

Glacier National Park: Restoration Monitoring Report

2014

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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
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
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
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 2013 season. The report includes: (1) data from six revegetation projects (303-C, West Entrance, St. Mary Visitor Center, and Phases VI, VIIa, and XI 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. HEADQUARTERS-APGAR VILLAGE BICYCLE PATH

A. BACKGROUND AND PURPOSE

In 2004, a water line was replaced between the Headquarters Area and Apgar Village. A paved bike path, used by both visitors and park staff, was re-built and widened significantly subsequent to water line installation, following the route of this water line. Restoration activities began in 2004 to revegetate areas that had been disturbed by replacement of the water line and/or resurfacing of the bike path. Minor amounts of soil were imported to provide fill in a few low areas along the route of the bike path/water line. Restoration activities included hydroseeding and hydromulching disturbed soil (either native or imported) on either side of the path and planting shrubs in a few areas. Hydroseeding and hydromulching was done in May 2004 by Agrotech, a hydroseeding-hydromulching contractor. The hydroseed/hydromulch application contained 20 lb/acre of a native seed mixture that included at least seven graminoid species, seven forb species, and four shrub species (Lapp and Turecek 2004, Table 3). Shrubs were planted in a few areas to deter foot and bicycle traffic and for aesthetic purposes; these areas were not monitored.

Revegetation and monitoring objectives are as follows:

1. To restore native vegetation to areas of bare ground, thus preventing soil erosion and exotic plant invasion.
2. To enhance the aesthetics of these areas and begin to blend into the adjacent undisturbed vegetation.
3. To document changes in species composition and cover over time.
4. To photomonitor progress at each site.

Table 3. Bike Path Revegetation Project: Species Seeded in 2004

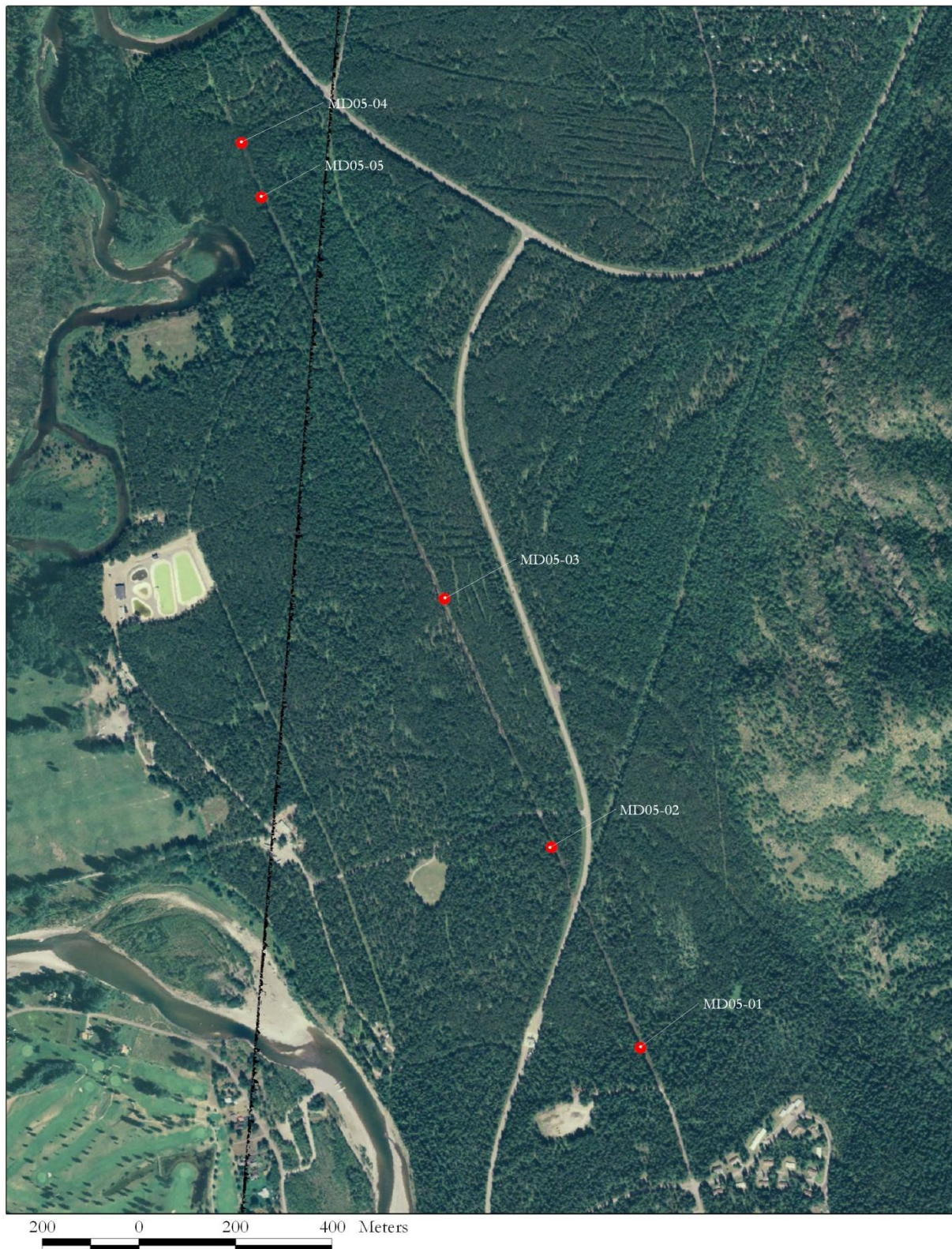
Grasses	Forbs:	Shrubs:
<i>Bromus carinatus</i>	<i>Achillea millefolium</i>	<i>Cornus sericea</i>
<i>Carex athrostachya</i>	<i>Anaphalis margaritacea</i>	<i>Rosa woodsii</i>
<i>Carex species</i>	<i>Aster sp.</i>	<i>Spiraea betulifolia</i>
<i>Elymus glaucus</i>	<i>Chamerion angustifolium</i>	<i>Symphoricarpos albus</i>
<i>Elymus trachycaulus</i>	<i>Penstemon confertus</i>	
<i>Festuca idahoensis</i>	<i>Solidago canadensis</i>	
<i>Festuca ovina</i>	<i>Solidago sp.</i>	
<i>Pseudoroegneria spicata</i>	<i>Symphyotrichum laeve var. laeve</i>	
	<i>Xerophyllum tenax</i>	

B. METHODS

Five non-permanent plots were established along the bike path between Headquarters and Camas Road (Figure 1) and evaluated with Level II protocol in August 2005. This included ground cover estimates and canopy cover estimates for all species present. Plot locations were selected to sample representative vegetation zones along the bike path. No permanent markers were placed at the plots, but UTM data and written descriptions of plot locations were recorded. Plots were 20 square meters each. Plots were either 20m x 1m or 10m x 2m, dependent on the linear nature of the site.

Plots were revisited on August 2, 2007, July 9, 2009, and July 2, 2014. Percent cover of each species present and ground cover was recorded. Although plots are not permanently marked, photographs were very useful in locating each plot. While plots were likely not put in the exact same locations to past years, plots were generally in the same spot to accurately record vegetation change.

Figure 1. Bike Path Revegetation Project: Location of Monitoring Plots.



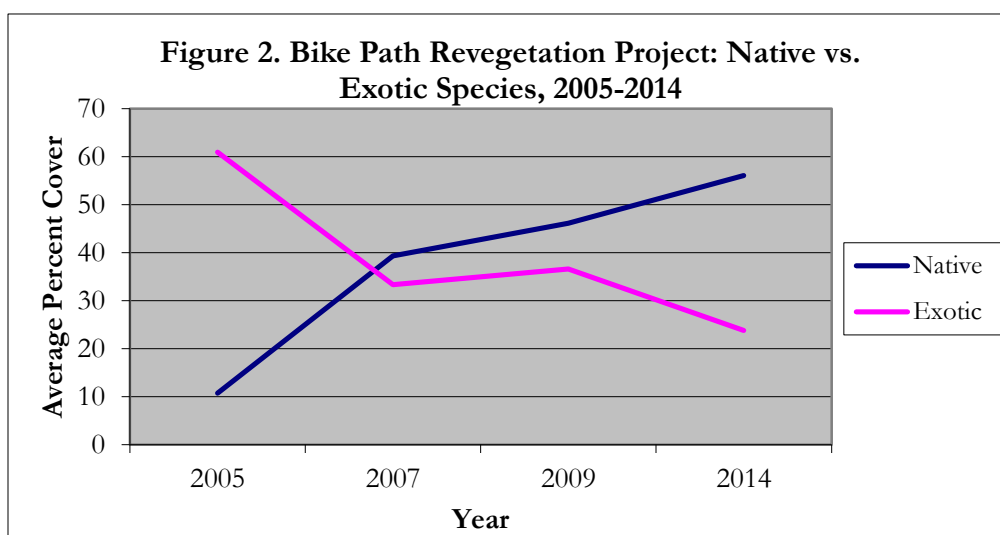
C. RESULTS

1. Meeting Revegetation Objectives

- a. **To restore native vegetation to areas of bare ground, thus preventing soil erosion and exotic plant invasion.**

Overall vegetative cover is approximately 80%, down slightly from 83% cover in 2009. There is adequate plant cover within the entire project area with no signs of soil erosion anywhere along the bike path shoulder. Moss cover has increased dramatically adding to soil stability and water retention for vascular plants.

In terms of restoring native vegetation to this area, the dominance of native plants over exotic species continues to improve over time (Figure 2). Clearly at the beginning of the project, non-native plants, particularly clover species, dominated the revegetation areas. The shift to native plants dominating the restoration area began at year five after planting when clovers declined, opening up habitat for seeded native species. During that year in 2009, 46% of the cover was due to native plants and only 37% of the cover was due to exotic plants. In 2014, this ratio improved with 56% of the cover due to native plants and only 24% of the cover due to exotic plants. This result is due to the fact that all native lifeforms have increased in cover from 2009 to 2014, while exotic forbs have drastically decreased in cover. Exotic grasses have increased in cover over time but still have less cover than both native grasses and native forbs. Overall, native vegetation has been restored to this area with comparatively low cover of exotic species, including noxious weeds.



- b. **To enhance the aesthetics of these areas and begin to blend into the adjacent undisturbed vegetation.**

In many areas, the dominance of native grass *Elymus glaucus* creates a taller profile than the understory in the adjacent community, often resulting in a visual vegetation break between the revegetated area and the undisturbed adjacent forest. Trees and shrubs, however, both planted and naturally occurring, are finally beginning to add a woody dimension to this revegetation site, blending the planted area with the nearby forest. In particular, *Betula papyrifera*, *Populus balsamifera*, *Pinus contorta*, and *Salix bebbiana* seedlings are providing a visual blending of the two areas. In addition, several native forbs and grasses, such as *Calamagrostis rubescens*, *Osmorhiza berteroi*, *Pteridium aquilinum*, and *Adenocaulon bicolor*, have naturally colonized the revegetation area and are increasing in cover. Future monitoring should a) document if dominant understory species of the adjacent forest, such as *Xerophyllum tenax*, *Arctostaphylos uva-ursi* and *Vaccinium* species, continue to move into the bike path shoulder; b) document the change in *E. glaucus* over time; c) assess the ongoing success of seeded species; and d) document if the visual vegetation break between the existing forest and the replanted swath begins to diminish.

c. **To document changes in species composition and cover over time.**

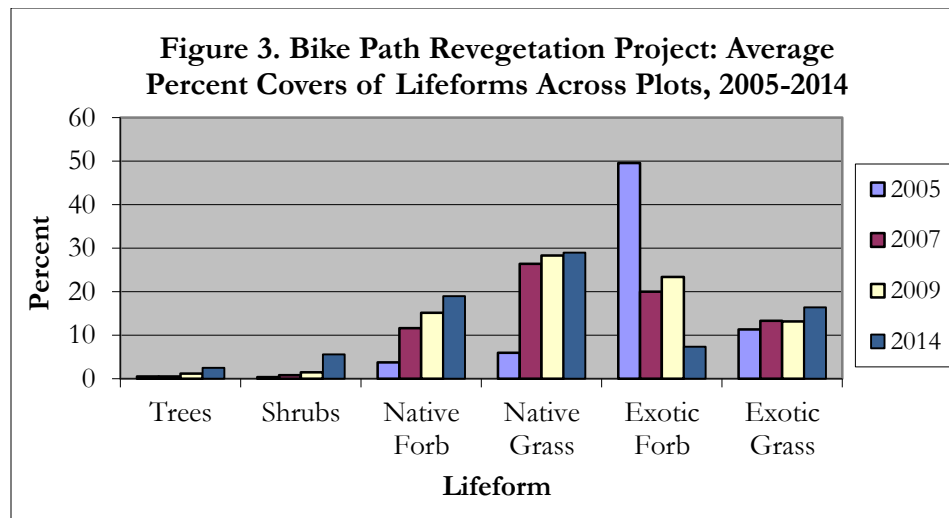
Results below describe percent covers of all species found in plots for all years.

d. **To photomonitor progress at each site.**

Photos of plots were taken again in 2014.

2. Results by Lifeform

Native grasses continued to be the dominant lifeform in 2014, exhibiting a small increase in the last five years of 1% (Figure 3 & Table 4). Average cover of most lifeforms has generally increased over the past five years, with the largest increases from shrubs and native forbs. Exotic forbs were the only lifeform to decrease in cover from 2009 to 2014, decreasing dramatically by 16%.



2a. Native Forbs

Total native forb cover across the five plots averaged 19% (Figure 3, Table 4), 3.8% higher than in 2009. Increases were mainly due to increases of seeded species *Penstemon confertus* on four of five plots. While these increases ranged from trace to 2% on most plots, *P. confertus* particularly increased on plot MD05-03 from 3% to 20%.

An increase in naturally regenerating forbs is the other important source of overall native forb increase. *Antennaria racemosa*, present with 3% cover in one plot, could prove to be a good ground cover once established. *Apocynum androsaemifolium*, a species that colonizes open spaces, notably increased on two plots to 3% and 10% cover. *Equisetum arvense* increased from 2% to 25% on the one plot where it is present. In addition, naturally colonizing species such as *Maianthemum stellatum*, *Fragaria virginiana*, *Galium triflorum*, *Osmorhiza berteroi*, *Adenocaulon bicolor*, and *Senecio pseudolaureus*, are consistently present on two to four plots and are slowly increasing in cover where they are established. Finally, new species are continuing to establish along the bike path edge from the adjacent forest and could continue to add higher native forb cover over time. These include *Eurybia conspicua*, *Geum triflorum*, *Geum macrophyllum*, *Viola orbiculata*, and *Melampyrum lineare*.

Other seeded species are showing sporadic success. Two of the most dominant seeded forb species from the past, *Achillea millefolium* and *Anaphalis margaritacea*, are now exhibiting decreases in cover. This is not unusual as both of these species are colonizers and, as members of the Aster family, vulnerable to herbicide. Notes from the 2009 report indicate that *A. millefolium* had definitely been sprayed with herbicide and was in the process of dying back in several locations. Overall, this species decreased on all five plots, decreasing from 8.4% average cover in 2009 to 1.7% average cover in 2014. This high initial cover that decreases by year ten is a typical trend for colonizer *A. millefolium* and has been observed on several other revegetation projects. *A. margaritacea*, another colonizer, is showing similar results. While this seeded species increased on

plot MD05-01 from 2% to 4%, this species typically decreased in cover on three of the plots by 2-4%. Overall average cover for *A. margaritacea* decreased from 2.5% in 2009 to 1.2% in 2014, due mostly to herbicide impact and competition from other vegetation.

As for other seeded forb species, at ten years after seeding, *Symphyotrichum laeve* var. *laeve* and *Solidago canadensis* are each finally present on four out of five plots. *S. laeve* has trace to 4% cover while *S. canadensis* has only trace cover where it is present. Conversely, *Chamerion angustifolium* is now only present on one plot with trace cover after germinating on four of the five plots in previous years. Finally, *Xerophyllum tenax* has never been observed within monitoring plots.

2b. Native Grasses

Similar to 2007 and 2009, native grasses provided the highest cover of all lifeforms in 2014, averaging 29% over all five plots. This is a small increase over 28.3% native grass cover in 2009 but remains much higher than 6% native grass cover in 2005. It appears that native grasses took advantage of open habitat left behind by the decline of *Trifolium agrarium* after 2005. While exotic grasses are expanding in certain areas as well, it appears that native grasses have been able to effectively establish themselves throughout the project area.

Elymus glaucus remains the native grass with the highest cover, due primarily to a ten-fold increase in average cover from 2.7% in 2005 to 21% in 2007. *E. glaucus* cover decreased slightly in 2009 due to mixed trends over the project area, but has increased slightly from 18.8% average cover in 2009 to 22.6% average cover in 2014, surpassing 2007 cover estimates. In 2014, *E. glaucus* increased in cover by 5-25% on three plots, remained the same on one plot, and decreased dramatically on one plot. Due to the fact that *E. glaucus* is a nurse grass that tends to exhibit a large increase in cover soon after seeding and then gradually decline to lower covers by year ten after seeding, the results on this project are surprising and not typical. Perhaps two factors are at play here: 1) high cover of clover species that dominated the project area early on may have delayed the germination and growth of *E. glaucus* until later years; and 2) continued herbicide application along the bike path continues to both disturb vegetation as well as open up areas for on-going establishment. Future monitoring of this seeded grass will assess if this species continues to dominate the bike path edges or gradually decline to more moderate cover.

Similarly, *Bromus carinatus*, another seeded nurse grass species that typically has notable establishment immediately after seeding, took three years to reach its highest cover. This species, however, has exhibited a typical decline, actually disappearing from all plots on this project this year. As observed on other projects, *E. glaucus* tends to decrease to moderately low amounts within five to ten years, while *B. carinatus*, unable to effectively compete with other vegetation, often disappears altogether within the same time frame as seen here.

Complementing the cover of *E. glaucus*, sedges continue to have consistent cover throughout the project, providing solid secondary native grass cover. Although no sedges occur in plot 1, all other plots have at least 1% cover of a sedge species. From 2009 to 2014, sedges have maintained 15% cover in plot 5, maintained 4% cover in each of plots 2 and 3, and maintained 1% cover in plot 4. *Carex rossii* is the most common sedge species found, although *Carex microptera*, *Carex pachystachya*, *Carex geyeri*, and *Carex aquatilis* are each contributing notable cover in certain areas. A mix of unnamed sedge species was seeded in this project so it is unknown if some of these species originated from seed, specifically *C. microptera* and *C. pachystachya* that are sometimes collected, or are all naturally regenerating. *Carex athrostachya*, the only seeded sedge species that was identified, has not been observed in the project.

Other seeded grass species are generally not providing significant cover to this project. *Festuca idahoensis* has trace to 5% cover on 3 plots but generally continues to decline over time. *Festuca ovina* is only present in one plot with trace cover, while *Elymus trachycaulus* and *Pseudoroegneria spicata* have disappeared from all plots since 2009. Many of these species are grassland species and may be too shaded in the forest canopy to succeed.

Finally, other native grass species present with greater than trace cover include *Danthonia intermedia* with trace to 1% cover in three plots and *Poa palustris* with trace to 4% cover in four plots. A few remaining native grasses that were observed in select areas have established from the adjacent forest and were present only in trace amounts. Of particular interest is the natural establishment of *Calamagrostis rubescens* on three

plots in 2014. This grass species is the dominant grass of the adjacent forest and would be a positive trend to see this grass increase along the bike path shoulders.

2c. Exotic Forbs

After a substantial decline in exotic forb cover between 2005 and 2007 and a small increase in exotic forb cover from 2007 to 2009, exotic forb cover once again substantially decreased from 2009 to 2014. Exotic forbs decreased from 23.4% cover in 2009 to an all-time low of 7.4% cover in 2014.

This decrease is due primarily to continued decline of all the clover and sweet clover species, including *Trifolium* spp. (*T. agrarium*, *T. hybridum*, *T. pratense*, and *T. repens*), *Melilotus officinalis*, and *Melilotus alba*. Where once *Trifolium* species had 66% cover in 2005, cover of clovers has steadily declined to 18.5% cover in 2007, to 5.8% cover in 2009, and to trace cover on only one plot in 2014. Similarly, 25% cover of *M. officinalis* on plot MD05-01 has now been reduced to trace cover, with little sweet clover present along the bike path anymore. This decline of clover species has been observed on various other revegetation projects in the past. Clovers are good colonizers and with little competition, clovers in the seed bank along the bike path likely took early advantage of the open space to establish. As other native species begin to grow, however, clover cover typically declines over time. It has also been observed that clover species are sensitive to precipitation levels, increasing under wetter years and decreasing in drier years. The last few years have been within a moderate drought supporting the decline of clovers in drier years. For all of these reasons, clovers can be ephemeral species and thus have not been considered long term threats to the success of native plant restoration projects.

Other concerns of past monitoring reports are also not materializing to be issues ten years after replanting. Specifically, at one time, it appeared that both noxious weeds and *Veronica officinalis*, an aggressive creeping species that is able to penetrate tree canopy and grow in the shade, were on the rise. All covers of noxious weed species and *V. officinalis*, however, decreased from 2009 to 2014. While *Chrysanthemum leucanthemum* remains present on four of the five plots, cover of this weed species decreased by 1-3% on three plots, resulting in only trace cover in all areas. *Hypericum perforatum*, once with 4% cover on plot MD05-03, now only has trace cover on that plot and there was no evidence of *Cirsium arvense* on any plot. Finally, while cover of *V. officinalis* remains with 5% cover on plot MD05-04, it generally decreased in cover on the remaining four plots 1-8% over the past five years. These particular weed species always have the potential to increase over time, but effective weed control, increased shade, and competition from other native species is keeping them in check.

The only two exotic forb species that appear to be persistent and potentially increasing are *Prunella vulgaris* and *Plantago major*. Both species are tenacious perennial weeds that can form dense populations of individual plants that can crowd out desirable species and reduce the vigor of those plants that survive. While not a major concern due to their size, they do appear increasing in some areas with covers reaching 7-10% on certain plots.

2d. Exotic Grasses

Exotic grass cover increased slightly from 13.2% cover in 2009 to 16.4% cover in 2014. Most of this increase was due to notable increases of *Phleum pratense* on all five plots. This exotic grass has generally been increasing since 2007, spreading from an average cover of 1.9% in 2007 to an average cover of 7.8% in 2014. *Agrostis stolonifera*, a weedy grass species of high concern due to its aggressive, rhizomatous nature, increased on two plots but also decreased on two plots. Its overall average cover increased slightly from 7% in 2009 to 7.4% in 2014. Only two other exotic grass species were found in monitoring plots. *Poa pratensis* was observed with trace-2% cover in all five plots, while *Poa compressa* was observed with trace-1% in three plots. *Elymus repens* and *Lolium multiflorum*, observed in the past, were not documented in 2014.

While exotic grasses appear to be stable and not increasing dramatically over time, this lifeform is traditionally the most problematic for revegetation projects and should be closely monitored.

2e. Shrubs

Shrub cover showed a dramatic increase from 2009 to 2014, increasing from 1.5% cover to 5.6% cover. This is the largest increase of any lifeform over the past five years, finally adding some woody

structure to this otherwise grassy path edge. *Salix bebbiana*, a naturally regenerating shrub, is responsible for most of this increase. *S. bebbiana* is present and increased on all five plots, particularly plot MD05-05 where it increased from trace to 8% cover since 2009. *Spiraea betulifolia* and *Symphoricarpos albus*, both seeded species, were each found on two to three plots but had notable cover on plot MD05-04 where each species had 6% cover. No other shrub species had higher than trace cover but it should be noted that a diversity of shrub species are adding to the overall shrub cover. New shrub species continue to establish throughout the project from the adjacent forest, adding diversity and woody structure. Over the past five years, these new recruits included *Linnaea borealis*, *Amelanchier alnifolia*, and *Vaccinium membranaceum*.

2f. Trees

While overall tree cover remains relatively low in 2014 at 2.5%, this is actually double the tree cover present in 2009. Most of this is due to growth of *Populus balsamifera* seedlings that are consistently present with 1-3% cover on four of the five plots. Increases were also observed for *Betula papyrifera* on two plots and *Pinus contorta* on three plots. The establishment and increase of *P. contorta* is a positive step to blend with the adjacent forest and provide for structural change along the edges of the bike path. *Populus tremuloides* seedlings are now present on four plots, while *Picea engelmannii* seedlings are present on three plots. No observations were noted of *Pseudotsuga menziesii* or *Larix occidentalis*, trees that had colonized at least one plot in the past.

D. CONCLUSIONS AND RECOMMENDATIONS

Overall vegetation continues to be dominated by native lifeforms. Native grasses continue to dominate the project with 29% average cover. *Elymus glaucus*, hydroseeded on this project, continues to be the dominant species with an average of 22.6% cover, a slight increase from 18.8% cover in 2009. Native forbs, shrubs and trees are also increasing in cover, due to both increases of seeded material and continued colonization of native species from the adjacent forest. While there still is a visual break between the revegetation area and the nearby forest due to the height of seeded grasses, the increase in woody species and the continued colonization of adjacent understory plants will eventually blend these areas together.

The challenge for this area will be twofold. First, as this area continues to be treated with herbicides for non-native forbs, certain native species may be impacted and habitat is opened up for exotic grasses to increase. A variety of native species, rather than weed species, must be able to fill those empty niches. To date, native species appear able to do this as many native lifeforms are increasing at a greater percentage than exotic grasses. Second, *Elymus glaucus* may begin to decline over time, as it is considered a nurse grass and often does not maintain high cover over the long term. Similarly, shrubs, trees, native forbs, and later seral grasses such as sedges, *Calamagrostis rubescens*, and *Oryzopsis asperifolia*, must be able to fill space left open by declining *E. glaucus*. Exotic grasses are the biggest threat to the success of this project. Rhizomatous species such as *Agrostis stolonifera*, the exotic grass species with the highest cover in this project, can especially increase quickly.

This project should be monitored again in 2024, twenty years after revegetation. At this time, trends of nurse grasses, exotic grasses, herbicide resistant native forbs, cover of woody species, and visual blending with the adjacent forest should become clearer.

Table 4. Bike Path Revegetation Project: Ocular Canopy Cover of all Species by Plot, 2005-2014.

	Planted/ Seeded?	MD-05-01				MD-05-02***				MD-05-03			
		2005	2007	2009	2014	2005	2007	2009	2014	2005	2007	2009	2014
GROUND COVER													
Bare soil		0	0	0	0	0	0	0	0	1	0	1	0
Gravel		1	1	0	0	0	0	0	0	45	45	0	0
Rock (>3cm)		1	0	0	0	T	0	0	0	4	4	0	1
Litter		96	96	93	53	97	97	94	66	33	32	66	46
Wood		0	1	1	5	0	0	0	3	5	5	8	8
Moss/lichen		0	T	1	40	1	T	3	25	10	10	20	40
Basal vegetation		2	3	5	2	2	3	3	6	2	3	5	5
Other		0	0	0	0	0		0	0	0	0	0	0
TREE													
<i>Picea engelmannii</i> seedlings			T	T	1				T				
<i>Pinus contorta</i> seedlings					T			T	T		T	T	1
<i>Populus balsamifera</i>		T	T	1	3			T		T	T+	1	1
<i>Populus tremuloides</i> seedlings					T				T		T	T	T
<i>Pseudotsuga menziesii</i>						T						T	
SHRUB													
		0	1	1+	1	T	T+	2-	2	T	T+	T	3
<i>Amelanchier alnifolia</i>									T				
<i>Arctostaphylos uva-ursi</i>											T		T
<i>Linnaea borealis</i>					T				T				T
<i>Mahonia repens</i>									T+			T	T
<i>Rosa woodsii</i>			T	T+	T		T	T	T				
<i>Rubus idaeus</i>							T	T	T	T	T		T
<i>Rubus parviflorus</i>			T+	1		T	T	T	T				
<i>Salix bebbiana</i>			T+	T	1		T		T+	T	T+		2
<i>Spiraea betulifolia</i>	S					T	T	1	T+				T
<i>Symphoricarpos albus</i>	S							T	T+				
NATIVE FORB													
		9	20	27	15	3	9	24	8	3	10	10	22
<i>Achillea millefolium</i>	S	8	15	20	5	2	6	16**	2	2	3-	3	1
<i>Adenocaulon bicolor</i>					T								
<i>Anaphalis margaritacea</i>	S		1-	2	4	T	1	4	T+	T	5	3+	T
<i>Antennaria howellii</i>												T	
<i>Antennaria sp.</i>											T		
<i>Apocynum androsaemifolium</i>			T+	1-		T	1	T*	3				
<i>Campanula rotundifolia</i>										T	T+		
<i>Cerastium arvense</i>							T	T					
<i>Chamerion angustifolium</i>	S		T-		T		T			1	1-	T	
<i>Collinsia parviflora</i>										T	T		
<i>Epilobium halleanum</i>										T			
<i>Eurybia conspicua</i>					T				T				
<i>Fragaria virginiana</i>					T				T				
<i>Galium triflorum</i>		T	T		T	T	T+	2	T				
<i>Geum macrophyllum</i>					T								
<i>Hieracium albiflorum</i>										T	T		
<i>Hieracium sp.</i>								T					
<i>Hieracium umbellatum</i>										T	T		
<i>Melampyrum lineare</i>									T				
<i>Microsteris gracilis</i>											T		
<i>Osmorhiza berteroi</i>			T	T	T		T				T	T	T+
<i>Penstemon confertus</i>	S		T	T	1			T	T	T	1	3	20
<i>Potentilla pensylvanica</i>										T			
<i>Pteridium aquilinum</i>			2	1	1								
<i>Smilacina stellata</i>			T	T+	T	T	T	1-	1				
<i>Solidago canadensis</i>	S	T	T+	T+	T		T		T		T		T
<i>Symphyotrichum laeve</i> var. <i>laeve</i>	S	T	T	2	4	T	T	1	1				
<i>Viola orbiculata</i>					T				T				
<i>Xerophyllum tenax</i>	S												

Table 4 con'd. Bike Path Revegetation Project: Ocular Canopy Cover of all Species by Plot, 2005-2014.

	Planted/ Seeded?	MD-05-01				MD-05-02***				MD-05-03			
		2005	2007	2009	2014	2005	2007	2009	2014	2005	2007	2009	2014
NATIVE GRAMINOIDS		3	30	21	1	4	25	20+	40	19	30	50	50
<i>Agrostis scabra</i>			T	1		T	T		T	T	T+	T+	T
<i>Bromus carinatus</i>	S	T	3-	T		1	4			7	8	T	
<i>Calamagrostis rubescens</i>									T				T
<i>Carex athrostachya</i>	S												
<i>Carex concinnoides?</i>								T					
<i>Carex geyeri</i>												1	1
<i>Carex microptera</i>							T	1+	1				
<i>Carex pachystachya</i>									T			T	T
<i>Carex rossii</i>					T	T	T	3	3	T	T+	6	3
<i>Carex sp.</i>	S		T		T								
<i>Danthonia intermedia</i>						T	T+	1	T	T			1
<i>Elymus glaucus</i>	S	2	30	20	1	2	20	15	40	8	18	32	40
<i>Elymus trachycaulus v. trachycaulus</i>	S	T+				T+	T			T+	1		
<i>Festuca idahoensis</i>	S	T	T	T	T	T	T	T	T	2	2+	9	5
<i>Festuca ovina</i>	S								T		T	T	
<i>Oryzopsis asperifolia</i>									T				
<i>Poa palustris</i>									T			T	T
<i>Pseudoroegneria spicata</i>	S									T		1	
<i>Trisetum canescens</i>						T	T						
EXOTIC FORB		83	41	47	11	85	24	6	3	18	12	25	6
<i>Chrysanthemum leucanthemum</i>		T	T	T	T						T	3	T
<i>Cirsium arvense</i>				T									
<i>Cirsium vulgare</i>		T				T	T	T* (dead)					
<i>Filago arvensis</i>										T			
<i>Hypericum perforatum</i>										T	2-	4*	T
<i>Medicago lupulina</i>		1				T	T			2	3		
<i>Melilotus alba</i>		T	T										
<i>Melilotus officinalis</i>		T		25	T								
<i>Plantago lanceolata</i>			T	T	1		T					T	T
<i>Plantago major</i>		T	T	T	T								
<i>Prunella vulgaris</i>		T	T	1+	10					T	T	4	5
<i>Taraxacum officinale</i>			T	1	T				T				T
<i>Trifolium agrarium</i>		80	40	12		80	20			7	2		
<i>Trifolium hybridum</i>		1	T	6		5	2			1	T		
<i>Trifolium pratense</i>				T									
<i>Trifolium repens</i>										4			
<i>Trifolium sp.</i>								4*				6*	
<i>Verbascum thapsus</i>						T	T			2	T		
<i>Veronica officinalis</i>			T	1+	T	T+	1+	2	1	T	5	8	T+
<i>Veronica serpyllifolia ssp. serpyllifolia</i>					T	T			2	T			T
EXOTIC GRASS		1	2	2	10	1	19	10	19	T+	1+	3	2
<i>Agrostis stolonifera</i>		1	1	1	7	1	15	7	15	T+	1+	2	1
<i>Elymus repens</i>			1-	T+									
<i>Lolium multiflorum</i>						T							
<i>Phleum pratense</i>		T			1+	T	T+	1	2				T
<i>Poa compressa</i>			T	T	T			T		T		1	1
<i>Poa pratensis</i>			T	T	1+	T	3	1	2				T
<i>unknown grass</i>								1					

*** 2009: Plot heavily sprayed recently

* sprayed: all or mostly dead

** sprayed: some dead

Table 4 con'd. Bike Path Revegetation Project: Ocular Canopy Cover of all Species by Plot, 2005-2014.

	Planted/ Seeded?	MD-05-04				MD-05-05			
		2005	2007	2009	2014	2005	2007	2009	2014
GROUND COVER									
Bare soil		3	1	3	0	1	3	1	0
Gravel		T	T	1	1	0	0	0	0
Rock (>3cm)		0	0	1	1	0	0	0	0
Litter		88	94	68	50	64	62	88	62
Wood		2	1	2	3	3	2	2	3
Moss/lichen		5	1	20	40	30	30	5	30
Basal vegetation		2	3	5	5	2	3	4	5
Other		0	0	0	0	0	0	0	0
TREE		T	T	2	5	T	T+	1	1
<i>Betula sp.</i>				T	3				T
<i>Larix occidentalis</i>				T					
<i>Picea engelmannii</i> seedlings				T	T				
<i>Pinus contorta</i> seedlings			T	T	1				
<i>Populus balsamifera</i>		T		1	1		T+	1	1
<i>Populus tremuloides</i> seedlings				T	T				
<i>Pseudotsuga menziesii</i>		T	T			T			
SHRUB		1	1	3	14	0	1-	T	8
<i>Rubus idaeus</i>				T					
<i>Salix bebbiana</i>		T	T	T	2		1-	T	8
<i>Spiraea betulifolia</i>	S	T	T	1	6				
<i>Symphoricarpos albus</i>	S	T	1	2	6				
<i>Vaccinium membranaceum</i>					T				T
NATIVE FORB		3	14	10	20	1	5	5-	30
<i>Achillea millefolium</i>	S	T	T	2	T	T	T	1	
<i>Adenocaulon bicolor</i>			T		1-				
<i>Anaphalis margaritacea</i>	S		3	3	1				
<i>Antennaria bonellii</i>			T						
<i>Antennaria racemosa</i>				1	3				
<i>Apocynum androsaemifolium</i>		2	5	1**	10				
<i>Aster spp. (skinny)</i>									T
<i>Cerastium arvense</i>			5	1			4		
<i>Chamerion angustifolium</i>	S							T	
<i>Epilobium halleanum</i>						T	T		
<i>Equisetum arvense</i>				T		T		2	25
<i>Erigeron spp.</i>									T
<i>Eurybia conspicua</i>									T
<i>Fragaria vesca</i>				T					
<i>Fragaria virginiana</i>		T		T	T		T	T	T
<i>Galium triflorum</i>			T				T	T	T
<i>Geum triflorum</i>									T
<i>Hieracium sp.</i>		T	T	1**			T	T	
<i>Melampyrum lineare</i>					T				
<i>Osmorhiza berteroi</i>			T	T	1		T	T	
<i>Penstemon confertus</i>	S				T				2
<i>Pyrola asarifolia</i>									T
<i>Ranunculus uncinatus</i>						T			
<i>Senecio pseudolaureus</i>				T	1	T	T	1-	1
<i>Smilacina stellata</i>		T		T	2		T	1-	
<i>Solidago canadensis</i>	S	T	T				T	T	T
<i>Symphyotrichum laeve var. laeve</i>	S		T	T	T	T	T		T
<i>Viola orbiculata</i>					T				
<i>Xerophyllum tenax</i>	S								

Table 4 con'd. Bike Path Revegetation Project: Ocular Canopy Cover of all Species by Plot, 2005-2014.

	Planted/ Seeded?	MD-05-04				MD-05-05			
		2005	2007	2009	2014	2005	2007	2009	2014
NATIVE GRAMINOIDS		1	9	18	18	3	38	32	36
<i>Bromus carinatus</i>	S	T	1	T		T			
<i>Calamagrostis rubescens</i>					T				
<i>Carex aquatilis</i>									1
<i>Carex athrostachya</i>	S								
<i>Carex microptera</i>				1	T	T		12	*
<i>Carex pachystachya</i>							5	3	
<i>Carex petasata</i>									*
<i>Carex rossii</i>		T		T	T		T	T	*
<i>Carex sp.</i>	S		T			T	T	1	14*
<i>Danthonia intermedia</i>					1				
<i>Elymus glaucus</i>	S	T	7	12	12	1	30	15	20
<i>Elymus trachycaulus v. trachycaulus</i>	S	T				1	2		
<i>Festuca idahoensis</i>	S	T				T			
<i>Festuca ovina</i>	S				T				
<i>Grass sp.</i>						T			
<i>Juncus ensifolius</i>							T	T	
<i>Poa palustris</i>		T	1	5-	4	T	T	1	2
<i>Pseudoroegneria spicata</i>	S								
<i>Trisetum canescens</i>							T		
EXOTIC FORB		100	19	19	7	39	4	20	10
<i>Cerastium fontanum</i>		T				T			
<i>Chrysanthemum leucanthemum</i>		2	5	4**	T	1	3	1	T
<i>Cirsium arvense</i>		T	T	T					
<i>Cirsium vulgare</i>						T			
<i>Medicago lupulina</i>		T				T	T+		
<i>Melilotus officinalis</i>						T			
<i>Plantago lanceolata</i>						T			
<i>Plantago major</i>		T		2	1	2	1	T	7
<i>Prunella vulgaris</i>		T	3	5	T	1	5	9	T
<i>Taraxacum officinale</i>		T	T	T	T	T			T
<i>Trifolium agrarium</i>		70	3			2	16		
<i>Trifolium hybridum</i>		50	2			25	6		
<i>Trifolium pratense</i>		1				2	T		
<i>Trifolium repens</i>		T				2			
<i>Trifolium sp.</i>				T					T
<i>Veronica officinalis</i>		T	5	5	5			5	1
<i>Veronica serpyllifolia ssp. serpyllifolia</i>		T	1	3	T	3	1	5	1
EXOTIC GRASS		9	25	29	28	45	19	22	23
<i>Agrostis stolonifera</i>		8	20	16	12	25	15	9	2
<i>Elymus repens</i>								1	
<i>Phleum pratense</i>		1	5	12	15	20	4	12	20
<i>Poa compressa</i>								T	T
<i>Poa pratensis</i>				1	1			T	1

Carex spp. = includes *C. microptera*, *C. rossii*, *C. petasata*, and possibly other *Carex spp.*

III. CAMAS ROAD HYDROMULCH

A. BACKGROUND AND PURPOSE

The Camas Creek Road hydro-mulch project was created as a post-fire restoration effort. After the Robert Fire swept through portions of the North Fork subdistrict of Glacier National Park in July 2003, weeds invaded many roadside areas. Fire suppression activities, coupled with normal road use, caused additional disturbance and helped to further weed propagation along the Camas Creek Road corridor. Rehabilitation of these sites was sought to restore roadsides to more native conditions and to reduce potential weed spread into the recently burned areas.

An interagency Burned Area Emergency Rehabilitation (BAER) team produced a report documenting the fire and fire suppression effects on the road corridor, and made recommendations for mitigation and management (USDA Forest Service and USDI National Park Service, 2003). Based on the conclusions of that report, funding was provided by the BAER program to perform rehabilitation along the Camas Creek Road corridor.

Efforts to rehabilitate a disturbed area can sometimes have inadvertent adverse effects. Following a disturbance such as fire, revegetation efforts can detrimentally impact soils by reducing existing vegetative cover, reworking existing soil, and introducing new soil. Additionally, imported soil can be contaminated with weed seeds even when care is taken to obtain sterile soil. In an effort to avoid this type of added disturbance, an alternative method for rehabilitating this recently burned roadside was sought.

The methodology tested in this project sought to minimize soil disturbance while reducing weeds and increasing native plant cover. The course of action chosen was to spray the area with an herbicide prior to planting to reduce broadleaf noxious weeds, followed by a “two-pass” hydro-seed / hydro-mulch application of native seed. Hydro-seeding is a process that mixes, distributes and plants seed in a spray of water. Hydro-mulching is often used as a method to mix seeds with water and mulch for improved germination. Hydro-mulching stabilizes soil, holds seeds in place for germination, and provides protection from desiccation. However, seeding with hydro-mulch also poses problems. Seedlings sometimes germinate within the mulch, rather than within the soil, and fail to properly establish (Lapp 2004). Therefore a combination of the two methods was used in this project. By hydro-seeding first, followed by a second “pass” with hydro-mulch alone (no seed), the benefits of mulch are gained with less detrimental effect to survival of germinants. This project was performed on a small scale, since hydro-seeding and hydro-mulching are expensive, and results compared with traditional revegetation methods are unknown.

B. METHODS

A small portion of the Camas Creek Road corridor was selected for this experimental project. Application of the hydro-seed/mulch began shortly after the turnoff for Fish Creek Campground and extended approximately three miles northwest along the Camas Creek Road. To reduce existing weeds and prepare the site for seeding, the area was sprayed with a series of broad leaf herbicides between June 15 and August 5, 2004. A “two-pass” hydro-seed / hydro-mulch mixture was subsequently applied on September 30, 2004. Native grasses were chosen for this project since the germination rate for this lifeform on similar projects has been generally more successful than native forb establishment. Four native grass species were seeded in different proportion at a rate of 30 pounds per acre (Table 5).

Table 5. Camas Creek Road Hydro-mulch Project: Grasses Seeded, 2004.

Species:	Percent of mix:
<i>Bromus carinatus</i>	36%
<i>Elymus glaucus</i>	33%
<i>Festuca idahoensis</i>	10%
<i>Pseudoroegneria spicata</i>	21%

Six permanently marked monitoring plots were established along the roadside between October 3rd and 6th, 2004 (Figure 4). Plots measured 10m long by 1m wide to accommodate the linear nature of the treated area. Plots were marked with a nail in the upper right corner (when facing the plot from the road). Plots differed slightly in physical aspects such as burn severity, slope, adjacent habitat, ground cover, gravel content, soil moisture content, presence of ditches, and shade. Level II Site Analyses were conducted in 2004 and Level II Monitoring was performed in 2005, 2007, 2009 and 2014 (Table 6). Photographs were taken during all monitoring events. An ocular estimate of canopy cover for all species, as well as ground cover, was collected for each plot.

Figure 4. Camas Creek Road Hydro-mulch project: Location of Monitoring Plots



C. RESULTS

1. Effects of Hydro-seeded Species

Table 6 summarizes all of the data between 2004 and 2014 for all plots within the Camas Creek Road Hydro-mulch project. Three of the four species of hydro-seeded native grasses were present in the plots in 2014, compared with two species in 2009, three species in 2007, and two species in 2005. *Bromus carinatus* continued to be unobserved throughout the project. *Festuca idahoensis* continued to be the most successful hydro-seeded species in the project and the only hydro-seeded species that has had more than 1% cover throughout monitoring of the project. It was found in every plot in 2007, in 2009, and 2014. Cover continues to be variable. In the two plots where cover of *F. idahoensis* was highest, it was present before germination of hydro-seeded material. In both of these plots, cover continues to decrease from 25% in 2005 to 15% in 2009 to 10% in 2014 on plot 3 and from 25% in 2005 to 12% in 2009 to 8% in 2014 on plot 4. On the other hand, the plots with *F. idahoensis* presence only after hydroseed germination all increased or maintained cover from 2007 to 2014. The data from these plots may be more indicative of germination rather than natural regeneration with 7%, 4%, 4%, and 1% cover in these plots. As for the remaining two hydroseeded species, *Pseudoroegneria spicata* is slowly establishing on 4 plots but remains with trace to 1% cover. *P. spicata* was found on the project for the first time in 2007. Lastly, *Elymus glaucus* was present on one plot with trace cover in 2014 after disappearing from three plots in 2009. At ten years after seeding, it does not appear that *E. glaucus* will become a significant component of this roadside vegetation.

2. Lifeform Results

In general, cover of most lifeforms was similar to estimates from 2009 (Table 6). In fact, cover estimates were so similar across all lifeforms that these small changes may be just be observer differences. It appears that the vegetation along this stretch of the Camas Road is relatively stable, kept constant by regular mowing and herbicide treatments for noxious weeds. While regular treatment with herbicide is a necessary management tactic for roadsides to curb exotic forb invasion, herbicide has been repeatedly shown to have negative impacts on native species as well, particularly native forbs and certain woody species. Many native forb species disappeared from monitoring plots entirely in 2009, most likely as non-targeted casualties of herbicide use. Some of these species were also annuals whose populations naturally fluctuate.

Exotic species continue to dominate the area with 45.2% average exotic cover in comparison to 14.5% average native cover across plots (Figure 5). Average exotic cover across plots in 2014 is virtually the same as in 2009 when it was estimated to be 45.6%. Average native cover across plots appears to have increased slightly from 13.0% in 2009 to 14.5% in 2014. This may be due to the slight increase in average native grass cover. Average native grass cover still remains much lower than in 2007 when it was estimated to be 22.3%. A decline of all native lifeforms from 2007 to 2014 has contributed to that trend.

Exotic grasses continue to be the dominant lifeform in all plots with 40.3% average cover (Figure 6). This is slightly lower than in 2009 when exotic grass cover was 42%. *Bromus inermis* is the dominant species in most plots, ranging from 5% to 30% cover. In most cases, it has similar cover to 2009 values. Interestingly, a number of exotic grasses have decreased in cover since 2009, most notably *Agrostis stolonifera* and *Phleum pratense*. It is possible that the early reading of these plots caused identification of these species to be difficult, but it is also possible that *A. stolonifera* and *P. pratense* are being outcompeted by *B. inermis*.

Exotic forb cover increased slightly, although the difference is likely within the realm of observer differences. Average exotic forb cover increased from 3.6% in 2009 to 4.8% in 2014. This is a substantial decrease from 2005, however, when exotic forb cover was 19.7%. Herbicide application is clearly working to keep non-native forbs in check.

Native grasses provide the second highest cover of lifeforms on average with 10.7% cover. This lifeform increased slightly from 9.5% cover in 2009 to 10.7% cover in 2014, mostly due to increases in cover from naturally regenerating native grass species. Native forb, tree and shrub cover has remained virtually the same in 2014 to 2009 values.

Figure 5. Native and Exotic Covers Across Plots for the Camas Hydromulch Project, 2004 - 2014

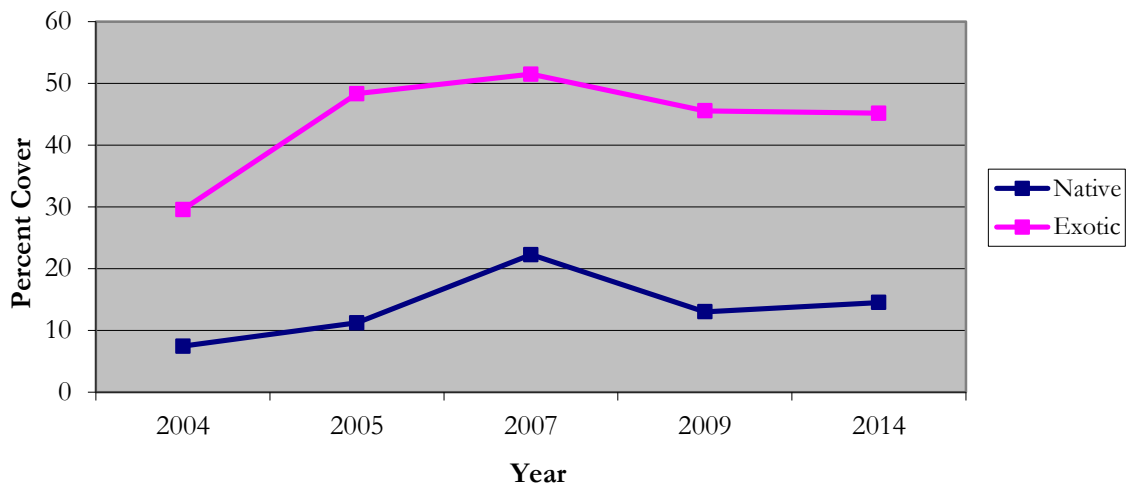
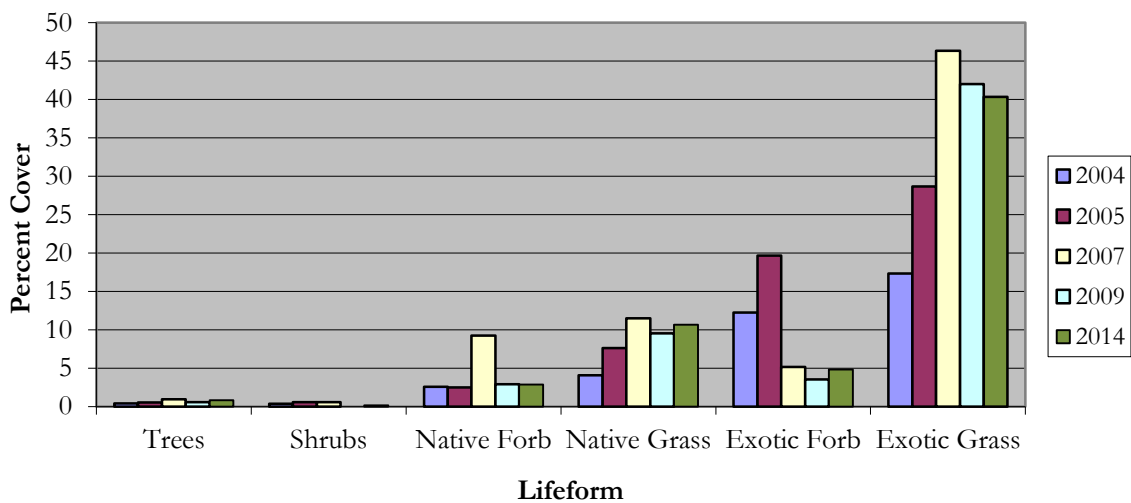


Figure 6. Average Percent Cover Across Plots for Lifeforms for the Camas Hydromulch Project, 2004 - 2014



2a. Trees and Shrubs

While no shrubs were observed in plots in 2009, a small amount *Symphoricarpos albus* established over the past five years in two plots, raising the overall average shrub cover to 0.2% across all plots. Clearly, shrubs are not a significant component of this revegetated road area, likely due to annual mowing and herbicide application.

Tree cover has also remained low on all plots in 2014 with no species having more than 3% cover in any plot. Currently, the only plots to have notable tree cover are plot MD04-01 that has 3% cover of *Pinus*

contorta and plot MD04-04 that has 1% cover of *Populus balsamifera* and trace cover of *Larix occidentalis* and *Betula papyrifera*. The remaining four plots have no tree cover. Many tree species have been negatively impacted by herbicide over the past ten years, including *P. contorta* which has disappeared from 3 plots and *Pseudotsuga menziesii* and *Abies lasiocarpa* which are no longer present within the project area. Even this year, *L. occidentalis* in plot MD04-04 clearly looked wilted due to herbicide. This is additional evidence that supports the hypothesis that herbicide application is affecting woody material in these roadside plots. Similar to shrubs, it is likely that cover from tree species will continue to be negligible due to mowing and herbicide application.

2b. Native Forbs

Native forb cover has had vacillating trends since 2005. Native forb cover remained low at 2.5% in 2004 and 2005, only to triple in 2007 to 9.3% cover due to the dramatic increases of *Collinsia parviflora*, *Anaphalis margaritacea*, and *Rhinanthus crista-galli*, specifically on plot MD04-05. Native forb cover then dramatically decreased in cover in 2009 back to 2.9% when these same species either disappeared or were greatly reduced. Now in 2014, the seesaw trend appears to have stopped with native forb cover remaining at 2.9%. Overall, one plot dramatically decreased in native forb cover, one plot dramatically increased in native forb cover, and the remaining four plots had similar native forb cover to 2009. Cover ranged from trace to 9%.

Currently, three native forb species have particularly notable cover. These include *Senecio pseudolaurens* that is present on 3 plots with trace to 4% cover, *Solidago canadensis* that is present on 3 plots with trace to 3% cover, and *Aster laevis* that is present on 2 plots with trace to 2% cover. Other species that have at least 1% cover on 1 plot include *Collinsia parviflora*, *Anaphalis margaritacea*, *Microsteris gracilis*, *Fragaria virginiana*, and *Apocynum androsaemifolium*. In 2014, there were only 15 native forb species present in all of the plots. In total, 25 native forb species have been observed within these plots over time, indicating disappearance of several native forb species in the past few years. It is very likely that herbicide treatment has negatively impacted several native forb species, particularly in the aster and pink families. Hopefully, with less noxious weed cover to spray, some of these native forb species will recover as evidenced by small increases in cover by *S. canadensis* and *A. laevis*. These are both aster family forbs that were on the decline a few years ago but have increased in cover since 2009.

2c. Native Grasses

Since 2007, native grass cover has remained high enough to be the second highest lifeform cover on the project. Average native grass cover increased slightly from 9.5% in 2009 to 10.7% in 2014. Overall, four of the six plots increased in native grass cover by 2-5%, while the remaining two plots decreased in native grass cover by 2-4%.

The hydroseed mix utilized was composed solely of native grass species which continue to show varied results. *Festuca idahoensis* remains the most successful of the four hydro-seeded species with presence on all six plots and cover ranging from 1% to 10%. *Pseudoroegneria spicata* is slowly establishing on 4 plots but remains with trace to 1% cover. In 2014, *Elymus glaucus* was present on one plot with trace cover after disappearing from three plots in 2009. At ten years after seeding, it does not appear that *E. glaucus* will become a significant component of this roadside vegetation. *Bromus carinatus* has never germinated in the project and is currently not present in any plot.

Two naturally regenerating native grass species are fortunately providing good secondary cover to complement the cover of seeded *F. idahoensis*. The first species is *Carex rossii* that is present on 5 plots with trace to 4%, maintaining or increasing in cover since 2009. This naturally establishing sedge is proving to be the only sedge with long-term cover on this project as *Carex microptera* has disappeared and *Carex petasata* and *Carex concinnoides* have been reduced to trace cover on 1 plot. *Carex pachystachya*, present on 2 plots with trace to 2% cover, could increase over time to offer additional sedge cover. The second species is *Danthonia intermedia* that is present on all six plots with trace to 8% cover. This species increased in cover on four of the plots since 2009, adding solid secondary native grass cover to several plots. Given that this species is not a natural component of the nearby forest type, there is the chance that this species was inadvertently seeded. It also could be that this species was present in the seed bank from prior revegetation work.

While native grasses appear to have the most potential for long term success in this project, their survival is threatened by exotic grasses.

2d. Exotic forbs

Overall cover of exotic forbs across plots has remained relatively stable since 2007, due to a diligent herbicide application regime. Average exotic forb cover is 4.8%, up slightly from 3.6% cover in 2009 but remaining much lower than the 19.7% exotic forb cover in 2005. High weed cover in the past was due to high cover of a variety of exotic forb species, including *Trifolium agrarium*, *Verbascum thapsus*, *Silene cucubalus*, *Prunella vulgaris*, *Hypericum perforatum*, and *Veronica officinalis*. Herbicide application has eliminated *V. thapsus* and *T. agrarium* within the plots, minimized *H. perforatum* to trace cover, and dramatically lowered cover of *S. cucubalus*, *P. vulgaris*, and *V. officinalis*. These last three exotic forb species, however, remain the exotic forbs with the highest and most consistent cover on the project. *P. vulgaris* is present on 5 plots with trace to 4% cover, *S. cucubalus* is present on 4 plots with trace to 5% cover, and *V. officinalis* is present on 4 plots with trace to 4% cover. Herbicide is clearly keeping them under control but research indicates that these species are difficult to eliminate completely without annual spraying and intensive combinations of herbicides.

Noxious weeds are also not being completely eliminated by herbicide. Whereas only one plot harbored a noxious weed species in 2009, five plots had at least one noxious weed in 2014. *Hypericum perforatum* was observed on 3 plots with trace cover, *Centaurea maculosa* was observed on 2 plots with trace to 1% cover, *Chrysanthemum leucanthemum* was observed on 2 plots with trace cover, and *Hieracium aurantiacum* was observed on one plot with 1% cover. Clearly, seed of these noxious weed species is either nearby or remains in the seed bank, requiring ongoing herbicide along this stretch of the Camas Road. Only *Potentilla recta*, observed on 3 plots in 2004 and 2005, has not re-established within the project area.

2e. Exotic Grasses

The overall success of this project remains threatened by the invasion of exotic grasses. While overall cover of exotic grasses has decreased slightly in both 2009 and 2014, it continues to be the overwhelmingly dominant lifeform with 40.3% average cover. *Bromus inermis*, a quickly spreading rhizomatous exotic grass, remains the most dominant species in five of the six plots. Covers of *B. inermis* in 2014 have remained relatively similar to those estimated in 2009, ranging from 5% to 30%. Plot MD04-01, where cover of *B. inermis* is at its lowest at 5%, is conversely dominated by *Festuca arundinacea*, another tall, exotic grass. *F. arundinacea* has 45% cover on this plot, but is also present on three other plots with trace to 2% cover. In addition, *Phleum pratense* is consistently present on all six plots with 1-5% cover, although this is dramatically lower than in 2009 when cover of *P. pratense* ranged from 8-30% cover on four plots. Similarly, cover of *Agrostis stolonifera*, currently present on five of the six plots with trace to 8% cover, is much lower than in 2007 when all five plots had 5-15% cover. It could be that these exotic grasses are actually being outcompeted by *B. inermis* which has been on the rise since 2007. It could also be some of the covers of these grasses were misidentified in earlier years when plants were often small, without seed heads, or mowed.

It should be noted that several other exotic grasses are present on several plots. *Dactylis glomerata* is present on four plots with 1-8% cover, *Poa compressa* is present on five plots with trace to 1% cover, and *Poa pratensis* is present on two plots with trace to 1% cover. Any of these non-native grasses can increase with new disturbance.

As stated in earlier reports, once exotic grasses become established, they tend to dominate areas and are almost impossible to eradicate. Short of using Round-Up to kill all vegetation prior to revegetation, there is little that can be done to diminish exotic grasses once established. These grasses were present before germination of hydro-seeded native grasses took place, making it difficult for natives to compete.

D. CONCLUSIONS AND RECOMMENDATIONS

In 2014, the Camas Creek Hydroseeding project was monitored ten years after revegetation. Major trends include:

- Exotic grasses are dominating all plots. On average, exotic grasses have approximately four times more cover than the next most abundant lifeform in the project.
- Success of the project is severely threatened by rhizomatous weedy grasses, especially *Bromus inermis*.
- One of the four hydro-seeded species is not present in the project by year ten. *Bromus carinatus* has never been found within monitoring plots. *Elymus glaucus* is only present one plot with trace cover after disappearing from three plots in 2009. At ten years after seeding, it does not appear that *E. glaucus* will become a significant component of this roadside vegetation.
- *Festuca idahoensis* continues to be the most successful hydro-seeded species in the project and the only hydro-seeded species that has had more than 1% cover throughout monitoring of the project. It was found in every plot in 2007, 2009, and 2014 with an average cover of 7%. This species was present in some plots before hydroseeding, however.
- Exotic forb covers have been kept low over the course of the project by diligent herbicide use. However, five plots had at least one noxious weed in 2014 in comparison to one noxious weed species one plot in 2009. *Hypericum perforatum*, *Centaurea maculosa*, *Chrysanthemum leucanthemum*, and *Hieracium aurantiacum* were all observed on at least one plot within the project. Clearly, seed of these noxious weed species is either nearby or remains in the seed bank, requiring ongoing herbicide along this stretch of the Camas Road.
- It is very likely that herbicide treatment is continuing to negatively impact several native forb species, particularly in the aster and pink families. That said, three species in the aster family, specifically *Senecio pseudolaurens*, *Solidago canadensis*, and *Aster laevis*, are currently the native forb species with the most consistently high covers. Hopefully, with less noxious weed cover to spray, some of these native forb species will recover over time.
- Tree and shrub cover remain very low throughout the entire project area. Mowing and herbicide use are clearly affecting woody species along this stretch of road. At ten years after revegetation, it is not likely that trees and shrubs will be a long-term component of the vegetation along the Camas Road.

Future monitoring of the Camas Creek Road Hydro-mulch Project should track longer-term success of hydro-seeded material. Additional monitoring will also determine how well native species can compete with rhizomatous weedy grasses over time under rigorous annual herbicide application. It is difficult to combat exotic grasses under any conditions but especially when they are present at the beginning of a revegetation project. This project should be monitored in 2024, twenty years after revegetation.

Table 6. Camas Road Hydro-mulch Project: Canopy Cover of Species (%) by Plot, 2004-2014.

	MD-04-01					MD-04-02					MD-04-03				
	2004	2005	2007	2009	2014	2004	2005	2007	2009	2014	2004	2005	2007	2009	2014
Bare ground			T	T	0			0	T	T			0	T	T
Basal Vegetation			3	5	10			2	3	5			2	4	3
Moss			10	24	40			23	45	60			35	50	80
Gravel			5	1	5			15	7	5			20	4	4
Litter			82	70	45			60	45	30			43	42	13
TREE	T	T	2-	2-	3-	T	T+	2	T	0	0	T	1	T	0
conifer seedlings	T	T	T			T						T			
<i>Abies lasiocarpa</i>													1	T	
<i>Pinus contorta</i>		T	2-	2*	3-		T+	2	T			T			
<i>Larix occidentalis</i>				T*											
SHRUB	T	T	T	0	0	0	0	2	0	0	T+	2	0	0	0
<i>Arctostaphylos uva-ursi</i>		T						2 (dying)			T+	2			
<i>Salix boothii</i>	T	T	T												
NATIVE FORB	T	2	7	2	7	0	1	21	8	T	1	2	1+	T	T
<i>Anemone multifida</i>	T	T	1												
<i>Antennaria bonellii</i>			T	T	T							T			T
<i>Arabis drummondii</i>		T			T								T	T	T
<i>Botrychium multifidum</i>		T	T	T	T										
<i>Chamerion angustifolium</i>	T												T		
<i>Cerastium arvense</i>	T		T										T		
<i>Collomia linearis</i>			T					T	T			T			
<i>Collinsia parviflora</i>		1	2				T+	20	8		T	T	1	T	T
<i>Fragaria virginiana</i>					1						1-	T+	T		
<i>Galium boreale</i>											T	T			
<i>Gentianella amarella</i>		T	T									T			
<i>Microsteris gracilis</i>		T	1		1		T	T+		T		T	T		
<i>Penstemon confertus</i>												1			
<i>Senecio pseudolaurens</i>	T	T+	2	2	4				T	T					
<i>Solidago canadensis</i>					1										
NATIVE GRASSES	2	1	9	17	19	T	T+	2	5+	7	12	31	25	16	12
<i>Agrostis scabra</i>		T													
<i>Carex microptera</i>		T+										T+			
<i>Carex rossii</i>	T+		T+	2	2				T	T					T
<i>Danthonia intermedia</i>	T+	T	4	4	8	T	T+	1+	1+	2				T	T
<i>Deschampsia caespitosa</i> ?	T														
<i>Elymus trachycaulus</i> v. <i>trachycaulus</i>											T	T			
<i>Festuca idahoensis</i>			2	7	7			T+	3	4	12	30	25	15	10
<i>Festuca campestris</i> ?															1
<i>Koeleria macrantha</i>		T	T+									T			
<i>Carex petasata</i>			T	2											
<i>Pseudoroegneria spicata</i>			T	T				T	1	1			T	1	1
<i>Carex pachystachya</i>			2	2	2			T					T		
<i>Carex concinnoides</i>				T						T					

Table 6 con'd. Camas Road Hydro-mulch Project: Canopy Cover of Species (%) by Plot, 2004-2014.

	MD-04-01					MD-04-02					MD-04-03				
	2004	2005	2007	2009	2014	2004	2005	2007	2009	2014	2004	2005	2007	2009	2014
EXOTIC FORB	29	16	6	6	7	7+	15	T	T	2	2	5	T	1-	3
<i>Arenaria serpyllifolia</i>		T		1	T	5+			T					T	T
<i>Centaurea maculosa</i>	T					T				T^					
<i>Cerastium fontanum</i>	T				T										
<i>Chrysanthemum leucanthemum</i>		T				T	T				T	T			
<i>Cirsium arvense</i>						T									
<i>Hypericum perforatum</i>	7	1	T		T	T	T	T			T	1			
<i>Medicago lupulina</i>						1+					T+				
<i>Melilotus officinalis</i>		T													
<i>Myosotis micrantha</i>					T	T	T			1+	T				
<i>Potentilla recta</i>						T					T				
<i>Prunella vulgaris</i>			2		1						1+	3	T	T	2
<i>Silene cucubalis</i>	2	9	4	5	5	T+	T		T	T					
<i>Taraxacum officinale</i>					T										
<i>Trifolium agrarium</i>							14					T			
<i>Verbascum thapsus</i>	20	5	T			T	T								
<i>Veronica officinalis</i>		T		T								T	T	T	T
<i>Veronica arvensis</i>		1	T	T	T				T	1				T	T
EXOTIC GRASS	13	63	39	46	60	33	35	37	30	31	12	12	51	43	35
<i>Agrostis stolonifera</i>	T	T	5	T	T			1			3	2	8	2	1
<i>Bromus inermis</i>		2	8	8	5	3	35	35	30	30	3+	2	20	30	30
<i>Dactylis glomerata</i>		T	1	10	5										
<i>Festuca arundinacea</i>	10	60	7	15	45					T					
<i>Phleum pratense</i>	3	1	8	3	3	30	T	1	T	1	4-	5	15	8	3
<i>Poa compressa</i>	T	T	8	8	T		T	T		T	2	T	5	3	T
<i>Poa pratensis</i>	T		2	2	1							3	3	T	T

*= shriveled; sprayed

^ appeared to be affected by herbicide treatments

Table 6 con'd. Camas Road Hydro-mulch Project: Canopy Cover of Species (%) by Plot, 2004-2014.

	MD-04-04					MD-04-05					MD-04-06				
	2004	2005	2007	2009	2014	2004	2005	2007	2009	2014	2004	2005	2007	2009	2014
Bare ground			0	1	0			2	T	0			0	2	0
Basal Vegetation			3	5	5			3	4	4			2	3	3
Moss			40	50	45			1	6	10			35	44	70
Gravel			12	3	10			25	12	20			15	6	1
Litter			45	41	35			69	78	64			48	45	24
Wood				T	5				T	2					2
TREE	T	T	T+	T	2	T	T	0	0	0	T	T	0	0	0
conifer seedlings	T					T									
<i>Abies lasiocarpa</i>											T	T			
<i>Betula papyrifera</i>					T										
<i>Pinus contorta</i>		T	T												
<i>Populus balsamifera</i>					1										
<i>Pseudotsuga menziesii</i>		T^					T				T	T			
<i>Larix occidentalis</i>			T+	T	T+^										
SHRUB	0	0	T	0	T	T	T	0	0	1	T	T	T	0	0
<i>Salix bebbiana</i>											T	T			
<i>Spiraea betulifolia</i>						T	T								
<i>Symphoricarpos albus</i>					T					1					
<i>Paxistima pyrsinites</i>			T										T		
NATIVE FORB	1	1	T	T	1	11	8	25	7	9	2	1	T	0?	T
<i>Achillea millefolium</i>						T	T			T					
<i>Anaphalis margaritacea</i>		T^				2	2	13	T	1		T			T^
<i>Antennaria bonellii</i>		T				2	3	3	1						
<i>Apocynum androsaemifolium</i>										1+					
<i>Arabis drummondii</i>										T		T			
<i>Aster laevis</i>					T+		T		T	2					
<i>Botrychium multifidum</i>															
<i>Castilleja miniata</i>	T	T													
<i>Chamerion angustifolium</i>								1-							
<i>Cerastium arvense</i>								2					T		
<i>Collomia linearis</i>								T		1		T	T		T
<i>Collinsia parviflora</i>			T	T	T	4-					1-		T		T
<i>Equisetum arvense</i>												T^			
<i>Fragaria virginiana</i>		T				T	T				T+	T			
<i>Galium boreale</i>															
<i>Gentianella amarella</i>					T										
<i>Microsteris gracilis</i>	T	T	T			1	T			1	1	T			
<i>Penstemon confertus</i>						T+	1		3						
<i>Rhinanthus crista-galli</i>		T					T	5							
<i>Senecio pseudolaureus</i>	T+	T^			T										
<i>Sisyrinchium montanum</i>					T										
<i>Solidago canadensis</i>					T	1	1^	3	2+	3					
<i>Spiranthes romanoffiana</i>							T								
<i>Viola spp.</i>						T									
NATIVE GRASSES	8	7	27	13	11	1	2	4	4	9	1	4	2	2	4
<i>Agrostis scabra</i>							1								
<i>Carex microptera</i>												T			
<i>Carex rossii</i>		T+		1	1		1		1	4				T	

Table 6 con'd. Camas Road Hydro-mulch Project: Canopy Cover of Species (%) by Plot, 2004-2014.

	MD-04-04					MD-04-05					MD-04-06				
	2004	2005	2007	2009	2014	2004	2005	2007	2009	2014	2004	2005	2007	2009	2014
<i>Danthonia intermedia</i>			T	T	1		T			1	T+	2+	2	1	2
<i>Elymus glaucus</i>			T		T+			T				T			
<i>Elymus trachycaulus</i> v. <i>trachycaulus</i>						1		T			T+	1			
<i>Festuca idahoensis</i>	8	6	25	12	8	T		T	2+	4			T	1	1
<i>Koeleria macrantha</i>								T	T	T					
<i>Stipa nelsonii</i>							T		T						
Grass spp. (unknown)*						T									
<i>Carex petasata</i>										T					
<i>Pseudoroegneria spicata</i>			T	T	T			T	T					T	T
<i>Trisetum spicatum</i>													T	T	T
<i>Carex pachystachya</i>			2					4					T		T
<i>Carex concinnoides?</i>				T	T										
EXOTIC FORB	3	10	2	1-	2	21	43	18	10	10	11	29	4	3	5
<i>Arenaria serpyllifolia</i>				T	T										
<i>Centaurea maculosa</i>										1^					
<i>Cerastium fontanum</i>		T					1+	3	T			T			
<i>Chrysanthemum leucanthemum</i>					T	T	T^			T	T	1^			
<i>Hieracium aurantiacum</i>						T+	T+			1					
<i>Hypericum perforatum</i>	T	4^			T^		T^	T	T		1	2^			T^
<i>Melilotus officinalis</i>										2^					
<i>Plantago major</i>					T										
<i>Potentilla recta</i>							T								
<i>Prunella vulgaris</i>	3	6	2	T	1	T	T	T	T	4		T			T+
<i>Silene cucubalis</i>		T	T	T	T	4	14	8	4	T	T	T			
<i>Taraxacum officinale</i>					T	T				T					
<i>Trifolium agrarium</i>						15	20^					T			
<i>Trifolium hybridum</i>						1	2					T			
<i>Verbascum thapsus</i>		T													
<i>Veronica officinalis</i>				T	T	T	5	7	5	1	10	25	5	3	4
<i>Veronica arvensis</i>		T			T		T		T			T	T		
EXOTIC GRASS	16	20	53	42	35	12	22	38	50	38	18	20	60	41	43
<i>Agrostis stolonifera</i>	T+	2+	9		T	4	4	15		1	1+	T	10	2	8
<i>Bromus inermis</i>	3	2	18	20	25	3	6	8	25	25	10	15	26	28	30
<i>Dactylis glomerata</i>	2+	2	9	7	8	2	1	1+	5	2		T	T	T	1
<i>Festuca arundinacea</i>	2	2	4	2	1	T	T				T	1	1	1	2
<i>Phalaris arundinacea</i>						1	2	4		4					
<i>Phleum pratense</i>	8	11	16	10	2	2	8	9	30	5	4	3	14	8	1
<i>Poa compressa</i>			T	1	T						2	T	9	3	1
<i>Poa pratensis</i>	T						T			1	T	T	T	T	T
<i>Elymus repens</i>			1	2				T					T	T	

^ appeared to be affected by herbicide treatments

IV. LAKE MCDONALD – LEWIS DORM

A. BACKGROUND AND PURPOSE

The new Lewis Dorm in Lake McDonald village was completed in 2009 and is located approximately 40 meters southeast of the general store (Figure 7). Prior to construction, the building site was a wooded area of about 50% conifer cover, mainly western larch (*Larix occidentalis*) and western hemlock (*Tsuga heterophylla*). Several other conifers were present in the area, including western red-cedar (*Thuja plicata*), plus lesser amounts of deciduous trees closer to existing developed areas. A site analysis completed prior to construction, with details of the vegetation and forest composition, is described in the 2007 Revegetation Monitoring Report for further reference (Asebrook et. al. 2007).

Revegetation of the building site occurred in the spring of 2009, including seeding and the planting of nursery stock. This effort is being monitored with two methods: 1) three permanent, cover estimate plots and 2) three photo monitoring plots. All plots are adjacent to Lewis Dorm (Figure 7).

Also, three existing dorms (Jammer Dorm, Boys 1 and Boys 2) were moved from their original location near Snyder Creek to southwest of Lewis Dorm. These 3 dorms served as temporary housing for GPI employees until a second larger dorm was completed. Construction of this new dorm, similar in design to the Lewis Dorm, commenced in September 2010 and was completed in 2011. No native plant restoration was required following the construction of this new dorm.

Figure 7. Lake McDonald Dorm: Site and plot locations



B. METHODS

In the fall of 2009, three permanent level II monitoring plots were installed to monitor ocular estimates of canopy cover for all native and exotic species within the plot, as well as estimates of ground cover (Table 10). Photographs were taken of each plot (Figure 10). The three plots were chosen to depict three distinct revegetated areas on the north, south and west sides of the dorm. The first two plots, MD09-03 and MD09-04, were located in the areas that were seeded only. MD09-03 is located on the west side of the dorm alongside the sidewalk where soil had been brought in from outside the park prior to hydroseeding. MD09-04 is south of the Lewis Dorm in between the dorm and the temporary dorms. This site has local soil that was replaced after construction. The third plot, MD09-05, was located on the north side of the dorm where it was seeded and planted with nursery and salvage plants. Photomonitoring occurred in other revegetated areas that were not monitored with survey plots (Table 7), although these photos are not included in this report.

Table 7. Lake McDonald Dorm: Photomonitoring Plots at Lewis Dorm.

Site #	Facing	Description	Purpose
1	East	On North side of dorm next to grate in center of ditch facing East toward drain pipe.	To document planted vegetation. Two <i>Rubus parviflorus</i> , 3 <i>Cornus sericea</i> , patch of <i>Symphoricarpos albus</i> .
2	North	On E side of Dorm. 10 Paces S of gravel area for drain pipe in ditch facing <i>Cornus</i> (north).	To document planted <i>Cornus sericea</i> . 12 live plants present in 2009.
3	Northeast	Taken right at SE corner of building facing NE.	To document planted vegetation. <i>Betula papyrifera</i> and <i>Cornus sericea</i> .

The seed prescription used at the Lewis Dorm site is shown in Table 8. All areas that were disturbed during construction were hydro-seeded using a cultivar grass blend and a native forb, sedge and shrub mix sufficient for approximately 18,000 ft².

Approximately 500 plants were planted at the site in the spring of 2009. One hundred and thirty of these were salvaged before dorm construction and then replanted. The rest were containerized plants from the nursery (Table 9). Plants were only installed along the north and east sides of the dorm.

Table 8. Lake McDonald Dorm: Hydro-seed Prescription used for Lewis Dorm.

Shrubs	Wt.	Forbs	Wt.	Sedges	Wt.	Grass Cultivar Blend	Wt.
<i>Rosa sp.</i>	45g	<i>Anaphalis margaritacea</i>	10g	<i>Carex athrostachya</i>	384g	<i>Achnatherum hymenoides</i>	2lb
<i>Rubus parviflorus</i>	10g	<i>Antennaria sp.</i>	5g	<i>Carex pachystachya</i>	1.86lb	<i>Festuca occidentalis</i>	3lb
<i>Spirea betulifolia</i>	10g	<i>Aster sp.</i>	11g			<i>Elymus trachycaulus</i>	2lb
<i>Symphoricarpos albus</i>	205g	<i>Chamerion angustifolium</i>	10g			<i>Deschampsia caespitosa</i>	1lb
		<i>Geum macrophyllum</i>	10g				
		<i>Penstemon albertinus</i>	10g				
		<i>Penstemon confertus</i>	10g				

Blue denotes species included in 2007 recommended species list.

Seed weights are total amounts included in hydro-seed for an 18,000ft² area.

Table 9. Lake McDonald Dorm: Containerized Nursery Plants Planted around Lewis Dorm.

Trees	Shrubs	Forbs
<i>Betula papyrifera</i>	<i>Acer glabrum</i>	<i>Apocynum androsaemifolium</i>
<i>Tsuga heterophylla</i>	<i>Amelanchier alnifolia</i>	<i>Arnica cordifolia</i>
	<i>Arctostaphylos uva-ursi</i>	<i>Dryopteris filix-mas</i>
	<i>Mabonia repens</i>	<i>Fragaria virginiana</i>
	<i>Prunus virginiana</i>	<i>Geum macrophyllum</i>
	<i>Rubus parviflorus</i>	
	<i>Spiraea betulifolia</i>	

Blue denotes species included in 2007 recommended species list.

All plots were formally installed and monitored in 2009 when this area was planted. Plots were also monitored in 2010 at year one after planting and in 2011 at year two after planting. Due to time constraints, these plots were not monitored in 2012 at year three after planting.

All plots were monitored in 2014 at year five after planting. The decision was made, however, that this will be the last monitoring event for this revegetation area. As almost all of this area is now being mowed, this revegetation is serving less as a restoration area and more as a lawn. Valuable data to further our restoration program is not currently being collected, rendering this project ineffective to improving our knowledge about restoration techniques. It should also be noted that in 2014, only general assessments were made for species in each plot. Attempts were made to note all species that were observed within the plot and give them general cover values of low, scattered, common or dominant (Table 10). Comparison of 2014 data to previous years is only qualitative.

C. RESULTS

As of 2011, two years after planting, cover of plant material was substantial enough to prevent erosion and provide a significant amount of cover from native species (Figure 9). Overall vegetation cover had increased from 2009 to 2011 and, despite being mowed, native grasses clearly dominated the revegetation area (Figure 8), mostly as a result of seeded material. *Festuca occidentalis*, in particular, increased dramatically over time and dominated most revegetation areas. While tree and shrub cover remained low over time, native forb cover was moderate with many of the seeded forb species offering scattered or common cover. In terms of weed cover, exotic grass cover remained relatively low two years after planting. After initial invasions of ephemeral weed species, exotic forb cover actually decreased each year to a moderate cover of 5% to 10% (Figure 8). Overall, of the 32 species originally seeded, planted or salvaged in 2009, 23 were observed in 2010 and 22 were observed in 2011 (Table 10).

Qualitative data collected in 2014 continues to support the success of establishing native species in the areas around the Lewis Dorm. Overall, *Festuca occidentalis* still dominates all 3 plots, providing a majority of the cover. Seeded species *Elymus trachycaulus*, *Carex pachystachya*, and *Festuca idahoensis* (presumed seeded) are also providing secondary, common cover, while planted *Elymus glaucus* remains with low cover in the one area it was planted. Of the remaining seeded grasses, *Carex athrostachya* did not appear to germinate in any revegetation area, while a few *Deschampsia caespitosa* and *Achnatherum hymenoides* plants germinated and promptly died. *C. athrostachya* and *D. caespitosa* require wetter conditions and may not have been suitable species for this site.

Native forb cover in each of the planting areas has only been moderate, ranging from 2% to 4%, but 2014 data support the use of many seeded forb species for restoration. Species that have had success in other restoration projects, including *Anaphalis margaritacea*, *Antennaria bonellii*, *Geum macrophyllum*, *Penstemon confertus*, *Solidago canadensis*, and *Symphyotrichum laeve*, have established at this site as well, often with scattered cover. *P. confertus* and *S. canadensis*, in particular, have consistent cover throughout the project. Of the remaining seeded

Figure 8. Lake McDonald Dorm: % canopy cover by lifeform and plot, 2009-2011

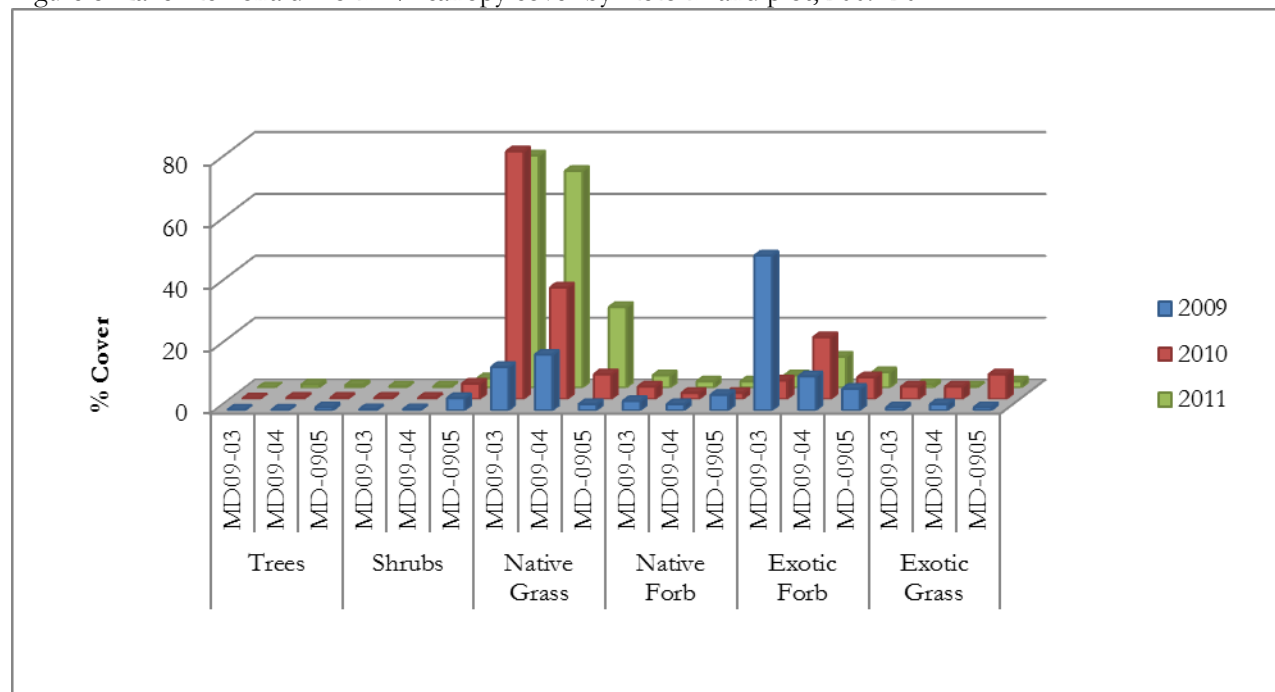
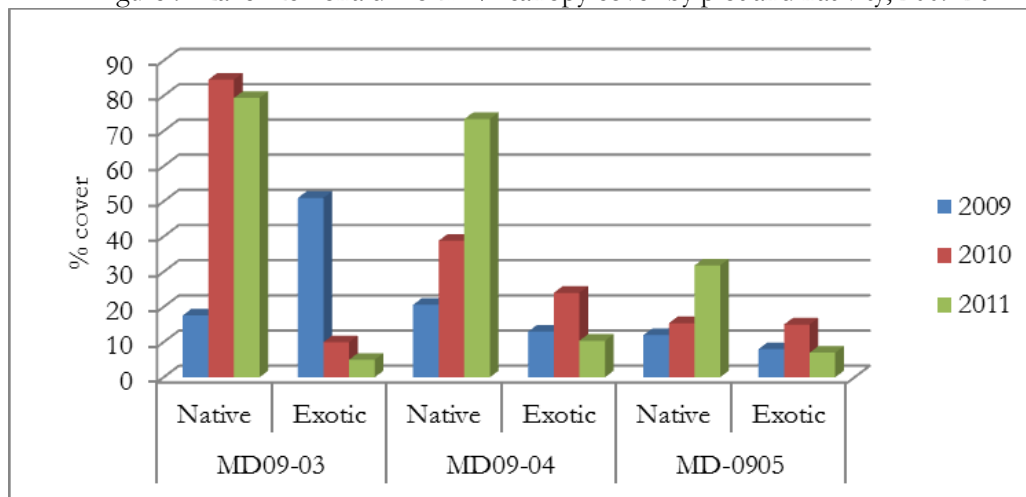


Figure 9. Lake McDonald Dorm: % canopy cover by plot and nativity, 2009-2011



forbs, *Tiarella trifoliata* did not appear to germinate in any revegetation area, while a few *Chamerion angustifolium* plants germinated and promptly died. Again, *T. trifoliata* requires wetter conditions. Planted species *Geum macrophyllum* and *Athyrium filix-femina* remain with low cover in the areas where they were planted.

Several species of shrubs were planted at this site, most specifically in plot MD-09-05. All of the shrubs species that were planted have survived with the exception of *Salix bebbiana* (Table 10). This species, however, as well as several *Cornus sericea* shrubs, were observed in swale areas outside of monitoring plots.

While native species dominate these revegetation areas, attention should continue in this area for a few species of noxious weeds that are present. *Centaurea biebersteinii* (spotted knapweed) and *Cirsium arvense* (Canada thistle) continue to have low to scattered cover in small areas and could easily be eradicated with control. *Hypericum perforatum* (St. Johnswort) was observed for the first time in 2014 in one small area and should be eradicated soon to prevent further spread. *Leucanthemum vulgare* (oxeye daisy) may be the hardest

noxious weed to control as it is commonly scattered throughout this area. While not a noxious weed, control efforts should also be considered for *Veronica officinalis*, a common weed in these areas that can be persistent and create mats of vegetation. Similarly, if possible, control efforts could reduce the low cover of a handful of exotic grasses. These include *Agrostis stolonifera*, *Bromus inermis*, *Dactylis glomerata*, *Elymus repens*, *Pbleum pratense*, and *Poa pratensis*. *A. stolonifera*, a rhizomatous grass, currently has scattered cover in all revegetation areas and poses the greatest threat for increase.

Finally, *Corydalis sempervirens*, after being observed in all 3 plots in 2009 and 2010 (Table 10), was no longer observed in any area in 2014. This species is almost exclusively found in burned areas following disturbance and is generally fire or disturbance dependent. The seeds were clearly in the seed bank in this area and germinated with the disturbance caused by the construction of the Lewis dorm. As *C. sempervirens* is a biennial, these plants were not expected to persist in the Lewis dorm area but should be noted for their past presence in regards to any future work, as they remain in the local seed bank. In the state of Montana, this plant has an S2 ranking meaning it is “at risk because of very limited or declining numbers, range, and/or habitat, making it vulnerable to global extinction or extirpation in the state”.

D. CONCLUSIONS AND RECOMMENDATIONS

For what this project aimed to achieve, restoration efforts at the Lake McDonald Lewis Dorm were a success. As stated above, cover of plant material was substantial enough to prevent erosion and provide a significant amount of cover from native species. Overall vegetation cover increased over time and, despite being mowed, native grasses clearly dominate the revegetation area, mostly as a result of seeded material. Native forb cover is moderate with a decent diversity of native forbs that are now present with scattered cover. Native shrubs and forbs were only planted in a few areas but they appear to have high survival.

Weed species are present but they are generally low. Management of this area should include control of noxious weeds, as well as minor control of exotic grasses and *Veronica officinalis*. No other planting needs to take place here.

2014 marks the last year that this project will be monitored with this chapter serving as the final report for this revegetation area. As almost all of this area is now being mowed as a lawn, further monitoring will not provide valuable data to improving our knowledge about restoration techniques.

If future ground disturbance should occur in this area, surveys should take place to assess if *Corydalis sempervirens* returns to this location.

Table 10. Lake McDonald Dorm: % canopy cover by species for each plot at Lewis Dorm, 2009-2014

Ground Cover		MD-09-03				MD-09-04				MD-09-05			
		2009	2010	2011	2014	2009	2010	2011	2014	2009	2010	2011	2014
Basal Veg		4	8	18		3	0.2	8		2	3	7	
Bare Ground		60	45	5		20	27	5		5	10	10	
Gravel		2	2	2		56	25	20		20	40	10	
Litter		34	45	75		20	35	64		66	40	62	
Moss		0	0	0		0	3	2	30	1	1	0.2	
Rock		0	0	0		1	2	1		5	5	10	
Wood		0	0	0		0	0	0		1	1	1	
Other		0	0.2	0.2		0	3	0		0	0	0	
Species	source												
Trees		0.2	0.2	0		0.2	0.4	1		1	0.4	0.8	
<i>Abies lasiocarpa</i>	regen						0.1	0.1	low				
<i>Betula papyrifera</i>	regen						0.1	0.1		0.5	0.2	0.2	
<i>Pinus contorta</i>	regen											0.2	
<i>Pinus monticola</i>	regen									0.2		0.2	
<i>Populus balsamifera</i>	regen	0.2	0.2			0.2	0.2	1	scattered	0.2	0.2	0.2	
Shrubs		0.4	0.4	0.4		0.4	0.4	0.4		4	5	3	
<i>Acer glabrum</i>	planted									0.2	0.2	0.2	low
<i>Amelanchier alnifolia</i>	planted									0.2	0.2	0.2	low
<i>Arctostaphylos uva-ursi</i>	planted									0.5	0.2	0.2	low
<i>Cornus sericea</i>	planted												
<i>Holodiscus discolor</i>	regen					0.2							
<i>Linnaea borealis</i>	planted									0.2	0.5	0.2	low
<i>Mahonia repens</i>	planted									0.5	0.5	0.2	low
<i>Prunus virginiana</i>	regen										0.2	0.2	
<i>Rosa sp.</i>	seeded			0.2									
<i>Rubus idaeus</i>	planted	0.2	0.2						low	0.5	0.5	0.2	
<i>Rubus idaeus</i>	regen					0.2	0.2	0.1		0.2			
<i>Rubus parviflorus</i>	regen							0.2					
<i>Salix bebbiana</i>	planted									0.2	0.2		
<i>Spirea betulifolia</i>	seeded										0.2	0.2	low
<i>Symphoricarpos albus</i>	planted									1	2	1	scattered
<i>Symphoricarpos albus</i>	seeded	0.2	0.2	0.2			0.2	0.1	low	0.2			
Native Forbs		3	4	4		2	2	2		5	2	2	
<i>Achillea millefolium</i>	regen	0.1	0.2	0.2			0.2	0.2	low				
<i>Athyrium filix-femina</i>	planted									1	0.2	0.2	
<i>Anaphalis margaritacea</i>	seeded	0.2	0.2	0.2	low	0.2	0.2	0.2	scattered	0.2			low
<i>Antennaria boveii</i>	seeded				low	0.2		0.2	scattered	0.2	0.2		low
<i>Apocynum androsaemifolium</i>	regen												low
<i>Aquilegia flavescens</i>	regen									0.2			
<i>Arnica cordifolia</i>	regen								low				
<i>Chamerion angustifolium</i>	seeded					0.2							
<i>Chimaphila umbellata</i>	regen									0.2			low
<i>Comiza canadensis</i>	regen	0.2											
<i>Corydalis sempervirens</i>	regen	0.2	0.2		none	0.2	0.2		none	0.7	0.2	0.2	none
<i>Fragaria vesca</i>	regen	0.1	0.2	0.2	low	0.2	0.2	0.2	low	0.2	0.2	0.2	low
<i>Galium triflorum</i>	regen					0.2							
<i>Geum macrophyllum</i>	seeded	0.1	0.2	0.2	low	0.2	0.2	0.2	low				
<i>Geum macrophyllum</i>	planted									0.1	0.2	0.2	low

Table 10 con'd. Lake McDonald Dorm: % canopy cover by species for each plot at Lewis Dorm, 2009-2014

Species	source	MD-09-03				MD-09-04				MD-09-05			
		2009	2010	2011	2014	2009	2010	2011	2014	2009	2010	2011	2014
Native Forbs con'd													
<i>Hieracium albiflorum</i>	regen								low	0.2	0.2	0.2	low
<i>Maianthemum stellatum</i>	regen						0.1		low	0.2	0.2	0.2	scattered
<i>Penstemon confertus</i>	seeded				low		0.1	0.2	scattered		0.2	0.2	scattered
<i>Polygonum douglasii</i>	regen												low
<i>Solidago canadensis</i>	seeded	2	3	3	common	0.2	0.2	0.2	scattered	0.2	0.2	0.2	scattered
<i>Symphyotrichum laeve</i>	seeded	0.2	0.2	0.2	scattered	0.2	0.2	0.2	low				low
<i>Tiarella trifoliata</i>	seeded												
<i>Viola orbiculata</i>	regen					0.2							
<i>Xerophyllum tenax</i>	salvage									0.5			
<i>Xerophyllum tenax</i>	regen/undisturbed						0.2	0.2		0.5	1	0.5	scattered
Native Grasses		14	80	75		18	36	70		2	8	26	
<i>Agrostis scabra</i>	regen	0.2				0.2	0.2						
<i>Carex athrostachya</i>	seeded												
<i>Carex concinnoides</i>	salvage?									0.2	0.2	0.2	scattered
<i>Carex pachystachya</i>	seeded	0.2	0.2	0.2	scattered			0.2	common				low
<i>Carex rossii</i>	regen									0.2	1	0.2	scattered
<i>Carex</i> spp.	seeded					0.5	0.2						
<i>Deschampsia caespitosa</i>	seeded		0.2	0.2			0.1	0.1					
<i>Elymus trachycaulus</i> v. <i>trachycaulus</i>	seeded	3	15	10		2.2	0.2	0.1		1	0.2	0.2	
<i>Elymus glaucus</i>	planted			0.2						0.2	0.2	0.2	
<i>Festuca occidentalis</i>	seeded	11	65	65	dominant	15	35	70	dominant	0.5	6	25	dominant
<i>Festuca idahoensis</i>	regen		0.2	0.2	common		0.2	0.1	common			0.2	low
<i>Poa palustris</i>	regen						0.1	0.1			0.2	0.2	
Exotic Forbs		50	6	4		11	20	10		7	7	5	
<i>Amaranthus</i> (flowers in axils)	regen	0.2											
<i>Arenaria serpyllifolia</i>	regen	0.5	0.2	0.2			0.2	0.2		0.2	0.2		
<i>Capsella bursa-pastoris</i>	regen	25		0.2		0.2	0.2	0.2		0.5	0.2	0.2	
<i>Centaurea biebersteinii</i>	regen							0.1		0.2	0.2	0.2	low
<i>Cerastium fontanum</i>	regen						0.2						
<i>Cirsium arvense</i>	regen		0.2	0.2	scattered		0.2	0.1					
<i>Cirsium vulgare</i>	regen								low	0.2	0.5		
<i>Digitalis?</i>	regen					0.2							
<i>Descurainia sophia</i>	regen	0.2											
<i>Erodium cicutarium</i>	regen	0.2	0.2										
<i>Filago arvensis</i>	regen	0.2	0.2	0.2		0.2	0.2	0.1	low	0.2			
<i>Hypericum perforatum</i>	regen								scattered				
<i>Leucanthemum vulgare</i>	regen	1.2	2	1	common	0.2	3	2+	common	1	1	0.2	low
<i>Lactuca serriola</i>	regen	0.2											
<i>Medicago lupulina</i>	regen	1.2	0.2	0.2	low	0.2	0.2	0.2	low	0.2	0.2	0.2	low
<i>Melilotus</i> spp.	regen		0.2			2							
<i>Plantago major</i>	regen	0.2			low			0.2		0.2	0.2	0.2	
<i>Polygonum aviculare</i>	regen	0.2								0.2			
<i>Polygonum convolvulus</i>	regen	2.7				0.1				0.2	0.2		
<i>Potentilla argentea</i>	regen								low	0.2	0.2	0.2	low
<i>Potentilla norvegica</i>	regen					0.1	0.2	0.2		0.2	0.2	0.2	

Table 10 con'd. Lake McDonald Dorm: % canopy cover by species for each plot at Lewis Dorm, 2009-2014

Species	source	MD-09-03				MD-09-04				MD-09-05			
		2009	2010	2011	2014	2009	2010	2011	2014	2009	2010	2011	2014
Exotic Forbs con'd													
<i>Prunella vulgaris</i>	regen					0.1							
<i>Rumex acetocella</i>	regen				common	0.5	0.2	0.2	low	0.7	2	0.2	scattered
<i>Silene latifolia</i>	regen	0.2								0.2	0.2		
<i>Sisymbrium altissimum</i>	regen	0.7											
<i>Taraxacum officinale</i>	regen	0.2	0.2	0.2	low		0.2						low
<i>Thlaspi arvense</i>	regen	16		0.2			0.2			0.2			
<i>Tragopogon dubius</i>	regen		0.2										
<i>Trifolium agrarium</i>	regen			0.2	low		2	2	scattered	0.5	0.5	2	scattered
<i>Trifolium hybridum</i>	regen					0.5	0.2			0.5	0.2		
<i>Trifolium pratense</i>	regen	0.2											
<i>Trifolium spp.</i>	regen	0.2	0.2										
<i>Verbascum thapsus</i>	regen	0.5	1	0.2	low	1	0.2	0.2	low	1	0.5	0.2	
<i>Veronica officinalis</i>	regen	0.2	1	1	low	6	13	4	scattered	0.7	2	1	scattered
<i>Veronica serpyllifolia</i>	regen					0.2							
Exotic Grasses		1	4	1		2	4	0.4		1	8	2	
<i>Achnatherum hymenoides</i>	seeded?	0.2				1				0.2			
<i>Agrostis stolonifera</i>	regen		2	0.2	scattered		3	0.2	scattered		4	1	
<i>Avena sativa</i>	regen	0.2				0.2							
<i>Bromus inermis</i>	salvage		1	1						0.5	1	0.2	low
<i>Dactylis glomerata</i>	regen	0.2	0.2	0.2	low		0.2						
<i>Elymus repens</i>	salvage		0.2		low		0.2	0.1		0.2	1	0.2	low
<i>Lolium multiflorum</i>	regen					0.2							
<i>Poa compressa</i>	regen						0.2				0.2		
<i>Phleum pratense</i>	regen	0.2	0.2			0.2					1	0.2	low
<i>Poa pratensis</i>	regen	0.2	0.2		scattered	0.2				0.2		0.2	low
"Regreen"	seeded?						0.2	0.1					
<i>Setaria glauca</i>	regen					0.2							

Figure 10. Photopoints of Lake McDonald dorm revegetation areas, 2009-2014



Plot MD-09-03 in 2009



Plot MD-09-03 in 2010



Plot MD-09-03 in 2011



Plot MD-09-03 in 2014



Plot MD-09-04 in 2009



Plot MD-09-04 in 2010



Plot MD-09-04 in 2011



Plot MD-09-04 in 2014



Plot MD-09-05 in 2009



Plot MD-09-05 in 2010



Plot MD-09-05 in 2011



Plot MD-09-05 in 2014

V. GOING-TO-THE-SUN ROAD: PHASE VIIA MONITORING

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 VIIa of the project, including the roadside from Logan Pit to the West Tunnel, began in 2010 and continued into 2011. Construction during this phase included installation of retaining walls, culverts and drains, as well as base stabilization and new paving of the road. Additionally, turnouts in Phase VIIa were either rebuilt or newly constructed providing visitors with good pullouts at several key scenic vista points. Elevation for this phase of the GTSR Rehabilitation Project ranges from approximately 3,550 to 4,130 feet.

Dominant vegetation within the project area consists of *Populus balsamifera*, *Cornus sericea*, *Acer glabrum*, *Maianthemum stellatum*, and *Fragaria vesca*. This project is located in a mid-mountain slope where soils are relatively shallow, gravelly loam. The area has been greatly impacted by construction and there is the potential for future disturbance at these turnouts from visitors. Non-native invasive plants are scattered throughout the area.

A species list was created for this segment of road in 2007 which directed seed collection. Disturbance created from construction of this phase, estimated at 3,995 ft², was revegetated in 2011 and 2012. The restoration goal is to blend the existing vegetation around these turnouts with the new plantings. Restoration objectives aim:

- To install plant materials to blend the disturbance into the adjacent undisturbed area.
- To provide soil stabilization and cover to the disturbed soil to 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 2011, 1,335 forbs, shrubs, trees, sedges and grasses were planted in five turnouts between the West Tunnel and Logan Creek (Table 11). 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 just above the Packer's Roost road and is most likely used as a slow vehicle turnout not a scenic vista turnout and it is unlikely to get trampled. Apex, a slow release fertilizer was added to amend the native soil in the planting hole. Plants were watered with a Vitamin B1/ water mix. After watering, the plants were sprayed with Wiltpruf which coats the needles and leaves diminishing desiccation from wind and sun. All of the turnouts, including three additional small turnouts for a total of eight planting areas, were seeded focusing on the edges of the plantings especially toward the roadside (Table 12).

In 2012, two turnouts were planted with supplemental material (Table 11) to increase vegetation cover. A total of 361 forbs, shrubs, trees, sedges and grasses were planted at the Lower Grizzly and Bird Woman Falls overlook turnouts. Lower Grizzly turnout is where a large avalanche swept across the road in 2010. The upper portion of this turnout was heavily planted in 2011 but the lower portion was only hydroseeded. To increase vegetation in this lower portion, 732 ft² were planted behind and in between the large boulders. To increase vegetation at the Bird Woman Falls turnout, an additional 180 ft² were planted here. A slow release fertilizer was added to amend the native soil in the planting hole. Plants were watered with a Vitamin B1/ water mix and sprayed with Wiltpruf. In both locations, *Leucanthemum vulgare*, *Verbascum thapsus*, and *Centaurea stoebe* were pulled and bagged.

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, 6 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 2012, 2013, and 2014 at years 1, 2 and 3 after replanting (Figure 11). Notes on species were made in 2013 and 2014.

Table 11. Plant material planted within turnouts on GTSR – Phase VIIa

Species	Container	# planted 2011	# planted 2012
<i>Alnus viridis</i>	cones	8	
<i>Amelanchier alnifolia</i>	cones	38	
<i>Anaphalis margaritacea</i>	cones	70	40
<i>Antennaria</i> spp.	cones	19	37
<i>Antennaria umbrinella</i>	cones	39	
<i>Arctostaphylos uva-ursi</i>	4" pots	53	
<i>Arnica</i> spp.	cones	43	
<i>Betula papyrifera</i>	1 gal	11	
<i>Carex athrostachya</i>	cones	94	
<i>Carex deweyana</i>	cones	97	
<i>Carex pachystachya</i>	cones	79	
<i>Carex rossii</i>	cones	16	
<i>Carex</i> spp.	cones		40
<i>Eurybia conspicua</i>	cones	69	30
<i>Fragaria</i> spp.	dynaflat	1	
<i>Fragaria vesca</i>	dynaflat	1	
<i>Fragaria virginiana</i>	dynaflat	2	
<i>Fragaria virginiana</i>	4" pots	13	
<i>Galium boreale</i>	cones	14	
<i>Geum macrophyllum</i>	cones	45	22
<i>Holodiscus discolor</i>	cones	15	10
<i>Iliamna rivularis</i>	1 gal	2	
<i>Iliamna rivularis</i>	cones		8
<i>Lonicera utahensis</i>	cones	19	
<i>Maianthemum stellatum</i>	1 gal	16	20
<i>Paxistima myrsinites</i>	4" pots	27	
<i>Penstemon confertus</i>	cones	121	48
<i>Penstemon hyallii</i>	cones	58	15
<i>Philadelphus lewisii</i>	1 gal	34	
<i>Rosa woodsii</i>	cones		26
<i>Rosa woodsii</i>	D cells	97	
<i>Rubus idaeus</i>	1 gal	3	
<i>Rubus parviflorus</i>	1 gal	4	
<i>Rubus parviflorus</i>	cones	82	15
<i>Sambucus racemosa</i>	1 gal	1	
<i>Symphotrichum leave</i>	cones	65	30
<i>Symphoricarpos albus</i>	1 gal	79	20
TOTAL PLANTS		1335	361

Table 12. Seeded species list within turnouts on GTSR – Phase VIIa

Species	seeds/ft ²	grams
FORBS	38.15	1867.17
<i>Achillea millefolium</i>	5	99.1
<i>Adenocaulon bicolor</i>	0.24	34.96
<i>Anaphalis margaritacea</i>	5	33
<i>Chamerion angustifolium</i>	5	40
<i>Eurybia conspicua</i>	6	643.64
<i>Fragaria vesca/virginiana</i>	0.1	7.3
<i>Geum macrophyllum</i>	5	538.11
<i>Heuchera cylindrica</i>	1.49	19.88
<i>Monarda fistulosa</i>	0.08	5
<i>Osmorhiza berteroi/occidentalis</i>	0.24	93.51
<i>Solidago canadensis</i>	5	67.14
<i>Symphytotrichum laeve</i>	5	285.53
GRASSES	54	19622.32
<i>Bromus carinatus</i>	1.44	923.48
<i>Calamagrostis canadensis</i>	0.15	3
<i>Carex microptera</i>	5.49	529.41
<i>Carex pachystachya</i>	12.1	1124.43
<i>Carex rossii</i>	?	97
<i>Elymus glaucus</i>	1.97	1195
<i>Elymus trachycaulus</i>	25	14107
<i>Festuca occidentalis</i>	7	1643

C. RESULTS AND RECOMMENDATIONS

Turnouts 3, 4, and 5 were revegetated with plant material and seed. A longer species list and species observations were recorded for these areas. Turnouts 1, 2, 6, 7, and 8 were only seeded. Only a few observation notes were recorded for these areas.

Turnout 1

Turnout 1 does not appear to have any planted material but had distinct patches of *Elymus trachycaulus* and low cover of *Symphytotrichum laeve*, *Solidago canadensis*, and *Achillea millefolium*, indicating that it had been seeded. The *E. trachycaulus* looks good, although weed cover is high here. Exotic species present with notable cover include non-native grasses (*Agrostis stolonifera*, *Pbleum pratense*, *Poa pratensis*, *Dactylis glomerata*), *Verbascum thapsus*, *Melilotus officinale* and *M. alba*. Lower cover of *Lactuca serriola*, *Plantago major*, and *Silene cucubalis* was noted, along with low cover of noxious weeds *Hypericum officinale* and *Leucanthemum vulgare*. Noxious weed *Cynoglossum officinale*, observed in 2013, was not seen in 2014. No photopoints were taken at this turnout.

Turnout 2

Turnout 2 appears to have a small number of planted shrubs. These appear to be doing fine. Otherwise, this turnout is quite weedy, dominated by *Melilotus alba* and *Poa pratensis*. No photopoints were taken at this turnout.

Turnout 3

Turnout 3 appears to be increasing in weed cover since 2013. The turnout was planted and seeded but still could use additional plant material. Currently, this area seems weedier than the other planted turnouts. Weeding should be scheduled for this area to remove non-native grasses, sweetclovers, clovers, and noxious weeds, including oxeye daisy, spotted knapweed, houndstongue, Canada thistle, and St. Johnswort, several of which are new this year. All native plants listed below would be appropriate for additional planting. Two photopoints were taken at this location.

Table 13. GTSR Phase VIIa: Species Present at Turnout 3

Native Species Present	Notes 2013	Notes 2014
NATIVE SHRUBS & TREES		
<i>Arctostaphylos uva-ursi</i>	Looks good	Looks good
<i>Holodiscus discolor</i>	Low cover	Low cover
<i>Symphoricarpos albus</i>	Looks good	Looks good
<i>Rosa woodsii</i>	Low cover	Low cover
<i>Betula papyrifera</i>	X	Low cover
NATIVE FORBS		
<i>Achillea millefolium</i>	Low cover	Low cover
<i>Anaphalis margaritacea</i>	Low cover	Looks good
<i>Geum macrophyllum</i>	X	Low cover
<i>Symphyotrichum laeve</i>	Looks good	Looks good
<i>Penstemon confertus</i>	Looks good	Looks good
<i>Fragaria virginiana</i>	Looks good	Looks good
<i>Fragaria vesca</i>	X	Low cover
<i>Penstemon hyallii</i>	Low cover	Low cover
<i>Solidago canadensis</i>	Looks good	Looks good
NATIVE GRASSES		
<i>Elymus trachycaulus</i>	Looks great	Looks great - dominant
<i>Carex spp.</i> (planted)	Looks good	Looks good
<i>Elymus glaucus</i>	X	Low cover
<i>Bromus carinatus</i>	X	Low cover
Exotic Species Present		
EXOTIC FORBS		
<i>Melilotus officinale</i>	Moderate cover	patchy
<i>Melilotus alba</i>	Low cover	Low cover
<i>Leucanthemum vulgare</i>	Low cover - pulled	Moderate cover – not pulled
<i>Plantago major</i>	Low cover	Moderate cover
<i>Verbascum thapsus</i>	Low cover	Low cover
<i>Silene cucubalis</i>	Low cover	Low cover
<i>Plantago lanceolata</i>	Low cover	X
<i>Lactuca serriola</i>	Low cover	X
<i>Trifolium agrarium</i>	Low cover	Low cover
<i>Trifolium pratense</i>	Low cover	Low cover
<i>Rumex crispus</i>	Low cover	X
<i>Centaurea maculosa</i>	X	Low cover - pulled
<i>Medicago lupulina</i>	X	patchy
<i>Cynoglossum officinale</i>	X	Low cover – not pulled

EXOTIC FORBS, con'd	Notes 2013	Notes 2014
<i>Veronica officinalis</i>	X	Low cover
<i>Prunella vulgaris</i>	X	patchy
<i>Cirsium arvense</i>	X	Low cover – not pulled
<i>Hypericum perforatum</i>	X	One patch - not pulled
<i>Potentilla norvegica</i>	X	Low cover
EXOTIC GRASSES		
<i>Phleum pratense</i>	Low cover	Low cover
<i>Agrostis stolonifera</i>	patches	patchy
<i>Bromus inermis</i>	Low cover	X
<i>Elymus repens</i>	Low cover	Low cover
<i>Dactylis glomerata</i>	Low cover	Low cover
<i>Poa pratensis</i>	Low cover	Low cover

Turnout 4

Turnout 4 was both planted and seeded. In general, this turnout looks good with a fair diversity of native species that are doing well. Weeding should continue in this area to reduce, if not remove, the low amounts of exotic species at this turnout, particularly the noxious weeds. While this turnout looks the best of all the planting area, this area could still use a few more plants. Two photopoints were taken at this location.

Table 14. GTSR Phase VIIa: Species Present at Turnout 4

Native Species Present	Notes 2013	Notes 2014
NATIVE SHRUBS		
<i>Symphoricarpos albus</i>	Looks great	Looks great
<i>Alnus viridis</i>	Looks good	Looks good
<i>Cornus sericeus</i>	Looks good	Looks good
<i>Rosa woodsii</i>	Looks good	Looks good
<i>Paxistima myrsinites</i>	Looks good	Looks OK
<i>Rubus parviflorus</i>	Looks good	Some good/some weak
<i>Holodiscus discolor</i>	X	Looks good
NATIVE FORBS		
<i>Anaphalis margaritacea</i>	Looks great	Looks good
<i>Symphyotrichum laeve</i>	Looks good	Looks good
<i>Eurybia conspicua</i>	Looks good	Looks good
<i>Penstemon confertus</i>	Looks good	Looks very good
<i>Geum macrophyllum</i>	Looks good	Looks good
<i>Fragaria virginiana</i>	Looks good	Looks good
<i>Fragaria vesca</i>	Looks good	Looks good
<i>Anemone multifida</i>	X	Low cover
<i>Monarda fistulosa</i>	X	Low cover
<i>Collomia linearis</i>	X	Low cover
<i>Senecio pseudolaureus</i>	X	Low cover – coming in from forest
NATIVE GRASSES		
<i>Elymus trachycaulus</i>	Looks great	Looks great
<i>Carex spp. (pachystachya, deweyana, athrostachya, rossii)</i>	Looks good	Looks good
<i>Bromus carinatus</i>	X	Low cover
<i>Elymus glaucus</i>	X	Low cover

Exotic Species Present	Notes 2013	Notes 2014
EXOTIC FORBS		
<i>Medicago lupulina</i>	Low cover	Low cover
<i>Leucanthemum vulgare</i>	Low cover - pulled	Low cover - pulled
<i>Prunella vulgaris</i>	Low cover	Moderate cover
<i>Plantago major</i>	Low cover	Low cover
<i>Verbascum thapsus</i>	Low cover	Low cover
<i>Silene cucubalis</i>	Low cover	Low cover
<i>Centaurea maculosa</i>	Low cover - pulled	Low cover - pulled
<i>Cynoglossum officinale</i>	X	Low cover – tried to pull
<i>Plantago lanceolata</i>	X	Low cover
<i>Cerastium fontanum</i>	X	Low cover
<i>Rumex crispus</i>	X	Low cover
<i>Trifolium repens</i>	X	Moderately patchy @ road edge
<i>Taraxacum officinale</i>	X	Low cover
<i>Veronica serpyllifolia</i>	X	Low cover
<i>Melilotus officinale</i>	X	Low cover
<i>Trifolium pratense</i>	X	Low cover @ road edge
EXOTIC GRASSES		
<i>Phleum pratense</i>	Low plus cover	Low plus cover
<i>Agrostis stolonifera</i>	Low @ road edges	Moderate @ road edges
<i>Poa pratensis</i>	X	Low cover
<i>Poa compressa</i>	X	Low cover
<i>Dactylis glomerata</i>	X	Low cover

Turnout 5

Turnout 5 was also both planted and seeded. Overall, this turnout has a bit less cover and appears to need a few more plants. The downhill portion of the turnout looks a bit better than the uphill portions. All native plants listed below would be appropriate for additional planting. All seeded material other than *Elymus trachycaulus* does not appear to be germinating well here so planted material should be used instead of seed. Similar to Turnout 4, weeding should continue in this area to reduce, if not remove, the low amounts of exotic species at this turnout, particularly the noxious weeds. Two photopoints were taken at this location.

Table 15. GTSR Phase VIIa: Species Present at Turnout 5

Native Species Present	Notes 2013	Notes 2014
NATIVE SHRUBS AND TREES		
<i>Symphoricarpos albus</i>	Looks great	Looks great
<i>Rosa woodsii</i>	Looks ok	Looks good
<i>Crataegus douglasii</i>	Looks good	Looks good
<i>Holodiscus discolor</i>	Looks good	Looks good
<i>Arctostaphylos uva-ursi</i>	Looks good – low cover	Looks good – low cover
<i>Populus balsamifera</i>	X	Low cover
<i>Betula papyrifera</i>	X	Low cover
<i>Acer glabrum</i>	X	Patchy cover
<i>Cornus sericea</i>	X	Looks good
<i>Amelanchier alnifolia</i>	X	Low cover
NATIVE FORBS		
<i>Anaphalis margaritacea</i>	Looks ok	Looks good

NATIVE FORBS CON'D	Notes 2013	Notes 2014
<i>Achillea millefolium</i>	Looks good – low cover	Looks good – low cover
<i>Symphytotrichum laeve</i>	Looks good – low cover	Looks good – low cover
<i>Penstemon confertus</i>	Looks good	Looks good
<i>Geum macrophyllum</i>	Looks good	Looks good
<i>Iliamna rivularis</i>	Looks good	Low cover
<i>Fragaria vesca</i>	X	Low cover
<i>Fragaria virginiana</i>	X	Low cover
<i>Antennaria howellia</i>	X	Looks good
<i>Arnica cordifolia</i>	X	Low cover
<i>Eurybia conspicua</i>	X	Low cover
<i>Maianthemum stellatum</i> (natural regen)	X	Low cover
<i>Solidago canadensis</i> (natural regen)	X	Low cover
NATIVE GRASSES		
<i>Elymus trachycaulus</i>	Looks great	
<i>Carex pachystachya</i>	Looks ok	
Exotic Species Present	Notes 2013	Notes 2014
EXOTIC FORBS		
<i>Trifolium agrarium</i>	Low cover	Low cover - scattered
<i>Leucanthemum vulgare</i>	Low cover - pulled	Low cover – pulled one
<i>Prunella vulgaris</i>	Low cover	Low cover
<i>Plantago major</i>	Low cover	Low cover
<i>Verbascum thapsus</i>	Low cover	Low cover
<i>Silene cucubalis</i>	Low cover	Low cover
<i>Centaurea maculosa</i>	Low cover	Low cover - pulled
<i>Cirsium arvense</i>	Low cover	X
<i>Veronica serpyllifolia</i>	Low cover	Low cover - scattered
<i>Cerastium fontanum</i>	Low cover	Low cover - scattered
<i>Chenopodium album</i>	X	Low cover @ road edges
<i>Linaria vulgaris</i>	X	Low cover - pulled
EXOTIC GRASSES		
<i>Phleum pratense</i>	Low @ road edges	Low cover @ road edges
<i>Agrostis stolonifera</i>	Patchy @ upper road	Patchy @ upper road
<i>Poa pratensis</i>	Low cover	Low cover - scattered
<i>Dactylis glomerata</i>	X	Low cover

Turnout 6 (east side of road)

Turnout 6 is a wet little turnout that appears to be only seeded. While there is moderate cover of native grasses *Bromus carinatus*, *Elymus glaucus*, *Carex* spp., and *Elymus trachycaulus* and low cover of *Geum macrophyllum*, *Equisetum arvense*, *Urtica dioica*, *Rubus parviflorus*, and *Mentha arvensis*, this area is dominated by non-native grasses. These include *Agrostis stolonifera*, *Phleum pratense*, *Poa pratensis*, *Elymus repens* and *Dactylis glomerata*. In addition to a patch of *Linaria vulgaris* (noxious weed), other exotic species present here with low cover include *Phalaris arundinacea*, *Bromus inermis*, *Poa annua* (on road edges), *Plantago major*, *Silene cucubalis*, *Veronica serpyllifolia*, and *Prunella vulgaris*. We did not pull any *Linaria vulgaris* during the site visit. No photopoints were taken at this turnout.

Turnout 7 (east side of road with paved sidewalk; near bridge)

Turnout 7 appears to have been seeded. Observations were made of moderate cover of *Elymus trachycaulus* and low cover of *Elymus glaucus*. There is high cover of *Equisetum arvense*, a native forb that is naturally

regenerating at this turnout. Like certain turnouts, non-native grasses dominate the vegetation here. These include *Phleum pratense* and *Poa pratensis*. High cover of *Prunella vulgaris* and low cover of *Plantago lanceolata*, both exotic forbs, were also observed here. No photopoints were taken at this turnout.

Turnout 8 (close to creek)

Turnout 8 appears to have been seeded. Observations were made of low cover of *Elymus trachycaulus*, as well as low cover of seeded forbs *Geum macrophyllum*, *Symphyotrichum laeve*, *Achillea millefolium*, and *Solidago canadensis*. *Senecio pseud aureus* and *Heracleum maximum*, both naturally regenerating native forbs, were also observed with low cover. In general, this area remains dominated by non-native plants. These include dominant cover by *Dactylis glomerata*, *Phleum pratense*, and *Poa pratensis*, as well as patchy or low cover from non-native species *Agrostis stolonifera*, *Elymus repens*, *Bromus inermis*, *Festuca arundinacea*, *Plantago major*, *Silene cucubalis*, and noxious weeds *Hypericum perforatum* and *Leucanthemum vulgare*. No photopoints were taken at this turnout.

Figure 11. Photopoints on GTSR Phase VIIa: 2012-2014



Turnout 3. Uproad – 2012



Turnout 3. Uproad – 2013



Turnout 3. Uproad - 2014



Turnout 3. Downroad – 2012



Turnout 3. Downroad – 2013



Turnout 3. Downroad - 2014



Turnout 4. Uproad – 2012



Turnout 4. Uproad – 2013



Turnout 4. Uproad - 2014



Turnout 4. Downroad – 2012



Turnout 4. Downroad – 2013



Turnout 4. Downroad - 2014



Turnout 5. Uproad – 2012



Turnout 5. Uproad – 2013



Turnout 5. Uproad - 2014



Turnout 5. Downroad – 2012



Turnout 5. Downroad – 2013



Turnout 5. Downroad - 2014

VI. GOING-TO-THE-SUN ROAD: PHASE XI (LUNCH CREEK) MONITORING

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 XI of the project, including the roadside from Logan Pass to Siyeh Bend, began in 2010 and continued into 2011. Construction during this phase included base stabilization of the road, new pavement, improved turnouts, and upgraded culverts and drains. Additionally, an accessible walkway was constructed on the south side of the road and a trail was installed to the north of the road. Ground along these trails was disturbed. Elevation for this phase of the GTSR Rehabilitation Project ranges from 6,400 to 6,650 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 September 2011. Within the estimated 1, 018 ft² of disturbance, 734 forbs, shrubs, trees, sedges and grasses were planted in the areas of bare ground created by the construction of the walkway to Lunch Creek on both sides of the road (Table 16). Large pieces of salvage were piled in the parking area and some of this was planted into the disturbance. To the west of the creek, a social trail was planted and blocked off since there is now a turnout above the creek and this trail may be a tempting place to walk. Apex, a slow release fertilizer, was added to amend the native soil in the planting hole. Plants were watered with a Vitamin B1/ water mix. After watering, the plants were sprayed with Wiltpruf which coats the needles to minimize desiccation from wind and sun.

Table 16. Species planted at GTSR Phase XI: Lunch Creek

Species	Container	# planted
<i>Abies lasiocarpa</i>	Cones	7
<i>Achillea millefolium</i>	Cones	117
<i>Anaphalis margaritacea</i>	Cones	3
<i>Antennaria media</i>	Cones	26
<i>Arnica cordifolia</i>	Cones	2
<i>Arnica sp.</i>	Cones	84
<i>Carex microptera</i>	Cones	22
<i>Carex mix</i>	Cones	11
<i>Dasiphora floribunda</i>	Gallon	100
<i>Fragaria spp.</i>	4" pot	59
<i>Lonicera involucrata</i>	Cones	36
<i>Penstemon albertinus</i>	Cones	26
<i>Phleum alpinum</i>	Cones	81
<i>Poa alpina</i>	Cones	41
<i>Pseudoroegneria spicata</i>	Cones	30
<i>Ribes lacustre</i>	Cones	2
<i>Ribes lacustre</i>	Cones	21
<i>Salix commutata</i>	Gallon	7
<i>Sorbus scopulina</i>	Cones	4
<i>Spiraea splendens</i>	Gallon	55
Total Plants		734

B. METHODS

Given the small area of revegetation at this site, no formal monitoring plots were established for this project. Instead, 4 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 2012, 2013, and 2014 at years 1, 2, and 3 after replanting (Figure 12). Notes on species were made in 2013 and 2014.

C. RESULTS AND CONCLUSIONS

1. Area 1: thin strip along walkway (south of road)

Area 1 was planted. In general, cover for this planted strip is very high and overall looks good, blending in with surrounding vegetation at year 3 after planting. One small patch of *Cirsium arvense* is present in this planting area and should be removed. Due to its low cover, *Poa pratensis* should also be pulled in this area. No additional plants are needed for this planting area.

An interpretive sign was installed within this revegetation area during the past year (see photos in Figure 12). Clearly plants were removed to install this sign but it appears that the installation had no overall negative impact on the revegetation efforts. All plants except *Juncus drummondii* were re-located and 4 additional native species were observed in the planting area this year.

Table 17. GTSR Phase XI: Species Present in Planting Area 1

Native Species Present	Notes 2013	Notes 2014
NATIVE SHRUBS		
<i>Dasiphora floribunda</i>	Looks good	Looks good
<i>Spiraea betulifolia</i>	Looks good	Looks good
<i>Ribes lacustre</i>	Low cover	Low cover
<i>Lonicera involucrata</i>	X	Low cover
NATIVE FORBS		
<i>Achillea millefolium</i>	Looks good	Looks good
<i>Fragaria virginiana</i>	Looks good	Low cover
<i>Fragaria vesca</i>	Looks good	Looks good
<i>Penstemon confertus</i>	Low cover	Low cover
<i>Arnica diversifolia</i>	Low cover	Low cover
<i>Aquilegia flavescens</i>	Low cover	Looks good
<i>Chamerion angustifolium</i>	Low cover	Low cover
<i>Penstemon albertinus</i>	X	Low cover
<i>Antennaria</i> spp.	X	Low cover
<i>Thalictrum occidentale</i>	X	Low cover
NATIVE GRASSES		
<i>Bromus carinatus</i>	Looks good	Looks good
<i>Elymus glaucus</i>	Looks good	Looks good
<i>Juncus drummondii</i>	Looks good	X
<i>Carex</i> spp. (<i>athrostachya</i> , others)	Low cover	Low cover
Exotic Species Present		
EXOTIC FORBS		
<i>Cirsium arvense</i>	Large patch	Small patch (8 plants)
<i>Stellaria</i> spp.	Low cover	Low cover
<i>Taraxacum officinale</i>	X	Low cover – 1 plant
EXOTIC GRASSES		
<i>Poa pratensis</i>	Low cover	Low cover

2. Area 2: Slope at bottom of walkway (south of road)

Area 2 was also planted. Generally, the photos from 2012 to 2014 illustrate that cover is indeed increasing on this slope. Overall cover, however, remains moderate and this area could be planted with additional plant material. Shrubs and sedges appear to be doing the best.

With low cover of *Cirsium arvense*, this species should be pulled. The other groundcover weeds are likely ephemeral and will decrease on their own over time.

Table 18. GTSR Phase XI: Species Present in Planting Area 2

Native Species Present	Notes 2013	Notes 2014
NATIVE SHRUBS		
<i>Dasiphora floribunda</i>	Looks great	Looks great
<i>Spiraea betulifolia</i>	Looks great	Looks great
<i>Ribes lacustre</i>	Low cover	Low cover
<i>Lonicera involucrata</i>	Low cover	Low cover
NATIVE FORBS		
<i>Achillea millefolium</i>	Looks great	Looks good
<i>Arnica cordifolia</i>	Looks good	Looks great
<i>Penstemon albertinus</i>	Low cover	Looks great
<i>Minnuartia rossii</i>	Low cover	Low cover
<i>Cirsium hookerianum</i>	Low cover	Low cover
<i>Antennaria media</i>	Low cover	Low cover
<i>Penstemon confertus</i>	Low cover	Many dying/uprooted
<i>Draba</i> spp.	Low cover	X
<i>Artemisia michauxiana</i>	Low cover	X
<i>Aquilegia flavescens</i>	Low cover	Looks good
transplanted <i>Xerophyllum tenax</i>	Looks ok	Looks ok
<i>Epilobium</i> spp.	X	Low cover
<i>Fragaria vesca</i>	X	Low cover
<i>Anaphalis margaritacea</i>	X	Low cover
<i>Castilleja miniata</i>	X	Low cover
<i>Chamerion angustifolium</i>	X	Low cover
<i>Penstemon ellipticus</i>	X	Low cover – on edges
<i>Valeriana sitchensis</i>	X	Low cover
<i>Polygonum douglasii</i>	X	Low cover
NATIVE GRASSES		
<i>Carex</i> spp.	Looks great	Looks great
<i>Trisetum spicatum</i>	Looks good	Low cover
<i>Elymus trachycaulus</i>	Low cover	Low cover
<i>Elymus glaucus</i>	Looks good	Looks good
<i>Bromus carinatus</i>	Low cover	Low cover
<i>Phleum alpinum</i>	Low cover	Low cover
Exotic Species Present	Notes 2013	Notes 2014
EXOTIC FORBS		
<i>Cirsium arvense</i>	Low cover	Low cover
<i>Stellaria</i> spp.	Low cover - pulled	Low cover
<i>Veronica arvensis</i>	Low cover	Low cover
<i>Trifolium</i> spp.	X	Low cover – 1 plant

3. Area 3: Area along trail (north of road)

Area 3 was also planted. Overall vegetative cover is very low in this planting area, due likely to visitors walking through the revegetation site. A diverse array of species is present but each has very low cover, exposing a high amount of bare ground. This area should be replanted, particularly with containerized material for quick cover. Temporary barriers should also be installed until the plants get established. Shrubs, several species of forbs, and sedges are all doing well and should be used as supplementary restoration species. With such low cover, attempts should be made to pull all weedy species.

Table 19. GTSR Phase XI: Species Present in Planting Area 3

Native Species Present	Notes 2013	Notes 2014
NATIVE SHRUBS		
<i>Dasiphora floribunda</i>	Looks good	Low cover – looks fairly good
<i>Spiraea betulifolia</i>	Looks good	Looks good
<i>Lonicera involucrata</i>	Looks good	Low cover - looks fair
NATIVE FORBS		
<i>Achillea millefolium</i>	Looks good	Low cover
<i>Arnica diversifolia</i>	Looks good	Looks good
<i>Penstemon confertus</i>	Looks good	Low cover – 1 plant
<i>Fragaria vesca</i>	Low cover	Low cover
<i>Symphyotrichum laeve</i>	Low cover	Low cover
<i>Epilobium</i> spp.	X	Low cover
<i>Cirsium hookerianum</i>	X	Low cover
<i>Agoseris aurantiaca</i>	X	Low cover
<i>Senecio triangularis</i>	X	Low cover
<i>Allium schoenoprasum</i>	X	Low cover
<i>Phacelia hastata</i>	X	Low cover
<i>Minuartia rossii</i>	X	Low cover
NATIVE GRASSES		
<i>Carex</i> spp.	Looks good	Looks good
<i>Elymus glaucus</i>	Low cover	Low cover
<i>Elymus trachycaulus</i>	Low cover	Low cover
<i>Poa alpina</i>	Low cover	X
<i>Poa secunda</i>	Low cover	Low cover
<i>Agrostis scabra</i>	Low cover	Low cover
<i>Phleum alpinum</i>	Low cover	Low cover
<i>Bromus carinatus</i>	X	Low cover
Exotic Species Present	Notes 2013	Notes 2014
EXOTIC FORBS		
<i>Taraxacum officinale</i>	Low cover	X
<i>Plantago major</i>	Low cover	X
<i>Veronica arvensis</i>	X	Low cover
EXOTIC GRASSES		
<i>Poa annua</i>	Low cover – pulled some	Low cover
<i>Agrostis stolonifera</i>	In planted sedge; pulled one	X

Figure 12. Photomonitoring Points at GTSR Phase XI: Lunch Creek, 2012-2014



Area A. Looking down walking path – 2012



Area A. Looking down walking path – 2013



Area A. Looking down walking path – 2014



Area A. Looking up walking path – 2012



Area A. Looking up walking path – 2013



Area A. Looking up walking path – 2014



Area B. Open slope at end of walkway - 2012



Area B. Open slope at end of walkway – 2013



Area B. Open slope at end of walkway – 2014



Area C. Trail north of the road - 2012



Area C. Trail north of the road – 2013



Area C. Trail north of the road – 2014

VII. 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, and mostly along the eastern margin of the Park. Glacier National Park has many fewer limber pine stands than whitebark pine stands, and 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 regarding limber pine stands indicates that current mortality and infection rates for this species have increased since 2001 and may be comparable to those observed in whitebark pine populations.

Some mature whitebark and limber pines 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. Sites were selected based on accessibility for planting, appropriate habitat characteristics, and recent burn activity, if possible. Due to a shortage of suitable planting sites, seedlings were planted at 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 seventeen sites, twelve of which continue to have live trees in monitoring plots (Table 20 & Figure 13). A total of 9,170 seedlings have been planted in the park between 2002 and 2013. No limber pine seedlings were planted in 2014. Plantings typically occurred in the fall but a few plantings occurred in the spring. Planting sites and the total number of seedlings planted varied between years. Monitoring plots have captured 24% of total planted seedlings overall (Table 20).

Limber pine seedlings were planted at thirteen sites between 2002 and 2006 (Figure 13 & Table 20). 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. Planting sites and the total number of seedlings planted varied between years. Monitoring plots have captured 23% of total planted seedlings during this five year period (Table 20).

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 with 2,390 trees planted.

Due to lack of suitable limber pine habitat that has burned, no limber pine seedlings from any year were planted in burn areas. Additionally, limber pine has not been utilized in the Montana State ectomycorrhizal inoculation study, so none of these seedlings have been inoculated. Recently, most seedlings have 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. Additionally, 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. These plantings correlated with an extended hot, dry climatic cycle.

b. Limber Pine Planting Sites Currently Monitored

Five sites were planted with limber pine seedlings 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 utilized as microsites. Planting elevations ranged from 5,575 to 5,735 feet. Altogether, 1,264 seedlings were planted in this area in 2012; 284 in the spring and 980 in the fall. A total of 26% of seedlings from 2012 are being monitored at Scenic Point.

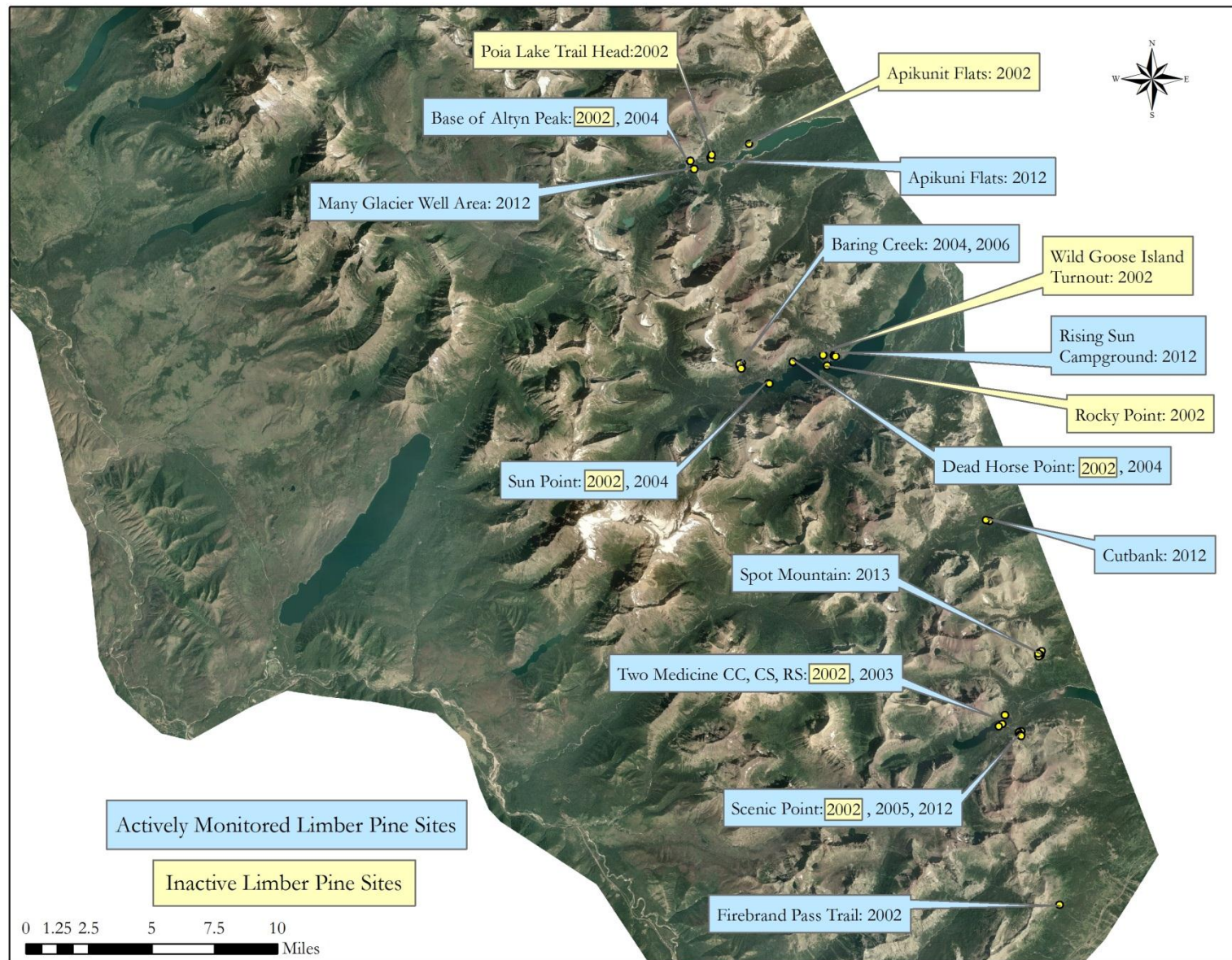
A total of 662 seedlings were planted at Apikuni Flats in 2012; 270 in the spring and 392 in the fall with 19% of the seedlings being captured in monitoring plots. Apikuni Flats is located near the confluence of Apikuni Creek and Lake Sherburne in a very gently sloped area of the Many Glacier Valley. Limber pine have historically been scattered in this area and a few mature limber pine trees survive in this area today. Plot elevations range from 4,904 to 4,927 feet. 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.

Table 20. Limber Pine Monitoring Plot Establishment to Date

<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	130	23%
		2			570	130	23%
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	2158	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 13. Limber Pine Seedling Monitoring Sites



A total of 570 limber pine seedlings were planted at the Rising Sun Campground in 2012; 286 in the spring and 284 in the fall. Only spring plantings were monitored at this site, capturing 23% of seedlings. Rising Sun Campground is located in a relatively flat area at the confluence of Rose Creek and St. Mary Lake, ranging from 4,525 to 4,540 feet in elevation. 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.

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. Elevations range from 5,185 to 5,240 feet. 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 when possible. Microsites were more prevalent in the campground area in the form of stumps and snags. This site was only planted in the spring; 286 seedlings were planted with 29% seedlings captured in monitoring plots.

Additionally, 196 seedlings were 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, 33% of which were captured in monitoring plots. This area is also highly vegetated with grasses and forbs so scalping of planting sites also occurred at this site. This is a more naturally rocky area, bordering a small cliff band, and rocks were primarily utilized as microsites. Elevation is 5,125 feet.

In 2013, 1,414 limber pine seedlings were planted. 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 utilized 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 cliff bands. Elevation ranged from 6,244 to 6,480 feet. Seedlings were planted in both the spring and the fall; 669 in the spring and 745 in the fall. Twenty-four percent of seedlings were captured in monitoring plots.

No limber pine seedlings were planted in the Park in 2014.

2. *Whitebark Pine Restoration*

Whitebark pine seedlings have been planted at fourteen sites between 2000 and 2014, all of which continue to support live trees (Figure 14 & Table 21). A total of 20,147 seedlings have been planted in the park between 2002 and 2014. 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, specifically 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. These are not included in the tally of planted 5-needle pines in the Park. In 2013, small plantings took place at Morningstar and Atlantic Creek, on the Blackfoot Reservation near Divide Mountain, and at the eastern saddle of Divide Mountain. Additionally, small plantings have taken place over the years during general revegetation projects in areas such as Old Man Lake Campground.

Monitoring plots have captured 21% of total planted whitebark pine seedlings (Table 21). 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. Additionally, seedlings from multiple cones are often planted together in one microsite to mimic clumping of seedlings produced from Clark's Nutcracker seed caches.

Figure 14. Whitebark Pine Seedling and Seed Monitoring Sites

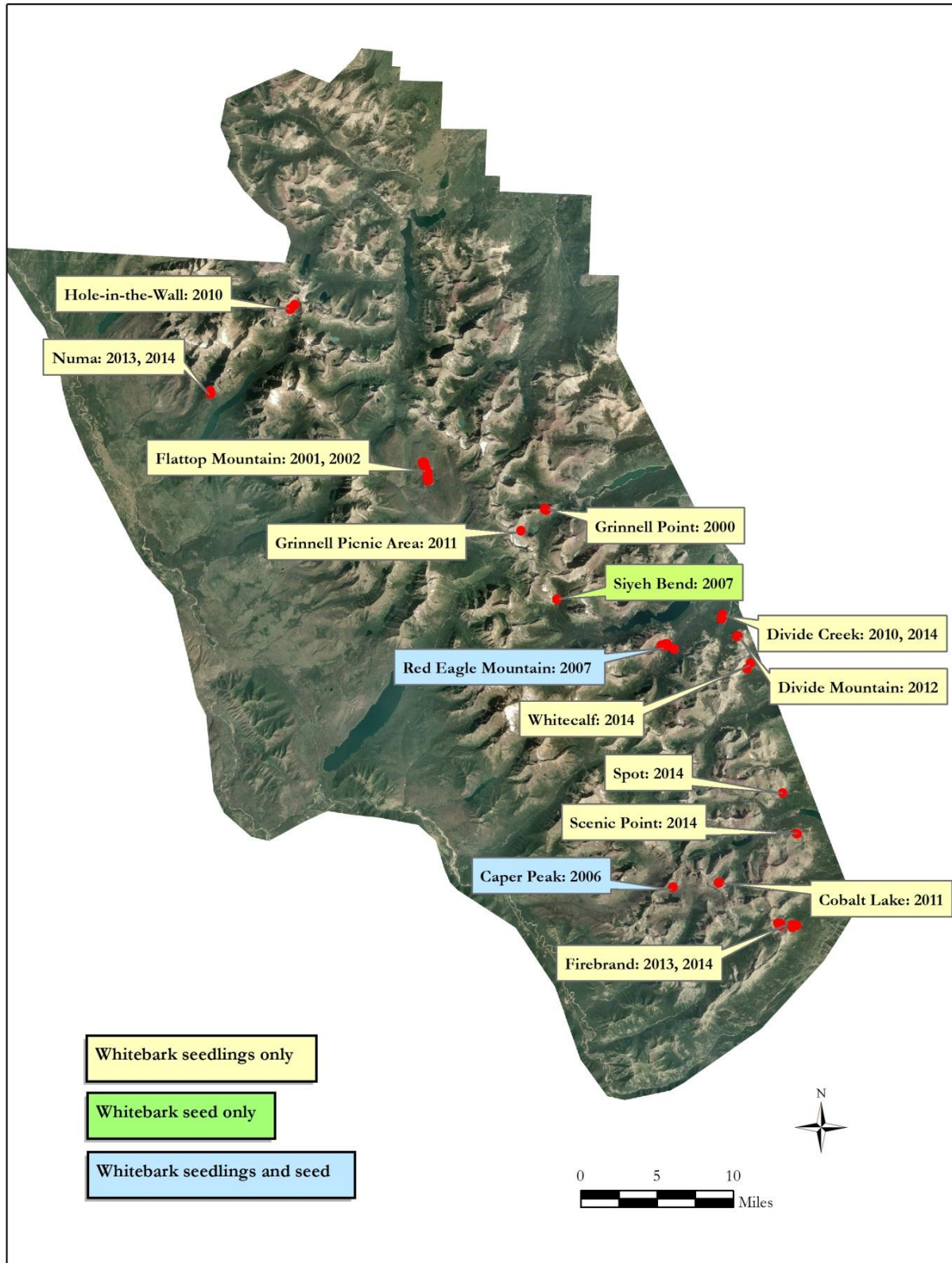


Table 21. Whitebark Pine Seedling Monitoring Plot Establishment to Date

<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			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%
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%
Spot Mtn.	2014 (spring)	1	219	1.9	416	36	9%
Whitecalf Mtn.	2014 (fall)		657	1.2	788	146	19%
Overall Total					20,147	4,207	21%

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a. Whitebark Pine Planting Areas

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. Plantings in this area range in elevation from 6,560 to 7,320 feet. All seedlings planted at this site were incorporated into monitoring plots. Due to the difficulty of accessing this site, these plots have not been visited by Glacier National Park Staff since planting.

The largest whitebark pine planting site to date is at Flattop Mountain, another site that has experienced fairly recent fire. Seedlings were planted at this location, which burned in the McDonald Creek Fire of 1998, at elevations between 6,300 and 6,800 feet. A total of 5,160 trees were planted on Flattop Mountain between 2001 and 2002 with 927 trees incorporated in monitoring plots, capturing 18% of planted seedlings (Table 21). Plantings occurred in early summer and fall with various numbers of seedlings planted during each planting event.

In fall of 2006, 139 seedlings were planted at Caper Peak above Lake Isabel. This site is located at 6,520 feet and burned in the Rampage Fire of 2003. All seedlings planted at this site were included in monitoring plots. Due to the remote location of these sites, they were not monitored until 2008. In addition, whitebark pine seeds were directly planted in the ground at this site (Figure 14 & Table 22). A total of 423 whitebark pine seeds were planted in the fall of 2006 in caches of 4 to 13 seeds. 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 that burned in the 2006 Red Eagle Fire (Figure 14). A total of 422 seedlings, 21% of the planted trees, were captured in nine monitoring plots; 359 seedlings are being monitored on the midslope of Red Eagle Mountain at elevations between 5,700 and 5,900 feet, while 63

seedlings were monitored on an open knoll near the campground at 4,800 feet in elevation. A new methodology was used to install two transects to monitor whitebark pine seed directly planted into the ground (see Methods section). A total of 102 whitebark pine seeds were planted in caches along a 25m transect on the midslope of Red Eagle Mountain, while 98 whitebark pine seeds were planted in caches along a 20m transect on the same open knoll near the Red Eagle Campground (Table 22).

Table 22. 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 14). Thirty-one seeds were planted along one 20m transect that was installed on a flatter section of slope, while 70 seeds were planted within two transects that were installed on flat benches near Siyeh Bend (Table 22).

In the fall of 2010, two sites were planted with whitebark pine seedlings. The Hole-in-the-Wall Campground area was the first site where whitebark pine seedlings were planted in a non-burned area. Whitebark pine, however, 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 area and in the cirque area above the campground. Elevations of planting sites ranged from 6,349 to 6,922 feet. 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. Five monitoring plots were established containing 159 seedlings, monitoring 19% of planted trees.

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. The elevation of this area ranged from 5,720 to 5,760 feet. 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. Five monitoring plots were installed, encompassing 261 seedlings or 21% of the total trees planted. Forty of the monitored seedlings were inoculated, 13% of the total inoculated seedlings.

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. The elevation near this planting area is approximately 6,600 feet. 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 nearby to existing whitebark pine trees. There were few natural microsites here so rocks and logs were placed near planting sites to create small microsites. Three monitoring plots were established that captured 108, or 43%, of planted seedlings.

Also in August 2011, 146 whitebark pine seedlings were planted at the Grinnell Glacier Picnic Area. The elevation near this planting area is approximately 6,240 feet. 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 nearby 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. Two monitoring plots were established that captured 98, or 67%, of planted seedlings.

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, spanning from 7,070 to 7,150 feet in elevation. On occasion, plots spanned both burned and non-burned areas, although the majority of seedlings were planted in burned areas. Location within or outside of the burn was recorded for each tree. 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. Four plots were installed, containing 216 seedlings and representing 17% of seedlings planted. Almost half (47%) of seedlings planted had been inoculated with ectomycorrhizal fungi; 54% of monitored seedlings were inoculated. 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, a total of 2,061 containers (estimated at 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, Morningstar 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 has 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 (516 containers) were planted on a relatively flat bench below the cirque of Firebrand Pass, starting about 200 meters north of a small unnamed lake. Elevations range from 6,515 to 6,540 feet. 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. None of these seedlings were inoculated with ectomycorrhizae. Four monitoring plots were installed to follow survivorship and health over time, capturing 20% of the seedlings planted during this event.

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 (1,175 containers). The lowest spot is located on a bench, ranging in elevation from 6,047 to 6,043 feet, which is very close to the plus trees identified 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 mixes 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. The upper bench in this fall planting ranged in elevation from 6,348 to 6,404 feet. 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. Sixteen percent of seedlings planted at this site in the fall were captured in a total of 5 monitoring plots, 3 on the upper bench and 2 on the lower.

Also in the fall of 2013, approximately 558 whitebark pine seedlings (310 conetainers) were planted at Numa Ridge on south-facing slopes just below the lookout. Elevations ranged from 6,896 to 6,920 feet. 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 utilized again at this site, including downed trees, snags, logs, rocks and stumps. Three plots were installed at this site, capturing 30% of planted seedlings.

Monitoring did not take place at Morningstar or Atlantic Creek Campgrounds, due to the small size of plantings at these sites. 30 conetainers were planted at each of the sites during restoration efforts.

Finally, in 2014, 3,975 whitebark pine seedlings (2,802 conetainers) were planted at seven sites. Three sites were planted in the spring including the planting of 452 seedlings (238 conetainers) near the Firebrand Pass area, 802 seedlings (422 conetainers) at Scenic Point, and 416 seedlings (219 conetainers) at Spot Mountain. Four sites were planted in the fall including the planting of 1,026 seedlings (933 conetainers) at Upper Divide Creek (above the 2010 planting), 569 seedlings (517 conetainers) near Firebrand Pass itself, 710 seedlings (473 conetainers) near Numa Lookout, and 788 seedlings (657 conetainers) at Whitecalf Mountain. Only one of these sites, Divide Creek, has burned. Details surrounding these planting sites are included in the Results section below. Additionally, two other sites received minor plantings deemed too small for monitoring; one on the Blackfeet Indian Reservation along the eastern border with the Park and one along the saddle of Divide Mountain.

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, presence and type of microsite, and whether or not a seedling was inoculated with ectomycorrhizal fungi) are recorded as well.

Plots are distributed throughout the entire planting site to avoid over sampling any given area. 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 we have 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 (Table 22). Due to their remote location, these plots were not monitored in 2007 but were monitored in 2009, three years after seeding.

As stated above, 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 (Table 22). 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*

As stated above, limber pine seedlings have been planted at seventeen sites, twelve of which continue to have live trees in monitoring plots. Table 23 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 2014.

a. *2004 Plantings*

i. *Baring Creek*

On May 24, 2004, 450 limber pine seedlings were planted in the lower Baring Creek area (Figure 15). Five monitoring plots were established, encompassing 91 trees and following 20% of planted trees. This area has not burned. Ten years after planting at Baring Creek, 23% of monitored seedlings are alive (Table 20, 23, 24, 25, 26). Of these, 17 trees, or 81% of live trees, were rated in “good” condition, while only 4 trees, or 19%, were considered in “fair” condition. Average height was 30.71 cm, 11.01 cm taller than 5 years ago (Table 24). Average width was 23.9 cm, which is 10.95 cm wider than 5 years ago.

While these trees are healthy and appear to be thriving, they are smaller than many 10-year-old trees at other sites (Table 25). The one live 10-year old limber pine tree at the Firebrand Pass Trail site measured a similar 30 cm in height but was much wider than the Baring Creek trees at 65cm in width. The one live 10-year old limber pine tree at the Two Medicine Camp store was taller by 12 cm and wider by 17 cm than the

Table 23. Health and Survival of Remaining Live Limber Pine Seedlings 2002 – 2014.

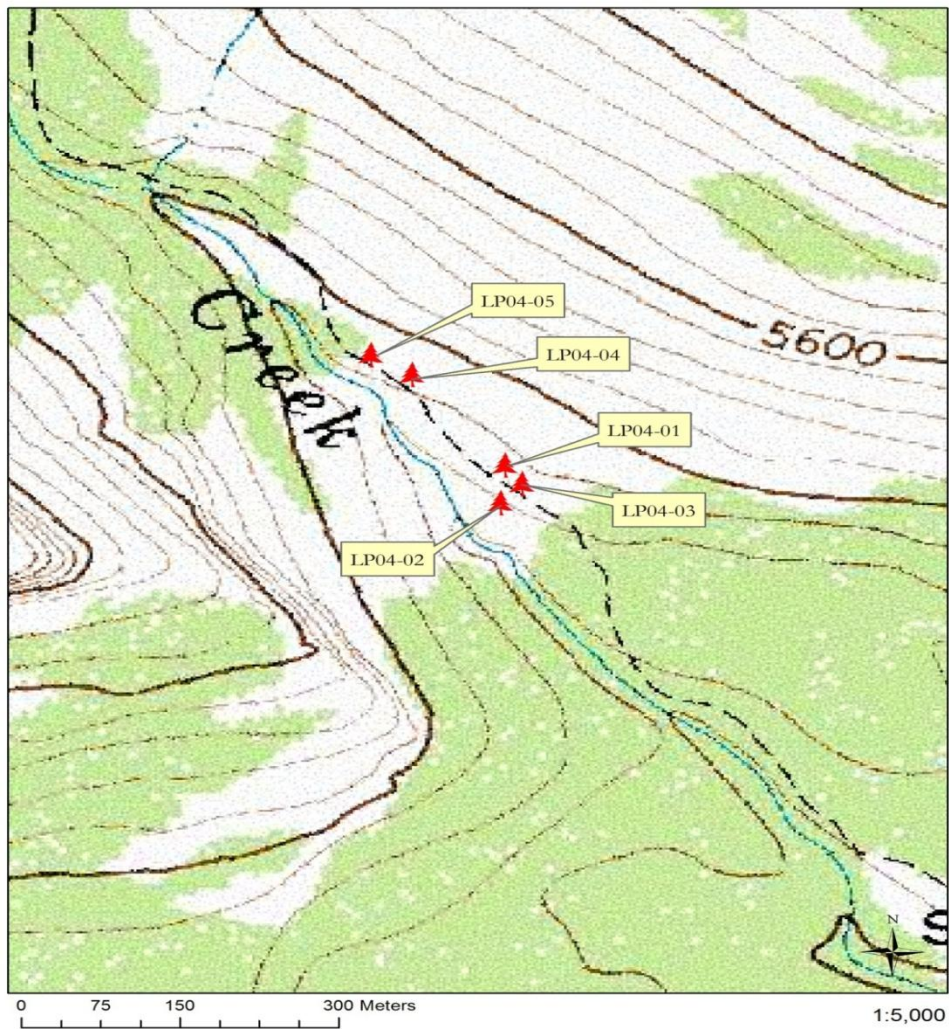
<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Last Year Monitored</i>	<i>Dead / Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Unk.</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
Various	2002	fall	2004	547	0	0	0	0	0	547	0%
Firebrand Pass Trail	2002	fall	2012	37	0	0	1	0	1	38	3%
Total 2002				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				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				195	0	4	31	0	36	240	15%
Scenic Point	2005	fall	2010	128	1	5	15	0	21	149	14%
Total 2005				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				68	0	1	2	0	3	91	3%
Cutbank	2012	spring	2013	16	1	11	54	0	66	82	80%
Apikuni Flats (Spring)	2012	spring	2013	47	3	4	24	0	31	78	40%
Apikuni Flats (Fall)	2012	fall	2013	17	11	14	7	0	32	49	65%
Rising Sun CG	2012	spring	2013	77	9	13	41	0	63	140	45%
Scenic Point	2012	spring	2013	76	0	9	65	0	74	150	49%
Scenic Point	2012	fall	2013	67	4	7	109	0	120	187	64%
Many Glacier Well Area	2012	fall	2013	25	1	8	29	0	38	63	60%
Total 2012				325	29	66	329	0	424	749	57%
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				1419	47	134	556	0	738	2186	34%
Percentage of Surviving Trees					6%	18%	75%	0%			
Percentage of Monitored Trees				65%	2.2%	6%	25%	0%			34%

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Baring Creek trees. Ten-year old whitebark pine trees were also larger than Baring Creek limber pine trees. Whitebark pine seedlings planted at Flattop in the spring of 2001 averaged 15 cm taller and 5 cm wider than Baring Creek limber pine trees, and seedlings planted at Flattop in the fall of 2001 averaged 16 cm taller and 2 cm wider than Baring Creek trees at ten years old. Many of the seedlings at Baring Creek were located underneath krumholz Douglas-fir trees. Survival is relatively good at Baring Creek, suggesting that while the seedlings are offered protection by shelter from larger trees, they may have traded growth for added protection, since many had very little access to sunlight. However, of the limber pine planted in 2004, seedlings at Baring Creek were actually larger on average than those at Sun Point and the Many Glacier Hotel Slope. Both of these sites other sites are rocky area that may be more harsh and nutrient deficient.

In the 2004 plantings, there does not appear to be an advantage of planting in spring or fall. Since so few survived at two of the sites (Dead Horse Point and Sun Point), it is difficult to make an overall conclusion. Seedlings at Baring Creek, the only site planted in the spring, were extremely sheltered. Survival was similar in this plot to seedlings planted in the fall in the more exposed Many Glacier Hotel site. In general, fall plantings appear to have higher survival, presumably since they do not need to endure hot dry conditions immediately after planting, but more data is needed to make a more definitive conclusion.

Figure 15. Limber Pine Monitoring Plots at Baring Creek, Planted in 2004.



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Table 24. Average Height and Width of Limber Pine Seedlings planted in 2004, 5 to 10 Years After Planting.

Site	Year	Survival	Average Height (cm)	Average Width (cm)
Baring Creek	2009	22%	19.7	12.95
	2014	23%	30.71	23.9
Base of Altyn Peak (slope above MG Hotel)	2009	30%	10.17	9.42
	2014	25%	19.3	23.9
Dead Horse Point	2009	2%	27	9
	2014	2%	61	39
Sun Point	2009	7%	13	12.25
	2014	7%	22.25	28

Table 25. Sizes and Survival of Ten Year Old Limber Pine and Whitebark Pine Trees Planted in 2002-2004.

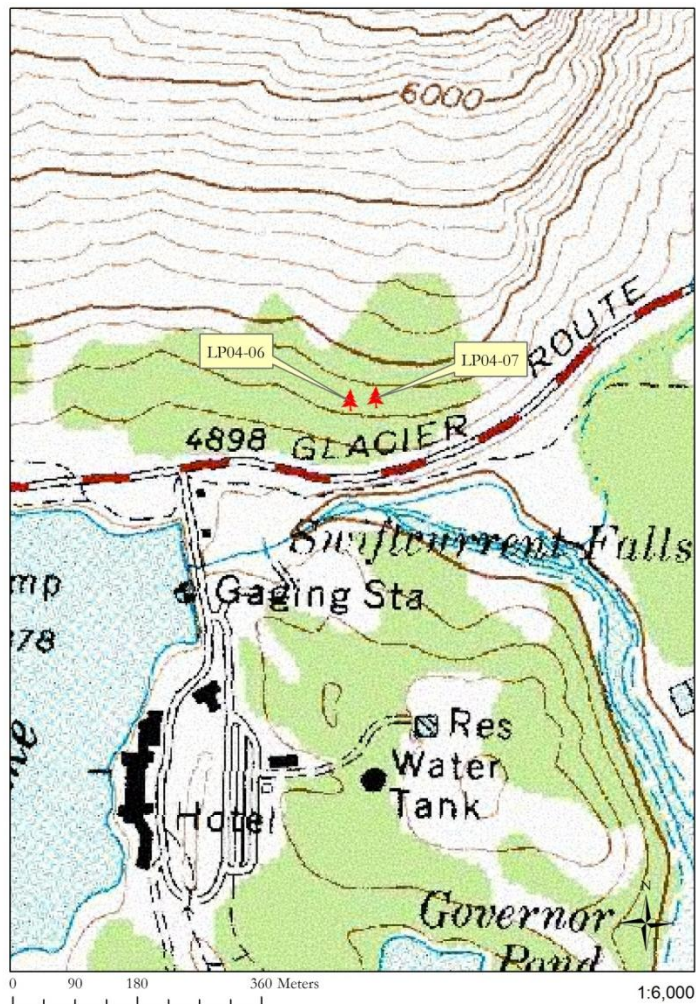
Site	Species	Year Planted	Season Planted	Last Year Monitored	Year 10		Number Alive	Percent Alive
					Height	Width		
Firebrand Pass Trail	Limber pine	2002	fall	2012	30	65	1	3%
Two Medicine Camp Store	Limber pine	2003	fall	2013	43	41	1	4%
Baring Creek	Limber pine	2004	spring	2014	30.71	23.9	21	23%
Dead 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%
Flattop Mtn. Spring	Whitebark pine	2001	spring	2011	45.44	29.35	107	28%
Flattop Mtn. Fall	Whitebark pine	2001	fall	2011	46.06	25.98	89	35%

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ii. Base of Altyn Peak

On September 14, 2004, 200 limber pine were planted at the base of Altyn Peak (the Many Glacier Hotel Slope). Two plots were established, monitoring 40 trees or 20% of planted seedlings (Figure 16).

Figure 16. Limber Pine Monitoring Plots at the Base of Altyn Peak (Many Glacier Hotel Slope), Planted in 2004.

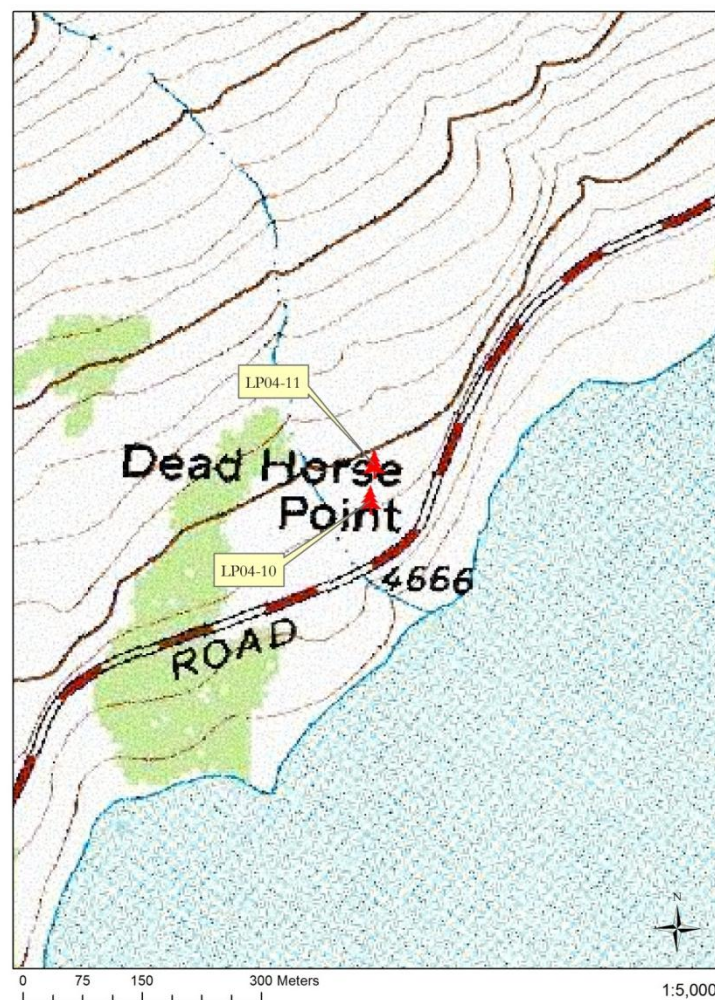


Seedlings had a 25% survival rate 10 years after planting, the highest of all the sites planted in 2004 (Tables 20, 23, 24, 25, 26). This site is rocky and exposed with very few protective microsites, so there is no clear hypothesis as to why this site has higher survival. However, average size of these seedlings was the smallest of all 10-year old plantings in the Park for both height and width (Tables 23, 24). Average height was 19.3 cm, 9.1 cm taller than five years ago, while average width was 23.9 cm, 14.5 cm wider than five years ago. Seedlings at this site grew the least in height of any 2004 planting sites and the second least in width. Perhaps more energy goes into survival at this harsh site than into growth. This area historically harbored a relatively large limber pine stand, and several small but mature limber pine trees still survive here, so conditions are clearly favorable for these trees once they are established.

iii. Dead Horse Point

On September 14, 2004, 250 seedlings were planted at Dead Horse Point (Figure 17). Two monitoring plots were established, encompassing 53 seedlings or 21% of planted trees. Ten years after planting, only one tree survived at Dead Horse Point from the 2004 planting, a 2% survival rate (Tables 20, 23, 24, 25, 26). This site has historically seen avalanche activity, which has buried seedlings in the past. In this planting, downed snags from previous slides were utilized as microsites and there was no recent avalanche activity responsible for the low survival. It is unknown why there was such low survival rate at this site. The one surviving tree, however, is the largest on average across sites at 61 cm in height 39 cm in width. It grew 34 cm in height and 30 cm in width in the past 5 years, a much higher growth rate than the average for 10-year-old limber pine or whitebark pine seedlings in the Park.

Figure 17. Limber Pine Monitoring Plots at Dead Horse Point, Planted in 2004.



iv. Sun Point

On September 14, 2004, 250 seedlings were planted at Sun Point (Figure 18). Two monitoring plots were established, capturing 54 seedlings or 22% of planted trees. At 10 years after planting, survival was a relatively low 7% with only 4 trees surviving (Tables 20, 23, 24, 25, 26). Surviving trees were also relatively small averaging 22.3 cm in height, a 9.3 cm increase over the last 5 years, and 28 cm in width, a 16.8 cm increase. These seedlings were slightly larger than those at the base of Altyn Peak and had a slightly faster growth rate, but are the next smallest and slowest growing of the 10-year old trees in the Park. Surviving seedlings were thriving, however, suggesting once again that once seedlings become established at these harsher sites that traditionally supported limber pine, they have good survival, perhaps in exchange for of faster growth.

Figure 18. Limber Pine Monitoring Plots at Sun Point, Planted in 2004.

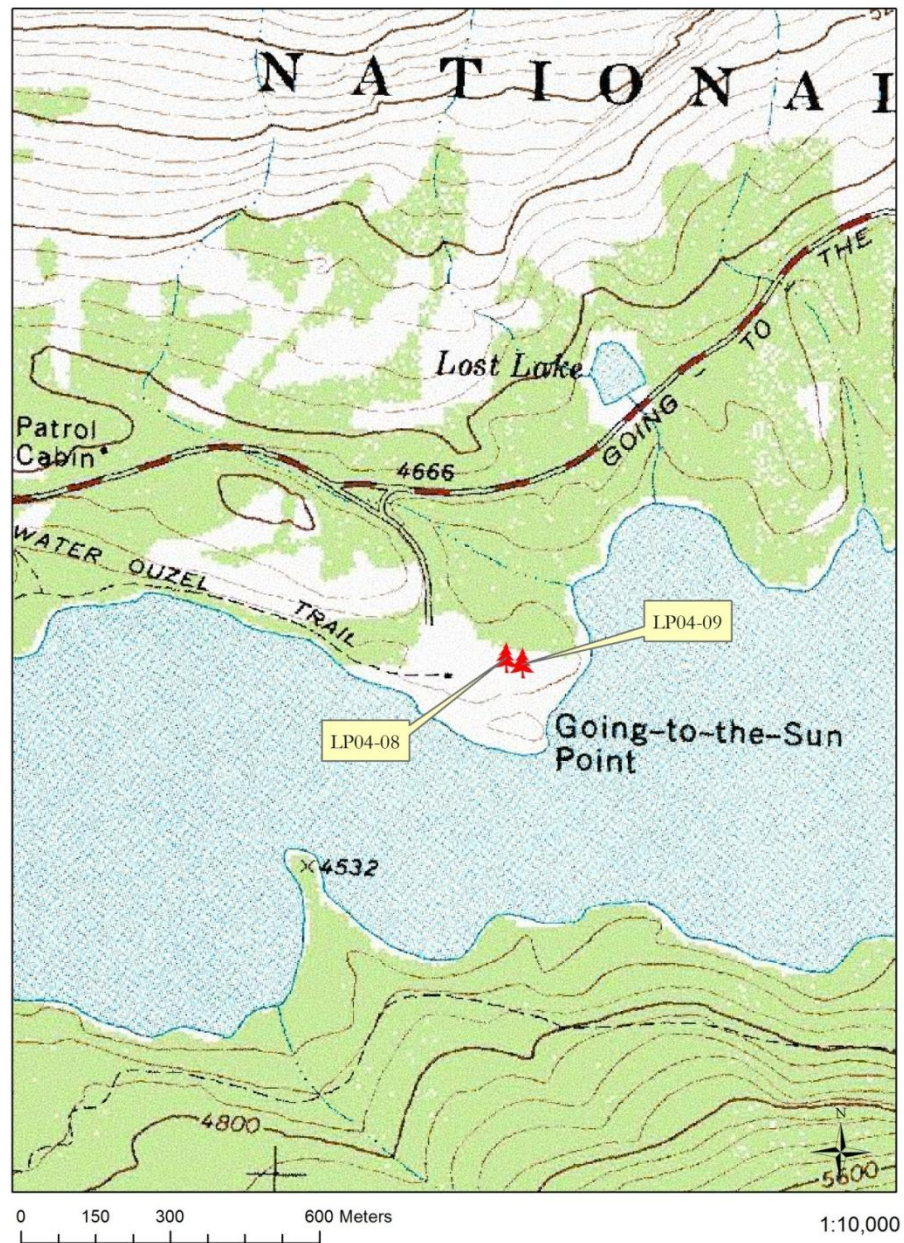


Table 26. Survival of Limber Pine Seedlings by Site, Planted in 2004.

<i>Site</i>	<i>Monitoring Year</i>	<i>Total # Trees Monitored</i>	<i># Trees Survived</i>	<i>% of Trees Survived</i>
Baring Creek	2005	90	47	52%
	2006	90	39	43%
	2007	90	28	31%
	2008	90	20	22%
	2009	90	20	22%
	2014	92	21	23%
Base of Altyn Peak	2005	39	23	59%
(slope above MG Hotel)	2006	40	21	53%
	2007	40	13	33%
	2009	40	12	30%
	2014	40	10	25%
Dead Horse Point	2005	53	11	21%
	2006	53	7	13%
	2007	53	3	6%
	2009	53	1	2%
	2014	53	1	2%
Sun Point	2005	51	28	55%
	2006	54	26	48%
	2007	54	18	33%
	2009	55	4	7%
	2014	55	4	7%
Total One Year Survival	2005	233	109	47%
Total Two Year Survival	2006	237	93	39%
Total Three Year Survival	2007	237	62	26%
Total Four Year Survival	2008	90	20	22%
Total Five Year Survival	2009	238	37	16%
Total Ten Year Survival	2014	240	36	15%

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b. 2013 Plantings

All limber pine seedlings planted in 2013 were planted at Spot Mountain in both the spring and in the fall (Figure 19). Seedlings were planted in the spring on June 27, 2013. 352 cones were planted at this time. Often several seeds were planted in a cone, resulting in a higher number of actual trees being planted than is represented by the number of cones planted. Therefore, a multiplier was applied based on the estimated number of trees per cone. In this case, a multiplier of 1.9 was used, estimating that 669 seedlings were planted at this time. On October 23, 2013, an additional 392 cones were planted in the same area, approximately 745 trees. Four monitoring plots were established in the spring and three plots were established in the fall at this site, capturing 20% and 27% of planted trees, respectively. All plots were monitored in 2014, one year after planting.

Trees planted in the fall had 89% survival, higher than trees planted in the spring that had 49% survival (Table 27). Quite a few seedlings were rated “fair” or “almost dead” at year two, although when only seedlings rated “good” are considered, fall plantings still outperformed spring plantings. 30% of trees planted in the spring were rated “good”, while 66% of trees planted in the fall were rated “good”. Seedlings planted in the fall were smaller on average, however, than seedlings planted in the spring; 0.14 cm shorter and 0.58 cm less in width. As is typically the case, seedlings were smaller one year after planting than at the time of planting. Seedlings tend to shed their long nursery-grown needles after the first season and usually grow

Figure 19. Limber Pine Monitoring Plots on Spot Mountain, Planted in 2013.

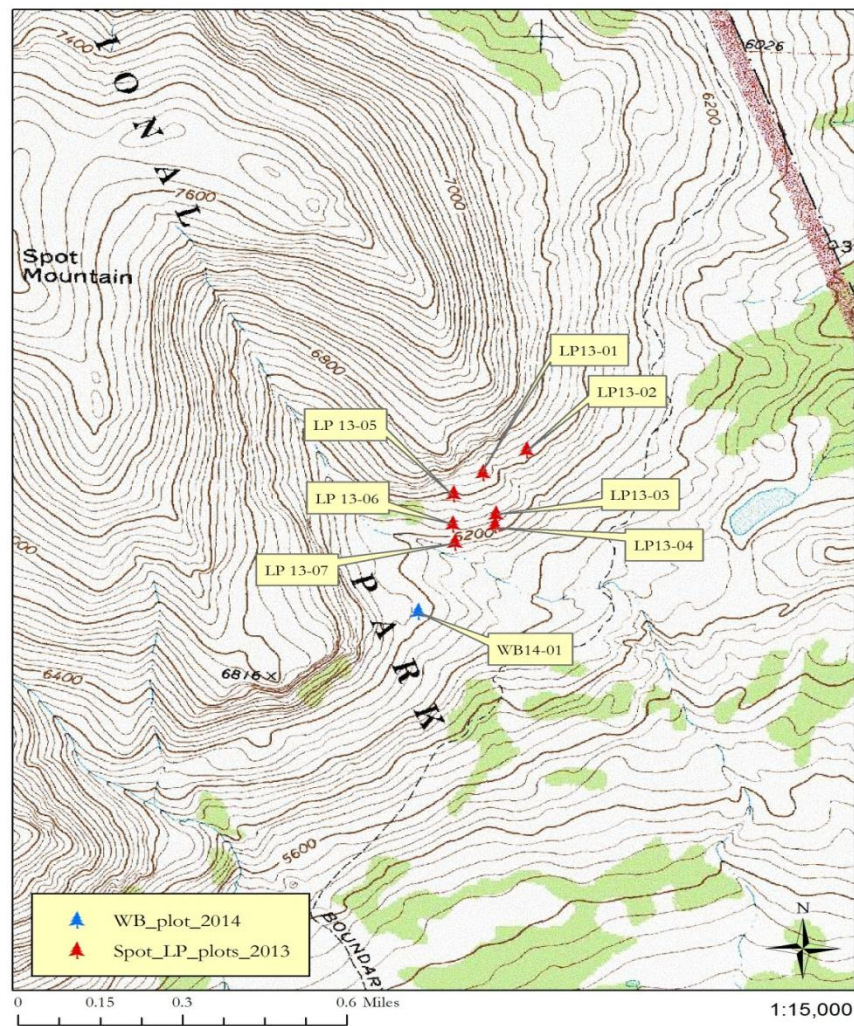


Table 27. Overall Survival and Average Height and Width of Limber Pine Seedlings planted in 2013.

Site	Year	Survival	Average Height (cm)	Average Width (cm)
Spot Mtn. - Spring	2013	100%	9.09	9.6
	2014	49%	7.59	8.11
Spot Mtn.- Fall	2013	100%	8.87	8.87
	2014	89%	7.45	7.53

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shorter, often more dense, bundles of needles in replacement. Both spring and fall planted seedlings shrunk in size after the first year. Spring-planted seedlings shrunk 1.5 cm in height and 1.4 cm in width. Fall-planted seedlings also shrunk 1.5 cm in height and shrunk 1.3 cm in width.

It has been a slight trend that spring plantings have had lower survival, presumably due to hotter and drier conditions that ensue in early summer after being transplanted from relatively controlled nursery conditions. Conditions other than the weather may be at least partially responsible for the lowered success of this spring planting, however. Young or inexperienced planters were utilized in the spring and it was noted that several of the seedlings were not planted deep enough and had exposed roots. Differing environmental conditions between planting areas may also have an effect.

2. *Whitebark Pine Seedling Results*

As stated above, whitebark pine seedlings have been planted at fourteen sites between 2000 and 2014, all of which continue to support live trees. Table 28 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.

Further discussion in this report is only for the sites monitored this year. Twelve whitebark pine plantings were monitored in 2014. Six existing whitebark pine planting sites were re-monitored: Cobalt Lake, Divide Creek, Divide Mountain, Firebrand Pass Area, Grinnell Glacier Picnic Area and Numa Lookout. Six sites were newly planted with whitebark pine seedlings in 2014, and monitoring sites were established. Three of these sites, specifically Divide Creek, Firebrand Pass Area and Numa Lookout, had previously been planted with whitebark pine seedlings. The three remaining sites, Scenic Point, Spot Mountain and White Calf Mountain, were new planting areas for whitebark pine.

a. Divide Creek

i. 2010 Planting

On September 20-22, 2010, a total of 1,126 whitebark pine seedlings were planted on a ridge above Divide Creek (Figures 20 and 21). This area burned in the Red Eagle fire of 2006 with moderate severity. An experimental planting occurred at this site where 300 of the planted seedlings had been inoculated by Cathy Cripps' lab from Montana State University. Inoculum was prepared from mushroom species known to have ectomycorrhizal relationships with whitebark pine. These were planted together, usually in groupings of 3 seedlings per hole, throughout the revegetation site.

Five monitoring plots were installed in 2010 tracking 263 seedlings, 40 of which were inoculated. This captured 21% of planted seedlings. This site was opportunistically re-monitored this year, although it was not due for monitoring until next year, 5 years after planting.

At year four after planting, 94% of monitored seedlings continue to survive (Table 29). No seedlings perished since last year, making this site the most successful long term planting site in Glacier National Park. By comparison, other projects had much lower survival rates four years after planting. The Red Eagle upper slope planting had 57% survival, the Flattop spring 2001 planting had 35% survival, the Flattop fall 2001 planting had 36% survival and the Flattop 2002 fall planting had a 45% survival rate four years after planting.

Additionally, more seedlings were rated in good health this year than they were last year. In 2013, 11 seedlings were rated as "fair", while in 2014 only 3 seedlings received that rating; the rest were elevated to a "good" health rating. This may be attributed to subjective differences among observers, however. This year, 246 seedlings (93%) were rated in "good" health, 3 (1%) were rated "fair", and 16 (6%) were dead or missing.

Several factors may play into the success of this site. Seedlings were planted in cool, wet conditions, during an early season snow event, followed by cool, autumn or early winter weather. Seedlings were probably induced to go into dormancy relatively quickly after planting. Additionally, this area burned but not so hot as to sterilize the soil. Other vegetation has responded well to these conditions, which may reflect a flush of nutrients released post-burning, while retaining beneficial soil fungi.

After shrinking in average height after the first year and shrinking in average width the second year after planting, growth increased in years three and four (Table 30). 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. Average height four years after planting was 16.4 cm and average width was 17.1 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.

Table 28. Overall Health and Survival of Whitebark Pine Planted in Glacier National Park, 2001-2014.

<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>
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	41.4%
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	2010	fall	2014	4	16	0	3	246	0	249	265	94%
Hole-in-the-Wall	2010	fall	2012	2	93	4	32	43	0	79	172	46%
Total 2010					109	4	35	289	0	328	437	75%
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	2014	2	79	3	1	141	0	145	224	65%
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	2014	fall	2014	0	0	0	2	214	0	216	216	100%
Firebrand Pass Area	2014	spring	2014	0	0	2	3	97	0	102	102	100%
Firebrand Pass Area	2014	fall	2014	0	0	0	16	131	0	147	147	100%
Numa Lookout	2014	fall	2014	0	0	2	10	108	0	120	120	100%
Scenic Point	2014	spring	2014	0	1	0	0	187	0	187	188	99%
Spot Mountain	2014	spring	2014	0	0	1	0	35	0	36	36	100%
Whitcalf	2014	fall	2014	0	0	0	1	145	0	146	146	100%
Total 2014					1	5	32	917	0	954	955	100%
Overall Total					1291	31	199	2561	0	2791	4082	68%
Percentage of Surviving Trees						1%	7%	92%	0%			
Percentage of Monitored Trees					32%	0.8%	5%	63%	0%			68%

Figure 20. General location of Whitebark Pine Seedling Plots Established at Divide Creek in 2010 and 2013.

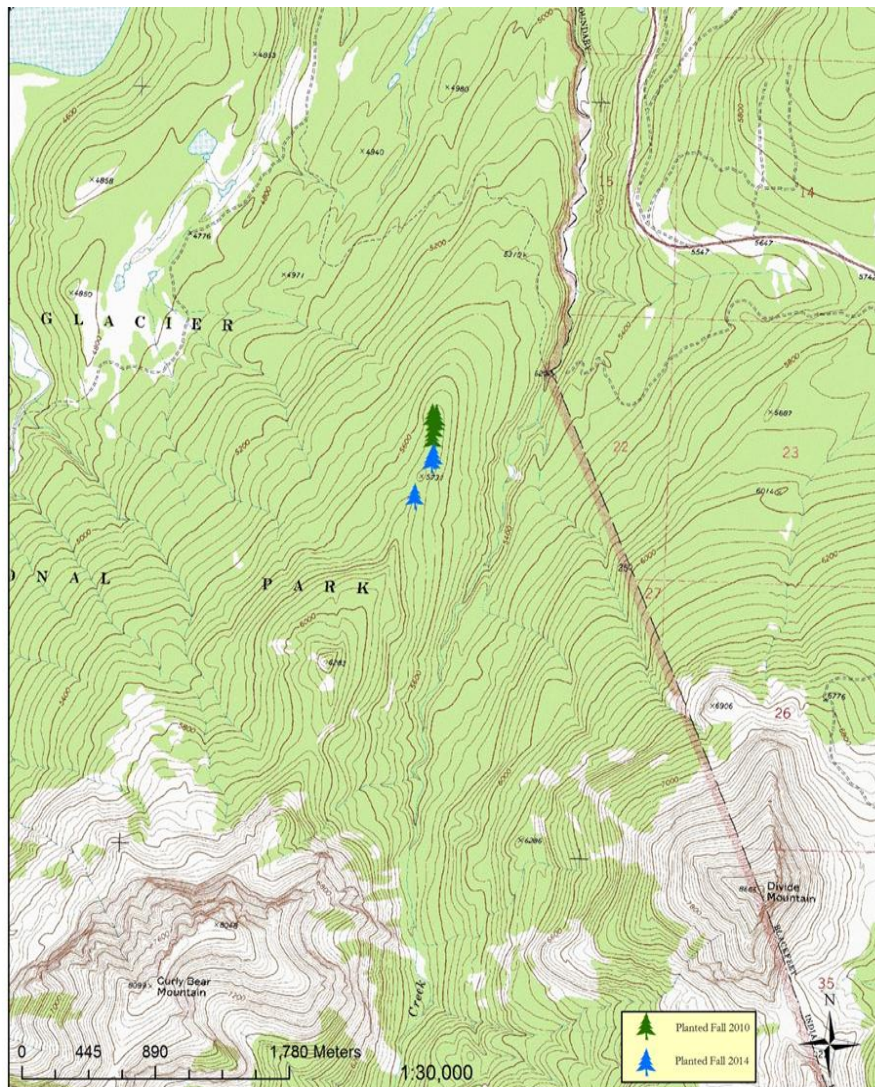


Figure 21. Whitebark Pine Seedling Monitoring Plots Established at Divide Creek, 2010 and 2014.

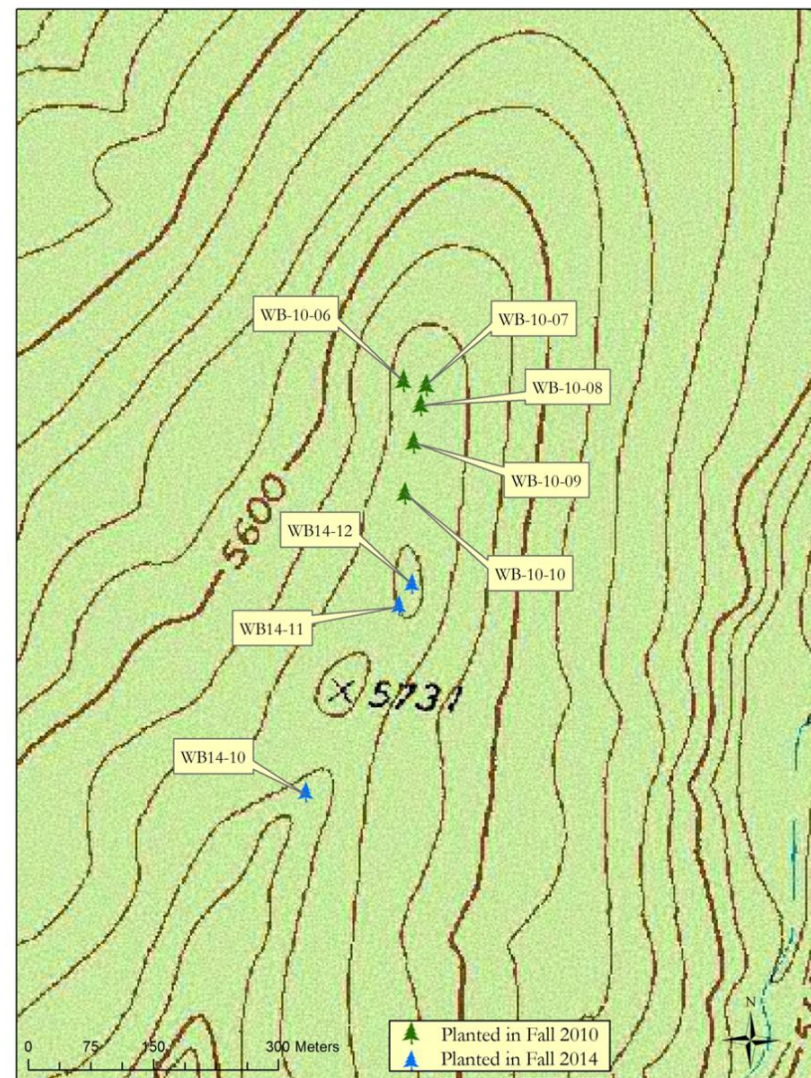


Table 29. Divide Creek: Health and Survival of Whitebark Pine Seedlings Monitored in 2012-2014.

<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%

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Table 30. Divide Creek: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2010-2014.

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

The potential barrier to overall success of this planting is the high competition from lodgepole pine at this site. Lodgepole seedlings averaged 1 to 1.5 meters in this area in 2014, 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.

At Divide Creek, the effect of inoculating whitebark pine seedlings with an ectomycorrhizal slurry is not yet evident four years after planting. Differences between the inoculated and non-inoculated seedlings are minor (Tables 31 and 32) and are currently difficult to attribute solely to the impact of inoculation. This year, both inoculated and non-inoculated seedlings increased substantially in height and width, although inoculated seedlings are currently a bit shorter and narrower than non-inoculated seedlings. While these changes are minor and likely not statistically significant, it appears that non-inoculated seedlings are growing at a slightly greater rate than inoculated seedlings. Non-inoculated seedlings grew 4.02 cm in height and 2.77 cm in width from 2013 to 2014, compared to inoculated seedlings that grew 3.89 cm in height and 2.11 cm in width over the same time period. In addition, survival of inoculated seedlings remains lower than survival of

non-inoculated seedlings (87.8% vs. 95.1%) for the second year in a row. These differences in growth and survival are likely not yet significant and may not be attributed to the effect of inoculation.

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

Table 31. Divide Creek: Treatment Survival and Average Height and Width of Whitebark Pine Seedlings, 2010-2014.

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%	16.25	16.39	16.67	17.15

Table 32. Divide Creek: Treatment Health Ratings of Whitebark Pine Seedlings, 2010-2014.

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%)

ii. 2014 Planting

a. Divide Creek

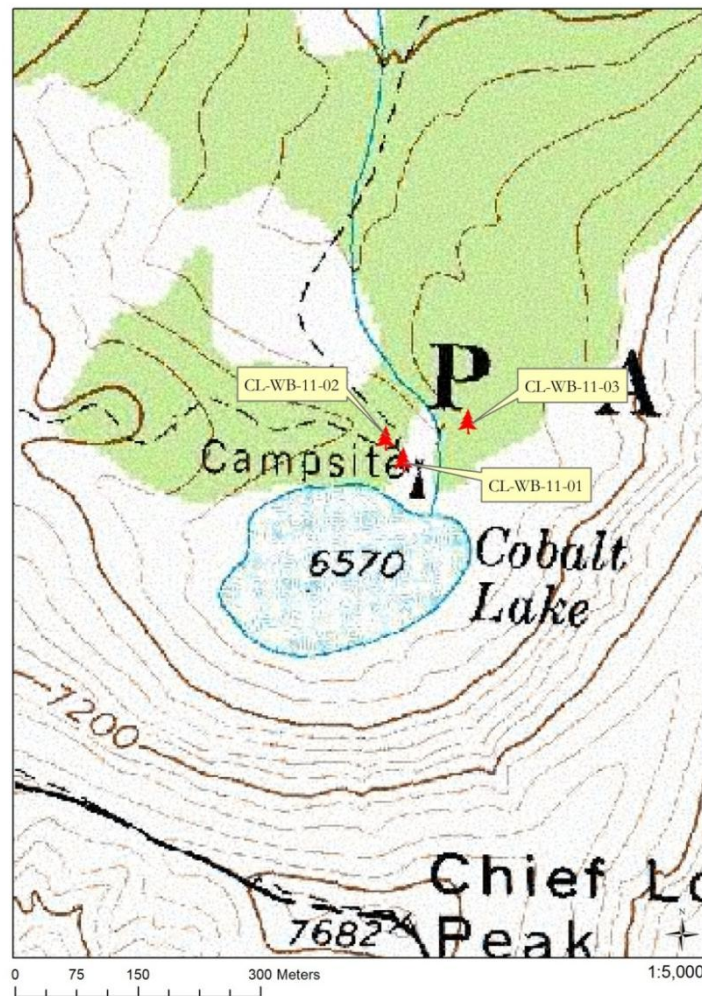
Due to the success of the 2001 planting at Divide Creek, it was decided to plant more whitebark pine seedlings at this site in 2014. This planting took place further upslope from the 2010 planting on open slopes and knobs where competition from lodgepole pine was lower. On September 23, 2014, whitebark 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". Average height was 10.01 cm and average width was 19.08 cm.

b. Cobalt Lake

In August 2011, a total of 250 whitebark pine seedlings were planted in open, flat areas to the north of the Cobalt Lake Campground (Figure 22). This area is not within a burn requiring that vegetation was 'scalped' around the planted whitebark seedling to reduce competition. Seedlings were planted in forest openings nearby to existing whitebark pine trees and typically planted together in groupings of 2 to 3 trees per planting hole. Three monitoring plots were established, encompassing 108 trees or 21% of planted seedlings.

Figure 22. Whitebark Pine Seedling Monitoring Plots Established at Cobalt Lake, Planted in 2011.



Seedlings at Cobalt Lake were monitored on August 25, 2014 for the second time since planting. Only 10% (11 trees) of seedlings are surviving at this site three years after planting. Of these, 4 trees were considered almost dead, 4 trees were rated in “fair” condition, and only 3 trees were in good health (Table 33). In 2012, the last monitoring event, 31% of seedlings were alive, one year after planting. Ten of the surviving trees were considered almost dead, 5 were considered “fair” and 18 were in good condition. Poor initial survival at this site was likely due to the fact that seedlings were planted in late August, followed by hot and dry weather, which proves to be challenging for initial survival. Almost half (49%) of seedlings were in fair condition or worse one month after planting. Subsequent poor performance at this site is likely due to lack of shelter and adequate resources. The Cobalt Lake Campground area did not provide many microsites, and this site is located in an open, very rocky site, where soil is not ideal for planting. Small microsites were improvised but, in general, these microsites are not providing the protection and shade that these seedlings often require. Additionally, these seedlings endured a high amount of handling and many of them did not look healthy upon planting. Trees came as bare root plants from the Coeur d’Alene nursery and needed to be put back into containers prior to planting.

Surviving seedlings continued to grow, on average (Table 34). Unlike most outplanted 5-needle pines in Glacier National Park, these trees have continued to grow in height since initial planting. Many seedlings shrink in size after the first year due to shedding longer, nursery-grown needles. Average height is now 13.0 cm, a 2.85 cm increase from 2012. However, average width is 11.27 cm, a 0.73 cm decline from two years ago.

Table 33. Cobalt Lake: Health and Survival of Whitebark Pine Seedlings Monitored in 2011-2014.

<i>Plot</i>	<i>Treatment</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>
CL-WB-11-01	water polymer + watered in	0	9	9	14	32	32	100%
CL-WB-11-02	watered in only	1	7	10	20	37	38	97%
CL-WB-11-03		0	0	17	21	38	38	100%
Total 2011		1	16	36	55	107	108	99%
CL-WB-11-01	water polymer + watered in	23	2	3	4	9	32	28%
CL-WB-11-02	watered in only	24	6	2	6	14	38	37%
CL-WB-11-03		28	2	0	8	10	38	26%
Total 2012		75	10	5	18	33	108	31%
CL-WB-11-01	water polymer + watered in	29	1	2	0	3	32	9%
CL-WB-11-02	watered in only	36	0	1	1	2	38	5%
CL-WB-11-03		32	3	1	2	6	38	16%
Total 2014		97	4	4	3	11	108	10%

Table 34. Cobalt Lake: Survival and Average Height and Width of Whitebark Pine Seedlings, 2011-2014.

Year	Survival	Average Height (cm)	Average Width (cm)
2011	99%	9.54	10.55
2012	31%	10.15	12.0
2014	10%	13.0	11.27

c. Grinnell Picnic Area

In August, 2011, a total of 146 whitebark pine seedlings were planted in relatively flat areas near the Grinnell Glacier Picnic Area (Figure 23). This area was not within a burn but does contain sparsely vegetated, open areas and denuded soil areas (from social trails) under trees. Seedlings were typically planted together in groupings of 2 or 3 trees per hole throughout the revegetation site. Two monitoring plots were installed in 2011 tracking 98 seedlings. In 2012, supplemental planting took place in this area and five seedlings were added to plots. Monitoring plots captured 67% of planted seedlings.

Monitoring of Grinnell Picnic Area took place on September 17, 2014. Three years after planting, 40% of seedlings were still alive with 39 of the 42 surviving trees in good health (Table 35). Only three trees were rated “fair” and none were almost dead. While this is a 9% decline from the last monitoring event in 2012, this site has seen much more success than Cobalt Lake that was also planted at about the same time in 2011. Seedlings at Grinnell Glacier have grown continuously in both height and width since the time of planting (Table 36). Trees experienced a burst of growth since 2012, increasing 2.27 cm in height and 3.97 cm in width, indicating that the surviving trees are thriving. As seen at Cobalt Lake, seedlings here defy what appears to be the normal trend of shrinking after the first year of outplanting. Average height of seedlings at Grinnell Glacier Picnic Area in 2014 is 12.79cm and average width is 15.81 cm.

High early mortality at this site has been attributed to early season planting, transplantation in the nursery and inadequate microsites. These seedlings were planted at the end of August when temperatures remained high and rainfall was low (Appendix A). Although seedlings were well watered in when planted, the results of this project may again indicate how important weather is to surviving whitebark pine seedlings. This time of year appears to be too hot and dry for prime survival rates. Later planting dates should be targeted for cooler temperatures and more reliable precipitation. Additionally, these seedlings came as bare root plants from the Coeur d’Alene nursery and needed to be put back into containers prior to planting. This is a high amount of handling for tree seedlings and many of them did not look healthy upon planting. However, surviving seedlings appear to be thriving now that they are established, suggesting that the environment is more favorable for whitebark than previously suspected.

Figure 23. Whitebark Pine Seedling Monitoring Plots Established at Grinnell Glacier Picnic Area, Planted in 2011.

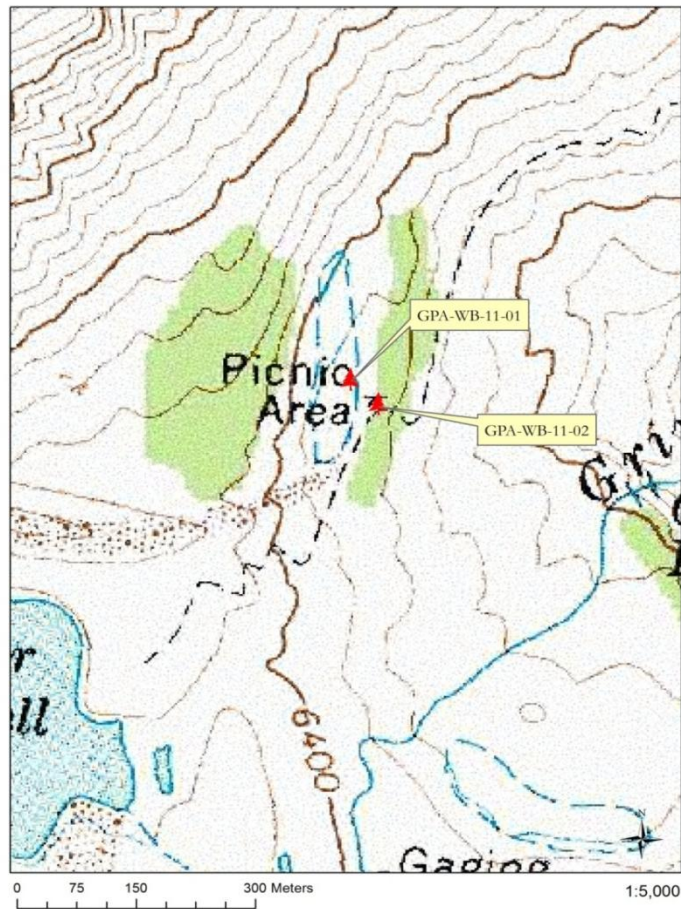


Table 35. Grinnell Picnic Area: Health and Survival of Whitebark Pine Seedlings Monitored in 2011-2014.

<i>Plot</i>	<i>Treatment</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>
GPA-WB-11-01	water polymer + watered in	5	17	2	41	60	65	92%
GPA-WB-11-02	watered in only	1	10	11	11	32	33	97%
Total 2011		6	27	13	52	92	98	94%
GPA-WB-11-01	water polymer + watered in	28	2	2	35	39	67	58%
GPA-WB-11-02	watered in only	25	1	2	8	11	36	31%
Total 2012		53	3	4	43	50	103	49%
GPA-WB-11-01	water polymer + watered in	35	0	0	33	33	68	49%
GPA-WB-11-02	watered in only	27	0	3	6	9	36	25%
Total 2014		62	0	3	39	42	104	40%

Table 36. Grinnell Picnic Area: Survival and Average Height and Width of Whitebark Pine Seedlings, 2011-2014.

Year	Survival	Average Height (cm)	Average Width (cm)
2011	94%	9.41	10.03
2012	49%	10.52	11.84
2014	40%	12.79	15.81

d. Divide Mountain

In September 2012, a total of 1,283 whitebark pine seedlings were planted at tree line on a bench and a gentle slope on the northwest flank of Divide Mountain (Figure 24). 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.

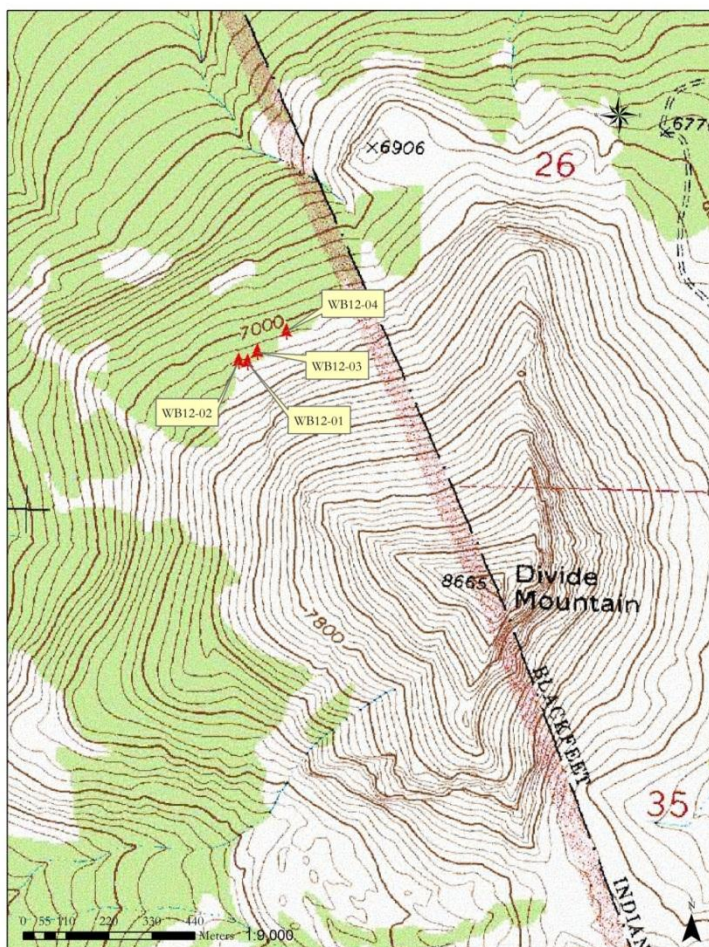
Divide Mountain is the second site in the park to utilize seedlings that have been inoculated by Cathy Cripps' lab from Montana State University. Divide Creek, planted in 2010, was the first site where experimental seedlings were planted. Inoculum was prepared from mushroom species known to have ectomycorrhizal 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 tracking 216 seedlings. This captured 17% of planted seedlings.

This site was slated to be monitored in 2013, the first year after planting, but weather did not permit this monitoring event. Plots were monitored on August 20, 2014, two years after planting. Looking at the all the seedlings together, 65% survived two years after planting (Table 37). However, there is high variability among plots. Plot 1, with the highest number of dead or missing trees, showed the highest evidence of predation. Of the 33 dead or missing trees, comments regarding predation and potential predation were made on 22 trees. This plot also had the second highest mortality rate at 55%. Only 4 trees were suspected to have experienced herbivory in each of plots 2 and 3, which had survival rates of 68% and 54%, respectively. No evidence of predation was noted for plot 4 that had the highest survival (91%) by far. This plot is also located in a favorable environment with late snowmelt providing increased moisture to seedlings. While herbivory obviously played a role in survival rates at this site, other factors, such as inoculation or being planted in a burn area likely also contributed to seedling success at this site.

Table 37. Divide Mountain: Health and Survival of Whitebark Pine Seedlings Monitored in 2012-2014.

<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%

Figure 24. Whitebark Pine Seedling Monitoring Plots Established at Divide Mountain, Planted in 2012.



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 has taken place since initial planting. Seedlings have an average height of 9.31 cm, only 0.21 cm taller than in 2012 (Table 38). Seedlings were still smaller in width after two years than they were at planting time, shrinking by an average of 0.38 cm. Shrinking is typical after planting as longer needles are shed and replaced by shorter, denser needles. Not much data exists for year 2 monitoring events but from the sites where data exists, no clear growth trend has been seen for the second year after planting. Seedlings planted at Hole-in-the-Wall were distinctly smaller than at planting time at year 2. Trees were 2.37 cm shorter and 0.18 cm less wide after two years (Table 59). However at Red Eagle, seedlings grew in height by 3.37 cm from planting to year 2. No data on width was taken at planting time so no conclusions can be made about width at year two at this site.

Table 38. Divide Mtn.: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2012-2014.

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

As for an analysis of environmental and treatment conditions at the Divide Mountain planting site, a comparison of treatments from 2012 to 2014 highlighted some interesting results about planting in burns and the use of 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 39). 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 did show some consistent results. First, in terms of growth, width of whitebark seedlings consistently decreased under all treatments except for those trees that were inoculated and planted in non-burned areas, where tree width average virtually stayed the same (Table 39). This trend is fairly typical of second-year seedlings that often decrease in size due to needle shed. More interestingly, height of whitebark seedlings generally increased in most of the treatments except when looking at all trees planted in non-burn areas or, more dramatically, when looking at trees planted in non-burn areas that were not inoculated (Table 39). 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 non-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, similar trends were observed. First, trees planted in burns appear to have the biggest effect on survival with double the survival than those trees not planted in burns. Second, inoculation at this site did have a positive impact on survival with 22% 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 92.8%. Similarly, when trees were not planted in a burn and not inoculated, seedlings had the lowest overall survival at 30.8%. 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. This result differs from data at Divide Creek but the answer may be due to the specific site. 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 more positively here. 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 is not as necessary for survival and growth and thus no differences are detected between inoculated and non-inoculated trees. These sites will continue to be monitored to assess this hypothesis and further research should be implemented to address this question.

Table 39. Divide Mtn: Comparison of Survival, Height and Width by Treatment, 2012-2014

Treatment	Survival		Survival w/out predation		Height (cm)		Width (cm)		Change 2012 to 2014 (in cm)	
	2012	2014	2012	2014	2012	2014	2012	2014	Height	Width
In Burn	100%	77.4%	100%	80.8%	8.94	9.36	8.96	8.68	+0.42	-0.28
Not In Burn	100%	21.4%	100%	44.1%	9.57	8.87	8.95	7.53	-0.70	-1.42
Inoculated	100%	72.7%	100%	84.6%	9.14	9.39	8.89	8.67	+0.25	-0.22
Not Inoculated	100%	55.3%	100%	62.6%	9.06	9.19	9.03	8.40	+0.13	-0.63
Inoculated/In Burn	100%	90.6%	100%	92.8%	9.02	9.32	9.05	8.69	+0.30	-0.36
Not Inoculated/In Burn	100%	63.9%	100%	70.0%	8.85	9.42	8.86	8.68	+0.57	-0.18
Inoculated/Not In Burn	100%	30.6%	100%	52.4%	9.36	9.82	8.53	8.55	+0.46	+0.02
Not Inoculated/Not In Burn	100%	20%	100%	30.8%	9.90	6.25	9.70	4.75	-3.65	-4.95

e. Firebrand Pass Area

Four plantings have taken place near Firebrand Pass on flanks of Calf Robe Mountain. Whitebark pine seedlings were planted in the spring and fall of 2013 and in the spring and fall of 2014. On July 2, 2013, approximately 1,032 seedlings were planted on a relatively flat bench below the cirque of Firebrand Pass. Four monitoring plots were installed to follow survivorship and health over time, capturing 20% of the seedlings planted during this event (Figure 25). Seedlings were again planted at the Firebrand Pass Trail area on October 22, 2013, but at lower elevations. Two spots, about 400 meters apart, were planted with a total of 2,350 trees in the fall. 16% of seedlings planted at this site in the fall were captured in a total of 5 monitoring plots, including 3 plots on the upper bench and 2 plots on the lower bench (Figure 25). The lower section was again planted in the spring of 2014. On June 23, 2014, approximately 452 trees were planted on an open slope on the eastern flank of Calf Robe Mountain. Two monitoring plots were established in this area, following 102 trees or 23% of planted seedlings. Finally, the upper area was planted again in the fall of 2014. On September 24, 2014, a total of 517 seedlings were planted on the eastern flank of Calf Robe Mountain. Three monitoring plots were installed, encompassing 133 trees or 23% of planted seedlings.

i. Spring 2013

Seedlings planted at the Firebrand Pass Area in the spring of 2013 were monitored on August 5, 2014. One year after planting, 93% of seedlings are surviving (Table 40). This high survival rate is typical of trees planted in 2013. Planting techniques have improved since the beginning of 5-needle pine restoration in Glacier National Park, with much care taking place in constructing adequate microsites and planting in desired areas. Most of the trees from this planting (67%) were rated in good health, while 25% were rated in “fair” condition and 1% was rated as almost dead.

There were some differences in survival among plots. Survival rates ranged from 86% in plot 1 to 98% in plot 2. It is unclear at this time what may be causing these differences as the plots are quite close together, have similar environmental conditions, and are from the same parent seed source population.

It will be interesting to track survival at year 3 to determine whether trees in fair condition will survive and improve vigor. This site is now one of several unburned sites that have been chosen for planting. Trends over time should be tracked to determine if unburned locations can produce high survival.

As is the trend in most plantings after year 1, seedlings decreased in size since the time of planting. Seedlings were 1.29 cm shorter and 0.94 cm less in width than in 2013 (Table 41). Average height for seedlings in 2014 was 8.82 cm and average width was 8.31 cm.

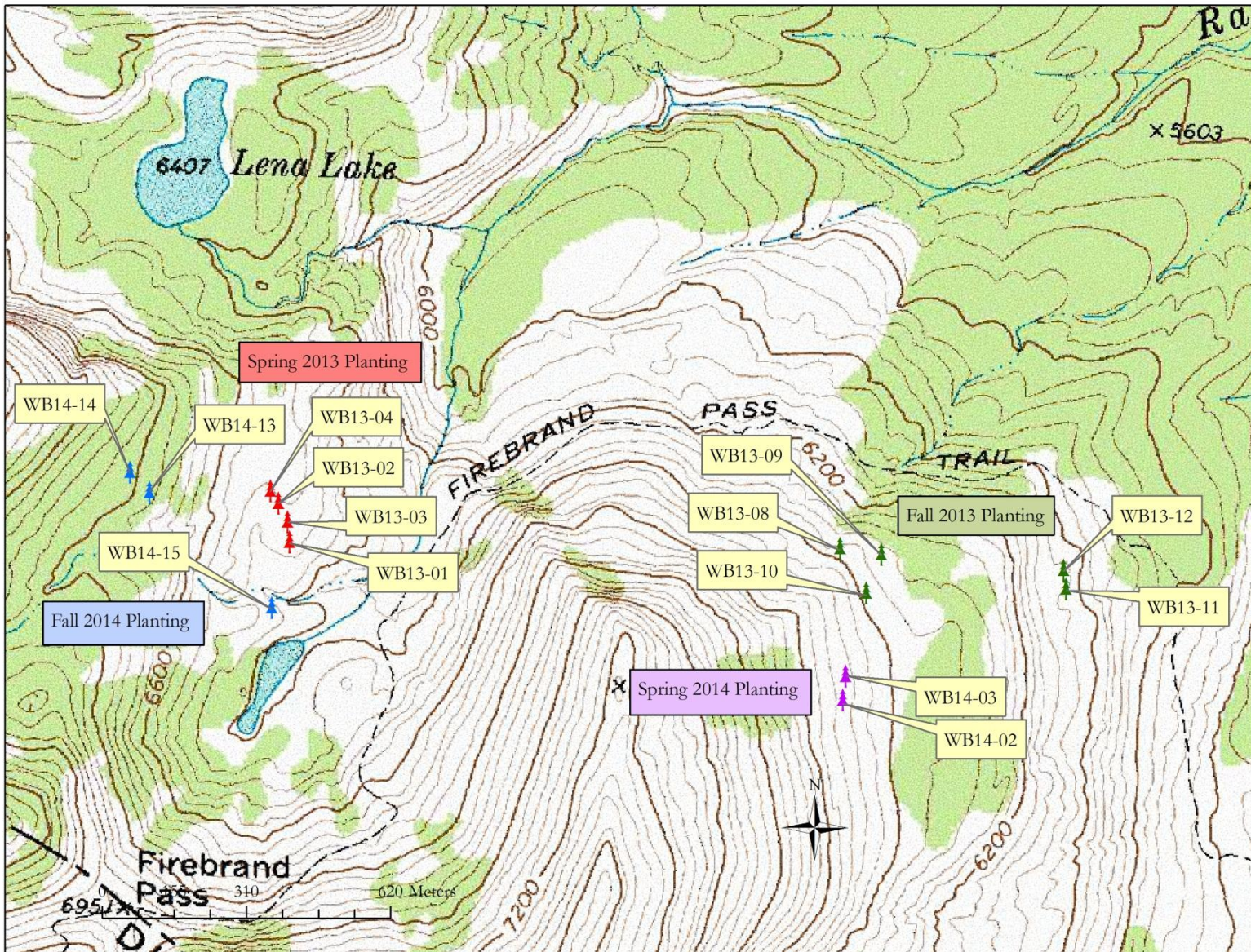
Table 40. Firebrand Pass Area, Spring 2013: Health and Survival of Whitebark Pine Monitored in 2013-2014.

<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-13-01	Old Man	0	0	0	44	44	44	100%
WB-13-02	Old Man	0	0	0	51	51	51	100%
WB-13-03	Old Man	0	0	0	59	59	59	100%
WB-13-04	Old Man	0	0	2	52	54	54	100%
	Total 2013	0	0	2	206	208	208	100%
WB-13-01	Old Man	6	0	16	22	38	44	86%
WB-13-02	Old Man	1	1	11	38	50	51	98%
WB-13-03	Old Man	2	1	23	34	58	60	97%
WB-13-04	Old Man	5	0	2	47	49	54	91%
	Total 2014	14	2	52	141	195	209	93%

Table 41. Firebrand Pass Area Spring 2013: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2013-2014.

Year	Survival	Average Height (cm)	Average Width (cm)
2013	100%	10.11	9.25
2014	93%	8.82	8.31

Figure 25. Whitebark Pine Seedling Monitoring Plots Established along the Firebrand Pass Trail, 2013 - 2014.



ii. Fall 2013

Monitoring of whitebark pine seedlings planted in the fall of 2013 at the Firebrand Pass Area took place on July 25, 2014. Survival was a high 95% at this site one year after planting (Table 42). A much higher percent of seedlings were rated in good health in this planting (89%) than those planted in the spring near this site (67%) one year after being outplanted. Few trees were rated in fair condition (3.4%) or almost dead (2.6%). Results of spring vs. fall plantings is still inconclusive at this time, although trends do tend to lean towards fall plantings outperforming spring plantings, particularly with whitebark pine.

As in the spring planting, there were survival differences among plots with survival rates ranging from 89% to 100%. Plots 8, 9 and 10 were grouped together on an open bench further upslope. These plots experienced better survival rates at 96% to 100%. Plots 11 and 12 were located on benches further downslope at lower elevations. These plots had slightly lower survival rates at 89% to 92%. Although these differences are small at this point, perhaps this reflects that environmental conditions are more favorable at the higher elevation sites. It was also noted that almost all of the seedlings did not look great at the time of planting in plot 11, although few were rated “fair” condition at that time. Seedlings in the lower plots originated from seed from different parent seed sources than in the upper plots as well. Lower plot seed sources were from the Old Man Lake area and Triple Divide, while seedlings in the upper plots originated from seed from Rising Wolf and White Calf.

As seen in the spring planting near this site and similar to most one-year plantings, seedlings decreased in size since the time of planting. Seedlings were 0.77 cm shorter and 0.89 cm less in width than in 2013 (Table 43). Average height for seedlings in 2014 was 7.96 cm and average width was 8.05 cm.

Table 42. Firebrand Pass Area, Fall 2013: Health and Survival of Whitebark Pine Seedlings Monitored in 2013-2014.

<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-13-08	Rising Wolf	0	0	0	33	33	33	100%
WB-13-09	Rising Wolf	0	0	1	112	113	113	100%
WB-13-10	Whitecalf	0	0	0	88	88	88	100%
WB-13-11	Old Man	1	0	3	70	73	74	99%
WB-13-12	Triple Divide*	0	0	0	68	68	68	100%
	Total 2013	1	0	4	371	375	376	99.73%
WB-13-08	Rising Wolf	0	0	0	33	33	33	100%
WB-13-09	Rising Wolf	3	1	1	110	112	115	97%
WB-13-10	White Calf	4	0	0	89	89	93	96%
WB-13-11	Old Man	6	7	7	56	70	76	92%
WB-13-12	Triple Divide*	8	2	5	55	62	70	89%
	Total 2014	21	10	13	343	366	387	95%

*very close to White Calf planting site, so this plot may also encompass some trees from White Calf parent trees.

Table 43. Firebrand Pass Area, Fall 2013: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2013-2014.

Year	Survival	Average Height (cm)	Average Width (cm)
2013	99.7%	8.73	8.94
2014	95%	7.96	8.05

iii. Spring 2014

On June 23, 2014, approximately 452 whitebark pine seedlings were planted in the lower Firebrand Pass area, on an open slope on the eastern flank of Calf Robe Mountain (Figure 25). Two monitoring plots were established on July 25, 2014, encompassing 102 trees or 23% of planted seedlings. Survival was 100%, although not all seedlings were rated in good health. In plot 3, 2 trees (4%) were rated “almost dead” and 3 trees (5%) were given a “fair” health assessment. Seedlings averaged 8.46 cm in height and 8.35 cm in width at the time of planting.

Table 44. Firebrand Pass Area, Spring 2014: Health and Survival of Whitebark Pine Seedlings Monitored in 2014.

<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 2013	0	2	3	97	102	102	100%

Table 45. Firebrand Pass Area Spring 2014: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2014.

Year	Survival	Average Height (cm)	Average Width (cm)
2014	100.0%	8.46	8.35

iv. Fall 2014

In the fall of 2014, approximately 569 whitebark pine seedlings were planted in the upper Firebrand Pass area. Planting took place on June 23, 2014 between 6,500 and 6,800 feet on the northeastern flank of Calf Robe Mountain (Figure 25). This site is near the spring 2013 planting area. Three monitoring plots were established on September 24, 2014, tracking 133 trees or 23% of planted seedlings. Plots 13 and 14 are located on a bench at a higher elevation than the spring planting area, while plot 15 is located on a bench just below the spring planting. Most seedlings originated from seed from the Old Man Lake area, but 98 cones were from seed from Whitecalf Mountain parent trees.

All seedlings were alive at the time of planting with most trees rated as “good” health. 16 trees overall (11%) were rated in “fair” condition. Plot 13 was rated the healthiest with only 2 trees in fair condition, while plots 14 and 15 each had 7 trees considered in fair health. Seedlings averaged 10.52 cm in height and 9.68 cm in width at the time of planting. These seedlings are considerably larger than those planted at the Firebrand Pass area in spring by 2.06 cm in height and 1.33 cm in width. It is presumed that they are larger due to an additional summer growing in the nursery prior to planting.

Table 46. Firebrand Pass, Fall 2014: Health and Survival of Whitebark Pine Seedlings Monitored in 2014.

<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 2013	0	0	16	131	147	147	100%

*Most trees from Old Man seed; 98 cones from White Calf seed

Table 47. Firebrand Pass Area, Fall 2014: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2014.

Year	Survival	Average Height (cm)	Average Width (cm)
2014	100%	10.52	9.68

f. Numa Lookout

i. Fall 2013

The Numa Lookout area was planted with whitebark pine seedlings in both the fall of 2013 and the fall of 2014. On September 24, 2013, approximately 558 seedlings were planted at Numa Ridge on south-facing slopes just below the lookout. Three monitoring plots were installed at this site, monitoring 167 trees or 30% of planted

seedlings (Figure 26). Seedlings were grown from seed collected from the Numa Lookout area. This site has not burned.

First year survival at this site, at 99%, is the best that Glacier National Park has seen to date (Table 48). Only two trees died since planting (1.1%), with only one tree looking almost dead (0.6%). Five trees (2.9%) were rated in “fair” health, while 173 trees (95.4%) were considered in good health.

There are several potential reasons why survival was so high at this unburned site. The weather was cold and wet at the time of planting, prime conditions for tree survival. Seedlings were not required to experience a lack of adequate water supply or heat exchange challenges. Seedlings were also watered in well after planting. These trees were also planted late in the season so that they likely went straight into dormancy. Additionally, mostly experienced planters were planting trees at this site and great care was taken to plant in appropriate sites with high quality microsites of logs, rocks or standing snags. Seedlings were also in good shape at the time of planting.

These first-year seedlings once again followed the typical trend of shrinking the first year after being planted. Trees shrunk by an average of 0.92 cm in height and by an average of 0.59 cm in width since planting (Table 49). Long, nursery-grown needles tend to shed the first year and are replaced by shorter, denser needles. Average height for Numa seedlings one year after planting was 9.11 cm and average width was 9.55 cm.

Figure 26. Whitebark Pine Seedling Monitoring Plots Established Near Numa Lookout, 2013 - 2014.

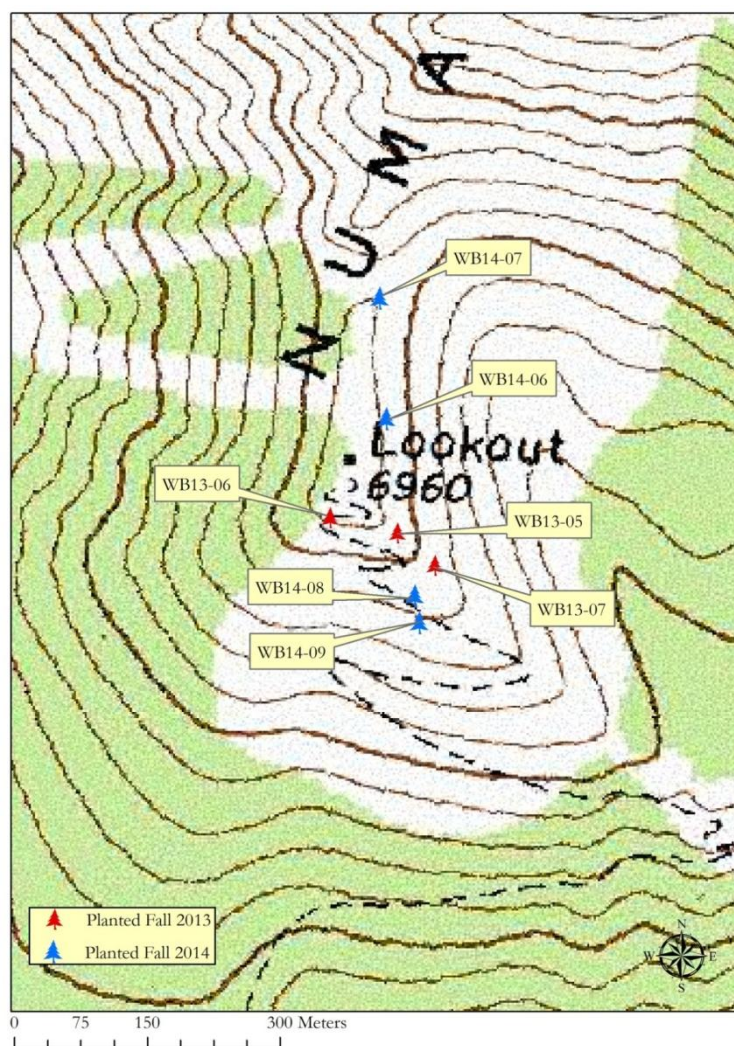


Table 48. Numa Lookout, Fall 2013: Health and Survival of Whitebark Pine Seedlings Monitored in 2014.

<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-13-05	Numa	0	0	0	75	75	75	100%
WB-13-06	Numa	0	0	0	49	49	49	100%
WB-13-07	Numa	0	0	0	43	43	43	100%
	Total 2013	0	0	0	167	167	167	100%
WB-13-05	Numa	1	0	1	80	81	82	99%
WB-13-06	Numa	1	1	4	44	49	50	98%
WB-13-07	Numa	0	0	0	43	43	43	100%
	Total 2014	2	1	5	167	173	175	99%

Table 49. Numa Lookout, Fall 2013: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2014.

Year	Survival	Average Height (cm)	Average Width (cm)
2013	100.0%	10.03	10.14
2014	99%	9.11	9.55

ii. Fall 2014

In the fall of 2014, whitebark pine seedlings were again planted 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 26). 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 to the north of the lookout. Plots encompassed 208 trees, monitoring 29% of seedlings planted in 2014.

All seedlings were alive in monitoring plots at the time of planting, although two trees (2%) were considered almost dead (Table 50). Ten trees were rated in “fair” condition (8%) and 108 trees were in good condition (90%). It will be interesting to see if this planting fares as well as the fall 2014 planting for several reasons. 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, several trees were rated “fair” or almost dead at the time of planting (10% total), while in 2013 all trees were rated “good”. Lastly, several relatively new planters were utilized for this project. Experienced planters tend to have developed a better eye for favorable microsite conditions, as well as have better planting skills.

Table 50. Numa Lookout, Fall 2014: Health and Survival of Whitebark Pine Seedlings Monitored in 2014.

<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%

Table 51. Numa Lookout, Fall 2014: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2014.

Year	Survival	Average Height (cm)	Average Width (cm)
2014	100%	11.43	10.01

g. Spot Mountain

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 perished to blister rust. Most surviving trees at this site are limber pine. Whitebark pine also exists sparingly in this stand, and interestingly, one large plus tree is located at a lower elevation than the existing limber pine stand. This tree is located south of the 2013 limber pine planting. The current whitebark pine planting site is located closer to this tree but at a slightly higher elevation. This site also has not burned.

On June 24, 2014, approximately 416 whitebark pine seedlings were planted on the lower flank of Spot Mountain, on an east-facing slope at about 6,230 feet in elevation. The seed source for most of these trees was from Triple Divide, although 23 of 219 containers containing seedlings were from seed from the Old Man Lake Area. One monitoring plot was established on July 21, 2014, capturing 36 trees or 9% of planted seedlings (Figure 27).

One month after planting, one tree was almost dead (3%) and the rest were considered in good health (35 trees, 97%, Table 52). Average height of trees was 8.64 cm and average width was 7.58. Seedlings planted in the spring tend to be smaller than fall planted trees that have had the summer to grow in the nursery.

Figure 27. Whitebark Pine Seedling Monitoring Plot Established at Spot Mountain, 2014

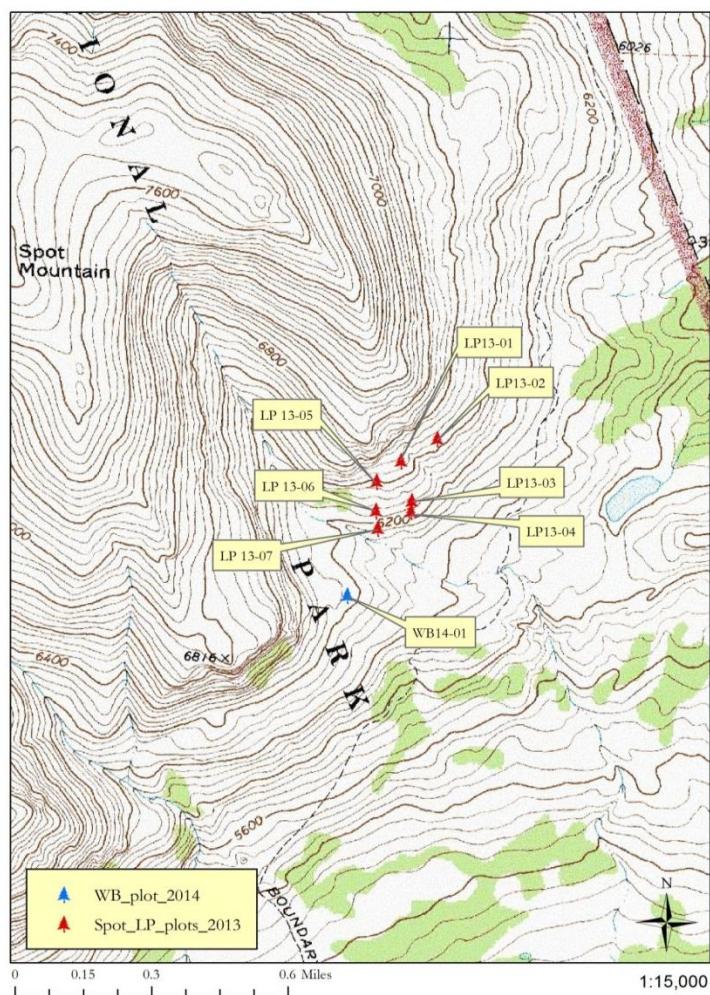


Table 52. Spot Mountain, Spring 2014: Health and Survival of Whitebark Pine Seedlings Monitored in 2014.

<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%

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

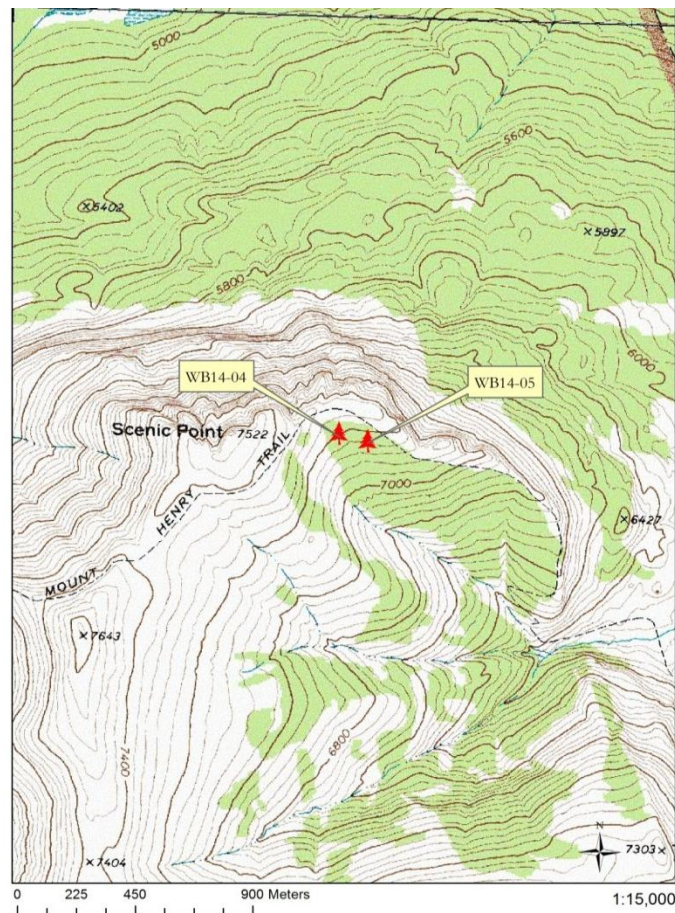
Table 53. Spot Mountain, Spring 2014: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2014.

Year	Survival	Average Height (cm)	Average Width (cm)
2014	100%	8.64	7.58

h. Scenic Point

Scenic Point was the second of three new whitebark pine seedling planting sites in 2014. This planting site is located southeast and downslope from Scenic Point proper (Figure 28). 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.

Figure 28. Whitebark Pine Seedling Monitoring Plots Established at Scenic Point, 2014.



On June 25, 2014, approximately 802 whitebark pine seedlings were planted in the Scenic Point Area on a southeast facing slope at elevations ranging from 7,210 to 7,164 feet. The seed source for these seedlings was from Rising Wolf. On July 28, 2014, two monitoring plots were established, encompassing 188 trees or 23% of planted seedlings (Figure 28). Approximately one month after planting, one tree was dead (0.5%), but all the rest were considered in good health (187 trees, 99.5%) (Table 54). Average height was 9.28 cm and average width was 8.88 cm (Table 55).

In general, spring plantings have not fared quite as well as fall plantings, so it will be important to track these results over time. This site was deemed a very good planting site by the revegetation crew due to good, deep soil conditions.

Table 54. Scenic Point, Spring 2014: Health and Survival of Whitebark Pine Seedlings Monitored in 2014.

<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%

Table 55. Scenic Point, Spring 2014: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2014.

Year	Survival	Average Height (cm)	Average Width (cm)
2014	99%	9.28	8.88

i. White Calf Mountain

White Calf Mountain was the third of three new whitebark pine planting sites for 2014. It 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.

On October 20, 2014, this area was planted with approximately 788 whitebark pine seedlings on southeast facing slopes on the lower flanks of White Calf Mountain. Elevation ranged from 6,735 to 6,765 feet. Seedlings originated from seed collected from trees on Whitecalf Mountain near this planting site.

Two monitoring plots were set up two days after planting on October 22, 2014 (Figure 29). Plots captured 146 trees or 19% of planted seedlings. At the time of planting, all trees were alive and only one tree (0.7%) was considered in fair condition (Table 56). All other trees were considered healthy (145 trees, 99.3%). These seedlings were planted under cooler conditions than most other plantings in 2014 and likely have the added benefit of being able to go directly into dormancy. Seedlings looked mostly healthy at the time of planting as well, setting this planting up well for success.

Average height for seedlings planted at White Calf Mountain in the fall of 2014 was 10.52 cm and average width was 9.45 cm (Table 57). As is true for most fall-planted seedlings, these trees are slightly larger than those planted in spring, on average.

Table 56. White Calf, Fall 2014: Health and Survival of Whitebark Pine Seedlings Monitored in 2014.

<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%

Table 57. White Calf, Fall 2014: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2014.

Year	Survival	Average Height (cm)	Average Width (cm)
2014	100%	10.52	9.45

Figure 29. Whitebark Pine Seedling Monitoring Plots Established at Whitecalf Mountain, 2014.

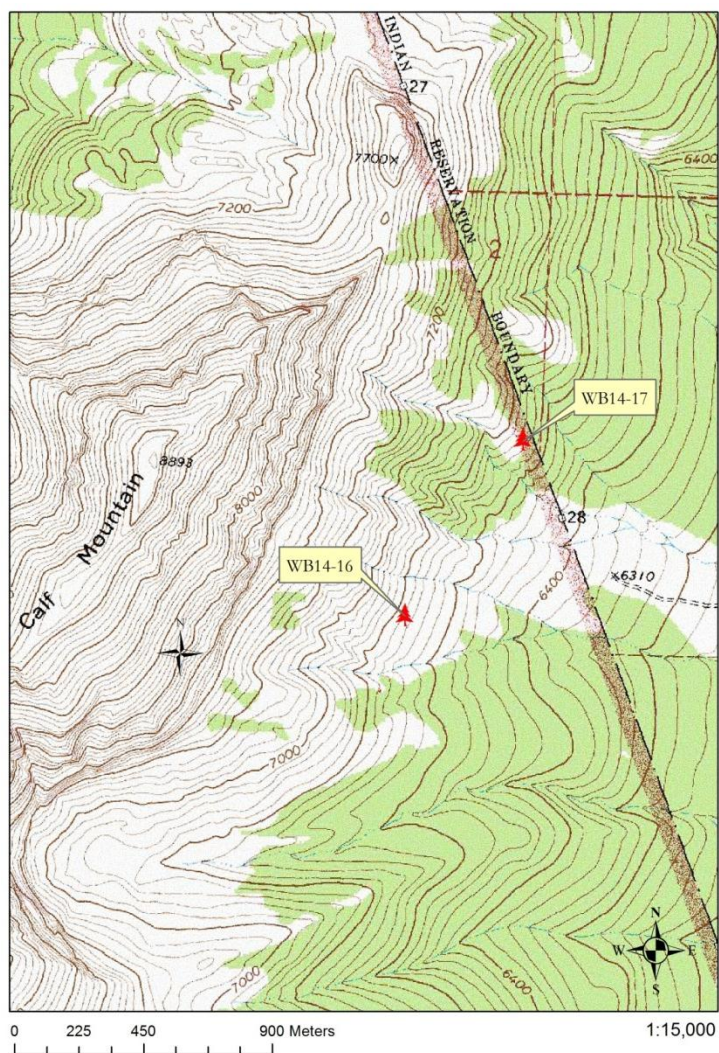


Table 58. Overall Survival and Average Height and Width of Whitebark Pine Seedlings Planted in 2014.

Site	Planting Season	Initial Survival	Average Height (cm)	Average Width (cm)
Divide Creek	Fall	100%	10.01	9.48
Firebrand Pass - spring	Spring	100%	8.46	8.35
Firebrand Pass - fall	Fall	100%	10.52	9.68
Numa Lookout	Fall	100%	9.11	9.55
Scenic Point	Spring	99.5%	9.28	8.88
Spot Mountain	Spring	100%	8.64	7.58
Whitecalf Mountain	Fall	100%	10.52	9.45

Table 59. Changes in Height and Width in Whitebark Pine Seedlings from Planting Time to Year 10.

Site	Year Planted	Season Planted	Last Year Monitored	Change from year 0-1		Change from year 1-2		Change from year 0-2		Change from year 1-3		Change from year 2-3		Change from year 3-4		Change from year 3-5		Change from year 4-7		Change from year 5-8		Change from year 7-9		Change from year 8-10	
				Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width
Flattop Mtn. Spring 2001	2001	spring	2011																	17.4	9.11			7.74	5.77
Flattop Mtn. Fall 2001	2001	fall	2011																	18.37	13.42			7.83	-4.69
Flattop Mtn. Fall 2002	2002	fall	2011															15.23	12.27			6.51	5.74		
Red Eagle - lower	2007	fall	2012	-1.31	*																				
Red Eagle - upper	2007	fall	2012	0.03	*	3.34	4.25	3.37				3.57	3.58			11.94	9.39								
Divide Creek	2010	fall	2014	-0.79	0.77	0.44	-0.36					2.1	3.92	3.99	2.56										
Hole-in-the-Wall	2010	fall	2012					-2.37	-0.18																
Cobalt Lake	2011	late summer	2014	0.61	1.45					2.85	-0.73														
Grinnell Picnic Area	2011	late summer	2014	1.11	1.81					2.27	3.97														
Divide Mountain	2012	fall	2014					0.21	-0.38																
Firebrand Pass Area	2013	spring	2014	-1.29	-0.94																				
Firebrand Pass Area	2013	fall	2014	-0.77	-0.89																				
Numa Lookout	2013	fall	2014	-0.92	-0.59																				
Average				-0.42	0.27	1.89	1.95	0.40	-0.28	2.56	1.62	2.84	3.75	3.99	2.56	11.94	9.39	15.23	12.27	17.89	11.27	6.51	5.74	7.79	0.54

D. CONCLUSIONS AND RECOMMENDATIONS

1. *Limber Pine*

In 2014, two cohorts of limber pine seedlings were monitored; seedlings planted in 2004, which are now 10 years old, and seedlings planted in 2013, which are one year old. This is the first major planting to reach ten years old in Glacier National Park since 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 survivorship. Ten-year-old seedlings planted in 2004 averaged 15% survival. It is likely that some of the subsequent plantings will have higher survivorship than this at ten years 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 survivorship over the years as we have learned more about planting successfully and have had more favorable weather conditions.

One-year-old seedlings, planted in 2013 at Spot Mountain, averaged 73% survival, the highest survivorship for limber pine in the Park to date. This likely reflects good site selection, good planting techniques, and healthy plant material, as well as adequate rainfall. Most sites provided some shade and wind protection and planting crews utilized existing microsites or brought in microsite material. 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, however, spring-planted sites only had a 49% survival rate, compared to the 89% survival rate, nearly double, of fall-planted sites. While this trend is not always the case, seasonal comparisons tend to favor planting in the fall. It does appear in many cases that the stress of being transplanted into an active growing state in harsh environments may take its toll on seedlings the following winter. Rocky soil and other environmental parameters may prevent seedlings from thriving through the summer at certain sites as well, 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.

A year-one survival rate of 73% for limber pine monitored this year is particularly encouraging, since earlier limber pine plantings had not been very promising. Steady improvement has been taking place, however. Nearly 60% of limber pine seedlings planted in 2012 survived to year one, a vast improvement over the previous planting from 2006 where year-one survival was only 13%.

For plantings prior to 2012, overall survival of limber pine planted in the park is a very low 6%. Most of this overall low survival rate was due to a large planting event in 2002 that preceded an extremely hot, dry summer in 2003. Only 0.5% of the trees survived by year two and only 0.2% of the trees survived by year seven. Average survival for trees planted from 2003 to 2006 was 13%. It is hopeful that plantings over the last two years will show a marked increase in overall survival over time. The revegetation crew is utilizing what we have learned from previous plantings as well as information from other parks and national forests to provide much better planting techniques and planting sites.

Information from Waterton Lakes National Park (WLNP) has proven to be especially helpful. 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. Until suitable limber pine habitat burns in GNP, we will have to utilize protected planting sites as well as possible.

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). 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 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.
- 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. Again, 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 reliable.
- 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.

Limber pine monitoring scheduled for 2015 includes seedlings planted in 2005 at Scenic Point, which will be ten years old. Also slated for monitoring are seedlings planted in 2013 at Cutbank, Apikuni Flats, Many Glacier Well area, Rising Sun Campground and Scenic Point (Table X). Spot Mountain seedlings would typically have been scheduled for monitoring next year as well, for second year after planting data, but time and money constraints have caused us to re-evaluate monitoring frequency. It has been decided to skip year two monitoring events and retain years 1, 3, 5 and 10 monitoring. No limber pine seedlings were planted in the Park in 2014. In 2015 and 2016, 500 limber pine seedlings are planned to arrive each year for planting. Monitoring plots will be established to capture approximately 20% of these seedlings.

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 68%. It is hopeful that limber pine seedlings planted in 2012 through 2014 will begin to see equal success.

This year's results continue to follow recent trends with initial survival rates continuing to rise. One site, Numa Lookout, had 99% first-year survival, the highest yet recorded in the Park. Overall first year survival for trees planted in 2012 is 95%.

Second year survival, only monitored at one site, was a bit lower this year. Seedlings at Divide Mountain had only 65% survival. Much of this was due to herbivory in the area, as this site supports a healthy population of pikas and golden mantled ground squirrels. Herbivory was noted as soon as the next day after planting at this site. A complex relationship between inoculation of seedlings and burned vs. non-burned areas appears to be a factor in survival here as well. In general, seedlings showed the best survival when planted in a burn and inoculated with an ectomycorrhizal slurry. Trees that were not inoculated and not planted in a burn had the lowest survival rates and shrunk in size. Future controlled studies should be

considered that 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 WLNP 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.

Although monitoring does not usually take place at year four after planting, seedlings planted at Divide Creek were opportunistically monitored this year. Year four survival remained the same as last year, at 94%, and continues to be one of the most successful plantings to date. Seedlings also grew substantially from year three to year four.

Fifth year survival, at 25% overall, was not as high as many of the other recent whitebark pine restoration projects. Much of this appears to be due to hot and dry conditions during planting in late summer, as well as less desirable planting sites. Only 10% of seedlings at Cobalt Lake continue to be alive. This site has very little shade and poor soil for planting. Seedlings at Grinnell Glacier Picnic area fared slightly better with a 40% survival rate. Conditions were more favorable at this site with more shade available, at least in some areas, and better soil.

Seedlings were not monitored this year at these sites, but year ten survival was 31% at Flattop Mountain, year six survival was 41% at Grinnell Point, year five survival was 47% at Red Eagle (55% for upper plots), year two survival at Hole-in-the-Wall was 46% and year two survival was 46% at Caper Peak.

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 vast 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 much more 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.

Divide Creek remains the most successful long term planting site to date. These seedlings were planted late in the season with ample moisture, which appears to be very important. Overall survival of 94% at Divide Creek is well above the three-year average of 38%. This high survival rate may 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. Several sites have equally high initial survivorship as Divide Creek; future results should help to reveal refined understandings of factors that play into increased survivorship over time. Additionally, future success of this site may be hampered by high competition from lodgepole pine in this area. Some trees are reaching 1 to 1.5 meters tall and form relatively thick stands in areas.

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. Burned areas should be utilized when possible.

From 2012 to 2014, several large plantings took place in non-burned areas: Divide Mountain in 2012, along the Firebrand Pass Trail and below Numa Lookout in 2013 and 2014, and at Scenic Point, Spot Mountain and Whitecalf Mountain in 2014. First year survivorship at these sites is excellent with the possible exception of Divide Mountain, which experienced high herbivory. Continued monitoring of non-burned sites should help to guide future site selection.

Direct seeding of whitebark pine seed 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 2015, several limber pine monitoring plots are scheduled to be revisited. One Scenic Point planting will be monitored at 10 years after planting. Additionally, seedlings at Apikuni Flats, Cutbank, Rising Sun Campground, the Many Glacier Well area and another Scenic Point planting area are scheduled to be monitored three years post-planting. Several whitebark pine plantings are also due for monitoring. Two plantings will reach 15 years of age next year. One site, at Dutch Creek, has no location information and likely will not be monitored again. Grinnell Point is a remote area and seedlings were opportunistically planted during a post-fire helicopter operation. It is possible that this site may be revisited in 2015. Sites that are scheduled for monitoring include a five year visit to Hole in the Wall. The lower Divide Creek planting will also reach five years of age, but may not be monitored since it was just monitored this year at year four. Divide Mountain will be monitored at year three and several year one plantings are also scheduled for monitoring: Upper Divide Creek, the Firebrand Pass Area, Numa Lookout, Scenic Point, Spot Mountain and Whitecalf Mountain.

In 2015, 500 limber pine and 500 whitebark pine seedlings are scheduled to be delivered for planting in Glacier National Park. Monitoring plots will be installed at planting areas to capture a targeted 20% of seedlings.

Table 60. Whitebark and Limber Pine Monitoring Schedule

black text = completed

orange text = scheduled but not completed

red text = notes about trees in plots with high mortality

blue text = scheduled for future

Plot(s)	Species	Location	Year Planted	Year Monitored: 2000	2001	2002	2003	2004	2005	2006	2007	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 0)						X (year 6)				X (year 10)		
FT01 -01 to -27	Whitebark pine	Flattop	2001		X (year 0)	X (year 1)			X (year 4)	X (year 5)			X (year 8)		X (year 10)	
FT02 -01 to -11	Whitebark pine	Flattop	2002			X (year 0)			X (year 3)	X (year 4)			X (year 7)		X (year 9)	
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		X (year 7) ALL DEAD			
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		X (year 7) ALL DEAD			
LP02-24	Limber pine	Firchbrand Pass	2002			X (year 0)	X (year 1)	X (year 2)		X (year 4) 1 TREE LEFT		X (year 6)				X (year 10)
LP03-01	Limber pine	Two Med Camp Store	2003				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
LP04 -01 to -05	Limber pine	Baring Creek	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)	X (year 4)	X (year 5)			
LP04 -06 to -07	Limber pine	Many Glacier Hotel Slope	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5)			
LP04 -08	Limber pine	Sun Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5) ALL DEAD			
LP04 -09	Limber pine	Sun Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5)			
LP04 -10	Limber pine	Dead Horse Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5) 1 TREE LEFT			
LP04 -11	Limber pine	Dead Horse Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5) ALL DEAD			
LP05 -01 to -06	Limber pine	Scenic Point	2005						X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5)		
LP06 -02	Limber pine	Baring Creek	2006							X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5)	
LP06 -01 & -03	Limber pine	Baring Creek	2006							X (year 0)	X (year 1)	X (year 2) ALL DEAD				
LP06 -04	Limber pine	Dead Horse Point	2006							X (year 0)	X (year 1)	Not done: all dead but 1 missing	X (year 3) ALL DEAD			
CP06 -01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006							X (year 0)		X (year 2)			X (year 5)	
WB07 -01 to -09	Whitebark pine	Red Eagle (seedlings)	2007								X (year 0)		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	Synch Bend (seeds)	2007										X (year 2)	X (year 3)		X (year 5) NOTHING COMING UP
WB10-01-05	Whitebark pine	Hole-in-the-Wall	2010											X (year 0)	X (year 1)	X (year 2)
WB10-06-10	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													
CL-WB-11-01 to -03	Whitebark pine	Gobalt 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													

Table 60, con't. Whitebark and Limber Pine Monitoring Schedule

black text = completed

orange text = scheduled but not completed

red text = notes about trees in plots with high mortality

blue text = scheduled for future

Plot(s)	Species	Location	Year Planted	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
None installed	Whitebark pine	Dutch Creek	2000?			X (year 15)					X (year 20)					X (year 25)
GP00 -01 to -07	Whitebark pine	Ginnell Point	2000			X (year 15)					X (year 20)					X (year 25)
FT01 -01 to -27	Whitebark pine	Flattop	2001				X (year 15)					X (year 20)				
FT02 -01 to -11	Whitebark pine	Flattop	2002				X (year 14)					X (year 19)				
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					X (year 20) 1 TREE LEFT			
LP03-01	Limber pine	Two Med Camp Store	2003	X (year 10)					X (year 15)					X (year 20)		
LP04 -01 to -05	Limber pine	Baring Creek	2004		X (year 10)					X (year 15)					X (year 20)	
LP04 -06 to -07	Limber pine	Many Glacier Hotel Slope	2004		X (year 10)					X (year 15)					X (year 20)	
LP04 -08	Limber pine	Sun Point	2004													
LP04 -09	Limber pine	Sun Point	2004		X (year 10)					X (year 15)					X (year 20)	
LP04 -10	Limber pine	Dead Horse Point	2004		X (year 10) 1 TREE LEFT					X (year 15) 1 TREE LEFT					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 10)					X (year 15)					X (year 20)
LP06-02	Limber pine	Baring Creek	2006				X (year 10)					X (year 15)				
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)					X (year 15)				
WB07 -01 to -09	Whitebark pine	Red Eagle (seeds + trees)	2007					X (year 10)					X (year 15)			
WBS07 -04 to -05	Whitebark pine	Red Eagle (seeds)	2007					X (year 10)					X (year 15)			
WBS07 -01 to -03	Whitebark pine	Sreeh Bend (seeds)	2007													
WB10-01-05	Whitebark pine	Hole-in-the-Wall	2010	X (year 3)		X (year 5)					X (year 10)					X (year 15)
WB10-06 to -10	Whitebark pine	Divide Creek lower	2010	X (year 3)	X (year 4)	did year 4					X (year 10)					X (year 15)
GP0A-WB-11-01 to -02	Whitebark pine	Ginnell Picnic Area	2011		X (year 3)		X (year 5)					X (year 10)				
CL-WB-11-01 to -03	Whitebark pine	Graball Lake	2011		X (year 3)		X (year 5)					X (year 10)				
WB12-01 to -04	Whitebark pine	Divide Mountain	2012	X (year 1)	X (year 2)	X (year 3)		X (year 5)					X (year 10)			
LP12-01 to -02	Limber pine	Cutbank	2012	X (year 1)		X (year 3)		X (year 5)					X (year 10)			
LP12-03 and -11	Limber pine	Apikuni Flats	2012	X (year 1)		X (year 3)		X (year 5)					X (year 10)			
LP12-04 to -05	Limber pine	Rising Sun CG	2012	X (year 1)		X (year 3)		X (year 5)					X (year 10)			
LP12-06 to -09	Limber pine	Scenic Point	2012	X (year 1)		X (year 3)		X (year 5)					X (year 10)			
LP12-10	Limber pine	Many Glacier Well Area	2012	X (year 1)		X (year 3)		X (year 5)					X (year 10)			
WB13-01 to -04	Whitebark pine	Firebrand Pass upper (spring)	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)		
WB13-08 to -12	Whitebark pine	Firebrand Pass lower (fall)	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)		
WB13-05 to -07	Whitebark pine	Numa Ridge	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)		
LP13-01 to -07	Limber pine	Spot Mtn.	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)		
WB14-01	Whitebark pine	Spot Mtn. (spring)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	
WB14-02 to -03	Whitebark pine	Firebrand Pass lower (spring)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	
WB14-04 to -05	Whitebark pine	Scenic Point upper (spring)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	
WB14-06 to -09	Whitebark pine	Numa Ridge (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	
WB14-10 to -12	Whitebark pine	Divide Creek upper (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	
WB14-13 to -15	Whitebark pine	Firebrand Pass upper (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	
WB14-16 to -17	Whitebark pine	Whitetail (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	

VIII. WHITEBARK AND LIMBER PINE PLUS TREE MONITORING

A. INTRODUCTION

Whitebark pine (*Pinus albicaulis*) 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 17 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. GNP should begin to get preliminary results about the resistance of our tree as early as 2015.

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 resistant, meaning that plus trees are 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 ward off 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 98 whitebark pine trees that are being monitored as part of the plus tree pool, although cone information was only collected on 92 trees in 2014 due to missed trees (these include 3 trees at Scenic Point and 1 tree at Numa, Firebrand, and White Calf) (Figure 31; Table 61). This is down 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, two 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, and 2 trees were added to the pool in 2014. Of these 104 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 98 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. Finally, two of the six potential trees at Old Man were officially added to the pool in 2014. Currently, there are nine limber pine trees present in the plus tree monitoring pool (Figure 30; Table 63). 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. Finally, four trees, all at Spot Mtn., were identified in 2013.

In 2014, due to time and money constraints, only cone counts were performed on whitebark and limber pine plus trees. This is similar to 2012 and 2013. 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, 92 of the existing 98 whitebark pine plus trees were monitored for cone production in 2014. Health of individual plus trees was not assessed this year. As GNP completed the seed requirement in 2013 for the rust-resistance genetics testing program with the USFS, cones were also not collected from any tree for this first time in several years.

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 (Table 61; Figure 31). In 2014, 85% of monitored trees produced cones, as compared to 82% in 2013, 57% in 2012, and 89% in 2011. Despite the higher percentage of cone producing trees in 2013 and 2014, however, the average number of cones per tree is much lower than the average number of cones per tree in 2011, GNP's most recent ‘mast’ year. The average number of cones per tree was 24 in 2014 and 19 in 2013, compared to 66 average cones per tree in 2011. Overall, 2014 only had a moderate number of cones per tree given the high number of trees producing cones. 2008 and 2012, the years with the lowest percent of trees that were cone producing, also had the lowest average cones per tree at 5 and 12, respectively.

Figure 30. Location of Whitebark and Limber Pine Plus Trees for Monitoring

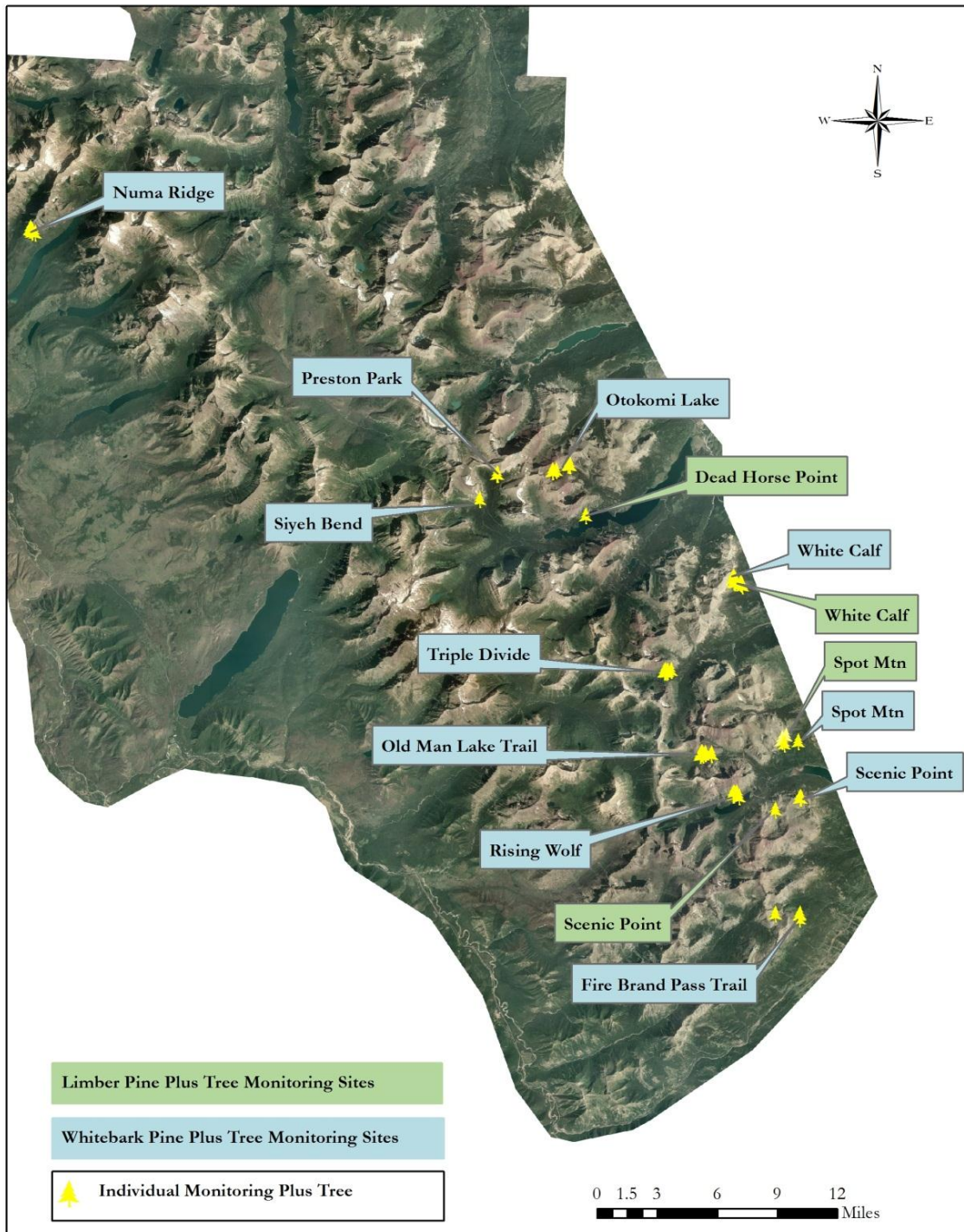


Table 61. Whitebark Pine Plus Trees: Comparison of Health and Cone Production, 2007-2014.

<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
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
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
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
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
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

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

Table 61 con'd. Whitebark Pine Plus Trees: Comparison of Health and Cone Production, 2007-2014.

<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
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
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
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
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
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
% 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%

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

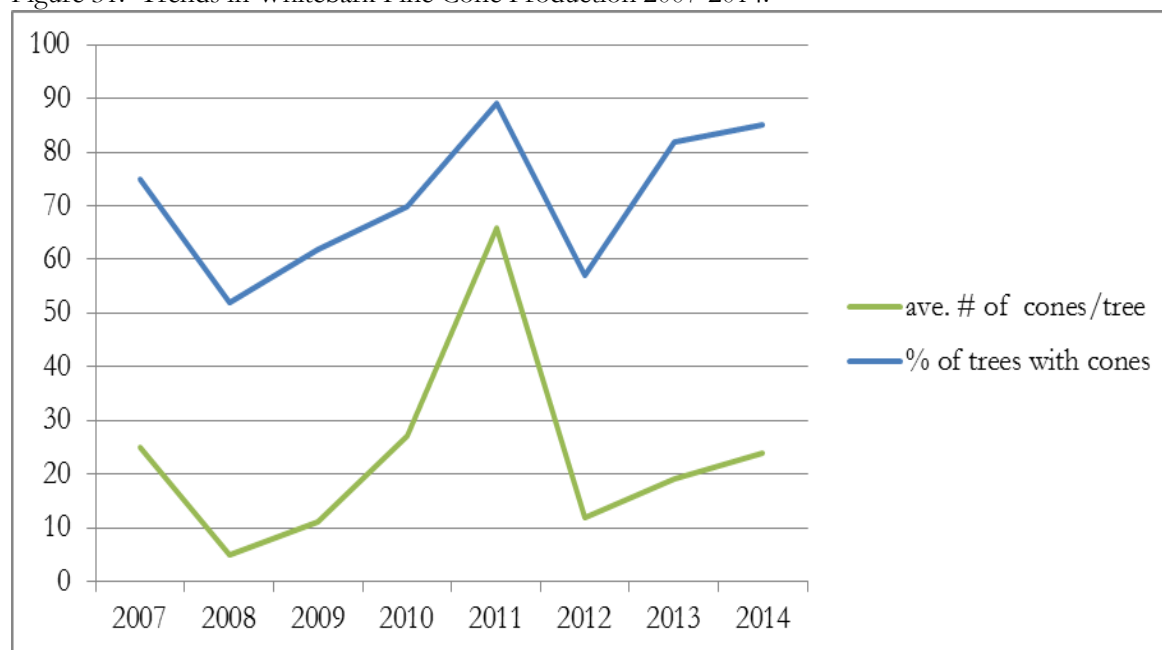
Table 62. Whitebark Pine Plus Trees: Average Cones Per Tree, 2007 – 2014.

<i>Site</i>	<i>2007</i>			<i>2008</i>			<i>2009</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

<i>Site</i>	<i>2010</i>			<i>2011</i>			<i>2012</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

<i>Site</i>	<i>2013</i>			<i>2014</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
Numa Lookout	11	145	13.2	10	61	6.1
Old Man Trail	10	151	15.1	12	251	20.9
Otokomi Lake	6	172	28.7	6	63	10.5
Preston Park	24	876	36.5	24	185	7.7
Rising Wolf	6	80	13	6	368	61.3
Scenic Point	15	66	4	12	25	2.1
Siyeh Bend	0	n/a	n/a	3	104	34.7
Spot Mtn.				1	250	250.0
Triple Divide	0	n/a	n/a	5	316	63.2
White Calf	11	62	6	10	563	56.3
TOTAL	87	1614	19	92	2220	24

Figure 31. Trends in Whitebark Pine Cone Production 2007-2014.



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 2 or 3 times from 1980-1990 (Morgan and Bunting 1990). It appears that we may be on about a 4 year cycle (Figure 31), although too little data is available to make any predictions. Data for percent trees with cones and average number of cones per trees are generally following similar trends (Figure 31), 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.

Finally, three limber pine trees were monitored this year; one at Dead Horse Point, one at Scenic Point and one at White Calf. Each tree is healthy, although only two of the three trees were producing cones this year (Tables 63 and 64). Average numbers of cones per tree in 2014 is double the estimate for average cones per tree in 2013, although still half the estimate of average cones per tree in 2011, the most recent mast year (Table 64). Trends are still being assessed for limber pine cone production given the small sample size and only seven years of data. It should be noted that four additional limber pine trees were added to the plus tree pool at Spot Mountain in 2013. No cone counts or other information was documented for these trees this year so they were omitted from the data tables.

Table 63. Limber Pine Plus Trees: Health and Cone Production, 2014.

<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	2014	1	n/a	n/a	n/a	n/a	1
Scenic Point	2014	1	n/a	n/a	n/a	n/a	1
White Calf	2014	1	n/a	n/a	n/a	n/a	1
	TOTAL	4	n/a	n/a	n/a	n/a	3
	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%

Table 64. Limber Pine Plus Trees: Average Cones Per Tree, 2007 – 2014.

<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>	<i># of Trees Monitored 10</i>	<i># of Cones in 2010</i>	<i>Avg Cones per tree 10</i>
Dead Horse Point	1/2	100	100	50	50	200	200	1	46	23
Scenic Point	1	10	10	20	20	0	0	1	15	15
Whitecalf	0							1	75	75
TOTAL	2/4	110	55	70	35	200	100	3	136	34

<i>Site</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>	<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>
Dead Horse Point	0	n/a	n/a	1	40	40	1	50	50	1	149	149
Scenic Point	1	55	55	1	40	40	1	0	0	1	10	0
Whitecalf	1	100	100	2	249	125	2	130	65	1	105	105
TOTAL	2	155	78	4	329	82	4	180	45	3	264	88

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. It appears that we may be on about a 4 year cycle for true mast years (Figure 31), although too little data is available to make any predictions. 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 pine trees is unknown, a larger pool of trees is imperative for seed collection and genetic integrity of our seedling stock. In 2014, two new plus trees were added to the monitoring pool from the Old Man area. 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 the 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, no 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 2015. 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 2015 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.

IX. 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 howellii
Fragaria virginiana/vesca
Symphotrichum 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.

X. MONITORING SCHEDULE: 1992 - 2015

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)
- 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)
- 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
- Apgar Transit Center – Level II (year 5) – did not do
- 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

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 5) – did not do
- West Entrance (year 5)
- GTSR – Phase 6 (year 3)
- GTSR – Phase X : Lunch Creek (year 1)
- GTSR – Phase VIIb: West tunnel to Avalance (year 1)
- St. Mary Visitor Center (year 3)

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)

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)

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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	42.1	52.6	55.6	67.4	64.8	54.6	47.6	#
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	2.2	2.0	5.9	1.1	2.3	1.7	2.6	#

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	36.0	#	51.2	63.0	59.8	50.3	#	#
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	2.0	#	7.1	0.8	2.3	0.7	#	#

* 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.