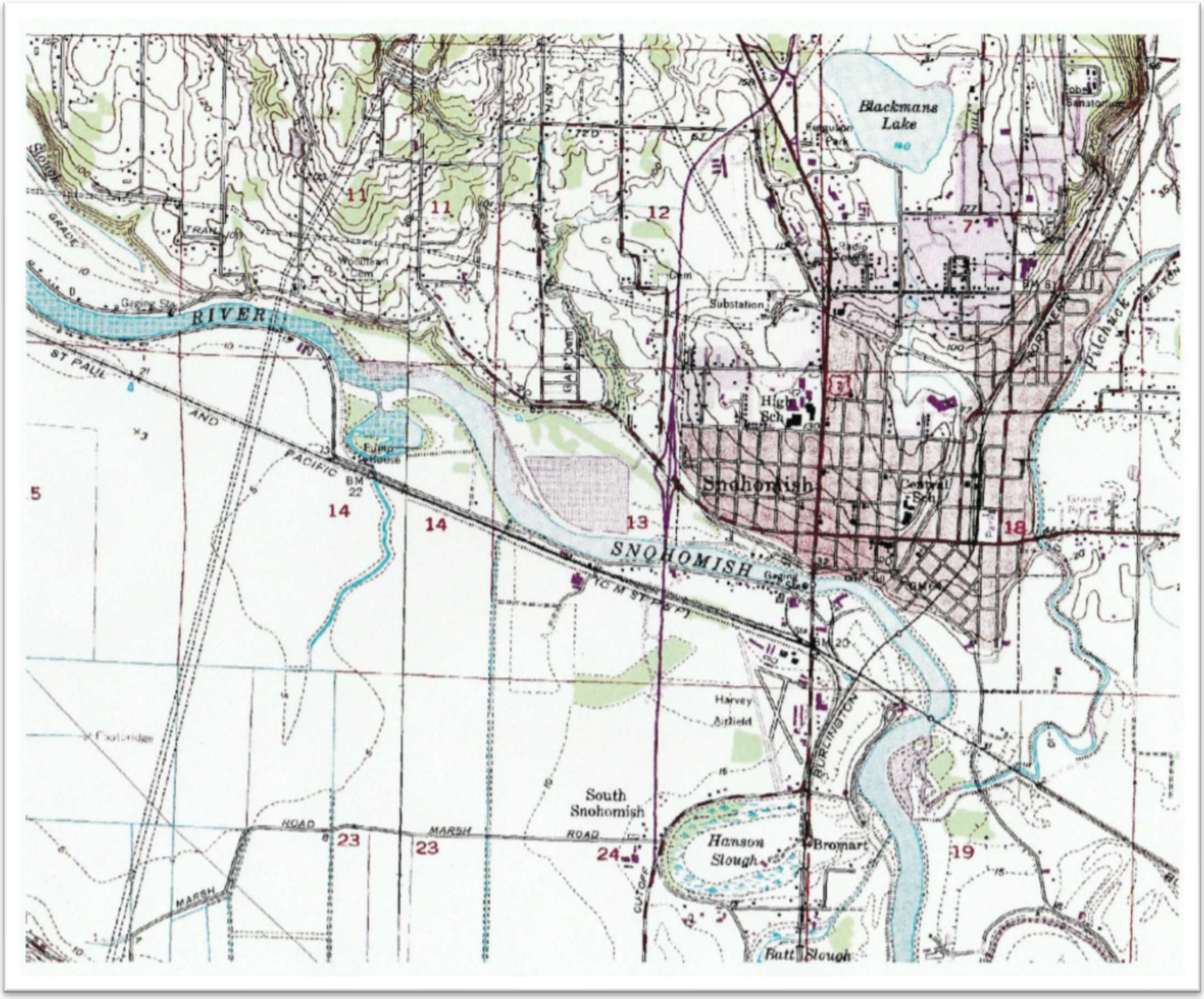
CITY OF SNOHOMISH WASTE WATER TREATMENT PLANT

Impacts of Climate Change and Policy Recommendations

Abstract

The City of Snohomish Wastewater Treatment Plant is critical infrastructure that must be prepared for potential negative impacts of a changing climate. The research and reports developed by the University of Washington Climate Impacts Group provide a well-researched projection of the potential future impacts, with specific research focused on Snohomish County. The American Planning Association, along with other professional organizations provide several best practices that will enable the City of Snohomish to appropriately ameliorate and mitigate climate impacts while making the City a more beautiful, livable, and resilient community

John Calvin, Paige Hazen



Blackmans Lake
RIVER
ST PAUL
AND
PACIFIC
SNOHOMISH
Snohomish
High Sch
Central Sch
Substation
Pump House
Gaging Sta
Harvey Airfield
South Snohomish
Hanson Slough
Bromart
Batt Slough
BURLINGTON
Pilchuck
ROAD
MARSH
ROAD
MARSH
CUTOFF
Footbridge
11
11
12
7
5
14
14
13
18
23
23
24
19

Contents

Executive Summary

Extensive research and reporting from the University of Washington Climate Impacts Group projects enhanced flood risk for the City of Snohomish Wastewater Treatment Plant (WWTP), as well as greatly increased stormwater runoff due to changing patterns in precipitation. Increased precipitation, resulting in higher streamflow on the Snohomish River, in addition to sea level rise of up to two feet will affect both the frequency and intensity of future flooding events. This represents a significant hazard after 2050. Increased stormwater runoff during heavier than normal rain events can potentially overwhelm the existing stormwater system, conveying pollution from the city streets directly to the Snohomish River.

Protecting the WWTP from flooding may entail elevating the height of the levee that surrounds it and will require consult with the Army Corps of Engineers and other state and federal partners. There are however several policies and practices that can be enacted in the short term and are effective at mitigating the projected potential hazards. Low Impact Development (LID) practices and Green Stormwater Infrastructure (GSI) are two examples.

We begin this report with a brief site description of the WWTP. We cover relevant highlights from research conducted by the University of Washington Climate Impacts Group. The bulk of this report discusses and describes a variety of policy recommendations, along with examples of the technologies discussed and how they have been implemented in other cities in the region. At the end of the report we provide a list of available tools for understanding the potential climate impacts and assessing the likely results from a variety of mitigation techniques. This is not intended to be a definitive report, but rather it is an initial foray into looking at what the future may hold for the City of Snohomish.

Wastewater Treatment Plant

Site Description

The Wastewater Treatment Plant (WWTP) for the City of Snohomish is located along the north bank of the Snohomish River on the Southwest corner of the City. (Latitude 47.91587, Longitude -122.11129)

Figure 1-Facility Location

The City of Snohomish's WWTP, has been upgraded several times since its construction in 1958, most recently in 2012. These upgrades include the addition of several aerated lagoons, installation of submerged fixed-filled media systems, a new chemical injection feed system, and Combined Sewer Overflow (CSO) reduction plans to decrease the incidents of untreated stormwater being released into the Snohomish River (City of Snohomish, 2013). As a result, CSO events decreased substantially between 2011 and 2012, addressing the effects of development and increasing runoff. Unfortunately, although mentioned occasionally, climate change projections do not seem to have been incorporated into planning for the future as of yet (City of Snohomish, 2005).

The river gauge used by the National Weather Service is located approximately 1000 yards upstream of the WWTP. Gauge elevation is listed as 0' and examining the gauge data demonstrates that it is heavily influenced by tidal flux.

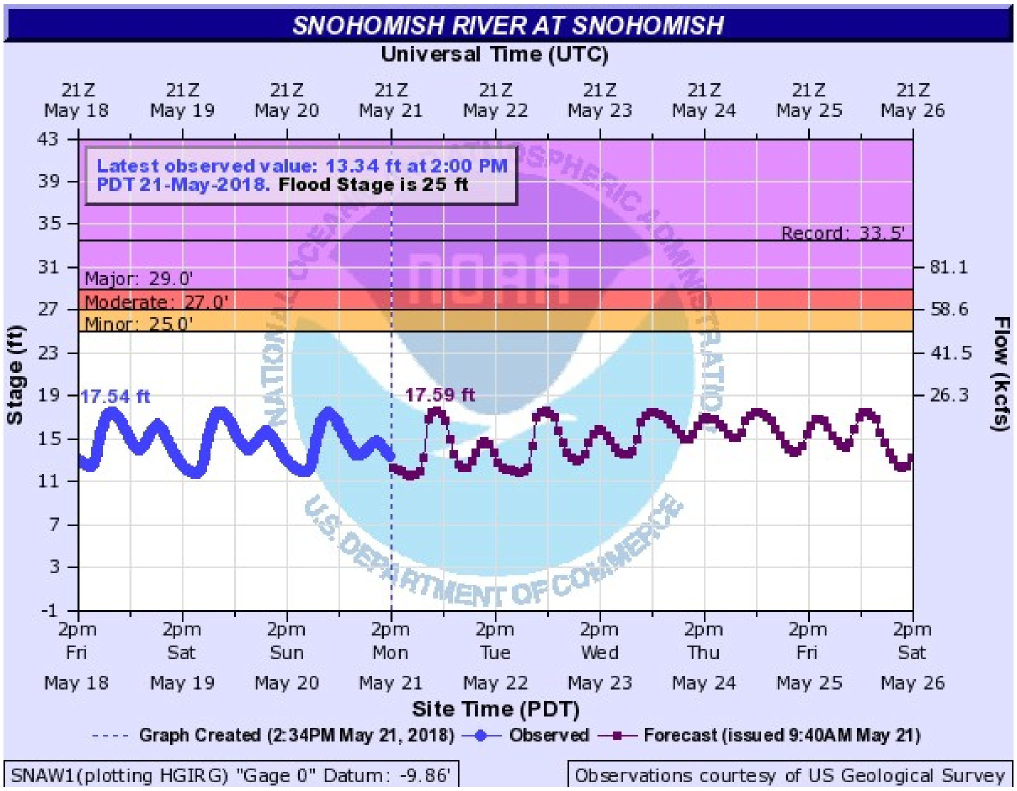


Figure 2-SNAW1 Gauge Record (Accessed 5-21-2018)

Combined Sewer Overflow (CSO)

The Wastewater System is a Combined Sewer System in the historic district and nearby zones, while the sewer and stormwater systems are separated in the northern part of the city and built after 1958. A combined sewer overflow system (CSO) is designed to connect both the sewer and stormwater systems into the same pipes. They are also designed to overflow into a nearby river if they become overwhelmed by stormwater runoff during heavy precipitation and flooding. The permit for WWTP operations limits them to one event per year, and the City can be fined for subsequent events.

The WWTP was originally built as a 40-acre facultative lagoon in 1958, then upgraded in 1989, 1995, and finally in 2012. The WWTP serves all residents and businesses within the incorporated boundaries of the City of Snohomish. The old downtown section of the city of Snohomish is served by a Combined Sewer Overflow system (CSO) and the remaining area of the city is served by a separated service area. During normal operation, treated water is returned to the Snohomish River at Outfall 001. When the CSO experiences heavier than usual volumes, excess overflows to the Snohomish River at CSO No. 1 and CSO No. 2.

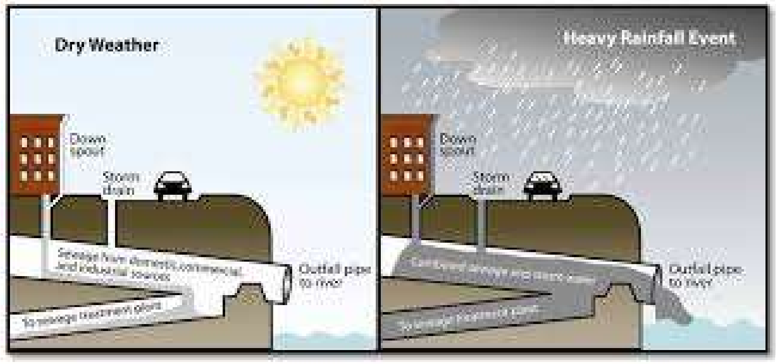


Figure 3 -- Graphic of CSO (Akron waterways, 2018).

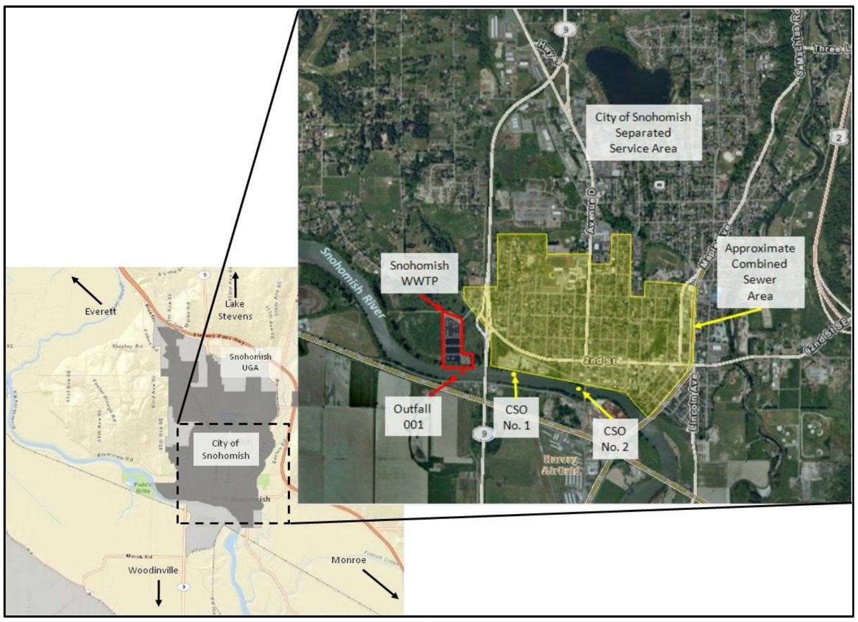


Figure 4 - Breakout map of CSO area

The highlighted section of the area map shows the estimated portion of the City of Snohomish that is still serviced by a combined sewer system. As well, the two locations of the Combined Sewer Overflow outfalls are indicated on the map.

Historical Influent Data

We received data from Karen Allen, staff lab researcher for the WWTP for daily influent flows and daily average rainfall. Data was examined and graphed to look for a mathematical correlation between rainfall and increased influent flows.

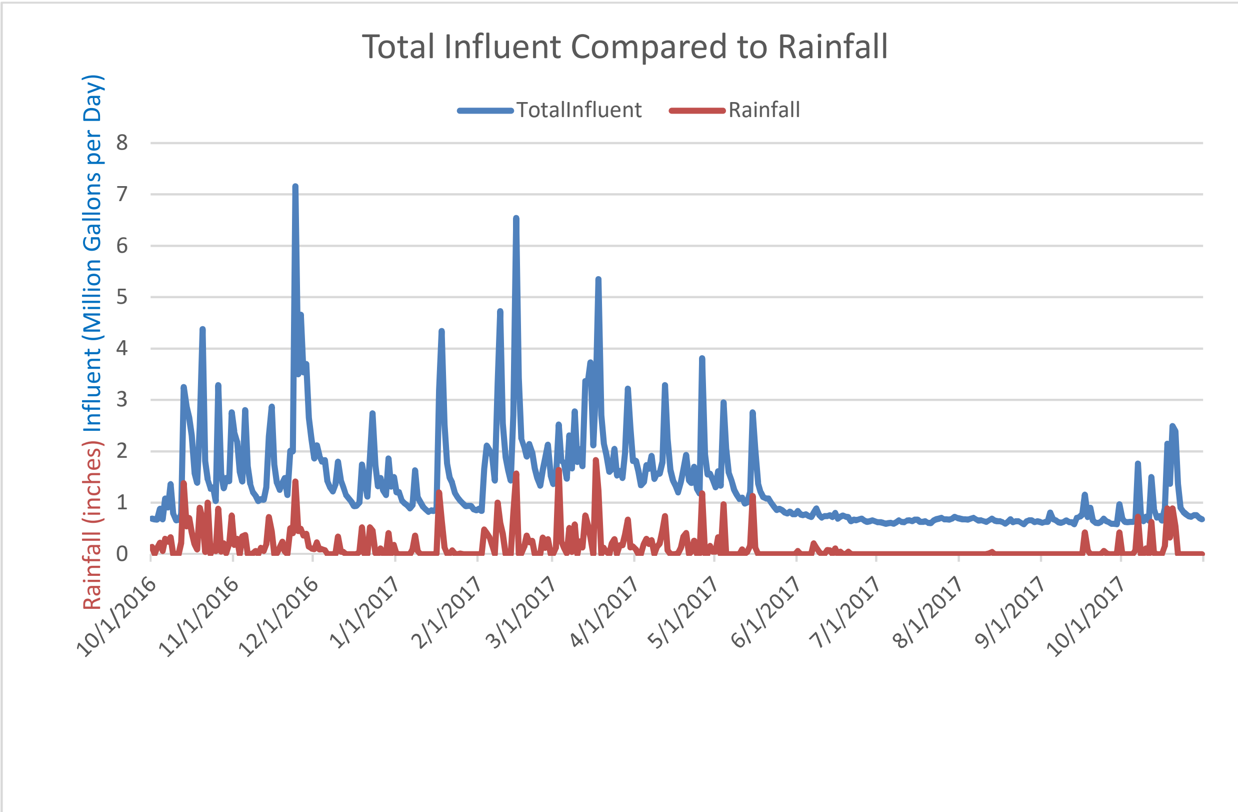


Figure 5-Graph of WWTP Influent Flow and Rainfall

The graphed data visually shows that there is some correlation, but closer examination shows periods where the correlation was not as expected. A challenge in the rainfall data we were supplied with is the 24-hour time period as opposed to hourly data. Nearby the WWTP is the French Creek weather station with hourly rainfall data, but we have not yet had the time to analyze it. We expect that intensity of precipitation matters as much as volume, and higher intensity precipitation over short periods will result in higher volumes of stormwater runoff.

University of Washington Climate Impacts Group

The University of Washington Climate Impacts Group has been developing research and reports on the wide range of potential climate impacts on the Pacific Northwest for well over a decade. They have over 700 publications providing detailed information on the impact of climate change and projections on environmental effects, wildfire impact, watershed resources, human health, and more.

> We're lucky to have leading U.S. climate change science experts in our state. The University of Washington Climate Impacts Group (CIG) is an internationally recognized, interdisciplinary research group studying the impacts of natural climate variability and global climate change
>
> https://www.doh.wa.gov/CommunityandEnvironment/ClimateandHealth/ClimateImpactsGroupInformation

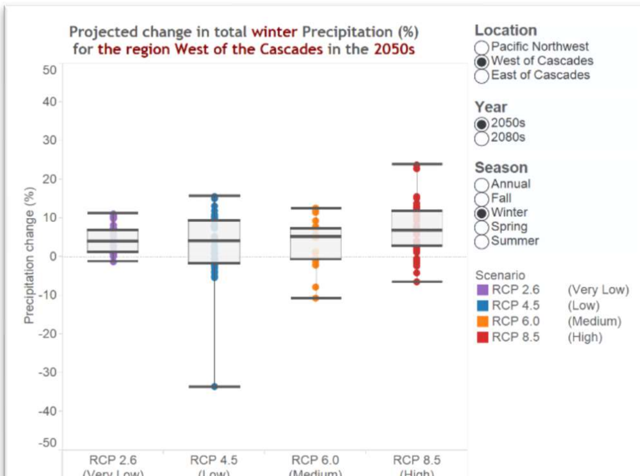
The Climate Impacts Group provides facilities for interdisciplinary research on climate change, mitigation strategies and community resilience.

Much of the research developed by the Climate Impacts Group utilizes a methodology of Dynamic Downscaling in order to produce Regional Climate Models and better understand the potential impacts of Global Climate Change here amongst the communities of the Pacific Northwest.

Climate Impacts at the WWTP

Precipitation

An email dialogue was initiated with the University of Washington Climate Impacts Group in January, and Guillaume Mauger responded with a new report produced for the City of Everett on heavy precipitation projections. This provided a great deal of information on what Snohomish might expect in the future, as Everett is only 8 miles away. The graphic to the left shows projected changes in winter precipitation for Western Washington in the 2050s (UWCIG, 2018).



Precipitation projections are mixed: some models project wetter conditions, while others project drier conditions. However, a majority of models project increases in fall, winter, and spring precipitation, and decreases in summer precipitation.

All results are shown as the change relative to the 1950-1999 average.

Figure source: Rohan Bhatt, UW Climate Impacts Group, based on climate projections obtained from the CMIP5 global model archive (Taylor et al., BAMS, 2012).

Figure 6 - Projected Rainfall Winter 2050

The University of Washington Climate Impacts Group (CIG) has conducted significant research into regionalization of climate change projections and applied that research to assessing the potential impacts of climate change on the landscape and environment of the pacific northwest. Of particular relevance is the potential increase in streamflow on the Snohomish River during enhanced precipitation events.

Streamflow Change 2040-2069, relative to 1970-1999	
Emissions Scenario	Projected Change in Streamflow
low emissions (RCP 4.5):	+26% (range: +17 to +38%)
high emissions (RCP 8.5):	+34% (range: +20 to +55%)

Figure 7 -Streamflow Table (CIG)

Sea Level Rise

Through the CIG reports and research, we found projections for Sea Level Rise (SLR) and increased streamflow with high and low emission scenarios. Averaged between the models, CIG shows a potential SLR for the Puget Sound in 2100 of +28 inches with the largest projected SLR being up to +54 inches. The period between 2050 and 2100 show the most significant SLR change

Year	Projected Sea Level Rise: Puget Sound
2030	+ 4 inches (+1 to +8 in.)
2050	+9 inches (+4 to +18 in.)
2100	+28 inches (+14 to +54 in.)

Figure 8 - Projected Sea Level Rise (CIG)

Flood Hazard

The confluence of Seal Level rise of an estimated 28 inches, and increased stream flow of up to ~34%, introduce an enhanced risk of flooding at the City of Snohomish Wastewater Treatment plant. Flooding has long been a risk at the WWTP, as evidenced by the following image taken on January 9th, 2009.

Figure 9 - Flooding at WWTP January 9th, 2009

There is a clear indication that an increase in river height at maximum flood stage would inundate the WWTP.

Policy, Hazard Mitigation, and Resiliency Implications

For this portion of the project the American Planning Association, the University of Washington Climate Impacts Group, and other various local green infrastructure resources were utilized to provide examples of what other areas are doing to prepare for climate change impacts. The good news is that there are many local and regional governments working on making their cities and counties more resilient by utilizing LID and more sustainable systems to help with their water issues. The challenge then is motivating others to do the same.

The goal for the City of Snohomish is not necessarily to apply pressure to act, but to provide enough information to guide any future decisions surrounding the WWTP and stormwater infrastructure. By providing some basic knowledge, examples of successful upgrades in other areas in the region, and available tools to properly evaluate multiple options, we hope to motivate policy makers to plan for the future.

Policy-Best Practices

Adapting to the effects of climate change is becoming an integral part of planning and policy making, and it is imperative that hazard mitigation and resilience are incorporated into these plans. Critical infrastructure within any developed area should be a priority for all stakeholders, and looking to the potential of any future natural, or manmade events, must be considered (Susman, 2017). As the City of Snohomish is located on the Snohomish River, which, according to current projections, is highly vulnerable to climate change effects (Mauger & Lee, 2014), the city must include mitigation and resilience in any future planning efforts. In addition, projected increases in large rain events will also cause detrimental effects on the WWTP's capacity requiring further planning for stormwater runoff.

According to the American Planning Association (APA), "hazard mitigation plans form the foundation for a community's short and long-term strategy to reduce disaster losses and break the cycle of inappropriate building, disaster damage, reconstruction, and repeated damage" (Draine, 2014). Furthermore, identifying any critical infrastructure that may be more vulnerable must be a priority, and adaptation goals must be set and implemented in a timely manner. Proper channels of communication need to be established to ensure that if a natural disaster occurs, necessary parties are aware of their tasks, and essential functions within the community are restored as soon as possible.

The APA outlines specific processes to help with planning for resilient infrastructure. The process entails;

1) Understanding the risks to infrastructure by performing a risk analysis, including all potential hazards and causes
2) Identify projects to reduce risk by identifying mitigation actions, and the feasibility of implementation, including costs, benefits, and impacts
3) Finding funding opportunities to assist in mitigating risk through federal and state grant programs, and cooperation with local utilities
4) Incorporating ongoing learning to refine and adjust mitigation according to best available science, and technological advances (Crouch et al., 2014).

They also provide various resources to help with assessment and planning, including the Department of Homeland Security's Integrated Rapid Visual Screening Methodology, FEMA's Map Service Center for Flood Hazards and Hazard Mitigation Assistance (HMA) program, the Federal Highway Administration Emergency Relief Program, and the U.S. Department of Agriculture's Natural Resource Conservation Service Emergency Watershed Protection Program. Once hazards have been identified and assessed, there are various pathways to ensure that mitigation and resilience can be attained regarding the determined threats.

Low-Impact Development

As the region continues to grow, so does necessary development which adds more challenges to how water is dealt with. The City of Snohomish, although smaller than our neighbors, is also growing with several new variably scaled housing developments under construction within city limits. This development will add more people and impervious surfaces and therefore, more sewage and polluted runoff to the city's WWTP and waterways which must be addressed.

The most ideal way to offset the challenge of excessive stormwater runoff, river flooding, and the effects on the WWTP is to incorporate more Low-Impact Development (LID) into the city's planning, building codes, and operations department. Also referred to as Green Infrastructure (GI), or Green Stormwater Infrastructure (GSI), these options provide more on-site stormwater controls that will lessen the burden on the WWTP, making it more resilient. Although it is stated "in 2009 and 2016 the City adopted ordinances encouraging the use of low impact development techniques" in the City of Snohomish Restoration Plan (2017, p.9), a more definitive code should be established and put into practice as soon as is feasible.

Additionally, according to the Washington State Department of Ecology's Western Washington Phase II Municipal Stormwater Permit, the city's Stormwater Management Program is to "include an education and outreach program designed to reduce or eliminate behaviors and practices that cause or contribute to adverse stormwater impacts and encourages public participation" (City of Snohomish SWMP, 2018 p. 2). It would be advisable to be more proactive with this facet of outreach and community education, encouraging homeowners and community members to apply more GSI practices at their residences.

In our region, there are already many examples of LID practices and applications that help to keep or reuse the water at the point of runoff, instead of directing excess water away. This helps to "remove runoff from a site as quickly as possible with more decentralized green systems that seek to infiltrate and store stormwater near to where the rain lands" (Cesanek et al, 2017, p. 82). In addition, these efforts filter toxins and pollutants on site, as opposed to relying on the WWTP, which can potentially be overwhelmed during large rain and flooding events. The Natural Resource Defense Council defines LID principles and practices as follows;

> LID is grounded in a core set of principles based on the paradigm that stormwater management should not be seen as stormwater disposal and that numerous opportunities exist within the developed landscape to control stormwater runoff close to the source. Underlying these principles is an understanding of natural systems and a commitment to work within their limits whenever possible. Doing so creates an opportunity for development to occur with low environmental impact. The principles are:
>
> - integrate stormwater management early in site planning activities
> - use natural hydrologic functions as the integrating framework
> - focus on prevention rather than mitigation
> - emphasize simple, nonstructural, low-tech, and low-cost methods
> - manage as close to the source as possible
> - distribute small-scale practices throughout the landscape

- rely on natural features and processes
- create a multifunctional landscape (Lehner, Peter, et al. 2001)

Types of Low Impact Development (LID) and Green Stormwater Infrastructure (GSI)

There are several types of Green Stormwater Infrastructure Best Management Practices (BMP's) that can be utilized by the City, developers, builders, homeowners, and community members. Costs are variable depending on each project but are considerably less than installing more conventional gray water systems, treating stormwater at the WWTP, or having more CSO events. Furthermore, incorporating LID practices enhances the aesthetic value and livability of the city for the community and visitors alike. The different types of Green Infrastructure that might be utilized in the City of Snohomish are listed and described below.

Rain Water Harvesting

The collection of water on-site for use in irrigation is an inexpensive and effective way to reduce both runoff and potable water consumption.

Figure 10-City of Everett rain barrels, Let It Rain Program (2018).

This can also include installing larger cisterns for higher volumes, and downspout disconnection which "is the process of directing roof runoff away from sewer systems and onto local property for irrigation purposes" (CNT, 2010 p.12). The Snohomish Conservation District sells rain barrels and full rain bed systems at cost starting at $50.00 and provides guidance and other resources on their website, snohomishcd.org. Inviting a representative to do a community workshop on rain harvesting would promote the practice and help keep potentially thousands of gallons of rainwater out of the WWTP and on-site where it can recharge groundwater resources. They could also be installed along First Street and utilized for the seasonal flower baskets. Promoting a rain barrel painting contest within our schools would be a fun way to educate the next generation of the City of Snohomish on the importance of water conservation and stormwater runoff reduction. Other benefits include reducing energy usage for treatment and transport of potable water as well as reduction in water demand, which is highly beneficial during times of drought.

Tree Planting and Retention

Planting trees or leaving them in place during building and development provide many ecological services including water retention and rainfall interception to reduce runoff, shade to reduce urban heat island effect and energy costs, CO_2 sequestration, cleaner air, improved wildlife habitat, and aesthetic beauty. They improve livability and create open spaces that bring communities together (CNT, 2010 pp, 6-7). The City's Tree Retention code (SMC 14.31.020) properly covers regulations surrounding trees within new or existing development, but community outreach and education on their importance as GSI would be reinforcing and promote proper care. According to the National Tree Benefit Calculator, one 45-inch Western Red Cedar on a residential property "provides overall benefits of $118.00 per year" (treebenefits.com, 2018).

Figure 11-Annual cost-savings provided by one 45" Western Red Cedar (on right) (treebenefits.com, 2018).

In addition, this tree will keep 7,290 gallons of stormwater per year out of the CSO system. It is vital that the city keeps or replaces any trees and adds more where possible to the Hal Moe pool, Carnegie Library, and any other city sites to provide the benefits described above. Another possibility is to start an annual tree planting day to involve and educate the community.

Permeable Pavement

Permeable pavement allows rainwater to infiltrate on site while preventing runoff to the CSO.

Other benefits include increasing groundwater recharge, reducing or eliminating the need to salt on icy days, reducing heat island effect which provides cooler temperatures, lowering cost of water treatment, and providing more attractive livable communities. Various types include pavers and porous concrete and asphalt (CNT 2010, pp. 10-11). In addition, permeable pavement can reduce construction costs for developers, increasing property values while decreasing stormwater fees for residents (See City of Sultan Case Study).

Figure 12 - Permeable pavement at the High Point development, Seattle (Buildabetterburb.org, 2018).

Pavers can be utilized in the City of Snohomish residential, commercial, and public areas in addition to other GSI features in complimentary configurations providing more walkable streets and inviting communities.

Figure 13 - - Permeable pavement and tree plantings, Stone Way, Seattle (sdot, 2018).

Bioretention – Rain Gardens and Bioswales

Bioretention consists of depressed areas of ground landscaped with low maintenance native plants that allow water to pool and slowly infiltrate back into the groundwater system and include rain gardens, bioswales, and natural wetlands. The differences are that "in rain gardens, stormwater filters through the soil and plant root area to the underlying native soil, and excess water overflows to an adjacent drainage system. In contrast to rain gardens, bioretention facilities are engineered systems that may have additional underdrains, control structures, and regulatory requirements" (Snohomish Conservation District, 2018). Benefits other than infiltration and groundwater recharge include filtering out toxins, improving air quality, reducing the use of potable water, and improving aesthetics and livability.

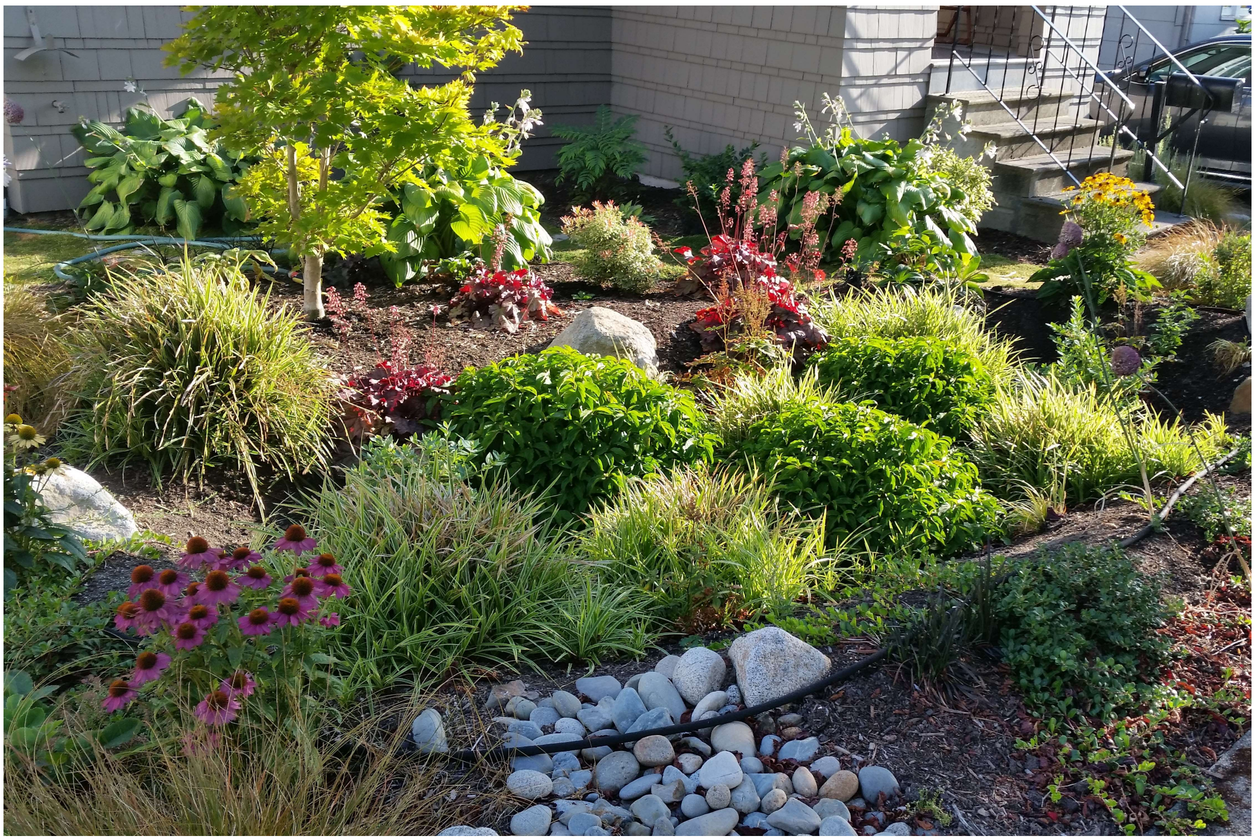


Figure 14-Residential Rain Garden in Seattle. Photo: Ashley Blazina (2015).

Rain gardens can be installed in sloped residential yards by disconnected downspouts which provide water infiltration during rain events while preventing stormwater runoff. The City of Snohomish can provide workshops, rain garden events, and educational materials to promote their installation throughout the community including benefits to the city and residents alike.

Figure 15-Bioswale on SEA Street, Seattle (2018).

Bioswales can be installed in areas of the city where excessive runoff is most prevalent, specifically on sloping hills that tend to be inundated during large rain events. Certain roadside culverts could be redesigned into bioswales, improving infiltration and adding beauty to existing neighborhoods. They could also be installed more frequently in new developments along with other GSI applications to negate a large amount of runoff to the WWTP.

Green Roofing

Green roofing is used on rooftops instead of traditional roofing materials to infiltrate and filter rainfall. It consists of a waterproof membrane, layered growing medium, and appropriate vegetation for the region and elements. Extensive green roofs are between two and six inches deep, and Intensive roofs are more than six inches deep and are generally found on commercial buildings. Benefits of green roofs include reduced stormwater runoff and energy costs, increased cooling and CO_2 sequestration, improved habitat, and aesthetic beauty and livability.

Figure 16 - Green garage roof, Seattle – Rob Harrison (2010).

Figure 17 - Green roof, Mukilteo City Hall, Mukilteo (City of Mukilteo, 2018).

Green roofs also last longer than traditional roofing systems with little maintenance.

LID/GSI Program Examples and Case Studies

City of Everett

The City of Everett's Let it Rain program was implemented in 2014 after a successful pilot program constructed seven rain gardens in the northern part of the city in response to basement flooding and a large CSO overflow event in June of 2010. Originally focused only in North Everett, it now runs citywide and offers rain garden rebates for the first 25 homeowner applicants up to $2500, as well as rain barrel sales and downspout disconnection assistance. They even provide free site assessments and soil infiltration tests to those that qualify, with priority given to those who have experienced flooding (Tatistcheff, 2018).

Figure 18-Rain Garden, Let It Rain program, Everett (2015).

Similar rain garden rebate programs exist all around the Puget Sound including in Bellingham, Shoreline, Lake Forest Park, and Port Angeles. Seattle's RainWise is described on page 33.

City of Sultan

In 2006, CMI Homes built the Stratford Place in Sultan, WA utilizing 100% pervious concrete. At that time, Craig Morrison, owner of CMI had to convince the city to allow him to pave all the surfaces with permeable material totaling 32,000 square feet. According to the Concrete Network, "the Stratford Place project was the first in Washington to use pervious concrete for all its surfaces including driveways, sidewalks, and the main street" (n.d.). Pervious concrete is porous, allowing water to flow through and infiltrate the soil below it preventing puddling and runoff.

Figure 19-In this project, pervious concrete was used as a 2-part on-site storm water management system consisting of pervious concrete pavement (8-inches) and a coarse gravel retention layer (8-inches) for storm water storage (Concrete Network, n.d.).

Because the stormwater runoff was kept on site, the need for catch basins, detention vaults, and other stormwater infrastructure was eliminated providing substantial cost benefits, including two extra building lots. Detailed cost benefits are included in the next section.

Figure 20 - Stratford Place permeable pavement, Sultan (Concrete Network, n.d.).

The neighborhood of Stratford Place is a perfect example of GSI and BMP's providing excellent stormwater management as well as aesthetic beauty and livability for the community.

Figure 21-SEA Street

Seattle – SEA Street

Located on 2nd Street between NW 117th and NW 120th Streets in the Broadview neighborhood of Seattle, the Street Edge Alternatives project, or SEA Street, was a pilot project by Seattle Public Utilities completed in 2001. The project was based on improving livability while decreasing stormwater runoff into Piper's Creek and Puget Sound through LID and GSI. The main component of SEA Street was to increase natural on site stormwater filtration and retention through the utilization of bioswales, rain gardens, and permeable paving materials. The street was narrowed and reconfigured into a meandering, curvilinear design to help slow traffic and increase areas of bioretention and reduce impervious surfaces by 18% (EPA, 2007). This has resulted in significant stormwater runoff reduction and "if a conventional curb-and-gutter system had been installed along 2nd Avenue instead of the SEA Street design, 98 times more stormwater would have been discharged from the site" (EPA, 2007). Detailed cost benefits are included in the next section.

The community involvement in this project was substantial, from the planning process to ongoing maintenance of the rain gardens and bioswales. There has also been an increase in community members' environmental awareness and active stewardship of Piper's Creek (Matsuno & Chiu, 2010).

Figure 22 Aerial view and sloping bioswale, SEA Street, Seattle (2018).

Seattle RainWise Program

The RainWise program was started in 2010 and is run by Seattle Public Utilities (SPU) and King County Wastewater Treatment Division (WTD) and provides rebates and assistance to homeowners living within the CSO area for rain garden and cistern installations. The average rebate is $4000.00 and there is additional assistance for low-income participants for pilot loans to offset the initial cost through the National Resources Defense Council's Center for Market Innovation and Water Program with Washington State University Stewardship Partners. They offer "RainWise Pilot Access Loans (RPALs) to RainWise contractors and improv[e] access to RainWise for homeowners and landowners who don't have cash available up front" (Valderama, 2016).

Figure 23 -Rain barrel and cistern installations, Seattle RainWise program (SPU, 2018).

Figure 24 - Rain garden, Seattle, RainWise program (2018).

They have completed 3,982 rain garden installations across Seattle, with a goal of 12,000 in the Puget Sound area which will keep over 160 million gallons of runoff on-site and out of our waterways. Cost and stormwater information can be found in the next section.

ROI and Cost Benefits of LID

One of the greatest incentives for cities, developers, and homeowners to utilize LID and GSI is the cost benefit and return on investment (ROI). By helping to determine these short-term and long-term savings, city governments can increase motivation to utilize these techniques within both the public and private sectors. In *Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide,* the authors look at various benefits of different types of GSI for all stakeholders:

> Green infrastructure alternatives have demonstrated a positive economic effect in a number of communities, particularly for those using these approaches to both reduce polluted stormwater and CSOs. Communities across the country are demonstrating that CSO control plans that incorporate green infrastructure elements as a way to achieve pollution reduction goals add cost-effective complements to grey infrastructure and provide additional value to the local community. The lesson learned so far by early adopter communities who have already implemented green infrastructure in a significant fashion is that a wide-ranging commitment to including green infrastructure stormwater approaches, on public as well as private properties, can result in long-term fiscal savings for local governments as well as provide numerous, tangible economic and community benefits through related ecosystem services (2012).

A commonly held belief may be that investing in LID practices is more expensive than traditional grey infrastructure, but the metrics used to confirm this opinion may not include the full realm of benefits. Figure 25 from the Center for Neighborhood Technology highlights the economic, social, and environmental benefits of the five previously discussed GSI Practices, attributing more than simply monetary value.

Green Infrastructure Benefits and Practices

This section, while not providing a comprehensive list of green infrastructure practices, describes the five GI practices that are the focus of this guide and examines the breadth of benefits this type of infrastructure can offer. The following matrix is an illustrative summary of how these practices can produce different combinations of benefits. Please note that these benefits accrue at varying scales according to local factors such as climate and population.

Benefit	Reduces Stormwater Runoff											Improves Community Livability						
	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding	Increases Available Water Supply	Increases Groundwater Recharge	Reduces Salt Use	Reduces Energy Use	Improves Air Quality	Reduces Atmospheric CO_2	Reduces Urban Heat Island	Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture	Improves Habitat	Cultivates Public Education Opportunities
Practice										CO_2								
Green Roofs	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes	Yes
Tree Planting	Yes	Yes	Yes	Yes	No	Maybe	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Bioretention & Infiltration	Yes	Yes	Yes	Yes	Maybe	Maybe	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe	No	Yes	Yes
Permeable Pavement	Yes	Yes	Yes	Yes	No	Maybe	Yes	Maybe	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes
Water Harvesting	Yes	Yes	Yes	Yes	Yes	Maybe	No	Maybe	Maybe	Maybe	No	No	No	No	No	No	No	Yes

Yes Maybe No

Figure 25 - CNT (2010)

There are currently many tools available to determine the initial costs and ROI to help evaluate and promote more widespread utilization of these GSI applications which are listed in Tools and Resources.

The cost benefit analyses below assess several of the previous case studies, as well as the benefits of other projects and individual GSI practices.

Permeable Pavement - Stratford Place, Sultan

This site includes 32,000 square feet of permeable concrete used for the street, sidewalks, and driveways of 20 homes in 2006. It does not include the cost benefit to the city for reduced stormwater treatment.

From the Concrete Network (n.d.)

Pervious Concrete Eliminated Costs:

- Traditional storm water catch basins, embeds, and piping infrastructure, labor ($175,000)
- Need for detention vaults with lid
- Interior plat curbing ($37,000)
- Asphalt roadway system ($48,000)
- Developer estimate of traditional storm water system ($460,000)
- City/county future maintenance of roadway and storm system

Pervious Concrete Site Benefits

- Builder reclaimed two additional lots versus land used for detention vaults, ponds, perimeter structures. Lot values: $100,000 each
- City receives two additional real estate tax parcels
- Develop cost for pervious concrete system—approx. $196,000
- Net savings to developer—approx. $264,000
- Rain water from roofs directed to recharge area under pervious concrete street
- Eliminated untreated storm water and creates zero runoff
- Directly recharges ground water, mimics natural infiltration of site
- Mitigates "first flush" potential by reducing pollutant loading

SEA Street – Seattle

This site includes rain gardens, bioswales, permeable pavement, and reduced and reconfigured street design completed in 2001.

From the EPA (2007)

Cost Comparison for 2nd Avenue SEA Street

Item	Conventional Development Cost	SEA Street Cost	Cost Savings*	Percent Savings*	Percent of Total Savings*
Site preparation	$65,084	$88,173	–$23,089	–35%	–11%
Stormwater management	$372,988	$264,212	$108,776	29%	50%
Site paving and sidewalks	$287,646	$147,368	$140,278	49%	65%
Landscaping	$78,729	$113,034	–$34,305	–44%	–16%
Misc. (mobilization, etc.)	$64,356	$38,761	$25,595	40%	12%
Total	**$868,803**	**$651,548**	**$217,255**	—	—

* Negative values denote increased cost for the LID design over conventional development costs.

Figure 26 - Cost comparison 2nd Ave SEA Street

Below is a comparison graph of SEA Street and several other GSI projects in Seattle. It is important to note that the other projects were completed after SEA Street and the cost effectiveness of those has increased.

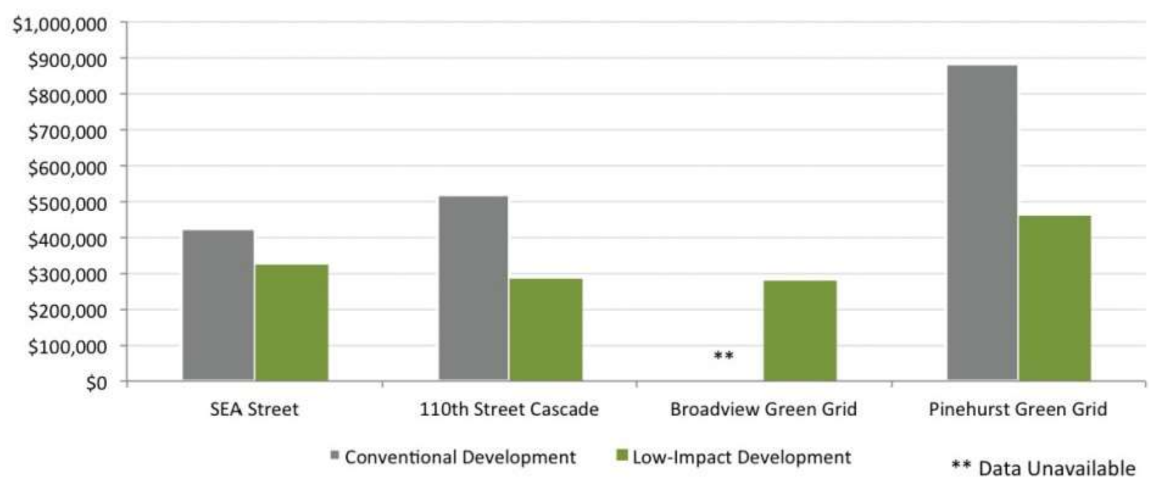


Figure 4. Cost Analysis of Seattle Public Utilities Natural Drainage Systems

Figure 27 - Cost Analysis Seattle Public Utilities Natural Drainage System

From the EPA, a short cost benefit analysis;

Naperville, Illinois: Developers at the 55-acre Tellabs corporate campus preserved much of the site's natural drainage features and topography, reducing grading and earthwork costs. They used bioswales and other infiltration techniques in parking lots to manage stormwater. They maximized the amount of natural areas, eliminating the need for irrigation systems and lowering maintenance costs when compared to turf grass. Results? As seen in the table below, total LID project costs were $461,510 less than a conventional design would have been (2012).

Sample Costs: Comparing Conventional Stormwater Controls with LID Techniques in a Corporate Development (Tellabs) in Naperville, Illinois

Construction Item	Cost of Conventional Development	Cost When Using LID Practices	Dollars Saved with LID
Site preparation	$2,178,500	$1,966,000	$212,500
Stormwater management	$480,910	$418,000	$62,910
Landscape development	$502,750	$316,650	$186,100
Total	**$3,162,160**	**$2,700,650**	**$461,510**

Figure 28-Cost Comparison Stormwater/LID

Stormwater Volume – City of Portland, Oregon

Marginal cost per gallon and stormwater volume removed through different forms of GSI in the City of Portland, Oregon.

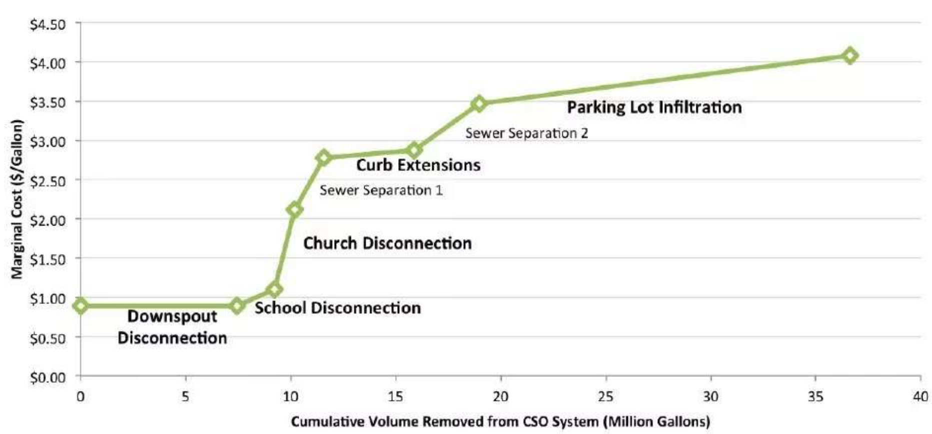


Figure 2. Costs and Cumulative Volume of Stormwater Removed from the CSO System through Various Grey and Green Strategies (Green in Bold). Source: ECONorthwest, with data from City of Portland 2005

Figure 29 - Costs and Cumulative

City of Seattle

The table below summarizes the total amount of stormwater that is diverted from the specified system through various GSI applications; Right-of-way refers to Seattle Public Utilities capital projects; Code-triggered are those that were required by the municipal code; RainWise is Seattle's incentive program for homeowners to install GSI on their property; Other refers to various public and private projects.

Summary of Existing GSI Inventory (gallons managed per year)

Basin	Right-of-way	Code-triggered	RainWise	Other	Total
Combined Sewer Basin	4.4 million	3.3 million	2.3 million	3.4 million	13.4 million
Creek Basin	62.1 million	0.8 million	--	< 0.1 million	63.0 million
Direct Discharge Basin	0.3 million	4.6 million	0.2 million	4.9 million	10.0 million
Total	66.9 million	8.7 million	2.4 million	8.4 million	**86.4 million**

Figure 30 - GSI Inventory

The basins refer to two types of sewer systems; CSO's or the Combined Sewer Basin, and separate sewer systems where the stormwater either flows directly into a Creek Basin, or a Direct Discharge Basin like the Puget Sound (EPA, 2017).

Seattle's goal is to manage 400 million gallons of stormwater annually through GSI by the year 2020 (SPU, 2015).

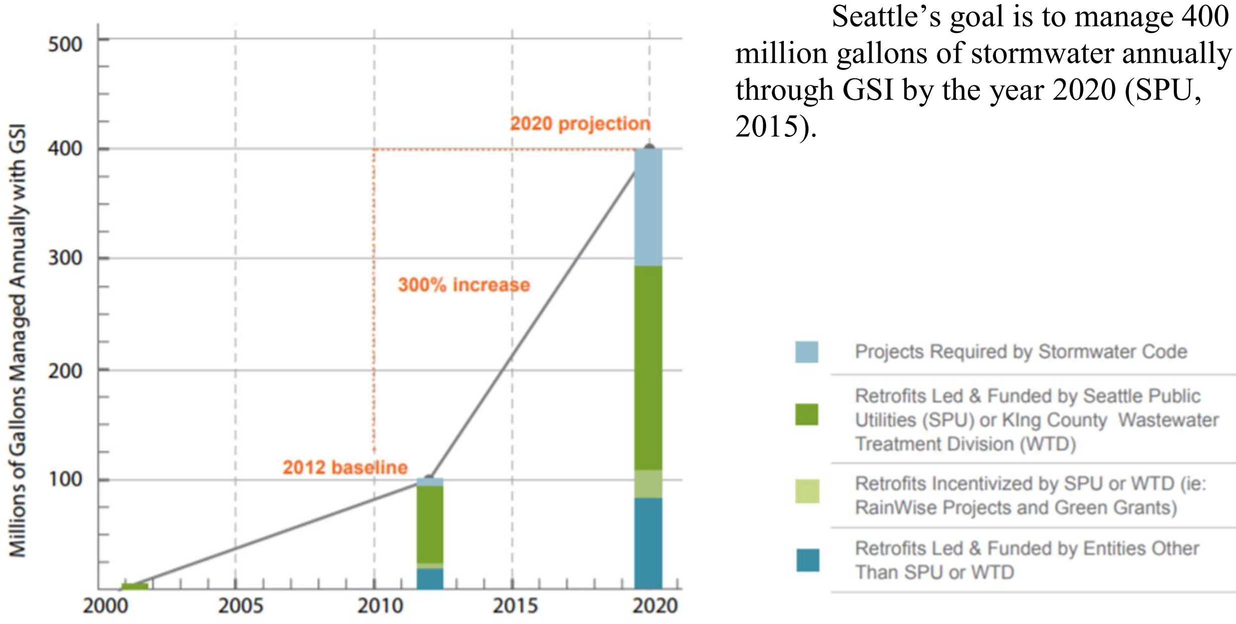


Figure 31-Projected Managed Stormwater in Seattle

RainWise

The following table and graph illustrate the costs and associated stormwater runoff amounts managed by Seattle's RainWise program installations as of Fall 2012.

Table 19. Summary of RainWise Projects (as of September 2012)

Project Description	Number of Facilities	Volume Managed (gallons/year)	Total Cost
Rain Garden	108	1,712,869	$502,904
Rain Garden and Cistern	18	345,601	$114,305
Cistern Overflowing to Conveyance Furrow	3	15,458	$12,496
Cistern Overflowing to Sewer	8	40,800	$31,164
Cistern	8	39,116	$35,134
Cistern Overflowing to Rain Garden	17	312,590	$99,533
Total	**162**	**2,466,433**	**$795,536**

Figure 32 - RainWise Projects

Source: Personal Communication. Emerson, Pam. Seattle Public Utilities. E-mail. October 3, 2012.

Project Costs and Management Volume for RainWise Facilities

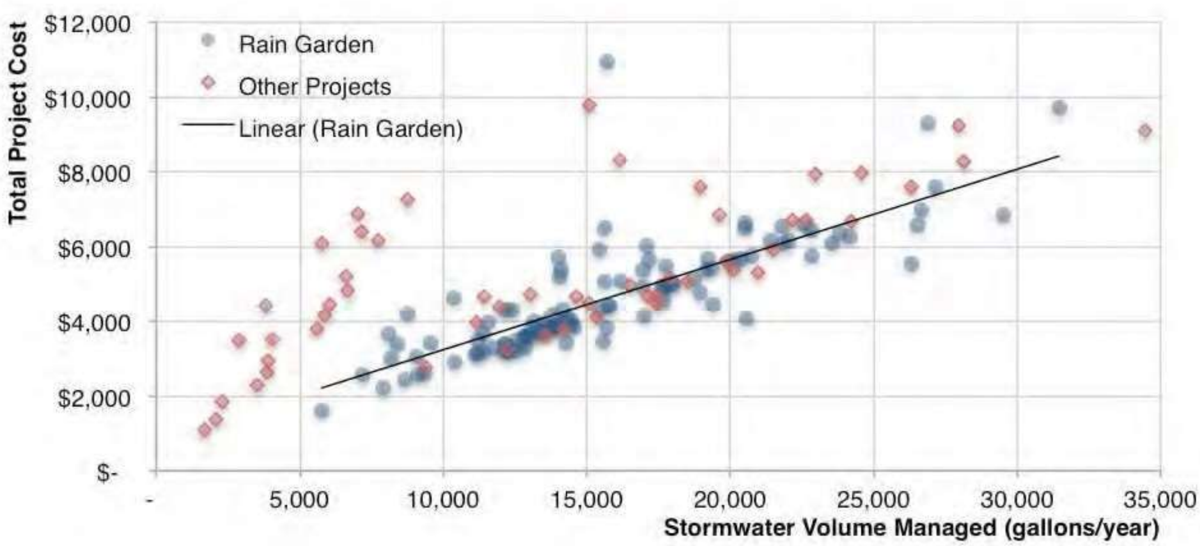


Figure 33 - Storm Water Volume Managed

There are numerous benefits to incorporating Green Stormwater Infrastructure into future private and public projects in the City of Snohomish. There are also various formulas, tools, and resources available to assist individuals, city planners, and sustainability professionals to determine these benefits. A list of these resources can be found in Tools and Resources.

Recommendations

An essential part of hazard mitigation is realistically planning for future events. This involves multi-agency cooperation on federal, state, and local levels, and it is imperative that any pertinent data needed is current and agreed upon. Hazard mapping must be accurate, and reflect the best available science, with any possible future climate change projections as a guideline. The APA suggests that "to the extent practicable, maps should predict the extent of flooding at least 50 years into the future" (Draine, et al, 2014). They also recommend preparing for the worst-case scenario, which for the City of Snohomish, would be planning for a 500-year flood event including the effects of sea-level rise, and more frequent intense rain events. This is where current climate science and hazard mitigation and resilience planning must merge to provide a safe future and community protection.

Current sea-level rise projections should be utilized in determining possible flood levels that may detrimentally affect the WWTP to properly analyze corrective actions that can protect its operations. For example, the highest flood crest on record was 33.50 ft. on November 25, 1990. If average SLR projections are added to that height, the increases would measure 33.83 ft. in 2030 (+4 inch projected average), 34.25 ft. in 2050 (+9 inch projected average), and 35.83 ft. in 2100 (+28 inch projected average). The APA recommends that "local governments can add projected sea-level rise to flood zone hazard maps, currently based exclusively on historical events, to better plan for future conditions" (Susman, 2017). How these projections can best be applied to protecting the WWTP facility will need to be determined by qualified city staff members along with assistance by the Department of Ecology and most likely, the Army Corps of Engineers.

The most plausible actions then are actively applying more stringent Low Impact Development and Green Stormwater Infrastructure goals to all future capital, public, and private development projects. According to a Puget Sound Partnership and AHBL Inc. LID local regulation assistance project from 2005 through 2009, "the single greatest tool to encourage LID is to have technical design standards in place that allow the applicant, agency, and public to understand if the design meets the technical requirements for water quality treatment and flow control under the local government's stormwater management manual" (Carlson, 2010 p. 5). They also determined that it was beneficial to integrate small amendments to the municipal code and allow for modifications over time that reflected the current best available science and best management practices.

Another recommendation was to develop pilot projects to reduce skepticism within the jurisdiction and provide evidence of GSI efficacy to better promote changes to zoning and land use requirements. This could be accomplished through a community outreach program that provides education and encouragement to utilize rain-water harvesting and rain gardens within the city. Investigating possible discounts, available grants, or funding for incentives from local organizations, the Department of Ecology, or the State of Washington should be a priority and would help finance these projects. It is quite feasible for the City of Snohomish to mirror Everett's Let it Rain program and there should be many avenues for assistance from 12,000 Rain Gardens, the Snohomish Conservation District, and many other organizations in the region.

It is also beneficial to review LID requirements in other cities in the region. For example, the City of Redmond used to utilize a point system as incentive for developers to apply LID to their projects but have since removed the points as LID is now a requirement. In addition, the Department of Ecology is in the process of updating the Stormwater Management Manual for Western Washington for 2019 which will require more LID to better manage stormwater runoff. Other cities with LID requirements include Sammamish, Langley, and Everett.

> LID approaches will change how development occurs. It is critical for local governments to employ public outreach strategies that engage the community early and often around LID, the important role it plays in managing stormwater, and its multiple benefits.
>
> Association of Washington Cities (n.d.)

The City of Snohomish will greatly benefit from integrating more LID and GSI into its development regulations. These applications will be instrumental in reducing the amount of stormwater runoff that is currently directed to the WWTP while improving the overall beauty of the community. They will also address climate change mitigation and create more resiliency to ensure that Snohomish remains a vital city for future generations.

Glossary

Bioretention: Naturally based systems that store and infiltrate stormwater

Bioswale: A depressed, vegetated area that infiltrates and filters stormwater, keeping it on-site and out of CSO systems

BMP: Best Management Practices – practices that are based on scientific and applied usage review within the disciplines of planning and development

Cistern: A larger containment system similar to rain barrels

CO_2 Sequestration: The process of removing CO_2 from the atmosphere and storing it in soils or other living systems, as well as some technological approaches. As part of the respiration process, plants naturally sequester CO_2 and store much of the carbon in their organic structure while releasing O_2 back into the atmosphere.

CSO: Combined Server Overflow. Combined Sewer systems are constructed in such a way that both sewage and stormwater are collected in the same set of pipes. Combined Sewer Overflow is used to refer to these systems, and also to refer to specific overflow events where excess wastewater is directed out to nearby water systems such as rivers when the infrastructure is overwhelmed.

Ecological or Ecosystem Services: Services such as water filtration, habitat, air quality, and recreation provided by a well-functioning ecosystem. We are sometimes able to place an economic value on these services by determining the cost of replacement with a built system.

GI/GSI: Green Infrastructure/Green Stormwater Infrastructure. Includes landscaping techniques such as bioswales, rain gardens, stormwater ponds etc.

Green Roof: A vegetated roof that holds rain water keeping it out of the stormwater system, provides water filtration as well as insulation value.

Groundwater Recharge: The process of infiltration restoring stocks of groundwater.

Heat Island Effect: In built environments, especially in urban areas, the larger areas of constructed surfaces retain heat and can elevate the average temperature in the immediate area. There are research and statistical methods that allow us to correct for the heat island effect, much like we would adjust historical prices for today's dollar value.

Infiltration: Water seeping into soil.

LID: Low Impact Development - development that has little to no impact on the environment.

Rain Garden: A vegetated area that removes stormwater from a local area like a roof downspout or other place of runoff or precipitation.

Rain Barrel: A form of harvesting that collects rain water from roof tops to use for irrigation.

Stormwater Infrastructure: Includes rain-water harvesting, rain gardens, bioswales and conventional stormwater systems

WWTP: Wastewater Treatment Plant; for this report we specifically refer to the City of Snohomish Wastewater Treatment Plant.

Table of Figures

Tools and Resources

University of Washington Climate Impacts Group

Tableau Climate Projection Tool

- Regional Climate Projections - How is climate projected to change in the Northwest?
- "Shows projected changes in temperature and precipitation for 2 future time periods in 3 regions in the Pacific NW" (UW CIG, 2019).

https://cig.uw.edu/resources/analysis-tools/projections/

Tableau Precipitation Projection Tool

- How will heavy rains change in western Washington?
- Regional Model Projections of Heavy Precipitation for Use in Stormwater Planning
- "Allows users to browse changes in precipitation for two new regional climate model simulations" (UW CIG, 2019).

https://cig.uw.edu/resources/analysis-tools/how-will-heavy-rains-change-in-western-washington/

New Projections of Changing Heavy Precipitation for the City of Everett

- A report specifically addressing heavy precipitation for the City of Everett that also would be helpful to the City of Snohomish – downloadable PDF

https://cig.uw.edu/news-and-events/publications/new-projections-of-changing-heavy-precipitation-for-the-city-of-everett/

Center for Neighborhood Technology

The Value of Green Infrastructure; A Guide to Recognizing Its Economic, Environmental and Social Benefits

- Benefit Measurement and Valuation Tools - pages 17-58 – Provides guidance and formulas for assessing cost and stormwater benefits for all types of Green Stormwater Infrastructure

https://www.cnt.org/sites/default/files/publications/CNT_Value-of-Green-Infrastructure.pdf

Green Values National Stormwater Management Calculator

- "The National Green Values™ Calculator is a tool for quickly comparing the performance, costs, and benefits of Green Infrastructure, or Low Impact Development (LID), to conventional stormwater practices" (CNT, 2018). http://greenvalues.cnt.org/national/calculator.php

LIDRA

Low Impact Development Rapid Assessment Tool

- "A tool for comparing the cost effectiveness of reducing runoff with different green infrastructure / low impact development technologies" (LIDRA, 2018). http://www.lidratool.org

Casey Trees and Davey Tree Expert Co.

The National Tree Benefit Calculator

- Calculates the economic and ecological benefits of a variety of trees specific to location. http://www.treebenefits.com/calculator/

Environmental Protection Agency - Green Infrastructure Modeling Toolkit

National Stormwater Calculator

- "EPA's National Stormwater Calculator (SWC) is a software application that estimates the annual amount of rainwater and frequency of runoff from a specific site. Estimates are based on local soil conditions, land cover, and historic rainfall records. It is designed to be used by anyone interested in reducing runoff from a property, including site developers, landscape architects, urban planners, and homeowners" (EPA, 2018).

  https://www.epa.gov/water-research/national-stormwater-calculator

Green Infrastructure Wizard (GIWiz)

- "GIWiz is an interactive web application that provides users with customized reports containing EPA tools and resources with direct links and overview information" (EPA, 2018). https://cfpub.epa.gov/giwiz/

Watershed Management Optimization Support Tool (WMOST)

- "WMOST is a software application designed to facilitate integrated water resources management across wet and dry climate regions. It allows water resources managers and planners to screen a wide range of practices across their watershed or jurisdiction for cost-effectiveness and environmental and economic sustainability" (EPA, 2018).

  https://www.epa.gov/ceam/wmost

Storm Water Management Model (SWMM)

- "SWMM is used for single event or long-term simulations of water runoff quantity and quality in primarily urban areas–although there are also many applications that can be used for drainage systems in non-urban areas" (EPA, 2018).

  https://www.epa.gov/water-research/storm-water-management-model-swmm

Visualizing Ecosystem Land Management Assessments (VELMA) Model

- "VELMA can be used to help improve the water quality of streams, rivers, and estuaries by making better use of both natural and engineered green infrastructure (GI) to control loadings from nonpoint sources of pollution. It is designed to help users assess green infrastructure options for controlling the fate and transport of water, nutrients, and toxics across multiple spatial and temporal scales for different ecoregions and present and future climates" (EPA, 2018).

https://www.epa.gov/water-research/visualizing-ecosystem-land-management-assessments-velma-model-20

Green Infrastructure Flexible Model (GIFMod)

- "GIFMod is a computer program that can be used to evaluate the performance of urban stormwater and agricultural green infrastructure practices. It allows users to build conceptual models of green infrastructure practices to predict hydraulic and water quality performance under given weather scenarios" (EPA, 2018).

http://gifmod.com/download-gifmod-installation-file/

Washington Stormwater Center

GSI_CALC SOFTWARE

- "The Western Washington NPDES (National Pollutant Discharge Elimination System) Phase I and Phase II Municipal Stormwater Permits include several provisions related to low impact development (LID). GSI-Calc was developed to assist permittees in implementing these requirements by providing a regional sizing tool for LID stormwater Best Management Practice (BMP) design in western Washington lowlands" (WA Stormwater Center, 2018).

http://www.wastormwatercenter.org/gsicalc/

Washington State Department of Ecology

Low Impact Development (LID) guidance website

- Provides tools and resources for WA State policy makers including planning and code update information, maintenance and inspection resources, and the LID Code Update and Integration Toolkit.

https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Low-Impact-Development-guidance

References

Association of Washington Cities. (n.d.). Low Impact Development (LID). Retrieved May 31, 2018, from https://wacities.org/data-resources/low-impact-development/planning-for-lid

Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide. (n.d.). Retrieved April 19, 2018, from https://www.americanrivers.org/conservation-resource/banking-on-green/

Ben-Eli, M. (2015). Sustainability: definition and five core principles a new framework. Retrieved November 12, 2017, from http://www.sustainabilitylabs.org/assets/img/SL5CorePrinciples.pdf

Buotte, P.C., Peterson D.L., McKelvey K.S., & Hicke J.A.. (2016). Capturing subregional variability in regional-scale climate change vulnerability assessments of natural resources. *Journal of Environmental Management* 169:313-318. Retrieved from https://doi.org/10.1016/j.jenvman.2015.12.017

Bureau, U. C. (n.d.). Census.gov. Snohomish city. Retrieved November 15, 2017, from https://www.census.gov/

Carlson, W. E., AICP. (2010, August). Puget Sound Partnership Low Impact Development Local Regulation Assistance Project. Retrieved March 4, 2018, from https://www.planning.org/publications/document/9006937/

Center for Neighborhood Technology. (2010). The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits. Retrieved April 13, 2018, from https://www.cnt.org/publications/the-value-of-green-infrastructure-a-guide-to-recognizing-its-economic-environmental-and

Cesanek, W., AICP, Elmer, V., PhD, & Graeff, J., AICP. (2017, August). Planners and Water - PAS Report 588. Retrieved March 4, 2018, from https://www.planning.org/publications/report/9131532/

City of Seattle, & Office of Sustainability and Environment. (2015, July). Green Stormwater Infrastructure in Seattle Implementation Strategy 2015-2020. Retrieved May 5, 2018, from http://www.seattle.gov/Documents/Departments/OSE/GSI_Spreads_v2_July_2015_WEB.pdf

City of Snohomish. (2000, April 18). Tree retention ordinance 1917 SMC 14.31.020. Retrieved May 3, 2018, from http://www.snohomishwa.gov/DocumentCenter/View/1899/Ord-1917---Tree-Retention

City of Snohomish combined sewer overflow report 2011-2012. (2013, April). Retrieved November 28, 2017, from file:///C:/Users/paige_000/Downloads/2011-2012CSOReport.pdf

City of Snohomish capital facilities element. (2015). Retrieved November 28, 2017, from http://www.snohomishwa.gov/documentcenter/view/2276

City of Snohomish comprehensive plan. Revised: (2016, March 15). Ord. 2308. Retrieved May 09, 2017, from http://www.snohomishwa.gov/documentcenter/view/2353

City of Snohomish. (2018, February 27). Stormwater management program. Retrieved April 22, 2018, from http://www.snohomishwa.gov/DocumentCenter/View/4697/Snohomish-2018-SWMP-Final-rev-Feb-27-2018

Climate Impacts Group. (2009). The Washington climate change impacts assessment. M. McGuire Elsner, J. Littell, & L. Whitely Binder (Eds). Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington.

Coastal resilience floodplains by design. [Maps]. (2017). Retrieved November 22, 2017, from http://maps.coastalresilience.org/washington/#

Collins, W., Colman, R., Haywood, J., Manning, M., & Mote, P. (2007). The physical science behind climate change. *Scientific American, 297*(2), 64-73. Retrieved from http://www.jstor.org.offcampus.lib.washington.edu/stable/26069416

Concrete Network. (2017, March 13). Pervious Concrete Project- Stratford Place Residential Community in Washington. Retrieved April 22, 2018, from https://www.concretenetwork.com/pervious/design-ideas/pervious-concrete-washington.html

Dalton, M., Mote, Philip W., & Snover, Amy K. (2013). Pacific northwest climate impacts research consortium. national climate assessment, & geological survey. *Climate change in the Northwest: Implications for our landscapes, waters, and communities* (National climate assessment regional technical input report series). Washington; Covelo; London: Island Press.

Drane,K.W.,Gattis, D.R., & Homewood, G.M. (2014, July 18). *Hazard mitigation policy guide*. Retrieved November 18, 2017, from APA, https://www.planning.org/policy/guides/adopted/hazardmitigation.htm

EPA. (2007, December). Reducing Stormwater Costs through Low Impact Development. Retrieved April 19, 2018, from https://planning-org-uploaded-media.s3.amazonaws.com/document/product_EIP_E_IP15.pdf

EPA. (2012, March). Costs of Low Impact Development - US EPA. Retrieved May 13, 2018, from https://www.epa.gov/sites/production/files/2015-09/documents/bbfs3cost.pdf

EPA. (2013, August). Case Studies Analyzing the Economic Benefits of Low Impact ... Retrieved April 19, 2018, from https://www.epa.gov/sites/production/files/2015-10/documents/lid-gi-programs_report_8-6-13_combined.pdf

EPA. (2016, November 01). Integrated planning for municipal stormwater and wastewater. Retrieved November 22, 2017, from https://www.epa.gov/npdes/integrated-planning-municipal-stormwater-and-wastewater

EPA. (2017, April 10). Climate resilience evaluation and awareness tool (CREAT) Version 3.0. Methodology Guide for Water Utilities. Retrieved December 10, 2017, from https://www.epa.gov/crwu/climate-resilience-evaluation-and-awareness-tool-creat-version-30-methodology-guide-water

EPA. (2017, April 25). Stormwater Planning. Retrieved November 15, 2017, from https://www.epa.gov/npdes/stormwater-planning

FEMA. (n.d.). What is mitigation? Retrieved December 14, 2017, from https://www.fema.gov/what-mitigation

IPCC, 2014: Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 117-130

Kunkler, L., PE, Staeheli, P., PLA, FASLA, & City of Redmond. (2017, March 29). City of Redmond LID Integration: Process Summary. Retrieved May 19, 2018, from http://www.redmond.gov/common/pages/UserFile.aspx?fileId=210946

Matsuno, H., & Chiu, S. (2010). The Stormwater Management Challenge SEA Street Seattle Public Utilities Seattle, U.S.A. (2001) DESIGN PRECEDENT STUDIES. Retrieved April 19, 2018, from https://nacto.org/docs/usdg/stormwater_management_challenge_matsuno.pdf

Mauger, G.S., J.S. Won, K. Hegewisch, C. Lynch, (2017). New Projections of Changing Heavy Precipitation for the City of Everett. Report prepared for the City of Everett. Climate Impacts Group, University of Washington, Seattle. Retrieved March 8, 2018 from https://cig.uw.edu/news-and-events/publications/new-projections-of-changing-heavy-precipitation-for-the-city-of-everett/

Mauger, G. S., & Lee, S.Y., (2014). *Climate Change, Sea Level Rise, and Flooding in the Lower Snohomish River Basin.* Report prepared for The Nature Conservancy by the Climate Impacts Group, University of Washington, Seattle.

Mote, P.W., Salathé, E.P. 2010. Future climate in the Pacific Northwest. Climatic Change 102(1-2): 29-50, doi: 10.1007/s10584-010-9848-z.

Salathé, E.P., Leung, L.R., Qian, Y., Zhang, Y. 2009. Regional climate model projections for the state of Washington. Chapter 2 in The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate, Climate Impacts Group, University of Washington, Seattle, Washington.

Seattle Public Utilities. (2009, December). RainWise - Managing Stormwater at Home. Retrieved April 22, 2018, from http://www.seattle.gov/util/cs/groups/public/@spu/@usm/documents/webcontent/spu01_006289.pdf

Snohomish conservation district. Rain Barrel Program. (2018). Retrieved April 19, 2018, from http://snohomishcd.org/rain-barrel-program

Snohomish County, WA. (2011, June 24). *The Natural Environment*. Countywide Planning Policies for Snohomish County. Retrieved November 18, 2017, from https://snohomishcountywa.gov/documentcenter/view/8043

Snohomish County, WA (2015, September). Snohomish County Hazard Mitigation Plan. Chapter 17: *City of Snohomish Annex.* Retrieved November 18, 2017, from https://snohomishcountywa.gov/2429/Hazard-Mitigation-Plan

Stewardship Partners. (n.d.). 12,000 Rain Gardens in Puget Sound - Who We Are. Retrieved May 13, 2018, from http://www.12000raingardens.org/who-we-are/

Susman, Megan M. American Planning Association. (2017, February). Practice Climate Adaptation. *Zoning Practice* (Issue Number 2). Retrieved November 18, 2017, from https://planning-org-uploaded-media.s3.amazonaws.com/document/Zoning-Practice-2017-02.pdf

Tatistcheff, A. (2017, March 29). Everett Wants to Pay for your Landscaping - Everett Rain Gardens. Retrieved April 22, 2018, from http://www.liveineverett.com/blog//everett-rain-gardens

The Sustainability Laboratory. (n.d.). Retrieved November 19, 2017, from http://www.sustainabilitylabs.org/approach/

University of Washington. Climate Impacts Group, International Council for Local Environmental Initiatives, & King County. (2007). *Preparing for climate change: A guidebook for local, regional and state governments.* Seattle, Wash. Center for Science in the Earth System.

US Department of Commerce, NOAA, National Weather Service. (n.d.). National weather service advanced hydrologic prediction service. Retrieved November 22, 2017, from http://water.weather.gov/ahps2/hydrograph.php?gage=snaw1&wfo=sew

Valderrama, A. (2016, March 8). Seattle's Pioneering RainWise Program. Retrieved April 13, 2018, from http://www.greenbuildingadvisor.com/blogs/dept/guest-blogs/seattle-s-pioneering-rainwise-program

WA State Dept. of Ecology. (2012, April). *Appendix C*. Priority Response Strategies and Actions. Washington State Integrated Climate Response Strategy. Retrieved November 18, 2017, from http://www.ecy.wa.gov/climatechange/ipa_responsestrategy.htm

Washington Stormwater Center. (n.d.). GSI_Calc software Washington Stormwater Center. Retrieved May 5, 2018, from http://www.wastormwatercenter.org/gsicalc/

World Commission on Environment Development. (1987). *Our common future* (Oxford paperbacks). Oxford ; New York: Oxford University Press. Retrieved November 5, 2017, from http://www.un-documents.net/our-common-future.pdf

Images

Everett rain barrels [Digital Image]. Retrieved May 9, 2018 from https://everettwa.gov/ImageRepository/Document?documentID=1509

Tree pie chart [Digital Image]. Tree calculator. Retrieved May 4, 2018 from http://www.treebenefits.com/calculator/flashes/overallbenefitsPIPU45Single%20family%20residential_8584.png

Western Red Cedar [Digital Image].Tree calculator. Retrieved May 4, 2018 from http://www.treebenefits.com/calculator/tree_images/Thuja%20plicata.jpg

High Point Seattle permeable pavement [Digital Image]. Buildabetterburb. Retrieved May 9, 2018 fromhttp://buildabetterburb.org/2013/wp-content/uploads/2013/07/Seattle_article_slideshow_04.jpg

Stone way permeable pavement, Seattle [Digital Image]. Retrieved May 5, 2018 from https://farm9.static.flickr.com/8745/30032983771_37a9a81a88_b.jpg

Residential Rain Garden in Seattle [Digital Image]. Photo: Ashley Blazina, (2015). Retrieved from May 4, 2018 from http://cossdotblog.wpengine.netdna-cdn.com/wp-content/uploads/2015/07/CROP20150721_183656.jpg

Bioswale SEA Street, Seattle [Digital Image]. Retrieved April 30, 2018 from http://www.solaripedia.com/images/large/4959.jpg

Everett rain garden [Digital Image]. Retrieved May 5, 2018 from https://static1.squarespace.com/static/55f34138e4b0300e70bfe909/55f35b78e4b05f0b68c15448/58d93c73d2b857f33fc5ebde/1522096049508/2015RainGarden.png?format=1500w

Sultan permeable concrete [Digital Image]. Retrieved May 5, 2018 from https://static.concretenetwork.com/photo-gallery/images/550x412Exact_0x4/site_26/aggregates-concretenetwork-com_71679.jpg

Stratford Place, Sultan street view [Digital Image]. Retrieved May 5, 2018 from https://static.concretenetwork.com/photo-gallery/images/550x412Exact_0x4/site_26/street-concretenetwork-com_71678.jpg

Sea Street aerial [Digital Image]. Retrieved May 3, 2018 fromhttp://www.solaripedia.com/images/large/4914.jpg

Sloping bioswale [Digital Image]. Retrieved May 3, 2018 from https://i.pinimg.com/474x/29/30/66/29306608b605365a57f54b886191e49c--green-design-ecology.jpg

Seattle green roof garage [Digital Image]. Retrieved May 13, 2018 fromhttp://www.greenroofs.com/blog/wp-content/uploads/2010/04/SEA-Green_Roof_Garage_View_from_Alley.gif

Mukilteo city hall [Digital Image]. Retrieved May 13, 2018 fromhttps://mukilteowa.gov/wp-content/uploads/City-Hall-With-Concrete-Sign-e1458762874191.jpg

RainWise rain garden [Digital Image]. Retrieved May 13, 2018 from http://www.monsoonraingardens.com/uploads/4/1/2/0/41203943/7018160_orig.jpg

RainWise rain cisterns [Digital Image]. Retrieved May 13, 2018 from https://3.bp.blogspot.com/-KVXv7A4RyX8/V6zouZbmncI/AAAAAAAABT8/FXHQwnrgzBguIsnxytgWh8PMBX9xR4XWwCLcB/s1600/eaz_cistern%2528stitch%2529.jpg