GOOD DRAINAGE, GOOD VIBES: REVITALIZING, REPROGRAMMING, AND REVEALING STORMWATER AT SOUTH EUGENE HIGH SCHOOL

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ABSTRACT

Located in close proximity to downtown Eugene and the University of Oregon, South Eugene High School sits directly adjacent to Amazon Creek, which is currently listed as an impaired waterway under the Clean Water Act. Although they are in close proximity to each other, the connection between the creek and the school is currently invisible, as runoff from the school drains into stormwater inlets and flows underground, directly into Amazon Creek. The front entrance of the school is occupied by over 2 acres of lawn which becomes waterlogged in the wet Oregon winters and goes largely underutilized by students. The water flowing off the school's lawns, parking lots, and rooftops is piped unfiltered into the degraded and channelized creek, significantly contributing to the poor water quality downstream.

"Good Drainage, Good Vibes"--named after a comment by a student during a stakeholder engagement activity-- envisions a school campus that manages stormwater onsite and makes the flow of stormwater demonstrable and legible to the community. Through extensive community engagement and student participation, this project pairs green infrastructure interventions, primarily designed to reduce runoff pollution from the SEHS campus, with strategies to increase visibility of urban stormwater management, provide hands-on educational experiences for students, and connect the broader community to their watershed. This project demonstrates a regionally relevant green infrastructure site redesign that combines the benefits of stormwater treatment, climate mitigation, active transportation planning, and ecological education, catering to the current user experience with an eye towards informing resilient urban watershed management.

SITE SELECTION

REGIONAL CONTEXT

The Pacific Northwest is well known for the rain, and Eugene, Oregon is no exception, receiving over 46 inches of annual precipitation; however there is an enormous degree of seasonal variability in precipitation. On average, Eugene receives over 60% of its annual rainfall between November and February, while receiving less than 5 inches of total rainfall during June through September, the four hottest months of the year (**Figure 1**). With climate change, most models predict that this seasonal rainfall variability will grow even more extreme, resulting in hotter, drier summers and even wetter winters (May et al. 2018). Furthermore, reduced snowpack in the neighboring Cascade Mountains will further exacerbate summer water scarcity and poor quarter quality, as reduced quantities of snowmelt will reach the Willamette River mainstem and tributaries (Dalton et al. 2017). These conditions illustrate the importance of maximizing the benefits from local precipitation, while considering the design implications of extremely seasonal precipitation patterns.

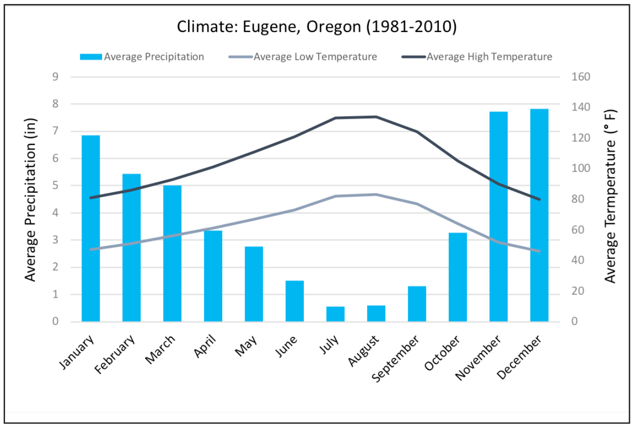


Figure 1: *Average monthly precipitation and temperature range for Eugene, Oregon*

SITE DESCRIPTION

South Eugene High School (SEHS) is located less than 2 miles from the heart of downtown Eugene and just three blocks southeast of the University of Oregon. The SEHS campus faces many of the same stormwater management challenges inherent to any urban site, but its unique proximity to Amazon Creek, the major drainage for much of Eugene, makes stormwater treatment on site particularly important. Conversations with the Eugene 4J School District Architect revealed that, while current master plans for the school grounds include plans to renovate the sports complex to the south of the building, the large problems associated with the expansive lawns and impervious surfaces at the school's front entrance are not addressed (**Figure 2**), thus opening a timely opportunity for our design intervention (Heffernan 2018). The school's location on a major bike and pedestrian route and adjacent to a large city park make this area highly visible, not only to students and their families, but to the community at large.

In 1956, the Army Corps of Engineers attempted to alleviate the risk of urban flooding by confining Amazon Creek to a concrete-walled channel through the residential and commercial portions of the watershed (City of Eugene, 2004). Non-point source pollution from residential, commercial, and industrial properties is a significant issue in Amazon Creek, leading to the watershed being listed as water quality limited under the Clean Water Act (City of Eugene 2004). Turbidity, dissolved oxygen, mercury, and bacterial concentrations are currently exceeding the Total Maximum Daily Loads (TMDLs) developed for Amazon Creek, and elevated stream temperature from limited riparian vegetation further impairs aquatic ecosystem conditions (City of Eugene 2004).

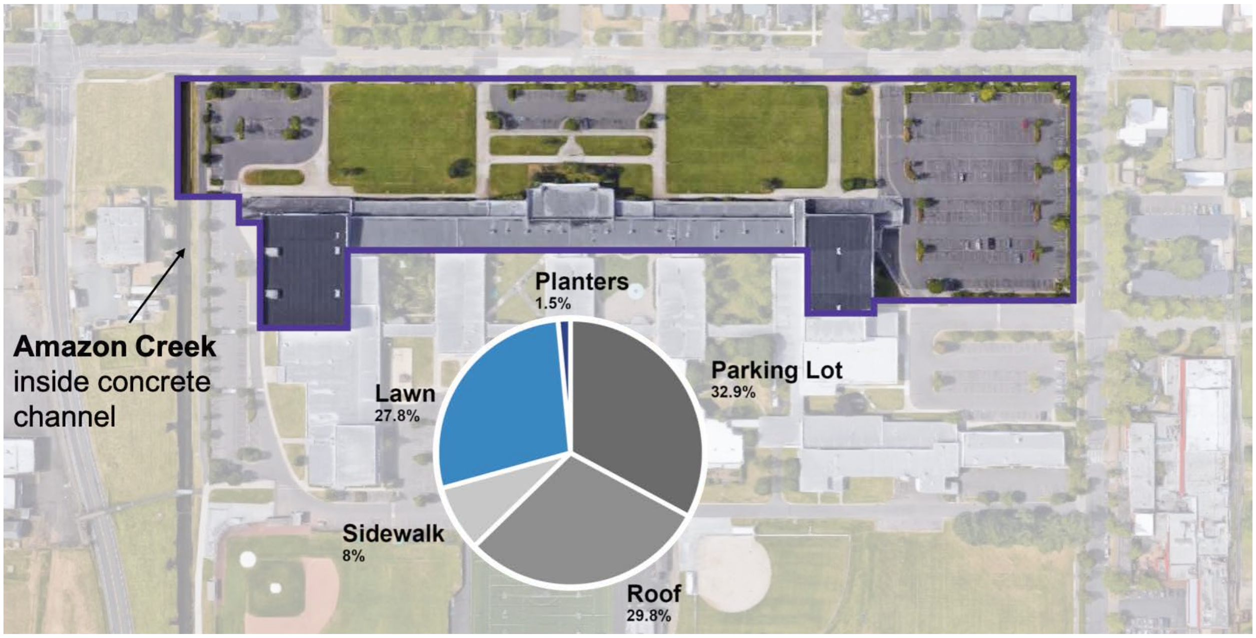


Figure 2: *Aerial photograph of South Eugene High School campus, including breakdown of land cover on the demonstration project site*

Current initiatives being undertaken by the City of Eugene make this not just the right location, but also the right time for a green infrastructure project at SEHS. A City of Eugene Public Works project, written in to the city's capital expenditures for 2020, will dechannelize Amazon Creek for several blocks, south of the main school grounds. This project will widen the channel and grade gradually sloping creek banks. The SEHS campus is the first property directly downstream of this restoration and could further contribute to improved watershed health by filtering and treating site runoff before it enters the first channelized section of the creek.

The City of Eugene is also planning for a separated two-way bike lane to be installed on High Street, a minor northbound arterial which originates on the northwest corner of the school property. Although bike path users regularly access the existing northbound bike lane on High Street, this unprotected mid-block connection is challenging and dangerous for cyclists to navigate. A redesign of this junction will be necessary to accommodate increased volume and two-way bike traffic. Situated just feet from the banks of Amazon Creek, the school has the opportunity to use thoughtful design to contribute to pedestrian and cyclist safety while treating stormwater before its outfall into the creek.

SITE PROBLEMS

The existing conditions of the SEHS campus present a number of problems, as well as opportunities for design intervention. While there are many problem areas throughout the site, the major stormwater challenges can be clustered under three major themes: the invisible, the underutilized, and the degraded (**Figure 3**).

Invisible: Although Amazon Creek is a major tributary of the Willamette River and bisects downtown Eugene, the connection between the urban landscape and the Amazon watershed is currently invisible to students and community bike path users, as surface runoff flows to storm drain inlets, through underground infrastructure, and expelled directly out of the channelized creek sidewall. Despite being the destination of the 7.6 million gallons of water per year from the site, this connection is completely hidden from plain view. Indeed, in a climate known for its incessant rain, the SEHS campus is devoid of any visual or physical acknowledgement of the 46 inches of annual rainfall.

Underutilized: Although the site occupies 7.8 acres, much of this area is minimally used by students and the public, aside from parking. The front entry to SEHS is flanked by large, flat expanses of lawn which become waterlogged in the wet Oregon winters and go largely underutilized by students. Due to poor infiltration and little topography, the 2.5 acres of lawn become muddy and virtually inaccessible during the rainy winter months. These areas are currently irrigated and fertilized in the dry summer months, but school is not in session during these times so few users are present. Although the west parking lot is relatively well used by vehicles, its current configuration uses space inefficiently and creates an awkward and dangerous intersection for pedestrians and bicyclists.

Degraded: Perhaps the most problematic aspect of the site is the enormous quantity of unfiltered water that drains directly into Amazon Creek. Even in theoretically permeable areas covered in lawn, clay soils prevent infiltration, causing water to flow rapidly across the surface, carrying pollutants with them. A vast majority of the site is covered parking lots and rooftops which, in addition to being impermeable, may also have high pollutant loads. Stormwater flowing from the SEHS campus lawns, parking lots, and rooftops, is piped, unfiltered, into the Amazon Creek, contributing to the creek's degraded water quality.

Figure 3: *Photos depicting invisible (left), underutilized (center), and degraded (right) qualities of the SEHS campus.*

DESIGN GOALS

With the neighboring bike path and clear sight lines across the creek, SEHS is a highly visible and prominent site, perfect for revealing and displaying stormwater solutions. The proximity of SEHS to downtown Eugene, Amazon Park, the University of Oregon, and the bike path makes connections to the wider community especially possible and increases the opportunity for visible, educational programming and displays on site. Finally, upcoming creek restoration and bike lane reconfigurations provide opportunities for holistic collaboration between the City of Eugene and the Eugene 4J School District.

Revitalize the degraded

Provide a multitude of ecosystem services, with the primary purpose of filtering stormwater before it makes its way into Amazon Creek.

Program the underutilized

Transform the currently bare and unprogrammed front lawns of the school into a multifunctional social and educational spaces that provide learning opportunities for students, as well as a beautiful and functional campus entrance.

Reveal the invisible

Educate and inspire interest in urban stormwater management through the prominent use of sensors, lighting and highly interactive stormwater facilities.

PARTICIPATORY SITE SELECTION

A fundamental component of this project was the process of incorporating input from various community stakeholders. Throughout the design process, the team consulted with the Eugene 4J School District Architect; SEHS students, facilities, and administrators; and City of Eugene Public Works officials from Urban Forestry, Stormwater Management, Civil Engineering, and Ecological Services departments.

Before the final site was delineated, the design team coordinated a meeting with the SEHS Environmental Club, an extracurricular group of 50 highschool students. This first meeting with students allowed students to provide feedback on the types of stormwater facilities that would be most positively received by the student body (**Figure 4**) as well as allowing the design team to solicit input regarding specific areas on the SEHS campus that go underutilized by the student body, have drainage issues, or raise other environmental concerns (**Figure 5**). The results from this initial meeting provided further evidence that the ideal focal area for green infrastructure intervention was along the front of the school.The results from this activity influenced green infrastructure decisions, encouraging the design team to incorporate a variety of interventions that peaked students' interest. Using student generated data, the design team delineated a site for the project that covers 7.8 acres on the north side the school building.

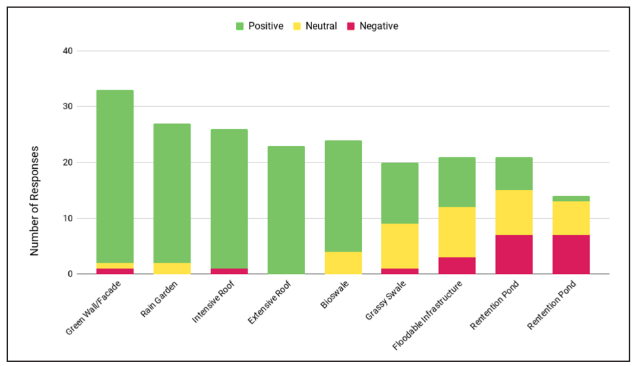


Figure 4: *Students were asked to look at a variety of green infrastructure facilities and vote on each facility to indicate a positive, neutral, or negative opinion.*

Figure 5: *Students examined a map of the SEHS campus and placed sticky notes, with comments, to identify areas with positive and negative attributes.*

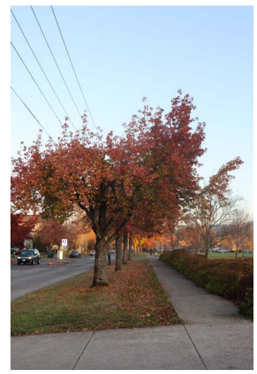
SITE ANALYSIS

SOILS

The SEHS campus is situated within the historic floodplain of Amazon Creek, and the entire site is characterized by clay-rich soils and a shallow water table, ranging from 6 to 12 inches deep (NRCS n.d.). The SEHS campus is underlain by the Bashaw-Urban land complex and the Natroy-Urban land complex, both of which are in the hydrologic soil group D (NRCS n.d.).

EXISTING VEGETATION

Currently, 79 trees exist on the SEHS site, most of which are planted in parking lot tree wells and planting strips (n=39), or in the right-of-way along 19th Avenue (n=25). None of the trees are fully mature and all are below 30 feet tall. The dominant tree species throughout the site is the narrow-leafed ash (Fraxinus angustifolia), although Oregon white oak (Quercus garryana) and western white pine (Pinus monticola) are also present. The street trees on 19th Avenue (n=25) are all American Sweetgum (Liquidambar styraciflua). These trees are mature but have been severely pruned to keep them below the height of overhead utility lines.



WATER FLOW AND DRAINAGE

All water on the site drains from stormwater inlets into the 12-foot-deep concrete channel of Amazon Creek to the west of the school. The existing site has very little topographic variation with less than 0.5% grade in most places. What little slope there is drains water away from the building in all directions to a series of inlets (**Figure 6**). Those along the west side of the site outfall directly into the creek, while those to the north connect to pipes running along 19th Avenue, which also ultimately terminate in the creek. The east parking lot is strongly crowned, directing water to the same pipes along 19th Avenue and Patterson Street. The roof of the building is currently drained by a series of downspouts off the front and sides. These have been poorly maintained, and water often pools at the base of the school.

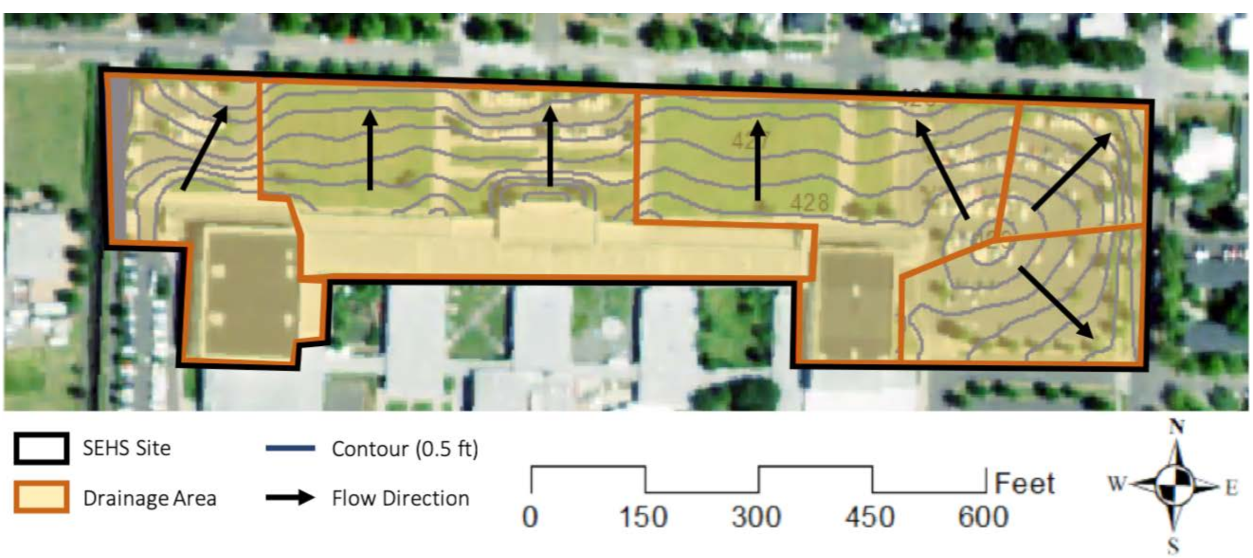


Figure 6: *Map depicting demonstration site elevation contours, flow direction, and drainage areas*

DESIGN SOLUTION

The City of Eugene Stormwater Management Manual dictates the types of green infrastructure interventions that can be used, based on the hydrologic soil group (City of Eugene 2014). To conform to the City of Eugene Stormwater Management standards, any stormwater management facility in hydrologic soil group D is limited to stormwater pollution control through filtration and cannot be designed as an infiltration facility (City of Eugene 2014). Filtration facilities are designed with underdrains, which allows water to percolate through the added soil media, removing suspended solids and reducing peak flow. If sized correctly, filtration facilities are designed to retain 80 percent of the total suspended solids from runoff (City of Eugene 2014).

The design team prioritized working with existing drainage patterns, where possible, to minimize regrading and of existing parking lots. Based on the existing slopes and drainage of the site the total area of pervious and impervious surfaces was calculated for each drainage area (**Figure 7**).

While the primary goal in siting green infrastructure on the SEHS campus was to reduce runoff pollutant loads into the adjacent Amazon Creek, the multifunctionality of green infrastructure interventions allowed our design team to maximize a variety of ecosystem services, including improved habitat for birds, amphibians, and pollinators; increased native plant biodiversity and carbon sequestration; reduced energy usage and air pollution; and expanded opportunities for outdoor recreation and education. This project incorporates a variety of green infrastructure interventions including stormwater planters, permeable parking, rain gardens, downspout diversion, a green facade, and an ecoroof (**Figure 8**). Each element of the design was selected and sited to not only manage stormwater onsite, but to provide opportunities for students, and the surrounding community, to engage with a diversity of stormwater management interventions and gain an appreciation for the variety of benefits that can be provided.

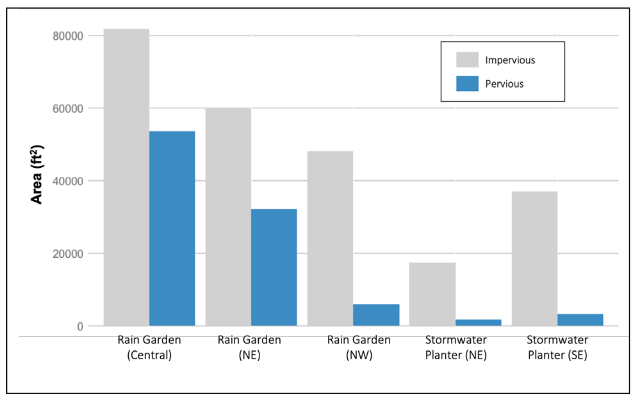


Figure 7: Pervious and impervious surface area for the five distinct drainage areas

DESIGN INTERVENTIONS

1. RAIN GARDENS

All runoff from the school roof, the central and west parking lots, and existing pervious surfaces is accommodated by three, gently sloped, flat bottomed filtration rain gardens. These shallow depressions accommodate 12 inches of surface pooling and are vegetated with diverse native groundcovers, shrubs, and trees selected to provide food and habitat for pollinators, birds, and amphibians. To meet the standards in the Eugene Stormwater Management Manual, these facilities will be planted with over 24,000 individual plants (City of Eugene 2014). While the rain gardens will need to be irrigated during plant establishment, replacing 25% of the lawn (0.5 acres) with native plants will reduce the long-term water usage and irrigation costs.

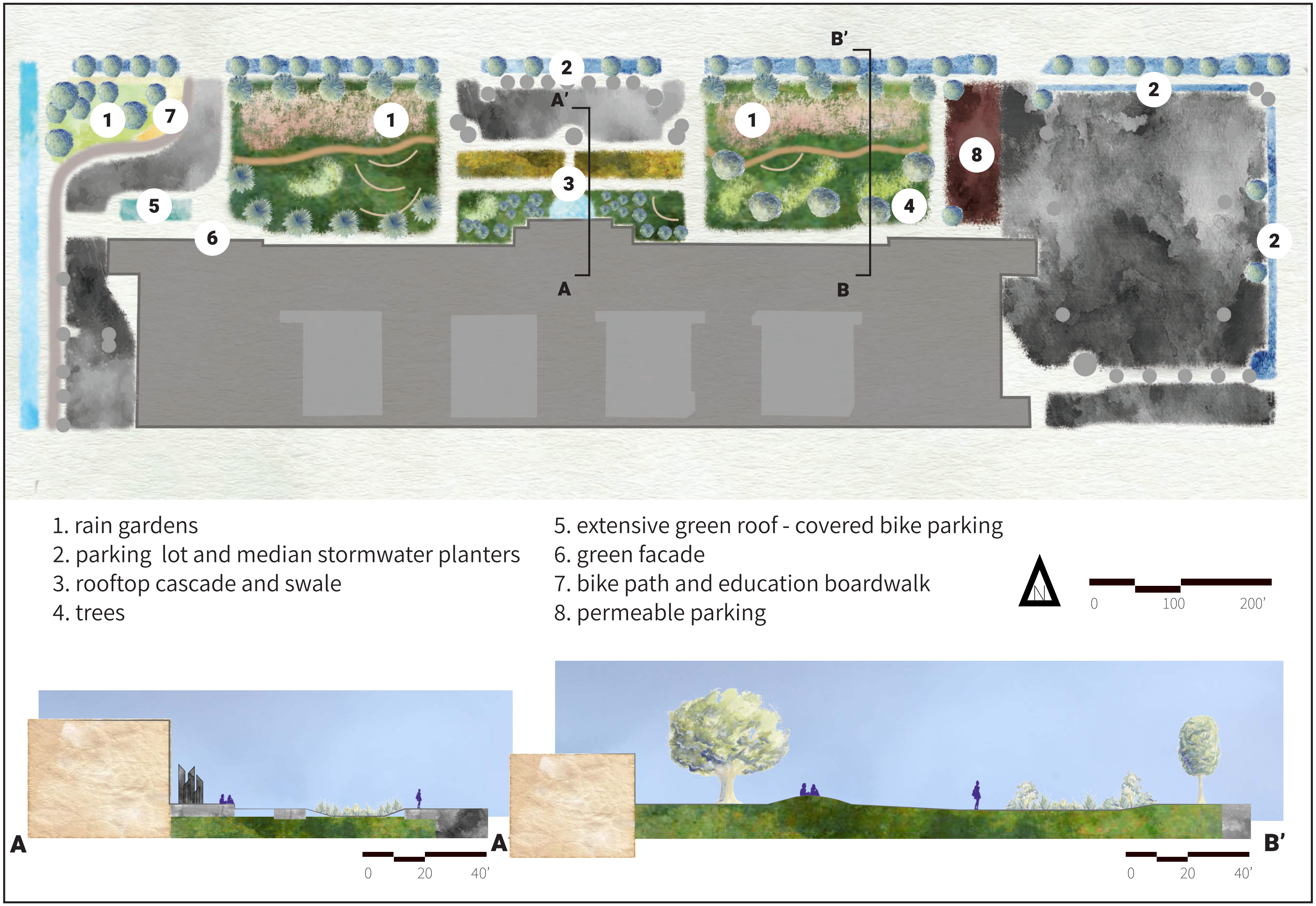


Figure 8: *South Eugene High School design intervention site plan and cross sections*

2. PARKING LOT AND MEDIAN STORMWATER PLANTERS

Runoff from the high school's largest parking lot will be captured in stormwater planters on the eastern and northern borders of the lot. There is also an opportunity to coordinate with the City of Eugene's ongoing effort to install median stormwater planters to manage street runoff. The medians of 19th St. on the north edge of the SEHS campus is currently occupied by 25 mature American sweetgums (*Liquidambar styraciflua*), which require annual pruning to avoid above-ground utility wires. Although this project proposes that the City of Eugene installs stormwater planters along the right-of-way, replacing the American sweetgums with with 30 smaller paperbark maples (*Acer griseum*), the right-of-way design benefits were not factored in to the design performance.

3. ROOFTOP CASCADE AND SWALE

The central feature in the redesign of SEHS is a columnar basalt cascade, which receives runoff from the school roof. This feature, surrounded by native trees such as vine maple (*Acer circinatum*), pacific dogwood (*Cornus nuttallii*), and red alder (*Alnus rubra*) is intended to showcase Oregon's shade-tolerant tree diversity and geologic history, providing a captivating aesthetic at the school entry. The roof runoff flows from the cascade into a swale, designed to with a 1 percent grade, that channelizes and directs the flow towards the central rain garden, just to the west.

4. TREES

Trees provide a multitude of benefits including precipitation interception, carbon sequestration, air pollution reduction, energy savings. In our design, we propose the planting of 51 new trees on the SEHS campus and suggest that the City of Eugene plants 30 replacement paperbark maple trees for the 25 heavily pruned sweetgums.

5. EXTENSIVE GREEN ROOF - COVERED BICYCLE PARKING

Students from the environmental club unanimously agreed that they would like to see extensive green roofs incorporated into the SEHS campus (**Figure 4**); however, none of the existing school structures have visible roof surfaces. As one of the primary goals of this project is to make the green infrastructure interventions visible, the design team proposed a new bicycle parking area, covered by an extensive green roof, planted with sedum.

6. GREEN FACADE

Students from the environmental club were enamoured with the idea a green facade on SEHS (**Figure 2**), and we selected the gymnasium facade on the west end of the building to create the artistic landmark feature of the design. Facilities staff warned us that an elaborate facade would be quite difficult to maintain, so we elected to create a simple design using a wire structure to support Virginia Creeper (*Parthenocissus quinquefolia*), a low-maintenance, shade-tolerant vine.

7. BIKE PATH AND EDUCATION BOARDWALK

To improve the safety and circulation for pedestrians and bicyclists, our design team rerouted the existing bike path to connect to the proposed two-way bike path down High Street. This design move effectively disconnected an existing parking lot, and we used this opportunity to incorporate a rain garden and education boardwalk directly adjacent to Amazon Creek and the bike path, reducing the impervious surface area of the site by 6,028 square-feet.

8. PERMEABLE PARKING

Modifications to the bike trails on the west side of campus will necessitate the removal of 36 existing parking spaces. As parking is at a premium for students and staff, this plan compensates for this parking reduction with the the construction of a 9576 ft^2 porous asphalt parking lot, which provides an additional 26 parking spots. This intervention provides an opportunity to monitor and assess the stormwater benefits of porous asphalt over a poorly drained soil at a small scale.

DESIGN PERFORMANCE

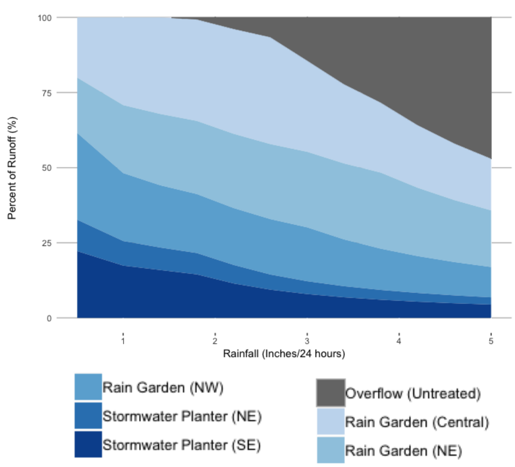
FACILITY SIZING AND STORMWATER PERFORMANCE:

We used the Presumptive Method, outlined in the Eugene Stormwater Management Manual, and required for permitting of facilities with drainage areas larger than 15,000 ft^2 (City of Eugene 2014). As our site is limited to filtration facilities, the Eugene Stormwater Management Manual requires facilities, designed solely for improving water quality, to be sized to accomodate 100 percent of the runoff from a 1.4 inch, 24-hour design storm (City of Eugene 2014). Meeting the Presumptive Method sizing requirements for water quality ensures that facilities treat 80 percent of average annual rainfall, reducing concentrations of suspended solids, heavy metals, nutrients, and bacteria (City of Eugene 2014; results are displayed in **Table 1 , Figure 9,** and **Figure 10**.)

ECOSYSTEM SERVICES CALCULATED USING ITREE:

Trees planted in the SEHS redesign provide a multitude of ecosystem services including stormwater runoff reduction, air quality improvements, carbon sequestration, and energy savings. Using

24-hour Design Storm Event	Treated (cubic feet)	Untreated Overflow (cubic feet)	Total Site Volume (cubic feet)	Percent Treated (%)
Water Quality Design Storm (1.4 in)	22786	0	22786	100
2-year Storm Event (3.12 in)	48772	15387	64159	76.0
5-year Storm Event (3.6 in)	56766	19327	76093	74.6
10-year Storm Event (4.46 in)	58702	38946	97648	60.1
25-year Storm Event (5.18 in)	59120	56672	115792	51.1



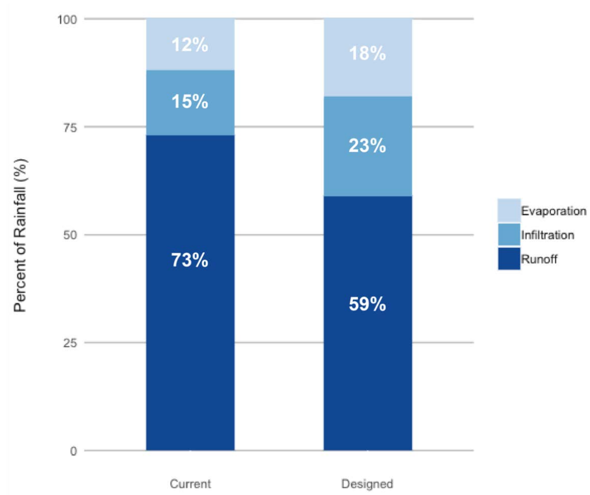


Table 1 (top): *The Presumptive Method was used to model the volume of treated and untreated runoff for the water quality design storm, as well as the 2-year, 5-year, 10-year, and 25-year events.* ***Figure 9 (bottom left):*** *Presumptive Method results demonstrate that facilities surpass the City of Eugene's pollution control requirements for the Water Quality Design Storm.* ***Figure 10 (right)****: The EPA National Stormwater Calculator models the average annual decrease in runoff. These results show that our design proposal reduce annual runoff by 14%*

the i-Tree Design web application, we calculated the projected benefits provided by the 51 newly planted trees (**Figure 11**).

- The trees benefits outweigh the costs of planting and maintenance in the first 25 years.
- Over the next 50 years
- Combined benefits reach $105,000, more than $2,000/year, on average
- Over the next 99 years:
- An estimated $388,000 in combined benefits
- Intercept 10.4 million gallons of rain-fall
- Remove 1.5 million pounds of atmo-spheric carbon dioxide CO2

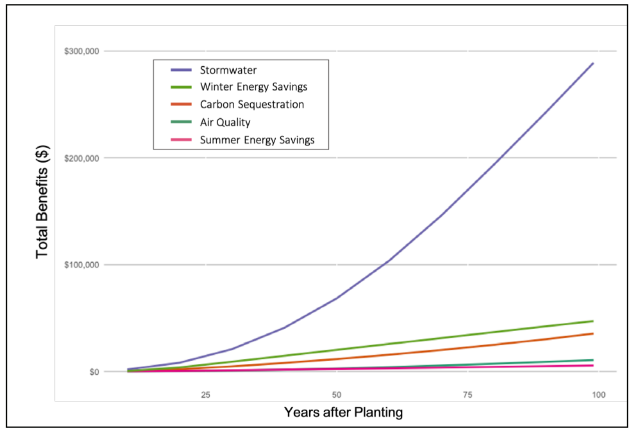


Figure 11 *Benefits from newly planted trees (n=51), mod-eled using the iTree Design*

COMMUNITY ENGAGEMENT AND EDUCATION

"In Chemistry last year we learned about acidity, so I think that measuring how that changes over time here in the rain gardens and maybe in Amazon Creek could be really unique and a really good experience because it would be a chance for some hands-on science."

Dover Sikes, SEHS Junior

This project is designed to highlight and utilize the many benefits of stormwater green infrastruc-ture. The academic setting of a high school inspired a project goal of turning the landscape of SEHS into a living laboratory and place of education. We envision this redesign as a space for SEHS students, University of Oregon researchers, City of Eugene designers and maintenance staff, and the general public to engage with green infrastructure and become better informed about water-shed health, local ecology, and green infrastructure interventions. Performance monitoring and testing is a vital part of the green infrastructure design and maintenance process, but it is often overlooked and under budgeted. Because education is a central tenet of our landscape design, a range of testing, monitoring, demonstration, and general education strategies are proposed. There are a variety of sensors and measurement devices, both digital and analog, that can be installed around the site to provide real-time data.

Many sensor types can be paired with LED displays that can be incorporated in the building facade or bike path and light up to indicate sensor readings. Water temperature and pH can be measured with small digital sensors and placed in both green and gray stormwater drains and inlets. Small water turbines can be installed in outflow pipes to track water flow rate and can be paired with LED lights to demonstrate small-scale hydroelectric power generation.

There are also opportunities for onsite demonstrations and experiments to be conducted by students and stormwater professionals. Sediment traps can be installed in parking lot stormwa-ter planters and can be removed to demonstrate the problems of erosion and pollution in urban waterways, as well as the benefits of green infrastructure. Rainfall volume can be measured using plastic graduated cylinders to track precipitation levels of rain events from year to year, the distribution and severity of which are expected to change with the warming climate (Dalton et al. 2017; May et al. 2018). The infiltration rate associated with porous asphalt proposed for the new parking area can be measured each year to inform facility efficacy and maintenance schedules. Yearly plant and wildlife surveys can be conducted by SEHS biology and environmental science classes to monitor plant community health and habitat benefits provided by facilities.

We envision the SEHS site to be a source of education for the general public, as well. The education boardwalk, in the northwest corner of the site, is located at the convergence of the Amazon Creek bike path and 19th Street, which are subject to heavy bicycle and foot traffic. This would be the ideal location to install interpretive signage, as well as QR codes, to inform curious visitors about the benefits provided by green infrastructure onsite.

There are also many opportunities for citizen science on the site. Educational displays can direct visitors to sites like eBird, where birders can report sightings of species on SEHS campus. Photo monitoring stations can also be set up where people can take photos of a specific view of the site, usually prompted with a sign and designated ledge or platform on which to place their phone or camera. Photos can be uploaded to social media with hashtags that would allow students or researchers to track the visual condition of the site across seasons and years.

PHASING

Phase 1 (year 1-2): Phase 1 of the project will focus on the entrance of the school. Establishing the two largest rain gardens, trees, paths, seat walls, and basalt cascade will require the most landscape disturbance and, once complete, will provide the most stormwater benefits immediately. Focusing on the front of the school first provides the additional benefits of an improved campus aesthetic and increased community awareness for the remaining phases.

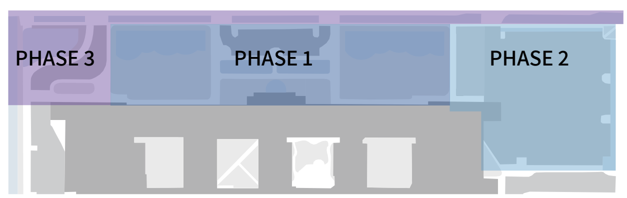


Figure 12: *Three proposed phases for completing design interventions*

Phase 2 (year 3-4): Phase 2 will prioritize the parking lot stormwater planters, which is the final site alterations that will not need to be conducted in coordination with the City of Eugene.

Phase 3 (year 5-10): As rerouting the bike path will require extensive cooperation with the City of Eugene Public Works, we recommend that the west parking lot redesign is implemented last. This will allow for detailed consultation and the potential for a jointly funded public space renovation.

MAINTENANCE

Green infrastructure interventions on the site can easily be incorporated into existing school district maintenance regimes and costs. Feedback received from City of Eugene officials and 4J School District facilities staff has been integrated into our site's maintenance plan.
The overall maintenance cost has been estimated at $23,064.04 annually, including an additional

15% for contingency costs (**Table 2**). Costs will be further offset by a reduction in SEHS's stormwater utility fee paid to the City of Eugene. By treating 244,373 ft2 of impervious surface on site, SEHS can reduce its monthly stormwater utility fee by $1,033.70 (City of Eugene 2018).

Operations & Maintenance (Annual Costs)					
Item	**Quantity**	**Unit**	**Cost/Unit**	**Total**	**Notes**
Rain Gardens	28338	Sq. Ft	$0.31	$8,784.78	CNT n.d.
Stormwater Planters	5170	Sq. Ft	$0.25	$1,292.50	EPA n.d.
Porous Asphalt	9576	Sq. Ft	$0.09	$861.84	CNT n.d.
Walking Path - Gravel	1762	Sq. Ft	$0.02	$26.43	CNT n.d.
Seat Walls - Concrete	250	Linear Ft	$0.15	$37.50	CNT n.d.
Swales	7094	Sq. Ft	$0.06	$425.64	CNT n.d.
Extensive Green Roof	1800	Sq. Ft	$0.02	$36.00	CNT n.d.
Green Facade	625	Sq. Ft	$0.04	$25.00	CNT n.d.
Tree Planting & Establishment	51	Each	$20.00	$1,020.00	CNT n.d.
Sensors	4	Each	$400.00	$1,600.00	Allenby and Burke n.d.
Boardwalk	2121	Sq. Ft	$2.78	$5,896.38	IPRE n.d.
Bike Path - Concrete	1711	Sq. Ft	$0.03	$49.62	CNT n.d.
Downspout Disconnection	19	Each	$0.25	$4.75	CNT n.d.
			SUBTOTAL	$20,055.69	
			15% Contingency	$3,008.35	
			TOTAL	$23,064.04	

Table 2: *Itemized annual operations and maintenance costs after design implementation*

Rain Gardens:
Maintenance including plant care, mowing, weeding, fertilizing, and trash removal can efficiently be included into ongoing activities performed on existing planter beds on campus. Many of these routine maintenance tasks can also be performed monthly by students and volunteers using the green infrastructure facilities for educational purposes.

Stormwater Planters:
Regular weeding and maintenance of vegetation for the stormwater planters can be accomplished in a similar manner as the rain gardens. Inspection of structural components should be performed regularly, especially after heavy rain events (Charles River Watershed Association 2008).

Green facade & Extensive Green Roof:
Due to the use of Virginia Creeper for the green facade little maintenance will need to be performed outside of annual pruning and monitoring of the structural integrity of metal wiring. Regular watering and fertilizing of the extensive green roof can be accomplished by accessing the low bike rack roof via ladder.

Permeable Pavement:
The permeable asphalt sections of the parking lot should be inspected regularly to prevent clogging and losses to irrigation efficiency. The US Department of Transportation recommends vacuuming or power washing porous asphalt two to four times per year to remove debris and prevent clogging (Federal Highway Administration 2015).

COSTS AND FUNDING

The total capital costs of our design implementation on SEHS campus accounts for approximately $633,861.53, which accounts for an additional 15% in contingency costs (**Table 3**). Many of the estimates are based on similarly sized green infrastructure projects in the Portland-metro area, supporting our calculations with regionally specific pricing data (CNT n.d.).

Extensive and flexible funding opportunities are available to pay for the project due to the multi-faceted and multi-stakeholder integration of the design. As the City of Eugene works to dechannelize Amazon Creek and enhance the bike path, opportunities abound to leverage partnerships for additional funding. Land easements and public right-of-way may be implemented to complete aspects of the project, particularly for construction of the bike path redesign and the addition of median planters along 19th Street. Additionally, municipal bonds have been a successful financing tool for capital projects for the 4J School District in the past. In 2018, voters approved a multi-million dollar bond measure by 66% to update schools in the 4J district (Roemeling 2018).

Due to the multiple benefits provided by the project, many opportunities for loans and grant funding are available. The Safe Drinking Water Revolving Loan Fund, managed by the Oregon Health authority, is eligible for construction or installation projects for improvements to water treatment systems and can loan up to $6 million per project. Grant programs such as the Geos Institute's Drinking Water Providers Partnership as well as the National Fish & Wildlife Foundation's

Capital Costs					
Item	**Quantity**	**Unit**	**Cost/Unit**	**Total**	**Source**
Rain Gardens	28338	Sq. Ft	$5.15	$145,940.70	CNT n.d.
Stormwater Planters	5170	Sq. Ft	$7.16	$37,017.20	EPA n.d.
Porous Asphalt	9576	Sq. Ft	$5.50	$52,668.00	CNT n.d.
Walking Path - Gravel	1762	Sq. Ft	$1.72	$3,030.64	CNT n.d.
Seat Walls - Concrete	250	Linear Ft	$13.00	$3,250.00	CNT n.d.
Swales	7094	Sq. Ft	$5.50	$39,017.00	CNT n.d.
Bike Rack	1	Each	$1,200.00	$1,200.00	IPRE n.d.
Extensive Green Roof	1800	Sq. Ft	$8.75	$15,750.00	CNT n.d.
Basalt Cascade	150	Cu. Ft	$26.62	$3,993.00	Cascade Stoneworks n.d.
Green Facade	625	Sq. Ft	$8.00	$5,000.00	CNT n.d.
Tree Planting & Establishment	51	Each	$450.00	$22,950.00	CNT n.d.
Sensors	4	Each	$550.00	$2,200.00	Allenby and Burke n.d.
Interpretive Signage	5	Each	$250.00	$1,250.00	IPRE n.d.
Boardwalk	2121	Sq. Ft	$100.00	$212,100.00	IPRE n.d.
Bike Path - Concrete	1711	Sq. Ft	$3.40	$5,817.40	CNT n.d.
Downspout Disconnection	19	Each	$9.00	$171.00	CNT n.d.
Art Installation	625	Sq. Ft	$15.00	$9,375.00	Fixr n.d.
			SUBTOTAL	$551,183.94	
			15% Contingency	$82,677.59	
			TOTAL	$633,861.53	

Table 3: *Itemized capital costs for design implementation*

Five Star Urban Waters Restoration Program provide funding for projects that provide water quality enhancements in addition to benefits to species habitat. Grant opportunities to capitalize on the educational benefits of the project exist with organizations such as the Umpqua Bank Charitable Foundation.

REFERENCES

Allenby, J. and Burke, D.G. (n.d.). Low Cost Water Quality Monitoring Needs Assessment. The Chesapeake Conservancy.

Cascade Stoneworks. (n.d.) https://www.cascadestoneworks.com/basalt-columns/ grand-coulee-basalt-columns/grand-coulee-basalt-column-20-diameter//.

Charles River Watershed Association. (2008). Low Impact Best Management Practice (BMP) Information Sheet. https://nacto.org/docs/usdg/stormwater_planter_crwa.pdf.

City of Eugene. (2004). Open Waterway Maintenance Plans.

City of Eugene. (2014). Stormwater Management Manual.

City of Eugene. (2018). Stormwater Waste Water User Fees.

Dalton, M.M., K.D. Dello, L. Hawkins, P.W. Mote, and D.E. Rupp. (2017). The Third Oregon Climate Assessment Report, Oregon Climate Change Research Institute, College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, OR.

EPA. (n.d.). National Stormwater Calculator.

Federal Highway Administration. (2015). Porous Asphalt Pavements with Stone Reservoirs. https://www.fhwa.dot.gov/pavement/asphalt/pubs/hif15009.pdf.

Fixr. (n.d.). https://www.fixr.com/costs/paint-wall-mural#cQ.

CNT. (n.d.) Green Values: Stormwater Management Calculator. http://greenvalues.cnt.org/national/cost_detail.php

Heffernan, M. (2018, November 26). Personal Interview.

IPRE. (n.d.). Institute for Policy Research & Engagement. https://ipre.uoregon.edu/.

May, C., Luce, C., Casola, J., Chang, M., Cuhaciyan, J., Dalton, M., et al. (2018). Northwest. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program, Washington, DC, USA, pp. 1036–1100.

NRCS. (n.d.). Web Soil Survey. Accessed on November 30, 2018. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx.

Roemeling, Alisha. (2018). Eugene School District bond measure passes; Siuslaw bond measure defeated, The Register-Guard, Eugene, OR. https://www.registerguard.com/news/20181106/eugene-school-district-bond-measure-passes-siuslaw-bond-measure-defeated?start=5.

Sikes, D. (2018, November 29). Personal Interview.