Watershed Park Borrow Pit Stewardship Plan

Prepared for the Green Kirkland Partnership

Presented to Dr. Kern Ewing, Dr. Jim Fridley and Dr. Darlene Zabowski, University of Washington, in partial fulfillment of the requirements for the degree of Masters in Environmental Horticulture

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EXECUTIVE SUMMARY

The project site is a 9.9-acre abandoned borrow pit in the southeastern corner of Watershed Park in Kirkland, Washington. Watershed Park is one of the areas targeted for restoration under the Green Kirkland Partnership's 20-year forest restoration plan. Students and staff at Eastside Preparatory School, a local private school, have been involved in restoration of the site since 2008. However, despite ongoing restoration efforts, the area remains largely treeless and overrun with non-native invasive plants. The purpose of this project was to assess site conditions and propose guidelines for future stewardship of the borrow pit.

In keeping with the Green Kirkland Partnership Program, the restoration goals for the site are to facilitate successional change towards forested communities typical of the Puget Lowland, and to encourage long-term stewardship of this site specifically, and natural areas in general.

The likelihood of autogenic recovery at this site is low. In the more than 40 years since the cessation of mining activities, the site has become dominated by non-native, invasive vegetation. Himalayan and evergreen blackberry, and in some areas, Scot's broom, dominate the pit slopes; the pit floor is characterized by pervasive Scot's broom cover with an understory of introduced grasses and forbs.

A mature stand of Douglas-fir trees in the southeastern corner of the site represents the only major native vegetation on the site. Native understory species associated with this area include western sword fern and Oregon grape. In the rest of the pit, native tree cover is limited to scattered Douglas-fir, black cottonwood and Pacific madrone trees of varying sizes and ages. Along the slopes, Indian plum and red elderberry shrubs persist despite being overgrown by Himalayan blackberry and Scot's broom.

Harsh site conditions, combined with limited resources for restoration, present some daunting challenges to restoration. In addition to pervasive invasive vegetation cover, removal of topsoil layers during mining has resulted in soils that are poor in nutrients and organic matter and lacking in structure. The mostly sandy soils are either excessively well-drained, or compacted. Both conditions results in installed plants succumbing to drought during the dry summer months.

To facilitate management, the site was subdivided into 16 management units. Restoration needs and management recommendations were proposed for each management unit. It is proposed that restoration efforts on controlling invasive species combined with the introduction of species better adapted to these site conditions, such as those growing in dry forests and woodlands in the Puget lowland area. Shore pine, Ponderosa pine and Garry oak are all drought-tolerant trees native to the area.

Because this is such a large site, and conditions are so challenging, it will take many decades to restore the site—the timeline will depend largely on availability of resources. Short-term priorities include maintaining areas already in restoration, releasing existing native vegetation on the site from encroaching invasive vegetation, and control of smaller infestations of invasive species of concern. These species include shade-tolerant species, especially yellow archangel, ivy and herb Robert, and weeds that are difficult to control such as Canada thistle. Another plant prioritized for removal is tansy ragwort. This plant occurs widespread throughout the pit area. Because removal of this weed is required by King County, it is proposed that City of Kirkland staff take responsibility for tansy ragwort control.

All management units were prioritized according to likelihood of a successful restoration outcome, accessibility to volunteers, proximity to other areas in restoration, and threat its current status presents to forest areas in the rest of the park. Restoration of these areas will be initiated as resources become available over several years.

Acknowledgements

I would like to thank various people for their contribution to this project. Drs. Kern Ewing, James Fridley, and Darlene Zabowski, my advising committee members, provided guidance and feedback throughout the course of this project. I have learnt so much from them and other faculty at the UW School of Environmental and Forest Sciences and for that, I am very grateful. Many thanks to Sharon Rodman of the City of Kirkland Parks and Community Services for introducing me to the project site, and for giving me the opportunity to be a part of the Green Kirkland Partnership. Riz Reyes and Lauren Clark helped water my trees when I could not--I truly appreciate your kindness and willingness to help. To the graduate student community at the Center for Urban Horticulture, many thanks to all of you for the camaraderie and encouragement. Finally, to Cecil and Martin, my long-suffering family, thank you for your unwavering support and patience, and for jumping in to help when I needed more hands.

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1 INTRODUCTION

The Green Kirkland Partnership was created in 2008 in response to perception that the health of urban forests in Kirkland was declining. The Partnership is modeled after the Green Seattle Partnership, and draws on City of Kirkland resources, volunteers, and non-profit partners such as Forterra and EarthCorps, to restore publicly owned forests in Kirkland. Watershed Park is one of the areas targeted for restoration under the Green Kirkland Partnership's 20-year forest restoration plan (Green Kirkland Partnership 2008).

Students and staff at Eastside Preparatory School, a local private school, have been involved in restoration of an abandoned borrow pit in the southeast corner of Watershed Park since 2008. Although restoration efforts at this site have been ongoing for a number of years, there is no management plan in place. This is a challenging site to restore—despite restoration efforts, the area remains largely treeless and overrun with non-native invasive plants. The purpose of the current project was to assess site conditions and propose guidelines for future stewardship of the borrow pit.

The restoration goals are twofold:

- Facilitate successional change towards forested communities typical of the Puget Lowland.
- Encourage long-term stewardship of this site specifically, and natural areas in general.

The following objectives have been developed to achieve these goals:

- Protect and maintain existing native vegetation.
- Install a structurally and compositionally diverse suite of native plants resistant to invasion.
- Manage non-native, invasive vegetation.
- Continue to engage Eastside Preparatory School in restoration activities.

2 LOCATION AND CONTEXT

2.1 Landscape setting

Watershed Park is an undeveloped, publicly owned park in the City of Kirkland, located in the Puget Lowland ecoregion of western Washington (Figure 1). The 73.3-acre park is surrounded by low- to medium-density residential areas, with Interstate 405 forming the eastern boundary.

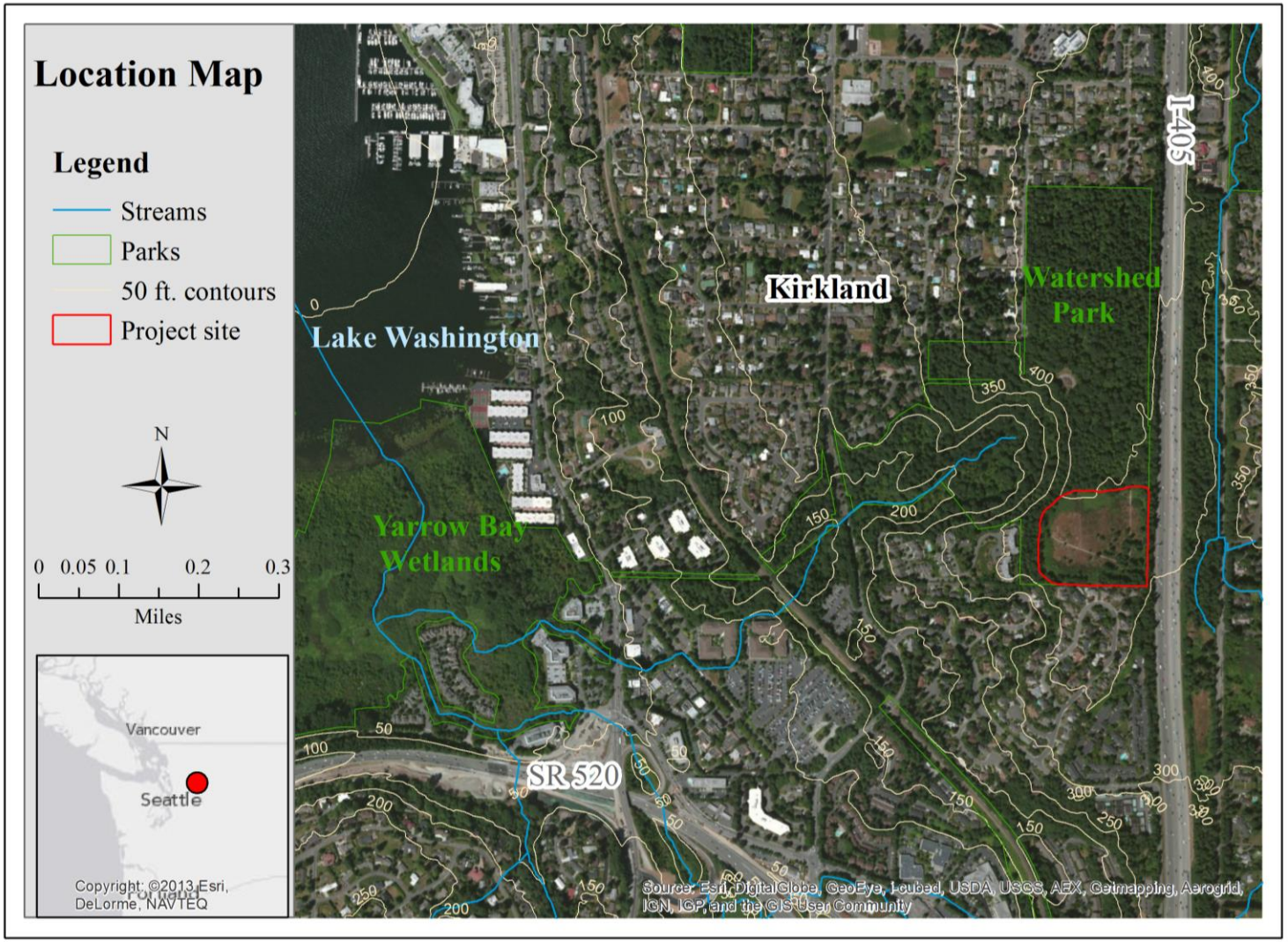

Figure 1. Map of Watershed Park and surrounding landscape.

Located on the western slope of a north-south oriented ridge east of Lake Washington, the park contains a mosaic of riparian, wetland and upland forested areas. The landscape in the western part of the park is dominated by a deep ravine that forms the headwaters of Cochran Springs Creek. The creek is fed by numerous springs and small seeps, and drains into the Yarrow Bay Wetlands on the shores of Lake Washington, about 0.5 miles downslope. The greenbelt formed by the upland forests in Watershed Park, the Cochran Springs Creek riparian corridor, and the Yarrow Bay wetlands is considered an important wildlife corridor in this increasingly urban environment (Way et al. 1998).

The project site, historically upland forest, comprises a 9.9-acre area in the southeast corner of the park. It is bounded on the east by the I-405, forested parkland to the north and west, and residential neighborhoods to the south.

2.2 Climate

The climate in this area is mild, with wet and cloudy winters and relatively dry summers. Average annual precipitation ranges from 29 to 45 inches, occurring mostly as rainfall; annual snowfall averages only 3.6 inches. July and August are the driest months, when several weeks may pass with no measurable rainfall. The average daily maximum during the summer months is 74°F, and the minimum 55°F, but summer temperatures as high as 105°F have been recorded. Winter temperatures generally range between 37 and 48°F, seldom dropping below 10°F. The growing season is from the latter half of April until the middle of October (Western Regional Climate Center 2013a, 2013b).

2.3 Geology

About 18,000 years ago, a sheet of ice advanced from British Columbia, covering the Puget Lowland all the way to the south of Olympia. The ice scoured and gouged the landscape as it advanced; 5,000 years later, the ice started to retreat, leaving behind thick deposits of glacial drift. These deposits included till, i.e. unsorted debris deposited by the glacier, fine-grained lacustrine deposits, and sand and gravel transported and deposited by glacial meltwater (Booth et al. 2007, Troost & Booth 2008). These coarse-grained sands and gravels are a valuable resource of raw materials for construction (Washington State Department of Natural Resources 2013).

2.4 Soils

The soils in Watershed Park and surrounding areas formed in these glacial deposits, and have been mapped as Alderwood gravelly sandy loam and Indianola loamy fine sand (USDA NRCS 2013).

2.5 Vegetation

The vegetation of the upland areas in Watershed Park consists mostly of mature, mixed coniferous and deciduous forest with a canopy of Douglas-fir (*Pseudotsuga menziesii)*, western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), Pacific madrone (*Arbutus menziesii*), bigleaf maple (*Acer macrophyllum*), black cottonwood (*Populus trichocarpa*) and red alder (*Alnus rubra*). The shrub layer contains beaked hazelnut (*Corylus cornuta*), Indian plum (*Oemleria cerasiformis*), salal (*Gaultheria shallon*), salmonberry (*Rubus spectabilis*), red elderberry (*Sambucus racemosa*), red huckleberry (*Vaccinium parvifolium*), vine maple (*Acer circinatum*), and low Oregon grape (*Berberis nervosa*). Western sword fern (*Polystichum munitum*), bracken fern (*Pteridium aquilinum*), stinging nettle (*Urtica dioica*), and trailing blackberry (*Rubus ursinus*) forms the herbaceous layer (Sheldon et al. 2006).

Invasive species include Himalayan blackberry (*Rubus armeniacus*), herb Robert (*Geranium robertianum*), holly (*Ilex aquifolium*), cherry laurel (*Prunus laurocerasus*), English/Atlantic ivy (*Hedera helix/hibernica*), and yellow archangel (*Lamiastrum galeobdolon*). In general, these forests are in good condition with more than 25% native tree canopy cover. Invasive species cover is relatively low, and mostly confined to the areas along trails and park edges (Sheldon et al. 2006).

3 HISTORY

William Cochrane, an Irish immigrant, homesteaded Watershed Park towards the end of the 19th century (Ely 1975). We do not know exactly when the park was logged, but on a 1936 aerial photograph, much of the upland area of current-day Watershed Park appears to lack significant tree cover (Figure 2).

The forest seems to have recovered rapidly; a 1965 aerial photograph shows what seems to be dense forest at the project site and the surrounding parkland (Figure 2). The photograph also shows how rapidly the area surrounding the park was being developed. The springs on the Cochrane homestead provided the City of Houghton, now part of the City of Kirkland, with water from 1915 to 1967, and are the reason why Watershed Park escaped development. Water

was collected in a reservoir located in the stream, and then pumped to another reservoir at the top of the ravine (Ely 1975). The two water reservoirs, located to the northwest and to the north of the project site respectively, can be seen on the 1965 aerial photograph.

Work on Interstate 405, adjacent to the park, was in full swing at this time. In the late 1960s, the project site was mined for gravel and sand, and used as a staging area during construction of the freeway, before being abandoned in 1968 (Sheldon et al. 2006). The extent of the destruction at the site is clearly visible on a 1970 aerial photograph (Figure 2). The site appears to be mostly bare of vegetation, and crisscrossed by a network of roads.

No reclamation was done at the site—Washington State Legislature does not require reclamation of surface mines where mining activities were completed prior to 1971 (Washington State Legislature 2012). The site may have been seeded with grasses to prevent erosion, a common practice at the time.

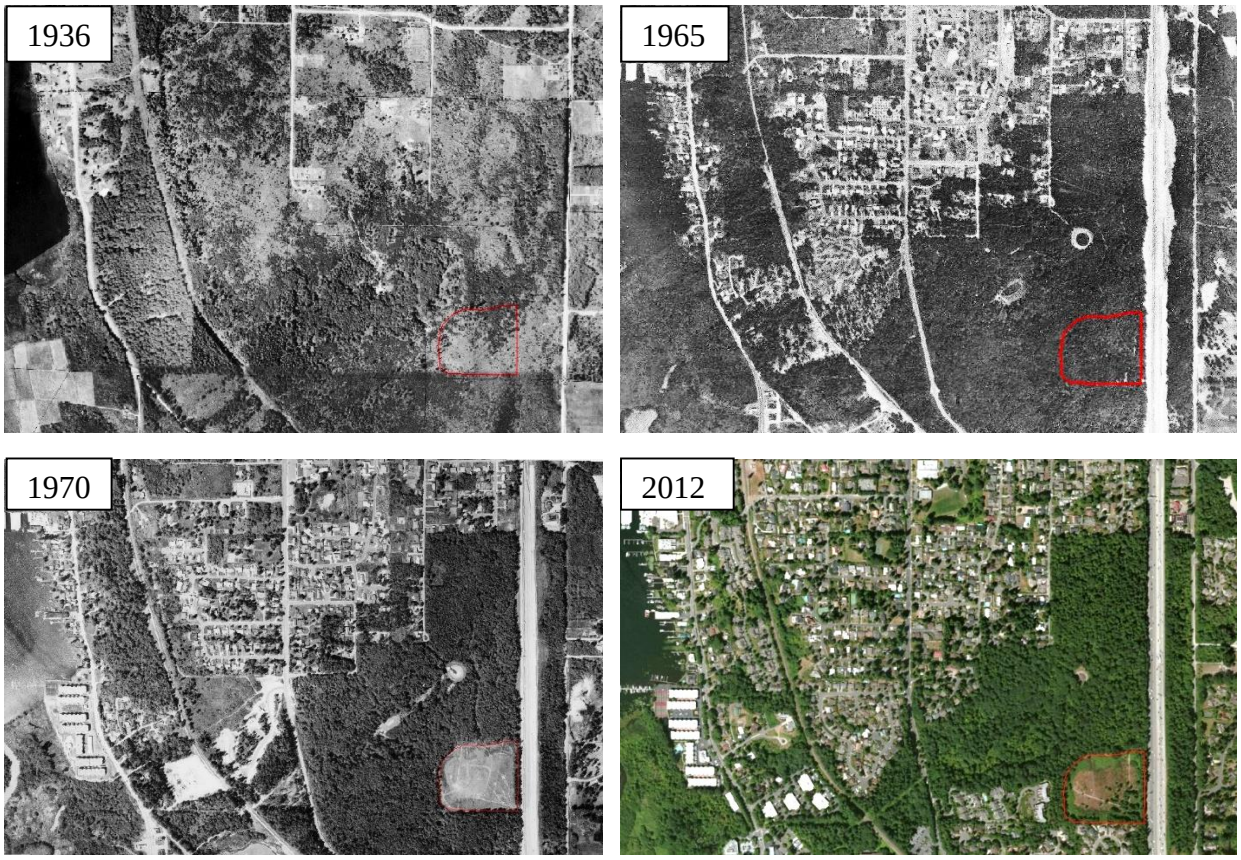

Figure 2. Watershed Park and surrounding landscape over time (King County 2008; Pacific Aerial Surveys 1965; Washington State Department of Natural Resource 1970; ESRI 2013). The project site is outlined in red.

As can be seen from the 2012 satellite image (Figure 2), recovery has been slow—very little natural reforestation has occurred. Unfavorable site conditions are mostly to blame, but increasing levels of anthropogenic disturbance in the surrounding areas are probably also contributing to the continued degraded state of this site.

The forests surrounding the site have shrunk significantly since the 1960s—previously forested areas to the south and west are now residential developments. More recently, in June 2013, trees and shrubs were removed from the edge of the freeway corridor adjacent to the park as part of the Washington State Department of Transportation's Bellevue to Lynwood Widening and Express Toll Lanes Project, further limiting the likelihood of recovery of this site.

4 LOGISTICS

4.1 Site access

There are several entrances to the park. Parking is on street only. The closest entrance to the site is where 112th Ave NE dead-ends against the park. A number of old access roads, now used as trails, crisscross the park. Some of these access roads are drivable, but use is restricted to official City of Kirkland vehicles. The borrow pit can be reached on foot via several trails--from the park entrance it is a short walk, approximately 1,500 feet, to the site.

The pit itself can be accessed by vehicle from the northeast corner via one of these old access roads (Figure 3). The road is poorly maintained and the grade fairly steep where it enters the pit, necessitating a 4-wheel drive vehicle. The road traverses the site from north to south, and then turns west, continuing all the way to the western edge of the pit. Mulch and other supplies can be delivered to any point along the road. However, because of the poor road conditions, deliveries are limited to the drier months of the year.

4.2 Water availability

Lack of water at the site has been hampering restoration efforts. There is a fire hydrant at the top of the northern slope (Figure 3), but use for irrigation purposes is not permitted at this time. Cochran Springs Creek is difficult to access from the site, and there is no other readily available source of water nearby.

Green Kirkland Partnership staff irrigated a small area planted with native plants during the summer of 2012, using a pickup truck equipped with a 200-gallon portable water tank, pump and hose. However, this proved to be very time-consuming, and the drive down into the pit somewhat hazardous.

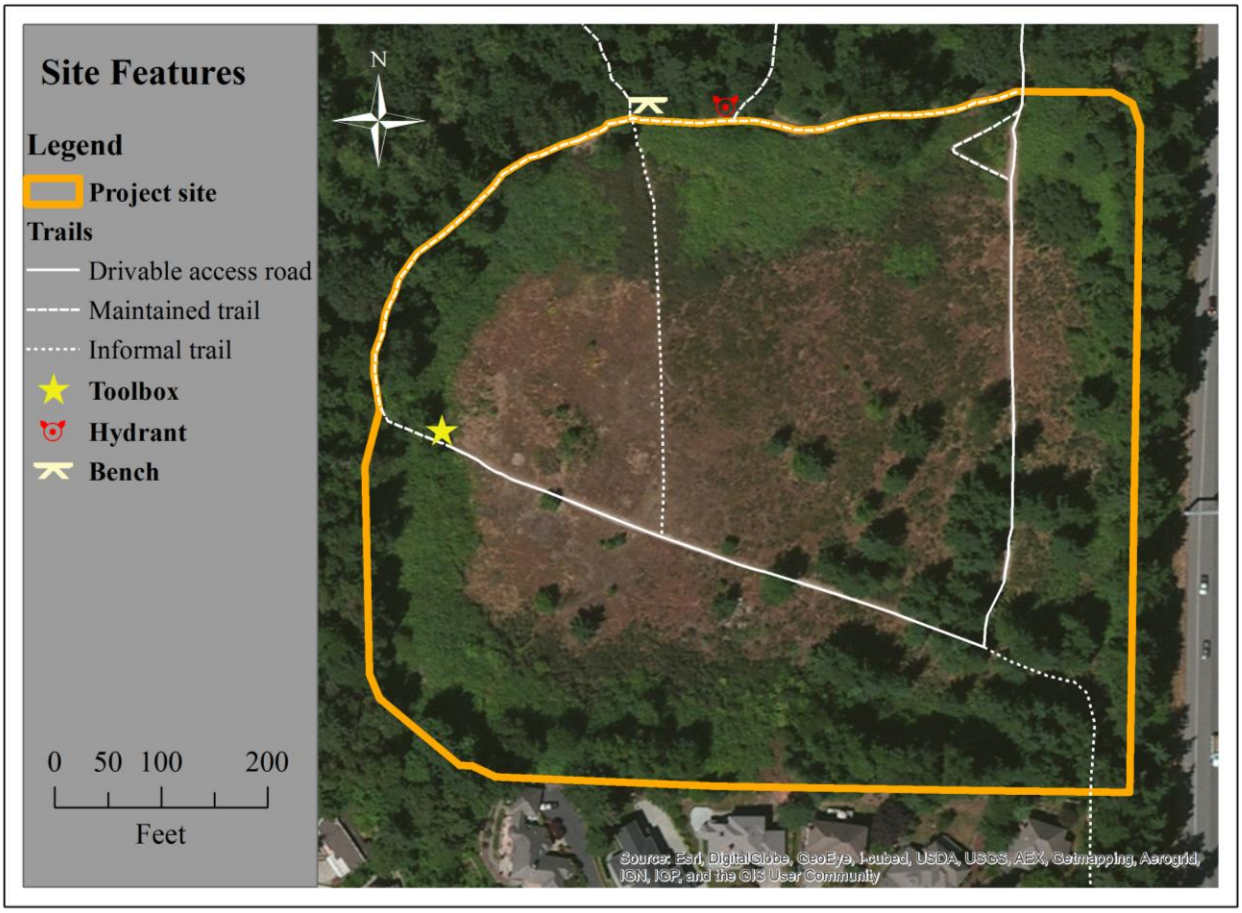

Figure 3. Plan view showing the main features of the project site.

4.3 Tools

There is a tool locker equipped with shovels and loppers on site. The Green Kirkland Partnership also has a tool trailer that can be requested for large work parties.

4.4 Mulch

The Green Kirkland Partnership provides arborist wood chips for mulching.

4.5 Other facilities

There are no restrooms or other facilities at Watershed Park.

4.6 Volunteer availability

- Eastside Preparatory School has been the main volunteer group involved in restoration at the Watershed Park borrow pit. Staff and students are available to volunteer only during the school year. Because Eastside Preparatory School volunteers are available only for part of the year, it may be necessary to recruit additional volunteers to share the responsibility of restoration activities at the project site.
- The Green Kirkland Partnership has a large database of volunteers working in Kirkland Parks. Volunteer park stewards typically lead work parties.

5 SITE CHARACTERISTICS

5.1 Methods and data collection

As part of a larger Green Kirkland Partnership project, all the natural areas in Watershed Park have been mapped and subdivided into management units. The borrow pit is management unit 15. To facilitate management of the project site, management unit 15 was further subdivided into 16 smaller units based on vegetation, aspect and slope, soil characteristics, physical features such as trails, and current restoration status.

Field data, collected between September 2011 and June 2013, were supplemented by information extracted from orthoimages, topographical maps and City of Kirkland documents. For each management unit a number of characteristics were recorded:

- Slope was measured using a compass clinometer. Slope was also calculated from 2 feet contour maps obtained from the City of Kirkland.
- Aspect was noted in the field and confirmed from contour maps.
- Soil characteristics were determined by digging 186 small test pits using a shovel. The depth of each pit was between 12 and 16 inches, but in places, soil compaction prevented digging that deep. Initial pits were located about 150 feet apart along a rough grid pattern, to get a general idea of the distribution of soil types. Additional pits were then added as necessary to locate boundaries between different soil types. Relatively few locations were sampled along some parts of the pit slopes because of difficulty accessing those areas due to dense Himalayan blackberry cover. Pit locations were noted on an orthoimage using a combination of landmark features (trees etc.) and by pacing out distances.

Features noted were litter depth, vegetation cover, and presence of soil horizons. For each soil horizon, the thickness, color, texture, structure, presence or absence of redoximorphic features, and presence or absence of earthworms and roots were recorded. Soil texture was estimated by feel and doing a ribbon test.

The degree and depth of soil compaction were also recorded. Soil was classified as very compacted if penetration with a shovel was difficult to impossible, moderately compacted if there were indications of compaction, but not to the extent that it appeared to inhibit drainage or root penetration, or not compacted.

- Tree canopy cover characteristics: Total tree canopy cover was estimated from on areal cover on orthoimages. Per cent tree canopy cover was recorded in the following coverage classes: 0-5, 5-25, 25-50, 50-75, 75-95 and 95-100 per cent after Daubenmire (1959).

  All tree species present were identified in the field and species abundance estimated by counting the number of stems. Where trees could be accessed, diameter at breast height (DBH) was measured for a subsample of trees. Trees with a DBH less than 5 inches were considered regenerating trees.

- Total percentage native and non-native shrub cover was visually estimated and recorded in Daubenmire coverage classes. In areas where non-native shrub cover was close to 100%, percentages of Himalayan blackberry and Scot's broom were estimated from areal cover on orthoimages. All shrub species were identified and order of dominance noted.

- Total percentage of native and non-native forb and graminoid cover was visually estimated and recorded in Daubenmire coverage classes. Species were identified and order of dominance noted.

- Presence of features such as trails was noted.

- Restoration status was determined from records kept by the Green Kirkland Partnership combined with field observations.

5.2 Overview of site characteristics

5.2.1 Topography

The elevation at the project site drops from about 410 feet at the northern edge of the pit, to 355 feet at the lowest point in the southeastern corner (Figure 4). The slopes surrounding the central

pit floor are variable and moderately steep, especially to the north and south, with grades varying between 21 and 36%. The pit floor slopes gently towards the southeast corner at a grade of <5%. The topography of the pit floor is often uneven —ridges, swales, mound and pits, relicts of past human activities, are common features of the pit floor (Figure 5), and are often associated with local variations in vegetation cover. The vertical scale of these features is small, rarely exceeding 18 inches.

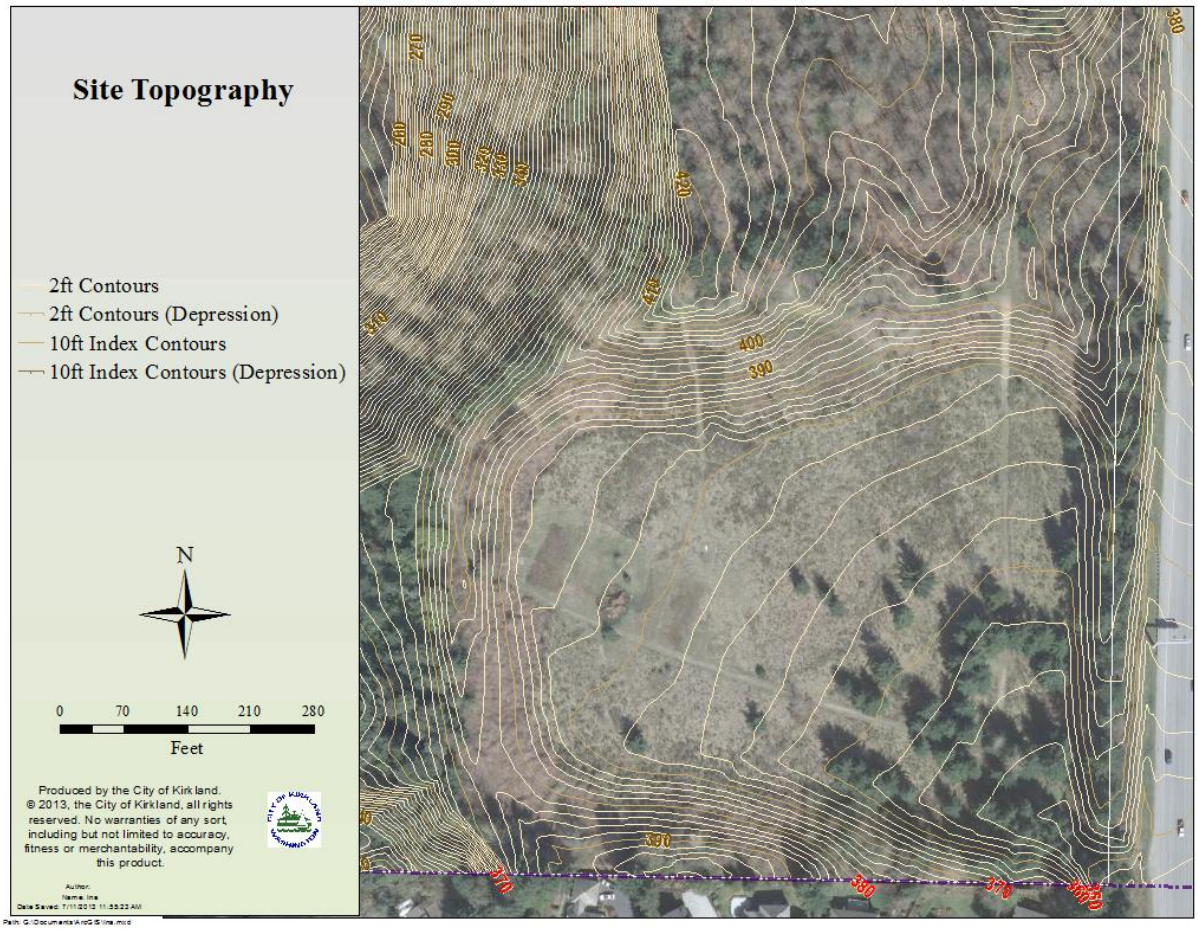

Figure 4. Two feet contour lines at the Watershed Park borrow pit (Obtained from the City of Kirkland).

5.2.2 Soils

Soils at the site are poorly developed and altered because of anthropogenic activity. During extraction of sand and gravel, a thickness of at least 25 feet of topsoil and underlying material appears to have been removed, exposing relatively unweathered glacial drift deposits. In

addition to topsoil removal, soils were compacted by heavy equipment and vehicles. Artifacts, such as crushed rock, metal fragments, and pieces of asphalt, were also introduced, and have been incorporated into the upper soil layers. Soils at the site were classified based on texture and the degree of compaction. Figure 6 shows the distribution of different types of soil across the site. Note that this map reflects general trends; soil characteristics at the site were very variable.

Figure 5. Uneven pit floor topography: Aerial photographs suggest that the shallow ridges and swales in this image are old wheel track ruts. Note the sparse vegetation associated with these features.

Sandy soils (Figure 7)

Across most of the pit floor and the slopes (Figure 6), the subsoil consists of well-sorted, loose, fine-to medium-grained, grayish-to yellowish-brown, well-drained sand, probably representing outwash deposited by glacial meltwater.

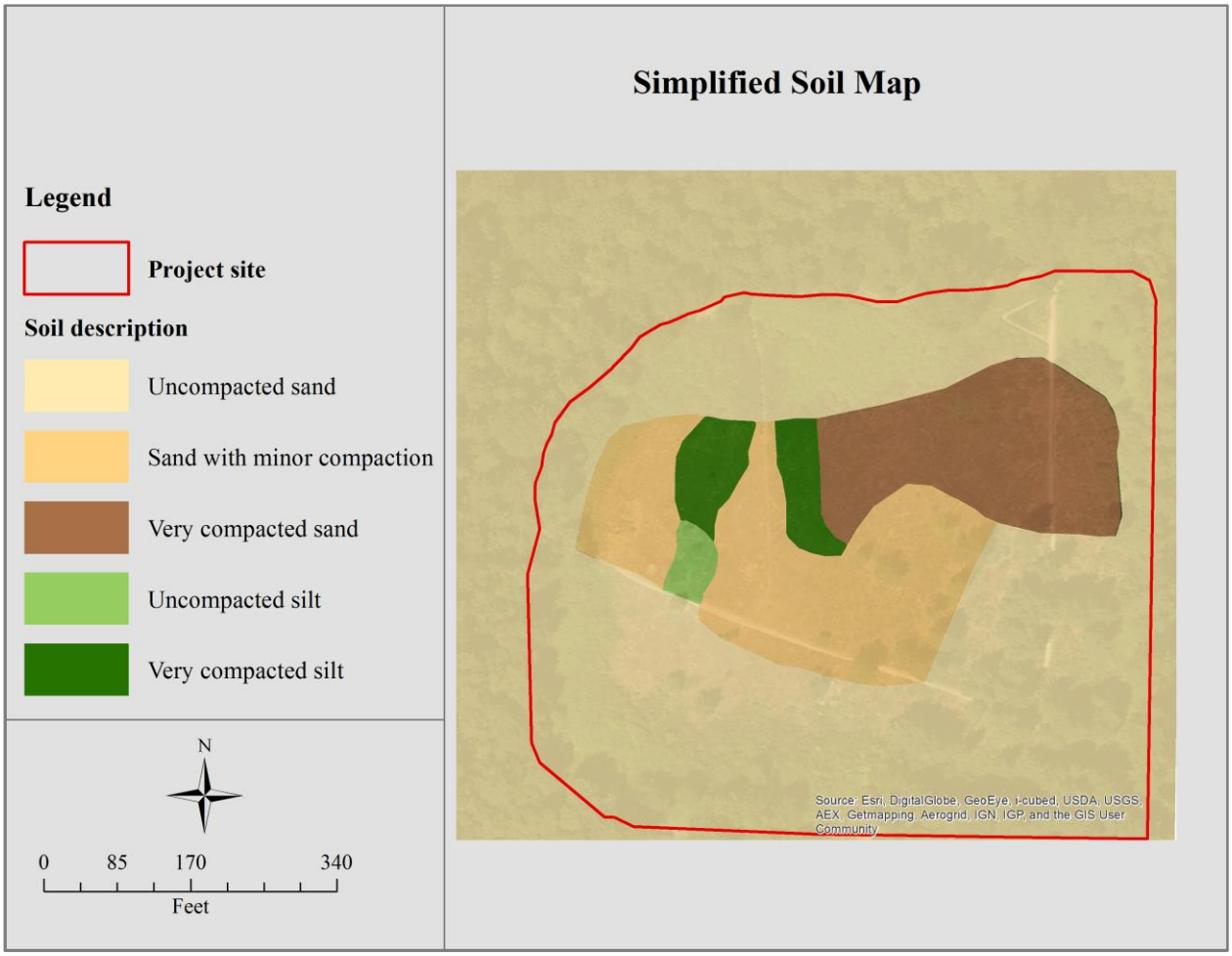

Figure 6. Generalized soil map of the project area.

This is typically overlain by a layer of yellowish- to light-brown, loamy sand to sandy loam, up to 10 inches thick. This layer may contain small pebbles and reworked fine-grained lake sediments. It is generally massive in appearance and more cohesive than the underlying subsoil.

In some areas, particularly in the northern and northeastern parts of the pit, and along trails, part of this layer is very compacted. The depth and degree of compaction is highly variable, often changing within a few feet. Where the degree of compaction is high, this layer is so dense that it cannot be penetrated with a shovel. The degree of compaction depends on a number of factors including as the grain-size distribution of the mineral particles, the type and intensity of anthropogenic activity, as well as processes acting on the soil since it was compacted. Such processes would include earthworm activity or root penetration, which may have helped to

loosen compacted soils. Highly compacted areas are often poorly drained— the soil in some of these areas is very wet during the winter months, as evidenced by the development of redoximorphic features.

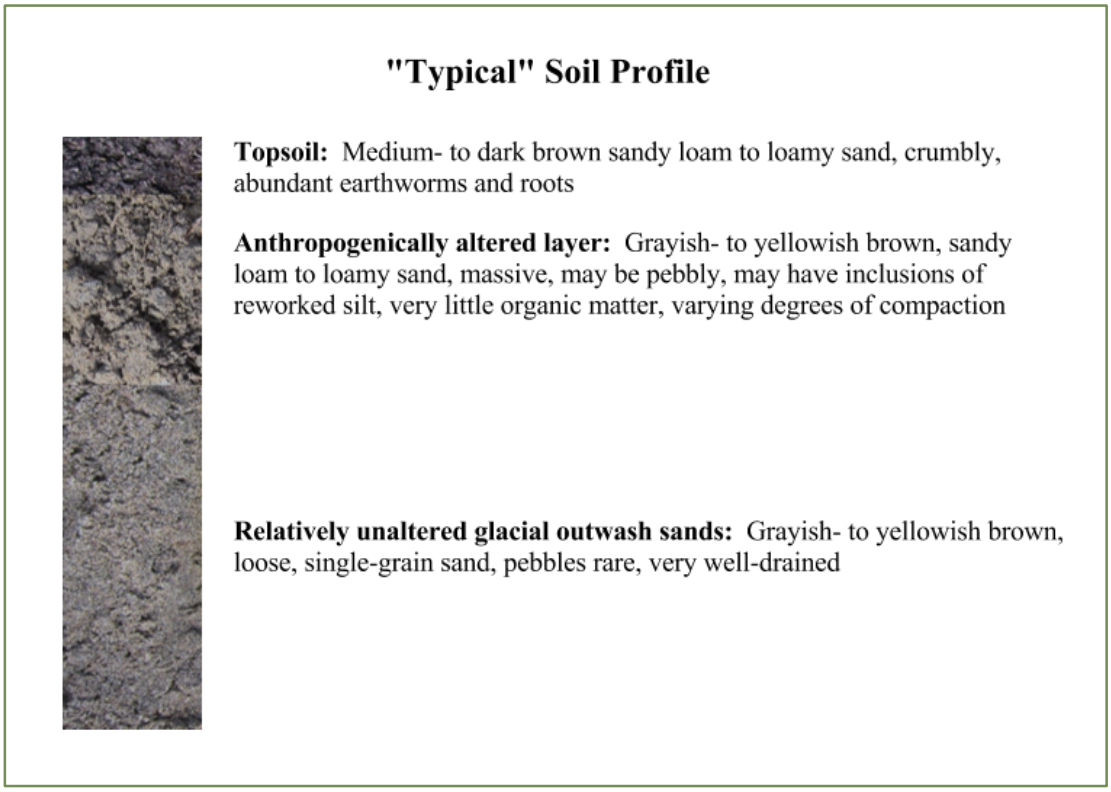

Figure 7. "Typical" soil profile of sandy soils at Watershed Park borrow pit.

Some topsoil development did occur over the past four decades. The surface layer of the soil, generally 1 to 3 inches thick, but as thick as 12 inches in some locations, is typically a medium- to dark-brown, sandy loam with granular structure. The dark color of this material can be attributed to the addition of organic material in the form of decaying vegetation. Abundant earthworms were commonly observed in this layer.

Silt

In a few areas along the pit floor (Figure 6), the subsoil consists of finer-grained lake sediments, composed of dark- to medium-grey silt. This layer is generally overlain by dark-gray to grayish-

brown sandy clay loam or clay loam. While occasional reddish redox concentrations are common towards the bottom of this layer (Figure 8), poor drainage does not appear to be a significant problem where these soils have not been compacted. Where compaction of these soils did occur, mostly in the northern half of the site, very wet, poorly drained conditions prevail (Figure 9).

A layer of silt, up to a foot thick, was also encountered sandwiched between deposits of sand, at several locations along the northern and western slopes. It is not clear how far this layer extends laterally—its presence along the eastern and southern slopes could not be confirmed.

Figure 8. Soil overlying uncompacted silt. Occasional small reddish redox concentrations are present lower down in the soil profile (an example indicated by the arrow). Note how the color of the soil changes from dark brown to grayish brown with depth and the presence of earthworms and grass roots.

Figure 9. Red and gray mottling in layers overlying compacted fine-grained soils. These redoximorphic features are typical of seasonally saturated soils.

Erosion

Although examination of the soil surface along the slopes revealed no major erosional features such as rills or gullies, there are indications that water does run down the slope and evidence of washout of the sandy soils (Figure 10). Vegetation along the slopes typically exists of 100% cover of Himalayan blackberry and/or Scot's broom. The root systems of these plants are not effective at binding soil particles, and the dense canopy cover shades out species such as grasses that may have helped to prevent erosion. While there is no risk of eroded sediments posing a threat to any water bodies, a stable slope is a prerequisite for successful establishment of vegetation.

5.2.3 Hydrology

There is no surface water present at the project site. In many areas of the pit, rainfall rapidly infiltrates the well-drained, sandy soils. However, where the soil is very compacted, drainage is

poor, resulting in a seasonally perched water table during the winter months. The irregular topography of the pit floor helps to slow down and retain storm water run-off. During periods of heavy or extended rainfall, stormwater run-off, some of it generated in other areas of the park, can be seen flowing downhill along the compacted trails towards the southeast corner of the pit (see figure 3 for a map of the trails present on site).

Figure 10. Soil erosion occurring along the slope under a canopy of Scot's broom and Himalayan blackberry. Arrows indicate areas where the soil is being washed away.

5.2.4 Vegetation

The vegetation on the site is predominantly non-native and invasive. Significant native vegetation cover is present only in the southeast corner of the site. This is also the only area with significant tree canopy cover (Figure 11).

Native vegetation

- A stand of mature Douglas-fir trees (*Pseudotsuga menziesii*) provides significant canopy cover (up 100% in places) in the southeast corner of the site. Other tree species include black cottonwood/balsam poplar (*Populus trichocarpa*), red alder (*Alnus rubra*) and bitter cherry (*Prunus emarginata*). Western sword fern (*Polystichum munitum*), cleavers (*Galium aparine*), tall Oregon grape (*Berberis aquifolium*) and black cap raspberry (*Rubus leucodermis*), can be found along the drip line of Douglas-fir trees. Indian plum (*Oemleria cerasiformis*) seedlings are common, but most do not seem to survive past the seedling stage.

Figure 11. 2012 satellite image of the site (ESRI 2013). Slopes surrounding the pit area have dense cover of Himalayan blackberry (lighter green) and Scot's broom (grayish green). Sparser Scot's broom cover characterizes the central pit area. Note that Scot's

broom was cleared from the western third of the pit in 2008. Significant tree canopy cover is limited to the southeastern corner.

The stand of trees extends up the slope in the southeast corner. In addition to the species already mentioned, the understory along the slope also includes trailing blackberry (*Rubus ursinus*), salal (*Gaultheria shallon*), bracken fern (*Pteridium aquilinum*), red elderberry (*Sambucus racemosa*) and Indian plum.

- Along the rest of the pit floor, native vegetation is limited to a few scattered trees and shrubs, often occurring in clumps, mostly Douglas-fir, black cottonwood, Pacific madrone (*Arbutus menziesii*), red elderberry and greasewood/snowbrush (*Ceanothus velutinus*). Hooded ladies tresses (*Spiranthes romanzoffiana*) is the only native forb present (Figure 13). Tree ages vary from seedlings to mature (Figure 14). The few red alder trees are generally small and appear stressed; dead branches are common. Pacific madrone trees are invariably diseased (Figure 15).

Figure 12. Douglas-fir stand in the southeastern corner of the site. Note the sparse understory beneath the trees. Sword ferns are growing along the drip line of the trees. Introduced grasses and forbs represent the dominant vegetation in canopy gaps.

Figure 13. Hooded ladies tresses (white flowers) growing with St. John's wort (yellow flowers), Scot's broom and introduced grasses.

Figure 14. Douglas-fir seedling growing in the grass.

Figure 15. Cankers on stem of a Pacific Madrone tree.

- Apart from the southeast corner, native plant cover along the slopes consist predominantly of isolated red elderberry and Indian plum shrubs. Occasional trees, occurring singly or in clumps, mostly bitter cherry, black cottonwood, bigleaf maple (*Acer macrophyllum*), Douglas-fir and red alder, occur towards the tops of the slopes, providing some canopy cover.

Non-native vegetation

Figure 16 shows the distribution of non-native vegetation on the site.

- The pit floor is dominated by Scot's broom (*Cytisus scoparius*) (cover between 25 and 75%) (Figure 17) with an understory of introduced grasses and forbs. Grasses include

both perennials such as redtop (*Agrostis* spp.) and common velvet grass (*Holcus lanatus*), and winter annuals such as bromes/cheat grasses (*Bromus* spp.), rat's tail fescue (*Vulpia myuros*) and silver hair-grass (*Aira carophyllea*).

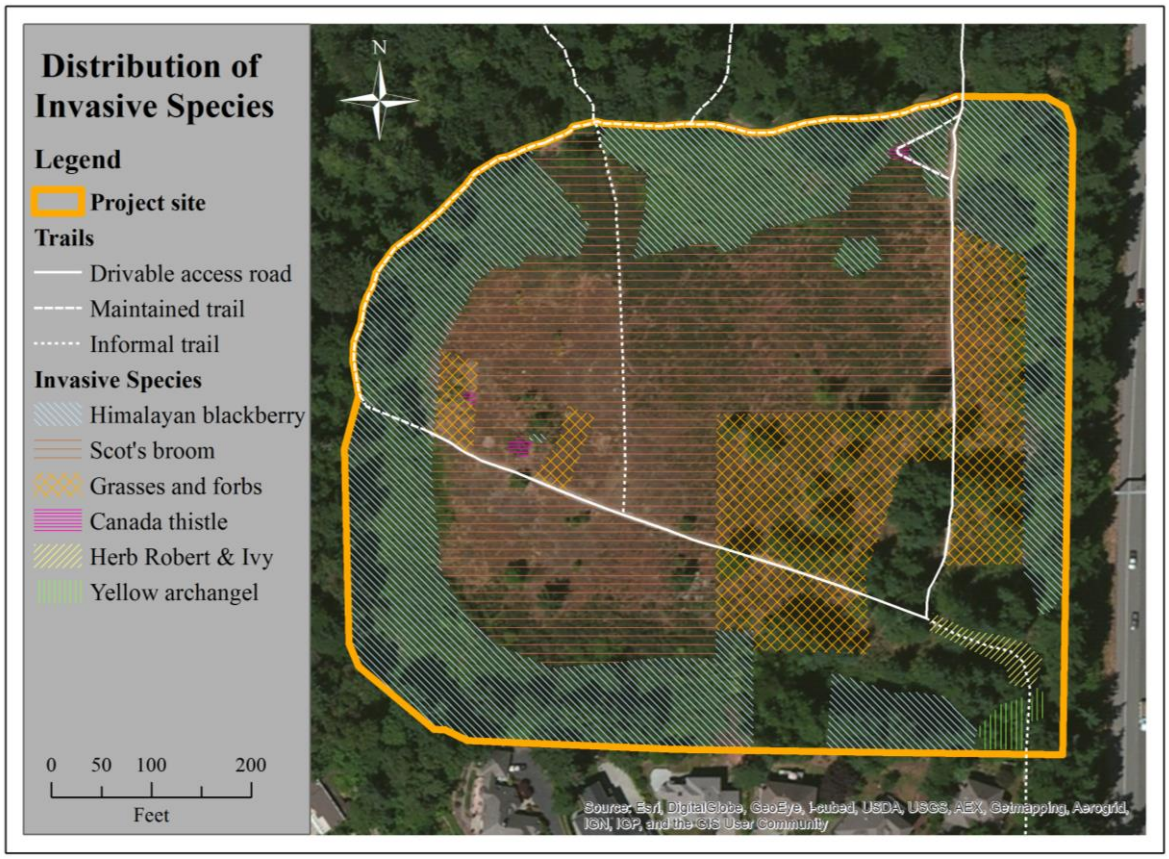

Figure 16. Distribution of non-native, invasive vegetation at the site. Note that introduced grasses and forbs dominate in areas from which Scot's broom has been removed.

Common forbs include hairy cat's ear (*Hypochaeris radicata*), narrowleaf plantain (*Plantago lanceolata*), common sheep sorrel (*Rumex acetosella*), common St. John's wort/Klamath weed (*Hypericum perforatum*), tansy ragwort (*Senecio jacobaeae*), bull thistle (*Cirsium vulgare*) and moth mullein (*Verbascum thapsus*). Oxeye daisy (*Leucanthemum vulgare*), nipplewort (*Lapsana communis*), garden radish (*Raphanus sativus*) and prickly lettuce (*Lactuca serriola*) are less common. Canada thistle (*Cirsium arvense*) is present as clonal colonies, several feet in diameter, mostly in recently disturbed areas. Scattered one-seed hawthorn trees (*Crataegus monogyna*) represent are the only non-native trees on site.

- The slopes are covered mostly by Himalayan blackberry (*Rubus armeniacus*) and less commonly Scot's broom (Figure 17), with cover close to 100%. Evergreen blackberry (*R. laciniatus*), a close relative of Himalayan blackberry is present in minor amounts. For the remainder of this document, references to Himalayan blackberry can be assumed to include evergreen blackberry.

Figure 17. Scot's broom dominating the pit floor (foreground), with Himalayan blackberry along the slopes in the background.

- In the southeast corner of the site where the vegetation is dominated by native plants—Himalayan blackberry, Scot's broom and introduced grasses and forbs are limited to canopy gaps. Of more significance is the presence of infestations of shade tolerant invasive species: yellow archangel/golden dead-nettle (*Lamiastrum galeobdolon*), English/Atlantic ivy (*Hedera helix/hibernica*) and herb Robert (*Geranium robertianum*).

5.3 Restoration History

Restoration has been initiated at several locations at the site (Figure 18).

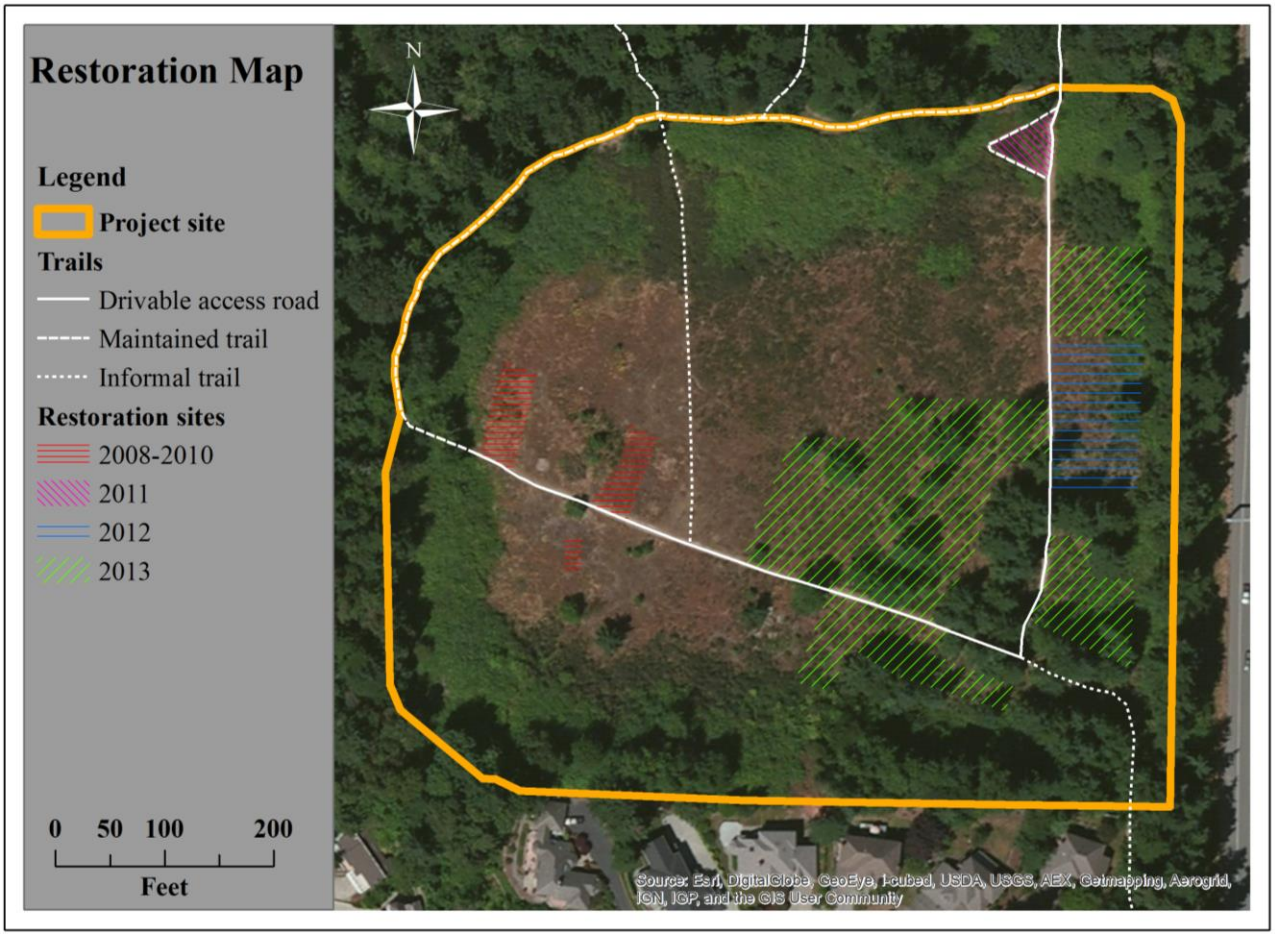

Figure 18. Map showing the locations of current restoration activities at the Watershed Park borrow pit. 2008-2010 sites where no plants survived and which have not been maintained are not shown on this map.

2008-10

Restoration efforts at the site started in 2008 when students and staff at Eastside Preparatory School cleared several acres of Scot's broom and installed a number of test plots in the western third of the pit area. These test plots were tilled and amended with varying amounts of GroCo biosolids compost. Wood chip mulch rings were installed around plants. Plants did not receive any supplemental water during the summer. Survival rates were very poor on all plots, but

compost addition did appear to delay mortalities until later in the summer. However, tilling and compost addition also triggered vigorous growth of grasses and weedy herbaceous species, likely contributing to mortalities later in the season (Henry 2012).

Some of the plots have been tilled and replanted several times since. Survival rates were variable and low, ranging between 0 and 25% for all species combined (13% for all plots and all species combined). Survival rates do not appear to be directly related to the amount of compost applied, although the plot that received the most compost (about 6.5 inches), was also the plot with the lowest mortality. Competition from forbs and grasses remains a problem (Figure 19).

Figure 19. Native trees and shrubs facing fierce competition from introduced grasses and forbs. This area was cleared, amended with 6.5 inches of compost, tilled and planted in 2008. It has been cleared and replanted in 2010 and 2012.

Most of the surviving plants are shrubs—snowberry (*Symphoricarpos albus*), red elderberry, oceanspray (*Holodiscus discolor*), vine maple (*Acer circinatum*) and red-flowering currant (*Ribes sanguineum*). The survival rate for shrubs ranged between 0 and 43% for the different plots, and was 21% for all plots combined.

Tree establishment was less successful. Of 215 Douglas-fir trees installed in all of the plots, only four are still alive. Other species installed were red alder and western hemlock, none of which survives; Oregon ash (*Fraxinus latifolia*) was the most successful tree species with a survival rate of almost 50%.

Plots where survival was negligible and which have not been maintained, have been reclaimed by Scot's broom. About 6,013 square feet (0.14 acres) of an original 10,300 square feet (0.24 acres) can still be considered to be in restoration.

2011

In 2011 a group of Boy Scouts constructed a switchback off the steeply inclined access road where it enters the site in the northeast corner. They also installed native plants in the triangular area (~0.05 acres) inside the switchback (Figure 18). A small cascara tree (*Frangula purshiana*) and a few struggling red-osier dogwoods (*Cornus stolonifera*), a Sitka spruce (*Picea sitchensis*) and western sword ferns are all that remain of the plantings. The City of Kirkland Park Maintenance division is currently maintaining this site.

Fall 2011-Spring 2012

During fall of 2012, an area of about 11,900 square feet (0.27 acres) along the eastern edge of the pit was cleared of Scot's broom. This area was planted with Douglas-fir, grand fir (*Abies grandis*), vine maple, red-flowering currant, thimbleberry (*Rubus parviflorus*), and oceanspray. No soil amendments were applied, but mulch rings were installed. Plants were irrigated weekly during the month of August. Survival rates by the end of summer 2012 were 100% for vine maple and oceanspray, 95% for Douglas-fir, 85% for grand fir, and 43% for thimbleberry.

Fall 2012-Spring 2013

During the 2012-2013 school year, an additional 59,310 square feet (1.36 acres) in the southeastern corner of the site were cleared of Scot's broom. About half of this area was planted with native plants; the remaining area already has good native plant canopy cover. Native plants installed include Douglas-fir, grand fir, shore pine (*Pinus contortus* var. *contortus*), Western white pine (*Pinus monticola*), Garry oak (*Quercus garryana*), western redcedar, red-flowering currant, snowberry, oceanspray, Nootka rose (*Rosa nutkana*), salmonberry (*Rubus spectabilis*), baldhip rose (*Rosa gymnocarpa*). Several Douglas-fir trees were already dying by the end of June 2013.

5.4 Management Units

Figure 20 shows the location and extent of each of the restoration management units delineated. The narrative below summarizes the main features of each management unit. More detailed information about each management unit can be found in Table I and Table II.

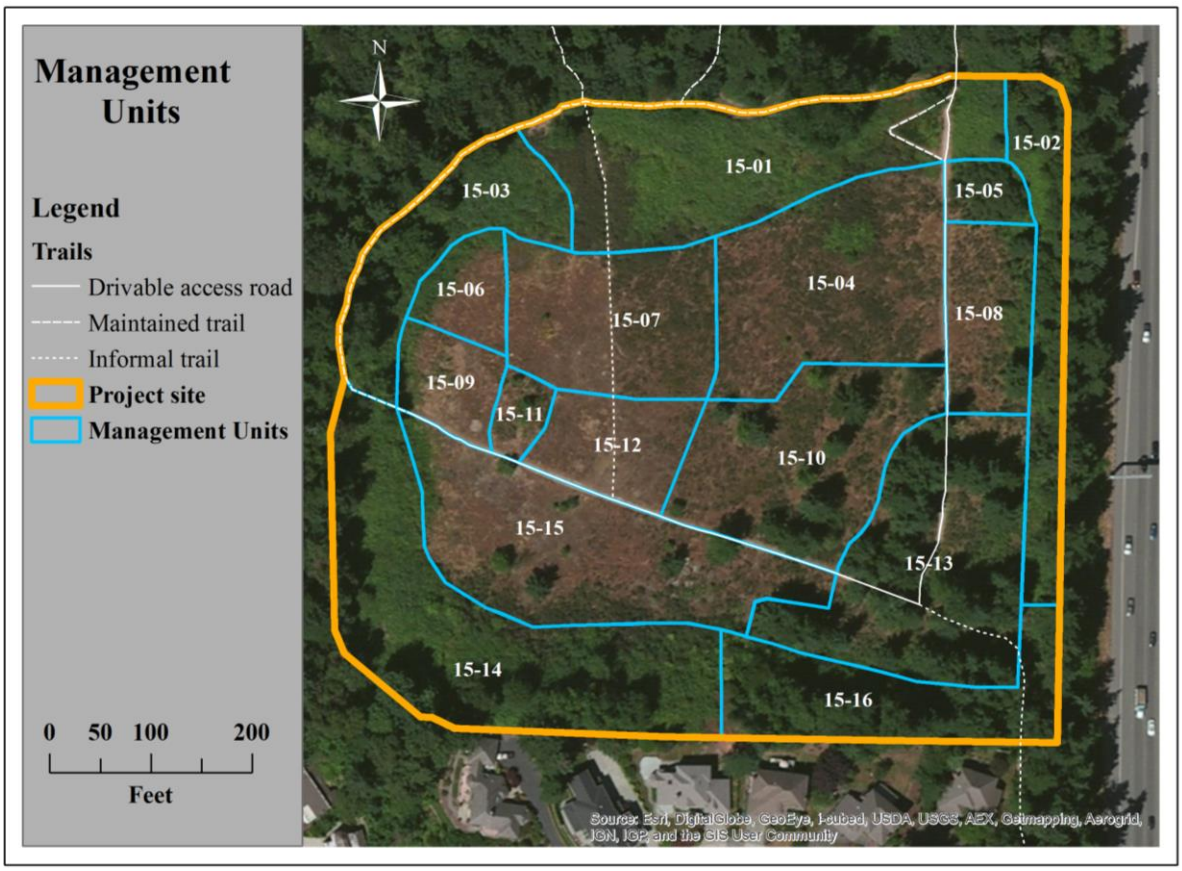

Figure 20. Management units.

15-01

Management unit 15-01 comprises the south-facing slope bounding the site to the north. This is a very exposed, moderately steep area (Figure 21). The only shade is provided by a small clonal stand of black cottonwood trees and a few red alders, all growing at the top of the slope. Himalayan blackberry and Scot's broom form dense thickets; non-native forbs and grasses occur along trail edges. Canada thistle is also present along the trail switchback. Soils are mostly well-drained, loamy sand, and generally not compacted--where compaction was observed it was minor and associated with access roads and trails.

Figure 21. View of the northern slope (15-01) from the south. Most of the trees visible in the photo are part of the forested upland areas adjacent to the project site.

15-02

This unit includes most of the eastern slope bounding the central pit area. A chain-link fence separating the park from I-405 marks the eastern edge. There are some deciduous trees growing along the slope, mostly black cottonwood, bitter cherry and red alder (Figure 22). Trees at the top of the slope and along the edge of the I-405 right-of-way provide additional shade—total tree canopy cover is 50-75%. Trees at the top of the slope are mostly evergreen Douglas-fir, Pacific madrone and western redcedar. The dominant understory species is Himalayan blackberry. Soils are well-drained, loamy sand.

15-03

Management unit 15-03 comprises the western slope north of the main E-W trail. The vegetation is dominated by Himalayan blackberry. A few surviving native shrubs, mostly Indian plum and red elderberry, are being swamped by invasive blackberry (Figure 23). Deciduous trees, mostly black cottonwood, red alder, bitter cherry and bigleaf maple provide some shade, especially towards the top of the slope. Native tree canopy cover is less than 25%. Minor amounts of western sword fern and tall Oregon grape are associated with clumps of deciduous trees. The soil is well-drained, sandy loam, with minor compaction, mostly along the edges of the trail.

Figure 22. View of the eastern slope (15-02). Coniferous trees occur along the top of the slope, while vegetation along the slope itself consists of smaller deciduous trees and Himalayan blackberry.

Figure 23. Himalayan blackberry in 15-03 encroaching on red elderberry.

15-04

This area is in the northeast corner of the pit, west of the N-S access road. There is no significant tree canopy cover in this management unit. The soil is sandy loam with a very compacted subsoil at between 8 and 12" deep. Because of the compaction, poor drainage results in a few seasonally wet areas, particularly in the northern half of the unit. The vegetation is predominantly Scot's broom with an understory of non-native grasses and forbs (Figure 24).

15-05

15-05 is a small management unit in the northeast corner of the pit, east of the N-S trail. Tree canopy cover is between 50 and 75% and consists predominantly of a grove of regenerating bitter cherry trees (Figure 25). The understory is comprised predominantly of non-native grasses. The soil is well-drained, loamy sand with minor compaction along the edge of the trail.

Figure 24. View of management unit 15-04 from the south. Vegetative cover includes Scot's broom, non-native grasses, St. John's wort (yellow flowers in the photo) and other introduced forbs. The small tree on the left is a western white pine.

Figure 25. Regenerating bitter cherry grove with an understory of non-native grasses—15-05.

15-06

This is a fairly flat area in the northwestern corner of the pit. It was cleared of Scot's broom in 2008-09, but because of regeneration of Scot's broom from seed, cover of this species is back to about 25%. Non-native grasses and forbs dominate the understory. Himalayan blackberry is restricted to the toe of the slope where more resources are available. There are no trees in this management unit. The soil is loamy sand to sandy loam—although the subsoil consists of well-drained sand, significant amounts of fine-grained material appear to have been mixed into the top layers of the soil. The soil is moderately compacted in some areas, but not to the extent that it is likely to impede drainage or restrict penetration by plant roots.

15-07

This area lies directly to the east of management unit 15-06. The subsoil appears to be silt, but it is not clear how deep this fine-grained layer is. The soil is very compacted at a depth of about 8", resulting in poor drainage and seasonally saturated soils, but becoming drier towards the northern boundary at the toe of the slope. Redoximorphic features are present from a depth of about 2 to 3". In contrast, in the central portion of this area, on both sides of the informal trail, the soil is well-drained, loose sand. The western half of this area was also cleared of Scot's broom in 2008. The vegetation consists of 50-75% Scot's broom with an understory of non-native grasses and forbs.

15-08

15-08 is the northeastern corner of the pit, south of the bitter cherry grove, east of the N-S trail (Figure 26). The soil in this management unit is loamy sand, and very compacted in the northern half. There is some native tree canopy (<25%), mostly along the bottom of the slope where several Douglas-fir trees of various ages are present. Regenerating bitter cherry saplings are also common in the northern part. This site was cleared of Scot's broom during the winter of 2012; native trees and shrubs were also installed at that time. Additional trees and shrubs were installed during fall 2012. The dominant vegetation is non-native grasses and forbs.

15-09

This area is located at the bottom of the western slope, north of the E-W trail. It was cleared of Scot's broom in 2008. The western half of this management unit was treated with biosolids compost, planted in 2008, and replanted in 2010 and 2012. Survival was poor, but native shrub cover is now close to 25%, consisting of vine maple, oceanspray, red-flowering currant, snowberry and red elderberry (see Figure 19). With the exception of Oregon ash, attempts to establish native trees were unsuccessful. One Douglas-fir seedling is still alive. The eastern half of this unit was not treated with biosolids compost. It was planted in 2008, but not replanted. With the exception of one Douglas-fir seedling, no native plants survived.

Non-native vegetation is comprised of a wide variety of non-native species, mostly grasses and forbs, including some species not observed in other management units such as garden radish (*Raphinus sativa*) and prickly lettuce (*Lactuca serriola*). Scot's broom seedlings are common in the unmaintained eastern half of this management unit. The presence of a colony of Canada thistle is a particular concern. There also a butterfly bush (*Buddleia davidii*) at the eastern edge of this management unit.

Figure 26. Management unit 15-08 (left of the trail)-view from the north. Tree cover is <25% and consists of Douglas-fir and regenerating bitter cherry at the toe of the slope. This area has been cleared of Scot's broom and planted with native trees and shrubs during 2012.

Figure 27. Clonal colony of Canada thistle (purple flowers) in an area of restoration in 15-09.

15-10

15-10 covers an area in the southern half of the central pit, bounded to the east by the N-S trail, and to the south by the E-W trail. This area is characterized by a number of scattered trees, mostly mature Douglas-fir trees, but also red alder, black cottonwood and Pacific madrone. Total canopy cover is 25 to 50%. Trees often clump together. The soil is sandy loam to loamy sand, and moderately compacted in places.

This area was cleared of Scot's broom in 2012-2013 and planted with native trees and shrubs (Figure 28 and Figure 29). The presence of tansy ragwort is a particular concern in this management unit. Along with common sheep sorrel and St. John's wort, tansy ragwort seems to be spreading rapidly since the removal of the Scot's broom shrub layer.

Figure 28. The western half of 15-12 before clearing and planting in October 2012. Vegetation consists of Scot's broom with an understory of mostly grasses and hairy cat's ear.

Figure 29. The same area in July 2013. Tansy ragwort (tall yellow flowers) and St. John's wort (shorter yellow flowers) are thriving, along with common sheep sorrel (reddish tint)

15-11

This is a small, densely vegetated area along the E-W trail, sandwiched between 15-09 and 15-12 (Figure 30). The vegetation consists of a few small Douglas-fir trees, estimated to be between 8 and 15 years old, a red elderberry bush and a one-seed hawthorn tree, surrounded by vigorously growing Scot's broom seedlings with an understory of introduced grasses. Scot's broom seedlings in this area are as much as 10 feet tall, compared to about 3 feet in the adjacent area that was cleared at the same time. The soil is silt, with generally very little compaction, except for the southern end of this area, next to the trail, which is highly compacted.

At the southern end of this unit, next to the trail, there is a pile of organic matter covered in Canada thistle, Himalayan blackberry and grasses, about 10 feet by 10 feet in size. A 2009 satellite image suggests that this may be the remainder of the 2008 biosolids compost pile.

15-12

15-12 is located directly east of 15-11 and straddles the informal north-south trail. The soil in this management unit is mostly well-drained sandy loam to loamy sand, but is very variable. This area was also cleared of Scot's broom in 2008. The current vegetation consists mostly of sparse Scot's broom cover with an understory of introduced grasses and forbs.

The southwestern half of this management unit (west of the informal trail) was treated with biosolids compost, tilled and planted with native trees and shrubs in 2008, and replanted in 2010 and 2012. Survival was poor. As of April 2013 there were some surviving vine maple, Oregon ash, snowberry, red-flowering currant and red elderberry, but these plants do not seem to thriving (Figure 31). In addition, this plot has been invaded by Canada thistle and oxeye daisy along the western edge.

Figure 30. 15-11--island of vigorously growing trees and shrubs on fine-grained soils surrounded by predominantly grass and sparse Scot's broom seedlings.

Figure 31. Southwestern corner of 15-12 towards the end of summer 2012. Vegetation consists of introduced grasses and forbs, Scot's broom saplings and some very stressed vine maples.

15-13

This is the area of the pit with the most tree canopy cover--average cover in this unit is about 75%, ranging from 0 to100%. The dominant tree species is Douglas-fir, with subordinate black cottonwood and red alder. Where tree cover is dense, understory vegetation is absent to sparse, the only ground cover being moss (Figure 32). No regenerating trees were observed. Several trees have fallen down, especially towards the back of the site where the ground starts sloping, contributing to downed woody debris recruitment (Figure 33).

Along the trails, herb Robert often carpets the ground beneath Douglas-fir trees. Small English ivy infestations are also present in these areas (Figure 34).

Figure 32. Douglas-fir tree stand in 15-13. Understory cover is absent to sparse, the only ground cover being moss.

Figure 33. Fallen trees contributing to downed woody debris recruitment.

Where the canopy starts to open up, western sword fern commonly occurs along the drip line of Douglas-fir trees along with tall Oregon grape, cleavers and blackcap raspberry (see Figure 12; Figure 35). Indian plum seedlings are common, but most do not seem to survive past the seedling stage (Figure 36).

Before removal, Scot's broom was the dominant vegetation in canopy gaps. Most of the Scot's broom in this area was removed between 2011 and 2013, and currently Scot's broom cover consists mostly of a few regenerating seedlings. The dominant vegetation in canopy gaps is non-native grasses, with subordinate amounts of hairy cat's ear, sheep sorrel, narrow-leaf plantain, Himalayan blackberry and oxeye daisy. Native vegetation in canopy gaps consists of trailing blackberry.

Soils in this area typically consist of well-drained loamy sand. Minor soil compaction is present in the southeastern corner of this unit.

15-14

15-14 comprises the slope in the southwestern corner of the site. The slope is very exposed; minor canopy cover is provided by trees growing at the top of the slope, and a few scattered black cottonwoods and bitter cherry trees growing on the slope. The vegetation is dominated by Himalayan blackberry, and, along the lower slopes, Scot's broom. Apart from the few trees, the only native vegetation is scattered Indian plum and red elderberry bushes being overgrown by Himalayan blackberry (Figure 37).

Figure 34. Herb Robert and English ivy growing in the shade of Douglas-fir trees.

Figure 35. Tall Oregon grape seedling growing with cleavers and western sword fern at the Douglas-fir canopy drip line.

Figure 36. Indian plum seedlings growing along with sword ferns at the edge of the Douglas-fir tree canopy in 15-13.

15-15

15-15 covers the southwestern corner of the pit. This area is characterized by very loose, sandy soils. Compaction is rare, and there does not appear to be much fine-grained material mixed into the soil. Vegetation is sparse, likely because of the droughty soils. Scot's broom cover is about 30%, with an understory of introduced grasses and forbs. Scattered Douglas-fir, Pacific madrone, red alder and black cottonwood trees of various ages and sizes provide sparse canopy cover (Figure 38).

Scot's broom was cleared from the western part of this management unit during 2008. Two small areas in the center of this management unit were tilled, treated with biosolids compost, and planted in 2010. A few shrubs and trees remain. Restoration was also initiated along the eastern edge of this unit, adjacent to 15-13, in 2012-2013.

Figure 37. Indian plum and red elderberry in a sea of Himalayan blackberry along the slope in the southwestern corner of the site (15-14).

Figure 38. Scattered Douglas-fir trees surrounded by sparse Scot's broom cover in the southwestern corner of the borrow pit (15-15).

15-16

This management unit comprises the slopes in the southeast corner of the site. The native tree canopy consists predominantly of mature Douglas-fir, with subordinate black cottonwood, bigleaf maple and red alder. Himalayan blackberry comprises about 50% of the understory. Native understory species include trailing blackberry, Indian plum, red elderberry, sword fern, tall Oregon grape, salal and bracken fern.

There is a significant stand of yellow archangel present on both sides of the informal trail. The yellow archangel is growing with trailing blackberry and salal (Figure 39). It will be difficult to eradicate the yellow archangel without damaging these native plant species. Scot's broom and herb Robert are present in small amounts along trail edges.

As in 15-13, a number of fallen trees contribute downed woody debris. Soils are as in the adjacent management units, sandy loam to loamy sand with minor compaction.

Figure 39. Salal growing with yellow archangel (variegated leaves).

6 SITE CONSTRAINTS

Implementation options and restoration outcomes at this site are limited by a number of physical and social constraints:

- The Green Kirkland Partnership has very limited resources with which to support restoration efforts at the site.
- Because restoration is done under the umbrella of the Green Kirkland Partnership there is an emphasis on volunteer involvement. Since volunteers are not allowed to use mechanized equipment or herbicides, fewer restoration options are available.
- Removal of topsoil layers during excavation has resulted in soil that is poor in nutrients, organic matter and soil micro-organisms. This creates stressful growing conditions for plants. Plants do not grow as fast as they may in environments that are more productive, may be more susceptible to disease, and are more likely to succumb to drought.

Table I. A comparison of the main features of each management unit. MU=Management Unit

MU	Location	Vegetation summary	Size (acres)	Soil	Slope (%)	Slope length (feet)	Aspect	Exposure	Comments
15-01	Northern slope	Himalayan blackberry and Scot's broom.	1.12	Loamy sand; minor compaction along trails	~36	70-135	South	Full sun	Trail; 2011 Boy Scout restoration site
15-02	Eastern slope	50-75% deciduous and evergreen tree cover. Himalayan blackberry dominates canopy gaps.	0.47	Loamy sand	~36	30-40	West	Partial shade	Along I-405
15-03	Western slope	Himalayan blackberry; <25% native deciduous canopy cover.	0.52	Loamy sand; minor compaction along trails	22-36	55-100	East	Full sun-partial shade	Trail
15-04	NE corner of pit, west of N-S trail	Scot's broom with an understory of non-native grasses and forbs.	0.95	Loamy sand, very compacted	<5	-	South	Full sun	Trail
15-05	NE corner of pit, east of N-S trail	Bitter cherry with an understory of non-native grasses & forbs.	0.11	Loamy sand; minor compaction in places	<5	-	South	Shade – partial shade	Trail
15-06	NW corner of pit	Scot's broom with an understory of non-native grasses and forbs.	0.19	Loamy sand to sandy loam	<5	-	SE	Full sun	Cleared of Scot's broom 2008

Continued on next page

Table I continued. A comparison of the main features of each management unit. MU=Management Unit

MU	Location	Vegetation summary	Size (acres)	Soil	Slope (%)	Slope length (feet)	Aspect	Exposure	Comments
15-07	NW quadrant, east of 15-06	Scot's broom with an understory of non-native grasses and forbs	0.68	Compacted silt; poor drainage. Well-drained loamy sand in central portion	<5	-	SE	Full sun	Western half cleared of Scot's broom 2008; Informal trail
15-08	NE corner, south of 15-05	Non-native grasses and forbs; native tree & shrub seedlings	0.37	Loamy sand; very compacted	<5	-	S	Full sun	Cleared of Scot's broom, planted 2012; Trail
15-09	NW corner, adjacent to E-W trail	Non-native grasses and forbs; native tree & shrub seedlings	0.22	Loamy sand, minor compaction	<5	-	SE	Full sun	Cleared of Scot's broom, planted 2008; Trail
15-10	Center of pit, north of E-W trail	Non-native grasses and forbs; scattered native trees (cover ~25%)	0.82	Loamy sand, minor compaction	<5	-	SE	Mostly full sun; some shade	Cleared of Scot's broom, planted fall & spring 2012; Trail
15-11	NW quadrant, between 15-08 and 15-11	Scot's broom, non-native grasses & forbs, small Douglas-fir trees	0.09	Silt; compacted along trail.	<5	-	SE	Full sun	Cleared of Scot's broom 2008; Trail

Continued on next page

Table I continued. A comparison of the main features of each management unit. MU=Management Unit

MU	Location	Vegetation summary	Size (acres)	Soil	Slope (%)	Slope length (feet)	Aspect	Exposure	Comments
15-12	Central area of pit, east of 15-11	Sparse Scot's broom with an understory of non-native grasses and forbs	0.33	Variable, mostly well-drained loamy sand to sandy loam	<5	-	SE	Full sun	Cleared of Scot's broom; part planted 2008-09; Informal trail
15-13	SE corner of pit	Douglas-fir canopy, native understory; non-native grasses & forbs in canopy gaps	1.06	Loose, very well-drained sand to loamy sand	<5	-	SE	Full shade to full sun	Cleared of Scot's broom; planted 2012-13; Trail
15-14	Slope in the SW corner	Himalayan blackberry; Scot's broom towards the bottom of the slope	1.32	Loamy sand to sandy loam, minor compaction	~36	90-110	N & E	Full sun	
15-15	SW corner of pit	Sparse Scot's broom with understory of non-native grasses and forbs. Scattered native trees and shrubs.	1.05	Loose, excessively well-drained sand to loamy sand	<5	-	E	Full sun	Partially cleared of Scot's broom, planted 2008, 2013; Trail
15-16	Slope in SE corner	Douglas-fir canopy with mostly native understory	0.62	Loamy sand, minor compaction	~36	40-90	N & W	Full to partial shade	Informal trail

Table II. Comparison of the vegetative characteristics of each management unit. MU=Management Unit. Dominant species = bold; * = installed plants. Height=Average height; DBH=diameter at breast height; n.r. not recorded

MU	Trees				Shrubs		Graminoids & Forbs	
15-01	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	5-25	n.r.	6-30”	Total native	<5	Total native	<5
	Black cottonwood, red alder, cascara*, Sitka spruce*				Trailing blackberry, red elderberry, western sword fern*, red-osier dogwood*			
	Total non-native	<5	-	-	Total non-native	95-100	Total non-native	<5-25
					Himalayan blackberry, Scot’s broom, evergreen blackberry		Grasses, Canada thistle, bull thistle, moth mullein, nipplewort	
MU	**Trees**				**Shrubs**		**Graminoids & Forbs**	
15-02	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	50-75	n.r.	n.r.	Total native	<5	Total native	<5
	Bitter cherry, black cottonwood, Douglas-fir, red alder (Pacific madrone, western redcedar and Douglas-fir along top of slope).							
	Total non-native	<5	n.r.	<5”	Total non-native	75-95	Total non-native	<5
	One-seed hawthorn				**Himalayan blackberry**, Scot’s broom		Grasses	
MU	**Trees**				**Shrubs**		**Graminoids & Forbs**	
15-03	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	5-25	n.r.	<5-90”	Total native	<5	Total native	<5
	Black cottonwood, red alder, bitter cherry, bigleaf maple, Douglas-fir				Indian plum, red elderberry, tall Oregon grape		Western sword fern	
	Total non-native	<5	-	-	Total non-native	95-100	Total non-native	<5
					Himalayan blackberry, evergreen blackberry, Scot’s broom		Grasses	

Table II cont. Comparison of the vegetative characteristics of each management unit. MU=Management Unit. Dominant species = bold; * = installed plants. Height=Average height; DBH= diameter at breast height; n.r. not recorded

MU	Trees				Shrubs		Graminoids & Forbs	
15-04	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	<5	n.r.	<5-30"	Total native	<5	Total native	<5
	Douglas-fir, western white pine, black cottonwood, Pacific madrone, Western white pine				Pacific crabapple, snowbrush			
	Total non-native	<5	n.r.	<5"	Total non-native	50-75	Total non-native	25-50
	One-seed hawthorn				**Scot's broom**, Himalayan blackberry		**Grasses**, hairy cat's ear, St. John's wort, tansy ragwort, sheep sorrel, narrowleaf plantain, bull thistle, moth mullein	
MU	**Trees**				**Shrubs**		**Graminoids & Forbs**	
15-05	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	>50-75	n.r.	<5"	Total native	<5	Total native	<5
	Bitter cherry, Douglas-fir				-		-	
	Total non-native	<5	-	-	Total non-native	<5	Total non-native	50-75
					Himalayan blackberry		**Grasses**	
MU	**Trees**				**Shrubs**		**Graminoids & Forbs**	
15-06	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	<5	-	-	Total native	<5	Total native	<5
							Hooded ladies' tresses	
	Total non-native	<5	-	-	Total non-native	25-50	Total non-native	75-95
					Scot's broom, Himalayan blackberry		**Grasses**, hairy cat's ear, tansy ragwort, narrowleaf plantain, sheep sorrel, bull thistle	

Table II continued. Comparison of the vegetative characteristics of each management unit. MU=Management Unit. Dominant species = bold; * = installed plants. Height=Average height; DBH= diameter at breast height; n.r. not recorded

MU	Trees				Shrubs		Graminoids & Forbs	
15-07	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	<5	-	-	Total native	<5	Total native	<5
	-				-		Hooded ladies' tresses	
	Total non-native	<5	-	<5"	Total non-native	50-75	Total non-native	75-95
	One-seed hawthorn				**Scot's broom**, Himalayan blackberry		**Grasses**, hairy cat's ear, tansy ragwort, narrowleaf plantain, sheep sorrel, bull thistle	
MU	**Trees**				**Shrubs**		**Graminoids & Forbs**	
15-08	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	5-25	n.r.	<5"	Total native	<5	Total native	<5
	Douglas-fir, bitter cherry, Douglas-fir*, shore pine*, grand fir*				Vine maple*, red-flowering currant*, thimbleberry*, oceanspray*, snowberry*		-	
	Total non-native	<5	-	-	Total non-native	5-25	Total non-native	95-100
					Scot's broom, Himalayan blackberry		**Grasses, sheep sorrel**, narrowleaf plantain, hairy cat's ear	

Table II continued. Comparison of the vegetative characteristics of each management unit. MU=Management Unit. Dominant species = bold; * = installed plants. Height=Average height; DBH= diameter at breast height; n.r. not recorded

MU	Trees				Shrubs		Graminoids & Forbs	
15-09	**Species**	**% cover**	**Height**	**DBH**	**Species**	**Cover**	**Species**	**Cover**
	Total native	<5		<5”	Total native	5-25	Total native	<5
	Black cottonwood, Oregon ash*, Douglas-fir*				Red elderberry*, snowberry*, red-flowering currant*, vine maple*, oceanspray*			
	Total non-native	<5			Total non-native	<5	Total non-native	95-100
					Scot’s broom, Himalayan blackberry, butterfly bush		**Grasses**, **hairy cat’s ear**, Canada thistle, sheep sorrel, oxeye daisy, tansy ragwort, narrowleaf plantain, wall lettuce, garden radish	
MU	**Trees**				**Shrubs**		**Graminoids & Forbs**	
15-10	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	25-50	n.r.	20-30”	Total native	<5	Total native	<5%
	Douglas-fir, Pacific madrone, black cottonwood, red alder, Douglas-fir*, Garry oak*, shore pine*, grand fir*				Tall Oregon grape, red-flowering currant*, oceanspray*, snowberry*			
	Total non-native	<5	n.r.	<5”	Total non-native	<5	Total non-native	75-95
	One-seed hawthorn				Scot’s broom		**Grasses, sheep sorrel, tansy ragwort**, St. John’s wort, hairy cat’s ear, narrowleaf plantain	

Table II continued. Comparison of the vegetative characteristics of each management unit. MU=Management Unit. Dominant species = bold; * = installed plants. Height=Average height; DBH= diameter at breast height; n.r. not recorded

MU	Trees				Shrubs		Graminoids & Forbs	
15-11	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	5-25	n.r.	8-18”	Total native	<5	Total native	<5
	Douglas-fir				Red elderberry		-	
	Total non-native	<5	-	<5”	Total non-native	75-95	Total non-native	50%
	One-seed hawthorn				**Scot’s broom**, Himalayan blackberry		Grasses, Canada thistle, hairy cat’s ear, sheep’s sorrel, narrowleaf plantain, moth mullein	
MU	**Trees**				**Shrubs**		**Graminoids & Forbs**	
15-12	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	<5	n.r.	<5”	Total native	<5	Total native	<5
	Oregon ash*				Vine maple*, red elderberry*, snowberry*, red-flowering currant*		Hooded ladies’ tresses	
	Total non-native	<5	-	-	Total non-native	25-50	Total non-native	75-95
					Scot’s broom		**Grasses**, hairy cat’s ear, sheep sorrel, bull thistle, moth mullein, tansy ragwort, narrowleaf plantain, Canada thistle, oxeye daisy	

Table II continued. Comparison of the vegetative characteristics of each management unit. MU=Management Unit. Dominant species = bold; * = installed plants. Height=Average height; DBH= diameter at breast height; n.r. not recorded

MU	Trees				Shrubs		Graminoids & Forbs	
15-13	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	75	~45’	13-35’’	Total native	<10	Total native	<10
	Douglas-fir, black cottonwood, red alder				Trailing blackberry, tall Oregon grape, blackcap raspberry		Western sword fern, cleavers	
	Total non-native	<5	-	-	Total non-native	<5%	Total non-native	25%
	-				Scot’s broom, Himalayan blackberry		**Grasses**, hairy cat’s ear, sheep’s sorrel, narrowleaf plantain, ivy, herb Robert, oxeye daisy	
MU	**Trees**				**Shrubs**		**Graminoids & Forbs**	
15-14	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	5-25	n.r.	n.r.	Total native	<5	Total native	<5
	Black cottonwood, bitter cherry (red alder, bigleaf maple, Douglas-fir, Pacific madrone and western redcedar at top of slope)				Indian plum, red elderberry		-	
	Total non-native	0-5	n.r.	<5”	Total non-native	95-100	Total non-native	<5
	One-seed hawthorn				**Himalayan blackberry, Scot’s broom**		Grasses, hairy cat’s ear, sheep’s sorrel, narrowleaf plantain	

Table II continued. Comparison of the vegetative characteristics of each management unit. MU=Management Unit. Dominant species = bold; * = installed plants. Height=Average height; DBH= diameter at breast height; n.r. not recorded

MU	Trees				Shrubs		Graminoids & Forbs	
15-15	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	5-25	n.r.	6-15”	Total native	<5	Total native	<5
	Douglas-fir, black cottonwood, Pacific madrone, red alder, Oregon ash*, Douglas-fir*, shore pine*, western white pine*, Garry oak*				Snowbrush, red-flowering currant*, oceanspray*, snowberry*, salmonberry*		-	
	Total non-native	<5	-	-	Total non-native	25-50	Total non-native	75-95
					Scot’s broom, Himalayan blackberry		**Grasses, hairy cat’s ear, sheep’s sorrel**, narrowleaf plantain	
MU	**Trees**				**Shrubs**		**Graminoids & Forbs**	
15-16	**Species**	**% cover**	**Height**	**DBH**	**Species**	**% cover**	**Species**	**% cover**
	Total native	50-75	n.r.	13-35”	Total native	25-50	Total native	5-25
	Douglas-fir, black cottonwood, bigleaf maple, bitter cherry				**Trailing blackberry**, red elderberry, Indian plum, tall Oregon grape		Salal, western sword fern, bracken fern, cleavers	
	Total non-native	<5	n.r.	<5”	Total non-native	5-25	Total non-native	5-25
	One-seed hawthorn				**Himalayan blackberry**, Scot’s broom		**Yellow archangel**, herb Robert	

- Soils have been compacted in some areas, hampering root penetration, drainage and aeration.
- Because there are so many invasive species growing at the site, it is difficult to establish native plant species.
- There is continued disturbance at the site. Its location in such close proximity to the freeway results in, among other things, increased exposure to pollutants via air emissions and roadway runoff, changes in airflow and hydrology, and an increased vulnerability to invasion by non-native species (Southerland 1994).

  Trail users, many of them with off-leash dogs, create further disturbance. There have also been instances of vandalism with installed plants being uprooted.
- Vehicle access to the site is limited.
- There is no ready source of water at the site.
- Deer and rabbits frequenting the site are likely causing browse-damage to installed vegetation.

7 RESTORATION APPROACH

The likelihood of autogenic recovery at this site is low. It has been more than 40 years since the cessation of mining activities, and the vegetation is dominated by non-native, invasive species. However, some regeneration of native plant species is occurring: Seedlings of Indian plum, red elderberry, Pacific madrone and even Douglas-fir were observed on the site, but few survive, partly due to competition from non-native vegetation, and partly due to physical site conditions. Where there is some canopy cover, native understory plants such as tall Oregon grape and western sword fern are present. Indian plum and red elderberry shrubs persist along slopes, despite competition from Himalayan blackberry, suggesting that growing conditions along the slopes are less limiting.

Based on these observations, the basic restoration approach will be to:

- Create more favorable growing conditions for native plants, both by ameliorating physical site conditions and by reducing competition from invasive plant species
- Introduce native plant species better adapted to the site conditions

Considering the challenges to restoration at the site, the predicted level of repair is medium to low. Because of the degraded site conditions, it will take many years to establish native trees

and shrubs, especially considering the limited resources available. Invasive pressure will remain high and due to its location in an urban environment, the site will be exposed to continued disturbance. Restoration of this site will require a high degree of commitment from project leaders.

7.1 Site modification

Site modification includes recontouring the site, releasing native plants from competition from invasive species, treatments such as soil amendments and mulches, irrigation, and even establishing vegetation to act as nurse plants for other species. The following options were considered for this project site:

7.1.1 Restoring landforms

Nowadays recontouring of surface mine sites is a prescribed component of reclamation. This is done to create gentler and more varied slope forms. Reducing slope angles and creating concave slopes provide slope stability and minimize run-off and erosion. More complex, irregular slopes support the establishment and growth of a more diverse plant community, and provide more aesthetically pleasing landforms that blend in with surrounding landscapes (Norman et al. 1997; Badia et al. 2007). However, the slopes at the project site appear to be relatively stable, and able to support vegetation, and since earthwork is very costly, recontouring is not considered a feasible option for this site.

7.1.2 Invasive plant control

More than thirty introduced plant species have been recorded on site. Most of these have been designated as noxious weeds in King County and/or Washington State. This means that they have been listed as non-native plants that, once established, are difficult to control and have economic, ecological or health impacts (King County 2013). While control of most the noxious weed species present at Watershed Park is not required by these agencies, it is recommended. The exception is tansy ragwort—King County requires landowners to control this species.

At Watershed Park, we are concerned primarily with the ecological impacts of invasive plant species. These plants prevent the natural recruitment of native plants and outcompete native plants already on site. They do this through competition for light, water and nutrients, and by changing the soil chemistry and biology, making the growing environment less favorable for native plant species. The presence of invasive species at the project site also pose a risk to

natural areas in the rest of the park, as propagules such as seeds are dispersed by wind, birds, animals and people.

General approach

The complete eradication of all invasive species at the project site is not a realistic goal. The degree of degradation of the site, the large seed bank of undesirable species, and continued disturbance in the urban environment, will always make this site prone to invasion. However, most of the problem species need full sun to thrive. Over time, as native plants, especially trees and large shrubs, become established and create shade, there should be less need for intervention. The objective of managing introduced vegetation at the project site is twofold:

- suppress competing non-native vegetation, thereby creating conditions for native plants to become established and grow
- prevent future problems by removing populations of shade-tolerant invasive species while still relatively small and easy to control.

For each invasive species there are a number of possible control methods available. Each of these methods has advantages and disadvantages. Often a combination of techniques is used to control invasive species, or different techniques may be used at different areas of the site. Some general considerations are:

- Manual or mechanical methods that require digging up the roots of plants involve a significant amount of soil disturbance. In sloped areas, this increases the risk of erosion. Soil disturbance also stimulates the germination of seeds in the soil—at this site, mostly seeds of undesirable species.
- Herbicide application is a very effective and less labor-intensive method of controlling some plants species. This method also minimizes soil disturbance. However, because of environmental concerns, and because it cannot be applied by volunteers, the Green Kirkland Partnership considers this a method of last resort. Herbicide drift to non-target plants can also damage native plants.
- Mowing can be used to slow down the spread of some species, or as a first step prior to manual removal or herbicide application. However, mowing will also damage native plants that may be concealed underneath the targeted vegetation. Mowing is not a suitable approach for steep areas--it is not safe, and increases the risk of erosion on susceptible soils.
- Goats can be used instead of mowing equipment, especially where the terrain is difficult. However, goats are also non-selective and will graze on native plants as well as

introduced species. Not all areas are suitable for goats, as plants such as tansy ragwort and St. John's wort may sicken the animals (Rent a Ruminant 2013)

- For smaller infestations, aboveground biomass can be removed using loppers or pruning saws. Power equipment is a more effective option, but such tools may only be operated by City of Kirkland Parks and Community Services staff or contracted crews.

Regardless of which treatment is selected, treated areas will need to be monitored for vegetative regrowth and newly germinated seedlings for several years. Repeated treatments are likely to be necessary. Applying a layer of mulch to cleared areas will help suppress seed germination.

Removal of one invasive species may also facilitate invasion by another species. At Watershed Park the removal of Scot's broom has resulted in vigorous growth of introduced grasses and forbs, tansy ragwort and sheep sorrel in particular. Mulching and planting restoration sites soon after invasive plant removal should be a priority, as should continued maintenance.

Management of some species may be considered more of a priority than other species, and this also affects choice of control method. Invasive species at the project site were prioritized for control, based on the threat they present to restoration success at the site, to the health of surrounding forests, and on the likelihood of successful control:

- Canada thistle infestations at the site are still relatively small (Figure 16). This is a very difficult weed to kill. Eradicating this weed from the site while it is still possible should be a priority.
- Populations of shade-tolerant invasive species, namely ivy, yellow archangel and herb Robert are present in the southeast corner of the site. Populations of these weeds are small at this stage and should be relatively easy to control, but could become more of a problem at later stages of restoration.
- Control of Himalayan and evergreen blackberry is a priority because it is spreading to the rest of the park, and because its dominance on the slopes of the pit precludes the establishment of any other species. Management of introduced blackberry species has also been studied extensively--there are a number of control strategies to choose from and, with patience and persistence, the likelihood of successful management is high.
- Scot's broom has not spread to the rest of the park, but removal is a priority because it dominates so much of the landscape at the site--because of its large stature, it effectively precludes establishment of native species. Removal requires persistence, but it is relatively easy to eliminate by manual or mechanical methods.
- Tansy ragwort is a priority because control is required by King County.

- Most of the other non-native species will only be removed from the area directly around native plants to minimize competition for resources.

Recommendations for control strategies for specific species are discussed in the following section.

Control strategies for specific species

A detailed description of each invasive species is beyond the scope of this document. This discussion will be limited primarily to control methods. More information on these plants is available at the websites of the Washington State and King County Noxious Weed Control Boards http://www.kingcounty.gov/environment/animalsAndPlants/noxious-weeds/program-information.aspx and http://www.nwcb.wa.gov/nwcb_nox.htm).

Canada thistle

Canada thistle is a perennial herb that reproduces both by seed and vegetatively. Due to its extensive weed system, this is a particularly difficult weed to control once it is established—roots may grow to a depth of 6 to 15 feet, and spread over 15 feet horizontally. While seedlings can be easily removed, removing established plants by hand pulling or digging is not feasible due to the extensive root system. Small root fragments left behind can grow into new plants (King County Noxious Weed Management Program 2006a; Washington State Noxious Weed Control Board 2010a). A combination of approaches is recommended:

- Cut the plants down to the ground once they have formed buds and have the least reserves (usually by early June). Keep on cutting the new growth once buds appear again. This will weaken the roots over time (King County Noxious Weed Management Program 2007). Bag and remove cut plants from the site.

  This task will need to be repeated several times during the growing season—plants at the project site that were cut down at the beginning of June, were in bud again by the beginning of July.

- Herbicides, applied during the growing season, at or after the bud stage, are also effective, but avoid spraying drought-stressed plants. Cutting back Canada thistle plants a few weeks before application improves effectiveness--herbicide is more effective when applied to plants when roots have been weakened by previous treatments. (King County Noxious Weed Management Program 2006a; Washington State Noxious Weed Control Board 2010a).

Canada thistle does not tolerate shade and competitive plants, such as grasses, can help to control vegetative spread (King County Noxious Weed Management Program 2006a; Washington State Noxious Weed Control Board 2010a).

Herb Robert

Small infestations of herb Robert can be removed by hand. Pull from the base of the plant to prevent breakage of the brittle stems. Herb Robert reproduces entirely by seed. To avoid spreading seeds to other areas of the site, do not put the removed plants on compost piles; bag and remove from the site (King County Noxious Weed Control Program 2007a; 2009a). Apply a layer of mulch, 3 to 4 inches thick to prevent seed germination.

English/Atlantic Ivy

The small patches of ground-growing ivy can be removed any time of the year by loosening the soil with a shovel and pulling by hand. The removed plants can be disposed of by placing on top of the compost pile. Avoid contact with soil to prevent rooting (King County Noxious Weed Control Program 2004; 2009b).

Yellow archangel

Yellow archangel has a shallow root system. It can be removed manually when the soil is moist by digging and/or hand pulling. However, as this plant has the ability to sprout from very small stem and root fragments, care must be taken to remove all plant parts (King County Noxious Weed Control Board 2013b). For the same reason, yellow archangel should not be disposed of on compost piles.

Herbicide and sheet mulching are alternative approaches (King County Noxious Weed Control Board 2013b), but, since the yellow archangel is growing with salal and trailing blackberry at the project site, these options should only be considered if manual removal proves to be ineffective.

Himalayan and evergreen blackberry

Himalayan and evergreen blackberry are sprawling, fast-growing shrubs, capable of forming monocultures over large areas. It is generally found in open areas; growth is less vigorous in the shade. These plants spread by both seed and vegetatively (King County Weed Control Program 2010).

An estimated 3.4 acres of the site is covered by virtually impenetrable blackberry thickets, predominantly along the pit slopes. Smaller, isolated populations, occur in the pit itself in areas

where resource availability is higher, e.g. in areas where soil moisture is higher, and on old compost piles. A combination of approaches, listed in order of priority, is suggested:

- Smaller infestations in the pit itself can be removed by cutting the canes with loppers or pruners, followed by digging up the root-ball (King County Weed Control Program 2010). Removal of these infestations is a relatively easy task, and should be a priority to prevent further establishment of Himalayan blackberry in the pit area.
- Red elderberry and Indian plum along the slopes are encroached upon or overtopped by Himalayan blackberry. Indian plum commonly spread by root suckering (Gonzalves & Darris 2009). Release from competition will ensure the survival of these shrubs and, in the case of Indian plum, encourage spreading. Locate these plants and clear a six-foot radius around each tree or shrub. This can be done by cutting all canes to the ground two or more times per year, or by removing blackberry plants by digging up. If plants are dug up, apply a layer of wood-chip mulch, up to 6 inches, to the cleared area.
- Larger-scale removal of blackberry thickets will be more challenging. Where slopes are gentle, blackberry bushes can be removed by a combination of cutting and digging as described above, followed by mulch application. 1 acre can be cleared in 300 to 1,000 hours, depending on conditions and crew capabilities (Bennet 2006) and years of follow-up clearing will be necessary.
- Along steeper slopes, the need to minimize soil disturbance becomes more of a priority, both because of the increased risk of erosion, and because applying wood-chip mulch in these areas will be a problem. For these areas, mowing or cutting combined with herbicide treatment (Glyphosate or Triclopyr) is likely to be the most effective approach. After cutting, let the plants regrow to 18 inches and then apply herbicide. Herbicide applications are most effective when plants are not drought-stressed, and after they have been leafed out. September through early November is a good time because herbicide can be translocated to the roots more effectively. Early season application when the sap is rising is less effective because poor translocation leads to top killing only (Bennet 2006).

  Dabbing herbicide on the cut stump immediately after cutting is also an effective approach, and results in less herbicide use. However, it is more labor-intensive.

Blackberry thickets provide cover, nesting areas and food for a variety of smaller wildlife and bird species. If possible, refrain from large-scale blackberry removal during the bird-nesting season, generally about mid-March to the end of June (Bennet 2006).

Removed plants can be added to compost piles, but avoid contact with soil. Compost piles need to be monitored for blackberry regrowth.

Scot's broom

Approximately 3.7 acres of land still needs to be cleared of Scot's broom; 1.6 acres have already been cleared. Scot's broom is a fast-growing, long-lived perennial shrub; plants may live for up to 20 years. Reproduction occurs by seed. Seeds pods dehisce explosively during late summer, propelling seeds up to 20 feet away. Seed production is prolific and seeds are long-lived, remaining viable in the soil for up to 30 years. Scot's broom is generally found in open areas, but can tolerate significant amounts of shade (Graves et al. 2010, King County Noxious Weed Program 2008).

Scot's broom is a nitrogen-fixing species. Several studies have reported higher concentrations of nitrogen and carbon in soils under Scot's broom, and higher plant available nitrogen (Haubensak et al. 2004; Haubensak & Parker 2004; Caldwell 2006), but results have been highly site specific. Phosphorus deficiencies and drought stress may limit fixation.

However, beneficial nitrogen-fertilization effects on the growth of other species may be outweighed by allelopathic effects. Scot's broom leaves and stems contain high concentrations of sparteine, a N-based quinolizidine alkaloid, that appears to inhibit the growth of certain other species (Haubensak et al. 2004; Haubensak & Parker 2004; Grove et al. 2012). Parker and Haubensak (2011, cited by Grove et al. 2012) reported high mortalities of Douglas-fir trees in clear-cuts previously invaded by Scot's broom. A more recent study by Grove et al. (2012) found that growth of Douglas-fir in soils previously invaded by Scot's broom was suppressed both as a result of direct allelopathic effects, and because of suppression of ectomycorrhizal fungi. Results from limited greenhouse trials involving Douglas-fir seedlings grown in soils from the project site, did not seem to indicate this was a major factor in establishing Douglas-fir trees at the Watershed Park borrow pit (Appendix I).

Mature Scot's broom plants can be cut down using loppers or a pruning saw. Very little resprouting occurs, especially when plants are drought-stressed—at the project site regrowth was estimated to occur in less than 5% of cases. Younger plants are likely to resprout and can be pulled up by hand or, in the case of older seedlings, a weed wrench can be used (Oneto et al. 2010; Graves et al. 2010). Removed vegetation can be disposed of on compost piles.

Tansy ragwort

Tansy ragwort is typically a biennial plant. It reproduces by seed, but can also establish from root fragments. Tansy ragwort spends the first growing season in the vegetative stage, becoming

reproductively mature in the second growing season. This plant is a prolific seed producer; seeds are wind-dispersed and can remain viable in the soil for up to 10 years (King County Noxious Weed Control Program 2006b).

Tansy ragwort grows in full sun, but can also tolerate semi-shade. Grasses establish competition and help prevent tansy ragwort seed emergence. Isolated plants or small infestations can be removed by hand-pulling or digging plants up. Dispose of plants by bagging and removing (King County Noxious Weed Control Program 2006b).

For larger infestations, herbicide control is recommended. Rosettes should be sprayed in the spring or to new growth in the fall. Systemic products that are effective include glyphosate, dicamba, 2,4-D or triclopyr (King County Noxious Weed Control Program 2006b).

Other forbs & grasses

A number of species are not considered priorities for wide scale removal. All of these plants are of smaller stature, less likely to overtop installed plants, and are generally not shade tolerant. Control of these species is not a priority for management, but they do compete with native plant seedlings for water, nutrients and light. Most of these plants do respond to herbicide (Peachy 2013), but are so widespread that this is not currently considered an option at this site. These species include, but are not limited to:

- St. John's wort is a perennial herb that spreads both by seed, and by above- and underground stems. Seeds remain viable in the soil for up to 10 years. This is a difficult plant to eradicate because of its extensive root system and long-lived seeds. Sticky seed capsules adhere clothes and animal fur or are dispersed short distances by wind. Repeated pulling, digging or herbicide application is required for successful control St. John's weed (Washington State Noxious Weed Control Board 2010b).
- Hairy cat's ear is a perennial herbaceous plant, listed as a noxious weed in the state of Washington (Washington State Noxious Weed Control Board 2010c). Its deep taproot allows it to draw considerable amounts of water, giving it a competitive edge in dry areas. It may also release allelopathic chemicals that suppress the growth of other plant species (GOERT 2005). It spreads via seed and vegetative reproduction. According to some sources, it will not resprout from root fragments that do not contain a section of the crown, which extends to about an inch below the ground (Turkington & Aarsen 1983); according to others all root sections left behind has the potential to resprout (Washington State Noxious Weed Control Board 2010c). If the entire root system is removed, it will not grow back (GOERT 2005).

- Sheep's sorrel is an herbaceous perennial commonly found in open disturbed areas. It is not listed as a noxious weed in Washington or King County, but is considered invasive (LaForest & Tillery 2013). It spreads rapidly, both from seed and vegetatively. The roots can grow to depths of 5 ft. making it difficult to control by manual or mechanical techniques. Repeated manual removal of aboveground biomass and as much of the root as possible, has been found to be effective at reducing abundance. Removing only aboveground biomass leads appears to stimulate shoot growth, resulting in increased cover (Frey et al. 2008). Sheep's sorrel prefers sunny exposures, but can persist in forested areas (LaForest & Tillery 2013).
- Narrowleaf plantain is an herbaceous perennial generally found in grasslands and open disturbed areas (CABI 2013), and a very common component of the vegetation at the project site. It is not listed as a noxious weed in Washington or King County, but is considered invasive in many parts of the world. This plant requires light at ground level to thrive (van der Aart & Vulto 1992), and can be expected to disappear as shrubs and trees are established.
- Bull thistle spreads entirely by seed. Isolated occurrences of bull thistle occur throughout the site. Remove by digging up with a shovel when encountered. Removing the top 1 to 2 inches of root is usually sufficient to kill bull thistle (King County Noxious Weed Control Program 2013c).
- Oxeye daisy is a perennial herbaceous plant that can spread both vegetatively and by seed. It is a prolific seed producer and seed can remain viable in the soil for several years. Because of its shallow root system, oxeye daisy can easily be removed by hand. Roots fragments left behind in the soil will resprout. Repeated removals are likely to be necessary (Mangold et al. 2009, Washington State Noxious Weed Control Program 2010d).
- Introduced grasses are very effective competitors for resources and difficult to control, but do help to check the spread of invasive forbs.

The current approach at the project site is to hand weed these plants from the area immediately surrounding installed native plants. A ring of wood chips is installed around each plant to suppress resprouting and emergence of seedlings.

An alternative approach is to install a layer of wood chips 8 to 12 inches thick (Cahill et al. 2005), or cardboard with wood chips on top, over the entire area to be planted. Leave the mulch through fall and winter. In the spring the mulch can be pushed aside to allow installation of native plants.

Other shrubs and trees

Several scattered one-seed hawthorn trees occur on site (Figure 40), as well as a single butterfly bush in 15-09 (Figure 41).

- Butterfly bush is a deciduous shrub about 15 ft. tall that spreads by seed. Buried or broken-off branches can root. Seedlings can be hand-pulled. Larger bushes can be dug up, but trunks tend to be brittle and may break off and resprout. An alternative approach is to cut the plant off at the base and apply concentrated glyphosate or triclopyr to the freshly cut surface (King County Noxious Weed Control Program 2009c). Woody material can be discarded on the compost pile, provided they are not in contact with bare soil. Bag and remove seed heads and dispose of off-site.
- One-seed or common hawthorn is a small thorny, deciduous shrub or tree. In its native range, it is a forest understory species, and is likely to persist on this site after revegetation. One-seed hawthorn reproduces by seed; seeds are dispersed when birds and animals eat the berries. Seedlings and young saplings can be hand-pulled when the soil is moist. Larger trees can be removed by cutting and applying concentrated herbicide to the freshly cut stump. Cutting on its own is not an effective method of removal, since cut stumps will resprout (King County Noxious Weed Control Program 2012, Newton et al. 2013). Removed plant material can be disposed of on the compost pile.

Figure 40. Deer browsing one-seed hawthorn in 15-10.

Figure 41. Butterfly bush in 15-09.

7.1.3 Treatments

Current legislation requires that topsoil and overburden removed during surface mining be preserved for use during reclamation (Norman et al. 1997). Many consider this an essential step to successfully revegetating degraded mine sites (Ghose 2001; Alday et al. 2011). However, historically this was not the case. There are many sites, like the Watershed Park borrow pit, where the topsoil was removed, and the degraded land simply abandoned when mining operations ceased. Although there has been some topsoil development over the past 40 years, this layer is often very thin. As a result, the soil at the site is deficient in nutrients and organic matter, probably does not host a very diverse community of microorganisms, and has poor structure. The loose sandy soils are excessively well-drained, creating droughty conditions during the summer months. Where the soil is too compacted, it hampers penetration by plant roots, aeration and drainage, again leading to poor growing conditions. This makes it challenging to establish plant growth. A number of treatments were considered to ameliorate these conditions:

Importing topsoil

Importing topsoil seems like an obvious solution, but there is a limited supply of topsoil, it is prohibitively expensive, and often contaminated with seeds and other propagules of undesirable species (Bradshaw 1997; Daynes et al. 2010; Ballesteros et al. 2012).

Fertilizer and soil amendments

Mine spoil and substrata are often treated with mineral fertilizers, or amended by incorporating compost or other forms of organic material into the soil. Amending with organic material adds nutrients and organic carbon, and improves soil aggregation, water-holding capacity and biological function (Bradshaw 1997; Daynes et al. 2010; Curtis & Claassen 2009). Where conditions are droughty, these treatments are commonly combined with various surface treatments, irrigation or applications of polyacrylamide hydrogel to retain or increase soil moisture.

However, a number of recent publications have noted that the effect of these treatments on survival rates of woody species on harsh, degraded sites where water is the limiting factor, is unpredictable, species- and site-specific, and complicated by competition from herbaceous species (Snyman 2000; Clemente et al. 2004; Oliveira et al. 2011; Williamson et al. 2011; Soliveres et al. 2012, Fehmi and Kong 2012). Most notably:

- An increase in growth does not necessarily translate into better survival (Walker 2002; Soliveres et al. 2012)

- Improved nutrient status of the soil may result in increased vegetative cover, but do not necessarily promote the establishment of desirable species (Paschke et al. 2005). The effect of competition from herbaceous species at such sites may have more of an inhibitory effect on woody plant survival than poor nutrient status and droughty conditions (Clemente et al. 2004; Oliveira et al. 2011).

Furthermore, compost is usually incorporated into the soil by tilling, stimulating the germination of seeds in the soil. This practice also contributes to the proliferation of weedy species.

Surface treatments

Arborist wood chip mulch is commonly used on restoration sites in the Pacific Northwest as a surface treatment because it suppresses germination of weed seeds, reduces evaporation, increases infiltration, protects the soil from erosive forces such as raindrops, reduces surface run-off, and in the longer run adds organic matter, and to a lesser extent, some nutrients. It is also commonly available and usually free of charge.

A ring of mulch, 3- to 4-inches thick, is applied around each plant. The ring should be at least as wide as the roots, but not touching the stem of the plant. This equates to about two 5-gallon buckets of mulch (Green Kirkland Partnership 2012). An alternative approach is to cover the entire site with a layer of mulch and then push aside the mulch to install plants (Cahill et al. 2005).

There are instances where surface mulches may be a disadvantage, such as when rainfall is light. In such a case the rainfall may be captured by the mulch and evaporate before it reaches the soil (Bainbridge 2001). However, in most cases the benefits outweigh the disadvantages (Ballesteros et al. 2012; Fehmi and Kong 2012).

A number of other materials such as straw, sometimes adhered to the soil with a tackifier, or commercially available products will perform some or all of the same functions, and there are situations when it may be more appropriate to use these. For example, it is difficult to apply wood chips to sloped areas, and the mulch may not stay on the slopes for very long. In such cases erosion-control blankets made of coconut fiber, straw, woodstraw, wood shavings, jute or similar materials can be an alternative. However, these treatments are more costly and additional site preparation may be required.

Compost can also be used as a surface treatment, instead of being incorporated into the soil, retaining much of the benefits of compost addition, but avoiding the negative effects of tilling. Compost may be contaminated by seeds of invasive species, and seeds of invasive species on site may fall on the compost and germinate. Covering the compost with wood chip mulch will help

reduce weed seed germination. This approach has not yet been tried at the project site and may be worth considering.

Addition of mycorrhizal inoculant

The addition of commercially available mycorrhizal inoculant mixes appears to have little effect at restoration sites, probably because plants are already inoculated by spores present in the nursery soil, or because the inoculant mix is not appropriate for the site conditions or specific plant species (Clemente et al. 2004; Oliveira et al. 2011; Minnick & Alward 2012).

Hydrogel

The benefits of adding of polyacrylimide hydrogel to increase water-holding capacity on restoration sites have not yet been clearly demonstrated. In some studies, it did not seem to affect survival, but in others, improved survival was reported, at least in the short term (Bainbridge 2001; Clemente et al. 2004; Oliveira et al. 2011; Minnick & Alward 2012).

Coarse woody debris

Downed woody debris has been shown to reduce soil temperature and moisture extremes on restoration sites. Relatively cool and moist microsites are created on the north side of logs, facilitating survival and growth of transplanted seedlings (Haskell et al. 2012; Minnick & Alward 2012). Fallen logs, stumps, large branches and snags also introduce complexity, creating microsites, which allows for the establishment of a more diverse suite of plants (Kennedy & Quinn 2001). While the logistics of introducing significant amounts of woody debris into this site is daunting, this should be high on the wish list for this site.

Ripping

Highly compacted soils limit root penetration and cause poor drainage resulting in poorly aerated, waterlogged surface soils in the winter, and very dry soils in the summer. Different species respond differently to compaction (Godefroid & Koedam 2004). The effect of compaction on plant growth also depends on the depth and degree of compaction. Natural processes such as freezing and thawing cycles, plant roots and biological activity, such as earthworms and moles, help to alleviate compaction over time, but if the degree of compaction is high, recovery may be minimal, even decades later. In such cases, mechanical loosening of the soil is necessary to alleviate compaction (Batey 2009). Chisel plowing or ripping of compacted soils on surface mine sites have resulted in improved growth of installed plants (Ashby 1997; Skousen et al. 2009; Evans et al. 2013).

This is a relatively expensive treatment though, and will require large-scale removal of above- and belowground biomass of plants over the area to be treated—an estimated 1.6 acres—prior to plowing. Loosening the soil in the immediate vicinity of the planting hole using a pickaxe may be a more viable alternative for compacted areas at Watershed Park.

Irrigation

Many restoration sites in the Puget Sound area do well without supplemental water, especially if planting occurs in the fall and plants are mulched. However, due to the exceptionally harsh site conditions, survival rates at the project site have been very low. Plant survival can be improved dramatically by irrigation, preferably for the first two to three years, although supplementing rainfall with irrigation for even one year can have lasting effects.

Irrigation at the project site dramatically improved first year survival; without supplemental water, survival will remain low. The source of water remains a problem—the subject of using the fire hydrant at the site should be raised with the City again. Another solution may be to pump water from Cochran Spring Creek to the site. Even though the City does not have the resources to deliver enough water to the site to water all the areas in restoration, a special effort should be made to deliver at least some water during the summer months. This may mean watering only those species, Douglas-fir for example, that are particularly vulnerable and that can have a large impact on restoration outcomes. Actual watering will need to be done by volunteers. This will mean involving additional volunteers since Eastside Preparatory School volunteers are not be available during the months when watering is needed.

Deep pipe irrigation is a very effective system of delivering water to plants at water-limited sites. It consists of burying a 15-inch long, 2-inch diameter perforated PVC pipe vertically in the ground, 1 to 4 inches from the plant, with the top protruding slightly above the ground. Watering into the pipe delivers the water to the root zone. This also helps to reduce evaporative losses and avoid encouraging weeds (Bainbridge et al. 2001; Bainbridge 2007).

Water once a week during the early- to mid-summer if it does not rain. Cut back to once every two weeks by mid-August to encourage early dormancy (Alexander 2003; Sound Native Plants 2013a).

Tree shelters

Although no obvious herbivore damage has been reported from the areas in restoration, both deer and rabbits have been observed at the project site (Figure 40). Browsing damage is likely being underestimated because plantings have not been monitored very closely, and because mortality resulting from drought has been so high. Both deer and rabbits can cause extensive damage to

planted species—Douglas-fir is particularly vulnerable (Minore 1979). Herbivore damage may explain why only 43% of the thimbleberry plants installed in 15-08 could be located at the end of summer 2012, despite receiving supplemental water.

The tall grass surrounding install plants may help to conceal the plants from herbivores--treatments that make seedlings more accessible to herbivores, such as mowing around plants, have been reported to lead to increased browsing damage (Skousen et al. 2009). However, it has also been suggested that grasslands offer good habitat and cover for smaller mammals that feed on tree and shrub seedlings. It is recommended that plantings be more carefully monitored for browsing damage. If browsing damage proves to be significant, tree shelters or tree cages can offer protection (Sound Native Plants Nursery 2013b).

Tree shelters offer the additional benefit of preserving moisture around plants (Bainbridge 2007; Sound Native Plants Nursery 2013b). It is proposed that tree shelters be installed around a subset of installed plants, preferably Douglas-fir trees, during the next growing season to see if this treatment significantly improves survival rates.

7.2 Plant installation

On a site where nutrient and water availability are limited, and resources to amend conditions are just as limited, choosing plant species appropriate for the site conditions, using appropriate planting techniques, and planting in the right spot, are critical (Clemente et al. 2004; Williamson et al. 2011).

7.2.1 Plant selection

Because site conditions are so different from those prior to mining, the forest ecosystem that existed on the site historically, or that currently exists in the other upland areas of Watershed Park, is not an appropriate reference ecosystem on which to model restoration efforts. Once native trees and shrubs are established, site conditions will be less harsh, and the composition and relative abundance of plant species can be further manipulated, but it will take many decades before the site resembles its historical counterpart, if it ever does.

Reference Ecosystem

Dry areas west of the Cascades are commonly characterized by what has been termed Westside Oak and Dry Douglas-fir Forest and Woodlands habitat (Chappel & Kagan 2011). Because of the similarly dry conditions at the project site, these forests and woodlands will be used as references ecosystems, albeit somewhat loosely.

In the Puget Lowlands, this type of habitat occurs in and around the San Juan Islands and parts of Thurston, Pierce, and Mason counties, usually in a mosaic with, or adjacent to, mixed conifer-hardwood forests. The structure and composition of this habitat varies depending on local conditions, disturbance regime and successional stage (Chappel & Kagan 2011).

It is typically forest to woodland with a single-or multi-storied canopy, and an understory of grasses, shrubs and ferns. The canopy is dominated by one or more of the following species: Douglas-fir (*Pseudotsuga menziesii*), Oregon white oak (*Quercus garryana*), Pacific madrone (*Arbutus menziesii*), shore pine (*Pinus contorta* var. *contorta*), Ponderosa pine (*Pinus ponderosa*), grand fir (*Abies grandis*) and, in riparian stands, Oregon ash (*Fraxinus latifolia*). Because of the dry conditions, western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*) can generally not regenerate successfully (Chappel 2006; Chappel & Kagan 2011).

The understory consists of deciduous shrubs such as oceanspray (*Holodiscus discolor*), baldhip rose (*Rosa gymnocarpa*), serviceberry (*Amelanchier alnifolia*), beaked hazelnut (*Corylus cornuta*), trailing blackberry (*Rubus ursinus*), Indian plum (*Oemleria cerasiformis*), snowberry (*Symphoricarpos albus*), and evergreen shrubs, vines and ferns like salal (*Gaultheria shallon*), dwarf Oregongrape (*Berberis nervosa*), Pacific rhododendron (*Rhododendron macrophyllum*), hairy honeysuckle (*Lonicera hispidula*), evergreen huckleberry (*Vaccinium ovatum*), swordfern (*Polystichum munitum*) and bracken fern (*Pteridium aquilinum*). Native graminoids and forbs include western fescue (*Festuca occidentalis*), Alaska oniongrass (*Melica subulata*), blue wildrye (*Elymus glaucus*), and long-stolon sedge (*Carex inops*) (Chappel 2006; Chappel & Kagan 2011).

Plant palette

Suggested plants species for the project site are listed in Table III. The main sources consulted during plant selection included Franklin and Dyrness (1973), Pojar & McKinnon (1994), Leigh (1999), Chappel (2006), Chappel & Kagan (2011), Minore (1979), Sound Native Plant Nursery (2013c), University of Washington Herbarium (2013) and the Washington Native Plant Society (2013). Additional sources are referenced in the table below. All of these species are native to the Puget lowlands and were selected for a combination of the following characteristics: drought tolerance, tolerance for nutrient deficient soils, or ability to grow in compacted soils. Note, not all of these plants will do well in the central pit area; some of these plants are more suited to conditions along the slopes or other areas where conditions are less harsh. Plants suitable for these areas are indicated by blue shading (and also marked with an asterisk). Note that some very drought-tolerant species such as Pacific madrone were also marked as being more

appropriate for less harsh areas. This is because Pacific madrone is so susceptible to disease—all the madrone trees growing in the pit area are diseased, while madrones growing in the rest of the park appear to be healthy. Douglas-fir have also been included with this group because survival of planted Douglas-fir seedlings at the project site has been negligible, unless supplemental water was supplied.

For the foreseeable future, restoration efforts at the project site will focus on the establishment of trees and shrubs. For that reason, and because most native herbaceous groundcovers need mature soil rich in organic matter (Sound Native Plant Nursery 2013b), very few herbaceous species have been included in the suggested plant list below.

7.2.2 Planting strategies

Plant material—size and form

Most plants installed at the site have been 1-gallon size container plants. Although somewhat expensive, this is likely to continue to be the case:

- Container plants this size are large enough to be able offer resistance to competing vegetation, yet small enough to recover from transplant shock relatively quickly.
- Seeding although inexpensive is unlikely to succeed in this harsh environment.
- Bare root plants are less expensive than container plants and may adapt more quickly to the harsh conditions at restoration sites. However, bare root plants have to be installed when dormant, can only be stored for a short period, and are very vulnerable to desiccation during storing and transport.
- Some plant species will root if cut branches are planted into sufficiently wet soil. Such live stakes are inexpensive and easy to install, but do require a planting site that is sufficiently moist (Leigh 1999). This may be a way to establish native vegetation in compacted, seasonally wet areas of the site. Live staking of black cottonwood and Scouler's willow are generally very successful, and these species may be able to tolerate both poorly drained conditions in the winter and dry conditions in the summer in these areas.

Table III Suggested plant species for the project site. Plants in areas shaded in blue and marked with an asterisk are more appropriate for areas such as slopes or other sites where conditions are less growth-limiting.

Trees				
Binomial Common name	Habitat	Soils	Exposure	Comments
Abies grandis Grand fir	Coniferous or mixed forests, low to mid elevations	Dry to moist , deep, well-drained soils	Sun to partial shade	Deep wide-spread roots—good soil-binding properties Drought-tolerant High transplanting success
Acer macrophyllum Bigleaf maple*	Open forests, low to mid elevations	Dry to moist, well-drained soils; tolerates poor soil conditions	Sun to shade	Fast-growing Pioneer species; adapted to disturbed sites Good soil-binding properties High transplanting success
Alnus rubra Red alder*	Moist woods, floodplains, recently cleared land; low elevations	Moist	Sun to partial shade	N-fixer; Pioneer species; adapted to disturbed sites Fast-growing Can tolerate nutrient-poor soils Flood-tolerant
Arbutus menziesii Pacific madrone*	Forest edges, cliffs & rocky slopes; low to mid elevations	Dry, very well-drained sandy or gravelly soils; shallow soils	Sun to partial shade	Drought-tolerant Disease-prone Low transplanting success
Fraxinus latifolia Oregon ash	Flood plains & wet meadows, low elevations	Moist to wet; tolerant of seasonally saturated soils	Sun to partial shade	High transplanting success
Pinus contorta var. *contorta* Shore pine	Dunes to bogs, rocky hilltops to shorelines, low to subalpine elevations	Range of soil conditions; wet to dry, tolerates nutrient-poor soils	Sun to partial shade	High transplanting success Rapid growth rate Highly adaptable—Tolerant of compacted soils and flooding Drought-tolerant

Binomial Common name	Habitat	Soils	Exposure	Comments
Pinus monticola Western white pine*	Moist valleys to dry slopes, low to subalpine elevations	Well-drained, dry to moist soils; tolerates nutrient-poor, gravelly soils	Sun	Susceptible to white pine blister rust Deep roots
Pinus ponderosa Ponderosa/yellow pine (Wennerberg 2004)	Open forests	Well-drained dry soils	Sun	Fast-growing Drought-tolerant Do not tolerate poorly-drained soils
Populus trichocarpa Black cottonwood*	Mixed forests, floodplains & disturbed upland sites; low to mid elevations	Saturated to moist; tolerate seasonally saturated soils; tolerant of nutrient-poor soils	Sun to partial shade	High transplanting success Rapid growth rate Does well in disturbed areas
Prunus emarginata Bitter cherry	Forests and forest edges; low to mid elevations	Dry to moist, sandy to gravelly soils	Sun to partial shade	Pioneer species
Pseudotsuga menziesii var. *menziesii* Douglas-fir*	Forests & rocky slopes; low to mid elevations	Moist to dry, but grows bests on deep, moist sandy loam; tolerate gravelly soils	Sun to partial shade	Moderate to rapid growth rate Grows well in mineral soil High transplanting success Good for anchoring slopes
Quercus garryana Garry/Oregon white oak	Open forests & forest edges, grasslands; low elevations	Dry to moist, well-drained, sandy to gravelly soils	Sun to partial shade	Medium to high transplanting success; partial shade improves transplanting success Drought-tolerant once established; can tolerate winter flooding Slow-growing

Shrubs				
Binomial Common name	Habitat	Soils	Exposure	Comments
Acer circinatum Vine maple	Forest canopy openings & edges, low to mid elevations	Moist to dry, well-drained soils	Partial shade to shade	Good-soil binding properties Adapted to disturbed sites High transplanting success
Amelanchier alniflora Western serviceberry	Open forests, woodlands & rocky slopes; low to mid elevations	Moist to dry, well-drained soils	Sun to partial shade	Very drought-tolerant Branch tips root to form soil-holding thickets May be slow to establish Medium transplanting success
Arctostaphylos columbiana Hairy manzanita	Open areas, rocky slopes, low elevations	Loose, sandy to rocky, well-drained soil	Sun	
Berberis aquifolium Tall Oregon-grape	Open forests, forest edges & rocky slopes; low to mid elevation	Moist to dry, well-drained, gravelly, nutrient-poor soils	Sun to partial shade	High transplanting success Very drought tolerant
Berberis nervosa Low Oregon-grape*	Forests & woods; low to mid elevation	Moist to dry, well-drained	Partial shade to shade	Medium transplanting success Slow growing Less tolerant of dry, open sites than *B. aquifolium*
Ceanothus velutinus Snowbrush	Open forests & forest edges, rocky slopes; low to mid elevations	Dry to moist, sandy to gravelly soils	Sun	Adapted to disturbed areas Nitrogen-fixer
Corylus cornuta var. *Californica* Beaked/California hazelnut	Open forests & forest edges, forested wetlands, meadows, rocky slopes; low to mid elevations	Moist to dry, well-drained soils, can tolerate gravelly soils	Partial sun to shade	Prefers nutrient-rich soils

Binomial Common name	Habitat	Soils	Exposure	Comments
Crataegus suksdorfii Black/Suksdorf's hawthorn	Forest edges, pastures, along streams; low to middle elevations	Dry to moist, well-drained sandy or gravelly soils	Sun to partial shade	Stabilizes soil. Well-adapted to disturbed areas
Frangula purshiana Cascara/buckthorn*	Forests & forest edges; low to mid elevation	Wet to dry	Sun to shade	Rapid growth rate High transplanting success
Gaultheria shallon Salal	Forests & woods, rocky slopes; low to mid elevations	Moist to dry; can tolerate nutrient-poor soils	Partial sun to shade	Slow to establish Not a pioneer species—does not transplant well into open areas Good soil-binding properties
Holodiscus discolor Oceanspray	Open forests & forest edges, rocky slopes; low to mid elevations	Moist to dry, well-drained, gravelly soils	Sun to partial shade	Rapid growth rate High transplanting success Does well in disturbed areas Extremely drought tolerant Intolerant of saturated soils Good soil-binding properties
Oemleria cerasiformis Indian plum*	Open forests & forest edges; low elevation	Moist to dry; does not tolerate saturated soils	Partial shade to shade	High transplanting success Moderate to rapid growth rate Good for erosion control on slopes provided shade is available Does well on disturbed sites
Philadelphus lewisii Mock orange	Open forests & forest edges, rocky slopes; low to mid elevations	Moderately moist to dry, gravelly soils; prefers nutrient rich soils	Sun to partial shade	Rapid growth rate if sufficient moisture Does well on disturbed sites Can tolerate a wide range of environmental conditions

Binomial Common name	Habitat	Soils	Exposure	Comments
Ribes sanguineum Red-flowering currant	Open forests & forest edges, rocky slopes; low to mid elevations	Dry, well-drained soil; intolerant of saturated soils	Sun to partial shade	Does well on disturbed sites Alternative host for white pine blister rust
Rosa gymnocarpa Bald-hip rose	Forests & woods, forest edges, rocky slopes; low to mid elevations	Moist to dry	Partial shade to shade	Drought-tolerant
Rubus parviflorus Thimbleberry*	Open forests & forest edges; low to subalpine elevations	Moist to dry, well-drained soils; intolerant of saturated soils	Sun to shade	Rapid growth rate High transplanting success Can do well in dry soil if mulched or irrigated until established Good soil-binding properties Does well in disturbed areas
Salix scouleriana Scouler's willow	Upland forests, edges of forests and wetlands; low to mid elevations	Dry to moist, tolerates gravelly soils	Sun to partial shade	High transplanting success Rapid growth rate Drought tolerant Propagates well from live stakes
Sambucus cerulean Blue elderberry*	Open areas; low elevation	Moderately moist to dry, well-drained	Sun to partial shade	
Sambucus racemosa Red elderberry*	Open forests & forest edges, floodplains; low to mid elevations	Moist to dry	Sun to shade	Rapid growth rate once established Good soil-binding properties Does well on disturbed sites Can be propagated from live stakes

Binomial Common name	Habitat	Soils	Exposure	Comments
Symphoricarpos albus Common snowberry	Open forests and forest edges, rocky slopes; low to mid elevation	Moist to dry; tolerates occasional flooding & shallow soils	Sun to shade	High transplanting success Rapid growth rate Good soil-binding properties
Ferns				
Polystichum munitum Sword fern	Forests and woods, often on steep slopes with loose soil; low to mid elevations	Moist to dry	Partial shade to shade	High transplanting success Drought tolerant
Forbs, Vines & Graminoids				
Chamerion angustifolium Fireweed	Forest edges, meadows; low to mid elevation	Moist to dry	Sun	Does well on disturbed areas
Eriophyllum lanatum Woolly sunflower	Forest edges, meadows, rocky slopes; low to mid elevation	Moist to dry, sandy soils	Sun to partial shade	High transplanting success Rapid growth rate
Elymus glaucus Blue wild-rye	Open forests, forest edges & meadows, rocky slopes; low to mid elevation	Moist to dry, well-drained	Sun to partial shade	
Festuca rubra Red fescue	Forests, meadows, river banks; low to high elevations	Well drained, sandy to gravelly soils	Sun to shade	
Lupinus albicaulis Pine/Sickle-keeled lupine (Darris 2005)	Dry slopes and open areas; low to alpine elevations	Dry, well-drained, low-nutrient sites	Sun	Rapid grower Dry, low-nutrient slopes Pioneer species Does well on disturbed sites Nitrogen-fixer Can grow up to 5 ft. tall

Spacing

Since high mortalities and slow growth of surviving plants are expected, and since canopy cover is needed to create less favorable growing conditions for shade-intolerant invasive species, relatively dense plantings are recommended for this site. Trees can be spaced 6 to 12 feet apart, shrubs 5-6 feet, and smaller ground cover species 12 to 18 inches.

Installation

For container plants, late fall is the best time to plant. Fall planting allows plants to recover from transplant shock and expand their root systems before shoot growth starts in the spring. Bare root plants and live stakes need to be installed during the dormant season, before spring arrives. Planting can continue until the end of March, but plants installed this late will be more vulnerable to summer drought (Sound Native Plants Nursery 2013d).

- To install container plants, dig a hole twice as wide, and at least as deep as the plant roots. Break up the root ball and remove as much as possible of the nursery soil from the roots, straighten out any curving roots, and cut off encircling roots. This will encourage the roots to spread beyond the hole. Place the plant in the planting hole with the roots pointing outward. Fill the hole halfway with site soil. Water thoroughly—the soil should be saturated. Fill up the rest of the hole with soil and gently tamp down the soil to close up air holes. Now check that the plant has not been installed too deeply or too shallowly; gently tug on the stem to make sure that the plant is seated firmly in the soil. Create a shallow basin around the installed plant to help retain soil moisture around the plant. Water again. Spread nursery soil on top of the soil surface. Cover the bare soil with wood chip mulch, but be careful not to pile the mulch up against the stem.

  Availability of water is a problem at this site. However, considering the high rates of mortality of installed plants at this site, it is proposed that it may be worth carrying in a bottle of water along with each plant to be installed, even if that means installing fewer plants.

- Take cuttings, 2 to 3 feet long, from the parent plant during late fall to early spring. Cut the lower end of the stake at an angle, and the upper end straight across. Live stakes are often planted by pounding them into the soil with a mallet (Leigh 1999), but in the compacted soil at the project site, it may be necessary to create planting holes using a pickaxe to dig through the compacted layer. Stakes can be planted deeply—leave the top

two nodes above the ground. Make sure stakes are planted the right way up. Space about 5 to 6 feet apart.

Selecting the right spot for planting

Where plants are installed is as important as choice of species and planting technique:

- Some parts of the planting area will be more amenable to the establishment of native plants than other parts—these are microsites where resources such as moisture, organic matter and nutrients collect and are retained, or where soil temperatures are less extreme. Such microsites may be created by features such as woody debris—the area directly to the northeast of a downed log will be relatively protected from the heat of the sun (Haskell et al 2012), in local depressions, at the toe of the slope, or where existing vegetation creates shade. Once trees and shrubs are established, they can then act as nurse plants for other vegetation. Exploiting such microsites can lead to higher survival. Figure 42 to Figure 46 show examples of such microsites at the project site, and how plant establishment and performance are affected.
- It is also crucial to remember that different plant species have different requirements. For example, some species need full sunlight while others do better in shade. (More information about the requirements of specific species suggested for the project site can be found in Table III.) Figure 46 illustrates this effect.

Before purchasing plants, carefully survey the planting site conditions and create a planting plan to make sure plants are installed in the optimal location.

7.2.3 Sources of plant material

Choices of native plant stock in retail nurseries are limited. Access to a greater variety of plant material can be obtained in the following ways:

- Plant material can be ordered from wholesale nurseries through the Green Kirkland Partnership.
- Plant material can also be obtained from the volunteer-run Green Kirkland Partnership Native Plants Nursery. Plant material at the nursery are recovered from salvage sites, donations, or propagated from cutting and seeds.

Figure 42. In the image above, note how tansy ragwort (yellow flowers) is preferentially colonizing the toe of the slope where resources are higher.

Figure 43. Red elderberry shrub growing among the remains of a pile of removed Scot's broom that offers some protection and increased resources.

Figure 44. This photo was taken towards the end of summer 2012. Sword ferns growing along the drip line of the trees where there is more shade, and where moisture and nutrient levels are likely higher, are thriving, while those growing out in the open (in the foreground) are desiccated.

Figure 45. Indian plum seedlings growing at the base of a Pacific madrone tree. At the project site, Indian plum seedlings were only observed at such protected sites.

Figure 46. The two photos above were taken at the project site on the same day in July 2013. The two vine maples in the images were installed a few feet apart. The vine maple on the left is growing in a relatively shady spot. The leaves are green and the plant seems healthy. The one on the right is growing in full sun and appears stressed—the leaves are curling down and have turned color prematurely.

8 MANAGEMENT RECOMMENDATIONS

8.1 Maintenance and current status

The total area in restoration at the project site is now 1.82 acres--areas previously cleared of Scot's broom, but not maintained, are not included this estimate. Much of the restoration activities in the coming years will be focused on maintaining these areas already in restoration. A maintenance schedule is presented in Figure 47. Maintenance activities will include monitoring for new weed infestations and browse damage, continuous weeding, maintaining and supplementing mulch rings, watering and installing additional plants:

- Due to the extensive seed bank of invasive species in the soil, emergence of new seedlings can be expected following first-time removal. Areas cleared of Scot's broom in 2008 and not maintained, once again have extensive cover of seed-producing plants. Vegetative regrowth of plant parts remaining in the soil can also be expected. Clearing of Scot's broom, and soil disturbance associated with planting, have stimulated germination and growth of grasses and forbs, in particular tansy ragwort, St. John wort and sheep sorrel. Cleared areas will need continuous weeding for several years to come. Timing of invasive control treatments depends on species and method (see section 7.1.2).
- Installed plantings are relatively sparse—about 9 feet on center—and high mortalities are expected. This past year, plant selections have included more drought-tolerant species, and many areas targeted for planting had some native plant canopy cover, providing a modicum of protection, but without supplemental water, many plants will succumb to drought. Dead plants should be replaced with better-adapted species, or, in some areas it may be more appropriate not to replace plants until more resources are available.
- Mulch rings need to be maintained and supplemented to reduce competition from other vegetation, preserve soil moisture, and to keep adding organic matter to the soil.
- Supplemental water--if only a few plants can be watered, make it trees, especially Douglas-fir.

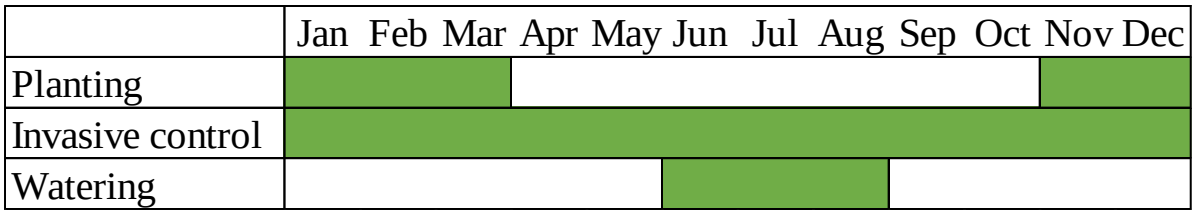

Figure 47. Maintenance schedule.

Future plantings should to be guided by survival rates of individual plant species. In the harshest areas in the center of the pit:

- Douglas-fir seedlings are unlikely to survive unless they receive supplemental water, regardless of compost amendments.
- Drought-tolerant shrubs such as snowberry, oceanspray and red-flowering currant fare somewhat better, as do Oregon ash, at least in compost-amended soils. Survival rates for these species planted in soil not amended with compost need to be assessed at the end of summer 2013.

- Garry oak and shore pine are generally more drought-tolerant than Douglas-fir (Minore 1979). This is the first year these species have been planted at the project site. Survival rates need to be evaluated at the end of the summer.
- Ponderosa pine, another very drought-tolerant species (Minore 1979), has yet to be tested.

Other tree and shrub species should continue to be tried out at this site, but if the species listed above cannot be successfully established at the site, it is unlikely that the site can be restored to a forest or even a woodland.

8.2 Restoration needs by management unit

Restoration needs and recommended action for each management unit are summarized in Table IV. Additional tasks that need to be done:

- Removing the remains of the compost pile next to the trail in 15-11 (spreading the material over the surrounding area will result in colonization of Canada thistle over a larger area).
- Use of the informal north-south trail transecting 15-01, 15-07 and 15-12 should be discouraged by blocking off the entrancing using woody debris, once these areas become active restoration site.

8.3 Management priorities

This is a large and complex site; there are many restoration challenges and resources are limited. Restoring this site will take many decades—the exact timeline will depend on the availability of resources. Restoration tasks have been separated into those that need to be attended to in the short term, and those that can be initiated as resources become available over the next several years.

8.3.1 Short-term priorities

Short-term priorities include tasks that need to be initiated as soon as possible, either to protect native vegetation already on the site, or to arrest emerging problems that may negatively affect restoration outcomes. Some of these tasks may need to be repeated or may be ongoing for several years. Short-term priorities for restoration are outlined in Table V.

Table IV. Restoration needs and recommended actions by management unit

	Scot's broom Removal	Blackberry Removal	Other Priority Invasive Species	Planting & Mulching	Erosion Control	Soil Compaction Treatment
15-01	Large scale; Cutting	Large scale; Cutting/Goats + Herbicide	Canada thistle: Spot removal; Repeated cutting + Herbicide	Extensive	Yes	No
15-02	Spot; Cutting	Large scale; Manual	One-seed hawthorn: Cut stump + Herbicide	Extensive	Yes	No
15-03	Spot removal; Cutting	Cutting/Goats; Manual + Herbicide	None	Extensive	Yes	No
15-04	Large scale; Cutting	Spot; Manual	Tansy ragwort: Manual/Herbicide One-seed hawthorn: Cut stump + Herbicide	Extensive	No	Yes
15-05	None	Spot; Manual	None	Supplemental	No	No
15-06	Large scale; Hand pulling/Weed wrench	Spot; Manual	Tansy ragwort: Manual/Herbicide	Extensive	No	No
15-07	Large scale; Cutting/Hand pulling/Weed wrench	Spot; Manual	Tansy ragwort: Manual/Herbicide One-seed hawthorn: Cut stump + Herbicide	Extensive	No	Yes
15-08	Spot; Hand pulling	Spot; Manual	None	Supplemental	No	N half

	Scot's broom Removal	Blackberry Removal	Other Priority Invasive Species	Planting & Mulching	Erosion Control	Soil Compaction Treatment
15-09	Spot; Hand pulling	Spot; Manual	Canada thistle: Spot removal; Repeated cutting + Herbicide Butterfly bush: Cut stump + Herbicide	Extensive	No	No
15-10	Spot; Hand pulling	None	Tansy ragwort: Manual/Herbicide One-seed hawthorn: Cut stump + Herbicide	Supplemental	No	No
15-11	Large scale; Hand pulling/Weed wrench	Spot; Manual	Canada thistle: Spot removal; Repeated cutting + Herbicide One-seed hawthorn: Cut stump + Herbicide	Extensive	No	Next to trail
15-12	Large scale; Hand pulling/Weed wrench	None	Canada thistle: Spot removal; Repeated cutting + Herbicide	Extensive	No	No
15-13	Spot; Hand pulling	Spot; Manual	Ivy: Manual Herb Robert: Manual	Supplemental	No	No
15-14	Large scale; Cutting	Large scale; Cutting/Goats + Herbicide	One-seed hawthorn: Cut stump + Herbicide	Extensive	Yes	No

	Scot's broom Removal	Blackberry Removal	Other Priority Invasive Species	Planting & Mulching	Erosion Control	Soil Compaction Treatment
15-15	Large scale; Cutting/ Hand pulling/Weed wrench	Spot; Manual	None	Extensive	Yes	No
15-16	Spot; Cutting	Large-scale; Manual/Cutting + Herbicide	Yellow archangel: Repeated digging/Hand pulling/Herbicide Herb Robert: Manual One-seed hawthorn: Cut stump + Herbicide	Supplemental	No; reassess at time of invasive removal	No

Table V. Short-term priorities for restoration at the project site.

(GKP-Green Kirkland Partnership EPS-Eastside Preparatory School)

Action	Parties involved	Timing
Evaluation of restoration outcomes (see section 9)	EPS with GKP staff	Fall 2013
Maintenance of areas in restoration: Continued weeding, reapplication of mulch, supplemental planting, summer watering	EPS; GKP staff and other volunteers during the summer months	Year-round
Removal and continued control of isolated infestations of ivy and herb Robert in 15-13 and 15-16 by manual removal and mulching.	EPS	Late fall to early spring
Removal and continued control of yellow archangel in 15-16. Manual removal should be attempted before resorting to herbicide application. Working conditions will be complicated by the sloping ground.	To avoid excessive trampling of native vegetation and erosion, this task should be assigned to a small group of volunteers.	Late fall to early spring
Action	**Parties involved**	**Timing**
Control of Canada thistle in 15-01, 15-09 and 15-12.	Since EPS volunteers are not available during the summer, this task will require recruitment of additional volunteers and/or herbicide application by GKP staff.	Late spring to early summer

Action	Parties involved	Timing
Release existing native trees and shrubs from Himalayan blackberry and/or Scot's broom, particularly along the slopes (15-01, 15-03, 15-14, 15-16). This is important because it may take several years before these management units become active restoration sites. While blackberry will grow back fast, a single cutting of Scot's broom encroaching on these shrubs could have a significant and long-lasting impact.	EPS, GKP staff, other volunteers depending on accessibility	Year-round (annually for blackberry)
Removal of tansy ragwort from 15-04, 15-06, 15-07, 15-10, 15-11 and 15-12. Monitor for tansy ragwort presence in other management units.	EPS--as part of ongoing maintenance of restoration sites. More widespread removal of tansy ragwort will require City of Kirkland staff involvement	Year-round
Removal of one-seed hawthorn (all management units) and butterfly bush (15-09)	GKP staff	Late fall

8.3.2 Medium- to long-term priorities

Medium- to long- term priorities include both additional restoration on management units already in restoration, and new areas to be restored. The Green Kirkland Partnership and/or Eastside Preparatory School will have to secure additional funding before restoration in some of these areas can be initiated, as crews will be needed to complete some tasks.

Each management unit was assigned a priority of between 1 and 4 for future restoration, 1 being the highest priority for restoration, and 4 the lowest. This rating was based on the likelihood of restoration success, current restoration status, proximity to areas already in restoration, degree of threat the current status presents to forested areas in the rest of the park, and whether restoration can be done exclusively by volunteers with minimal support from Green Kirkland Partnership staff or contracted crews.

For example, a management unit which is already in restoration, or in close proximity to areas in restoration, with high cover of native vegetation and significant canopy cover, and which is relatively flat, is considered a higher priority for restoration than an area with compacted soils, or steep slopes, and 100% non-native vegetation cover. Areas where restoration has already been initiated, are also included since so much restoration work still remains to be done in these areas. The results are presented in Figure 48.

Priority 1

Management units assigned a priority of 1 include 15-09, 15-10, 15-11 and 15-13. These areas generally have some tree canopy cover and/or established native shrubs, are either already in restoration, or in close proximity to areas where restoration have already been initiated.

Specific tasks include:

- Removal of priority invasive species listed under short-term priorities as listed under the short-term priorities.
- Removal of Himalayan blackberry and Scot's broom from areas not yet cleared.
- Plant installation--it is proposed that, unless supplemental water can be provided, planting efforts should focus on areas that offer more favorable growing conditions. Over time, these patches of native vegetation can be expected to grow and spread Corbin & Holl 2012). More sparsely planted areas in between should be managed for control of Scot's broom, Himalayan blackberry, tansy ragwort and Canada thistle, and maintained

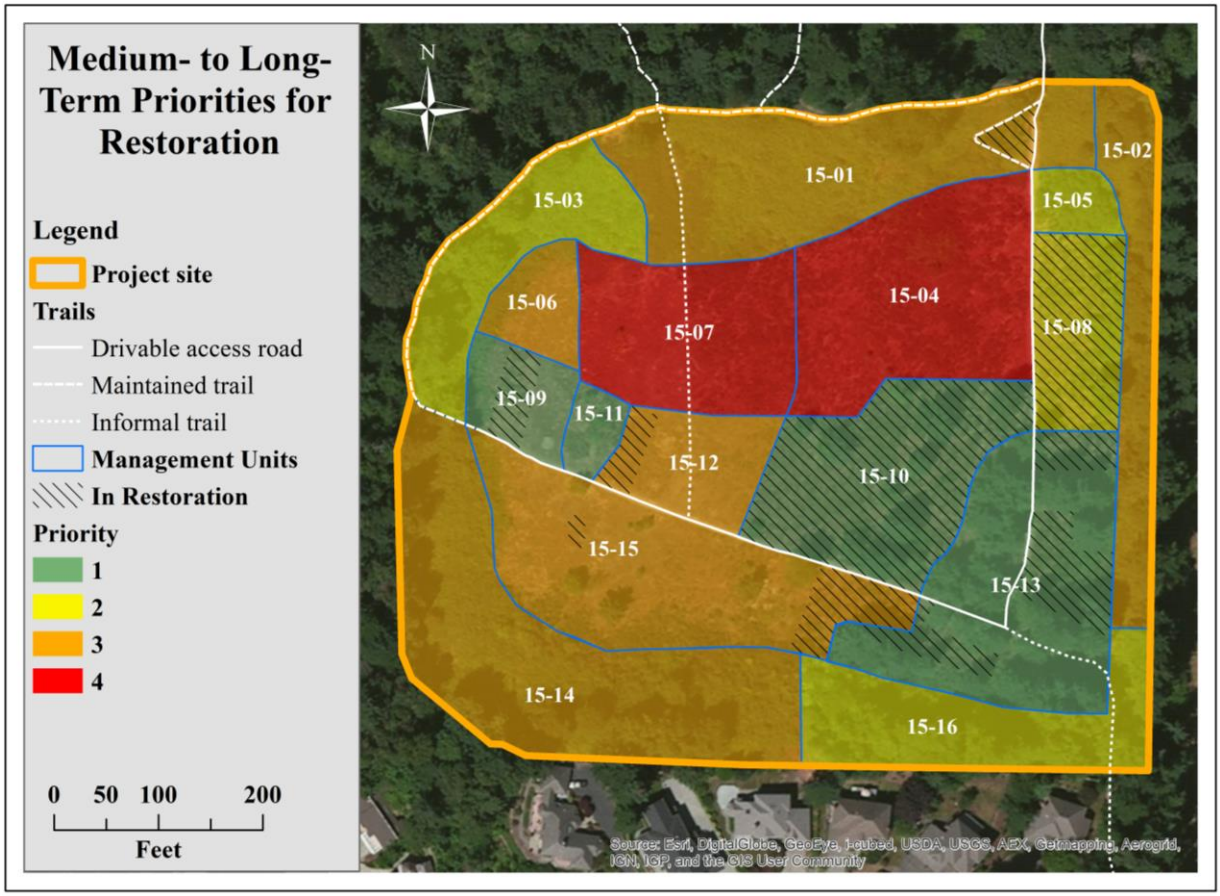

Figure 48. Medium- to long-term priorities for restoration, with one being the highest priority and 4 the lowest.

as open woodland. Only plant species that prove to be able to tolerate the harsh conditions in these areas should be installed here.

Proposed plant installation projects include:

- Installation of shrubs in small canopy gaps and along tree canopy edges in 15-13. Suggested species include salal, baldhip rose, vine maple and snowberry. Note: it is unlikely that any plants will be able to grow in the bare, moss-covered areas underneath dense Douglas-fir canopy (Figure 32). Avoid planting in those areas.
- Installation of additional trees and shrubs to supplement existing Douglas-fir and red elderberry in 15-11. Suggested plant species include black cottonwood, snowberry and Oregon ash.
- 15-09 between the slope and the area already in restoration. This area receives some shade in the afternoon and is being vigorously encroached upon by

Himalayan blackberry. Suggested species include bitter cherry, bigleaf maple, Douglas-fir, baldhip rose and snowberry.

- 15-10 has been planted with a variety of trees and shrubs. How many will survive remains to be seen, as some areas are very exposed. If mortalities are high, limit additional plantings to small trees and shrubs in areas that receive some shade from existing trees: Suggested species include bitter cherry, snowberry, oceanspray, red-flowering currant. For more open areas shore pine, Ponderosa pine, snowberry and red-flowering currant is suggested.

Priority 2

Management units assigned a priority of 2 include 15-03, 15-05, 15-08 and 15-16. All of these areas have some native vegetation cover and receive some shade.

- Control of yellow archangel in 15-16 has been identified as a short-term priority. Ongoing control of this species will be a necessary.
- 15-03 and 15-16 are along the slopes and, particularly in the case of 15-03, it is proposed that due to the density of blackberry thickets and its location along the slope, crews are brought in for first time removal of blackberry. Extensive erosion control is not likely to be necessary. Depending on removal method used, and because it will be difficult to apply wood chips to some areas, it may be necessary to install erosion control blankets. Based on existing vegetation cover, survival of installed vegetation may be better than in the main pit itself. A variety of trees and shrubs will do well in these areas. Specific recommendations include bitter cherry, Douglas-fir (especially at the rise and toe of the slope), bigleaf maple, oceanspray, black hawthorn, western serviceberry, snowberry and, in areas with some shade, vine maple and salal. Western swordfern, Indian plum, red elderberry, red alder and black cottonwood are likely to colonize naturally once the invasive species have been removed.
- 15-05 will need mostly spot removal of Himalayan blackberry. The bitter cherry stand that covers this management unit seems to be able to hold its own against encroaching Scot's broom and Himalayan blackberry. No planting is suggested at this time.
- 15-08 is already in restoration, but due to the very compacted soils in the northern half of this management unit, it is likely that the plantings in this area will fail. It is proposed that this area be used to test treatments and plant species for compacted areas at the site. If installed shore pine survives in this area, it will likely also do well in these other areas.

With the exception of clearing of Himalayan blackberry and Scot's broom from around native trees and shrubs, and spot treatment of priority weeds like Canada thistle, it will be many years before restoration is attempted in the remaining areas. Some general observations and insights are offered below.

Priority 3

Management units assigned a priority of 3 include 15-01, 15-02, 15-06, 15-12, 15-14 and 15-15.

- 15-01, 15-02 and 15-14 comprise the remaining slopes—with the exception of the slope along the eastern boundary, these slopes are long, steep and very exposed. Restoration will be challenging and will involve extensive crew time and other resources. Restoration in these areas should be guided partly by restoration outcomes for 15-03.
- With the exception of a few native shrubs installed along the western edge of 15-12, 15-06 and 15-12 have 100% non-native cover. Restoration in these areas will be challenging; plantings in the central part of 15-12 have failed. Restoration activities in these management units should be guided by the outcomes of restoration in other areas.
- 15-15 is characterized by very well-drained, loose sandy soils. There are scattered native trees and shrubs, and some plantings have already been initiated in parts of this management unit, with varying levels of success. Results have been very unpredictable. Further plantings should initially be limited to areas where some native cover already exists.

Priority 4

Management units assigned a priority of 4 include 15-04 and 15-07. The soil in these two adjacent areas is very compacted and there is no native plant cover to speak of. The likelihood of successful restoration is low, but will be much higher once native plant cover has been successfully established in the surrounding management units.

9 MONITORING

Continued monitoring is an important, but often neglected, component of any restoration project. Restoration outcomes are unpredictable and monitoring data informs adaptive management decisions. A very simplified monitoring protocol is proposed for Watershed Park. For the foreseeable future, the most important information needed to make management decisions are:

- Notes on treatments applied
- Invasive species identification and cover

- Survival rates of different native species

It is proposed that this information be collected for selected, well-defined planting areas. Collecting and recording data will include the following steps:

- Before clearing a new area, take a "before" picture. Record where the picture was taken from, and in which direction.
- Describe and record the boundaries of the area—it could be an entire management unit if it is a small unit, or part of it.
- Create an Excel spreadsheet for that planting area. Paste the "before" picture in the spreadsheet.
- When plants are installed record the number of each species installed on the same spreadsheet.
- Keep notes on treatments applied to the site in the spreadsheet. For example, if plants received supplemental water, make a note of that, also note the period over which plants were water, how frequently, and how much.
- Once a year, preferably at the beginning of the school year, but before leaf fall:
- Assess which invasive species are present and estimate cover. Record this information in the spreadsheet.
- At this time also count the number of living plants of each species. Record this information in the spreadsheet and calculate survival rates.
- Take a new picture of the site.

This will create a record of how the site changes over time, which species and treatments work, and which don't, guiding restoration activities. Having students participate in this exercise will also be a good educational opportunity and will contribute to making restoration activities about more than just removing one plant and planting another in its place.

To facilitate this task, available monitoring data have been compiled for 5 planting areas (Appendix I).

Once significant native plant cover has been established, it will become necessary to record other information as well, but for now, this is all that is needed.

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APPENDIX I: GREENHOUSE TRIALS

To gain more insight into factors controlling Douglas-fir growth in soils at the project site, some very limited trials were conducted at the Douglas greenhouse at the University of Washington Center for Urban Horticulture.

Method

Douglas-fir seeds were grown from seed for a period of 20 weeks in 3 different types of soil: soil collected from adjacent upland forest, soil collected from an area with predominantly Scot's broom cover at the site, and soil collected from an area with 100% Douglas-fir canopy cover at the project site. In each case, the litter layer was removed before excavating soil to a depth of about 15 cm. For each soil type, soil was collected from 3 separate sampling locations. Soils from sampling locations were thoroughly mixed to provide a composite sample for each soil type.

For each soil type 96 Stuewe & Sons D16 Deepot containers were filled with soil. The cell diameter of these containers is 2", cell depth 7" and cell volume 16 cu in. Three Douglas-fir seeds were planted in each container. The germinants were thinned out to 1 seedling per container. Containers were rotated weekly and watered as needed. Seedling heights were recorded 20 weeks after germination.

Results

The results were as follows:

Soil Type	Seedling Height (cm)		
	Range	Average	Standard Error
Forest soil (n=91)	4.0-18.0	10.6	0.4
Scot's broom soil (n=89)	3.0-10.0	5.2	0.1
Douglas-fir soil (n=94)	4.0-11.0	5.9	0.2

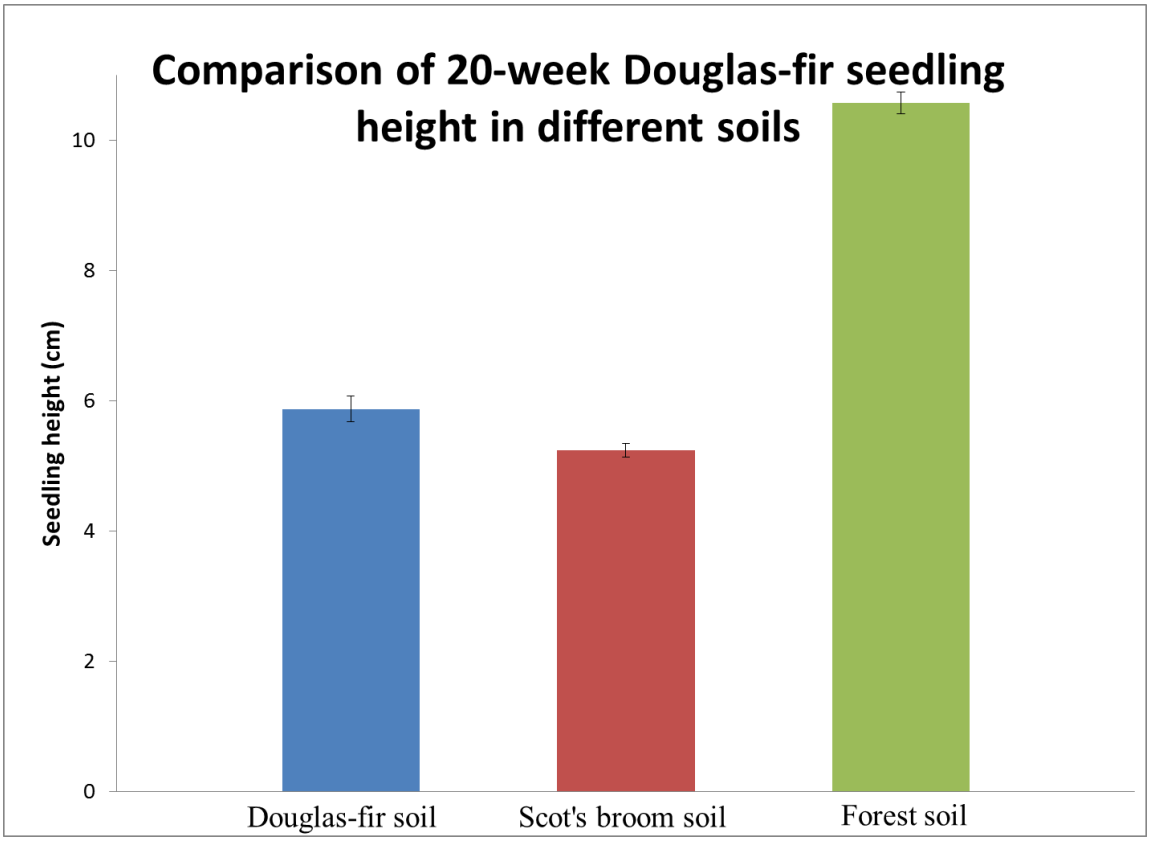

Figure 49. A comparison of 20-week Douglas-fir seedling height in three types of soil. Error bars indicate standard error.

Conclusions

- After 10 weeks, the average height of Douglas-fir seedlings growing in forest soil was significantly greater than those growing in soils from the project site.
- Allelopathic compounds in Scot's broom soils (Haubensak et al. 2004; Haubensak & Parker 2004; Grove et al. 2012) did not appear to inhibit Douglas-fir seedling growth greatly, at least not relative to seedlings growing in soil collected from the Douglas-fir stand at the site.
- Presumably, the soil from the Douglas-fir stand contained ectomycorrhizal inoculants. However, under greenhouse conditions, seedlings growing in this soil did not perform any better than seedlings growing in soil collected from an area dominated by Scot's broom.

- Overall conclusion: Even if Douglas-fir trees at the project site were regularly watered and weed competition removed, growth would still be severely limited by lack of nutrients in the soil.

APPENDIX II: MONITORING DATA FOR SELECTED PLANTING AREAS

Management Unit: 15-08
Planting area: 15-08
History: Cleared of Scot's broom by cutting; 02/2012; planted 02/2012; additional plants installed 02/2013

Species installed	02/2012 #	09/2012		06/2013 #	09/2013	
		#	%		#	%
Abies grandis/Grand fir	6	5	83	6		
Acer circinatum/Vine maple	8	8	100	7		
Holodiscus discolor/Oceanspray	6	6	100	12		
Pseudotsuga menziesii/Douglas-fir	38	36	95	48		
Pinus contorta/Shore pine	-	-	-	18		
Ribes sanguineum/Red-flowering currant	-	-	-	3		
Rubus parviflorus/Thimbleberry	30	13	43	7		
Symphoricarpos albus/Snowberry	-	-	-	6		
Total	88	68	77	108		

Photo points: Taken from N-S trail facing southeast corner of management unit. No before picture available.

March 2012 After planting

July 2013

Invasive cover: 09/2013: About 5% regrowth of Scot's broom from cut stumps; isolated seedlings
Other comments: 09/2013: Plants were watered once a week during July by the COK.

Management Unit: 15-12
Planting area: Eastern half
History: Cleared of Scot's broom by cutting 10/2012; planted 04/2013

Species Installed	**# 06/2013**	**09/2013**	
		#	**%**
Pseudotsuga menziesii/Douglas-fir	11		
Quercus garryana/Garry oak	3		
Pinus contorta/Shore pine	10		
Ribes sanguineum/Red-flowering currant	2		
Rubus spectabilis/Salmonberry	2		
Symphoricarpos albus/Snowberry	2		
Thuja plicata/Western redcedar	2		
Total	32		

Photo points: Taken from E-W trail facing north

October 2012 Before clearing

June 2013 After planting

Invasive cover: 09/2013
[To be completed: Note the major invasive species present and approximate % cover of each]
Other comments:
[To be completed: This section could contain any other relevant information e.g. whether plants have been watered over the summer]

Management Unit: 15-12
Planting area: Western half
History: Cleared of Scot's broom by cutting 10/2012; planted 04/2013

Species	**06/2013**	**09/2013**	
	#	**#**	**%**
Abies grandis/Grand fir	13		
Holodiscus discolor/Oceanspray	7		
Pseudotsuga menziesii/Douglas-fir	17		
Quercus garryana/Garry oak	5		
Pinus contorta/Shore pine	18		
Ribes sanguineum/Red-flowering currant	7		
Symphoricarpos albus/Snowberry	7		
Total	66		

Photo points: Taken from E-W trail facing north, not landmark trees in background

October 2012 Before clearing

October 2012 After planting

Invasive cover: 09/2013
[To be completed: Note the major invasive species present and approximate % cover of each]

Other comments:
[[To be completed: This section could contain any other relevant information e.g. whether plants have been watered over the summer]

Management Unit: 15-13
Planting area: Area east of N-S trail and north of informal E-W trail
History: Cleared of Scot's broom by cutting 10/2012; planted 04/2013

Species	06/2013 #	09/2013	
		#	%
Holodiscus discolor/Oceanspray	2		
Pseudotsuga menziesii/Douglas-fir	4		
Quercus garryana/Garry oak	3		
Pinus contorta/Shore pine	1		
Ribes sanguineum/Red-flowering currant	3		
Rosa nutkana/Nootka rose	7		
Total	20		

Photo points: No before picture available. Taken from N-S trail facing east.

June 2013 After planting

Invasive cover: 09/2013
[To be completed: Note the major invasive species present and approximate % cover of each]

Other comments:
[To be completed: This section could contain any other relevant information e.g. whether plants have been watered over the summer]

Management Unit: 15-09
Planting area: EPS Plot 1
History: Cleared of Scot's broom, tilled, 6.5" GroCo, planted 2008; replanted 10/2012; tilled & replanted 03/2012 (data from Henry 2012).

	12/2008	03/2010	03/2010*	10/2010	03/2012	04/2012*	04/2013		09/2013	
	#	#	#	#	#	#	#	%	#	%
Pseudotsuga menziesii Douglas-fir	30	0	25	5	3	3	1	2		
Tsuga heterophylla Western hemlock	0	0	8	1	0	0	0	0		
Acer circinatum Vine maple	0	0	6	5	5	26	6	22		
Symphoricarpos albus Snowberry	0	0	7	6	6	6	8	114**		
Fraxinus latifolia Oregon ash	0	0	3	3	3	23	8	35		
Ribes sanguineum Red-flowering currant	0	0	3	3	3	33	21	64		
Holodiscus discolor Ocean spray	30	8	0	8	7	7	5	17		
Sambucus racemosa Red elderberry	9	9	0	9	8	8	6	67		
Alnus rubra Red alder	30	0	0	0	0	0	0	0		

*Numbers after replanting **Snowberry is starting to spread

Photopoints: No before picture available. Taken from E-W trail facing northwest corner of the site

After planting 12/2008 (Photo credit: C. Henry)

After maintenance clearing 03/2012

04/2012

06/2013

Invasive cover:
06/2012: Himalayan blackberry encroaching from west. Canada thistle stand, 10ft x 10 ft

09/2013
[To be completed: Note the major invasive species present and approximate % cover of each]

Other comments:
[To be completed: This section could contain any other relevant information e.g. whether plants have been watered over the summer]