Memorandum of Agreement: Kincaid Ravine Natural Area

The Kincaid Ravine Natural Area is a 3.6 acre parcel of steeply sloping forested land with a native, deciduous tree dominated canopy located south of NE 45th Street, west of the Burke Gilman Trail, extending south to the North Physics Laboratory, and east to the student housing at the top of the slope. The forest contains a mixed understory of both native and non-native species. Two delineated wetlands and an unnamed stream channel are present within the project boundaries.

Restoration of this area was initiated during the 2012-2013 academic year as a partnership between the University of Washington Grounds Management (UW Grounds), the University Landscape Architect, the Campus Sustainability Fund (CSF), EarthCorps (EC), the UW-Restoration Ecology Network (UW-REN) and the UW-chapter of the Society for Ecological Restoration (SER-UW). Project management, including the coordination of stakeholders and events, is maintained by a yearly rotation of graduate students in the Masters of Environmental Horticulture program. Funding from the CSF and the King Conservation District's (KCD) Seattle Community Partnership grant is currently allocated to continue restoration through 2018.

I. Purpose of the Agreement

This Memorandum of Agreement (MOA) sets out the terms by which UW departments and other entities will work together with EC and the KCD to implement an ecological restoration plan and a natural areas conservation plan, establishing roles, responsibilities, and activities that will be allowed within the Natural Area.

This site will remain a 'Natural Area', free from significant development for the duration of this agreement, which will extend for 10 years (2015-2025), at which point it will be reassessed and negotiated as necessary. Potential activities that violate the terms outlined below will be evaluated by all Project Partners for approval prior to commencing any work within the Natural Area.

<u>Project Partner Key Contacts:</u>

University of Washington Grounds (UW Grounds)
Howard Nakase, Manager of Grounds Operations
hmnakase@uw.edu
206.685.1407

University of Washington-Restoration Ecology Network (UW-REN)
Kern Ewing, Professor of Plant Ecology
kern@uw.edu
206.543.4426

Society for Ecological Restoration-UW Chapter (SER-UW)
Cameron McCallum, Acting President
mccallum.cameron@gmail.com

University Landscape Architect
Kristine Kenney
kkenney@uw.edu
206.685.6430

Student Project Manager
2013-2014 Martha Moritz, moritzms@uw.edu
2014-15 Matt Schwartz, mateos@uw.edu
2015-16 Dan Hintz, daniel.j.hintz@gmail.com

Campus Sustainability Fund (CSF)
Graham Golbuff, CSF Coordinator
csfcoord@uw.edu
206.221.0392

EarthCorps
Kym Foley, Project Manager
kym@earthcorps.org
206.322.9296 x202

These individuals are responsible for ensuring the conduct of the activities listed below.

II. Statement of Mutual Benefits and Interests

The University of Washington is dedicated to ensuring the sustainability of its natural resources, including its natural areas. Services provided by the Kincaid Ravine Natural Area include:

a) Educational opportunity for increasing the public's knowledge and awareness of natural areas, as well as UW's commitment to environmental sustainability.
b) Aesthetic beauty that characterizes this section of campus, and the 'Forest Reach' segment of the Burke Gilman Trail.
c) Stormwater runoff quantity reduction and quality improvement.
d) Air pollution removal, including ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter.
e) Carbon sequestration and carbon storage by 3.6 acres of vegetation.
f) Public health incidence reduction based on the effect of trees on air quality improvement.
g) Erosion control on steep slopes upland of wetlands (steepest grades between 50-70%).
h) Noise attenuation for North Campus from noise pollution (NE 45th St. and Montlake Boulevard).

i) Habitat for native wildlife including birds, amphibians, insects, and the symbionts upon which they depend.

The Parties agree to:

1) Site Boundaries: As indicated in MAP 1, the boundaries of Kincaid Ravine establish the physical perimeter that within which is subject to the Permitted Activities. The site area totals 3.6 acres. Inside this established perimeter is a no development zone, the sole permitted activities are education + recreation, restoration, conservation, and transportation (and existing easements), as defined below. In MAP 2, a zone of influence in adjacent areas is suggested to encourage native plant selection complementing Kincaid Ravine and Whitman Walk during development planning, in order to link the two habitats for imperiled native pollinators.
2) Permitted Activities: Within the site boundaries will be defined as a natural area, which is a no-development zone, dedicated to a long term conservation plan.
   a. Education + Recreation
      i. Maximized educational and enjoyment opportunities with educational signage and log benches located in a way to preserve the integrity of the vegetation by minimizing trampling for access.
      ii. Classroom field trips, independent research opportunities and public enjoyment will follow a minimal-disturbance etiquette.
   b. Ecological Restoration, as outlined in the "Kincaid Ravine Restoration and Stewardship Plan", written by Martha Moritz (7.1.14)
      i. Initial removal and continued maintenance control of invasive plant species, including noxious weeds.
      ii. Initial native plant installation and continued supplemental planting, as appropriate for site-specific conditions.
      iii. Initial removal and continued maintenance removal of trash and debris. In the case of hazardous materials this includes contracting appropriate contractors.
      iv. Initial and continued erosion control, utilizing native plants, and mulch or wood straw, to stabilize soil, with supplemental jute netting as needed.
      v. Wetland enhancement through vegetative restoration and the introduction of course woody debris. Permit-dependent, this may include excavation or re-routing to increase on-site infiltration.
   c. Natural Area Conservation
      i. Adjacent construction (i.e. north campus residence halls, Burke Gilman Trail expansion) will continue to enhance the areas in and around Kincaid Ravine, taking all necessary precautions to not enter or affect the Natural Area, through erosion, soil compaction, contaminated runoff, air pollution or other ecologically negative means.
   d. Transportation
      i. Minimized disturbance of the Natural Area and concentration of foot traffic is desired to ensure protection of the natural environment.
         1. Walking trail will consist of predominately natural materials, and maintain a natural aesthetic, including wooden stairs.
         2. Walking trail will be constrained in width to minimize disturbance.

3. Walking trail will be emphasized for daytime use and any proposed illumination will be assessed to minimize impact on nesting birds and other wildlife while providing safe passage for pedestrians.
4. Walking trail will minimize direct contact with wetlands by means of avoidance or boardwalks.
    a. Where impacts cannot be avoided, efforts will be taken to minimize and mitigate the amount of area impacted.

III. Roles and Responsibilities

Responsibilities of Student Project Manager

The Student Project Manager is a rotating position that has been filled by Masters of Environmental Horticulture (MEH) students, in fulfillment of their capstone project. Continuity of this role is overseen by the MEH faculty advisers.

a) Serve as central coordinator between project partners.
b) Coordinate on-site activities and all related logistics.
c) Manage grants and seek new funding sources.
d) Execute the goals of the Kincaid Ravine Restoration and Conservation Plans, adapt it and add appendices as needed, using the best available science to promote ecosystem health.
e) Encourage and coordinate specialty projects, such as 'Educational Nook', 'Wetland Enhancement' and 'Pollinator Patches' in the interest of creating a campus Forest Laboratory for use by UW classes and the public.

Responsibilities of SER-UW

SER-UW is a student club with rotating members and inconsistent funding. All responsibilities are subject to constraints on membership and funding, but efforts will be made to prioritize Kincaid Ravine restoration as one of their primary goals. SER-UW agrees to:

a) Conduct public work parties to maintain native plantings and control invasive plants.
b) Provide native plants from the SER-UW nursery.

Responsibilities of UW Grounds

a) Provide support for student initiatives that may include: use of tools, removal of vegetation, delivery of wood chips and course woody debris, and other resources when appropriate.
b) Facilitate cleanup of debris and hazardous materials.
c) Assume primary responsibility for stewardship, active maintenance of native plants and removal of invasive plants into the future, and in the case that the role of Student Project Manager is not filled.

Responsibility of EarthCorps

a) Complete restoration and conservation plans as indicated in Scope of Work through 2018 or until funding provides for.

Role of University Landscape Architect

a) Provide support for student initiatives that may include: plan review, annual on-site meetings, coordination with administration, and guidance when appropriate.

Roles of Funders

b) The CSF has provided $100,124.44 to initiate restoration plans and perform public outreach and student engagement through June 2016.
c) The KCD has funded $38,696 to continue engaging the community in successful restoration efforts through native plantings and invasive plant removal while addressing site safety and accessibility through December 2018.

Role of UW-REN

a) The UW-REN capstone group has allocated a group of students each academic year (2013-14, 2014-15) to perform restoration on a 1/8-1/3 acre plot within Kincaid Ravine. This provides a valuable educational experience for the students and contributes to accomplishing the goals of the Kincaid Ravine Restoration and Conservation Plan.

IV. Signatures of Project Partners

Paul Jenny, Senior Vice President, 29 May 2015

____

Howard Nakase, Manager of Grounds Operations, 06.23.15

____

Kym Foley, EarthCorps Project Manager, 6/8/2015

____

Kern Ewing, faculty, 7 May 2015

____

Cameron McCallum, SER-UW President 6/3/15

____

Graham Golbuff, CSF Coordinator, 5.7.15

2015

"Transforming Science into Best Practice: Restoring Process in Kincaid Ravine"

By: Matt Schwartz

"Indian plum". Illustration by Matt Schwartz

In partial fulfillment of a Master's of Environmental Horticulture degree

University of Washington, School of Environmental and Forest Sciences

Prepared for:

Committee co-chairs, Dr. Kern Ewing and Dr. Sarah Reichard

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INTRODUCTION

Kincaid Ravine (KR) is a 3.6 acre natural area under active restoration on the University of Washington (UW) Seattle campus. It is one of two natural areas on campus, is the largest greenspace on central campus, and is in development as an outdoor forested laboratory for students, researchers and the public.

The purpose of "Transforming Science into Best Practice: Restoring Process in Kincaid Ravine" is to complement the "Kincaid Ravine Restoration and Stewardship Plan", by Martha Moritz (2014). Effort was made to avoid redundancy of themes, figures and tables- instead I focus on new aspects of restoration ecology and project management in KR. Moritz provided a thorough Site Analysis and summaries of Project Stakeholders, Budget, and Student and Volunteer Involvement- of which I did not elaborate on. She also developed a Site Design, as well as Native Vegetation, Integrated Pest and Invasive Species Management Plans. I elaborate on these only where progress, updates or adaptive management is relevant to document. Furthermore, incoming student Project Manager (student PM) Dan Hintz is undertaking a complete analysis of the hydrology in KR. Therefore I treat the hydrology theme according to my observations and work, but do not expound to the point of repeating his efforts.

My primary goals as student PM from April 2014- June 2015, were to fulfill standard project management responsibilities (Chapter 2), expand vegetative restoration (Chapter 3) and dive into what I refer to as *process projects*- pollinator habitat creation, hydrological improvement, and climate change adaptation (Chapters 4-6). These process projects strike me as critical themes in the practice of urban restoration. I attempt to relate these subjects from macro to micro scales: from global > regional > Seattle > UW > KR. All miscellaneous undertakings that are not science-based can be found in Chapter 2 Project Management. Additionally, I drafted and coordinated the review process of a Memorandum of Agreement. This document defines KR as a natural area and legally binds UW to restoration and conservation of the area. It was reviewed, edited and signed by stakeholders (see Appendix A).

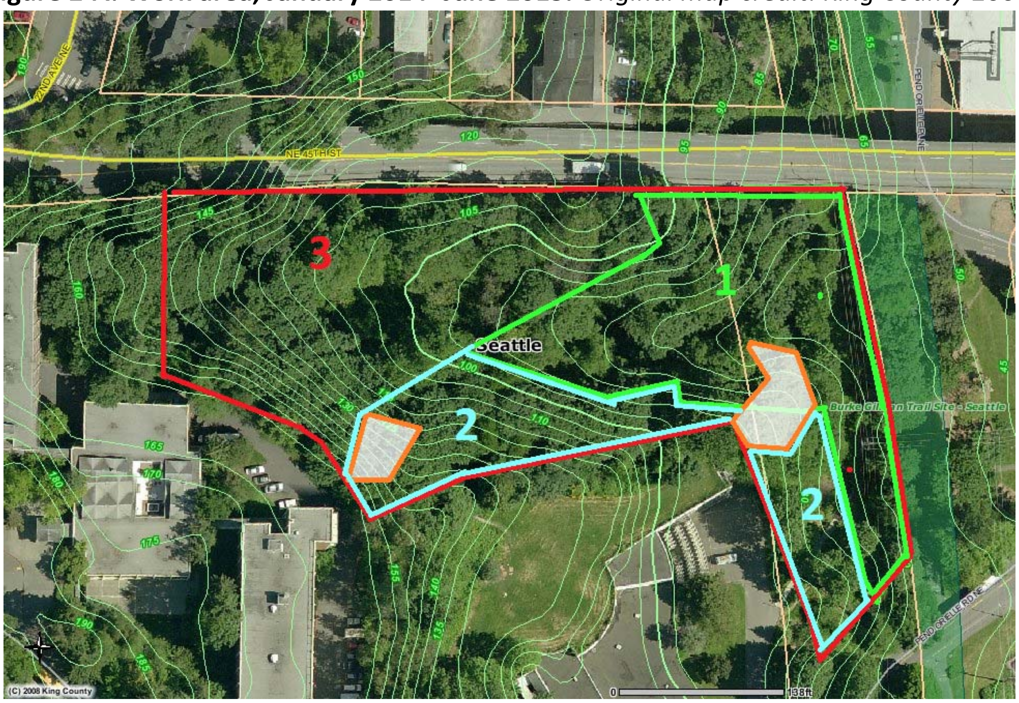
A partnership between UW Grounds Management (Grounds), the University Landscape Architect, the Campus Sustainability Fund (CSF), Earth Corps (EC), the UW-Restoration Ecology Network (UW-REN) and the UW-chapter of the Society for Ecological Restoration (SER-UW) was formed in 2013 to begin the restoration project. These relationships all continue to be maintained. Project management, including the coordination of stakeholders, is maintained by a yearly rotation of graduate students in the Masters of Environmental Horticulture program. This position is referred to as student Project Manager (student PM). King Conservation District (KCD) and Stewardship Partners (SP) joined the partnership in 2014. Funding from the CSF and the KCD Seattle Community Partnership grant is allocated to continue restoration through 2018.

Student PM refers to the author Matt Schwartz, unless otherwise indicated. Other student PMs include:
2013-2014 Martha Moritz, Master of Environmental Horticulture '14
2015-2016 Dan Hintz, Master of Environmental Horticulture candidate '16

Chapter 2 PROJECT MANAGEMENT

Project management during the 2014-15 academic year in the Kincaid Ravine (KR) Natural Area has centered on expanding restoration, maintaining restored areas, coordinating project partners and stakeholders, legally protecting KR (see Memorandum of Agreement, Appendix A), creating maps (see KR perimeter maps, Appendix A), coordinating stakeholders, expanding opportunities for education and outreach, managing interns and volunteers, writing and fulfilling grants, managing the budget, and documenting activities and accomplishments.

Figure 2-A: Work area, January 2014- June 2015. *Original map credit: King County 2008*



Key to Figure 2-A Polygons

Red= Kincaid Ravine (KR) perimeter
Area 1 Green= Initial Restoration Jan-June 2014, has received two rounds of weed control; invasive shrubs and trees herbicide injected; initial and supplemental plantings
Area 2 Blue= Secondary Restoration Nov 2014- April 2015, has received one round of weed control; invasive shrubs and trees herbicide injected; initial plantings
Area 3= Unrestored as of June 2015, invasive shrubs and trees herbicide injected
Orange= REN capstone sites

Section 2-1: Adapted Project Timeline

The project is occurring in several phases. The original KR Restoration and Stewardship Plan (Moritz 2014) had each phase pegged to certain dates. This adapted Project Timeline draws from the original timeline but is adapted to allow for each area to undergo phases as it is able:

1. <u>Planning phase</u> - This occurred for all areas from May- Dec of 2013. During that time, initial partnerships were formed, a restoration design was created, and baseline monitoring and site inventories were performed.

2. <u>Phase I</u> - This occurred in area 1 from Jan- June 2014; in area 2 from Nov-June 2015; and is pending in area 3 (due to herbicide permit waiting time and hazardous materials cleanup). Phase I work involves: removal of the encampment areas, removal of debris and hazardous materials, major removal of invasive species, initial installation of native plants, and other restoration work (e.g. slope stabilization, installing mulch, and creating maintenance access).

3. <u>Phase II</u> - This work began in area 1 in Nov 2015; and is pending in areas 2 and 3. Phase II involves two years of maintenance, including ongoing monitoring which will guide continued removal of invasive species regrowth, care for planted native species, supplemental planting, and the implementation of specialty projects (ie: pollinator patches, educational nook, hydrological improvements, climate change adaptation). This phase will be performed in partnership with UW Grounds, EarthCorps (EC), the Society for Ecological Restoration-UW chapter (SER-UW), Stewardship Partners (SP), and academic units (i.e. student project managers, REN Capstone).

4. <u>Phase III</u> - This will occur upon completion of phases I and II. The work during this time is anticipated to be minimal, and will be primarily performed by UW Grounds with support from SER-UW. The primary task will be continued invasive species maintenance. Ongoing support from volunteer groups, students, and community members can be integrated as part of a long-term stewardship plan.

Section 2-2: Project History

The project history was adapted from the KR Restoration and Stewardship Plan (Moritz 2014). This succinct and updated version provides a chronology of accomplishments in KR from March 2013-June 2015.

<u>Planning Phase</u>

1. March 2013
    - Original Letter Of Intent submitted to Campus Sustainability Fund (CSF) by Justin Hellier (UW alumni)
2. April 2013
    - Student project manager (student PM) position created for Martha Moritz, UW graduate student
    - Approval for KR restoration from UW Grounds, UW campus Landscape Architect Kristine Kenney, and UW Botanic Gardens (UWBG) faculty advisors received
3. May 2013
    - Project proposal, authored by Martha Moritz and Justin Hellier, approved by CSF
4. June-July 2013
    - Partnership secured with SER-UW regarding long-term project stewardship
    - Project approval and site access confirmed with adjacent landowner, SDOT
5. June 2013

- Initial site vegetation, habitat feature, wildlife, and hydrology inventory complete

6. August 2013
    - Baseline monitoring plot established
7. October 2013
    - Approval confirmed of EarthCorps Scope of Work and contract by UW Purchasing Department
8. October – December 2013
    - Restoration design planned and coordinated between EarthCorps PM Kym Foley and student PM Martha Moritz- installation plant list, prioritizing work areas, and restoration tasks
9. December 2013
    - Role finalized as Community Partner for Restoration Ecology Network (REN) Capstone class
    - Role finalized as Internship Advisor for Project on the Environment (POE) Capstone class

<u>Phases I and II</u>

10. February- April 2014
    - Phase I initial invasive species removal work was completed by EarthCorps, SER-UW, and REN Capstone group. The bulk of the green waste (Approximately 42 c.y) produced during this first phase of the work was hauled to UW managed Cedar Grove compost bins in order to reduce potential eyesores in the trail buffer area. EarthCorps crews injected 908 non-native woody trees with herbicide using an EZ Ject lance throughout the entire site. Targeted trees included cherry laurel (*Prunus laurocerasus*) and English holly (*Ilex aquifolium*)
    - Earth Corps' role was defined: (a) set the stage for volunteer events, (b) tackle the areas that are too steep or too sensitive for volunteers to work in, and (c) complete restoration activities in as great an area as possible. EC provided expertise in erosion control, working in wetlands, and invasive weed best management practices (BMPs) in accordance with Integrated Pest Management (IPM) principles. EC crews spent a total of 21 crew days from Feb- April 2014 in KR. Five of these crew days were the management of volunteer work parties.
    - Eight total volunteer work parties, led by EarthCorps, SER-UW, and REN
11. March – April 2014
    - Erosion control by EarthCorps, SER-UW, and REN of exposed soils following invasive species removal- jute netting, mulch, and wood straw were used in different areas of the site
    - Installation of native trees and shrubs throughout area 1 by EarthCorps, SER-UW, REN= combined 2,317 plants total installed on site
    - Martha Moritz begins transition of student program management to Matt Schwartz
12. June 2014
    - Student PMs Martha Moritz and Matt Schwartz are awarded supplementary funding ($29,945.44) from CSF

- EarthCorps PM Kym Foley awarded King Conservation District Seattle Community Partnership Grant ($38,696) for an additional 12 crew days for new restoration expansion, 12 crew days for maintenance, and 3 volunteer stewardship events through December 2018

13. Summer 2014
    - SER-UW hosts 3 work parties, removing invasive plants
14. Sept-Dec 2014
    - Phase I work begins for area 2, phase II work begins for area 1
    - POE Intern Andrew Jauhola secured as Plant Manager for winter quarter 2015
    - SER-UW hosts 4 work parties removing invasive plants, installing 2 pollinator patches
15. Feb 2015
    - Student PM Matt Schwartz and POE Intern Andrew Jauhola awarded CSF grant ($3,385) for educational signage and bench production
16. Feb- June 2015
    - SER-UW hosts 5 work parties removing invasive plants, installing 5 pollinator patches
    - Memorandum of Agreement drafted, reviewed, edited and signed by project partners
    - Hazardous materials cleanup complete
    - Student PM Dan Hintz awarded CSF grant ($5000) for KR Hydrological Assessment
    - Educational signage and benches designed, produced and installed

Section 2-3: Hazardous Materials

Figure 2-B: Kincaid Ravine haz-mat sites- *compiled by Kym Foley. Original map credit: King County iMAP – Property Information (http://www.metrokc.gov/GIS/iMAP)*

Debris and hazardous materials are ongoing concerns on site. Signs posted around the perimeter, ie: "Restoration Crews on Site Nov and Dec 2014" have proved useful to minimize homeless encampments. The issue of encampments and debris accumulation is a sensitive one. Parties, drug use and an accumulation of hypodermic needles in KR have created a serious gap in public safety on the UW campus. As KR is adjacent to north campus dormitories, this is a legitimate security problem. At the same time, considerations about displacing homeless populations have not been made but should be evaluated in the future. Reaching out to a local shelter, soup kitchen or homeless services provider would be an appropriate course of action as development in the University District and the greater Seattle area further gentrifies and displaces the poorest and most vulnerable sectors of society.

The following work order was submitted in Sept 2014 and returned as completed in April 2015 by the Grounds Department, in reference to hypodermic needles found in abundance at legacy encampments on site:

Work Order # 332064

Requested: 9/19/2014 Completed: 4/27/2015

"GROUNDS CLEANUP OF TRASH FROM HOMELESS ENCAMPMENTS IN CERTAIN SELECT AREAS OF KINCAID RAVINE BEHIND MCCARTY HALL. THIS INCLUDES SOILED CLOTHING, LARGER TRASH ITEMS LIKE MATTRESSES AND POSSIBLY HAZMAT ITEMS LIKE NEEDLES. THIS CLEANUP WILL ALLOW CONTRACTORS EARTH CORPS AS WELL AS STUDENT VOLUNTEERS TO WORK SAFELY AT RESTORATION ACTIVITIES STARTING ON SEPT 30TH. WE FEAR THAT A STUDENT VOLUNTEER OR CONTRACTED WORKER WILL BE AT RISK FOR CONTACT WITH SAID ITEMS."

Section 2-4: Educational Nook

"A key advantage of restoration in urban areas is the higher social value that nearby and green, semi-natural space has to local residents. This allows a greater concentration of resources, financial and labor, on a per-acre basis than is the case in most remote settings." (Apostol and Sinclair 2006)

The development of educational signage and benches for KR is a specialty project funded by a CSF grant. It includes installation of two benches hand milled from leftover timber cut down by the campus arborist, and produced by the Facilities Department. Three 18" x 24" educational signs designed by UW Museology students and produced professionally by Fossil Graphics will be situated around the benches. This educational "nook" is located on the eastern perimeter of KR, and borders the Burke Gilman Trail (BGT). An educational nook will directly amplify the environmental impact of the KR restoration project. Passersby will be able to connect the visible vegetation changes and flower blooms in the site, with written text and images that explain the purpose of these changes. It is also a technique for drawing more volunteers into the project as a way to channel the enthusiasm of the local community. This is an excellent opportunity for students from multiple departments to work with UW personnel to successfully fund, design, produce and install signage and benches. This project was approved by Landscape Architect Kristine Kenney, with the parameters that sign size would be relatively small and all installed items could be moved if need be.

Signage- Education, Outreach, & Behavior Change

Signage at this location will be an impactful tool to a) spread awareness about forest restoration ecology, and b) publicly recognize the partners and funders who have made this project possible. The location is considered high visibility due to the volume of pedestrians and bicyclists that travel the BGT, which follows the eastern perimeter of KR. The BGT will be reconstructed over the next several years to accommodate this high volume of users. Elisabeth McLaughlin, architect of the Forest Segment of the BGT reconstruction, is enthusiastic about incorporating this educational nook into design plans for the new trail to optimize the chance for pedestrians and bicyclists to take a rest off of the trail and learn about the restoration project (McLaughlin, E., personal communication, 11/3/14). Furthermore, many KR work party volunteers are accustomed to students, local community members and BGT users approaching to ask more about the project, or to comment on the visible success. Signage will legitimize the restoration by deeming it official, and invite curious passersby to become part of this natural oasis for a few minutes.

The signage is made of phenolic resin with a 10 year graffiti proof warranty (Fossil Industries). The signs will be solidly mounted on a single post, and can be moved if needed.

<u>Benches- Feasibility & Sustainability</u>

Precedence for bench production and installation by SER-UW at the Whitman Walk restoration site has facilitated the process for connecting with the UW Facilities Maintenance and Construction department to implement this project. Whitman Walk is a SER-UW native plant garden project on campus located southwest of KR. Benches were successfully installed at Whitman Walk, visible in Figure 2-C. Ed McKinley of UW Facilities Services has met with the KR student PM and set aside hazard tree timber for bench production. The sustainability factor of keeping dead wood on campus is marked. Rather than importing produced benches, or selling this lumber off campus, these downed trees will live out there life span on campus. We aspire to further smooth out this process in order to encourage more student projects to utilize UW timber for benches around campus. Additionally, a continuity of signage and bench design that will connect Whitman Walk and KR, creates an educational flow of environmental concepts throughout the campus. Both projects are working with the same designers and production company to achieve this design flow. As a future stop on the 'green tours of campus', already hosted by the UW- Environmental Stewardship and Sustainability (ESS) Office, a clear and connected culture of outreach will be achieved.

The benches are fixed in the ground, each with 2 long galvanized metal stakes. The benches are extremely heavy but can be moved as necessary. A chain with I-hooks and a lock will ensure that they are not stolen. They will eventually decompose in their natural process but will maintain their function for decades.

Figure 2-C: Bench design by Ed McKinley, Facilities Services

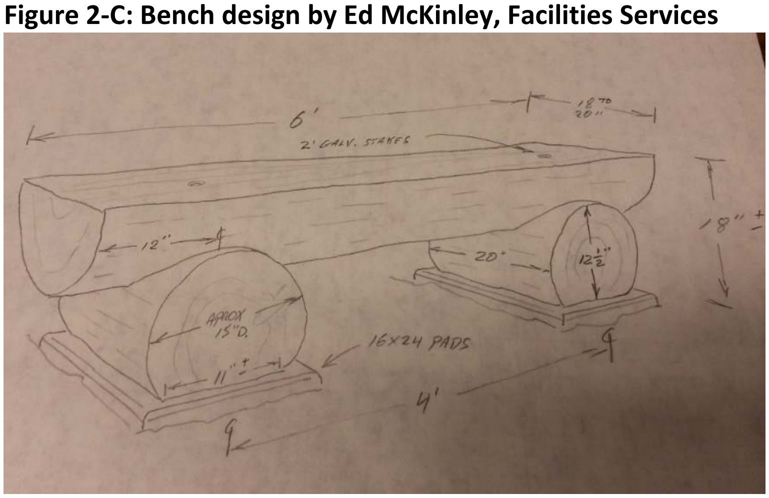


Figure 2-D: Bench installation at Whitman Walk

<u>Section 2-5: Educational Outreach</u>

Outreach for KR has included an electronic newsletter, presentations, a poster and a published article, all detailed below. The purpose of these outreach strategies is to increase awareness and support of restoration in the KR Natural Area, and of ecological restoration in general. The target audience is the student body, faculty, the general public and the ecological restoration community.

Presentations/posters about KR delivered by student PM May 2014- June 2015:

- SEFS Graduate Student Symposium: Clear as Mud, Interpreting a Changing Environment, 3/6/15: *“Restoring Process to a Puget Sound Lowland Urban Forest”*
- International Forestry Students Association: PechaKucha, 2/14/15: *“Transforming Science into Best Practice: Tools for restoring Native Pollinator Habitat in Pacific NW Urban Forests”*
- Classes SEFS 561 Public Presentation in Urban Horticulture, and SEFS 520 Introduction to Geographic Information Systems in Forest Resources: *“Restoring Kincaid Ravine: Healing for an Urban Forest”*
- Elizabeth Miller Library: Fifth Annual UWBG Student Mini-Poster Exhibit, 5/9/14- 6/19/14: Poster on display- *“Restoring Kincaid Ravine”*
- Society for Ecological Restoration (SER) World conference: “Towards resilient ecosystems: restoring the urban, the rural and the wild”, Manchester, England, 9/23/15-9/27/15: Abstract for oral presentation accepted- “*Transforming science into best practice: Tools for restoring native pollinator habitat in Pacific NW urban forests”*

Publications related to KR written by student PM:

- *“Restoring Native Pollinator Habitat: Puget Sound Lowlands”.* Douglasia, Journal of the WA Native Plant Society, Spring 2015 (see Appendix C)
- *“Biodiversity in Restoration: Pollinator Plant Lists”.* www.wnps.org, website of the WA Native Plant Society

Figure 2-E: Temporary signage- *designed and installed Oct 2014*

Section 2-6: Budget

The budget for KR includes a combination of four separate grants from two different sources, detailed below. Currently, funding is allocated through 2018 and combined funding totals $147,205.44. The budget is managed by the student PM.

Initial Funding: $70,179, May 2013. CSF award to Martha Moritz and Justin Hellier

Supplemental funding

- $ 29,945.44, June 2014. CSF award for Additional Restoration Crew Days to student PMs Martha Moritz and Matt Schwartz. Funds added to existing UW-KR budget ($100,124.44 total). Budget administrator: Carrie Cone, Center for Urban Horticulture (CUH).
- $ 38,696, June 2014. KCD Seattle Community Partnership Grant awarded to EC PM Kym Foley for an additional 12 crew days for new restoration expansion, 12 crew days for maintenance, and 3 volunteer stewardship events through December 2018. Funds are maintained by EC separate from the UW-KR budget. Budget administrator: EarthCorps
- $ 3,385, Feb 2015. CSF award for Educational Signage + Benches to student PM Matt Schwartz and POE Intern Andrew Jauhola. Funds are maintained separate from original UW-KR budget. Budget administrator: Wendy Starr, School of Environmental and Forest Sciences SEFS).
- $5,000, Feb 2015. CSF award for Hydrological Assessment to student PM Dan Hintz. Funds are maintained separate from original UW-KR budget. Budget administrator: Carrie Cone, CUH.

Expenditures

Key for Table 2-A

***01** Salaries + Wages, **07** Retirement + Benefits, **08** Grants + Subsidies* refer to stipends for student PMs

***03** Other Contractual Services* refers to costs associated with hosting volunteer work parties and the contract with EarthCorps- which includes crew days, PM hours, materials, parking and associated costs

05 *Supplies + Materials* refers to outreach materials and plants

Table 2-A: My Financial Desktop summary

Home > Reports > TRANSACTION SUMMARY   TRANSACTIONS ▾ REPORTS

View Budget # 164974   Biennium ▾ 2013 ▾ Go

Reporting Period: Biennium 2013 - July 1, 2013 through June 30, 2015

16-4974 CSF KINCAID RAVINE   Profile   **Budget period:** 07/01/2013 - 06/30/2015   **Status:** Open to revenue and expenditures

Account Code	Description	Transaction Date	Reference	Reference	FTE	Amount
01	**SALARIES AND WAGES**					**$3,000.00**
03	**OTHER CONTRACTUAL SERV**					**$55,104.89**
03-44	CAMPUS SERV-PRINT.PLNT					$14.06
03-49	CAMPUS SERVICES OTHER					$374.51
03-58	OUT/SERV-PRINT/REPROD.					$77.63
03-75	MEALS/COFFEE & REFRESH					$48.22
03-99	MISC CONTRACTUAL SERV					$54,590.47
03-99-00	EARTHCORPS	04/03/2014	T75591900	4513		$11,717.32
03-99-00	EARTHCORPS	05/12/2014	T75591900	*4549		$14,654.90
03-99-00	EARTHCORPS	05/12/2014	T75591900	5011401		$7,975.20
03-99-00	EARTHCORPS	09/22/2014	T75591900	4828		$5,183.46
03-99-00	EARTHCORPS	12/10/2014	T75591900	4967		$8,651.05
03-99-00	EARTHCORPS	02/26/2015	T75591900	*5058		$6,408.54
05	**SUPPLIES AND MATERIALS**					**$942.75**
07	**RETIREMENT & BENEFITS**					**$687.00**
08	**GRANTS & SUBSIDIES**					**$4,350.00**
08-02	STIPENDS					$4,350.00
	TOTAL EXPENDITURES					**$64,084.64**
9	**TOTAL REVENUE**					**($29,945.44)**
9-480	TRANSFERS-IN					($29,945.44)
9-480-98	FY14 SAF-CSF RT13-353	06/30/2014	JV# JVBO398			($29,945.44)
9-788	BEGINNING FUND BALANCE					$0.00
9-788-00	(Balance Forwarded - TC32)	08/09/2013		0000001		~~($70,179.00)~~

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Chapter 3 VEGETATION

"…it turns out that urban areas may have much more conservation value than had previously been thought. Ecologists increasingly are finding cities to be interesting ecosystems with surprisingly high levels of biodiversity. Improved understanding and protection of these ecosystems may contribute greatly to wider conservation efforts." (Stille 2002)

Pre-restoration, Kincaid Ravine (KR) was in a neglected, yet relatively stable condition. This stability allowed for the aggressive proliferation of already established invasive weeds through vegetative reproduction. English ivy (*Hedera helix),* hedge false bindweed *(Calystegia sepium),* Himalayan blackberry (*Rubus armeniacus),* and other non-native plants, dominated the vegetation through unimpeded rhizomatous, root and stolon reproduction, respectively. Once restoration began, disturbances in the soil and increased access to light changed the ground moisture and temperature, in tandem, to trigger germination of many other weed species seeds from the seed bank (Ziska and Dukes 2011). A vegetation management plan was outlined in the KR Restoration and Stewardship Plan (Moritz 2014). In addition, adaptive vegetation management is implemented in KR and detailed here. This takes into account several concepts of plant competition, and includes strategies to control invasive plants, encourage native plant genetic diversity and survivorship, and promote a rich soil community. Plant installation totals are also documented.

Section 3-1: Plant Competition

Inter-species competition is principally confined by three limiting factors: water, light and nutrient availability (Ziska and Dukes 2011). The struggle for resources between well-established invasive plants and newly installed native plants is determined by many factors. Key plant characteristics include: fecundity, vegetative reproduction (stolons, rhizomes, etc), seed production, use of C3 or C4 pathways, seed viability and longevity, early flowering or long flowering intervals, seed dispersal mechanisms, and root formations (mat forming, deep taproot, etc.) (Ziska and Dukes 2011).

Two factors that may allow invasive plants to dominate include the 'enemy release' and 'chemical exudate' hypotheses (Ziska and Dukes 2011). Enemy release suggests that an exotic plant, once removed from its home range, escapes its natural pathogens and herbivores (Ziska and Dukes 2011). This releases the plant to grow unchecked, and thrive over native plants which are still limited by natural enemies. Chemical exudate refers to the poisoning of neighboring plants or of the microbial community by invasive plants to directly sabotage the competition (Ziska and Dukes 2011). Many introduced species of plants have invaded KR and likely disturb associations of the historic soil community. Garlic mustard is an example that is present in KR. It does not associate with mycorrhizae, and is shown to release compounds that inhibit mycorrhizal associations between fungi and trees (Prati and Bossdorf 2004; Stinson et al. 2006; Nardi 2007).

In KR, the Burke Gilman trail (BGT) serves as a corridor for seed dispersal, with pedestrian, bicycle and avian vectors. Therefore, parts of the eastern and southeastern perimeter have been planted with hedgerow type plants to reduce the spread of invasive weed seeds.

Section 3-2: Adaptive Vegetation Management

Vegetative restoration in KR has followed the strategies, planting zones and site design as outlined in the KR Restoration and Stewardship Plan (Mortiz 2014), including plant installation, and manual, chemical and cultural control methods of invasive plant removal. Adherence to the UW Grounds Department *Integrated Pest*

Management for Outdoor Landscapes (2012) document has continued. Adaptive management tactics of June 2014-June 2015 focused on increasing the diversity, structural complexity and competitiveness of native vegetation and soils, and included the following:

- 100% of green waste was left on site in compost piles to enrich nutrient cycling, provide overwintering pollinator habitat, and to minimize the financial and ecological costs of additional labor and transport.
- Additional chemical control of *Clematis vitalba, Calystegia sepium, Hedera helix* and *Rubus armeniacus* by foliar herbicide applications on the steepest portions of the northwest slope is planned for early summer 2015.
- A reed canarygrass (RCG) (*Phalaris arundinacea*) control method called "tying" was implemented in 2014 where handfuls of RCG were tied into knots. This theoretically allowed the grass to continue to grow, but the weight of the knots decreases the vertical height of the grass, prohibiting inflorescence development. This technique did not appear to make a substantial difference by the time new RCG shoots came up in 2015 and has been ceased. A new weed control experiment was set up in April 2015 (detailed in Section 3-3).
- Native planting density was generally increased throughout the site to crowd out plant invaders.
- Mycorrhizal soil amendments of *Fungi Perfecti Plant Success tablets* were placed in the bottom of planting holes prior to installing plants by EarthCorps in November 2014. Plants up to 1 ft tall received 2 tabs and plants 1-2 ft tall received 4 tabs, in accordance with Fungi Perfecti Instructions. Plant Success Tabs contain endo- and ectomycorrhizal spore masses of the following species: *Glomus mosseae, Glomus intraradices, Glomus clarum, Glomus monosporus, Glomus deserticola, Glomus brasilianum, Gigaspora margarita, Pisolithus tinctorus* and four species of *Rhizopogon*. The makeup of the current mycorrhizal community is a subject for further research. The decision to utilize these amendments was made since they were obtained very inexpensively by the EarthCorps PM, are expected to improve plant establishment, and are assumed do no harm.
- Flagging was not originally attached to installed plant saplings in order to reduce a negative impact to site aesthetics. However, with the initiation of herbaceous plantings, pin flags are used to minimize trampling until these plants are established, at which point pin flags will be removed.

Section 3-3: Reed Canarygrass (RCG) Experiment

"Reed canarygrass is an aggressive grass species that is difficult to remove manually, and the location of the invasive species in a wetland area makes it undesirable to treat chemically. The grass species is sun loving, and the use of fast-growing native vegetation… will eventually shade out the grass." -KR Restoration and Stewardship Plan (Moritz 2014)

In April 2015, a cultural control experiment of reed canarygrass located in the lower portion of wetland E was implemented by creating three 12 x 12 plots. The purpose is to compare three control methods over a timeline of two years. Percent cover and height of RCG will be measured by the incoming student PM, Dan Hintz. Due to limited space and an urgent need to control the RCG, there is no control plot void of treatments. The three plots:

1) Burlap coverage: RCG mowed (using machetes); area covered in 3 ply burlap sacks; not planted
2) Live stake shading: RCG mowed (using machetes); area planted with live woody stakes at a density of 12-18" o.c.

3) Grub and mulch: RCG grubbed (root material removed as completely as possible); area planted at a density of 6” o.c. with herbaceous plants; mulched 4” thick

The entire area of infestation was mowed once in February 2014, but by the time of this experiment in April 2015 it had expanded its domain as the removal of surrounding invasive plants allowed more light into the area. Live cuttings were installed throughout the wetland in February 2014, except in the areas where plots 1 and 3 were eventually established. The live stakes of plot 2 include: salmonberry (*Rubus spectabilis*), red osier dogwood (*Cornus sericea*), Pacific willow *(Salix lasiandra*), and Scouler’s willow (*Salix scouleriana)*, 12-18” on center and to a minimum depth of 12”. The herbaceous plants of plot 3 include: wild ginger (*Asarum caudatum*), seep monkey flower (*Erythrathe guttata*), large leaved avens (*Geum macrophyllum*), tiger lily (*Lilium columbianum*), Cascade penstemon (*Penstemon serrulatus*), and coastal hedge nettle (*Stachys chamissonis var. colleyeae).*

Figure 3-A: RCG test plots pre-treatment

Figure 3-B: RCG test plots post-treatment

Figure 3-C: View of Live Stake plot #2

Section 3-4: Genetic Diversity

Since restoration began in KR, native plants have been sourced from multiple locations and nurseries. Although the genetic diversity of existing pre-restoration native plants in KR is unknown, varied sourcing diversifies the genetics of all installed plant species. A combination of bare root, live stake, 1 gallon container plants and 2 gallon container plants were obtained from nurseries and native plant salvages. Herbaceous plants for pollinator patches were primarily grown in the Society for Ecological Restoration-UW (SER-UW) nursery from seeds gathered from many locations.

Nursery sources: King Conservation District plant sales; Snohomish Conservation District plant sales; WA Native Plant Society plant sales; Hanging Gardens Native Plant Nursery in Black Diamond, WA; Fourth Corner Nursery located in Bellingham, WA

Wildcraft/ salvage plant locations: on-site live stakes harvested from Kincaid Ravine wetland E; plants harvested from Washington Park Arboretum; six different salvage locations in Issaquah, WA and Snoqualmie, WA

Seed sources: WA Native Plant Society plant sales; wildcrafted from various locations throughout western Washington and the San Juan Islands by SER-UW volunteers

Section 3-5: Plant Lists

As of June 2015, a total of 3,755 native plants and 73 different species have been installed in KR since restoration began in January 2014. Installation numbers and species are detailed below. Installation has been conducted by SER-UW, EarthCorps and two REN capstone classes.

SER-UW hosted 12 total work parties (between 3-4 work parties every quarter) from summer 2014- summer 2015. Plant installation focused on the herbaceous and woody shrubs in a 1/8 acre at the southwestern corner, and one acre over the entire eastern side of the ravine, with a particular focus on pollinator patches and the BGT border.

Table 3-a: Plant Installation List- SER-UW, 2014-2015

SER-UW 2014-15	**Total**	**331**
Trees		
Acer circinatum	vine maple	2
Alnus rubra	red alder	2
Tsuga heterophylla	western hemlock	12
Shrubs		
Amelanchier alnifolia	serviceberry	1
Holodiscus discolor	oceanspray	5
Lonicera hispidula	hairy honeysuckle	1
Lonicera involucrata	black twinberry	14
Berberis aquifolium	Oregon grape	3
Oplopanax horridus	devil's club	15
Philadelphus lewisii	California mock orange	1
Physocarpus capitatus	Pacific ninebark	5
Rhododendron macrophyllum	Pacific rhododendron	1
Ribes lacustre	swamp gooseberry	5
Ribes sanguineum	red flowering currant	5
Rosa gymnocarpa	woods rose	29
Rubus leucodermis	black cap raspberry	4
Rubus parviflorus	thimbleberry	5
Rubus spectabilis	salmonberry	30
Sambucus racemosa	red elderberry	13
Symphoricarpos albus	snowberry	12

Vaccinium ovatum	evergreen huckleberry	3
Vaccinium parvifolium	red huckleberry	8
Viburnum edule	highbush cranberry	5
Herbs		
Achillea millefolium	yarrow	26
Aquilegia formosa	red columbine	5
Asarum caudatum	wild ginger	2
Athyrium filix-femina	lady fern	5
Carex sitchensis	Sitka sedge	7
Claytonia sibirica	Siberian miner's lettuce	2
Dicentra formosa	bleeding heart	7
Eriophyllum lanatum	Oregon sunshine	2
Erythranthe guttata	seep monkey flower	4
Gaultheria shallon	salal	4
Geum macrophyllum	largeleaf avens	4
Lilium columbianum	tiger lily	2
Lupinus latifolius	broadleaf lupine	3
Maianthemum dilatatum	false lily-of-the-valley	2
Penstemon serrulatus	Cascade penstemon	5
Polystichum munitum	sword fern	18
Pteridium aquilinum	bracken fern	5
Solidago canadensis	Canada goldenrod	12
Stachys chamissonis var. colleyeae	coastal hedge nettle	2
Tellima grandiflora	fringecup	10
Tolmiea menziesii	piggyback plant	22

EarthCorps (EC) planting plans and lists were developed and agreed upon by EC PM Kym Foley, and UW student PMs Martha Moritz and Matt Schwartz. Plants were placed on site by EC crews. Trees were generally installed 6' on center (o.c.) with shrubs placed at 3' o.c..

Table 3-b: Plant Installation List- EC, 2014-2015

EARTHCORPS 2014-15	**Total**	**2591**
Trees		
Acer circinatum	vine maple	75
Corylus cornuta	beaked hazelnut	68
Acer macrophyllum	bigleaf maple	20
Alnus rubra	red alder	5
Fraxinus latifolia	Oregon ash	10
Picea sitchensis	Sitka spruce	30
Pinus contorta	shore pine	15
Pseudotsuga menziesii	Douglas fir	135
Rhamnus purshiana	cascara	20
Salix hookeriana	hooker's willow	50

Salix sitchensis	Sitka willow	100
Thuja plicata	western red cedar	245
Tsuga heterophylla	western hemlock	20
Shrubs		
Cornus sericea	red osier dogwood	500
Gaultheria shallon	salal	40
Holodiscus discolor	oceanspray	65
Lonicera involucrata	black twinberry	45
Berberis nervosa	dull Oregon grape	230
Oemleria cerasiformis	Indian plum	125
Physocarpus capitatus	Pacific ninebark	35
Ribes sanguineum	red flowering currant	23
Rosa nutkana	nootka rose	40
Rubus parviflorus	thimbleberry	55
Rubus spectabilis	salmonberry	60
Sambucus racemosa	red elderberry	160
Symphoricarpos albus	snowberry	95
Vaccinium ovatum	evergreen huckleberry	20
Herbs		
Athyrium filix-femina	lady fern	30
Polystichum munitum	sword fern	275

Restoration Ecology (REN) capstone class members took over the restoration planning and activities of 1/8 and 1/3 of an acre in the southeastern and southwestern portions of the site in 2014 and 2015, respectively. A variety of trees, shrubs, and groundcovers were installed in this planting areas, ranging from wetland adapted plants to upland species more tolerant of drier conditions. The plant installation plan completed by the REN Capstone group was developed by the students, and then confirmed by the student PMs.

Table 3-c: Plant Installation List- REN, 2014-2015

REN 2014	**Total**	**833**
Trees		
Abies grandis	grand fir	9
Acer circinatum	vine maple	50
Acer macrophyllum	bigleaf maple	20
Alnus rubra	red alder	11
Prunus emarginata	bitter cherry	10
Prunus virginiana	chokecherry	20
Pseudotsuga menziesii	Douglas fir	23
Salix lasiandra	Pacific willow	10
Salix scouleriana	scouler's willow	14
Thuja plicata	western red cedar	25
Tsuga heterophylla	western hemlock	20
Rhamnus purshiana	cascara	5

Shrubs

Cornus sericea	red osier dogwood	20
Fragaria chiloensis	coastal strawberry	5
Holodiscus discolor	oceanspray	60
Lonicera ciliosa	orange honeysuckle	1
Berberis aquifolium	tall Oregon grape	15
Berberis nervosa	dull Oregon grape	30
Oemleria cerasiformis	Indian plum	48
Oplopanax horridus	devil's club	2
Philadelphus lewisii	California mock orange	9
Physocarpus capitatus	Pacific ninebark	24
Ribes sanguineum	red flowering currant	10
Rosa nutkana	nootka rose	31
Rubus parviflorus	thimbleberry	63
Rubus spectabilis	salmonberry	38
Sambucus racemosa	red elderberry	16
Symphoricarpos albus	snowberry	59
Vaccinium ovatum	evergreen huckleberry	6
Vaccinium parvifolium	red huckleberry	3

Herbs

Achillea millefolium	yarrow	3
Athyrium filix-femina	lady fern	32
Blechnum spicant	deer fern	20
Carex obnupta	slough sedge	2
Dicentra formosa	bleeding heart	2
Gaultheria shallon	salal	6
Geum macrohpyllum	largeleaf avens	20
Juncus ensifolius	swordleaf rush	1
Maianthemum dilatatum	false lily-of-the-valley	32
Oxalis oregana	redwood sorrel	2
Polystichum munitum	sword fern	20
Solidago canadensis	Canada goldenrod	40
Tellima grandiflora	fringecup	2
Tolmiea menziesii	piggyback plant	2
Trillium ovatum	western trillium	1

Section 3-6: Future Research

- Further invasive plant control techniques
- Techniques for forest resilience to decrease the invasibility of ecosystems
- Use of endophytes to boost native plant establishment, specifically to filter water pollution in the stream and wetland areas

- Soil testing- the interplay between adjacent development, historical neglect and hydrological complexity make KR a fascinating study site, including:
    - soil profiles
    - soil pollution
    - soil microbial community
    - potential for soil amendments
    - nutrient availability as it determines plant competition
    - nutrient cycling as affected by invasive plants

Chapter 4 POLLINATOR HABITAT

Figure 4-A: *Nymphalis antiopa,* mourning cloak butterfly- *spotted 3/18/15*

Figure 4-B: *Vanessa atalanta*, red admiral butterfly- *spotted Earth Day 4/22/15*

As in many discontinuous urban forests, Kincaid Ravine (KR) restoration efforts cannot target habitat creation for large wildlife species. However, habitat for birds and insects, several of which are endangered in the Pacific NW, (Xerces Society 2015) has critical potential in urban restoration projects. In November 2014 a *process project* was initiated to create native pollinator habitat in KR. Research into pollinator resource and structural requirements resulted in the development of pollinator plant lists. The research was supported by the WA Native Plant Society (WNPS) and an article by the student PM was published in the WNPS journal, *Douglasia* (see Appendix C). Several of the plant combinations on the lists were outplanted in KR and habitat structures were installed.

Section 4-1: Biodiversity in Restoration

In many ecological restoration projects, restoring abiotic *process* takes priority over biological *biodiversity* as the primary objective, and is often the logical first step. However, the pollination process is a critical one. Incorporating diverse species, particularly flowering plants, into the plant palette, allows the native plant-pollinator relationship to support restoration projects in meeting long term goals.

Autogenic regeneration of a native ecosystem is a process reliant on the pollination feedback loop. Resilience of the ecosystem is strengthened by pollinators, in tandem with seed dispersers, because they enable long distance gene flow within a site and between neighboring habitat fragments. A healthy pollinator population facilitates a higher percent cover of more genetically diverse native plants, than a site without. This is critical in the first few years of restoration, establishing natives in the spaces that invasive plants would race to fill following initial removal. Furthermore, many invertebrate pollinators themselves provide an important source of fats and proteins for the food web.

Figure 4-C: Nearest green spaces to KR- *Ravenna Woods (RW), Union Bay Natural Area (UBNA). Map credit- Google maps*

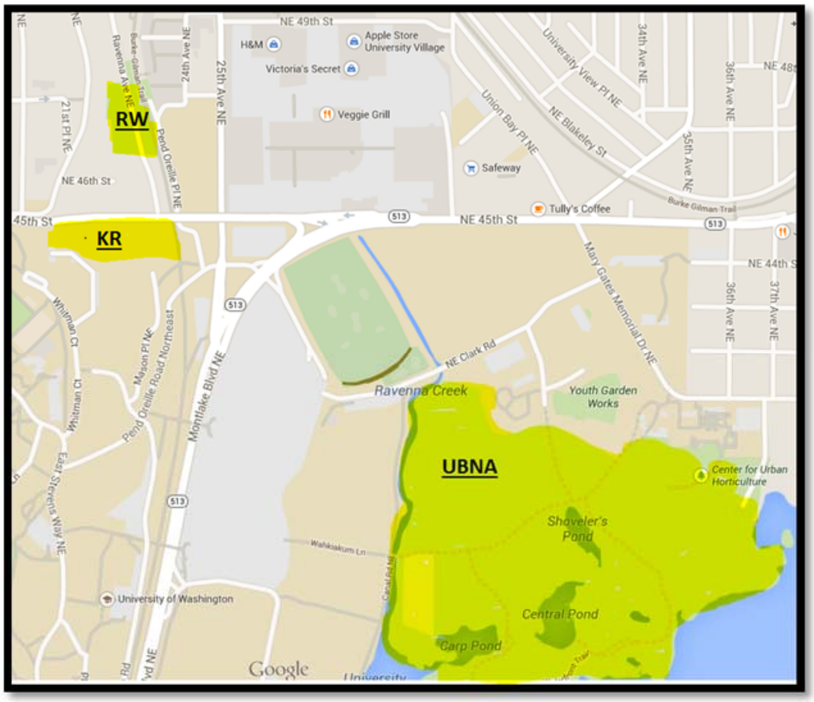
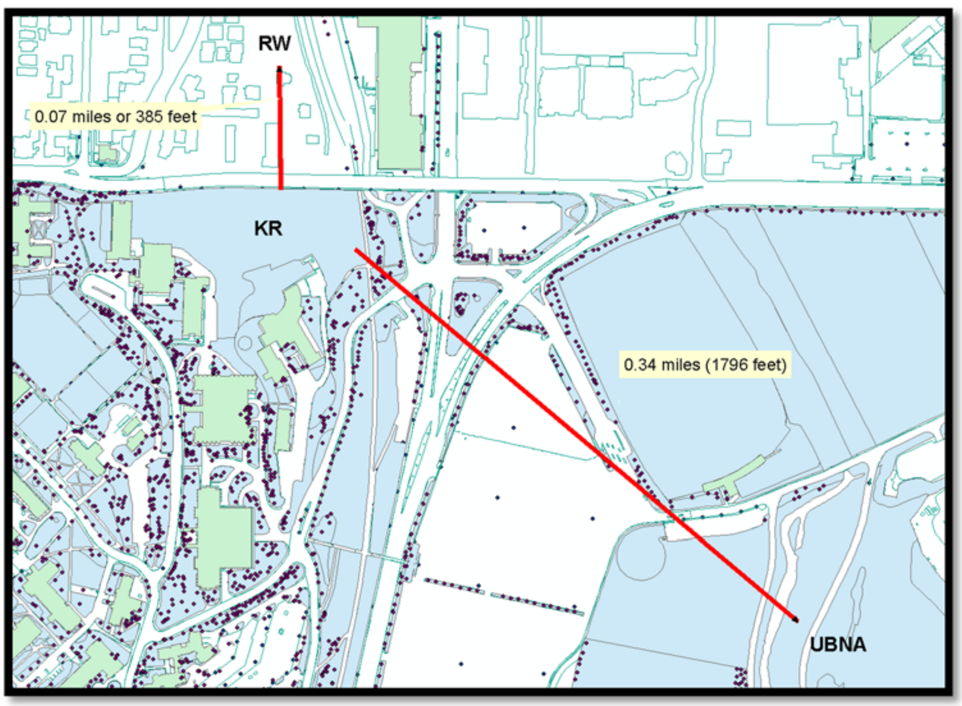


Figure 4-D: Distances to nearest green spaces to KR- *reveals the distances that some pollinators might travel between habitat. 385 ft to Ravenna Woods (RW), 0.34 miles to Union Bay Natural Area (UBNA)*



Section 4-2: Native Pollinator/Plant Mutualisms

Angiosperms (flowering plants) have two basic strategies to transport pollen grains from the anther of the male stamen to the stigma of the female pistil. About 20 percent of angiosperms reproduce abiotically by wind or water, and about 80 percent reproduce biotically through animal vectors. The plant-pollinator partnership evolved over millennia, developing an enduring ecological relationship. Flower shape, coloring, scent, and high-sugar nectar are examples of pollination syndromes, evolved plant traits to attract animal pollinators (Mader et al. 2011). Birds, bats, bees, butterflies, moths, flies, wasps, and beetles are examples of pollinators that feed on the sweet flower nectar, protein-rich pollen, and/or other plant parts. The abundance (population quantity) and diversity (number and even distribution of different species) of both native plants and their pollinator counterparts is often mutually dependent.

The native plant/pollinator mutualism is under grave threat (Mader et al. 2011). Habitat is increasingly being lost to development, and the slivers that remain are fragmented or degraded by light, noise, and air pollution. The ubiquity of pesticides in modern agriculture and landscaping damages pollinators, such as the implication of neonicotinoids in disrupting the homing mechanisms in bees, leading to Colony Collapse Disorder (Lu 2014). In many areas, the proliferation of non-native plants and pollinators introduces disease, outcompetes, and ultimately displaces the abundance and diversity of native species. Pollination may be a factor in plant competition as invasives do not rely on specialist pollinators. They tend towards high pollen-volume wind dispersion or production of nectar rich flowers to attract generalist pollinators (Ziska and Dukes 2011). In contrast, native plants who have coevolved specialist pollinators are threatened by phenological mismatches during climate instability (Fitter and Fitter 2002; Gordo and Sanz 2005). Thus, many specialist pollinator species cannot survive in areas where their native plant matches have disappeared (Ziska and Dukes 2011). Moreover, climate change alters the rates and patterns of temperature and moisture, placing different selective pressures on plants and pollinators. Life cycle adaptations have been shown to disrupt dynamics, such as temporal mismatches between plant flowering and pollinator arrival, or the spatial mismatch when migrating plants are forced to seek out cooler or moister areas (Burkle et al. 2013; Steltzer and Post 2009).

Section 4-3: Pollinator Plant Lists

Ten lists of pollinator plants were researched and compiled by the student PM. They are suitable for pollinator habitats of several different conditions and site types commonly found in the terrestrial lowland Puget Sound. Several of these plant combinations are outplanted as ‘pollinator patches’ in KR. The lists are accompanied by site type descriptions below and have been published on the WA Native Plant Society website. They are ordered according to bloom times. See Appendix B for an alphabetized index of all the plants found on these lists, divided into two categories: Trees/Shrubs and Herbaceous. The indices additionally include information for the restoration practitioner about each plant’s growth habits, as well as more detailed site types (ie: coastal bluff, parking lot swale, floodplain, etc.)

Plant species on the Pollinator Plant Lists are all native to the Puget Trough and are attractive to native pollinators. Plants were chosen according to site type, moisture, and light levels. Other factors include positive associations with other plants on the same list and availability at local nurseries. It is intended that each list have plants of different bloom colors, and sequential-as-possible bloom times. They are ordered according to bloom time to emphasize the importance of this consideration for planting plans. The lists are intended to complement restoration plans and are not exhaustive by any means. The intention is simply to diversify restoration plantings and encourage habitat for native pollinators in the Puget trough.

Figure 4-E: Wet/shady-riparian pollinator patch-
carved out of reed canarygrass (Phalaris arundinacea)

Figure 4-F: Moist/partial shade understory pollinator patch- *planted by SER-UW Officer Anna Carragee*

Ten site types were chosen that represent many of the common terrestrial ecosystems around Puget Sound that require restoration, or landscaping (in the case of rain gardens). All of these habitats appear in KR to different degrees, with the exception of the wet meadow and sunny rain garden site types. Plant selection for the shady rain garden site type will have relevance in the development of the trailside ditch conversion to bioswale (see Chapter 5 Hydrology). The site types and corresponding plant lists:

Hedgerow: Sunny/Dry: Generally either thorny, thicket forming, tenacious or somehow complementary to forming a living barrier under mostly sunny and mostly dry conditions.

Hedgerow: Dry/Sunny				
scientific	**common**	**form**	**pollinators**	**bloom**
Ribes sanguineum	red-flowering currant	shrub	hummingbirds; bees; butterflies, butterfly larvae	**feb**-apr, pink + red
Arctostaphylos uva-ursi	kinnikinnick	shrub	hummingbirds; bees; butterflies: hoary elfin + brown elfin	mar-apr, pink
Arbutus menziesii	Pacific madrone	tree	bees; butterflies: blue echo, brown elfin larvae; ceanothus silk moth larvae	april, white
Amelanchier alnifola	serviceberry	shrub	hummingbirds; butterflies: echo blue, larvae: swallowtail, Lorquin's admiral	apr-may, white
Eriophyllum lanatum	Oregon sunshine	herb	bees; butterflies: orange sulfur, red admiral, comma, skipper	apr-jun, yellow
Rubus parviflorus	thimbleberry	shrub	bees; butterflies; yellow-banded sphinx moth	may-jun, white

Rosa gymnocarpa	baldhip rose	shrub	bumble bees (nesting material), leaf-cutter bee (leaves); mourning cloak butterfly larvae	may-jun, pink
Gaultheria shallon	salal	shrub	hummingbirds; brown elfin butterfly larvae	may-jun, white + pink
Holodiscus discolor	oceanspray	shrub	hummingbirds; bees; butterflies: pale swallowtail, brown elfin, Lorquins admiral, blue echo	may-jun, white
Lonicera hispdula	hairy honeysuckle	vine	hummingbirds; bumble bees	may-jul, pink + purple
Ceanothus velutinus	snowbrush	shrub	bees; butterflies, butterfly larvae: echo azure, brown elfin, pale swallowtail; ceanothus silk moth larvae; attracts pest predators	may-jul, white
Philadelphus lewisii	mock orange	shrub	bees; western tiger swallowtail butterfly	may-jul, white
Symphoricarpos albus	snowberry	shrub	hummingbirds; bumble bees; snowberry checkerspot butterfly; vashti sphinx moth larvae	may-aug, pink
Lupinus latifolius	broadleaf lupine	herb	bees, bumble bees; butterflies: Puget blue, silvery blue larvae	jun-aug, blue + purple
Campanula rotundifolia	harebell	herb	hummingbirds; bumble bees; swallowtail butterflies	jul-aug, blue + purple
Anaphalis margaritacea	pearly everlasting	herb	butterflies: mylitta crescent, skipper, American lady (adult and larvae), painted lady (adult and larvae); syrphid flies; small wasps	jun-sept, white + yellow
Achillea millefolium	common yarrow	herb	bees; butterflies; syrphid flies; attracts pest predators	apr-**oct**, white

Understory or Hedgerow: Partial Shade/Moist: Happy to live in partial or full shade and requiring moist or wet soil, these plants can be planted as a living barrier hedgerow, or in a forest understory.

Understory or Hedgerow: Moist/Partial Shade				
scientific	**common**	**form**	**pollinators**	**bloom**
Oemleria cerasiformis	Indian plum	shrub	anna's hummingbird; bees	**feb**-apr, white
Berberis aquifolium	tall Oregon grape	shrub	bumble bees, orchard mason bees; butterflies: painted lady, brown elfin larvae	apr-may, yellow
Vaccinium parvifolium	red huckleberry	shrub	bees; butterflies	mar-may, pink + green
Rubus spectabilis	salmonberry	shrub	rufous hummingbirds; bees (nesting materials), bumblebees; butterflies, margined whites	mar-jun, red + pink
Dicentra formosa	Pacific bleeding heart	herb	hummingbirds; clodius parnassian butterfly larvae	mar-jun, pink + purple
Crataegus douglasii	black hawthorne	tree	bees; butterfly larvae: swallowtail, gray hairstreak, mourning cloak	apr-may, white
Malus fusca	Pacific crabapple	tree	bees, bumble bees; butterflies: echo blue, Lorquins admiral	apr-may, white + pink

Rhamnus purshiana	cascara	tree	butterfly larvae: pale swallowtail, gray hairstreak	apr-may, yellow + green
Cornus sericea	red osier dogwood	shrub	butterflies: orange sulphur, blue echo larvae	apr-jun, white
Fragaria vesca	woodland strawberry	herb	butterflies, two-banded checkered skipper larvae	apr-jun, white
Vaccinium ovatum	evergreen huckleberry	shrub	hummingbirds; bees; butterfly larvae: brown elfin and echo blue	apr-jul, pink
Lonicera involucrata	black twinberry	shrub	hummingbirds; bumble bees; margined white butterfly	apr-jul, yellow
Tellima grandiflora	fringecup	herb	hummingbirds	apr-jul, white + pink
Rosa gymnocarpa	baldhip rose	shrub	bumble bees (nesting material), leaf-cutter bee (leaves); mourning cloak butterfly larvae	may-jun, pink
Geum macrophyllum	largeleaf avens	herb	margined white butterflies; flies	may-jun, yellow
Lonicera ciliosa	orange honeysuckle	vine	hummingbirds; bumble bees; butterflies	may-jun, orange
Acer circinatum	vine maple	tree	bees; moths: brown tissue, polyphemus	may-jun, white
Gaultheria shallon	salal	shrub	hummingbirds; brown elfin butterfly larvae	may-jun, white + pink
Ceanothus velutinus	snowbrush	shrub	bees; butterflies, butterfly larvae: echo azure, brown elfin, pale swallowtail; ceanothus silk moth larvae; attracts pest predators	may-jul, white
Philadelphus lewisii	mock orange	shrub	bees; western tiger swallowtail butterfly	may-jul, white
Rosa nutkana	nootka rose	shrub	bees (structure), bumble bees; mourning cloak butterfly larvae	may-jul, pink
Sambucus racemosa	red elderberry	tree	hummingbirds; bees (nesting materials/structure), bumble bees; butterflies	may-jul, white
Spiraea douglasii	hardhack	shrub	bees; butterflies, echo blue larvae	may-jul, pink
Aruncus dioicus	goatsbeard	herb	hummingbirds; bees; mourning cloak butterfly; wasps	may-jul, white
Rubus ursinus	trailing blackberry	shrub	bees (nesting materials and structure), bumble bees; butterflies	apr-aug, white
Heracleum lanatum	cow parsnip	herb	anise swallowtail butterfly larvae; attracts pest predators	feb-**sep**, white

<u>Road/Trailside</u>: Many beautiful and colorful flowering plants that will do great along a road, bike path, walking trail or in a parking lot median. Many of these thrive in disturbed or logged areas, and several do well in poor soils. Watch out- some are potentially weedy and would do best where they can be physically constrained- like a parking lot median or a sidewalk strip.

<u>Road/Trailsde</u>				
scientific	**common**	**form**	**pollinators**	**bloom**

Ribes sanguineum	red-flowering currant	shrub	hummingbirds; bees; butterflies, butterfly larvae	**feb**-apr, pink + red
Sisyrinchium idahoense	western blue-eyed grass	herb	bees	mar-jun, blue
Arbutus menziesii	Pacific madrone	tree	bees; butterflies: blue echo, brown elfin larvae; ceanothus silk moth larvae	april, pinkish-white
Crataegus douglasii	black hawthorne	tree	bees; butterfly larvae: swallowtail, gray hairstreak, mourning cloak	apr-may, white
Amelanchier alnifola	serviceberry	shrub	hummingbirds; butterflies: echo blue, larvae: swallowtail, Lorquin's admiral	apr-may, white
Eriophyllum lanatum	Oregon sunshine	herb	bees; butterflies: orange sulfur, red admiral, comma, skipper	apr-jun, yellow
Prunus emarginata	bitter cherry	tree	hummingbirds; bees; butterflies, butterfly larvae: pale swallowtail, Lorquins admiral, echo blue	apr-jun, white
Acer circinatum	vine maple	tree	bees; moths: brown tissue, polyphemus	may-jun, white
Rubus parviflorus	thimbleberry	shrub	bees; butterflies; yellow-banded sphinx moth	may-jun, white
Geum macrophyllum	largeleaf avens	herb	margined white butterflies; flies	may-jun, yellow
Acer circinatum	vine maple	tree	bees; moths: brown tissue, polyphemus	may-jun, white
Spiraea douglasii	hardhack	shrub	bees; butterflies, echo blue larvae	may-jul, pink
Rosa nutkana	nootka rose	shrub	bees (structure), bumble bees; mourning cloak butterfly larvae	may-jul, pink
Rhododendron macrophyllum	Pacific rhododendron	shrub	bumble bees; butterflies: swallowtail, brown elfin larvae	may-jul, pink + purple
Aquilegia formosa	red columbine	herb	hummingbirds; swallowtail butterflies	may-aug, red + yellow
Symphoricarpos albus	snowberry	shrub	hummingbirds; bumble bees; snowberry checkerspot butterfly; vashti sphinx moth larvae	may-aug, pink
Lupinus latifolius	broadleaf lupine	herb	bees, bumble bees; butterflies: Puget blue, silvery blue larvae	jun-aug, blue + purple
Anaphalis margaritacea	pearly everlasting	herb	butterflies: mylitta crescent, skipper, American lady (adult and larvae), painted lady (adult and larvae); syrphid flies; small wasps	jun-sept, white + yellow
Solidago canadensis	Canadian goldenrod	herb	bees, bumble bees; butterflies; syrphid flies; small wasps; attracts pest predators	jun-sep, yellow
Achillea millefolium	common yarrow	herb	bees; butterflies; syrphid flies; attracts pest predators	apr-**oct**, white

Slopes: A full spectrum mix of erosion control plants from shallow and fibrous root systems for topsoil stabilization, to deep and strong taproots for structural integrity. Control erosion right away with quick growing groundcovers, mat-forming herbs, thicket forming shrubs and live willow and red osier dogwood stakes.

Slopes				
scientific	**common**	**form**	**pollinators**	**bloom**

Arctostaphylos uva-ursi	kinnikinnick	shrub	hummingbirds; bees; butterflies: hoary elfin + brown elfin	**mar**-apr, pink
Salix hookeriana	Hooker's willow	tree	bees, bumble bees; butterflies (adults + larvae)	mar-apr, green
Salix scouleriana	scoulers willow	shrub	bees; butterflies (adults + larvae)	mar-apr, yellow
Salix sitchensis	Sitka willow	tree	bees; butterflies (adults + larvae)	mar-apr, green
Rubus spectabilis	salmonberry	shrub	rufous hummingbirds; bees (nesting materials), bumblebees; butterflies, margined whites	mar-jun, red + pink
Armeria maritima	sea thrift	herb	bees; butterflies	april, pink
Arbutus menziesii	Pacific madrone	tree	bees; butterflies: blue echo, brown elfin larvae; ceanothus silk moth larvae	april, pinkish-white
Crataegus douglasii	black hawthorne	tree	bees; butterfly larvae: swallowtail, gray hairstreak, mourning cloak	apr-may, white
Amelanchier alnifola	serviceberry	shrub	hummingbirds; butterflies: echo blue, larvae: swallowtail, Lorquin's admiral	apr-may, white
Salix lucida ssp. Lasiandra	Pacific willow	tree	bees; butterflies (adults + larvae)	apr-may, yellow
Cornus sericea	red osier dogwood	shrub	butterflies: orange sulphur, blue echo larvae	apr-jun, white
Prunus emarginata	bitter cherry	tree	hummingbirds; bees; butterflies, butterfly larvae: pale swallowtail, Lorquins admiral, echo blue	apr-jun, white
Vaccinium ovatum	evergreen huckleberry	shrub	hummingbirds; bees; butterfly larvae: brown elfin and echo blue	apr-jul, pink
Rubus ursinus	trailing blackberry	shrub	bees (nesting materials and structure), bumble bees; butterflies	apr-aug, white
Acer circinatum	vine maple	tree	bees; moths: brown tissue, polyphemus	may-jun, white
Gaultheria shallon	salal	shrub	hummingbirds; brown elfin butterfly larvae	may-jun, white + pink
Physocarpus capitatus	Pacific ninebark	shrub	bees; butterflies	may-jun, white + pink
Rubus parviflorus	thimbleberry	shrub	bees; butterflies; yellow-banded sphinx moth	may-jun, white
Holodiscus discolor	oceanspray	shrub	hummingbirds; bees; butterflies: pale swallowtail, brown elfin, Lorquins admiral, blue echo	may-jun, white
Spiraea douglasii	hardhack	shrub	bees; butterflies, echo blue larvae	may-jul, pink
Symphoricarpos albus	snowberry	shrub	hummingbirds; bumble bees; snowberry checkerspot butterfly; vashti sphinx moth larvae	may-aug, pink
Lupinus latifolius	broadleaf lupine	herb	bees, bumble bees; butterflies: Puget blue, silvery blue larvae	jun-aug, blue + purple
Achillea millefolium	common yarrow	herb	bees; butterflies; syrphid flies; attracts pest predators	apr-**oct**, white

Riparian**:** A combination of stream/river bank, wetland, floodplain and riparian corridor plants. The list is split into trees/shrubs and herbaceous only because together it is quite long.

Riparian: Trees/Shrubs

scientific	**common**	**form**	**pollinators**	**bloom**
Oemleria cerasiformis	Indian plum	shrub	anna's hummingbird; bees	**feb**-apr, white
Salix hookeriana	Hooker's willow	tree	bees, bumble bees; butterflies (adults + larvae)	mar-apr, green
Salix sitchensis	Sitka willow	tree	bees; butterflies (adults + larvae)	mar-apr, green
Rubus spectabilis	salmonberry	shrub	rufous hummingbirds; bees (nesting materials), bumblebees; butterflies, margined whites	mar-jun, red + pink
Salix lucida ssp. Lasiandra	Pacific willow	tree	bees; butterflies (adults + larvae)	apr-may, yellow
Rhamnus purshiana	cascara	tree	butterfly larvae: pale swallowtail, gray hairstreak	apr-may, yellow + green
Crataegus douglasii	black hawthorne	tree	bees; butterfly larvae: swallowtail, gray hairstreak, mourning cloak	apr-may, white
Malus fusca	Pacific crabapple	tree	bees, bumble bees; butterflies: echo blue, Lorquins admiral	apr-may, white + pink
Cornus sericea	red osier dogwood	shrub	butterflies: orange sulphur, blue echo larvae	apr-jun, white
Prunus emarginata	bitter cherry	tree	hummingbirds; bees; butterflies, butterfly larvae: pale swallowtail, Lorquins admiral, echo blue	apr-jun, white
Cornus sericea	red osier dogwood	shrub	butterflies: orange sulphur, blue echo larvae	apr-jun, white
Lonicera involucrata	black twinberry	shrub	hummingbirds; bumble bees; margined white butterfly	apr-jul, yellow
Ribes lacustre	black gooseberry	shrub	hummingbirds; bees	apr-jul, red
Acer circinatum	vine maple	tree	bees; moths: brown tissue, polyphemus	may-jun, white
Physocarpus capitatus	Pacific ninebark	shrub	bees; butterflies	may-jun, white + pink
Holodiscus discolor	oceanspray	shrub	hummingbirds; bees; butterflies: pale swallowtail, brown elfin, Lorquins admiral, blue echo	may-jun, white
Sambucus racemosa	red elderberry	tree	hummingbirds; bees (nesting materials/structure), bumble bees; butterflies	may-jul, white
Rubus ursinus	trailing blackberry	shrub	bees (nesting materials and structure), bumble bees; butterflies	apr-aug, white
Symphoricarpos albus	snowberry	shrub	hummingbirds; bumble bees; snowberry checkerspot butterfly; vashti sphinx moth larvae	may-**aug**, pink

<u>Riparian: Herbaceous</u>				
scientific	**common**	**form**	**pollinators**	**bloom**
Heracleum lanatum	cow parsnip	herb	anise swallowtail butterfly larvae; attracts pest predators	**feb**-sep, white

Dicentra formosa	Pacific bleeding heart	herb	hummingbirds; clodius parnassian butterfly larvae	mar-jun, pink + purple
Sisyrinchium idahoense	western blue-eyed grass	herb	bees	mar-jun, blue
Armeria maritima	sea thrift	herb	bees; butterflies	april, pink
Dodecatheon hendersoni	Henderson's shooting star	herb	bumble bees	apr-may, pink
Tellima grandiflora	fringecup	herb	hummingbirds	apr-jul, white + pink
Dodecatheon pulchellum	darkthroat shooting star	herb	bumble bees	apr-aug, pink + purple
Geum macrophyllum	largeleaf avens	herb	margined white butterflies; flies	may-jun, yellow
Aruncus dioicus	goatsbeard	herb	hummingbirds; bees; mourning cloak butterfly; wasps	may-jul, white
Aquilegia formosa	red columbine	herb	hummingbirds; swallowtail butterflies	may-aug, red + yellow
Symphyotrichum subspicatum	Douglas aster	herb	bees; butterflies	jul-**oct**, purple

<u>Rain Garden</u>: Stormwater runoff is recognized as a major cause of water pollution in the urban environment, sending oil and grease, bacteria, heavy metals, and other pollutants untreated into streams, lakes and the Puget Sound (EPA 2012). Green stormwater infrastructure utilizes the natural processes of plants, soils, and microbes. This reduces the *quantity* of stormwater flows by increasing on-site infiltration, and improves the *quality* by taking up inorganic pollutants and degrading organic pollutants. Plants on this list serve a secondary purpose by attracting pollinators to green stormwater infrastructure projects, like rain gardens or bioswales. *Please note that although sedges and rushes are not included here, since they are generally wind pollinated, they are key plant families necessary for Zones 1 and 2 and should be planted in most all PNW rain gardens.

Three Rain Garden planting zones are characterized by soil moisture:

“Zone 1: Areas of periodic, or frequent, standing or flowing water. Zone 1 plants should also tolerate the seasonally dry summers in western Washington without extra watering (except during the initial 1 to 2 year establishment period).

Zone 2: Periodically moist or saturated soils during larger storms. Plants are typically planted on the side slopes in this zone and can help to protect against erosion once established.

Zone 3: Drier soils, infrequently subject to inundation or saturation. May be planted on a berm or just outside the perimeter of the rain garden. This zone can blend with the existing landscape of the site if desired.”

-Rain Garden Handbook for Western Washington (Hinman et al. 2013)

<u>Rain Garden: Partial Shade/Shade</u>				
scientific	**common**	**form**	**pollinators**	**bloom**
Oemleria cerasiformis	Indian plum	shrub	anna's hummingbird; bees	**feb**-apr, white

Dicentra formosa	Pacific bleeding heart	herb	hummingbirds; clodius parnassian butterfly larvae	mar-jun, pink + purple
Rubus spectabilis	salmonberry	shrub	rufous hummingbirds; bees (nesting materials), bumblebees; butterflies, margined whites	mar-jun, red + pink
Berberis aquifolium	tall Oregon grape	shrub	bumble bees, orchard mason bees; butterflies: painted lady, brown elfin larvae	apr-may, yellow
Berberis nervosa	dwarf Oregon grape	shrub	bees	apr-may, yellow
Rhamnus purshiana	cascara	tree	butterfly larvae: pale swallowtail, gray hairstreak	apr-may, yellow + green
Dodecatheon hendersoni	Henderson's shooting star	herb	bumble bees	apr-may, pink
Fragaria vesca	woodland strawberry	herb	butterflies, two-banded checkered skipper larvae	apr-jun, white
Lonicera involucrata	black twinberry	shrub	hummingbirds; bumble bees; margined white butterfly	apr-jul, yellow
Tellima grandiflora	fringecup	herb	hummingbirds	apr-jul, white + pink
Vaccinium ovatum	evergreen huckleberry	shrub	hummingbirds; bees; butterfly larvae: brown elfin and echo blue	apr-jul, pink
Viola adunca	early-blue violet	herb	fritillary butterfly larvae: zerene, hydaspe, mormon	apr-jul, blue
Gaultheria shallon	salal	shrub	hummingbirds; brown elfin butterfly larvae	may-jun, white + pink
Rubus parviflorus	thimbleberry	shrub	bees; butterflies; yellow-banded sphinx moth	may-jun, white
Geum macrophyllum	largeleaf avens	herb	margined white butterflies; flies	may-jun, yellow
Acer circinatum	vine maple	tree	bees; moths: brown tissue, polyphemus	may-jun, white
Aruncus dioicus	goatsbeard	herb	hummingbirds; bees; mourning cloak butterfly; wasps	may-jul, white
Dodecatheon pulchellum	darkthroat shooting star	herb	bumble bees	apr-aug, pink + purple
Symphoricarpos albus	snowberry	shrub	hummingbirds; bumble bees; snowberry checkerspot butterfly; vashti sphinx moth larvae	may-**aug**, pink

Rain Garden: Sunny				
scientific	**common**	**form**	**pollinators**	**bloom**
Ribes sanguineum	red-flowering currant	shrub	hummingbirds; bees; butterflies, butterfly larvae	**feb**-apr, pink + red
Arctostaphylos uva-ursi	kinnikinnick	shrub	hummingbirds; bees; butterflies: hoary elfin + brown elfin	mar-apr, pink
Sisyrinchium idahoense	western blue-eyed grass	herb	bees	mar-jun, blue
Armeria maritima	sea thrift	herb	bees; butterflies	april, pink
Rhamnus purshiana	cascara	tree	butterfly larvae: pale swallowtail, gray hairstreak	apr-may, yellow + green
Camasia quamash	common camas	herb	bees; butterflies	apr-may, blue

Amelanchier alnifola	serviceberry	shrub	hummingbirds; butterflies: echo blue, larvae: swallowtail, Lorquin's admiral	apr-may, white
Malus fusca	Pacific crabapple	tree	bees, bumble bees; butterflies: echo blue, Lorquins admiral	apr-may, white + pink
Berberis aquifolium	tall Oregon grape	shrub	bumble bees, orchard mason bees; butterflies: painted lady, brown elfin larvae	apr-may, yellow
Fragaria vesca	woodland strawberry	herb	butterflies, two-banded checkered skipper larvae	apr-jun, white
Cornus sericea	red osier dogwood	shrub	butterflies: orange sulphur, blue echo larvae	apr-jun, white
Ribes lacustre	black gooseberry	shrub	hummingbirds; bees	apr-jul, red
Vaccinium ovatum	evergreen huckleberry	shrub	hummingbirds; bees; butterfly larvae: brown elfin and echo blue	apr-jul, pink
Symphoricarpos albus	snowberry	shrub	hummingbirds; bumble bees; snowberry checkerspot butterfly; vashti sphinx moth larvae	may-aug, pink
Holodiscus discolor	oceanspray	shrub	hummingbirds; bees; butterflies: pale swallowtail, brown elfin, Lorquins admiral, blue echo	may-jun, white
Geum macrophyllum	largeleaf avens	herb	margined white butterflies; flies	may-jun, yellow
Physocarpus capitatus	Pacific ninebark	shrub	bees; butterflies	may-jun, white + pink
Rubus parviflorus	thimbleberry	shrub	bees; butterflies; yellow-banded sphinx moth	may-jun, white
Spiraea douglasii	hardhack	shrub	bees; butterflies, echo blue larvae	may-jul, pink
Philadelphus lewisii	mock orange	shrub	bees; western tiger swallowtail butterfly	may-jul, white
Aquilegia formosa	red columbine	herb	hummingbirds; swallowtail butterflies	may-aug, red + yellow
Lupinus latifolius	broadleaf lupine	herb	bees, bumble bees; butterflies: Puget blue, silvery blue larvae	jun-aug, blue + purple
Achillea millefolium	common yarrow	herb	bees; butterflies; syrphid flies; attracts pest predators	apr-oct, white
Symphyotrichum subspicatum	Douglas aster	herb	bees; butterflies	jul-**oct**, purple

Meadows**:** Meadow is a general term for an open space dominated by herbaceous grasses or forbs. Plants on this list can be used to restore or complement an abandoned city lot, a planned garden alternative to lawn, a rare prairie, a pasture, or a forest clearing. *Note that grasses, sedges and rushes, are not on the lists since they are pollinated by wind and not animals. However, they are the key plant forms in many meadow ecosystems, and are essential to restoration. Also, pay close attention to elevation when planting meadow plants, as a few thousand feet can exclude several of these species.

Wet meadow refers to a grassland with waterlogged soil near the surface but without standing water for most of the year. A dry meadow is often nutrient poor and receives limited precipitation, requiring drought-tolerant plants. Many plants from both the wet and dry meadow lists would do well in mesic meadow conditions. The South Puget Sound Prairies is an important local area under this site type. It is an endangered grassland ecosystem unique to the PNW, carved out by retreating glaciers and historically maintained for millennia by Native American burning. A shallow water table and gravelly, well-drained, nutrient poor soils, allow wildflowers, bunch grasses and oak trees to create a rare habitat for butterflies.

Meadow: Dry				
scientific	**common**	**form**	**pollinators**	**bloom**
Arctostaphylos uva-ursi	kinnikinnick	shrub	hummingbirds; bees; butterflies: hoary elfin + brown elfin	**mar**-apr, pink
Balsamorhiza deltoidea	deltoid balsamroot	herb	bees	mar-jul, yellow
Quercus garryana	Garry oak	tree	propertius duskywing butterfly larvae	april, green
Armeria maritima	sea thrift	herb	bees; butterflies	april, pink
Amelanchier alnifola	serviceberry	shrub	hummingbirds; butterflies: echo blue, larvae: swallowtail, Lorquin's admiral	apr-may, white
Eriophyllum lanatum	Oregon sunshine	herb	bees; butterflies: orange sulfur, red admiral, comma, skipper	apr-jun, yellow
Viola adunca	early-blue violet	herb	fritillary butterfly larvae: zerene, hydaspe, mormon	apr-jul, blue
Castilleja hispida	harsh paintbrush	herb	taylor's checkerspot butterfly larvae (federal endangered list)	apr-aug, scarlet or yellow
Allium cernuum	nodding onion	herb	hummingbirds; bees; attracts pest predators	may-jun, pink
Lupinus latifolius	broadleaf lupine	herb	bees, bumble bees; butterflies: Puget blue, silvery blue larvae	jun-aug, blue + purple
Erigeron speciosus	aspen fleabane	herb	bees; butterflies; attracts pest predators	jun- aug, blue
Campanula rotundifolia	harebell	herb	hummingbirds; bumble bees; swallowtail butterflies	jul-aug, blue + purple
Solidago canadensis	Canadian goldenrod	herb	bees, bumble bees; butterflies; syrphid flies; small wasps; attracts pest predators	jun-sep, yellow
Anaphalis margaritacea	pearly everlasting	herb	butterflies: mylitta crescent, skipper, American lady (adult and larvae), painted lady (adult and larvae); syrphid flies; small wasps	jun-sept, white + yellow
Achillea millefolium	common yarrow	herb	bees; butterflies; syrphid flies; attracts pest predators	apr-**oct**, white

Meadow: Moist				
scientific	**common**	**form**	**pollinators**	**bloom**
Sisyrinchium idahoense	western blue-eyed grass	herb	bees	**mar**-jun, blue
Armeria maritima	sea thrift	herb	bees; butterflies	april, pink
Camasia quamash	common camas	herb	bees; butterflies	apr-may, blue
Dodecatheon hendersoni	Henderson's shooting star	herb	bumble bees	apr-may, pink
Viola adunca	early-blue violet	herb	fritillary butterfly larvae: zerene, hydaspe, mormon	apr-jul, blue
Dodecatheon pulchellum	darkthroat shooting star	herb	bumble bees	apr-aug, pink + purple

Geum macrophyllum	largeleaf avens	herb	margined white butterflies; flies	may-jun, yellow
Aquilegia formosa	red columbine	herb	hummingbirds; swallowtail butterflies	may-aug, red + yellow
Lupinus latifolius	broadleaf lupine	herb	bees, bumble bees; butterflies: Puget blue, silvery blue larvae	jun-aug, blue + purple
Symphyotrichum subspicatum	Douglas aster	herb	bees; butterflies	jul-**oct**, purple

Section 4-4: KR Pollinator Patch Planting Guidelines

The following guidelines were established for Pollinator Patch plantings in KR:

1. **Determine site conditions and type**
   - Site conditions- consider access to light (sun, partial shade, or full shade) and moisture (dry, moist, or wet)
   - Plant traits- consider bloom times and plant associations
   - Site types include hedgerows, understory, rain gardens, road/trailsides, riparian zones, open meadows, and steep slopes

2. **Consider flowers**
   - Use a diversity of species, colors, and perfumes
   - Aim to overlap bloom times throughout the season
   - Use framing species- provide a major nectar or pollen source, a stabilizing core of the plant-pollinator network
   - Use bridging species- provide food during resource-limited times of late fall, early spring, or winter
   - Use magnet species- generally use colorful and powerfully scented plants that advertise widely, drawing pollinators to areas where smaller or less flashy plants can subsequently receive pollinator services

3. **Provide nesting, egg laying, and overwintering sites**
   - Maintain areas of bare ground: ground nesting bees need some areas that are not tilled or mulched
   - Keep it messy: compost piles of weeds, leaf debris, rotting wood, snags and stumps are all potential homes for bees and beetles
   - Provide secure, undisturbed areas for diapause (winter dormancy)

4. **Plant smart**
   - Plant in clumps of the same species, rather than as solitary individuals. This aggregates the smell and color of a species, increasing its visual and olfactory attractiveness to pollinators.
   - Plant patches close together (a maximum of 500-foot separation for the smallest bees)
   - Plant corridors or stepping stone habitats to increase connectedness, such as along sidewalks
   - Place plants according to the *aspect* and appropriate *micro-topography* to maximize plant survivorship- hummocks, hollows, downed logs, and any small scale roughness in the landscape all provide micro-sites that can dictate a certain plant's survival
   - Many herbs have sister species in the same or a closely related genus that will also serve similar pollinators. For example, a certain nursery may carry one species of lupine that does not match the species chosen in these lists, but will still meet restoration goals and serve native pollinators
   - Depending on the site and desired plant spacing, some plants can mutually exclude each other, ie: in a tightly planted hedgerow, short herbs might become shaded or boxed out by shrubs

- In many restoration scenarios, herbaceous plants are most appropriate for a secondary planting, 2-5 years after initial restoration. This can often be accomplished at the same time that crews return to the site for maintenance of the initial restoration plantings.

Chapter 5 HYDROLOGY

Kincaid Ravine (KR) is a steep sloped basin, and water is directed into a stream channel and accumulates in wetland E, indicated in Figure 5-D. When saturated, water discharges from wetland E into wetland D. Sources include ground seeps, overland runoff and one stormwater input. KR's basic hydrology and associated restoration goals are described in the KR Restoration and Stewardship Plan (Moritz 2014). An expansion of the original hydrological goals, progress on these goals and stormwater considerations are important developments included here. Furthermore, a complete Hydrological Analysis was funded in 2015 and is proposed to evaluate green infrastructure potential in KR. The purpose behind these efforts includes a general improvement of hydrological function, halting of Burke Gilman Trail (BGT) flooding, improved candidacy for amphibian habitat in wetland E, and optimization of educational and outreach opportunities.

Figure 5-A: Devils club rhizome. *SER-UW Chapter President Jim Cronan planting Oplopanax horridus rhizome at a KR volunteer work party*

Section 5-1: KR Hydrology Goals (expanded upon 2014 KR Restoration and Stewardship Plan)

1) Slow down overland runoff
   - place coarse woody debris (CWD) in stream, upper wetland E, wetland E outlet
   - increase surface roughness of slopes
   - increase native plant coverage
   - establish evergreen canopy
2) Improve water quality of wetlands and discharge
   - minimize turbidity
   - decrease water temperatures
3) Improve infiltration of wetlands
   - control invasive plants
   - enhance native vegetation diversity with plants of varying root depths
   - encourage pooling of water with CWD and berms
4) Educate students and the public about forest hydrology and wetland/stream restoration
   - install educational sign alongside BGT
   - provide on-campus field trip/research opportunities for classes and students to utilize KR as an outdoor laboratory

Section 5-2: Progress on Hydrology Goals

The tactics listed below slow down the downhill rush of water and spread it out over a greater surface area, allowing it to seek out unsaturated soils for infiltration. Sediments, contaminants, and nutrients are also dispersed. Rather than rush them to the bottom of the ravine, this deceleration facilitates a wider distribution of sediments, the breakdown of organic contaminants, and a more even cycling of nutrients.

Progress on Goals # 1-3

- Instream placement of CWD introduced curves, bends and channel diversions into the water course, slowing down the speed of runoff and decreasing the quantity of runoff. Tree residues, including branches and rounds cut from trunks of downed campus trees, were obtained on site and from campus arborist Sara Shores. They were placed on site by student PM.
- Fascines were installed at mid-slope and green waste piles were placed at toe-slopes, in order to disperse overland sheet flow. These were installed by EarthCorps (EC) and the Restoration Ecology Network (REN).
- Native plants of varying root depths and forms were installed in order to increase soil porosity, water interception, and water uptake. They were installed by EC, REN and the Society for Ecological Restoration-UW chapter (SER-UW).
- Hundreds of conifers were installed to create a long lived, year-round canopy. As the canopy develops, it slows the amount of time it takes water to travel from the atmosphere to the ground, through increased interception and stemflow. This slows down the accumulation of runoff and minimizes erosion from raindrop impact. This action of conifers, functions throughout the year, as opposed to the current deciduous canopy.
- Vegetative enhancement of wetland E improves storage function. It includes experimental weed control treatments and the installation of live stakes (see Chapter 3 Vegetation Management).

Canopy diversification of species and structural complexity has a local cooling effect on the forest floor and water bodies (EPA 2008). Lowered temperatures in the stream and wetlands increase the holding capacity for dissolved oxygen- necessary for wildlife. As the evergreen canopy matures it will also increase humidity in the understory on hot, dry summer days. By shielding the moisture that either evaporates or is transpired by understory plants from escaping into the atmosphere, soil moisture can be maintained for shrubs and herbaceous plants. As summer soil moisture is expected to decrease further with climate change, evergreen canopies can help prevent swings in the plant physiological balance between carbon acquisition and water loss.

Inter-species plant competition, as limited by water availability during the dry summers, is an important dynamic in KR. Restoring hydrologic and soil processes is necessary to complement the vegetative restoration, as concerned by fluxes in the quantity of available water inputs. Precipitation, stormwater inflows, and groundwater seeps are the water inputs in the ravine. KR is a hydrologically diverse site where moisture levels in the shaded low lying areas, the partly shaded mid-slope and the sunny upland areas represent three distinct moisture zones. However, all three of these zones dry out significantly during the naturally dry PNW summers. A primary factor to consider as far as establishment of installed native plants as affected by water availability, includes soil properties and soil compaction in each of the three areas. Soil permeability determines water infiltration rates, and thus, availability of water in this zone. Secondly, incision of the stream channel also affects infiltration and determines water availability in the wetland. Thirdly, hillside erosion lowers infiltration rates and raises peak flow rates, affecting water availability. Fourthly, climate and access to light affect soil moisture and temperature, affecting rates of evapotranspiration. In conclusion, progress on goals 1-3 has sought to address these four factors.

Progress on Goal # 4

Presentations and outreach materials targeted at the UW community and the greater restoration/green infrastructure community have brought awareness and enthusiasm to hydrological restoration in KR (see Chapter 2 Project Management). Educational signage about KR's hydrology is pending until the Hydrology Assessment is complete and a plan for addressing the long term hydrologic concerns is in place. At that point, educating the UW community and BGT users with signage designed similarly to existing signage, is recommended.

Section 5-3: Stormwater

The KR Restoration and Stewardship Plan reveals that "Currently, only one stormwater pipe empties into the ravine. The stormwater drains that capture the runoff from the North Campus residential halls are connected to sanitary sewers. These stormwater drains could be disconnected from the sanitary sewer lines and emptied into the Ravine for storage and treatment" (Moritz 2014). Moritz describes that with north campus re-designs, there exists potential to pipe more stormwater into the ravine. KR would act as a natural drainage basin for the treatment and storage of runoff from impervious areas adjacent to the project site, including parking lot and roof runoff from the new dormitories. Wetlands and constructed swales within KR would slow down this runoff and allow it to infiltrate. This has the benefit of mitigating UW campus water pollution discharge into Lake Union. It has the drawback of adding contamination and flooding potential to KR. Student PM Dan Hintz wrote and was awarded a Campus Sustainability Fund grant to analyze the hydrology of KR and will investigate this topic further. The analysis includes a determination of the volume of water discharged into storm drains, storage capacity of the wetland areas and surrounding soils, and projections of peak flows in KR.

Section 5-4: Wetland D to Bioswale Conversion

Figure 5-B: Outlet of Wetland E flooding BGT

Figure 5-C: Sediment filled wetland D flooding BGT

Wetland D is the trailside ditch that runs parallel to the BGT, visible in Figures 5-C and 5-D. It was delineated as a Category IV (lowest level of function) 2,014 sq ft palustrine emergent wetland (PEM) in 2010 by the Seattle Department of Transportation (SDOT) and again as a Category III (disturbed, moderate level of function) 2,908 sq ft PEM by Raedeke and Associates for the BGT expansion in 2014. In December 2014, the student PM discovered that the UW Grounds Department (Grounds) had been dredging wetland D for years with a backhoe, to keep it clear of sediment and to avoid BGT flooding. Grounds workers were not aware of its wetland status. Howard Nakase (Manager of Grounds Operations) was alerted and dredging has ceased. However, as this wetland receives most of the discharge from the entire ravine into a constricted channel, sediment re-accumulated quickly and flooding of the BGT has since worsened. The other drainage for KR is a manhole located in lower wetland E retrofitted with drilled holes. Gary Casad, an engineer with the King County Inspection Unit came out to inspect and disapproved of water draining into this manhole. Efforts to divert the channel out of the manhole are in progress. This problem is further justification for the bioswale conversion project.

The concept to analyze feasibility for conversion of wetland D into a functioning bioswale was approved by Howard Nakase, Kristine Kenney (UW Campus Landscape Architect) and Jan Arntz (Capitol Projects

Environmental/Land Use Compliance Officer). The KR Hydrology Analysis grant includes a Bioswale Assessment that will measure storage potential in and around Wetland D, and design several bioswale options. Consultant Dr. Aaron Clarke of Stewardship Partners and the 12,000 Rain Gardens project was hired to assist the student PMs in this feasibility study. The project is in the early stages of assessment and will continue through 2016 under student PM Dan Hintz.

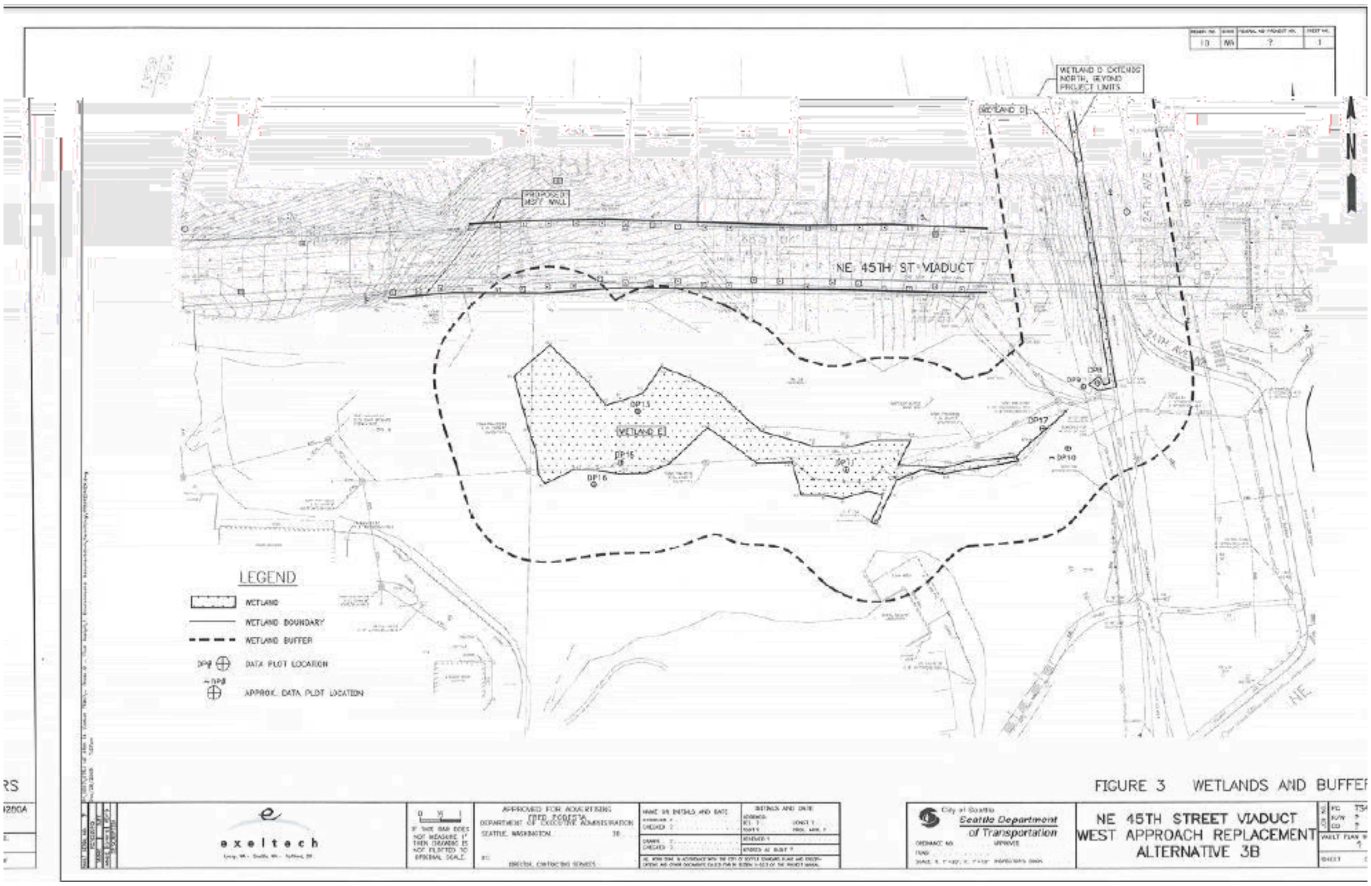


Figure 5-D: SDOT delineation of wetlands E and D

Initial percolation tests conducted by student PM Dan Hintz revealed fast infiltration rates. The first saturation trial represents infiltration during dry conditions. The following two saturation trials represent infiltration during increasingly wet conditions where soil saturation is high before an input of additional water. The latter two trials are most representative of the actual infiltration capabilities of the site. The percolation tests will be repeated with complete results for three trials each. These initial tests were constrained by time and while they provide a valuable impression, a complete test will be needed as evidence to determine whether a future bioswale could handle peak floods. Hole specifications and observations:

<u>Hole #1</u> – Located in 1st ditch on edge of trail about 6 feet NE of metro sewer on berm. 2’ deep x 1’ wide. Manual soil texture analysis: abrupt change in soil texture and color at 12” depth. Top 12” = silt/clay; bottom 12” = mostly sand/slightly silty.

<u>Hole #2</u> – Located in the 1st ditch on edge of the trail about 30 feet south of hole #1. 2’ deep x 1.3’ wide. Manual soil texture analysis: abrupt change in soil texture at 8” depth. Top 8” = mostly silt/slightly clay; from 8”-24”= silt/sand.

Hole #3 – Located in the 2nd ditch away from the trail just SW of 2nd big leaf maple clump south of the metro sewer. 2' deep x 1' wide. Manual soil texture analysis: no change in soil texture or color throughout the hole depth. Mostly clay.

Hole #4 **–** Located in the 2nd ditch just south of the big brush pile in the ditch. 18" deep x 1.5' wide. Manual soil texture analysis: top 12"= silt/clay; bottom 6"= silt/clay/sand.

04/22/15: It had rained 0.2 in in the previous 24 hours, with a 6-day antecedent dry period.

Table 5-a: 04/22/15 and 04/10/15 percolation tests of four sites measured in inches/hour.

Date	**Test location**	**Trailside north hole (#1)**	**Trailside south hole (#2)**	**West ditch north hole (#3)**	**West ditch south hole (#4)**
04/22/15	1st saturation	13.3	8	38	3.2
	2nd saturation	3.3	12	39	
	3rd saturation		2.89	6	
04/10/15	1st saturation	9.2	4.6	37	
	2nd saturation	4.1		10.6	

Response to percolation test results of 4/10/15 by consultant Dr. Clarke:

"I wonder if the sandy layer below is related to the old train grade. The upper layer of finer silt could have been deposited over the years from the Kincaid ravine stream/seepage. Those perc rates are very fast, so even if they slow down a lot in the second round of testing, bioswales in either or both ditches should be able to accommodate a really large amount of runoff. That could open up the possibility for using bioretention at our site as a potential runoff mitigation for the planned new dorms. That still seems like a bit of a stretch and directing an increased volume of runoff into the ravine would have impacts to the wetlands and potential for increased erosion and slope stability in the ravine itself." (Dr. Aaron Clarke, personal communication 04/13/15)

Chapter 6 CLIMATE CHANGE AND FOREST HEALTH

Anthropogenic climate change has led to increases in temperature and changes in precipitation that have drastic implications for the natural processes of the Pacific Northwest (PNW) (Snover et al. 2013). Unprecedented levels of carbon dioxide (CO_2) and other gasses in the atmosphere have triggered variability in local climates and have direct effects on ecosystems and public health (Snover et al. 2013). Urban areas, like Seattle, act as heat islands, as the high ratio of low-albedo manmade surfaces to green spaces elevates temperatures (EPA 2008). This compounds the problem of air pollution. "'We are, I would venture to say, one good heat wave away,' said Alice Collingwood, spokeswoman for the Puget Sound Clean Air Agency" (Cornwall 2008). Alice was referring to violating federal limits for dangerous levels of ozone in Seattle- created from the reaction of heat and sunlight with car exhaust and industrial solvents. Urban green spaces, like Kincaid Ravine (KR), keep temperatures down and sequester air pollutants. A high density of plant life (especially mature trees) allows KR to have a stronger sequestration capacity than nearby landscaped areas. Also, in contrast to the manicured landscapes on campus, carbon storage capacity is high, as dead wood and debris is left on site, and soils are less disturbed. Several of the gasses which contribute to climate change and air pollution that are sequestered by KR include CO_2, sulfur dioxide (SO_2), ozone (O_3), nitrous oxides (N_x) and particulates (PMs) (i-Tree canopy 2015). KR is home to 3.6 acres of forest, which is estimated to sequester 19,800 lbs/yr of CO_2 (i-Tree canopy 2015) and store 738.108 tons of CO_2 over a 55 year period (American Forests 2015). This chapter elucidates KR climate change adaptation goals and provides background information on global, regional and local climate change implications.

Section 6-1: KR Climate Change Adaptation Goals

For KR and the greater PNW restoration community, the importance of understanding current and projected climates is critical. Shifts in hydrology, vegetation and soils over the next century may nullify many of the current efforts to restore processes and create habitat today. In KR, restoration goals specifically envisioned to adapt to climate change are in line with the general restoration goals outlined in the KR Restoration and Stewardship Plan (Moritz 2014). The following goals are explained in more detail throughout the chapter:

- Strengthen resilience of native vegetation by ensuring that installed plants are obtained from varied sources
- Improve species diversity of plants to account for range shifts and species loss
- Encourage an evergreen canopy to cool local microclimate
- Monitor invasive species proliferation and introduction of new species
- Maximize water storage capacity to account for increased peak flows and flooding

Section 6-2: Natural Climate Variation

Influences including latitude, landforms like the Cascade and Olympic Mountain ranges, proximity to the Pacific Ocean, and many other factors, determine weather and climate in the PNW. One important pattern that triggers climate variability in the PNW is the El Nino- Southern Oscillation (ENSO). Other climate dynamics, many of which are poorly understood like the Pacific Decadal Oscillation (PDO), also contribute to weather and climate shifts.

ENSO is an irregularly occurring pattern of 6-18 month neutral, warm and cool phases in the central and eastern equatorial Pacific Ocean. In neutral phase, sea surface temperatures (SST) are average. Warm, moist air is drawn east to west across the surface of the Pacific- normal trade winds. The central Pacific stays relatively cool.

El Nino warm phases (higher than average SST) weaken (or even reverse) the east to west trade winds, allowing the warmed waters to creep westward across the Tropical Pacific (CIG 2015). This shifts intense tropical rainfall eastward. In the PNW, El Nino causes generally drier and warmer winters, reducing snowpack and streamflows. La Nina cool phases (lower than average SST) strengthen the east to west trade winds, blowing cooler water into the Central Pacific, shifting intense tropical rainfall westward (CIG 2015). In the PNW, La Nina causes generally wetter and cooler winters, increasing snowpack and streamflows.

Accelerated climate change has unforeseen effects on ENSO, PDO and other circulation rhythms, that are very difficult to predict. The interaction between natural climate variability and human caused climate change has unforeseen effects, which may result in opposite or masked trends for much of the 21st century in the PNW, such as local cooling, or increased snowpack (Capalbo et al. 2014).

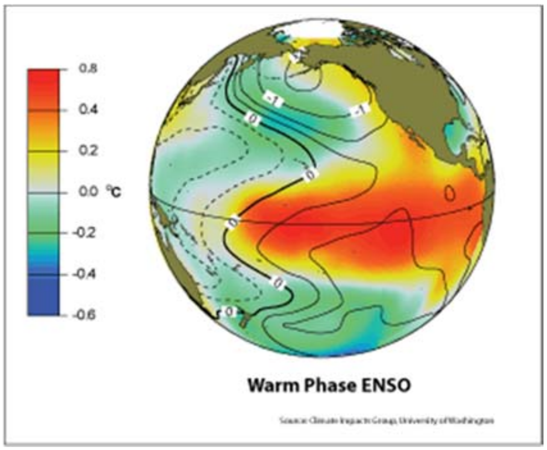


Figure 6-A: 1900-1992 warm phase ENSO. *The spatial pattern of anomalies in sea surface temperature (shading, degrees Celsius) and sea level pressure (contours). Contour interval is 1 millibar, with additional contours drawn for +0.25 and 0.5 mb. Positive (negative) contours are dashed (solid). Caption adapted from CIG About PNW Climate webpage 2015.*

Section 6-3: Greenhouse Gasses

There are many challenges in isolating sources of global climate shifts. Although the output of the sun is the most important determinant of climate on earth, it has been shown that solar output has not increased. "Changes in solar activity may be partly responsible for the cool period in the 16th–18th centuries and for the warming early in the 20th century, but observations from satellites of solar output since late 1978 demonstrate that solar changes cannot be responsible for the large increase in global temperatures during the last 34 years: solar output has not increased over that period" (Snover et al. 2013).

The external forcing of long lived greenhouse gasses is widely implicated as the catalyst for changes in climate outside of normal fluctuations. Excessive CO_2 is the most serious contributor to the greenhouse effect, causing about 63% of the increase in radiative heating (Forster et al. 2007). Dr. Charles Miller, a research at NASA confirms (2015) that "current [atmospheric] CO_2 values are more than 100 ppm higher than at any time in the last one million years (and maybe higher than any time in the last 25 million years). Even more disturbing than the magnitude of this change is the fact that the rate of CO_2 accumulation in the atmosphere has been steadily increasing over the last few decades, meaning that future increases will happen faster. When averaged over 55 years, the increase has been about 1.55 ppm CO_2 per year. However, the most recent data suggest that the annual increase is more than 2.75 ppm CO_2 per year."

The greenhouse effect of trapped radiation on global climates and extreme weather is becoming well understood. As traditional carbon sinks (predominantly oceans and plant systems) are overwhelmed, local weather, hydrology, vegetation and wildlife are responding directly to the effects of rising CO_2. Other greenhouses gasses affect the atmosphere in different ways and in a range of potencies. Some of these gasses and their major sources include sulfur dioxide (SO_2) (coal burning, refining and combustion of petroleum products), ozone (O_3) (vehicular and industrial emission reaction to heat and sunlight), nitrogen oxides (NO_x) (automotive exhaust), carbon monoxide (CO) (partial fuel combustion) and particulates (PM) (burning fuel, especially diesel) (USDS 2014). Through the sequestration capabilities of plants, the restoration of forests, is justified to partially mitigate the accumulation and damage of these gasses. This is particularly important in urban areas, where emission sources are often concentrated.

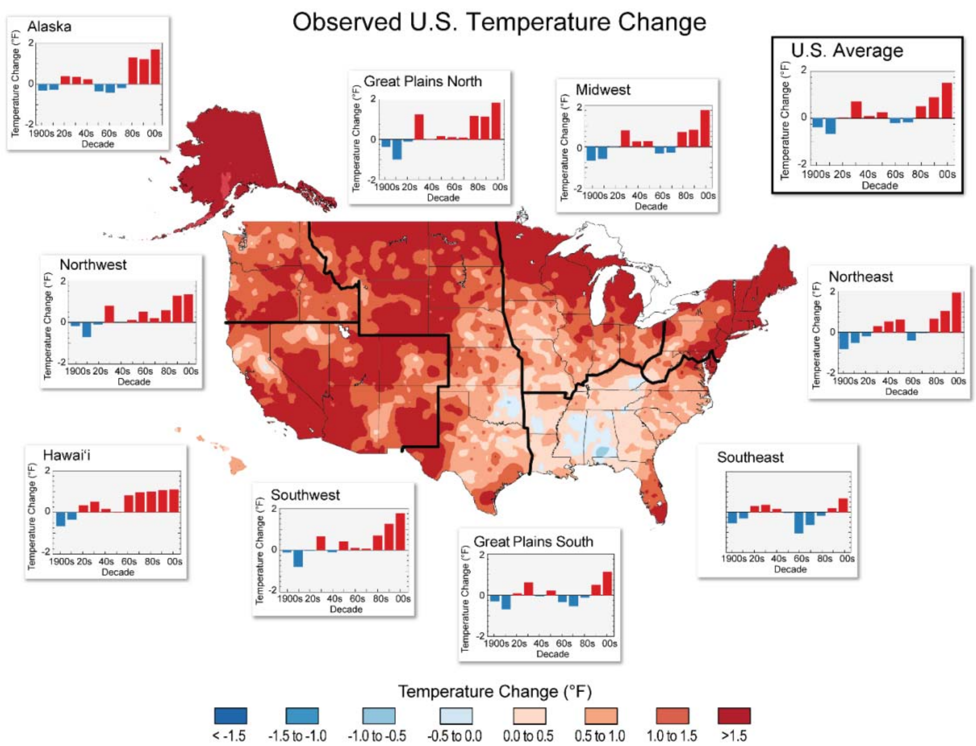


Figure 6-B: observed national and regional temperature change. *Difference in temperatures between 1991-2011 avg temp and 1901-1960 avg temp. Since 1920, northwest temperatures have risen 1.5°, although northwestern WA has remained insulated compared with SE Alaska and eastern Oregon. Figure and caption adapted from Ch. 2 in Draft 2014 US National Climate Assessment.*

Section 6-4: Climate Models

Climate models are evolving quickly as increasingly comprehensive tools for simulating the effects of external forcing on past and future climates. Atmosphere–Ocean General Circulation Models (AOGCMs) are extensively used, and were the standard in the IPCC's Assessment Report 4. They compute the physical dynamics of the climate system (atmosphere, ocean, land and sea ice) to project interactions with external forcing, like greenhouse gases (Flato 2011). While Earth System Models (ESM) are now the most cutting edge models because they additionally consider biogeochemical cycling (such as carbon, sulfur or ozone), AOGCMs are still used for predicting climate where biogeochemical feedbacks are not critical, or for regional focused studies (Flato et al. 2011).

Section 6-5: Regional Projections

It remains a challenge to pinpoint regional projections. Several different tactics of downscaling data generates locally relevant data from AOGCMs. They aim to transpose large scale predictions onto regional dynamics. This method can provide useful analysis, as in Figure 6-C, but is limiting due to the difficulties of combining detailed local physical and ecological processes into global models (Flato et al. 2013).

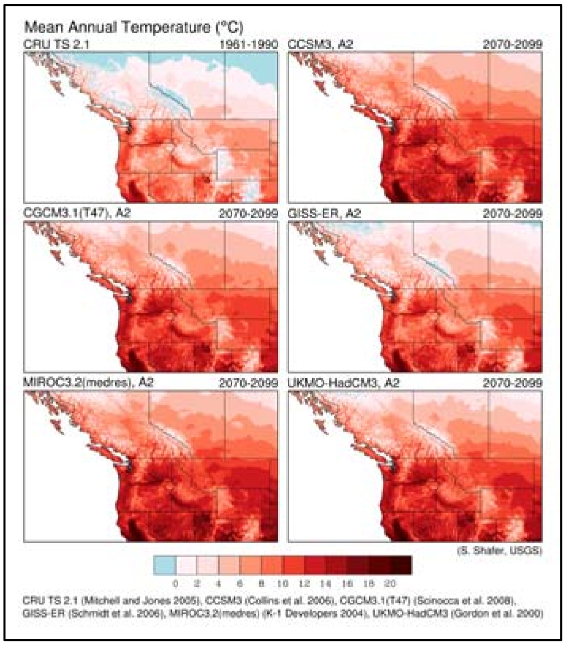


Figure 6-C: PNW vulnerability assessment project mean annual temperature 1961-1990 and 2070-2099. *Five AOGCMs simulate increased mean annual temperatures for 2070-2099 (30-year mean) as compared to a 1961-1990 (30-year mean) base period (top left map). However, the spatial pattern of the projected increases in mean annual temperature varies among the five AOGCM simulations. Caption and image adapted from Shafer 2010.*

Regionally downscaled climate models for the PNW, unanimously project increases in annual temperature with an upsurge in heat waves. Seasonal shifts towards wetter autumns and winters, and drier summers, are expected. Due primarily to the complicated dynamics of clouds, models do not agree on changes in annual precipitation in the PNW. However, rainfall is projected to fall in more extreme events, increasing flooding and landslide risk. Snowpack reductions will impede late summer streamflow, leading to increased probability of drought and wildfire (Littell et al. 2009; Snover et al. 2013).

Figure 6-D: projected changes in key Pacific northwest climate variables. (Snover et al. 2013)

- **Average annual temperature**, for 2050s: +4.3°F (range: +2.0 to +6.7°F) for a low greenhouse gas scenario or +5.8°F (range: +3.1 to +8.5°F) for a high greenhouse gas scenario (both relative to 1950- 1999).
- **Extreme precipitation**, for 2050s: number of days with more than one inch of rain increases +13% (±7%) for a high greenhouse gas scenario (relative to 1971-2000).
- **Average April 1 snowpack** in Washington State, for 2040s: -38 to -46% for a low and a medium greenhouse gas scenario (relative to 1916-2006).
- **Sea level** in Washington State, for 2100: +4 to +56 inches for low to high greenhouse gas scenarios (relative to 2000). Local amounts of sea level rise will vary.
- **Ocean acidity**, for 2100: +38 to +41% for a low greenhouse gas scenario and +100 to +109% for a high greenhouse gas scenario (relative to 1986-2005).

Section 6-6: PNW Hydrology Observations, Projections and Effects

The quickly changing interplay between temperature, water movement and water availability will severely impact western Washington's hydrology over the 21st century. Rising temperatures have a dual effect on the water cycle- more rain and less snow (Littell et al. 2009). Inhibited snow pack formation in the Cascades speeds the metered movement of snowmelt down the mountains. Over the last 40-70 years, snowpack in the Cascade Mountains, has been reduced 25% on average (Littell et al. 2009). Since around 1950, spring snowmelt occurred 0 to 30 days earlier in the Cascades, depending on the specific location (Stewart et al. 2005). The slow release of water into the lowlands that normally arrives as late summer streamflows, will instead flood waterways throughout the winter and early spring. Changes already observed since around 1950, reveal the portion of total annual flow contributed by late winter/early spring streamflows has swollen by 0% to 20% (Hidalgo et al. 2009); contributions to total annual flow by summer flows decreased 0% to 15%. (Stewart et al. 2005). Downstream water temperatures will continue to rise, lowering dissolved oxygen capacity, which has debilitating effects on fish and other freshwater organisms.

Into the future, more extreme rain events will likely increase flooding on the UW Seattle campus, and further overloading of Seattle's Combined Sewer Overflow (CSO) system. Overloads of the design-flawed CSO system (combined sewage and stormwater) overwhelm Seattle treatment facilities and result in untreated sewage discharges directly into Lake Union and Puget Sound. These overloads are visible from the UW campus several times a year.

As a ravine, KR is profoundly shaped by its relationship with water. Efforts to mitigate the derailment of the hydrologic system include vegetative enhancement of the stream, two wetlands and the entire riparian corridor. Addition of course woody debris, installation of an evergreen canopy and enhancement of the forest's cooling effect through dense native plantings, all serve to improve water quality and decrease water discharge from the ravine. Furthermore, as flooding dangers increase, maximizing the storage capacity of KR will serve the surrounding micro-basin.

Section 6-7: Vegetation Observations, Projections and Effects

There are many uncertainties about how plant species, plant biology, nutrient availability and forest health will react to quickly changing terrestrial, hydrologic and atmospheric conditions. Composition, density and range shifts in plant communities have already been observed (EPA 2014). Delays in plant flowering were observed over the last century (Primack 2012; Leicht-Young et al. 2013), and are implicated in phenological mismatch (Winder and Schindler 2004). Water deficits, increasing wildfire, insect outbreaks, and tree diseases, already occurring in the western United States, will be exacerbated in the PNW (Capalbo 2014). The interaction of these factors is difficult to predict but the cumulative effect will permanently transform forest dynamics.

The ranges of plants on a global scale are generally expected to shift polewards, or upwards in elevation. However, many factors will ultimately determine the new ranges of these plants, including the volatility of temperature and precipitation patterns, tropospheric increases in nitrogen, ozone, and CO_2, and increases in damaging UV light passing through an increasingly ozone-depleted stratosphere (Ziska and Dukes 2011). These atmospheric related factors are continuously compounded by land use changes and voluntary or involuntary invasive seed and plant dispersal. As plants move into new ranges they will encounter competition with plants they are not accustomed to, and this may be to their advantage or disadvantage. They will find limits due to soil type that don't support their establishment and may lose relationships with traditional pollinators or soil microbes, and may gain new ones. Therefore, shifts in plant ranges on a local scale is perplexing to predict. Some plants may expand ranges, while others may contract, and some may simply shift (Ziska and Dukes 2011).

PNW summers are normally dry, and the increased moisture stress of intensified summer dryness will affect vegetation growth. Other factors like, increased atmospheric CO_2, a lengthened growing season and higher temperatures, have influences on plants that are difficult to forecast. Some plants, like subalpine firs and mountain hemlock are expected to increase growth, while some, like Douglas firs, may see reduced growth in some parts of its range (Albright and Peterson 2013). Overall, growth responses will be varied between species, elevation and location.

Effects on vegetation due to anthropogenic climate change will be felt on the UW campus. Climate change may be implicated in hastened forest succession, particularly in the 'heat island' urban environment. These effects may make plant selection for landscapers and restoration practitioners more difficult as typical landscape plants and certain native plants may not thrive in Seattle as they surpass thermal or moisture thresholds. More intense rainfall events could damage plants susceptible to submersion. Increased summer dryness may demand more frequent irrigation over a longer dry season.

In KR, the installation of 3,755 plants has a net cooling effect on the forest floor, and the local micro-atmosphere, including nearby buildings. Shading and evapotranspiration reduce surface temperatures and maintain soil moisture. Efforts to install a diversity of native plants in KR, and surrounding green spaces on campus, like Whitman Walk and the Union Bay Natural Area, will increase ecosystem resilience, reinforce the native seed bank, and decrease invasibility by weeds.

Invasive Plant Proliferation

Weed control may become more challenging on global and local levels, as speedy and aggressive plants thrive under destabilized conditions. A study by Ziska et al. in 2003 (Ziska and Dukes 2011) showed that the elevated temperatures and CO_2 levels in an urban environment favored fast growing woody perennials during primary succession, as compared to a rural environment with lower temperatures and CO_2 levels. These fast growers produced more biomass and litter, hindering seed germination of slow growers and annuals. In a forest context, rapid establishment of pioneer vegetation may squeeze out slower growing plants as the system skips quickly towards secondary succession. This shift in plant demography could widely favor weedy species, which often grow quickly post-disturbance (Ziska and Dukes 2011).

Traits of many invasive species that cause them to flourish outside of their native range may allow them to dominate competition with their new native neighbors during range shifts. These traits often include rapid colonization (due to long distance seed dispersal, and an abbreviated juvenile stage), high adaptability to climate, 'enemy release' from traditional pathogens and herbivores, and lack of dependence on specialists (ie: pollinators, mycorrhizae) (Ziska and Dukes 2011).

In particular it has been shown that certain vine species benefit considerably from increased CO_2 (Condon et al. 1992), as they can allocate photosynthates directly to leaf development, rather than structural tissues, since they rely on trees for structural support (Putz and Mooney 1991). In the case of KR, infestations of hedge false bindweed *(Calystegia sepium)*, old man's beard (*Clematis vitalba*) and English ivy (*Hedera helix*) are well established. Growth may accelerate and threaten tree health. This will likely demand additional manual and chemical control treatments.

In KR, an Invasive Species Management Plan was developed in the KR Restoration and Stewardship Plan (Moritz 2014). Additional techniques for controlling invasive plant proliferation, seed production, rhizomatous reproduction and the introduction of new species is detailed in Chapter 3 Vegetation.

Section 6-8: Soil Carbon Projections and Effects

"The soil carbon pool is approximately 3.1 times larger than the atmospheric pool of 800 GT (Oelkers and Cole 2008)."

"Only the ocean has a larger carbon pool (than soil), at about 38,400 GT of C, mostly in inorganic forms (Houghton 2007)."

Soil organic matter (SOM) is an interactive web of microbes, decaying plants and animals, and fecal material at varying stages of decomposition. SOM correlates directly to soil organic carbon (SOC), the product of an intricate biogeochemical process. Soil gains and loses carbon through photosynthesis, root growth, plant associations with microbes, plant and microbial respiration, decomposition, erosion, and leaching (Beldin and Perakis 2009). In wet, temperate forests like in the PNW, high primary productivity during summer outpaces the slowed down decomposition process during winter, allowing carbon to build up in the forest floor over time as humus (Beldin and Perakis 2009).

Climate change will have complex effects on soils. Increased CO_2 may boost photosynthetic rates and carbon intake as plant biomass increases. However, carbon loss will also increase through plant respiration. Additionally, a rise in microbial activity that will surge to decompose the higher biomass plants, may break down and release the carbon from soil organic matter into the atmosphere more quickly. (Drake et al. 1997; Zak et al. 2000). Areas of water deficit due to increasing temperatures in the PNW, will likely experience decreases in nutrient availability, plant growth and ultimately, carbon storage in soils (Beldin and Perakis 2009). In sum, it appears that the destabilization of atmospheric chemistry will make homeostasis improbable for plants as it is understood now, between the absorption, storage, and loss of carbon and water.

During restoration activities like invasive plant removal and tree planting, disturbances including the churning up of soil, and exposure to the warming and drying effects of direct sunlight, release CO_2 to the atmosphere. However, the actions of restoring the forest to a healthy state and controlling erosion will improve sequestration and storage, eventually filling the carbon deficit in the soil, accomplishing a net sink effect on CO_2. Furthermore, wetland restoration is of essential value since carbon storage potential is high due to slow decomposition rates of hydric soils (Ontl, 2012).

In KR, efforts to fulfill soil carbon capacity include erosion control, a policy of leaving green waste on site, and improvement of soil health. Soil erosion control measures include mulching, jute netting, fascines, debris piles placed at toe slopes, and immediate planting of bare ground. Soil health improvements include aeration through diverse native plantings that include deep taproots, mid-depth roots, and shallow fibrous roots. Enhancement of the stream and wetlands will encourage the carbon storage potential of the slow-decomposing hydric soils.

Section 6-9: Forest Sequestration and Storage Calculations

Carbon sequestration in forest ecosystems, like KR, occurs in live plants, and accumulates in dead wood, litter, and soil organic matter. The most active carbon accumulators are live trees, due to their quick accumulation of biomass, and that is the focus of the following analysis. A temperate climate and highly productive soil makes the PNW old growth forests the highest carbon storage biome on the planet (Beldin, 2009). The implication for restoring forests in this system on an old growth trajectory is explicit. KR is presently dominated by a deciduous tree canopy, but a thick planting of conifers will eventually follow in succession.

Several sources list different figures on carbon sequestration. An old report from the USDA/Forest Service (1992) states a live tree carbon accumulation rate of **1,252 lbs/acre/yr**, a rate of increase of 2.7 percent of the amount stored in live trees. This report is not PNW specific. It also discounts understory vegetation as "such a small percentage of the total carbon stock in forests that it is often ignored or added to the trees in estimates of all live vegetation" (USDA 1992). The EPA Clean Energy "Acres of U.S. forests storing carbon for one year" webpage (2014) states **2,689.64 lbs/acre/yr** CO_2 sequestered annually by one acre of average U.S. forest. There is such wide variation in US forests, however, that this EPA statistic is not relevant for individual restoration projects in the PNW. The USDA i-Tree Canopy program (2015) individualizes carbon calculations by county. It lists a **8,434.331 lbs/acre/yr** CO_2 sequestration rate and a **251,395.359 lbs/acre** CO_2 storage rate for King County, WA. Strangely, i-Tree does not disclose its CO_2 calculations, or clarify for how many years the CO_2 storage amount is calculated for, in the i-Tree Canopy Technical Notes. However, I have chosen i-Tree Canopy as the most useful for restoration projects as it is updated with current information, is county-specific and is widely used. I selected the American Forest's "Tree Carbon Sequestration and Storage" (2015) calculations of **~410,060 lbs/acre** CO_2 sequestered and stored (over a 55 yr lifespan) to complement the i-tree calculation for KR. See Appendix E for step by step photos of using the i-Tree application.

i-tree also provides calculations on annual sequestration for carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide and particulate matter, which is seen below in Table 6-a. When produced by modern civilization at levels above normal, these compounds degrade air quality and instigate atmospheric imbalance in unique ways, contributing significantly to climate change.

KR Carbon Calculator Results and Descriptions

i-Tree Canopy: carbon dioxide sequestered annually/ stored in trees for KR

19,800 lbs/yr CO_2 sequestration, based off of 8,434.331 lbs/acre/yr for King County

590,080 lbs total CO_2 storage, based off of 251,395.359 lbs/acre for King County

American Forests: forest carbon sequestration and storage (55 yr lifespan)

1,476,216 lbs or 738.108 tons **CO_2 sequestered + stored for 55 years**, based off of 410,060 lbs/acre X 3.6 acres i-Tree Canopy: carbon dioxide sequestered annually/ stored in trees

8,434.331 lbs/acre/yr CO_2 sequestration rate for King County, WA

i-Tree Canopy is a tool "*designed to allow users to easily and accurately estimate tree and other cover classes (e.g., grass, building, roads, etc.) within their city or any area they like. This tool randomly lays points (number determined by the user) onto Google imagery and the user then classifies what cover class each point falls upon.*"

i-Tree Canopy Annual Tree Benefit Estimates based on King County values:

CO 0.787 | NO2 6.863 | O3 45.682 | PM2.5 2.899 | SO2 2.529 | PM10 14.312 | CO_2seq 8,434.331 | CO_2stor is a total biomass amount of 251,395.359*

Limitations of I Tree Canopy

The accuracy of the analysis depends upon the ability of the user to correctly classify each point into its correct class. If too few data points are classified, the standard error will be too high to have any real certainty of the estimate. Another limitation of this process is that the Google imagery may be difficult to interpret in all areas due to relatively poor image resolution (e.g., image pixel size), environmental factors, or poor image quality."
- i-tree Tools for Assessing and Managing Community Forests 2015

American Forests: tree carbon sequestration and storage (55 yr lifespan)

~410,060 lbs/acre CO_2 sequestered and stored (55 yr lifespan) rate for US forests

"The first step in determining how much carbon is sequestered by a single tree is to convert carbon to carbon dioxide (CO_2) or carbon dioxide equivalent (CO_2e). For our calculations, we used the common conversion of:

1 ton of carbon = 3.666 tons of CO_2
This represents the weight of carbon dioxide (44) divided by the atomic mass of carbon (12). Next, it is estimated that one acre of trees stores 50.8 metric tons of carbon, so…

50.8 metric tons of carbon X 3.666 tons of CO_2 = ~186 metric tons of CO_2 per acre of forest
Since we don't use metric tons as a common measurement in the U.S., we next need to convert tons to pounds:

1 metric ton = 2204.62262 pounds
186 metric tons X 2204.62262 pounds = ~410,060 pounds of CO_2 sequestered per acre of trees

**As you may be able to surmise from the above, to get this calculation, we did need to make a few assumptions. For instance, we choose 55 years as the age for estimating carbon sequestration and storage, and we started with the U.S. Forest Service's averages for carbon stored by trees (58.8 tons per acre) and made slight alterations for significant outliners, which gave us 50.8 metric tons per acre."*

-American Forests 2015

Table 6-a. i-tree canopy results for KR- canopy composition and tree benefit estimates.

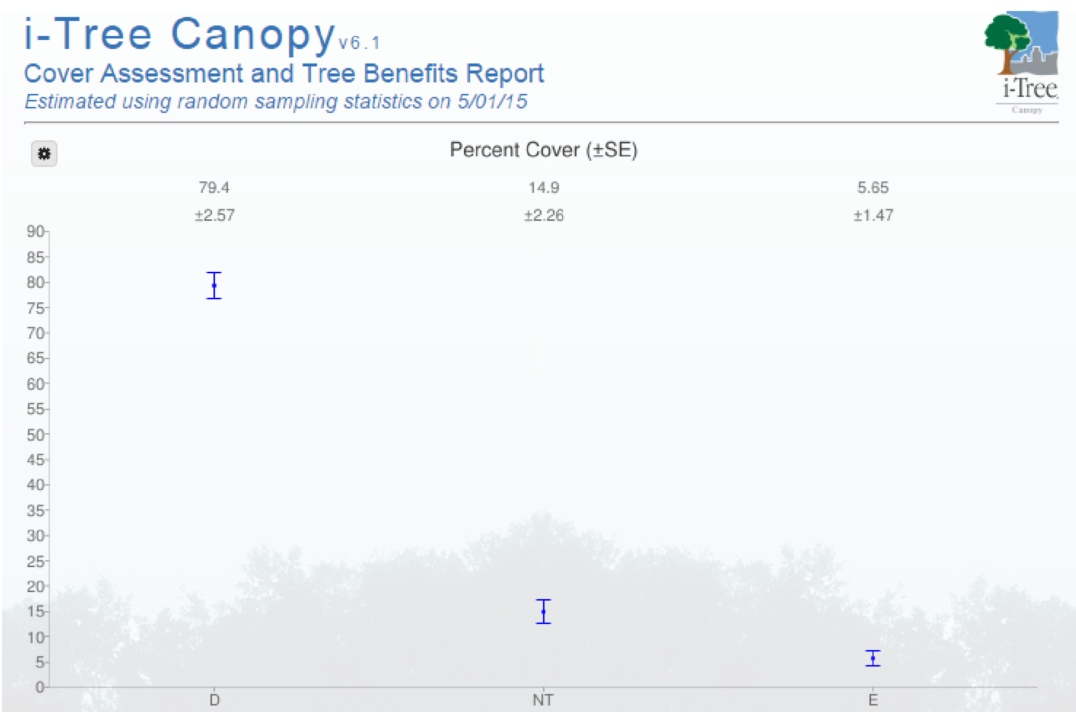
Cover Class	Description	Abbr.	Points	% Cover
Deciduous	Tree, non-shrub	D	197	79.4 ±2.57
Non-Tree	All other surfaces	NT	37	14.9 ±2.26
evergreen		E	14	5.65 ±1.47

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$1.23	±0.03	1.85 lb	±0.05
NO2	Nitrogen Dioxide removed annually	$3.15	±0.08	16.11 lb	±0.43
O3	Ozone removed annually	$200.34	±5.33	107.23 lb	±2.85
PM2.5	Particulate Matter less than 2.5 microns removed annually	$574.57	±15.28	6.80 lb	±0.18
SO2	Sulfur Dioxide removed annually	$0.47	±0.01	5.94 lb	±0.16
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$104.92	±2.79	33.60 lb	±0.89
CO2seq	Carbon Dioxide sequestered annually in trees	$191.67	±5.10	9.90 T	±0.26
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$5,713.05	±151.92	295.04 T	±7.85

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and $/T/yr: CO 0.787 @ $1,333.50 | NO2 6.863 @ $391.85 | O3 45.682 @ $3,749.93 | PM2.5 2.899 @ $169,479.81 | SO2 2.529 @ $157.74 | PM10 14.312 @ $6,268.44 | CO2seq 8,434.331 @ $19.43 | CO2stor is a total biomass amount of 251,395.359 @ $19.43*
Note: Standard errors of removal amounts and benefits were calculated based on standard errors of sampled and classified points.

Figure 6-E: i-tree canopy results for KR: canopy composition. D= deciduous; NT= non-tree E= evergeen



Section 6-10: Implications for Restoration and Future Research

Implications for restoration

- Planting of large volume, long-lived trees maximizes carbon sequestration and storage
- Wetland restoration critically improves the high carbon storage potential of hydric soils
- Restoration of existing natural lands to increase the resiliency of native plant and soil communities, will minimize the climate change induced effects of wildfire and insect outbreak
- Calculating and publishing carbon storage data for urban green spaces elucidates the importance of restoring these areas to the public

Future Research

5) Cooling effect of KR- measure forest floor temperatures v.s. nearby open pavement surface temperatures
6) Biosolid soil ammendments- expedite plant growth, increase soil carbon sink
7) Compare soil carbon of KR Natural Area vs nearby landscaped garden on campus

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APPENDIX A: Memorandum of agreement and KR perimeter maps 1 and 2

Memorandum of Agreement: Kincaid Ravine Natural Area

The Kincaid Ravine Natural Area is a 3.6 acre parcel of steeply sloping forested land with a native, deciduous tree dominated canopy located south of NE 45th Street, west of the Burke Gilman Trail, extending south to the North Physics Laboratory, and east to the student housing at the top of the slope. The forest contains a mixed understory of both native and non-native species. Two delineated wetlands and an unnamed stream channel are present within the project boundaries.

Restoration of this area was initiated during the 2012-2013 academic year as a partnership between the University of Washington Grounds Management (UW Grounds), the University Landscape Architect, the Campus Sustainability Fund (CSF), EarthCorps (EC), the UW-Restoration Ecology Network (UW-REN) and the UW-chapter of the Society for Ecological Restoration (SER-UW). Project management, including the coordination of stakeholders and events, is maintained by a yearly rotation of graduate students in the Masters of Environmental Horticulture program. Funding from the CSF and the King Conservation District's (KCD) Seattle Community Partnership grant is currently allocated to continue restoration through 2018.

I. Purpose of the Agreement

This Memorandum of Agreement (MOA) sets out the terms by which UW departments and other entities will work together with EC and the KCD to implement an ecological restoration plan and a natural areas conservation plan, establishing roles, responsibilities, and activities that will be allowed within the Natural Area.

This site will remain a 'Natural Area', free from significant development for the duration of this agreement, which will extend for 10 years (2015-2025), at which point it will be reassessed and negotiated as necessary. Potential activities that violate the terms outlined below will be evaluated by all Project Partners for approval prior to commencing any work within the Natural Area.

Project Partner Key Contacts:

University of Washington Grounds (UW Grounds)
Howard Nakase, Manager of Grounds Operations
hmnakase@uw.edu
206.685.1407

University of Washington-Restoration Ecology Network (UW-REN)
Kern Ewing, Professor of Plant Ecology
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206.543.4426

Society for Ecological Restoration-UW Chapter (SER-UW)
Cameron McCallum, Acting President
mccallum.cameron@gmail.com

University Landscape Architect
Kristine Kenney
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206.685.6430

Student Project Manager
2013-2014 Martha Moritz, moritzms@uw.edu
2014-15 Matt Schwartz, mateos@uw.edu
2015-16 Dan Hintz, daniel.j.hintz@gmail.com

Campus Sustainability Fund (CSF)
Graham Golbuff, CSF Coordinator
csfcoord@uw.edu
206.221.0392

EarthCorps
Kym Foley, Project Manager
kym@earthcorps.org
206.322.9296 x202

These individuals are responsible for ensuring the conduct of the activities listed below.

II. Statement of Mutual Benefits and Interests

The University of Washington is dedicated to ensuring the sustainability of its natural resources, including its natural areas. Services provided by the Kincaid Ravine Natural Area include:

a) Educational opportunity for increasing the public's knowledge and awareness of natural areas, as well as UW's commitment to environmental sustainability.
b) Aesthetic beauty that characterizes this section of campus, and the 'Forest Reach' segment of the Burke Gilman Trail.
c) Stormwater runoff quantity reduction and quality improvement.
d) Air pollution removal, including ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter.

e) Carbon sequestration and carbon storage by 3.6 acres of vegetation.
f) Public health incidence reduction based on the effect of trees on air quality improvement.
g) Erosion control on steep slopes upland of wetlands (steepest grades between 50-70%).
h) Noise attenuation for North Campus from noise pollution (NE 45th St. and Montlake Boulevard).
i) Habitat for native wildlife including birds, amphibians, insects, and the symbionts upon which they depend.

The Parties agree to:

1) Site Boundaries: As indicated in MAP 1, the boundaries of Kincaid Ravine establish the physical perimeter that within which is subject to the Permitted Activities. The site area totals 3.6 acres. Inside this established perimeter is a no development zone, the sole permitted activities are education + recreation, restoration, conservation, and transportation (and existing easements), as defined below. In MAP 2, a zone of influence in adjacent areas is suggested to encourage native plant selection complementing Kincaid Ravine and Whitman Walk during development planning, in order to link the two habitats for imperiled native pollinators.
2) Permitted Activities: Within the site boundaries will be defined as a natural area, which is a no-development zone, dedicated to a long term conservation plan.
    a. Education + Recreation
        i. Maximized educational and enjoyment opportunities with educational signage and log benches located in a way to preserve the integrity of the vegetation by minimizing trampling for access.
        ii. Classroom field trips, independent research opportunities and public enjoyment will follow a minimal-disturbance etiquette.
    b. Ecological Restoration, as outlined in the "Kincaid Ravine Restoration and Stewardship Plan", written by Martha Moritz (7.1.14)
        i. Initial removal and continued maintenance control of invasive plant species, including noxious weeds.
        ii. Initial native plant installation and continued supplemental planting, as appropriate for site-specific conditions.
        iii. Initial removal and continued maintenance removal of trash and debris. In the case of hazardous materials this includes contracting appropriate contractors.
        iv. Initial and continued erosion control, utilizing native plants, and mulch or wood straw, to stabilize soil, with supplemental jute netting as needed.
        v. Wetland enhancement through vegetative restoration and the introduction of course woody debris. Permit-dependent, this may include excavation or re-routing to increase on-site infiltration.
    c. Natural Area Conservation
        i. Adjacent construction (i.e. north campus residence halls, Burke Gilman Trail expansion) will continue to enhance the areas in and around Kincaid Ravine, taking all necessary precautions to not enter or affect the Natural Area, through erosion, soil compaction, contaminated runoff, air pollution or other ecologically negative means.
    d. Transportation
        i. Minimized disturbance of the Natural Area and concentration of foot traffic is desired to ensure protection of the natural environment.
            1. Walking trail will consist of predominately natural materials, and maintain a natural aesthetic, including wooden stairs.
            2. Walking trail will be constrained in width to minimize disturbance.

3. Walking trail will be emphasized for daytime use and any proposed illumination will be assessed to minimize impact on nesting birds and other wildlife while providing safe passage for pedestrians.
4. Walking trail will minimize direct contact with wetlands by means of avoidance or boardwalks.
    a. Where impacts cannot be avoided, efforts will be taken to minimize and mitigate the amount of area impacted.

III. Roles and Responsibilities

Responsibilities of Student Project Manager

The Student Project Manager is a rotating position that has been filled by Masters of Environmental Horticulture (MEH) students, in fulfillment of their capstone project. Continuity of this role is overseen by the MEH faculty advisers.

a) Serve as central coordinator between project partners.
b) Coordinate on-site activities and all related logistics.
c) Manage grants and seek new funding sources.
d) Execute the goals of the Kincaid Ravine Restoration and Conservation Plans, adapt it and add appendices as needed, using the best available science to promote ecosystem health.
e) Encourage and coordinate specialty projects, such as 'Educational Nook', 'Wetland Enhancement' and 'Pollinator Patches' in the interest of creating a campus Forest Laboratory for use by UW classes and the public.

Responsibilities of SER-UW

SER-UW is a student club with rotating members and inconsistent funding. All responsibilities are subject to constraints on membership and funding, but efforts will be made to prioritize Kincaid Ravine restoration as one of their primary goals. SER-UW agrees to:

a) Conduct public work parties to maintain native plantings and control invasive plants.
b) Provide native plants from the SER-UW nursery.

Responsibilities of UW Grounds

a) Provide support for student initiatives that may include: use of tools, removal of vegetation, delivery of wood chips and course woody debris, and other resources when appropriate.
b) Facilitate cleanup of debris and hazardous materials.
c) Assume primary responsibility for stewardship, active maintenance of native plants and removal of invasive plants into the future, and in the case that the role of Student Project Manager is not filled.

Responsibility of EarthCorps

a) Complete restoration and conservation plans as indicated in Scope of Work through 2018 or until funding provides for.

Role of University Landscape Architect

a) Provide support for student initiatives that may include: plan review, annual on-site meetings, coordination with administration, and guidance when appropriate.

Roles of Funders

b) The CSF has provided $100,124.44 to initiate restoration plans and perform public outreach and student engagement through June 2016.
c) The KCD has funded $38,696 to continue engaging the community in successful restoration efforts through native plantings and invasive plant removal while addressing site safety and accessibility through December 2018.

Role of UW-REN

a) The UW-REN capstone group has allocated a group of students each academic year (2013-14, 2014-15) to perform restoration on a 1/8-1/3 acre plot within Kincaid Ravine. This provides a valuable educational experience for the students and contributes to accomplishing the goals of the Kincaid Ravine Restoration and Conservation Plan.

IV. Signatures of Project Partners

Paul Jenny, Senior Vice President, 29 May 2015

Howard Nakase, Manager of Grounds Operations, 06.23.15

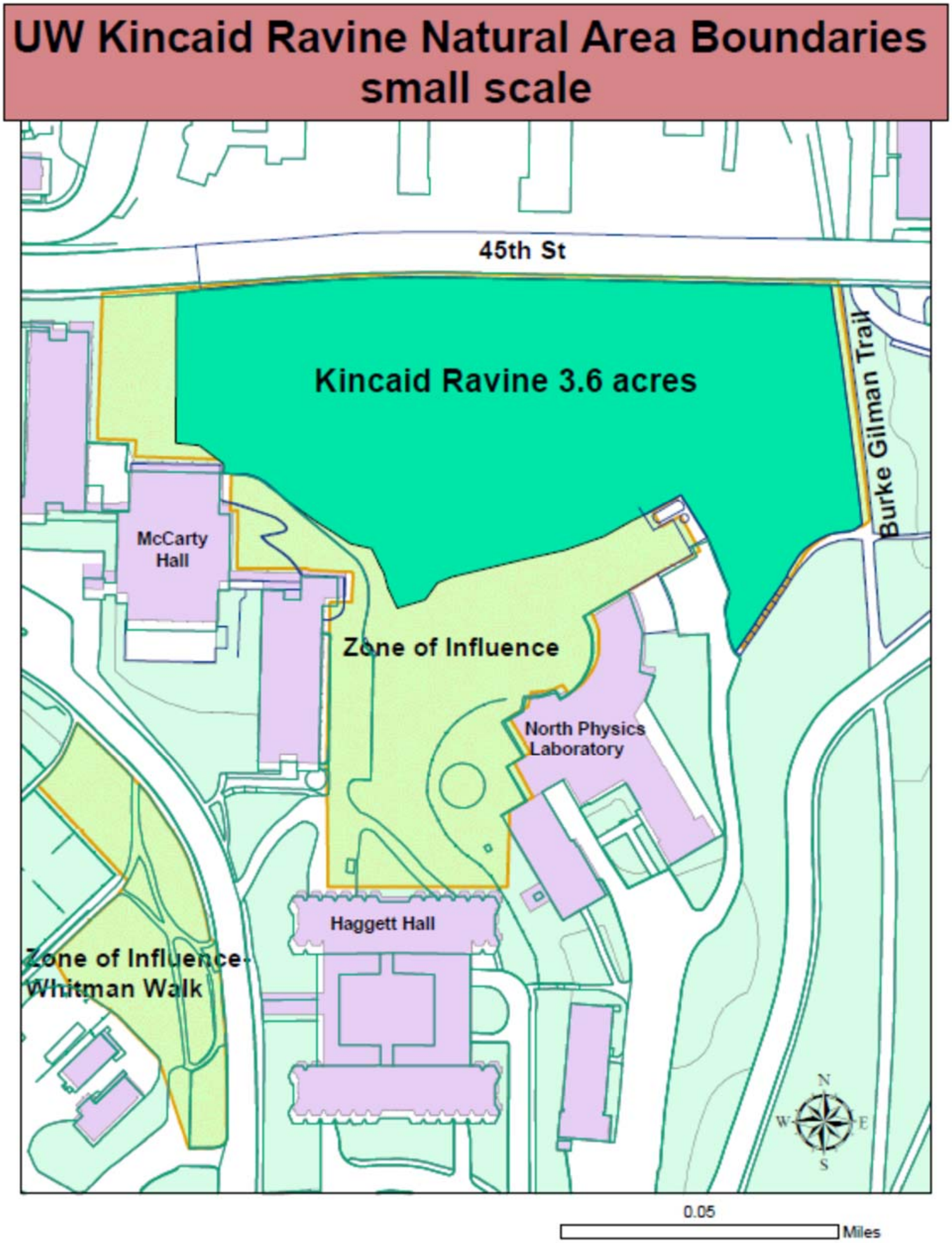
Kym Foley, EarthCorps Project Manager, 6/8/2015

Kern Ewing, faculty, 7 May 2015

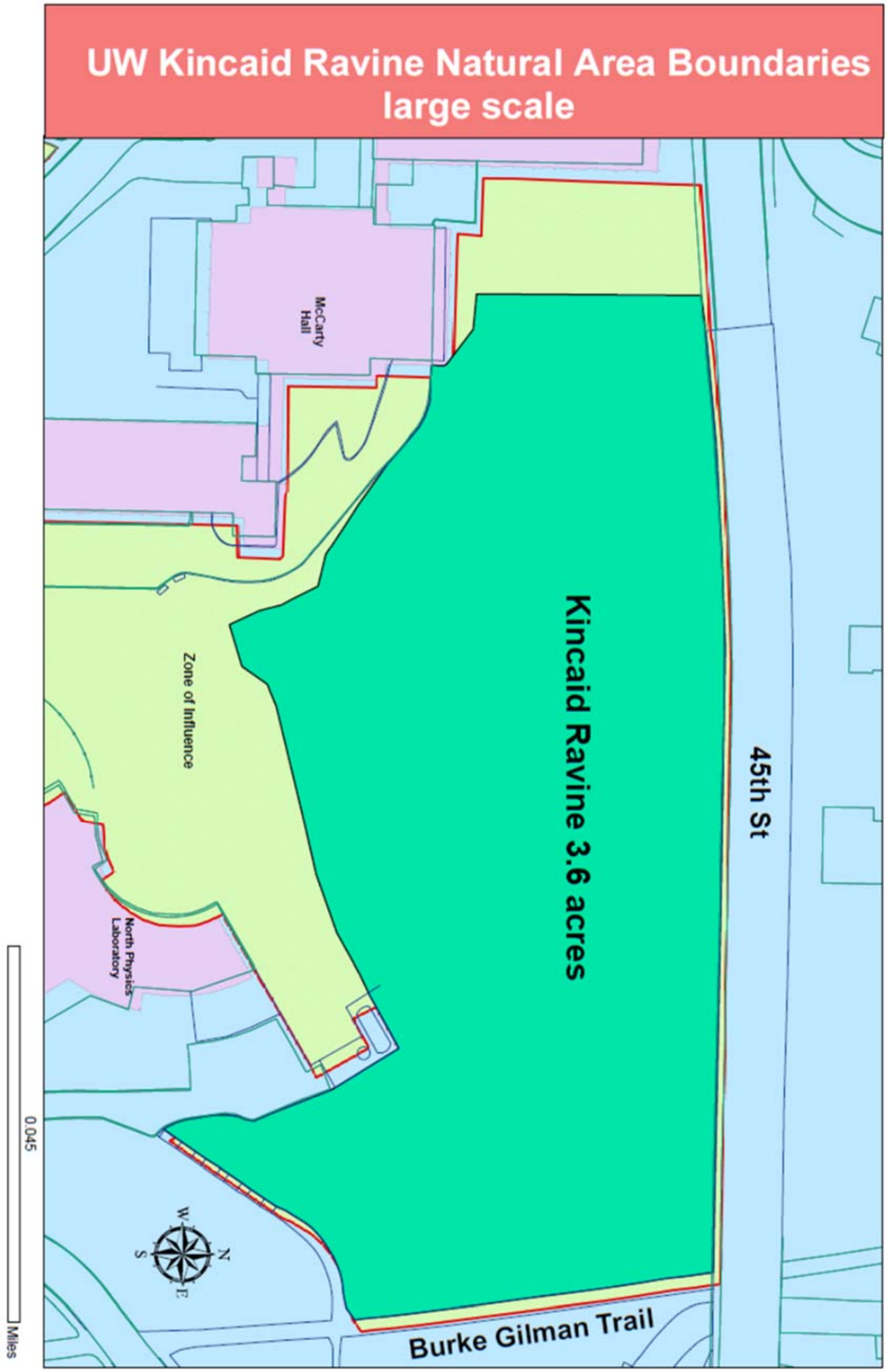
Cameron McCallum, SER-UW President 6/3/15

Graham Golbuff, CSF Coordinator, 5.7.15

KR perimeter map 1



KR perimeter map 2



APPENDIX B:

Pollinator Plant Index: tree/shrub list

latin	common	form	growth notes	moisture	light	specific site type
Acer circinatum	vine maple	tree	average 10'-15' tall, up to 20' wide	moist, wet	part shade	hedge; riparian; roadside; slopes
Amelanchier alnifola	serviceberry	shrub	well drained soils, deep wide root system	dry, moist	sun, part shade	hedge; roadside; rocky slopes; meadows; open forests
Arbutus menziesii	Pacific madrone	tree	well drained soils; deep, wide roots	dry	sun	hedge; roadside; slopes
Arctostaphylos uva-ursi	kinnikinnick	shrub	acidic, well drained soils	dry	sun	dry hedge; slopes
Ceanothus velutinus	snowbrush	shrub	well drained, rocky, sandy soils; nitrogen fixer	dry, moist	sun, part shade	dry hedge; rocky slope; forest opening; burned sites
Cornus sericea	red osier dogwood	shrub	grows quickly from live stakes	moist, wet	sun, part shade	wet hedge; riparian, wetlands; slopes
Crataegus douglasii	black hawthorne	tree	deep, strong roots; prefers moist soil	moist	sun, part shade, shade	roadside; slope; riparian; coastal bluff; forest opening
Gaultheria shallon	salal	shrub	difficult to establish; thick groundcover; wide root system	dry, moist	sun, part shade, shade	hedge; forest understory; slope
Holodiscus discolor	oceanspray	shrub	well drained soils; shallow roots stabilize topsoil	dry, moist	sun, part shade	dry hedge; slope; riparian; coastal bluff
Lonicera ciliosa	orange honeysuckle	vine	climber	moist	sun, part shade	wet hedge; forest understory
Lonicera hispdula	hairy honeysuckle	vine		dry	sun, part shade	dry hedge; forest opening; coastal bluff
Lonicera involucrata	black twinberry	shrub		moist, wet	part shade	wet hedge; riparian, wetland, streambank
berberis aquifolium	tall oregon grape	shrub	well-drained soils, tolerant of nutrient poor soils	dry, moist	sun, part shade	hedge; road/trailside; rocky slopes
Berberis nervosa	dwarf oregon grape	shrub	groundcover	dry, moist	part shade, shade	slopes; forest understory
Malus fusca	Pacific crabapple	tree	can be thicket forming	moist, wet	sun, part shade	hedge; streambank, wetland, estuary; coastal dune
Oemleria cerasiformis	indian plum	shrub	grows fast to 15'-20'; tolerant of polluted soils	dry, moist	part shade	hedge; riparian; roadside; forest opening
Philadelphus lewisii	mock orange	shrub	well drained, rocky soils	dry, moist	sun, part shade	hedge; forest opening; coastal bluff
Physocarpus capitatus	Pacific ninebark	shrub	needs moisture to establish; extensive roots	moist, wet	sun, part shade	slope; riparian, ditch

Prunus emarginata	bitter cherry	tree	soil stabilizer	moist	sun	wet hedge; roadside; slope; riparian
Quercus garryana	Garry oak	tree	well drained, sandy soils	dry	sun, part shade	rocky slope; dry meadow; open forest
Rhamnus purshiana	cascara	tree	to 30'; strong roots	dry, moist, wet	part shade	riparian, marsh
Rhododendron macrophyllum	Pacific rhododendron	shrub	acidic, well drained soil	dry, moist	sun, part shade	roadside, parking lot swale; forest understory, opening; burned sites
Ribes lacustre	black gooseberry	shrub		moist	sun, part shade	slopes; seep, streambank
Ribes sanguineum	red-flowering currant	shrub	well drained soils	dry	sun, part shade	rocky slope; roadside, parking lot swale; riparian; forest edge
Rosa gymnocarpa	baldhip rose	shrub		dry, moist	sun, part shade	hedge; rocky slope
Rosa nutkana	nootka rose	shrub		dry, moist	sun, part shade	road/trailside, parking lot swale; riparian; meadow; coastal bluff
Rubus parviflorus	thimbleberry	shrub	quickly forms dense thickets	dry	sun, part shade	hedge; slope; streambank; roadside
Rubus spectabilis	salmonberry	shrub	quickly forms dense thicket	moist, wet	sun, part shade	wet hedge; slope; riparian, wetland, streambank ditch
Rubus ursinus	trailing blackberry	shrub	fast, easy to grow groundcover	moist	sun, part shade, shade	roadside; slope; burned site
Salix hookeriana	hookers willow	tree	fibrous, moderately deep roots	moist, wet	sun, part shade	slope; riparian, wetland, river bar
Salix lucida ssp. Lasiandra	Pacific willow	tree	fast grower; 25 year lifespan; fibrous, moderately deep, widespread roots	moist, wet	sun, part shade, shade	slope; riparian, wetland, floodplain
Salix scouleriana	scoulers willow	shrub	fibrous, moderately deep, widespread roots; most dry-tolerant willow on list	dry, moist	sun, part shade, shade	slope
Salix sitchensis	sitka willow	tree	fast grower; fibrous, moderately deep, widespread roots	moist, wet	sun, part shade	slopes; riparian, wetland
Sambucus racemosa	red elderberry	tree	tolerates poor soils	moist, wet	sun, part shade	wet hedge; riparian, wetland, floodplain
Spiraea douglasii	hardhack	shrub	aggressive; can absorb toxins from water, air, and soil	moist, wet	sun, part shade	hedge; parking lot swale; wetland, streambank
Symphoricarpos albus	snowberry	shrub	well drained soils; spreads by underground runners to form thickets	dry, moist	sun, part shade	dry hedge; slope; riparian; coastal dune, beaches
Vaccinium ovatum	evergreen huckleberry	shrub	slow growing; well drained soil	dry, moist	sun, part shade, shade	hedge; forest opening; coastal dune, beach, bluff

Vaccinium parvifolium	red huckleberry	shrub	rich soils, nurse logs	moist	part shade, shade	forest understory

Pollinator Plant Index: herbaceous list

latin	**common**	**form**	**growth notes**	**moisture**	**light**	**site type**
Achillea millefolium	common yarrow	herb	well drained, sandy soils; quickly forms dense mats	dry, moist	sun, part shade	dry hedge; roadside; slope; dry meadow
Allium cernuum	nodding onion	herb	well drained soils; plant in small groups; can be weedy	dry	sun, part shade	dry meadow; coastal bluff
Anaphalis margaritacea	pearly everlasting	herb	tolerates poor or polluted soils	dry	sun, part shade	dry hedge; roadside; slope; dry meadow
Aquilegia formosa	red columbine	herb	propagated easily from seed	moist	sun, part shade	streambank, seep; roadside; open woodland; meadow; coastal dune, beach
Armeria maritima	sea thrift	herb	groundcover; well drained soils; propagate by seed or cuttings	dry, moist	sun	stream bank; dry or moist meadow; coastal dune erosion control, beach
Aruncus dioicus	goatsbeard	herb	tolerates seasonal flooding; needs a lot of space; grows to 6'	moist	part shade, shade	wet hedge; riparian corridor; forest edge or opening
Balsamorhiza deltoidea	deltoid balsamroot	herb	rare in several counties; transplants best in the fall	dry	sun	dry meadow; salt water shoreline
Camasia quamash	common camas	herb	bulb; tolerates heavy clay	moist, wet	sun	moist meadow; vernal pool
Campanula rotundifolia	harebell	herb	well drained, sandy soils	dry	sun	dry hedge; road/trailside; dry meadow
Castilleja hispida	harsh paintbrush	herb	hemi-parasitic, plant alongside host like Roemer's fescue; well drained soils	dry	sun	dry openings in forests; meadows, grassy slopes
Dicentra formosa	Pacific bleeding heart	herb	keep mulched with decaying humus, especially in cold winters; seeds dispersed by ants	moist	part shade, shade	shady moist woodland; riparian
Erigeron speciosus	aspen fleabane	herb	tolerates drought	dry, moist	sun	forest openings; rocky slopes; meadows
Eriophyllum lanatum	oregon sunshine	herb	annual; sandy soils	dry	sun	dry hedge; roadside; dry meadow
Dodecatheon pulchellum	darkthroat shooting star	herb	well drained soils	moist	part shade	streamside; coastal prairie; mountain meadow

Dodecatheon hendersoni	Henderson's shooting star	herb	flowers after first 2-3 years	moist	part shade, shade	riparian; wet meadow; rocky slope
Fragaria vesca	woodland strawberry	herb	groundcover spreads easily by runners	moist	sun, part shade	forest opening
Geum macrophyllum	largeleaf avens	herb	reseeds easily	moist, wet	sun, part shade	trailside; streambank; forest edge; moist meadow
Heracleum lanatum	cow parsnip	herb	up to 10'; well drained soils ; can cause rash on humans	moist	shade	streambank; open or lightly shaded woods
Lupinus latifolius	broadleaf lupine	herb	pioneer species, spreads quickly	dry, moist	sun	dry hedge; roadside; slope; moist woodland
Sisyrinchium idahoense	Western blue-eyed grass	herb	prefers early spring moisture	moist, wet	sun, part shade	roadside; marsh, seep, floodplain; wet meadow
Solidago canadensis	Canadian goldenrod	herb	can be weedy; wide tolerance of soil conditions, nutrient poor soils	moist, dry	sun, part shade	roadside; dry meadow; coastal dune, beach, bluff
Symphyotrichum subspicatum	Douglas aster	herb	to 2' tall; well drained soils	moist, wet	sun, part shade	streamside, fresh and tidal wetland; moist meadow; coastal dune, beach
Tellima grandiflora	fringecup	herb	rich soils; somewhat aggressive; propagate by division or seeds	moist	part shade, shade	wet hedge; cool, moist forest; streambank
Viola adunca	early-blue violet	herb		dry, moist	sun, partial shade	meadow near trees, prairie; rocky coastal outcrop

APPENDIX C: WA Native Plant Society Journal *Douglasia article*: "Restoring Native Pollinator Habitat: Puget Sound Lowlands"

The following article appeared in the WA Native Plant Societies journal *Douglasia,* May 2015. It references Kincaid Ravine and describes the pollinator plant protocols established for Kincaid Ravine:

"Restoring Native Pollinator Habitat: Puget Sound Lowlands"

by Matt Schwartz, Conservation Committee, Central Puget Sound Chapter

Angiosperms (flowering plants) have two basic strategies to transport pollen grains from the anther of the male stamen to the stigma of the female pistil. About 20 percent of angiosperms reproduce abiotically by wind or water, and about 80 percent reproduce biotically through animal vectors. The plant-pollinator partnership coevolved over millennia, developing an enduring ecological relationship. Flower shape, coloring, scent, and high-sugar nectar are examples of pollination syndromes, evolved plant traits to attract animal pollinators. Birds, bats, bees, butterflies, moths, flies, wasps, and beetles are examples of pollinators that feed on the sweet flower nectar, protein-rich pollen, and/or other plant parts. The abundance (population quantity) and diversity (number and even distribution of different species) of both native plants and their pollinator counterparts is often mutually dependent.

The native plant/pollinator mutualism is under grave threat. Habitats is increasingly being lost to development, and the slivers that remain are fragmented or degraded by light, noise, and air pollution. The ubiquity of pesticides in modern agriculture and landscaping damages pollinators, such as the implication of neonicotinoids in disrupting the homing mechanisms in bees, leading to Colony Collapse Disorder (Lu, 2014). In many areas, the proliferation of non-native plants and pollinators has introduced disease, outcompeted, and ultimately displaced the abundance and diversity of native species. Moreover, climate change alters the rates and patterns of temperature and moisture, placing different selective pressures on plants and pollinators. Life cycle adaptations have been shown to disrupt dynamics, such as temporal mismatches between plant flowering and pollinator arrival, or the spatial mismatch when migrating plants are forced to seek out cooler or moister areas (Burkle, 2013; Steltzer, 2009).

Restoration Projects and Backyard Habitats

In ecological restoration, the ultimate goal is autogenic regeneration of a native ecosystem, a process exemplified by the pollination feedback loop. Resilience of the ecosystem is backboned by pollinators, in tandem with seed dispersers, because they ensure long-distance gene flow by connecting neighboring habitats (Foster & Robinson, 2007). Furthermore, many invertebrate pollinators themselves provide an important source of fats and proteins source for the food web.

As in many discontinuous urban forests, restoration efforts cannot target habitat creation for large wildlife species. However, habitat for birds and insects, several of which are endangered in the Pacific NW, has critical potential in urban restoration projects. Based on my research, I've developed 10 lists of pollinator plants that are suitable for pollinator habitat depending on the different conditions and site types commonly found in the lowland Puget Sound. These plant combinations are outplanted as 'pollinator patches' in Kincaid Ravine, a 4 acre restoration site on the University of Washington Seattle campus. To view the lists, see Appendix A, or visit the WNPS website at <LINK TO PLANT LISTS - TBD>

To encourage native pollinator habitat, follow these four steps.

5. Determine site conditions and type.

The pollinator plant lists are grouped according to the appropriate site conditions, plant traits, and site types. See Table 1 for an example of a pollinator plant list for a dry, sunny hedgerow.

- Site conditions - Consider access to light (sun, partial shade, or full shade) and moisture (dry, moist, or wet).
- Plant traits - Consider bloom times and plant associations.
- Site types include hedgerows, rain gardens, road/trailsides, riparian zones, open meadows, and steep slopes.

An example pollinator plant list for a dry, sunny hedgerow. See Appendix for all 10 lists, complete with growth notes, moisture and light requirements, and site type details.

Hedgerow: Dry/Sunny				
latin	**common**	**form**	**pollinators**	**bloom**
Ribes sanguineum	red-flowering currant	shrub	hummingbirds; bees; butterflies, butterfly larvae	feb-apr, pink + red
Arctostaphylos uva-ursi	kinnikinnick	shrub	hummingbirds; bees; butterflies: hoary elfin + brown elfin	mar-apr, pink
Arbutus menziesii	Pacific madrone	tree	bees; butterflies: blue echo, brown elfin larvae; ceanothus silk moth larvae	april, pinkish-white
Amelanchier alnifola	serviceberry	shrub	hummingbirds; butterflies: echo blue, larvae: swallowtail, Lorquin's admiral	apr-may, white
Eriophyllum lanatum	oregon sunshine	herb	bees; butterflies: orange sulfur, red admiral, comma, skipper	apr-jun, yellow
Rubus parviflorus	thimbleberry	shrub	bees; butterflies; yellow-banded sphinx moth	may-jun, white
Rosa gymnocarpa	baldhip rose	shrub	bumble bees (nesting material), leaf-cutter bee (leaves); mourning cloak butterfly larvae	may-jun, pink
Gaultheria shallon	salal	shrub	hummingbirds; brown elfin butterfly larvae	may-jun, white + pink
Holodiscus discolor	oceanspray	shrub	hummingbirds; bees; butterflies: pale swallowtail, brown elfin, Lorquins admiral, blue echo	may-jun, white
Lonicera hispdula	hairy honeysuckle	vine	hummingbirds; bumble bees	may-jul, pink + purple
Ceanothus velutinus	snowbrush	shrub	bees; butterflies, butterfly larvae: echo azure, brown elfin, pale swallowtail; ceanothus silk moth larvae; attracts pest predators	may-jul, white
Philadelphus lewisii	mock orange	shrub	bees; western tiger swallowtail butterfly	may-jul, white
Symphoricarpos albus	snowberry	shrub	hummingbirds; bumble bees; snowberry checkerspot butterfly; vashti sphinx moth larvae	may-aug, pink
Lupinus latifolius	broadleaf lupine	herb	bees, bumble bees; butterflies: Puget blue, silvery blue larvae	jun-aug, blue + purple
Campanula rotundifolia	harebell	herb	hummingbirds; bumble bees; swallowtail butterflies	jul-aug, blue + purple
Anaphalis margaritacea	pearly everlasting	herb	butterflies: mylitta crescent, skipper, American lady (adult and larvae), painted lady (adult and larvae); syrphid flies; small wasps	jun-sept, white + yellow
Achillea millefolium	common yarrow	herb	bees; butterflies; syrphid flies; attracts pest predators	apr-oct, white

6. Consider flowers

- Use a diversity of species, colors, and perfumes.
- Aim to overlap bloom times throughout the season.
- Use framing species: provide a major nectar or pollen source, a stabilizing core of the plant-pollinator network.
- Use bridging species: provide food during resource-limited times of late fall, early spring, or winter.
- Use magnet species: generally use colorful and powerfully scented plants that advertise widely, drawing pollinators to areas where smaller or less flashy plants can subsequently receive pollinator services.

7. Provide nesting, egg laying, and overwintering sites

- Maintain areas of bare ground: ground nesting bees need some areas that are not tilled or mulched.
- Keep it messy: compost piles of weeds, leaf debris, rotting wood, snags and stumps are all potential homes for bees and beetles.
- Provide secure, undisturbed areas for diapause (winter dormancy).

8. Plant smart

- Plant each species in clumps, rather than as a solitary plant.
- Plant patches close together (a maximum of 500-foot separation for the smallest bees).
- Plant corridors or stepping stone habitats to increase connectedness, such as along sidewalks.

This article preludes publication of the handbook *Native Pollinator Habitat for Restoration Projects: Puget Sound Lowlands*. Please visit the Washington Native Plant Society web site (wnps.org) for extensive plant lists and online access to the handbook; or schwartzmateo@gmail.com for more information.

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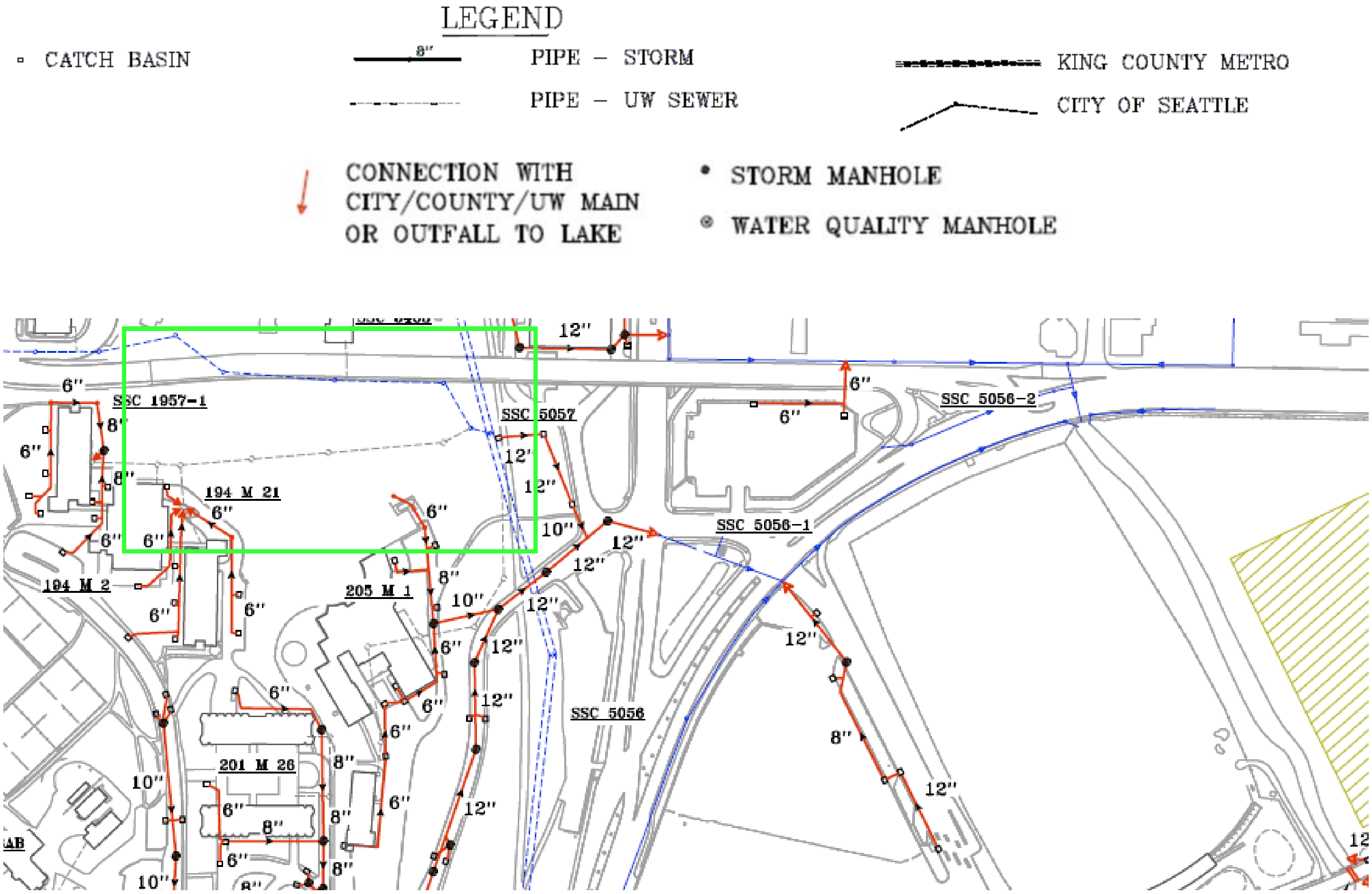
Indian plum (Oemleria cerasiformis) is a great early season nectar source for hummingbirds, bees, moths and butterflies. Illustration by Matt Schwartz.

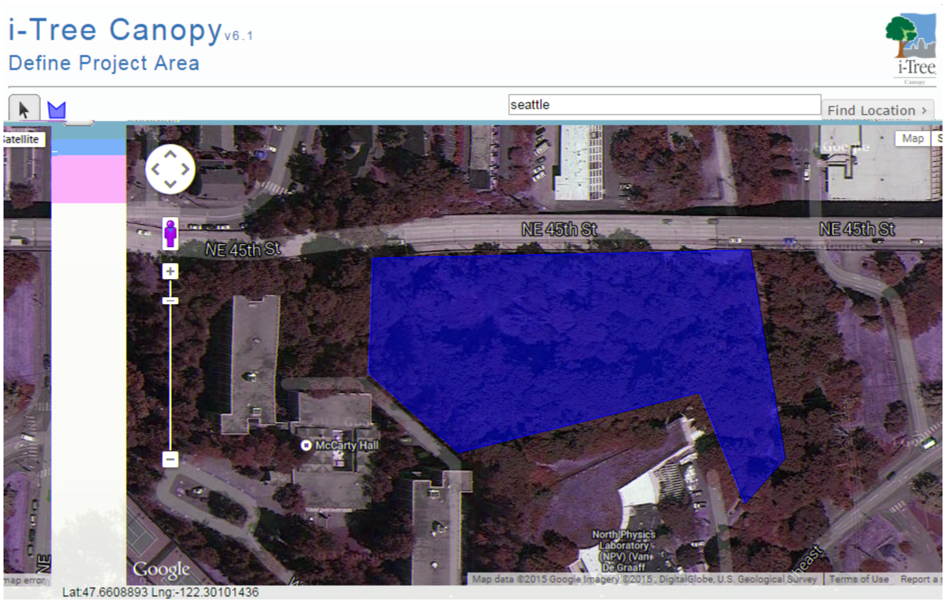
APPENDIX D: KR Stormwater Map

Green= KR basin

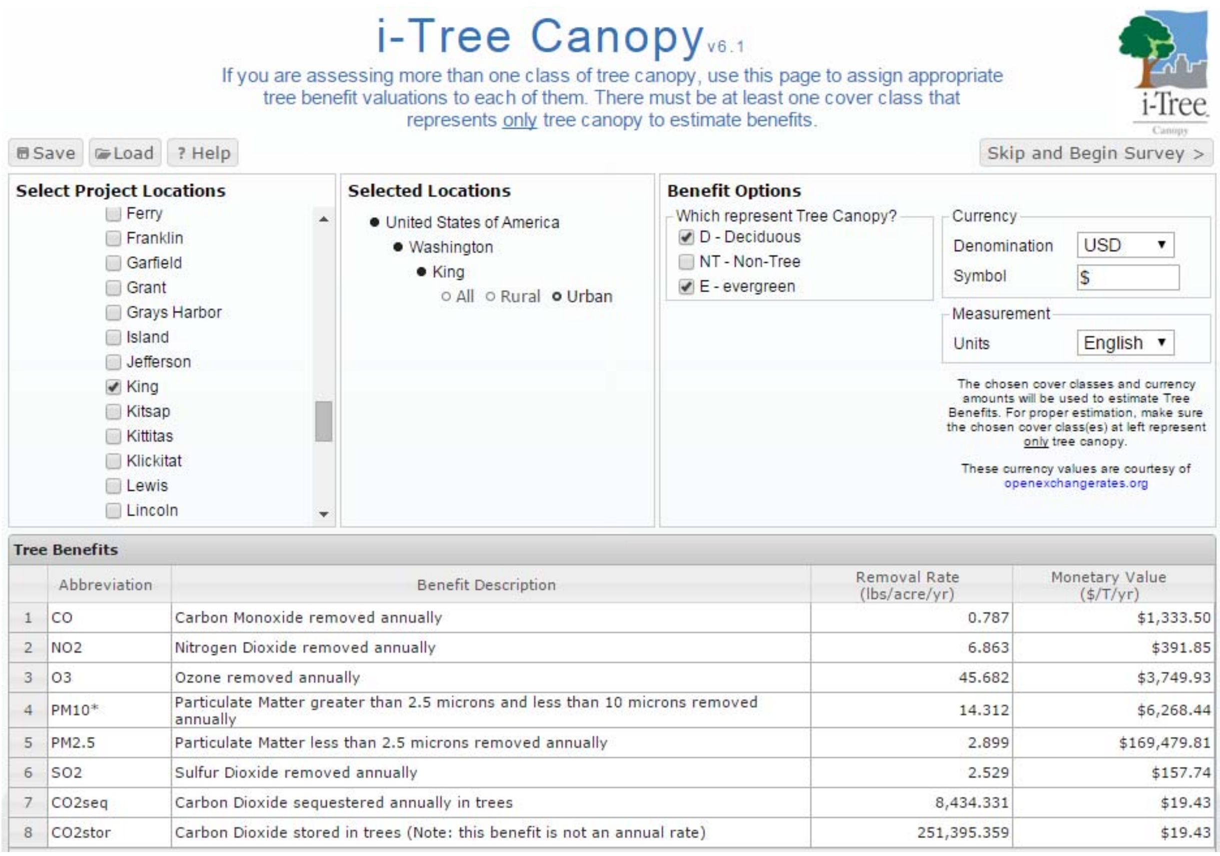


APPENDIX E: i-Tree steps for assessing gas sequestration

i-tree canopy step 1: Define project area



i-tree canopy step 2: Select County- sequestration rates for King County seen below under "Tree Benefits"



	Abbreviation	Benefit Description	Removal Rate (lbs/acre/yr)	Monetary Value ($/T/yr)
1	CO	Carbon Monoxide removed annually	0.787	$1,333.50
2	NO2	Nitrogen Dioxide removed annually	6.863	$391.85
3	O3	Ozone removed annually	45.682	$3,749.93
4	PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	14.312	$6,268.44
5	PM2.5	Particulate Matter less than 2.5 microns removed annually	2.899	$169,479.81
6	SO2	Sulfur Dioxide removed annually	2.529	$157.74
7	CO2seq	Carbon Dioxide sequestered annually in trees	8,434.331	$19.43
8	CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	251,395.359	$19.43

i-tree canopy step 3: Select data points