STUDY: MATURE SUBALPINE TREE & SHRUB TRANSPLANTING AT THE CLIMAX MINE, CLIMAX, CO[1]

R. F. Bay[2], K. E. Carlson, and A. Hilshorst

Abstract: As part of reclamation activities, 1,459 trees and shrubs were transplanted on the Climax Mine property during the summers of 2005, 2006 and 2007. The majority of transplants were Engelmann spruce (*Picea engelmannii*), the dominant tree species on the Climax property. Other transplanted species included subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta*), several willow species (*Salix* spp.), shrubby cinquefoil (*Dasiphora fruticosa*), dwarf birch (*Betula nana*), and currant species (*Ribes* spp.). Trees and shrubs with 32 – 60-in root balls were harvested using a tree spade within the mine's affected area and placed in burlap-lined cages for transport and temporary storage before planting in reclaimed areas. Transplants were placed in holes deep enough to cover to the root crown, backfilled with a mixture of topsoil, old woodchips, and composted biosolids (4:1:1), and mulched with woodchips. All transplants were watered in within 2 days of planting and treated with a general mycorrhizal inoculant.

Each transplanted tree and shrub was monitored for survival and growth in 2005, 2006, 2007, 2008, 2010 and 2012. Overall, transplanting was relatively successful with 68% total survival as of 2012. Shrubs were more successful than trees with 96% of shrubs surviving compared to only 63% of trees. Survival was greater for spruce trees (64%) than fir trees (41%). Also, survival was greater in shorter (<6 ft tall) trees with 72% still alive in 2012 compared to only 56% of taller trees. Tree survival dropped substantially between 2010 and 2012 from 71% to 63%, likely due to drought conditions and heavy elk damage. Elk damaged 25% of the trees, but only 26% of damaged trees died. There was also a significant difference in survival for different planting locations and soil types. The goal for this project was 50% survival after the first growing season. Thus, survival is better than expected and the goal has been surpassed after several growing seasons.

Additional Key Words: Mine reclamation, revegetation, shrub, spruce, willow

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Introduction

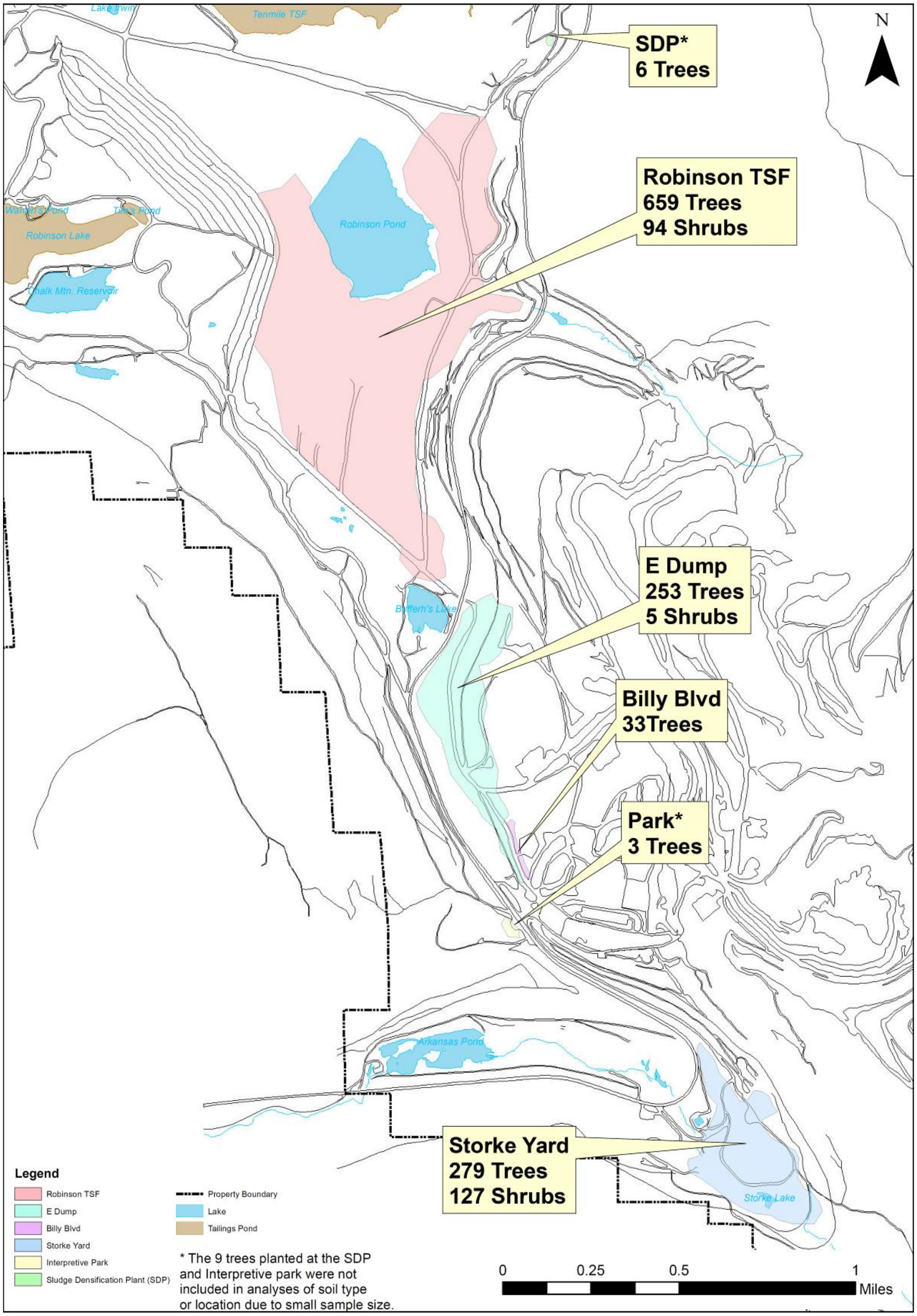
The Climax Molybdenum Company's Climax Mine (Climax) has been actively reclaiming areas affected by mining since the 1980s. Climax operated from 1918 to the early 1980s, then intermittently through 1995 and re-opened in 2012. During the non-operational period between 1995 and 2012, Climax conducted closure and reclamation on areas that would no longer be affected by mining. To date, approximately 1,000 acres have been reclaimed with nearly 300 acres in the process of reclamation. As part of these activities, 1,459 trees and shrubs were transplanted into reclamation areas from other areas on the property during the summers of 2005, 2006 and 2007.

The addition of mature trees and shrubs to the reclamation areas provides several layers of vegetation structure above the reclaimed subalpine grassland community. The trees and shrubs were planted in small groups to provide visual cover, which has benefited bird and mammal populations that use the reclaimed land. Hawks use the tallest trees for hunting perches and small birds and mammals are regularly seen on the smaller trees and shrubs. Willow (*Salix* spp.) and birch (*Betula nana*) shrubs planted in the wettest areas of reclamation and along the reconstructed Arkansas River channel provide the additional benefits of wetland community establishment and soil stabilization. Additionally, the trees and shrubs have added to the aesthetic value of the site from the public highway.

Climax had a goal of 50% survival of trees and shrubs after the first growing season. This paper presents the methods used for transplanting, challenges encountered during transplanting, an analysis of survival after several growing seasons, and evaluation of costs associated with this project.

Site Description

The Climax property straddles the Continental Divide at Fremont Pass in Summit and Lake Counties, CO. The transplanting program included four primary reclamation areas on both sides of the Divide: the Storke Yard, Billy Blvd Haul Road, E Dump Overburden Storage Facility (E Dump), and the Robinson tailings storage facility (Robinson TSF) (Figure 1). Two additional areas (the Interpretive Park and the Sludge Densification Plant, SDP) were planted with a total of nine trees. The elevation of transplant locations ranges from 11,150 ft to 11,300 ft asl. Reclamation activities are particularly difficult at this site due to the high altitude, short growing season, harsh winters, heavy snow pack, intense summer thunderstorms, periodic flood events and poor soils.



* The 9 trees planted at the SDP and Interpretive park were not included in analyses of soil type or location due to small sample size.

Figure 1. Tree planting locations.

Climate

The climate at Climax is typical of the central Rocky Mountain region and characterized by short cool summers and long cold winters. The average daily high and low temperatures in July are 65°F and 39°F, respectively, while the average daily high and low temperatures in January are 25°F and 2°F, respectively (Western Regional Climate Center, 2013). Average precipitation is approximately 25” of which 80 - 90% is snowfall. Snow can fall during any month of the year and average annual snowfall is 280”. During the seven growing seasons (2006 – 2012) since the first trees were transplanted, precipitation was unusual in several years (Figure 2). In 2007, above average, growing season precipitation peaked in August with 2.5 times the average for that month. While 2009 and 2011 both experienced slightly above average growing season precipitation, the distribution was far from normal with 2009 experiencing significantly below average July and August rainfall and 2011 experiencing above average July rainfall. In 2012, the growing season precipitation was relatively average, but late season warm temperatures allowed elk to stay active in the reclamation area much later in the season than usual.

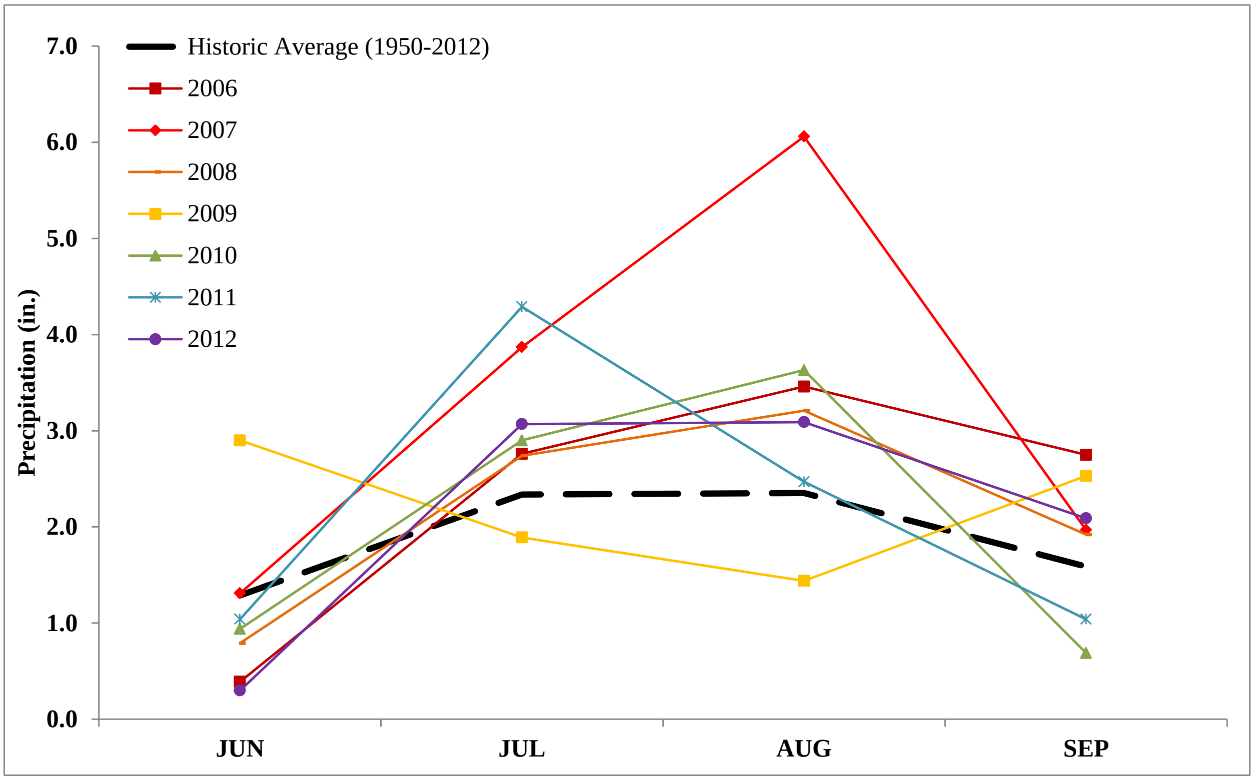


Figure 2. Growing-season precipitation at the Climax Mine site (Western Regional Climate Center 2013).

This same period also included extreme variations in winter snowfall (Figure 3). The winter of 2010-2011 had the greatest snowfall on record (since 1950) followed by the winter of 2011-2012 which was the third lowest snowfall recorded and the lowest since 1977.

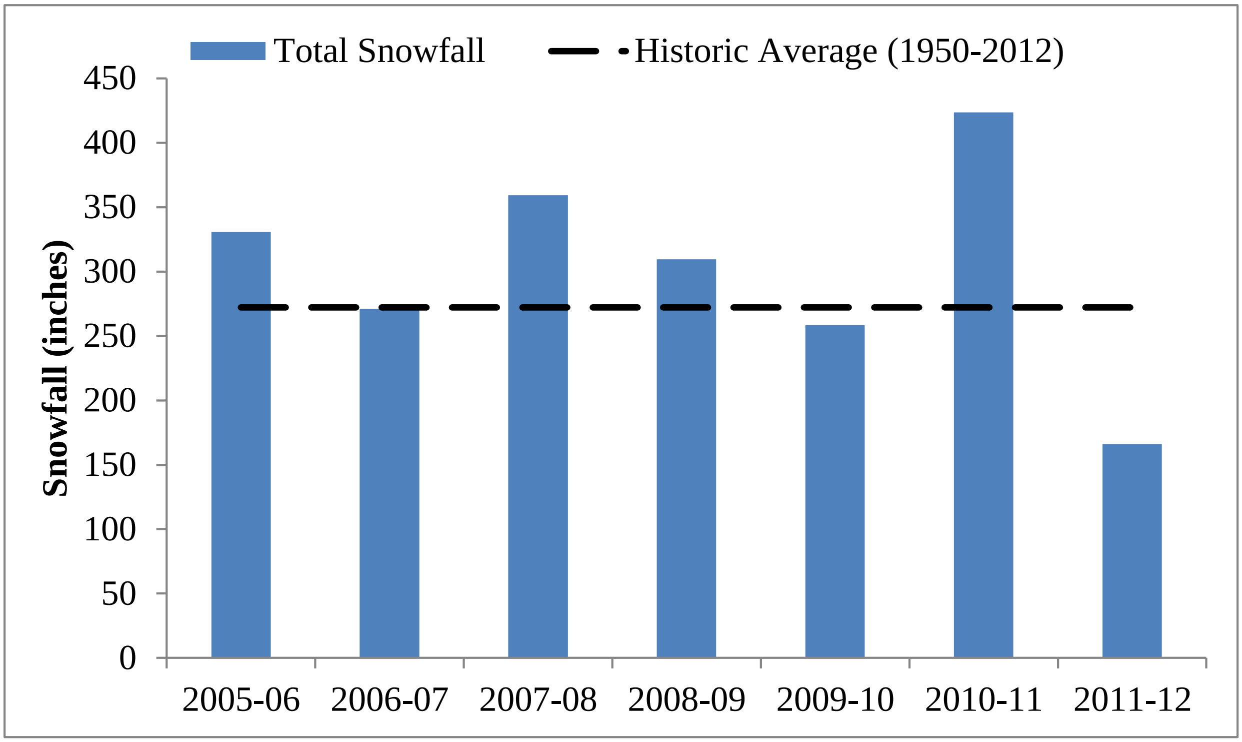


Figure 3. Winter snowfall at the Climax Mine site (Western Regional Climate Center 2013).

Reclamation and Soils

Transplanting areas were all reclaimed between 1996 and 2008 with a variety of soil materials and reclamation treatments. Many of the reclaimed areas were amended with Class A biosolids composted on-site as a part of Climax's EPA award-winning biosolids program. Composted biosolids (sewage sludge and woodchips, hereafter "compost") offer a cost-effective source for the organics and nutrients necessary for successful reclamation, and Climax's program offers an economical and environmentally sound solution to local municipalities for the disposal of their water treatment waste that meets all state and federal regulatory standards. Compost has proven beneficial in many reclamation settings to immobilize heavy metals in mine waste while increasing organic matter, microbial activity, nutrient cycling, decomposition of organics and water holding capacity (Sopper, 1993; Bengson, 2000; Jenness, 2001). A study of Climax's composted biosolids program in 2005 found that Climax's compost amendments reduced soil phytotoxicity, neutralized acidity, improved wildlife habitat, and introduced the necessary constituents to sustain vegetation communities (Carlson et al., 2006).

The Storke Yard was filled and graded with clean material comprised of development rock from the construction of shafts and adits in this area as well as construction debris from structure demolition in the early 1990s. Some of the Storke Yard was reclaimed in 1996 with minimal soil amendment, other areas were reclaimed in 2005 with the addition of 800 yd^3/acre of compost to the surface, and about 15 acres were reclaimed in 2007 with 400 yd^3/acre of compost incorporated (12”) into the fill material. The Storke Yard fill material is generally a sandy loam with no lime requirement (Table 1).

Table 1. Reclamation soil summary.

Location	**Soil Type**	**Geologic Description**	**Rock Content**	**Surface Texture**	**Lime Required*** (t/acre)
Robinson TSF E Dump	Pit Run	Decomposed granite	High	Sandy Loam	30
Robinson TSF	Cirque	Decomposed granite	High	Sandy Loam	10
	Maroon	Conglomeratic sandstone	Low	Sandy Loam	0
	Brown	Mosquito Fault	Low	Sandy Clay Loam	0
	Dark Brown	Mosquito Fault	Low	Sandy Loam	0
Robinson TSF Billy Blvd	Dark Grey	Mosquito Fault	Low	Sandy Loam	0
Storke	Fill	Variable	Moderate	Sandy Loam	0

*Lime requirement considered pH and acid/neutralization potential to achieve a neutral pH through the addition of agricultural lime (CaCO3) and quicklime (CaO).

The Billy Blvd transplanting area was a visual berm constructed in 2005 with clean overburden covered with a layer of compost at a rate of 400 yd^3/acre. The overburden used for this berm was excavated out of the Mosquito Fault during mining on Little Bartlett Mountain. It was dark grey in color with moderate rock content and no lime requirement.

E Dump is an overburden storage facility constructed during previous mining activities. The material is a very rocky and somewhat acid-producing granitic material requiring 30 t/acre of lime amendment as a part of reclamation. The E Dump transplanting area was reclaimed in 1997 with a thin layer of subsoil for growth media, which was excavated from below the reclaimed oxide tailings pond. The surface material is a sandy loam.

Capping on Robinson TSF began in the 1980s after tailings deposition was complete. Capping began on the edges and progressed toward the center of the TSF with a final design for a permanent clean-water pond to remain in the center. Cap material was placed at a minimum of 12” deep with some areas, especially the wettest areas around the pond, up to 36” deep. Early cap material was very rocky, granitic, pit run material like that used for E Dump, which required 30 t/acre of lime amendment. Later cap materials included cirque rock material from a portion of the pit which required only 10 t/acre of lime amendment and several brown and grey colored clean overburden materials excavated from the Mosquito Fault that did not require lime. These Mosquito Fault materials were segregated by color when they were excavated and were sampled prior to placement on the TSF for suitability (pH and acid/neutralization potential). The dark grey and dark brown materials were found to have a sandy loam texture, while the brown material was a sandy clay loam. The last material used for cap on Robinson TSF was Maroon Formation material stripped from other areas on the mine during facility construction. The Maroon Formation is red-colored decomposed sandstone with a sandy loam texture and no lime requirement.

Revegetation on Robinson TSF began in 1997 and is ongoing. Between 1997 and 2004, compost was applied to the surface of the cap material at a rate of 400 yd^3/acre over the lime amendment with little to no incorporation. After 2005, compost was incorporated into the cap material up to 12” deep to mix the organic, lime and mineral soils. Transplanting areas include all cap materials as well as areas that were reclaimed with and without compost both before and after tree transplanting was completed. In those areas where the cap material was not as deep as the root ball, the bottom of the root ball did have contact with tailings. The tailings range from a silty slime in wetter areas to a loamy sand in drier areas and tend to be very acidic.

All reclamation areas were revegetated using Colorado Division of Reclamation, Mining and Safety approved reclamation seed mixtures and are now well established, reclaimed, subalpine grassland communities. The reclamation on Robinson TSF, E Dump, Billy Blvd, and most of the

Storke Yard is dominated by common timothy[3] (*Phleum pratense*), Rocky Mountain fescue (*Festuca saximontana*), Kentucky bluegrass (*Poa pratensis*), common yarrow (*Achillea millefolium*), and white clover (*Trifolium repens*). The remaining 15 acres in the Storke Yard were reclaimed with a new, all native reclamation seed mixture and this area is dominated by tufted hairgrass (*Deschampsia caespitosa*), slender wheatgrass (*Elymus trachycaulus*), Idaho fescue (*Festuca idahoensis*), Rocky Mountain fescue, alpine bluegrass (*Poa alpina*), alpine timothy (*Phleum alpinum*), common timothy, spike trisetum (*Trisetum spicatum*), and common yarrow.

Methods

Transplanting

During the summers of 2005, 2006, and 2007, 1,459 individual trees and shrubs were transplanted into reclamation areas (Table 2). The trees were harvested and planted by Colorado Tree Spade Services with oversight from Habitat Management, Inc. and the Climax Environmental Department. The majority of transplants were Engelmann spruce (*Picea engelmannii*), the dominant tree species on the Climax property. In addition, 90 subalpine fir (*Abies lasiocarpa*) and 3 lodgepole pine (*Pinus contorta*) were transplanted. These species, while present on the Climax property, are not as dominant as spruce. The majority of these trees were harvested from within the Climax permitted affected area; however, 67 of the 90 subalpine firs were imported from the Shoshone National Forest near Saratoga, Wyoming in 2005 in an effort to use taller trees for transplanting.

The majority of transplanted shrubs were willow species, mainly diamondleaf willow (*Salix planifolia*), but also some Geyer's willow (*S. geyeri*) and shortfruit willow (*S. brachycarpa*). In addition, several shrubby cinquefoil (*Dasiphora fruticosa*), dwarf birch (*Betula nana*), and currant species (*Ribes* spp.) were also transplanted. All transplanted shrubs were harvested on-site from within the Climax permitted affected area.

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[3] Vegetation nomenclature follows USDA, 2012.

Table 2. 2005 - 2007 transplant summary.

Common Name	**Species**	**2005**	**2006**	**2007**	**Total**
Engelmann Spruce	*Picea engelmannii*	410	435	295	1,140
Subalpine Fir	*Abies lasiocarpa*	65	11	14	90
Lodgepole Pine	*Pinus contorta*	2	1		3
Total Trees		*477*	*447*	*309*	*1,233*
Willow	*Salix* spp.	91		100	191
Cinquefoil	*Dasiphora fruticosa*		2	14	16
Dwarf Birch	*Betula nana*	2		12	14
Currant	*Ribes* spp.	4		1	5
Total Shrubs		*97*	*2*	*127*	*226*
Total Transplants		**574**	**449**	**436**	**1,459**

Digging of the selected trees and shrubs began in August of each year. By this time, seasonal growth was completed and the plants were hardening off the new growth and setting terminal buds for the next growing season. A variety of tree spade sizes were used to obtain root balls ranging in size from 24” to 60” in diameter for trees 1 – 21 ft tall. Due to dry soil conditions, trees and shrubs were drip-irrigated prior to digging by placing containers of water around the base of each tree or shrub. Smaller root balls received 25 gal. of water while large root balls received up to 150 gal. Tree spades were used to dig the plant material and place it in a burlap-lined wire basket for temporary storage and transportation by flat-bed truck to the transplanting site.

A backhoe was used to excavate a receiving hole in the reclamation area. Transplants were placed with a forklift in holes deep enough to cover to the root crown and backfilled with a mixture of topsoil, old woodchips, and compost (4:1:1). A bowl was created around the trees with woodchip mulch to maximize irrigation benefits. Mycorrhizal fungal inoculant and polyacrylamide polymer amendments were added to the backfill soil. A water truck was used to settle the backfilled soil and irrigate the transplants (10 – 25 gal. depending on root-ball size), once immediately after planting and again in late September or early October. Trees over six feet tall were staked and wired to help them withstand wind gusts that have locally been recorded at over 50 mph. Staking and wire materials were used in such a manner as to minimize girdling and were removed two or three years after transplanting. Due to dry early summer weather, all transplants were watered again in June or early July of 2006, 2007 and 2008.

Monitoring

Each transplant's location was recorded with a hand-held GPS unit at the time of planting, and the species, height, diameter and health were recorded. Monitoring was conducted by revisiting each transplanted tree and shrub in the fall of 2006, 2007, 2008, 2010 and 2012. In 2006 – 2008, the survival, height, diameter and health of each individual were again recorded. In 2010 and 2012, only survival and health were recorded. Trees were classified as "alive" if they had any green needles at the end of the growing season. The percentage of the needles that were green was recorded as one of four classes: 0-25%, 25-50%, 50-75% and 75-100%. The data presented in this paper are from 2012 unless specifically stated otherwise.

Data Analysis

Tree data were analyzed to evaluate trends between planting years, transplant species, transplant locations, soil types at transplant locations, elk damage and tree height. Statistical comparisons of data were completed using a Chi-Squared Test of Independence analyses. Analyses of tree height were made with Kruskal-Wallis non-parametric analysis of variance tests.

Results and Discussion

Overall, transplanting was relatively successful with 68% of all individuals' transplanted still living in 2012 (Table 3). Shrubs were more successful overall than trees with 96% (218) of all shrubs surviving compared to only 63% (771) of trees.

Shrub Transplants

Of the 226 shrubs monitored, 218 (96%) were still alive in 2012 (Table 3). This included 100% of the birch and cinquefoil transplants, 97% of willows, and 3 of 5 currants (60%).

All 127 shrubs transplanted in 2007 in the Storke Yard were still alive after five years in 2012, as were the two cinquefoils transplanted on E Dump in 2006. Of the 97 shrubs transplanted in 2005, one willow and one currant died in their third year (2007), four willows died between 2008 and 2010, and one willow and one currant died between 2010 and 2012. All of these shrubs that died were planted on Robinson TSF. As settling and capping have continued on Robinson TSF, many areas that were wetter than expected in the first few years have dried out. During the summers of 2009 – 2011, several of the pool areas on the cap dried completely for the first time since capping. All of the willows that died in 2009 – 2011 were in these areas and were likely stressed by the lack of water.

Table 3. Transplant survival summary by species and year transplanted (data collected 2012).

	Transplanted 2005		**Transplanted 2006**		**Transplanted 2007**		**All Transplants**	
Transplant Species	**Alive**	**% Survival**	**Alive**	**% Survival**	**Alive**	**% Survival**	**Alive**	**% Survival**
Engelmann Spruce	222	54%	316	73%	195	66%	733	64%
Subalpine Fir	22	34%	10	91%	5	36%	37	41%
Lodgepole Pine	1	50%		0%			1	33%
Tree Total	***245***	***51%***	***326***	***73%***	***200***	***65%***	***771***	***63%***
Willow	85	93%			100	100%	185	97%
Birch	2	100%			12	100%	14	100%
Cinquefoil			2	100%	14	100%	16	100%
Currant	2	50%			1	100%	3	60%
Shrub Total	***89***	***92%***	***2***	***100%***	***127***	***100%***	***218***	***96%***
Grand Total	**334**	**58%**	**328**	**73%**	**327**	**75%**	**989**	**68%**

Tree Transplants

In general, spruce trees (64%) had greater survival than fir trees (41%) ($\chi^2 = 18.18$, $P<0.005$). However, if the fir trees imported from Wyoming are removed from the analysis, then there is no difference between species ($\chi^2 = 0.2$, $P \geq 0.25$). The trees from Wyoming were harvested at a site that was lower in elevation (~9,500 ft asl) than Climax and had a very dense stand structure. The transplant site at Climax on Robinson TSF was at a higher elevation (~11,150 ft asl) and had much less shade and protection than the harvest site.

Trees transplanted in 2005 were the least successful with only 51% survival compared to 73% for 2006 transplants and 65% for 2007 transplants ($\chi^2 = 46.66$, $P<0.005$). Again, the Wyoming trees were in this group of 2005 transplants; however, removing the Wyoming trees from analyses, the trend holds true with 2005 transplant survival at 54%, still significantly lower than 2006 and 2007 ($\chi^2 = 33.02$, $P<0.005$).

The lower survival of 2005 trees could be due to planting location. The majority of these trees were planted on the south side of Robinson TSF in areas where the soil cap was only 2 to 3 ft thick over tailings. Also, most of the cap in this area was installed in 2005 and continued to settle over the next season. Some of the trees planted in the area just south of the pool, which were anticipated to be in dry upland areas, were inundated in the spring of 2006 and 2007, which may have killed them.

Trees planted in 2006 were concentrated on E Dump and the northeast portion of Robinson TSF. These trees were not inundated and were generally transplanted into deeper, better drained soil material. The 2007 trees were concentrated on the Storke Yard and around the newly constructed Arkansas River Channel. These trees benefited from much better transplant soil than those planted on Robinson TSF. However, while the trees planted in 2005 and 2006 were watered once during the dry season for at least three years after planting (2005, 2006, 2007, 2008) the trees planted in 2007 were only watered for two years (2007 and 2008). A curtailment of watering in 2009 could have led to the decreased survival of 2007 transplants.

These hypotheses are supported by the results of analyses of survival by location ($\chi^2 = 74.81$, $P<0.005$). The greatest survival was on Billy Blvd and E Dump (85% and 81%, respectively) while survival on Storke (68%) and Robinson TSF (52%) was lower (Figure 4).

Evaluating tree survival based on year of planting or based on planting location is confounded by several other intertwined factors including soil type, soil amendments, elk damage, annual climate variation, aspect, slope, and even the size of the trees transplanted. The interconnectedness of these factors complicates interpretation of the data set; however, only the factors that can best inform or that can have an impact on future projects are described in more detail. Factors that cannot be controlled such as climate will be discussed only as they assist in the understanding of the results.

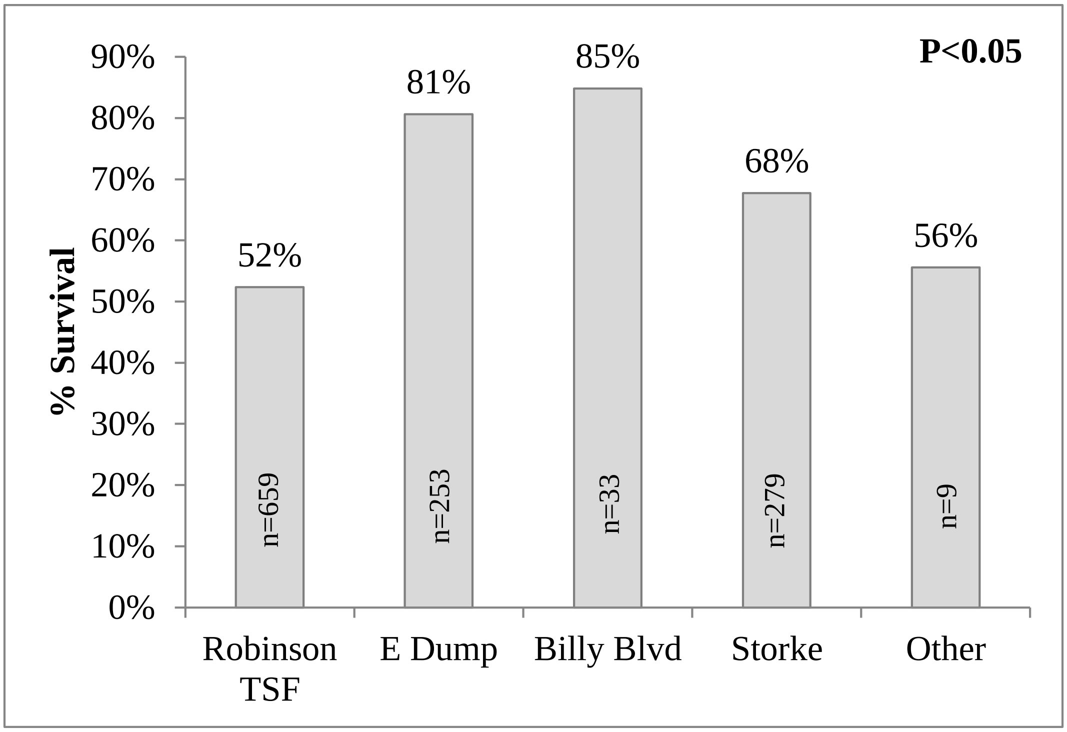

Figure 4. Tree survival by location.

Transplant Size. One factor that appears to have played a large role in transplant survival is tree height at the time of transplanting. Overall, shorter trees had a greater survival rate than taller trees ($P<0.001$, Figure 5). However, this trend was driven by spruce trees ($P<0.001$) because there was no difference in height when comparing alive and dead fir trees ($P=0.184$). This may also explain part of the lower survival on Robinson TSF and Storke because the trees planted on Storke and Robinson TSF tended to be taller on than those planted on E Dump and Billy Blvd.

One likely reason for greater mortality in taller trees could be the loss of root biomass in the harvesting process. While larger trees were harvested using larger trees spades and were placed in larger baskets, they are likely to have lost a larger percentage of their root biomass than smaller trees given the general root growth patterns of these species. Engelmann spruce roots are concentrated in the top 12 to 18" of soil and tend to spread laterally (Alexander and Sheppard, 2004). Thus, the percentage of a 12-ft trees roots captured in a 60" root ball is less than that of a 9-ft tree. In contrast, subalpine fir develops a relatively deep lateral root system under favorable conditions (Alexander et al., 2004) allowing a greater percentage of roots to be captured in the root ball than would be captured for a spruce tree.

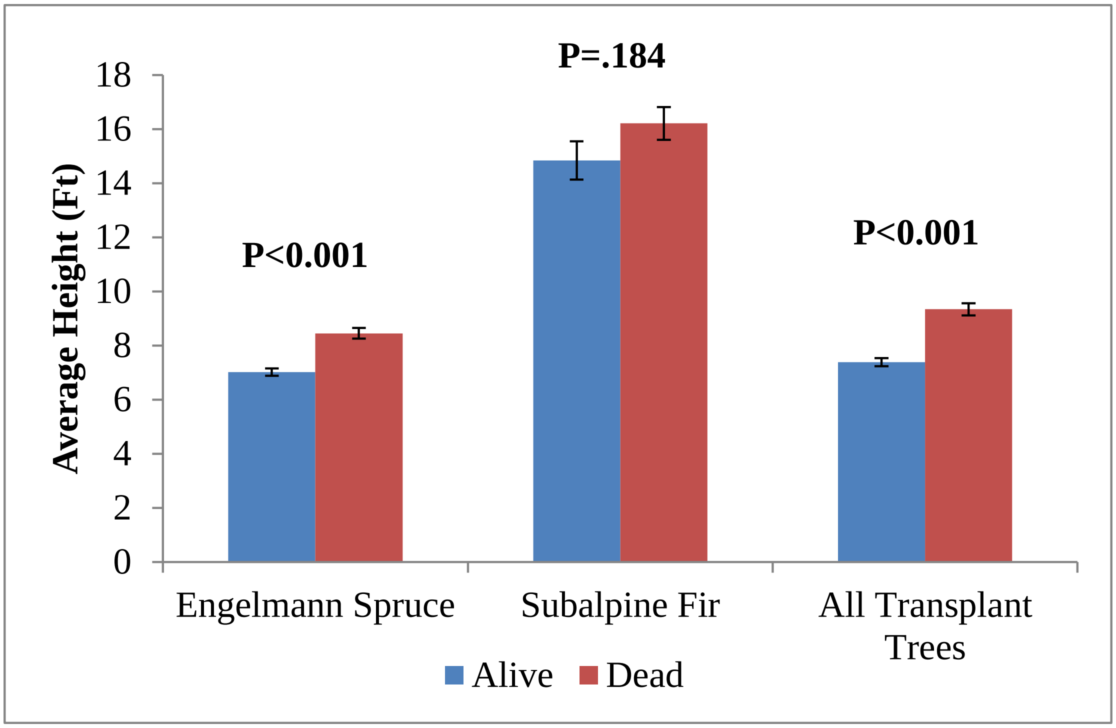

Figure 5. Average height (at the time of transplanting) of transplants by species.

Another factor that could have contributed to mortality of taller trees was sun and wind scalding causing needle loss and ultimately tree death. The sun reflecting off the snow warms the needles and cambium on the south side of the tree; however, colder temperatures overnight freeze and rupture these cells cutting off water flow to distal portions of the tree (Cox, 2010). Anecdotally, we noticed needle death at 50-60” up the trunk of taller trees and little to no needle death on trees that were short enough to spend most of the winter under snow. This is supported by average daily snow depth data showing spring snow depth at Climax is between 40” and 50” (Western Regional Climate Center, 2013). Additionally, needle death was concentrated on the south side of the trees suggesting that sun reflecting off of the snow surface could be a factor.

Transplant Soils and Soil Amendments. Trees were transplanted into eight different soil types. While the soil in E Dump and Billy Blvd was the same as those used to cap areas of Robinson TSF, the different treatments of these soils greatly affected tree survival (Table 4). As previously discussed, tree survival on E Dump and Billy Blvd was better than on other areas and was much better than those areas on Robinson TSF where the same soil was used. This likely has to do with the material underneath the cap soil. On Robinson TSF, the cap material was placed over tailings and while attempts were made to keep the transplanted trees in the cap material the roots did not need to go far to reach the tailings. On E Dump and Billy Blvd, there was no tailings material within the rooting zone. This deeper soil was also much better drained without the layer of saturated tailing underneath.

Table 4. Transplant survival by soil type.

		Spruce		**Fir**		**Total**	
Location	**Soil Type**	**Alive**	**% Survival**	**Alive**	**% Survival**	**Alive**	**% Survival**
E Dump	Pit Run	198	80%	6	100%	204	81%
Robinson TSF	Pit Run	154	46%			154	46%
	Cirque	39	49%	6	38%	46	47%
	Maroon	113	72%	14	64%	127	71%
	Brown	10	77%	5	42%	15	60%
	Dark Brown	5	71%			5	71%
	Dark Grey	1	100%	1	11%	2	20%
Billy Blvd	Dark Grey	28	85%			28	85%
Storke	Fill	184	69%	5	36%	189	68%
Native	Topsoil	1	33%			1	33%
Total		**551**	**71%**	**37**	**47%**	**589**	**69%**

On the Robinson TSF there was also considerable discrepancy between survival on different soil types ($\chi^2 = 16.75$, $P<0.005$, Table 4). Survival was much greater on the maroon and brown soils than on other soil types. However, this difference disappears with the addition of compost to the soils. Survival was lower in all soil types with the addition of compost than without compost and survival did not differ between soil types when compost was applied ($\chi^2 = 4.11$, $P<0.25$, Figure 6). In areas with no compost addition, survival was significantly lower in the pit run cap material than other cap materials ($\chi^2 = 12.84$, $P<0.005$). The pit run is the rockiest cap material and also the most acid producing. The same trend held true for compost application on the Storke Yard with greater survival (72%) in areas without compost compared to those with compost (65%).

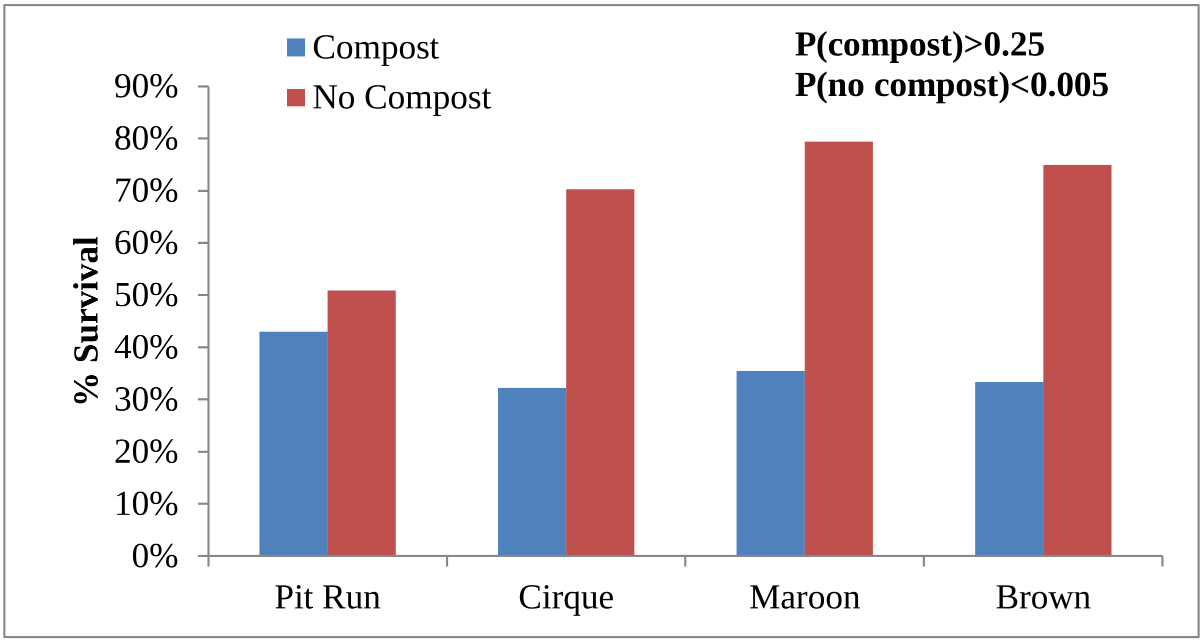

Figure 6. Tree survival by soil type and compost application on Robinson TSF.

The difference between areas with and without compost also could be due to competition with the grasses seeded around the trees. According to a 2010 internal reclamation monitoring report, those areas on Robinson TSF that received 400 cy/ac of compost had an average herbaceous cover of 43% while areas without compost that were reclaimed at the same time had an average herbaceous cover of only 16%. In both cases, 80% of the herbaceous cover was aggressive grass species used in the Climax reclamation seed mixture. These grasses compete effectively with the trees for moisture. On all sites, trees planted into soils with compost amendment had only 50% survival while those without compost had 74% survival ($\chi^2 = 76.06$, $P<0.005$). Therefore, while the addition of compost has been shown to improve vegetative cover on reclaimed areas, it may hinder the success of large woody vegetation. This result could be further supported with additional soil analyses to determine if survival could have also been affected by increased nitrogen, salts or microbial activity.

Elk Damage. Many of the transplanted trees, especially those planted on Robinson TSF, experienced elk damage including broken branches, bark loss, and occasional uprooting. Most of the damage appears to be due to antler rubbing in the fall. A total of 312 trees (25%) experienced elk damage sometime after transplanting; however, only 26% (80) of those trees appear to have died from the elk damage (Table 5). A much larger percentage of trees planted on Robinson TSF were damaged than in other location (220 or 71%). There is anecdotal evidence that Robinson

TSF is heavily used by elk which would explain the high amount of damage to trees planted in this area.

Table 5. Elk damaged trees.

Location Planted	**Trees Damaged By Elk**	**% of Planted Trees Damaged**	**Dead Elk Damaged Trees in 2012**	**% of Elk Damaged Trees Killed**
Robinson TSF	220	33%	73	33%
E Dump	44	17%	0	0%
Storke	48	17%	7	15%
Total	**312**	**25%**	**80**	**26%**
Species Planted				
Spruce	301	26%	77	26%
Fir	10	11%	3	30%
Lodgepole	1	33%	0	0%
Total	**312**	**25%**	**80**	**26%**

Elk damage was highly variable by year with fewer than 5% of living trees damaged in 2005, 2007, and 2008, 0% in 2006, 22% in 2010 and 15% in 2012 (Figure 7). Elk presence appears to be greatest in the years when fall temperatures and precipitation allow the elk to stay at Climax until later in the season before they are forced to lower elevations.

There is also evidence that the elk preferentially damage shorter trees (Figure 8, $P<0.001$). The average height of all trees that have been damaged by elk at least once since transplanting is 7.2 ft compared to an average height of 8.4 ft on undamaged trees. The trend is stronger for fir trees ($P<0.001$) than for spruce trees ($P=0.061$), but there are also considerably more spruce trees than firs and survival has been higher for spruce trees. We hypothesize that the elk prefer shorter trees for rubbing due to the branch flexibility at the height of their antlers. To our knowledge there is little research on the topic of elk preference for antler rubbing. Bishaw et al. (2003) found that elk preferentially rubbed on western white pine trees with small diameters, but this was not the focus of their study. This would be an interesting topic to evaluate further.

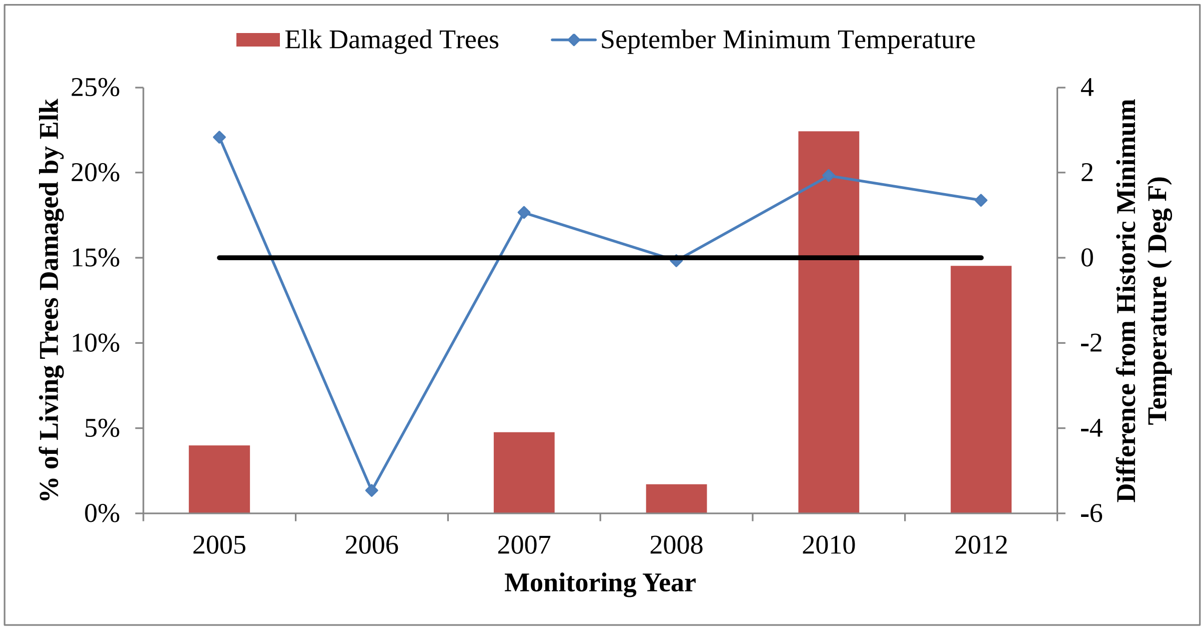

Figure 7. Elk damage compared to variations in minimum temperatures.

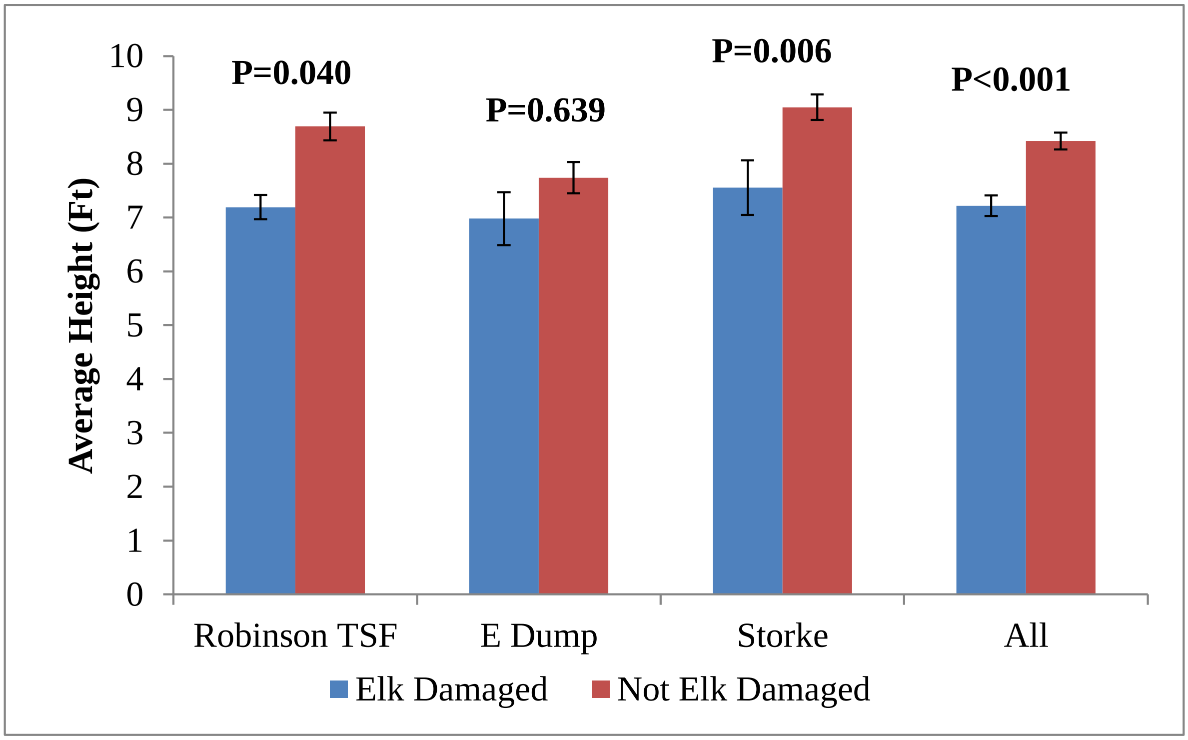

Figure 8. Elk damage by initial tree height and location.

Project Costs

This tree transplanting project was completed for approximately $650,000, including all harvesting, planting, watering, and maintenance in 2005 – 2007. The costs for each tree (including labor, equipment, and materials for harvest and planting, but not follow-up watering, maintenance, management, or monitoring) varied by tree size (Table 6) and increased by approximately 20% from 2005 to 2007. These costs were at or below the costs that would have been associated with the installation of purchased balled and burlapped nursery stock (Table 6, current retail costs) and had the added advantage of local provenance.

Table 6. Average harvest & planting cost per tree compared to current retail cost.

Root Ball Size	Height Range	2005-2006*	2007*	2013 Estimated Retail **
32"	2 – 6 ft	$ 275	$ 330	$ 330 – $ 490
44"	6 – 10 ft	$ 425	$ 510	$ 550 – $ 1,010
60"	10 – 16 ft	$ 550	$ 660	$ 1,070 – $ 1,560
72”	> 16 ft	$ 695	n/a	Variable

* includes labor, equipment, and materials

** range depends on tree height and includes a 2x factor on retail purchase price for delivery and planting

Conclusions

Climax’s stated goal for this project was 50% survival after the first growing season. Thus, survival is better than expected and the goal has been surpassed after six, seven and eight growing seasons (for 2007, 2006 and 2005 transplants, respectively). The goal of the post-planting monitoring was to learn from the process for use in future reclamation efforts at Climax and elsewhere. Several conclusions were drawn from these results.

1. The trees harvested locally were much more successful than those trees imported from Wyoming. They were adapted to the local environment, subjected to less stress in the transporting process, and cost less to transplant.
2. Shorter trees were more successful than tall trees. They were more likely to have greater root:shoot ratio and less likely to be damaged by harsh winter climate, although they sustained greater damage by elk. The shorter trees were also less expensive to transplant.
3. On Robinson TSF, trees planted into locally stripped subsoil materials were more successful than those transplanted into rocky pit run material.

4. Trees planted in areas reclaimed without compost were more successful than those planted into compost. While the compost is very beneficial to the establishment and growth of herbaceous cover on the reclamation, this can lead to increased competition with woody species.
5. Elk damage was a significant concern especially on the Robinson TSF. While only 80 trees were killed by elk, this represents a preventable loss of $20,000 to $50,000 in trees. Future trees transplanted into areas known for heavy elk use might benefit from fencing to exclude elk.
6. There is some evidence that a spring watering before the monsoons start for the first few years may be beneficial, but this could use further study.

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