



TriMet Southwest Barbur Boulevard Stormwater Capstone Project

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ALBA Consulting: Aryk Atkinson • Lucien Friedenfels • Bernadel Garstecki
Abdullah Saleem
Bernadel Garstecki • Report Compilation

Patrick McLaughlin • Instructor • Civil and Environmental Engineering
Maseeh College of Engineering and Computer Science
Portland State University

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Project Disclaimer

This report was prepared as part of a class project for the Civil and Environmental Engineering Project Management and Design course at Portland State University. The contents of this report were developed by the student authors and do not necessarily reflect the views of Portland State University. The analyses, conclusions, and recommendations contained in the report should not be construed as an engineering report or used as a substitute for professional engineering services.

About SCI

The Sustainable Cities Initiative (SCI) is a cross-disciplinary organization at the University of Oregon that promotes education, service, public outreach, and research on the design and development of sustainable cities. We are redefining higher education for the public good and catalyzing community change toward sustainability. Our work addresses sustainability at multiple scales and emerges from the conviction that creating the sustainable city cannot happen within any single discipline. SCI is grounded in cross-disciplinary engagement as the key strategy for improving community sustainability. Our work connects student energy, faculty experience, and community needs to produce innovative, tangible solutions for the creation of a sustainable society.

About SCYP

The Sustainable City Year Program (SCYP) is a year-long partnership between SCI and a partner in Oregon, in which students and faculty in courses from across the university collaborate with a public entity on sustainability and livability projects. SCYP faculty and students work in collaboration with staff from the partner agency through a variety of studio projects and service-learning courses to provide students with real world projects to investigate. Students bring energy, enthusiasm, and innovative approaches to difficult, persistent problems. SCYP's primary value derives from collaborations resulting in on-the-ground impact and expanded conversations for a community ready to transition to a more sustainable and livable future.

SCI Directors and Staff

Marc Schlossberg, SCI Co-Director, and Professor of Planning, Public Policy, and Management, University of Oregon

Nico Larco, SCI Co-Director, and Associate Professor of Architecture, University of Oregon

Megan Banks, SCYP Manager, University of Oregon

About TriMet

The Tri-County Metropolitan Transportation District of Oregon was created by the Oregon Legislature in 1969 to operate and oversee mass transit in the Portland Metropolitan region. This public entity was formed by the legislature as a municipal corporation to replace the multiple private interest mass transit companies that previously operated in Multnomah County, Clackamas County, and Washington County; the counties that make up TriMet.

In addition to operating bus lines, light rail, and paratransit in the defined Tri-Metropolitan district, TriMet also connects to external mass transit services to provide wider blanket coverage for the region. TriMet's nationally recognized transit system provides more than 100 million rides annually, and carries 45% of rush hour commuters going into the downtown Portland area. TriMet not only moves people, but helps build sustainable cities by improving public health; creating vibrant, walkable communities; supporting economic growth; and working to enhance the region's livability.

Several civic leaders have been highlighted as key Figures in the creation, establishment, and ultimate success of TriMet. Governor Tom McCall is credited with the initial call for the creation of the public corporation; other key contributors include Congressman Earl Blumenauer, Rick Gustafson, Dick Feeney, and Mayor Neil Goldschmidt. All were instrumental in shaping the organization itself, as well as the land use, civic development, and transformation policies that make TriMet the success that it is today.

The vision and efforts of these individuals and countless others have borne fruit. Recently, TriMet celebrated the second anniversary of the opening of its most recent light rail line. Since its inauguration the 7.3-mile MAX Orange Line has experienced continued growth, having a six percent year-to-year increase in ridership. Illustrating the holistic approach that has been a part of TriMet from its inception, there have been wider community benefits such as a positive impact on employment and a focus on sustainable practices such as bio-swales, eco-roofs, a first-in-the-nation eco-track segment, solar paneling, and regenerative energy systems.

TriMet is a key partner in the region's Southwest Corridor Plan and Shared Investment Strategy. Eleven partner agencies are participating in planning for a new 12-mile light rail line in southwest Portland and southeast Washington County that will also include bicycle, pedestrian, and roadway projects to improve safety and access to light rail stations. Southwest Corridor stakeholders include Metro (the regional government), Washington County, Oregon Department of Transportation, and the cities of Beaverton, Durham, King City, Portland, Sherwood, Tigard, and Tualatin. This collaborative approach strives to align local, regional, and state policies and investments in the Corridor, and will implement and support adopted regional and local plans. These initiatives and outcomes from participation with the UO's Sustainable City Year Program will help develop ideas that are cost effective to build and operate, provide safe and convenient access, and achieve sustainability goals while supporting the corridor's projected growth in population and employment.

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This report represents original student work and recommendations prepared by students in the University of Oregon's Sustainable City Year Program for TriMet's Southwest Corridor project. Text and images contained in this report may not be used without permission from the University of Oregon.

Course Participants

ALBA Consulting, an undergraduate alliance formed for the *TriMet SW Barbur Boulevard Stormwater Capstone Project at Portland State University*:

Aryk Atkinson, Environmental Engineering, Undergraduate

Lucien Friedenfels, Environmental Engineering, Undergraduate

Bernadel Garstecki, Civil Engineering, Undergraduate

Abdullah Saleem, Environmental Engineering, Undergraduate

Executive Summary

This project was designed by ALBA Consulting. ALBA Consulting is an academic exercise comprised of four members of an undergraduate capstone class in engineering at Portland State University during winter and spring terms, 2018. ALBA Consulting strives to be a steward of sustainable solutions by engineering effective future assets for the communities we serve. The group sorted itself into professional roles, including: a Project Manager, an Assistant Project Manager, a Scribe, and a Quality Control Technician. Furthermore, each member also had a technical role providing supplemental content generated in AutoCAD, GIS, and Excel.

The following design report consists of preliminary facility designs and an alternative analysis for the TriMet Southwest Barbur Boulevard Stormwater Capstone Project. Over the course of six months, ALBA consulting prepared a construction cost estimates, a construction schedule, a drawing set, calculations, and site hydrographs in addition to other deliverables for this project.

This capstone project was developed from the ongoing Southwest Corridor Light Rail Transit (SWC) Project, which is presently underway at TriMet. The purpose of the SWC Project is to connect downtown Portland, Tigard, and Tualatin with public transportation, thus providing a more convenient way for people to commute within the area while also reducing the number of personal vehicles on the roads. This project is currently in the preliminary design phase, and many aspects of the project have not been finalized, therefore, this report will focus on only one aspect of the overall project: the light rail line alignment option. The chosen alignment option runs along Barbur Boulevard, with a focus on a one-mile-long segment, south of downtown Portland. This particular alignment option was chosen for the purpose of addressing the issues of stormwater drainage from Barbur Boulevard and Interstate 5 into Stephens Creek. Currently, stormwater that flows into Stephens Creek has a high level of pollutants from the highways. This compromises the quality of the stream and increases erosion and toxic sediment levels in the creek. The objective of ALBA Consulting's portion of the project is to provide TriMet with stormwater designs and analyses for the Barbur Boulevard alignment option. This information can be used to assist TriMet with their design of the alignment along Barbur Boulevard, with the goal of treating and detaining stormwater onsite to meet the criteria of predevelopment discharge levels. Treating stormwater onsite reduces the load on the conveyance pipes and helps recharge the groundwater system. The stormwater from the chosen section of the boulevard will then be discharged at the approved outfall for Stephens Creek. By treating the stormwater from the possible expansion on the boulevard, improvements in the water quality at Stephens Creek are expected.

ALBA Consulting focused on the preliminary design of planters and ponds for this project. Planters and ponds were chosen because of their low maintenance costs, ability to improve greenspace, and effectiveness at managing stormwater. The recommendation is planters are placed along the length of Barbur Boulevard to meet pollution reduction requirements. Since planters alone will not meet detention requirements (due to low soil infiltration rates in the surrounding area), ponds were chosen as the preferred facility to meet detention requirements. Therefore, the preliminary design of one planter and one pond was conducted. The locations of potential planters along the length of the boulevard were identified, as well as two additional pond locations. Due to elevation and space constraints along the new road development, no location large enough to install one pond to detain all the stormwater from this section was found on the boulevard itself. As a result, the design of one pond was selected to treat water from approximately one-third of the road section in the southeastern end of the area. Additional ponds or other detention facilities will be needed to meet the total detention requirements for the stormwater from this section of Barbur Boulevard as well. The planter that was designed using a presumptive approach calculator online showed that the planter was able to meet

pollution reductions requirements. Based on this information, it is assumed that planters placed along the length of the boulevard will be adequate to meet the total pollution reduction requirements of the road section considered.

The information provided in this report is intended to be used as a preliminary design for stormwater detention and treatment along Barbur Boulevard if this alignment option is chosen. All designs were based on preliminary site assessments from previous geotechnical reports of the surrounding area as well as a hydrograph based on estimated values for the Portland area as found from the Stormwater Management Manual (SWMM, 2016). Further analysis of the site should be conducted in order to ensure that all facilities are sized appropriately.

Introduction

In the months between January and June 2018, ALBA Consulting designed stormwater management solutions for TriMet’s Southwest Corridor Light Rail Transit (SWC) project. This design report covers the stormwater for a section of the light rail line along the boulevard’s alignment option south of downtown Portland and includes the following sections: background, alternatives analysis, facility design, and regulatory compliance and permitting.

The purpose of TriMet’s SWC project is to encourage public transportation connectivity between downtown Portland, Tigard, and Tualatin. This will provide a convenient way for people to commute within the area, while also reducing the number of personal vehicles on the roads. This project is currently in the preliminary design phase, and so many aspects of the project remain concepts. This SCYP design report will focus on one of the light rail alignment options. The alignment option chosen for the basis of the design project for this PSU capstone class runs along Barbur Boulevard, with a focus on a one-mile segment, south of downtown Portland, as shown in Figure 1 below.



Figure 1: Aerial Site Location, Google Maps, 2018

The objective of ALBA Consulting's portion of TriMet's project is to provide TriMet with stormwater designs and analyses for the one-mile segment. This student work can be used to assist TriMet with their design if an alignment option is chosen along Barbur Boulevard. All stormwater that travels above ground to the chosen section of Barbur Boulevard needs to be collected and infiltrated into the ground or sent to the storm sewer system. All new development projects are required to infiltrate and treat stormwater onsite to the maximum extent possible. This reduction in the load on the conveyance pipes will help recharge the groundwater system, a method whereby a route for surface water to enter the aquifer is ensured. Specific requirements for stormwater management are outlined in the Alternatives Analysis section following.

Existing Site Conditions

The existing site is located south of downtown Portland along Barbur Boulevard. As shown in Figure 1, the chosen section includes both vegetated (pervious) areas and built-up (impervious) areas. Each type of area requires its own stormwater design calculations. All new development projects are required by the city of Portland to treat and detain the stormwater generated on the site, regardless of whether the project creates pervious or impervious area. The stormwater from the section of Barbur Boulevard chosen for this project will feed entirely into a separated storm sewer system. Stormwater north of the chosen section of Barbur Boulevard will feed into a combined sewer system as shown in Figure 1 above. Separated sewer systems have specific requirements that are outlined by the city of Portland's Bureau of Environmental Services.

Barbur Boulevard is currently a low speed highway that is used by private, public, and freight transportation. Portions of the boulevard will be entirely rebuilt in order to incorporate the new light rail line alignment. South of downtown Portland was chosen for this project in order to address the issues of stormwater from Barbur Boulevard and I-5 impacting Stephens Creek. The stormwater that flows into Stephens Creek has a high level of pollutants from the highways and it flows into the creek at higher velocities and for longer durations than what is presently supported by the stream. This is due to inadequate management at receiving facilities upstream. As a result, there is an increase in erosion and sediment levels in the creek. ArcGIS was used to estimate the drainage area of Stephens Creek Watershed as shown below in Figure 2. The stormwater management at this location is unique and challenging due to the steep slopes of the land surrounding Stephens Creek and the amount of runoff that accumulates. Therefore, the stormwater runoff from Barbur Boulevard will first need to be infiltrated to the maximum extent possible at facilities located along the boulevard before overflow stormwater is piped or channeled into Stephens Creek, where it will then be treated at additional facilities.

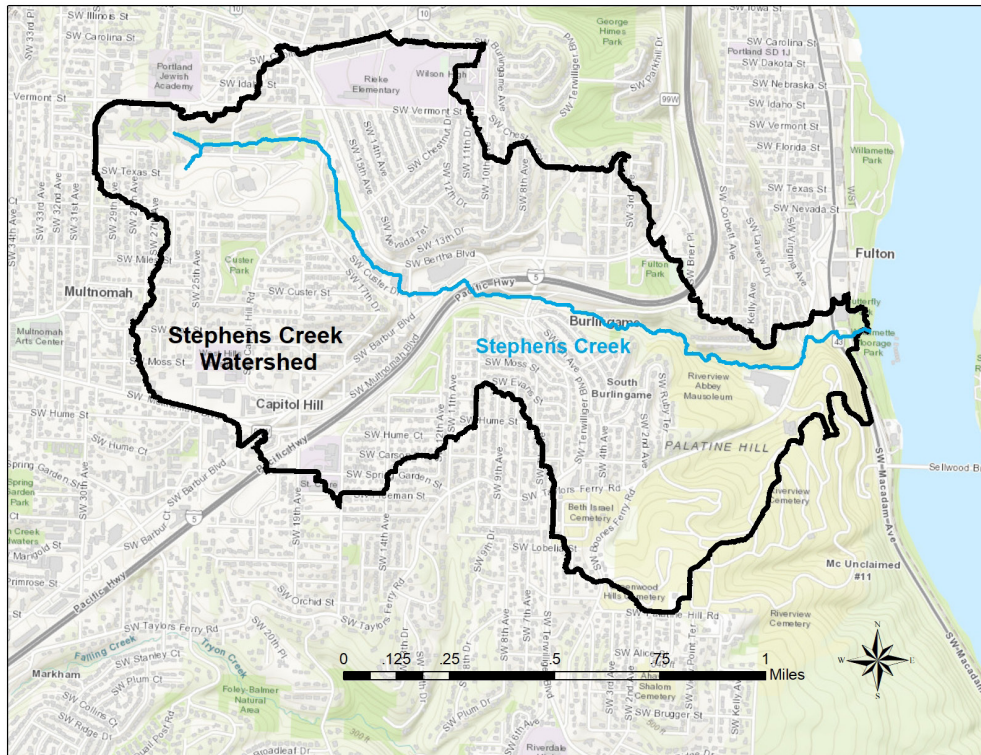


Figure 2: Stephens Creek Watershed (Data from DOGAMI and ESRI)

Stakeholders

The client for this project is TriMet, and as such will be the primary stakeholder in the design and implementation process. Secondary stakeholders include the city of Portland, as much of the project would involve construction on public property; ODOT, as this project would be redesigning Oregon roadways; and Oregon Department of Environmental Quality (DEQ) and city of Portland Bureau of Environmental Services (BES), as they are responsible for many municipal environmental regulations in the region where the project will be implemented. Furthermore, stakeholders like DEQ, BES, and the city of Portland have set the design code and permitting process that would dictate the specifics of any such final design (i.e. how stormwater is dealt with, acceptable TMDLs [Total Maximum Daily Loads], and etc.). Also, the city of Portland would be responsible for maintaining the project facilities after completion. Other stakeholders, in varying degrees, would be property owners in the path of construction who would play a role as designs and routes are finalized. Lastly, a group of stakeholders potentially impacted would be surrounding businesses and storefronts that would utilize the end result or be impacted by their proximity to construction. TriMet strives to follow a transparent process whereby it seeks to incorporate input from the community as part of the design and implementation process, so it is likely more stakeholder would be added throughout the project execution.

Alternatives Analysis

For this project, an Alternatives Analysis was performed for specific stormwater management facilities to determine the feasibility of each within the project location. Seven facility alternatives were analyzed. Alternatives A and B (planters and swales) were chosen based on their commonality of use within Portland and their ability to treat for water quality. Alternatives C and D (basins and ponds) were chosen for their commonality of use as well as ability to

detain larger volumes of water than planters and swales. Alternative E (vaults) was chosen as an alternative method of storing water underground. Alternative F (pervious pavement) was chosen since it doesn't require as many site restrictions, and Alternative G (Drywell) was chosen as a potential method to help infiltrate stormwater underground. All facility alternatives for this project are based on design criteria outlined in the BES Stormwater Management Manual (SWMM) and the Sewer and Drainage Facilities Design Manual (SDFDM) (SWMM, SDFDM, 2016, 2007). This section outlines the required standards for stormwater facilities, descriptions of the seven facility alternatives, selection criteria and Pugh matrix, as well as the results from the Pugh Matrix analysis with the chosen alternatives.

Standards

The BES Stormwater Management Manual (SWMM) states that stormwater must be managed to meet standards for water quality, water quantity, and conveyance. Each of these three standards are outlined below.

Water Quality

The BES SWMM requires that there is at least 70% removal of TSS (Total Suspended Solids) from 90% of average annual runoff. This is the only requirement for this project since the site location is not in a watershed that regulates TMDL (Total Maximum Daily Loads).

Water Quantity

The BES SWMM requirements for storm only sewers for flow control are to maintain peak flow rates at their predevelopment levels for the 2-year, 5-year, 10-year, and 24-hour runoff events.

Conveyance

The BES SWMM requires that pipes have the capacity to convey flows from the 25-year design storm from all contributing upstream drainage areas.

Facility Alternatives

The seven facility alternatives that have been chosen to treat the runoff onto Barbur Boulevard are outlined and summarized below. These are threshold criteria that influenced ALBA's recommendations for the purpose of this report; however, it should be noted that additional criteria were considered in subsequent sections as well as the methodology for analysis.

Alternative A - Planters



Figure 3: Planters (SWMM Manual)

Description: Planters would be an alternative between the sidewalks and roadway along Barbur Boulevard to help collect, retain, and convey stormwater to an authorized discharge. Planters are landscaped reservoirs used to collect, filter, and infiltrate stormwater by allowing pollutants to settle and filter out as water percolates through vegetation, growing mediums, and gravel. Depending on the site's condition, planters can be designed for partial or total infiltration of stormwater. Excess stormwater can be conveyed to an approved discharge location by a perforated pipe at the bottom of the planter. Because lined planters can be constructed immediately next to buildings, they are ideal for sites with setback requirements, poorly draining soils, steep slopes, or other buildability constraints. Planters are widely applicable for various soil infiltration rates. If the tested infiltration is less than two inches per hour, the planter must be designed as a partial infiltration facility with an overflow to an approved discharge. Setbacks for planters must be five feet from property lines and ten feet from foundations. There are no setback requirements for lined planters. The minimum width of planters is 30 inches. The maximum longitudinal slope is six percent, but multiple planters can be placed with check dams between them to reduce slopes. The growing medium for planters is a sandy loam mixed with a compost/soil blend and must be at least 18 inches deep. This is to allow for fast infiltration rates through the medium to help with pollution reduction. Vegetation in planters cannot block the line of view of traffic and cannot require mowing due to the small size.

Alternative B - Swales



Figure 4: Swales (SWMM Manual)

Description: Swales are a potential alternative good for collecting, conveying, and treating water. The size requirement is substantial. Swales are typically long, narrow, gently sloped landscaped depressions that collect and convey stormwater. Planted with dense vegetation and punctuated with check dams to slow water and treat water from streets, roofs, and sidewalks, they serve to infiltrate water into the ground while having an overflow that can convey stormwater to an approved discharge station, such as a drywell or sump. Swales are applicable for various soil infiltration rates. If tested, infiltration is less than two inches per hour, however the swale must be designed as a partial infiltration facility with an overflow to an approved discharge station. Setbacks for swales must be five feet from property lines and ten feet from foundations, and there are no setback requirements for lined swales. The minimum swale width is nine feet in the right of way with a two feet wide flat bottom. The maximum slope for swales is 3 horizontal to 1 vertical or 4 horizontal to 1 vertical adjacent to pedestrian areas. Vegetation that does not block the line of site can be used in swales.

Alternative C - Basins



Figure 5: Basins (SWMM Manual)

Description: Infiltration basins are shallow, vegetated depressions that are used to collect and hold stormwater runoff, which allow pollutants to settle and filter out. Inlet pipes or sheet flow convey the stormwater into the basin, where it is stored until it can infiltrate into the ground. Basins can often provide complete onsite infiltration for small storm events and, if adequate space and soil infiltration rates are available, they can also be sized to infiltrate larger storm events. If the area or soil infiltration is not available for complete onsite infiltration, then an overflow pipe can be installed to discharge to another location. Setbacks for basins are five feet from the property line and ten feet from the building foundation. The minimum width is nine feet for basins. Vegetation must be planted with a minimum growing medium of 18 inches for right-of-way areas and must not block line-of-site.

Alternative D - Ponds



Figure 6: Ponds (EPA, 2018)

Description: Ponds are broken into three main categories, wet pond, extended wet pond, and dry detention pond. Wet ponds are designed to hold a permanent pool of water. Water from storm events runs into one end of the pool, which displaces the detained water, which is held in the pond. Pollutants are removed through gravitational settling and biological processes. Extended wet ponds, like wet ponds, are designed to hold a permanent pool of water but include additional storage above the permanent pool that fills during storm events. Water is released slowly after the storm event over a duration of time. The permanent pool is sized to provide pollutant reduction through the same process as a wet pond while the area above the permanent storage is designed to meet flow control requirements. Dry detention ponds are basins that fill during storm events and are designed to slowly release water for a number of hours. Ponds restrict flow rates exiting the pond in order to reduce erosion and flooding of receiving streams or systems. Additional facilities are required to meet pollution reduction requirements unless the bottom flow path of the pond was designed as a swale and meets the design criteria. Detention ponds are appropriate for sites with infiltration rates less than two inches per hour. Setbacks are required for property lines, septic tanks, slopes, and wells. Surrounding slopes must not exceed ten percent. Wet and extended wet detention ponds should be designed for drainage areas between five and 150 acres to help avoid problems associated with long periods of stagnant water.

Alternative E - Vaults



Figure 7: Vaults (Highmark Enterprises, 2011)

Description: Vaults are used as storage facilities for stormwater as part of a flow control system. Vaults must be designed to detain a specified amount of water and should have the ability to withstand environmental conditions such as inundation, chemical, or electrochemical soil conditions, heavy ground, and surface loadings. Vaults must also be accessible for maintenance. Vaults are not used for meeting pollution reduction requirements, so they must be used in conjunction with other facilities. Subsequently, a sediment manhole or surface sediment containment pond must be placed upstream of a vault, and periodic maintenance is required. Internal height and width of a vault must be a minimum of three feet. The maximum height of a vault is 20 feet. If a vault is designed for sediment containment, a minimum half foot of dead storage must be provided and the vault must be laid flat. In soils where ground water may induce flotation and buoyancy, measures must be taken to counteract these forces with ballasting, backfill, or concrete anchors. The vaults must be placed on stable consolidated native soils with suitable bedding. Tanks and vaults must not be allowed to fill slopes unless a geotechnical analysis was performed. Vaults require flow control requirements such as ponds. Orifices can be used to control flow back to regulated levels.

Alternative F – Pervious Pavement



Figure 8: Pervious Pavement (SWMM Manual)

Description: Pervious Pavement would be an alternative on impervious areas, such as sidewalks, to reduce the amount of water that would need to be managed. The maintenance would be relatively low, while the cost is significant. Pervious pavement is useable in pedestrian areas and commercial parking lots to reduce the obligation of stormwater management of project site. Pervious asphalt and concrete can be used on public roadways on a case-by-case basis. Pervious pavement can be used where there is a minimum of five feet to the seasonal high groundwater table. If infiltration is less than two inches per hour, the section must flow into an adequately sized filter strip (500 square foot limit for pavement) or a collection area that leads to a vegetated facility that is sized to treat the entire pervious area. There are no setback requirements for pervious pavement. Liners are recommended between base rock and adjacent foundations. Liners may be required if the pervious pavement is within five feet of structures or infrastructure. Pervious pavement is not allowed in slopes greater than ten percent.

Alternative G – Drywells



Figure 9: Drywell (SWMM Manual)

Description: Drywells are typically precast concrete rings that are perforated to allow for infiltration. These facilities allow for stormwater storage at depths that range from five to 20 feet before the water infiltrates into the ground. UICs can have substantial impacts on groundwater and so it is required that stormwater is treated for pollution prior to being discharged into them. Drywells should not be located in dense silt or clay soils. Bore tests must be performed in order to determine the feasibility of drywells, as well as supporting geotechnical evidence, which is required for all slopes greater than 20 percent. Drywells are typically setback ten feet from the foundation and five feet from the property line.

Facility Selection: Threshold Criteria

The project site has many limitations and restrictions on the types of facilities that can be installed. The seven facility alternatives were first analyzed with regards to threshold criteria in order to determine which facilities can or cannot be used due to the project site's steep slopes, small area available, and low infiltration rates. Each threshold criteria was either rated "Pass," the facility can be used, or "Fail," the facility cannot be used due to the criteria. Some facilities will be rated as a conditional pass, "Pass*," which means that the facility cannot be used in existing site conditions. The two threshold criteria that can fall under this category area are "Steep Slopes" and "Small Area Available." If TriMet is able to regrade an area to decrease the slopes or purchase additional area near the new roadway development to meet facility requirements, then a facility received a "Pass*" rating. The three threshold criteria were based on requirements for each facility in the Stormwater Management Manual (SWMM 2016).

Steep Slopes

The ground slopes in the surrounding site area are greater than ten percent on average, and the road slopes range between one percent to three percent. Setbacks for slopes limit the types of facilities that can be installed. If a stormwater facility is needed in an area that has steeper slopes than the criteria for the stormwater facility allows, TriMet could regrade the area as needed in order to meet the requirements.

Small Area Available

Determining what type of facility can be installed depends on how much area is available and what of that area is available. The threshold criteria for “small area available” means the area is readily available for facility installment. The readily available area for installing facilities on Barbur Boulevard is limited to the planting strip between the sidewalk and roadway on either side of the boulevard. Thus, planters are the only facility that can be installed in the planting strip, but they have a 30-inch minimum width requirement. Since the planting strip is only 24 inches wide, the assumption is made for this project that TriMet would apply and be granted a land use design exception to install planters with a width of 24 inches. The area that is not readily available refers to possible locations near Barbur Boulevard where buildings would theoretically be removed to make room for the light rail line. Detention is required for stormwater management, and if needed, TriMet could acquire additional land in order to comply with the quantity and detention requirements. If additional area is needed for facilities, this will be identified in the facility design portion of the report.

Low Infiltration Rates

According to PortlandMaps, the soil class at the project site is Class C (PortlandMaps, 2018). Class C soils are defined by the NRCS as soils having a slow infiltration rate and a moderately high runoff potential when thoroughly wet (NRCS, 2007). Group C soils typically have between 20% to 40% clay. In order to determine the actual infiltration rates of the site, infiltration testing must be completed using one of three methods outlined in the SWMM manual. Due to time and resources, local infiltration testing was not performed and so an assumed value of 0.5 inches per hour was chosen for the native soil infiltration rate. The value is the average of four infiltration tests that were done in 2009 for Fred Meyer’s expansion on Barbur Boulevard (Abbott Construction, 2011). While this value may not be the actual soil infiltration rates of the project site, Class C does indicate low infiltration rates. The assumed rate of 0.5 inches per hour will be the assumed value for infiltration and will be used for any calculations in this report. However, TriMet is encouraged to commission a full infiltration testing prior to choosing the final design.

Facility Considerations: Additional Criteria

If multiple facilities were found to be suitable for the site through the threshold criteria, three additional criteria (cost, ease of maintenance, and aesthetics) were used to determine which facility to select for the project location. Each additional criterion will be ranked from 1 to 5, with 5 being the most ideal ranking for the criteria. A median score of 3 will indicate satisfactory, while 1 shows that the design does not satisfy the criteria at all. The additional criteria will also be weighted on a scale from 1 to 3, whereby the weight of 3 will indicate the most important criterion for this project. A Pugh Matrix was used to analyze each facility alternative and choose which facilities would work best for the site location. The following are descriptions of the three additional threshold criteria used to analyze the facilities.

Cost

The cost criterion will indicate all associated costs for the building and installation of each alternative. Cost was graded for the initial investment cost associated with the scope of the respective design. Furthermore, construction and materials associated with each potential facility were factored. A score of 1 indicates the most expensive options while a score of 5 indicates the least expensive option. A higher score given simply indicates a less expensive cost of building the facility.

Maintenance

The maintenance criteria will indicate which maintenance would be associated with each alternative. Maintenance can include upkeep, replacement of plants, and growing medium as well as regularity of required maintenance. Maintenance criteria was graded from 1 to 5 with a score of 1 indicating regular maintenance (weekly) and how it would be associated with which time and what cost requirements. A score of 5 indicates relatively no annual maintenance requirement.

Aesthetics

The aesthetic of each alternative will be ranked to indicate how visually appealing the facility or structure would be. Aesthetic grades were assigned if proposed facilities would improve the aesthetic of the surrounding area. If a facility would greatly improve the appearance of its location, a score of 5 would be assigned. If the facility didn't detract from the appearance of the location or add to its appearance, a score of 3 would be given. And, if a facility greatly degraded the appearance of the existing area, a grade of 1 would be assigned.

Pugh Matrix & Results

The following Pugh Matrix shows the threshold criteria used to determine facility feasibility as well as the additional criteria used to choose the preferred facility for the site.

Project Site Threshold Criteria	Weight	Alt. A (Planter)	Alt. B (Swale)	Alt. C (Basin)	Alt. D (Pond)	Alt. E (Vault)	Alt. F (Perv. Pave.)	Alt. G (Drywell)
Steep Slopes	N/A	Pass	Pass*	Pass*	Pass*	Pass	Pass	Pass
Small Area Available	N/A	Pass	Fail	Pass*	Pass*	Pass	Pass	Pass
Low Infiltration Rates	N/A	Pass	Pass	Pass	Pass	Pass	Pass	Fail
Additional Criteria								
Cost	3	3(3)	NA	2(3)	2(3)	1(3)	2(3)	NA
Maintenance	2	4(2)	NA	4(2)	4(2)	1(2)	3(2)	NA
Aesthetics	1	5(1)	NA	5(1)	5(1)	3(1)	3(1)	NA
Total		22	NA	19	19	8	15	NA

Table 1 – Pugh Matrix

Swales were eliminated for this project based on the land availability. Swales are used to slow water so it can infiltrate or flow into an overflow, and not to store water. The only area that swales could be used would be next to the road for overflow into a pipe conveyance, which is not recommended. This stretch of the boulevard has two feet on each side and since swales have a much larger width requirement of eight feet they were eliminated as an alternative.

Based on infiltration rates obtained from the Geotechnical Investigation from the Burlingame Fred Meyer by Abbott Construction (Abbott, 2011) adjacent to our project location, the infiltration rate was found too low to make drywells a viable alternative. Drywells require a minimum infiltration rate of two inches per hour and the geotechnical investigation found that the infiltration rate near our project location was less than 0.1 inches per hour. As a result, this alternative was eliminated from selection and is not recommended.

The information gathered eliminated swales and drywells from consideration for the purposes of our project, however further geotechnical investigation could potentially reveal that they are viable alternatives should be existing conditions change.

Basins and ponds both conditionally passed the slope and area threshold criteria. If an area is identified that TriMet can purchase to install these facilities and regrade the area as needed, then both of these facilities can be used for this project. Detention is required for stormwater management and since this project site has low infiltration rates, these facilities will need to be used for detention and storage.

Planters, basins, ponds, vaults, and pervious pavement all passed the threshold criteria-- indicating they are viable alternatives. The viable options were then comparatively graded in the Pugh Matrix that scored them based on cost, maintenance, and aesthetic on a score from 1 to 5. A score of 5 indicates the most ideal and 1 was the least satisfactory for the respective criterion.

Cost

Planters were given a score of 3 for cost as they have an initial investment associated with their design and build. However, they are cheaper to build than the other facilities, since they can be built into the planter strip. They are made from poured concrete with cut curbs and have an overflow pipe and a perforated pipe below the growing medium that tie into the existing storm pipe infrastructure.

Basins and ponds received a score of 2 for cost because they require excavation and grading. They also require overflow pipes and conveyance discharge facilities.

Vaults received a score of 1 for cost because they are expensive to build. They are made of concrete and require substantial excavation. They are also very expensive to maintain due to limited accessibility.

Pervious pavement was given a score of 2 because of the cost of installation and the upfront materials cost. Pervious pavement can be installed in discrete units or can be poured from a special cement mix, which results in added cost when compared to conventional concrete.

Maintenance

Planters, basins, and ponds were given a maintenance score of 4 because maintenance is minimal. Maintenance would be seasonal, with increased inspection during the wet parts of the year.

Vaults received a score of 1 for maintenance because they require very regular maintenance. They require frequent inspection and cleaning or risk sediment backup. Any maintenance that is required on vaults is difficult due to limited accessibility after installation.

Pervious pavement earned a score of 3 because pervious pavement requires more regular inspection to make sure it is kept clean to allow infiltration. The pervious pavement would also function as pedestrian walkways. This would result in frequent sidewalk inspections to ensure safety because pervious pavement is susceptible to cracking and breaking, more so than conventional cement sidewalks.

Aesthetics

Planters, basins, and ponds were given a score of 5 for aesthetics as they improve the appearance versus a conventional sidewalk because they add plant variety and greenspace to an otherwise potentially bland paved area.

Vaults and pervious pavement earned a score of 3 for aesthetics because they do not improve or detract from the appearance of a paved sidewalk.

Preferred Alternative

Based on the threshold criteria and the selection criteria in the Pugh matrix, the preferred alternatives are planters, basins, and ponds for stormwater facilities. ALBA's Alternatives Analysis determined they are cheaper, require less maintenance, and are more aesthetically pleasing than the pervious pavement and vault alternatives. Planters should be used along the roadway in as much of the planter strip as possible. Likewise, basins and ponds will be used near the project site where land is identified for acquisition. Basins will be used for smaller areas and ponds will be used if larger areas are available.

If basins and ponds can be installed at the project site, they are preferred over vaults because the cost of vaults is more expensive and, furthermore, difficult to maintain. However, vaults can be used if additional detention is required. The ponds and basins should be placed in a designated area in proximity of Stevens Creek in order to meet the flow requirement of stormwater from the SWC project. Once the design area is implemented, a pond or other detention facility will be necessary as facilities located along the roadway will not be able to meet flow requirements set by the city of Portland alone.

Although the pervious pavement passed the threshold criteria, the pervious pavement does not seem to be as effective an alternative as the soil infiltration rates for the project area, and it has low infiltration rates. With infiltration rates lower than two inches per hour a filter strip or basin is required for sheet flow from impervious pavement. This makes the pervious pavement behave as impervious pavement, which negates any benefit. The cost and maintenance of this option simply outweighs any potential benefits.

Facility Design

ALBA's final consideration for the TriMet Southwest Light Rail stormwater design project consisted of several treatment facilities and a detention facilities. Locations and geometries of these treatment locations are presented and discussed below. Due to scope of work constraints for this project, conveyance sizing will not be addressed. Therefore, further analysis of the routing of water from the facilities to an existing or new conveyance system will need to be conducted.

This section describes considered treatments along Barbur Boulevard. It is divided into sections for each treatment facility. Planters were chosen in the Pugh Matrix analysis as the preferred treatment facility. This section also describes the design of the detention facility for which a pond was chosen as the preferred alternative. The Santa Barbara Urban Hydrograph (SBUH) method was used to analyze the treatment and detention requirements as outlined in the BES Stormwater Management Manual (SWMM) and the Sewer and Drainage Facilities Design

Manual (SDFDM) (SWMM, SDFDM, 2016, 2007). This section also describes the presumptive approach and SBUH calculations that were used to design the stormwater facilities.

As mentioned above, the SWMM details the design criteria and requirements for all redevelopment projects within the city of Portland. The project location is entirely within city limits and so this manual will likely be the primary reference for the eventual design. The second main reference manual that we used in this section is the BES Sewer and Drainage Facilities Design Manual, which details specific equations and design criteria (SWMM, SDFDM, 2016, 2007). During construction, additional manuals and codes such as the Erosion and Sediment Control Manual could also be used to prevent pollution from inevitable erosion.

The following section describes the selected facilities for the project including locations, types, and calculations. The conveyance, treatment, and detention requirements as outlined in the BES SWMM and SDFDM are also discussed.

Project Design Criteria

This section describes the general methods and criteria used to determine the water quality and detention requirements.

Pre-Development Conditions

BES requires new development to manage water to the same level as pre-development conditions at minimum. Pre-development conditions are considered with regard to the land coverage before any development at all. Depending on the type of facility being designed (quality or quantity) there are specific pre-development requirements that must be met with upon development.

Hierarchy Category

One of the first steps in stormwater design is to determine which hierarchy category is applicable to the site. The SWMM states that the highest feasible category must be used (1 = highest, 4 = lowest), unless otherwise directed by BES. Categories 1 and 2 require total onsite infiltration, which is not feasible in this project due to the low infiltration rates. Category 3 is used for overflows to storm-only pipes, drainageways, or streams. Category 4 is reserved for overflows to combined sewer. ALBA recommends utilizing Category 3 for this design because the project is entirely within the separated storm system and discharges to a stream.

Soil Group

Another important step in the design process is to determine which soil group the site is classified as. According to the National Resources Conservation Service, the selected stretch of Barbur Boulevard has soil group C. Group C soils are classified as having moderately high runoff potential. The soil class affects the curve numbers that are used in runoff calculations. Due to the very low infiltration rates of the project site, as well as not having site specific infiltration testing, soil infiltration will be considered negligible for the purposes of facility design.

Santa Barbara Urban Hydrograph Method

Our project utilized the Santa Barbara Urban Hydrograph (SBUH) method outlined in the SDFDM for runoff calculations. This method can be used if the area under analysis is less than 50 acres. The SBUH does not work to design conveyance facilities. The SBUH method creates hydrographs for pre- and post-development flows to determine what the detention and flow-control sizing must be for each facility. A discharge point is selected and the pre-development discharge at this point is determined using a curve number based on the type of

land coverage and soil class. The pre-development curve number is based on only vegetated land cover, which, in the case of the project location, was chosen as a wooded area. The post-development flow to the same point is determined using a new curve number, which will include impervious areas as well as pervious areas depending on the site. The discharge to the point of interest is found by using a time to concentration at that point. This is the travel time from the point-of-interest to the most remote point of the tributary area. The time of concentration used in calculations cannot be less than 5 minutes.

The SBUH method also uses a SCS Type 1A rainfall distribution along with a total of 24-hour storm rainfall depths for each design storm (2-year, 5-year, etc.) to compute a final hydrograph volume and peak flow rate. This information is provided in tables in Appendix D.

The online Presumptive Approach Calculator (PAC) calculator created hydrographs automatically for the planter design. The pond hydrographs were created using excel formulas consistent with the equations provided in the SDFDM. The calculations used in creating the SBUH are shown in Appendix D as well as associated hydrographs in Appendix G, which are based on the pre-development and post-development stormwater design guidelines of the detention facility.

Facility Details and Requirements

This section describes the treatment, detention, and conveyance requirements as outlined in the BES Stormwater Management Manual for each facility.

Water Quality Treatment

The area of water to be treated for water quality is the newly developed area of Barbur Boulevard as well as approximately ten feet of easement on either side of the roadway. Additional water that sheet flows onto the boulevard from areas outside of this treatment area is not considered in this design calculation. Water is not required to be treated for the SWC project and so will be considered as pass-through. Furthermore, during peak flows, this water will be considered as pass-through flow and travel into the overflow devices of the facilities. The conveyance pipes will have to be sized to handle the pass-through flow.

The options ALBA considered required runoff treatment from all of the impervious development. This area was calculated from the total width of the new road section. An assumption was made for this project that the track will be ballasted throughout the length of the road segment, except for intersections. The ballasted area is treated as pervious and will be subtracted from the impervious area for this segment. Due to low infiltration rates, this area will not be able to infiltrate fully in the ballasted section. Also, it is assumed that any additional runoff from the ballasted area will be collected in an under-drain below the ballast, which will connect, to the storm conveyance system.

The following section outlines the area available for planters along the chosen stretch of Barbur Boulevard. The option proffered by ALBA is to place planters in as many locations adjacent to the boulevard as possible in order to treat and detain as much water from the impervious area as possible. This will minimize the amount of treatment required by the ponds prior to discharge to Stevens Creek.

Quality Requirements

Water quality facilities in hierarchy category 3 are required to achieve 70 percent total suspended solids (TSS) removal from 90 percent of the average annual runoff. The design storm for pollution requirement is 0.83 inches of rainfall over 24 hours using the National

Resources Conservation Service (NRCS) (SCS) Type 1A rainfall distribution (SWMM, 2016). This information is used with the SBUH method to size the facility to meet annual pollution reduction.

Facility Design

The PAC on the city of Portland website (BES, 2018) was used for a preliminary planter design. This approach utilizes the Santa Barbara Urban Hydrograph (SBUH) method. The impervious area of the new roadway was divided into subcatchments for each planter section to treat. One planter was chosen for which to run the PAC calculations, and this planter design is to be used as a template for the other planters in this road section. The chosen planter location and subcatchment are shown in Appendix C with associated typical details. The PAC calculations are shown in Appendix F. Infiltration was not done for this project so the values found in the Fred Meyer report were used for the PAC calculator with an average value of 0.5 inches per hour. The open pit falling head test was selected as the infiltration testing procedure to match how the Fred Meyer test was performed. The curve numbers that were chosen for the calculator were 70 for the pre-development wooded area and 98 for the post-development impervious roadway.

The recommended facility configuration for the planter is flat-bottomed with rock storage with an underdrain. The bottom width for all planters will be two feet, which is the maximum space available to use for the planters in the TriMet road design of Barbur Boulevard. While the SWMM requires two-and-a-half-foot minimum width for planters in the right-of-way, it is assumed for this project that TriMet will apply and be granted an exception. The default values of 12 inches of rock storage depth and 0.3 rock porosity were used in the PAC. The rock storage depth below the underdrain assumes six inches. And, the storage depth above the growing medium assumes six inches if the growing medium depth was kept at the default of 18 inches.

The results from the PAC calculator showed that the pollution reduction would pass the requirements, but the flow control would fail. The results also revealed that only 19% of the surface capacity would be used in the planter (Appendix F). From these results, it is likely that pollution reduction for the entire project site could be met by lining Barbur Boulevard with planters in the locations shown in the drawing set in Appendix C. The below image shows the typical cross-section of a planter from the SWMM manual (SWMM, 2018).

Plant selection for the planters should be completed in compliance with the SWMM and the provided template in Appendix C.

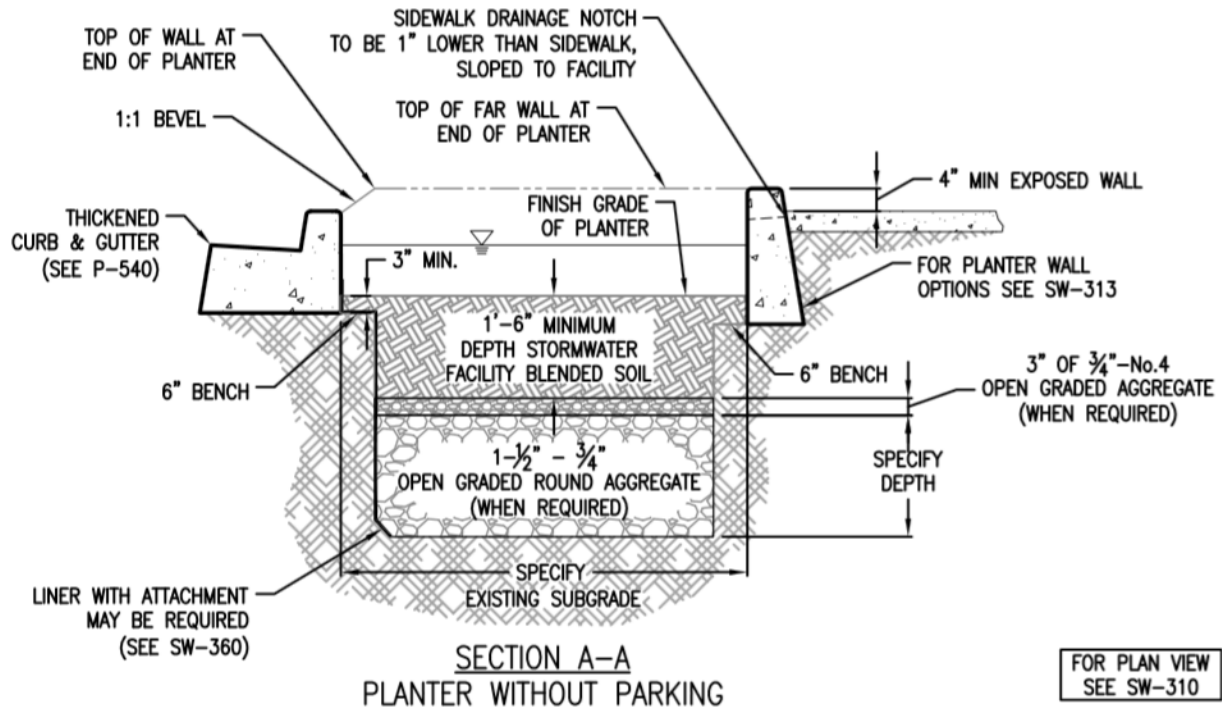


Figure 10: Green Street Detail - Planter (SWMM Manual)

Water Quantity and Detention

This section outlines the proposed area for ponds near the one-mile stretch of the boulevard selected for this project. The SBUH was used to determine the peak runoff to the pond in order to size the pond to maximize and detain the desired flow during the two, five, ten, and 25-year flows (with a 100-year overflow capacity).

Quantity Requirements

The flow control requirements for each hierarchy category are shown below in Table 2 (SWMM 2016). The project location falls within Hierarchy Category 3, and the stormwater system would discharge to a surface water body so the requirements for these specifications could be followed.

Hierarchy Categories

Hierarchy Category	Flow Control Requirements
Hierarchy 1 Vegetated infiltration facility with no overflow	Infiltrate the 10-year design storm.
Hierarchy 2 Vegetated facility or pervious pavement with overflow to subsurface infiltration facility (sump, drywell, soakage trench)	Infiltrate the 10-year design storm and meet underground injection control requirements.
Hierarchy 3 Vegetated facility with overflow to drainageway, stream, river, or storm-only pipe	Flow control required for discharge to surface water bodies directly or via stormwater systems, such as ditches or drainageways: <ul style="list-style-type: none"> • 2-year post-development peak runoff rate to one-half of the 2-year predevelopment peak rate • 5-year post-development peak runoff rate to 5-year pre-development peak rate • 10-year post-development peak runoff rate to 10-year pre-development peak rate • 25-year post-development peak runoff rate to 25-year pre-development peak rate Flow control required for discharge to storm only sewers: <ul style="list-style-type: none"> • Maintain peak flow rates at their predevelopment levels for the 2-year, 5-year, and 10-year, 24-hour runoff events.
Hierarchy 4 Vegetated facility with overflow to combined sewer	Limit the 25-year post-development peak runoff rate to the 10-year pre-development peak rate

Considered Facility Design

Sizing, flow control, and plant selection could be completed for the proposed pond at the southwest end of this stretch of Barbur Boulevard. However, due to low infiltration rates as found from the Fred Meyer report, infiltration on site is not possible, and flow control cannot be achieved with planters alone. In order to meet the flow control requirements for stormwater management, a pond could be utilized to detain and release water to Stephens Creek at regulated pre-development flowrates. Due to the variations in elevation as well as limited space available, it would not be considered feasible to have just one pond to detain all of the runoff at the site. Therefore ALBA would recommend a pond placed to treat a portion of the runoff from the southwest end of the section. Furthermore, to meet BES requirements, additional detention facilities would need to be designed to handle the remaining runoff from the site. The design of the remaining detention facilities is outside of ALBA's scope and, thus, wasn't considered.

The release of stormwater from the pond would be controlled using orifice sizing that will release at flowrates to meet the pre-development flow rates for each designed storm. Pre-development flow rates are markedly lower than post-development flow rates due to the land being heavily

vegetated and forested prior to development. The difference of the land cover type is represented by the difference in curve numbers employed in the presumptive approach (i.e. pre-development is 70 for a wooded area, post-development is 98 for impervious surfaces). To find pre- and post-development flow velocity, Manning's equation was employed using Manning's coefficients of 0.6 for pre-development sheet flow (wooded area), 0.05 for pre-development shallow concentrated flow (wooded area), and 0.013 for post-development flows (smooth road surfaces and gravity conduits) (SDFDM, 2007). Slopes were obtained from topographic maps, and the velocities were used to find time of concentration (Tc). Appendix C shows the calculations used to find the flows and times of concentration for the pond and Appendix G were associated with hydrographs for each design storm.

Potential locations for detention ponds have been identified. Current lots that will be encroached as a result of development along the boulevard were targeted as possible locations for detention ponds. Another factor that was considered was elevation, and locations at low points where they can collect water from surrounding roadway at higher elevations were selected. Using lots that will be intersected by the new development along with lots that were at lower elevation that surrounding road ways resulted in three potential locations, as shown in Appendix C. The location of the pond that was designed for this project is located in the southeastern portion of the road segment. The area for the pond was chosen because it is likely that the buildings on the existing adjacent lots would need to be removed since the new road development will expand into them. This assumption was made based on the alignment option that was analyzed in ALBA's capstone class.

A conservative estimate of the required storage volume was calculated by taking the difference in total volumes of the pre- and post-development 25-year design storm. The area selected for the pond will be sufficient based on this volume. Hydraulic modeling software could indicate that the proposed volume is larger than needed, which could potentially result in an eventual reduction in pond size.

From SWMM regulations, ALBA considered the design for a detention pond, which would be placed at the boundaries of the facility at least 20 feet from any adjacent property lines. Additionally, the side slope of the pond must be 4:1, meaning for every one foot of depth there are four feet of horizontal distance (see Appendix C for pond shape and detail). Finally, detention ponds are required to have a maximum depth of four feet.

As part of ALBA's considerations, a dry pond was selected that does not have permanent water storage, as opposed to a wet pond that would have water at all times. A wet pond was not selected because of the difficulty in growing plants as well as the nuisance caused by increase in mosquitoes and other pests. In order to meet these design requirements, the pond was set 20 feet from the property lines of the allotted area, and detention volumes were calculated for the two, five, ten, and 25-year 24-hour storm events. Based on these volumes, as well as the area of the pond, the required depth was found to be 3.5 ft, with a total volume of 18,756 ft. The minimum depth meets the required constraint of four feet and the area fits within the chosen lot. Therefore, the pond is adequately sized.

To meet flow control regulations, three orifices could be placed in a manhole downstream of the detention pond to control discharge flow rates. The three orifices are sized to discharge stormwater at predevelopment flow rates for half of a two-year 24-hour design storm; a ten-year 24-hour design storm; and a 25-year 24-hour design storm. The predevelopment flow rate for the five-year design storm could be achieved by the additional hydraulic head above the two-year orifice. Each orifice could be placed based on the height of the water level each design storm reaches in the detention pond.

Upon preliminary analysis, orifices could overlap for the ten and 25-year 24-hour design storm.

This is due to the small difference in storage volume between the two design storms. Due to scope of work constraints, the orifice design was not considered. More calculations would need to be done to properly design the orifice locations and size. Orifice sizing and required volume storage calculations can be found in Appendix D. ALBA assumes the plant selection would be consistent with the SWMM and the provided template, found in Appendix C.

Conveyance

Conveyance Requirements

Conveyance facilities in hierarchy category 3 are required to have the capacity to convey flows from the 25-year design storm from all contributing upstream drainage areas. The rational method can be used to size the conveyance facilities.

Facility Design

Due scope of work constraints, pipe sizing was not addressed. Additional information is needed regarding pipe slopes and inverse elevations of existing pipes. ALBA recommends the conveyance pipes are sized to convey all upstream runoff as well as Barbur Boulevard runoff. While the planters do not need to treat the pass-through flow, this flow would have to be considered for the final conveyance facility design, as the pipes will need to be sized to handle all incoming flows regardless of origin. Separate conveyance pipes will be placed from all the planters to the pond in order to treat runoff from the boulevard in the pond. Underdrain pipes that convey the runoff from below the ballast would also connect to the conveyance and add to the flow that the conveyance pipes will need to handle. It is likely that the current conveyance system would be adequate for new development on Barbur Boulevard since the facility designs would implement more flow control than is currently being employed, which would reduce peak flows. The new roadway would increase the width of Barbur Boulevard, which would reduce current pervious area, but if the new road includes planters, pervious area would increase. A preliminary analysis of the net difference in impervious area appears to be small, and so it is likely that current conveyance pipes would be able to support the separate storm sewer requirements of the new development. Manholes would also need to be installed every 500 feet, unless BES provides approval for alternate spacing, for maintenance and access to pipes.

Outfall

After detention requirements are met on Barbur Boulevard, the stormwater should be sent to Stephen's Creek at pre-development levels in existing pipes that are sent to the creek.

Construction Cost and Schedule

The cost estimate includes all proposed planters along the length of Barbur Boulevard and one pond as detailed in the drawings. The cost estimate also includes conveyance piping between planters and ponds and between the pond and existing conveyance. All the costs were estimated using the Portland Bureau of Transportation's (PBOT) estimating template for projects greater than one million dollars (PBOT, 2018) The planter cost was estimated using information from TriMet. The total estimated cost of the stormwater facilities is \$2,322,585 Million. See Appendix A for Construction Cost Estimate.

The construction schedule includes only the construction of the stormwater facilities for the one-mile section of Barbur Boulevard. For the purposes of the construction schedule, the stormwater design is treated as a standalone project from the larger SWC project. The total estimated construction time is approximately six months. See Appendix B for Construction Schedule.

Regulatory Compliance and Permitting

ALBA Consulting is currently working with TriMet, but there are other agencies that have investments in this project as well as permit requirements. The three regulatory compliance agencies as well as the required permits that are relevant to this project are:

Portland Bureau of Transportation (PBOT)

The road will be transferred from ODOT to PBOT and will be designed to city standards. PBOT has broad code authority over public improvements in the public right-of-way. PBOT is responsible for maintaining storm drains, sewer pipes, and streets.

Department Of Environmental Quality (DEQ)

DEQ regulates environmental quality and pollution control.

1200-C National Pollutant Discharge Elimination System (NPDES) Stormwater Discharge Permit

DEQ would be consulted for regulation of point and non-point source dischargers, effluent limits, and required best management practices to remove pollutants from discharges. And, a permit is required for construction activities that may discharge to surface waters or conveyance systems leading to surface waters. This permit applies for areas greater than one area of which clearing, grading, or excavation will occur. These criteria applies to the stormwater facilities being developed for this project.

Bureau Of Development Services (BDS)

BDS oversees the building and development codes within the city of Portland.

Building Permit

Site development permits are required for work such as clearing, grading, and groundwork. Clearing consists of cutting or removal of vegetation, which results in exposing any bare soil. Grading consists of earthwork, excavation, or filling in excess of ten cubic yards. All of these apply to the stormwater facilities being designed for this project.

Bureau Of Environmental Services (BES)

BES regulates environmental quality and pollution control. BES oversees the Stormwater Management Manual, which is the primary source of regulations for stormwater design in Portland. This manual was used for the student design work of the facilities for this project. The mission of BES is to protect public health, water quality, and the environment. Some of BES's federal regulations include the Clean Water Act, National Pollutant Discharge Elimination System, Total Maximum Daily Load, and Safe Drinking Water Act.

Conclusion

In order to meet the regulatory requirements of stormwater management for this portion of the Southwest Corridor Light Rail Transit (SWC) Project, ALBA Consulting considered the use of both pollution reduction planters and a detention pond. The water that falls on the newly developed Barbur Boulevard would flow into planters placed adjacent to the road on both sides of the boulevard. These planters would allow the project to meet water quality standards for storm runoff and would help slowpeak flows by storing some storm runoff within the rock storage layer below the planter. The majority of the flow control would be achieved through the use of a detention pond designed to detain the 25-year storm with overflow for the 100-year storm event, which would subsequently discharge the stormwater at pre-development flow rates to meet environmental regulations. The pond could contribute to pollution reduction through settling of particulates using an underdrain with a compost layer above it to filter water prior to discharge. By keeping all facility designs as surface facilities rather than underground options, the construction and maintenance costs could be greatly reduced. To increase the community value, the pond and all planters could be planted to contribute to overall greenspace and neighborhood aesthetic.

ALBA considerations were selected not only for performance but also for ease and cost of maintenance, in addition to aesthetic appeal. This design report is intended to be a preliminary analysis/design package of student considerations as part of a Capstone exercise focused on TriMet's SWC project. The location of the pond was done based on preliminary analysis of our site and potential locations that would become available during the routine acquisition process of the land for this project. Due to the fact that the area of this project has significant slopes, which provides difficulties in choosing a location for a detention facility, ALBA did not determine a specific alignment choice for the SWC project, and rather used the example of one potential alignment. Based on our assumptions, the preliminary cost for this project would be an estimated \$2.3 Million and the estimated time to complete the project is approximately six months.

To progress the project to the next steps, ALBA acknowledged that various agencies would be consulted on the final design. A geotechnical engineering consultant could be brought in to conduct infiltration testing and to test for slope stability in the potential detention pond locations. With more accurate infiltration rates, more accurate runoff rates can be calculated, and the number of planters needed may be reduced. If that is the case, our current design can still be used to attain a pollution reduction credit for other parts of the SWC project. Furthermore, City Planners could make sure that the location of the stormwater facilities are acceptable.

And, regulating agencies like BES, DEQ, and ODOT could be consulted throughout the design and implementation process to ensure regulatory requirements are met. Hypothetically, once the project met final design standard, a landscape architect could be brought in to assist with everything from plant selection to the detention pond in order to meet compliance for planting standards in stormwater facilities.

Appendices

A. Construction Cost Estimate

A construction cost estimate is provided in this appendix section. Only the materials cost is shown in the estimate.

PRELIMINARY COST ESTIMATE

Project: TriMet SW Barbur Blvd Stormwater
Group: 16

Prepared By: AA, AS
Date Prepared: 5/18/18
Checked By: BG
Date Checked: 6/4/18

Material Description	Qty	Units	Cost		Source/Notes
			\$/Unit	Total	
PLANTERS					
Stormwater Planters & Plants	17,102	SQFT	\$ 109.00	\$ 684,080	Cost per TriMet. Planter cost including walls, soil, and plants
SUBTOTAL				\$ 684,080	
POND					
General Excavation	3,578	CUYD	\$ 50.00	\$ 178,889	Item No. 0105000K. Estimate of volume using area from drawings, and excavation depth of 6 ft (4 ft plus 18 in media plus 6 in freeboard)
Stormwater Plantings	16,100	SQFT	\$ 20.00	\$ 322,000	Area of triangle (approx.) for potential pond location 1 from drawing
Manhole - Water Quality Concrete	1	PER ITEM	\$ 12,410.00	\$ 12,410	Item No. 0110000E. Need one treatment/detention manhole for pond
SUBTOTAL				\$ 513,299	
CONVEYANCE					
Piping - 8 in PVC	11,120	FOOT	\$ 90.00	\$ 1,008,000	Piping along both sides length of roadway for connecting planters to pond. Piping for 8 inch PVC.
Manhole - Concrete	12	PER ITEM	\$ 4,582.00	\$ 54,984	Item No. 110048AE. Manholes required every 500 ft along roadway, rounded to highest integer
Trench	2,489	CUYD	\$ 25.50	\$ 62,222	Item No. 1101000K. Assumed 2 foot wide, 3 foot deep trench required to lay the pipe
SUBTOTAL				\$ 1,125,206	
TOTAL				\$ 2,322,585	
Contingency	10%			\$ 232,300	
Total				\$ 2,554,885	

Notes:

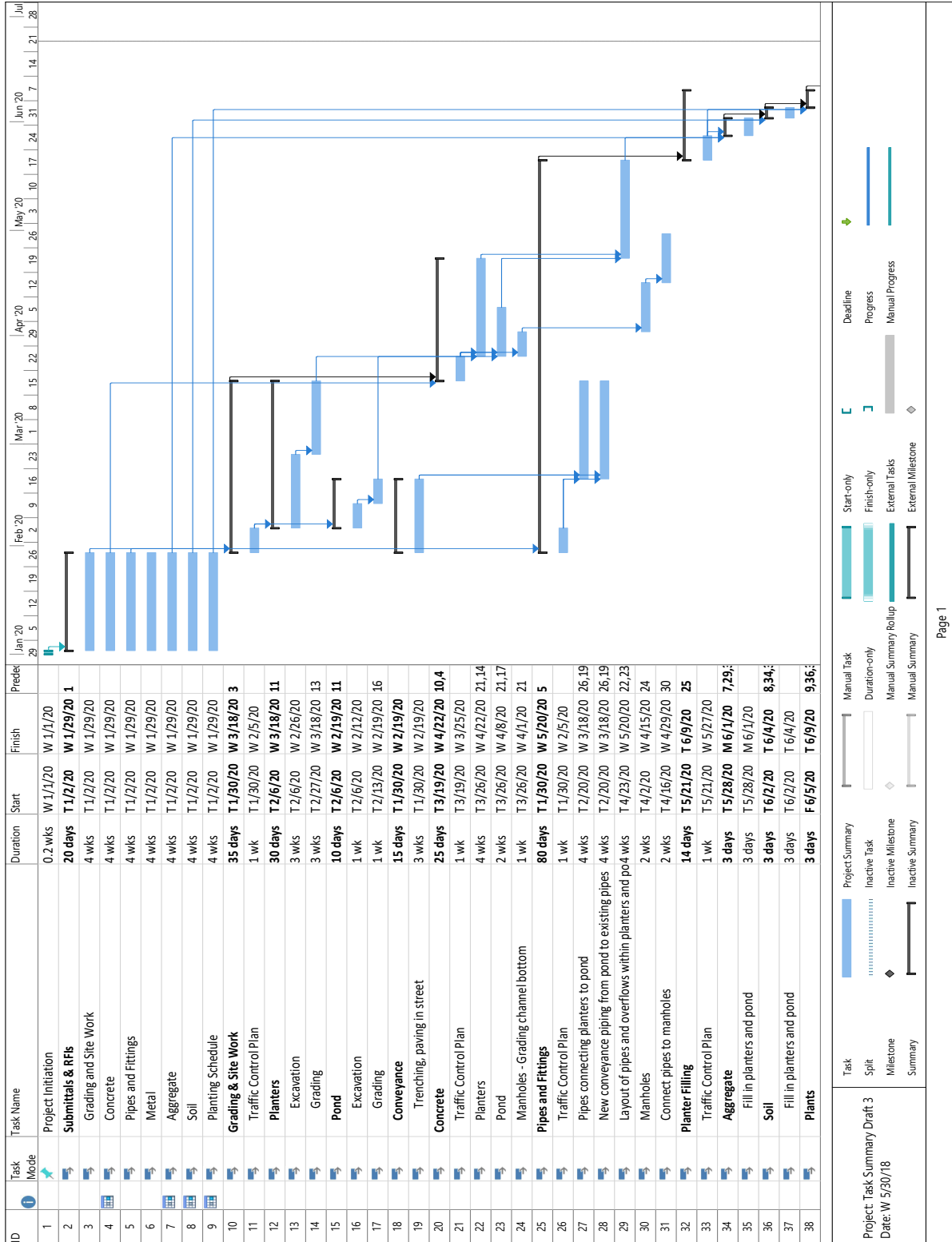
*All unit prices include labor

*All cost data from PBOT (COP) estimate template (2018) unless noted otherwise

*Only cost of one pond included - more will be needed for water quantity

B. Construction Schedule

A construction schedule is shown in Gantt chart format in this appendix section. Microsoft Project was used to create the schedule.



C. Drawings

The drawings referenced in the project are shown in this appendix section.

PORTLAND STATE UNIVERSITY CAPSTONE 2018
ALBA CONSULTING (GROUP 16)
TRIMET SW BARBUR BLVD STORMWATER
MULTNOMAH COUNTY - OREGON

PORTLAND STATE UNIVERSITY
 2018 CIVIL AND ENVIRONMENTAL
 ENGINEERING CAPSTONE
Portland State
 UNIVERSITY

CLIENT: TRIMET

VICINITY MAP
SCALE: NO SCALE

PROJECT LOCATION
SCALE: NO SCALE

ABBREVIATIONS:

- NB - NORTHBOUND
- SB - SOUTHBOUND
- S.F. - SIDEWALK FOOT
- L.F. - LINEAR FOOT

SHEET #	DRAWING #	SHEET TITLE
1	G-01	TITLE SHEET, PROJECT LOCATION, & SHEET INDEX
2	G-02	DEVELOPMENT AREA PLAN
3	G-03	BARBUR BLVD ELEVATION 1 OF 2
4	G-04	BARBUR BLVD ELEVATION 2 OF 2
5	G-01	CONFORMANCE AND FACILITY LAYOUT SECTION 1
6	G-02	CONFORMANCE AND FACILITY LAYOUT SECTION 2
7	G-03	CONFORMANCE AND FACILITY LAYOUT SECTION 3
8	G-04	CONFORMANCE AND FACILITY LAYOUT SECTION 4
9	C-01	POND DRAINAGE AREA PLAN
10	C-02	ROADWAY SECTION
11	C-03	PLANTER DETAILS 1 OF 4
12	C-04	PLANTER DETAILS 2 OF 4
13	C-05	PLANTER DETAILS 3 OF 4
14	C-06	PLANTER DETAILS 4 OF 4
15	C-07	POND DETAILS 1 OF 2
16	C-08	POND DETAILS 2 OF 2

PROJECT: TRIMET SW BARBUR BLVD STORMWATER
 DRAWN BY: BG
 CHECKED BY: BG
 DATE: 2/18/18

ALBA Consulting
 PORTLAND STATE UNIVERSITY
 CIVIL AND ENVIRONMENTAL ENGINEERING
 1000 W. UNIVERSITY AVENUE
 PORTLAND, OREGON 97201

PROJECT TITLE: TRIMET SW BARBUR BLVD STORMWATER
 SHEET TITLE: GENERAL TITLE SHEET, PROJECT LOCATION, & SHEET INDEX
 SHEET 1 OF 16
 DATE: 2/18/18
 GROUP: 16

DRAFT
 PROJECT NUMBER: G-01

D. Calculations

All calculations used for the design of this project are shown in this appendix section. Calculations were completed using Microsoft Excel.

CEE Capstone

Design Report Final Calculations

Prepared by AA

Checked by BG

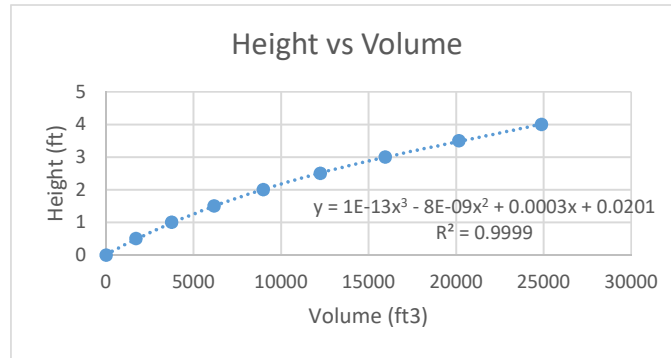
Total Impervious Area		
Given	Value	Notes
Atotal (ft ²)	756994	Found from AutoCAD
Ltotal (ft)	5600	Found from AutoCAD
Lballasted (ft)	5100	Subtract 5 nonballasted intersections at approximately 100 ft each
Wballast (ft)	28	14 feet each direction
Find	Value	Notes
Aballast (ft ²)	142800	Length x width of ballast
Aimpervious (ft ²)	614194	square feet
Aimpervious (ac)	14.1	acres

Pond Impervious Area		
Given	Value	Notes
Atotal (ft ²)	299339	Found from AutoCAD
Ltotal (ft)	2096	Found from AutoCAD
Lballasted (ft)	1996	Subtract 1 nonballasted intersection at approximately 100 ft
Wballast (ft)	28	14 feet each direction
Find	Value	Notes
Aballast (ft ²)	55888	Length x width of ballast
Aimpervious (ft ²)	243451	square feet
Aimpervious (ac)	5.6	acres

Total Impervious Area		
Given	Value	Notes
Atotal (ft2)	756994	Found from AutoCAD
Ltotal (ft)	5600	Found from AutoCAD
Lballasted (ft)	5100	Subtract 5 nonballasted intersections at approximately 100 ft each
Wballast (ft)	28	14 feet each direction
Find	Value	Notes
Aballast (ft2)	142800	Length x width of ballast
Aimpervious (ft2)	614194	square feet
Aimpervious (ac)	14.1	acres

Pond Impervious Area		
Given	Value	Notes
Atotal (ft2)	299339	Found from AutoCAD
Ltotal (ft)	2096	Found from AutoCAD
Lballasted (ft)	1996	Subtract 1 nonballasted intersection at approximately 100 ft
Wballast (ft)	28	14 feet each direction
Find	Value	Notes
Aballast (ft2)	55888	Length x width of ballast
Aimpervious (ft2)	243451	square feet
Aimpervious (ac)	5.6	acres

Pond Design CAD		
Height (ft)	Area (ft ²)	Volume (ft ³)
0	3087	0
0.5	3738	1704
1	4451	3748
1.5	5225	6164
2	6062	8983
2.5	6961	12236
3	7919	15950
3.5	8933	20150
4	10002	24861



$$H = 1E-13x^3 - 8E-09x^2 + 0.0003x + 0.0201$$

Volume Storage Sizing					
	2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	Notes
V pre (ft ³)	30005	39886	49767	59648	From hydrograph
V post (ft ³)	47930	58088	68246	78404	From hydrograph
Vs Reqd (ft ³)	17925	18202	18479	18756	Storage volume = Vpost - Vpre
H Design (ft ³)	3.403	3.433	3.463	3.492	Total water level above bottom of pond using volume as a function of height found from H vs V graph

Orifice Sizing					
Given	2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	Notes
Predev Q (cfs)	0.4685	1.499	2.009	2.446	From hydrograph, 1/2 of 2-year
C	0.9	0.9	0.9	0.9	Assumed value for orifice type
g (ft/s ²)	32.2	32.2	32.2	32.2	
Chosen	2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	Notes
Htotal (ft)	3.403	3.433	3.463	3.492	Water surface elevation (above)
Ho (ft)	0.000	0.000	3.433	3.463	Orifice Height
H2 (ft)	3.403	3.433	3.463	3.492	Water level above 2-yr orifice
H10 (ft)	NA	NA	0.030	0.059	Water level above 10-yr orifice
H25 (ft)	NA	NA	NA	0.029	Water level above 25-yr orifice
D (in)	3	3	5	5	5-year uses same orifice as 2-year
D (ft)	0.250	0.250	0.417	0.417	
Find	2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	Notes
Q (cfs)	0.654	0.657	0.830	1.071	Summation of all orifice flows, need to keep value below predev Q

Pond Pre-Development - Tc		
Sheet	Value	Notes
S	0.032	*Change in elevation per length of flow path from CAD
n	0.600	*mannings roughness for moderate brush forest
L (ft)	300	*Maximum sheet flow path length
Tt (min)	67.104	*Equation 6.12
SCF	Value	Notes
L (ft)	1801	*Longest Flow path delineated from CAD subtracting 300 ft sheet flow
S	0.032	*Change in elevation per length of flow path from CAD
nch	0.050	*Mannings roughness coefficient open channel unpaved
V (ft/s)	2.886	*Equation 6.15 for unpaved surfaces
Tt2 (min)	10.400	*Simplify $t=L/v$ with a conversion to minutes
Total Tc (min)	77.504	*Sum of Tt from two phases
Pond Post-Development - Tc		
Sheet	Value	Notes
S	0.032	*Change in elevation per length of flow path from CAD
n	0.013	*mannings roughness for sheet flow over smooth pavement
L (ft)	300	*maximum sheet flow path length
Tt (min)	3.129	*Equation 6.12
OCF	Value	Notes
S	0.032	*Change in elevation per length of flow path from CAD
nch	0.013	*Mannings roughness for smooth pipe
L (ft)	1501	*Longest Flow path delineated from CAD subtracting 300 ft sheet flow
Q (cfs)	7.000	*Approximate max flow to be conveyed for 25 year 24 hour storm
D (ft)	1.036	*Equation 6.17 rearranged to solve for Diameter (reported value in feet=11.05 in.)
A (ft ²)	0.843	*Using diameter from 6.17 find A using area of a circle
v (ft/s)	8.305	*from A above find v using continuity equation
Tt (min)	3.012	*Simplify $t=L/v$ with conversion to minutes
Total Tc (min)	6.141	*Sum of Tt from two phases

E. QC Checklist

The completed and signed quality control checklist is included in this appendix section.

CEE Capstone

Design Report Final QA/QC Checklist

2018

Group	<i>ALBA Consulting (Group 16)</i>
Project	<i>Trimet SW Barbur Blvd Stormwater (16)</i>

Preparer	Checker	Checklist Item
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	GENERAL
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Proper grammar, spelling, punctuation, etc.
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Single, combined PDF file
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Single, word doc (without appendices)
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Descriptive file name
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Consistent formatting
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Cover Page
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Project Disclaimer
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Acknowledgements
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Table of Contents
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	All sections, subsections listed, with page numbers
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Appendices listed in order (no page numbers)
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	EXECUTIVE SUMMARY
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Concise summary of project and design (not summary of report)
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	1-2 pages long, no figures
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	1.0 PROJECT BACKGROUND
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Short description of project history, location, need/purpose
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Annotated figure showing project location
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	1.1 Existing Site Conditions
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Detailed information regarding location (current uses, topo, etc)
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Site photos
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	1.2 Stakeholders
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	2.0 ALTERNATIVES ANALYSIS
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Introduction
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Detailed description of considered alternatives (figures if relevant)
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Detailed description of selection criteria

F. PAC Calculations

Calculations done through the online City of Portland presumptive approach calculator.

5/5/2018

BES Stormwater PAC | The City of Portland, Oregon

Environmental Services

working for clean rivers

Phone: 503-823-7740 Fax: 503-823-6995 MAILING ADDRESS: 1120 SW 5th Ave, Room 1000, Portland, OR 97204
More Contact Info (<http://www.portlandoregon.gov/bes/article/87768>)

[My Projects](#) > [Project Overview](#) > **Catchment**

Details

Stormwater Presumptive Approach Calculator

Project Name: Test

Permit No.:

Catchment Details

Catchment ID: 1

Catchment Name

SITE SOILS & INFILTRATION TESTING DATA

Infiltration Testing Procedure

Native Soil Infiltration Rate (I_{test})

in/hr

Correction Factor (CF_{test})

in/hr

Design Infiltration Rate for Native Soil (I_{dsgn})

in/hr

Design Infiltration Rate for Imported Growing Medium

in/hr

CATCHMENT INFORMATION

Hierarchy Category

Flow control standards will vary depending on the sensitivity of and distance to the receiving water body. Please describe the disposal point:

- This project directly discharges to a river or Multnomah County Drainage District facilities.
- This project discharges to an overland storm drainage system, such as a stream, drainageway or ditch, either directly or through a storm pipe system.
- None of the above; this project discharges to a storm sewer or drainage system that does not meet either of the above conditions.

https://www.portlandoregon.gov/bes/pac/index.cfm?action=CatchmentDetails&project_id=2484

1/3

G. SBUH Tables and Hydrographs

Tables with calculations for the pond hydrographs.

Pre-Development 25-year, 24-hr Storm		Values to be changed per SBUH			
Given:	Area (ac) = 5.6	Table 6.10			
	P (in) = 3.9	(25-yr, 24-hr. event)			
	dt (min) = 10				
PERVIOUS AREA	Area (ac) = 5.6	CN =	70	Equation 4	
IMPERVIOUS AREA	Area (ac) = 0	CN =	98	S = 4.286	0.2S = 0.857
				S = 0.204	0.2S = 0.041
				Where S = potential maximum natural detention (as defined earlier)	
	Equation 2				
	Tc (min) = 77.5	w =	0.060606		

Column 3	Found from Table 6.12
Column 4	=P*Column3
Column 5	=Column 4 at T+Column 5 at T-1
Column 6	=(Column 5-0.2S(pervious))^2/(Column 5-0.2S(pervious)) if greater than 0, else 0, Equation 3
Column 7	=Column 6 at T-Column 6 at T-1
Column 8	=(Column 5-0.2S(impervious))^2/(Column 5-0.2S(impervious)) if greater than 0, else 0, Equation 3
Column 9	=Column 8 at T-Column 8 at T-1
Column 10	=(Pervious Area/Total Area)*Column 7+(Imervious Area/Total Area)*Column 9
Column 11	=(60.5*Column 10*Total Area)/dt, Equation 5
Column 12	=(Column 12 at T-1)+w*((Column 11 at T-1)+(Column 11 at T)-2*(Column 12 at T-1)), Equation 6

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10	Column 11	Column 12
Time Increment	Time, T (min)	Rainfall Distrib. (fraction)	Incr. Rainfall (in)	Accumul. Rainfall (in)	Pervious		Impervious		Total Runoff (in)	Instant Flowrate (cfs)	Design Flowrate (cfs)
					Accum. Runoff (in)	Incr. Runoff (in)	Accum. Runoff (in)	Incr. Runoff (in)			
1	0	0	0	0	0	0	0	0	0	0	0
2	10	0.004	0.016	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	20	0.004	0.016	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	30	0.004	0.016	0.047	0.000	0.000	0.006	0.006	0.000	0.000	0.000
5	40	0.004	0.016	0.062	0.000	0.000	0.022	0.016	0.000	0.000	0.000
6	50	0.004	0.016	0.078	0.000	0.000	0.037	0.016	0.000	0.000	0.000

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