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Technical Memorandum

Date: February 13, 2009

To: Trinh Truong – King County

From: Alan Black – HNTB

Subject: South Park Bridge Replacement Project
HNTB Job Number 45647-DS-001
Work Element 11.2.4
Low Impact Development/Natural Drainage System Evaluation

This document is intended to establish and document the water quality design effort and requirements pertaining to *green* building concepts and Low Impact development (LID). Included are project specific issues and site constraints relating to the storm drainage design for the South Park Bridge. This memorandum is a follow up to the Eco-Charrette (08-06-2008), Landscape/Artist workshop (09-29-2008), and Value Engineering study.

Information shared during the Eco-Charrette was included in the evaluation and decisions for the implementation of LID methods on this project. The Eco-Charrette (08-06-2008) was a task force established covering a broad range of project disciplines tasked with looking at the entire project, proposed improvements, and immediate vicinity surrounding the site to come up with ideas for green construction techniques. Ideas ranged from recycling/reusing existing materials for the proposed improvements to implementing LID measures for water quality and aesthetic appeal.

The Landscape/Artists workshop was held to explore the integration of art and *green* construction methods with the Stormwater design approach. The focus of the Landscape/Artist workshop (09-29-2008) was to take a closer look at some of the LID methods and explore possibilities to incorporate artistic elements into the design. The feasibility, associated cost, and schedule implications were discussed for water features, lighting features, use of space, texture, colors, plantings, paths, artwork, and other visual aspects of the project.

PROJECT DESCRIPTION

The King County Department of Transportation (KCDOT) proposes to replace the South Park Bridge No. 3179. A new bridge will be constructed adjacent to the existing bridge and the roadway will be regraded to meet the new bridge. Utilities, sewer, water, lighting, and storm drainage will be revised and/or reconstructed to meet new conditions. The existing 77-year-old bridge is located in an industrial area on the Duwamish Waterway, five miles south of downtown Seattle and will be removed. The existing bridge is approximately 1,045 feet long between abutments and the overall length of the project area is 1,340 feet. The roadway consists of four 11-foot-wide lanes and two 5-foot-wide bicycle lanes for a total barrier to barrier (or curb face to curb face) width of 54 feet. With the additional two 6-foot-wide sidewalks on each side of the roadway, the typical impervious surface is approximately 66 feet wide.

As shown in Figure 1, the project area lies south of the industrial Georgetown area of Seattle and the King County International Airport (Boeing Field). It encompasses the roadway corridor defined by 16th Avenue South (between East Marginal Way South and the South Park Bridge) and 14th Avenue South (between the bridge and South Cloverdale Street).

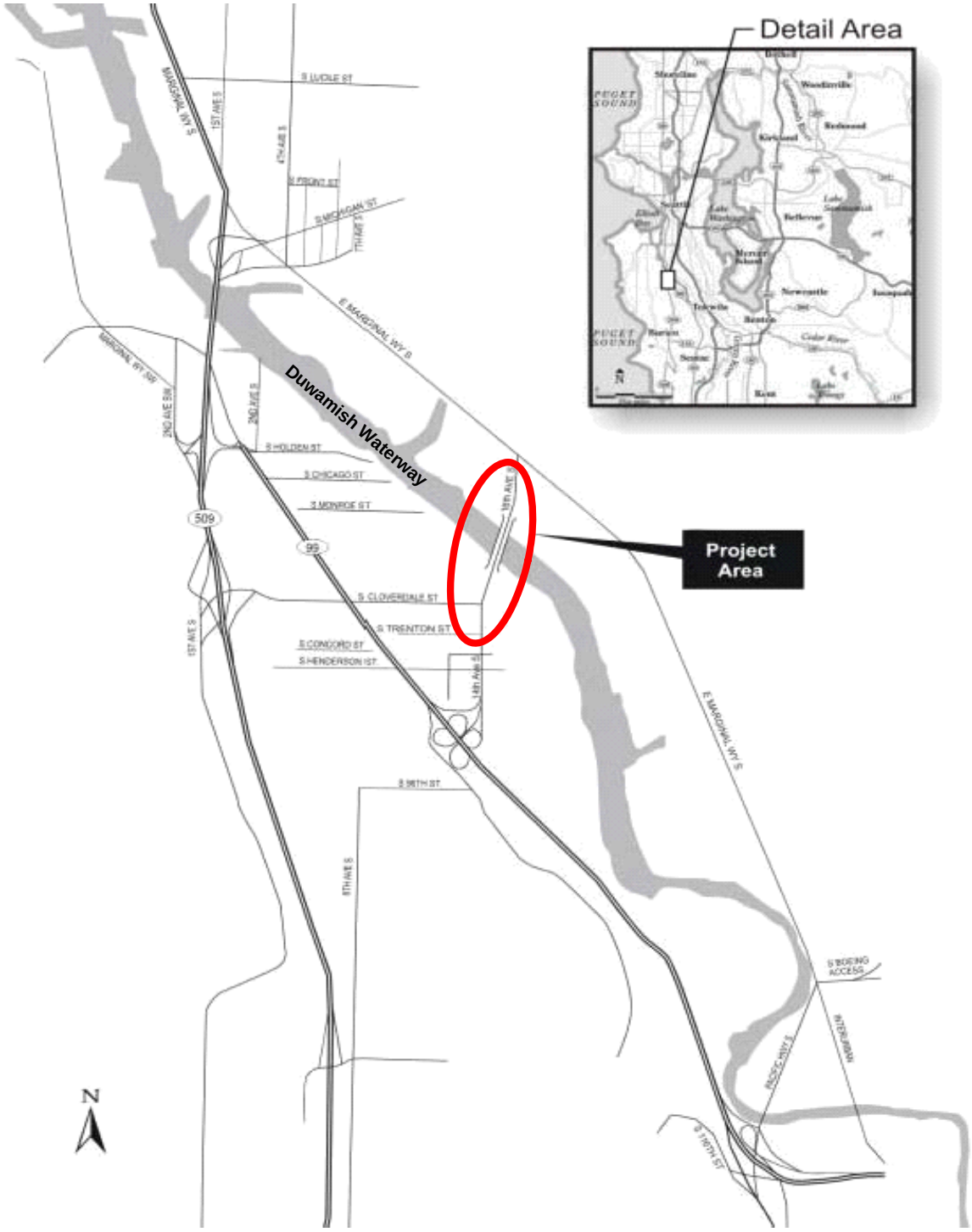


Figure 1 – Project Area Map

The project area is governed by three local jurisdictions. The area north of the Duwamish Waterway (between East Marginal Way South and the waterway) lies within the city limits of both the City of Seattle and the City of Tukwila. The area south of the Duwamish Waterway (between the waterway and S. Cloverdale Street) lies in unincorporated King County and the City

of Seattle. The two-block area between the riverbank and Dallas Avenue South is part of unincorporated King County.

Land uses in the project area are retail, commercial, industrial, and mixed residential. The Boeing Company Plant 2 dominates the north side of the Duwamish Waterway. On the south side, retail commercial and light industrial land fronts 14th Avenue South and the banks of the Duwamish Waterway. Single family residences also exist in the area south of the bridge. The roadway corridor is classified as a Principal Arterial according to the Seattle Arterial Classifications Map (12-11-2003) and serves as a major route connection between SR 99 and East Marginal Way.

SITE CONDITIONS

Soils

Limited geotechnical analysis has been performed for the soils within the project vicinity. The review and of historic data, and soil borings were conducted within the project vicinity to perform alternative analysis and design criteria selection for the preferred bridge replacement method. The geologic report did not address soil drainage characteristics of the project site. As a result, no percolation/infiltration tests were performed within the project vicinity. However, septic systems are being used for sewer treatment in the residential region along the river on the south side of the bridge. Additional soil data can be found in Section 5.2.4 of the South Park Bridge Geology and Soils Technical Report (February 2004). Additional soil will need to be collected to support the drainage design and approach. The Soil Conservation Service did not evaluate the soils within the project vicinity because it was an urbanized area when the study was performed. Data from 1952 (prior to any filling) indicate the soils consist of Puget and Puyallup Series materials containing silty clay loam and fine sandy loam. For the purposes of this analysis, the infiltration rate was assumed to be 120-minutes per inch (0.5-inches per hour). Lacking a site specific/location specific infiltration rate, a conservative value was used based on the 2005 Department of Ecology (DOE) Manual Vol III Section 7.7 Bioretention Areas (rain gardens). The soils surrounding bioretention facilities are a principle design element for determining infiltration capacity, sizing and rain garden type. The planting soil mix placed in the cell or swale is a highly permeable soil mixed thoroughly with compost amendment, and a surface mulch layer. Soil depth should be a minimum of 18 inches to provide acceptable minimum pollutant attenuation and good growing conditions for elected plants. The texture for the soil component of the bioretention soil mix should be a loamy sand (USDA Soil Textural Classification). Clay content for the final soil mix should be less than 5 percent. The final soil mix (including compost and soil) should have a minimum short-term hydraulic conductivity of 1.0 inches/hour per ASTM Designation D 2434 (Standard Test Method for Permeability of Granular Soils) at 80 percent compaction per ASTM Designation D 1557.

North Basin

The north basin is predominantly impervious surface that is either paved roadway or private paved parking and storage areas. Due to the existing off-site commercial business land use, off-site business traffic circulation, off-site storm water quality treatment facilities, and constraints between the proposed improvements and existing right-of-way, the north basin was not selected for implementing LID methods requiring significant surface area. Existing environmental contamination of the subsurface soils is thought to be present in the northern basin based on the soil classifications and reports developed for the Lower Duwamish Superfund Site. The extents or validity of the assumption have not been investigated thoroughly at this time and will be evaluated as the project develops.

South Basin

Stormwater on the south side of the Duwamish Waterway is collected in a system of catch basins that connect directly to the City of Seattle combined sewer system. This sewer system conveys sanitary and stormwater flows to the King County West Point Treatment Plant before discharging to the Puget Sound. The project proposes to reduce some of the flows to the King County West Point Treatment Plant and divert the flows to the natural discharge location in the Duwamish Waterway. Flows will be collected in a storm water conveyance system and treated for water quality in a rain garden and bioswale prior to discharge into the Duwamish Waterway.

Duwamish Waterway

The Duwamish Waterway is the primary water resource affected by the removal and replacement of the South Park Bridge. The Duwamish Waterway is used for industrial, commercial and recreational purposes. The South Park Bridge is within the intertidal zone near the upstream limit of the dredged waterway maintained by the U.S. Army Corps of Engineers. The Duwamish Waterway has been impacted by previous dredging, filling activities, and development along the shoreline. Currently, the waterway consists of a straightened river channel with narrow intertidal mud flats extending to steep middle and upper intertidal shorelines.

Flows in the waterway are influenced by tidal conditions in the Puget Sound and the Green River outlet flows that are regulated by the operation of the Howard Hanson dam. Characterized by wet and dry seasons, discharge from the river varies seasonally. The wet season extends from October 1st to April 30th, and the dry season from August to October. The mean monthly flow rate varies from 400 cfs in August to 2,600 cfs in January. According to FEMA, the maximum regulated flow for the 100-year-recurrence interval is 12,000 cfs at the project site. A flow of this magnitude will result in a tidal elevation in the Duwamish Waterway of 11.84 NAVD88 (South Park Bridge Project Water Resources Technical Report, 2004).

The Duwamish Waterway at the South Park Bridge is within the regulated floodway. Constructed levees and dikes line portions of the waterway. The Boeing plant on the north side of the waterway acts as a levee. The floodway width is 450 feet within the levees on either side of the waterway. The area to the landward side of the levees is not within the regulated floodplain. The bridge approach piers on either side of the waterway are protected from the 100-year flood by the levees. The levees, along with the regulation of flood flows from Howard Hanson dam, have effectively disconnected the historic floodplain area from the river.

The Duwamish Waterway is on the Washington State DOE, Water Quality Assessment 303(d) list of impaired and threatened water bodies for multiple parameters at many sites. At the project site, the waterway exceeds the standards for pH (outside the range of 6.5 to 8.5), and has high temperatures and low Dissolved Oxygen (DO) levels during summer low flow periods and the project site is within the Lower Duwamish River Superfund Site.

Wellhead Protection Areas

There are no sole source aquifer or wellhead protection areas influencing the project site design. The area to the south of the Duwamish Waterway is characterized as having a high susceptibility to groundwater contamination according to the King County Department of Natural Resources. Groundwater in the project area ranges from a depth of 9 feet to 12 feet below the existing surface according to the South Park Bridge Project Geology and Soils Technical Report, 2004 and monitoring well readings in the area from 10/31/2008 to 11/06/2008. The general direction of

groundwater flow is toward the waterway, although the direction may vary locally depending upon the nature of the subsurface material and proximity to the waterway where tidal action can alter groundwater flows.

Project Site

The proposed location of the facility lies over the Previous Duwamish Channel which was likely filled largely with spoils from the dredging of the waterway. Prior to its filling, the abandoned channel was a marsh, with much of the original channel depth already filled by natural processes with organic, fine grained sediments and wood debris. The majority of the fill was likely placed hydraulically, and thus the bulk of the fill is likely to consist of fine to medium sand with variable amounts of silt and layers of silt, sandy silt, and clayey silt to silty clay.

Due to the location of the project, underground soil contamination, river characteristics, existing levees and dikes, available land, right-of-way, local businesses and residences, and the physical constraints for phasing the project construction, the most feasible location for an LID drainage facility is where the existing south bridge approach and abutment will be removed. This area, as shown in Figure 2, is south of the Duwamish Waterway between South Orr Street and Dallas Avenue South, and east of 14th Avenue South to Boat Access Road. Boat Access Road leads to the existing boat ramp on the south side of the South Park Bridge.

The existing project area is approximately 11.59 acres comprising 9.58 acres of impervious area and 2.01 acres of pervious area. The proposed project area is approximately 11.99 acres comprising 9.07 acres of impervious area and 2.92 acres of pervious surface. Both the north and south side of the bridge have been evaluated for roadway geometrics, utility improvements, storm drainage issues, right-of-way, and Temporary Erosion and Sediment Control impacts related to the proposed improvements. Table 1 shows the existing and proposed pervious and impervious areas for the entire project:

Table 1
Existing and Proposed Project Areas (in Acres)

Project Basin	Existing Pervious Area	Existing Impervious Area	Total Existing Area	Proposed Pervious Area	Proposed Impervious Area	Total Proposed Area
North Basin	0.11	5.33	5.44	0.10	5.52	5.62
South Basin	1.90	4.25	6.15	2.82	3.55	6.37
Total Project	2.01	9.58	11.59	2.92	9.07	11.99

Source: HNTB Corporation, 2009

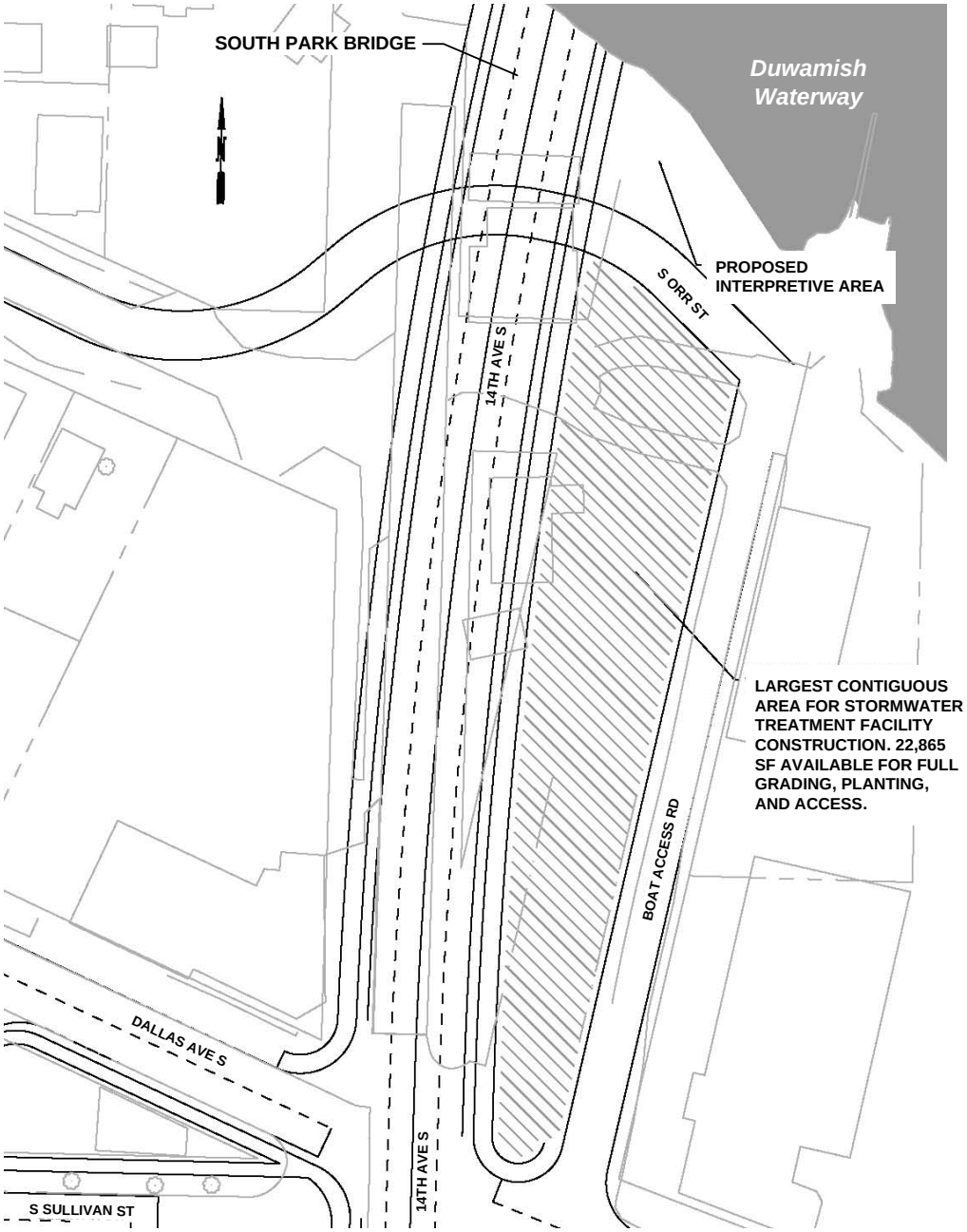


Figure 2 – Potential Drainage Facility Area

WATER QUALITY DESIGN CRITERIA

The design of the water quality facility will follow the design criteria of the King County Surface Water Design Manual 2005 (KCSWDM). The South Park Bridge Project is located within a Basic Water Quality Treatment Area. Although the land use type would indicate that enhanced water quality treatment menu be used for the site, because the project outlets via non-fish bearing, man-made conveyance to the ordinary high water mark of the Duwamish River (which has a mean annual flow of more than 1,000 cfs) the basic water quality menu can be used (KCSWDM section 1.2.8.1). Therefore, basic water quality treatment options were the minimum requirement and the primary focus for treatment of runoff from the project site during the preliminary design

phase. During the intermediate design phase, an Eco-Charrette was to come up with ideas and explore the possibilities to reasonably implement *green* design into the stormwater treatment facilities.

The minimum water quality treatment design event is 60 percent of the developed two-year peak-flow rate. The area needed to treat this design event is the targeted water quality treatment area. The acreage required to meet the targeted water quality treatment area is 1.15. This rate was determined using King County Runoff Time Series (KCRTS) continuous hydrologic model for an area within King County (Sea-Tac model) and hourly time steps for reduced data sampling. The areas used to evaluate the hydrology for the proposed south basin LID treatment totaled 1.88 acres of proposed area impacts comprised of 1.26 acres of pollution generating impervious surface area, 0.27 acres of impervious surface area (assuming impervious standing water in the water quality treatment facility), and 0.35 acres of pervious surface area. Only the southern basin proposed areas were used to determine the two-year peak-flow rate for water quality treatment. The rain garden was sized as an offline facility bypassing the 100-year storm event. The bioswale was designed to convey the 100-year storm event to the conveyance system and ultimate discharge into the Duwamish Waterway.

The large bioswale was designed to convey the 100-year storm event to the conveyance system and ultimate discharge into the Duwamish Waterway (based on a 1.35 acre tributary area). A smaller bioswale was designed to provide additional treatment adjacent to South Orr Street. The small bioswale was designed using a smaller tributary area (0.53 acres), and also allowing the 100-year storm event to pass through the bioswale into the conveyance system for discharge into the Duwamish Waterway.

The wetpond alternative was sized as an offline facility providing treatment for 60% of the 2-year storm event based on a 1.35 acre tributary area and bypassing the 100-year storm event. The wetpond pool depth was minimized due to surface grading impacts, and the close proximity of the pond bottom and the groundwater elevation.

The Stormwater wetland option was designed using the same tributary areas and grading constraints as the wetpond.

Basic Water Quality Treatment

An 80 percent removal of total suspended solids is the treatment goal for Basic Water Quality facilities. Flows in excess of the Water Quality design flow can be routed around the treatment facility or passed through untreated. For this project, the most efficient mechanism for discharging excess flows will be determined as the project develops. For this exercise the assumption is that flows will be allowed to pass though all facilities (except the rain garden) to an emergency overflow drain which will be routed to the new 18 inch outfall. The KCSWDM Basic Water Quality Treatment menu includes biofiltration swales (bioswales), filter strips, wetponds, wet vaults, stormwater treatment wetlands, combined detention/wet pool facilities, and sand filters. Based on the direction from the Eco-Charrette and the Value Engineering Study, the South Park Bridge project is considering Low Impact Development (LID) and/or natural drainage facilities which include, but are not limited to, wet biofiltration swales and rain gardens. These LID facilities have been adopted from the Puget Sound Action Team's *LID Technical Guidance Manual for Puget Sound*, January 2005.

The desired approach is to use a natural bioretention drainage facility to meet water quality treatment requirements. Bioretention facilities are any facility retaining water and treating the water using natural vegetation and organisms through biological processes. The approach for

designing bioretention facilities for this project is to incorporate the facility into the landscaping features adapted to treat stormwater runoff on the project site. Surface runoff is directed through natural meandering or straight shallow ditches or swales into landscaped depressions. These depressions are designed to incorporate many of the pollutant removal mechanisms that operate similarly in forested ecosystems. During storm events less than the 2 year storm, runoff collects in graded depressions and is treated through the natural biological process. Runoff from larger storms is generally diverted past the facility to the storm drain system via internal or external bypass mechanisms (internal has been assumed with the exception of the rain garden). The runoff remaining in the depressions filters through the mulch and prepared soil mix, and typically infiltrates into the soil.

Because the soils in the project area are contaminated, infiltration is not recommended. Infiltration into contaminated soils would cause the contaminants to migrate within the soils and potentially increase contaminant discharge into the Duwamish Waterway. Therefore, all of the facilities utilizing this treatment mechanism may require an impervious liner and perforated pipe collection system to re-collect water that has perked through the treatment mix to prevent infiltration into the underlying soils. The filtered runoff discharged from any bioretention facility would be collected in a perforated underdrain and returned to the storm drain system. A geotechnical investigation may be necessary in the location of the proposed water quality treatment facility to have the soils tested for levels of contamination. Based on these findings, it will be possible to evaluate the extents of contamination. If very little contamination is present, membranes/liners may not be necessary for the water quality treatment facility.

LID/Natural Drainage Facilities

Below are four drainage facility options that would meet the basic water quality requirements and incorporate LID and/or natural drainage systems into the project:

Basic Biofiltration Swale

A biofiltration swale is a long, gently-sloped, vegetated ditch designed to filter pollutants from stormwater. The swales are designed so that water will flow evenly across the entire width of the densely-vegetated area. Swales can be designed for both treatment and conveyance of onsite stormwater flow. The combined use for treatment and conveyance can eliminate the cost of a separate conveyance system.

Biofiltration swales are best applied on relatively small scales of less than five acres of impervious surface. They work well along the side of roadways, driveways, and walkways. Site specific considerations for swale applications are listed below.

- Biofiltration swales should be located in a non-shaded area to promote healthy plant growth. In order to maintain healthy plant growth, the swale must be able to dry between storm events.

- In areas where there are high concentrations of oil and grease, the runoff must first be treated with an oil control facility, preferably as early as possible to prevent the entrainment of the oil molecules. High concentrations of oil and grease can impair the treatment ability of the swale. Oil-water separators are not being proposed as part of the water quality treatment approach. Down-turned elbows are proposed for use in catch

basins up stream of bioretention facilities to limit floatable contaminants from reaching the swales, rain garden, or other type of bioretention facility.

- In situations when the longitudinal slope is 1 to 2 percent or less, water tables are high, or continuous low base flow is likely to result in saturated soil conditions, a wet biofiltration swale can be used.

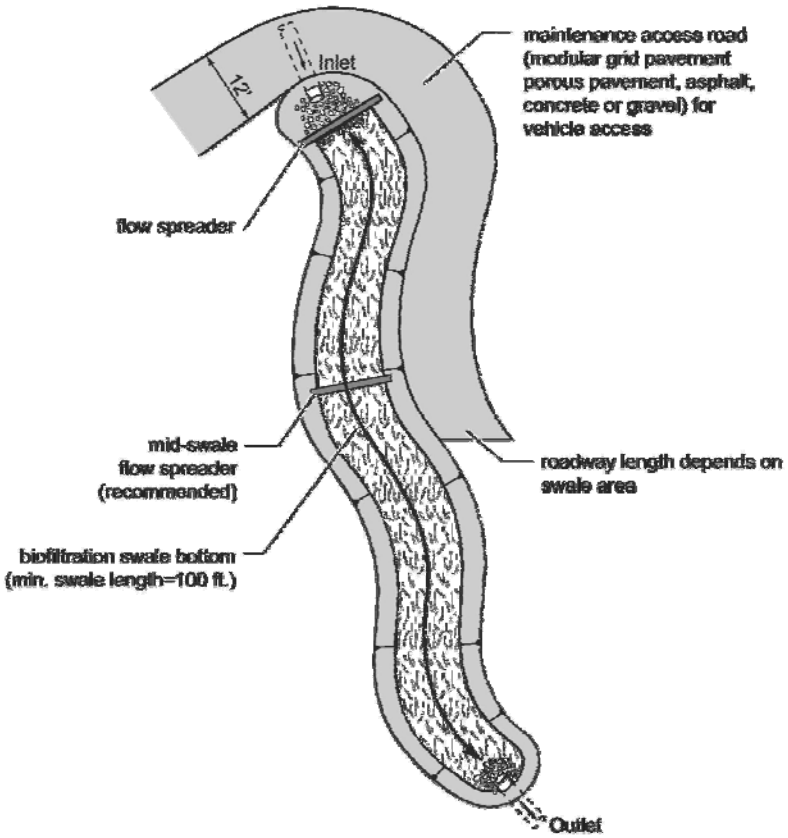
The performance of a biofiltration swale is dependent on several criteria such as:

- Swale geometry
- Design water depth and base flow
- Flow velocity
- Energy dissipation
- Flow spreading
- Underdrains.

Typical swale maintenance includes:

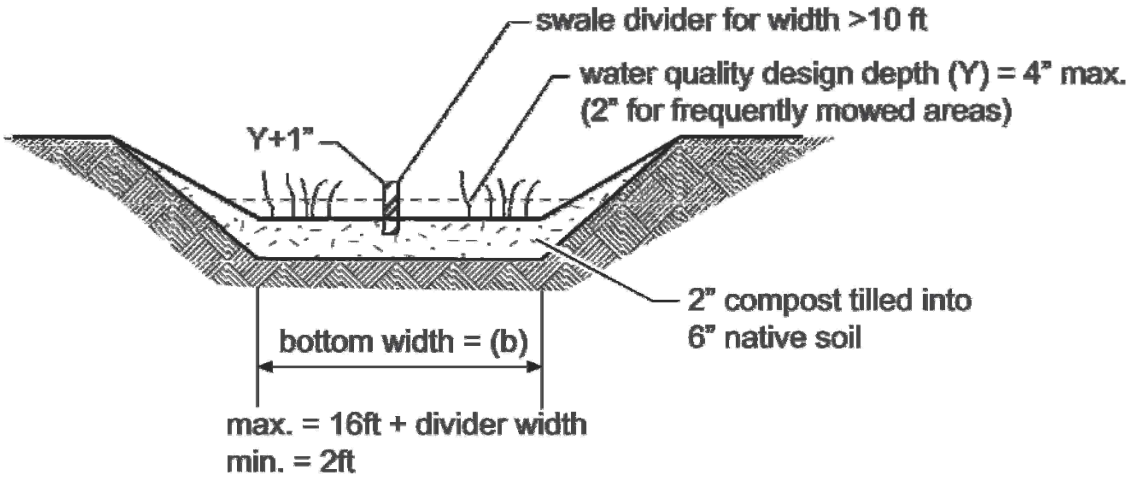
- Routine mowing for water quality design depths of 2 inches or less
- Sediment and debris removal
- Repair of eroded or scoured channel sections

Grass clippings should be removed if the swale is mowed. Sediment buildup should be removed if vegetation growth is being inhibited for more than 10 percent of the swale's length, or if sediment is restricting even flow within the swale. See Figure 3 through Figure 5 for schematics of a biofiltration swale.



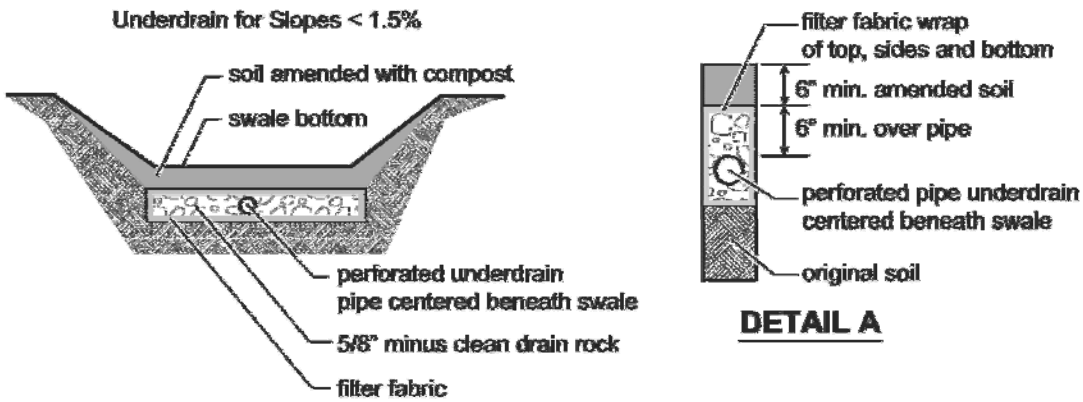
Note: Figure not to scale
Source: KCSWDM 2005

Figure 3 – Plan View of Typical Swale



Note: Figure not to scale
Source: KCSWDM 2005

Figure 4 – Typical Swale Section



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Source: KCSWDM 2005

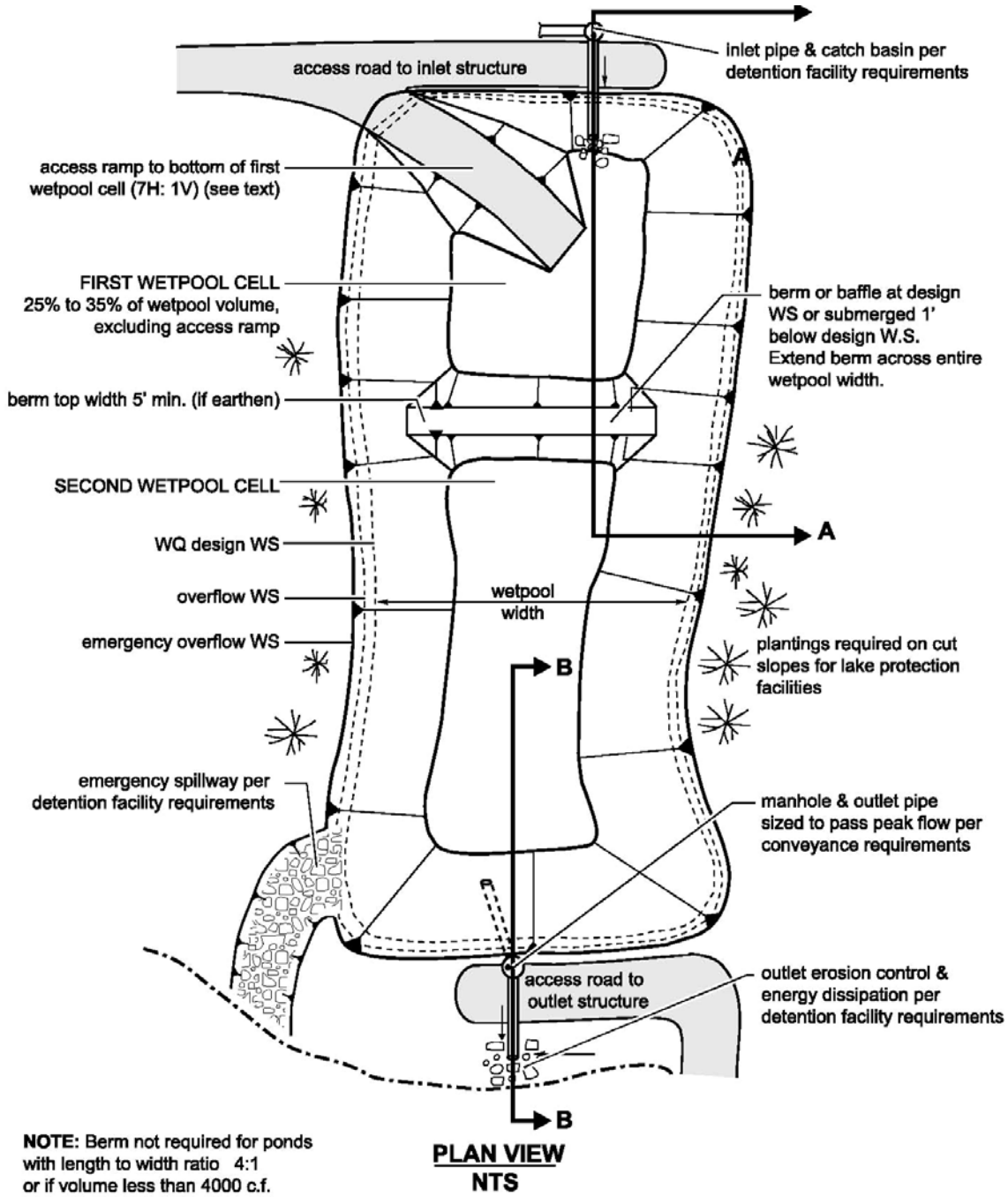
Figure 5 – Swale Underdrain Detail

Wetponds

A wetpond is a constructed stormwater pond that retains a permanent pool (a wetpool) of water (at least during the wet season). The volume of the wetpool establishes the time that particles have to settle and is therefore directly related to the effectiveness of the wetpond facility.

A wetpond requires a larger area than a biofiltration swale, but it can be integrated to the contours of a site fairly easily. In the existing glacial till soils, the wetpond holds a permanent pool of water that could provide an attractive aesthetic feature.

Wetponds treat water both by gravity settling and by biological uptake of algae and microorganisms. Wetponds work best when water already in the pond is displaced entirely by incoming flows. This is called plug flow. Because treatment works on this displacement principle, the detention storage of wetponds cannot be provided below the groundwater level without interfering unduly with treatment effectiveness.



Source: KCSWDM 2005

Figure 6 – Typical Wetpond Layout

A wetpond facility requires annual inspection. Floating debris and accumulated petroleum products should be removed when the sediment is a minimum of one-foot deep. Nearby vegetation should be pruned as necessary to keep the wetpond free of debris and to maintain aesthetic conditions. Areas that have become bare should be revegetated and eroded areas should be regraded prior to planting. Sediment should be removed when the one-foot sediment zone is half full. The removed sediments should be tested for toxicants in compliance with current disposal requirements. Any water drained or pumped from the pond prior to sediment removal

may be discharged into storm drains if it is not excessively turbid and if floating debris and visual petroleum sheens have been removed. See Figure 6 for a typical wetpond layout and additional design criteria.

Rain Gardens

Rain gardens are not an approved King County Surface Water Design Manual basic water quality treatment facility. But within the Puget Sound Partnership LID Manual and the Department of Ecology's(DOE) *Stormwater Management Manual for Western Washington Volume V*, Rain Gardens are an acceptable method to obtain basic water quality treatment. DOE notes that any stormwater runoff that infiltrates though the imported soil mix of the rain garden will have received the equivalent of enhanced treatment.

Rain gardens are shallow landscaped depressions with a designed soil mix, plants adapted to the local climate, and soil moisture conditions that receive stormwater from small contributing areas. The facility is designed to more closely mimic natural conditions where healthy soil structure and vegetation promote the infiltration, storage, and slow release of stormwater flows. Typically, rain gardens are small-scale dispersed facilities that are integrated into the site as landscape amenities. However, they can also be implemented as part of a larger LID approach. Rain gardens may be designed to infiltrate runoff (with an underdrain), and are not considered a conveyance system. See Figure 7 for a cross-section of a rain garden.

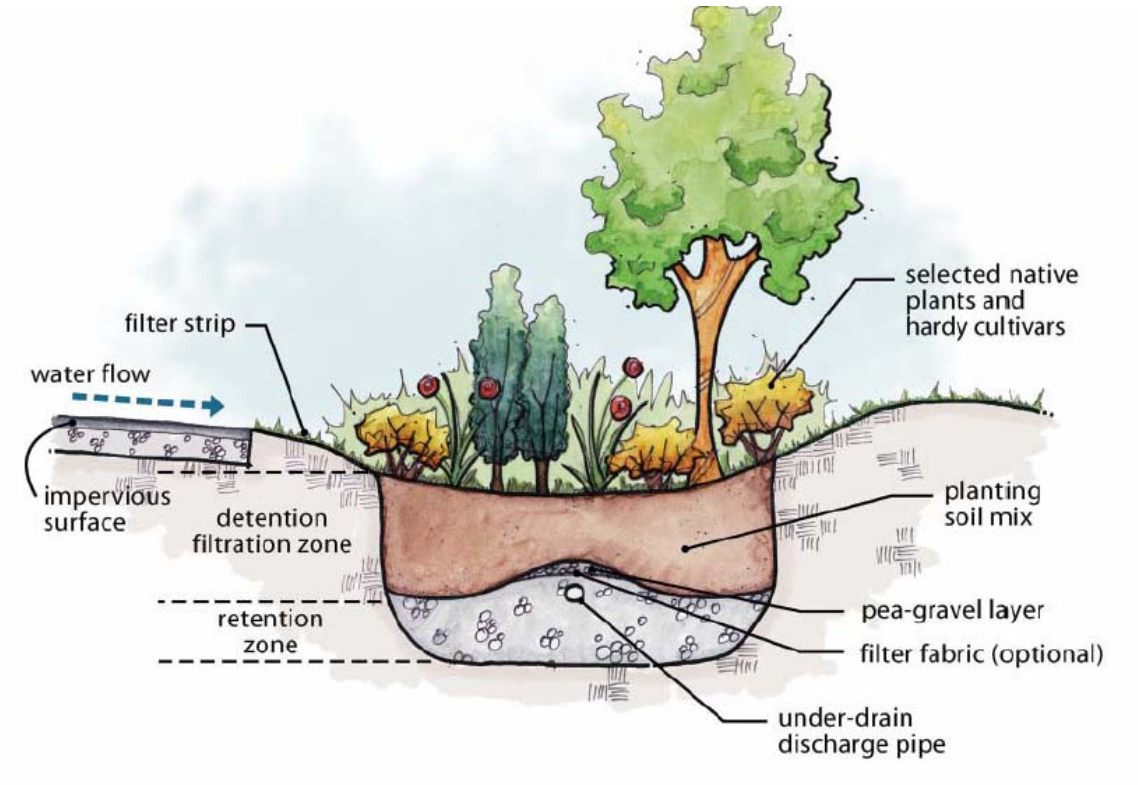
Soil placed in a rain garden must be highly permeable, high in organic matter and surface mulch layer, and have a minimum depth of 18 inches. The plant types are also a critical element of the design. Typically, the soils underlying the rain garden pooling area are a principal design element for determining infiltration capacity, sizing, and rain garden type. For this project, the current proposal is to provide and underdrain collection system and impermeable liner to recapture treated stormwater that has infiltrated through the soil mixture. The impermeable liner is currently proposed as a mechanism to prevent infiltration of water into potentially contaminated soils. The presence and extent of contamination is unknown at this time and our approach is conservative.

The preferred method of delivering flows into a rain garden is to disperse the flow across a landscaped area, but a pipe flow entrance is acceptable as long as erosion protection and a flow spreader is designed to assure flow dispersion.

Maintenance of a rain garden facility includes, but is not limited to:

- Weeding.
- Watering.
- Replacement of dead plant material for a minimum of three years from installation in order to achieve a minimum of 80 percent survival of all plantings.
- Replacement of soil filtration mix.
- Flushing lines free of organic debri.

If additional planting is required to maintain 80 percent coverage, the cause of the plant mortality should be determined and corrected.



Source: LID Technical Guidance Manual for Puget Sound, 2005

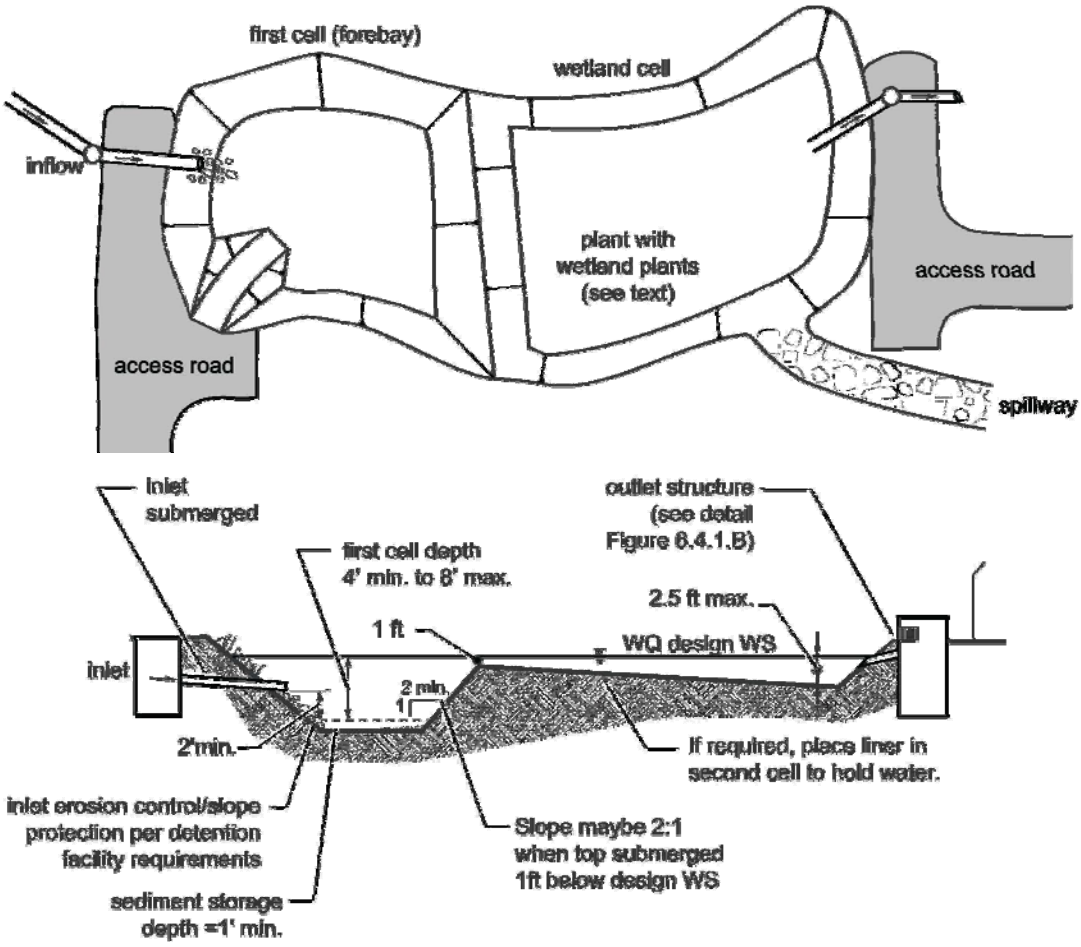
Figure 7 – Rain Garden

Stormwater Treatment Wetlands

Stormwater treatment wetlands provide both basic and enhanced basic water quality treatment. Stormwater treatment wetland facilities consist of two cells. The first is the presettling cell; the second is the wetland cell. The wetland cell includes shallow ponds designed to treat stormwater through the biological processes associated with emergent aquatic plants. See Figure 8 for a wetland layout.

Stormwater treatment wetlands are used to capture pollutants in a managed environment. The most critical factor for a successful wetland design is an adequate supply of water for most of the year. Careful planning in needed to be sure sufficient water will be retained to sustain good wetland plant growth. Stormwater wetlands are a good water quality facility in areas with high winter groundwater levels.

Maintenance of the stormwater treatment wetland is the same as for the wetpond, except for the added responsibility of managing the plantings. Plant maintenance would be similar to the rain garden.



Note: Figures not to scale
Source: KCSWDM 2005

Figure 9 – Typical Wetland Layout and Section

EVALUATION OF LID/NATURAL DRAINAGE FACILITIES

The goal for this project is to implement an LID/natural drainage facility, using Best Management Practices, which is aesthetically pleasing to the residents of the South Park Community and can be incorporated as part of the urban landscape design. A public pathway is proposed along the east side of the bridge from Dallas Avenue South to the proposed interpretive center adjacent to the shoreline. The trail would wind through the facility and could provide the public with information on the LID treatment facility.

Due to their low impact and natural characteristics, each of the options presented in this document were evaluated as LID/natural drainage facility alternatives for the South Park Bridge Replacement Project. Each alternative was configured to fit within the boundaries of the available space shown in Figure 2. This trapezoidal area is long and narrow ranging in width from 36 to 65 feet with an approximate length of 450 feet. The resulting drainage area is approximately 22,865 square feet.

Option 1A - Biofiltration Swale

When designing the biofiltration swale as a primary treatment option for this project, a four-inch water quality design depth was used. This depth was selected to minimize the width of the swale bottom, thus minimizing the required width of the total swale facility. The design slope of the swale was set to 1.2 percent to minimize the elevation change from the top of the swale to the bottom due to the restrictions of the outfall elevation. The design roughness coefficient, Manning's n, was set 0.09 to represent the conditions of the grass and plant lined channel. The resulting swale would have a bottom width of 10 feet and a length of 408 feet. The width of the swale was held under 10 feet to prevent the requirement for a divided channel.

The side slopes of the swale were set at 3:1 (horizontal:vertical). The swale was designed to allow for the 25-year and 100-year peak flows (which are 1.22 cfs and 1.59 cfs respectively) to pass though the swale. The peak flows were based on 1.35 acres of tributary area. One foot of free board was included. This resulted in a total swale area of approximately 7,750 square feet.

With the slope of the swale less than 1.5 percent, an underdrain system must be provided. A separate maintenance road would not be required because maintenance personnel could access the swale facility from Boat Access Road/South Orr Street. Because of the slope of the swale and the outlet invert brackish water would likely enter the facility during a 100-year flood or tidal event, therefore the planting in the facility would have to sustain these conditions. The key advantage of this approach is that it would allow for a significant portion of the available space would be remaining for landscaping and a pedestrian pathway to the proposed interpretive site along the Duwamish Waterway. Unfortunately, this alternative requires a swale length that is very difficult to grade into the available space. This option would require grade boards, channel dividers, and complicated grading to fit in the available area. See Figure 10 for a conceptual layout of the biofiltration swale.

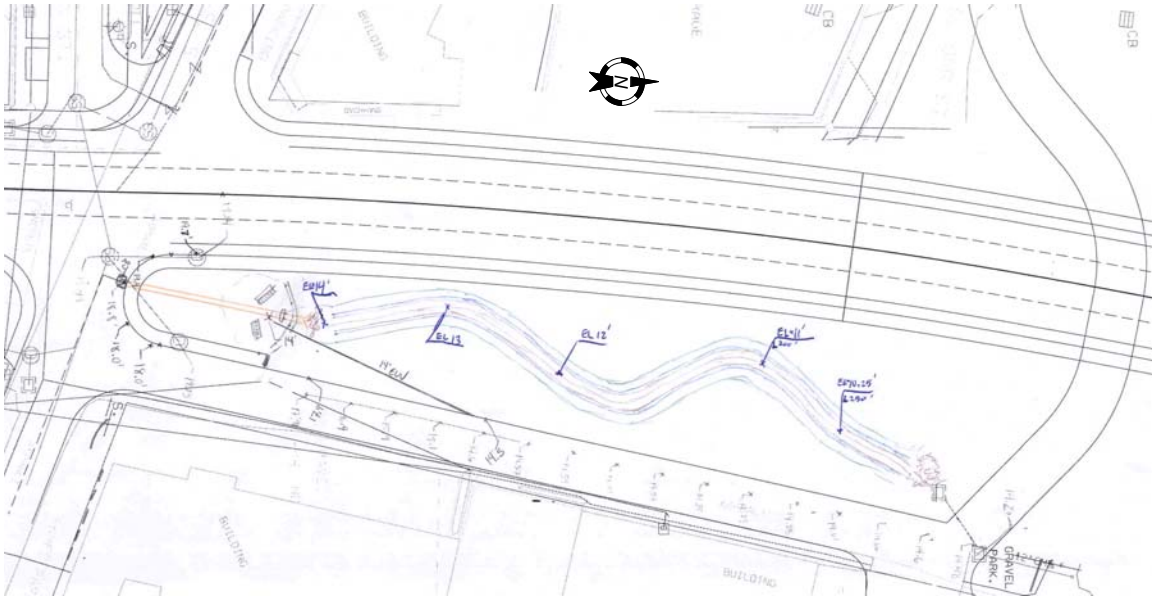


Figure 10 – Conceptual Layout for Biofiltration Swale

Option 1B - Bioswale

Since the bioswale did not fit in the available area when sized as a primery treatment alternative, a smaller bioswale was designed to parallel South Orr Street and supplement the rain garden treatment option. It was sized with the same parameters as the Option 1A biofiltration swale, but does not require underdrains. The bioswale would use the 0.53 acres of tributary area, 1.5% slope, and an 8-foot-wide bottom as grading parameters. The resulting swale would have a bottom width of 8 feet and a length of 220 feet. The small bioswale would work well in combination with the rain garden option.

Option 2 - Wetpond

The characteristics that control the performance of a wetpond facility are:

- The wetpool volume factor (basic wetponds require a factor of 3).
- The runoff volume from the mean annual storm for the developed site conditions.
- The wetpool depth.
- The side slopes of the cell.
- The available area for the wet pool.

The water quality design volume was calculated for the developed site conditions and the depth and plan dimensions were adjusted to meet the available site area.

The volume was based on the runoff volume of the mean annual storm which was calculated to be 2,096 cubic feet based on the 1.356 acres of tributary area. The resulting total wetpool volume would be 6,285 cubic feet, approximately three times the basic calculated volume. The depth of the wetpool was set to five feet (including 1-foot sediment depth) in order to accommodate the length and width restrictions of the available area. The first cell would hold approximately 35 percent of the total volume or 2,095 cubic feet (to the water quality surface). This pre-settling pond was designed with a bottom length of 10-feet and a width of 5-feet. To meet the maintenance access requirement of the facility, the inlet side of the first cell was designed with a side slope of 7H:1V; the remaining side slopes were set to a 3:1 slope. To accommodate for the necessary head water and one foot of free board depth, the length and width dimensions of the pre-settling pond were set to 63-feet long by 44-feet wide (not including a berm or fill slope).

The second cell of the wetpond facility was sized to hold the remainder of the total wetpool volume. The side slopes of all four sides were set to 3H:1V. In order to accommodate the 4,104 cubic foot volume (to the water quality surface), the bottom dimensions of the second cell were set to 48 feet long by 5 feet wide. Adding the head water and free board depth, the length and width of the second pool would be 81-feet long by 44-feet wide. Consequently, the overall dimension of the wetpond facility was determined to be 144 feet long by 44 feet wide, with a total area of 6,336 square feet. The initial concept shows that these cells could be connected by a river rock liner swale added as an aesthetic treatment for the site. As the design progresses, this concept would be developed further through close collaboration with the landscape architect.

This facility (without berms) would encompass roughly 30 percent of the available site and would be smaller than the biofiltration swale. However, berms and fill slopes would make the grading impacts of this option more significant, and the overall impact would be larger than the bioswale. Incorporating landscaping and a pedestrian path would be more difficult, but still possible. An impervious liner may be required for the wetpond configuration due to the grades, storage pool depth and elevation of the groundwater. The liner would prevent water from infiltrating into the

potentially contaminated groundwater aquifer, but also prevent groundwater from re-charging the storage cell.

While berms are not illustrated in the conceptual layout, too effectively construct the wetpond large enough to treat the required volume of water, maintain minimum storage depths, and miss the groundwater, the pond may need to be bermed. Additional grading would be required to construct a minimum 4-foot-wide berm and 2:1 fill slopes. The additional area required to construct the berms will be difficult to grade within the practical space available. Based on the boring data, the groundwater is approximately 9 to 12 feet below existing ground. The wetpond needs to be approximately 6-feet deep to the pond bottom and an additional 2-feet of depth for the bottom pond section material which means the pond section is in direct conflict with high groundwater elevations. The groundwater is influenced by tides which could be in conflict with the bottom of the facility at approximately elevation 6.5 feet. Therefore, this facility might not be feasible for this site. See Figure 11 for a conceptual layout of the Wetpond.

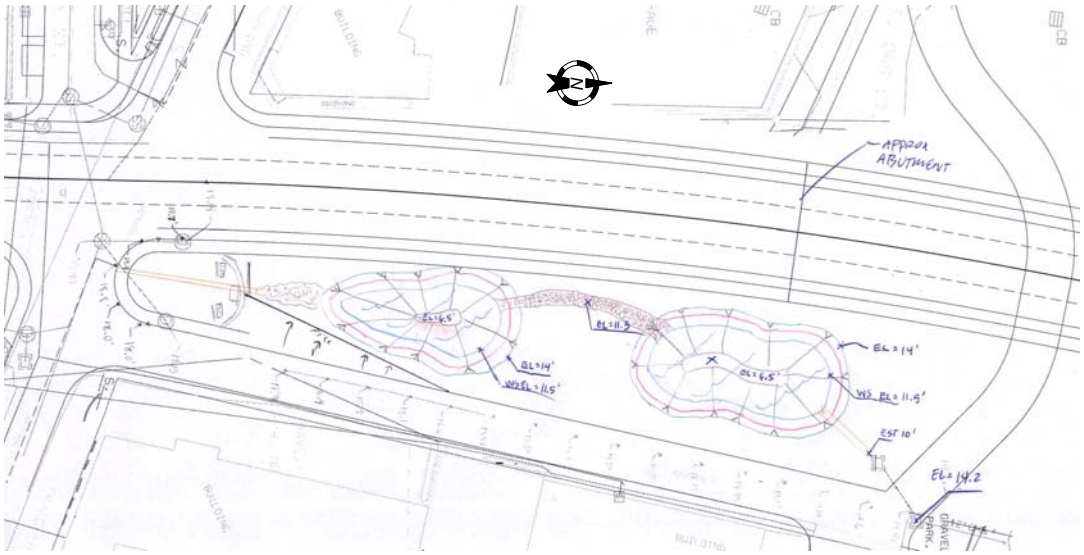


Figure 11 – Conceptual Layout for Wetpond

Option 3 - Rain Garden

To design the rain garden facility, King County Runoff Time Series (KCRTS) was used to model the proposed conditions. The rain garden was modeled as an infiltration pond with the following properties:

- Riser Diameter = 12 inches
- Riser Head = 12 inches
- Vertical Permeability = 120 minutes per inch (0.5-inches per hour infiltration rate)
- Side slope = 3H:1V

This facility has been designed to treat 100% of the 2-year storm event flow rate and infiltrate though the media based on a 1.35 acre tributary area. All larger storms would be allowed to bypass the rain garden and discharge into the waterway. (Please note this exceeds the required 60% of the 2-year storm event volume).

Based on the KCRTS model, the facility would require a bottom area of approximately 5,590-square feet, and a top area of 10,775-square feet (including 1-foot freeboard). The rain garden is sized based on treating 1.35 acres of tributary area and having a temporary water quality storage pool 1-foot deep. While the area is approximately two times larger than the wetpond and 1.4 times larger than the size of the bioswale, the depth of the facility is relatively shallow and does not have deep construction impacts adjacent to the walls and roadway. This alternative also treats 100 percent of the 2-year storm event that none of the other options provide. The available area left for landscaping and pedestrian path would be greater than the wetpond facility. Please note this is somewhat larger and more conservative an approach than modeling the rain garden as a basic sand filter using the KCSWDM.

The rain garden was quickly evaluated as an online facility to determine if an online design was feasible. The rain garden treatment method relies on infiltration for full treatment. As a result, the larger the bottom media surface area is, the more volume can be treated, and the faster an infiltration facility can function without having a large storage pool depth. The idea is to minimize the storage pool depth, maximize the media infiltration surface area, and reduce the depth impacts for design and construction. Online rain gardens are required to pass the 100-year storm event. Due to site and grading constraints between the roadway, walls, earthquake drains, walking path, and surface grades, the rain garden could not be very large. This required the typical water quality storage pool depth to be 1-foot during the 2-year storm event. The rain garden will have 1-foot of storage depth, 1-foot of freeboard, and 1.5 feet of media bed. To effectively pass the 100-year event, the rain garden needed to be much deeper and have slope stabilization measures to reduce flow velocities. Consequently, the rain garden depth would be close to the depth required for a traditional pond or wetland treatment pond.

To reduce the facility depth, and grading impacts, the rain garden was designed as an offline facility allowing all storm event water to bypass through the facility. An emergency overflow mechanism (pipe or weir outfall) would be required to allow additional emergency outlet capacity even though the water entering the rain garden would be restricted with an orifice or weir control structure. All flows greater than the 2-year event would be conveyed directly to the 18-inch outfall.

If the rain garden were to be selected and constructed over contaminated soils, it might require an impervious liner and underdrain system beneath the planting soil mix to prevent infiltration of water into the contaminated soil zone. Further soils exploration may be necessary in the immediate vicinity of a water quality treatment facility to determine if infiltration would be an acceptable approach and not have an adverse affect on potentially existing contamination. The rain garden infiltration capabilities will depend on the type of contamination, extents of contamination, and the volume of infiltrated water. The soil mix is required to meet or exceed a 0.5-inch-per-hour infiltration rate (used for designed hydraulic model). Should a mix be selected that could not achieve a 0.5-inch-per-hour percolation rate, the facility would need to be re-modeled and re-sized.

Rain gardens with liners have more rigorous planting restrictions because large root systems cannot penetrate the liner. The minimum planting depth of a typical rain garden is 18 inches. Non-deep rooting plants may be selected should the liner prove to be necessary during further design analysis. The depth is required to be a minimum of 3 feet above the elevation of the underdrain layer and the seasonal high groundwater elevation or other impermeable layer. Furthermore, a tideflex valve may need to be installed to prevent ocean/river water from backing up into the underdrain system during a 100-year flood and/or tidal event. A level spreader (not shown in Figure 12) or rock energy dissipater would need to be designed to reduce the

concentrated flows from the pipe conveyance system at the upstream end of the rain garden. See Figure 12 for a conceptual layout of the rain garden.

Figure 12 – Conceptual Layout of Rain Garden

Option 4 - Stormwater Treatment Wetland

The stormwater treatment wetland was sized in the same way as the wetpond, except the second cell was designed to sustain emergent aquatic vegetation. This was done by setting the maximum depth of the second cell to 2.5 feet and maintaining an average depth of 1.5 feet (plus or minus 3 inches). The first cell of the stormwater treatment wetland would have the same surface area and dimensions as the first cell of the wetpond: 63 feet long and 44 feet wide for a total of 2,775 square feet and a volume of 2,095 cubic feet (to the water quality surface). The resulting surface area of the wetland cell would be approximately 760 square feet. In order to fit the wetland within the limits of the available area of the project site, the width was set to 44-feet resulting in a wetland length of 17 feet. Therefore, the overall dimensions of the stormwater treatment wetland facility would be approximately 80 feet long by 44 feet wide (or 3,520 square feet). The surface impacts would be relatively small for this option. However, the wetland wetpond would require significant grading depth and potential conflicts with the groundwater as well as continuous water for the wetland plants. The tributary area may not be able to provide sustained drainage flows during summer months and a supplemental irrigation system may be required.

As mentioned above, this type of facility works best in a wet environment especially where groundwater is high. This facility could be impacted by the high groundwater during the rise in tide. The possibility of contamination from the existing soil would require the wetland to be lined with an impervious liner. Similar to the wetpond option, the bottom of the facility would be located at an elevation of 6.5 feet; therefore, this option might not be feasible for this site.

The size of a stormwater treatment wetland facility would be smaller than a wetpool, rain garden, or biofiltration swale so that landscaping and a pedestrian path could be incorporated within the available area. See Figure 13 for a conceptual layout of the stormwater treatment wetland.

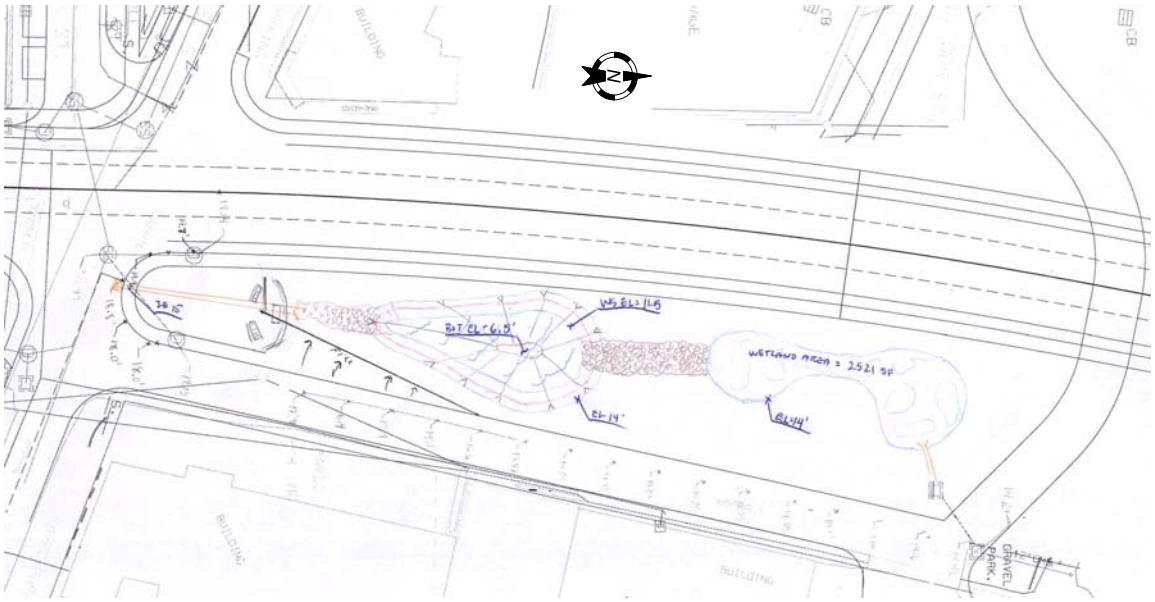


Figure 13 – Conceptual Layout for Stormwater Treatment Wetland

FACILITY COMPARISONS

Table 2 provides a comparison of the water quality alternatives. This table summarizes the findings and characteristics of the evaluated facilities based on an available area for LID water quality treatment of 22,865 square feet. The cost ranking of each alternative includes consideration of both the construction and maintenance costs. The maintenance requirements were previously described in the design criteria section for each of the facility options and were ranked based upon the necessary equipment and time required to maintain the facility. Finally, the aesthetic capabilities of each facility were considered. Aesthetic capabilities were based on how well the facility could be integrated into a pedestrian friendly landscape. See Attachment B for grading parameters pertaining to each alternative and Attachment C for typical sections.

Table 2 – Evaluation of Facility Alternatives

Facility	Cost	Maintenance Requirements	Facility Area (sf)	% of Total Area	Treatment Capacity	Aesthetic Capabilities
Swale	Low	Low	7,750	34%	60% of the 2-year event	High (w/ additional planting)
Wetpond	Medium	Medium	6,336	28%	At least 60% of the 2-year event	Low
Rain Garden	High	Medium/High	10,775	47%	100% of the 2-year event	High
Stormwater Wetland	High	High	3,520	15%	At least 60% of the 2-year event	High

Source: HNTB Corporation, 2008

Only a portion of the project area can be used to implement LID options. All of the proposed treatment options are within the south basin. No LID improvements are proposed in the north basin. The areas used for sizing the LID options in the south basin are shown in Table 3. The water quality rain garden surface area that is quantified as impervious surface assumes one foot of standing water in the facility.

Table 3
South Basin LID Option Areas (in Acres)

Treatment Option	Proposed Pervious Area	Proposed Impervious Area	Total Treated Area	Treated PGIS Area	Comments
Option 1A Biofiltration Swale		1.35	1.35	1.35	Biofiltration swale as the primary water quality treatment method.
Option 1B Orr Street Bioswale	0.35	0.18	0.53	0.18	The bioswale would treat 0.18 acres of PGIS and 0.35 acres of pervious surface. The bioswale is included in the pervious area.
Option 2 Wetpond		1.35	1.35	1.27	Wetpond as a primary water quality treatment facility.
Option 3 Rain Garden	0.00	1.35	1.35	1.08	The 0.27 acre rain garden area would be considered impervious when full and accepting 1.08 acres of PGIS. The rain garden exceeds the targeted treatment threshold when combined with the Orr Street bioswale.
Option 4 Stormwater Treatment Wetlands		1.35	1.35	1.30	
Combined Option 1B & Option 3	0.35	1.53	1.88	1.26	The rain garden and bioswale would treat an additional 0.27 acres impervious and 0.35 acres of pervious surfaces for the grand total of 1.88 acres.

Note: PGIS – Pollution generating impervious surface
Source: HNTB Corporation, 2009

SUMMARY AND RECOMMENDATIONS

The wetpond alternative (Option 2) provides approximately the same treatment for pollution generating surfaces as the combined rain garden and small bioswale (Combined Option 1B and 3). The wetpond would be medium in cost because of the necessary excavation to construct and maintain it. It would require the largest amount of area thus limiting the available area to incorporate planting and a pedestrian trail to the proposed interpretive center. This facility could also be affected by high groundwater as a result of tidal fluctuations. The wetpond would require a significant permanent storage pool depth, and a long quarry spall access road to provide maintenance. Due to the site constraints, an off-street parking, and hammer-head turn-around would be required for maintenance access and area may not be feasible. Maintenance would need to be performed from Boat Access Road and would require a gate to prevent non-authorized vehicles from having access.

Based only on the amount of pollution generating impervious surface the stormwater wetland (Option 4) can treat, this would be a very good alternative. However, the stormwater treatment wetland would be a costly alternative because it would require a similar amount of excavation for constructing the facility as the wetpond, as well as be time consuming to meet maintenance requirements. The facility is deep on one end, requires an access road, access gate, and would be difficult to grade around the earthquake drains within the available area. The analysis does not take into account necessary berms and fill slopes that may need to be constructed to grade out this option. But this option does provide the aesthetic and natural feeling that is desired for the project. There is potential that the wetland plants would not receive enough water to survive and would need to be supplemented with an irrigation system. In addition, the bottom of the pond could be affected by high groundwater due to tidal fluctuations.

While the rain garden alone (Option 3) does not provide treatment for the most pollution generating impervious surface, it does provide excellent treatment when combined with a small swale (Combined Option 1B and Option 3). The rain garden would also be an expensive alternative because of the extra excavation during construction, the volume of the planting soil mixture and the extensive maintenance requirements. While it would provide an aesthetically park-like environment, the size required to treat the runoff flows for such a facility is large, which will decrease the area to plant without restrictions. The biggest benefit for this type of facility, is it can be designed and constructed as a fairly shallow facility with small pools of water that slowly infiltrate or evaporate. The shallow depth and temporary storage pool makes it ideal for grading and incorporating with other project deign elements.

The biofiltration swale (Option 1A) cannot be used for a primary treatment option without significant engineered solutions to divide the swale to increase the residence time and allow for the required length to fit within the available space. Grade boards, channel dividers, and grading challenges make this alternative unpractical.

A smaller bioswale is a much better option for water quality treatment facility when it is reduced in size (Option 1B) and constructed in conjunction with another more viable option (Combined Option 1B and Option 3). The small bioswale would be relatively cost-effective to construct in comparison to the above referenced alternatives since it does not require a divided section and a lot of meandering to achieve length and slope requirements. The maintenance requirements would be minimized by planting vegetation that requires minimal mowing. Most significantly, the swale's flexible geometry and wide dimension would allow it to be incorporated into a park-like environment. A sketch of the Option 1A alternative by the landscape architect is attached as part of this document to show the aesthetically pleasing aspects of the bioswale alternatives (see Attachment A).

The preferred water quality treatment facility approach to this project is to combine a small bioswale (Option 1B) with the larger rain garden alternative (Option 3) and create a diverse and interesting facility maximizing the treatment capacity as well as optimizing the aesthetic qualities of the alternatives. The bioswale and rain garden do not requires deep water quality facilities making it easier to grade into the available area, avoid conflict with the earthquake drains, and provide easier maintenance access..

ATTACHMENT A

Landscape Architect's sketch showing a natural concept incorporating a swale.

ATTACHMENT B

Design Results for LID Facilities

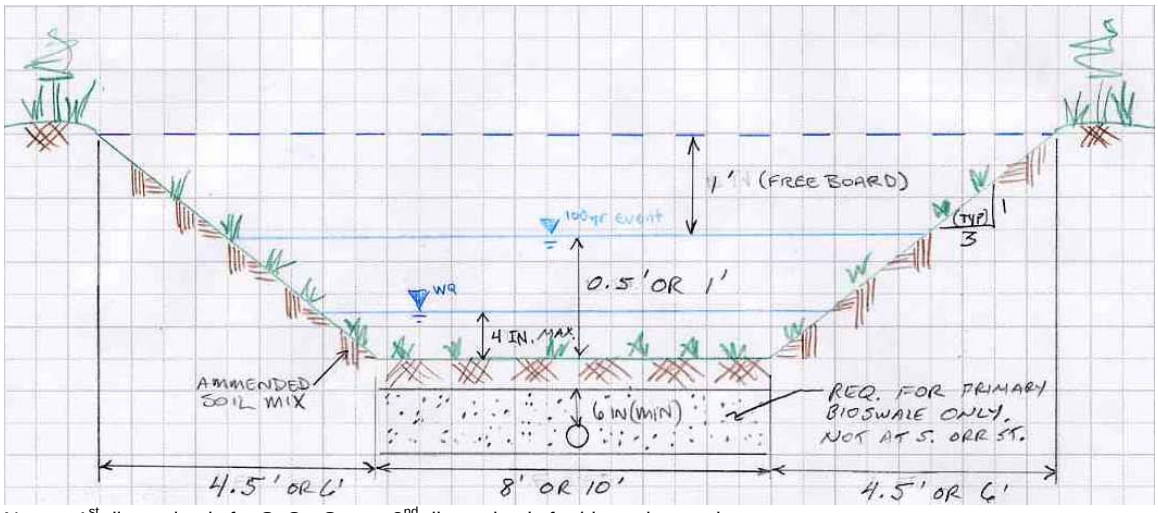
	Option 1A	Option 1B	Option 2	Option 3	Option 4
Type of Facility	Biofiltration Swale	Bioswale at S. Orr Street	Wetpond[1]	Rain Garden	Storm Treatment Wetland[2]
Bottom Width (ft)	10	8	1st cell: 5 2nd cell: 5	NA	1st cell: 5 2nd cell: 5
Top Width (ft)	19	17	1st cell: 44 2nd cell: 44	NA	1st cell: 44 2nd cell: 44
Length (ft)	408	220	1st cell: B - 10, T - 63 2nd cell: B - 48, T - 81	NA	1st cell: B - 10, T - 63 2nd cell: B - 17, T - 44
Depth (ft)	1.5	1.5	1st cell: 5 2nd cell: 5	1	1st cell: 5 2nd cell: 2.5
Side Slope	3:1	3:1	1st cell: 7:1 (1), 3:1 (3) 2nd cell: 3:1 (4 sides)	3: 1	3:1
Capacity (ft^3)			1st Cell: 2,095 2nd cell: 4,104	8,181	1st Cell: 2,095 2nd cell: 1,870
Surface Area (ft^2)	7,750	3,740	1st Cell: 1,334 2nd cell: 2,117	T:10,774 B: 5,590	1st Cell: 1,334 2nd cell: 748
Free Board (ft)	1	1	1	1	1
Under-drain	Yes	No	No	Yes	No
Slope	1.20%	1.50%		0%	

Note: [1] First cell holds 33% volume. Second cell holds 67% volume. Overall dimension: L=144', W=44', A=6,336 sf
[2] Overall dimension: L=80', W=44', A-3,520 sf

Source: HNTB Corporation, 2009

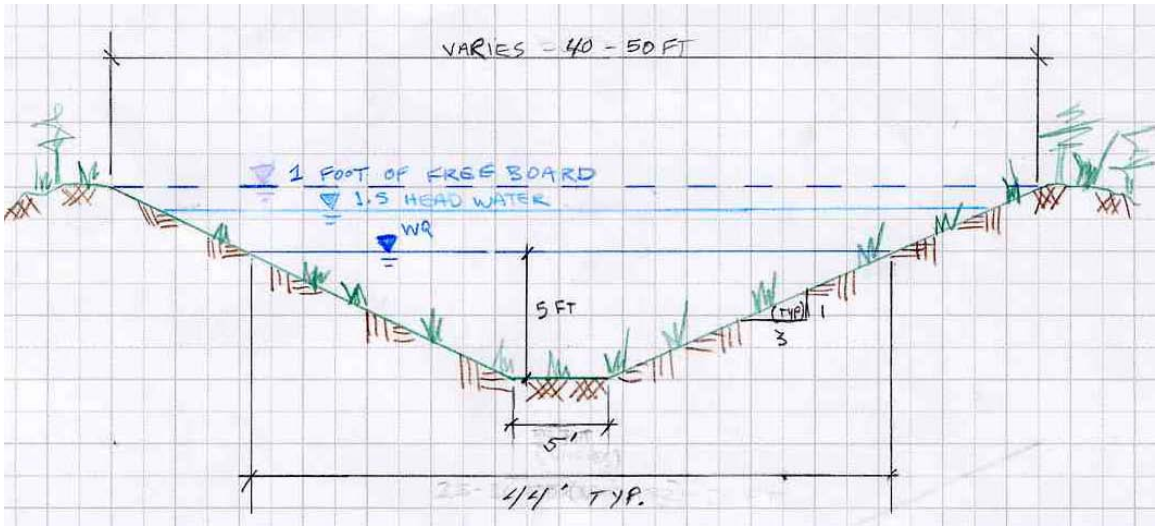
ATTACHMENT C

Typical Sections for All Treatment Facility Options



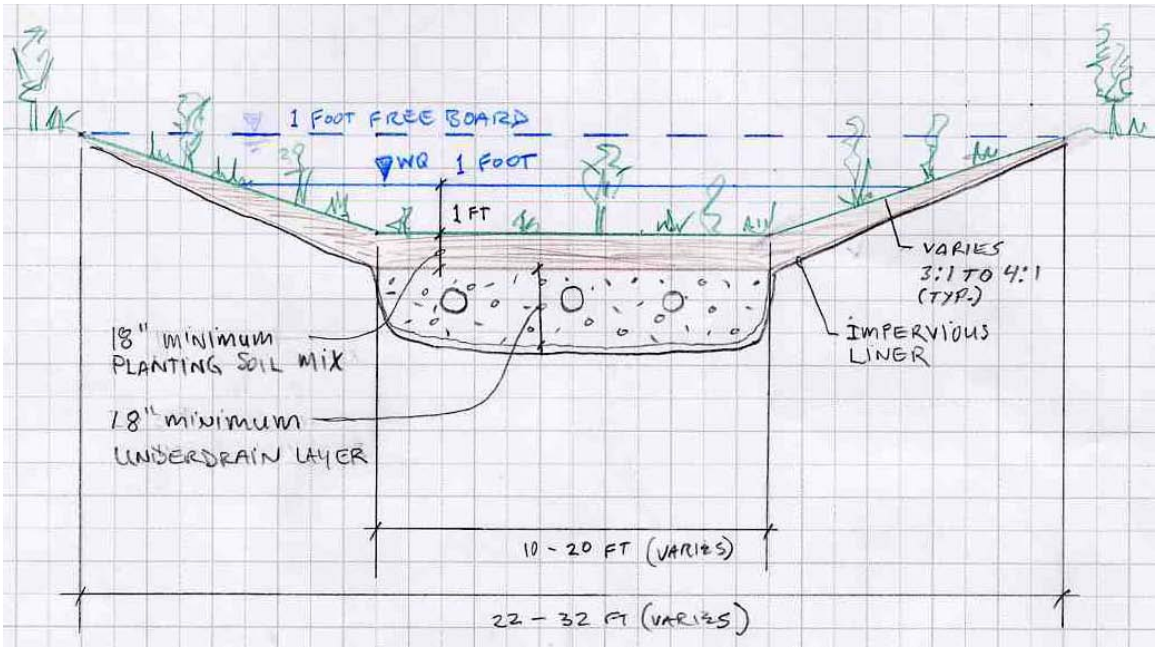
Note: 1st dimension is for S. Orr Street, 2nd dimension is for bioswale as primary treatment
Source: HNTB Corporation, 2009

Swale Cross-Section (NTS)



Source: HNTB Corporation, 2009

Wet Pond Typical Cross-Section (NTS)

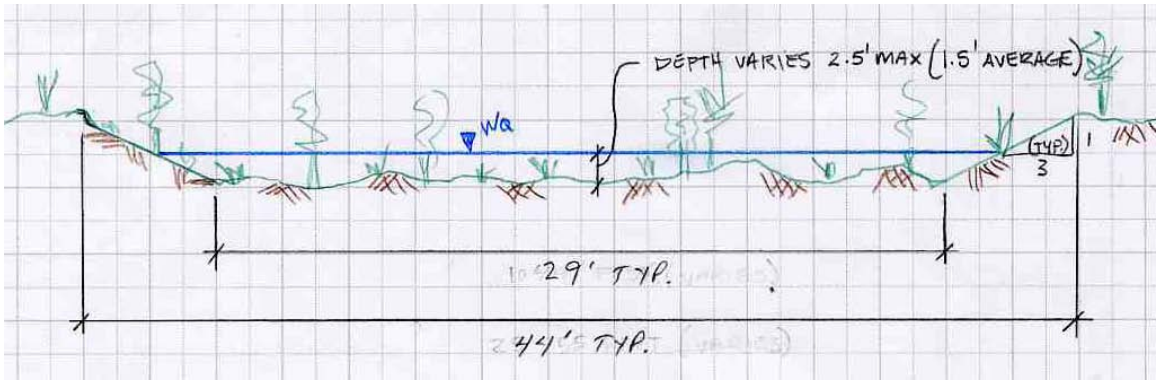


Source: HNTB Corporation, 2009

Rain Garden Typical Cross-Section (NTS)

Source: HNTB Corporation, 2009

PRESETTLING CELL



Source: HNTB Corporation, 2009

WETLAND CELL

Wetland Treatment Facility Cross-Section (NTS)