REINING IN THE RAIN

A case study of the city of Bellingham's use of rain gardens to manage stormwater

City of Bellingham Washington

Puget Sound Action Team

Puget Sound Action Team Partners

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City of Burien, representing Puget Sound cities
Whatcom County, representing Puget Sound counties

Washington State Government, directors of the following agencies

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Department of Ecology
Department of Fish & Wildlife
Department of Health
Department of Natural Resources
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The Puget Sound Action Team's Public Involvement and Education (PIE) program helped fund the construction of two rain gardens in Bellingham and the printing of this booklet.

Introduction

Staff from the city of Bellingham installed a rain garden at the City Hill parking lot to protect Whatcom Creek from stormwater runoff.

Each year, inadequately treated stormwater runoff carries pollutants to the streams, rivers, and bays of Puget Sound. Pollutants from parking areas typically include oil, grease, sediment, and heavy metals. These pollutants degrade water quality and harm fish and other wildlife and their habitat.

In 2003, the City of Bellingham chose to advance its knowledge and commitment to protect the quality of water in its watershed by retrofitting two parking areas with a new technique to manage stormwater runoff. Rather than using a conventional control, such as an in-ground vault, which tends to be very costly, the City chose to install two "rain gardens" and **saved 75 to 80 percent in construction costs.** (See page 10 for a cost comparison of rain gardens and conventional vaults). Workers from the City and Washington Conservation Corps installed the rain gardens at Bloedel Donovan Park near Lake Whatcom and at City Hall.

The Puget Sound Action Team provided funding for the construction of the rain gardens, and asked City staff to document their experiences for this booklet. Staff from the City provided most of the content, with editorial assistance from Puget Sound Action Team staff. The City and the Puget Sound Action Team hope that other cities, businesses and citizens find this information useful when they consider options for reducing and better managing the stormwater runoff from their property.

The Puget Sound Action Team appreciates the City of Bellingham for piloting this innovative stormwater technology and for sharing its knowledge and experience in this booklet.

Finding new ways to manage stormwater

West of the Cascade crest in Washington state, evergreen forests dominate the landscape. They cover about 80 percent of the land and comprise some of the world's most productive forests. Now, landscapes of roads, rooftops, and other hard surfaces are rapidly replacing these forests.

Because water and land are so closely connected in the ecosystem, these dramatic changes in land cover have caused equally profound changes in how water moves through the ecosystem. Processes such as infiltration and recharge that are mediated by plants and soil have been overwhelmed as the forest gives way to the impenetrable shell of the built environment.

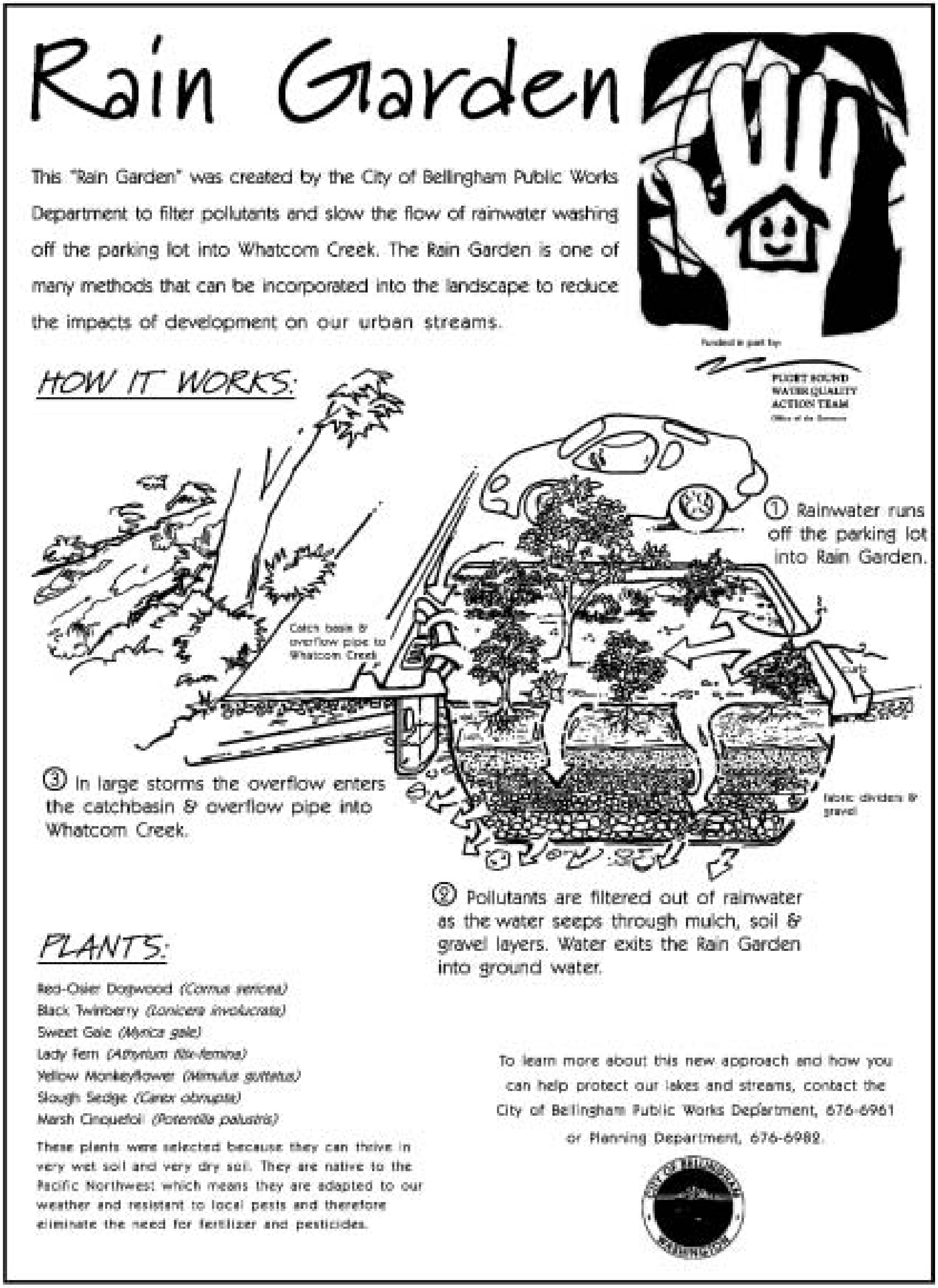
Conventional stormwater systems engineered to replace the functions of a healthy, vegetated forest are often not able to prevent water pollution or protect habitat for fish and other wildlife. Hard surfaces convey large quantities of stormwater that move with great force and pick up pollutants and sediments as it surges through the landscape. When stormwater enters the natural system of fresh and marine waters, it can cause erosion, scour streambeds, and degrade water quality. The Washington Department of Ecology (Ecology) estimates that of the state waters listed as "impaired" or those having some pollution-related problems, about one-third are impaired due to stormwater runoff.

As ecosystems become covered with large percentages of impervious land cover, their ability to support salmon and other wildlife species is compromised. Federal government agencies have listed several species of salmon as threatened with extinction under the federal Endangered Species Act. One reason for the listing is loss of habitat, which is often the result of stormwater runoff. A multi-year study in King County showed that stormwater runoff has severely degraded the county's wetlands and wildlife habitat. The Washington Department of Health has closed many shellfish-growing areas to harvest because stormwater runoff has polluted the water.

These problems have led resource managers to seek new ways to protect or restore the hydrology of the environment while accommodating the development of homes and other buildings, structures, and roads. This new approach to stormwater management is called **low impact development** (LID). LID can be summed up in three principles:

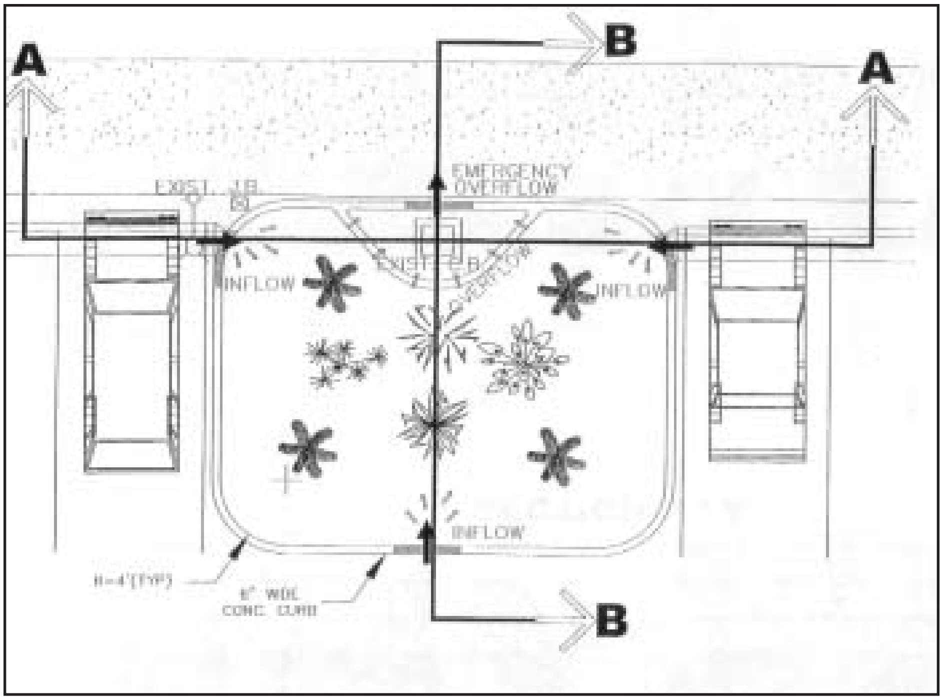
- Assess and understand the site.
- Protect native vegetation and soils.
- Minimize and manage stormwater at the source.

Rain garden design incorporates each of these principles into a low impact development technology that intercepts and infiltrates stormwater on the site. Other key activities in low impact development include maintenance, source control, and public education.



The City of Bellingham built rain gardens at two sites to filter pollutants and slow the flow of rainwater washing off parking lots into an urban stream and Lake Whatcom.

Structure and function



City of Bellingham rain garden (top view).

Rain gardens are sometimes called biofiltration cells. Well-designed rain gardens work in harmony with the hydrology of the site. They are either natural or excavated depressions planted to look like gardens. They are used as an alternative to detention ponds-the conventional facility used to manage stormwater runoff.

Stormwater infiltrates through layers of soil and gravel as plants take up pollutants. Rain gardens can be sized to detain and infiltrate stormwater that would otherwise flow into the storm system and into natural bodies of water.

Rain gardens are appealing for many reasons. They are attractive, low cost, easy to install, can provide habitat for wildlife, and are effective in treating stormwater.

Rain gardens protect habitat and water quality

The goal of a rain garden is to mimic, as best as possible, the natural function of a riparian area such as this setting along Whatcom Creek.

Rain gardens provide many of the same functions as the riparian zone (the vegetated area next to streams or other bodies of water). Riparian areas reduce the volume of rainwater flowing into streams and rivers during storm events.

Forests and other vegetated areas have the capacity to store large quantities of water in the canopy and duff layer. Rain falling on leaves and branches can evaporate or drip slowly into the soil. Rainwater in the duff eventually seeps into the ground water and is slowly released into rivers and streams. This storage and release slows the rate at which water moves through the ecosystem during and after storms. The water stored in the soil recharges the stream with cool ground water during the dry season. The slow return rate doesn't have the force to erode, so stream banks are stable and sediments remain in balance.

Few intact riparian areas remain in Puget Sound's developed landscape, so engineers design stormwater systems to provide the benefits of healthy riparian systems.
Rain gardens mimic natural riparian functions. They reduce the volume of runoff and pollutants entering streams during storm events. They help recharge groundwater and allow the water to cool as it moves through the ground before reaching the stream. By slowly releasing stormwater to streams, a rain garden can help stabilize flow rates by decreasing high flows that cause streams to erode and by supplementing low flows during dry summer months.

Rain gardens also filter pollutants from stormwater runoff. As the stormwater runoff moves through the soil and plants of the rain garden, pollutants are trapped in the soil particles. The plants in the garden take up many pollutants as well. The rain garden thus acts like a big filter, cleaning the stormwater before infiltrating it or discharging it slowly.

Installation

The City of Bellingham built two rain gardens. One is located downtown at City Hall and the other is at Bloedel Donovan Park.

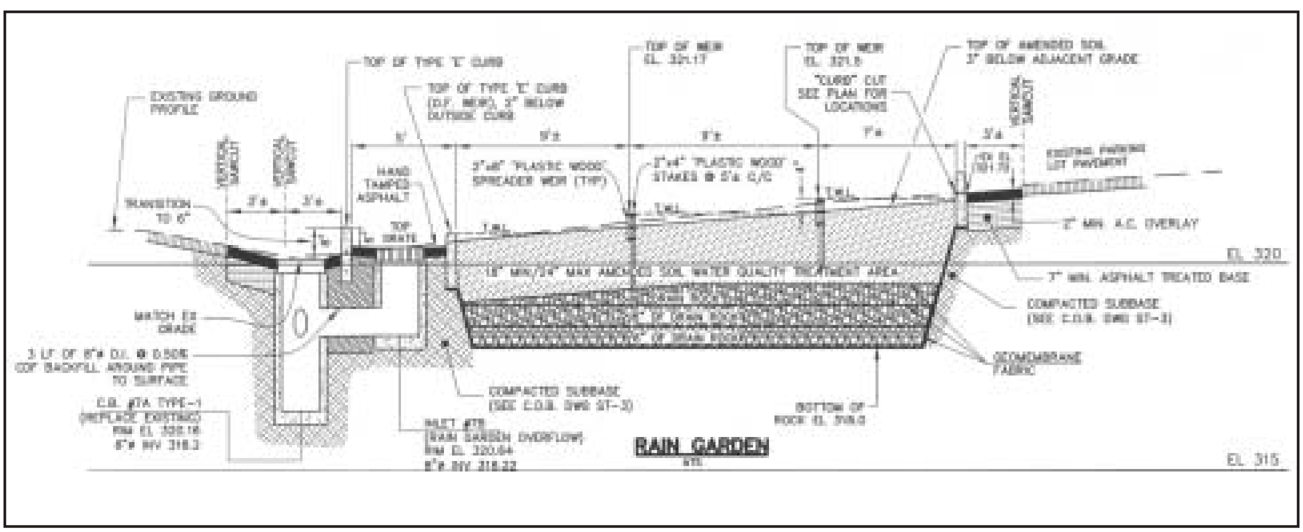
Bloedel Donovan Park has a heavily used parking lot that drains into Lake Whatcom. The City retrofitted a 550-square-foot section in the parking lot near the catch basin with a rain garden to reduce runoff into the lake. The rain garden treats runoff from about 80 parking spaces and two parking lanes. At the Bellingham City Hall, City workers converted three of the 60 spaces in the parking lot into a rain garden.

City staff created the rain gardens using the following steps:

- They excavated both garden areas to a depth of 3 to 4 feet.
- Starting from the bottom, they laid down a layer of non-woven geotextile fabric and topped it with 6 inches of drain rock. Three layers of drain rock were alternated with layers of fabric to comprise about half the depth of the garden.
- They spread a final layer of fabric over the last layer of rock to separate it from the top layer of soil.
- Staff amended an 18- to 24-inch layer of sand with 20 to 25 percent organic material and placed it on the top.
- They planted a variety of native plants in the garden.

The City used a curb to catch and direct stormwater to the rain gardens. Rain gardens can either be enclosed by a curb or they can drain sheet flow. If a curb is used to direct flow to the garden, it is constructed to surround the garden and several curb cuts are left open for drainage. Water flows from the surrounding paved area into the rain garden and filters down through the porous layers. As the water percolates down through the layers, pollutants are taken up by the plants and filtered by the sand and gravel. Rain gardens should be constructed with an overflow catch basin to discharge runoff quickly during very heavy rains to prevent flooding. The City uses a backup system consisting of an overflow weir and stormwater management filter cartridges in a second infiltration bed.

Bloedel Donovan Park rain garden (cross section).



Site and design considerations

Rain garden construction site at Bloedel Donovan Park.

The design of rain gardens can vary in complexity depending on the volume and toxicity of runoff the gardens are expected to treat. City staff advise that site analysis coupled with knowledge of state stormwater standards and guidelines are essential considerations when designing a rain garden.

The City recommends reviewing the standards for the drainage area as a first step toward deciding whether a rain garden is appropriate for the site. They consulted Ecology's *Stormwater Management Manual for Western Washington* to determine specific detention standards and the level of water quality treatment that was applicable for their sites.

To create a rain garden that fully meets water quality and quantity requirements for areas that discharge to a stream or other places sensitive to stormwater runoff, designers must size the garden to store and/or infiltrate the water from a 50-year storm. It must treat 91 percent of the polluted runoff from the site.

City staff believe that rain gardens are most effective for reducing water quantity in areas with soils that have moderate to high infiltration rates. However, even in areas with lower infiltration rates, the City believes that rain gardens have the potential for reducing the size of conventional stormwater ponds and vaults. Key considerations by City of Bellingham staff include the following:

1. City staff recommend analyzing the site and construction design for ways to reduce hydrologic impacts and lower the amount of detention and infiltration needed. For instance, they consider using flow dispersal and infiltration techniques for individual houses or buildings, using amended soils in lawn areas to improve water capture, using permeable materials for parking areas, or reducing the footprint of the impervious surface by building higher.

2. They conducted a soils analysis to determine the infiltration capability and to gauge the rain garden's ability to protect groundwater from pollution, noting the depth to bedrock, groundwater, or impermeable layers as required in the *Stormwater Management Manual for Western Washington*. According to state standards there must be a minimum of 1.5 feet from the bottom of the rain garden to groundwater. There should be at least 3 feet separating the rain garden from bedrock or clays for quantity control.

3. In accordance with the *Stormwater Management Manual for Western Washington*, the City of Bellingham used field infiltration data from soils reports to determine the design infiltration rate for the rain garden.

4. City staff looked at the site topography and soils logs to determine a maximum allowable depth for water to "pond" in the rain garden. They determined depth by a variety of factors including effect on vegetation, draw-down time, and safety. A reasonable maximum depth at the water quality design storm is 1 foot or less. The depth under the 50-year storm should not exceed 6 feet and is preferably no more than 3 feet. Storage within a 1.5 foot layer of washed rock was also accounted for in the storage design using a typical void ratio of 30 percent.

5. They quantified the effects of development on stormwater by using the Washington State Department of Ecology's Western Washington Hydrology Model Version 2 (WWHM2), to look at peak water flows during storms with durations ranging from one-half the 2-year to the 50-year storm. They calculated the amount of storage needed to offset the increase from development using a traditional pond design.

6. To determine the actual size of the rain garden, including the portion that would infiltrate, designers used an iterative process to calculate the amount of infiltration as the area increased or decreased. City staff suggest that the infiltration pond-sizing feature from the WWHM2 model, which calculates the infiltration pond automatically could also be used

7. To protect water quality, City staff used a minimum of 1.5 feet of amended sand or soil over the washed rock infiltration area (as shown in the cross-section view on page 6.) The mixture met the minimum specifications of a sand filtration media as provided in the *Stormwater Management Manual for Western Washington*. The City amended the top layer of sand with 20 to 25 percent organic material to hold moisture and to support plant growth.

Selecting plants

City staff used diverse plant material native to the Pacific Northwest to ensure greater survival and researched recommended planting densities for each species.

The City of Bellingham recommends using native perennial plants for landscaping a rain garden. Fertilizers and pesticides should not be used in rain gardens, so native plants that are adapted to the environmental conditions of the region are the best choice. City staff consulted the *Stormwater Management Manual for Western Washington* for lists of plant species that can be used in rain gardens. City staff chose plants that will survive the year-round environmental conditions of the rain garden. The amended soils used in rain gardens provide good drainage because of their high sand content, but the whole garden will be inundated with stormwater during heavy rainfall. Plants that prefer wet soil but can tolerate drought are the best choice.

City staff considered the solar exposure of the site, noting the amount and direction of sun exposure to guide plant selection. They used bigger plants to provide shade to those that need it through proper placement within the garden.

The planting plan for the rain garden included a variety of ground covers and shrubs in their planting plan, but did not plant trees that mature to large heights. Small trees or large shrubs can be considered if removing them for maintenance doesn't present a problem.

The following native plant species are appropriate for use in rain gardens in the Pacific Northwest:

- Red-Osier Dogwood *(Cornus sericea)*
- Sweet Gale *(Myrica gale)*
- Yellow Monkeyflower *(Mimulus guttalus)*
- Hardhack *(Spiraea douglasii)*
- Peafruit Rose *(Rosa pisocarpa)*
- Evergreen Huckleberry *(Vaccinium ovatum)*
- Wool Grass *(Scirpus cyperinus)*
- Slough Sedge *(Carex obnupta)*
- Black Twinberry *(Lonicera involucrate)*
- Lady Fern *(Athyrium filix-femina)*
- March Cinquefoil *(Potentilla palustris)*
- Nootka Rose *(Rosa Nutkana)*
- Kinnikinnik *(Arctostaphylos uva-ursi)*
- Snowberry *(Symphoricarpus albus)*
- Merten's Sedge *(Carex mertensii)*

City staff discovered that recommendations differ about mulching the garden with wood chips or bark. Mulch may inhibit weed growth and retain water during dry periods, but some researchers speculate that it may interfere with the infiltration process.

Cost

Rain gardens can be a significantly cost-effective way to manage stormwater runoff. The City of Bellingham saved about 75 to 80 percent per project by constructing rain gardens rather than conventional in-ground storage and treatment systems (vaults) in the parking lots. Rain gardens can be a cost-effective way to manage stormwater runoff. The City of Bellingham saved more than 75 percent per project by constructing rain gardens rather than conventional in-ground storage and treatment systems (vaults) in the parking lots. In addition to substantial savings in construction and equipment costs, it was able to reduce costs even further by using volunteers to landscape the rain gardens.

Project	Conventional vault estimate*		Rain garden cost
Bloedel Donovan Park parking lot	(4400 ft^3 wet vault)	**$52,800**	**$12,800**
City Hall parking lot	(2300 ft^3 wet vault)	**$27,600**	**$5,600**

**City of Bellingham's estimate using approximate cost of $12.00/$ft^3$ for an in-ground storage and treatment device and based on construction costs for similar projects in the Bellingham area*

The cost of the rain garden retrofit at Bloedel Donovan Park (2003):

labor:	$3,600
vehicle use:	1,900
1 ½ day excavator rental:	500
washed rock	805
*amended soil:	1,650
PVC/grates/catch basins/fabric/other misc:	1,000
concrete:	1,200
asphalt:	1,200
debris removal:	300
plants:	400
WCC crew planting time:	265
TOTAL:	**$12,820**

*soil mixed with compost

Maintenance

The City recommends regular maintenance of the plants and soil to keep the rain garden functioning properly. Even though it's a rain garden, the plants may need watering during their first summer after planting. In dry years, the garden may need to be watered periodically because the top layer in the garden is designed to conduct, not hold water. Over the first few years, some species may not survive while others may thrive. City staff plan to make plant substitutions if it appears that some of the species aren't doing well.

City of Bellingham staff expect that the soil's ability to adsorb and filter pollutants will decrease through time and require periodic replacement. The U.S. Environmental Protection Agency (EPA) advises that soils be replaced within five to 10 years after construction. However, this is open to debate. Staff at Prince George's County in Maryland and the Low Impact Development Center have found that the soil in numerous rain gardens on the east coast has not needed replacing even after many years of operation.

Monitoring

Monitoring provides information about how well the rain garden functions to reduce the volume and toxicity of stormwater. The City uses the following monitoring protocol to monitor the rain garden's ability to handle runoff from the parking lot at Bloedel Donovan Park on Lake Whatcom.

- During excavation, City staff collected soil samples from the substrata of the rain garden site and analyzed them for grain size and texture to determine the infiltration rate for the facility.
- The site has an existing rainwater gauging station located within 300 feet of the rain garden. City staff measured the concrete and asphalt parking lot area that drains to the rain garden and used the rainfall data to determine inflow to the garden.
- City staff installed a monitoring well consisting of a four-inch pipe within the filter bed. Staff are using a flow/level sensor unit from the city's sewer section to provide stage and storage information about the rain garden. The sensor is capable of reading elevations to less than 0.1 feet and allows data recording up to 10-minute intervals.

Information from these procedures will enable City staff to compare the theoretical infiltration rate with actual measured data on infiltration. They will be able to compare stage and discharge information to determine the capacity of the rain garden to hold and infiltrate stormwater. Staff will take grab samples of water from the rock filter bed that has undergone filtration through the upper sand and soil zone to test for zinc, oil and grease, pH, turbidity, and e-coli bacteria. They will compare these samples to untreated water samples taken at the inflow point to the garden. The City plans to produce a report that summarizes the data and results of the monitoring work after the rain garden weathers a few seasons.

Resources

Stormwater Management Manual for Western Washington
http://www.ecy.wa.gov/programs/wq/stormwater/manual.html

The **Puget Sound Action Team's** Web site has many resources on low impact development (LID). Check out the document ***Natural Approaches to Stormwater Management,*** which shows a broad range of LID applications, including rain gardens. Also follow links to "Web resources" and "Bioretention" for a list of resources on rain gardens: http://www.psat.wa.gov/Programs/LID.htm

Wisconsin Department of Natural Resources Web site includes several resources on rain gardens: http://www.dnr.state.wi.us/org/water/wm/dsfm/shore/raingarden.htm

The national **Low Impact Development Center** has a great deal of information about rain gardens and other low impact development techniques:
http://www.lowimpactdevelopment.org/