Being relatively shade-intolerant, it is mostly a pioneer species and maintains its presence only on somewhat severe sites. Like whitebark pine, this species also provides valuable cover, shelter and nesting opportunities. The large seeds are a nutritious food source for birds, rodents, and bears.

Whitebark and limber pine populations have declined dramatically in Glacier National Park, largely due to the introduction of a non-native fungus, white pine blister rust (*Cronartium ribicola*). White pine blister rust is a disease of five-needled pines and has been linked to the decline of all five-needled pines in the Park. Severe climatic events, mistletoe, fire exclusion, and/or mountain pine beetles may have also contributed to the poor health of these trees. Whitebark pine mortality has been estimated at 44% within the park with approximately 78% of the remaining live trees infected (Kendall and Keane 2001). Kendall and Keane (2001) have also estimated limber pine mortality in Glacier National Park at 39% with 78% of the remaining live trees infected. Recent anecdotal evidence indicates that current mortality and infection rates for both species have increased since 2001.

Some mature whitebark and limber pine individuals have shown phenotypic genetic resistance to blister rust including few to no blister rust cankers, healthy needles, and cone production. These 'plus' trees continue to be identified in the park. Restoration efforts for these two species began in 1997 when seeds were collected from trees that showed phenotypic genetic resistance. In 1998, Glacier National Park received funding from the Intermountain Region Natural Resource Fund to continue collection efforts, grow seedlings from collected seeds, and plant seedlings at specific sites around the park. These seedlings have been planted in an effort to restore the ecosystem with disease-resistant trees. Limber pine seedlings have been planted at 17 sites on the east-side of the Park and whitebark pine seedlings have been planted at 14 sites, 10 on the east-side and 4 on the west-side (not counting Dutch Creek). Sites were selected based on accessibility for planting and appropriate habitat characteristics. If possible, sites were chosen in areas with recent burn activity, since these areas most mimic seed caching sites from Clark's nutcrackers, as well as provide the most advantageous growing conditions. Due to a shortage of burned habitat, limber pine seedlings have been planted exclusively in non-burned sites, while whitebark seedlings have been planted in several non-burned sites beginning in 2010. Planting years have been chosen based on the availability of seedlings.

Due to the mortality and expense associated with growing and planting seedlings, another restoration approach was initiated in 2006 and continued in 2007. To date, seeds from potentially resistant whitebark pine trees were directly planted at three sites, two of which have burned in recent years. Seeds were cached in groups, mimicking planting schemes of Clark's nutcrackers. The idea behind this strategy is not only to minimize expense, but also to provide a more natural scenario whereby seed can germinate when environmental conditions are favorable. Seedlings were also planted at two of the sites for comparison.

1. Limber Pine Restoration

Limber pine seedlings have been planted at 17 sites, 12 of which continue to support live trees in monitoring plots (Table 22 & Figure 22). A total of 9,170 seedlings have been planted in the park between 2002 and 2013. No

limber pine seedlings were planted in 2014 or 2015. Plantings typically occurred in the fall but a few plantings occurred in the spring. Monitoring plots have captured 24% of total planted seedlings overall (Table 22).

During the first wave of limber pine planting, seedlings were planted at 13 sites between 2002 and 2006 (Figure 22 & Table 22). A total of 4,778 seedlings were planted in the Park during this time. Plantings typically occurred in the fall but a few plantings occurred in the spring. Monitoring plots have captured 23% of total planted seedlings during this five year period (Table 22).

No limber pine seedlings were planted in the Park between 2006 and 2012. A concerted limber pine planting effort re-emerged in 2012 when 2,978 limber pine seedlings were planted, the most limber pine trees that have been planted in Glacier National Park since the restoration program began. The second largest planting took place in 2002, the inaugural limber pine planting year, with 2,390 trees planted.

Due to lack of suitable limber pine habitat that had burned prior to 2015, no limber pine seedlings from any year were planted in burn areas. However, the Reynolds Creek fire of 2015 recently provided acres of accessible limber pine habitat and planting is planned for these areas in 2016. Additionally, limber pine has not been utilized in the Montana State ectomycorrhizal inoculation study; therefore no limber pine seedlings have been inoculated. Recently, most seedlings have been grown in the nursery with several trees in one container. The result is that multiple trees are often planted in one hole during restoration plantings. To determine the number of actual trees planted in an area, a multiplier was applied based on the estimated average number of trees per cone and the number of cones was multiplied by this number to obtain an estimate of number of trees planted. Finally, seedlings from multiple cones are often planted together in one microsite to mimic clumping of seedlings produced from Clark's Nutcracker seed caches.

a. Limber Pine Planting Sites No Longer Monitored

Eleven sites were planted with limber pine seedlings in 2002: Apikuni Flats, the base of Altyn Peak (Many Glacier Hotel Slope), Dead Horse Point, Firebrand Pass Trail, Poia Lake Trail Head, Rocky Point, Scenic Point, Sun Point, Two Medicine Campground, Two Medicine Ranger Station and Wild Goose Island Turnout. Of all seedlings monitored at these sites, only one tree has survived at Firebrand Pass Trail. This tree was last monitored in 2012 at ten years after planting. As there are no surviving trees at the other sites, these areas are no longer monitored. Plantings in 2002 correlated with an extended hot, dry climatic cycle. Little information on planting techniques was available at this time so few correlations for cause of mortality, other than a hot summer, can be made.

b. Limber Pine Planting Sites Currently Monitored

i. 2012 Limber Pine Plantings

A total of 2,978 limber pine seedlings were planted at 5 sites in 2012. Three of these areas, Apikuni Flats, Rising Sun Campground, and Scenic Point, had been previously planted in 2002. No trees survived in plots in these areas from 2002, a drought year, although no monitoring plots were installed at Rising Sun Campground to monitor 2002 trees. Additionally, two new sites, Cutbank Campground and the Many Glacier water supply (well) area, were planted with limber pine in 2012.

In 2012, the largest number of planted seedlings occurred at the Scenic Point area, a site that had also been planted with limber pine in 2002 and 2004. This area historically harbored one of the park's largest limber pine stands, most of which are no longer living. However, some mature trees and seedlings do persist in this area. Although the soil is rocky at this site, microsites and natural shade were utilized as much as possible to prevent desiccation of seedlings. Rocks, logs, stumps and snags were used as microsites.

Seedlings were also planted in both spring and fall at Apikuni Flats in 2012. Apikuni Flats is located near the confluence of Apikuni Creek and Lake Sherburne in a very gently sloped area of the Many Glacier Valley. Limber pine have historically been scattered in this area and a few mature limber pine trees survive in this area today. Vegetative cover is high at this site, particularly with grasses, so some scalping of vegetation at planting sites occurred to reduce competition. Natural microsites were limited in this area as well, so rocks, logs and branches were re-located for use as planting microsites.

Both spring and fall plantings also took place at the Rising Sun Campground in 2012. Only spring plantings were monitored at this site, however. Rising Sun Campground is located in a relatively flat area at the confluence of Rose Creek and St. Mary Lake. Limber pine have historically been scattered in this area. Seedlings were planted in an open meadow area and in wooded areas of the campground with low understory cover. Logs were mostly utilized as planting microsites.

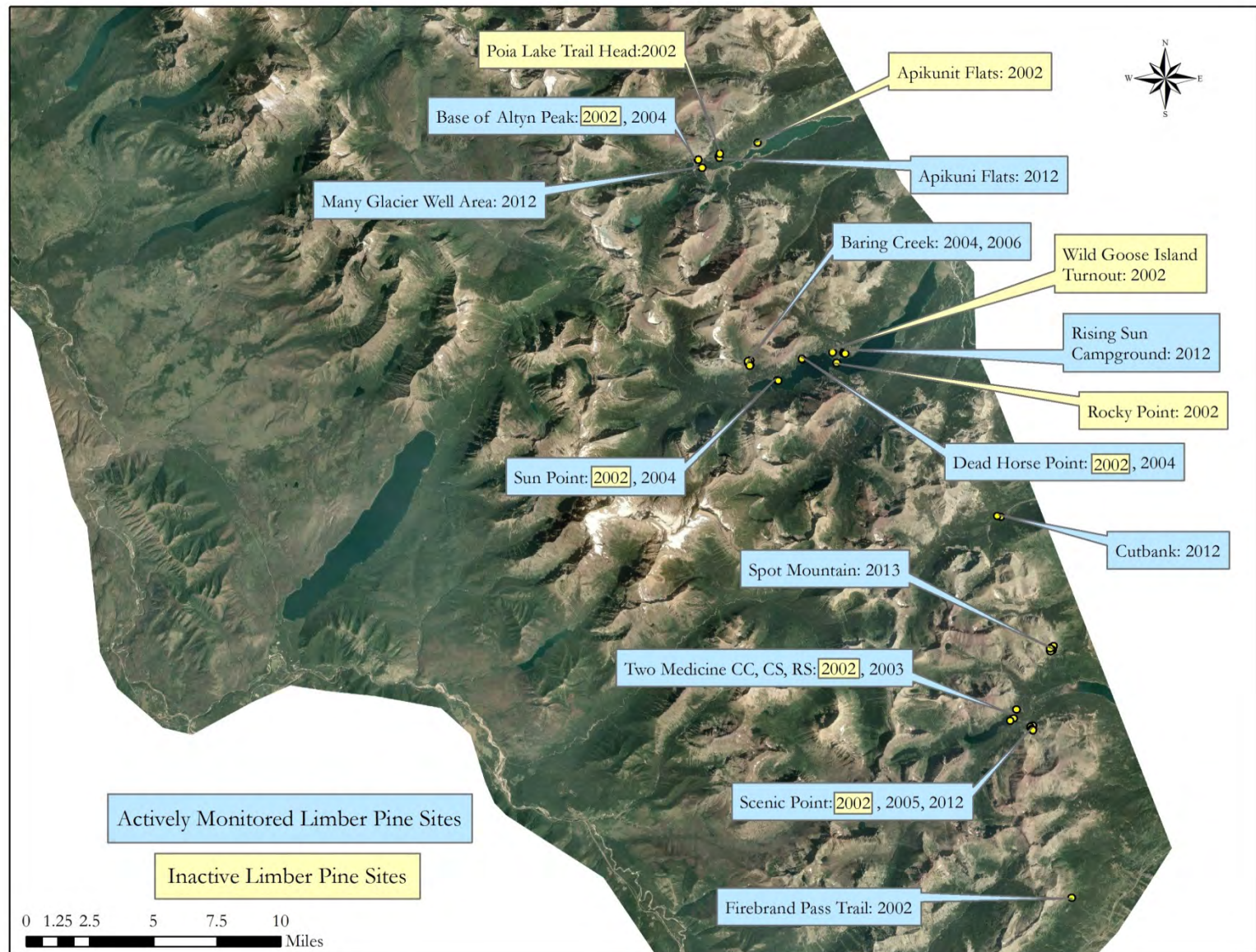
Table 22. Limber Pine Monitoring Plot Establishment to Date

S:VegUnit/Whitebark and Limber Pine/Whitebark and Limber Pine report tables.xls. (Limber Establishment tab)

<i>Site</i>	<i>Year</i>	<i># of Plots Established</i>	<i># of Cones Planted</i>	<i>Multiplier*</i>	<i># of Trees Planted Overall</i>	<i>Total # Trees Captured</i>	<i>% Trees Monitored</i>
Apikuni Flats	2002	2			160	25	16%
	2012	2			662	123	19%
Total		4			822	148	18%
Baring Creek	2004	5			450	91	20%
	2006	3			250	71	28%
Total		8			700	162	23%
Base Altyn Peak	2002	1			160	27	17%
	2004	2			200	40	20%
Total		3			360	67	19%
Cutbank	2012	2			286	82	29%
Total		2			286	82	29%
Dead Horse Point	2002	5			800	188	24%
	2004	2			250	53	21%
	2006	1			262	20	8%
Total		8			1312	261	20%
Firebrand Pass	2002	2			140	38	27%
Total		2			140	38	27%
Many Glacier Well	2012	1			196	64	33%
		1			196	64	33%
Poia Lake TH	2002	2			160	41	26%
Total		2			160	41	26%
Rising Sun	2012	2			570	140	25%
		2			570	140	25%
Rocky Point	2002	2			150	37	25%
Total		2			150	37	25%
Scenic Point	2002	4			200	74	37%
	2005	6			700	149	21%
	2012	4			1264	335	27%
Total		14			2164	558	26%
Spot Mountain	2013 (spring)	4	352	1.9	669	134	20%
	2013 (fall)	3	392	1.9	745	201	27%
Total		7			1414	335	24%
Sun Point	2002	2			220	53	24%
	2004	2			250	54	22%
Total		4			470	107	23%
Two Medicine CG	2002	2			160	35	22%
Total		2			160	35	22%
Two Medicine CS	2003	1			26	26	100%
Total		1			26	26	100%
Two Medicine RS	2002	2			140	38	27%
Total		2			140	38	27%
Wild Goose Island TO	2002	1			100	29	29%
Total		1			100	29	29%
Overall Total		62			9170	2168	24%

*a multiplier was applied based on the estimated average number of trees per cone, and the number of cones was multiplied by this number to obtain an estimate of number of trees planted

Figure 22. Limber Pine Seedling Monitoring Sites



A new planting area was established at the Cutbank Campground area in 2012. One site lies within the campground itself and a second site is located about 220 meters west of the campground in a small opening just above the Triple Divide trail. Limber pine are not historically present in this area but have grown nearby. The campground area offers shade from a mature canopy and little groundcover competition. The site above the trail, however, is highly vegetated and provides ample vegetative competition for seedlings. Microsites were provided here when possible, using small logs or branches. Microsites were more prevalent in the campground area in the form of stumps and snags. This site was only planted in the spring.

Seedlings were also planted on a ridge near the Many Glacier water supply area in 2012, another new site. All of these trees were planted in the fall. This area is also highly vegetated with grasses and forbs so scalping of planting sites occurred at this site. This is a more naturally rocky area, bordering a small cliff band, and rocks were primarily utilized as microsites. Physical characteristics of planting sites are listed in Table 23.

Table 23. Characteristics of Limber Pine Planting Sites.

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Site	Year Planted	Season Planted	Elevation of Plots (feet)	In burn?	Inoculated?
Apikuni Flats	2002	Fall	4,829 - 4,850	No	No
	2012	Spring	4,904	No	No
	2012	Fall	4,927	No	No
Baring Creek	2004	Spring	5,040 - 5,130	No	No
	2006	Spring	5,280 - 5,520	No	No
Base of Altyn Peak	2002	Fall	5,115	No	No
(Many Glacier Hotel Slope)	2004	Fall	5,080 - 5,090	No	No
Cutbank	2012	Spring	5,185 - 5,241	No	No
Dead Horse Point	2002	Fall	4,720 - 4,920	No	No
	2004	Fall	4,720 - 4,780	No	No
	2006	Spring	4,730	No	No
Firebrand Pass Trail	2002	Fall	5,670 - 5,710	No	No
Many Glacier Well	2012	Fall	5,125	No	No
Poia Lake Trail Head	2002	Fall	4,898	No	No
Rising Sun	2012	Spring	4,527 - 4,541	No	No
		Fall	N/A	No	No
Rocky Point	2002	Fall	4,562	No	No
Scenic Point	2002	Fall	5,670 - 5,775	No	No
	2005	Fall	5,765 - 5,800	No	No
	2012	Spring	5,575 - 5,740	No	No
	2012	Fall	5,575 - 5,734	No	No
Spot Mountain	2013	Spring	6,244 - 6,480	No	No
	2013	Fall	6,175 - 6,401	No	No
Sun Point	2002	Fall	4,600	No	No
	2004	Fall	4,560	No	No
Two Medicine Campground	2002	Fall	5,166	No	No
Two Medicine Camp Store	2003	Fall	5,164	No	No
Two Medicine Ranger Station	2002	Fall	5,199	No	No
Wild Goose Island Turnout	2002	Fall	4,650	No	No

ii. 2013 Limber Pine Plantings

In 2013, 1,414 limber pine seedlings were planted in both the spring and the fall. All seedlings were planted at Spot Mountain, a new planting site. This area historically supported another of the park's larger limber pine stands, most of which are no longer living as evidenced by standing snags that scatter the slopes of these foothills. However, some mature trees and seedlings do persist in this area. Microsites and natural shade were used as much as possible to prevent desiccation of seedlings. Rocks, logs, stumps and snags were utilized as microsites.

Plantings occurred on lower slopes on the southeastern flank of Spot Mountain about 200 meters below a stretch of cliffbands.

No limber pine seedlings were planted in the Park in 2014 or in 2015. Plans were in place to plant limber pine in 2015, but due to drought conditions it was decided to postpone limber pine plantings until 2016. This will also allow for utilizing new burned habitat created during the Reynolds Creek Fire of 2015 for limber pine planting. To date, no limber pine plantings have occurred within a burned area in the Park.

2. Whitebark Pine Restoration

Whitebark pine seedlings have been planted at 14 sites between 2000 and 2015, all of which continue to support live trees (Figure 23 & Table 24). A total of 20,591 seedlings have been planted in the park between 2002 and 2015. More sites were planted in the fall than in the spring, although some areas at Flattop Mountain, along the Firebrand Pass Trail, Scenic Point and Spot Mountain were planted in the spring. Two sites, Cobalt Lake and Grinnell Glacier Picnic Area, were planted in late summer. A few other small plantings have occurred that were too small to warrant monitoring plots and are not included in the tally of planted 5-needle pines in the Park. In 2013, small plantings took place at Morning Star and Atlantic Creek, on the Blackfeet Reservation near the Park boundary on Divide Mountain, and at the eastern saddle of Divide Mountain. Additionally, small plantings have taken place over the years during general revegetation projects and memorial tree plantings in areas such as Old Man Lake Campground.

Monitoring plots have captured 21% of total planted whitebark pine seedlings (Table 24). The number of plots created at each site was dependent on planting densities and number of seedlings planted at the site. Data on the survival and health of individuals were collected during each monitoring event.

As is the case with limber pine seedlings, whitebark pine seedlings have recently been grown in the nursery with several trees in one container. Multiple trees, therefore, are often planted in one hole during restoration plantings. To determine the number of actual trees planted in an area, a multiplier was applied based on the estimated average number of trees per cone and the number of cones was multiplied by this number to obtain an estimate of number of trees planted. Like limber pine, seedlings from multiple cones are often planted together in one microsite to mimic clumping of seedlings produced from Clark's Nutcracker seed caches.

a. Whitebark Pine Planting Areas

A brief chronological description of planting sites follows. Additionally, Table 24 contains information on numbers of seedlings planted and monitored and Table 26 lists physical characteristics of planting sites.

In the fall of 2000, 96 seedlings were planted at Grinnell Point after the Grinnell Point Fire passed through the site earlier in the season. Access was granted by helicopter. This site is located in rugged, rocky, windswept terrain. Since this was the initial 5-needle pine planting in the Park, little was known about planting techniques and microsites were not utilized. In 2015, the revegetation crew re-monitored these trees, the first time that this site has been visited by Glacier National Park Staff since planting due to challenging access.

The largest whitebark pine planting site to date is at Flattop Mountain where a total of 5,160 trees were planted. This area was burned in the McDonald Creek Fire of 1998 prior to planting. Plantings occurred in early summer and fall with various numbers of seedlings planted during each planting event. Planting sites were located on relatively flat benches, many of which retain late season snowmelt. Planting crews had not yet begun using microsites for seedling protection at this point in time.

In the fall of 2006, 139 seedlings were planted at Caper Peak above Lake Isabel, a site that burned in the Rampage Fire of 2003. All seedlings planted at this site were included in monitoring plots. Microsites were still not a strategy used when planting. Due to the remote location of these sites, they were not monitored again until 2008. In addition, whitebark pine seeds were directly planted in the ground at this site (Figure 23 & Table 25). All seeds planted at this site were placed in monitoring plots. Germination rates and survival results of direct seeding may take several years to determine.

In 2007, 2,000 whitebark pine seedlings were planted along the eastern flank of Red Eagle Mountain and near the Red Eagle Campground, areas that burned in the 2006 Red Eagle Fire (Figure 23). Seedlings were planted at two sites; one site on the midslope of Red Eagle Mountain and one smaller site on an open knoll near the campground. A new methodology was used to install transects to monitor whitebark pine seed directly planted into the ground (see Methods section and Table 25).

Figure 23. Whitebark Pine Seedling and Seed Monitoring Sites

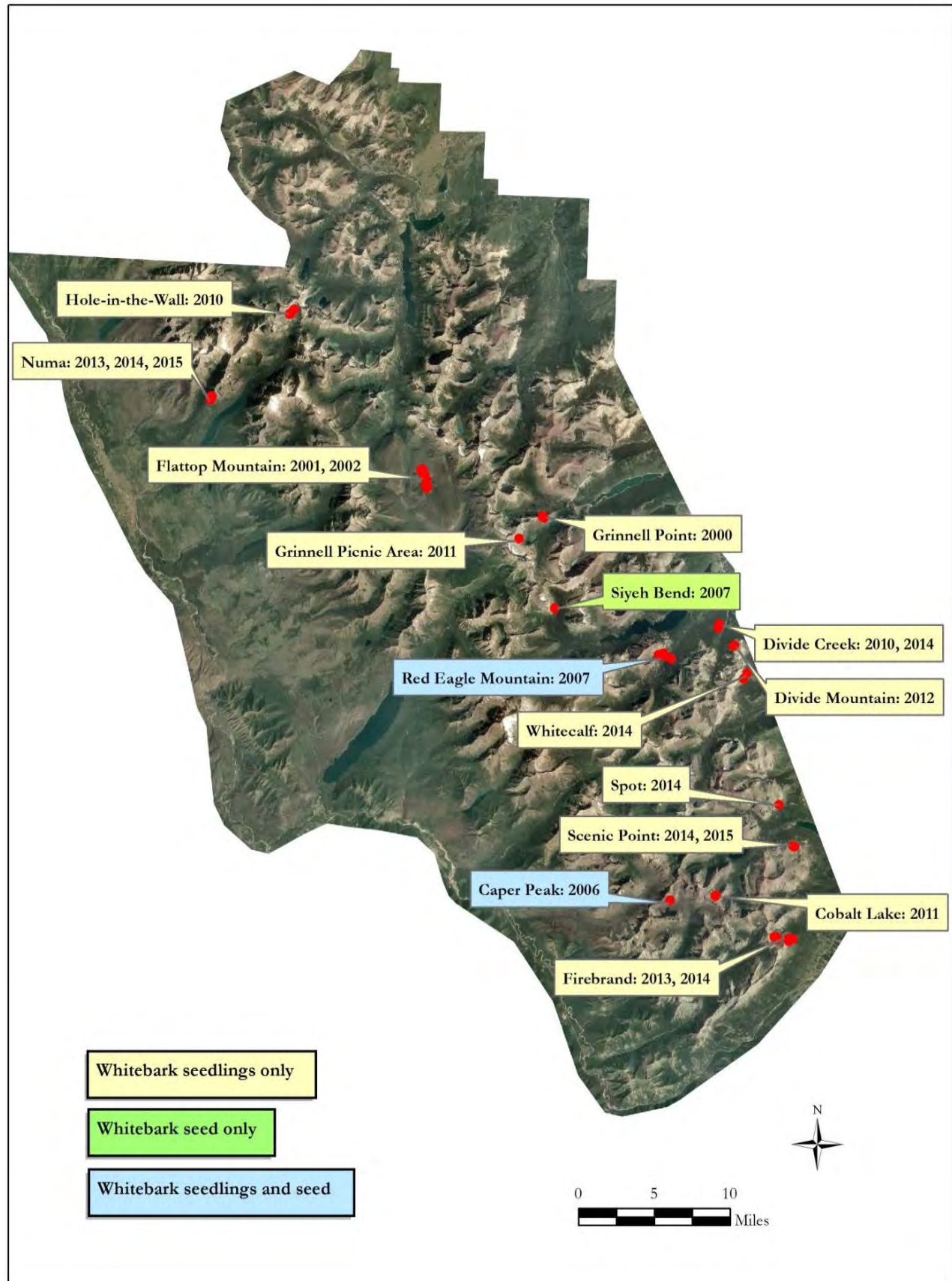


Table 24. Whitebark Pine Seedling Monitoring Plot Establishment to Date

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Whitebark Establishment tab)

<i>Site</i>	<i>Year Established</i>	<i># of Plots Established</i>	<i># of Cones Planted</i>	<i>Multiplier</i>	<i># of Trees Planted</i>	<i># of Trees Monitored</i>	<i>% Trees Monitored</i>
Flattop Mtn.	2001 (spring)	16			1,500	285	19%
	2001 (fall)	11			1,438	350	24%
	2002 (fall)	11			2,222	292	13%
Total		38			5,160	927	18%
Grinnell Point	2000 (fall)	7			96	96	100%
Caper Peak	2006 (fall)	2			139	139	100%
Red Eagle	2007 (fall)	9			2,000	422	21%
Divide Creek	2010 (fall)	5			1,126	263	23%
	2014 (fall)	3	933	1.1	1,026	216	21%
Hole-in-the-Wall	2010 (fall)	5	222		830	159	19%
Grinnell Glacier Picnic	2011 (summer)	2	150	2	300	98	33%
Cobalt Lake	2011 (summer)	3	250	2.04	510	108	21%
Divide Mountain	2012 (fall)	4	686	2	1,283	216	17%
Numa	2013 (fall)	3	310	1.8	558	167	30%
	2014 (fall)	4	473	1.5	710	208	29%
	2015 (fall)	2	219	1.1	222	64	29%
Firebrand	2013 (spring)	4	516	2	1,032	208	20%
	2013 (fall)	5	1,175	2	2,350	375	16%
	2014 (spring)	2	238	1.9	452	102	23%
	2014 (fall)	3	517	1.1	569	133	23%
Scenic Point	2014 (spring)	2	422	1.9	802	188	23%
	2015 (fall)	2	219	1.1	222	68	31%
Spot Mtn.	2014 (spring)	1	219	1.9	416	36	9%
Whitetail Mtn.	2014 (fall)	2	657	1.2	788	146	19%
Overall Total					20,591	4,339	21%

Table 25. Whitebark Pine Seed Plot Establishment.

<i>Site</i>	<i>Year Established</i>	<i># of Plots Established</i>	<i># of Seeds Monitored</i>	<i>Source of Seed</i>
Caper Peak	2006 (fall)	2	423	unknown
Siyeh Bend	2007 (summer)	3	101	Preston Park, 2005 (#155)
Red Eagle Mtn.	2007 (fall)	1	102	Preston Park, 2005 (#155)
Red Eagle CG	2007 (fall)	1	98	Preston Park, 2005 (#155)
Total		7	724	

Using the same methodology, three additional transects were installed in 2007 at Siyeh Bend along the Going-To-The-Sun Road to monitor whitebark pine seed germination and tree growth in a more natural setting (Figure 23). Seeds were planted along a flatter section of slope and on flat benches near Siyeh Bend (Table 25).

In the fall of 2010, two sites were planted with whitebark pine seedlings. Whitebark pine seedlings were planted in a non-burned area at the Hole-in-the-Wall Campground area. Whitebark pine currently grows in this area and historic whitebark pine stands also existed in the area. In August 2010, a total of 830 whitebark pine seedlings were planted in the Hole-in-the-Wall campground and in the cirque area above the campground. Since this site has not been burned, an area of vegetation was “scalped” surrounding planting sites to reduce competition. Additionally, special attention was given to planting in sites with minimal surrounding vegetation, especially *Xerophyllum tenax*. Seedlings were preferentially planted near *Vaccinium scoparium*, *Luzula hitchcockii*, *Carex geyeri* and *Carex rossii*, since whitebark pine is disproportionately associated with these species (Izlar 2007). Microsites were utilized or provided for seedlings when possible.

Divide Creek was the second planting site established in 2010. This site burned in the 2006 Red Eagle Fire with moderate severity. Whitebark pine has not historically grown at this site but the area is located within potential whitebark pine habitat. In September 2010, a total of 1,126 whitebark pine seedlings were planted on a ridge above Divide Creek. Existing burned stumps and logs were used as planting microsites. As part of the planting, 300 of the seedlings planted at Divide Creek had been previously inoculated at Montana State University with a slurry made from ectomycorrhizal (ECM) mushroom species. Pines require ECM fungi for normal growth and survival and studies have confirmed whitebark pine to be ectomycorrhizal (Cripps and Mohatt 2005). These seedlings were planted together in groupings of 3 trees per hole throughout the revegetation site.

Two sites were planted in 2011 with a small number of trees. In August 2011, 250 whitebark pine seedlings were planted near the campground at Cobalt Lake. This area is not within a burn and, similar to the Hole-In-The-Wall site, vegetation was ‘scalped’ around the planted whitebark seedling to reduce competition. Seedlings were planted in forest openings near to existing whitebark pine trees. There were few natural microsites here so rocks and logs were placed near planting sites to create small microsites.

Also in August 2011, 146 whitebark pine seedlings were planted at the Grinnell Glacier Picnic Area. This area was also not within a burn but had both sparsely vegetated, open areas and denuded soil areas from social trails under trees. Both areas were used as planting sites and are near to existing whitebark pine trees. Similar to the Cobalt Lake site, there were few natural microsites, particularly in the open areas, so rocks and logs were placed near planting sites to create small microsites.

In 2012, one whitebark pine planting site was added. In September 2012, 1,283 whitebark pine seedlings were planted on the northwest flank of Divide Mountain. Plantings occurred on the edge of the 2006 Red Eagle Fire. On occasion, plots spanned both burned and non-burned areas, although the majority of seedlings were planted in burned areas. This site is located at the edge of treeline among a standing dead forest of subalpine fir with a small whitebark pine component. Natural regeneration of whitebark pine seedlings is high here. This site is located at the base of a boulder field with abundant boulders, rocks, stumps and snags for use as planting microsites. It is important to note that most of the seedlings planted at Divide Mountain were grown in the USFS Coeur d’Alene Nursery and were in good health at the time of planting. A smaller amount of planted trees at this site had been grown in the Glacier National Park Nursery and were not in as good of health due to the fact that they had been held over in cones to the point of being root-bound. While some of these trees may be within monitoring plots, the majority of the monitored trees appeared healthy and were likely trees from the Coeur d’Alene nursery.

In 2013, an estimated 4,060 whitebark pine seedlings were planted at four sites, including the Firebrand Pass Trail area in both the spring and fall, Numa Ridge in the fall, Morning Star campground in the fall, and Atlantic Creek campground in late summer. All of these areas are new planting sites and were selected due to their habitat suitability and the presence of healthy whitebark pine plus trees in or near the vicinity. These sites also supported larger whitebark stands historically, most of which have suffered significant mortality in the past few decades. Since there had not been any recent fire activity in suitable whitebark pine habitat recently, all of these plantings occurred in unburned areas.

In the spring of 2013, approximately 1,032 whitebark seedlings were planted on a relatively flat bench below the cirque of Firebrand Pass, starting about 200 meters north of a small unnamed lake. Since planting areas are exposed to full sun, microsites were carefully utilized as protection for young fragile seedlings. Downed trees, standing snags, rocks, logs and stumps were used as microsites.

Whitebark seedlings were again planted at the Firebrand Pass Trail area in the fall of 2013 but at lower elevations. Two spots, about 400 meters apart, were planted with a total of approximately 2,350 seedlings. The lowest spot is located on a bench that is near an identified plus tree in this area. Seedlings at this site originated from parent trees from the Old Man Lake trail, Whitecalf, and Triple Divide areas. While we know the general area of seedling origin, the nursery in Coeur d’Alene still bulks seed together by site making it impossible to associate the seedling back to an individual parent tree. No seedlings on this lower bench were inoculated with ectomycorrhizal slurry. Seedlings were also planted at a slightly higher elevation bench in this fall planting. Some, but not all, seedlings at this site were inoculated with ectomycorrhizal slurry. Seedlings in these upper bench plantings were identified to parent tree populations from either the Rising Wolf or Whitecalf areas. Microsites were well utilized at both sites, including downed trees, snags, logs, rocks and stumps.

Also in the fall of 2013, approximately 558 whitebark pine seedlings were planted at Numa Ridge on south-facing slopes just below the lookout. Seedlings planted in this area originated from seed collected from plus trees on Numa Ridge. Most, but not all, seedlings at this site were inoculated with ectomycorrhizal slurry. Microsites were well used again at this site, including downed trees, snags, logs, rocks and stumps. Monitoring did not take place at Morning

Star or Atlantic Creek Campgrounds due to the small size of plantings at these sites. 30 containers were planted at each of the sites during restoration efforts.

A large-scale planting effort continued in 2014 with 3,975 whitebark pine seedlings planted at 7 sites. Three sites were planted in the spring, including the planting of 452 seedlings near the Firebrand Pass area, 802 seedlings at Scenic Point, and 416 seedlings at Spot Mountain. Four sites were planted in the fall including the planting of 1,026 seedlings at Upper Divide Creek (above the 2010 planting), 569 seedlings near Firebrand Pass itself, 710 seedlings near Numa Lookout, and 788 seedlings at Whitecalf Mountain. Only one of these sites, Divide Creek, has burned. Additionally, 2 other sites received minor plantings that were too small for monitoring; one on the Blackfoot Indian Reservation along the eastern border with the Park and one along the saddle of Divide Mountain.

Finally, in late September of 2015, 2 sites were planted with whitebark pine seedlings. A total of 444 seedlings were planted, including 222 seedlings at Scenic Point and 222 seedlings at Numa Lookout. Both sites have been planted in previous years.

Table 26. Characteristics of Whitebark Pine Planting Sites.

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (WBP Site Chars tab)

Site	Year Planted	Season Planted	Elevation of Plots (feet)	In burn?	Burn	Inoculated w/ ectomycorrhizae?
Grinnell Point	2000	Fall	6,500 - 7,320	Yes	Grinnell Point Fire, 2000	No
Flattop Mountain	2001	Spring	6,340 - 6,750	Yes	McDonald Creek Fire, 1998	No
	2001	Fall	6,750 - 6,840	Yes	McDonald Creek Fire, 1998	No
	2002	Fall	6,750	Yes	McDonald Creek Fire, 1998	No
Caper Peak	2006	Fall	6,520	Yes	Rampage Fire, 2003	No
Red Eagle	2007	Fall	5,700 - 5,900	Yes	Red Eagle Fire, 2006	No
Divide Creek	2010	Fall	5,720 - 5,760	Yes	Red Eagle Fire, 2006	Yes, 27%
	2014	Fall	5,753 - 5,775	Yes	Red Eagle Fire, 2006	Yes, some
Hole-in-the-Wall	2010	Fall	6,349 - 6,922	No	N/A	No
Grinnell Glacier Picnic	2011	Late summer	6,240 - 6,280	No	N/A	No
Cobalt Lake	2011	Late summer	6,570 - 6,670	No	N/A	No
Divide Mountain	2012	Fall	7,070 - 7,150	Yes/No	Red Eagle Fire, 2006	Yes, 47%
Numa Lookout	2013	Fall	6,896 - 6,920	No	N/A	Yes, most
	2014	Fall	6,710 - 6,870	No	N/A	No
	2015	Fall	6,780 - 6,850	No	N/A	No
Firebrand Pass Trail	2013	Spring	6,515 - 6,540	No	N/A	No
	2013	Fall	6,037 - 6,404	No	N/A	Yes, some
	2014	Spring	6,506 - 6,520	No	N/A	No
	2014	Fall	6,500 - 6,850	No	N/A	No
Scenic Point	2014	Spring	7,164 - 7,210	No	N/A	No
	2015	Fall	7,100	No	N/A	No
Spot Mountain	2014	Spring	6,232	No	N/A	No
Whitecalf Mountain	2014	Fall	6,736 - 6,763	No	N/A	No

B. METHODS

1. *Seedling Monitoring Plots*

Shortly after seedlings are planted, monitoring plots are installed. Plot locations are chosen based on areas that are representative of the planting site and that contain a relatively high concentration of newly planted trees. UTM coordinates are taken at plot center and directions to the plot are recorded. To further assist with center stake location, a photo is taken of each stake and its associated location and azimuth are recorded.

Plot center is permanently marked with a large nail, often painted florescent orange for visibility, and tagged with the plot number. Plot numbers are either engraved on brass tags or hand pressed on aluminum tags. Plot center is chosen in order to capture as many trees in all directions as possible. Descriptive data are recorded for the plot,

including slope, aspect, elevation, light availability, landform, moisture regime, dominant lifeform cover, potential animal disturbance, and soil type. Special attention is given to describing the location of the center nail.

Each planted seedling within the plot is located and assigned a number. For each seedling, the distance from plot center, in meters, and azimuth from plot center are recorded. The health of each tree is assessed and recorded, using the following scale: 1=dead, 2=missing (not found), 3=almost dead, 4=fair, 5=good (healthy). Comments that further describe the tree's health or may have a bearing on its ability to survive (e.g. growth, dead needles, number of seedlings planted together, presence and type of microsite, and whether or not a seedling was inoculated with ectomycorrhizal fungi) are recorded as well. In 2015, recording of the cardinal direction that the tree is located from the microsite was added.

Plots are distributed throughout the planting site to avoid over sampling any given area, if possible. Monitoring plots attempt to capture 20% to 25% of the total seedlings planted at each site. The number of seedlings captured per plot and plot radius varies between plots but ideally plots contain 15 to 50 trees with a radius not much larger than 10 meters. It is difficult to obtain accurate distances or see all seedlings in plots with radii greater than 10 meters.

Subsequent monitoring events entail locating each plot and each seedling within the plot and utilizing the 5 point scale of health and survival assessment with comments as deemed necessary. Trees assigned a "2" (missing) were either previously dead and subsequently had disintegrated or were not found. Many times a tree can be given a "2" one year and then be found alive the next year. Additionally, beginning in 2007, height and width of whitebark pine seedlings began to be measured (in cm), although only height was recorded the first year at Red Eagle (2007).

Initially, plots were scheduled to be monitored at years 1, 2, 3, 5, 10, 15 and 20 years after planting. Due to high numbers of scheduled plantings between 2013 and 2015, however, it was decided to skip year 2 monitoring. This ensures that there is time to establish plots at new sites, as well as visit existing monitoring plots.

2. *Whitebark Pine Seed Monitoring Transects*

There have been two methodologies used to install plots that monitor whitebark pine seed that is planted directly into the ground. On Caper Peak, two plots were installed in 2006 that resembled the whitebark and limber pine seedling plots. A center nail was installed, tagged, and documented with a GPS. Azimuth and distance from plot center measurements were then recorded for each seed cache, similar to the seedling plots described above. Multiple plantings occurred at each azimuth but with different distances from the center point. In this case, seed caches were interspersed with planted seedlings so that these two plots contain both seedlings and seed in the same plot. Plots ranged in size from 18 to 19 foot radius. Thirty eight and twenty nine caches of seed were installed in these respective plots with each cache containing 4 to 13 seeds. Due to their remote location, these plots were not monitored in 2007 but were monitored in 2009, three years after seeding.

A new methodology was used in 2007 near Siyeh Bend and Red Eagle Campground to monitor whitebark pine seed. In both locations, transects ranging from 20 to 30m were installed along relatively flat benches or mild slopes. These locations were chosen for their stability and the fact that large-scale snow movement that could take out both seedlings and monitoring stakes did not seem likely. Transects generally ran parallel to any slope that existed and were staked at the start and end of the transect line. GPS locations were recorded for these start and end points. A tape was laid out between these two points and then planting sites were haphazardly located at different distances either upslope or downslope originating from different lengths along the center line. Eight to thirteen caches of seed were then planted along the transect with 3 to 5 seeds per cache at Siyeh Bend and 6 to 10 seeds per cache at Red Eagle. The location of each cache was staked with a tagged nail and the distance along the transect line and direction and distance up or down from the transect line was recorded. Attempts were made to plant the seed caches in appropriate microsites for shade or to prevent erosion and snow damage. Attempts were also made to plant the seed caches within relatively open areas to reduce competition from other vegetation. Associated species, microsite slope, and description of the microsite were recorded for each cache site.

C. RESULTS

1. *Limber Pine Seedling Results*

Limber pine seedlings have been planted at 17 sites, 12 of which continue to have live trees in monitoring plots. Table 27 is a summary of all the limber plantings to date indicating the number of trees that have survived to date, percent survival, and the overall health rating at each site. Further discussion in this report is only for the sites monitored in 2015.

Table 27. Health and Survival of Remaining Live Limber Pine Seedlings, 2002 – 2015.

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Limber Health and Survival tab)

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Last Year Monitored</i>	<i>Dead / Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Unk.</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
Various	2002	fall	2004	547	0	0	0	0	0	547	0%
Firebrand Pass Trail	2002	fall	2012	37	0	0	1	0	1	38	3%
Total 2002 Plantings				584	0	0	1	0	1	585	0.2%
Two Med Camp Store	2003	fall	2012	25	0	0	1	0	1	26	4%
Total 2003 Plantings				25	0	0	1	0	1	26	4%
Baring Creek	2004	spring	2014	62	0	4	17	0	21	92	23%
Base of Altyn Peak	2004	fall	2014	30	0	0	10	0	10	40	25%
Dead Horse Point	2004	fall	2014	52	0	0	0	0	1	53	2%
Sun Point	2004	fall	2014	51	0	0	4	0	4	55	7%
Total 2004 Plantings				195	0	4	31	0	36	240	15%
Scenic Point	2005	fall	2015	138	0	2	9	0	11	149	7%
Total 2005 Plantings				128	1	5	15	0	21	149	14%
Baring Creek	2006	spring	2011	68	0	1	2	0	3	71	4%
Dead Horse Point	2006	spring	2009	20	0	0	0	0	0	20	0%
Total 2006 Plantings				68	0	1	2	0	3	91	3%
Cutbank	2012	spring	2015	27	3	7	45	0	55	82	67%
Apikuni Flats (Spring)	2012	spring	2015	51	1	5	22	0	28	79	35%
Apikuni Flats (Fall)	2012	fall	2015	36	0	7	6	0	13	49	27%
Rising Sun CG	2012	spring	2015	118	2	1	19	0	22	140	16%
Scenic Point	2012	spring	2015	78	0	37	40	0	77	155	50%
Scenic Point	2012	fall	2015	88	4	19	83	1	106	195	54%
Many Glacier Well Area	2012	fall	2015	36	0	1	26	0	27	63	43%
Total 2012 Plantings				434	10	77	241	1	328	762	43%
Spot Mountain	2013	spring	2014	72	3	25	42	0	70	142	49%
Spot Mountain	2013	fall	2014	22	14	33	135	0	182	204	89%
Total 2013				94	17	58	177	0	252	346	73%
Overall Total				1528	28	145	468	1	642	2199	29%
Percentage of Surviving Trees					4%	23%	73%	0%			
Percentage of Monitored Trees				69%	1.3%	7%	21%	0%			29%

a. 2005 Plantings (10 Year Seedlings)

i. Scenic Point

On September 29, 2005, 700 limber pine seedlings were planted in the lower Scenic Point Trail area (Figure 24). Six monitoring plots were established in October of that year, encompassing 149 trees and following 21% of planted trees. This area is a relatively open, rocky slope and has not burned.

Ten years after planting at this site, 11 trees, or 7% of monitored seedlings are alive (Tables 27, 28, 29). Of these, 9 trees, or 82% of live trees, were rated in “good” condition while 2 trees, or 18%, were considered in “fair” condition. Average height was 13.64 cm which is actually 0.9 cm shorter than 5 years ago (Table 28). Average width was 21.3 cm, 8.2 cm wider than 5 years ago. This likely reflects a windswept environment where it is difficult for trees to grow in height but easier to spread outwards. It was noted that several trees appeared windswept. These trees are smaller than limber pine seedlings and whitebark pine seedlings at all other sites 10 years after planting (Table 29). Seedlings at most other planting sites were quite a bit taller after ten years, averaging 6 to 47 cm taller at other sites. Trees at other sites also averaged 3 to 44 cm wider than those at Scenic Point ten years after planting. Several of these other areas are more protected sites, however, and less battered by wind.

Figure 24. Limber Pine Monitoring Plots at Scenic Point, Planted in 2005.

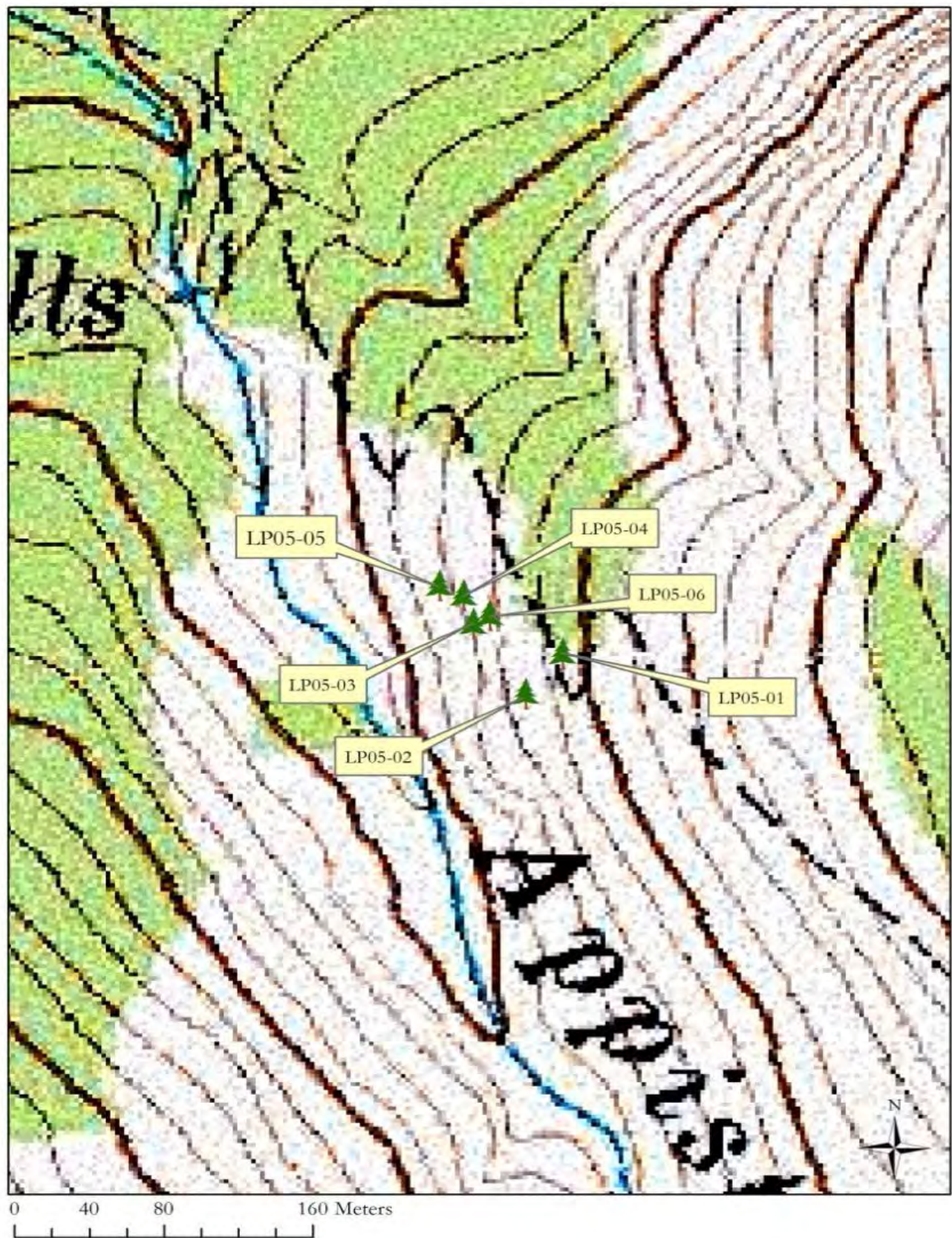


Table 28. Survival and Average Height and Width of Limber Pine Seedlings planted in 2005.

* Height and Width not recorded prior to 2010

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Planted 2005 tab).

<i>Site</i>	<i>Monitoring Year</i>	<i>Years Post Planting</i>	<i># Trees Survived</i>	<i>% of Trees Survived</i>	<i>Average Height</i>	<i>Average Width</i>
Scenic Point	2005	0	146	98%	*	*
	2006	1	37	25%	*	*
	2007	2	21	14%	*	*
	2008	3	21	14%	*	*
	2010	5	21	14%	14.52	13.05
Year 10 Survival	2015	10	11	7%	13.64	21.27

Table 29. Sizes and Survival of Ten Year Old Limber Pine and Whitebark Pine Trees Planted in 2002-2005.

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (LP Height and Width tab)

<i>Site</i>	<i>Species</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Last Year Monitored</i>	<i>Year 10</i>		<i>Number Alive</i>	<i>Percent Alive</i>
					<i>Height</i>	<i>Width</i>		
Firebrand Pass Trail	Limber pine	2002	fall	2012	30	65	1	3%
Two Medicine Camp Store	Limber pine	2003	fall	2013	43	41	1	4%
Baring Creek	Limber pine	2004	spring	2014	30.71	23.9	21	23%
Dead Horse Point	Limber pine	2004	fall	2014	61	39	1	2%
Base of Altyn Peak (MG Hotel Slope)	Limber pine	2004	fall	2014	19.3	23.9	10	25%
Sun Point	Limber pine	2004	fall	2014	22.25	28	4	7%
Scenic Point	Limber pine	2005	fall	2015	13.64	21.27	11	7%
Flattop Mtn. Spring	Whitebark pine	2001	spring	2011	45.44	29.35	107	28%

b. 2012 Plantings (Third Year Seedlings)

Overall, three-year survival for limber pine seedlings planted at 5 different sites in 2012 was 43% (Table 30). Highest survival was found at Cutbank with 67% of the seedlings surviving. The lowest survival rate was seen at the Rising Sun Campground area with only 16% of the seedlings surviving.

i. Apikuni Flats

A total of 662 seedlings were planted at Apikuni Flats in the Many Glacier area in 2012 (Figure 25); 270 in the spring and 392 in the fall. Nineteen percent of seedlings were captured in monitoring plots. One plot was established at this site after planting in the spring and an additional plot was installed at this site after planting in the fall. All trees were alive and in good health at the time of planting in the spring.

Grouping spring and fall plots together, 32%, or 41 trees, were still alive three years after planting. Twenty two percent, or 28 trees, were in good health. Sixty eight percent, or 87 trees, were dead or missing. Average height was 10.56 cm and average width was 7.12 cm.

Trees planted in the spring fared slightly better than those planted in the fall. Three years after planting, survival was 35% for trees planted in the spring and 27% for trees planted in the fall (Tables 31 and 32). Additionally, 28% of trees planted in the spring were rated in good health, compared to only 12% of trees planted in the fall that had the same rating (Tables 31 and 32). Seedlings planted in the spring were also larger than those planted in the fall. Spring-planted trees averaged 11.04 cm in height and 7.39 cm in width, while those planted in the fall averaged 9.54 cm in height and 6.54 cm in width. At this relatively protected site, perhaps it was advantageous to have the growing season to establish root mass and food storage ability before the first winter of dormancy.

Table 30. Survival, Height and Width of Limber Pine Seedlings by Site, Planted in 2012.

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Planted 2012 tab)

<i>Site</i>	<i>Year Monitored</i>	<i>Season Planted</i>			<i>Total # Trees Mon.</i>	<i>Number Alive</i>	<i>Percent Alive</i>
			<i>Height</i>	<i>Width</i>			
Apikuni Flats (Spring)	2015	spring	11.04	7.39	79	28	35%
	2013		8.09	8.55	79	33	42%
	2012 (fall)		9.03	8.53	79	66	84%
	2012 (spring)		8.12	7.81	79	77	97%
Apikuni Flats (Fall)	2015	fall	9.54	6.54	49	13	27%
	2013		6.72	7.56	49	32	65%
	2012		8.46	7.98	49	46	94%
Cutbank (spring)	2015	spring	9.80	8.13	82	55	67%
	2013		8.29	7.77	82	69	84%
	2012 (fall)		8.43	8.04	82	76	93%
	2012 (spring)		7.89	6.22	82	82	100%
Many Glacier Well (Fall)	2015	fall	11.37	10.07	63	27	43%
	2013		9.20	8.00	63	40	63%
	2012		10.62	7.67	63	63	100%
Rising Sun (Spring)	2015	spring	12.18	8.59	140	22	16%
	2013		8.33	8.76	140	63	45%
	2012		7.43	8.48	140	130	93%
Scenic Point (Spring)	2015	spring	9.01	8.13	155	77	50%
	2013		7.73	8.43	155	74	48%
	2012 (fall)		9.01	8.39	155	131	84%
	2012 (spring)		7.76	7.59	155	129	83%
Scenic Point (Fall)	2015	fall	10.04	8.86	195	106	54%
	2013		8.67	7.88	195	120	62%
	2012		10.63	8.22	195	179	92%
Total One Year Survival	2012	Ave. height/width yr. 1	9.09	8.19	763	706	93%
Total Spring to Fall Year One	2012 (fall)				316	273	86%
Total Two Year Survival	2013	Ave. height/width yr. 2	8.15	8.14	763	431	56%
Total Three Year Survival	2015	Ave. height/width yr. 3	10.43	8.24	763	328	43%

The spring of 2012 experienced good moisture, and in sites that were less windswept, desiccation may have been less of an issue as plants were establishing themselves.

ii. Many Glacier Well Area

A total of 196 seedlings were planted on a ridge near the Many Glacier water supply area in 2012 (Figure 25). All of these trees were planted in the fall, 33% of which were captured in a single monitoring plot. All trees were initially in good health.

Three years after planting, 43% of seedlings, or 27 trees, were still alive (Table 30). All but one of these trees were rated in good health (Table 31). One tree was rated as “fair”. Seedlings at this site were the largest from the cohort that was planted in 2012 with an average height of 11.37 cm and average width of 10.07 cm (Table 30). Seedlings grew, on average, 0.75 cm in height and 2.4 cm in width since planting.

iii. Cutbank

In the spring of 2012, the Cutbank area was planted with 286 seedlings (Figure 26). Trees were only planted in the spring at this site. Twenty-nine percent of trees were captured in monitoring plots. Two plots were established in the spring near the Cutbank Campground. All trees were alive and most were in good condition at the time of planting. Three trees, or 4%, were considered in fair condition at the time of planting while the rest were in good health.

Of the sites planted with limber pine in 2012, this site had the highest survival by 2015. Three years after planting, 67% of seedlings were still alive (Table 30). Eighty-one percent of living seedlings (45 trees) were rated in good health, 13% (7 trees) were rated as “fair”, and 5% (3 trees) were almost dead (Table 32). Average height was 9.80 cm and average width was 8.13 cm (Table 30). Seedlings grew 1.91 cm, on average, in height since planting and 1.91 cm in width.

iv. Rising Sun

A total of 570 limber pine seedlings were planted in the Rising Sun Campground area in 2012 (Figure 27); 286 in the spring and 284 in the fall. While seedlings were planted in both spring and fall at this site, due to time constraints, only seedlings planted in the spring were monitored, capturing 25% of seedlings planted at that time. At the time of planting, 96% of seedlings were rated in good health, while 3% were rated fair and 0.7% (1 tree) was considered “almost dead”.

Of all sites planted with limber pine in 2012, seedlings at this site had the lowest survival by 2015. Three years after planting, only 16% of seedlings were still alive (Table 30). Most living trees, however, were in good condition. Eighty-six percent (19 trees) of living seedlings were considered in good health. One tree was in fair condition (5%) and two trees (9%) were almost dead (Table 32). Interestingly, living trees were some of the largest seedlings from the 2012 planting. Seedlings averaged 12.18 cm in height, the tallest of the 2012 plantings, and 8.59 cm in width, the third widest (Table 30). Seedlings grew 4.75 cm, on average, in height and 0.11 in width in the three years since planting.

v. Scenic Point

Altogether, 1,264 seedlings were planted in the Scenic Point area in 2012; 284 trees were planted in the spring and 980 trees were planted in the fall (Figure 28). Twenty six percent of trees were captured in monitoring plots, including 155 trees from the spring planting and 195 trees from the fall planting.

At the time of planting, all trees were in at least fair condition in the spring planting with 97% considered in good health. By fall, 91% of these seedlings had survived, although only 52% were rated as “good”. Three percent were rated in “fair” condition and 36% were considered “almost dead”. Of seedlings planted in the fall, 96% were initially rated in “good” health. About 2% of trees were rated in “fair” condition, 2% were considered “almost dead”, and 0.5% (1 tree) was dead.

Three years after planting, the fall planting was faring slightly better than the spring planting with 54% survival for fall planted seedlings compared to 50% survival for spring planted seedlings (Tables 31 and 32). Additionally, most seedlings from the fall planting were considered in good health three years later (78% of living trees). Only 18% were in fair condition, while 4% were almost dead. In contrast, only 52% of living seedlings from the spring planting were in good condition, 48% were fair, and none were almost dead. It appears that trees that are planted in the spring, surviving a summer in a harsh, open, rocky habitat, may be more difficult than for those planted in the fall which is usually followed by more moisture and a dormancy period. Both the spring and fall of 2012 received ample moisture (Appendix A), so perhaps the habitat at this site provided too much warm exposure in late spring and summer that resulted in lower spring survival.

Fall-planted trees were also larger than those planted in the spring (10.04 cm tall by 8.86 cm wide for fall planted trees vs. 9.01 cm tall by 8.13 cm wide for spring planted trees)(Table 30). However, fall-planted trees were also much larger at the time of planting, likely reflecting a summer of growing in a nursery setting with ample water and low environmental stress from factors such as wind. Fall-planted trees were actually shorter by 0.59cm three years after planting compared to initial heights. Often, nursery-grown needles are much longer than field-grown needles and tend to shed in the field, only to be replaced by shorter, denser needles. Fall-planted trees did grow slightly in width over three years by an average of 0.64 cm. Spring-planted trees grew 1.25 cm in height and 0.54 cm in width over the course of three years.

Table 31. Average Percent Health and Survival for Spring-Planted Limber Pine Seedlings Planted in 2012.

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Last Year Monitored</i>	<i>Dead / Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Unk.</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
Apikuni Flats (Fall)	2012	fall	2015	36	0	7	6	0	13	49	27%
Scenic Point	2012	fall	2015	88	4	19	83	1	106	195	54%
Many Glacier Well Area	2012	fall	2015	36	0	1	26	0	27	63	43%
Total spring 2012				160	4	27	115	1	147	307	48%

Table 32. Average Percent Health and Survival for Fall-Planted Limber Pine Seedlings Planted in 2012.

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Last Year Monitored</i>	<i>Dead / Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Unk.</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
Cutbank	2012	spring	2015	27	3	7	45	0	55	82	67%
Apikuni Flats (Spring)	2012	spring	2015	51	1	5	22	0	28	79	35%
Rising Sun CG	2012	spring	2015	118	2	1	19	0	22	140	16%
Scenic Point	2012	spring	2015	78	0	37	40	0	77	155	50%
Total fall 2012				274	6	50	126	0	182	456	40%

When looking at all sites combined that were planted in 2012, spring-planted limber pine seedlings showed a slightly higher survival, on average, than fall-planted seedlings across all three-year old seedlings monitored in 2015 (Tables 31 and 32). There is a large variance among sites, however. This suggests that site characteristics may prove more important than season in determining future success of seedlings. Planting season should continue to be assessed in order to determine more planting guidelines for the future.

Figure 25. Limber Pine Monitoring Plots in the Many Glacier Area, Planted in the Spring and Fall, 2012.

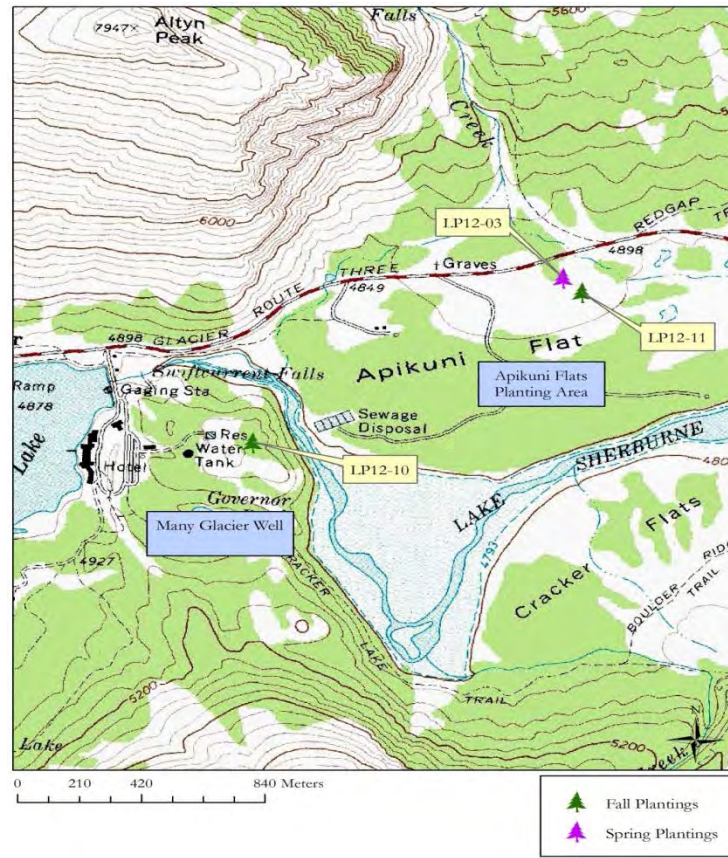


Figure 26. Limber Pine Monitoring Plots in the Cutbank Campground Area, Planted in the Spring, 2012.

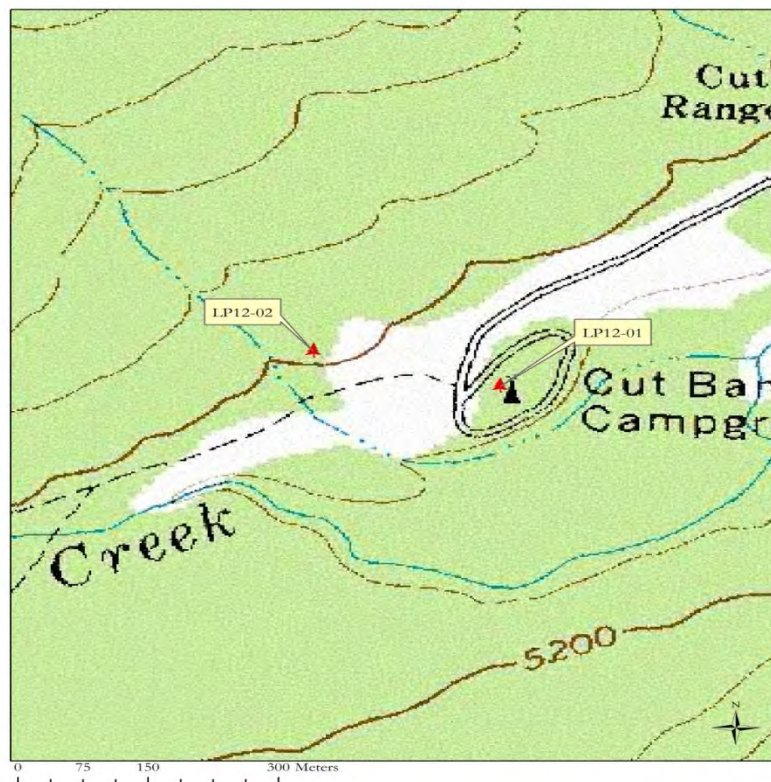


Figure 27. Limber Pine Monitoring Plots in the Rising Sun CG Area, Planted in the Spring, 2012.

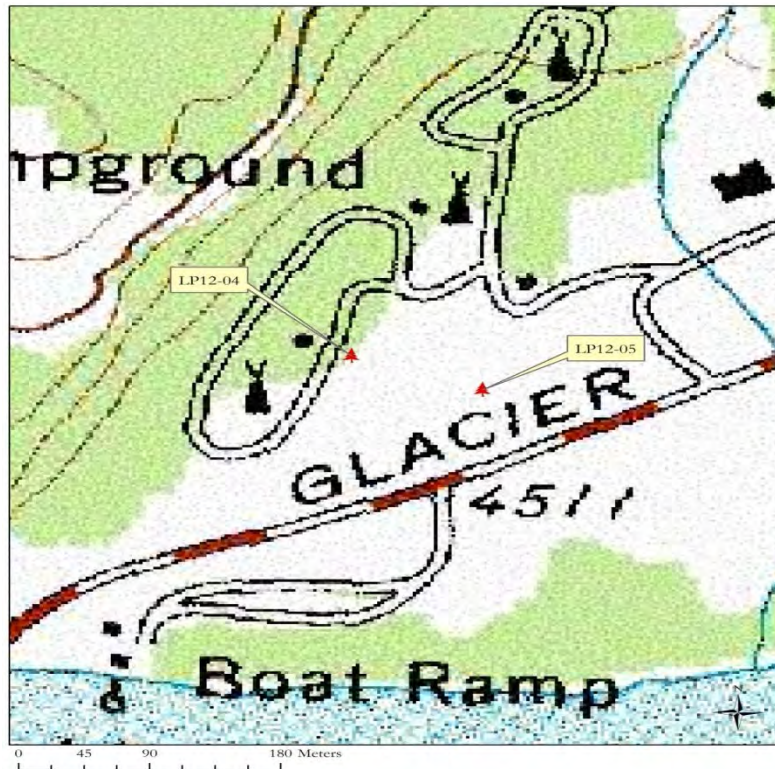
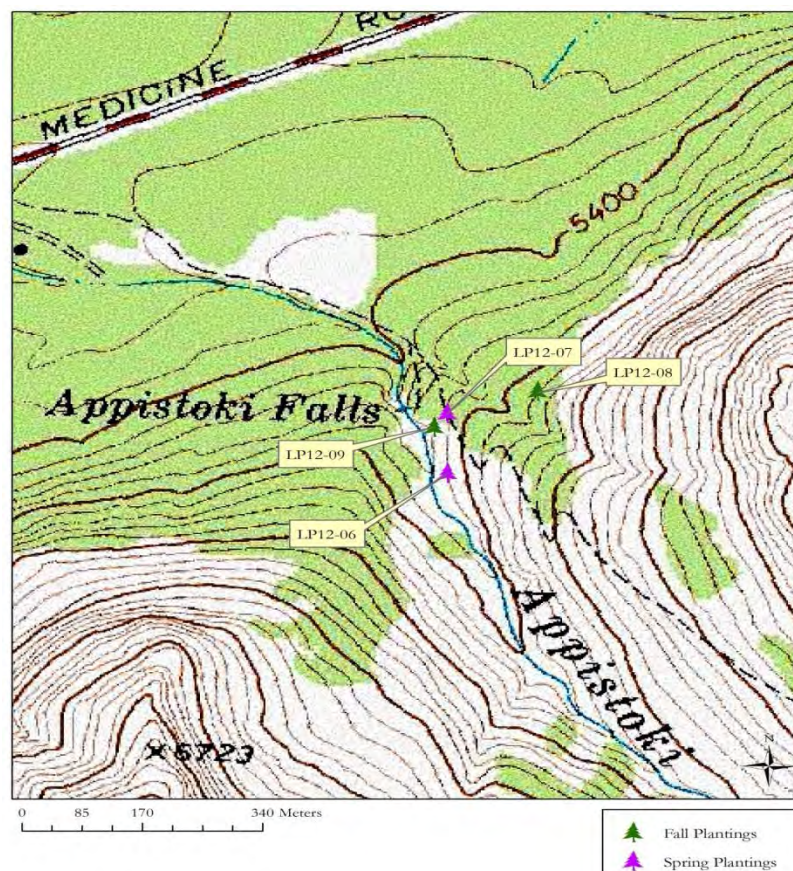


Figure 28. Limber Pine Monitoring Plots in the lower Scenic Point Trail Area, Planted in the Spring and Fall of 2012.



2. *Whitebark Pine Seedling Results*

Whitebark pine seedlings have been planted at 14 sites between 2000 and 2015, all of which continue to support live trees. Table 33 is a summary of all the whitebark plantings to date, indicating the number of trees that have survived to date, percent survival, and the overall health rating at each site. Overall survival for whitebark pine seedlings planted in the park is 62% based on the most recent monitoring event at each site.

Further discussion in this report is only for the sites monitored this year. Nine whitebark pine plantings were monitored in 2015: Grinnell Point, Divide Creek, Hole-in-the-Wall, Divide Mountain, Firebrand Pass Area, Numa Lookout, Scenic Point, and Whitecalf Mountain. All of these sites contained existing whitebark pine plantings that were re-monitored. Two of these sites had whitebark pine plantings in the past, specifically Scenic Point and Numa Lookout. Additional plants and monitoring plots were installed in 2015.

a. 2000 Plantings (15 Year Trees)

i. Dutch Creek

Although 2015 marks the 15th year since planting whitebark pine at Dutch Creek, this site was not monitored. Due to lack of specific information on where this planting took place, no monitoring plots were established at this site, and thus, this site has not been visited since the time of planting.

ii. Grinnell Point

On September 2, 2000, 96 whitebark pine seedlings were planted on Grinnell Point immediately after the subsidence of the Grinnell Point Fire that year (Figure 29). This area was opportunistically planted during a post-fire helicopter operation. Seven plots were installed at the time of planting, encompassing all of the planted trees. This is the oldest monitored planting site for either whitebark pine or limber pine in the Park.

Due to its remoteness, Grinnell Point has not been monitored by Glacier National Park staff since the time of planting. In 2015, however, fifteen years after planting, this site was monitored by the revegetation crew. All plots were relocated with the aid of a high quality metal detector, although the center pin was missing in one plot. Fifteen years after planting, 65% of trees were surviving at this site (Tables 33, 34, 35). All but one tree, which was rated as fair, were rated in good condition. No other sites have been monitored at 15 years post-planting, but this survival rate is better than the averages for all cohorts monitored in the Park that are older than two years post-planting (Table 34). Survival was not equal across plots, ranging from 0% in plot 5 to 89% in plot 3. It is unclear what influenced the differences in survivorship since all sites are relatively exposed, open, and windswept. Survival in the upper plots was higher and more consistent than in the lower plots, however, and may reflect some sort of environmental gradient. Likely, planting immediately after a burn had extremely positive benefits for most plots, as well as being followed by favorable environmental conditions after planting.

This is a very rugged, wind-swept area and many trees are forming krummholz stature, often wider than tall. Average height of trees at Grinnell Point 15 years after planting was 53.81 cm and average width was 66.66 cm (Table 36). The largest tree monitored was 110 cm by 131 cm.

Table 33. Overall Health and Survival of Whitebark Pine Planted in Glacier NP from 2001-2015; as of Latest Monitoring Event.

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Whitebark Health and Survival tab)

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Last Year Monitored</i>	<i>Monitoring Year</i>	<i>Dead / Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Unk.</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
Grinnell Point	2000	fall	2015	15	34	0	1	61	0	62	96	65%
Total 2000					34	0	1	61	0	62	96	65%
Flattop Mtn. Spring 2001	2001	spring	2011	10	277	0	14	93	0	107	384	28%
Flattop Mtn. Fall 2001	2001	fall	2011	10	166	1	4	84	0	89	255	35%
Total 2001					443	1	18	177	0	196	639	31%
Flattop Mtn. Fall 2002	2002	fall	2011	9	171	0	19	102	0	121	292	41%
Total 2002					171	0	19	102	0	121	292	41%
Caper Peak	2006	fall	2008	2	75	1	6	57	0	64	139	46%
Total 2006					75	1	6	57	0	64	139	46%
Red Eagle - upper	2007	fall	2012	5	162	0	11	185	0	196	358	55%
Red Eagle - lower	2007	fall	2012	5	55	0	0	0	0	0	55	0%
Total 2007					217	0	11	185	0	196	413	47%
Divide Creek (Lower)	2010	fall	2015	5	16	0	0	249	0	249	265	94%
Hole-in-the-Wall	2010	fall	2015	5	123	2	5	42	0	49	172	28%
Total 2010					139	2	5	291	0	298	437	68%
Cobalt Lake	2011	late summer	2014	3	97	4	4	3	0	11	108	10%
Grinnell Picnic Area	2011	late summer	2014	3	62	0	3	39	0	42	104	40%
Total 2011					159	4	7	42	0	53	212	25%
Divide Mountain	2012	fall	2015	3	92	3	12	119	0	134	226	59%
Total 2012					79	3	1	141	0	145	224	65%
Firebrand Pass Area	2013	spring	2014	1	14	2	52	141	0	195	209	93%
Firebrand Pass Area	2013	fall	2014	1	21	10	13	343	0	366	387	95%
Numa Lookout	2013	fall	2014	1	2	1	5	167	0	173	175	99%
Total 2013					37	13	70	651	0	734	771	95%
Divide Creek (Upper)	2014	fall	2015	1	28	0	37	154	0	191	219	87%
Firebrand Pass Area (Lower)	2014	spring	2015	1	10	0	6	90	0	96	106	91%
Firebrand Pass Area	2014	fall	2015	1	112	17	25	5	0	47	159	30%
Numa Lookout	2014	fall	2015	1	42	1	15	62	0	78	120	65%
Scenic Point (Upper)	2014	spring	2015	1	44	25	31	88	0	144	188	77%
Spot Mountain	2014	spring	2015	1	9	1	7	19	0	27	36	75%
Whitecalf	2014	fall	2015	1	57	41	18	35	0	94	151	62%
Total 2014					302	85	139	453	0	677	979	69%
Numa Lookout	2015	fall	2015	0	0	0	1	67	0	68	68	100%
Scenic Point (Upper)	2015	fall	2015	0	0	0	0	64	0	64	64	100%
Total 2015					0	0	1	131	0	132	132	100%
Overall Total					1622	109	277	2230	0	2616	4238	62%
Percentage of Surviving Trees						4%	11%	85%	0%			
Percentage of Monitored Trees					38%	2.6%	7%	53%	0%			

Table 34. Average Survival, Height and Width for Whitebark Pine Seedlings from the Most Recent Monitoring Year

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Whitebark Height and Width tab)

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Last Year Monitored</i>	<i>% Survival</i>	<i>Monitoring Year</i>	<i>Average</i>	
						<i>Height</i>	<i>Width</i>
Grinnell Point	2000	fall	2015	65%	15	53.81	66.66
Average 15 year-old-trees				65%	15	53.81	66.66
Flattop Mtn. Spring 2001	2001	spring	2011	28%	10	45.44	29.35
Flattop Mtn. Fall 2001	2001	fall	2011	35%	10	46.06	35.98
Average 10 year-old-trees				31%	10	45.75	32.67
Flattop Mtn. Fall 2002	2002	fall	2011	41%	9	34.50	31.54
Average 9 year-old-trees				41%	9	34.50	31.54
Red Eagle - upper	2007	fall	2012	55%	5	27.81	26.94
Divide Creek	2010	fall	2015	94%	5	19.42	20.71
Hole-in-the-Wall	2010	fall	2015	28%	5	11.92	11.06
Average 5 year-old-trees				59%	5	19.72	19.57
Cobalt Lake	2011	late summer	2014	10%	3	13.00	11.27
Grinnell Picnic Area	2011	late summer	2014	40%	3	12.79	15.81
Divide Mountain	2012	fall	2015	59%	3	9.96	10.45
Average 3 year-old-trees				36%	3	11.92	12.51
Caper Peak	2006	fall	2008	46%	2	13.64	11.81
Average 2 year-old-trees				46%	2	13.64	11.81
Red Eagle - lower	2007	fall	2008	0%	1	8.79	8.82
Firebrand Pass Area	2013	spring	2014	93%	1	8.82	8.31
Firebrand Pass Area	2013	fall	2014	95%	1	7.96	8.05
Numa Lookout	2013	fall	2014	99%	1	9.11	9.55
Divide Creek	2014	fall	2015	87%	1	10.40	9.69
Firebrand Pass Area	2014	spring	2015	91%	1	8.44	8.86
Firebrand Pass Area	2014	fall	2015	30%	1	7.36	8.89
Numa Lookout	2014	fall	2015	65%	1	11.19	9.23
Scenic Point	2014	spring	2015	77%	1	8.97	9.17
Spot Mountain	2014	spring	2015	75%	1	9.04	8.59
Whitcalf	2014	fall	2015	62%	1	9.39	9.55
Average 1 year-old-trees				70%	1	9.04	8.97
Scenic Point	2015	fall	2015	100%	0	10.76	12.07
Numa Lookout	2015	fall	2015	100%	0	11.55	12.09
Average 0 year-old-trees				100%	0	11.16	12.08

Figure 29. Whitebark Pine Monitoring Plots at Grinnell Point, Planted in the Fall of 2000.

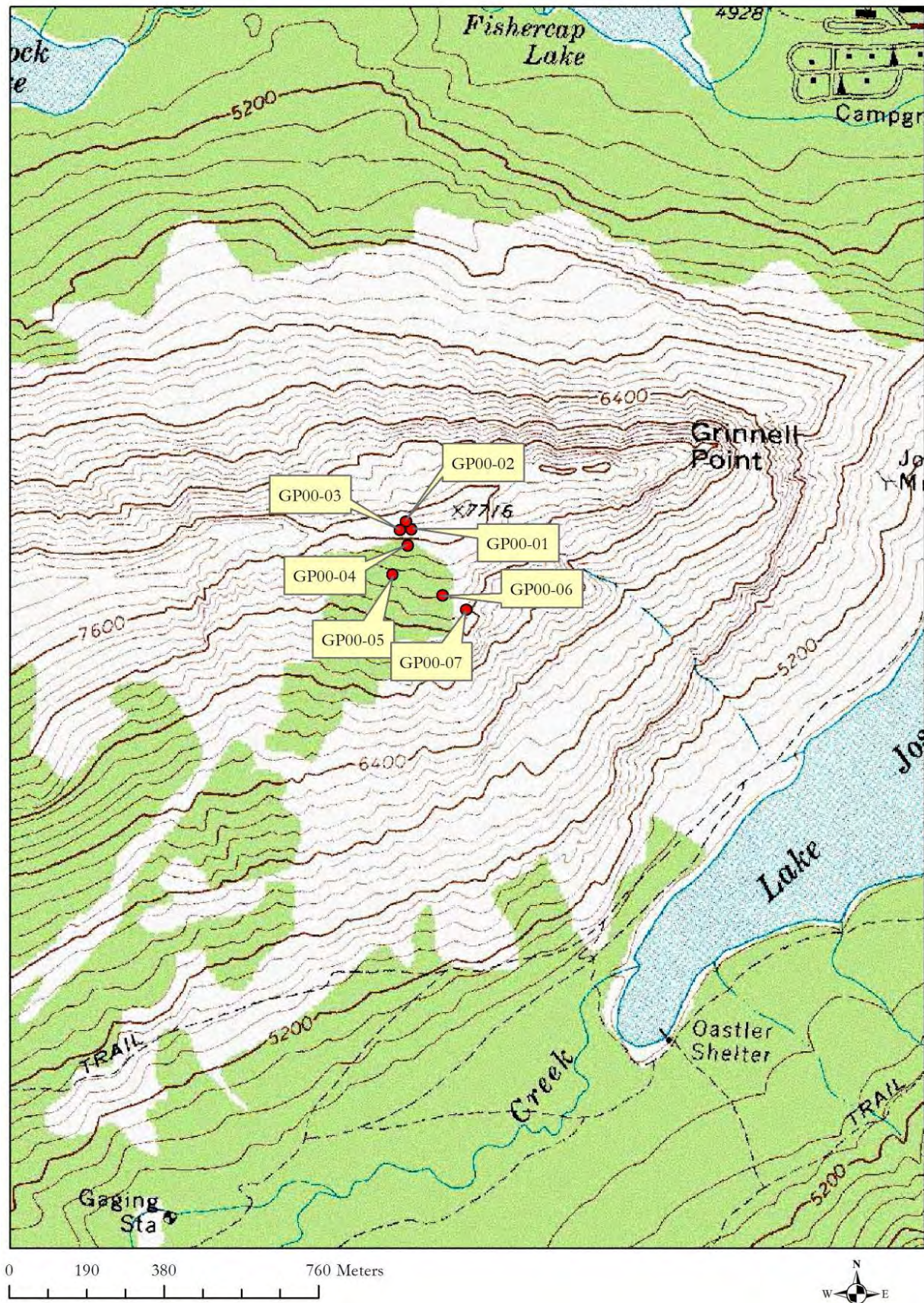


Table 35. Grinnell Point, 2000: Overall Survival and Average Height and Width of Whitebark Pine Seedlings Monitored in 2015.

<i>Plot</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
GP00-01	0	0	0	14	14	14	100%
GP00-02	0	0	0	11	11	11	100%
GP00-03	0	0	0	9	9	9	100%
GP00-04	0	0	0	22	22	22	100%
GP00-05	0	0	0	10	10	10	100%
GP00-06	0	0	0	22	22	22	100%
GP00-07	0	0	0	8	8	8	100%
Total 2000	0	0	0	96	96	96	100%
GP00-01	4	0	0	10	10	14	71%
GP00-02	3	0	1	7	8	11	73%
GP00-03	1	0	0	8	8	9	89%
GP00-04	6	0	0	16	16	22	73%
GP00-05	10	0	0	0	0	10	0%
GP00-06	7	0	0	15	15	22	68%
GP00-07	3	0	0	5	5	8	63%
Total 2015	34	0	1	61	62	96	65%

Table 36. Grinnell Point, 2000: Survival, Average Height and Average Width of Seedlings, 2000 -2015.

*Height and Width were not measured prior to 2015

Year	Survival	Average Height (cm)	Average Width (cm)
2000	100%	*	*
2015	65%	53.81	66.66

b. 2010 Plantings

i. Divide Creek

On September 20-22, 2010, a total of 1,126 whitebark pine seedlings were planted on a ridge above Divide Creek (Figures 30 and 31). This area burned in the Red Eagle fire of 2006 with moderate severity. This site is the first area where some planted seedlings had been inoculated with a slurry produced from mushroom species known to have ectomycorrhizal relationships with whitebark pine. Three hundred trees from this planting were inoculated. These were planted together in groupings of 3 seedlings per hole throughout the revegetation site. Five monitoring plots were installed tracking 261 seedlings. This captured 21% of planted seedlings, 40 of which were inoculated. This area was again planted in the fall of 2014. This took place further upslope from the 2010 planting and is discussed under the 2014 Plantings Section.

This site has supported one of the most successful plantings in the Park to date. First year survival was 97%. By 2015, five years after planting, 94% of seedlings continued to survive (Table 37), well above the average survival of 49% for all sites monitored in Glacier National Park at five years post-planting (Table 38). Additionally, all of these seedlings were thriving as all were rated in good condition (Table 37). Several factors may play into the success of this planting. First, seedlings were planted in cool, wet conditions during an early season snow event, followed by cool, autumn or early winter weather. As a result, seedlings were probably induced to go into dormancy relatively quickly after planting. Second, this area burned but not so hot as to sterilize the soil. Other vegetation has responded well to these conditions, indicating a flush of nutrients released post-burning as well as preservation of beneficial soil fungi. Ironically, the future threat to continued success at this site will most likely be

from competition from lodgepole pine seedlings and saplings that are also thriving post-burn. Lodgepole seedlings averaged 1 to 1.5 meters in this area, sometimes forming dense stands in or near planting areas. This site is at the lower extent of whitebark pine habitat, and while the environmental conditions appear to be less harsh than many higher elevation sites, perhaps the tradeoff is higher vegetative competition.

Seedlings monitored five years after planting at Divide Creek averaged 19.42 cm in height (Table 39), slightly below average for all whitebark pine seedlings at sites in Glacier National Park that have been monitored at five years (Table 38). However, these trees were slightly wider than average at 20.71 cm. Growth rates have been increasing in either height or width over the course of the last several years (Table 39, Figure 32). After shrinking in average height after the first year and shrinking in average width the second year after planting, growth increased in both dimensions in years three to five. Three years after planting, average height increased by 2.1 cm and average width increased by 3.9 cm. Four years after planting, average height increased by 4 cm and average width increased by 2.6 cm. Five years after planting, average height increased by 3 cm and average width increased by 3.6 cm.

This trend has been observed in most of the whitebark pine plantings with the average height of seedlings decreasing the first year after planting, followed by a slight increase the second year. The initial small changes in size are due mostly to the fact that long needles that often grow on nursery-raised seedlings are often shed after the first year and are replaced by dense, short new growth needles. This usually results in a slightly smaller seedling after the first year of planting. Data from other projects has shown that it often takes four to five years before whitebark pine seedlings will grow significantly in both height and width. Seedlings are using energy to establish root systems and new growth after initial needle shed.

At Divide Creek, the effect of inoculating whitebark pine seedlings with an ectomycorrhizal slurry was not evident in the first four years after planting. However, this year at five years after planting, slight differences in size are becoming apparent between seedlings inoculated with the slurry and those without. Differences between the inoculated and non-inoculated seedlings remain small (Table 40) but height and width measurements over time are both currently higher on inoculated seedlings than non-inoculated seedlings, despite inoculated seedlings starting off the same size in height as non-inoculated seedlings and slightly smaller in width at the time of planting in 2010. While both inoculated and non-inoculated seedlings continue to increase in height and width, inoculated seedlings currently have a greater rate of growth for both dimensions, flipping the trend of last year. Inoculated seedlings have grown 9.90 cm in height and 12.98 cm in width from 2010 to 2015, compared to non-inoculated seedlings that have grown 8.61 cm in height and 10.06 cm in width over the same time period. Currently, survival of non-inoculated seedlings remains higher than inoculated seedlings, however, it is important to note that almost all dead seedlings at this planting site have been due to physical disturbance (tree has fallen, fallen tree has removed tree/soil from ground) and not in situ mortality. Inoculation of seedlings with ectomycorrhizae does not appear to be positively or negatively affecting survival, however, it does appear to be having a positive impact on growth.

It is interesting to note that differences between inoculated and non-inoculated seedlings are even more evident at the nearby Divide Mountain planting site. See that section for a discussion on site variables that may impact inoculation importance.

Figure 30. General location of Whitebark Pine Seedling Plots Established at Divide Creek in 2010 and 2014.

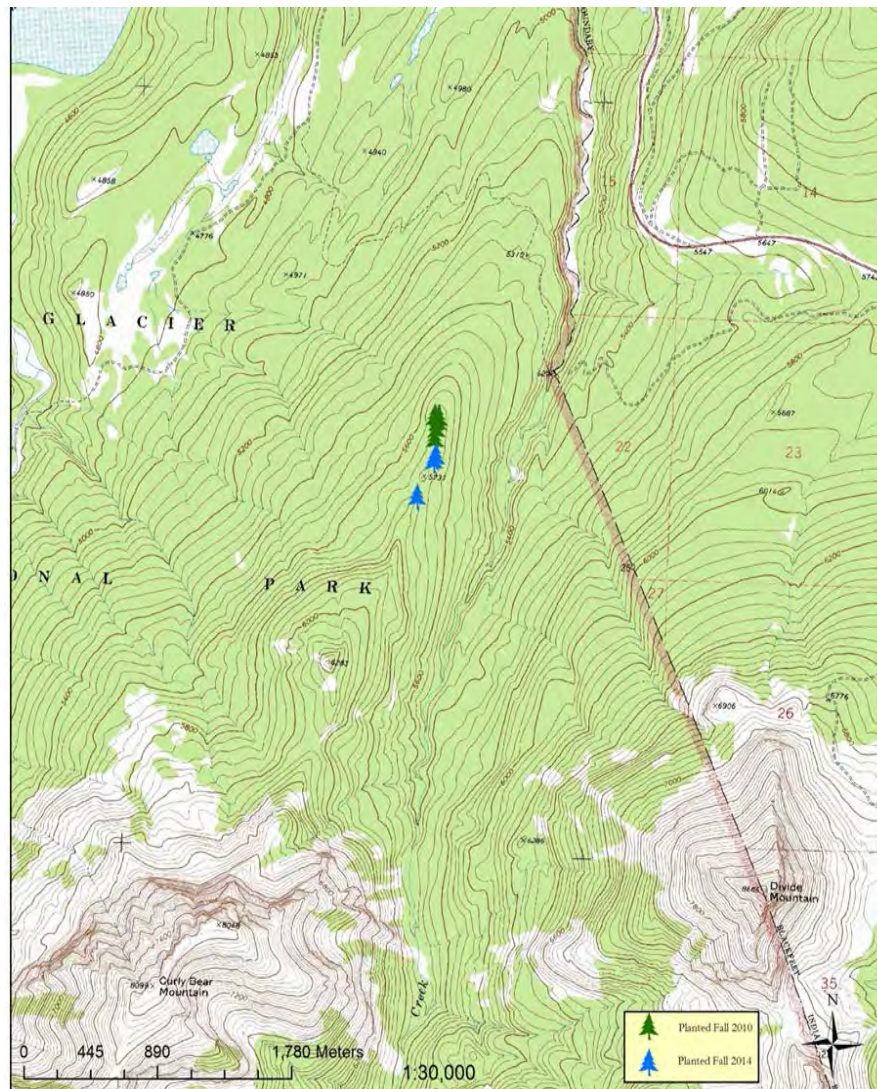


Figure 31. Whitebark Pine Seedling Monitoring Plots Established at Divide Creek, 2010 and 2014.

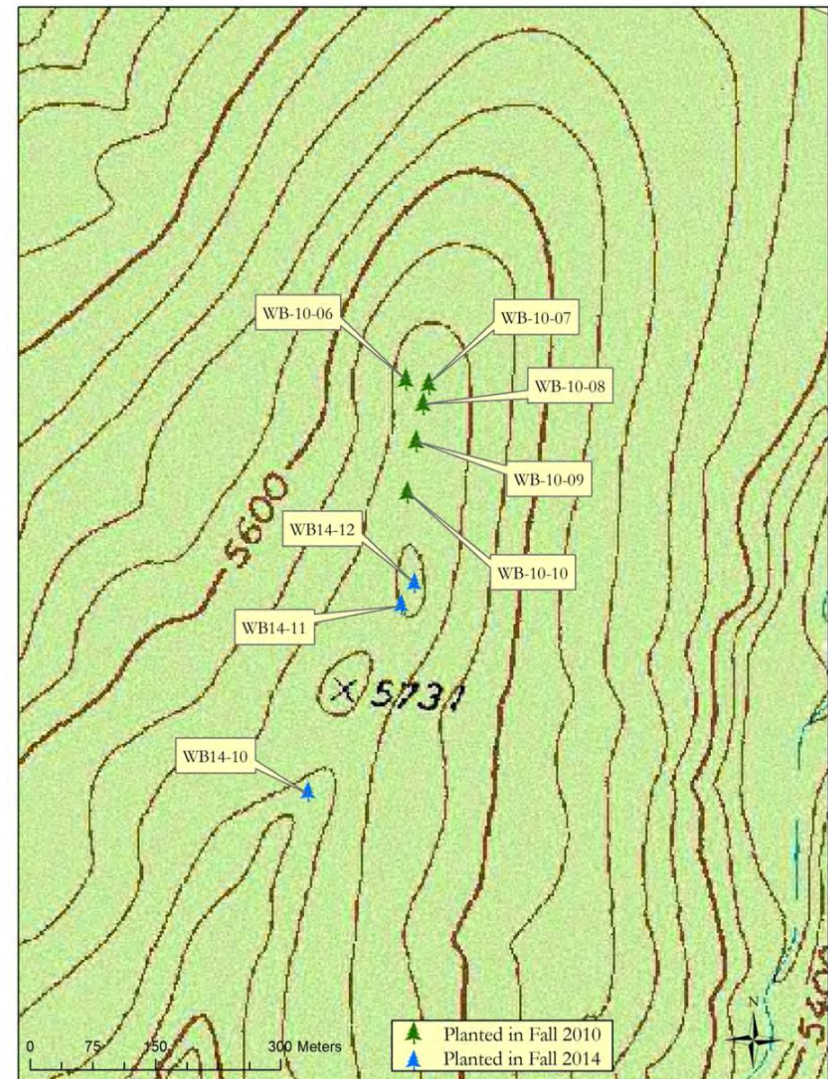


Table 37. Divide Creek: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2010 - 2015.
S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Divide Creek tab)

<i>Plot</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-10-06	1	0	34	17	51	52	98%
WB-10-07	1	0	7	45	52	53	98%
WB-10-08	6	1	26	32	59	65	91%
WB-10-09	2	7	13	45	65	67	97%
WB-10-10	0	0	7	19	26	26	100%
Total 2012	10 (3.8%)	8 (3.0%)	87 (33.1%)	158 (60.1%)	253	263	96%
WB-10-06	1	0	1	50	51	52	98%
WB-10-07	1	0	1	51	52	53	98%
WB-10-08	7	0	2	58	60	67	90%
WB-10-09	4	0	4	59	63	67	94%
WB-10-10	3	0	3	20	23	26	88%
Total 2013	16 (6.0%)	0 (0%)	11 (4.2%)	238 (89.8%)	249	265	94%
WB-10-06	1	0	1	50	51	52	98%
WB-10-07	1	0	0	52	52	53	98%
WB-10-08	8	0	0	59	59	67	88%
WB-10-09	3	0	2	62	64	67	96%
WB-10-10	3	0	0	23	23	26	88%
Total 2014	16 (6.0%)	0 (0%)	3 (1.1%)	246 (92.8%)	249	265	94%
WB-10-06	1	0	0	51	51	52	98%
WB-10-07	1	0	0	52	52	53	98%
WB-10-08	8	0	0	59	59	67	88%
WB-10-09	3	0	0	64	64	67	96%
WB-10-10	3	0	0	23	23	26	88%
Total 2015	16 (6.0%)	0 (0%)	0 (0%)	249 (94.0%)	249	265	94%

Table 38. Survival, Height and Width of All Seedlings Monitored in GNP Five Years After Planting.
S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Whitebark Height and Width tab)

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Year Monitored</i>	<i>% Survival</i>	<i>Year 5</i>	
					<i>Height</i>	<i>Width</i>
Flattop Mtn. Spring 2001	2001	spring	2006	33%	20.30	14.47
Flattop Mtn. Fall 2001	2001	fall	2006	36%	19.86	17.26
Red Eagle - upper	2007	fall	2012	55%	27.81	26.94
Hole-in-the-Wall	2010	fall	2015	28%	11.92	11.06
Divide Creek - lower	2010	fall	2015	94%	19.42	20.71
Average 5- year-old-trees				49%	19.86	18.09

Table 39. Divide Creek: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2010-2015.

Year	Survival	Average Height (cm)	Average Width (cm)
2010	100%	10.62	10.22
2011	97%	9.87	10.96
2012	96%	10.27	10.59
2013	94%	12.37	14.52
2014	94%	16.36	17.08
2015	94%	19.42	20.71

Figure 32. Divide Creek: Average Height and Width of Whitebark Pine Seedlings, 2010 – 2015.

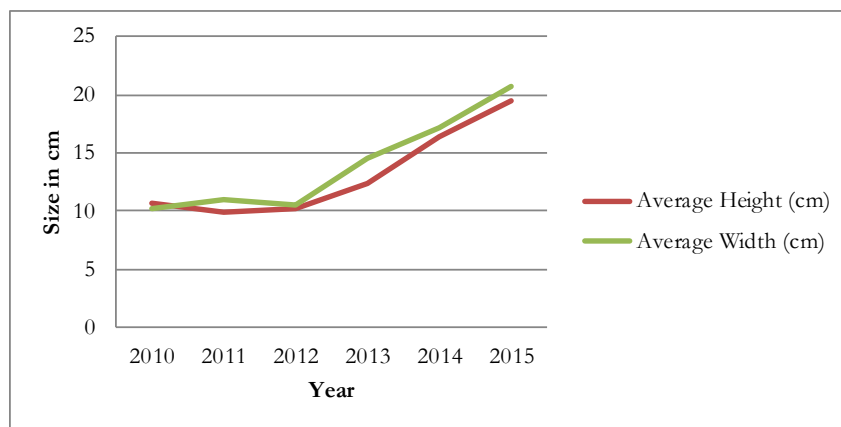


Table 40. Divide Creek: Treatment Survival and Average Height and Width of Whitebark Pine Seedlings, 2010-2015.

Year	Survival		Average Height (cm)		Average Width (cm)	
	Inoculated	Not inoculated	Inoculated	Not inoculated	Inoculated	Not inoculated
2010	100%	100%	10.85	10.58	9.88	10.29
2011	97.6%	96.8%	9.70	9.90	11.55	10.85
2012	97.6%	96.4%	10.18	10.24	11.00	10.43
2013	87.8%	95.1%	12.36	12.37	14.56	14.38
2014	87.8%	95.1%	16.17	16.39	16.67	17.15
2015	87.8%	95.1%	20.75	19.19	22.86	20.35
Change (cm) between 2010-2015			9.9	8.61	12.98	10.06

Table 41. Divide Creek: Treatment Health Ratings of Whitebark Pine Seedlings, 2010-2015.

Year	5 (Good)		4 (Fair)		3 (Almost Dead)		2 or 1 (Dead or Missing)	
	Inoculated	Not inoculated	Inoculated	Not inoculated	Inoculated	Not inoculated	Inoculated	Not inoculated
2010	41 (100%)	216 (97.3%)		6 (2.7%)				
2011	34 (82.9%)	197 (88.7%)	6 (14.7%)	17 (7.7%)			1 (2.4%)	8 (3.6%)
2012	24 (58.6%)	134 (60.3%)	15 (36.6%)	72 (32.4%)	1 (2.4%)	7 (3.2%)	1 (2.4%)	9 (4.1%)
2013	33 (80.5%)	205 (91.5%)	3 (7.3%)	8 (3.6%)			5 (12.2%)	11 (4.9%)
2014	36 (87.8%)	210 (93.8%)		3 (1.3%)			5 (12.2%)	11 (4.9%)
2015	36 (87.8%)	213 (95.1%)					5 (12.2%)	11 (4.9%)

ii. Hole-in-the-Wall

A total of 830 whitebark pine seedlings were planted in the Hole-in-the-Wall campground area and in the cirque area above the campground in the fall of 2010. This was the first whitebark pine planting site that has not been burned, so was somewhat experimental in nature. Areas of vegetation were “scalped” surrounding planting sites to reduce competition. Seedlings were preferentially planted near *Vaccinium scoparium*, *Luzula hitchcockii*, *Carex geyeri* and *Carex rossii*, since whitebark pine is disproportionately associated with these species (Izlar 2007). Microsites were utilized or provided for seedlings when possible. Five monitoring plots were established near the Hole-in-the-Wall Campground between August 23 and 25, 2010 (Figure 33). Plots contained 172 seedlings, monitoring 21% of planted trees.

Overall survival was 28% five years after planting, the lowest of all sites monitored five years after planting, and quite a bit lower than the average of 49% survival for 5-year-old-trees (Table 42). Of the monitored seedlings, 42 (24%) were given a “5” or “healthy” rating, 5 (3%) were assigned a “4” or “fair” rating, 2 (1%) were considered “almost dead”, 21 and 123 (72%) were missing or dead (Table 43). However, these trends do not hold true across all plots as survivorship has dropped disproportionately across plots since 2010.

Figure 33. Whitebark Pine Monitoring Plots at Hole-in-the-Wall Campground Area, Planted in 2010.



Table 42. Hole-in-the-Wall: Health and Survival of Whitebark Pine Seedlings Monitored in 2012 and 2015

S: VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Hole-in-the-Wall tab)

<i>Plot</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-10-01	21	1	11	7	19	40	48%
WB-10-02	25	0	2	0	2	27	7%
WB-10-03	11	2	3	12	17	28	61%
WB-10-04	19	1	10	15	26	45	58%
WB-10-15	17	0	6	9	15	32	47%
Total 2012	93	4	32	43	79	172	46%
WB-10-01	28	0	1	11	19	40	48%
WB-10-02	25	0	0	2	2	27	7%
WB-10-03	17	0	0	11	11	28	39%
WB-10-04	30	2	2	11	15	45	33%
WB-10-05	23	0	2	7	9	32	28%
Total 2015	123	2	5	42	49	172	28%

In 2012, survival was highest in the meadows north of the campground near the trail to Boulder Pass, with 61% survival in plot 3 and 58% survival in plot 4. In 2015, however, both of these plots saw a dramatic decline in survival, dropping to 39% and 33% survival, respectively. Survival also dropped substantially in campground plot 5 from 47% in 2012 to 28% in 2015. The highest survival rate was found near the old food cable site, remaining at 48% from 2012 to 2015. Survival continued to be lowest in the herbaceous meadow west of the campground with only 7% of trees alive in this plot in both 2012 and 2015 (Table 42).

Table 43. Hole-in-the-Wall: Overall Survival and Average Height and Width of Whitebark Pine, 2010-2015.

*13 trees were added to the pool after detection in 2012

S: VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Hole-in-the-Wall tab)

<i>Year</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>	<i>Average Height</i>	<i>Average Width</i>
2010	0	0	8	151	159	159	100%	10.94	9.42
2012	93	4	32	43	79	172	46%	8.57	9.24
2015	123	2	5	42	49	172	28%	11.92	11.06

Surviving seedlings did grow since 2012 after initially declining in both height and width. Average height of seedlings grew by 3.35 cm and average width increased by 1.82 cm since 2012 (Table 43).

The lower than average overall survival at Hole-in-the-Wall suggests that non-burned sites may not be as ideal of planting sites as burned sites. This planting also took place at the end of August, so perhaps seedlings experienced high levels of temperature stress and temporary drought stress. These trees were not monitored the first year after planting, but by year two, survival had already declined to 46%. Seedlings were also planted at Divide Creek in the fall of 2010 and experienced a much higher survival rate of 94% after five years. Seedlings at Divide Creek were planted in a burn, later in the season, and just after a snowfall. Other environmental factors may play a role as well, making Hole-in-the-Wall a less suitable planting site.

c. 2012 Plantings

i. Divide Mountain

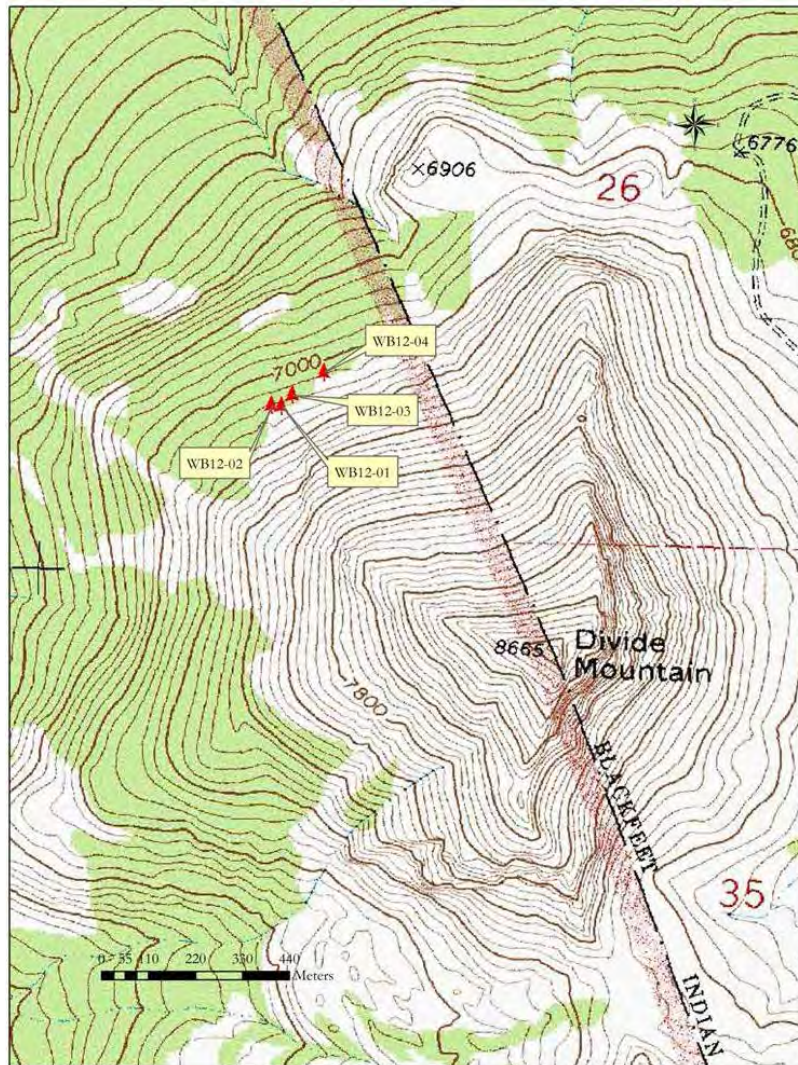
In September 2012, a total of 1,283 whitebark pine seedlings were planted at tree line on a bench on the northwest flank of Divide Mountain (Figure 34). The total number of trees planted is an estimate based on an average of two seedlings per cone. Cone numbers are known but individual seedlings were not counted in each cone. This planting site is on the edge of the Red Eagle Fire which burned the area in 2006. Seedlings were planted among standing snags of subalpine fir and some whitebark pine. Naturally regenerating whitebark pine seedlings are abundant at this site.

A variety of environmental conditions were included within planting sites. Some planting areas contained fairly thick mats of mountain avens or kinnikinnick and required some scalping. Plot 4 is located in a swale that likely holds late snow melt, indicated by plants of this moisture regime, which may aid in holding soil moisture for seedlings. Plot 3 is located on a slope with more open scree on the lower half. Many, but not all, seedlings were planted in the burned area; location inside or outside of the burn was noted. Being as the site was situated just below a boulder field, ample rocks and existing boulders were available for planting microsites. Seedlings were typically planted together in groupings of 2 to 3 trees per planting hole with some single trees and some planted in groupings of 4. Unseen in other planting areas, herbivory by pikas and golden mantled ground squirrels was observed on newly planted trees within a day of planting. In some cases, trees had been totally removed. Data was recorded on herbivory and if the tree was suspected to be dead due to predation.

Divide Mountain is the second site in the park to utilize seedlings that have been inoculated by Cathy Cripps' lab from Montana State University. Divide Creek, planted in 2010, was the first site where experimental seedlings were planted. Inoculum was prepared from mushroom species known to have ectomycorrhizal relationships with whitebark pine. Just over half of the seedlings planted at Divide Mountain had been inoculated (608 trees; 51%). Four monitoring plots were installed in 2012 to track 216 seedlings, capturing 17% of planted seedlings. At the time of plot establishment, all of the monitored seedlings were given a "5" or "healthy" rating. This site was slated to be monitored again in 2013, the first year after planting, but weather did not permit this monitoring event. Plots were monitored in 2014, however, two years after planting.

In 2015, three years after planting, survival was 59% at Divide Mountain, a 6% decline from the previous year (Table 44). This survival rate is slightly above the 51% average for all plantings in the Park where trees were monitored three years after planting (Table 45). Since this site was planted partially in a burn and partially out of a burn and experienced high rates of herbivory, it might be expected that survival rates would be in the average range. Several other sites monitored at three years, specifically Cobalt Lake and Grinnell Picnic Area, experienced quite low survival rates at three years, likely due to heat stress after being planted in non-burn areas in late summer. Flattop, Red Eagle and Divide Creek were all planted in fall in burned areas.

Figure 34. Whitebark Pine Monitoring Plots at Divide Mountain, Planted in 2012.



There was a wide range of survival rates among plots at Divide Creek three years after planting (Table 44). The highest survival was 88% in plot 4. All trees in this plot were planted in the burn area. Additionally, the topography of this area, as well as the plant species present, suggest that this is an area that harbors late snowmelt, offering early summer moisture to these seedlings. Furthermore, ground moisture may puddle in the swale later in the season offering additional moisture throughout the season. For unknown reasons, this area also appeared to escape herbivory. Plot 3, with the lowest survival rate at 38%, coincidentally experienced high levels of herbivory. This plot was also located partially within a burn and partially out of the burn.

Most surviving seedlings at Divide Mountain were in good health. Overall, 119 trees (53%) were rated as good, 12 trees (5%) were rated as fair, 3 trees (1%) were almost dead and 92 trees (41%) were dead or missing (Table 44).

As this site was not monitored in 2013, there is no data to show growth rates the first year after planting. Size data from 2014, two years after planting, show that little growth in height had taken place since initial planting and seedlings shrunk in width. By three years post-planting, seedlings had grown an average 0.86 cm in height and an average 1.5 cm in width since planting (Table 46). However, seedlings at this site are the smallest of any other planting site that has been monitored at three years post-planting. This could reflect environmental differences at this site, a slightly different climate than other plantings experienced, or other factors such as size and condition of trees at the time of planting.

Table 44. Divide Mtn.: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2012-2015.
(VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Divide _Mtn tab))

<i>Plot</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-12-01	0	0	0	70	70	70	100%
WB-12-02	0	0	0	73	73	73	100%
WB-12-03	0	0	0	40	40	40	100%
WB-12-04	0	0	0	33	33	33	100%
Total 2012	0	0	0	216	216	216	100%
WB-12-01	33	2	1	37	40	73	55%
WB-12-02	25	0	0	53	53	78	68%
WB-12-03	18	0	0	21	21	39	54%
WB-12-04	3	1	0	30	31	34	91%
Total 2014	79	3	1	141	145	224	65%
WB-12-01	36	3	1	33	37	73	51%
WB-12-02	27	0	9	44	53	80	66%
WB-12-03	25	0	0	15	15	40	38%
WB-12-04	4	0	2	27	29	33	88%
Total 2015	92	3	12	119	134	226	59%

Table 45. Survival, Height and Width of Whitebark Pine at All Sites Monitored Three Years After Planting.
(VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Whitebark Height and Width tab))

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Year Monitored</i>	<i>% Survival</i>	<i>Year 5</i>	
					<i>Height</i>	<i>Width</i>
Flattop Mtn. Fall 2002	2002	fall	2005	48%	*	*
Red Eagle - upper	2007	fall	2010	55%	15.87	17.55
Divide Creek - lower	2010	fall	2013	94%	12.37	14.52
Grinnell Picnic Area	2011	late summer	2014	40%	12.79	15.81
Cobalt Lake	2011	late summer	2014	10%	13.00	11.27
Divide Mountain	2012	fall	2015	59%	9.96	10.45
Average 3- year-old-trees				51%	13.51	14.79

Table 46. Divide Mtn, 2012: Survival, Average Height and Average Width of Seedlings, 2012 -2015.
(VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Divide _Mtn tab))

Year	Survival	Average Height (cm)	Average Width (cm)
2012	100%	9.1	8.95
2014	65%	9.31	8.57
2015	59%	9.96	10.45

In analyzing environmental and treatment conditions at the Divide Mountain planting site, a comparison of treatments from 2012 to 2015 highlighted some interesting results about planting in burns and the use of mycorrhizal inoculum. There are, however, several caveats that must be considered when looking at trends. First, as with all field experiments, this is not a controlled planting where all variables are held equal other than the treatment. Aspect, slope, microsite quality, health of plant at planting time, wind, and skill of planters are all variables that differ among individual trees, adding “noise” to the assessment of treatment. Second, as stated above, herbivory of whitebark seedlings by pikas and other animals had a large negative impact on this planting. To the best of our ability, we removed those trees that were evidently killed by herbivory from analysis (see survival in second column of Table 47). It was difficult to

determine, however, if pikas chewed on other seedlings, reducing their size, or if missing seedlings were caused by pika herbivory. This adds additional “noise” to this data analysis.

With those caveats in mind, it is interesting to note that the data are continuing to show some consistent results. First, unlike results from 2014, all seedlings except those not planted in burns and not planted in burns/not inoculated grew in height and width from 2012 to 2015 (Table 47). This trend is fairly typical of third-year seedlings that often reach or slightly surpass their initial planting size after decreasing in size at year two due to needle shed. It should be noted, however, that seedlings planted in non-burned areas without inoculation still remain approximately 3cm smaller in height and width than when they were planted. These seedlings are clearly missing effective nutrients and/or soil microbes to aid in their growth. More interestingly, the greatest change in size over the three year monitoring period comes from seedlings that were planted in burns (Table 47). The greatest change in height came from seedlings planted in burns that were also inoculated, while the greatest change in width came from seedlings planted in burns that were not inoculated. This data suggests that planting in burns had the biggest positive effect on initial growth, while planting in non-burned areas, particularly when not inoculated, had the biggest negative impact on initial growth. Total inoculated trees grew slightly more than inoculated trees, although this result is likely not statistically significant. It also did not appear that inoculated trees planted in burns grew any faster initially than non-inoculated trees planted in burns.

In terms of survival, trends supporting the positive impacts of planting in burns and using mycorrhizal inoculum are even stronger. First, trees planted in burns appear to have the biggest effect on survival with more than double the survival than those trees not planted in burns. Second, inoculation at this site did have a positive impact on survival with 16% higher survival for inoculated trees in comparison to non-inoculated trees. Finally, when trees were both planted in a burn and inoculated, seedlings had the highest overall survival at 90.0% when controlling for pika predation. Similarly, when trees were not planted in a burn and not inoculated, seedlings had the lowest overall survival at 30.0% when controlling for predation. For those seedlings not planted in burns, inoculation appears to increase the survival rates of seedlings by over 20%.

Overall, this preliminary data suggests that the best sites for whitebark pine planting are, indeed, in burned areas that resulted in trees with higher survival rates and higher growth rates. This result is in keeping with recommended whitebark planting guidelines and other studies. Little data is available, however, on the field effectiveness of inoculation with mycorrhizae. This data also suggest that inoculation is also having a positive effect on whitebark pine survival and growth. Preliminary results at nearby Divide Creek are beginning to support this trend, although differences between inoculated and non-inoculated trees are not yet significant. Staff at Waterton National Park has noted that inoculation has more of an impact on seedlings that have been planted at poorer sites with rocky, shallow soil and low nutrients (personal communication, 2014). Divide Mountain fits this description and may be the reason that inoculated seedlings are responding in a more dramatic way at this site compared to Divide Creek. Divide Creek, on the other hand, burned much hotter, has much deeper and more nutrient rich soil. It may be under these good planting conditions, inoculation has less of an impact on tree survival and growth. These sites will continue to be monitored to assess this hypothesis and further research should be implemented to address this question.

Table 47. Divide Mtn: Comparison of Survival, Height and Width by Treatment, 2012-2015

Treatment	Survival			Survival w/out predation			Height (cm)			Width (cm)			Change 2012 to 2015 (in cm)	
	2012	2014	2015	2012	2014	2015	2012	2014	2015	2012	2014	2015	Height	Width
In Burn	100%	77.4%	71.6%	100%	80.8%	77.1%	8.92	9.33	10.02	8.87	8.66	10.62	+1.10	+1.75
Not In Burn	100%	27.2%	23.6%	100%	45.5%	44.8%	9.75	8.87	9.38	9.11	7.53	9.08	-0.37	-0.03
Inoculated	100%	72.9%	67.2%	100%	84.8%	82.0%	9.10	9.34	10.13	8.78	8.63	10.44	+1.03	+1.66
Not Inoculated	100%	55.9%	51.0%	100%	63.3%	60.5%	9.17	9.19	9.67	9.12	8.40	10.52	+0.50	+1.40
Inoculated/In Burn	100%	90.7%	83.7%	100%	92.9%	90.0%	8.97	9.27	10.13	8.88	8.64	10.50	+1.16	+1.62
Not Inoculated/In Burn	100%	63.9%	59.0%	100%	67.9%	63.6%	8.88	9.42	9.86	8.86	8.68	10.80	+0.98	+1.94
Inoculated/Not In Burn	100%	30.6%	27.8%	100%	52.4%	50.0%	9.39	9.82	10.20	8.53	8.55	10.00	+0.46	+0.02
Not Inoculated/Not In Burn	100%	20%	15%	100%	30.8%	30.0%	9.90	6.25	6.67	9.70	4.75	6.00	-3.23	-3.70

Green = largest positive change

Red = largest negative change

d. 2014 Plantings (First Year Seedlings)

a. Spot Mountain (Spring)

Spot Mountain was one of three new sites chosen for planting whitebark pine in 2014. It is located on the eastern margin of the park and supported one of the larger limber pine stands in Glacier National Park before it diminished due to blister rust. Most surviving trees at this site are limber pine, but whitebark pine also exists sparingly in this stand. This site has not burned.

In June of 2014, approximately 416 whitebark pine seedlings were planted on the lower flank of Spot Mountain on an east-facing slope. A single monitoring plot was established in July of 2014, capturing 36 trees or 9% of planted seedlings (Figure 35).

Initial monitoring in 2014 revealed that one tree was almost dead, while the rest were considered in good health (Table 48). In 2015, one year after planting, 75% of seedlings were still alive. This is slightly above the overall average of 72% for all planting sites that have been monitored in the Park one year after planting (Table 50). Most trees were in good condition with 53% of trees rated as good, 19% rated as fair, and only 1 tree (3%) considered almost dead (Table 48). This site is relatively open with few existing microsites and little material from which to build microsites during planting. Likely the trees that died suffered from heat and drought stress, especially given that a year of drought and excessive heat followed planting.

Seedlings at this site grew during their first year after planting (Table 49). This is counter to the normal trend of seedlings that typically shrink in size their first year after planting due to needle shed. Until recently, most whitebark pine plantings have taken place in the fall. However, several spring whitebark pine plantings have taken place since 2013, some of which have shown a reversal in this growth trend. Trees in several of these sites are showing growth the first year after planting, likely due to these seedlings experiencing two summers of growing in the field. The first year, trees probably undergo some transplantation stress, as well as shed nursery needles. The second summer, however, trees are more established and may then have an opportunity to grow. Plots are usually read in the fall, so first year monitoring of trees planted in the spring are documenting growth over two summers.

Table 48. Spot Mountain, Spring 2014: Health and Survival of Whitebark Pine Seedlings Monitored in 2015.

<i>Plot</i>	<i>Seed Source</i>	<i>Dead/Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB14-01	Triple Divide*	0	1	0	35	36	36	100%
	Total 2014	0	1	0	35	36	36	100%
WB14-01	Triple Divide*	9	1	7	19	27	36	75%
	Total 2015	9	1	7	19	27	36	75%

*Most seed came from Triple Divide parent trees, 23 cones came from Old Man seed

Table 49. Spot Mountain, Spring 2014: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2015.

Year	Survival	Average Height (cm)	Average Width (cm)
2014	100%	8.64	7.58
2015	75%	9.04	8.59

Figure 35. Whitebark Pine Seedling Monitoring Plots at Spot Mountain, 2014.

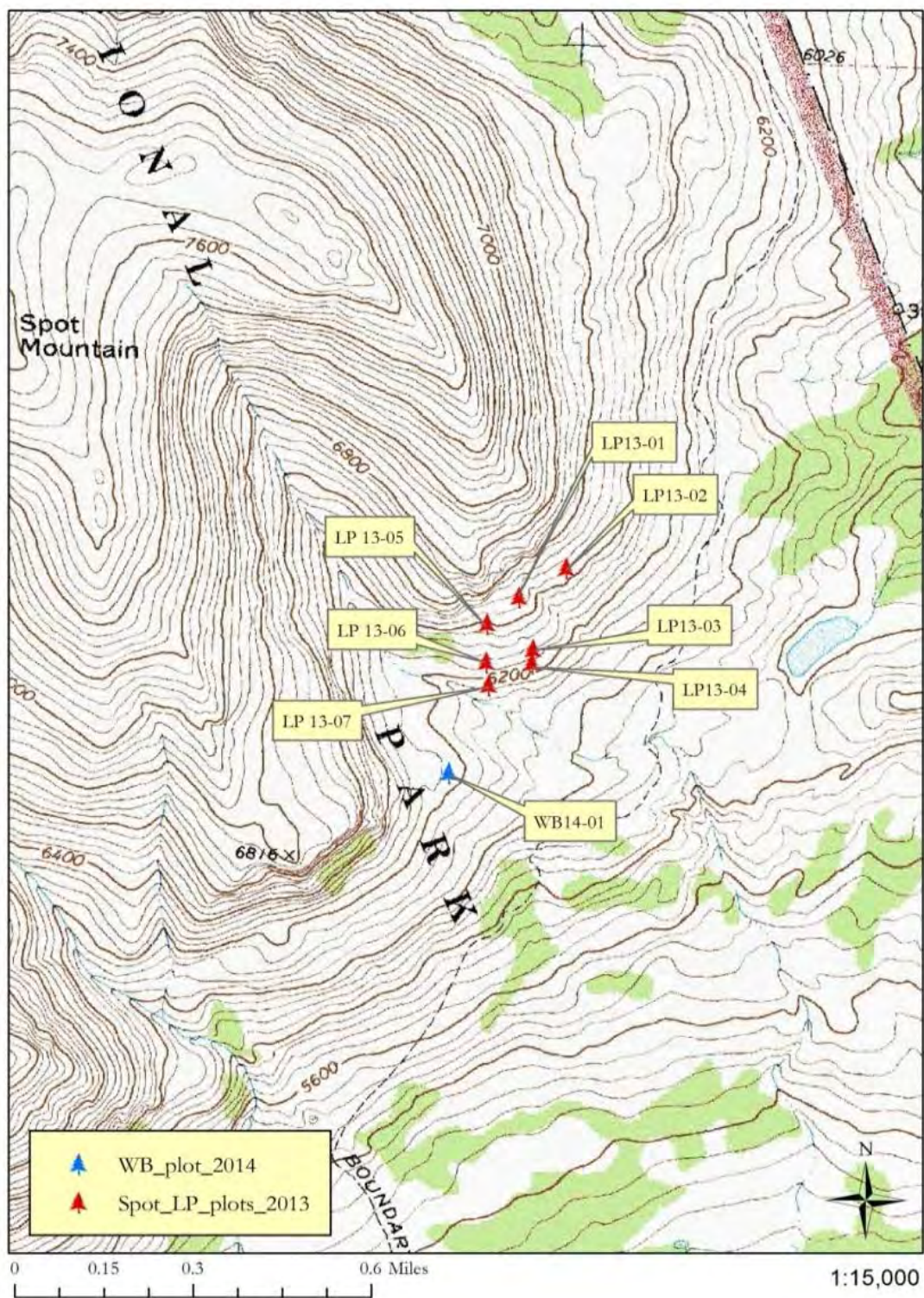


Table 50. Survival and Average Height and Width of Whitebark Pine for All Sites Monitored One Year After Planting. S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Whitebark Height and Health tab)

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Year Monitored</i>	<i>% Survival</i>	<i>Year 1</i>	
					<i>Height</i>	<i>Width</i>
Flattop Mtn. Spring 2001	2001	spring	2002	43%	*	*
Average 2001 trees				43%	*	*
Red Eagle - upper	2007	fall	2008	77%	8.96	9.72
Red Eagle - lower	2007	fall	2008	90%	8.79	8.82
Average 2007 trees				84%	8.875	9.27
Divide Creek - lower	2010	fall	2011	95%	9.83	10.96
Average 2010 trees				95%	9.83	10.96
Grinnell Picnic Area	2011	late summer	2012	48%	10.52	11.84
Cobalt Lake	2011	late summer	2012	31%	10.15	12.00
Average 2011 trees				40%	10.34	11.92
Firebrand - upper 2013	2013	spring	2014	93%	8.82	8.31
Firebrand - lower 2013	2013	fall	2014	95%	7.96	8.05
Numa 2013	2013	fall	2014	99%	9.11	9.55
Average 2013 trees				96%	8.63	8.64
Spot	2014	spring	2015	75%	9.04	8.59
Firebrand - lower 2014	2014	spring	2015	91%	8.44	8.86
Scenic Point 2014	2014	spring	2015	77%	8.97	9.17
Numa 2014	2014	fall	2015	65%	11.19	9.23
Divide Creek - upper	2014	fall	2015	87%	10.4	9.69
Firebrand - upper 2014	2014	fall	2015	30%	7.36	8.89
Whitecalf	2014	fall	2015	62%	9.39	9.55
Average 2014 trees				70%	9.26	9.14
Average 1- year-old-trees				72%	9.26	9.55

b. Scenic Point (Spring)

Scenic Point is the second of three new sites that was planted with whitebark pine for the first time in 2014. The Scenic Point planting site is located southeast and downslope from Scenic Point proper (Figure 36). Historically, this area supported one of the larger whitebark pine stands in the Park. It remains one of the Park's healthiest stands with a fair amount of live trees and documented plus trees despite a substantial amount of blister rust present on all age classes. There is also a notable amount of natural regeneration of whitebark pine here. This area has not been burned.

In June of 2014, approximately 802 whitebark pine seedlings were planted in the Scenic Point area on a southeast facing slope. This site was deemed a very good planting site by the revegetation crew due to good, deep soil conditions. In July of 2014, two monitoring plots were established, encompassing 188 trees or 23% of planted seedlings (Figure 36). Approximately one month after planting, one tree was dead (0.5%), but all the rest were considered in good health (Table 51).

Overall survival at this site was 77% one year after planting (Table 51). Although the overall survival is higher than the 72% one-year average, there was a vast discrepancy between plots. Trees in Plot 4 had a much lower survival rate at 66% than trees in Plot 5 that had a 90% survival rate. Plot 4 is higher in elevation and slightly more open than Plot 5 and thus may have been more susceptible to heat and drought stress. Several notations were made at the time of monitoring that trees appeared drought-stressed in this plot.

As is the usual trend for first-year seedlings, average size of trees shrunk in height since being planted in the spring of 2014 (Table 52). Seedlings grew in width, however. As described above, seedlings planted in the spring will often grow in the first year of monitoring, responding to two full summers of growth. Trees will also commonly grow in width before height, especially in wind-swept areas. First-year seedlings were smaller than average first-year trees at this site, but were also relatively small when planted (Table 50).

Figure 36. Whitebark Pine Seedling Monitoring Plots at Scenic Point, 2013 - 2015.

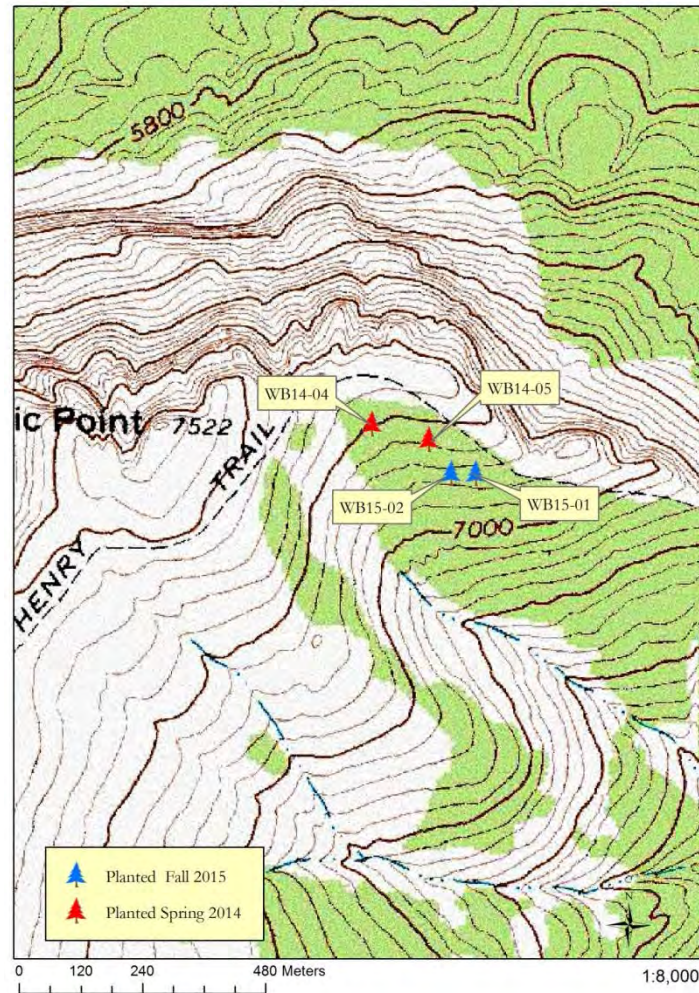


Table 51. Scenic Point, Spring 2014: Health and Survival of Whitebark Pine Seedlings Monitored in 2015.

<i>Plot</i>	<i>Seed Source</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB14-04	Rising Wolf	1	0	0	101	101	102	99%
WB14-05	Rising Wolf	0	0	0	86	86	86	100%
	Total 2014	1	0	0	187	187	188	99%
WB14-04	Rising Wolf	35	17	25	25	67	102	66%
WB14-05	Rising Wolf	9	8	6	63	77	86	90%
	Total 2015	44	25	31	88	144	188	77%

Table 52. Scenic Point, Spring 2014: Overall Survival and Average Height and Width of Whitebark Pine, 2015.

<i>ii.</i>	Year	Survival	Average Height (cm)	Average Width (cm)
	2014	99%	9.28	8.88
	2015	77%	8.97	9.17

iii. *Firebrand Pass Trail*

Four plantings have taken place near Firebrand Pass and on the flanks of Calf Robe Mountain. Whitebark pine seedlings were planted in both the upper and lower regions of the Firebrand Pass area in the spring and fall of 2013 and 2014.

a. *Lower Firebrand Pass Trail (Spring)*

On June 23, 2014, approximately 452 trees were planted on a bench on an open slope on the eastern flank of Calf Robe Mountain. This planting was upslope and south/southeast of the fall 2013 lower Firebrand Pass Trail planting. Two monitoring plots were established in this area, tracking 102 trees or 23% of planted seedlings (Figure 37).

One year after planting, overall survival at this site was a high 91% (Table 53). This is considerably higher than the 72% average of all first-year monitored trees in the Park (Table 50). Health and survival was similar among the two plots monitored from this planting with most trees rated in good condition (85% overall). No trees fell in the “almost dead” category and only 6% were considered in fair condition.

Figure 37. Whitebark Pine Seedling Monitoring Plots along the Firebrand Pass Trail, 2013 - 2014.

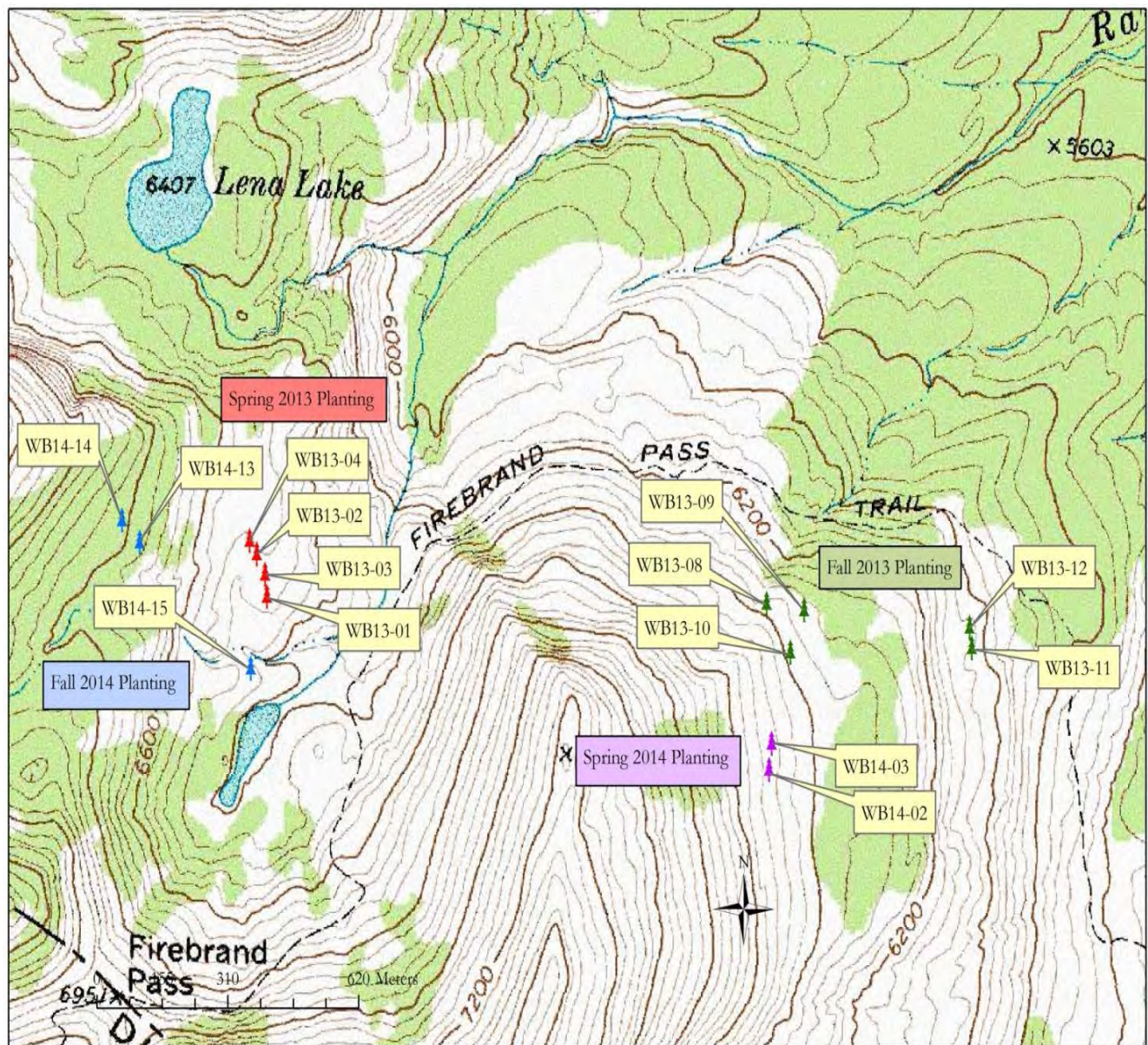


Table 53. Survival and Average Height and Width of Whitebark Seedlings Planted at Firebrand Pass in Spring, 2014. VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Firebrand tab)

<i>Plot</i>	<i>Seed Source</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB14-02	White Calf	0	0	0	48	48	48	100%
WB14-03	White Calf	0	2	3	49	54	54	100%
	Total 2014	0	2	3	97	102	102	100%
WB14-02	White Calf	4	0	3	41	44	48	92%
WB14-03	White Calf	6	0	3	49	52	58	90%
	Total 2015	10	0	6	90	96	106	90.57%

Seedlings at the Firebrand Pass area planted in the spring of 2014 averaged 8.44 cm in height and 8.86 cm in width (Table 54) one year after planting, smaller than average size for first year seedlings in the Park (Table 50). Trees were almost identical in average height from the height at the time of planting (0.02 cm shorter) and grew only slightly in width (by 0.51 cm). Results from most of the plantings in the Park show that first-year trees are typically smaller than they are at the time of planting, due to needle-shed of nursery-grown needles. In the case of spring planted trees, however, the first summer after being planted can facilitate more growth than would be found in fall planted trees the first year after planting.

Table 54. Firebrand Pass, Spring 2014: Overall Survival and Average Height and Width of Whitebark Pine, 2014-2015. VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Firebrand tab)

Year	Survival	Average Height (cm)	Average Width (cm)
2014	100%	8.46	8.35
2015	91%	8.44	8.86

b. Upper Firebrand Pass Trail (Fall)

The upper Firebrand Pass area was planted for the second time in the fall of 2014. On September 24, a total of 569 seedlings were planted. Three monitoring plots were installed (Figure 37), tracking 159 trees or 23% of planted seedlings. Two of the plots are located west and further upslope of the site of the spring 2013 planting in the vicinity, just above a large, healthy plus tree (WB13-02). The third monitoring plot is located at slightly lower elevation, south of the spring 2013 planting site on a slope above an unnamed lake.

In 2015, one year after planting, only 30% of seedlings are still alive in monitoring plots (Table 55). Furthermore, few of the surviving seedlings were in good health. Only 5 trees (3%) were rated as healthy. Twenty five trees (16%) were considered in fair health and 17 trees (11%) were almost dead. This planting site was exposed, gravelly and dry, likely contributing to poor survival. Additionally, planting was followed by a warm dry fall, conditions which continued throughout the winter, spring and subsequent summer.

Table 55. Survival, Average Height and Average Width of Seedlings Planted at Firebrand Pass in Fall, 2014. VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Firebrand tab)

<i>Plot</i>	<i>Seed Source</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB14-13	Old Man*	0	0	2	39	41	41	100%
WB14-14	Old Man*	0	0	7	48	55	55	100%
WB14-15	Old Man*	0	0	7	44	51	51	100%
	Total 2014	0	0	16	131	147	147	100%
WB14-13	Old Man*	33	2	7	2	11	44	25%
WB14-14	Old Man*	51	8	2	0	10	61	16%
WB14-15	Old Man*	28	7	16	3	26	54	48%
	Total 2015	112	17	25	5	47	159	29.56%

Seedlings shrunk in both average height and width in the year since planting (Table 56). Average height was 7.36 cm, a full 3.16 cm shorter than at planting, and average width was 8.89 cm, a 0.79 cm decrease. Again, this follows the trend of trees shedding their long, nursery-grown needles the first year after planting. However, this decline in height is larger than usual. These seedlings are also smaller than the average for one-year-old trees in the Park (Table 50).

Table 56. Firebrand Pass, Fall 2014: Overall Survival and Average Height and Width of Whitebark Pine, 2014-2015. VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Firebrand tab)

Year	Survival	Average Height (cm)	Average Width (cm)
2014	100%	10.52	9.68
2015	30%	7.36	8.89

Until recently, the thought was that spring plantings have not fared quite as well as fall plantings. This was mainly concluded from results from just a few sites. At Flattop Mountain, fall survivorship of whitebark pine seedlings planted in 2001 was slightly higher (by 7%) than in spring after 10 years (Table 24). More dramatically, survival in limber pine seedlings planted in the fall of 2013 at Spot Mountain was 40% higher than spring survival after one year. Recently, this trend has seen a reversal in some cases, with several sites supporting higher survival in spring plantings than fall plantings in the same year. At the Firebrand Pass area, seedlings planted in spring of 2014 had a 61% higher survival rate than fall plantings from 2014. This difference likely reflects, at least in part, different environmental parameters at each planting site, since the spring planting site was located at a lower elevation on a bench while the fall planting site was at higher elevation on a slope in open gravelly soil. However, it is worth continuing to monitor spring versus fall plantings to ascertain whether a clearer trend emerges. Averaging survival of all first-year trees monitored in the last few years, spring plantings show a slight edge with 86% overall survival compared to 78% survival of fall plantings (Tables 57 and 58).

Table 57. Average % Health and Survival for Spring-Planted Whitebark Pine Seedlings Monitored at Year One.

Site	Year Planted	Season Planted	Last Year Monitored	Dead / Missing	Almost Dead	Fair	Good	# Survived	# of Trees Monitored	% Survival
Firebrand Pass Area	2013	spring	2014	14	2	52	141	195	209	93%
Firebrand Pass Area (Lower)	2014	spring	2015	10	0	6	90	96	106	91%
Scenic Point (Upper)	2014	spring	2015	44	25	31	88	144	188	77%
Spot Mountain	2014	spring	2015	9	1	7	19	27	36	75%
Overall Total				77	28	96	338	462	539	86%

Table 58. Average Percent Health and Survival for Fall-Planted Whitebark Pine Seedlings Monitored at Year One.

Site	Year Planted	Season Planted	Last Year Monitored	Dead / Missing	Almost Dead	Fair	Good	# Survived	# of Trees Monitored	% Survival
Firebrand Pass Area	2013	fall	2014	21	10	13	343	366	387	95%
Numa Lookout	2013	fall	2014	2	1	5	167	173	175	99%
Divide Creek (Upper)	2014	fall	2015	28	0	37	154	191	219	87%
Firebrand Pass Area	2014	fall	2015	112	17	25	5	47	159	30%
Numa Lookout	2014	fall	2015	42	1	15	62	78	120	65%
Whitetail	2014	fall	2015	57	41	18	35	94	151	62%
Overall Total				262	70	113	766	949	1211	78%

iv. Numa Lookout (Fall)

In the fall of 2014, whitebark pine seedlings were planted for the second time in the Numa Lookout area. Approximately 710 trees were planted on September 16, 2014. Seedlings were planted below the lookout and mostly below the 2013 planting area at elevations around 6,870 feet (Figure 38). Seedlings were also planted on a bench on the north side of the lookout on the ridge towards Numa Peak at elevations ranging from 6,710 to 6,740 feet. This site has not burned.

Four monitoring plots were established in 2014: two plots south of the lookout below the 2013 plantings and two plots on the bench past and to the north of the lookout. Plots encompassed 208 trees, monitoring 29% of seedlings planted in 2014.

At the time of planting, all seedlings were alive in monitoring plots with 90% rated in good condition (Table 59). One year later, 65% of trees are still alive (Table 59). Most trees (52%) were in good condition, however, 13% were in fair condition and 1% (1 tree) was almost dead. While this percentage is below the 72% average for all first year planted whitebark pine seedlings in the Park (Table 50), it is somewhat higher than expected due to conditions at the time of and following planting. It was unseasonably warm and dry at the time of planting, followed by several very warm days and an extended “Indian summer” through much of the month of October (Appendix A). Generally, whitebark pine seedlings have not survived as well under these types of weather conditions. Also, 10% of the trees were rated “fair” or almost dead at the time of planting. Additionally, several relatively new planters were used for this project. Experienced planters tend to have developed a better eye for favorable microsite conditions, as well as have better planting skills.

Table 59. Numa Lookout, Fall 2014: Health and Survival of Whitebark Pine Seedlings Planted in 2014.

VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Numa tab)

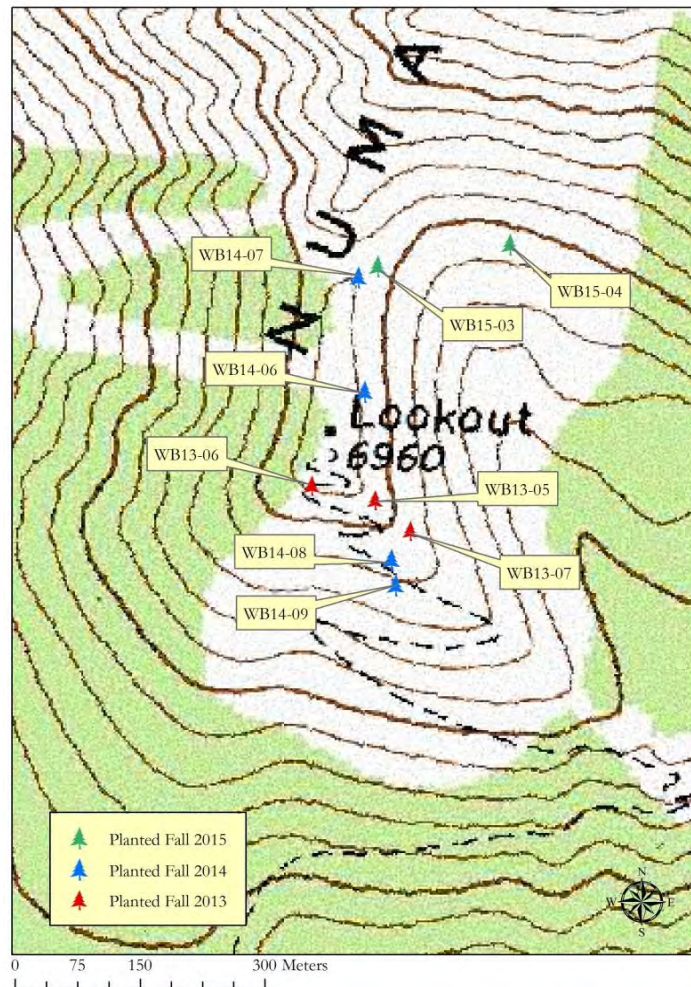
<i>Plot</i>	<i>Seed Source</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-14-06	Numa	0	1	4	24	29	29	100%
WB-14-07	Numa	0	0	1	23	24	24	100%
WB-14-08	Numa	0	1	1	20	22	22	100%
WB-14-09	Numa	0	0	4	41	45	45	100%
	Total 2014	0	2	10	108	120	120	100%
WB-14-06	Numa	13	0	2	14	16	29	55%
WB-14-07	Numa	4	0	3	17	20	24	83%
WB-14-08	Numa	11	0	5	6	11	22	50%
WB-14-09	Numa	14	1	5	25	31	45	69%
	Total 2015	42	1	15	62	78	120	65%

As is the usual trend for first-year seedlings, average size of trees shrunk at this site since being planted in the fall of 2014 (Table 60), although they were still larger than average first-year trees (Table 50). This is likely a reflection, however, of seedlings being relatively large at the time of planting.

Table 60. Numa Lookout, Fall 2014: Overall Survival and Average Height and Width of Whitebark Pine, 2014-2015. VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Numa tab)

Year	Survival	Average Height (cm)	Average Width (cm)
2014	100%	11.43	10.01
2015	65%	11.19	9.23

Figure 38. Whitebark Pine Seedling Monitoring Plots Near Numa Lookout, 2013 - 2015.



v. *Divide Creek (Fall)*

Due to the success of the 2010 planting at Divide Creek, it was decided to plant more whitebark pine seedlings at this site in 2014. This planting took place further upslope from the 2010 planting on open slopes and knobs where competition from lodgepole pine was lower (Figures 30 and 31). In September of 2014, 1,026 whitebark pine seedlings were planted at the Divide Creek planting site on the flank of Curly Bear Mountain. This site also burned in the Red Eagle fire of 2006 and all seedlings were planted within the burn. Some seedlings planted in this area were inoculated with ectomycorrhizal slurry and some were not. Most seedlings were grown in the nursery as single trees per cone, but occasionally more than one seedling was present in a cone. Therefore, a multiplier of 1.1 was utilized to estimate the number of trees planted at this site. 933 cones were planted in this upper Divide Creek area resulting in an estimated total of 1,026 trees. Often more than one cone was planted in a microsite, mimicking multiple whitebark pine trees often found in clumps as a result of seed caches buried by Clark's nutcrackers. These seedlings originated from Whitecalf parent trees.

Three monitoring plots were installed in 2014, tracking 216 seedlings. This captured 21% of planted seedlings. At the time of monitoring, 100% of the seedlings were alive, almost all of which (214) were rated in good health. Two seedlings were rated as "fair".

Monitoring these plots in 2015 revealed that 87% of seedlings had survived their first year after planting (Table 61). In comparison with all other plantings in the Park that were monitored one year after planting, this is above the average survival of 72% (Table 50).

Survival, however, was not consistent across plots. Percent survival ranged from 83% to 94% (Table 61). Trees from plot 10, the plot with the lowest survival, generally had the least healthy trees. On this plot, 24% of trees were rated in fair condition while only 59% were considered healthy. Plots 11 and 12, situated near each

other lower down the slope on a small knob, had healthier trees. 14% or less of the trees were in fair condition on these plots with 79% to 84% of trees in good health.

On average, seedlings in this planting grew in size since the time of planting (Table 62). Trees averaged a 0.39 cm increase in height and a 0.21 increase in width. This does not follow the common trend of seedlings shrinking the first year after planting, which is often seen due to needle-shed of long nursery grown needles after being planted in the field. Trees at this site were also larger than average compared to all first year seedlings monitored in the Park to date (Table 50).

Table 61. Survival, Average Height and Average Width of Seedlings Planted at Divide Creek in 2014.

VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Divide Creek 2014 tab)

<i>Plot</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-14-10	0	0	1	103	104	104	100%
WB-14-11	0	0	0	75	75	75	100%
WB-14-12	0	0	1	36	37	37	100%
Total 2014	0	0	2	214	216	216	100%
WB-14-10	18	0	25	61	86	104	83%
WB-14-11	5	0	11	61	72	77	94%
WB-14-12	5	0	1	32	33	38	87%
Total 2015	28	0	37	154	191	219	87%

Table 62. Divide Creek, 2014: Overall Survival and Average Height and Width of Whitebark Pine, 2014-

2015. VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Divide Creek 2014 tab)

Year	Seed Source	Survival	Average Height (cm)	Average Width (cm)
2014	Whitecalf	100%	10.01	9.48
2015	Whitecalf	87%	10.40	9.69

vi. Whitecalf (Fall)

White Calf Mountain was the third of three new whitebark pine planting sites for 2014. This site is located along the eastern margin of the Park about 7 miles south of St. Mary and just south of Divide Mountain. It also historically sustained one of the larger whitebark pine stands in Glacier National Park, which is now mostly dead. This site has not recently burned.

In October of 2014, this area was planted with approximately 788 whitebark pine seedlings on southeast facing slopes on the lower flanks of White Calf Mountain. Two monitoring plots were set up two days after planting in 2014 (Figure 39). Plots captured 146 trees or 19% of planted seedlings. At the time of planting, all trees were alive and only one tree was considered in fair condition (Table 63). All other trees were considered healthy.

In 2015, one year after planting, 62% of seedlings are still alive (Table 63). This is below the overall average of 72% for all one-year-old trees that have been monitored in the Park to date (Table 50). However, there is a large discrepancy among plots at this site. Plot 16, located further south, was planted in an open area with high low-growing vegetation dominated by subshrubs kinnikinnick and grasses. Survival was higher at this plot at 76%. Plot 17, on the other hand, had higher cover of short-stature trees but the actual ground surface was only lightly vegetated and dominated by scree. Survival at this plot was only 48%. Notes on several of the trees that perished on this plot indicated drought and/or heat stress. It is interesting to note that these seedlings were planted under cooler conditions than most other plantings in 2014, as well as later in the season. While the trees had a higher likelihood of being able to go directly into dormancy, the subsequent winter, however, was warmer and drier than usual, followed by a hot, dry spring and summer, which may have counteracted these benefits.

Seedlings shrunk in height since planting, following the usual pattern for fall-planted trees (Table 64). Height was still slightly above the overall average, however, for all first-year seedlings monitored in the Park (Table 50). This may reflect larger than average seedlings at the time of planting, which is common for fall-planted trees that spend the summer growing in a nursery. Trees did grow slightly in width. One-year width was average at this site compared to all one-year seedlings monitored in the Park.

Figure 39. Whitebark Pine Seedling Monitoring Plots at Whitecalf Mountain, 2014.

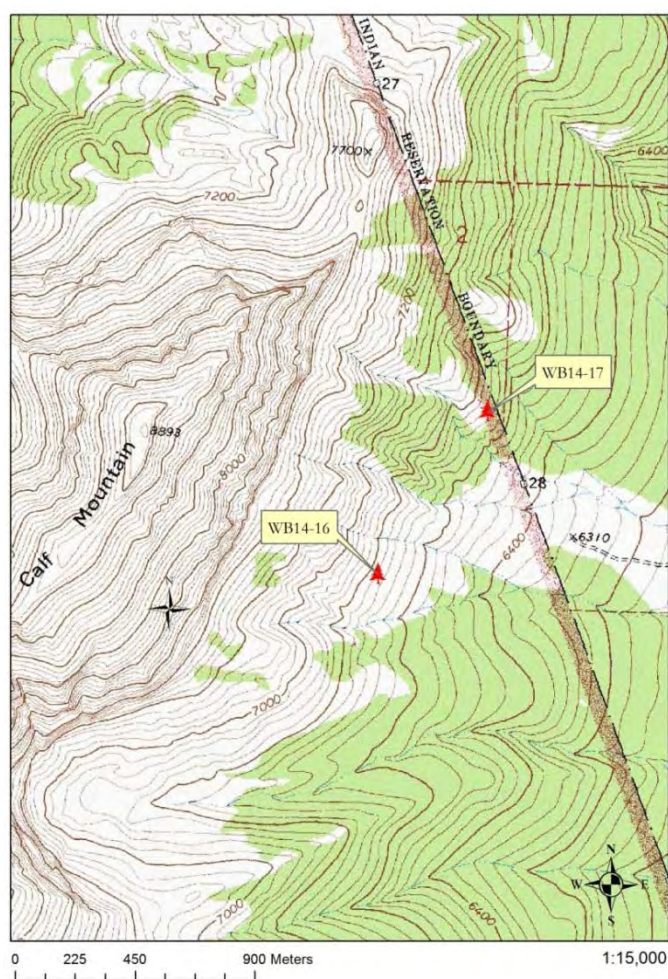


Table 63. White Calf, Fall 2014: Health and Survival of Whitebark Pine Seedlings Planted in 2014.

VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (White Calf tab)

<i>Plot</i>	<i>Seed Source</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB14-16	White Calf	0	0	1	72	73	73	100%
WB14-17	White Calf	0	0	0	73	73	73	100%
	Total 2014	0	0	1	145	146	146	100%
WB14-16	White Calf	19	28	9	22	59	78	76%
WB14-17	White Calf	38	13	9	13	35	73	48%
	Total 2015	57	41	18	35	94	151	62%

Table 64. White Calf, Fall 2014: Overall Survival and Average Height and Width of Whitebark Pine, 2014-

2015. VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (White Calf tab)

Year	Survival	Average Height (cm)	Average Width (cm)
2014	100%	10.52	9.45
2015	62%	9.39	9.55

e. 2015 Plantings

Two sites were planted with whitebark pine seedlings in the fall of 2015, specifically Scenic Point and Numa Lookout. Both sites have been planted with whitebark pine before and neither site has burned.

i. Scenic Point

The Scenic Point planting site is located southeast and downslope from Scenic Point proper (Figure 36, above). Historically, this area supported one of the larger whitebark pine stands in the Park. It remains one of the Park's healthiest stands with a fair amount of live trees and documented plus trees despite a substantial amount of blister rust present on all age classes. There is also a notable amount of natural regeneration of whitebark pine here. This area has not been burned.

On September 22, 2015, this area was planted for the second time with 222 whitebark pine seedlings. Plantings took place southeast of the fall 2014 planting area and of the plus trees identified in the area. This site is located among an existing whitebark pine stand with open, gravelly soil between trees. Two monitoring plots were installed on the same day, encompassing 68 trees or 31% of planted seedlings.

All trees were alive at the time of planting and all but one tree, which was rated as fair, were rated in good condition (Table 65). Average height was 10.76 cm and average width was 12.07 cm (Table 66). This is relatively large for seedlings at the time of planting which may reflect a summer of growth in a nursery setting. It should be noted that all seedlings had burnt needle tips which the Coeur d'Alene nursery reports resulted from heat stress.

The success of these trees may be largely dependent on weather patterns. At the time of planting, weather was warm and dry, following an excessively warm and dry summer. This weather pattern continued over the fall of 2015. In addition, a very strong El Niño is predicted for the upcoming winter, possibly resulting in warmer and drier than average weather.

Table 65. Scenic Point, Fall 2015: Health and Survival of Whitebark Pine Seedlings Planted in 2015.

VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Scenic Point tab)

<i>Plot</i>	<i>Seed Source</i>	<i>Dead/Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-15-01	Rising Wolf	0	0	0	32	32	32	100%
WB-15-02	Rising Wolf	0	0	1	35	36	36	100%
	Total 2015	0	0	1	67	68	68	100%

Table 66. Scenic Point, Fall 2015: Overall Survival and Average Height and Width of Whitebark Pine, 2015. VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Scenic Point tab)

Year	Survival	Average Height (cm)	Average Width (cm)
2015	100%	10.76	12.07

b. Numa Lookout

The Numa Lookout planting site is located on the slopes south and north of the lookout. This site has been planted with whitebark pine in the fall of 2013, 2014 and 2015. The area supports a population of living, mature whitebark pine trees, although most are not very large in stature. Blister rust is present in the area and has recently weakened or killed several mature trees in the area, including some plus trees. Regenerating whitebark seedlings and saplings are found in the area, although many of these have also been affected by blister rust.

On September 24, 2015, the area north of the lookout, on the flank of Numa Peak, was planted with 222 whitebark pine seedlings. This site is the furthest north that seedlings have been planted in the area. Plantings took place in short stature open forested areas, dominated by subalpine fir, whitebark pine and/or subalpine larch. The understory was relatively thick with beargrass and big huckleberry. Two monitoring plots were installed on the same day, encompassing 64 trees or 29% of planted seedlings (Figure 38, above).

All trees were alive at the time of planting and all were rated in good condition (Table X). Average height was 11.55 cm and average width was 12.09 cm. This is relatively large for seedlings at the time of planting which may reflect a summer of growth in a nursery setting.

As was seen in the seedlings planted at Scenic Point two days prior, all seedlings had burnt needle tips which resulted from heat stress in the Coeur d'Alene nursery. Again, the success of these trees may be largely dependent on weather patterns described above in the Scenic Point section.

Table 67. Numa Lookout, Fall 2015: Health and Survival of Whitebark Pine Seedlings Planted in 2015.

VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Numa tab)

<i>Plot</i>	<i>Seed Source</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-15-03	Rising Wolf	0	0	0	35	35	35	100%
WB-15-04	Numa	0	0	0	29	29	29	100%
	Total 2015	0	0	0	64	64	64	100%

Table 68. Numa Lookout, Fall 2015: Overall Survival and Average Height and Width of Whitebark Pine, 2015.

VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Numa tab)

Year	Survival	Average Height (cm)	Average Width (cm)
2015	100%	11.55	12.09

D. CONCLUSIONS AND RECOMMENDATIONS

1. *Limber Pine*

In 2015, two cohorts of limber pine seedlings were monitored; seedlings planted in 2005, now ten years old, and seedlings planted in 2012, now three years old. A trend of increasing limber pine survival is emerging.

Scenic Point is the second major planting to reach ten years old in Glacier National Park. Only one tree from monitoring plots planted in each of 2002 and in 2003 survived for 10 years. Those were drought years, which was likely one of the major causes of such poor survival. Plantings from 2004, monitored at several sites last year, averaged 15% survival at 15 years. The Scenic Point planting experienced very similar survival at 14% monitored 15 years after planting. Although this area has supported one of the largest whitebark pine stands in the past, under current climate regimes, seedlings have had a difficult time establishing at this site. It is likely that some of the subsequent plantings at other sites will have higher survival at ten years than at these first sites for several reasons. Many of the following plantings performed better after year one, which can be somewhat predictive of future success. Additionally, there has been a more successful trend in survival over the years as we have learned more about successful planting techniques and have generally planted in better weather windows that bring moisture.

Results from three-year-old seedlings appear much more promising for long-term success. Overall, survival across the five sites planted in 2012 was 43%. While this is still not considered excellent survival, seedlings tend to show the highest death rate in the first few years after planting, so it is possible that long term survival in these areas will be markedly improved over many of the previous plantings. Applying lessons that we have learned over the years, the most recent limber pine plantings in 2013 have provided the highest survival to date with an overall survival of 73% one year after planting. Good site selection and good planting techniques, including the use of microsites for seedling protection, have likely been responsible for improved success in the later plantings. Healthy plant material and adequate rainfall have also been contributing factors. Starting in 2012, limber pine seedlings also began to be grown in short cones, preventing the j-rooting that occurred in the past in the often rocky planting terrain in Glacier.

When separated by planting season, spring-planted sites experienced slightly higher survival at 48% than 40% survival for fall-planted sites looking at this three-year cohort. While spring-planted trees have the benefit of a season of growth and establishment before dormancy, immediate harsh conditions such as heat or drought can prove fatal. Rocky soil and other environmental parameters may prevent seedlings from thriving through the summer at certain sites, even with ample precipitation. Spring planting of limber pine does appear to be feasible in protected sites with deeper soils, however, as we have seen at sites such as Cutbank. Planning planting events around predicted rainfall also appears critical to the success of these seedlings, especially when planted in the spring.

High variability across sites in both spring- and fall-planted areas suggests that environmental factors may be more pertinent to survival than planting season. Trends should continue to be tracked over time to determine if

clear guidelines can be given regarding planting season. At this time, it appears that plantings should be assessed on a case by case basis, taking into account specific conditions at each site in conjunction with short-term weather and longer-term climatic predictions. With extremely warm and dry conditions throughout 2015, and a predicted El Niño that likely will bring more of the same, care should be exercised to select the optimum sites and timing of plantings. No limber pine seedlings were planted in the Park in 2015 for precisely this reason. The Reynolds Creek Fire that began in July of this year created ample habitat for limber pine planting in the future. Limber pine planting is planned for 2016 to utilize some of this habitat. Since the inception of limber pine restoration in the Park, no suitable burned habitat has been available for planting. Hopefully this will provide enhanced survival and vigor in future limber pine plantings.

Information from Waterton Lakes National Park (WLNP) has proven to be especially helpful in determining planting strategies in Glacier National Park. Results from a smaller planting of limber pine seedlings at WLNP (which came from the same source of seed as GNP limber pine seedlings) in 2003 had an 85% survival rate at year one after planting, 76% survival rate at year two after planting, and 72% survival rate at year three after planting (Smith et al., 2007). While the number of monitored trees is lower than GNP's data set and only looked at one planting location, survival rates of this one trial in WLNP were much higher than plantings in GNP at that time. In their study, they began to see three trends that explained our earlier low survival rates and confirm some of our observations over the past few years. First, they found limber pine seedling survival was marginally better in seedlings planted near cover (Smith et al., 2007). Supporting our theory that seedlings may need some shade and some protection from wind to prevent desiccation, cover from microsites appears to increase survival of limber pine seedlings. As stated above, our planting technique has changed to incorporate microsites that offer cover that did not occur during 2002 and in the 2006 Baring Creek planting when we had high mortality. Following advice from these studies has increased our limber pine survival rate dramatically.

Smith et al. also found that survival and seedling health was improved when more seedlings were planted together in a clump. Singly-planted seedlings had the lowest survival rate at the end of three monitoring seasons while three- and five-clumped seedlings had higher survival rates. They argue that once emerged, seedling growth and survivorship are enhanced by the presence of other vegetation or seedlings (Powell 1996; Feldman et al. 1999) that may alleviate the abiotic effects of the surrounding environment, thus making the microclimate more suitable. The presence of other vegetation may promote growth since soil nutrients, density and moisture are retained, due to an established root system from the other plants. On the whole, a significant majority of limber pine trees planted in GNP prior to 2012 were planted as single trees, possibly putting them at a disadvantage to retain soil moisture and nutrients, as well as to obtain protection from nearby vegetation. There is also conjecture that the survival benefit of being in a larger clump may not be a long-term effect. It is conceivable that the increased competition from being surrounded by more seedlings may result in lower survival once the seedlings are large enough to compete with one another (Smith et al., 2007). This year, trees were often planted in clumps, which consisted of between 2 to 4 trees per clump.

Finally, the WLNP study showed that seedling health was marginally better in burned areas than unburned areas within the experimental area. In general, burned soils carry a higher mineral load and more nutrients than unburned soils, thus having a positive effect on the growth of seedlings. To date, no limber pine seedlings have been planted in burned areas in GNP, although current studies with whitebark pine in GNP support the positive effects of planting in burned areas. Instead, all limber pine have been planted in unburned areas where limber pine is either present or has been present in the past. Some of those areas appear to be more amenable to limber pine survival, perhaps because they offer more soil nutrients and moisture, as well as appropriate microsites. These areas include the shadier areas of Baring Creek and Sun Point. It is likely that a site such as Scenic Point that is hot and exposed with little top soil or vegetation development offers too little protection, moisture, and nutrients. Suitable limber pine habitat had not burned in the Park until the summer of 2015. Subsequent plantings will take advantage of this new planting habitat.

More studies throughout the west are continuing to find similar results and suggest new planting techniques for limber pine. Not only have they also documented the importance of microsites for successful seedling survival, one study in the southern Rocky Mountains found higher survival of limber pine seedlings when planted under a dense canopy (Casper 2011). They found 80% of planted limber pines survived under a dense canopy compared to a 60% survival rate for limber pines planted in open canopy, indicating that overstory vegetation may be beneficial. We have seen similar results in our surviving ten-year-old Baring Creek limber pine, which are surviving completely underneath krummholz Douglas fir trees. They also documented higher limber pine survival when the seedlings were planted on the north or west side of microsites. Finally, they documented

that spring plantings in moist soils can be highly successful. Overall limber pine survival was 76% after 3 years when trees were planted during a time of good precipitation. From this research, spring plantings of limber pine were experimented with in Glacier in 2012 and 2013 at five locations and seedlings are being planted on cooler aspects of microsites at all planting locations in the park.

Continued monitoring is critical as results become even more complicated with impacts from annual changes in precipitation and temperature. On the east side of GNP, where all of the limber pine sites are located, there was considerably low precipitation and in both 2002 and 2003 and higher temperatures in 2003. Increased rain and cooler temperatures since 2004 may be contributing to higher survival rates (Appendix A). However, another warm, dry regime began in 2015 which may impact future survival of recently planted seedlings. Climate change research on five-needled pines is still in its infancy but early results from these studies have documented the importance of soil moisture for the survival of limber pine (Kueppers, in press). Research has shown that limber pine seedlings shut down if there is no moisture due to zero stomatal conductance during this time. This study showed that watering clearly aids in survival across the study's entire elevation gradient. While seedlings are watered in at the time of planting in Glacier, perhaps supplemental watering should occur during the first year when possible.

In recent years, we have been more critical about choosing sites that are appropriate for limber pine planting in GNP. We have also taken greater care in planting techniques for each seedling. The following recommendations have recently been and should continue to be considered when choosing a site and when planting seedlings:

- Plant in burn areas when available.
- Continue to consider spring plantings until further research is conclusive. Plant when precipitation is high at or near the time of planting to increase soil moisture. Consider supplemental watering in areas that are accessible during the first year of planting if precipitation levels are not as expected during the spring.
- For fall plantings, plant only in later September and October, when precipitation is more likely.
- Plant in areas with good microsite availability that provides some shade and wind protection. Consider planting under tree canopy, when available, for additional shade.
- Plant on the north and west sides of microsites to the extent that is possible.
- Try to plant in areas that have decent to good soil moisture and soil nutrients, including low to moderate vegetation and/or an area that has burned. Consider supplemental watering in areas that are accessible during the first year of planting.
- Do not plant in areas that have on-going disturbance that would cause soil movement or trampling. Do not plant in avalanche-prone areas.
- Continue to grow limber pine seedlings in short containers to prevent the need for j-rooting in shallow soils.
- Plant seedlings in groups of 3 to 5 seedlings as this appears to increase survival.
- Assess the health of the seedlings prior to planting to assure that the healthiest material is being planted.
- Plant in appropriate habitat to prevent competition.
- Do not use netting on limber pine trees, as it does not appear to be increasing their survival from our observations.
- Do not use water polymers or hydrogels with seedlings when planted. If these amendments are still of interest, a more controlled experiment should be conducted to determine the benefits of its use.
- Continue to research the effectiveness of fertilizer amendments on the success of planted limber pine.

2. *Whitebark Pine*

Traditionally, revegetation of whitebark pine seedlings has shown better progress than limber pine restoration. Overall survival of all monitored whitebark pine seedlings to date in Glacier National Park is 62%. It is hopeful that limber pine seedlings planted in 2012 and beyond will begin to see equal success.

This year's results show continued relatively high survival rates. A dip in first-year survival rates was observed this year, most likely due to warmer and drier conditions during and following some fall plantings. First year survival for trees planted in 2014 was 70%, just slightly lower than the overall first-year survival of 72% from all projects to date. First year survival recorded last year for trees planted in 2013 was 96%. Weather following

planting that year was cool and wet. There was a wide range in first-year survival across plots this year, however, from 30% to 91%, with season and site appearing to contribute to survival. In general, spring-planted trees fared better, likely reflecting a relatively wet spring following planting. Fall sites planted in burns and/or in areas where there was ample vegetation to provide shade and/or moisture retention also performed better. Sites with open, gravelly soil showed the lowest survival rates, particularly if planted in the fall that was followed by warmer and drier than average conditions.

Third year survival was monitored at one site, Divide Mountain. Third-year survival at this site was 59%, slightly higher than the 51% average for all sites monitored at three years in the Park to date. This is a complicated planting site with a variety of environmental conditions including burned and non-burned areas, as well as drier areas and areas where late snowmelt is retained. In general, seedlings showed higher survival in the snow catchment areas and in burn areas. In addition, some seedlings were inoculated with an ectomycorrhizal slurry. Generally, inoculated seedlings showed higher survival than non-inoculated seedlings at this site. Trees that were not inoculated and not planted in a burn had the lowest survival rates and shrunk in size. Many of the seedlings that did not survive showed evidence of herbivory. This site supports a healthy population of pikas and golden mantled ground squirrels and herbivory was noted as soon as the next day after planting at this site. The 6% decline in survival since last year is likely mostly due to herbivory, as often signs of predation were noted. Future controlled studies should be considered that focus directly on comparing burned vs. non-burned areas and the use of inoculating seedlings across a range of planting sites. Initial observations from our studies and studies at WLNPN indicate that seedlings planted at poor sites with shallow, rocky soil and low nutrients may benefit more from inoculation than those seedlings planted at high nutrient sites with deeper soils.

Fifth year survival was monitored at two sites this year, Divide Creek and Hole-in-the-Wall, with highly variable results. Survival at Divide Creek was 94%, by far the highest 5-year survival rate that has been seen in the Park, while survival at Hole-in-the-Wall was 28%, well below the overall average of 49% for all sites monitored five years after planting. Clearly, environmental conditions, including weather at and just following planting, contributed to the success of these plantings.

Divide Creek remains the most successful long-term planting site to date. These seedlings were planted late in the season with ample moisture. Overall survival of 94% at Divide Creek is well above the five-year average of 49%. In addition to excellent soil conditions created by the Red Eagle Fire, this high survival rate may also be due to protection from the elements for individual seedlings as well as ample precipitation at the time of planting in the form of snow. Since these seedlings were planted late in the season, they were able to avoid heat stress and potentially go directly into dormancy. Future success of this site, however, may be hampered by high competition from lodgepole pine in this area. Some lodgepole trees are reaching 1 to 1.5 meters tall and form relatively thick stands in areas. Several sites have equally high initial survivorship as Divide Creek; future results should help to reveal refined understandings of factors that play into increased survival over time.

Hole-in-the-Wall has proven to be a more difficult site for whitebark pine seedling survival. This site exhibits the lowest survival for all five-year monitoring sites to date at 28%. However, survival is only 5% to 8% lower than five-year survival at Flattop Mountain, a site that is considered a relatively successful restoration area. Additionally, this is only slightly lower than the 30% average found in Izlar's 2007 paper compiling data from 37 whitebark planting events over 15 years in Montana, Wyoming, and Idaho. The lower than average overall survival at Hole-in-the-Wall suggests that non-burned sites may not be as ideal of planting sites as burned sites. This planting also took place at the end of August, so perhaps seedlings experienced high levels of temperature stress and temporary drought stress soon after planting.

This year, one of the original plantings in the park was revisited. Grinnell Point, which was planted opportunistically in 2000 immediately following the Grinnell Point Fire, was monitored for the first time by GNP staff this year. Fifteen year survivorship here is 65%, a very promising number, especially given that it was planted in a very harsh site before planting protocols had been refined. Again, this illustrates the benefits of planting in recent burn areas.

From 2012 to 2015, several medium to large-scale plantings took place in non-burned areas: Divide Mountain, the Firebrand Pass Trail, below Numa Lookout, Scenic Point, Spot Mountain and Whitecalf Mountain. First year survivorship at most of these sites is excellent, with the exception of the fall 2013 planting in an open gravelly area higher up in the Firebrand Pass Area. Divide Mountain, which experienced high herbivory, also showed slightly lower survival. Continued monitoring of non-burned sites should help to guide future site selection.

Most sites were planted using some of the recommendations learned from limber pine plantings, including planting in burned areas when possible, planting in microsites, and not using shade netting. However, due to lack of accessible burned whitebark pine habitat in the park, most of the recent planting sites currently occur in non-burned areas. Additionally, several sites lacked adequate natural shelter or available microsite materials.

These results are in keeping with, or better than, results from other whitebark pine planting projects. Izlar (2007) compiled data from 37 whitebark planting events over the last 15 years in Montana, Wyoming, and Idaho. That summary reported that typical year one survival of planted whitebark seedlings is 74% (59-92% range), typical year three survival is 38% (31-47% range), and typical year five survival is 30% (19-42% range). Many of our first year plantings are now well exceeding this survival rate at year one with several sites having survivorship in the 90% range.

As with limber pine plantings, we need to continue to be critical about assessing a site as an appropriate whitebark pine planting site in GNP. The planting recommendations listed above for limber pine should also continue to be applied to whitebark pine plantings. In addition, there should be assessments made concerning the influence of slopes within planting areas, the possibility of falling bark of dead trees, and the impacts of competition from regenerating vegetation. Plantings should ideally occur in the fall when temperatures are lower and precipitation is more reliable, although spring plantings are beginning to show promise, if planted when precipitation is high. Burned areas should be utilized when possible.

Direct seeding of whitebark pine seed, while not monitored this year, has not been very successful so far at Glacier National Park. Only two of the five seed plots saw any germination and only one plot continues to support a few seedlings. Site selection was likely at least part of the problem at Siyeh Bend, which experiences frequent avalanches or snow slides and where seed predation by small mammals appeared high. If seed plots are to be experimented with again in the future, sites should be carefully selected and small screens should be installed to protect the seeds from herbivory. Seeds were not scarified or treated in any way prior to planting, which may also play a role. Additionally, seed was not extremely fresh or stored perfectly, which should also be taken into consideration in the future.

3. *Future Monitoring*

In 2016, two limber pine monitoring sites are scheduled to be revisited. The Baring Creek planting will be monitored at 10 years after planting, although likely no seedlings survived the Reynolds Creek Fire that burned through the area starting in July of this year. Additionally, limber pine planted at Spot Mountain will reach three years of age, and are scheduled for monitoring.

Several whitebark pine plantings are also due for monitoring. Flattop Mountain, which contains multiple plantings, will reach 14 and 15 years of age next year. Caper Peak, at ten years old, is also scheduled for monitoring. Two three-year-old sites, Cobalt Lake and Grinnell Picnic Area, and three two-year old sites, Upper and Lower Firebrand Pass Trail and Numa Lookout, are also scheduled for monitoring.

It was decided to forgo limber pine planting and limit whitebark pine planting in 2015, due to unusually warm, dry weather. Inability to access the newly-burned limber pine planting habitat also factored into this decision. Therefore, larger-scale plantings are planned for 2016. Recently burned habitat will be utilized for the first time next year for limber pine. Hopefully burned habitat can be utilized for whitebark pine planting as well, although the whitebark habitat is less accessible. In the spring, 850 limber pine and 1306 whitebark pine seedlings are scheduled for planting in Glacier National Park. An additional 500 whitebark pine and 500 limber pine seedlings were requested for fall planting. Monitoring plots will be installed at planting areas to capture a targeted 20% of seedlings. In 2017, 500 whitebark pine seedlings are scheduled for planting. No limber pine are scheduled for planting in 2017.

Table 69. Whitebark and Limber Pine Monitoring Schedule

Plot(s)	Species	Location	Year Planted	Year Monitored: 2000	2001	2002	2003	2004	2005	2006	2007
None installed	Whitebark pine	Dutch Creek	2000?								
GP00 -01 to -07	Whitebark pine	Grinnell Point	2000	X (year 0)						X (year 6)	
FT01 -01 to -27	Whitebark pine	Flattop	2001		X (year 0)	X (year 1)			X (year 4)	X (year 5)	
FT02 -01 to -11	Whitebark pine	Flattop	2002			X (year 0)			X (year 3)	X (year 4)	
LP02 -01 to -25	Limber pine	Various	2002			X (year 0)	X (year 1)	X (year 2) ALL DEAD			
LP02-05	Limber pine	Many Glacier Hotel Slope	2002			X (year 0)	X (year 1)	X (year 2)		X (year 4) 1 TREE LEFT	X (year 5) 1 TREE LEFT
LP02-22	Limber pine	Sun Point	2002			X (year 0)	X (year 1)	X (year 2)		X (year 4) 1 TREE LEFT	X (year 5) 1 TREE LEFT
LP02-24	Limber pine	Firebrand Pass Trail	2002			X (year 0)	X (year 1)	X (year 2)		X (year 4) 1 TREE LEFT	
LP03-01	Limber pine	Two Med Camp Store	2003				X (year 0)	X (year 1)		X (year 3)	
LP04 -01 to -05	Limber pine	Baring Creek	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)
LP04 -06 to -07	Limber pine	Many Glacier Hotel Slope	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)
LP04 -08	Limber pine	Sun Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)
LP04 -09	Limber pine	Sun Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)
LP04 -10	Limber pine	Dead Horse Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)
LP04 -11	Limber pine	Dead Horse Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)
LP05 -01 to -06	Limber pine	Scenic Point	2005						X (year 0)	X (year 1)	X (year 2)
LP06 -02	Limber pine	Baring Creek	2006							X (year 0)	X (year 1)
LP06 -01 & -03	Limber pine	Baring Creek	2006							X (year 0)	X (year 1)
LP06 -04	Limber pine	Dead Horse Point	2006							X (year 0)	X (year 1)
WB06 -01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006							X (year 0)	
WB07 -01 to -09	Whitebark pine	Red Eagle (seedlings)	2007								X (year 0)
WBS07 -04 to -05	Whitebark pine	Red Eagle (seeds)	2007								
WBS07 -01 to -03	Whitebark pine	Siyeh Bend (seeds)	2007								X (year 0)
WB10-01 to -05	Whitebark pine	Hole-in-the-Wall	2010								
WB10-06 to -10	Whitebark pine	Divide Creek	2010								
GPA-WB-11-01 to -02	Whitebark pine	Grinnell Picnic Area	2011								
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011								
WB12-01 to -04	Whitebark pine	Divide Mountain	2012								
LP12-01 to -02	Limber pine	Cutbank	2012								
LP12-03; 11	Limber pine	Apikuni Flats	2012								
LP12-04 to -05	Limber pine	Rising Sun CG	2012								
LP12-06 to -07	Limber pine	Scenic Point	2012								
LP12-10	Limber pine	Many Glacier Well Area	2012								

black text = completed

orange text = scheduled but not completed

red text = notes about trees in plots with high mortality

blue text = scheduled for future

Table 69, con't. Whitebark and Limber Pine Monitoring Schedule

Plot(s)	Species	Location	Year Planted	2008	2009	2010	2011	2012
None installed	Whitebark pine	Dutch Creek	2000?			X (year 10)		
GP00 -01 to -07	Whitebark pine	Grinnell Point	2000			X (year 10)		
FT01 -01 to -27	Whitebark pine	Flattop	2001		X (year 8)		X (year 10)	
FT02 -01 to -11	Whitebark pine	Flattop	2002		X (year 7)		X (year 9)	
LP02 -01 to -25	Limber pine	Various	2002					
LP02-05	Limber pine	Many Glacier Hotel Slope	2002		X (year 7) ALL DEAD			
LP02-22	Limber pine	Sun Point	2002		X (year 7) ALL DEAD			
LP02-24	Limber pine	Firebrand Pass Trail	2002	X (year 6)				X (year 10)
LP03-01	Limber pine	Two Med Camp Store	2003	X (year 5)				
LP04 -01 to -05	Limber pine	Baring Creek	2004	X (year 4)	X (year 5)			
LP04 -06 to -07	Limber pine	Many Glacier Hotel Slope	2004		X (year 5)			
LP04 -08	Limber pine	Sun Point	2004		X (year 5) ALL DEAD			
LP04 -09	Limber pine	Sun Point	2004		X (year 5)			
LP04 -10	Limber pine	Dead Horse Point	2004		X (year 5) 1 TREE LEFT			
LP04 -11	Limber pine	Dead Horse Point	2004		X (year 5) ALL DEAD			
LP05 -01 to -06	Limber pine	Scenic Point	2005	X (year 3)		X (year 5)		
LP06 -02	Limber pine	Baring Creek	2006	X (year 2)	X (year 3)		X (year 5)	
LP06 -01 & -03	Limber pine	Baring Creek	2006	X (year 2) ALL DEAD				
LP06 -04	Limber pine	Dead Horse Point	2006	done: all dead but 1 mis	X (year 3) ALL DEAD			
WB06 -01 to -02	Whitebark pine	Caper Peak (seeds + tree)	2006	X (year 2)			X (year 5)	
WB07 -01 to -09	Whitebark pine	Red Eagle (seedlings)	2007	X (year 1)	X (year 2)	X (year 3)		X (year 5)
WBS07 -04 to -05	Whitebark pine	Red Eagle (seeds)	2007	X (year 1)	X (year 2)	X (year 3)		X (year 5)
WBS07 -01 to -03	Whitebark pine	Siyeh Bend (seeds)	2007	X (year 1)	X (year 2)	X (year 3)		X (year 5) NOTHING COMING UP
WB10-01 to -05	Whitebark pine	Hole-in-the-Wall	2010			X (year 0)	X (year 1)	X (year 2)
WB10-06 to -10	Whitebark pine	Divide Creek	2010			X (year 0)	X (year 1)	X (year 2)
GPA-WB-11-01 to -02	Whitebark pine	Grinnell Picnic Area	2011				X (year 0)	X (year 1)
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011				X (year 0)	X (year 1)
WB12-01 to -04	Whitebark pine	Divide Mountain	2012					X (year 0)
LP12-01 to -02	Limber pine	Cutbank	2012					X (year 0)
LP12-03; 11	Limber pine	Apikuni Flats	2012					X (year 0)
LP12-04 to -05	Limber pine	Rising Sun CG	2012					X (year 0)
LP12-06 to -07	Limber pine	Scenic Point	2012					X (year 0)
LP12-10	Limber pine	Many Glacier Well Area	2012					X (year 0)

black text = completed

orange text = scheduled but not completed

red text = notes about trees in plots with high mortality

blue text = scheduled for future

Table 69, con't. Whitebark and Limber Pine Monitoring Schedule

Plot(s)	Species	Location	Year Planted	2013	2014	2015	2016	2017	2018	2019
None installed	Whitebark pine	Dutch Creek	2000?			X (year 15)				
GP00 -01 to -07	Whitebark pine	Grinnell Point	2000			X (year 15)				
FT01 -01 to -27	Whitebark pine	Flattop	2001				X (year 15)			
FT02 -01 to -11	Whitebark pine	Flattop	2002				X (year 14)			
LP02 -01 to -25	Limber pine	Various	2002							
LP02-05	Limber pine	Many Glacier Hotel Slope	2002							
LP02-22	Limber pine	Sun Point	2002							
LP02-24	Limber pine	Firebrand Pass Trail	2002					X (year 15) 1 TREE LEFT		
LP03-01	Limber pine	Two Med Camp Store	2003	X (year 10)					X (year 15)	
LP04 -01 to -05	Limber pine	Baring Creek	2004		X (year 10)					X (year 15)
LP04 -06 to -07	Limber pine	Many Glacier Hotel Slope	2004		X (year 10)					X (year 15)
LP04 -08	Limber pine	Sun Point	2004							
LP04 -09	Limber pine	Sun Point	2004		X (year 10)					X (year 15)
LP04 -10	Limber pine	Dead Horse Point	2004		X (year 10) 1 TREE LEFT					X (year 15) 1 TREE LEFT
LP04 -11	Limber pine	Dead Horse Point	2004							
LP05 -01 to -06	Limber pine	Scenic Point	2005			X (year 10)				
LP06-02	Limber pine	Baring Creek	2006				X (year 10)			
LP06 -01 & -03	Limber pine	Baring Creek	2006				X (year 10)			
LP06 -04	Limber pine	Dead Horse Point	2006							
WB06 -01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006				X (year 10)			
WB07 -01 to -09	Whitebark pine	Red Eagle (seeds + trees)	2007					X (year 10)		
WBS07 -04 to -05	Whitebark pine	Red Eagle (seeds)	2007					X (year 10)		
WBS07 -01 to -03	Whitebark pine	Siyeh Bend (seeds)	2007							
WB10-01 to -05	Whitebark pine	Hole-in-the-Wall	2010	X (year 3)		X (year 5)				
WB10-06 to -10	Whitebark pine	Divide Creek lower	2010	X (year 3)	X (year 4)	X (year 5)				
GPA-WB-11-01 to -02	Whitebark pine	Grinnell Picnic Area	2011		X (year 3)		X (year 5)			
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011		X (year 3)		X (year 5)			
WB12-01 to -04	Whitebark pine	Divide Mountain	2012	X (year 1)	X (year 2)	X (year 3)		X (year 5)		
LP12-01 to -02	Limber pine	Cutbank	2012	X (year 1)		X (year 3)		X (year 5)		
LP12-03 and -11	Limber pine	Apikuni Flats	2012	X (year 1)		X (year 3)		X (year 5)		
LP12-04 to -05	Limber pine	Rising Sun CG	2012	X (year 1)		X (year 3)		X (year 5)		
LP12-06 to -09	Limber pine	Scenic Point	2012	X (year 1)		X (year 3)		X (year 5)		
LP12-10	Limber pine	Many Glacier Well Area	2012	X (year 1)		X (year 3)		X (year 5)		
WB13-01 to -04	Whitebark pine	Firebrand Pass upper (spring)	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)	
WB13-08 to -12	Whitebark pine	Firebrand Pass lower (fall)	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)	
WB13-05 to -07	Whitebark pine	Numa Ridge	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)	
LP13-01 to -07	Limber pine	Spot Mtn. (spring & fall)	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)	
WB14-01	Whitebark pine	Spot Mtn. (spring)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB14-02 to -03	Whitebark pine	Firebrand Pass lower (spring)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB14-04 to -05	Whitebark pine	Scenic Point upper (spring)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB14-06 to -09	Whitebark pine	Numa Ridge (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB14-10 to -12	Whitebark pine	Divide Creek upper (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB14-13 to -15	Whitebark pine	Firebrand Pass upper (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB14-16 to -17	Whitebark pine	White Calf (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB15-01 to -02	Whitebark pine	Scenic Point upper (fall)	2015			X (year 0)	X (year 1)		X (year 3)	
WB15-03 to -04	Whitebark pine	Numa Ridge (fall)	2015			X (year 0)	X (year 1)		X (year 3)	

black text = completed

blue text = scheduled for future

red text = notes about trees in plots with high mortality

orange text = scheduled but not completed

Table 69, con't. Whitebark and Limber Pine Monitoring Schedule

Plot(s)	Species	Location	Year Planted	2020	2021	2022	2023	2024	2025	2026	2027
None installed	Whitebark pine	Dutch Creek	2000?	X (year 20)					X (year 25)		
GP00 -01 to -07	Whitebark pine	Grinnell Point	2000	X (year 20)					X (year 25)		
FT01 -01 to -27	Whitebark pine	Flattop	2001		X (year 20)					X (year 25)	
FT02 -01 to -11	Whitebark pine	Flattop	2002		X (year 19)					X (year 24)	
LP02 -01 to -25	Limber pine	Various	2002								
LP02-05	Limber pine	Many Glacier Hotel Slope	2002								
LP02-22	Limber pine	Sun Point	2002								
LP02-24	Limber pine	Firebrand Pass Trail	2002			X (year 20) 1 TREE LEFT					X (year 25) 1 TREE LEFT
LP03-01	Limber pine	Two Med Camp Store	2003				X (year 20)				
LP04 -01 to -05	Limber pine	Baring Creek	2004					X (year 20)			
LP04 -06 to -07	Limber pine	Many Glacier Hotel Slope	2004					X (year 20)			
LP04 -08	Limber pine	Sun Point	2004								
LP04 -09	Limber pine	Sun Point	2004					X (year 20)			
LP04 -10	Limber pine	Dead Horse Point	2004					X (year 20) 1 TREE LEFT			
LP04 -11	Limber pine	Dead Horse Point	2004								
LP05 -01 to -06	Limber pine	Scenic Point	2005	X (year 15)					X (year 20)		
LP06-02	Limber pine	Baring Creek	2006		X (year 15)					X (year 20)	
LP06 -01 & -03	Limber pine	Baring Creek	2006								
LP06 -04	Limber pine	Dead Horse Point	2006								
WB06 -01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006		X (year 15)					X (year 20)	
WB07 -01 to -09	Whitebark pine	Red Eagle (seeds + trees)	2007			X (year 15)					X (year 20)
WBS07 -04 to -05	Whitebark pine	Red Eagle (seeds)	2007			X (year 15)					X (year 20)
WBS07 -01 to -03	Whitebark pine	Sivah Bend (seeds)	2007								
WB10-01 to -05	Whitebark pine	Hole-in-the-Wall	2010	X (year 10)					X (year 15)		
WB10-06 to -10	Whitebark pine	Divide Creek lower	2010	X (year 10)					X (year 15)		
GPA-WB-11-01 to -02	Whitebark pine	Grinnell Picnic Area	2011		X (year 10)					X (year 15)	
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011		X (year 10)					X (year 15)	
WB12-01 to -04	Whitebark pine	Divide Mountain	2012			X (year 10)					X (year 15)
LP12-01 to -02	Limber pine	Cutbank	2012			X (year 10)					X (year 15)
LP12-03 and -11	Limber pine	Apikuni Flats	2012			X (year 10)					X (year 15)
LP12-04 to -05	Limber pine	Rising Sun CG	2012			X (year 10)					X (year 15)
LP12-06 to -09	Limber pine	Scenic Point	2012			X (year 10)					X (year 15)
LP12-10	Limber pine	Many Glacier Well Area	2012			X (year 10)					X (year 15)
WB13-01 to -04	Whitebark pine	Firebrand Pass upper (spring)	2013				X (year 10)				
WB13-08 to -12	Whitebark pine	Firebrand Pass lower (fall)	2013				X (year 10)				
WB13-05 to -07	Whitebark pine	Numa Ridge	2013				X (year 10)				
LP13-01 to -07	Limber pine	Spot Mtn. (spring & fall)	2013				X (year 10)				
WB14-01	Whitebark pine	Spot Mtn. (spring)	2014					X (year 10)			
WB14-02 to -03	Whitebark pine	Firebrand Pass lower (spring)	2014					X (year 10)			
WB14-04 to -05	Whitebark pine	Scenic Point upper (spring)	2014					X (year 10)			
WB14-06 to -09	Whitebark pine	Numa Ridge (fall)	2014					X (year 10)			
WB14-10 to -12	Whitebark pine	Divide Creek upper (fall)	2014					X (year 10)			
WB14-13 to -15	Whitebark pine	Firebrand Pass upper (fall)	2014					X (year 10)			
WB14-16 to -17	Whitebark pine	White Calf (fall)	2014					X (year 10)			
WB15-01 to -02	Whitebark pine	Scenic Point upper (fall)	2015	X (year 5)					X (year 10)		
WB15-03 to -04	Whitebark pine	Numa Ridge (fall)	2015	X (year 5)					X (year 10)		

black text = completed

blue text = scheduled for future

red text = notes about trees in plots with high mortality

orange text = scheduled but not completed

Table 69, con't. Whitebark and Limber Pine Monitoring Schedule

Plot(s)	Species	Location	Year Planted	2028	2029	2030	2031	2032	2033	2034	2035
None installed	Whitebark pine	Dutch Creek	2000?			X (year 30)					
GP00 -01 to -07	Whitebark pine	Grinnell Point	2000			X (year 30)					
FT01 -01 to -27	Whitebark pine	Flattop	2001				X (year 30)				
FT02 -01 to -11	Whitebark pine	Flattop	2002				X (year 29)				
LP02 -01 to -25	Limber pine	Various	2002								
LP02-05	Limber pine	Many Glacier Hotel Slope	2002								
LP02-22	Limber pine	Sun Point	2002								
LP02-24	Limber pine	Firebrand Pass Trail	2002					X (year 30) 1 TREE LEFT			
LP03-01	Limber pine	Two Med Camp Store	2003	X (year 25)							
LP04 -01 to -05	Limber pine	Baring Creek	2004		X (year 25)						
LP04 -06 to -07	Limber pine	Many Glacier Hotel Slope	2004		X (year 25)						
LP04 -08	Limber pine	Sun Point	2004								
LP04 -09	Limber pine	Sun Point	2004		X (year 25)						
LP04 -10	Limber pine	Dead Horse Point	2004		X (year 25) 1 TREE LEFT						
LP04 -11	Limber pine	Dead Horse Point	2004								
LP05 -01 to -06	Limber pine	Scenic Point	2005			X (year 25)					
LP06-02	Limber pine	Baring Creek	2006				X (year 31)				
LP06 -01 & -03	Limber pine	Baring Creek	2006								
LP06 -04	Limber pine	Dead Horse Point	2006								
WB06 -01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006				X (year 25)				
WB07 -01 to -09	Whitebark pine	Red Eagle (seeds + trees)	2007					X (year 25)			
WBS07 -04 to -05	Whitebark pine	Red Eagle (seeds)	2007					X (year 25)			
WBS07 -01 to -03	Whitebark pine	Siyeh Bend (seeds)	2007								
WB10-01 to -05	Whitebark pine	Hole-in-the-Wall	2010			X (year 20)					
WB10-06 to -10	Whitebark pine	Divide Creek lower	2010			X (year 20)					
GPA-WB-11-01 to -02	Whitebark pine	Grinnell Picnic Area	2011				X (year 20)				
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011				X (year 20)				
WB12-01 to -04	Whitebark pine	Divide Mountain	2012					X (year 20)			
LP12-01 to -02	Limber pine	Cutbank	2012					X (year 20)			
LP12-03 and -11	Limber pine	Apikuni Flats	2012					X (year 20)			
LP12-04 to -05	Limber pine	Rising Sun CG	2012					X (year 20)			
LP12-06 to -09	Limber pine	Scenic Point	2012					X (year 20)			
LP12-10	Limber pine	Many Glacier Well Area	2012					X (year 20)			
WB13-01 to -04	Whitebark pine	Firebrand Pass upper (spring)	2013	X (year 15)					X (year 20)		
WB13-08 to -12	Whitebark pine	Firebrand Pass lower (fall)	2013	X (year 15)					X (year 20)		
WB13-05 to -07	Whitebark pine	Numa Ridge	2013	X (year 15)					X (year 20)		
LP13-01 to -07	Limber pine	Spot Mtn. (spring & fall)	2013	X (year 15)					X (year 20)		
WB14-01	Whitebark pine	Spot Mtn. (spring)	2014							X (year 20)	
WB14-02 to -03	Whitebark pine	Firebrand Pass lower (spring)	2014							X (year 20)	
WB14-04 to -05	Whitebark pine	Scenic Point upper (spring)	2014							X (year 20)	
WB14-06 to -09	Whitebark pine	Numa Ridge (fall)	2014							X (year 20)	
WB14-10 to -12	Whitebark pine	Divide Creek upper (fall)	2014							X (year 20)	
WB14-13 to -15	Whitebark pine	Firebrand Pass upper (fall)	2014							X (year 20)	
WB14-16 to -17	Whitebark pine	White Calf (fall)	2014							X (year 20)	
WB15-01 to -02	Whitebark pine	Scenic Point upper (fall)	2015			X (year 15)					X (year 20)
WB15-03 to -04	Whitebark pine	Numa Ridge (fall)	2015			X (year 15)					X (year 20)

black text = completed

blue text = scheduled for future

red text = notes about trees in plots with high mortality

orange text = scheduled but not completed

VII. WHITEBARK AND LIMBER PINE PLUS TREE MONITORING

A. INTRODUCTION

Whitebark pine (*Pinus albicanlis*) and limber pine (*Pinus flexilis*) populations have declined dramatically in Glacier National Park, largely due to the introduction of a non-native fungus, white pine blister rust (*Cronartium ribicola*). White pine blister rust is a disease of five-needled pines and has been linked to the decline of all five-needled pines in the park. Spores from a secondary host infect trees through the needles and the fungus subsequently grows into the stem, producing fusiform cankers, almost always eventually killing the tree (Hoff 1992). Glacier National Park not only has a high mortality rate associated with blister rust, but it also has an extremely high blister rust infection rate of remaining live trees. Infection is estimated at 78% for both whitebark and limber pine trees that remain in the Park (Kendall and Keane 2001). A massive effort at removing secondary hosts for white pine blister rust in the Park was attempted between 1930 and 1970. Enormous numbers of *Ribes* species were removed by hand pulling and chemical control with no success at curtailing the disease (USGS 2003). Additionally, climate change may favor conditions that enhance distribution of blister rust spores. Recent climatic conditions produce frequent “wave years” that promote massive numbers of infections (Koteen 2002). Therefore, it does not appear that preventing the spread of blister rust is an effective strategy for preservation of whitebark or limber pine.

Taking advantage of natural blister rust resistance may be a more effective strategy for restoration of whitebark and limber pine. Natural genetic resistance has been found in several species of five-needled pines and there is preliminary evidence that whitebark pine may also exhibit natural resistance (Schwandt 2006). A protocol has been implemented by U.S. Forest Service nurseries whereby potential rust-resistant seedlings are tested for resistance. Preliminary tests have revealed resistance in many whitebark pine seedlings (Maholovich et al. 2006).

Glacier National Park has been attempting to utilize naturally resistant trees in its restoration program for the past 18 years. Cones have been collected from phenotypic-resistant whitebark pine trees since 1997. Phenotypic indicators of blister rust resistance include no or very few active blister rust cankers, no or very few inactive blister rust cankers, no to little impact to canopy cover of tree (flags, dead branches, etc.), and the presence of cones. Wire cages are placed around cones during seed production for protection from predators with seed then collected later in the season. Despite best intentions, seed was combined from years 1997 to 2006 so that it is now impossible to tell which seedlings were grown from which potential rust resistant cone tree. Beginning in 2007, seedlings were able to be tracked to a parent tree in a particular location in the park (i.e., Preston Park) but surviving seedlings have not been traceable with their seed source tree.

Occasionally, trees were inadvertently caged that were infected with blister rust, and over time some of the potentially rust resistant trees have become infected. This influenced the decision to expand upon the initial purpose for monitoring potential plus trees purely as a seed source. Previously, cone trees have not been monitored over time for long-term health and resistance. Initially the purpose of this study was to identify and build baseline data for potential phenotypically rust resistant whitebark pine trees (“plus trees”) for field monitoring over time, as well as to identify potential cone collection trees for the future. Since whitebark pine often grow in very remote and isolated areas, this survey was also designed to reduce the amount of time and effort required when searching for cone trees to cage. Information is now being gathered concerning the trees’ ability to resist infection, how quickly the infection spreads and how long a tree may survive with infection. Additionally, more is now known about multiple forms of blister rust resistance in whitebark pine. Varying degrees of resistance exist, from showing no symptoms when exposed to spores to active cankers on trees that never die (Maholovich, pers. comm.). While this information may aid in future cone collection, it may also help answer questions about resistance of specific trees in Glacier’s populations that are highly infected with blister rust, as well as the fate of trees that have mild blister rust infection.

In 2009, Glacier National Park had the opportunity to join the U.S. Forest Service’s study on genetic resistance in whitebark pine plus trees. Since then, collection efforts have centered on caging from trees that meet requirements for the study. In order to be accepted into this experiment, seed must be collected from 25

individual trees, with no more than three trees per stand and individual trees being at least 300 feet apart. Protocol requires 1,800 seeds per tree to be donated to the program. One-third of the seeds will be grown into seedlings for exposure to blister rust and resistance testing, one-third will go into a seed bank and one-third will be grown into seedlings for an off-site seed orchard, if Glacier decides to participate in this. Glacier met the seed requirements for all 25 trees in 2012 and genetic testing began. In 2015, GNP has begun to receive preliminary results about the resistance in some trees, but full results are not yet available. Glacier NP may also have the option to add additional trees to the genetics study in the near future.

In addition to blister rust, whitebark pine is also susceptible to attack from mountain pine beetle (*Dendroctonus ponderosae*), a native bark beetle. While alpine environments in Glacier have not experienced much pine beetle exposure, it has caused extensive damage to whitebark pine forests in other areas in the state in recent years. Pine beetle infestation has been moderate in the middle fork region of Glacier over the last few years and potentially could reach some plus tree sites. Additionally troublesome is that there seems to be an inverse relationship between blister rust resistance and mountain pine beetle resistance, meaning that plus trees that have survived blister rust invasion may be more at risk from pine beetle attack (Maholovich, pers. comm.). Beginning in 2011, verbenone patches have been applied to plus trees in an attempt to protect trees from a pine beetle attack. Verbenone is an anti-aggregation pheromone thought to trick beetles into thinking the tree is already infected and that they need to look elsewhere for a suitable host tree.

B. METHODS

Beginning in 2007, whitebark pine tree populations were scouted for potential plus trees. Limber pine was also targeted in a few sites. For each population, trees were assessed for the presence of blister rust as well as overall health. Mostly blister rust canker-free trees were chosen for inclusion in the monitoring pool. Occasionally, trees that looked healthy but were mildly infected were also selected for monitoring to document the impacts of mild infestation on whitebark pine trees. Resistant trees can suppress cankers by a defense reaction whereby the tree builds a periderm around the infection (Hoff 1992). As cone production is variable by year, the presence of cones was not initially a determining factor for including a tree in the monitoring pool. Monitoring these plus trees on an annual to biannual basis should also provide information on cone production trends over time.

Potential plus trees were each numbered and their locations were recorded using a GPS unit. In 2007 and 2008, identification numbers were written on each tree bole with a waterproof marker to reduce impacts to the tree. By 2009, after realizing that this marking does not persist over time, some of the plus trees were marked with nails and flagging in the ground at the base of the tree to further assist with re-location. This method is working well for tree identification and will be continued for all plus trees in the future. Trees were assessed for percent live canopy and measured for DBH and height. Presence and number of cones was noted. A digital photograph was taken of each tree with the distance and azimuth from the tree recorded. Evidence of blister rust on the bole or branches of the tree was recorded and categorized as active or inactive canker. Additional information about the site, such as the canopy cover of the surrounding forest, state of surrounding whitebark pine trees, whitebark regeneration in the area, and general site characteristics, was documented. Also noted were associated species, particularly any known or potential secondary hosts to blister rust, such as *Ribes* or *Castilleja* species. Presence of Clark's nutcrackers, whitebark pine seed dispersers, was also recorded.

Blister rust was identified in trees by the presence of active cankers, inactive cankers, or by old dead cankers evidenced by bark cracking or spindle-shaped branches (Hoff 1992). Signs of active (sporulating) cankers were orange-colored spore casings emerging from small cracks in the branches. Inactive cankers were identified by empty white fruiting bodies leftover from sporulation from the current year or spindle-shaped limbs characterized by extensive bark cracking. Early infections, prior to fruiting, were more difficult to identify but were recorded when recognized. Heavy sap flow and discoloration on the outside of the bark can be an early sign of blister rust (Hagle et al. 2003) and was also recorded when sighted. Yellow-orange patches on the stem and the beginnings of spindle-shaped stems may also be one of the only signs of blister rust infection for the first 4-5 years. Additionally, "bark stripping" was noted as possible evidence of cankers. High amounts of sugars are produced in cankers and animals such as rodents, ants and grasshoppers feed on

them (Hoff, 1992) causing areas where bark has been scraped or chewed off. “Flagging”, or ends of branches where needles have died that leave a red-needled branch tip, was also recorded as a potential sign of blister rust infection. Whenever signs were encountered that were most likely the early signs of blister rust, but could not be definitively called so, it was recorded as “probable”.

Currently, there are 113 whitebark pine trees that are being monitored as part of the plus tree pool, although cone information was only collected on 104 trees in 2015 due to missed trees (these include 3 trees at Kupunkamint, 2 trees at Many Glacier, 2 trees at Old Man and 1 tree at Preston Park) (Figure 40; Table 70). This is up from the 92 trees monitored in 2014, up from 100 trees that were monitored in 2011, up from 94 trees that were monitored in 2012, and up from 97 trees that were monitored in 2013. From 2011 to 2012, six “potential” plus trees at Old Man were not monitored. From 2012 to 2013, one plus tree died at Numa, two new trees were identified as plus trees at Scenic Point, one new plus tree was identified at Spot Mtn., and one new plus tree was identified at Firebrand Trail. From 2013 to 2014, three of the “potential” trees at Old Man were officially added to the plus tree pool, while one tree was removed at Triple Divide by an avalanche.

Over the years, 56 trees were added to the pool in 2007, 4 trees were added to the pool in 2008, 13 trees were added to the pool in 2009, 9 trees were added to the pool in 2010, 18 trees were added to the pool in 2011 (6 of these were potential trees), 4 trees were added to the pool in 2013, 3 trees were added to the pool in 2014, and 13 trees were added to the pool in 2015. Of these 119 trees, one tree died in 2013 and is now out of the pool, one tree was removed by an avalanche, and 4 trees are still considered potential trees for monitoring, leaving 113 trees in the monitoring pool. Monitoring sites for whitebark pine established in 2007 include Numa Lookout (7 trees), Old Man Lake Trail (7 trees), Otokomi Lake (6 trees), Preston Park (20 trees), Rising Wolf (6 trees), Scenic Point (7 trees) and Siyeh Bend (3 trees). In 2008, only one site was added at Triple Divide with 4 trees. In 2009, 5 additional trees were added at Scenic Point, 5 additional trees were added at Numa Lookout and 3 additional trees were added at Preston Park. In 2010, one additional tree was added at Preston Park, one additional tree was added at Scenic Point, and 7 additional trees were added at White Calf, a new site for plus tree monitoring. In 2011, 4 new plus trees were added to the pool at White Calf, 2 new trees were added at Triple Divide Trail and 3 new trees were added at Fire Brand Trail, which is a new monitoring site. Additionally, 9 new trees were added to the pool from Old Man Lake Trail, although 6 of these trees are considered potential plus trees. In 2013, two new plus trees were added to the pool at Scenic Point, one new plus tree was added at Firebrand Trail, and one new plus tree was added at Spot Mtn., another new monitoring site. In 2014, three of the six potential trees at Old Man were officially added to the pool in 2014. Finally, in 2015 8 new trees were added to the pool from Kupunkamint Mt., 3 new trees were added to the pool from the Two Medicine area, and 2 new trees were added to the pool from Many Glacier. Currently, there are 22 limber pine trees present in the plus tree monitoring pool (Figure 40; Table 72). Two trees, one at Dead Horse Point and one at Scenic Point, were identified in 2007. Three additional trees were identified in 2010, two at White Calf and a second tree at Dead Horse Point. Additionally, four trees, all at Spot Mtn., were identified in 2013. In 2015, 2 limber pine trees were added to the pool from Spot Mountain, 8 trees were added from Many Glacier, 3 trees were added from Kupunkamint Mt., and 1 additional tree was added from Scenic Point. Of these 23 trees, one tree at Dead Horse Point was removed from the pool in 2015, leaving 22 limber pine trees in the plus tree pool. This tree had already succumbed to greater blister rust infection by 2014 but was officially killed in 2015 in the Reynolds Creek Fire.

In 2015, due to time and money constraints, the only data taken on whitebark and limber pine plus trees were cone counts. This is similar to 2012, 2013 and 2014. Cone counts were done at the time the revegetation crew applied verbenone patches to plus trees in the spring as well as while climbing trees for cone caging and collection.

C. RESULTS

As stated above, 104 of the existing 113 whitebark pine plus trees were monitored for cone production in 2015. Health of individual plus trees was not assessed this year. Cones were again collected for the rust-resistance genetics testing program with the USFS after a brief hiatus last year. GNP completed the seed requirement in 2012 for the genetics testing program with the USFS, but more seed was collected to round out these collections, as well as potentially add new trees to the genetic testing pool.

After a banner whitebark pine cone year in 2011, cone production dropped in 2012, only to increase again in 2013 and 2014, almost to 2011 levels. Typical of the pattern after high cone production, cone production began to decline again in 2015 (Table 71; Figure 41). It is important to note, however, that cone production was patchy this year. Some areas, such as Numa Lookout, Old Man Trail, Otokomi Lake, White Calf and Kupunkamint, had high cone counts, averaging 24 to 34 cones per monitoring tree. Other sites, such as Preston Park and Two Medicine, averaged 0 or 1 cone per tree. Additionally, within a site, cone production varied widely from tree to tree. For instance, at Kupunkamint, some trees produced no cones while others produced 250 or more cones. In 2015, 72% of monitored trees produced cones, as compared to 85% in 2014, 82% in 2013, 57% in 2012, and 89% in 2011. The average number of cones per tree is lower than the average number of cones per tree over the past two years. In 2011, GNP's most recent 'mast' year, the average number of cones per tree was 66 compared to 16 in 2015. The average number of cones per tree was 24 in 2014 and 19 in 2013, years with about a 10% higher number of trees producing cones. Similar to 2014, this year only had a moderate number of cones per tree given the relatively high number of trees producing cones. The unevenness of cone production between trees and between sites is also noteworthy.

Very little is known about the frequency of mast years in whitebark pine, although it has been found that healthy stands of whitebark pine in the Greater Yellowstone area had moderate or large cone crop years two or three times from 1980-1990 (Morgan and Bunting 1990). It appears that we may be on about a three to four year cycle (Figure 41) in terms of a high percentage of trees with cones, but trends are unclear about true mast years with high numbers of cones per tree. Data for percent trees with cones and average number of cones per trees generally follow similar patterns (Figure 41), although the rate of increase and decrease is much steeper with average number of cones per tree, the more reliable indicator of a mast year.

It should be noted that the healthiest whitebark pine trees, now that they have been identified, are currently being targeted for cone monitoring. The actual cone production rate for the overall stand could indeed be much lower. It should also be noted that many of these cone counts were assessed from the ground looking up at the tree. After comparing cone counts from the ground to cone counts when the observer has climbed the tree, we have observed that cone estimates can be two to three times lower from the ground. Since most of the cone numbers listed in the tables were estimated from the ground over time, the data is comparable but it should be noted that actual cone estimates may be significantly underestimated.

Twenty-two limber pine trees were also monitored in 2015, the most to date. New plus trees were added at three sites, Spot Mountain, Many Glacier and Kupunkamint. Most trees were considered healthy at the time of monitoring in the spring, although 1 tree was completely lost in the Reynolds Creek Fire that began in July of 2015 and a larger cone tree at this same site appeared singed. All monitoring limber pine trees produced cones in 2015 (Tables 72 and 73). With an average of 91 of cones per tree in 2015, this year appeared to be one of the most productive since monitoring data began to be collected. Cone production in 2009 averaged 100 cones per tree and cone production in 2007 averaged 110 cones per tree. However, much of cone production is due to adding trees from new, apparently productive sites. When looking only at trees from the three sites monitored since 2010 (Dead Horse Point, Scenic Point and Whitecalf), the average number of cones per tree was only 57, in line with an average cone year. Trends are still being assessed for limber pine cone production given the small sample size and only eight years of data.

Figure 40. Location of Whitebark and Limber Pine Plus Trees for Monitoring

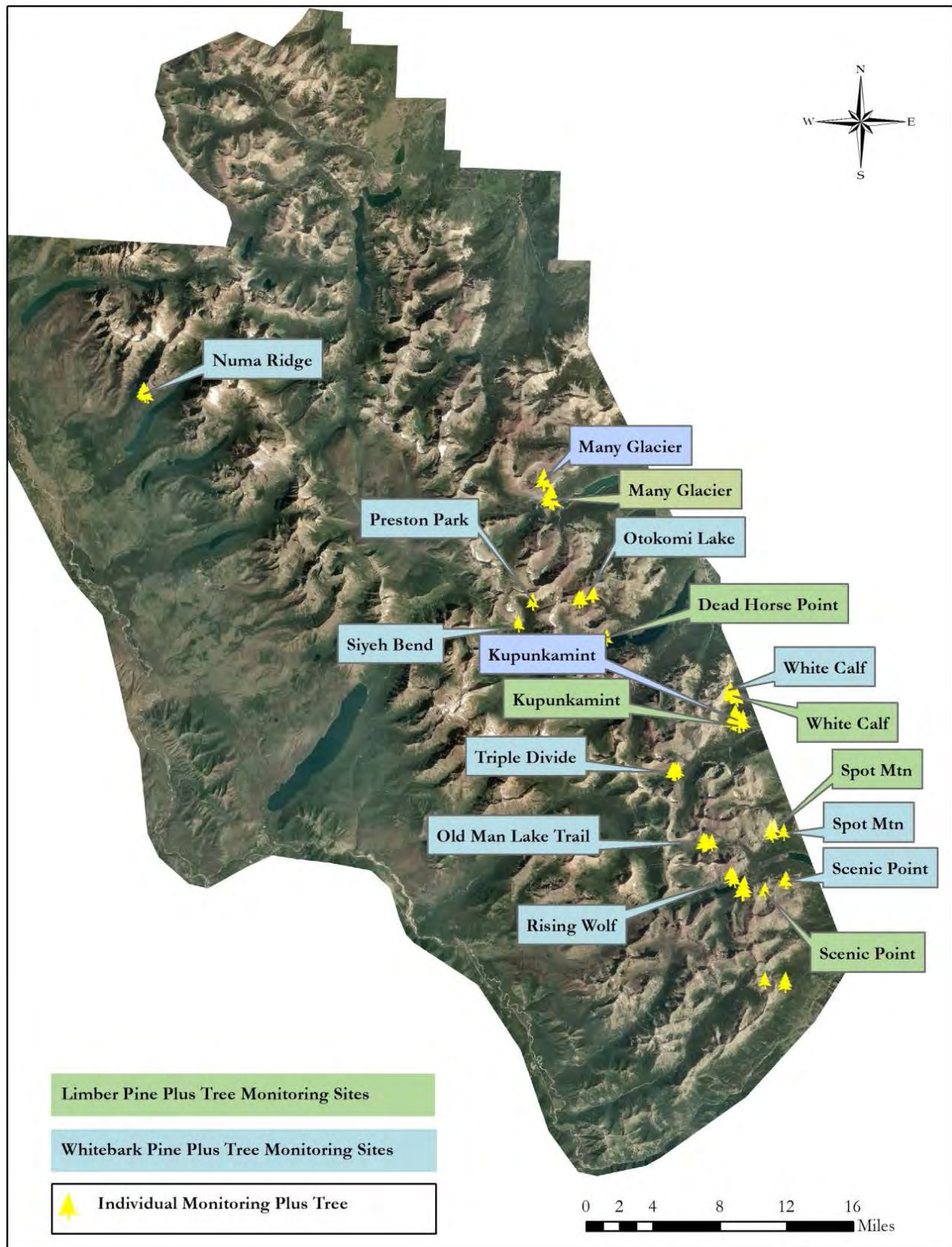


Table 70. Whitebark Pine Plus Trees: Comparison of Health and Cone Production, 2007-2015.

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<i>Site</i>	<i>Date</i>	<i># of Trees Monitored</i>	<i># of Healthy Trees¹</i>	<i># with Active Cankers</i>	<i># with Inactive Cankers</i>	<i># with Possible Cankers</i>	<i># With Cones</i>
Numa Lookout	2007	7	5	1	0	2	7
Numa Lookout	2008	7	4	3	2	1	1
Numa Lookout	2009	12	6	5	4	1	6
Numa Lookout	2011	12	3	8	5	1	11
Numa Lookout	2012	12	n/a	n/a	n/a	n/a	8
Numa Lookout	2013	11 *	n/a	n/a	n/a	n/a	9
Numa Lookout	2014	10	n/a	n/a	n/a	n/a	9
Numa Lookout	2015	11	n/a	n/a	n/a	n/a	11
Old Man Lake Trail	2007	7	5	1	2	0	2
Old Man Lake Trail	2010	7	4	3	3	2	2
Old Man Lake Trail	2011	16	7	7	6	5	16
Old Man Lake Trail	2012	10	n/a	n/a	n/a	n/a	8
Old Man Lake Trail	2013	10	n/a	n/a	n/a	n/a	8
Old Man Lake Trail	2014	12	n/a	n/a	n/a	n/a	10
Old Man Lake Trail	2015	10	n/a	n/a	n/a	n/a	10
Otokomi Lake	2007	6	4	0	0	2	4
Otokomi Lake	2010	6	3	2	3	4	3
Otokomi Lake	2012	6	n/a	n/a	n/a	n/a	5
Otokomi Lake	2013	6	n/a	n/a	n/a	n/a	6
Otokomi Lake	2014	6	n/a	n/a	n/a	n/a	6
Otokomi Lake	2015	6	n/a	n/a	n/a	n/a	6
Preston Park	2007	20	13	5	4	1	20
Preston Park	2008	20	13	7	3	1	13
Preston Park	2009	23	12	4	8	3	18
Preston Park	2010	24	13	9	7	8	21
Preston Park	2011	24	n/a	n/a	n/a	n/a	19
Preston Park	2012	24	n/a	n/a	n/a	n/a	21
Preston Park	2013	24	n/a	n/a	n/a	n/a	23
Preston Park	2014	24	n/a	n/a	n/a	n/a	18
Preston Park	2015	23	n/a	n/a	n/a	n/a	5
Rising Wolf	2007	6	5	0	0	1	2
Rising Wolf	2009	6	2	3	4	1	3
Rising Wolf	09 & '11	6	1	3	4	0	6
Rising Wolf	2012	6	n/a	n/a	n/a	n/a	3
Rising Wolf	2013	6	n/a	n/a	n/a	n/a	6
Rising Wolf	2014	6	n/a	n/a	n/a	n/a	6
Rising Wolf	2015	6	n/a	n/a	n/a	n/a	6
Scenic Point	2007	7	4	1	1	2	7
Scenic Point	2008	7	2	1	3	2	5
Scenic Point	2009	12	3	6	6	2	8
Scenic Point	2010	13	2	8	8	3	13
Scenic Point	2011	13	5	6	7	2	13
Scenic Point	2012	13	n/a	n/a	n/a	n/a	12
Scenic Point	2013	15	n/a	n/a	n/a	n/a	10
Scenic Point	2014	12	n/a	n/a	n/a	n/a	8
Scenic Point	2015	13	n/a	n/a	n/a	n/a	11

¹ Some of these trees have active, inactive and/or probable cankers on the same tree.

Table 70, cont. Whitebark Pine Plus Trees: Comparison of Health and Cone Production, 2007-2015.

<i>Site</i>	<i>Date</i>	<i># of Trees Monitored</i>	<i># of Healthy Trees¹</i>	<i># with Active Cankers</i>	<i># with Inactive Cankers</i>	<i># with Possible Cankers</i>	<i># With Cones</i>
Siyeh Bend	2007	3	1	2	2	0	0
Siyeh Bend	2008	3	0	3	3	0	1
Siyeh Bend	2012	3	n/a	n/a	n/a	n/a	0
Siyeh Bend	2013	3	n/a	n/a	n/a	n/a	2
Siyeh Bend	2014	3	n/a	n/a	n/a	n/a	3
Siyeh Bend	2015	3	n/a	n/a	n/a	n/a	3
Triple Divide	2008	4	3	1	0	0	3
Triple Divide	2010	4	3	0	1	0	1
Triple Divide	2011	6	4	1	2	1	6
Triple Divide	2012	6	n/a	n/a	n/a	n/a	5
Triple Divide	2013	6	n/a	n/a	n/a	n/a	3
Triple Divide	2014	5	n/a	n/a	n/a	n/a	5
Triple Divide	2015	5	n/a	n/a	n/a	n/a	5
White Calf	2010	7	2	4	4	0	7
White Calf	2011	11	5	5	6	3	11
White Calf	2012	11	n/a	n/a	n/a	n/a	11
White Calf	2013	11	n/a	n/a	n/a	n/a	9
White Calf	2014	10	n/a	n/a	n/a	n/a	9
White Calf	2015	11	n/a	n/a	n/a	n/a	10
Firebrand Pass Trail	2011	3	0	1	2	2	3
Firebrand Pass Trail	2012	3	n/a	n/a	n/a	n/a	0
Firebrand Pass Trail	2013	4	n/a	n/a	n/a	n/a	3
Firebrand Pass Trail	2014	3	n/a	n/a	n/a	n/a	3
Firebrand Pass Trail	2015	4	n/a	n/a	n/a	n/a	4
Spot Mountain	2013	1	n/a	n/a	n/a	n/a	1
Spot Mountain	2014	1	n/a	n/a	n/a	n/a	1
Spot Mountain	2015	1	n/a	n/a	n/a	n/a	1
Kupunkamint	2015	8	n/a	n/a	n/a	n/a	3
Two Medicine	2015	3	n/a	n/a	n/a	n/a	0
Many Glacier	2015	0	n/a	n/a	n/a	n/a	0
TOTAL 2007		56	37	10	9	8	42
TOTAL 2008		60	36	16	13	7	31
TOTAL 2009		73	35	23	27	9	45
TOTAL 2010		82	35	37	37	19	57
TOTAL 2011		100	41	45	45	26	89
TOTAL 2012		94	n/a	n/a	n/a	n/a	54
TOTAL 2013		97	n/a	n/a	n/a	n/a	80
TOTAL 2014		92	n/a	n/a	n/a	n/a	78
TOTAL 2015		104	n/a	n/a	n/a	n/a	75
% 2007			66%	18%	16%	14%	75%
% 2008			60%	27%	22%	12%	52%
% 2009			48%	32%	37%	12%	62%
% 2010			43%	45%	45%	23%	70%
% 2011			41%	45%	45%	26%	89%
% 2012			n/a	n/a	n/a	n/a	57%
% 2013			n/a	n/a	n/a	n/a	82%
% 2014			n/a	n/a	n/a	n/a	85%
% 2015			n/a	n/a	n/a	n/a	72%

¹ Some of these trees have active, inactive and/or probable cankers on the same tree.

Table 71. Whitebark Pine Plus Trees: Average Cones Per Tree, 2007 – 2015.

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	2007			2008			2009		
<i>Site</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>
Fire Brand Pass Tr.	0	n/a	n/a	0	n/a	n/a	0	n/a	n/a
Numa Lookout	7	165	24	7	5	1	6	52	9
Old Man Trail	7	38	5	0	n/a	n/a	0	n/a	n/a
Otokomi Lake	6	14	2	0	n/a	n/a	0	n/a	n/a
Preston Park	20	925	46	20	176	9	23	267	12
Rising Wolf	6	16	3	0	n/a	n/a	6	89	15
Scenic Point	7	237	34	7	10	1	10	109	11
Siyeh Bend	3	4	1	3	10	3	0	n/a	n/a
Triple Divide	0	n/a	n/a	4	4	1	0	n/a	n/a
White Calf	0	n/a	n/a	0	n/a	n/a	0	n/a	n/a
TOTAL	56	1395	25	41	195	5	45	517	11

	2010			2011			2012		
<i>Site</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>
Fire Brand Pass Tr.	0	n/a	n/a	3	246	82	3	0	0
Numa Lookout	0	n/a	n/a	12	305	25	12	193	16
Old Man Trail	7	9	1	15	1399	103	10	95	10
Otokomi Lake	6	25	4	0	n/a	n/a	6	171	29
Preston Park	24	718	30	21	219	10	24	189	8
Rising Wolf	0	n/a	n/a	3	500	167	6	31	5
Scenic Point	11	599	54	13	631	56	13	152	12
Siyeh Bend	0	n/a	n/a	0	n/a	n/a	3	0	0
Triple Divide	4	1	0	6	723	121	6	44	7
White Calf	7	232	33	11	1484	135	11	269	24
TOTAL	59	1584	27	84	5507	66	94	1144	12

	2013			2014			2015		
<i>Site</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>
Fire Brand Pass Tr.	4	62	15.5	3	34	11.3	4	38	10
Numa Lookout	11	145	13.2	10	61	6.1	11	285	26
Old Man Trail	10	151	15.1	12	251	20.9	10	226	23
Otokomi Lake	6	172	28.7	6	63	10.5	6	203	34
Preston Park	24	876	36.5	24	185	7.7	23	32	1
Rising Wolf	6	80	13	6	368	61.3	6	104	17
Scenic Point	15	66	4	12	25	2.1	13	97	7
Siyeh Bend	0	n/a	n/a	3	104	34.7	3	93	31
Spot Mtn.				1	250	250.0	1	60	60
Triple Divide	0	n/a	n/a	5	316	63.2	5	76	15
White Calf	11	62	6	10	563	56.3	11	269	24
Kupunkamint							8	271+	25+
Two Medicine							3	0	0
Many Glacier							0	0	0
TOTAL	87	1614	19	92	2220	24	104	1754+	16+

Figure 41. Trends in Whitebark Pine Cone Production, 2007-2015.

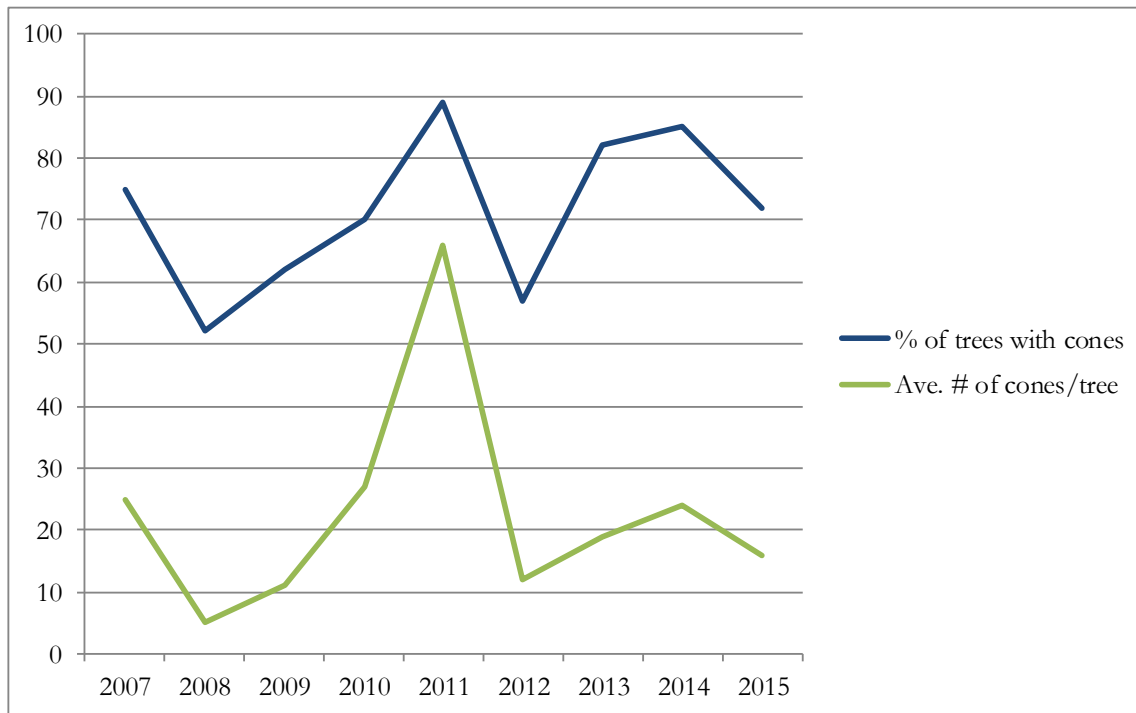


Table 72. Limber Pine Plus Trees: Health and Cone Production, 2015.

S:\VegUnit\Whitebark & Limber Pine\Cones and Seeds\Cone_Tree_Monitoring\Plus tree tables.xls (trees tab)

<i>Site</i>	<i>Date</i>	<i># of Trees Monitored</i>	<i># of Healthy Trees¹</i>	<i># with Active Cankers</i>	<i># with Inactive Cankers</i>	<i># with Possible Cankers</i>	<i># With Cones</i>
Dead Horse Point	2015	1	n/a	n/a	n/a	n/a	1
Scenic Point	2015	2	n/a	n/a	n/a	n/a	2
White Calf	2015	2	n/a	n/a	n/a	n/a	2
Spot	2015	6	n/a	n/a	n/a	n/a	6
Many Glacier	2015	8	n/a	n/a	n/a	n/a	8
Kupunkamint	2015	3	n/a	n/a	n/a	n/a	3
	TOTAL	22	n/a	n/a	n/a	n/a	22
	2007 PERCENT		100%	0%	0%	0%	100%
	2008 PERCENT		100%	0%	0%	0%	100%
	2009 PERCENT		100%	0%	0%	0%	50%
	2010 PERCENT		75%	0%	25%	0%	100%
	2011 PERCENT		100%	0%	0%	0%	100%
	2012 PERCENT		n/a	n/a	n/a	n/a	100%
	2013 PERCENT		n/a	n/a	n/a	n/a	75%
	2014 PERCENT		n/a	n/a	n/a	n/a	100%
	2015 PERCENT		n/a	n/a	n/a	n/a	100%

Table 73. Limber Pine Plus Trees: Average Cones Per Tree, 2007 – 2015.

S:\VegUnit\Whitebark & Limber Pine\Cones and Seeds\Cone_Tree_Monitoring\Plus tree tables.xls (cones tab)

<i>Site</i>	<i># of Trees Monitored</i>	<i># of Cones in 2007</i>	<i>Avg Cones per Tree 07</i>	<i># of Cones in 2008</i>	<i>Avg Cones per tree 08</i>	<i># of Cones in 2009</i>	<i>Avg Cones per tree 09</i>
Dead Horse Point	1/2	100	100	50	50	200	200
Scenic Point	1	10	10	20	20	0	0
Whitecalf	0						
TOTAL	2/4	110	55	70	35	200	100

<i>Site</i>	<i># of Trees Monitored 10</i>	<i># of Cones in 2010</i>	<i>Avg Cones per tree 10</i>	<i># of Trees Monitored 11</i>	<i># of Cones in 2011</i>	<i>Avg Cones per tree 11</i>	<i># of Trees Monitored 12</i>	<i># of Cones in 2012</i>	<i>Avg Cones per tree 12</i>
Dead Horse Point	1	46	23	0	n/a	n/a	1	40	40
Scenic Point	1	15	15	1	55	55	1	40	40
Whitecalf	1	75	75	1	100	100	2	249	125
TOTAL	3	136	34	2	155	78	4	329	82

<i>Site</i>	<i># of Trees Monitored 13</i>	<i># of Cones in 2013</i>	<i>Avg Cones per tree 13</i>	<i># of Trees Monitored 14</i>	<i># of Cones in 2014</i>	<i>Avg Cones per tree 14</i>	<i># of Trees Monitored 15</i>	<i># of Cones in 2015</i>	<i>Avg Cones per tree 15</i>
Dead Horse Point	1	50	50	1	149	149	1	35	35
Scenic Point	1	0	0	1	10	0	2	161	81
Whitecalf	2	130	65	1	105	105	2	90	45
Spot							6	324+	54
Many Glacier							8	945	118
Kupunkamint							3	441+	147
TOTAL	4	180	45	3	264	88	22	1996	91

D. CONCLUSIONS AND RECOMMENDATIONS

Monitoring data is beginning to document the cyclic nature of cone production in whitebark pine trees. While 2008 and 2009 showed a decline in whitebark pine cone production throughout the park, cone production was higher in 2010 at 70% and much higher in 2011 with 89% of plus trees having cones. Data from 2012 showed a decline in cone production again, similar to 2009 and 2010 levels, along with a lower average number of cones per tree. In 2013 and 2014, cone production increased again to 82% and 85%, respectively, although the average number of cones per tree only went up slightly, resulting in just moderate numbers of cones per tree. Typical of the pattern after higher cone production, cone production declined again in 2015. It appears that we may be on about a 3 to 4 year cycle for having a higher percentage of trees with cones (Figure 41), although too little data is available to make any predictions about high average cone counts, a more reliable indicator of a mast year. It is also important to note that the overall park-wide cone production was likely lower, given that the healthiest trees were targeted for cone collection and thus monitoring. Future monitoring over the next several years will begin to document the local trends of cone production in the park, as well track the impacts of increasing blister rust on cone production of the plus tree pool.

Since the future of healthy whitebark and limber pine trees is unknown, a larger pool of trees is imperative for seed collection and genetic integrity of our seedling stock. In 2015, 13 new plus trees were added to the whitebark pine monitoring pool from the Kupunkamint Mt., Two Medicine and Many Glacier, while 14 new plus trees were added to the limber pine monitoring pool from Spot Mountain, Many Glacier, Kupunkamint Mt., and Scenic Point. There continue to be areas within known whitebark stands that could be scouted for additional plus trees, including White Calf, Preston Park, Firebrand Pass Trail, Spot Mountain, and Scenic Point. Other possible sites to search for healthy whitebark pine in 2015 include additional trails in the Many Glacier subdistrict, the Morning Star Lake trail, and Bighorn Basin.

Additionally, care of currently identified plus trees continues to be a goal. Since 2008, limbs with active cankers have been removed or cut off, a recent practice that may prolong the life of certain whitebark pine plus trees in the monitoring pool. Since 2011, verbenone patches have been applied to plus trees for the in an effort to protect them from mountain pine beetle attacks. A Whitebark Pine Management Plan needs to be written to address the continued care of these trees, including protection from encroaching subalpine fire and from wildfire.

Due to time and money constraints, very little data on the health of plus trees was taken this year, similar to last year. As time and money permit, health data should continue to be collected to learn more about the potential resistance of these trees. Now that more is known about varying levels of resistance to blister rust in whitebark pine trees, it is more encouraging that some infected trees may be able to remain functional for some time. The highest level of resistance is obtained when a tree contains two recessive “no spot genes”; there is no evidence these trees have been infested even after exposure. Needle shed resistance, from a single recessive gene, is another form of defense whereby blister rust spores penetrate stomates and grow down needles, but the tree is able to shed infected needles and not become further infected. A third form of defense, fascicle shed resistance, is observed when the entire 5-needled fascicle is shed after infection. A fourth form of resistance, bark reactive resistance, is a polygenetic form. The bark forms a callus or “scab” and walls off the disease. This can even happen at the bole, so contrary to popular belief, bole cankers can still be present on a resistant tree. Finally, trees can still have a form of resistance while harboring active cankers that never die. As long as cankers do not girdle the tree, some trees are able to survive with one or more persistent active cankers (Maholovich pers. comm.).

As mentioned in the introduction, Glacier is participating in a genetic resistance program with the U.S. Forest Service to test the resistance of whitebark pine plus trees to blister rust. We currently have 25 plus trees that in the study that should be providing information on Glacier’s whitebark resistance to blister rust as early as 2016. Glacier may be adding to the number of trees in the genetics study in the future. Information from this study will provide us with guidance for whitebark seed collection in the future and protection of our plus tree pool. In order to target our most potentially resistant trees, our current strategy for collecting whitebark and limber pine seed is to collect seed from trees that either show no or very little sign of blister rust. With the amount of energy, time and money it takes to restore whitebark and limber pine trees in the park, it seems prudent to begin the process with seed that has the best chance of restoring healthy trees to the area. Gathering long-term data on these plus trees will help to ensure that the healthiest trees in the park are being used for seed collection.

As monitoring continues, data may help to answer whether some trees that exhibit mild blister rust infection can fend off lethal infection and remain healthy. It may also help us determine a timeline for survival of trees that

succumb to infection. Data may also determine whether trees that appear healthy in the midst of dead and dying trees can remain blister rust free. Monitoring plus trees should also provide data on cone production cycles that could help plan future seed collection efforts.

All whitebark and limber pine plus trees should be monitored in 2016 and at subsequent 3 to 5 year intervals after that as funding and time exists. Additionally, it is recommended that verbenone continue to be applied to trees annually to protect against mountain pine beetle attack, which exists as a threat in the southern and northwestern edges of the park. Cone counts for all plus trees should continue annually at the time that verbenone packets are applied.

VIII. OVERALL RECOMMENDATIONS FOR REVEGETATION AND REVEGETATION MONITORING

The revegetation and revegetation monitoring programs have made positive strides in restoring disturbed communities in Glacier National Park. One area in which we have made improvements is assessing appropriate species to use in specific revegetation areas. Listed below are recommendations for general plant species that are typically found in common forest, grassland, and subalpine meadow types. While these lists should not override the use of specific information found in site analysis data, these general lists should help guide the nursery and restoration planners in common plants that we consistently see across the park in common habitats. Due to the complexity and site specific nature of wetland, shrubland, and alpine types, there are no general lists for these areas. A few additional recommendations are also listed that address communication between programs.

SPECIES SELECTION:

Certain plant species are common in Glacier National Park and have a wide amplitude of habitats in which they grow. From our observations, the following species are often present in these common plant communities. As a result, we have found that we recommend them frequently for revegetating areas. Adding to the complexity of the restoration process, many of these listed species are generally difficult to grow in the nursery. Species listed with a * are species that have been difficult to grow in the past and are species that are currently being experimented with in the nursery. Given their common presence in a number of plant communities, however, these species should be salvaged whenever possible.

Moist cedar-hemlock forest (montane - west side):

Trees

Betula papyrifera
Larix occidentalis
Picea engelmannii
Pinus monticola
Pseudotsuga menziesii
Thuja plicata
Tsuga heterophylla

Shrubs

Acer glabrum
Amelanchier alnifolia
*Linnaea borealis**
Lonicera utahensis
Menziesia ferruginea
Paxistima myrsinites
Rosa acicularis
Rubus parviflorus
Spiraea betulifolia
*Vaccinium membranaceum**

Forbs/Ferns

*Adenocaulon bicolor**
*Aralia nudicaulis**
Athyrium filix-femina
*Chimaphila umbellata**
*Clintonia uniflora**
Cornus canadensis
*Disporum hookeri/trachycarpum**
Dryopteris expansa
*Goodyera oblongifolia**
Gymnocarpium dryopteris
*Maianthemum stellatum**
*Orthilia secunda**
*Osmorhiza berteroi**
*Thalictrum occidentale**
*Tiarella trifoliata**
*Viola orbiculata**
*Xerophyllum tenax**

Grasses

Bromus vulgaris
Calamagrostis rubescens
Carex concinnoides
Carex rossii
Elymus glaucus

Engelmann spruce-subalpine fir forest (montane – east and west):

Trees

Abies lasiocarpa
Larix occidentalis
Picea engelmannii
Pinus contorta

Shrubs

Acer glabrum
Amelanchier alnifolia
*Linnaea borealis**
Mahonia repens
Paxistima myrsinites
Salix scouleriana
Sorbus scopulina
Spiraea betulifolia
Symphoricarpos albus
*Vaccinium caespitosum**
*Vaccinium membranaceum**
*Vaccinium myrtillus**

Forbs/Ferns

Arnica cordifolia
*Clintonia uniflora**
*Disporum hookeri**
*Disporum trachycarpum**
Eurybia conspicua
*Maianthemum racemosum**
Oryzopsis asperifolia
*Osmorhiza berteroi**
*Thalictrum occidentale**
*Viola orbiculata**
*Xerophyllum tenax**

Grasses

Bromus vulgaris
Calamagrostis rubescens
Elymus glaucus
Festuca occidentalis
Festuca subulata

Engelmann spruce-subalpine fir forest (subalpine – east and west):Trees

Abies lasiocarpa
Picea engelmannii
Pinus contorta

Shrubs

Alnus viridis
Arctostaphylos uva-ursi
Menziesia ferruginea
Paxistima myrsinites
Ribes lacustre
Rubus parviflorus
Sorbus scopulina
Spiraea betulifolia
*Vaccinium membranaceum**
*Vaccinium myrtillus**
*Vaccinium scoparium**

Forbs/Ferns

Arnica cordifolia/latifolia
Erigeron peregrinus
*Erythronium grandiflorum**
Eucephalus engelmannii
Luzula glabrata var. hitchcockii
*Mitella breweri**
Pedicularis bracteosa
*Thalictrum occidentale**
Valeriana sitchensis
Veratrum viride
*Viola orbiculata**
*Xerophyllum tenax**

Grasses

Calamagrostis rubescens
Carex geyeri

Douglas fir forest (mesic montane – east and west):Trees

Abies lasiocarpa
Larix occidentalis
Pinus contorta
Pseudotsuga menziesii

Shrubs

Acer glabrum
Amelanchier alnifolia
*Linnaea borealis**
Lonicera utahensis
Mahonia repens
Menziesia ferruginea (higher)
Paxistima myrsinites
Rosa woodsii
Rubus parviflorus
Shepherdia canadensis

Forbs/Ferns

Achillea millefolium
Arnica cordifolia
*Clintonia uniflora**
Eurybia conspicua
*Goodyera oblongifolia**
*Orthilia secunda**
*Thalictrum occidentale**
*Xerophyllum tenax**

Grasses

Calamagrostis rubescens
Carex geyeri
Carex rossii
Festuca occidentalis

Douglas fir and/or ponderosa pine forest (drier montane – mostly west): species listed in Douglas fir forest above plus these additional speciesTrees

Pinus ponderosa

Shrubs

Arctostaphylos uva-ursi
Dasiphora floribunda
Juniperus communis
*Vaccinium caespitosum**

Forbs/Ferns

Antennaria rosea
Heuchera cylindrica
Penstemon confertus
Potentilla gracilis

Grasses

Festuca campestris
Danthonia intermedia
Pseudoroegneria spicata

Lodgepole pine and/or western larch forests (montane – mostly west):Trees

Larix occidentalis
Pinus contorta
Pseudotsuga menziesii
Subcanopy:
Abies lasiocarpa
Pseudotsuga menziesii
Thuja plicata
Tsuga heterophylla

Shrubs

Acer glabrum
Amelanchier alnifolia
*Linnaea borealis**
Mahonia repens
Rosa woodsii
Rubus parviflorus
Spiraea betulifolia
Symphoricarpos albus
*Vaccinium caespitosum**
*Vaccinium membranaceum**
*Vaccinium myrtillus**

Forbs/Ferns

Arnica cordifolia
Chamerion angustifolium
*Chimaphila umbellata**
*Clintonia uniflora**
Eurybia conspicua
Symphyotrichum laeve var. laeve
*Xerophyllum tenax**

Grasses

Calamagrostis rubescens
Carex concinnoides
Carex geyeri
Oryzopsis asperifolia

Quaking aspen (montane – east and west):Trees

Abies lasiocarpa
Picea engelmannii
Pinus contorta
Populus tremuloides

Shrubs

Acer glabrum
Amelanchier alnifolia
Mahonia repens
Prunus virginiana
Rosa acicularis
Rubus parviflorus
Salix scouleriana
Spiraea betulifolia
Symphoricarpos albus

Forbs/Ferns

Aster conspicuus
*Castilleja miniata**
Chamerion angustifolium
Equisetum arvense
Fragaria virginiana
Heracleum sphondylium
*Maianthemum racemosum**
*Maianthemum stellatum**
*Osmorhiza occidentalis**
*Thalictrum occidentale**
Veratrum viride
*Viola canadensis**

Grasses

Bromus carinatus
Calamagrostis canadensis
Calamagrostis rubescens
Carex geyeri
Elymus glaucus

Quaking aspen/black cottonwood/conifer (montane – east and west):Trees

Abies lasiocarpa
Betula papyrifera
Picea engelmannii
Pinus contorta
Populus tremuloides
Populus balsamifera

Shrubs

Alnus viridis
Amelanchier alnifolia
Cornus sericea
Lonicera utahensis
Ribes inerme
Rubus parviflorus
Spiraea betulifolia
Symphoricarpos albus/occidentalis

Forbs/Ferns

Actaea rubra
*Angelica arguta**
Chamerion angustifolium
*Disporum trachycarpum**
*Equisetum arvense**
Eurybia conspicuus
Fragaria virginiana
Geranium viscosissimum
Heracleum sphondylium
*Maianthemum stellatum**
*Osmorhiza occidentalis**
Pteridium aquilinum
*Thalictrum occidentale**
*Viola canadensis**

Grasses

Calamagrostis canadensis
Carex geyeri
Elymus glaucus
Melica smithii

Idaho Fescue/rough fescue (montane – east and west):Shrubs

Arctostaphylos uva-ursi
Dasiphora floribunda

Forbs/Ferns

Achillea millefolium
Agoseris glauca
Anemone multifida
Antennaria rosea
Antennaria umbrinella
Cerastium arvense
Eriogonum umbellatum
Fragaria virginiana
Gaillardia aristata
Galium boreale
Geranium viscosissimum
Geum triflorum
Hedysarum sulphurescens
Heuchera cylindrica
Lithospermum ruderales
Lomatium triternatum
Lupinus sericeus
Penstemon confertus
Potentilla glandulosa
Potentilla gracilis
Sedum lanceolatum

Grasses

Achnatherum occidentale
Achnatherum richardsonii
Carex obtusata
Carex petasata
Carex rossii
Danthonia intermedia
Elymus trachycaulus var. subsecundus
Elymus trachycaulus var. trachycaulus
Festuca campestris
Festuca idahoensis
Koeleria macrantha
Pseudoroegneria spicata

Subalpine meadow (subalpine – east and west):

Trees

Abies lasiocarpa

Shrubs

Dasiphora floribunda

Salix arctica

*Vaccinium caespitosum**

*Vaccinium scoparium**

Forbs/Ferns

Achillea millefolium

Agoseris glauca

Anemone occidentalis

Antennaria alpina/umbrinella

Arenaria capillaris

Arnica diversifolia/mollis

Castilleja spp.*

Chamerion angustifolium

Epilobium anagallidifolium

Erigeron compositus

Erigeron peregrinus

Eriogonum flavum

Galium boreale

Hedysarum sulphurescens

Heracleum sphondylium

Hypericum scouleri

Oxyria digyna

Pedicularis bracteosa

Phacelia hastata

Polygonum bistortoides

Potentilla diversifolia

Senecio cymbalarioides

Sibbaldia procumbens

Solidago multiradiata

Symphyotrichum foliaceum var. *foliaceum*

Symphyotrichum laeve var. *laeve*

Valeriana sitchensis

Veratrum viride

Veronica wormskejoldii

*Xerophyllum tenax**

Zigadenus elegans

Grasses

Agrostis variabilis

Carex haydeniana

Carex nigricans

Carex paysonis

Carex phaeocephala

Carex spectabilis

Deschampsia atropurpurea

Juncus drummondii

Juncus mertensianus

Juncus parryi

Luzula glabrata / *spicata*

Phleum alpinum

Poa alpina

Poa secunda

Trisetum spicatum

See 2008 Revegetation Monitoring Report to see suggestions about which species should be seeded or grown in containers, or both.

Road sides (montane – east and west):

Trees

various by site

Shrubs

Arctostaphylos uva-ursi

Juniperus communis

*Linnaea borealis**

Mabonia repens

Rosa woodsii

Spiraea betulifolia

Symphoricarpos albus

Forbs/Ferns

Achillea millefolium

Anaphalis margaritacea

Antennaria howellii

Antennaria rosea

*Aralia nudicaulis**

Arnica cordifolia/latifolia

Chamerion angustifolium

Eurybia conspicua

Fragaria virginiana/vesca

Geranium viscosissimum

Geum macrophyllum

Heracleum sphondylium

*Maianthemum stellatum**

*Osmorhiza berteroi**

Solidago canadensis

Symphyotrichum laeve var. *laeve*

*Xerophyllum tenax**

Grasses

Bromus carinatus

Bromus vulgaris

Calamagrostis rubescens

Carex concinnoides

Carex geyeri

Carex microptera

Carex rossii

Deschampsia elongata

Elymus glaucus

Elymus trachycaulus v.

trachycaulus

Festuca occidentalis

Festuca subulata

Oryzopsis asperifolia

Other generally good revegetation species to use that have wide ecological amplitude:

Achillea millefolium
Anaphalis margaritacea
Antennaria bowellii
Fragaria virginiana/vesca
Symphyotrichum laeve var. *laeve*

Species to continue experimenting with in the nursery:

<i>Adenocaulon bicolor</i> *	<i>Maianthemum stellatum</i> *
<i>Angelica arguta</i> *	<i>Orthilia secunda</i> *
<i>Aralia nudicaulis</i> *	<i>Osmorhiza berteroi</i> *
<i>Castilleja</i> spp.*	<i>Osmorhiza occidentalis</i> *
<i>Chimaphila umbellata</i> *	<i>Thalictrum occidentale</i> *
<i>Clintonia uniflora</i> *	<i>Tiarella trifoliata</i> *
<i>Disporum bookeri</i> *	<i>Vaccinium</i> spp.*
<i>Disporum trachycarpum</i> *	<i>Viola canadensis</i> *
<i>Hieracium albiflorum</i> *	<i>Viola orbiculata</i> *
<i>Linnaea borealis</i> *	<i>Xerophyllum tenax</i> *
<i>Maianthemum racemosum</i> *	

COMMUNICATION:

- (1) Continue to conduct revegetation monitoring meetings for discussion about the monitoring data and evaluation of revegetation program. It may be more useful to hold several meetings that focus on certain revegetation issues. These issues could include: (1) use of fertilizers; (2) road shoulder revegetation strategies; (3) setting goals and objectives; (4) evaluation of monitoring techniques; (5) seed bank analysis and its impact on revegetation; and (6) research ideas for the field and for the nursery.

IX. MONITORING SCHEDULE: 1992 - 2020

1992

- 303-B - Level III (year 1)

1993

- 303-B - Level III, photomonitor (year 2)
- 303-B road shoulders - Level II (year 1)
- 303-C - Level II, photomonitor (year 1)
- Rob Tyser's Two Dog Flats plots - Level IV (year 1)
- 303-D - site analysis, photomonitor
- 303-E - site analysis, photomonitor
- Polebridge Developed Area - Level II, photomonitor
- Polebridge Bridge - Level II, photomonitor
- Bowman Creek Campground - Level II, photomonitor
- River Campground - Level II, photomonitor
- Swiftcurrent Apartments - Level II
- Three Bears Lake - Level II
- St. Mary Housing - Level II

1994

- 303-B - Level III, photomonitor (year 3)
- 303-B road shoulders - Level II, photomonitor (year 2)
- 303-C - Level II, photomonitor (year 2)
- 303-C road shoulders - Level II, photomonitor (year 1)
- 303-D - set up first series of shrub plots and established monitoring plots for Level IV experiment
- 303-F - site analysis along road corridor
- Granite Park Chalet - site analysis, photomonitor
- Two Medicine Housing Area - site analysis, photomonitor
- Camas Road - site analysis (2 sites)

1995

- 303-B road shoulders - Level II, photomonitor (year 3)
- 303-C - Level II, photomonitor (year 3)
- 303-C road shoulders - Level II, photomonitor (year 2)
- Rob Tyser's Two Dog Flats plots - Level IV (year 3)
- 303-D - Level IV, photomonitor (year 1)
- 303-E - photomonitor, wrote preliminary monitoring plans
- 303-F - continued site analysis along road corridor
- Camas Road - site analysis (10 sites)

1996

- 303-B - Level III, photomonitor (year 5)
- 303-D - Level IV, photomonitor (year 2)
- 303-D road shoulders - Level II, photomonitor (year 1)
- 303-E - photomonitor, set up Level IV experiments
- 303-F - Avalanche campground site analysis

1997

- Rob Tyser's Two Dog Flats plots - Level IV (year 5)
- 303-D - Level IV, photomonitor (year 3)
- 303-D road shoulders - Level II, photomonitor (year 2)
- 303-E - Level IV (year 1), photomonitor, set up additional experiments
- 303-F (Avalanche Picnic Area) - photomonitor (pre-disturbance)
- Camas Road - photomonitor (pre-disturbance)

1998

- 303-B road shoulders - Level II, photomonitor (year 6)
- 303-C - Level II, photomonitor (year 6)
- 303-C road shoulders - Level II, photomonitor (year 5)
- 303-E - Level IV, photomonitor (year 1 and 2)
- Polebridge Developed Area - Level II, photomonitor
- Polebridge Bridge - Level II, photomonitor
- Bowman Creek Campground - Level II, photomonitor
- River Campground - Level II, photomonitor

1999

- 303-D - Level IV, photomonitor (year 5)
- 303-E - Level IV, photomonitor (year 2 and 3)
- Camas Road - photomonitor (year 1)

2000

- 303-F - Level II, photomonitor (year 1)
- Logan Pass Unit D: seed vs. seed & plant experimental plots (year 4)
- Camas Road - Level II, photomonitor (year 2)
- Three Bears Lake - Level II
- Oberlin Bend / Jones Flat Social Trail Assessment
- Logan Pass Visitor's Center Handicapped Access Trail Assessment
- Lunch Creek Social Trail Assessment

2001

- 303-B - Level III, photomonitor (year 10)
- 303-E - Level IV, photomonitor (year 4 and 5)
- 303-F - Level II, photomonitor (year 2)

2002

- Camas Road - Level II, photomonitor (year 4)
- Rob Tyser's Two Dog Flats plots - Level IV (year 10)
- 303-F – Level II, photomonitor (year 3)

2003

- 303-C - Level II, photomonitor (year 10)
- Camas Road - Level II, photomonitor (year 5)
- Hidden Lake – Level II (year 3)

2004

- 303-D – Level III, photomonitor (year 10)
- 303-F - Level II, photomonitor (year 5)
- GTSR Phase VII Site Analysis

2005

- 303D Shrub Monitoring – Level IV (year 11)
- Apgar-Headquarters Bike Path – Level II (year 1)
- Camas Road Hydromulch – Level II (year 1)
- Hidden Lake Social Trails – Level II (year 5)

2006

- 303-E - Level IV, photomonitor (year 10)
- Apgar Transit Center Site Analysis

2007

- Apgar-Headquarters Bike Path – Level II (year 3)
- Camas Road Hydromulch – Level II (year 3)
- Apgar Transit Center – Level II (year they were planted)
- Apgar Transit Center Experimental Plots - Level IV (year they were planted)
- GTSR Phase VI Site Analysis

2008

- Camas Road - Level II, photomonitor (year 10)
- Apgar Transit Center – Level II (year 1)
- Apgar Transit Center Experimental Plots - Level IV (year 1)
- Logan Pass Unit D: seed vs. seed & plant experimental plots (year 12)
- Above St. Mary Campground Weed/Reveg. (site analysis)
- Camas Creek Overlook Weed/Reveg. (site analysis)
- West Entrance (site analysis)

2009

- 303-F - Level II, photomonitor (year 10)
- Apgar-Headquarters Bike Path – Level II (year 5)
- Camas Road Hydromulch – Level II (year 5)
- Apgar Transit Center – Level II (year 2)
- Apgar Transit Center Experimental Plots - Level IV (year 2)
- Above St. Mary Campground Weed Rev. (year 1 after spraying)
- Camas Creek Overlook Weed Rev. (year 1)
- West Entrance (year 1)
- Lake McDonald Dorms (site analysis)

2010

- Hidden Lake Social Trails – Level II (year 10)
- Apgar Transit Center – Level II (year 3)
- Apgar Transit Center Experimental Plots - Level IV (year 3)
- Above St. Mary Campground Weed Rev. (year 2 after spraying)
- Camas Creek Overlook Weed Rev. (year 2)

- West Entrance (repeat site analysis when construction is completed)
- Lake McDonald Dorms (year 1)
- GTSR – Phase 6 (year of planting)

2011

- 303-B - Level III, photomonitor (year 20)
- 303-E – Level IV, photomonitor (year 15)
- West Entrance (year 3)
- Lake McDonald Dorm (year 2)
- GTSR – Phase 6 (year 1)
- St. Mary Visitor Center (year 1)

2012

- Rob Tyser's Two-Dog Flats (year 20) – did not do: NOT MONITORING THIS ANYMORE
- Apgar Transit Center – Level II (year 5) – did not do: NOT MONITORING THIS ANYMORE
- Apgar Transit Center Experimental Plots - Level IV (year 5)
- Lake McDonald Dorm (year 3) – did not do
- GTSR – Phase 6 (year 2)
- St. Mary Visitor Center (year 2) – did not do
- Above St. Mary Campground Weed Reveg. (year 1 after seeding)
- Camas Creek Overlook Weed Reveg. (year 1 after seeding) – did not do: NOT MONITORING THIS ANYMORE

2013

- 303-C - Level II, photomonitor (year 20)
- Logan Pass Unit D: seed vs. seed & plant experimental plots (year 17) – did not do
- Above St. Mary Campground Weed Reveg. (year 2 after seeding) – did not do
- West Entrance (year 5)
- GTSR – Phase 6 (year 3)
- St. Mary Visitor Center (year 3)
- GTSR – Phase XI: Lunch Creek (year 1)
- GTSR – Phase VIIb: West tunnel to Avalanche (year 1)

2014

- 303-D – Level III, photomonitor (year 20) – did not do
- Apgar-Headquarters Bike Path – Level II (year 10)
- Camas Road Hydromulch – Level II (year 10)
- Lake McDonald Dorm (year 5): LAST YEAR OF MONITORING
- GTSR – Phase XI: Lunch Creek (year 2)
- GTSR – Phase VIIb: West tunnel to Avalanche (year 2)

2015

- 303-D – Level III, photomonitor (year 21)
- GTSR – Phase 6 (year 5)
- St. Mary Visitor Center (year 5)
- Hidden Lake Social Trails – Level II (year 15) – did not do

2016

- 303-E - Level IV, photomonitor (year 20)
- Logan Pass Unit D: seed vs. seed & plant experimental plots (year 20)
- Above St. Mary Campground Weed Reveg. (year 5 after seeding)
- Hidden Lake Social Trails – Level II (year 16)

2017

- Apgar Transit Center Experimental Plots - Level IV (year 10): LOOK AT AGAIN TO SEE IF ENOUGH REPS REMAIN
- GTSR – Phase XI: Lunch Creek (year 5)
- GTSR – Phase VIIb: West tunnel to Avalance (year 5)

2018

- West Entrance (year 10)
- Camas Road - Level II, photomonitor (year 20)

2019

- 303-F - Level II, photomonitor (year 20)
- GLORIA monitoring (year 15)

2020

- GTSR – Phase 6 (year 10)
- St. Mary Visitor Center (year 10)
- Peter Lesica's tundra monitoring plots (year 30)

2021

- 303-B: Level III, photomonitor (year 30)
- Peter Lesica's tundra monitoring plots (year 31)

2022

- Peter Lesica's tundra monitoring plots (year 32)

2023

- Peter Lesica's wetland monitoring plots (year 18)

2024

- Peter Lesica's wetland monitoring plots (year 18)
- GLORIA monitoring (year 20)

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APPENDIX A. TEMPERATURE AND PRECIPITATION DATA *

WEST GLACIER

= Missing Data

	April	May	June	July	August	September	October	November
Mean Temperature (degrees F) **								
1949-2013	41.4	50.6	57.5	63.7	62.5	53.2	42.3	31.3
1993	43.2	55.7	56.1	56.3	59.0	51.2	43.7	24.0
1994	43.8	53.4	56.8	65.7	65.4	55.5	42.5	28.4
1995	41.1	51.4	56.2	63.1	58.5	54.0	40.2	32.6
1996	42.0	46.3	58.5	65.0	61.5	51.0	40.2	26.4
1997	36.0	51.5	57.4	63.1	63.5	54.5	42.5	31.8
1998	44.0	54.9	56.4	68.4	64.5	59.4	42.3	36.0
1999	41.5	49.3	55.2	60.5	65.7	51.8	42.8	37.7
2000	43.0	50.2	56.7	63.4	63.0	51.0	42.8	28.3
2001	40.0	52.4	55.4	62.8	64.8	57.6	42.7	35.5
2002	39.7	47.8	57.4	67.0	60.3	54.1	37.5	33.2
2003	43.1	50.9	59.7	68.7	67.9	56.8	46.0	26.6
2004	45.8	51.5	58.5	66.7	64.9	52.4	43.2	33.7
2005	43.9	52.7	57.1	65.9	63.3	52.8	44.4	32.6
2006	44.4	53.7	61.8	68.5	64.2	55.3	43.3	30.7
2007	44.0	53.4	60.0	72.3	63.8	54.2	43.5	33.4
2008	37.4	51.3	56.6	65.4	64.2	52.9	43.4	36.4
2009	40.9	51.8	58.2	66.2	63.3	57.9	37.6	34.2
2010	42.2	47.3	56.5	62.7	60.3	53.4	45.1	28.7
2011	37.4	48.8	54.1	62.1	64.9	57.0	44.2	31.8
2012	45.7	49.1	56.7	67.1	63.7	56.2	41.5	35.2
2013	40.4	53.0	58.6	68.2	66.3	57.7	40.3	29.7
2014	41.7	52.2	55.5	66.3	62.4	52.7	46.4	26.6
2015	43.6	53.6	64.9	64.9	63.8	52.0	46.5	Not avail.
Precipitation (inches)								
1949-2013	1.9	2.6	3.5	1.7	1.6	2.1	2.4	3.1
1993	3.2	1.9	4.5	5.1	2.2	2.3	1.0	0.7
1994	1.2	2.2	3.1	0.6	0.2	0.5	4.2	2.7
1995	1.7	1.2	6.9	3.4	2.1	1.4	5.2	7.5
1996	3.0	6.1	1.9	1.2	1.9	3.1	4.1	4.4
1997	2.0	1.8	3.0	1.5	1.4	3.0	3.0	1.6
1998	2.0	4.6	4.9	2.6	1.2	1.7	1.0	3.3
1999	0.9	1.2	3.1	1.8	1.1	0.5	3.8	3.2
2000	1.8	1.6	3.0	1.0	0.4	3.2	0.9	0.7
2001	3.0	1.3	4.0	0.6	0.1	1.2	3.8	2.3
2002	2.4	2.7	3.0	1.5	0.7	1.7	0.5	2.5
2003	1.4	1.9	1.8	0.04	0.1	2.0	2.7	4.1
2004	2.2	2.4	2.2	2.5	4.4	3.7	4.3	3.2
2005	1.7	2.1	7.5	0.5	1.1	4.4	4.6	3.0
2006	1.4	2.3	4.2	0.6	0.8	1.4	1.9	6.2
2007	1.4	2.6	2.4	0.6	0.2	2.1	2.5	0.6
2008	1.2	3.0	3.2	0.9	1.9	1.5	1.4	3.2
2009	1.0	4.0	1.4	2.7	1.6	0.3	3.3	1.4
2010	2.6	3.5	6.6	1.3	1.9	3.9	2.4	3.7
2011	4.7	3.3	4.4	1.7	0.2	1.7	3.9	1.5
2012	3.6	2.5	7.9	2.8	0.5	0.3	6.2	4.6
2013	1.9	2.4	3.0	0.4	1.8	3.9	0.6	4.3
2014	2.5	1.2	5.3	1.2	2.4	1.0	2.4	5.8
2015	0.7	1.2	1.4	0.6	0.5	1.4	2.4	Not avail.

SAINT MARY
= Missing Data

	April	May	June	July	August	September	October	November
Mean Temperature (degrees F) **								
1981-2013	39.9	48.2	55.4	62.5	62.1	53.0	43.5	31.5
1993	42.5	53.8	54.1	54.9	57.6	52.4	44.1	27.7
1994	42.1	52.0	56.9	62.8	63.1	58.9	43.0	27.6
1995	38.8	46.4	54.3	61.9	59.8	53.9	40.4	32.5
1996	43.2	45.0	56.6	64.7	64.0	50.2	42.0	21.0
1997	35.8	47.9	56.2	62.5	62.6	58.3	45.1	34.8
1998	42.1	53.8	53.0	67.8	62.3	58.5	45.8	33.1
1999	39.7	46.9	53.7	59.2	65.7	52.1	43.0	40.1
2000	43.7	50.1	65.3	65.7	65.5	52.6	43.9	28.0
2001	38.2	53.1	56.3	64.7	67.7	59.1	43.5	38.5
2002	34.4	43.9	52.7	63.8	56.6	50.3	36.1	38.2
2003	39.9	52.9	55.7	66.5	66.6	54.5	46.0	26.9
2004	42.5	43.5	52.7	62.6	59.3	49.8	41.1	35.8
2005	38.3	46.9	51.6	63.0	57.2	49.3	42.4	33.6
2006	40.5	48.7	55.8	65.8	59.2	52.5	39.0	26.4
2007	39.1	49.4	56.9	69.0	60.2	52.1	44.5	32.5
2008	35.4	46.5	53.0	#	#	#	44.4	37.2
2009	34.8	47.2	52.2	62.0	58.8	57.2	34.7	35.0
2010	36.0	38.7	48.3	56.6	53.0	46.3	45.8	15.4
2011	29.6	42.2	52.3	60.0	61.1	54.9	41.4	28.6
2012	40.6	44.3	52.7	62.3	60.2	52.0	36.1	32.7
2013	32.1	48.1	54.2	62.0	62.1	52.5	38.4	30.2
2014	38.8	47.3	51.9	64.1	60.2	50.4	48.0	25.7
2015	39.3	43.8	59.2	60.1	61.2	50.8	47.3	Not avail.
Precipitation (inches)								
1981 - 2013	1.9	3.0	3.6	1.8	1.7	2.0	2.2	2.4
1993	0.8	1.9	3.1	6.3	3.6	3.1	0.9	2.0
1994	2.7	2.8	1.4	2.2	0.5	0.2	4.4	1.9
1995	1.9	5.5	7.2	3.3	1.2	3.2	4.2	5.1
1996	1.8	5.0	4.1	0.8	0.4	2.2	1.3	3.6
1997	1.4	3.6	4.1	0.9	2.6	1.1	1.6	0.8
1998	2.2	3.7	5.1	1.7	0.3	1.0	0.2	4.9
1999	1.5	1.5	1.8	0.9	2.2	1.7	3.1	4.1
2000	2.0	1.5	3.8	0.3	0.7	2.2	0.6	0.5
2001	3.8	1.2	3.9	0.7	0.03	0.8	2.3	0.5
2002	1.1	2.0	5.1	0.6	1.5	2.3	1.0	0.2
2003	1.5	1.2	1.6	0.1	0.0	1.0	1.0	2.2
2004	1.6	2.6	3.2	0.7	1.8	1.1	0.8	2.4
2005	1.6	1.3	7.4	0.2	2.0	3.8	2.0	2.0
2006	2.3	2.4	4.3	0.5	0.8	1.9	1.3	5.7
2007	1.5	2.7	1.1	0.4	0.7	2.8	2.0	1.8
2008	0.6	6.7	3.9	#	#	#	0.6	1.6
2009	2.9	1.2	1.4	4.9	1.8	0.1	2.7	1.5
2010	2.0	4.4	4.7	1.3	1.9	2.4	0.1	2.1
2011	4.0	3.1	2.5	0.6	0.7	0.9	3.1	2.5
2012	1.1	1.0	3.9	0.7	0.6	#	3.1	2.7
2013	2.6	2.1	2.8	0.3	1.6	3.0	0.5	1.7
2014	2.2	1.2	7.2	1.0	2.4	1.5	1.7	3.8
2015	1.4	2.3	1.7	1.4	1.0	1.7	1.2	Not avail.

* This data was obtained from U.S./NOAA weather stations operated by Glacier NP and from the Western Regional Climate Center.

** Mean temperature calculated by summing the daily maximum temperature and daily minimum temperature and dividing by two.