2011 Planting for Resilience Project
Project Plan, As-Built Report, and Initial Results
Cedar River Municipal Watershed

Project Plan, June 2011
As-Built Report, February 2012
Initial Results, July 2013

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Project Objective

Evaluate selected tree species and selected populations from southern seed zones for their ability to grow and reproduce in glacial outwash soils in the lower Cedar River Municipal Watershed (CRMW) under conditions expected with global climate change.

Rationale

Glacial outwash soils (Barneston coarse gravelly sandy loam) in the lower CRMW have high permeability and low available water capacity that typically result in droughty conditions for tree growth. Areas of Douglas-fir mortality due to laminated root rot (*Phellinus sulphurascens*) are common in these soils in the lower watershed. In addition, the lower CRMW location in the foothills of the Cascade Mountains experiences periodic high winds that descend from the Cascade crest and cause crown abrasion, likely root stress, and substantial tree blow-down. Douglas-fir stress and mortality caused by laminated root rot and blow down can result in increased Douglas-fir bark beetle populations that can then spread to live trees.

This combination of factors – drought stress, laminated root rot, windthrow, and bark beetles – makes forests on glacial outwash soils in the lower CRMW particularly sensitive to projected warmer temperatures resulting from global climate change. Greater moisture deficits resulting from warmer summer temperatures and reduced summer precipitation will make these forests vulnerable to disturbance from fire, insects, and pathogens, which in turn threaten the ability of the watershed to provide a clean water supply. Diversifying these forests will help to reduce their vulnerability to global climate change.

This project aims to evaluate several tree species and a Douglas-fir genotype from a more southern seed zone to create more tree diversity in these Douglas-fir dominated stands. Incorporating additional species into these forests is intended to make them more resistant to large-scale disturbance and be resilient following disturbance, should it occur under future climatic conditions.

Tree species/seed zones

Douglas-fir. Douglas-fir (*Pseudotsuga menziesii*) from seed zones in currently warmer/drier areas may be more adapted to future climate conditions. The Seedlot Selection Tool (an online system developed by the Oregon State University College of Forestry and the U.S. Forest Service Pacific Northwest Research Station for matching seed zones with locations) includes a feature that models future climate scenarios to match up current seed zones with predicted future climate conditions at a given location. Using this tool, the lower Willamette Valley in Oregon and foothills of the Cascade Mountains just to the east of the Willamette Valley were identified as a good match for the lower CRMW for climate modeled in 2050. Seedlings obtained from Marcola, OR (lower end of Oregon seed zone 9) will be planted for this project and compared to seedlings from Washington zone 5 (Kitsap), which are appropriate for current conditions.

Western redcedar. Western redcedar (*Thuja plicata*) is known to be adaptable to a variety of conditions and has fairly wide-ranging genotypes. Consequently, evaluating seedlings from different seed zones is not as important as with Douglas-fir. Seedlings from Washington zone 2 (Puget Sound), currently suitable for the lower CRMW location, were obtained for planting in this project. Because western redcedar is resistant to laminated root rot, it is a good candidate species for diversifying Douglas-fir dominated stands with known pathogen activity in glacial outwash soils.

Western white pine. Western white pine (*Pinus monticola*) is another species with more generalized genotypes and is well suited to the droughty conditions of glacial outwash soils. Like western redcedar, it is resistant to laminated root rot. It would be an ideal species to incorporate into lower CRMW forests, but is vulnerable to white pine blister rust. Use of seedlings that are resistant to blister rust is important, as white pine blister rust is known to occur in the CRMW. Blister rust resistant white pine seedlings from WDNR from Washington zone 6 (Lower Columbia) were obtained for the 2011 planting.

Shore pine. Shore pine (*Pinus contorta* var. *contorta*) is found with Garry oak in dry outwash soils of Thurston and Pierce counties and may be more suited to glacial outwash soils in the lower CRMW under a future climate with warmer, drier summers. Although shore pine occurs in the CRMW currently, these individuals may have been planted. The plant communities in which shore pine occurs in southern Puget Sound are successional communities maintained by periodic fire, eventually developing into Douglas-fir dominated forests if undisturbed. Thus, shore pine's ecological role in the southern Puget Sound region suggests that it would need some form of management to be maintained over the long term. Also, its present distribution along marine shorelines of the Pacific Northwest suggests that it may have an affinity for coastal environments and not do well in more inland locations like the CRMW, perhaps because of cold temperature sensitivity. Seedlings from Washington zone 2 (Twin Harbors) from WDNR were obtained for the 2011 planting.

Garry oak. Garry oak (*Quercus garryana*) is currently not found in the CRMW but does occur on dry glacial outwash soils in the Puget Sound lowlands, particularly in the southern portion. It also occurs on the San Juan Islands and on the eastern side of the Cascade Mountains in southern Washington. Like shore pine, it is mid-seral in the south Puget Sound area and has historically been maintained in the area by fire. Consequently, it too may require management for long-term persistence. Garry oak seedlings to be used in this project were obtained from 4th Corner Nursery in Bellingham; however we have no information on the provenience of these seedlings, as 4th Corner obtains seedlings from various locations in the state.

Site Locations

The project was located at three sites, named Foothills, Barneston, and Thompson (Figure 1).

1. The Foothills site is a 20-30 year old Douglas-fir dominated stand on Barneston soils south of the 50 Road. The site has a dense salal (*Gaultheria shallon*) understory with scattered vine maple (*Acer circinatum*). Although there are three cleared areas currently within the stand,

they are being managed for elk forage habitat by the Muckleshoot Indian Tribe and will not be used. Instead, new openings approximately 0.9 acre in size will be created for this project.

2. The Barneston site is a 25 year old Douglas-fir dominated site north of the 10 Road near the old Barneston townsite and is primarily on Klaus sandy loam soils formed in alluvium over glacial outwash. This site offers somewhat less droughty conditions than the Foothills or Thompson sites. There are some laminated root rot infected areas in the western portion of the site. Understory is dominated by salal. As with the Foothills site, three 0.9 acre openings will be created for planting.
3. The Thompson site is an approximately 75 year old stand near the old Thompson research area adjacent to the 58.1 Road. It occurs on Barneston glacial outwash soils and has areas 0.5 to 1.0 acres in size that are partially open due to extensive laminated root rot infection. As with the other two sites, the understory is dominated by salal. Douglas-fir will not be planted in this site because of the laminated root rot. Planting areas will be located within the existing openings, with some cutting of mostly smaller trees already present.

Initial Design

Because this is a long-term evaluation (several decades) and will involve continued monitoring, the planting design will need to be straightforward enough to easily track. The created openings will be oriented North-South to maximize direct sunlight to the most seedlings. Within each opening, a set of planting blocks will be laid out to provide discrete areas within each planting site to provide a nested-block design. Each block will consist of rows having 10 seedlings, each with 8 foot spacing. There will be seven rows per block for Foothills and Barneston and four rows per block for Thompson (no Douglas-fir to be planted at Thompson). Order of rows by species will be randomized. There will be two blocks per opening. Description of the design is provided in Figure 2 and Table 1.

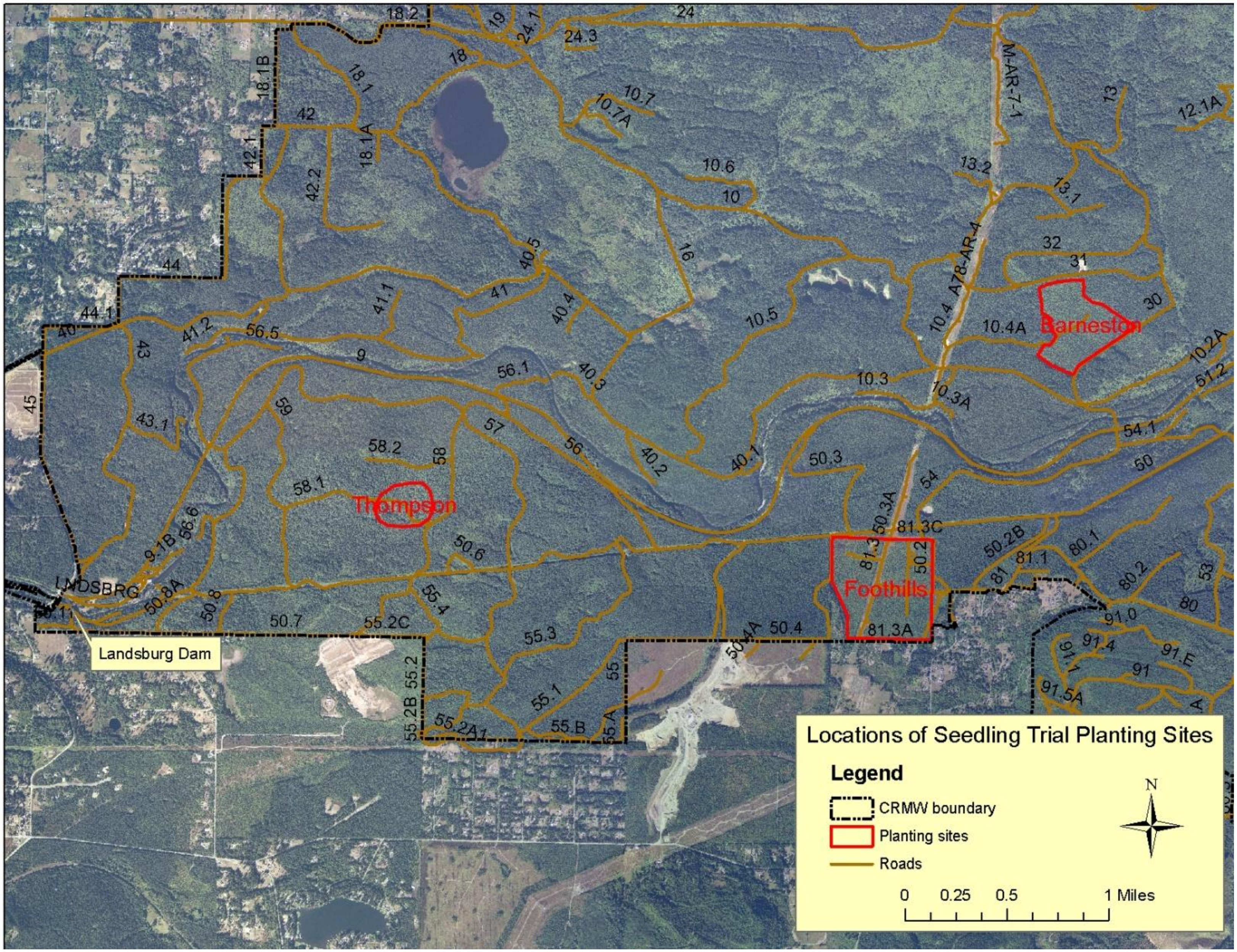

Figure 1. Locations of planting sites for 2011 resilience planting trial.

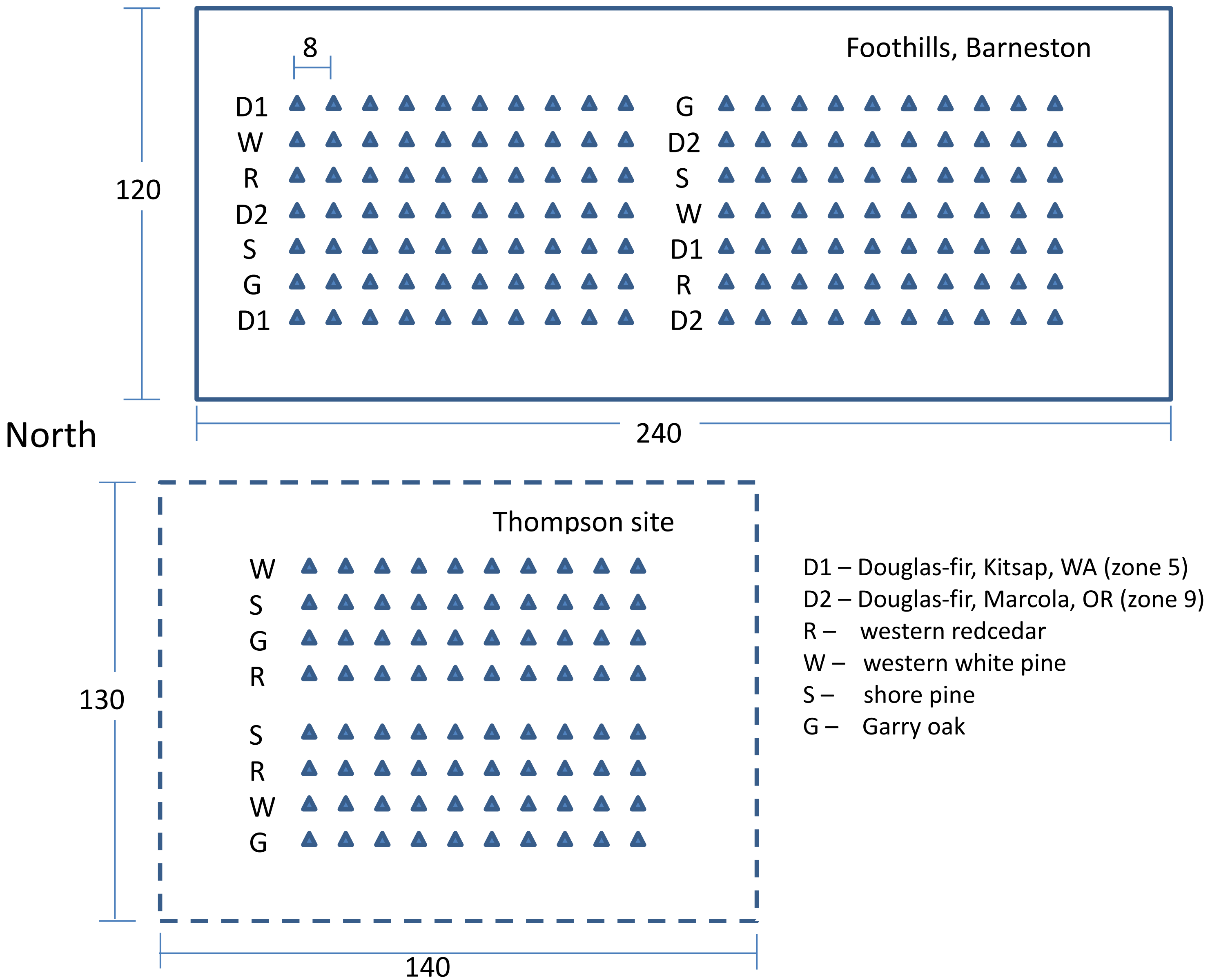

Figure 2. Diagram of planting area lay-out for 2011 seedling trials. Order of rows by species is for illustrative purposes only – actual order will be determined randomly

Table 1. Proposed layout for planting seedlings at three sites.

Foothills and Barneston	Thompson
3 x 0.9 acre openings	Existing openings
Two blocks per opening	Six blocks (grouped in pairs)
1 row per block (each species): • Western redcedar • Western white pine • Shore pine • Garry oak	1 row per block(each species): • Western redcedar • Western white pine • Shore pine • Garry oak
1.5 rows per block (each zone): • Douglas-fir 1 • Douglas-fir 2	(No Douglas-fir)
Total 7 rows per block	Total 4 rows per block
10 seedlings per row	10 seedlings per row
Total 70 seedlings per block	Total 40 seedlings per block
60 seedlings each species per site (except 90 Douglas-fir seedlings)	60 seedlings each species

Gap Creation, 2011

In order to clear the planting areas, a request for bids was extended to logging contractors, and was awarded to TimberTec Inc. TimberTec used a tracked logging processor to cut and delimb trees growing within the planting areas. Trees were cut to 20 foot lengths. At one planting areas (Foothills Area 1), trees were left whole and unlimbed to be used for stream restoration projects. A forwarder was used to move some trees either to the road edge for later pick-up (either as tribal firewood or for restoration use) or to the buffer around the planting rows. Clearing and forwarding was completed the end of October.

Planting Material

All of the seedlings except Douglas-fir were obtained as bare root or plug seedlings in March 2011 and delivered to Wabash Nursery in Enumclaw, WA for potting and growing during spring-summer-fall of 2011. Seedlings at Wabash were grown in fertilized potting soil in pots of different sizes, depending on species. Douglas-fir seedlings of both Oregon and Washington seed zones were obtained as 1+1 bare root seedlings pulled about two weeks prior to planting. Table 2 shows the characteristics for the seedlings of each species used in the planting trial. All seedlings were delivered to the CRMW in late November 2011.

Table 2. Characteristics of seedlings used in the resilience planting trial				
Species	**Seed zone**	**Source**	**Age**	**Pot size**
Shore pine (*Pinus contorta* var. *contorta*)	Twin Harbors,WA (zone 2)	WDNR - Webster Nursery	2+0, bare root; potted 3/24/11	1 gal
Western white pine (*Pinus monticola*)	Lower Columbia WA (zone 4)	WDNR - Webster Nursery	P+0 (styro 10) frozen; potted 3/24/11	1 gal
Western redcedar (*Thuja plicata*)	Puget Sound, WA (zone 2)	WDNR - Webster Nursery	P+1, bare root; potted 3/24/11	2 gal
Garry oak (*Quercus garryana*)	seed source: within state of Washington or Willamette Valley, OR	Fourth Corner Nursery	6-12" potted 3/3/11	14 inch tree pot
Douglas-fir (*Pseudotsuga menziesii*)	Snoqualmie, WA (zone 8, 412-15)	SilvaSeed Nursery	1+1 bareroot; not potted; pulled late Nov.	---
Douglas-fir (*Pseudotsuga menziesii*)	Marcola, OR (zone 262-10)	SilvaSeed Nursery	1+1 bareroot; not potted; pulled late Nov.	---

Final Planting Design

The planting design developed in the project plan was followed, with only slight modification. A total of 180 seedlings of each species or seed zone (Douglas-fir) were planted. The planting design consisted of two blocks of seven rows at Foothills and Barneston and two blocks of four rows at Thompson. Each row had 10 seedlings. Each of the four species other than Douglas fir is represented by one row in each block. The two seed zones of Douglas-fir were only planted at Foothills and Thompson, where 15 seedlings of each seed zone were planted in each block (i.e., three rows of Douglas-fir). In the end, each site had 60 seedlings of shore pine, western white pine, western redcedar, and Garry oak; and the Foothills and Barneston sites had 90 seedlings of each Douglas-fir seed zone.

The placement of each species in the block rows was randomized. Each Douglas-fir row was divided into two, with half the row planted with the Oregon and the other half with the Washington seed zone. The placement of the Oregon or Washington seed zone within a row was randomized, with the requirement that all three Douglas-fir rows in a block could not be of the same arrangement.

The blocks were arranged north and south at Foothills and Barneston, along the long axis of the planting areas. At Thompson, the blocks were arranged east-west, which conformed better with the shape and size of the openings created by root rot. The nested-block design will allow analysis of variance among planting locations (Foothills, Barneston, and Thompson), including the effects of planting area (1, 2, and 3) and of block position (north, south).

Final Site Preparation and Planting, 2011

A request for bids was made to several contractors from the restoration thinning contractor list and one additional contractor who had a blanket contract with Seattle Parks (Frank Maduzia). Bids were received from Maduzia and Sierra Reforestation, Inc. Time estimates for completing the project were very similar between the two, and Sierra Reforestation was selected to do the work because of lower rates.

Prior to final site preparation, locations of planting sites were marked with color coded pin flags. The planting rows were established beginning with the north end, which was positioned in the approximate east-west center of the planting area and 50 feet from the northern end of the unit. Rows and planting locations were positioned with a tape measure and compass. Rows and planting locations within a row were both established with 8 foot spacing. Space between blocks was approximately 16 feet.

Final site preparation consisted of clearing shrubs and remaining saplings and moving larger debris to the buffer around the planting rows. The 11-member Sierra Reforestation crew generally cleared larger shrubs and saplings first, then began clearing the areas around each seedling location before planting. The planting crew grubbed out existing understory plants within a 3-foot radius of the planting spot and dug a hole of appropriate size for the seedling being planted, which varied by species container size. After each unit was planted, it was checked to make sure that no species or Douglas-fir seed zones were planted in the wrong places.

Temperatures were mostly below freezing during the planting period (Dec. 5 through 9). As a result, the soil of the potted plants was mostly frozen and the bare root Douglas-fir also had frozen roots. Although the soil surface was frozen, grubbing and digging the hole broke up the frozen surface (1 to 2 inches) and mixed it in with the unfrozen soil below. We had concern that the frozen condition of the plant roots may have damaged the seedlings, but the extent of the damage wasn't known until spring of 2012. (In fact, survival was over 90% despite the poor planting conditions; see Figures 3 and 4.)

Browse and Weed Protection

Browse protection was placed around Garry oak and western redcedar seedlings. Browse protection consisted of 14 gage wire fencing (2 x4 inch mesh) formed into a cylinder 4 feet high and approximately 1 foot in diameter. The wire fence cylinder was held together and fastened with zip ties to two 4 foot (1 x2 in) wooden stakes driven into the ground.

A weed protection mulch product was placed around Garry oak seedlings prior to the installation of the browse protection. The mulch consisted of Brush Blankets® (Arbortec Industires, British Columbia). These were 4 x4 foot sheets of a photo selective polyethylene film that blocks photosynthesis but does not absorb energy from longer wavelengths, instead transferring the heat generated from sunlight to the soil. Small perforations allow precipitation to also pass through. The Brush Blanketswere fastened to the ground with 6-inch metal staples and rocks were placed on them to further hold them in place.

Costs

The planting for resilience seedling trial costs totaled $38,526, not including SPU staff labor or other internal expenses (Table 3). Seedling costs, including buying and growing the seedlings at a nursery, were $4,145, and costs for browse and weed protection were $1,644. Site preparation costs were $20,321 and final site preparation and planting costs were $12,416. Final site preparation costs were about $4,000 lower than estimated for the not-to-exceed bid. Final site preparation and planting costs were also lower than the not-to-exceed bid, which was $17,820.

Table 3. Costs of 2011 resilience planting trial	
Seedlings (200 of each species)	**Cost**
western redcedar	$ 225.00
Douglas-fir (WA)	$ 136.91
Douglas-fir (OR)	$ 136.91
western white pine	$ 297.00
Garry oak	$ 137.00
shore pine	$ 150.00
subtotal seedling purchase costs	*$ 1,082.82*
potting and growing at Wabash	$ 3,062.52
subtotal total seedling cost	$ 4,145.34
Plant protection	
cage materials	$ 1,188.96
brush blankets	$ 454.74
misc.	$ 225.05
subtotal plant protection	*$ 1,643.70*
Site preparation	
TimberTec invoiced	$ 20,321.00
Final site prep and planting	
Sierra Reforestation invoiced	$ 12,416.00
Total	**$ 38,526.04**

Monitoring and Maintenance Plan

Regular monitoring and maintenance of the planting for resilience seedling trial is critical to its success. Collection of information about plant growth and survival in the short-term is important for evaluating feasibility of planting varied species on these harsh sites, as well as growth and survival of each species and genotype under current climatic conditions and in the long-term in a changing climate. As in any monitoring program, the challenge is to sustain monitoring in the face of turnover in personnel, changing institutional priorities and organization, and reduced interest in "old" projects. Maintenance of the project is needed to minimize the effects of confounding factors, such as shrub competition and browsing.

Monitoring Objectives

There are essentially two objectives of monitoring the resilience seedling trial:

- Evaluate survival and growth under current climatic conditions
- Evaluate survival and growth under future climatic conditions

It is somewhat of a conundrum to evaluate now how seedlings might grow under a future changed climate. We can only evaluate how the seedlings will do at the study sites under current conditions. However, short-term monitoring of seedlings will provide information about whether or not site conditions are potentially unsuitable, and if current conditions are a barrier to begin planting these species on an operational level. Ultimately, knowing the long-term performance of the different species and genotypes is the goal of the seedling trial, which only long-term monitoring can address.

Monitoring Variables

The following seedling or tree variables will be measured in the monitoring program for the resilience seedling trial: dead/alive, height, caliper, vigor, browse, and timing of bud break.

Alive or Dead. Each seedling will be scored as either alive or dead. A dead seedling is one that has no green leaf tissue or live buds. There will be two categories of dead, dead in place (seeding is present but tissue is dead) and plant missing (likely pulled out of the hole by deer or elk).

Height. Height to the top of the leader will be measured in centimeters. If the leader is drooping (e.g., cedar) or the plant is bent, the height of the natural plant form is measured, not the linear extent of a plant straightened out by pulling on the drooping leader or propping the plant up, as is sometimes done for monitoring seedling height. Where the leader has been browsed, the height is measured as the top of evident live stem.

Vigor. Vigor can include a variety of characteristics, including live/dead tissue, leaf color, leaf shape and size, and general appearance. In order to have a more objective metric that can be consistently applied from one observer to the next, only one of these characteristics will be used, the percentage of live leaf tissue. In order for this to be a consistent evaluation from one year to the next, it is important for the observer not to include these other aspects of vigor in scoring a plant, even if the plant may not look completely healthy. However, additional notes can be added to describe other aspects of poor vigor.

One of four vigor classes will be assigned to each seedling:

- High: more than 80% of leaf tissue is alive
- Medium: between 50 and 80% of leaf tissue is alive
- Low: less than 50% of leaf tissue is alive
- Leader dead only: the only tissue that has died is the leader

Vigor can be confounded by browse, since browsed branches might be interpreted as tissue that has died and fallen off. Consequently, the percentage of live leaf tissue should be evaluated relative to the branches present, not relative to those that would be present absent any browse. Branches that have apparently died over the past year and have no live buds or are no longer producing leaves should be included in the evaluation. Branches which have likely been dead for more than one year should not be included in the evaluation. However, it is sometimes difficult to tell whether or not a branch has been dead for more than a year. For conifers, we will use the presence of dead needles, without which the stem is presumed to be dead for more than one year. For oaks, monitoring just as leaves are opening up makes evaluation of vigor very difficult. For purposes of rating vigor, it would be better to monitor later than mid-May.

Browse. One of five browse classes will be assigned to each seedling:

- None: no browse evident
- Leader browsed only
- Low: browse evident on less than 20% of the branches
- Medium: browse evident on between 20 and 50% of the branches
- High: browse evident on more than 50% of the branches

Browse is recorded as leaves/branches/buds removed by mammals (primarily deer or elk). Some leaves, particularly of the oak, can show signs of insect browse, which is not recorded as browse, but with a note as "insect damage."

Timing of Budbreak. Budbreak timing will be monitored only on Douglas-fir seedlings. It is measured as the percentage of buds that have broken at the time of monitoring, with four classes:

- 0% of the buds broken
- 1-10% of the buds broken
- 11-50% of the buds broken
- 51-90% of the buds broken
- 91-100% of the buds broken

A broken bud is defined as one where the bud cap has completely broken away from the lower bracts and has exposed the emerging needles. Sometimes the thin bud cap remains on the needles as they emerge and grow, which would still be recorded as "broken." Optimal time to evaluate bud break would be in the early to middle stages, which is variable depending on the spring weather.

Environmental Variables. Other variables to be measured include tree height of surrounding forest and total solar radiation at selected locations. Tree height of forest on each side of the planting areas will be measured with a laser range finder at three locations and averaged. Total growing season solar radiation will be measured at designated locations (to be described in protocols) using photographs taken with a hemispherical lens and processed with the Gap Light Analyzer software.

Proposed Frequency and Timing of Monitoring

Proposed frequency of sampling seedling/tree variables will change as time since planting increases. Initially, sampling is planned for every year, with the interval increasing to every three years and then to every six years for most variables (Table 4). If possible, budbreak in Douglas-fir will be measured every year for the duration of the experiment.

Sampling of the seedling/tree variables should be at a consistent time during the growing season to ensure that leaves of Garry oak are out and that current-year conifer needles have developed, and before drought stress of the current year might cause current-year mortality or leaf dieback. June is the time when all these criteria are most likely to be met.

Environmental variables (tree height and solar radiation) should be measured once every ten years. The timing of sampling should likely be in June to have a consistent time within the growing season to measure solar radiation with respect to canopy closure.

The proposed frequency of monitoring will likely be re-evaluated annually based on staffing and funding availability.

Table 4. Sampling variables and planned frequency of sampling for resilience planting trial.

Variable	Species	Planned Sampling Years (after planting)
Alive or dead	all	1, 2, 3, 6, 9, 12, 18, 24, 30
Height	all	1, 2, 3, 6, 9, 12, 18, 24, 30
Caliper/Diameter	All, except western redcedar and Garry oak seedlings	1, 2, 3, 6, 9, 12, 18, 24, 30
Vigor	All	1, 2, 3, 6, 9, 12, 18, 24, 30
Browse	All	1, 2, 3, 6, 9, 12, 18, 24, 30
Budbreak timing	Douglas-fir only	annual
Surrounding tree height	NA	1, 10, 20, 30
Total growing season solar radiation	NA	1, 10, 20, 30

Maintenance

Maintenance will consist of three different tasks: control of plant competition, repair and adjustment of browse/weed protection, and thinning.

Control of Plant Competition

Although an approximately 3-foot diameter area around each seedling was cleared prior to planting, shrub competition, especially from salal and invasive species such as Scots broom (*Cytisus scoparius*), Himalayan blackberry (*Rubus armeniacus*), and evergreen blackberry (*Rubus laciniatus*) is expected to occur over time. Monitoring of shrub encroachment around seedlings should occur on an annual basis, with clearing of shrubs around the seedlings conducted as needed. We estimate that clearing will be needed within about three years. After seedlings reach 5 feet in height, maintenance to prevent shrub competition should no longer be necessary for most of the planting areas. However, resprouting vine maple will need to be maintained for a much longer period.

Repair and Adjustment of Browse/Weed Protection

The browse protection cages will need inspection and maintenance on at least an annual basis until the seedlings are large enough to escape browse damage by elk. Soon after planting there was some damage to a few cages by elk, which could be an ongoing problem. There has been similar damage in a browse control experiment at Webster Creek utilizing the same type of cage, with about 10% of cages being damaged over the course of a year.

When the leader of the redcedar and oak seedlings reaches the top of the cage, the cages may need to be raised. This could be within three to five years for the redcedar, but likely 10 years or more for the oak seedlings, which were very small when planted.

Thinning

Seedlings were planted with 8-foot spacing. Depending on the extent and timing of mortality, trees may eventually become crowded and need thinning. This is not likely to happen for at least 10 years, but as the seedling trial progresses, in terms of both growth and mortality, criteria will need to be developed for where and when thinning will occur.

Initial Results, 2012 and 2013

We sampled the seedlings in early to mid-June in 2012 and in mid- to late-May in 2013. Survival in 2012 was very high (Figure 3), and by 2013 was still above 90% for all species (Figure 4). Douglas-fir (seed source Oregon) had the largest drop in survival from 2012-2013: 99% to 93%. Also Douglas-fir (seed source Washington) showed a drop in survival. This is likely due to bare root seedlings stressed from poor planting conditions (freezing temperatures), with the seedlings hanging on through spring 2012, but dying in the subsequent year. White pine survival went from 95 to 92% from 2012 to 2013. Most of white pine mortality was at Foothills.

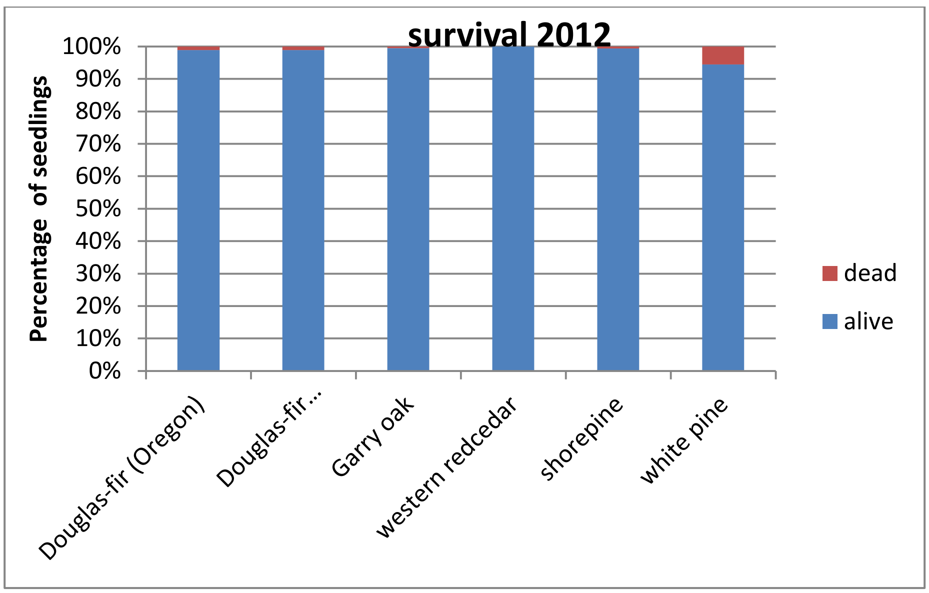

Figure 3. Seedling survival in 2012, one year post-planting

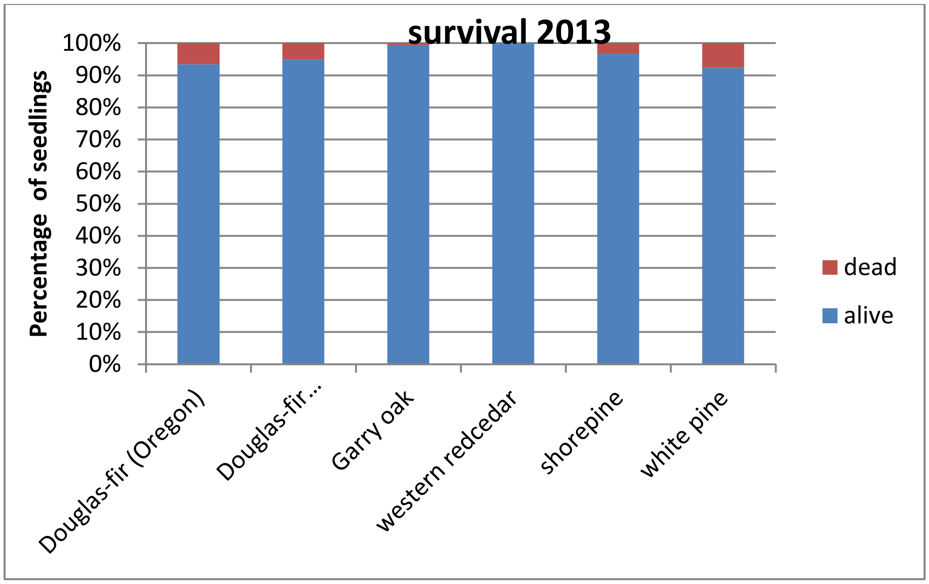

Figure 4. Seedling survival in 2013, two years post-planting

Seedlings with high vigor were above 70% and seedlings with low vigor were below 10% for all species (Figures 5 and 6). Western redcedar had the lowest percentage of high vigor seedlings. The relatively high amount of medium vigor for the cedar was associated with dieback of older branches, with new branches and leader typically still being healthy. Foothills had the most medium vigor seedlings.

Percentage of seedlings with high vigor went up from 2012 to 2013 in all species except shore pine. Since only living seedlings were scored for vigor, this could be partly due to seedlings with low to medium vigor in 2012, dying off by 2013. Percentage of seedlings with low vigor went down in all species except shore pine, which went from 3 to 8% low vigor from 2012 to 2013.

Numerous Garry oak had leaves that were not opening up as fast as most oaks at the time of sampling in mid- to late-May, 2013. Later observations indicated this was associated with curled leaves that appeared deformed. This was not scored as part of vigor, which was based entirely on the amount of leaf alive. In general, however, the oaks were looking good in 2013. There were also numerous Douglas-fir that had yellowish foliage, indicative of nutrient deficiency or some other stress. As with the Garry oaks, leaf color did not enter into vigor score.

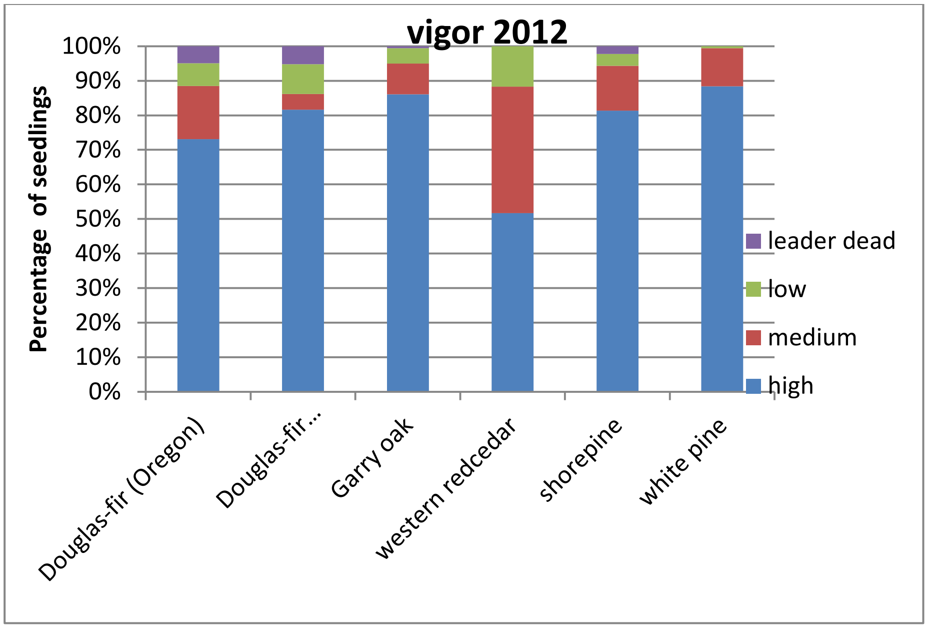

Figure 5. Seedling vigor in 2012, one year post-planting

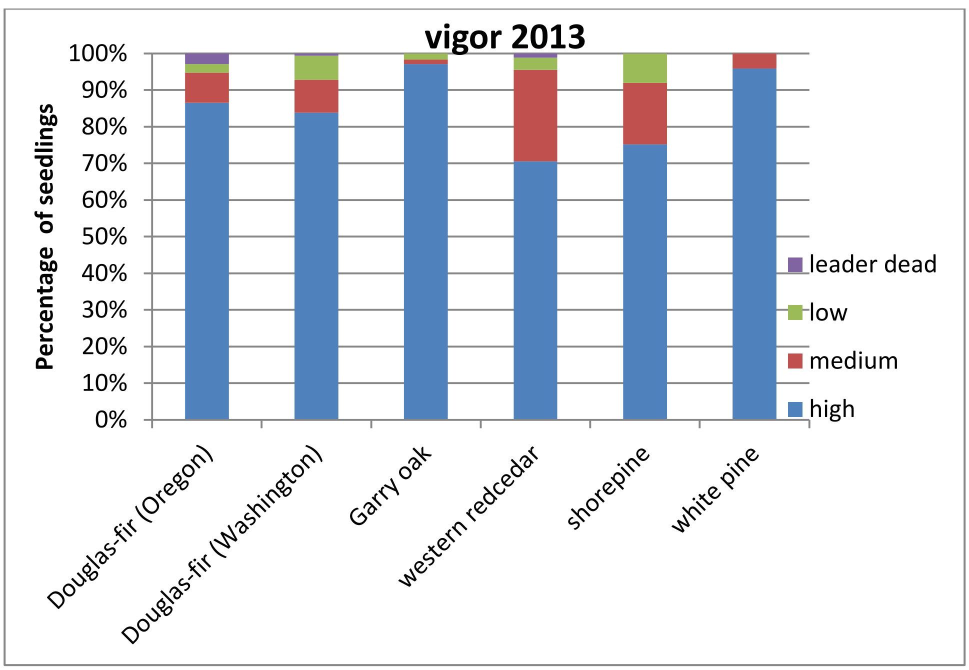

Figure 6. Seedling vigor in 2013, two years post-planting

From 2012 to 2013, the percentage of seedlings showing browse went down for western redcedar, shore pine, and white pine, but went up for Douglas-fir (Figures 7 and 8). Garry oak showed essentially no browse in either year. The percentage of cedar showing medium and high browse went down, likely due to improvements in cage construction in December 2012. Cedar browsed in 2012 due to cage removal were mostly recovering, but were behind in growth compared to unbrowsed cedar. Most of the light cedar browse was nibbling through or over the cage. There was much less high and leader-only browse of shore pine in 2013 compared to 2012. But a few emerging "candles" on shore pine were still browsed on many seedlings. There was little browse of Douglas-fir in 2012, but around 10% for both Oregon and Washington Douglas-fir in 2013. Barneston had most of the Douglas-fir browse.

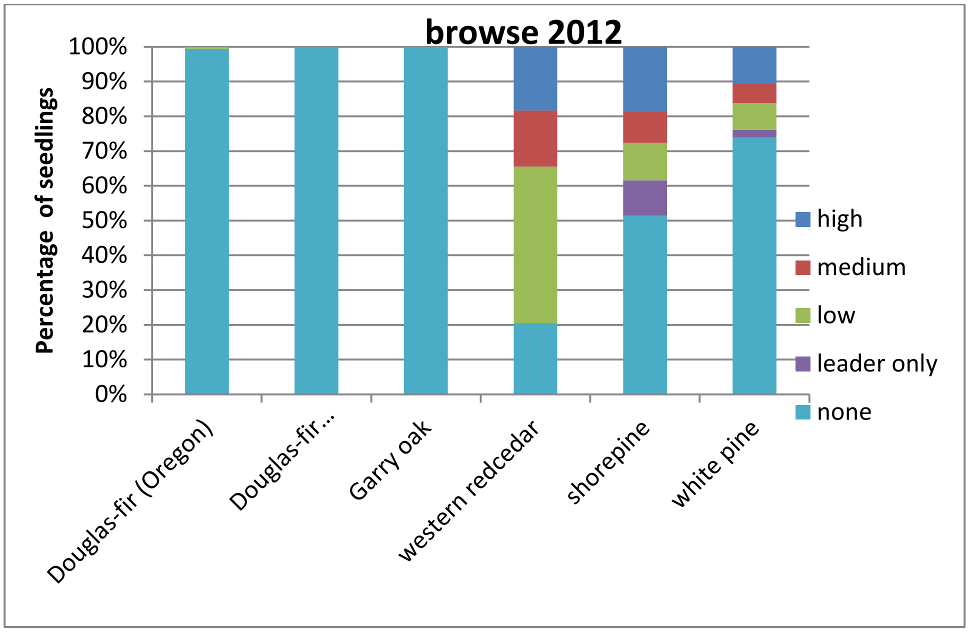

Figure 7. Seedling browse in 2012, one year post-planting

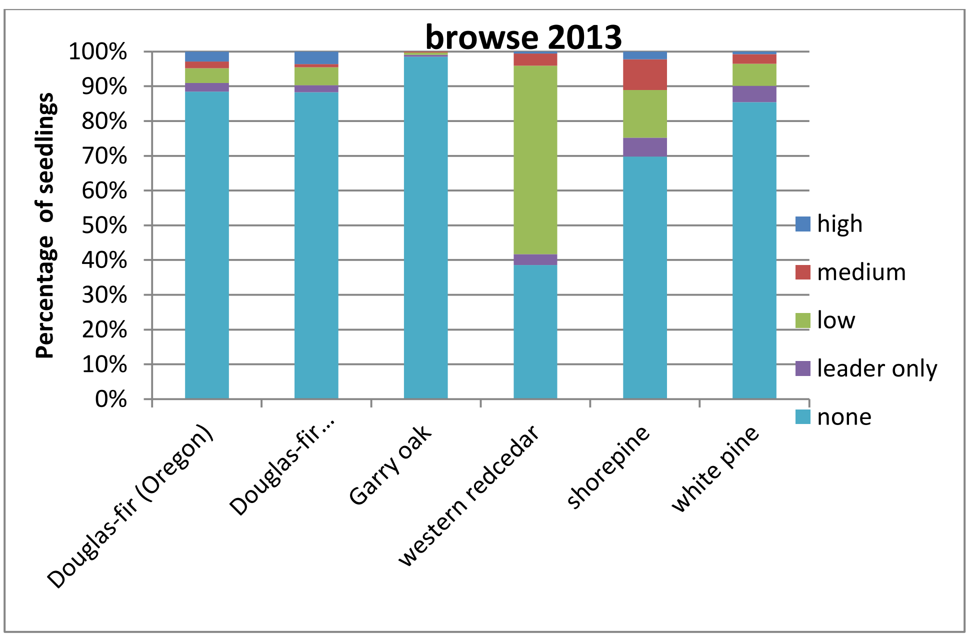

Figure 8. Seedling browse in 2013, two years post-planting