Prairie Rain Garden Design and Installation Project

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Introduction

The Prairie Rain Garden is a stormwater management and native prairie plant garden. It was built at the University of Washington Center for Urban Horticulture from July 2014 through March 2015. Objectives of the project are 1) to manage surface runoff to prevent water ponding on the trail; 2) to convert an underutilized/weedy site into a structurally/biologically diverse native prairie plant community; and 3) to collect baseline vegetation and hydrologic data to measure project results.

The project aimed to incorporate sustainable stormwater management into an ecological restoration project and was motivated by research related to incorporating plant ecology into design projects.

Part 1: Background

1.1 Urbanization

In 2010, 80.7 % of the U.S. population lived in urban areas, and Seattle was one of the fastest growing metro areas in the U.S. (U.S. Census 2013). With an increase in population, urbanization and associated landscape change can result in ecological degradation and loss of biodiversity from habitat destruction, invasive species and pollution.

Incorporating native plant communities (and the associated biodiversity they provide) into urban design projects can help create so called "coupled natural – human systems", reducing the negative ecological impacts of urbanization and population growth (Picket 2008).

1.2 Stormwater

Stormwater is runoff from impervious urban surfaces. Stormwater is considered a nonpoint source pollutant and can contain sediments, nutrients, chemicals and trash. It can have significant negative effects on waterways and water bodies surrounding urban and suburban areas and has recently been cited as the leading contributor to water quality impairment in surveyed estuaries (U.S Environmental Protection Agency 1999a, U.S EPA 2003).

Traditional stormwater management quickly removes and discharges runoff via drains, pipes and outfalls. The EPA generally regulates stormwater through a required permitting process. Stormwater discharges are considered a point source of pollution, and are regulated by the EPA under the Clean Water Act. Owners of stormwater discharges must follow stormwater best management practices as listed in the National Pollutant Discharge Elimination

System in order to get a permit to operate the outfall. These practices require specific flow, erosion and pollution control guidelines (U.S. EPA 2001). In addition to regulating discharges, the EPA requires states to implement stormwater permitting programs for construction and industrial activities.

The EPA and other state regulatory agencies can impose financial sanctions against municipalities for violating water quality permits related to stormwater discharges. This applies to cities like Seattle and Portland, Oregon where some portions of the city have combined sewer and stormwater systems. After heavy rain fall events, these systems can overflow and discharge raw sewage directly into water bodies during events known as combined sewer overflows or "CSOs". King County has 38 CSO outfalls. In 2010 King County was fined $46,000 by the Washington Department of Ecology for 46 CSO events over an 8 month period from four separate outfalls (Washington Department of Ecology 2010). All outfalls were located in Seattle and emptied raw sewage into Puget Sound and Elliott Bay.

1.3: Low Impact Development

To reduce negative effects of urbanization and stormwater pollution, some states in the United States, including Washington, are now incorporating Low Impact Development "LID" elements into development requirements. LID is defined by the EPA as "an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible" (U.S. Environmental Protection Agency 2009). In order to reduce stormwater at its source, LID emphasizes the creation of multifunctional landscapes that use small scale, on site natural features to manage runoff (Hinman 2005). The EPA encourages the implementation of LID through incentive programs and technical assistance.

1.4: Types of green stormwater infrastructure

Low Impact Design infrastructure incorporates green stormwater infrastructure "GSI" to manage stormwater. GSI aims to reduce stormwater quantity, improve stormwater quality and control flow by directing stormwater into planted facilities that retain, infiltrate and/or convey runoff (Gilbert 2006). They can include planted depressions (rain gardens, infiltration planters, bioretention cells), planted swales, (bioswales, biofiltration swales), stormwater ponds/wetlands, cisterns, permeable pavement and street trees/roadside plantings (U.S. Environmental Protection Agency 2014). GSI terminology is not uniformly used because it is an emerging field in which different agencies use different terminology, and designs recommendations can vary. Because of this lack of uniformity, the terms utilized in this report are defined below for clarity.

Rain gardens

The term rain garden typically refers to a simple planted depression, usually 6'-12" deep, that collects and infiltrates rainwater from impervious surfaces. Rain gardens usually have a planted flat bottom, planted slopes and an overflow. Designs can vary depending on the site, available resources and personal preferences. After some research and planning, a gardener or landscaper with minimal experience can build a rain garden. There are little to no specific requirements or permits involved in order to build most small scale rain gardens. However, rain gardens need to be planned more than an average garden (see section 2.1).

Bioretention

In Washington state, what are referred to as bioretention facilities are engineered planters or swales that fit specific design criteria (Hinman 2005). In Washington, bioretention cells are often designed as part of a larger engineered stormwater management system and are used in new developments as required by LID regulations (Hinman 2005).

A major element of bioretention facilities in Washington is the required bioretention soil mix. Design criteria requires removing native soil and adding 12"-18" of the designed soil mix which is 60% sand and 40 % compost (Washington Department of Ecology 2014). The soil mix insures the facility will infiltrate at a given rate, while supporting plant growth. Bioretention cells often include structural cement walls and a slotted underdrain pipe at the bottom of the bioretention mix (Hinman 2012). This underdrain pipe is installed to maintain aerobic soil conditions. After heavy rains, runoff that reaches the underdrain pipe flows into either another bioretention facility or back into the traditional stormwater system (Washington Department of Ecology 2014).

Stormwater wetlands

If infiltration is slow or non-existent on site, the site may be more appropriate for a stormwater wetland. Stormwater wetlands are constructed wetlands that store and treat stormwater through settling of sediment and biological uptake that removes excess nutrients (U.S. Environmental Protection Agency 1999a). Stormwater wetlands are similar to rain gardens and bioretention cells in that they retain stormwater, but unlike rain gardens they usually pond water for more than 2 weeks (Natural Resource Conservation Service 2005). Longer periods of standing water in stormwater wetlands may enable them to support wetland plants and wildlife that are more adapted to saturated conditions (National Oceanic and Atmospheric Administration 2012).

1.5: Benefits of green stormwater infrastructure

Rain gardens and other green storm water infrastructure can help urbanized landscapes mimic pre-developed, natural hydrologic systems (Hitchmough & Wagner 2013).

Reduce quantity of runoff entering stormwater systems

GSI intercepts runoff and prevents it from entering the stormwater system. Decreasing quantity of urban runoff can improve urban stream function by reducing stream bank erosion and channel incising that can occur from stormwater inputs. Reducing the quantity of runoff is especially important in older combined sewer systems, where reducing stormwater quantity reduces the number of combined sewer overflow events. Additionally, reducing quantity of runoff entering stormwater systems can also reduce urban flooding events and mitigate local street drainage problems.

Increase infiltration

GSI can act as temporary storage basins for stormwater, allowing the stormwater to gradually absorb into the soil. Most rain gardens are designed to fully drain 48 hours after a rainfall event (Oregon Sea Grant 2010). This infiltration can recharge groundwater to feed local streams and wetlands. Infiltration can also maintain riparian and aquatic habitat during dry months. The process of infiltration can also recharge aquifers that are used as municipal water sources, which is especially important in drier climates.

Improve quality of stormwater

Designing GSI to directly improve stormwater quality is an evolving process. The Washington Department of Ecology is currently redesigning the bioretention soil mix they require in GSI because recent research has found that the compost in the bioretention mix can cause bioretention facilities to export phosphorous (City of Redmond 2012). More research is needed in order to determine best management practices for using GSI to improving stormwater quality. Until these practices are established, it is best to determine project goals and base design decisions on the likely pollutants found in that location. Factors that influence a rain garden’s water purification performance include soil type, vegetation type, vegetation density, climate, and concentration of contaminants contained in runoff.

Although data on technical performance is limited and results vary widely, GSI facilities have been shown to improve the quality of stormwater via 8 processes (Hinman 2005). These processes include:

1) Sedimentation: the settling of particulates.

2) Filtration: the filtering of particulates by vegetation. Green stormwater infrastructure facilities are especially effective at sedimentation and filtration (Hinman 2012). Sediment is a primary non-point source pollutant which can severely degrade aquatic habitat by increasing turbidity and clogging spawning gravel for salmon and other fish (Nelson 2003).

3) Adsorption: the binding of ions to soil particles. Phosphorus can be adsorbed onto soil particles, further reducing nutrient loads (Hinman 2012). Heavy metals can also be adsorbed onto clay soil particles.

4) Infiltration: downward movement of soil water that initiates pollutant degradation by microbes and adsorption.

5) Phytoremediation: the assimilation (uptake) of nutrients by plants and degradation of pollutants in the rhizosphere (plant root -soil zone). Plants in GSI can uptake nutrients (e.g. nitrogen and phosphorous) contained in stormwater and use them to grow. Rain gardens can also act as a site for denitrification, where microbes convert soluble nitrates into nitrogen gas under anaerobic conditions (see number 7).

6) Plant resistance: the reduction in runoff flow velocities, which increases sedimentation, filtration, adsorption, infiltration and uptake.

7) Volatilization: the conversion of soluble substances into a volatile form e.g. hydrocarbons into carbon dioxide.

8) Thermal attenuation: the reduction in stormwater temperature as it moves through subsurface soil layers (Prince George’s County 2002).

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Habitat and microclimate creation

Vegetation and water in GSI can create habitat that attracts insects, birds and other pollinators. Rain gardens can contribute to decreased urban heat island effects by providing shade. Rain gardens can also cool the immediate environment via evapotranspiration and have a lower heat capacity than impervious services.

Cultural, Educational and Aesthetic value

Building rain gardens can be an interactive community activity. Students and volunteers can be incorporated into the planning and construction of the garden, engaging the rain garden as both an educational tool and a living laboratory once built.

Rain gardens are interesting land features, and their design offers room for creativity. Unique topography and moisture gradients can support a diverse plant palette. Rocks and other artistic elements can be added, incorporating running water into the site for a unique effect.

1.6: Prairie ecosystems

The Prairie Rain Garden incorporates plants native to Western Washington prairies. Prairies of Western Washington and the Willamette Valley are rare grassland ecosystems, as most native prairies were either developed, converted to farmland or were encroached by woody species after fire suppression (Chappell 1997). It is estimated that less than 3% of Western Washington prairies remain today (Caplow & Miller 2004). Most of the remaining prairies are located in the gravelly soils of Southwest Puget Sound and Whidbey Island.

Prairie ecosystems in the South Sound region support a diverse range of herbaceous perennial and annual plant species, often characterized as a Idaho fescue- white topped aster community (Chappell 1997). This community consists of bunchgrasses and a diverse suite of forbs, including several rare and endangered plants.

Installing prairie plants in the Prairie Rain Garden meets the restoration objectives of the Union Bay Natural area as the space transitions from the more formal botanic garden into the less managed natural area. The Prairie Rain Garden is currently being used for education and research related to prairie plants, encouraging collaboration of botanic gardens with ecological restoration objectives (Hardwick 2011).

Prairie plants and stormwater gardens

Using plants from prairie and grassland ecosystems can be practical for stormwater gardens. Individual prairie species are specifically adapted to the wet, dry or moist conditions that are typical of stormwater gardens (Cochrane 2000, O'Dell,Young & Claassen 2007). Most grassland plants are adapted to and thrive in sunny locations, which is often recommended as ideal for stormwater gardens (North Carolina Cooperative Extension 2014). Grass buffers are also effective at trapping sediment, which can improve water quality, especially when used in combination with microtopography that slows water flow (Eisenhower 2002).

Using prairie plants on roadside sites can also be practical in that it leaves vegetation relatively low growing, which maintains visibility at intersections. Using herbaceous as opposed to woody vegetation also allows the site to be mowed if it becomes overgrown. This allows maintenance departments to maintain prairie sites with the same equipment they use for grass medians.

Microtopography/Mounds

Portions of the South Sound prairies are characterized by undulating, mounded terrain which can influence vegetation patterns (Moral & Deardorff 1976). Installing earthen mounds (microtopography) on restoration sites is a method used in ecological restoration to introduce and restore topographical complexity (National Oceanic and Atmospheric Administration 2012). Mounds and associated pools create habitat variation and can increase structural and biological diversity in grasslands, wetlands and swamps (Smith 1997, Hough-Snee, Long & Ewing 2011 Bruland & Richardson 2005)

The Prairie Garden was designed to manage stormwater while mimicking the natural topographic variation of prairies.

Part 2: Planning a Stormwater Garden

2.1 Rain garden/GSI construction manuals

There are dozens of reliable rain garden manuals available for free online. Four rain garden manuals/fact sheets were used in the planning and construction process of the Prairie Rain Garden. Manuals used for this project include:

1) Rain Garden Handbook for Western Washington: A good comprehensive, step by step guide to rain garden construction. The handbook includes a comprehensive sizing section, and a good maintenance section.

2) Oregon Rain Garden Guide: Another comprehensive, step by step guide. The sizing section is simplified, and there is no maintenance section.

3) King County Surface Water Design Manual, small project section: A comprehensive technical manual aimed more for design and engineering professionals. In addition to design recommendations, this manual includes design recommendations and local regulations for stormwater management projects. It also includes large amounts of excellent design information, although it easy to get lost in the many pages of regulations and technical jargon.

4) City of Seattle Rainwise Program, Building a Rain Garden factsheet: A two page, simple factsheet on rain garden construction. This simple and abbreviated guide includes local regulations information if building a rain garden in Seattle.

2.2: Permitting

Small scale rain gardens can be built by the average gardener with hand tools at relatively low cost. These small scale projects are generally not subject to permit or review if they fit the siting criteria (section 3.2). In Seattle you will need to go through a permit or review process if the project:

- installs or replaces more than 2,000 feet of impervious surface
- disturbs more than 7,000 feet of land
- is located in a street right-of-way
- is seeking re-imbursement from a Rain-Wise rebate
- is attempting to meet a LID requirement (City of Seattle 2013).

Rain gardens require planning, but they can often be built without a permit and can be designed and installed by non-professionals, which is one of their advantages.

2.3 Siting a Rain Garden

There are several variables that must be considered in order to determine whether a given site will be appropriate for a rain garden. Laws and regulations for installing rain gardens vary depending on location. Certain sites do need either a permit or a review- for example, right -of -ways or areas near steep slopes are more likely to be regulated (Hinman 2012). Specific guidelines can vary by region, but there is some general criteria for sites that are not appropriate for rain gardens.

Where to not locate a rain garden:

- On site with a steep slope or near a steep slope. If slope of the site is greater than 10%, a rain garden could lead to slope failure (Oregon Sea Grant 2010). In Western Washington, sites within 300’ of steep slopes or landslide prone areas may not be appropriate for a rain garden and may require review by the city. In Seattle, homeowners can see if they live near steep slopes or in landslide prone areas by checking maps created by the Department of Planning and Development, which is available online (Seattle Public Utilities 2011)

- Within 10’ of a basement or retaining wall or within 5’ of any building with a slab. foundation or crawl space
- Sites that infiltrate less than 0.25 inches/per hour (see section 2.3).
- Near septic tanks or drainfields
- Above utility lines or structures. Call 811 before you dig to locate any underground utilities.
- Under the drip line of existing trees

Where to locate a rain garden:

- On a site downslope from an impermeable surface
- Where overflow from the rain garden will flow down to a street drain or other natural drainage feature
- On a gently sloped site, ideally 1%- 5%, to convey water to and away from the garden

2.4: Sizing

Before building, one must determine if a properly sized rain garden will fit on the site. Size is based on several variables including impermeable surface area, soil type, and climate. There are many different methods to size rain gardens. Some use volume, some use square footage, some use sizing factors based on infiltration rates, but all are based on impermeable surface area that drains to the garden. One way to size the garden is to check multiple sources from your region and see how they compare.

Sizing recommendations by agency:

Rain Garden Handbook for Western Washington

- Sizing factor based on rainfall region, ponding depth (6 or 12”), infiltration rate (0.1 - 2.5”/hr) and performance level.
- Performance level = (good, better, best) = capture 80%, 95%, and “most all” of stormwater from surface.
- Sizing factors for ponding depth range from 6%-39% for Seattle (Hinman 2013).

City of Seattle Rainwise

- Garden bottom area should be 15% of impervious surface, with 2.5: 1 slopes.
- Infiltration rates not mentioned, although advises using 12+" of bioretention soil mix.
- Use a 6-12" ponding depth (Seattle Public Utilities 2011).

King County Surface Water Design Manual (for projects requiring drainage review)

- Must store 3" of water from impervious surface (e.g. 10' x 10' impervious surface requires 0.25' x 10' x 10' = 25 cubic feet of storage).
- Storage requirements based on 25 year, 24 hour maximum precipitation for Seattle (King County 2009).

Oregon Rain Garden Guide

- Ponding area should be at least 10% of impervious surface area.
- Garden should drain at least ½ inch per hour.
- Use a 6'-24" ponding depth.
- If infiltration rate is slow, increase ponding depth (Oregon Sea Grant 2010).

As a first step to sizing, many manuals recommend using an infiltration test. To do an infiltration test, dig a hole to the desired depth in the middle of the potential rain garden location. Once the hole is dug, add a stake marked with inches. Fill the hole with water to the rim, and record how long it takes to drain completely. Fill the hole two more times. The third test will be the best indicator of how the garden will drain when the soil is fully saturated. Divide the distance the water level decreased by the time it takes to drop. Most rain gardens drain at least ¼ inch per hour. Infiltration rate can vary upon season, weather, soil saturation, and current groundwater level.

Once an infiltration test is complete, many manuals recommend determining soil texture by making a small ball with the soil. Knead the soil and attempt to make a ribbon. If the soil drains less than 1/4 inch per hour or you can form a 2 inch long ribbon, the soil likely has too much clay for a rain garden, although the site could be appropriate for a stormwater wetland (Oregon Sea Grant 2010, Natural Resource Conservation Service 2005).

Part 3: Prairie Rain Garden

The Prairie Rain Garden was designed as a do - it - yourself stormwater management garden. There were three main goals: 1) prevention of water ponding onto the gravel trail by creating depressions and berms; 2) creation of a diverse native prairie plant community; and 3) measurement of vegetation and hydrology to record baseline conditions.

Project goals were met by removing existing vegetation, grading the site, planting native species, and data collection. In addition, a maintenance plan helps guide site management.

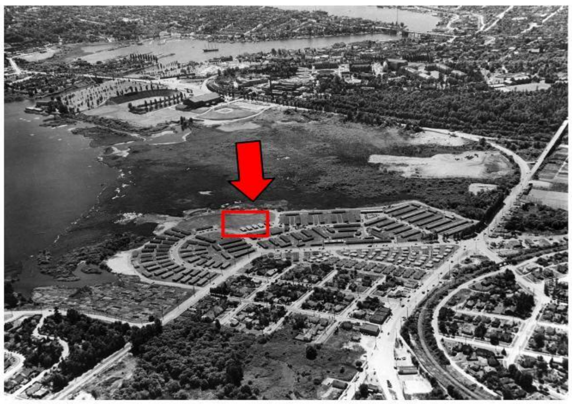
3:1: Site Description: Pre-existing conditions

Physical characteristics

The project site is located adjacent to Wahkiakum Lane, at the entrance to the Union Bay Natural Area, and on the western edge of the University of Washington Botanic Gardens property. Bordering the site are parking spaces to the north and two gravel paths to the east and west (Figure 2). The project site is approximately 650 square feet and slopes at roughly 5.5% from north to south (Figure 4).

The project site and all of the Union Bay Natural Area was previously a seasonally inundated marsh (Howell & Hough-Snee 2009). When lake water levels were lowered to connect Lake Washington to Puget Sound, the project area dried out and was converted into student housing (Figure 2) (Arnold 2013). The area directly adjacent to the project site was too wet to be developed, and was used as a landfill until 1966 (see Figures 5 & 6). In 1966 the landfill was closed, capped, graded and planted with European pasture grasses. The university has managed the former landfill as a natural area since 1972. Housing was removed from the project site in 1978. Management of the site was transferred to the UW Botanic Gardens in 1984 when the Center for Urban Horticulture was built (Figure 1) (Arnold 2013, University of Washington Botanic Gardens 2014).

Figure 1 *right and below right*: Aerial photos of project area with site area in red. **Figure 2** *below:* historical photo of student housing near project area (Sherrard 2013).



Pre-existing vegetation

Vegetation previously on site and currently bordering the site consists of weeds and non-native grasses. Species include perennial bunchgrasses tall fescue (*Festuca arundinacea*), sweet vernal grass (Anthoxanthum odoratum) perennial rhizomatous grasses quackgrass (*Elymus repens*), Kentucky bluegrass (*Poa pratensis*), and annual grass barnyard grass (*Echinochloa crusgalli*) (Huang 1988). Other weedy species include creeping buttercup (*Ranunculus repens*), clover (*Trifolium* spp.), common horse tail (*Equisetum arvense*) and a patch of common rush (*Juncus effusus*). Large shrubs across the trail to the east shade the site in the morning, especially during winter months. The site receives full sun through the afternoon hours.

Pre-existing hydrology

Surface runoff flows into the site from five asphalt parking spaces and one lane of an access road to the north (Figures 3 & 4). The site does not directly border the asphalt- surface runoff flows into the site through grass and an existing shrub. Impervious surface area draining into the site is approximately 1416 square feet.

After rainfall events, a small puddle often formed inside the site. The remaining runoff flowed into and across the eastern gravel trail, resulting in ponding water on the trail. During winter months, water on the trail could freeze and potentially create a safety hazard for trail users. The site and trail remained wet with areas of ponding throughout the winter months.

An old water pipe, likely leftover from the student housing, remains on site, just below the soil surface, in mound 2 (Figure 9).

Figure 3: Topographic map

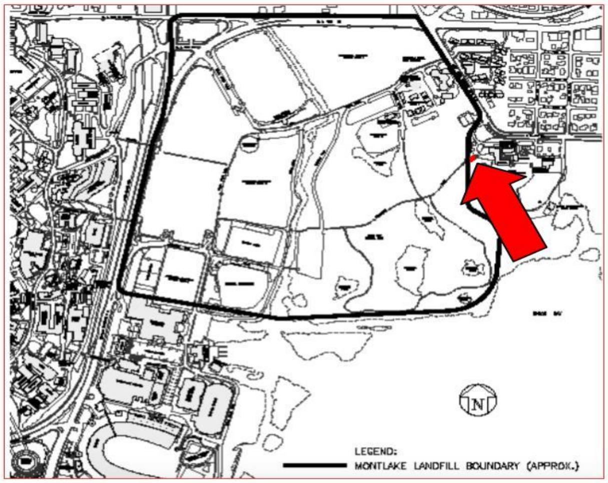
Figure 4 *above*: Impervious area draining to site, runoff and planting zones,

Soils

The project site is located very close to what was the Montlake Landfill (Figure 5 & 6). According to soil maps, the project site is on peat soils, leftover from the former marsh prior to the lowering of Lake Washington (Figure 6). As the project site was previously used for student housing, it contains fill leftover from demolition of the housing and construction of the current CUH parking lot and gravel trail. Dozens of small chunks of asphalt and several old bottles and cans were found mixed in the first 10 inches of soil.

Soil was surveyed from two locations on the project site - an upper sample location near the parking lot and a lower location near the kiosk. Soil horizons are weakly developed across the site. The soil is comprised of relatively recent imported fill, with a thin layer of organic matter at the soil surface.

Soil texture ranged from sandy clay loam to sandy clay. More silt was found in the upper portion of the site, creating a loamier A horizon. Increased silt near the parking lot could be caused by sediment contained in surface runoff. Both soil pits reached significant portions of gravel and clay roughly 8” deep.



(Map: University of Washington 2009)

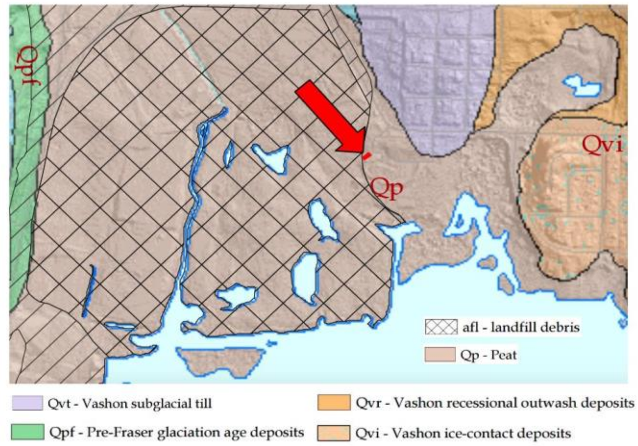


Figure 5 *above left:* landfill boundary map with site in red (University of Washington 2009). **Figure 6** *above right* : Soils map with site in red (Troost 2005)

3.2 Project Preparation

Up-potting

After receiving project approval, the installation work began in June 2014 by up-potting native bunchgrass plugs leftover from Kern Ewing's ESRM 473 class (Appendix 1).

A total of 277 plugs were up-potted into ½ gallon pots using Sunshine Mix #3 potting soil. This included 122 *Deschampsia cespitosa*, 96 *Festuca idahoensis* and 56 *Elymus glaucus* plants. These plants were up-potted over a 3 week period in late June/ early July and placed in the shade/hoop houses at UW-CUH.

Sod removal

In preparation for sod removal, the site was first mowed with a tractor and line trimmer. Sod/grass removal began in July 2014 by grubbing the grass using a pick/maddock tool, shaking soil off the roots, and carting off the above and belowground biomass to the green waste pile at UWBG.

Sod removal of the approximately 650 square foot site took approximately 40 hours, and was completed over a period of one month. About 90% of the sod removal was done by one person, a volunteer helped for one work day.

Infiltration test

An infiltration test was performed in August 2014, in the lowest pool. The hole was dug out to 10” deep, and 6” of water was added to this hole (6” ponding depth with a 4” of free board). On the 3rd test, water infiltrated 6” in 3 hours and 5 minutes, resulting in an infiltration rate of 1.95 inches/hour.

3.3: Grading

After sod removal was completed, the site was graded to retain runoff using hand tools, stakes and a line level. Grading of the site had two main objectives: 1) manage stormwater with 4 pools, an overflow pipe and a berm to prevent ponding on trail; and 2) utilize mounds to increase habitat complexity. Mounds create soil moisture gradients and niches for plant species. Previous research provides evidence that incorporating mounds on restoration sites may increase vegetative diversity (Figure 8) (Smith 1997, Hough-Snee 2011, Bruland 2005).

Initially, the project was designed as a rain garden with tiered pools, each with 6” ponding depth. The project design was later altered into a wetland swale or wet swale to accommodate for a high water table and slow infiltration rates.

In order to increase infiltration rates, some agencies recommend amending soil of GSI facilities with a sand and compost bioretention soil mix (Section 1.5). With the exception of drain rock added to the pool surfaces, inflow and outflow trenches, only native/existing soil was used on site. Existing soil without amendments was used for three reasons: 1) existing soil seemed sufficient to support plant growth, especially if used in combination with a wood chip mulch layer; 2) using native soil reduced project cost; and 3) concern about nutrient export issues with compost and bioretention soil mix (Chalker-Scott 2007, City of Redmond 2012, King County 2005).

Initial pool sizing

Four pools and four mounds were constructed in the Prairie Rain Garden. Pool sizing was based on guidelines as recommended by Rain Garden Handbook for Western Washington sizing guide and compared to recommendations from other manuals. Other variables considered in the garden sizing/planning process included available time, resources and maintenance costs.

- Impervious surface area draining to site: 1416 square feet
- UW Seattle campus: Region 2 (30-40 inches average annual precipitation)

- Infiltration rate of site: = 1.95 in/hr = 1.00- 2.40 in/hr range
- 6” ponding depth
- Ponding area = 15% of impervious surface. (This meets the Rain Garden Handbook for Western Washington and Oregon Rain Garden Guide sizing recommendations)
- Bottom area= 6% of impervious surface area. (This does not meet City of Seattle recommendations of 15%.)
- Storage volume = 76.77 cubic feet = 0.05 ft (0.6”) of rain from parking area, (This does not meet the King County Small project requirements of storing 0.25 ft (3”) of rain)

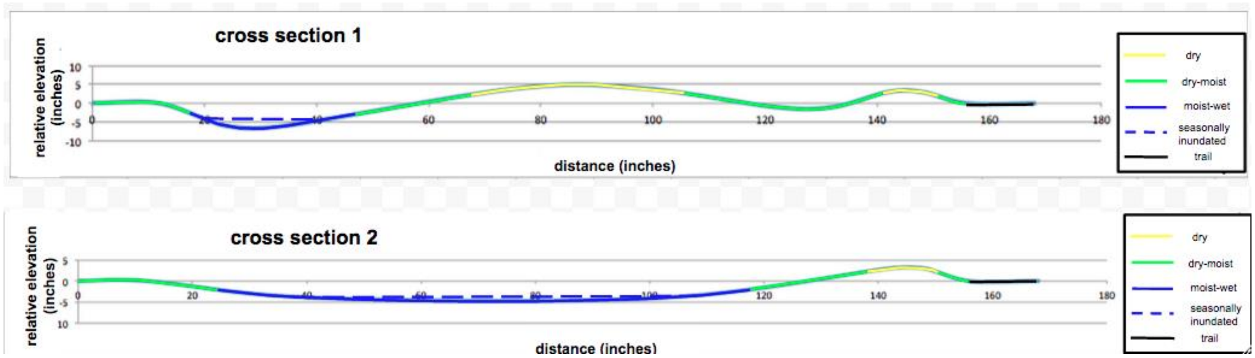
pool	bottom size (sq. ft.)	ponding size (sq. ft.)	storage volume (cubic feet)
1	14	45.5	12.63
2	11.38	40.63	10.75
3	12.25	42.25	11.38
4	51	132	42.01
Total	88.63	213	76.77

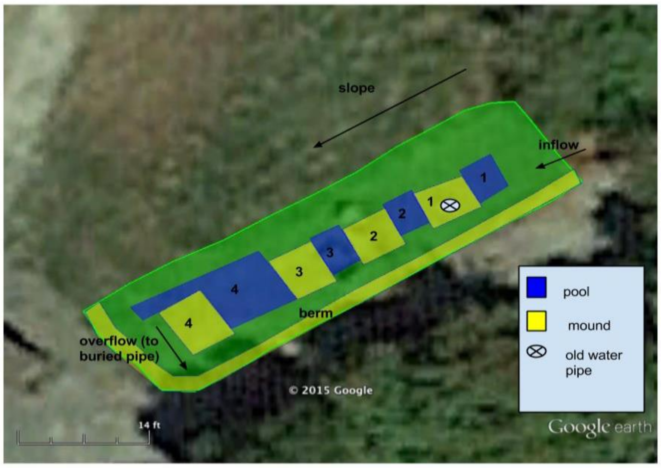
Figure 7: Pool ponding size and storage volume table from initial site grading, with 2:1 slopes.

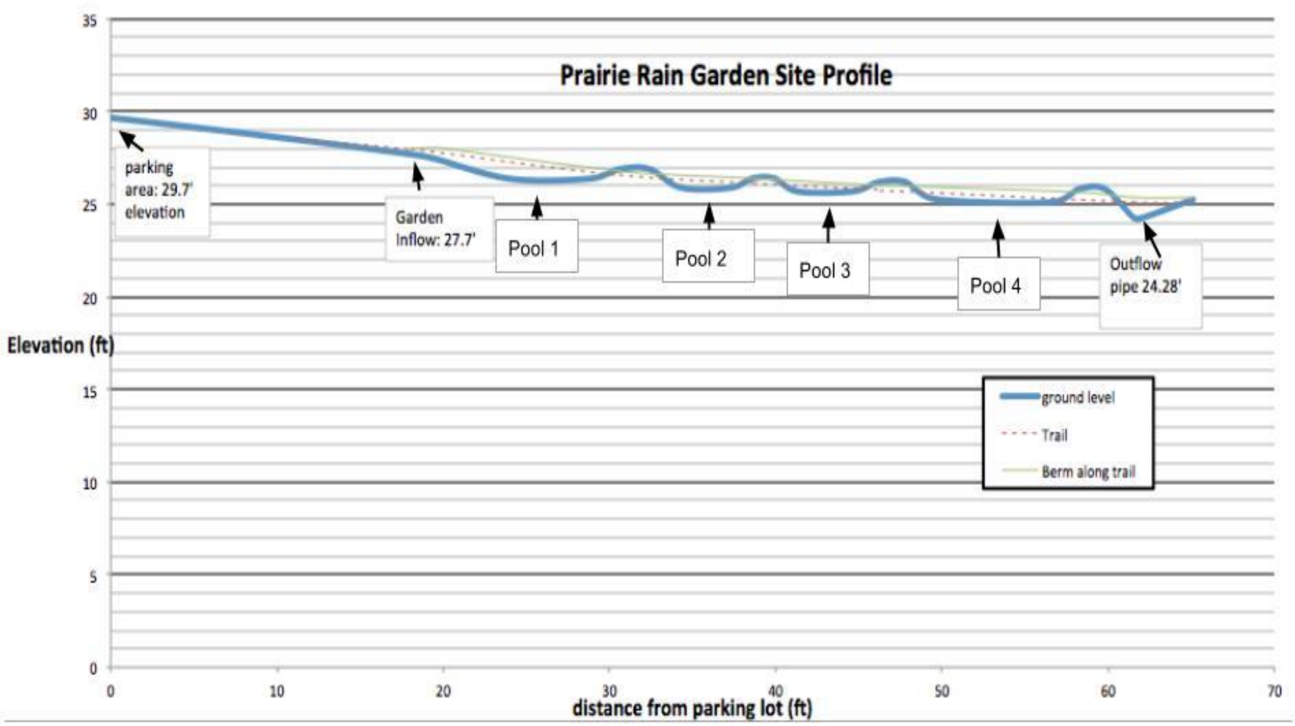
Outflow Pipe Installation

The 14’ long, 4” diameter ABS pipe was installed underneath the trail in September 2014 with the help of 3 volunteers (Appendix 1). The pipe was buried 6” deep with a 1% slope. Pipe size and slope were determined based on the drainage area and estimated peak flow rate for the site (see section 3.4).

Two additional outflow pipes were installed across the trail in February 2015. The two 10’ long, 4” diameter corrugated plastic pipes connect the ABS trail pipe to the drainage swale. They are covered with drain rock.







Clockwise from top: **Figure 8:** Pool 4 cross section. **Figure 10:** Cross section locations. **Figure 11:** Site profile with elevations. **Figure 9:** Site plan view with mound and pool numbers, from original grading (without swale).

Figure 12: Installation photos. *Clockwise from upper left:* growing bunchgrasses in hoop house; removing sod; pipe installation, ponding after initial grading; initial grading and sod removal complete; infiltration test.

First rains/ponding

After a period of several rain events in November 2014, Pools 2, 3 and 4 infiltration rates slowed dramatically, to less than 1 inch/3 days. The Prairie Rain Garden filled and overflowed into the pipe several times. Pool 1 was infiltrating at approximately 1 inch per day.

The small *D. cespitosa* plants in all pools were beginning to die from extended periods of near total inundation, with anaerobic conditions. Some hypotheses for why the infiltration rate differed from the infiltration test were 1) higher water table and/or perched water table on a clay layer; 2) constant seepage into the site from upslope; 3) compaction of pools during construction; 4) timing of the infiltration test in the summer; and 5) combination of above factors.

Grading modifications

In November 2014 after several days of inundation, the pools were notched and drained by digging a small swale. Once drained, the *D. cespitosa* plants in the pools were dug up, and soil previously preserved on-site was added to the pools. Approximately 1” of soil was added to the pools to raise elevation and potentially increase drainage and infiltration. The *D. cespitosa* were then replanted. Burlap fabric was added to the swale between pools and at the outflow to reduce erosion. Drain rock was added to the swale and pools to allow for drainage while making access to site easier for planting and maintenance.

Wet swales

After modifications, the Prairie Rain Garden functions similar to a wet swale, meaning that it conveys water but the lowest pool, pool 4, remains mostly saturated during the wet season (Figure 8). Wet swales can act as elongated wetlands, supporting wetland vegetation and are often used to treat stormwater along roadsides (U.S. Department of Transportation 2015). Wet swales also occur naturally in prairie ecosystems, located between upland prairies and more permanent wetlands (Easterly, R., Salstrom D. & Chappell 2005).

Runoff is conveyed through the drain rock swale. The drain rock creates a gravel filter which slows runoff and may increase infiltration, and/or improve stormwater quality via sedimentation, similar to a gravel-based stormwater wetland (U.S. Environmental Protection Agency 1999a, Rossen, R., Ballestero T., Houle, J. 2009).

3.4: Hydrology

Storage volume/Saturation levels

Methods

Storage volume of the Prairie Rain Garden was estimated by measuring average ponding depth over a week long period in April 2015 after an overflowing rainfall event of 0.53 inches. The site was considered saturated and above storage capacity when runoff was observed to steadily overflow through the outflow pipe. Average ponding depth was measured in 2 locations for pools 1-3, 3 locations for pool 4 and 3 locations for the gravel swale after the saturating rainfall event. Average ponding depth was measured daily for each area for 8 days, until the entire site dried out. Rainfall quantity to reach saturation was based on estimated storage capacity of the site, and observed overflows after measured rainfall.

Days to dry down was measured for each pool after the saturating rainfall, with pool 4 being the last to dry, after 8 days. Saturated days per year in each pool were estimated using number of days per month with precipitation greater than 0.1 inches and adding one dry down period per month. Rain fall and average precipitation measurements were taken from daily precipitation data measured at the National Weather Service, Seattle Weather Forecast Office in NE Seattle, 2.5 miles from the project site. (National Weather Service 2015).

Figure 13 *below*: Site hydrology table

pool/swale	area (square feet)	avg. maximum ponding depth (inches)	estimated maximum storage volume* (cubic feet)	avg. days to dry down post saturation rainfall (> 0.1")	estimated avg. saturated days per year
pool 1	16.9	0.4	0.22	2	115
pool 2	13.5	0-0.25	0.11	<1	91
pool 3	15.1	0.4	0.2	3	127
pool 4	56.8	1.4	2.65	8	187
swale	27.7	0.75	0.69	3	127
total	130		3.87**		

*Pools and swale are filled with drain rock. Estimated storage volume was computed using effective porosity value of 40% for course gravel (Yu, C et al. 1993) .

**Storage capacity for site estimated at 0.03 inches of precipitation, based on volume produced from impervious surface.

Figure 14: Wet moist-zone polygons

Estimated flow rate/conveyance

Flow rate for the swale/site exiting through the outflow pipe was estimated using the rational runoff method and Manning's equation. The rational method estimates surface runoff flow rate in cubic feet per second based on total drainage area, ground cover type and slope. Manning's equation determines the capacity of a waterway/stream reach in cubic feet per second based on channel size. Based on the rational method, estimated maximum flow through the swale is 0.1 cubic feet per second (Appendix 4). Based on Manning's equation, the outflow swale channel has a maximum capacity of 1.82 cubic feet per second (Appendix 4). This suggests that the outflow swale is sufficiently sized to manage runoff from the site.

It is estimated that the maximum capacity flow rate for a 4 inch pipe at a slope of 1% is 0.17 cubic feet per second (Fulhage & Pfost 2009). According to these calculations, it is estimated that the outflow pipe can manage runoff from a 25 year storm event without overflowing.

It is possible the flow rate could be higher due to the small scale of the site. The small scale may underestimate the time of concentration factor in the rational method equation (Appendix 4). The flow rate could also be slightly lower, due to storage capacity of the site.

Section 3.5: Vegetation

Planting zones

The site was separated into 3 planting zones (Figures 15 & 16). Species were planted according to habitat/moisture preference, with some species planted in two zones.

zone	**moisture level**	**size (sq ft)**	**% site cover**
pool/swale	wet-moist	130	20
slope/transition	moist-dry	429.6	65
mounds/berm	dry	98.4	15
total		658	100

Figure 15: Planting zone area table

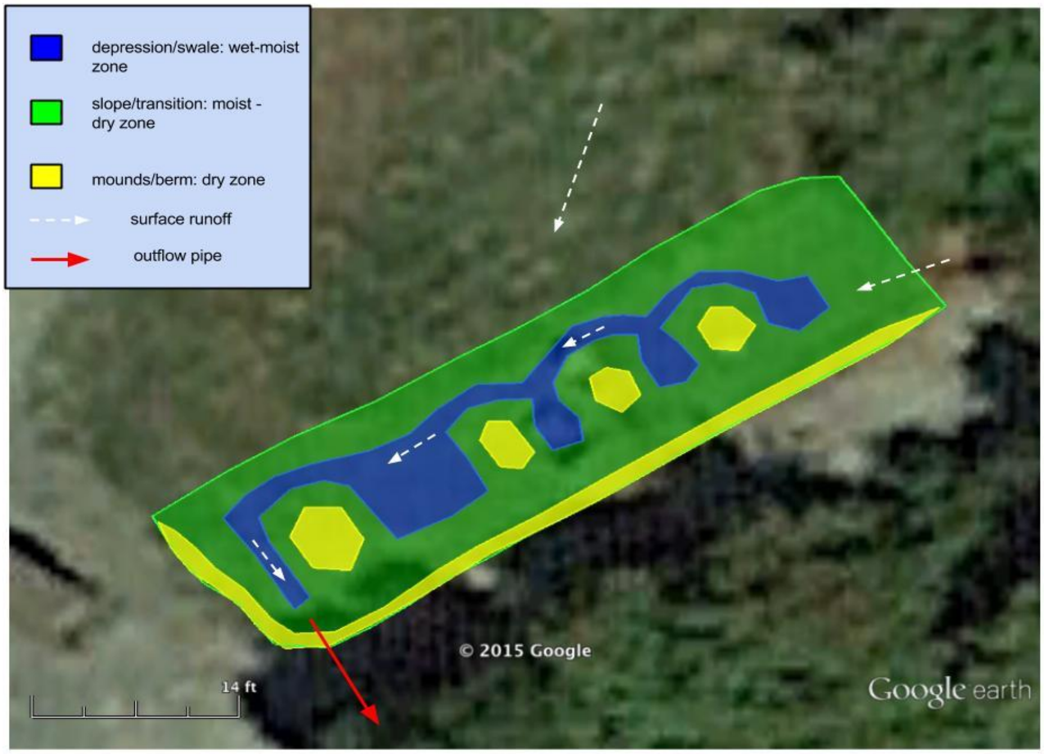


Figure 16: Planting zones plan view

Planting

Planting of the rain garden took place over a period of 7 months during the fall, winter and spring of 2014-2015 (Appendix 1). A total of 685 individual plants were installed on-site, consisting of 28 species (Figure 17). Most of the bunchgrasses were planted after the first site grading in the late fall. A majority of the forbs were planted in the spring after final site modifications.

Plant sources (Figure 17):

- Surplus plants from ESRM 473: Restoration of North American Ecosystems class
- Surplus plants from Bakker Lab experiments
- 11 *Festuca idahoensis* salvaged from near UW farm from prior project- via student Nate Haan
- MsK Rare Plant Nursery in Shoreline, WA.
- Plants grown from seed using Inside Passage Seeds, Port Townsend, WA
- *Sisyrinchium idahoense*: leftover from UWBG Rare Care project via student Chris Wong

	species	common name	planting zone	source	quantity planted on site (form) , [total]
1	*Achillea millefolium*	common yarrow	moist - dry	Bakker lab, seed	2 (1 gallon), 66 (plugs), [68]
2	*Allium cernuum*	nodding onion	moist - dry	MsK nursery	2 (4") , [2]
3	*Anaphalis margaritacea*	pearly everlasting	moist - dry, dry	MsK, seeds	3 (1 gallon), 18 (plugs), [21]
4	*Armenia maritima*	sea-thrift	moist - dry	Msk	2 (4"), [2]
5	*Campanula rotundifolia*	harebell	moist - dry	Msk	4 (4"), [4]
6	*Carex inops*	long-stolon sedge	wet - moist	Bakker lab	59 (plugs), [59]
7	*Carex obnupta*	slough sedge	wet - moist	MsK	6 (1 gallon), [6]
8	*Clarkia amoena*	farewell to spring	moist - dry	MsK	1 (4"), [1]
9	*Danthonia californica*	California oat grass	moist - dry	Bakker lab	18 (plugs), [18]
10	*Danthonia spicata*	poverty grass	moist - dry	MsK	3 (1 gallon) , [3]
11	*Deschampsia cespitosa*	tufted hairgrass	wet - moist, moist - dry	Ewing lab	122 (half gallon), [122]
12	*Dodecatheon hendersonii*	shooting star	moist - dry	MsK	2 (4"), [2]
13	*Elymus glaucus*	blue wild rye	moist - dry	Ewing lab	56 (1/2 gallon), [56]
14	*Erigeron speciosus*	showy fleabane	moist - dry, dry	MsK, seeds	2 (1 gallon), 30 plugs, [32]
15	*Eriophyllum lanatum*	Oregon sunshine	moist - dry, dry	Bakker lab, seeds	5 (1 gallon), 18 (plugs), [23]
16	*Festuca idahoensis*	Idaho fescue	moist - dry, dry	Ewing lab, Bakker lab	106 (1/2 gallon), 11 (salvaged), 10 (4"), [137]
17	*Fragaria vesca*	wild strawberry	moist - dry	seeds	16 (seedlings), [16]
18	*Fragaria virginiana*	Virginia strawberry	moist - dry	MsK	3 (4"), [3]
19	*Glyceria elata*	tall mannagrass	wet - moist	Ewing lab	24 (seedlings), [24]
20	*Hieracium scouleri*	Scouler's hawkweed	moist - dry	MsK	1 (4"), [1]
21	*Lupinus lepidus*	prairie lupine	moist - dry, dry	Bakker lab, seeds	4 (1 gallon), 36 (plugs), [40]
22	*Potentilla gracilis*	slender cinquefoil	moist - dry	Bakker lab, seeds	8 (plugs), 6 (seeds), [14]
23	*Ranunculus occidentalis*	western buttercup	moist - dry	seeds	6 (plugs), [6]
24	*Sidalcea malviflora*	dwarf checkermallow	moist - dry	MsK	2 (4"), [2]
25	*Sisyrinchium idahoense*	Idaho blue-eyed grass	moist - dry	Bakker lab, Chris Wong, MsK	11 (plugs), 8 (seedlings), 2 (4"), [21]
26	*Symphyotrichum hallii*	Hall's aster	moisty dry	MsK	1 (4"), [1]
27	*Symphyotrichum subspicatum*	Douglas aster	moist - dry	MsK	1 (1 gallon), [1]
28	*Viola adunca*	hookedspur violet	moist - dry	Msk	4 (4"), [4]
					Total quantity planted: 689

Figure 17: Plant species table

The final round of planting took place in March 2015 and consisted of forb seedlings started in the greenhouse. Many forb seedlings were grazed to the ground by slugs. Previously planted grasses were left undamaged by slugs. Slugs damaged all forb species but appeared to preferentially eat *Achillea millifolium*, and *Fragaria vesca* seedlings, of which they ate 60-80%. Slug damage to prairie plantings in urban settings has been researched by Hitchmough & Wagner (2013), finding some prairie species difficult to establish in slug-rich urban environments, especially if seedlings are small and not well established. Slug damage contributed to decreased vegetation cover on the site (Figure 18).

Vegetation measurements

Methods

Baseline vegetation data was measured by line-intercept transects, quadrats, and visual estimates by zone based on square footage per species (Figure 18). Transects were used to quantifiably measure vegetation species cover across the site. Three transects were placed across the site using a tape measure (Appendix 5). Length of species intercepting the tape were recorded and converted into percent cover, in order to monitor changes in vegetation cover over time (Caratti 2006).

Pools were measured separately in order to measure how species respond to different saturation periods and levels of inundation. Quadrats were used to measure pools. One square meter quadrants with 0.25 meter sub quadrants were placed in each pool in order to estimate percent cover by species in pools (Figure 19 & Appendix 5) (Fidelibus & Mac Aller 1993). Pools 2 and 3 were smaller than the quadrat. Consequently, half the quadrant was used to measure percent cover in pools 2 and 3.

Visual estimates by zone were used to monitor species habitat preferences and to account for species not intersected by quadrats or transects.

Vegetation Data Results

Based on the average of the site transects and visual estimates by zone, total vegetation percent cover is estimated to be 32% (Figure 18). Site ground surface not covered by vegetation is a either arborist chip mulch, drain rock, burlap erosion control fabric or bare soil. There are 29 total species currently on site. The three species of bunchgrasses planted in the fall are the most abundant species on site consisting of: *Deschampsia cespitosa* (16%), *Festuca idahoensis* (9%) and *Elymus glaucus* (4%). The remaining plant species currently cover approximately 3% of the site combined. Pools averaged 39.8 percent cover, with *D. cespitosa* accounting for most cover (Figure 19).

		Percent cover by transect					Percent cover by planting zone				% cover estimate
	species	T1	T2	T3	T average		wet-moist	moist - dry	dry	site	(T average + site)/2
1	*Achillea millefolium*	0	0	0	0		0	1	<1	<1	<1
2	*Allium cernuum*	0	0	0.1	0.03		0	<1	0	<1	<1
3	*Anaphalis margaritacea*	0	0	0	0		0	<1	<1	<1	<1
4	*Armenia maritima*	0	0	0	0		0	<1	0	<1	<1
5	*Campanula rotundifolia*	0	0	0	0		0	<1	0	<1	<1
6	*Carex inops*	0.3	0	0.3	0.2		5	<1	0	1	<1
7	*Carex obnupta*	0.6	0.7	0	0.43		5	0	0	1	<1
8	*Clarkia amoena*	0	0	0	0		0	<1	0	<1	<1
9	*Danthonia californica*	0	0	0	0		0	1	0	1	<1
10	*Danthonia spicata*	0	0	0	0		0	1	0	<1	<1
11	*Deschampsia cespitosa*	11	15	11	12.3		30	6	0	20	16
12	*Dodecatheon hendersonii*	0	0	0	0		0	<1	0	<1	<1
13	*Elymus glaucus*	2	8	2	4		0	5	0	3	4
14	*Equisetum arvense*	0.1	0.1	0	0.06		0	<1	<1	1	<1
15	*Erigeron speciosus*	0	0	0	0		0	<1	<1	<1	<1
16	*Eriophyllum lanatum*	0	0.6	0	0		0	<1	4	<1	<1
17	*Festuca idahoensis*	3	11	5	6.3		0	2	25	11	9
18	*Fragaria vesca*	0	0	0	0		0	<1	0	<1	<1
19	*Fragaria virginiana*	0	0	0	0		0	<1	0	<1	<1
20	*Glyceria elata*	0	0	0	0		1	0	0	<1	<1
21	*Hieracium scouleri*	0	0	0	0		0	<1	0	<1	<1
22	*Lupinus lepidus*	0.3	0.6	0	0.9		0	<1	5	<1	<1
23	*Potentilla gracilis*	0	0	0	0		0	<1	0	<1	<1
24	*Ranunculus occidentalis*	0	0	0	0		0	<1	0	<1	<1
25	*Sidalcea malviflora*	0	0	0	0		0	<1	0	<1	<1
26	*Sisyrinchium idahoense*	0	0	0	0		0	<1	0	<1	<1
27	*Symphyotrichum hallii*	0	0	0	0		0	<1	0	<1	<1
28	*Symphyotrichum subspicatum*	0	0	0	0		0	<1	0	<1	<1
29	*Viola adunca*	0	0	0	0		0	<1	0	<1	<1
	total percent cover	12.3	30	13	24.2		41	19	31	39	31.6

	C. inops	*C. obnupta*	*D. cespitosa*	*G. elata*	total % cover
% cover by saturated zone					
pool 1	10	5	35	<1	51
pool 2	8	5	30	0	42
pool 3	10	5	35	0	55
pool 4	8	8	30	<1	47
swale	0	0	4	<1	4
average % cover	7.2	4.6	26	<1	
total average % cover					39.8

Figure 18 *top*: Site vegetation cover by species table. **Figure 19** *above***:** Pool vegetation cover by species table.

3.6: Management plan

The site will be maintained once per quarter by the Society For Ecological Restoration - UW Chapter. The site is designed to function with little maintenance. The project will meet its main objective of keeping water off the trail as long as the outflow pipe is kept clear of debris. The project may be able to meet secondary objectives of creating a robust native plant prairie community if it is maintained regularly for a minimum of 1 year as the plants become established (Appendix 7).

Mowing of the site is an option if the site becomes over grown, as prairie grasses and forbs are adapted to disturbance. Mowing may also make the bunchgrasses more attractive by removing dead material and encouraging new growth. Although the adjacent grass area is mowed with a tractor, mounds may make using a line trimmer more practical.

Rhizomatous grasses and other weeds will likely start to invade the site with no maintenance. Although this is not ideal, the site will still meet its primary runoff management objective even if it is covered with weeds. Ideally, the adjacent site could be converted and restored by students into a prairie plant community or demonstration garden.

3.7: Outreach and educational/research opportunities

The Prairie Rain Garden can provide several outreach and educational opportunities for students and the public due to it’s location at the UWBG botanic gardens and Union Bay Natural Area. The garden is being used as a teaching tool for the Introduction to Restoration Ecology class, and was a featured site at the Green Infrastructure Partnership meeting in April 2015. In the future, students could expand the site, use the site for learning and identifying native plants, or collect seeds from the plants for future restoration projects.

The site may also be able to provide further research opportunities. In terms of vegetation, a competition study could use baseline measurements to compare future percent cover of native versus non-native species. It is possible that once established, native vegetation may be able to outcompete weeds, especially in the wettest zones (pools) and dry zones (mounds) as the vegetation planted in these zones are adapted to these more extreme conditions. Weeds amay be more competitive in mesic transition zones.

Vegetation patterns in relation to hydrology could be researched in order to measure how different species react to varied inundation levels, or see how these species survive through the dry months. The effect of vegetation cover on infiltration rate/saturation periods could also be measured, as these rates/periods may change as the plants and roots develop and change soil characteristics.

Stormwater quality is another area that presents research opportunities. It could be valuable to measure water quality from the parking lot in comparison to water quality entering the outflow pipe once it passes through the garden.

3.8: Discussion/Conclusion

The Prairie Rain Garden project attempted to combine stormwater management and ecological restoration objectives. The main project objectives were met: water no longer ponds on the trail, several native species are becoming established, and data were collected to help learn from the project.

Managing stormwater using gardens and swales can be tricky due to the numerous factors involved, including predicting stormwater quantity and flow, infiltration, groundwater effects, and establishing vegetation. As a result of numerous variables and fluctuating factors, it is best to be flexible during the design and installation phase, while also being prepared ahead of time for potential issues/problems that may arise. To be successful, designers should:

- Start small. Small projects are easier to build, maintain and require less resources.
- Be prepared to modify the hydrology after the first rainy season. If possible allow for an easy way to adjust the project's ponding depth.
- Plant densely, with well established plants. Dense plantings can account for plant mortality and reduce weed cover.
- Monitor and maintain the site. Confirm the site is meeting its project goals and adjust the management plan as needed.

Although stormwater gardens do take planning and some maintenance, there are many opportunities for gardeners with minimal experience to build and design their own stormwater garden. Similar projects could be installed on any given partly -sunny site, in private yards, parks or along roadways. In Seattle alone there are surely several acres of public land and underutilized roadside sites that could be converted into stormwater gardens (Figure 20).

With some planning and incorporation of simple techniques like earthen mounding, stormwater gardens have the potential to utilize urban runoff to increase biodiversity and help create more sustainable cities.

Figure 20: Potential stormwater garden site in Seattle

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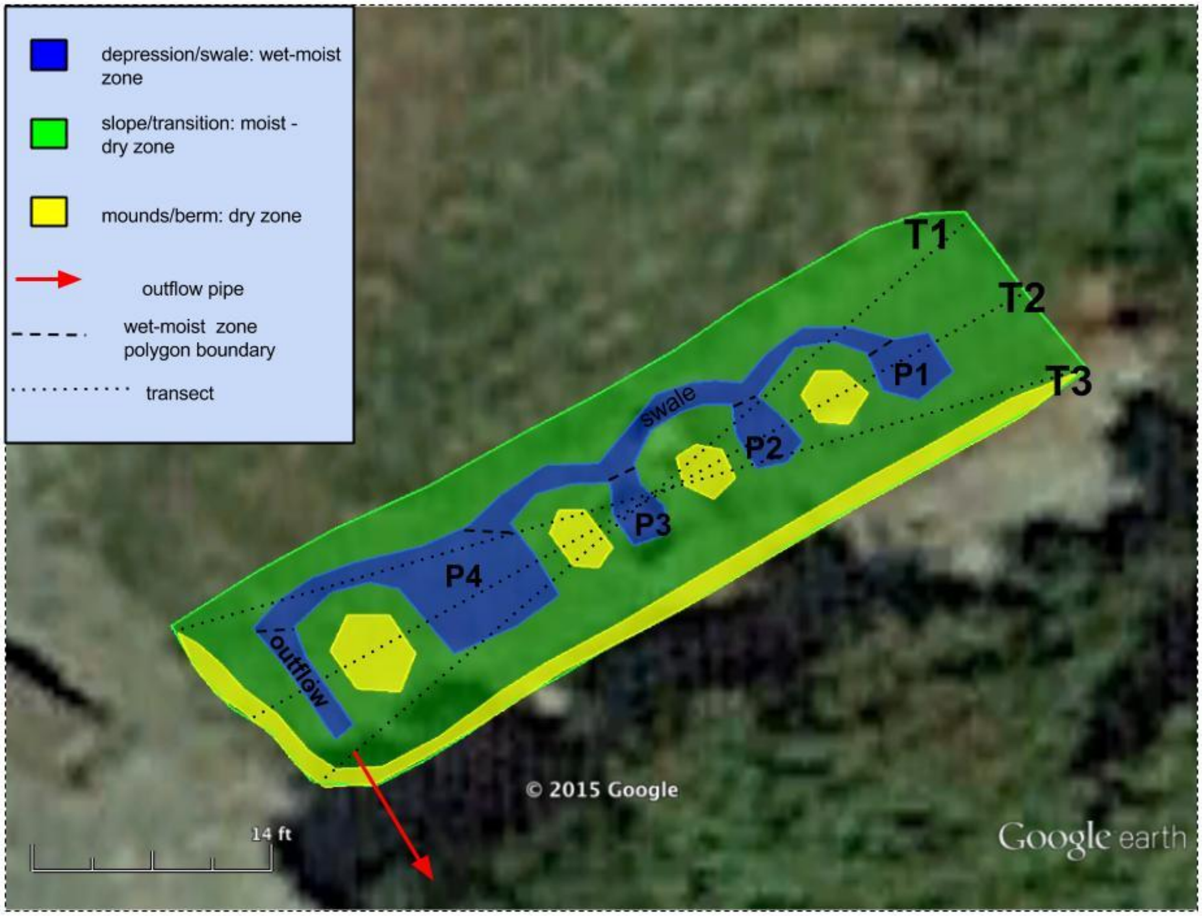
Appendix 1: Project Timeline

Task	Summer 2014		Fall 2014		Winter 2014/15		Spring 2015	
Up-potted plugs								
Manual sod removal								
Infiltration test								
Initial site grading								
Outflow pipe installation								
First planting								
Site re-grading								
Second planting								
Started seeds in greenhouse								
Completed outflow/inflow								
Up-potted greenhouse seedlings								
Burlap border and mulch								
Third planting (MsK plants)								
Fourth planting (seedlings)								
Mulched plants								
Weeding								

Appendix 2: Budget/Resources utilized

Material/Equipment	**Source**	**Quantity**	**Total cost**
seeds	Inside Passage	8 packets	$26
plants	Kern Ewing, Bakker lab, MsK Nursery, seedlings	see figure 15: plant sheet	$243* (paid with Campus Sustainability Fund grant)
pots/plug trays	UWBG	see figure 15	N/A
greenhouse	UWBG	¼ bench	N/A
hoop house	UWBG	1 bench	N/A
mulch (arborist wood chip)	UWBG	2 yards	N/A
burlap sack/ jute fabric	UWBG, Furney's Nursery Inc	3 rolls, 25 burlap sacks	$42
drain rock	Lowe's, Pacific Top Soil	1 yard delivered ¼ yard in bags	$217 ($154 paid with CSF grant)
4" ABS (plastic) pipe 4" corrugated plastic	Lowes, UWBG	1 10' piece ABS, 1 4' piece ABS, 1 coupling piece 2 10' corrugated	$48
ABS pipe glue		1 container	$8
potting soil (Sunshine Mix)	UWBG	2 bales	N/A
Labor	Volunteers	190 hours	N/A
Total cost:			$584

Appendix 3: Vegetation measurements



Clockwise from top: Transect diagram; pool 4 quadrat, T3 transect

Appendix 4: Rational Runoff Method and Manning's Equation for Estimating Flow Rate

Rational Method

Q = CIA, where:

Q = peak runoff rate in cubic feet per second

C = runoff coefficient, I = rainfall intensity, A = total area

C = ((C1)(A1) + (C2)(A2))/ total acres

C1 = pavement coefficient = 0.9

C2 = short grass pasture coefficient = 0.2

A1 = 0.03 acres

A2 = 0.06 acres

C= 0.43

I = (P) (i)

P = average maximum 24 hour precipitation for 25 year storm event at site = 3.1 inches

(i) = intensity factor = (a) $(Tc)^{(-b)}$ where coefficients (a) = 2.66 and (b) = 0.65

Tc = time of concentration = length/60V where v= K(√slope) and k= land cover coefficient

v_1= 20(√0.03) = 3.46

T_1=65/60(3.46) = 0.31 minutes

v_2=7(√0.05) = 1.57

T_2 = 104/60(1.57) = 1.1 min

Tc = 1.41 minutes*

*Due to the mathematical limits of the rational equation, one must use a minimum of 6.3 minutes for the time of concentration. This may underestimate the flow because the actual time of concentration is much shorter, at 1.41 minutes.

(i) = (a) $(Tc)^{(-b)}$ = 2.66 $(6.3)^{(-0.65)}$= 0.8

I = 3.1(0.8) = 2.48

A = total area = 0.09 acres

Q = 0.43 (2.48) (0.09) = 0.1 cubic feet per second

Manning's Equation

$Q = a \times 1.48/n \times R^{2/3} \times S^{1/2}$

Where:

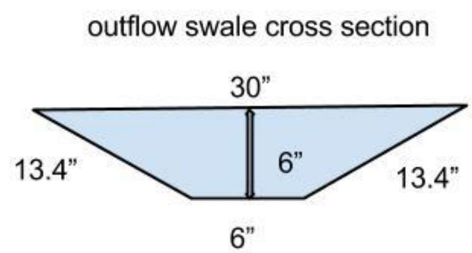
Q = capacity of stream channel (e.g. outflow swale) in cfs

a = cross sectional area of waterway

n = coefficient of roughness

R = hydraulic radius a/p (p = wetted perimeter)

S = slope



a= 0.75 square feet

n = stony bottom and weedy banks = 0.035 (King County 2009)

R = a/p = 0.23

S = 0.02

Q = 0.75 x 42.29 x 0.41 x 0.14

Q = 1.82 cfs

Appendix 5: Management and Maintenance Plan

Tools required: All required tools can be found in the UBNA tool cage.

- shovel or garden fork (for shoveling mulch)
- grass whip/ serrated weed cutter (for cutting grass)
- wheel barrow (for transporting mulch/water jug)
- watering can
- water jug
- rake (for spreading mulch along grass border)
- bucket (for mulching around plants)
- weeding tool (optional)

Additional Resources required:

- arborist wood chip mulch. Source: Available for free from UWBG pile located behind headhouse, or UW Grounds Department pile located behind UW farm
- plants (if available). Source: UWBG, SER-Nursery, Kern Ewing, Bakker lab

Estimated maintenance hours: 4 man (/woman) hours per academic quarter (e.g. would take 1 person 4 hours, or 4 people 1 hour per quarter).

Summer 2015

Task 1: Weed in between plants.
    Why: Reduce competition from weeds
Task 2: Cut back non native grass/weeds adjacent to site and along inflow trench with grass whip.
    Why: to reduce non-native grass/weed encroachment, maintain inflow drainage
Task 3: Water all plants (Once in July and August if possible)
    Why: Allow seedlings to become established during first dry season

Fall/Winter/Spring 2015/2016- and beyond

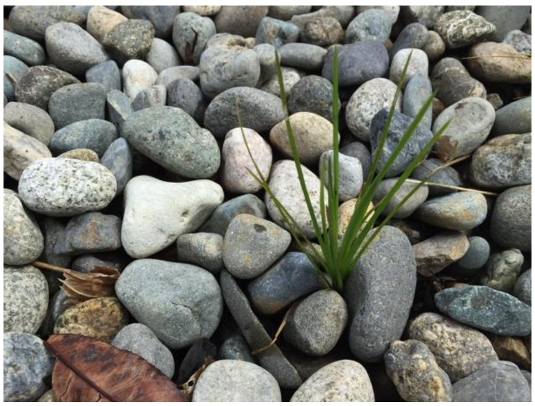
Task 1: Weed in between plants (once/quarter).
Task 2: Task 2: Cut back non native grass adjacent to site with grass whip.
Task 2: Add mulch to border, berm and mounds (twice/year).
    Why: Reduce weeds, increase soil moisture retention, reduce erosion.
Task 3: Clear vegetation/debris/sediment from outflow pipes, outflow trench, inflow (twice/year).
    Why: Keep pipe from becoming clogged, maintain drainage across trail.
Task 4: Replace dead plants, if resources available (once/year, water first summer of plant establishment).
    Why: Increase native plant cover.

Appendix 6: Process and site feature photos

Clockwise from top left: seedlings; mulching on top of burlap; garden inflow, garden outflow; outflow trench across trail; garden swale; parking lot and inflow trench

Appendix 7: Plant photos

Clockwise from top left: Achillea millefolium; Anaphalis margaritacea;, Deschampsia cespitosa; Festuca idahoensis; Elymus glaucus; Carex inops.



Clockwise from top left: Erigeron speciosus; Eriophyllum lanatum; Lupinus lepidus; Sisyrinchium idahoense; Viola adunca; Sidalcea malvifora; Glyceria elata.