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1 Executive Summary

The following is the concept design report for the Lafayette RiverSmart Low Impact Development (LID) and Green Infrastructure demonstration project. LID is the use of distributed stormwater Best Management Practices (BMPs) that replicate the predevelopment hydrologic, or water balance, functions on an individual site in response to precipitation. The use of LID to manage stormwater runoff on a watershed or large scale basis is considered to be Green Infrastructure. The purpose of this report is to recommend locations for LID improvements on publically owned lands within the study area that can be constructed within the project budget and time frame. The results of the report will be used as a basis for the development of 30% construction documents and public engagement. The investigation in the 30% design document development will included further field investigations and detailed engineering analysis that will confirm and refine the concept design. The project area was determined from the study and recommendations of an assessment of the potential of the area for Green Infrastructure retrofits that could potentially reduce the volume of runoff that enters the drainage infrastructure (LimnoTech, 2007). Figure 1 is a map of the project area.

The goal of the project is to establish the project area as an LID and Green Infrastructure signature demonstration site for the community. The project objective is to capture and infiltrate runoff that is generated from the 1.2 inch rainfall event over 24 hours within the drainage area through the retrofit of the infrastructure in the public Right-of-Way (ROW) with LID practices that can be used to achieve sustainably and community development goals identified by the District of Columbia. The 1.2 inch rainfall event is significant because it is the design storm volume for meeting the requirements of the Municipal Separate Storm Sewer System (MS4) permit. This event also falls within the 90th percentile of all storm events that occur within a given year. The project will demonstrate a planning, modeling, and design process for LID retrofits within the city. This project will also be used to develop construction details, permit review procedures, and construction techniques that can be used to develop standards, specifications, and details for public sector construction within the ROW.
Figure 1: Project Area Map
The concept plan includes the following key conclusions and recommendations:

Public Right-of-Way. There are significant opportunities for the use of curb bump-outs with bioretention, permeable pavement alleys, tree boxes retrofit with bioretention or permeable pavement, and permeable pavement parking lanes. These features can be used to create LID educational and community design reference points. The amount of runoff that is captured by the practices is determined by the geometric constraints for vehicular movement, the area of the existing travel ways, and the location of utilities. The assessment shows that most of the runoff can be captured in the ROW but some supplemental storage may be required. Some of the areas may be more difficult to construct due to utility locations, slopes, and geometric restrictions and alternative locations where there is a better ratio of cost to capture volume may be considered. The project report contains details and recommendations on specific areas.

This concept report is organized into the following sections:

**Background:** This section is a summary of the development of the project goals and objectives and the previous monitoring report recommendations (FORCE, 2011).

**Project Approach:** This is a description of the planning and design process and the metrics used in the selection of LID implementation areas.

**Site Design Recommendations:** The recommendations for the location and type of LID practices, the projected benefits, and alternatives are included in this section.

## 2 Background

Stormwater management in the District of Columbia has traditionally been focused on managing the peak rate of runoff from storm events and the use of filtering devices for stormwater management. The management of the runoff volume from storm events will be a critical component of addressing the limitations of the capacity in the existing drainage infrastructure and water quality of the receiving waters in the District. The capture and retention of the runoff volume from the 1.2 inch rainfall event is the design storm that is used for compliance with the recently adopted Municipal Separate Storm Sewer (MS4) permit. The 1.2 inch rainfall event is significant because it falls within the 90th percentile of all storm events that occur within a given year. The emphasis on the use of LID and Green Infrastructure is a prominent feature of compliance strategies and community development within the District of Columbia. There has been an increased demand to study the long-term effectiveness of using LID and how to integrate LID into existing public sector and private sector programs. A comprehensive model of the potential of LID in the District has been developed as the Green Buildout Model (LimnoTech, 2006). Most significant pilot projects have been constructed by DC Water, DDOT, and DDOE. The pilot construction efforts have been developed as individual projects and have not been focused on the catchment or watershed scale.

The construction of the project is managed by DDOT and is a joint effort between DDOE, DDOT and DC Water. The funding for the project is contributed by the agencies and a grant from the National Fish and Wildlife Foundation. This project will be used to assess many of the technical and administrative issues that are relevant to the implementation of LID in the District of Columbia at the catchment or watershed scale for public sector projects. The results can be used to develop criteria
and protocols for the use of LID for MS4 compliance and integration into the Long Term Control Plan (LTCP) for CSO control.

2.1 Design Objective

The design objective of the project is to fully implement green infrastructure and low impact development (LID) across a sewershed on public and private lands. The key goals are to

- Quantify stormwater volume reductions as predicted in the Green Build-Out Model;
- Compare cost efficiency with traditional stormwater infrastructure and the LTCP storage tunnels; and
- Examine the maximum extent practicable of LID in the ROW.

The project is to also provide educational opportunities, outreach, and enhance and reinforce the green and sustainable elements of the neighborhood.

The project team developed criteria, metrics, and protocols to accomplish the objectives. These are described in the project approach section.

2.2 Outreach

The inputs from the community will be provided by DDOT and DDOE staff, based on the results of previous grant efforts, such as the RiverSmart Homes and Schools efforts, outreach to affected communities, and the monitoring and modeling efforts in the neighborhoods. The evaluation of the design concept by DDOT and DDOE staff and any additional citizen or stakeholder input will be incorporated into the 30% design drawing effort.

3 Project Approach

The project planning and design approach is to create a highly visible signature demonstration project that will allow DDOT, DDOE, and DC Water to evaluate the potential of green infrastructure to reduce the volume of runoff that enters the drainage infrastructure within the drainage area. Described below are the key elements of the process and criteria that were used to develop the final recommendations.

3.1 Design Elements

The design elements are the key components of the planning, design, and construction program that are used as the basis for the final locations for LID practices. Described below are the considerations and their application to the program.

3.1.1 Green Infrastructure Technologies

The green technology design elements are the LID technologies that are appropriate within the public ROW or for construction on public property. Detailed descriptions of LID practices and their general hydrologic and hydraulic functions are found in the Anacostia Waterfront Initiative Standards (DDOT, 2007). The general list of practices includes bioretention cells, permeable pavements,
cisterns, green roofs, and vegetated swales. Many of techniques can be combined at curbside and be integrated into bump-outs in the curb that interrupt runoff from the street and sidewalks.

3.1.1.1 **Public ROW and Public Lands Construction**
The project constraints are to have all construction occur within the public ROW or within public property. This is done to develop the process for construction under the Capital Improvement Program (CIP) for each agency.

3.1.1.2 **Demonstration and Education Value**
The project elements should demonstrate a comprehensive approach to retrofit construction for the professional planning, design, and maintenance community. The project should increase public awareness about green infrastructure and act as a laboratory or demonstration for the surrounding neighborhoods and schools.

3.1.1.3 **Effectiveness and Monitoring**
The location and design of BMPs should allow for the construction and operation of effective and efficient monitoring that can be used to calibrate the stormwater models and measure the long-term efficiency of the project to reduce stormwater volume.

3.1.1.4 **Ancillary Benefits**
The project should address non-stormwater benefits that are consistent with the Mayor’s sustainability initiative. This includes, but is not limited to, the generation of green jobs, urban heat island reduction, and urban agriculture.

3.2 **Hydrologic Design Criteria**
The hydrologic design goal for the project is to capture and infiltrate the runoff that is generated from a 1.2 inch depth of volume storm event. The project work plan also includes the requirement to determine the annual runoff volume that can be prevented from entering the drainage infrastructure through the use of LID techniques.

3.2.1 **Modeling Description and Results**
Three (3) models were used to predict the effectiveness of the LID practices. The Retention Volume Method (RVM) and the Runoff Reduction Method (RRM) spreadsheet-based models were used to generate the runoff volume that would result from the 1.2 inch storm event. The Storm Water Management Model (SWMM) was used for both single-event design storm and continuous simulation modeling of runoff over a representative one-year period. The Rv (Retention Volume) method for estimating required stormwater retention volume is a regulatory tool that provides an Rv value on a per-site basis that is dependent the site’s land cover. The Rv value is a weighted average of impervious area, pervious area with compacted soils, and “natural cover” pervious area with undisturbed soils. Impervious area is assigned the Rv coefficient of 0.95, pervious compacted area is assigned 0.25, and natural cover has a coefficient of 0. The Rv value can be multiplied by the overall area and regulatory rain event to arrive at a required capture volume. Because the Rv coefficients are heavily weighted towards impervious cover, the Rv-calculated runoff volume provides a realistic estimate of the potential capture amount.
The Runoff Reduction Method (RRM) is a coefficient-weighted approach similar to the Rv method, but is based on land use instead of land cover. Right-of-way areas such as roads and sidewalks are assigned a coefficient of 0.95, while residential areas are assigned 0.65. Open areas are assigned a coefficient of 0. The weighted average is then applied as the Rv value is, by multiplying by total area and rainfall amount to arrive at an estimated runoff volume. Because of its reliance on land use, RRM may overestimate required retention volumes for low-density residential areas, and underestimate for high-density residential sites.

The LID practices were then sized to accommodate the runoff volume. These spreadsheet-based models cannot be used to assess unit processes of practices such as evapotranspiration, detention, infiltration, or the hydrologic routing of flows through the BMP or through BMPs in a series. They also cannot be used to directly determine water quality benefits of practices from the physical, chemical, and biological processes of the BMPs. These models are sufficient for estimating the sizing of BMPs, but are not rigorous enough to accurately determine the individual and aggregate effectiveness of the LID practices. The SWMM model was used to conduct that analysis.

The model that was selected to predict stormwater runoff and LID retention volume was EPA’s SWMM (Stormwater Management Model). The model is commonly used to solve complex hydrologic and hydraulic drainage problems. It has regulatory acceptance, is open-source, is free to use, and has a well-established user-based integrated LID module for simulation of individual LID practices. The model includes features that allow the user to calibrate the unit processes in the LID features and route the hydraulic processes through the system. The model was used as a tool to determine the effectiveness of the practices for a one-year, 24-hour NOAA design storm event and for an average year of rainfall. The continuous simulation used the rainfall from 1990 of 41 inches. This is slightly above the average of the 50 year rainfall record at National Airport from 1949 to 1998. This rainfall period was also used in the analysis that was part of DC Water’s CSO LTCP that used the forecast period of 1988 to 1990.

### 3.2.1.1 Model Development

The DC GIS land cover data, DC Water’s sewers geodatabase, and site survey data were used to develop the land cover and drainage system characteristics for the model. The drainage area was divided into 9 subcatchments. This is based on the location of the existing catch basins. Each of the subcatchments were assigned impervious and pervious percentages based on land use. The runoff from the subcatchments was routed into the pipe network model as local nodes that represent the catch basins’ connections to the collection system. The size of the drainage areas and the local drainage conditions were verified during the visits. During the site visits it was discovered that some roofs in the residential areas are directly-connected to the sewer system. The runoff from those roof areas was not included in the baseline model scenario, but was modeled as separate subcatchments that were directly connected to the SWMM pipe network. Table 1 is a summary of the areas and land covers of the subcatchment. Figure 2 is a map of the catchment areas.
Table 1: Summary of Subcatchment Areas

<table>
<thead>
<tr>
<th>Catchment Designation</th>
<th>Catchment Area (acres)</th>
<th>Roof Area</th>
<th>Total Impervious Area</th>
<th>Pervious Area</th>
<th>Road ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-01</td>
<td>3.12</td>
<td>0.29</td>
<td>1.16</td>
<td>1.97</td>
<td>0.26</td>
</tr>
<tr>
<td>L-02</td>
<td>1.50</td>
<td>0.05</td>
<td>0.60</td>
<td>0.90</td>
<td>0.23</td>
</tr>
<tr>
<td>L-03</td>
<td>2.79</td>
<td>0.16</td>
<td>0.90</td>
<td>1.89</td>
<td>0.23</td>
</tr>
<tr>
<td>L-04</td>
<td>0.49</td>
<td>0.00</td>
<td>0.25</td>
<td>0.24</td>
<td>0.25</td>
</tr>
<tr>
<td>L-05</td>
<td>1.72</td>
<td>0.14</td>
<td>0.73</td>
<td>0.99</td>
<td>0.34</td>
</tr>
<tr>
<td>L-06</td>
<td>0.95</td>
<td>0.07</td>
<td>0.34</td>
<td>0.61</td>
<td>0.12</td>
</tr>
<tr>
<td>L-07</td>
<td>0.16</td>
<td>0.00</td>
<td>0.14</td>
<td>0.02</td>
<td>0.14</td>
</tr>
<tr>
<td>L-08</td>
<td>0.46</td>
<td>0.02</td>
<td>0.18</td>
<td>0.28</td>
<td>0.12</td>
</tr>
<tr>
<td>L-09</td>
<td>1.68</td>
<td>0.07</td>
<td>0.78</td>
<td>0.91</td>
<td>0.49</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>12.88</strong></td>
<td><strong>0.79</strong></td>
<td><strong>5.07</strong></td>
<td><strong>7.81</strong></td>
<td><strong>3.29</strong></td>
</tr>
</tbody>
</table>

The model was calibrated to the Lafayette storm sewer metering data that was collected from mid-July to mid-December of 2010. Local rain gage data collected during that period were used as the boundary rainfall timeseries for the SWMM runoff model. The baseline Lafayette model results were compared with the metering data. Separate comparisons of the top ten (10) events by volume and by peak flow were used to develop Nash-Sutcliffe Efficiency Indices (NSEI) for both metrics. The NSEI is used to predict the efficiency of a hydrologic model. The SWMM model’s NSEI for volume was 0.87; any index value between 0.75 and 0.89 is considered “very good” by the NSEI. Its peak flow index value was 0.72, which is considered “good” by the NSEI. In consideration that the primary purpose of this modeling exercise was to predict retention volumes of LID practices, the model was considered to be calibrated.

The LID practices were characterized using the SWMM LID module as groupings, or the aggregate effect, of the individual practices within each subcatchment. For example, all permeable pavement surfaces within a subcatchment were modeled as a single parcel of permeable pavement with a footprint equivalent to the sum of the areas of individual parcels within the subcatchment.

Bioretention cells were represented in SWMM as 36-inch deep storage elements with a filter medium porosity value of 0.25 that is specified in the RiverSmart Washington Design Criteria. Bioretention cells were also assigned an allowable ponding level of 6 inches. Permeable pavement practices were similarly modeled as 36-inch deep storage elements. The porosity value for this practice type was 0.3, consistent with the design criteria.

The SWMM-LID modeling approach represents a finer-resolution approach to evaluation of LID practices than the Green Build-Out Model (GBOM) that was developed in 2007 to evaluate the effects of application of city-wide LID practices on stormwater and combined sewer overflows. The GBOM applied area-weighted characteristics of individual LID practices across entire catchment areas, and was thus able to evaluate large-scale applications of green practices quickly and efficiently by utilizing the existing DC Water Mike Urban collection system model. The SWMM-LID approach models individual LID practice types on the catchment or sub-catchment level, and is therefore well-suited for smaller-scale studies that seek to evaluate the performance of individual practices or types of practices.
A set of primary LID practices were developed for the analysis. The primary practices are bioretention cells and bump-outs, permeable pavement parking lanes, and permeable pavement alleys. The depths of the practices were set to less than three (3) feet in order to avoid conflicts for utility crossings. The widths of the practices were based on the street and tree box area width. The storage volumes, and if applicable ponding volumes, for the practices were developed from schematic concept cross sections and the length of the practices. A void ratio for storage in the bioretention media was assigned a value of 0.3. Any aggregate subbase for pavement or bioretention was assigned a ratio of 0.4. Practice width and length were modified to the specific site conditions. Figure 3 is a schematic of the bioretention cell. Figure 4 is a schematic of the permeable pavement parking lane. Figure 5 is a schematic of the permeable pavement alley.
Figure 2: Subcatchment Map
Figure 3: Schematic of Bioretention Cell

Figure 4: Permeable Pavement Parking Lane

Figure 5: Permeable Alley
For the single event modeling, the underdrains were not modeled because the dewatering rates are not relevant to the evaluation of the single storm event design. Variable soil infiltration rates, based on the Horton equations were used in both the single event and continuous year-long model scenario. Rates were based on HSG Type-D soils. The evapotranspiration rates for the plants in the vegetated BMPs were also considered in the model. An estimated discharge rate for underdrains was used in the continuous model scenario in order to dewater each BMP facility after a dry period of 72 hours.

The 1.2 inch volume of rainfall that is the capture goal is independent of duration and intensity of the storm. The intensity can be defined as the peak rate of rainfall that occurs over a portion of the duration. The SWMM model requires a duration and intensity of a given storm event that is derived from a synthetic, or design, storm event. The rain event that was used to evaluate the concept design requirement of the capture of 1.2 inches of rain was a one-year, 24-hour NOAA design storm with a 30-minute resolution, a total depth of 2.64 inches, and a peak hourly intensity of 1.6 inches.

3.2.1.2 Single Event Model Results
The LID concept model scenarios evaluated various levels of LID practice effectiveness for the single event storm using the RRV and RRM spreadsheet methods and the SWMM model. The RRM method was used to determine the required volume and the RRM method was used as a check of the volumes. Table 2 is a summary of the RRV method. It calculates the required retention volume for each subcatchment based on total land cover (including and rooftops that may be directly-connected to the collection system), given 1.2 inches of rainfall. This application of the RRV method assumes an even split of compacted and natural pervious land cover that was considered to be appropriate for a residential area with single-family homes with lawns. This summary also provides estimates of required retention volumes that differentiate ownership types (public/right-of-way versus private) and combinations of ownership types, both with and without fully-disconnected rooftops.

Table 3 is a summary of the RRM method values that were calculated using 1.2 inches of rainfall. The RRM method includes the analysis of surface runoff from the existing disconnected residential roofs and from a scenario where all the roofs were disconnected from the drainage system. It also includes an analysis of runoff by land ownership types. All RRM analysis considered residential lawn area to be part of the residential land use category and not “open area”. The consideration of roof downspouts that connect to LID practices is important because of the high percentage of the residential roofs in the catchment areas. The required volume for capture is shown in the last column of each table.
Table 2: Rv Runoff Results

<table>
<thead>
<tr>
<th>Catchment Designation</th>
<th>Rv Required, Private Property Only (gallons)</th>
<th>Rv Required, Public/ROW Property Only (gallons)</th>
<th>Rv Required, Public + Private (gallons)</th>
<th>Rv Required, Public + Private w/disconnected Roofs (gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-01</td>
<td>26,982</td>
<td>7,902</td>
<td>34,884</td>
<td>43,808</td>
</tr>
<tr>
<td>L-02</td>
<td>13,693</td>
<td>7,020</td>
<td>20,713</td>
<td>22,141</td>
</tr>
<tr>
<td>L-03</td>
<td>23,915</td>
<td>6,974</td>
<td>30,889</td>
<td>35,690</td>
</tr>
<tr>
<td>L-04</td>
<td>963</td>
<td>7,865</td>
<td>8,829</td>
<td>8,829</td>
</tr>
<tr>
<td>L-05</td>
<td>12,037</td>
<td>10,360</td>
<td>22,397</td>
<td>26,608</td>
</tr>
<tr>
<td>L-06</td>
<td>6,960</td>
<td>3,810</td>
<td>10,770</td>
<td>12,946</td>
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<tr>
<td>L-07</td>
<td>99</td>
<td>4,278</td>
<td>4,377</td>
<td>4,377</td>
</tr>
<tr>
<td>L-08</td>
<td>2,085</td>
<td>3,844</td>
<td>5,930</td>
<td>6,667</td>
</tr>
<tr>
<td>L-09</td>
<td>10,562</td>
<td>15,056</td>
<td>25,618</td>
<td>27,714</td>
</tr>
<tr>
<td><strong>sum</strong></td>
<td><strong>97,295</strong></td>
<td><strong>67,111</strong></td>
<td><strong>164,406</strong></td>
<td><strong>188,779</strong></td>
</tr>
</tbody>
</table>

Table 3: RRM Runoff Results

<table>
<thead>
<tr>
<th>Catchment Designation</th>
<th>Rv Required, Private Property Only (gallons)</th>
<th>Rv Required, Public/ROW Property Only (gallons)</th>
<th>Rv Required, Public + Private (gallons)</th>
<th>Rv Required, Public + Private w/disconnected Roofs (gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-01</td>
<td>54,652</td>
<td>7,902</td>
<td>62,555</td>
<td>68,660</td>
</tr>
<tr>
<td>L-02</td>
<td>25,901</td>
<td>7,020</td>
<td>32,921</td>
<td>33,898</td>
</tr>
<tr>
<td>L-03</td>
<td>51,118</td>
<td>6,974</td>
<td>58,092</td>
<td>61,377</td>
</tr>
<tr>
<td>L-04</td>
<td>5,005</td>
<td>7,865</td>
<td>12,870</td>
<td>12,870</td>
</tr>
<tr>
<td>L-05</td>
<td>26,423</td>
<td>10,360</td>
<td>36,783</td>
<td>39,664</td>
</tr>
<tr>
<td>L-06</td>
<td>16,023</td>
<td>3,810</td>
<td>19,834</td>
<td>21,323</td>
</tr>
<tr>
<td>L-07</td>
<td>518</td>
<td>4,278</td>
<td>4,796</td>
<td>4,796</td>
</tr>
<tr>
<td>L-08</td>
<td>6,541</td>
<td>3,844</td>
<td>10,385</td>
<td>10,890</td>
</tr>
<tr>
<td>L-09</td>
<td>23,913</td>
<td>15,056</td>
<td>38,969</td>
<td>40,403</td>
</tr>
<tr>
<td><strong>sum</strong></td>
<td><strong>210,094</strong></td>
<td><strong>67,111</strong></td>
<td><strong>277,205</strong></td>
<td><strong>293,881</strong></td>
</tr>
</tbody>
</table>
The SWMM single-event results for the one-year, 24-hour design storm are summarized in Table 4A (performance per subcatchment) and Table 4B (performance per practice type). The baseline runoff volume is the volume predicted by the model before simulation of any LID practices. The LID runoff volume is the predicted volume with LID practices simulated. The retention volume is the difference between predicted baseline and predicted LID runoff volumes. The efficiency metric quantifies the percentage of available LID practice volume that is utilized. The single-event SWMM simulation did not model underdrains, so retention volume is based on the static capacities of the practices. The predicted runoff reduction of 256,424 gallons approaches the RRM value of 277,205 gallons that was calculated for the present-day baseline conditions, which includes some roofs directly connected to the collection system. The predicted runoff reduction exceeds the RVM value of 188,779 gallons.

Table 4A: SWMM Results for 1-year, 24-hour NOAA Design Storm

<table>
<thead>
<tr>
<th>Catchment Designation</th>
<th>runoff from baseline scenario (gallons)</th>
<th>runoff from LID scenario(gallons)</th>
<th>retention (gallons)</th>
<th>Estimated retention from public/ROW areas (gallons)</th>
<th>available storage (gallons)</th>
<th>efficiency (actual vs. available storage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-01</td>
<td>77,951</td>
<td>18,403</td>
<td>59,549</td>
<td>17,513</td>
<td>67,985</td>
<td>88%</td>
</tr>
<tr>
<td>L-02</td>
<td>31,701</td>
<td>1,667</td>
<td>30,035</td>
<td>12,365</td>
<td>33,606</td>
<td>89%</td>
</tr>
<tr>
<td>L-03</td>
<td>63,090</td>
<td>12,257</td>
<td>50,833</td>
<td>15,285</td>
<td>61,142</td>
<td>83%</td>
</tr>
<tr>
<td>L-04</td>
<td>16,944</td>
<td>6,979</td>
<td>9,965</td>
<td>9,964</td>
<td>12,917</td>
<td>77%</td>
</tr>
<tr>
<td>L-05</td>
<td>51,111</td>
<td>15,729</td>
<td>35,382</td>
<td>19,955</td>
<td>39,135</td>
<td>90%</td>
</tr>
<tr>
<td>L-06</td>
<td>18,194</td>
<td>625</td>
<td>17,569</td>
<td>8,089</td>
<td>34,622</td>
<td>51%</td>
</tr>
<tr>
<td>L-07</td>
<td>12,187</td>
<td>7,292</td>
<td>4,896</td>
<td>4,897</td>
<td>4,959</td>
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<tr>
<td>L-08</td>
<td>15,764</td>
<td>7,257</td>
<td>8,507</td>
<td>6,817</td>
<td>10,394</td>
<td>82%</td>
</tr>
<tr>
<td>L-09</td>
<td>51,840</td>
<td>12,153</td>
<td>39,687</td>
<td>27,256</td>
<td>40,768</td>
<td>97%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>338,785</strong></td>
<td><strong>82,361</strong></td>
<td><strong>256,424</strong></td>
<td><strong>122,143</strong></td>
<td><strong>305,527</strong></td>
<td><strong>84%</strong></td>
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Table 4B Performance per Practice Type, SWMM 1-year Design Storm Results

<table>
<thead>
<tr>
<th>Type</th>
<th>total Inflow (gal)</th>
<th>total storage (gal)</th>
<th>estimated storage of public / ROW runoff (gal)</th>
<th>available storage (gal)</th>
<th>efficiency (actual vs. available storage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioretention</td>
<td>73,503</td>
<td>53,706</td>
<td>35,716</td>
<td>67,325</td>
<td>80%</td>
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<td>Permeable Pavement</td>
<td>223,115</td>
<td>201,742</td>
<td>91,700</td>
<td>238,223</td>
<td>85%</td>
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</table>
3.2.1.3 Continuous Year-Long Model Results

The SWMM continuous simulation results for 1990 are summarized in Table 4C. This scenario includes the presence of underdrains that supplement the infiltration into the soil and allow each practice type to drain within 72 hours under dry conditions. These underdrains were offset from the bottom depth of practices by 11.75 to 12.75 inches, depending on practice type, in order to maximize soil infiltration while still fulfilling the 72-hour drainage requirement. The results predict an overall runoff retention of 68% from all BMPs. Since the available storage is dynamic due to practice infiltration and underdrains, an efficiency percentage could not be estimated for the continuous simulation model runs.

Table 4C: SWMM Results for 1990 Continuous Simulation

<table>
<thead>
<tr>
<th>Catchment Designation</th>
<th>runoff from baseline scenario (gallons)</th>
<th>runoff from LID scenario (gallons)</th>
<th>retention (gallons)</th>
<th>Estimated retention from public/ROW areas (gallons)</th>
<th>available storage (gallons)</th>
</tr>
</thead>
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<tr>
<td>L-01</td>
<td>1,077,118</td>
<td>382,361</td>
<td>694,757</td>
<td>204,330</td>
<td>67,985</td>
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<tr>
<td>L-02</td>
<td>395,417</td>
<td>61,806</td>
<td>333,611</td>
<td>137,347</td>
<td>33,606</td>
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<tr>
<td>L-03</td>
<td>801,910</td>
<td>220,660</td>
<td>581,250</td>
<td>174,781</td>
<td>61,142</td>
</tr>
<tr>
<td>L-04</td>
<td>225,729</td>
<td>133,576</td>
<td>92,153</td>
<td>92,143</td>
<td>12,917</td>
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<tr>
<td>L-05</td>
<td>688,819</td>
<td>235,069</td>
<td>453,750</td>
<td>255,912</td>
<td>39,135</td>
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<td>L-06</td>
<td>252,361</td>
<td>10,174</td>
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<td>111,503</td>
<td>34,622</td>
</tr>
<tr>
<td>L-07</td>
<td>112,500</td>
<td>28,993</td>
<td>83,507</td>
<td>83,527</td>
<td>4,959</td>
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<tr>
<td>L-08</td>
<td>179,375</td>
<td>130,417</td>
<td>48,958</td>
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<td>L-09</td>
<td>701,111</td>
<td>216,910</td>
<td>484,201</td>
<td>332,535</td>
<td>40,768</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>4,434,340</strong></td>
<td><strong>1,419,965</strong></td>
<td><strong>3,014,375</strong></td>
<td><strong>1,431,311</strong></td>
<td><strong>305,527</strong></td>
</tr>
</tbody>
</table>

3.3 Site Assessment Approach

The site assessment for the project area used a sequential process that began with a desktop analysis for screening and development of base maps. Field investigations were then conducted to confirm the results of the desktop analysis and to develop opportunities and constraints. This information was then used in the development of metrics for the final selection of design elements and BMPs.

3.3.1 Site Description

The project team developed base maps from the DC GIS system and from the DC Water utility database. The base maps were used to develop drainage areas and land cover characteristics for the hydrologic modeling and to conduct an assessment of turning movements for vehicles.

3.3.2 Field Investigations

The project team conducted several field investigations during the course of the study. These visits were conducted to orient the team to the project, confirm and verify the GIS and topographic information, confirm drainage divides, conduct the site assessments, and develop and verify the concept plan.
Figure 6: Field Investigation and Notes
3.3.3 **Opportunities and Constraints**

The site opportunities and constraints analysis was conducted. The basis, or considerations, in the analysis were developed from key design and construction factors and a preliminary list of site metrics. A map of the opportunities and constraints was developed in order to identify potential retrofit opportunities.

Figure 6 is a map of the opportunities and constraints and site visit notes. Described below are the key focus areas for the opportunities and constraints.

3.3.3.1 **Geometric Considerations**

An assessment of the turning movements for various sizes of vehicles throughout the study area was conducted using Autoturn™. The City-Bus turning requirements were analyzed at the intersections. The existing conditions do not allow for unrestricted turning for the City-Bus because of the narrow street widths and skewed intersections. The width of each street in the project area is thirty (30) feet from curb to curb. There is parking on both sides. The current DDOT standard is thirty-four (34) feet. That includes twenty (20) feet of travel lane and seven (7) feet of parking on each side of the street. Most of the bus and large truck traffic travels along. The turning templates show that any parking or bump-outs would have to be located back from the intersection in order to allow for unimpeded movement. Figure 7 shows the City-Bus template overlay. This analysis, along with the draft DDOT curb bump-out guidance (DDOT, 2008) was used to determine the location of bump-outs at street and alley intersections.
Figure 7: Autoturn™Results
3.3.3.2 **Drainage Area and Catchment Determination**
The desktop evaluation of the drainage areas was verified in the field during a period of rainfall events. There are a significant amount of roof drains from the residential areas that discharge directly into the sewer system. A small percentage of them have been disconnected and now sheet flow into the alleys, rain barrels, or to lawn areas. There is a significant amount of bypass at the existing inlets within each subcatchment. This is typical for urban drainage systems because inlets on grade are not designed to be 100% efficient.

3.3.3.3 **Potential Utilities**
There are numerous Pepco lines that run along the streets and alleys and also that cross the streets. Washington Gas and Telephone lines are also located in the study corridor. Water and sewer house connections are located along the streets. The depth of BMP construction in these areas should be limited where there are crossings. This is because the cost to relocate or protect utilities for construction is expensive and takes substantial time to complete.

3.3.3.4 **Geotechnical**
The project area is developed and the original grades have been highly disturbed. The soil survey (USDA, 2011) shows the area divided into two (2) major soils areas. The intersection of Quesada Street NW and 32nd Street NW consists of the soil series Md: Manor-Urban land complex. The rest of the project area, which includes 33rd Street NW and Quesada Street NW, is classified as Gh: Glenelg-Urban land complex. Descriptions of the drainage characteristics that are a concern for stormwater management are as follows (USDA, 1976):

- **MdB, MdC**, Manor-Urban land complex, 0 to 8 percent slopes and 8 to 15 percent slopes respectively. These are well drained and moderately permeable soils with rapid stormwater runoff. They are classified as Hydrologic Soils Group (HSG) A. These soils include layers of loam, sandy loam and channery sandy loam. The infiltration rate is typically 0.57 to 1.98 inches per hour.

- **GhC**: Glenelg-Urban land complex, 0 to 15 percent slopes. These are well drained and moderately permeable soils with rapid stormwater runoff. They are classified as HSG B. These soils include layers of loam, clay loam, and very channery sandy loam. The infiltration rate is typically 0.20 to 1.98 inches per hour.

The soil survey indicates that the Lafayette site has a high potential for infiltration practices that meet the proposed guidelines in the DC DOE stormwater guidebook. It should be noted that the drainage, structural, and infiltration characteristics are highly variable within an urban disturbed soils series and that the survey may not accurately depict the local conditions where a BMP is to be located. A more intensive geotechnical investigation should be required in those areas in order to determine the structural and infiltration characteristics. The soils report is included in Appendix 7.1.

3.3.3.5 **Structures**
There are numerous utility vaults and manholes that are used to service the utilities in the streets and alleys. There are also numerous basements in the residential area that are adjacent to the alleys. There are a few property retaining walls within the alleys, some of which have failed and have
collapsed into the alley. Several utility poles are also located in the alleys. The location of infiltration practices in those areas should be restricted and impermeable liners and watertight seals should be used for necessary structures in those areas.

### 3.3.3.6 Constructability
Construction access and Maintenance of Traffic (MOT) issues were identified in the field. This includes potential mobilization areas. Areas where restrictions on heavy equipment use were identified. Alley construction will require the reconstruction of several driveways.

### 3.3.3.7 Maintenance
Existing conditions that would affect the performance of BMPs, such as high sediment and trash loads or restaurant service areas, were identified. Areas of low visibility or difficult access were also identified.

### 3.3.3.8 Opinion of Cost
Preliminary opinion of cost is included under separate cover.

### 3.4 Assessment of Practices and Locations
Preliminary opinions of cost for the concept plan were derived from information and cost data of existing DDOT LID projects and other DDOT cost estimates. Preliminary cross sections and details were developed for the potential BMPs so that square foot costs could be developed for planning purposes. The project team identified conditions in the field, such as potential utility conflicts, that would increase project costs.

#### 3.4.1 Site Selection Metrics
The project team developed site selection metrics that guided the selection of and location of implementation opportunities within the watershed. The assessment was then used to rank and prioritize implementation opportunities and to determine the final site recommendations. Three (3) major categories of metrics were developed:

- **Quantitative:** Criteria that can be directly measured and compared to alternatives.
- **Construction:** Assessment of the ability to construct the practice or feature in a cost-effective manner without major disruptions to traffic and services.
- **Qualitative:** Elements which are evaluated using the best professional judgment and professional experience of the project team.

The team also noted any ancillary benefits, such as green jobs, energy efficiency enhancements, etc.

Each category includes several metrics. The applicability or the projected benefits for each metric at a location are categorized as high, medium, or low and are correspondingly shown as full, half full, and open circles in Table 5. Table 5 is a summary of the assessment.

#### 3.4.1.1 Quantitative
*Infiltration of 1.2 Inch Storm Volume.* The ability to capture the runoff from the contributing drainage area. The range is from complete capture and infiltration, evapotranspiration, use, or a combination
of processes within a 72 hour time frame to partial capture due to facility size and location or soils conditions.

_Treatment of 1.2 Inch Storm Volume._ The ability to filter the runoff from the contributing area. Limitations of soils type, adjacent building structures, and utilities may limit the infiltration ability of the practice so that filtering and treatment of pollutants through biological, physical, and chemical processes can be achieved.

_Capture of 0.5 Inch Storm Volume._ The ability to capture and treat runoff through filtering or infiltration of the impervious area runoff that is generated from impervious areas within the watershed. The 0.5 inch storm event is the previous standard for water quality treatment.

_Treatment of ROW Drainage Area._ The ability to capture and treat the 1.2 inch storm volume from the Right-of-Way only. The range is from complete capture and infiltration, evapotranspiration, use, or a combination of processes within a 72 hour time frame to partial capture due to facility size and location or soils conditions.

_Cost/Volume._ The projected cost to provide the runoff volume in terms of square feet of coverage.

__Monitoring._ The ability to effectively install monitoring equipment and the ability to monitor the practice using the guidelines and procedures established in the monitoring feasibility study (FORCE, 2011).

### 3.4.1.2 Construction

_Connections._ This refers to ease of connecting LID practices to adequate outfalls and connections within the drainage infrastructure. This includes the requirements for new manholes, inlets, and extensions of the storm drain system which will increase the cost and time of construction.

_Utility Conflicts._ This refers to utility conflicts due to crossings or clearance. It considers both the level of complexity and the potential need for relocation.

_Unknown Conditions._ This refers to the difficulty of planning, design, and implementation due to incomplete information or determination of soils data utility information, or ownership, which result in unanticipated conflicts or risks.

_Liners._ This refers to the requirement for impermeable liners to prevent infiltration to critical utilities, building structures, or pavements. This requirement may potentially increase costs or create maintenance and liability issues.

_Constructability._ This refers to ease of construction equipment access and construction sequencing, and the amount of excavation required.

_Maintenance of Traffic (MOT)._ This refers to minimizing the disruption of traffic and the impacts on private property owners, as well as identifying sufficient area for mobilization.
Maintenance: This refers to long term maintenance issues that affect performance such as offsite sediment loads, potential for vandalism, and maintenance access.

3.4.1.3 Qualitative

System Applications. The applicability of the feature to typical conditions throughout the District.

Water Harvesting. The ability of the system to capture runoff or rainwater for irrigation or non-potable uses, such as vehicle washing.

Visibility. The ability of either, or ideally both, pedestrian and vehicular traffic to easily perceive/distinguish the design feature/practice.

Pedestrian Safety and Access. The ability to improve safe pedestrian movements, traffic calming, and accessible routes.

Educational Value. The ability of the design element to demonstrate green technology for school-age children, citizens, policy makers, or decision makers.

Neighborhood Amenity. The ability to provide a specific amenity desired by the community. These needs may change from neighborhood to neighborhood.

 Beautification. The ability to improve aesthetics and neighborhood appeal.

Demonstration of New Technology. The modification or enhancement of traditional LID features to increase adaptability or efficiency, or the introduction of new LID technology that has not been installed in the DDOT system.

Shade and Local Climate (Human Comfort): The ability of the practice to provide shade or reduce urban heat island effect.

Habitat Value. The ability to create desirable wildlife habitat that improves urban ecological processes.

Jobs. The potential for the creation of green jobs for maintenance, summer jobs programs, and construction is considered.
### Table 5: Assessment Criteria

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<thead>
<tr>
<th>No.</th>
<th>Location</th>
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<th>Construction</th>
<th>Qualitative</th>
<th>Ancillary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Infiltration of 1.2 inch Volume</td>
<td>Treatment of 1.2 inch Volume</td>
<td>Capture of 0.5 inch Volume</td>
<td>Drainage</td>
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<td>Quesada Street Permeable Parking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Quesada Street Bioretention Bump-outs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Quesada Street Full-width Perm. Pave.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>33rd Street Bump-outs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>33rd Street Permeable Parking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Permeable Walkway</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>32nd Street Bump-outs</td>
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<td></td>
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</tr>
<tr>
<td>8</td>
<td>Quesada Street @ 32nd NE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Quesada Street @ 32nd SE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Quesada Street @ 32nd SW</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Quesada Street @ 32nd NW</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
4 Site Design Recommendations

The design goal is to implement a high quality urban design that can demonstrate the effectiveness and constructability of a comprehensive set of landscape and hardscape LID practices. Described below is how the practices were integrated into the design and key features or areas where the practices were applied.

4.1 Site Elements

The site elements, or features, for the project are the LID BMPs that are integrated into the existing infrastructure. The design includes different combinations of landscape and hardscape technologies that will allow for observation and monitoring of different planning, design, and construction approaches. The Anacostia Waterfront Initiative (AWI) standards were used as the basis, or foundation, for each design element. Listed below are the design elements and how they were applied in the project.

4.1.1 Curb Bump-Outs

Curb bump-outs are used at the intersections and along the streets to reduce the volume of stormwater as well as promote traffic calming and increase the green aesthetic of the street. There is a high potential for the installation of bioretention bump-outs within the Lafayette project area because there is not as much need for street parking. Additionally, along steeper streets these structures would act to filter some of the silt washing down the road to reduce clogging in the downstream sections of permeable pavement. An illustration of a bioretention curb bump-out is shown in Figure 8.

4.1.2 Permeable Parking Lanes

Permeable parking lanes are proposed along Quesada Street NW and 33rd Street NW north of Quesada Street NW. These areas are to be within the existing parking areas. Some of the permeable parking lanes may be bordered by curb bump-outs or be functionally combined with bioretention cells in the tree box area. The permeable parking can be constructed out of concrete, asphalt, or PICP.

4.1.3 Permeable Sidewalks

Permeable sidewalks were used to replace the existing asphalt sidewalk along the west side of 33rd Street NW north of Quesada Street NW.

The permeable sidewalk areas were also used located adjacent to curb bump-outs at the intersection of Quesada Street NW and 33rd Street NW in order to create a combined storage area for runoff.

4.1.4 Permeable Alleys

Permeable alleys, constructed of either concrete, asphalt, or permeable interlocking concrete blocks (PICB) are located intermittently in the back of residential areas bounded by Broad Branch Road NW to the west, Rittenhouse Street NW to the north, 32nd Street NW to the east and Lafayette Park and Patterson Avenue NW to the south. Areas where there are high sediment loads, steep slopes, adjacent basements, or where there were underground utilities were excluded.
4.1.5 Tree Boxes

The tree box space is the area between the sidewalk and the edge of curb. Figure 9 is an illustration of a tree box with a bioretention cell and permeable pavers.
4.1.6 Permeable Streets
A full-width permeable street was used in the last 150 feet of Quesada Street NW. The area can be constructed out of permeable concrete, asphalt, or PICP.

4.2 Concept Plan and Focus Areas
A concept design was developed with LID features that satisfy the volume requirements from the 1.2 inch storm. The design features several areas where there is an intense focus or concentration of practices that can be used for education and to enhance the green aesthetic of the community. This entire section of Quesada Street NW is designed as a green street. It contains permeable pavement throughout, as well as a number of bioretention cells and bioretention bump-outs. It integrates the placement of stormwater management features with walkways and bikeways while adding traffic calming techniques. All these features are included while maintaining the existing travel lanes and without taking property from residents. The street design not only serves to treat rain where it falls and reduce the flow of stormwater pollution to nearby streams, but is also expected to be valued by the community as an amenity. Of particular interest are the intersections of Quesada Street NW with 32nd and 33rd Streets NW. The Concept Plan is shown in Figure 10. Note that the intersection of Quesada Street NW and 33rd Street NW touches the northeast corner of Lafayette Park (see Section 4.2.1, below). Its visibility makes it a good demonstration site for the community. The intersection of Quesada Street NW and 32nd Street NW currently contains no curb ramps at the intersection (see Section 4.2.2). The design serves to address this issue.

4.2.1 Intersection of Quesada Street and 33rd Street
Curb bump-outs have been proposed as traffic calming measures and will serve to increase the walkability and safety of the area. They also serve to reinforce the visual framework for the intersection. Permeable parking lanes have been proposed for both sides of the parking lanes along Quesada Street NW. Figure 11 is an illustration of the intersection of Quesada Street NW and 33rd Street NW. Figure 12 is a perspective view. The construction of the permeable pavement parking areas along Quesada Street NW would require the aggregate subbase to be constructed in steps with some type of retention system in the subbase to retain stormwater. This is because the slopes of the streets are fairly steep. Figure 13 is an illustration of the profile. This system would be difficult to construct and would potentially require extensive utility relocations because of the depth of the system.
Figure 10: Concept Plan
Figure 11: Illustration of Intersection

Figure 12: Quesada Street NW and 33rd Street NW
4.2.2 Quesada Street NW and 32nd Street NW

The intersection of Quesada Street NW and 32nd Street NW is developed for improved ADA compliance. Currently, the lack of curb ramps limits the access between the sidewalk and the street for people who use wheelchairs or would otherwise be excluded from using the sidewalk. Two handicap ramps have been added to the intersection across Quesada Street NW. The bump-outs at the intersection also act as traffic calming devices and help enhance the visual framework of the intersection. Figure 14 is a perspective view of the curb bumpout along 32nd Street NW. Figure 15 shows the permeable pavement in the full-width of the street and the handicap ramps to improve accessibility of this intersection.
4.2.3 Quesada Street NW

Quesada Street NW is to be developed as a green street. Bioretention cells, bioretention bump-outs, and permeable parking lanes are all incorporated into the design. Figure 16 is a perspective view of one of the bumpouts along Quesada Street NW with permeable parking upstream and integrated bioretention within. A number of the alleys which lead out onto Quesada Street NW will also be made permeable.
5 Finalization of Concept Plan and Recommendations

The final location and sizing of the concept plan LID elements was accomplished by comparing the storage volume and location of the practices with the runoff volume that would be generated from the ultimate disconnection of all the roof areas. The criteria of meeting the storage volume requirement for the 1.2 inch storm event was met. Figure 17 is a functional plan of the practices that was used to compare the storage volumes of the practices with the runoff volumes. Table is a summary of the practices. The concept design does not directly account for detailed engineering calculations for the practices. The 30% concept plan will include a more in-depth analysis of the site hydrology and the hydrologic functions, including but not limited to, storage, infiltration, and routing of flows of the LID practices. It is anticipated that the detailed analysis would show that the size of the practices could be slightly reduced through routing of flows. This potential reduction and the probability that all roof tops will not ultimately be disconnected function as the safety factor for the design.

The application of the LID practices may be problematic in some of the catchments or locations because of apparent utility conflicts and constructability issues. The design of permeable pavement alleys may require impermeable liners in some areas because of the proximity to structures. The construction of permeable parking lanes along Quesada Street NW would require the aggregate base to be constructed in a staircase manner as shown in Figure 13. This construction could potentially be considerably more expensive than construction on streets with a lower gradient.
Figure 17: Functional Plan
Table 6: Summary of LID Practices

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Runoff Volume (gallons)</th>
<th>LID Practice Volume (gallons)</th>
<th>LID Surplus or Deficit (gallons)</th>
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<tr>
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<td>TOTAL</td>
<td>293,881</td>
<td>305,527</td>
<td>1730</td>
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6 References


FORCE, 2011, Pre-Implementation Stormwater Volume Monitoring for Large Scale LID Implementation, FORCE, Washington, D.C.


USDA, 2011, Customized Soils Report for Lafayette Area, USDA NRCS, Washington, D.C.


7 Appendices

7.1 Soils Report

7.2 Cost Estimate
Appendix 7.1
Soils Report
Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://soils.usda.gov/sqi/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcregional) or your NRCS State Soil Scientist (http://soils.usda.gov/contact/state_offices/).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Soil Data Mart Web site or the NRCS Web Soil Survey. The Soil Data Mart is the data storage site for the official soil survey information.

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How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the
individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.
Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.
Custom Soil Resource Report

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot

Very Stony Spot
- Wet Spot
- Other

Special Line Features
- Gully
- Short Steep Slope
- Other

Political Features
- Cities

Water Features
- Oceans
- Streams and Canals

Transportation
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:2,750 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:12,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Coordinate System: UTM Zone 18N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: District of Columbia
Survey Area Data: Version 5, Sep 14, 2006

Date(s) aerial images were photographed: 6/21/2005

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.
**Map Unit Legend**

<table>
<thead>
<tr>
<th>Map Unit Symbol</th>
<th>Map Unit Name</th>
<th>Acres in AOI</th>
<th>Percent of AOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>GgB</td>
<td>Glenelg loam, 0 to 8 percent slopes</td>
<td>1.2</td>
<td>3.0%</td>
</tr>
<tr>
<td>GgC</td>
<td>Glenelg loam, 8 to 15 percent slopes</td>
<td>2.5</td>
<td>6.1%</td>
</tr>
<tr>
<td>GhC</td>
<td>Glenelg-Urban land complex, 8 to 15 percent slopes</td>
<td>28.4</td>
<td>71.0%</td>
</tr>
<tr>
<td>GmB</td>
<td>Glenelg variant-Urban land complex, 0 to 8 percent slopes</td>
<td>2.8</td>
<td>7.1%</td>
</tr>
<tr>
<td>MdB</td>
<td>Manor-Urban land complex, 0 to 8 percent slopes</td>
<td>1.8</td>
<td>4.5%</td>
</tr>
<tr>
<td>MdC</td>
<td>Manor-Urban land complex, 8 to 15 percent slopes</td>
<td>3.0</td>
<td>7.4%</td>
</tr>
<tr>
<td>U9</td>
<td>Udorthents, loamy, smoothed</td>
<td>0.4</td>
<td>0.9%</td>
</tr>
<tr>
<td><strong>Totals for Area of Interest</strong></td>
<td></td>
<td><strong>40.0</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

**Map Unit Descriptions**

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.
The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a soil series. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into soil phases. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A complex consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An association is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An undifferentiated group is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include miscellaneous areas. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.
District of Columbia

GgB—Glenelg loam, 0 to 8 percent slopes

Map Unit Setting
Elevation: 300 to 2,000 feet
Mean annual precipitation: 40 to 55 inches
Mean annual air temperature: 45 to 61 degrees F
Frost-free period: 110 to 235 days

Map Unit Composition
Glenelg and similar soils: 100 percent

Description of Glenelg
Properties and qualities
Slope: 0 to 8 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: High (about 10.7 inches)

Interpretive groups
Land capability (nonirrigated): 2e

Typical profile
0 to 10 inches: Loam
10 to 30 inches: Clay loam
30 to 54 inches: Loam
54 to 76 inches: Very channery sandy loam

GgC—Glenelg loam, 8 to 15 percent slopes

Map Unit Setting
Elevation: 300 to 2,000 feet
Mean annual precipitation: 40 to 55 inches
Mean annual air temperature: 45 to 61 degrees F
Frost-free period: 110 to 235 days

Map Unit Composition
Glenelg and similar soils: 100 percent

Description of Glenelg
Properties and qualities
Slope: 8 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high
(0.20 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: High (about 10.7 inches)

Interpretive groups
Land capability (nonirrigated): 3e

Typical profile
0 to 10 inches: Loam
10 to 30 inches: Clay loam
30 to 54 inches: Loam
54 to 76 inches: Very channery sandy loam

GhC—Glenelg-Urban land complex, 8 to 15 percent slopes

Map Unit Setting
Elevation: 250 to 2,000 feet
Mean annual precipitation: 35 to 55 inches
Mean annual air temperature: 45 to 61 degrees F
Frost-free period: 110 to 235 days

Map Unit Composition
Glenelg and similar soils: 40 percent
Urban land: 40 percent
Minor components: 20 percent

Description of Urban Land
Properties and qualities
Slope: 8 to 15 percent
Depth to restrictive feature: 10 inches to
Interpretive groups
Land capability (nonirrigated): 8s

Description of Glenelg
Properties and qualities
Slope: 8 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high
(0.20 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: High (about 10.7 inches)
Interpretive groups
Land capability (nonirrigated): 3e

Typical profile
0 to 10 inches: Loam
10 to 30 inches: Clay loam
30 to 54 inches: Loam
54 to 76 inches: Very channery sandy loam

Minor Components

Unnamed soils
Percent of map unit: 10 percent

Manor
Percent of map unit: 5 percent

Brandywine
Percent of map unit: 5 percent

GmB—Glenelg variant-Urban land complex, 0 to 8 percent slopes

Map Unit Setting
Elevation: 200 to 2,000 feet
Mean annual precipitation: 35 to 55 inches
Mean annual air temperature: 45 to 61 degrees F
Frost-free period: 110 to 235 days

Map Unit Composition
Glenelg variant and similar soils: 40 percent
Urban land: 40 percent
Minor components: 20 percent

Description of Urban Land
Properties and qualities
Slope: 0 to 8 percent
Depth to restrictive feature: 10 inches to

Interpretive groups
Land capability (nonirrigated): 8s

Description of Glenelg Variant
Properties and qualities
Slope: 0 to 8 percent
Depth to restrictive feature: 60 to 99 inches to
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high
(0.20 to 1.98 in/hr)
Depth to water table: About 6 to 36 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: High (about 10.7 inches)

**Interpretive groups**
Land capability (nonirrigated): 2e

**Typical profile**
- 0 to 10 inches: Silt loam
- 10 to 30 inches: Clay loam
- 30 to 54 inches: Loam
- 54 to 76 inches: Very channery sandy loam

**Minor Components**

**Unnamed soils**
Percent of map unit: 10 percent

**Brandywine**
Percent of map unit: 5 percent

**Glenelg**
Percent of map unit: 5 percent

---

**MdB—Manor-Urban land complex, 0 to 8 percent slopes**

**Map Unit Setting**
- Elevation: 250 to 5,000 feet
- Mean annual precipitation: 35 to 70 inches
- Mean annual air temperature: 45 to 61 degrees F
- Frost-free period: 90 to 235 days

**Map Unit Composition**
- Manor and similar soils: 40 percent
- Urban land: 40 percent
- Minor components: 20 percent

**Description of Urban Land**

**Properties and qualities**
- Slope: 0 to 8 percent
- Depth to restrictive feature: 10 inches to

**Interpretive groups**
Land capability (nonirrigated): 8s

**Description of Manor**

**Properties and qualities**
- Slope: 0 to 8 percent
- Depth to restrictive feature: More than 80 inches
- Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Available water capacity: Moderate (about 8.8 inches)

Interpretive groups

Land capability (nonirrigated): 2e

Typical profile

0 to 6 inches: Loam
6 to 22 inches: Sandy loam
22 to 72 inches: Channery sandy loam

Minor Components

Ashe

Percent of map unit: 5 percent

Brandywine

Percent of map unit: 5 percent

Glenelg

Percent of map unit: 5 percent

Unnamed soils

Percent of map unit: 5 percent

MdC—Manor-Urban land complex, 8 to 15 percent slopes

Map Unit Setting

Elevation: 250 to 5,000 feet
Mean annual precipitation: 35 to 70 inches
Mean annual air temperature: 45 to 61 degrees F
Frost-free period: 90 to 235 days

Map Unit Composition

Manor and similar soils: 40 percent
Urban land: 40 percent
Minor components: 20 percent

Description of Urban Land

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: 10 inches to

Interpretive groups

Land capability (nonirrigated): 8s
Description of Manor

Properties and qualities
- **Slope:** 8 to 15 percent
- **Depth to restrictive feature:** More than 80 inches
- **Drainage class:** Well drained
- **Capacity of the most limiting layer to transmit water (Ksat):** Moderately high to high (0.57 to 1.98 in/hr)
- **Depth to water table:** More than 80 inches
- **Frequency of flooding:** None
- **Frequency of ponding:** None
- **Available water capacity:** Moderate (about 8.8 inches)

Interpretive groups
- **Land capability (nonirrigated):** 3e

Typical profile
- 0 to 6 inches: Loam
- 6 to 22 inches: Sandy loam
- 22 to 72 inches: Channery sandy loam

Minor Components
- **Ashe**
  - **Percent of map unit:** 5 percent
- **Brandywine**
  - **Percent of map unit:** 5 percent
- **Glenelg**
  - **Percent of map unit:** 5 percent
- **Unnamed soils**
  - **Percent of map unit:** 5 percent

U9—Udorthents, loamy, smoothed

Map Unit Setting
- **Mean annual precipitation:** 38 to 44 inches
- **Mean annual air temperature:** 48 to 57 degrees F
- **Frost-free period:** 150 to 220 days

Map Unit Composition
- **Udorthents and similar soils:** 100 percent

Description of Udorthents

Properties and qualities
- **Slope:** 0 to 3 percent
- **Depth to restrictive feature:** 10 inches to
- **Drainage class:** Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to very high (0.01 to 19.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Very low (about 1.4 inches)

Interpretive groups
Land capability (nonirrigated): 8s

Typical profile
0 to 2 inches: Loam
2 to 72 inches: Gravelly loam
References


Custom Soil Resource Report

Appendix 7.2
Cost Estimate
7.2 Cost Estimate

The cost estimate was done by taking a collection of engineering cost estimates for alleys, bioretention and bioswale designed in The District such as Green alleys, Watts Branch and Nannie Hellen Burroughs Ave respectively. Engineering cost for each of the above mentioned projects included the cost for mobilization, tying into the existing storm sewer system, erosion and sediment control and some traffic maintenance. The facility area was then divided by the total cost to obtain a cost per square feet. Each facility in the concept plan was measured using the survey and GIS mapping to determine the square footage area and a square foot price was multiplied by the area to come up with an individual cost.

The cost has been broken down for each facility within the catchment areas and also broken down into the type of techniques used. Follow the map in the appendix to see the cost for each facility. All costs include the cost to tie into the existing storm drains and underdrains for all LID techniques:

- Bioretention cost was approximately $64 per square foot
- Bioswale cost was approximately $43 per square foot
- Permeable Alley was approximately $40 per square foot (not that much difference whether the alley is pavers, concrete or asphalt)
- Gravel Warning Strip was approximately $35 per square foot

The cost estimates used to come up with the above estimate do not give drainage area or indicate the amount of volume treated so to obtain a cost for treatment area would require getting the plans and computations for each to determine the drainage area for each of the facilities.
### Summary of Cost Estimate for Catchment

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Runoff Volume (gallons)</th>
<th>LID Practice Volume (gallons)</th>
<th>LID Surplus or Deficit (gallons)</th>
<th>Efficiency (Actual vs. Available Storage)</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-01</td>
<td>68,660</td>
<td>67,985</td>
<td>-100</td>
<td>88%</td>
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<tr>
<td>L-02</td>
<td>33,898</td>
<td>33,606</td>
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<tr>
<td>L-03</td>
<td>61,377</td>
<td>61,142</td>
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<tr>
<td>L-04</td>
<td>12,870</td>
<td>12,917</td>
<td>7</td>
<td>77%</td>
<td>$100,535</td>
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<tr>
<td>L-05</td>
<td>39,664</td>
<td>39,135</td>
<td>-52</td>
<td>90%</td>
<td>$255,558</td>
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<tr>
<td>L-06</td>
<td>21,323</td>
<td>34,622</td>
<td>1330</td>
<td>51%</td>
<td>$209,455</td>
</tr>
<tr>
<td>L-07</td>
<td>4,796</td>
<td>4,959</td>
<td>24</td>
<td>99%</td>
<td>$46,155</td>
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<tr>
<td>L-08</td>
<td>10,890</td>
<td>10,394</td>
<td>-74</td>
<td>82%</td>
<td>$112,184</td>
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<tr>
<td>L-09</td>
<td>40,403</td>
<td>40,768</td>
<td>54</td>
<td>97%</td>
<td>$293,172</td>
</tr>
<tr>
<td>TOTAL</td>
<td>293,881</td>
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### Summary of Cost Estimate for Type of LID Techniques

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<th>Area (SF)</th>
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<th>Vol (gallons)</th>
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