2012 Stormwater Management Master Plan

Johns Hopkins University
Homewood Campus

Johns Hopkins University 2012 Homewood Campus Stormwater Management Master Plan

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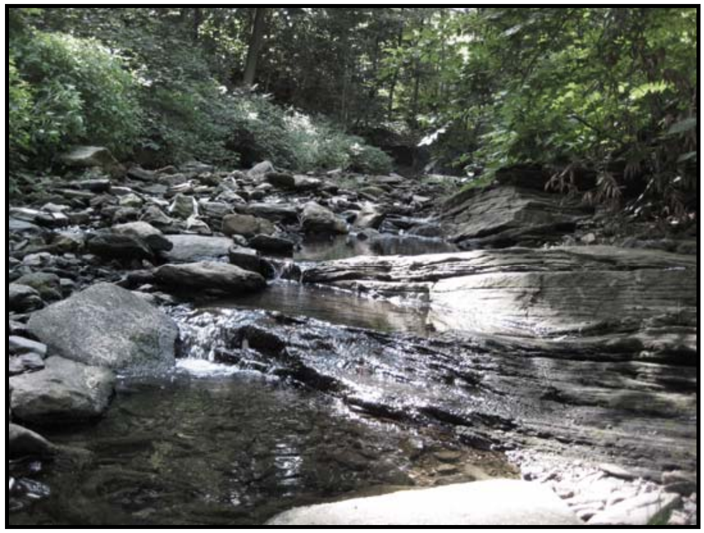

"When you put your hand in a flowing stream,
you touch the last that has gone before and the first of what is still to come."

- Leonardo da Vinci

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Stormwater Management Approach

The 2012 Homewood Campus Stormwater Management Master Plan (SWMMP) is strongly rooted in a new stormwater management design paradigm. This paradigm recognizes that stormwater management systems can and should play an integral role in advancing a broad set of interrelated planning goals including: improving water quality, reducing flooding, creating natural habitat, reducing water use on campus, reducing maintenance needs, educating the campus community about water-related issues, and furthering campus research opportunities.

Traditional stormwater management practices have historically focused on safe, efficient conveyance of stormwater from impervious surfaces to local streams in order to avoid on-site flooding. While generally effective at preventing on-site flooding, this rapid, downstream conveyance of stormwater has led to flooding, stream channel erosion, and stream water quality degradation further down in the watershed. In contrast to this traditional approach, the new, emerging multi-objective stormwater management paradigm that guides this SWMMP views stormwater as a valuable resource to be integrated into economic, environmental and social sustainability initiatives.

By adopting this new, multi-objective stormwater management paradigm to guide the master planning process, Johns Hopkins University (JHU) demonstrates its commitment to sustainability, as well as reinforces and reflects the careful juxtaposition of formal and natural landscapes that lend the Homewood campus its exceptional character.

SWMMP Overview

The SWMMP presents JHU's stormwater management regulatory compliance strategy associated with planned expansion activities at its Homewood campus. As such, the SWMMP supersedes the 2001 Stormwater Management Master Plan for JHU. The expansion activities include plans for development within six (6) designated limit of disturbance (LOD) areas on campus. The SWMMP is planned in accordance with Maryland's new regulations, adopted in 2007, which are based on the Stormwater Management Act of 2007.

In addition to the mandatory compliance requirements, the SWMMP considers ways in which enhanced stormwater management practices can help to achieve the campus's sustainability goals and improve the water resources of the wider region. To this end, the SWMMP defines a series of voluntary multi-objective stormwater management goals and measurable targets for the Homewood campus that were formulated by the SWMMP Steering Committee during the master planning process.

Stormwater Management Scenarios

The SWMMP addresses both the stricter regulatory environment and enhanced campus-wide goals and targets by detailing tiered stormwater management scenarios to implement Best Management Practices (BMP's): first, a baseline Regulatory Compliance Scenario and second, a broader, campus-wide Stormwater Management Master Plan (SWMMP) Scenario. The

Regulatory Compliance Scenario, as described in Chapter 5, identifies and details only stormwater BMPs necessary to meet regulatory requirements associated with planned campus expansion projects. These stormwater BMPs (or approved equivalent volume controls) are mandatory for compliance with City and State regulations. Stormwater BMP selection was optimized to achieve campus stormwater management targets to the extent possible, without exceeding treatment volume regulatory requirements.

The SWMMP Scenario builds upon the Regulatory Compliance Scenario to include stormwater BMPs necessary to meet both regulatory requirements and campus stormwater management targets. This scenario extends beyond expansion LOD boundaries to include BMP placement within other areas of the existing campus.

Order-of-magnitude implementation costs were estimated for both scenarios, based upon stormwater BMP type, and are summarized within Chapter 5.

Stormwater Design Guidance

The SWMMP provides design considerations within Chapter 6 that outline elements and principles for seamlessly integrating BMPs within the existing campus, as well as achieving other campus goals. These design considerations include: scale, safety, public health, aesthetics, maintenance, habitat, rain harvesting, safe conveyance, art and architecture, and other value-added elements.

To accompany the design considerations, the SWMMP provides design guidance within Chapter 7 to ensure successful implementation of BMPs for future individual campus expansion projects. The design guidance recommendations begin with site selection and continue through all phases of project design, including building and site layout and detailed design of stormwater BMPs.

Stormwater Administration, Implementation and Maintenance Guidance

While good planning and design sets the stage for a successful stormwater management system, streamlined administration, implementation and maintenance will ensure continued success over time. The SWMMP outlines recommendations for an organized system for administration, implementation and maintenance of BMPs. This includes a plan for tracking stormwater improvements as soon as they are completed so that progress towards regulatory requirements and campus goals can be assessed. In addition, it provides an outline for a maintenance program to ensure that stormwater practices continue to fulfill their core functions.

Chapter 1

Approach and Background

Chapter 1: Approach and Background

Stormwater Management Approach

Stormwater management has historically focused on safe, efficient conveyance of stormwater from impervious surfaces to local streams. While generally effective at preventing on-site flooding, this rapid, downstream conveyance of stormwater has led to flooding, stream channel erosion, and stream water quality degradation further down in the watershed. In contrast to this traditional approach, a new, emerging multi-objective stormwater management paradigm recognizes stormwater as a valuable resource to be integrated into economic, environmental and social sustainability initiatives.

The 2012 Homewood Campus Stormwater Management Master Plan (SWMMP) is strongly rooted in this new stormwater management design paradigm (see Image 1). The approach guiding stormwater planning for the Homewood campus recognizes that stormwater management systems can and should play an integral role in advancing a broad set of interrelated goals including: improving water quality, reducing flooding, creating natural habitat, reducing water use on campus, reducing maintenance needs, educating the campus community about water-related issues, and furthering campus research opportunities. In short, stormwater is about much more than stormwater.

Image 1 The Homewood campus provides a unique opportunity to manage stormwater in ways that advance a broad set of environmental and social goals.

The Homewood campus (the campus), with its interconnected mosaic of pathways, buildings, and courtyards (see Image 1), is replete with opportunities to manage stormwater in new, exciting ways that advance Johns Hopkins University's (JHU's) many environmental and social goals and improve the health of some of the region's most degraded water bodies. Most notably, the campus's many small green spaces (see Image 2) offer excellent opportunities to detain and treat roof runoff using vegetated surface best management practices (BMPs) such as **rain gardens** and **micro-bioretention** facilities which also contribute to campus beautification. These practices can, in many instances, replace poorly performing turf areas and landscape beds with vibrant low maintenance landscapes that provide wildlife habitat and core stormwater management functions (see Images 3 and 4). Reductions in turf areas allow the campus to reduce irrigation demand and energy usage.

In other areas, **rainwater cisterns** can provide the opportunity to harvest and reuse rainwater to reduce landscape water use and create a powerful demonstration of the campus's commitment to sustainability. **Green roofs**, while expensive from a first-cost perspective, can reduce energy consumption related to heating and cooling as they detain stormwater and create exciting showcase stormwater demonstrations for outreach and education. Closer to the Stoney Run forested area, opportunities for naturalizing impervious areas and turf to create forest and meadow habitat can extend the natural character of the Stoney Run valley into the developed campus, while reducing surface runoff to steeply sloping, gully-prone ravines (see Images 5 and 6).

Image 2 The campus's many landscaped beds and small green spaces create opportunities to integrate vegetated stormwater BMPs into the campus landscape.

Images 3 and 4 *Underperforming turf areas provide opportunities for reducing maintenance costs, improving aesthetics, and providing stormwater treatment of roof runoff (Before and After).*

Image 5 *Creating new meadow and forest patches can help to reduce stormwater runoff, while creating important habitats and extending the natural character of the Stoney Run Valley into the campus.*

Image 6 Strategic placement of stormwater BMPs upslope of gullied portions of the Stoney Run forested ravine can help to reduce erosion problems.

In campus expansion areas, regulatory requirements for new development projects mandate the inclusion of environmental site design (ESD) practices, creating opportunities to integrate stormwater features into the developed landscape in ways that are both functional and aesthetically pleasing.

In both existing and campus expansion areas, a new, multi-objective stormwater management paradigm creates opportunities that further JHU's commitment to sustainability, as well as reinforce and reflect the careful juxtaposition of formal and natural landscapes that lend the Homewood campus its exceptional character (see Images 7 and 8).

Images 7 and 8 Vegetated stormwater management features can be subtly integrated into more formal areas of campus through the use of formal planting schemes (Before and After).

SWMMP and Stormwater Management History

Concurrent with the development of the 2001 Homewood Campus Plan, JHU prepared a stormwater management master plan for the Homewood campus, the first significant effort to address stormwater management at the campus scale. The plan defined stormwater management measures required to comply with stormwater management regulations in place at the time. This plan was approved by Baltimore City in 2001. As an outgrowth of this plan, JHU constructed two stormwater management facilities: a stormwater quantity control basin located on the western side of campus, just north of Olin Hall, and a stormwater quality facility located down-slope of the Mattin Center, along the eastern side of campus.

In 2007, Maryland adopted new regulations based on the Stormwater Management Act of 2007. In addition to quantity control requirements, the updated regulations require the implementation of ESD practices to the Maximum Extent Practicable (MEP) to provide water quality treatment, groundwater recharge, and channel protection. In response to state regulation changes, Baltimore City approved a new Stormwater Management Ordinance in May of 2010, conforming to state law. The new regulations, in combination with the development of the 2008 Homewood Campus Plan Update, prompted JHU to initiate the development of a new stormwater management master plan for the Homewood campus in 2010. The 2012 Johns Hopkins University Homewood Campus SWMMP Concept Plan Design and Computations ("the Regulatory Plan"[AKRF 2012]), which provides concept-level regulatory approval for campus expansion in areas west of North Charles Street (i.e. within the Regulatory Plan boundary), was prepared by AKRF and approved by Baltimore City Department of Public Works (DPW) on August 24, 2012.

Prior Planning Efforts

Several campus-specific planning documents, including the 2001 Johns Hopkins Homewood Campus Plan (JHU 2001) and 2008 Homewood Campus Plan Update (JHU 2009) and the Johns Hopkins Sustainability Committee, define a number of environmental management goals related to stormwater management:

- Goals defined in the Homewood Campus Plans (JHU 2001 and 2009) include preserving natural areas; minimizing impacts to the Stoney Run stream valley; increasing tree canopy coverage and open space; and improving forest sustainability.
- Goals developed by the Johns Hopkins Sustainability Committee include reducing negative environmental impacts; managing stormwater runoff; and involving students, faculty, and the community in environmental enhancement initiatives.
- Broader planning efforts within Baltimore City and the Jones Falls watershed define additional environmental goals relevant to campus planning efforts. These planning efforts include the Baltimore Sustainability Plan (Baltimore City 2009), Baltimore City's Forest Conservation Plan (DNR 2003), and the 2008 Lower Jones Falls Small Watershed Action Plan (CWP 2008).
- Goals of the Baltimore Sustainability Plan (Baltimore City 2009) are similar to those of the Johns Hopkins Sustainability Committee and include protecting Baltimore's ecology and biodiversity; ensuring that Baltimore's water bodies are fishable and swimmable; reducing Baltimore's water use; increasing environmental awareness; and promoting Baltimore as a forward-thinking, green city.

- The 2003 Baltimore City Forest Conservation Plan (DNR 2003) seeks to maximize forest habitat value; prevent nutrients and sediments from reaching streams and reservoirs; improve the diversity and sustainability of forest stands; reduce negative impacts to soil, forests, and water quality; and reconnect fragmented parts of the landscape.
- Goals for the Stoney Run Subwatershed as outlined in the 2008 Lower Jones Falls Watershed Small Watershed Action Plan (CWP 2008) include reductions in the stormwater runoff volume entering storm drains.

The goals articulated in both JHU and external planning documents were incorporated into the development of the SWMMP.

SWMMP Overview

The SWMMP presents the JHU's stormwater management compliance strategy for expansion activities at its Homewood campus, as described in the 2008 Homewood Campus Plan Update (JHU 2009). As such, the SWMMP supersedes the current stormwater management master plan for the Homewood campus, which was prepared and approved in 2001 (RK&K 2001). The SWMMP incorporates content from the Regulatory Plan, which provides concept-level regulatory approval for campus expansion in areas west of North Charles Street that are located within the Regulatory Plan boundary (Figure 1). The SWMMP expands upon the Regulatory Plan by addressing volume controls (Chapter 2) for campus expansion areas east of North Charles Street that lie within the SWMMP boundary, but outside the Regulatory boundary (Figure 1) and strategies to support JHU's sustainability goals and enhance the water resources of the wider region. To this end, the SWMMP defines a series of voluntary multi-objective stormwater management goals and measurable targets for the campus. The SWMMP then details a pathway for achieving these management targets through incorporating various stormwater treatment practices into the existing campus landscape.

Specifically, the SWMMP:

- Provides a physical description of the campus including the physical constraints that limit the placement of stormwater treatment practices;
- Details JHU's expansion plans for the campus relative to changes in land cover;
- Defines quantity and quality requirements for stormwater management associated with campus expansion activities;
- Outlines campus stormwater management goals that further JHU sustainability initiatives and other planning initiatives;
- Recommends specific stormwater BMPs required to meet regulatory requirements and achieve campus stormwater goals;
- Demonstrates conformance with stormwater peak flow and volume management requirements within the Regulatory Plan boundary for the duration of the build-out period (through 2032);
- Recommends volume management strategies for campus expansion east of North Charles Street;
- Assesses progress towards campus multi-objective stormwater management goals relative to implementation costs;

- Provides building, site and stormwater design guidance to assist design professionals in implementing the SWMMP; and
- Provides administration, implementation and maintenance guidance to assist JHU in implementing the SWMMP.

Location

The 151-acre Homewood campus is located in the north central part of Baltimore City (Figure 2) and is defined, for purposes of this document, by the SWMMP boundary (Figure 1). The campus is bordered by Wyman Park to the west, University Parkway to the north, Remington Avenue to the southwest, West 31st Street, Wyman Park Drive and Art Museum Drive to the south, and North Charles Street to the east. The campus also includes areas located along North Charles Street in the Charles Village neighborhood of the City (Figure 3). Mixed-deciduous, forested ravines that descend to the Stoney Run valley dominate the western edge of campus (Figure 1).

Study Area Description

Geology

The campus is located in the Northeast Piedmont Physiographic Region, just west of the fall line, where the Coastal Plain meets the Piedmont's distinct topographic and geologic formations. The underlying geology of the campus is a mix of schist and sandy gravels, characteristic of the wider region (Figure 4).

Hydrology

The campus is located within the Patapsco River watershed, which drains into the Chesapeake Bay. Generally, the campus drains from east to west towards Stoney Run, a small tributary to the Patapsco River within the Jones Falls watershed, which forms the campus's western boundary (Figure 5). Drainage within developed portions of the campus occurs largely via subsurface stormwater pipe networks, which empty into small, ephemeral surface tributaries to Stoney Run, or directly into Stoney Run. No mapped wetlands and no critical areas are present within the campus.

Steep Slopes

Steep slopes of 20% or greater occur along the western edge of the campus, within the Stoney Run valley and along the southeastern edge of campus, along North Charles Street (Figure 6). The campus itself slopes from north to south, with an elevation loss of over 100 feet between Homewood Field and Olin Hall.

Soils

Campus soils are largely urban Udorthents, with many open areas underlain by development fill (Figure 7). In other parts of the campus, soils are covered over by pavement and buildings. The remaining natural soils are mainly well-drained upland loams of the Chester, Legore, and Manor series. Soils with Hydrologic Soil Groups (HSGs) B, C, and D are present within the campus (Figure 8). The percent of the campus covered by HSGs B, C, and D is 68%, 10%, 22%, respectively. Erodible soils are those with erosion factor (K_f) values greater than 0.35 (as defined in the Baltimore City DPW Stormwater Management Concept Plan Checklist), which indicates the soil's susceptibility to sheet and rill erosion by water. The highest K_f values present on the campus are the Beltsville-Urban land complex with a K_f value of 0.43 and 0 to 8 percent slopes (2UB), Manor loam with a K_f value of 0.37 and 15 to 50 percent slopes (21E), and Mattapex-Urban land complex with a K_f value of 0.43 and 0 to 8 percent slopes (25UB) (Figure 7).

Land Cover

Land cover was digitized from aerial photographs, engineering plans, and mapping from the 2008 Homewood Campus Plan Update. Land cover polygons were then field verified by AKRF staff. New buildings currently under construction were digitized based on detailed engineering plans and included as existing conditions.

The campus is largely characterized by a mosaic of campus buildings and paved pathways interspersed with expansive, open lawns and smaller, vegetated landscaping beds (Figures 9 and 10). Roadways and surface parking areas are mostly absent within the core campus. The campus's western edge is characterized by increasing forest cover and less intensive development. A twenty-acre Forest Conservation Zone lies in this corridor. The campus is 43% impervious (64.7 acres). Lawns and forest each account for 22% of the campus. The remaining land consists of lesser amounts of landscaped, athletic field, brush, meadow, woods-grass, or surface water cover types (Table 1).

Table 1
Existing Land Cover Types

Cover Type	Area (acres)	Percent of Campus Area
Athletic fields	7.4	5%
Brush, shrubs, and thickets	0.4	0%
Forest	33.6	22%
Landscaped areas	4.3	3%
Lawns	33.4	22%
Meadows and fields	0.9	1%
Ponds, streams, surface water	0.1	0%
Woods-grass, orchards	6.2	4%
Buildings	25.4	17%
Dirt	1.3	1%
Other impervious surfaces	0.1	0%
Roads, parking, vehicular ways	21.3	14%
Sidewalks, pedestrian ways	16.7	11%
Campus Total	**150.9**	**100%**

Campus Expansion Plans

Proposed Building Development

The 2008 Homewood Campus Plan Update outlines a twenty-year expansion plan for the campus, which JHU plans to implement in four, five-year phases. Each build-out phase includes construction of new buildings, pathways, and landscaping areas (Figures 10 and 11) and, in some cases, demolition of existing structures. Planned campus expansion and redevelopment projects include several new housing and recreation buildings at the north and east ends of the campus; several additions and improvements to existing buildings at the center of campus; and a major redevelopment of the Wyman Park building area.

For stormwater management compliance purposes, six (6) Limits of Disturbance (LOD) zones have been defined, which together encompass concentrated areas of planned infill development and expansion both within the Regulatory Plan boundary and for areas east of North Charles Street (Figure 12).

Changes to Impervious Cover

Changes to existing land cover during the build-out phases were digitized from engineering plans and mapping from the 2008 Homewood Campus Plan Update. Land cover mapping for the build-out phases incorporated changes in cover related to proposed stormwater BMPs and the conversion of lawns and landscaped areas to natural areas.

Impervious cover on the campus fluctuates during the twenty-year build-out, and is at times less than or greater than that associated with existing conditions (2012). By the completion of the twenty-year build-out, the campus impervious cover is estimated to increase by 2.0 acres (Table 2).

Table 2
Campus Impervious Cover Changes

Build-out Year	Impervious Area (acres)	Percent Impervious Cover (Total Campus Area = 150.9 acres)	Increase in Impervious Area from Previous Time Step (acres)
Existing	64.7	43%	-
2017	66.2	44%	1.5
2022	66.5	44%	0.3
2027	64.8	43%	-1.7
2032	66.7	44%	1.9
Total increase in impervious area during twenty-year build-out (acres)			**2.0**

Chapter 2

Regulatory Plan Requirements

Chapter 2: Regulatory Plan Requirements

The State of Maryland Stormwater Management Act of 2007 (the Act) sets forth regulations governing stormwater management within the State. The Act requires the State to establish a comprehensive process to approve stormwater management plans, to implement Environmental Site Design (ESD) to the maximum extent practicable (MEP), and to ensure that structural stormwater management practices are used only when ESD options are exhausted (Maryland Stormwater Design Manual [MDE 2000-2010] Section 5.0.2). Baltimore City defers to the State's Design Manual (the Manual) for determination of minimum control requirements (The Baltimore City Ordinance 10-277, Council Bill 10-0434, §22-3 [a]). The State requires the following minimum stormwater controls for any *site*, as specified in the Manual (Environmental Article, Title 26, Subtitle 17, Annotated Code of Maryland [COMAR] 26.17.02.06):

- Implement ESD to the MEP;
- Design using the ESD sizing criteria, recharge volume, water quality volume, and channel protection storage volume criteria;
- Control for the 2- and 10-year frequency storm event; and
- Control of peak discharge for the 100-year frequency storm event such that no increase occurs under proposed development conditions for watersheds designated as interjurisdictional flood hazard watersheds.

Redevelopment Criteria

The State of Maryland defines *redevelopment* as, "any construction, alteration, or improvement performed on sites where the existing land use is commercial, industrial, institutional, or multifamily residential and existing site impervious area exceeds 40 percent," and *site* as, "a single tract, lot, parcel of land, or combination of tracts, lots, parcels of land that are in one ownership, or are contiguous and in diverse ownership where development is to be performed as part of a unit, subdivision or project" (COMAR 26.17.02.02 and MDE 2000-2010 Section 5.5.1). Baltimore City defines these terms the same as the State (Baltimore City Ordinance 10-277, Council Bill 10-0434, §21-1 [t]).

The Regulatory Site includes the 144 acres of the campus west of North Charles Street within the Regulatory Plan boundary (Figure 1). The Regulatory Site is located in the City's 12th Ward and includes Block Lots 3669-001, 3690-001, 3690-002, and 3690-003. Campus expansion planned for areas east of North Charles Street (LOD B) were excluded from the Regulatory Plan and will require an independent concept plan approval from Baltimore City DPW for peak flow and volume compliance components. Under existing conditions, the Regulatory Site is 41% impervious and therefore meets the definition of a *redevelopment site* according to the State Maryland and Baltimore City definition. Areas of the campus east of North Charles Street would also meet the definition of a *redevelopment site*.

Peak Flow Requirements

Baltimore City requires that, under proposed conditions, the peak discharge rates of runoff, analyzed at a common downstream point of interest (POI), must be less than or equal to those of existing conditions (ETA 2003, Section 2.4.1 [6]). The State requires that development (which includes JHU campus redevelopment) result in no increase in peak discharge for the 100-year frequency storm event for interjurisdictional flood hazard watersheds (COMAR 26.17.02.06 [C]). Stoney Run is within the Jones Falls interjurisdictional flood hazard watershed (COMAR 26.17.02.07), and therefore must meet the no increase in peak discharge requirement for the 100-year frequency storm event (COMAR 26.17.02.06 [C]).

Hydrologic modeling of the Regulatory Site was performed to determine peak flows for regulated storm events through the build-out period. Hydrologic modeling was not performed for the areas east of North Charles Street (campus drainage area 6), but will be a requirement for concept plan approval from Baltimore City DPW for campus expansion in this area. Modeling results for the Regulatory Site show that peak flows for all regulated storm events are reduced from existing conditions (2012) over the course of the twenty-year build-out. Accordingly, the construction of quantity control facilities is not proposed within the Regulatory Plan. A detailed description of modeling methods and findings is presented in Appendix A.

Volume Requirements

The Baltimore City Ordinance 10-277, Council Bill 10-0434, §23-7 (A) (2) states that, "stormwater management measures must be consistent with the State's design manual." For *redevelopment sites*, the State of Maryland requires that stormwater be managed for all existing impervious areas within an LOD according to the redevelopment policy (MDE 2000-2010 Section 5.1.1) such that all existing impervious areas within the LOD for redevelopment sites be managed by reducing impervious cover by 50%, treating 50% of impervious cover with ESD practices, or a combination of the two (Baltimore City Ordinance 10-277, Council Bill 10-0434, §23-7 [C][(b)] and MDE 2000-2010 Section 5.1.2). The State requires that stormwater management for any net increase in impervious area within an LOD be addressed according to the new development criteria in the Manual Section 5.1.1 (MDE 2000-2010 Section 5.5.2 [4]). The Reduced Runoff Curve Number method (treating a site so that runoff is equivalent to a wooded site in good condition) was used to determine required ESD volumes (ESD_V), the recharge volumes (Re_V), water quality volume (WQ_V), and channel protection volumes (Cp_V) (MDE 2000-2010 Section 5.2.1).

The impervious treatment area (A_T), ESD_V, and Re_V required by Baltimore City for stormwater treatment volume compliance were calculated for each LOD within the Regulatory Plan boundary and summed to provide Regulatory Plan totals for the twenty-year build-out (Table 3). The five (5) LODs within the Regulatory Plan boundary were delineated to include demolition, new construction and other areas likely to be impacted by planned future construction staging and layout, several of which include construction activities proposed during multiple build-out phases. Throughout the twenty-year build-out, JHU will be permitted to run a cumulative ESD_V and/or A_T deficit of no more than 10% during any point in the campus expansion period for the sum of all LODs included in the Regulatory Plan boundary.

Campus expansion areas east of North Charles Street (LOD B) are excluded from the Regulatory Plan and will require independent approval from Baltimore City DPW. Similar to the Regulatory Plan LODs, LOD B was delineated to include demolition, new construction and other areas likely to be impacted by planned future construction staging and layout. Required treatment values for LOD B were computed (Table 3), but not included in the Regulatory Plan totals.

To track progress towards Regulatory Plan endpoints, JHU will prepare and submit a Regulatory Plan Accounting Log to Baltimore City DPW upon completion of each campus expansion project occurring within the Regulatory Plan boundary (see Chapter 8 for additional detail on regulatory compliance accounting). A detailed description of the calculation methods can be found in Appendix B and are summarized in Table 22.

Table 3

Required Treatment Area (A_T), Recharge Volume (Re_V), and Environmental Site Design Treatment Volume (ESD_V)

Limit of Disturbance (LOD)	Required A_T (ac)	Required Re_V (cf)	Required ESD_V (cf)
A - University Parkway	7.31	1,107.31	36,843.53
C - Wyman Park	3.33	0.00	13,198.35
D - Gilman	0.74	0.00	3,487.19
E - Whitehead	0.50	0.00	1,982.15
F - Decker	1.95	554.52	11,960.31
Regulatory Plan[1] LOD Totals	13.83	1,661.83	67,471.53
B - St. Paul[2]	1.13	98.97	5,514.14

[1]Excludes campus expansion activities east of North Charles Street (LOD B)

[2]LOD B - St. Paul is not included in the 2012 Johns Hopkins University Homewood Campus SWMMP Concept Plan Design and Computations ("the Regulatory Plan"). Stormwater best management practices to treat campus expansion activities occuring outside the Baltimore City DPW-approved LODs (i.e., A, C, D, E, F) must be submitted to Balitmore City DPW for concept plan approval independent of the Regulatory Plan.

Chapter 3

Goals, Strategies, Metrics and Targets

Chapter 3: Goals, Strategies, Metrics and Targets

Clearly articulated campus stormwater management goals and strategies are central to developing a cohesive and meaningful stormwater management master plan. Campus stormwater management goals presented in this chapter articulate the overall aims of the SWMMP, as formulated by the SWMMP Steering Committee, while campus stormwater management strategies outline the preferred means to achieving these goals.

Likewise, goals and strategies are effective only if accompanied by the means to measure outcomes and track progress. The second portion of the chapter presents numerical metrics and associated targets set by the SWMMP Steering Committee to drive stormwater management scenario development, and to evaluate and measure performance and adherence to the SWMMP during the 20-year implementation period.

Stormwater Management Goal and Strategy Development

As one of the first steps in the SWMMP development process, the project consultant team worked with the SWMMP Steering Committee to identify stormwater management goals and associated implementation strategies. Goals and strategies were developed collaboratively during workshops and through subsequent communication amongst SWMMP Steering Committee members. During these workshops, the SWMMP Steering Committee worked to achieve consensus around major goals and implementation strategies.

Prior to the workshop, SWMMP Steering Committee members independently ranked draft goals and strategies. Rankings were then adjusted through discussion both during and following the workshop, and through a formal re-ranking process conducted after the workshop.

Each goal and strategy was ranked according to the following rubric:

1 = Essential

Achieving the Goal is central to improving or maintaining key campus functions and/or to the successful implementation of numerous core campus planning goals and/or is required by external regulatory requirements. Major capitol investments are justified.

2 = Important

Goal is important, but not essential, to achieving campus goals or improving/maintaining campus functioning. Capital investment may be justified but must be evaluated in the context of other budget priorities.

3 = Value-added

Goal adds value to the campus by helping to implement less critical campus planning goals or maintaining existing campus functions. Significant capital investment would not be justified on the basis of this goal alone but should be considered when prioritizing projects.

4 = Peripheral

Goal may advance region-wide or other non-campus goals, but does not meaningfully advance campus planning goals. Goal does not significantly enhance quality of campus living or operations.

5 = Non-functioning

Goal would not have a positive impact on campus functioning and would not advance or conflict with other campus-wide goals. Goal should not be included as an evaluative criterion for project ranking.

In addition to composite rankings compiled from SWMMP Steering Committee member preferences, the group also ranked stormwater goals through a goal mapping process. This process involved considering the extent to which each stormwater management goal advanced specific goals outlined within other relevant planning documents from the campus and City, such as: 2001 Homewood Campus Plan, 2008 Homewood Campus Plan Update, Baltimore Sustainability Plan, and Baltimore City Forest Conservation Plan.

Final goal rankings integrated both the results of the goal mapping exercise and SWMMP Steering Committee rankings. Goals were segregated, on the basis of priority order, as either primary or supporting campus goals (Table 4).

The three highest ranking goals were designated as primary goals (goal ranking shown in parentheses):

- Improve the Quality of Downstream Waters (1)
- Enhance Ecological Integrity of the Campus Grounds (2)
- Reduce Water and Energy Usage on the Campus (3)

Additional goals, referred to as supporting goals, were also ranked in priority order:

- Complement and Enhance Existing Pedestrian and Vehicular Circulation Patterns (4)
- Enhance and Maintain Campus-Wide Spacemaking and Aesthetics through Stormwater BMPs (5)
- Create Learning Opportunities for Studying and Monitoring Stormwater BMPs (6)
- Enhance Student Body, Faculty, Alumni and Guest Awareness of Sustainable Stormwater Management Initiatives (7)
- Reduce Maintenance Activities and Costs Associated with Grounds Upkeep (8)
- Design Stormwater BMPs with Safety in Mind (9)
- Enhance Campus Open Space through Stormwater BMP Implementation (10), and
- Target Donor and External Support (11).

The final rankings of primary and supporting goals were used as a general framework to inform the development of stormwater management metrics and targets.

Table 4
Stormwater Management Goal and Strategy Ranking Results

Legend
Primary Goals
Primary Goal Strategy
Supporting Goals
Supporting Goal Strategy

GOAL
#1: IMPROVE THE QUALITY OF DOWNSTREAM WATERS
1.1 Reduce streambank erosion through large-scale BMPs to reduce peak flows
1.2 Reduce pollutant loads through detention, infiltration, and filtration of stormwater
1.3 Increase baseflow within Stoney Run through small infiltration BMPS
1.4 Other: Recharge aquifers through increased pervious surface
#2: ENHANCE ECOLOGICAL INTEGRITY OF THE CAMPUS GROUNDS
2.1 Where possible, replace existing impervious areas with natural or landscaped areas
2.2 Increase prevalence and diversity of plant life within core campus through BMPs
2.3 Restore woodland floor in West precinct by reducing erosive overland flows
2.4 Extend woodland fingers into core campus through naturalistic BMP patterns
2.5 Increase habitat for amphibians, reptiles, small mammals, and birds
2.6 Selectively transform turf areas into natural areas incl. meadow, forest, or shrub
#3: REDUCE WATER AND ENERGY USAGE ON CAMPUS
3.1 Reinvigorate underperforming landscape beds with native species (function as BMP)
3.2 Reduce turf grass on campus to reduce energy, lawn care, and other maintenance
3.3 Collect rain water in cisterns or underground tanks for non-potable irrigation
3.4 Convert landscape planting beds to drought-tolerant species that work as BMPs
3.5 Other: Rain water can be used for uses other than irrigation
#4: COMPLEMENT AND ENHANCE EXISTING PEDESTRIAN AND VEHICULAR CIRCULATION PATTERNS
4.1 Increase pedestrian connections from Stoney Run to main campus (trails)
4.2 Limit trampling of vegetation at path corners through installation of perimeter BMPs
4.3 Limit use of quads as pedestrian routes by placing linear BMPs along margins
4.4 Other: Identify opportunities for porous paths/walkways
#5: ENHANCE AND MAINTAIN CAMPUS-WIDE SPACEMAKING AND AESTHETICS THROUGH STORMWATER BMPS
5.1 Design BMPs to enhance the sense of place and existing character of spaces
5.2 Increase flowering plants within landscaped areas, particularly summer bloomers
5.3 Avoid disruption of visual impression formed by formal path and courtyard spaces
5.4 Complement formal courtyard aesthetic through natural looking stormwater practices
#6: CREATE LEARNING OPPORTUNITIES FOR STUDYING AND MONITORING STORMWATER MANAGEMENT BMPS
6.1 Create BMP research sites (coordinate with research staff)
6.2 Include student body in design of individual BMP areas
6.3 Other: Per goal #7, provide monitoring gages and showcase features

Table 4 continued
Stormwater Management Goal and Strategy Ranking Results

Legend
Primary Goals
Primary Goal Strategy
Supporting Goals
Supporting Goal Strategy

GOAL
#7: ENHANCE STUDENT BODY, FACULTY, ALUMNI AND GUEST AWARENESS OF SUSTAINABLE STORMWATER MANAGEMENT INITIATIVES
7.1 Create educational BMP sites, learning gardens, outdoor classrooms
7.2 Link BMPs to art goals through sculptural pieces and special material treatments
7.3 Include "showcase" features in central locations (gages, cistern fountains etc.)
7.4 Create interpretive stormwater management demonstration areas and gardens
7.5 Add interpretive signage at BMPs
7.6 Create BMPs for public health (healing garden near medical bldg., etc)
#8: REDUCE MAINTENANCE ACTIVITIES AND COSTS ASSOCIATED WITH GROUNDS UPKEEP
8.1 Use low-nutrient native species to minimize need for fertilizer
8.2 Reduce impervious area on campus by incorporating BMPs within existing hardscape
8.3 Replace turf mowing throughout campus by replacing turf with BMPs
8.4 Limit number of species used in BMP to reduce maintenance complexity
#9: DESIGN STORMWATER MANAGEMENT BMPS WITH SAFETY IN MIND
9.1 Maintain lines of sight along pathways and pedestrian areas
9.2 Provide lighting in/around BMP areas
9.3 Avoid creation of deep (>3ft) standing water
#10: ENHANCE CAMPUS OPEN SPACE THROUGH STORMWATER BMP IMPLEMENTATION
10.1 Transform small turf areas adjacent to buildings into vegetated, beautiful BMPs
10.2 Locate BMPs within existing hardscape to soften, shade, and cool surrounding areas
10.3 Enhance special event areas through manicured beds that double as BMPs
10.4 Design BMPs to function as edge spaces around recreation (shade, benches)
10.5 Increase opportunities for passive recreation through BMPs that link to trails & recreation
10.6 Use BMPs as means to transform turf acres into gathering spaces
10.7 Consider relocating some recreation or event spaces to accommodate BMPs
#11: TARGET DONOR AND EXTERNAL SUPPORT
11.1 Use BMPs that contribute to LEED certification for new construction (PR/visibility)
11.2 Target donor support through high profile projects related to research, demo & educ.
11.3 Other: Exceed regulator requirements to garner city support/flexibility for future projects

Opportunities and Constraints Mapping

During the goal, strategy, and metric development process, the SWMMP Steering Committee also identified specific areas that create unique opportunities to manage stormwater in ways that achieve various stormwater management goals including:

- Reducing localized flooding and gully formation within steeply sloping ravines in west campus through targeted stormwater BMP installation upslope of these areas,
- Improving underperforming landscapes through conversion of these spaces to low maintenance stormwater practices, and
- Enhancing aesthetic qualities of terraces and patios used as gathering spaces through introducing vegetated stormwater features.

Project consultants also performed field investigations to further identify and refine key opportunities for multi-objective stormwater management (see Images 9 and 10).

Further, the project consultant worked with the SWMMP Steering Committee to identify physical and institutional constraints that would constrain or limit the location or selection of stormwater management practices. This process included identifying areas, for example, where active recreational use and or key viewsheds would be disrupted by the introduction of stormwater management features.

Metrics and Targets Development

Metrics consist of quantifiable variables that relate to broad goal statements and help to translate goals into measurable outcomes. Targets refer to specific levels of attainment set for each metric. Following the development of stormwater management goals and strategies, the SWMMP Steering Committee selected quantifiable metrics and associated target implementation levels to enable JHU to measure stormwater management goal attainment through the 20-year SWMMP implementation period. Table 5 details the relationships between stormwater management goals, metrics, and targets. Table 6 presents stormwater management targets for each of the five-year SWMMP phase in periods for each primary metric.

Images 9 and 10 *Existing yard drains in turf areas were identified as good retrofit opportunities for stormwater BMP implementation.*

Table 5
Metrics and Associated Targets for Campus Stormwater Management Goals

Goals	Metrics	2032 Target
Improve the Quality of Downstream Waters	***Acreage of IA after reduction (1)**	58.9 acres
	***Acreage of IA treated (2)**	20.0 acres
Reduce Water and Energy Usage on Campus	***Gallons of stormwater reused (3)**	3,000,000 gallons[#]
	*** Amount of reduction in landscape energy use (kWh/yr)[##] (4)**	15%
Enhance Ecological Integrity of the Campus Grounds	***Acreage of natural habitat** area increased on campus (5)**	38.3 acres
	Acreage of natural habitat** created adjacent to woodlands (6)	1 acre
	Acreage of IA treated within gully DA (7)	1.2 acres
Enhance and Maintain Campus-Wide Spacemaking and Aesthetics through Stormwater BMPs	Acreage of lawn and landscape trouble spots converted to BMP (8)	1.3 acres
	Acreage of hardscape converted to BMP (9)	500 sf
Complement and Enhance Existing Pedestrian and Vehicular Patterns	Number of BMPs with trail access to forested areas (10)	5 BMPs
Enhance Student Body, Faculty, Alumni and Guest Awareness of Sustainable Stormwater Management Initiatives	Number of interpretive BMPs (11)	2 BMPs
	Number of showcase BMPs (12)	1 BMP
	Number of educational BMPs (13)	2 BMPs
Reduce Maintenance Activities and Costs Associated with Grounds Upkeep	Acreage of IA treated within flood prone DA (14)	3.6 acres

*primary metrics (bolded)

**natural habitat areas include forest, brush/shrub, and meadow

[#] based on current potable water use for campus landscape irrigation

[##] calculated by applying the multiplier 3,955 kWh/acre/yr to the area of lawn and landscaped areas converted to stormwater BMP or naturalized

Primary Metrics and Targets

Through facilitated workshops and follow-up discussions, the SWMMP Steering Committee selected the following five primary metrics as the core measuring tools for tracking progress towards achieving the SWMMP goals (Table 6):

Campus Imperviousness

Stormwater quality and quantity correlates strongly with the degree of landscape imperviousness, and as such, was selected by the SWMMP Steering Committee as the highest priority metric. However, since most of the impervious surfaces with existing campus areas consist of roof surfaces and pathways (a condition resulting in large part from JHU's efforts to eliminate roads and surface parking in core campus areas over the last decade), opportunities for significantly reducing gross imperviousness on campus are limited. As a result, the SWMMP Steering Committee established a modest target of reducing campus impervious area to 58.9 acres by 2032, a 4% reduction from existing levels.

Treated Impervious Area

The SWMMP Steering Committee selected the acreage of impervious area treated (A_T) using ESD practices as another priority metric. Since opportunities to eliminate impervious surfaces are limited, treating stormwater from remaining impervious areas using ESD practices offers an alternative strategy for reducing the impact of the campus on downstream water resources. The SWMMP Steering Committee established an aggressive goal of treating an additional 20.0 acres of impervious area (by draining to an ESD practice) to meet the 2032 treated impervious acreage target. Combined with the proposed reductions in impervious cover, meeting 2032 treated impervious targets will result in 74% of the campus consisting of either pervious cover (61%) or treated impervious cover (13%) by 2032.

Landscape Water Use

Reducing water use is a key objective for the Johns Hopkins Sustainability Committee. In terms of stormwater planning, the SWMMP Steering Committee decided to focus on eliminating the use of potable water for landscape irrigation, which accounts for approximately 3,000,000 gallons of water use per year, by 2032 through the installation of rainwater cisterns and by replacing water-hungry turf and landscape beds with self-irrigating, vegetated stormwater practices.

Landscape Energy Use

Replacement of turf areas with natural landscapes and vegetated practices can significantly reduce landscape-related energy use. Because of the link between stormwater treatment and potential reductions in landscape-related energy use, the SWMMP Steering Committee selected landscape energy use as another primary metric for the SWMMP. The SWMMP Steering Committee established a target of reducing annual landscape energy use by 15% or 137,000 kWh/yr through SWMMP implementation.

Natural Habitat Area

Although the western portions of the Homewood campus are largely characterized by forested lands, expanding the Stoney Run Natural Area into the core campus was a key goal articulated in the 2008 Homewood Campus Plan Update. Given this objective, SWMMP Steering Committee established natural habitat area as a primary SWMMP metric and set a 2032 target of increasing natural habitat area by 10%.

Table 6

Primary Metric Targets by Build-out Phase

Primary Metric Description	Existing Value	2017 Metric Target / Target Value	2022 Metric Target / Target Value	2027 Metric Target / Target Value	2032 Metric Target / Target Value
Campus imperviousness (acres of IA [%IA])	64.7 acres (43%)	Reduce IA by 1%	Reduce IA by 2%	Reduce IA by 3%	Reduce IA by 4%
		63.4 acres (42% IA)	61.9 acres (41% IA)	60.4 acres (40% IA)	58.9 acres (39% IA)
Treated impervious areas (acres of IA treated)	0 acres	Treat 13% of 2030IA	Treat 18% of 2030IA	Treat 24% of 2030IA	Treat 30% of 2030IA
		8.7 acres	12.0 acres	16.0 acres	20.0 acres
Landscape water use (gal [% reduction])	3,000,000 gal	Decrease use by 750,000 gal	Decrease use by 1,500,000 gal	Decrease use by 2,250,000 gal	Decrease use by 3,000,000 gal
		2,250,000 gal (25%)	1,500,000 gal (50%)	750,000 gal (75%)	0 gal (100%)
Landscape energy use (kWh/yr)	161,000 kWh / yr	Reduce kWh/yr by 3%	Reduce kWh/yr by 7%	Reduce kWh/yr by 11%	Reduce kWh/yr by 15%
		156,000 kWh/yr	150,000 kWh/yr	143,000 kWh/yr	137,000 kWh/yr
Increase natural habitat area* (acres)	34.9 acres	Increase by 2%	Increase by 5%	Increase by 8%	Increase by 10%
		35.6 acres	36.6 acres	37.6 acres	38.3 acres

*Natural habitat areas include forest, brush/shrub, and meadow

Supporting Metrics and Targets

In addition to the primary metrics, nine (9) supporting metrics and associated targets were established by the SWMMP Steering Committee:

Creation of Natural Habitat Area Adjacent To Woodlands or Woodland Fingers

Creating new natural habitats or habitat-creating stormwater practices in areas adjacent to and connected with existing habitats maximizes their ecological value (see Image 11). The SWMMP Steering Committee established a 2032 target of creating one (1) acre of additional natural habitat adjacent to woodlands or woodland fingers through SWMMP implementation.

Treatment of Impervious Area within Gully Drainage Areas

Erosive gullies extending into the Stoney Run forested ravine increase sediment and nutrient laden runoff, key waterborne pollutants, delivered to Stoney Run and other downstream waters (see Image 11). The SWMMP Steering Committee established a target of providing stormwater treatment for 25% of the drainage area to gullied channels, or 1.2 acres, by 2032 to help arrest the expansion of gullied areas on campus.

Image 11 *Opportunities exist throughout campus to incorporate stormwater BMPs as naturalized meadow and forested areas to increase habitat and to help reduce erosion of the gully drainage areas leading to Stoney Run.*

Conversion of Landscape Trouble Spots to Stormwater BMPs

Landscape trouble spots include areas where trampling or high recreation use has led to a deterioration in turf condition, or where plantings within landscaped beds were observed by the project consulting team to be in poor or suboptimal condition (see Images 12 and 13).

Targeting the installation of vegetated stormwater practices in these areas can provide core stormwater treatment while also improving landscape conditions and reducing maintenance needs. Accordingly, the SWMMP Steering Committee established a 2032 target of converting of 25% of existing landscape trouble spots, or 1.3 acres, to stormwater BMPs.

Images 12 and 13 *Underperforming turf areas and landscape beds provide opportunities for enhancement through vegetated stormwater BMP installation.*

Conversion of Hardscape Areas to Stormwater BMPs

The installation of vegetated stormwater practices adjacent to hardscape areas such as terraces and patios can provide stormwater treatment of runoff from these surfaces while improving the overall appeal of these gathering places through the introduction of attractive vegetation and shade (see Images 14 and 15). In light of these value added benefits, the SWMMP Steering Committee established a 2032 target of converting at least 500 sf of existing hardscape to vegetated stormwater BMPs.

Images 14 and 15 *Integrating ESD practices within available existing hardscape areas could reduce campus impervious area and create meaningful gathering spaces (before and after).*

Use of Stormwater BMPs as Trail Access Points to Forested Areas

Stormwater BMPs located close to trail networks within the Stoney Run Natural Area could also serve as trail access points, helping to meet another goal articulated in the 2008 Homewood Campus Plan Update. To help achieve this goal, the SWMMP Steering Committee established a target of incorporating trail access into five (5) stormwater management practice implementation sites by 2032.

Stormwater BMPs as Interpretive Areas

In select locations, stormwater BMPs can incorporate interpretive features to promote student, faculty, alumni and visitor awareness of sustainability and water-related issues. Interpretive features are typically located in visually prominent locations and incorporate signage or kiosks to interpret the site and provide information about the project design, campus planning initiatives, or wider watershed issues (e.g., Chesapeake Bay restoration) of the region. The SWMMP Steering Committee set a target of building at least (2) two interpretive stormwater BMPs by 2032.

Stormwater BMPs as Artistic or Showcase Features

Through incorporating sculptural, artistic, or architectural elements, stormwater practices can be designed to function as powerful artistic expressions of water movement through the campus landscape (see Image 16). These practices, while typically more expensive than other types of stormwater practices, enrich the overall campus environment by demonstrating the powerful connections between land, building, and water. The SWMMP Steering Committee established a target of creating at least one (1) showcase/artistic stormwater BMP as part of the SWMMP implementation.

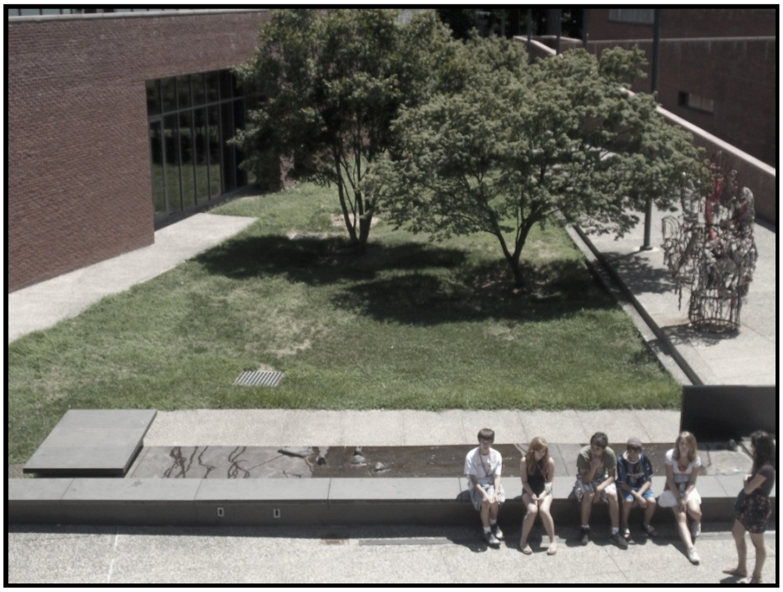


Image 16 *Gathering spaces on campus could be enhanced through the installation of vegetated stormwater BMPs. Interpretive or artistic stormwater pieces could be integrated into select areas as showcase features.*

Stormwater BMPs as Educational Resources

At many institutions, stormwater BMPs serve as research sites for students and faculty. The dual role helps to engage both facility and students more actively in stormwater management and provides an opportunity for the institution to extend the impact of its stormwater programs to include research contributions to the wider stormwater management field. To work towards this goal, the SWMMP Steering Committee established a target of creating two (2) research-based stormwater BMPs by 2032.

Treatment of Impervious Area within Flood Prone Drainage Areas

Several flood prone areas were mapped by members of the SWMMP Steering Committee during the goal setting workshop. To help alleviate localized flooding, the SWMMP Steering Committee established a target of treating 25% of the drainage area to identified flooding locations, or 3.6 acres by 2032 (Figure 13).

Chapter 4

Stormwater Management Scenario Development

Chapter 4: Stormwater Management Scenario Development

Following the goal, strategy, metric, and target development process described in Chapter 3, the project consulting team worked with the SWMMP Steering Committee to develop stormwater management scenarios, consisting of groupings of stormwater practices placed throughout existing and/or campus expansion areas, to meet both regulatory requirements and campus stormwater management targets.

A two-tiered approach to stormwater management scenarios was developed:

The Regulatory Compliance Scenario includes only stormwater BMPs necessary to meet regulatory requirements for campus expansion projects within the Regulatory Plan boundary (areas of campus west of North Charles Street), as described in Chapter 2. These stormwater BMPs (or approved equivalent volume controls) are mandatory for compliance with City and State regulations. Stormwater BMP selection was optimized to achieve campus stormwater management targets to the extent possible, *without* exceeding treatment volume regulatory requirements.

SWMMP Scenario builds upon the Regulatory Compliance Scenario to include stormwater BMPs necessary to meet regulatory requirements throughout campus (including areas east of North Charles Street) and campus stormwater management targets.

Scenario Development and Optimization

Recognizing that many potential combinations of stormwater BMPs are possible, an iterative design process was used to optimize each scenario based on a quantitative cost/benefit analysis. For both the Regulatory Compliance and SWMMP Scenarios, the optimization process involved first developing an initial stormwater BMP layout that:

1. Meet regulatory requirements by using ESD practices and principles as described in the Manual, and,
2. In the case of the SWMMP Scenario, fully-achieve campus stormwater management targets at each 5-year build-out phase, where possible.

Regulatory requirements for redevelopment sites are presented for campus expansion areas in Chapter 2. In summary, City and State regulations require that 50% of existing impervious area and 100% of new impervious area be treated using ESD to the MEP. Treatment following ESD to the MEP to achieve predevelopment conditions of "woods-in-good-condition" will meet criteria for recharge volume, water quality volume, and channel protection storage volume criteria (MDE 2000-2010 Section 5.2.1).

Following the development of initial scenario runs, the initial layouts were evaluated by quantifying benefits (as expressed as an aggregate of normalized, weighted primary metric scores) and costs (construction and operations and maintenance costs expressed as Net Present Value over a 40-year analysis period). Subsequently, designers attempted to improve cost/benefit relationships by altering the location or type of stormwater BMPs in a number of successive design iterations. Due to the complexity of the analysis, benefits were not monetized, but were instead normalized for comparison. Both scenarios were checked after each iteration to ensure that regulatory requirements for campus expansion areas were being met. A detailed description of metric computations, weighting methodology, and cost estimation is presented in Appendices C and D.

Chapter 5

Stormwater Management Scenarios

Chapter 5: Stormwater Management Scenarios

This chapter presents each stormwater management scenario in detail, including a summary of number, type, and location of proposed stormwater BMPs, projected implementation and operations and maintenance (O&M) costs, and a quantification and comparison of expected benefits. A Master List of stormwater BMPs associated with both scenarios is included in Appendix E.

Regulatory Compliance Scenario

The Regulatory Compliance Scenario includes ninety-five (95) stormwater BMPs, all located within the campus LODs, that were delineated based on campus expansion plans west of North Charles Street. As such, the Regulatory Compliance Scenario excludes areas east of North Charles Street (LOD B); campus expansion in this area will require an independent concept plan approval from Baltimore City DPW for peak flow and volume compliance components. Table 7 outlines the total number of practices, surface area, A_T, costs, rainwater harvested, and ESD_V treated for each stormwater BMP type for the Regulatory Compliance Scenario.

Table 7
Stormwater BMP Summary - Regulatory Compliance Scenario

BMP Type	Number of Practices	Total Footprint (sf)	Impervious Area Treated (sf)	Total Cost	Annual O&M Cost	Rainwater Harvested (gal)	ESD volume (cf)
Green Roofs	3	6,950	6,950	$ 55,000	$ -	-	588
Cisterns	5	730	55,600	$ 307,000	$ 3,000	1,372,520	6,750
Micro-bioretention	52	68,090	491,300	$ 2,307,000	$ 20,000	-	55,200
Rain Gardens	11	11,240	48,780	$ 82,000	$ 4,000	-	5,104
Naturalized Areas	24	184,440	-	$ 235,000	$ (91,000)	-	-
Totals	95	271,450	602,630	$ 2,986,000	$ (64,000)	1,372,520	67,642

*Annual O&M Cost is the net increase or decrease in the annual operation and maintenance (O&M) cost for the proposed BMPs compared to the O&M cost associated with the existing cover (i.e. turf grass, pavement, etc.) being replaced by the BMP.

Regulatory Compliance Scenario Summary by Practice Type

The Regulatory Compliance Scenario incorporates several types of stormwater BMPs, which are discussed in more detail, below:

Green Roofs

Proposed green roofs cover an area of 6,950 sf and treat 6,950 sf of impervious area. The order-of-magnitude construction cost estimate for green roof installation is $55,000. O&M costs are not estimated to increase beyond traditional O&M costs annually. In addition, energy savings due to green roof installation were not quantified in this study.

Cisterns

Proposed cisterns cover a surface area of 730 sf, treat 55,600 sf of impervious area, and harvest 1,372,520 gallons of rainwater annually. The order-of-magnitude construction cost estimate for cisterns is $307,000. Additional O&M costs were estimated at $3,000 annually.

Micro-bioretention Practices

Proposed micro-bioretention practices cover a footprint of 68,090 sf and treat 491,300 sf of impervious area. The order-of-magnitude construction cost for the micro-bioretention practices is $2,307,000. Additional O&M costs are estimated at $20,000 annually.

Rain Gardens

Proposed rain gardens cover an area of 11,240 sf and treat 48,780 sf of impervious area. The order-of-magnitude construction cost for rain gardens is estimated at $82,000. Additional O&M is estimated at $4,000 annually.

Naturalized Areas

The conversion of impervious, landscaped, or lawn-covered areas with forests or meadows covers an area of 184,440 sf. The order-of-magnitude cost for naturalized areas is estimated at $235,000 with a $91,000 savings in O&M relative to existing maintenance costs, annually.

Regulatory Compliance Scenario Summary by LOD

The stormwater BMPs described above are all located within campus LODs (Figure 14) per the methods required by regulation and described in Chapter 2. The regulatory requirements for treated IA (A_T), groundwater recharge (Re_V), and volume (ESD_V) and the actual provided A_T and treatment volumes are provided by LOD below. A more detailed description of regulatory compliance calculations are provided in Appendix B.

LOD A – University Parkway

Regulations require treatment of an ESD_V of 36,843.53 cf, of which 1,107.31 cf must be infiltrated to provide groundwater recharge, and A_T of 7.31 acres within LOD A (Figure 15). These requirements were met to the maximum extent practicable through a combination of green roof, rain garden, micro-bioretention, and cistern practices (Table A-1). LOD A spans two (2) campus drainage areas; however the portion of campus drainage area 5 within LOD F is less than 5% of the total LOD area. The portion of the required ESD_v attributable to campus drainage area 5 was treated within campus drainage area 1 in the LOD. The total ESD_V and A_T within the LOD using ESD practices are 36,930.03 cubic feet and 6.99 acres, respectively (Table A-2). Proposed ESD practices meet the required ESD_V, but fall 0.32 acres short of the A_T. The balance of the untreated A_T is treated within other campus areas, primarily LOD C. The required Re_V will be provided by micro-bioretention and rain garden practices, which treat 31,262.03 cubic feet of stormwater in LOD A.

LOD C—Wyman Park

Regulations require treatment of an ESD_V of 13,198.35 cf and A_T of 3.33 acres within LOD C (Figure 16). Because there was no net increase in IA, Re_V was not required. These requirements were met through a combination of rain garden, micro-bioretention, and cistern practices (Table C-1). LOD C spans two (2) campus drainage areas. The ESD_V requirements within each campus drainage area were met independently. The total A_T and ESD_V treated within the LOD using ESD practices are 4.27 acres and 15,560.82 cf, respectively (Table C-2).

Proposed ESD practices exceed A_T and ESD_V targets by 0.94 acres and 2,362.47 cf, respectively, providing treatment for LODs with treatment deficits.

LOD D—Gilman

Regulations require treatment of an ESD_V of 3,487.19 cf and A_T of 0.74 acres within LOD D (Figure 17). Because there was no net increase in IA, Re_V was not required. These requirements were met through a combination of rain garden and micro-bioretention practices (Table D-1). LOD D spans three (3) campus drainage areas. The portion of campus drainage area 4 (1) within LOD D is less than 5% of the total LOD area. Therefore, the portion of the required ESD_V attributable to campus drainage area 4 (1) was treated within the two other campus drainage areas. The total A_T and ESD_V treated within the LOD using ESD practices is 0.76 acres and 3,582.36 cf, respectively (Table D-2). Proposed ESD practices exceed the required A_T and ESD_V by 0.02 acres and 95.17 cf, respectively, providing treatment for LODs with treatment deficits.

LOD E—Whitehead

Regulations require treatment of an ESD_V of 1,982.15 cf and A_T of 0.50 acres within LOD E (Figure 18). Because there was no net increase in IA, Re_V was not required. These requirements were met to the maximum extent practicable through a combination of micro-bioretention, cistern, and green roof practices (Table E-1). LOD E spans one (1) campus drainage area. The total A_T and ESD_V treated within the LOD using ESD practices are 0.32 acres and 2,048.83 cf, respectively (Table E-2). Proposed ESD practices meet the required ESD_V, but fall 0.18 acres short of the A_T. The balance of the untreated A_T is treated within other campus areas, primarily LOD C.

LOD F—Decker

Regulations require treatment of an ESD_V of 11,960.31 cf, of which 554.52 cf must be infiltrated to provide groundwater recharge, and A_T of 1.95 acres within LOD F (Figure 19). These requirements were met to the maximum extent practicable using micro-bioretention practices (Table F-1), but due to constraints within the LOD, treatment targets could not be fully achieved. LOD F spans four (4) campus drainage areas. The portion of campus drainage area 2 within LOD F is less than 5% of the total LOD area. Therefore, the portion of the required A_T and ESD_V attributable to campus drainage area 2 was treated within the other campus drainage areas in the LOD, where possible. Under proposed conditions, the area near the intersection of campus drainage areas 1 and 3 within LOD F may be modified during construction and grading. BMP drainage areas are delineated under the assumption that this border will be modified in the future. At this level of conceptual planning, the exact drainage divide is unknown. The total A_T and ESD_V treated within the LOD using ESD practices are 1.49 acres and 9,519.38 cf, respectively (Table F-2). Proposed ESD practices fall 0.46 acres and 2,440.93 cf short of the A_T and ESD_V targets, respectively. The balance of untreated A_T and ESD_V is provided within other campus areas, primarily LOD C. The required Re_V will be provided by micro-bioretention practices which treat 9,519.38 cubic feet of stormwater in LOD F.

SWMMP Scenario

The SWMMP Scenario incorporates stormwater BMPs included in the Regulatory Compliance Scenario and additional practices required to achieve campus stormwater management goals to the extent possible (Figures 20-25). In addition, regulatory requirements within LOD B were addressed to the extent practicable with two green roofs, both with 4 in. deep soil media (see Appendix E, BMPs V1 and V2). These practices will require concept approval from Baltimore City DPW independent of the Regulatory Plan. A total of 156 stormwater BMPs are included within the SWMMP Scenario. The stormwater BMPs included within this are summarized within Table 8.

Table 8
Stormwater BMP Summary - SWMMP Scenario

BMP Type	Number of Practices	Total Footprint (sf)	Impervious Area Treated (sf)	Total Cost	Annual O&M Cost*	Rainwater Harvested (gal)	ESD volume (cf)
Green Roofs	5	85,340	85,340	$2,707,000	$ 3,000	-	6,624
Cisterns	22	1,700	165,120	$ 640,000	$ 7,000	4,079,880	16,110
Micro-bioretention	78	104,760	678,030	$3,843,000	$ 26,000	-	84,560
Rain Gardens	25	20,300	88,410	$ 174,000	$ 6,000	-	9,754
Naturalized Areas	33	270,180	-	$ 320,000	$(125,000)	-	-
Totals	163	482,280	1,016,900	$7,684,000	$ (83,000)	4,079,880	117,048

*Annual O&M Cost is the net increase or decrease in the annual operation and maintenance (O&M) cost for the proposed BMPs compared to the O&M cost associated with the existing cover (i.e. turf grass, pavement, etc.) being replaced by the BMP.

The SWMMP Scenario incorporates several types of stormwater BMPs, which are discussed in more detail, below:

Green Roofs

Proposed green roofs cover an area of 85,340 sf and treat 85,340 sf of impervious area. The order-of-magnitude construction cost estimate for green roof installation is $2,707,000. Additional O&M costs are estimated at $3,000 annually. Energy savings due to green roof installation were not quantified in this study.

Cisterns

Cisterns cover an area of 1,700 sf, treat 165,120 sf of impervious area, and harvest 4,079,880 gallons of rainwater annually. The order-of-magnitude construction cost estimate for cisterns is $640,000. Additional O&M costs are estimated at $7,000.

Micro-bioretention Practices

Proposed micro-bioretention practices cover a footprint of 104,760 sf and treat 678,030 sf of impervious area. The order-of-magnitude construction cost for the micro-bioretention practices is $3,843,000. Additional O&M costs are estimated at $26,000 annually.

Rain Gardens

Proposed rain gardens cover an area of 20,300 sf and treat 88,410 sf of impervious area. The order-of-magnitude construction cost for rain gardens is estimated at $174,000. Additional O&M costs are estimated at $6,000 annually.

Naturalized Areas

The conversion of impervious, landscaped, or lawn-covered areas to forests or meadows covers an area of 270,180 sf. The order-of-magnitude cost for naturalized areas is estimated at $320,000 with a $125,000 savings in O&M above existing maintenance costs, annually.

Primary Target Attainment

Primary target attainment for the Regulatory Compliance and SWMMP Scenarios is presented in Table 9. The Regulatory Compliance Scenario meets only one of the primary 2032 metric targets, that of increasing natural habitat areas by more than 10%. The SWMMP scenario fully meets three (3) of the five (5) primary targets: (1) Treated impervious area, (2) Landscape water use, and (3) Natural habitat area. Reduction of campus impervious and landscape energy use are not fully met within either scenario despite attempts to identify potential areas for conversion of IA to pervious area and lawns to naturalized areas. Future planning efforts should focus on identifying additional strategies to meet all targets.

Reduce Campus Imperviousness

The target value for campus imperviousness by 2032 is 58.9 acres. Neither scenario achieves the 2032 target value, but under the SWMMP Scenario, campus impervious cover does not increase from existing levels.

Treat Impervious Areas

The 2032 target value for this metric required treatment of 30% (20.0 acres) of impervious area, with interim targets set at 13% (8.7 acres) for 2017, 18% (12.0 acres) for 2022, and 24% (16.0 acres) for 2027. The Regulatory Compliance Scenario treats roughly 40% to 70% of the target values for each build-out phase. The SWMMP Scenario treats slightly less impervious area than that required to meet the 2017 target. However, by 2027 the treated impervious area target is exceeded.

Increase Water Reuse

The 2032 target for water reuse involves reducing annual potable water consumption by 3,000,000 gallons, with interim targets set at 2,250,000 gallons (25%) for 2017, 1,500,000 gallons (50%) for 2022, and 750,000 gallons (75%) for 2027. Under the Regulatory Compliance Scenario, annual potable water use is reduced by 3% to 16% from 2017 to 2032. By 2032 potable water use will be reduced to 1,627,480 gal. The SWMMP Scenario achieves the target value for annual water reuse by 2032.

Reduce Landscape Energy Use

The 2032 target for reducing landscape energy use involves reducing energy use by 15% to 137,000 kWh/yr, with interim targets of 3% (156,000 kWh/yr) for 2017, 7% (150,000 kWh/yr) for 2022, and 11% (143,000 kWh/yr) for 2027. Neither scenario achieves the 2032 target, but under the SWMMP Scenario, landscape energy use is reduced to 144,040 kWh/yr, or 95% of the 2032 target.

Create Natural Areas

The 2032 target for natural areas involves increasing natural habitat area by 10% to a total of 38.3 acres. Interim targets of 2% (35.6 acres), 5% (36.6 acres), and 8% (37.6 acres) were set for the 2017, 2022, and 2027 build-out phases, respectively. Both scenarios exceed the target for natural habitat creation at all build-out phases.

Table 9
Primary Metric Target Achievement by Build-out Phase

Primary Metric Description	Existing Value	2017	2022	2027	2032
		Metric Target	**Metric Target**	**Metric Target**	**Metric Target**
		Target Value	**Target Value**	**Target Value**	**Target Value**
		Regulatory Compliance Scenario	**Regulatory Compliance Scenario**	**Regulatory Compliance Scenario**	**Regulatory Compliance Scenario**
		SWMMP Scenario	**SWMMP Scenario**	**SWMMP Scenario**	**SWMMP Scenario**
Campus imperviousness [#] (acres of IA [%IA])	64.7 acres (43%)	Reduce IA by 1%	Reduce IA by 2%	Reduce IA by 3%	Reduce IA by 4%
		63.4 acres (42% IA)	61.9 acres (41% IA)	60.4 acres (40% IA)	58.9 acres (39% IA)
		66.1 acres (44%)	66.3 acres (44%)	64.7 acres (43%)	66.6 acres (44%)
		66.1 acres (44%)	64.5 acres (43%)	62.9 acres (42%)	64.7 acres (43%)
Treated impervious areas (acres of IA treated)	0 acres	Treat 13% of 2030IA	Treat 18% of 2030IA	Treat 24% of 2030IA	Treat 30% of 2030IA
		8.7 acres	12.0 acres	16.0 acres	20.0 acres
		3.3 acres	5.0 acres	8.1 acres	13.8 acres
		4.8 acres	10.6 acres	15.1 acres	23.2 acres
Landscape water use (gal [% reduction])	3,000,000 gal	Decrease use by 750,000 gal	Decrease use by 1,500,000 gal	Decrease use by 2,250,000 gal	Decrease use by 3,000,000 gal
		2,250,000 gal (25%)	1,500,000 gal (50%)	750,000 gal (75%)	0 gal (100%)
		2,903,230 gal (3%)	2,903,230 gal (3%)	2,681,800 gal (11%)	1,627,480 gal (46%)
		1,864,950 gal (38%)	1,157,950 gal (61%)	451,120 gal (85%)	0 gal (100%)
Landscape energy use (kWh/yr)	161,000 kWh / yr	Reduce kWh/yr by 3%	Reduce kWh/yr by 7%	Reduce kWh/yr by 11%	Reduce kWh/yr by 15%
		156,000 kWh/yr	150,000 kWh/yr	143,000 kWh/yr	137,000 kWh/yr
		163,460 kWh/yr	156,570 kWh/yr	159,990 kWh/yr	151,190 kWh/yr
		161,050 kWh/yr	153,190 kWh/yr	154,410 kWh/yr	144,040 kWh/yr
Increase natural habitat area (acres)**	34.9 acres	Increase habitat by 2%	Increase habitat by 5%	Increase habitat by 8%	Increase habitat by 10%
		35.6 acres	36.6 acres	37.6 acres	38.3 acres
		36.0 acres	37.1 acres	37.9 acres	38.6 acres
		36.6 acres	37.8 acres	39.2 acres	40.6 acres

[#] Campus Imperviousness for the scenarios is reduced by green roofs and other stormwater BMPs proposed over impervious surfaces.
**Natural habitat areas include forest, brush/shrub, and meadow

Scenario Benefit Comparison

The Regulatory Compliance Scenario meets or exceeds targets for six (6) of the 14 metrics, while the SWMMP Scenario meets or exceeds all but two (2) of the targets (impervious area reduction and landscape energy use reduction). To facilitate a more nuanced comparison of benefits among the two scenarios, weighted metric scores used to estimate total benefit, were compared (Table10). Under this ranking system, full attainment of all campus stormwater management targets equates to a score of 260. The SWMMP Scenario scores 257, indicating that the scenario nearly achieves full attainment of campus stormwater targets, while the Regulatory Compliance Scenario scores 208, approximately 80% of the SWMMP Scenario weighted score. By this measure, total benefits associated with the SWMMP Scenario exceed those associated with the Regulatory Compliance Scenario by approximately 20%.

Table 10
Metric-Based Scenario Score

Goals	Metrics*	Goal Weight	Regulatory Compliance Scenario 2032 Value*	Regulatory Compliance Scenario % Achievement	Regulatory Compliance Scenario Weighted Score	SWMMP Scenario 2032 Value*	SWMMP Scenario % Achievement	SWMMP Scenario Weighted Score
Improve the Quality of Downstream Waters	1	0.7	66.4 acres	89	31	64.7 acres	91	32
	2	0.7	13.8 acres	69	24	23.2 acres	100	35
Reduce Water and Energy Usage on Campus	3	0.4	1,627,480 gal	46	9	0 gal	100	20
	4	0.4	151,190 kWh/yr	91	18	144,040 kWh/yr	95	19
Enhance Ecological Integrity of the Campus Grounds	5	0.6	38.3 acres	100	20	40.6 acres	100	20
	6	0.6	2.7 acres	100	20	4.0 acres	100	20
	7	0.6	1.1 acres	92	18	1.6 acres	100	20
Enhance and Maintain Campus-Wide Spacemaking and Aesthetics through Stormwater BMPs	8	0.3	0.2 acres	15	2	1.5 acres	100	15
	9	0.3	0.04 acres	100	15	0.09 acres	100	15
Complement and Enhance Existing Pedestrian and Vehicular Patterns	10	0.4	4 BMPs	80	32	5 BMPs	100	40
Enhance Student Body, Faculty, Alumni and Guest Awareness of Sustainable Stormwater Management Initiatives	11	0.1	2 BMPs	100	3	2 BMPs	100	3
	12	0.1	1 BMPs	100	3	1 BMPs	100	3
	13	0.1	2 acres	100	3	2 BMPs	100	3
Reduce Maintenance Activities and Costs Associated with Grounds Upkeep	14	0.1	3.0 acres	83	8	5.4 acres	100	10
				Total Scenario Score:	**208**		**Total Scenario Score:**	**256**

***Performance Metrics**
1 - Reduction of impervious area (IA)
2 - Treatment of IA
3 - Reuse of stormwater
4 - Reduction in landscape energy use (kWh/yr)
5 - Creation of natural habitat (forest, shrub/brush, meadow)
6 - Creation of natural habitat adjacent to woodlands or woodland finger (forest, shrub/brush, meadow)
7 - Treatment of IA within gully drainage area
8 - Conversion of landscape trouble spots to stormwater BMP
9 - Conversion of hardscape to stormwater BMP
10 - BMP as trail access point to forested areas
11 - Interpretive BMP
12 - Showcase or artistic stormwater BMP
13 - Educational stormwater BMP
14 - Treatment of IA within flood prone drainage area

Scenario Cost Comparison

Implementation costs for both the Regulatory Compliance and SWMMP Scenarios were estimated at an order-of-magnitude scale. Unit costs for stormwater BMP implementation and O&M were developed (Table 11) and applied to both scenarios at the stormwater BMP level. The total construction costs and incremental O&M costs (above existing conditions) were used to calculate a Net Present Value for each scenario. To summarize the costs, individual stormwater BMP costs were summed by stormwater BMP type.

Order-of-magnitude installation and O&M costs were estimated for each scenario. Order of magnitude construction costs for the SWMMP Scenario total $7,684,000 and are approximately 61% higher than those estimated for the Regulatory Compliance Scenario, which totaled $2,986,000. Under the Regulatory Compliance Scenario annual O&M cost is projected to decrease by $61,000 from present levels. The annual O&M cost for the SWMMP Scenario is estimated to decrease by $83,000 from present levels. The reduction in the incremental O&M costs under both scenarios is due in large part to the savings realized from low maintenance costs for natural areas.

The net present value (NPV)—the total present value of cash flow minus the initial investment—is estimated at 2052 for both scenarios. NPV for the Regulatory Compliance Scenario is estimated at $-496,000. The NPV for the SWMMP Scenario is estimated at $-2,260,000.

Table 11
Implementation Cost Estimates

Scenario	Construction Cost*	Annual Operation and Maintenance**	2052 Net Present Value***
Regulatory Compliance	$ 2,986,000	$ (64,000)	$ (496,000)
SWMMP	$ 7,684,000	$ (83,000)	$ (2,260,000)

*Order-of-magnitude construction costs are presented in 2012$ and derived from unit costs per stormwater BMP and are marked up 35% for Design and Engineering and have a 50% contingency.

**Operation and Maintenance costs are derived from unit costs applied to the footprint of each stormwater BMP. They include incremental costs above or below costs estimated for the existing cover.

***Net Present Value is based on 80% financing, for a 40 year term loan at 6%.

Chapter 6

Stormwater BMP Design Considerations

Chapter 6: Stormwater BMP Design Considerations

In accordance with the design principles articulated in the SWMMP, the following criteria should be considered by the Stormwater Systems Designer and Lead Design Professional throughout the stormwater management design process:

Scale

Scale is an important consideration when designing campus stormwater BMPs. In general, ESD requirements discourage the use of larger stormwater BMPs, such as detention basins and constructed wetlands in favor of small, disconnected stormwater BMPs such as rain gardens and micro-bioretention systems. Generally, these systems treat no more than 10,000 square feet of drainage area and typically are no more than several thousand square feet in size. However, small scale stormwater BMPs can also increase maintenance requirements; initial construction costs; can be more susceptible to environmental conditions and "edge" effects; and generally have lower habitat value. Therefore, Stormwater Systems Designer should generally look to maximize the size of stormwater BMPs within the confines of ESD limits.

Stormwater BMP scale should also reflect the scale of the surrounding landscape. For example, when stormwater BMPs are placed adjacent to large natural areas of forest or meadow, the practice scale should reflect the larger landscape context. In contrast, when integrating stormwater BMPs into smaller landscaped areas surrounding buildings, the relative surface area and depth of the practice should respond to a smaller, human scale and be integrated so as not to detract from the intended use of the landscape.

In general, the Stormwater Systems Designer should look to incorporate a range of stormwater BMP sizes to maximize visual interest and habitat values.

Safety

Stormwater BMP design should respond to the safety concerns of the Homewood campus. Vegetation height and thickness within stormwater BMPs should maintain existing lines of site and campus safety standards along pathways and pedestrian areas. Appropriate lighting should be integrated into and surrounding stormwater BMP areas according to campus standards. Deep standing water (> 3 ft) in stormwater BMPs should be avoided.

Public Health

Screens should be provided to prevent mosquitoes and other insects from entering cistern tanks. While temporary standing water within stormwater BMPs after rain events is normal, prolonged standing water should be avoided. Planting schemes that create habitat for vermin should be discouraged in and around buildings and highly trafficked areas.

Aesthetics

Stormwater BMP design should incorporate the requirements of the existing landscape design standards for the Homewood campus, as well as the character of the different campus precincts. Per the 2008 Homewood Campus Plan Update, the three precincts of the Homewood campus are: West (woodland setting & stream valley), Central (historic heart of Homewood), and East (urban village within the City).

The SWMMP classifies stormwater BMPs into three aesthetic categories, with consideration for the surrounding campus precinct context. These categories are: formal, informal and formal-informal juxtaposition. The following narrative describes these aesthetic forms in more detail and provides design guidelines for each form:

Formal Stormwater BMP

Formal stormwater BMPs should be considered within key entry ways, within formal courtyards, or adjacent to high visibility locations. When designing formal stormwater BMPs, plant structure, form and spacing should respond to and complement the surrounding architectural elements and buildings. The edges and extent of planting beds should be clearly defined, extending beyond the depressional storage area and maintained through the use of shredded hardwood mulch, pea gravel, crushed shells or other appropriate vernacular material (see Image 17). Order and density of plants should be arranged in varying combinations, such as geometric grids, clusters, masses and offset grids to create interest and complexity, but plant form and habit should remain architectural in nature. Scale and proportion should respond to the surrounding architectural context. Ground plane vegetation, plant massing and focal points should be orderly and manicured with attention to specimen tree and shrub branching habit and pruning. Contrast in evergreen and deciduous textures and plant foliage should be emphasized. Land contouring should be subtle and blended into the existing landscape. Depressional storage areas should be blended into landscaping beds and mulched areas so as not to call attention to the stormwater BMP, unless there is specific design intent (e.g., eco-revelatory design). Formal architectural elements, such as low cheek walls, seating walls, and sculptures can be integrated into the stormwater BMP design (see Image 18). Native plant species are preferred to non-native species. Material selection for splash pads and conveyance should be in accordance with the landscape design standards for the campus and programmatic requirements outlined within the Homewood Campus Plan (JHU 2001) and the Open Space Implementation – Phase 1 Materials and Products Palette document (JHU 2004).

Image 17 *An example of a formal micro-bioretention practice integrated into a parking lot. The use of shredded hardwood mulch, river stone, and clearly defined shrub masses provide order and formality to the BMP.*

Image 18 *Architectural elements, such as the low cheek wall surrounding the above planter box, provide formal design cues to highlight vegetation within ESD practices.*

Informal Stormwater BMP

Plant structure, form, and spacing should respond to and complement the patterns of the surrounding natural setting, such as meadow or forest. Edges and extent of planting beds should blend into adjacent natural areas (see Image 19). Where informal stormwater BMPs are adjacent to turf or more manicured areas, edges of planting beds should be manicured and clearly defined (Nassauer 1995). Order and density of plants should replicate the patterns of natural areas through clumping and clustered arrangements. Plant form and habit should be less manicured and more picturesque in character. Scale and proportion should respond to the surrounding natural context. Ground plane vegetation, plant massing and focal points should have a high variety of texture, diversity, and variation. A high degree of diversity in plant foliage and textures should be considered. Land contouring should be subtle and blended into the existing landscape. Depressional storage areas should be blended into planted areas so as not to call attention to the stormwater BMP, unless there is specific design intent. Native plant species are preferred to non-native species. More aesthetically oriented materials (e.g. river stone) can be incorporated to enhance visual interest.

Image 19 *Example of an informal stormwater BMP with native wildflower drifts and grasses. Locating the informal BMP adjacent to an existing natural area provides appropriate context for the informal aesthetic. The mown edge and interpretive signage provide educational benefits and demonstrate intentional placement of the practice.*

Informal – Formal Juxtaposition Stormwater BMP

The Stormwater Systems Designer should consider intentionally contrasting various formal and informal stormwater BMP design elements to highlight and accentuate different features. An example of this would be an informal planting of native grasses contrasted with an architectural element, such as a brick seating wall or hardscaped edge (see Image 20) (Muller 2007). Another example of this is a native plant community surrounding a stormwater BMP, such as a fern glade that would extend to meet the geometric edge of a large building window. This approach highlights organic and geometric shapes and creates an interesting indoor/outdoor experience for studying from within the building, achieving both regulatory and value-added goals. Native plant species are preferred to non-native species.

Image 20 *Juxtaposition of a formal weir wall with informal vegetation within a micro-bioretention practice.*

In addition to vegetated stormwater BMPs, stormwater management measures may also include creating natural or semi-natural areas to reduce stormwater flows. The following aesthetic guidelines should be used when designing natural areas.

Formal Tree Grove

Stately tree habit, form, and canopy should be emphasized within formal tree groves. Degree of light and quality of shade per different varieties of tree species should be considered. Clear lines of sight and viewsheds beneath the tree groves should be maintained. Native plant species are preferred to non-native species. Native understory plantings, such as grasses, bulbs, wildflowers and shrubs should be considered as an alternative to turf.

Formal Meadow

Swaths of densely planted native grasses, shrubs, or wildflowers should be considered when designing formal meadows. Large masses of similar species contrasted against one another should be considered to add visual interest and organization within formal meadows. Planned wildflower drifts within certain areas of the meadow should be considered. The wildflower drifts should be maintained and supplemented yearly to provide continued visual interest. Focal shrubs and trees should be considered within the meadow to add visual interest and focal points. Geometric or organic arrangements can be used for planting schemes depending upon context. Underplanting of formal meadows with spring bulbs can add seasonal interest. Formal meadows should have a clearly defined, manicured edge. Native plant species are preferred to non-native species.

Informal Meadow

A highly diverse mixture of native grasses and forbs should be used within informal meadows. The edge of informal meadows should be soft when abutting natural areas, but clearly defined when abutting turf or a more formal area (Nassauer 1995). Planned wildflower drifts within certain areas of the meadow should be considered, depending upon context. The wildflower drifts should be maintained and supplemented yearly to provide continued visual interest. Shrubs and trees in organic arrangements, such as clumps and clusters, should be considered for habitat value and visual interest.

Maintenance

Low maintenance begins with good design and the Stormwater Systems Designer should incorporate maintenance considerations at all phases of stormwater management design. The two most important aspects to low maintenance design are vegetation design and sediment management.

Vegetation Design

The use of native plants in planting design is a key strategy for creating low maintenance stormwater BMPs. Native plants are more suited to respond to local weather patterns, require less water, are more resistant to drought, and minimize the need for fertilizer. Replacement of turf with tree groves, meadows and landscaped stormwater BMPs also reduces the amount of lawn mowing needed on campus. Limiting the number of species used within stormwater BMPs can also reduce maintenance complexity.

Sediment Management

The introduction of sediment into stormwater BMPs can create a variety of maintenance issues including the clogging of inlet piping and the clogging of infiltration surfaces. The quantity of sediment in urban runoff depends strongly on the type of impervious surface. The following strategies should be used to limit the build up of sediment with stormwater BMPs and associated conveyance systems, particularly when infiltration stormwater BMPs are proposed or when stormwater BMPs are treating street runoff:

- Mix roof and street runoff to dilute sediment concentration in street runoff,

- Convey runoff into stormwater BMPs via sheet flow to eliminate the potential for clogging within inlet piping and to spread sediment,
- Install hoods or similar anti-clogging devices over inlet orifices,
- Limit treatment drainage area-to-BMP surface area loading ratios for infiltration stormwater BMPs to 10:1 or less, particularly when treating street runoff,
- Provide sediment forebays at inlets to vegetated stormwater BMPs to reduce the introduction of coarse grained sediment onto vegetated surfaces, and
- Provide pre-treatment (e.g. hydrodynamic devices, etc.) when high sediment loads are expected (e.g., from maintenance yards, etc.)

Habitat

The SWMMP sets a target of increasing natural habitat area by 10% by 2032. Opportunities to create natural habitats within campus expansion projects should be identified and incorporated into the stormwater design process. Natural habitat areas include forest, brush/shrub, and meadow areas planted with native plant communities appropriate for the Upper Piedmont Region in Maryland.

Stormwater BMPs can provide valuable habitat for small mammals, birds, reptiles, amphibians, insects and arthropods. Two methods can be used to design vegetated stormwater BMPs for maximum habitat value. One method is to identify a specific species or group of species and design the habitat structure to support this species (e.g. a monarch butterfly garden, etc.). Another method involves designing to a target plant community, incorporating groups of plants that grow naturally together (plant communities) within the Upper Piedmont Region of Maryland. The plant community approach to building habitats generally supports a wider range of species.

When designing for habitat, areas on campus where habitat improvement is desired should first be identified. For example, encouraging habitat for small mammals directly adjacent to campus buildings may be undesirable; whereas in larger open areas it may be encouraged. Habitat quality should be considered when designing stormwater BMPs. Various landscape characteristics affect habitat quality, such as patch size, isolation, connectivity, diversity and arrangement (Forman 1997). In general, the larger the patch size, the more habitat value it provides (Forman 1997).

Where possible, it is best to connect patches of habitat to larger contiguous areas. Also, when considering arrangement of habitat patches, creating clusters or 'stepping stones' of patches that lead in a general direction to a larger tract of habitat area is desirable (Forman 1997). Physical characteristics should also be considered, such as vegetation type and structure, as well as different features that should be included, such as snags or basking rocks.

When designing habitats, care should be taken to prevent human-animal conflicts where possible. For example, animal mortality from vehicular traffic could be problematic where habitat-oriented stormwater BMPs forming stepping stones to larger contiguous habitat patches are bisected by a travel lane. These effects could be minimized through implementation of small, inexpensive wildlife passages beneath roads. Preventative measures to prevent animal mortality from vehicular traffic should be considered. Another common human-animal conflict is bird collisions with building windows. This is particularly prevalent where buildings abut large natural areas to take advantage of scenic views or where fruiting trees are placed adjacent to buildings. Simple methods can be used to retrofit window glass without detracting from aesthetics to prevent bird collision and mortality throughout the campus. The Design Team should consider these methods to prevent bird casualty.

Construction timing can also play an important role in minimizing impacts to existing natural areas and associated biological communities. Construction within or surrounding sensitive habitat areas should be planned to minimize impact during important amphibian or bird breeding times of the year.

Rain Harvesting

Under the SWMMP, JHU has set a goal of reducing landscape water use by 3,000,000 gallons annually by 2032. Rain harvesting options, such as cisterns, should be explored whenever possible to help the campus achieve this goal. Cisterns should be designed to meet ESD volume requirements. Additionally, capture of roof runoff should be the primary source of harvested water to eliminate pollutant loading and solids from entering the system.

The placement of cisterns within a project site should be consulted during the initial phases of design. These options should be explored on a case-by-case basis, weighing both mandatory ESD volume requirements and the campus sustainability goals. The primary intended use of collected rainwater in cisterns is for landscape irrigation purposes. Because of this, cisterns should be located so that they can be connected to the existing building roof leaders and irrigation system with minimal retrofits and additional piping. Additionally, when sizing cisterns, the design engineer should consider larger tanks that can hold water to irrigate the campus per smaller regional zones, rather than designing for several small cisterns, which could increase infrastructure and operating costs.

Pumping mechanisms should be considered within the cistern to facilitate usage for landscaping and grounds upkeep. The Stormwater Systems Designer should explore the feasibility of above ground and below ground tanks and determine which is most appropriate on a case-by-case basis. Each has advantages. Below ground tanks are typically more expensive to install and maintain and require larger pumps to distribute water but are less conspicuous and less susceptible to temperature fluctuation. Above ground tanks are typically less expensive to install and maintain and can sometimes be configured to provide water with little or no pumping. Above ground tanks must be enclosed or heat-traced to prevent freezing.

In addition to landscape irrigation, the Stormwater Systems Designer should explore other uses for rain harvesting, such as for cooling purposes and greywater supply for toilet flushing. Although not specifically included in the SWMMP, JHU is interested in evaluating other uses for harvested rain water on a project-by-project basis. The Stormwater Systems Designer should also work with JHU to identify areas for interpretive or artistic cisterns.

Safe Conveyance

Stormwater runoff conveyance should be routed through vegetated practices and areas in a non-erosive manner. It should be designed in accordance with the maximum slope requirements and design guidelines set forth in the Maryland ESD guidelines found within

Chapter 5 of the Manual (MD 2000-2010). Safe conveyance involves appropriate design of features in accordance with ESD requirements, such as, slopes, swales, discharge areas, overflows, outfalls, flow splitters, splash pads, rocks, splash blocks, stone dams, gravel beds, curb cuts, drains, downspouts, berms, and pipes.

Art and Architecture

In appropriate places, stormwater BMPs can be designed as artistic and architectural features. Some examples of these include: sculptural cisterns, decorative runnels and splash pads, creative fixtures, solar-powered fountains, and water features (Echols 2008). "Eco-revelatory" refers to the design of landscapes with built or artistic features to reveal an ecological process, such as hydrology (Brown, Harkness and Johnston 1998; Muller 2007). Incorporating an eco-revelatory component to artistic and architectural stormwater BMPs can add an interesting and important interpretive component to the feature. The Stormwater Systems Designer should consult the SWMMP for guidance on placement of artistic stormwater BMPs (see BMP master list in Appendix E) and work closely with the JHU Project Manager to incorporate artistic, architectural, and eco-revelatory stormwater BMPs.

Value-Added Elements

Value-added elements include stormwater BMPs that function as educational research areas, interpretive areas, and passive recreation spots for walking, studying or viewing wildlife. The Stormwater Systems Designer should consult the SWMMP and work with JHU to identify opportunities for incorporating value-added elements within stormwater BMPs.

Chapter 7

Building, Site and Stormwater BMP Guidance

Chapter 7: Building, Site and Stormwater BMP Guidance

Successful implementation of the SWMMP depends on applying the stormwater principles and management strategies outlined in the SWMMP to individual campus expansion projects. This process begins with development site selection. Once the development site has been identified the stormwater design process continues with refining mapping of existing natural features and site constraints and reviewing SWMMP requirements, and proceeds through all phases of project design including building and site layout and detailed design of stormwater BMPs. The following chapter provides guidance to the Design Team for incorporating the SWMMP into the site design process.

Site Selection

Although the selection of a development site typically precedes the involvement of an outside design professional, the first step in the design process should involve the consideration of potential site alternatives that may offer the opportunity to meet the development objectives while reducing environmental impacts. In particular, the Design Team should work with JHU staff to first assess the environmental implications of proceeding with the planned development at the preferred site and, secondly, to identify other potential sites that could accommodate the proposed development program. In particular, proposed sites with high concentrations of high quality or sensitive natural resources should prompt the Design Team to actively consider alternative site locations or, if the Design Team elects to proceed with the site in question, consider scaling back of the development program to reduce environmental impacts.

Site and Resource Mapping

Once the selection of a development site has been finalized, the Design Team should proceed with conducting site and resource mapping. Precise delineation and characterization of natural features plays a key role in assisting the Design Team in limiting environmental impacts through careful building and site layout, and informs the placement and design of stormwater management practices.

Mapping and Preservation of Natural Features

Per the State of Maryland's ESD guidelines found in the 2010 Maryland Stormwater Design Manual, the placement of stormwater BMPs per the SWMMP is informed in part by the type and arrangement of natural features within the development site. The stormwater BMP layouts within the SWMMP aim to protect and preserve the following natural features within the Homewood campus:

- Steep slopes;
- Erodible soils;
- Sensitive hydrologic resources including wetlands, major waterways, perennial and intermittent streams, springs, seeps, floodplains and respective buffers; and

- Forest cover.

At the master planning level, natural features were mapped per available data from state and federal sources and field verified, meeting the general requirements outlined for the Concept Design Phase, as defined in the Maryland's ESD guidelines (MD 2000-2010).

During the site and natural features mapping phase of site development, natural resources mapping presented in the SWMMP should be consulted and further field verified on a site-by-site basis prior to proceeding with initial building and site layout. Natural features mapping should be provided to the Lead Design Professional by the JHU Project Manager through distribution of the electronic PDF maps directly from the SWMMP or from the associated GIS data files. Field verification should indicate the spatial extent of any observed changes to natural resource since completion of the SWMMP.

Existing Conditions Survey

Prior to initial building and site layout, a detailed existing conditions survey of the project area by a licensed engineer or surveyor should be completed. The existing conditions survey should include:

- Existing surface and subsurface infrastructure, including electric, sewer, water, storm, gas and drain networks and associated inverts and elevations;
- Topography (minimum of 1' contour elevations and spot elevations as appropriate);
- Property lines;
- Trees of significant caliper;
- Woods lines;
- Hydrologic features;
- Existing buildings;
- Sidewalks;
- Light poles;
- Fence lines;
- Walls; and
- Other important features.

Survey should be collected using a horizontal datum of NAD 1983 State Plane Maryland FIPS 1990 Feet and vertical datum of NAVD 88 coordinate system. A local benchmark (a marker or feature with known horizontal and vertical coordinates) should be established for the survey or the survey should reference an existing benchmark.

Existing Constraints and Opportunities Mapping

During the development of the SWMMP, existing constraints and opportunities within the campus were evaluated and considered to inform the selection and placement of stormwater management practices. During project-specific design, the Design Team should conduct a more detailed evaluation of existing constraints and opportunities that may influence the arrangement of proposed buildings, site elements and stormwater management features (See Chapter 6 for a more detailed description of BMP design considerations).

These include, but are not limited to:

- Existing surface and subsurface infrastructure and associated elevations and inverts;
- Soil infiltration properties;
- Existing drainage patterns (overland and piped);
- Critical vistas;
- High value or sensitive natural resources such as steep slopes, wetlands, and specimen trees;
- Historical and cultural resources;
- Existing architecture and building layout;
- Pedestrian and vehicular circulation patterns;
- Property setbacks;
- Recreational areas;
- Lines of sight;
- Safety concerns;
- Site aspect; and
- Solar orientation.

Review of Development Program Objectives

A project's development objectives should strongly influence site layout and stormwater system design. Ultimately, stormwater systems should both complement and allow for proposed uses associated with a particular campus development project. For example, program objectives for a sports facilities building may involve accommodating crowds or lines of people. As such, large hardscape areas may be a required component within the site layout, thus limiting the amount of land area to place stormwater BMPs. Other examples of different program requirements may include event areas outside of alumni relations buildings, study or dining areas outside of classrooms, and recreation or gathering areas outside of dormitories. Prior to initial site layout and stormwater system design, the JHU Project Manager should convey to the Lead Design Professional and the Stormwater System Designer the development program objectives and associated facilities and site design requirements. These different development programming aspects should be carefully considered when designing stormwater systems.

Review of Stormwater Management Regulatory Requirements

The SWMMP provides a concept level stormwater management plan for each planned campus expansion project based on the anticipated project layout depicted in the 2008 Homewood Campus Plan Update. Prior to developing an initial building and site layout, the JHU Project

Manager should compare the most recent estimate of the anticipated impervious area associated with the campus expansion project with that depicted in the 2008 Homewood Campus Plan Update. Changes to the impervious area will require the JHU Project Manager to consult with Baltimore City DPW to determine if an update to the Regulatory Plan is required.

The JHU Project Manager should also determine whether the associated LOD and the Regulatory Plan boundary are in surplus or deficit status for A_T and ESD_V treatment requirements and, if so, the magnitude of the deficit or surplus. This information should be communicated to the Lead Design Professional.

The JHU Project Manager should also provide the relevant location, size, and type of stormwater BMPs and associated A_T and treatment volumes provided in the SWMMP to the Lead Design Professional, communicating any changes to the Regulatory Plan in the process. The Lead Design Professional should review the information provided by the JHU Project Manager and ensure that the Stormwater Systems Designer is also familiar with the requirements.

Initial Site and Building Layout

Site layout and building arrangement is a critical aspect of stormwater management design. Accordingly, stormwater management design should be a key consideration in arranging site and building features on the site during the early stages of design. Indeed, good stormwater management starts with smart building layout and site design.

Following the natural features inventory, topographic survey and existing constraints and opportunities mapping, the Lead Design Professional will begin to develop an initial site and building layout plan. During this initial building and site layout phase, the Lead Design Professional should work with the Stormwater System Designer to carefully consider how the arrangement of building and site elements will influence stormwater management requirements, attempting to create a building and site layout that minimizes the creation of stormwater runoff and provides adequate room for ESD practices to treat the remaining runoff.

The Lead Design Professional and Stormwater Systems Designer should review the stormwater BMP configuration proposed in the SWMMP, which should be used as a starting point for stormwater BMP placement and to assess ESD_V treatment requirements. While changes in funding, development goals, or understanding of site conditions may require changes in the building and site layout from that depicted in the 2008 Homewood Campus Plan Update, adherence to the approved SWMMP should be a priority. As such, the building and site layout should allow for the stormwater BMP layout presented in the SWMMP where possible. If the building and site layout significantly departs from that shown in the 2008 Homewood Campus Plan Update due to a change in the development program or review of additional site data, designers should make sure that the layout will allow for the management of an equivalent stormwater volume as the stormwater BMP configuration depicted in the SWMMP.

While the SWMMP provides a good starting point for understanding how building and site layout affect stormwater management requirements, the building and site layout process allows designers to conduct a more detailed review of natural features, existing constraints, and opportunities, and accordingly, to optimize the building and site layout with respect to stormwater management considerations. In doing so, the Stormwater System Designer should field verify the existing site conditions and make appropriate adjustments to stormwater BMP layout, as needed, in order to best protect and preserve natural features on an individual site-by-site basis. Additionally, the Stormwater Systems Designer should look for additional opportunities for implementing stormwater BMPs that enhance natural resources, such the as creation of habitat stormwater BMPs adjacent to existing natural areas, or the installation of stormwater BMPs upslope of gullied or otherwise erosion impacted areas.

During the initial building and layout process, the Design Team should specifically look to accomplish two key goals with respect to stormwater management:

1. To develop a building and site layout that minimizes the creation of stormwater runoff from impervious surfaces, and
2. To ensure that the building and site layout allows for the inclusion of ESD practices to treat and convey site runoff to offsite locations.

Reducing Runoff from Impervious Surfaces

During the building and site layout process, the Stormwater Systems Designer should employ the following strategies to reduce the quantity of stormwater runoff from the developed portion of the site.

Preserve Natural Areas

Preserving natural areas helps to reduce stormwater runoff from the development site. Buildings and parking areas should be arranged in clustered footprints at a reasonable distance from conservation areas, respecting buffers and other constraints.

Minimize Site Disturbance and Mass Grading

Minimization of site disturbance and mass grading reduces the amount of soil compaction and vegetation disturbance associated with development activity, which in turn reduces stormwater runoff volume. Building and site features should be located on flat portions of the site in locations that minimize grading requirements for access roads. Where possible, earth disturbance and grading should be limited to the footprint of the developed lot.

Reduce Impervious Cover

In the initial phases of site design, the Lead Design Professional and Stormwater Systems Designer should work towards a building and site layout that accommodates the required development program with the minimum amount of additional impervious cover.

The Lead Design Professional and Stormwater Systems Designer should consider the following strategies for reducing impervious cover:

- Narrowing or shortening streets, sidewalks and other rights-of ways;
- Reusing or repurposing existing structures and hardscapes to accommodate development objectives;
- Designing parking ratios, codes and lots to allow for minimum space requirements;
- Incorporating multiple level or subsurface parking structures where possible;
- Increasing building height to reduce building footprints;

- Using porous surfaces, such as stabilized turf, to accommodate overflow parking needs;
- Minimizing, to the extent possible, the width and total length of paved pathways.

Providing for Stormwater Treatment and Conveyance

In addition to minimizing the production of runoff, a good building and site layout will allow sufficient space to treat site runoff using ESD practices and to convey stormwater to and from ESD practices using natural conveyance systems where possible.

As buildings and site features are laid out, the Stormwater Systems Designer should concurrently define locations for ESD treatment and pathways for conveying stormwater to and from each practice. Although the exact location, sizing, and configuration of stormwater practices can be determined later in the design process, approximate locations of treatment practices should be defined during initial building and site layout. The stormwater BMP locations depicted in the SWMMP should be maintained where possible, but may be need to be adjusted based on a more detailed review of site constraints and opportunities and program requirements.

The SWMMP emphasizes the use of vegetated surface features such as micro-bioretention and rain gardens to provide treatment. In general, these practices offer a superior suite of benefits at lower costs than other practices, such as green roofs, and should be used as the preferred treatment options whenever possible.

Environmental and aesthetic considerations should guide the placement of practices (see Chapter 6 for a detailed treatment of BMP design considerations). For example, built features should be located on more impervious soil areas, while reserving areas with more porous soils for infiltrating stormwater practices. In general, treatment areas should be located within planned vegetated spaces close to and downslope of impervious surfaces. The Stormwater Systems Designer should verify that vegetated spaces are of sufficient size to capture and treat the approximate ESD volume that will be routed to the area. Stormwater BMP areas should not be located on steep slopes or within high quality natural areas and should be located in areas where stormwater can be conveyed to the practice using existing surface drainage features. However, where possible, ESD practices should be located in close proximity to natural areas, to increase habitat value. Conveyance to and from surface practices should be planned using existing drainage features or designed swales, rather than subsurface piping. Surface impervious surfaces (such as parking areas) should be arranged so that stormwater runoff can enter stormwater BMPs via sheet flow, rather than through concentrated discharges conveyed via inlet and piping systems.

Preliminary Stormwater Management Design

After the completion of building and site layout, the Stormwater Systems Designer should develop a preliminary stormwater management plan, which includes a more formal and refined layout of ESD practices and associated conveyance systems. By this point in the design process, the Stormwater Systems Designer will have a good general understanding of how stormwater will be conveyed through the site. In addition, the general locations and grading for ESD practices should be developed to ensure feasibility. During the preliminary design process, the layout should be iterative, gradually refining building, stormwater, site and program relationships.

Incorporate Stormwater BMP Design Considerations

The Stormwater Systems Designer should carefully consult the stormwater BMP design considerations in Chapter 6and begin to incorporate these strategies and recommendations as they develop the stormwater management design.

Revisit Existing Constraints and Opportunities

At the preliminary stormwater management practice design stage, the Stormwater Systems Designer should again revisit the existing constraints and opportunities mapping to confirm that the stormwater BMP selection is appropriate for the site.

Develop Relationships between Stormwater BMPs and Architectural Features

As features, such as sidewalks, hardscape plazas, courtyards, entryways, overlooks, parking lots and seating walls are added to the layout, consideration should be given to how stormwater management systems can complement these features in ways that enhance user experience and safety of the space. For example, stormwater features can be incorporated into architectural features to create additional visual interest and to call attention to the stormwater management process.

Update System Design to Reflect Layout Changes

During this stage, site layout may continue to evolve. The Stormwater Systems Designer should adjust stormwater BMP layout and conveyance system design to reflect changes in site layout.

Evaluate Opportunities for Surplus Treatment

The JHU Project Manager should work with the Lead Design Professional to consider the possibility of incorporating one or more nearby voluntary BMPs identified in the SWMMP into the campus expansion project and/or opportunities to cost effectively manage additional rainfall volume beyond that required. Both of these approaches can be used to generate impervious area and/or volume surpluses that can then be used to offset potential treatment deficits on future campus expansion projects.

Verify Regulatory Compliance

During preliminary design, the Stormwater Systems Designer should continue to refine treatment drainage areas and preliminary grading of ESD practices to check the feasibility of the site layout and program elements. The Stormwater Systems Designer should also review regulatory criteria for the selected stormwater BMPs at various stages during the preliminary design to ensure that the practice can meet appropriate parameters, such as maximum allowable treatment drainage areas and surface footprints (see Table 12). The Stormwater Systems Designer should report any unforeseen constraints that limit adherence to the Regulatory Plan to the Lead Design Professional. In addition, the Lead Design Professional should communicate any deviations from the Regulatory Plan to the JHU Project Manager. The JHU Project Manager should then work with the Design Team to adjust stormwater practice layouts to fully meet all regulatory requirements. If regulatory requirements cannot be fully met, the JHU Project Manager may discuss incurring a treatment deficit for the project with Baltimore

City DPW, provided sufficient deficit-cap room exists. If sufficient deficit-cap room is not available, additional ESD practices may be required elsewhere in the Regulatory Site to offset some or all of the treatment deficit for the project.

Incorporate Campus Stormwater Management Goals and Targets

During preliminary design, the Stormwater Systems Designer should review the campus stormwater goals and targets and work with JHU Project Manager to ensure that the stormwater BMP layout advances as many multi-objective campus goals as possible (see Table 5, which indicates how stormwater BMP types relate to campus stormwater management goals).

Confirm Avoidance of Natural Resources

The Stormwater Systems Designer should confirm that stormwater BMPs avoid disturbance to natural features to the extent possible, and also look for opportunities to complement and enhance these through the creation of additional vegetated habitat.

Initiate Regulatory Coordination

Because the SWMMP has been approved as a concept level plan, the Lead Design Professional will not have to formally submit site-scale concept plans for review by regulatory agencies. However, at this stage, it is recommended that the Lead Design Professional begin dialogue with regulatory agencies to ensure that the initial ESD layout and calculations comply with regulations.

Detailed Design

During the detailed design phase, the Stormwater Systems Designer should further develop and detail the specifics of the stormwater management system. Hydrologic calculations; grading plans; and sizing and specification of hydraulic control structures, pre-treatment systems, and conveyance systems; and planting plans should be fully developed by the end of the detailed design phase. During detailed design, the Stormwater Systems Designer will prepare site development plans that include: a stormwater management plan, erosion and sediment plans, and an overlay plan, per regulatory requirements. Prior to submittal of the final plan set, the Stormwater Systems Designer should reassess conformance with mandatory and voluntary goals, targets and requirements and report any modifications to the Lead Design Professional. As detailed design proceeds, the Stormwater Systems Designer should consult the BMP Design Considerations in Chapter 6 to ensure that BMPs provide maximum benefit.

Preparation of Regulatory Submissions

Per Chapter 5 of the Manual (MDE 2000-2010), the Stormwater Systems Designer must prepare stormwater management plans, erosion and sediment control plans, and an overlay that shows both the stormwater management plan and erosion and sediment control plan during detailed design.

Stormwater Management Plans

As outlined within the Manual, during the stormwater management phase, all of the ESD practices will be finalized according to sizing requirements, discharge computations, and storage volumes. ESD practices will be drawn to scale and proposed topography and final drainage areas will be determined. Details, calculations, and a narrative should be prepared by the designer to accompany drawings submitted to regulatory agencies. Specific requirements for stormwater management drawings and calculations can be found in the Manual.

Erosion and Sediment Plans

Erosion and sediment plans must be prepared in accordance with mandatory requirements. These should include detailed design of sediment controls and stabilization strategies. Chapter 5 of the Manual outlines specific strategies and recommendations for erosion and sediment control.

Overlay Plan

Because stormwater management systems and erosion and sediment measures can perform the same function and may be located in similar areas of the site, an overlay plan must be prepared to ensure that the site design and construction sequence can be executed with maximum efficiency, especially with regards to minimizing site disturbance and earthworks. Chapter 5 of the Manual provides an overview of items that must be included on the overlay plan.

Reassessment of Conformance with Site-Specific SWM Goals, Targets and Requirements

Prior to submittal for regulatory review, the designer should work with JHU Project Manager and JHU Stormwater Program Manager (who oversees consistent application of the SWMMP principles and processes across all Homewood campus expansion projects) to reassess that the regulatory and voluntary site specific SWMMP goals, targets and requirements are being met.

Agency Review of Site Development Plans

The detailed site development plans should be submitted by the Lead Design Professional on behalf of the JHU Project Manager to appropriate agencies for review. Chapter 5 of the Manual provides detailed information on information that should be included within the site development plans.

Design and Review of Final Plans

Final Plan Preparation and Agency Review

The Lead Design Professional should incorporate comments, feedback, and revisions to the site development plans from regulatory agencies. Following approval of the site development plans, a final plan set should be prepared. Final plans must be approved in order to obtain necessary permits. The final plans should conform to COMAR 26.17.01.05 and 26.17.02.09. Chapter 5 of the Manual outlines specific information for inclusion within the final plan set.

The Lead Design Professional should follow JHU procedures for completion of design drawings, construction documentation and bidding procedures. Detailed maintenance plans should be submitted along with the final plan set to ensure proper function and performance of stormwater BMPs from initial installation into future years. Maintenance inspection criteria are listed within Chapter 8 of the SWMMP. Additional guidance on stormwater BMP maintenance can be found within the Manual and within other readily available stormwater design documents online.

Table 12
BMP Menu and Design Checklist

This document w as compiled from referencing Maryland's 2010 Stormw ater Design Manual (the Manual), but does not serve as a substitute for it. Detailed design guidance should be obtained from the Manual. The Manual should be consulted regularly by JHU staff and design engineers to update design criteria based on potential revisions made to the Manual.
Unit costs w ere derived from recent literature, design guidance and consultation of RSMeans Site Work and Landscape Cost Data. Unit costs should be updated periodically by JHU staff to reflect current pricing of the different practices.

ESD Practice	DA* Requirements	Design Criteria	Unit Cost ($/cf)	Annual O&M Cost	Goals and Performance Metrics** 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Green Roofs	building drainage (e.g., gutters, deck drains, scuppers) must be sufficient for system support	< 30% or 4:12 pitch; structural integrity of structure must be thoroughly examined; must include a waterproof membrane	$94.73 - $439.06	$0.10	Y	Y	N	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y
Permeable Pavement	at-source treatment practice - runoff directed to permeable pavement from adjacent sources should be limited	Limited runoff from adjacent areas; <5% slope; do not use to treat hotspot areas with high concentrations of metals, toxins, or hydrocarbons; load bearing capacity should be evaluated for heavy traffic areas	$16.05 - $90.94	$0.06	Y	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	Y
Reinforced Turf	at-source treatment practice - runoff directed to reinforced turf from adjacent sources should be limited	1-5% slope; best in small areas and linear strips; best in sandy soils, but can work in all soils; do not use to treat hotspot areas with high concentrations of metals, toxins, or hydrocarbons	$78.46	$0.06	Y	Y	N	N	N	N	Y	N	N	N	N	N	N	Y
Disconnection of Roof Top Runoff	<500 sf per downspout	5% slope or less; 15-75 ft. flow path; >10 ft. from nearest impervious surface of equal or lower elevation	$2.93 - $17.56	$0.10 - $1.20	N	Y	N	N	N	N	Y	N	N	N	N	N	N	Y
Disconnection of Non-Rooftop Runoff	<1,000 sf per disconnection	5% slope or less; 10-75 feet flow path; max contributing impervious flow path of 75 ft; max contributing pervious flow path of 150 ft	$7.32 - $14.64	$1.20	N	Y	N	N	N	N	Y	N	N	N	N	N	N	Y
Sheetflow to conservation areas	average contributing slope <5% (if slope exceeds 5% a level spreading device must be used)	receiving areas must be 20,000 sf or larger; width of 50-100 ft; no guidelines on contributing areas	$0.00 - $7.32	$0.00 - $1.05	N	Y	N	N	N	N	Y	N	N	N	N	N	N	Y
Rainwater Harvesting	none indicated	At least 0.2 inches of rainfall from contributing rooftop area; no guidelines on loading ratios	$21.95 - $58.54	$4.19	N	Y	Y	N	N	N	Y	N	N	N	Y	Y	Y	Y
Submerged Gravel Wetlands	At least 1 acre of drainage area (large enough to maintain submerged flow conditions)	75% static storage; C or poorer soils; no guidance on storage volume; wetlands with no liner should not be used to treat hotspot areas with high concentrations of metals, toxins, or hydrocarbons	$25.25 - $43.91	$0.84	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Landscape Infiltration	10,000 sf or less	12:1 loading ratio for full credit; a or b soils only; > 4 ft to limiting layer,;10 feet from buildings; 850 sq ft max; should not be used to treat hotspot areas with high concentrations of metals, toxins, or hydrocarbons	$21.95 - $33.66	$0.84	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Infiltration berm	small enough to prevent flow concentration	slope <10%; avoid soils with low shear strength; should not be used to treat hotspot areas with high concentrations of metals, toxins, or hydrocarbons	NA	NA	N	Y	N	N	N	N	Y	N	N	N	Y	N	Y	Y
Dry Wells	< 500 sf	a or b soils only; < 20% slope; 10 feet from buildings; 100 feet from fill slopes of 15%; 200 feet from fill slopes of 25%	$17.56 - $19.76	$1.10	N	Y	N	N	N	N	Y	N	Y	N	N	N	N	Y
Micro-bioretention	< 20,000 sf	< 5% slope; 8:1 loading ratio for full credit; 75% ESDv storage	$15.37- $58.54	$0.84	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Rain Gardens	<10,000 sf	< 5% slope; 5:1 loading ratio for full credit; soil ammendments for C or D soils	$10.98 - $14.64	$0.84	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Swales	none indicated	Loading rations between 5:1 (grass swale) and 8:1 (bio-swale); can use wet swales for poor soils; channel slope < 4%; bottom width from 2-8 feet; channel slopes 3:1 or flatter	$18.29 - $32.20	$0.84	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

***DA = Drainage Area**
**** Goals and Performance Metrics**
1 - Reduction of impervious area (IA)
2 - Treatment of IA
3 - Reuse of Stormwater
4 - Reduction in landscape energy use (kWh/yr)
5 - Creation of natural habitat (forest, shrub/brush, meadow)
6 - Creation of natural habitat adjacent to woodlands or woodland finger (forest, shrub/brush, meadow)
7 - Treatment of IA within gully DA
8 - Conversion of landscape trouble spots to BMP
9 - Conversion of hardscape to BMP
10 - BMP as trail access point to forested areas
11 - Interpretive BMP
12 - Showcase or artistic BMP
13 - Educational BMP
14 - Treatment of IA within flood prone DA

Building, Site and Stormwater BMP Design Checklist

__Site Selection

__Site and Resource Mapping

__Mapping and Preservation of Natural Features

__Existing Conditions Survey

__Existing Constraints and Opportunities Mapping

__Review of Development Program Objectives

__Review of Stormwater Management Regulatory Requirements

__Initial Site and Building Layout

- __Reduce Runoff from Impervious Surfaces
    - __Preserve Natural Areas
    - __Minimize Site Disturbance and Mass Grading
    - __Reduce Impervious Cover
- __Provide for Stormwater Conveyance and Treatment

__Preliminary Stormwater Management Design

- __Incorporate Stormwater BMP Design Considerations
- __Revisit Existing Constraints and Opportunities
- __Develop Relationships between Stormwater BMPs and Architectural Features
- __Update System Design to Reflect Layout Changes
- __Verify Regulatory Compliance
- __Incorporate Campus Stormwater Management Goals and Targets
- __Confirm Avoidance of Natural Resources
- __Initiate Regulatory Coordination

__Detailed Design

- __Stormwater Management Plans
- __Erosion and Sediment Plans
- __Overlay Plan
- __Agency Review of Site Development Plans

__Design and Review of Final Plans

- __Final Plan Preparation and Agency Review

Chapter 8

Administration, Implementation and Maintenance Guidance

Chapter 8: Administration, Implementation and Maintenance Guidance

The SWMMP outlines a program for stormwater management improvements required to meet City and State regulations for campus expansion projects, and to meet campus stormwater management goals and targets. As stormwater management projects are designed and constructed, successful implementation of the SWMMP requires both a plan for tracking stormwater improvements over time so that progress towards regulatory requirements and voluntary goals can be assessed, and a maintenance program to ensure that stormwater practices continue to fulfill their core functions. The first portion of this Chapter outlines a process for tracking stormwater improvements using a GIS database and for using the GIS database to generate reports assessing progress towards regulatory requirements and campus stormwater management targets. The second portion of the Chapter discusses maintenance requirements for stormwater practices and outlines a process for implementing and tracking stormwater management-related maintenance activities.

Stormwater Master Plan Implementation Tracking and Reporting

Information pertaining to the Homewood campus' stormwater management systems is stored and managed using a GIS database, referred to herein as the Homewood Campus Stormwater Management System (HCSMS). As construction projects are completed, the JHU Project Manager should obtain project-specific information concerning stormwater management systems from the Lead Design Professional and provide the information to the JHU GIS coordinator who is responsible for processing, storing, and migrating the information into the HCSMS. Key documents such as permits and construction documents are linked to the HCSMS for orderly management and efficient retrieval. The JHU GIS Coordinator generates reports using the HCSMS to verify adherence to the Regulatory Plan with Baltimore City DPW following the completion of construction projects and, periodically, to detail progress towards campus stormwater management targets.

HCSMS Overview

The purpose of the HCSMS is to store stormwater management-related information in a systematic manner to support tracking and verification activities. The HCSMS is maintained by a JHU GIS Coordinator per the standards (or equivalent standards) outlined within this document. Aside from the JHU GIS Coordinator, access to the HCSMS should be provided only to other individuals with GIS training and knowledge of the HCSMS system. The naming structure defined in this document is descriptive ONLY and may not exactly reflect the nomenclature assigned to attribute names and data content. Wherever possible, unique identifiers (e.g., Project ID, BMP ID, etc.) should be consistent with the existing management systems and databases (e.g., the work flow management system, which is run using Maximo software, etc.)

The HCSMS is comprised of four (4) GIS geodatabases: Land Cover, Projects, BMPs, and Stormwater Infrastructure and an electronic repository for key supporting documents. Each geodatabase consists of point, line, and or polygon features each representing a single feature on campus. Features in the geodatabase represent current conditions and are updated as conditions change. Features are linked to attribute tables, which store pertinent information concerning each feature. Area and volume measurements should be derived from as-built data, except where noted. The geodatabases are projected in NAD 1983 State Plane Maryland FIPS 1990 Feet.

Folder Structure

HCSMS folder structure organizes the geodatabases and key supporting documents. As construction projects are completed, the geodatabases are updated or populated and new project folders are added to the SUPPORTING_DOCUMENTS folder. Key supporting document folders are hyperlinked to polygon features corresponding to individual construction project extents in the Project Geodatabase. The following is a generalized master file folder structure of the HCSMS:

- HCSMS
  - DATA (geodatabases)
    - Land_Cover
    - Project
    - Constructed BMP
    - Infrastructure_Stormwater
  - SUPPORTING_DOCUMENTS
    - Project_ID_XXX01
      - Design_Construction
      - Permits_Regulatory
    - Project_ID_XXX02
      - Design_Construction
      - Permits_Regulatory

Project Geodatabase

The Project Geodatabase includes polygon features representing each campus expansion or stand-alone stormwater management project. The spatial extent of each polygon feature is project's limit of disturbance. The Project Geodatabase includes the following attribute data for each project polygon:

- Unique JHU project identification (ID) number;
- JHU project name;
- Contact information for firm responsible for the detailed design;
- Contact information for firm responsible for as-built survey;
- Construction completion date;
- BMP IDs with the project extents;

- Project area (sf);
- Impervious area – existing (sf);
- Impervious area – as-built (sf);
- ESD_V (cf) provided;
- A_T (sf) provided;
- Re_V (cf) provided
- Hyperlink to folder containing final design and construction documents;
- Hyperlink to folder containing permitting and regulatory documents; and
- Data created or modified (YYYYMMDD)

BMP Geodatabase

The BMP Geodatabase includes polygons representing two types of features: built stormwater BMPs and their associated stormwater BMP drainage areas. The BMP Geodatabase includes the following attribute data for each stormwater BMP or stormwater BMP drainage area polygon:

- Stormwater BMP polygons:
  - Unique BMP ID number;
  - JHU project ID number;
  - Stormwater BMP drainage area ID;
  - Stormwater BMP type (e.g., rain garden, micro-bioretention, etc.);
  - Surface area (sf);
  - A_T (sf) provided;
  - ESD_V (cf) provided;
  - Re_V (cf) provided;
  - Stormwater BMP aesthetic class (e.g., informal, format, etc.);
  - Rainwater harvest volume (cf);
  - Binary (Y/N) data to indicate whether or not the stormwater BMP contributes to each campus stormwater management metric; and
  - Data created or modified (YYYYMMDD);
- Stormwater BMP drainage area polygons:
  - Unique stormwater BMP drainage area ID number;
  - Corresponding stormwater BMP ID number;
  - Surface area (sf);
  - Impervious area (sf); and
  - Data created or modified (YYYYMMDD)

Land Cover Geodatabase

The Land Cover Geodatabase includes polygons representing two types of features: impervious cover and pervious cover. The Land Cover Geodatabase includes the following attribute data for Impervious Cover and Pervious Cover polygons:

- Area (sf);
- Cover type (e.g., forest, roof, etc.);
- Common name (e.g. Whitehead Hall), as applicable;
- Hydrologic condition (e.g., poor, fair, good), as applicable (pervious cover only); and
- Data created or modified (YYYYMMDD)

Infrastructure Geodatabase

The Infrastructure Geodatabase includes point features representing stormwater structures (e.g., roof leaders, endwalls, headwalls, control structures, inlets, manholes, etc.) and line features representing pipes.

The geodatabase includes the following general types of information:

- Unique feature ID number;
- Type (e.g., endwall, headwall, inlet, etc.);
- Material (e.g., RCP, CMP, HDPE, etc);
- Dimensions (e.g., width, depth, length, or diameter, as applicable) (ft);
- Shape;
- Rim elevation (ft);
- Invert elevation(s) (ft);
- Vendor name;
- Model ID number;
- Date installed (YYYYMMDD);
- Condition;
- Hyperlink to structure photo database;
- Feature IDs of adjacent infrastructure;
- Data source (reference information for as-built drawing or survey)
- Status (abandoned, removal, or functioning)
- Additional features (e.g., sumps, grates, appurtenances, etc.)
- Notes (e.g., regarding accessibility, etc.)

Data Creation and Migration

As projects are completed, project specific data is transferred from the Lead Design Professional to the JHU GIS Coordinator and incorporated into the HCSMS. The JHU Project Manager is responsible for overseeing the transfer of information and ensuring that the JHU GIS Coordinator has received the information in the appropriate format. The JHU GIS Coordinator will update each geodatabase in the HCSMS from the as-built survey and will compile and file all key supporting documents. Data must be updated accurately and promptly to provide correct information for regulatory compliance verification, internal sustainability reporting, to maintain accurate mapping of existing stormwater infrastructure.

The Land Cover and Stormwater Infrastructure Geodatabases were developed in conjunction with the development of the SWMMP and will be modified as construction projects are implemented. The Project and BMP Geodatabases have not yet been created and but should be created by the JHU GIS Coordinator prior to the completion of the first construction project implemented under the SWMMP.

As-built Survey and Supporting Documentation

Developing and maintaining an accurate stormwater management database depends on obtaining information from an as-built survey. Upon completion of project construction, the JHU Project Manager will authorize the completion of an as-built survey from a certified engineer or licensed surveyor (i.e., Lead Design Professional) within 3 months of the construction completion date. The as-built survey records the size, type, location, and arrangement of stormwater systems as installed, which may vary from that presented in final construction documents. Along with the survey, the Lead Design Professional will provide tables of detailed information corresponding to stormwater-related features. The JHU Project Manager is responsible for obtaining the as-built survey and supporting tables in a timely manner and ensuring that the survey and supporting information is complete and in the correct format before providing it to the JHU GIS Coordinator for migration into the HCSMS.

As-built Survey

As-built surveys should be provided by the Lead Design Professional to the JHU Project Manager in PDF and AutoCAD (with all supporting external reference files) formats. As-built data should be collected on Horizontal Datum – NAD 1983 State Plane Maryland FIPS 1990 Feet and Vertical Datum – NAVD 88.

The as-built survey should include the following information:

- Datum information;
- Survey date(s); and
- Source of existing conditions mapping on each drawing.

Although a complete project as-built survey will contain a variety of information that does not pertain to stormwater systems, for purposes of updating the HCSMS the as-built survey should include the following listed stormwater-related features. Each type of feature should each be placed on a unique layer. Associated text should also be placed on similarly named layer affixed with a "txt" suffix. Features should be assigned unique identification numbers according to the numbering system devised by the JHU GIS Coordinator.

- Project features:
  - Limit of Disturbance (closed polyline).
- Stormwater BMP features:
  - Footprint (closed polyline); and
  - Drainage area (close polyline).

- Land Cover Features:
  - Impervious areas (closed); and
  -Pervious areas (closed) – not to include stormwater BMP footprints.
- Stormwater Infrastructure Features:
  - Installed, existing, removed, modified, or abandoned stormwater structures (points); and
  - Installed, existing, removed, modified, or abandoned stormwater pipes installed during construction project (lines).

Tabular Data

In addition to providing the as-built survey data, the Lead Design Professional should provide tabular data pertaining to each as-built feature listed above. The specific tabular data should include all attribute data listed under each HCSMS Geodatabase, above. Tabular data should be provided in MS Excel format or as a tab-, or comma-delimited text file.

Supporting Documentation

In addition to the as-built survey and as-built survey tabular data, the Lead Design Professional should provide the following documents to the JHU Project Manager. Documents should be provided in PDF format, except as noted:

- Design and Construction:
  - Final engineering design plans (AutoCAD and PDF format);
  - Final construction specifications;
  - Record drawings; and
  - Other relevant documents.
- Permitting and Regulatory:
  - Reports submitted to Baltimore City for stormwater management plan approval (Site Development Design and Final Design Phases);
  - Regulatory approvals and permit(s);
  - Stormwater management maintenance agreement(s);
  - Declaration of covenant(s);
  - Easement plat for the stormwater management facility and/or to provide access for maintenance and inspection from a public right-of-way, where applicable;
  - Performance bond, where applicable (structural practices);
  - Narrative description of how detailed design differs from SWMMP, if applicable, to include:
    - A table showing the following information for a given stormwater BMP as presented in the SWMMP and as presented in the final design: BMP ID, BMP footprint, BMP drainage area, BMP impervious drainage area, ESD volume, BMP type; and

- A narrative description of the modifications from the SWMMP including the rationale and statement of compliance with regulations; and

- Other relevant documents.

Updating the HCSMS

The JHU GIS Coordinator will be responsible for updating each HCSMS geodatabase upon receipt of the as-built survey, supporting tabular data, and supporting documentation are received from the JHU Project Manager.

Generally, updating the each geodatabase will involve the following tasks:

- Migrating AutoCAD polygon, line, and point data into appropriate GIS feature classes;
- Resolving any conflicts between existing and new feature data;
- Updating GIS attribute tables with as-built tabular data;
- Performing a QA/QC of modified feature classes and attribute tables;
- Creating hyperlinks to supporting documentation; and
- Updating the metadata file for each feature class.

Regulatory Compliance Accounting/SWMMP Tracking

The HCSMS will be sued to track progress towards meeting regulatory requirements and campus stormwater management targets, as defined in the SWMMP.

Regulatory Plan Compliance Accounting

Baltimore City DPW requires regular accounting to verify compliance with the City and State stormwater regulations and progress towards the approved volume-based controls. JHU will implement a project accounting system to track progress towards 2032 management goals for ESD_V and A_T included in the Regulatory Plan (portions of the campus west of North Charles Street) during the campus expansion period. Per discussion with Baltimore City DPW during the June 15, 2011 meeting and subsequent email correspondence dated June 17, 2011, JHU will be permitted to run a cumulative ESD_V and/or A_T deficit of no more than 10% during any point in the campus expansion period. The interim deficit provision does not change JHU's commitment to meet the full ESD treatment requirements by the end of the build out period in 2032. This interim 10% allowance will be computed on a Regulatory Site-wide basis. During the build out period, JHU will carry a cumulative ESD_V and/or A_T deficit for no more than two (2) consecutive years before implementing additional ESD practices to erase the deficit. The anticipated frequency of project implementation during the build out period should allow for deficits, should they be incurred, to be effectively mitigated within a two (2) year period.

To track progress towards SWMMP endpoints, JHU will prepare and submit a Regulatory Plan Accounting Log to Baltimore City DPW upon completion of each campus expansion project. The JHU GIS Coordinator will provide summary information to the JHU Stormwater Program Manager for inclusion into the Regulatory Plan Accounting Log. The summary information compiled by the JHU GIS Coordinator should contain the following:

- The cumulative required ESD_V and A_T by Regulatory Plan LOD for current build-out phase (e.g., if the project is completed in 2018 the corresponding build-out phase is 2022) and for the end of build-out (2032);
- The cumulative ESD_V and A_T treated by completed projects installed under the 2012 Regulatory Plan by Regulatory Plan LOD;
- The ESD_V and A_T treated by the most recent completed construction project;
- The remaining ESD_V and A_T to be treated by the end of the corresponding build-out phase by Regulatory Plan LOD; and
- The remaining ESD_V and A_T to be treated by end of build-out 2032 by Regulatory Plan LOD.

The JHU Stormwater Program Manager will then complete the report and provide the completed report to Baltimore City DPW. The Regulatory Plan Accounting Log will provide a summary of cumulative ESD_v and A_T managed to date and the cumulative ESD_v and A_T required to date for each Regulatory Plan LOD (LODs A, C, D, E, and F), specific expansion project, and for the Regulatory Site, which includes the area of campus west of North Charles Street. The log will also provide ESD_V and A_T managed for each individual ESD practice. A sample Regulatory Plan Accounting Log is provided in Table 13. Back up calculations and mapping indicating the location and type of ESD practice and the extents of associated treatment drainage areas will be provided along with the Regulatory Plan Accounting Log. Baltimore City DPW may dictate the inclusion of different or additional information and/or modifications to the format presented herein.

Table 13
Sample Regulatory Plan Accounting Log

Johns Hopkins Univeristy
Homewood Campus 2012 Regulatory Plan Accounting Log
Date:

Project ID	Project Name	Date Completed	ESD ID	ESD_v Provided (cf)	A_T Provided (sf)	ESD_v Required (cf)	A_T Required (sf)	ESD_v deficit/surplus		A_T deficit/surplus	
								cf	% of required	sf	% of required
LOD A											
A-1	XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
			A-1-1	XXX	XXX						
			A-1-2	XXX	XXX						
A-2	XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Total LOD A				**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**
LOD C											
C-1	XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
			C-1-1	XXX	XXX						
			C-1-2	XXX	XXX						
C-2	XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Total LOD C				**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**
Regulatory Plan Total				**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**

SWMMP Tracking

The JHU Sustainability Committee provides annual reports on campus sustainability activities. In support of this effort, the JHU GIS Coordinator will be responsible for providing an annual stormwater reports to JHU Sustainability Coordinator. These reports summarize progress towards both regulatory volume-based stormwater requirements and campus stormwater management targets. Similar to the Regulatory Plan Accounting Log, the SWMMP Accounting Log includes the ESD_V and A_T required, treated to date, and remaining to meet 2032 requirements by Regulatory Plan LOD. In addition, it includes these values for campus areas outside Regulatory Plan LODs (denoted with a Project ID beginning with "V" for voluntary) and campus-wide totals (Table 14).

Table 14
Sample SWMMP Accounting Log

Johns Hopkins Univeristy
Homewood Campus 2012 SWMMP Accounting Log
Date:

Project ID	Project Name	Date Completed	ESD ID	ESD_v Provided (cf)	A_T Provided (sf)	ESD_v Required (cf)	A_T Required (sf)	ESD_v deficit/surplus cf	% of required	A_T deficit/surplus sf	% of required
LOD A											
A-1	XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
			A-1-1	XXX	XXX						
			A-1-2	XXX	XXX						
A-2	XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Total LOD A				**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**
LOD C											
C-1	XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
			C-1-1	XXX	XXX						
Total LOD C				**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**
Regulatory Plan Total				**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**
Campus Areas Outside LODs											
V-1	XXX	XXX		XXX	XXX			XXX		XXX	
			V-1-1	XXX	XXX						
			V-1-2	XXX	XXX						
V-2	XXX	XXX		XXX	XXX			XXX		XXX	
Campus Areas Outside LODs Total				**XXX**	**XXX**			**XXX**		**XXX**	
Campus-Wide Total				**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**

In addition, annual reporting summarizing progress towards primary and supporting campus goals should include the following information:

- For each campus stormwater management target (see Tables 6 and 9 for targets) raw and percentage values, as applicable, for:

  - Existing (2012) level;

  - Current level;

  - Current build-out phase target;

  - 2032 target;

- Increase during prior calendar year;
- Remaining to achieve current build-out phase target; and
- Remaining to achieve 2032 target.

The following table (Table 15) suggests possible layout for presenting the information. The table was created as if the reporting year was 2021.

Table 15
Annual Progress Towards Primary and Supporting Campus Goals

Goals	Metrics*	2012 Value	Current Build-out Phase (2022) Target	2032 Target	Current (2021) Value	Increase from Prior Year	Remaining to Current Build-Out (2022) Target	Remaining to 2032 Target
Improve the Quality of Downstream Waters	1	64.7 acres	61.9 acres	58.9 acres				
	2	0.0 acres	12 acres	20.0 acres				
Reduce Water and Energy Usage on Campus	3	3,000,000 gal	1,500,000 gal	0 gal				
	4	161,000 kWh/yr	150,000 kWh/yr	137,000 kWh/yr				
Enhance Ecological Integrity of the Campus Grounds	5	34.9 acres	36.6 acres	38.3 acres				
	6	0.0 acres	1.0 acre**	1.0 acre				
	7	0.0 acres	1.2 acres**	1.2 acres				
Enhance and Maintain Campus-Wide Spacemaking and Aesthetics through Stormwater BMPs	8	0.0 acres	1.3 acres**	1.3 acres				
	9	0.0 acres	0.01 acres**	0.01 acres				
Complement and Enhance Existing Pedestrian and Vehicular Patterns	10	0 BMPs	5 BMPs**	5 BMPs				
Enhance Student Body, Faculty, Alumni and Guest Awareness of Sustainable Stormwater Management Initiatives	11	0 BMPs	2 BMPs**	2 BMPs				
	12	0 BMPs	1 BMP**	1 BMP				
	13	0 BMPs	2 BMPs**	2 BMPs				
Reduce Maintenance Activities and Costs Associated with Grounds Upkeep	14	0.0 acres	3.6 acres**	3.6 acres				

***Performance Metrics**
1 - Reduction of impervious area (IA)
2 - Treatment of IA
3 - Reuse of Stormwater
4 - Reduction in landscape energy use (kWh/yr)
5 - Creation of natural habitat (forest, shrub/brush, meadow)
6 - Creation of natural habitat adjacent to woodlands or woodland finger (forest, shrub/brush, meadow)
7 - Treatment of IA within gully drainage area
8 - Conversion of landscape trouble spots to stormwater BMP
9 - Conversion of hardscape converted to stormwater BMP
10 - Stormwater BMP as trail access point to forested areas
11 - Interpretive stormwater BMP
12 - Showcase or artistic stormwater BMP
13 - Educational stormwater BMP
14 - Treatment of IA within flood prone drainage area

**Interim targets were not set for supporting metrics.

Stormwater BMP Maintenance

Proper maintenance of stormwater management facilities is essential to successful implementation of the SWMMP. A good maintenance program requires clearly-articulated goals, well-defined roles and responsibilities, and standard operating procedures for performing site inspections, routine maintenance, and data tracking. The JHU Office of Facilities Management Maintenance Coordinator (JHU Maintenance Coordinator) will be primarily responsible for coordinating and overseeing the SWMMP maintenance program. The JHU Grounds and Plumbing Shop staff will be responsible for conducting maintenance tasks. As described below, the SWMMP maintenance program will be guided by the program goals and is structured around routine inspection and maintenance visits. This Chapter describes the SWMMP Maintenance Program in detail including defining program goals; outlining procedures for performing routine maintenance activities; describing routine inspection and maintenance activities for various stormwater BMP types; and outlining program administration and tracking procedures.

Maintenance Program Goals

The goals of the SWMMP maintenance program are to maintain each stormwater BMP to meet stormwater performance standards; to complete maintenance in the most sustainable and cost-effective manner practicable; to preserve the designed aesthetic standard of each stormwater BMP; and perform maintenance activities in a safe manner.

Performance

Stormwater management practices must be maintained in good condition to continuously provide the core stormwater management functions for which they were originally designed and constructed (e.g., storage volume, drainage time, and/or infiltration rate, etc.). For most practices, this means maintaining good vegetative cover and adequate storage volume; and ensuring that stormwater is conveyed to and from the site in a stable manner.

Sustainability

In keeping with JHU's commitment to sustainability, maintenance activities should be conducted in the most sustainable manner feasible. In general, sustainable practices reduce the quantity of materials imported or exported from stormwater BMP sites and limit the use of power tools and mechanized equipment to the extent possible. For example, retaining organic material (e.g., leaves, plant remains) on site as mulch can reduce the need for hauling this material off site, and reduce fertilization and watering needs. Maintenance activities should also be conducted *en masse* in a coordinated manner to avoid unnecessary trips to and from maintenance sites. As described in subsequent sections, inspection and maintenance activities should be performed concurrently.

Cost-effectiveness

Cost-effectiveness is a key goal of the SWMMP maintenance program. Maintenance activities can represent a significant drain on JHU's resources. However, maintenance costs can be significantly reduced by using more sustainable methods, as described above, and streamlining workflow.

Aesthetics

Each stormwater management practice is designed to provide a specific aesthetic that complements its surroundings. Maintenance activities should maintain this intended aesthetic, thereby preserving the intended aesthetic character of various areas of campus.

Safety

Campus safety is an important component of stormwater BMP design and must be considered during maintenance activities. Stormwater BMPs are designed to meet campus safety standards, and aspects of a practice that promote safety (e.g., maintaining existing lines of site along pathways) should be preserved. In addition, maintenance crews should be mindful of their safety and the safety of passers by while performing maintenance activities.

Regulatory Plan Requirements

In addition to program goals, maintenance activities are also governed by Baltimore City regulations. JHU is required by City law (Baltimore City Ordinance 10-277, Council Bill 10-0434, §27-1) to maintain stormwater management facilities required for regulatory compliance, including ESD and structural practices, in good condition. Stormwater BMPs installed to meet internal campus sustainability goals, whether requiring a binding maintenance agreement or not, should also be maintained in good condition. Maintenance schedules and maintenance agreements are required for every stormwater management facility or system of ESD practices required for regulatory compliance. The maintenance schedule (Baltimore City Ordinance 10-277, Council Bill 10-0434, §27-2) is a maintenance program, developed for the life of a practice that includes the following:

- Maintenance to be completed;
- Time frame in which it is completed; and
- Party responsible for performing the maintenance.

A maintenance agreement (Baltimore City Ordinance 10-277, Council Bill 10-0434, §27-3) is an agreement binding all current and subsequent landowners with parcels served by the facility to the proper inspection and maintenance of the facility. The maintenance agreement must be executed prior to the City issuing any grading or building permits. Some individual maintenance activities may require City or State permits (e.g., erosion and sedimentation control, etc). These permits should be obtained prior to the initiation of the regulated activity.

Definitions

For clarification purposes, common terms discussed within the sections below are defined as follows:

Structural Features – include most non-vegetated components of stormwater BMPs. These include items such as: planter boxes, weirs, rocks, berms, overflows, erosion fabric, control boxes, orifices, grates, concrete fixtures, and conveyance features (swales, discharge areas, slopes, underdrain cleanouts, overflows, outfalls, flow splitters, splash pads, rocks, splash blocks, stone dams, gravel beds, curb cuts, drains, downspouts, berms and pipes.

Vegetation – Vegetation can be broadly classified using one or more of the following terms:

Native – A plant species that is indigenous to the Upper Piedmont Region of Maryland.

Non-native – A plant species that is not indigenous to the Upper Piedmont Region of Maryland.

Target – A plant species that was selected specifically for and planted/seeded within the project area or stormwater BMP. Target species can be native or non-native species.

Non-target – A volunteer plant species that was not specifically selected for and planted/seeded within the project area. Non-target species include both native and non-native species and are often weedy, invasive or aggressive colonizers.

Invasive – A non-native, exotic plant species that has been introduced by humans, either by accident or intentionally, such as for agricultural, utilitarian or horticultural uses. Invasive plant species colonize rapidly, outcompeting or overwhelming other native species. Invasive plants grow vigorously and have high reproductive success. Because invasive plant species do not have natural controls, such as pathogens, predators, herbivores and parasites, they pose a threat to native plant communities and biodiversity (http://www.invasiveplantatlas.org/).

Aggressive – A plant species that colonizes rapidly, competing with or potentially outcompeting or overwhelming other species. Aggressive plants can be either native or non-native.

Weeds – A non-target plant species that is not desired within stormwater BMP practices.

Planting Media – Amended soil within stormwater BMPs that enables higher infiltration rates.

Storage Volume Depression – The topographical depression of the stormwater BMP designed to hold the required ESD volume or designed storage volume. The treatment capacity of this topographical depression must remain constant; therefore removal of accumulated organics may be required to maintain the full capacity of the storage volume depression.

Routine Inspection and Maintenance Visits

The SWMMP maintenance program is centered on routine inspection and maintenance visits (routine visits), during which maintenance crews will inspect stormwater BMP sites and implement, on an as needed basis, required maintenance actions. Follow-on maintenance activities will be identified during routine visits and logged for approval and scheduling.

Routine visits will be performed by a combination of JHU Grounds and Plumbing Shop staff. Routine visits will be incorporated into the campus's preventative maintenance program and will be scheduled using the campus's existing work flow management system, which is run using Maximo software. The Grounds staff will be responsible for inspecting and maintaining the vegetation, grading, mulch, and other landscape-related features. The Plumbing Shop staff will be responsible for structural features associated with stormwater BMPs.

During routine visits, maintenance crews will evaluate the condition of each stormwater BMP and identify problem areas. Routine maintenance activities, such as reseeding small areas, pruning, and sediment removal, will be conducted on an as needed basis during the visit. Repair or maintenance activities that cannot be performed during the routine visit, due to materials or labor requirements or because prior authorizations are required, will be identified by the maintenance crews during the visit and subsequently entered into the work flow system for approval and follow up.

Routine visits should be performed on a monthly basis for vegetated stormwater BMPs (e.g., rain gardens, micro-bioretention practices, meadows, forests and green roofs, etc.) during a two-year establishment phase and quarterly thereafter. Structural practices (e.g., cisterns, porous pavements, etc.) should be inspected on a quarterly basis. Inspection frequency can be reduced or increased for individual practices based on need, but practices should be inspected a minimum of two times per year.

Aesthetic Considerations for Routine Maintenance Activities

Routine visits are guided both by regulatory requirements for various stormwater BMP types and additional requirements determined by the stormwater BMP aesthetic class. While the regulatory requirements dictate the minimum maintenance activities acceptable, the stormwater BMP aesthetic, as recommended for each constructed stormwater BMP in the BMP geodatabase (HCSM), dictates acceptable standards for the 'look' of the maintained stormwater BMP, per campus design standards (Chapter 6). Because of this, the frequency and intensity of routine visits may vary depending on the intended aesthetic.

Stormwater BMP aesthetic classes include formal, informal, and informal juxtaposition designations. These different designations require different maintenance prescriptions. Formally planted practices require the maintenance of a more controlled aesthetic, which may require more frequent pruning, replanting, and organic matter removal to maintain the manicured look. Similarly, hardscape material palettes used within formal stormwater BMPs as functional structural devices, such as splash pads or conveyance features, may require more frequent sediment removal, upkeep and vegetation trimming surrounding them to maintain a polished aesthetic. Maintenance regimes, such as weeding and mulch application, will also need to be performed more diligently within formal areas to maintain a more controlled appearance.

Informal stormwater BMPs, by contrast, emphasize more naturalistic aesthetics that pattern the ecological function and habitat characteristics of native meadow and forest plant communities. While informal stormwater BMPs will contain vegetation with a less manicured aesthetic, routine maintenance planning will need to consider framing this 'wilder' looking landscape within its context (Nassauer 1995). For example, within an informal meadow, plant form and structure will be less manicured and more picturesque, mimicking patterns from natural succession processes. However, when juxtaposing this informal meadow against the context of a more manicured environment (informal juxtaposition), such as turf or a brick seating wall, planned maintenance activities should be centered on emphasizing clean, intentional edges that clearly delineate borders.

Although informal stormwater BMPs will be intentionally designed to look more naturalistic, weeding and removal of invasive, non-target species should be a primary concern during maintenance activities. This will help to achieve optimum function for desired habitats, as well as aesthetics. Wildflower drifts within meadows, both formal and informal, will need to be maintained and possibly supplemented annually with plugs or containerized species, to ensure that continued visual interest occurs in desired areas. Often, supplementing a few blooming species at the edges of meadows or in concentrated pockets is sufficient to create splashes of color throughout different times of the growing season, allowing the remaining matrix of the meadow to be dominated primarily by less showy grasses and forbs. Wildflower drifts, although meant to look 'natural' and accidental, will need to be thoughtfully planned by the grounds crew when identifying campus planting zones annually, especially when located within prominent areas of the campus, such as adjacent to the Serpentine Wall in front of Decker Hall, where a formal meadow is identified within the SWMMP.

Lastly, maintenance regimes for pruning within formal tree groves will need to consider several factors, such as: pedestrian safety, tree health, and sculptural tree habit and form. Measures to prevent, as well as alleviate soil compaction beneath mature trees should be a primary concern during maintenance planning, as soil compaction can lead to tree mortality and weakening root systems, which can then lead to safety, as well as aesthetic issues. When planning for the ongoing maintenance of formal tree groves, the campus grounds staff should consider underplanting these with ephemeral flowers, shrubs, or other alternatives to turf, and designating clear pathways. This may help to deter pedestrians from walking over tree roots, thus helping to alleviate a major source of soil compaction on campuses, as well as enhancing aesthetic interest, safety and experience of the space.

The unique context, aesthetic quality and functional characteristics of each stormwater BMP will require a maintenance regime that is tailored to achieve specific results. These desired results should be outlined at the onset of design and be carried through construction into subsequent routine maintenance activities for the life of the practice.

Routine Maintenance Requirements by Stormwater BMP Type

Each stormwater BMP type requires a different set of inspection and maintenance activities. This section outlines stormwater BMP-specific inspection and maintenance tasks that incorporate Maryland state requirements and serve as a suggested checklist for routine visits. A maintenance schedule is provided by City law (Baltimore City Ordinance 10-277, Council Bill 10-0434, §27-7) on the construction drawings for the stormwater BMP final plan. All items included in the maintenance schedule must be incorporated into the maintenance program and the final checklist, as appropriate. In addition, the JHU Maintenance Coordinator should incorporated recommendations from the designer and/or nursery when developing final check lists. Should other practices not included in the SWMMP be constructed on campus, refer to Chapter 5 of Maryland Stormwater Design Manual (MDE 2000-2010) for required and suggested maintenance tasks.

Table 16
Cistern

This document provides guidance for stand-alone cisterns and those connected to the campus-wide irrigation system. For cisterns used as components of gray water or drinking water systems, significant additional maintenance beyond the scope of this document is required. A final checklist should be developed based on the characteristics of the installed cisterns.

Task	Schedule	Special Considerations
Inspection Activities		
Structural features:		
Check that pumps are functional	Quarterly	
Check that nozzles, gaskets, spigots, spouts, and backflow preventers are intact	Quarterly	
Check that drain plug and lines are intact and not leaking	Quarterly	
Check that overflow protection and surrounding area is in place and functioning (no erosion, scouring, or undermining)	Quarterly	
Inspect for graffiti	Quarterly	
Check for ice blockages, frozen lines, cracks, leaks	Monthly*	*during winter for subsurface cisterns
Check condition and functioning of appurtenances, valves, etc. (e.g., loose bolts, nuts, screws, etc.)	Quarterly	
Maintenance Activities		
Clean debris from screens	As needed	
Replace and/or repair damaged structural features	As needed	
Clean debris from gutters and downspouts of building	As needed	
Brush inside surface, flush to remove sediment, and disinfect	Annually	
Drain, disconnect, and clean	Annually*	*above ground cisterns, prior to first hard freeze
Dislodge ice blockages and repair cracked lines	As needed*	*during winter for subsurface cisterns
Remove graffiti	As needed	
Repair damaged or broken appurtenances, valves, etc. (e.g., loose bolts, nuts, screws, etc.)	As needed	

Table 17
Green roof
During establishment phase, vegetation maintenance is the most intensive work. After establishment, the most critical inspection and maintenance points are the roof membrane and drainage flow paths. A final checklist should be developed based on the characteristics of the installed green roofs.

Task	Schedule	Special Considerations
Inspection Activities		
Roof and structural features:		
Check for visible indication of poor drainage or pooling in vegetated and vegetation-free areas of roof	Quarterly	
Check that growing medium, filter fabric, drainage layer, waterproof membrane, and roof structure are intact	Quarterly	
Check for cuts and punctures in waterproof membrane	Quarterly	In particular, check perimeter areas, appliances (e.g. air conditioning unit), roof vent pipes, abutting vertical walls, outlets and other breaks in the roof surface.
Check that critical flow paths are free of sediment and debris	Quarterly	
Check for visible indication of wind erosion (erosion channels in soil medium)	Quarterly	
Vegetation:		
Check plant material for insect herbivory, disease, wilting, browning, scorch, etc.	Quarterly	
Check for weed presence and density	Quarterly	
Nuisance Animals:		
Check for visible indication of evidence of nuisance geese	Quarterly	
Maintenance Activities		
Roof and structural features:		
Remove debris, sediment or any other obstruction from drainage flow paths	As Needed	
Remove debris and sediment from roof drains, gutters and vegetation-free areas	As Needed	
Stabilize areas of wind erosion by adding new growth medium	As Needed	
Vegetation:		
Water	1-3 times per week (for up to 6 months following installation) During extended droughts (If more than 2 months occur during the first 3 years)	Watering rates are variable based on the plants and type of roof membrane and should be specified by the designing engineer.
Supplement Planting	As Needed	If plant spreading has not occurring sufficiently or where plant density is waning during year two, supplement plant (using the same species used initially) with stem cuttings or plugs ordered from a green roof vendor.
Weed* Invasive / Non-target Plants	As Needed**	*Do not use digging tools, weed cutters/trimmers, or gasoline-operated machinery as they may damage the green roof system or the waterproof membrane. **Weed aggressively during the first two years.

Table 18
Meadow
Maintenance activities will depend, in part, on the size, location, method of establishment, and designed aesthetic for the planted meadow. A final checklist should be developed based on the recommendations from the designer and the nursery.

Task	Schedule	Special Considerations
Inspection Activities		
Check for visible indication of game or small rodent damage	Quarterly	
Check vegetation for insect herbivory, disease, wilting, browning, leaf loss, scorch, etc.	Quarterly	
Check for the presence of non-target plants	Quarterly	
Check for the presence of invasive plants	Quarterly	
Identify location and extent of eroded areas	Quarterly	
Evaluate specimen form, habit and structure*	Quarterly	*formal meadows only
Check that edge is intact and defined	Quarterly	Within formal meadows, edge should be very manicured and clearly defined. Within informal meadows, edge should blend into adjacent natural areas. Within informal juxtaposition meadows (adjacent to turf or formal area), edge should be manicured and clearly defined.
Maintenance Activities		
Mow	3 x (during first year) 2x (during second year) 1x (during subsequent years)	Mow prior to perennial weeds setting seed (spot mowing or hand cutting are useful as well). Mow to 6-12 inches in height. Avoid grassland breeding bird window.
Weed non-target / invasive species	As needed	Avoid hand weeding during first 3 years.
Remove cut or mowed herbaceous material	As needed*	*ONLY when necessary to maintain formal aesthetic and to avoid non-target and invasive propagation
Apply herbicide to invasive species	As needed*	*use only when necessary and per specifications for invasive species
Water	As needed*	*as specified for establishment phase ONLY
Prune	As needed	Within formal meadow, prune to maintain aesthetic (plant form and habit). Within informal meadow, prune to maintain plant condition.
Stabilize and/or repair damaged or eroded areas	As needed	
Supplement, repair or replace edge*	As needed	*to aesthetic standard

Table 19
Forest
Maintenance activities will depend, in part, on the size, location, method of establishment, and designed aesthetic for the planted forest. A final checklist should be developed based on the recommendations from the designer and the nursery.

Task	Schedule	Special Considerations
Inspection Activities		
Check for visible indication of game or small rodent damage	Quarterly	
Check vegetation for insect herbivory, disease, wilting, browning, leaf loss, scorch, etc.	Quarterly	
Check for the presence of non-target plants	Quarterly	
Check for the presence of invasive plants	Quarterly	
Identify location and extent of eroded areas	Quarterly	
Check soil for compaction	Annually	
Evaluate form, habit and structure*	Quarterly	*formal forest (mature tree grove) only
Check that edge is intact and defined*	Quarterly	*formal forest (mature tree grove) only - forest edge should be manicured and clearly defined, where appropriate
Maintenance Activities		
Water	Daily (during first two weeks after installation) Regularly (after the remainder of the first year)*	*as dictated by species and weather
Prune	As needed	Within formal forest (mature tree grove), prune to maintain aesthetic (plant form and habit). Within informal forest, prune to maintain plant condition.
Replace dead vegetation	As needed	Do not replace dead vegetation if site was overplanted to mimic natural succession in anticipation of mortality.
Remove woody debris	As needed	ONLY when necessary to maintain formal aesthetic
Stabilize and/or repair damaged or eroded areas	As needed	
Install game deterrents (tree tubes, tree shelters, fencing, etc.) or perform game deterring regime (e.g., ecologically friendly deer repellents, mowing, etc.)	As Needed	
Remove Invasive / Non-target Species	As Needed*	*annually at minimum and aggressively until full canopy is established
Replace or repair “No-Mow” edge, fencing or “No Trespassing” signage	As Needed*	*during establishment to prevent trampling or mowing of vegetation and compaction of soil
Supplement, repair or replace edge*	As needed	*to aesthetic standard

Table 20
Micro-bioretention and Rain Garden Maintenance Checklist
Maintenance activities will depend, in part, on the size, location, method of establishment, and designed aesthetic for the BMP. A final checklist should be developed based on the recommendations from the designer and the nursery.

Task	Schedule	Special Considerations
Inspection Activities		
Structural features:		
Check for accumulated debris and sediment	Quarterly	
Check for wear, erosion, cracking, spalling, tears, etc.	Quarterly	
Check for missing or damaged components	Quarterly	
Check for visible indications of clogging	Quarterly	
Check for graffiti	Quarterly	
Check for the presence of scour or undermining	Quarterly	
Condition and functioning of appurtenances, valves, etc. (e.g., loose bolts, nuts, screws, etc.)	Quarterly	
Vegetation:		
Check for insect herbivory, disease, wilting, leaf loss, scorch, etc.)	Quarterly	
Check for weed presence	Quarterly	
Check for damage from equipment, humans or animals	Quarterly	
Evaluate specimen form, habit and structure*	Quarterly	*formal practices only
Storage Volume Depression		
Identify location and extent of eroded areas	Quarterly	
Check for accumulated debris and sediment	Quarterly	
Check for visible indication of overtopping or clogging of infiltration surface (e.g., pooled water or debris on surfaces surrounding practice)	Quarterly	
Verify dimensions of practice – length, width, depth, etc. to ensure the BMP reflects as-built condition	Annually	Depressional storage areas should blend into landscaping beds and mulched areas so as not to call attention to the BMP, unless it is a specific design intent.
Check for areas of settling or sinkholes	Quarterly	
Mulch:		
Check of mulch, filter media, and/or planting media for compaction, sparseness, contamination, or mold	Quarterly	
Measure depth of mulch – verify depth of mulch to ensure BMP reflects as-built condition	Annually	
Edge:		
Check that edge is intact and defined	Quarterly	Within formal practices, edge should be very manicured and clearly defined. Within informal practices, edge should blend into adjacent natural areas. Within informal juxtaposition (adjacent to turf or formal area), edge should be manicured and clearly defined.
Monitoring Wells:		
Record depth of water	Quarterly	

Table 20 continued
Micro-bioretention and Rain Garden Maintenance Checklist

Task	Schedule	Special Considerations
Maintenance Activities		
Structural features:		
Stabilize eroded or undermined features	As needed	
Repair and/or replace damaged, cracked, or missing components and appurterences	As needed	
Flush underdrain / cleanout structures	Annually	
Remove debris and sediment from structure surfaces (e.g., inlet grates) and interiors	As needed	Do not allow sediment and debris to accumulate above lowest pipe invert.
Remove debris and sediment from the surface of forebay, stilling area, splash pad, level spreader and/or outlet protection	As needed	
Remove graffiti	As needed	
Vegetation:		Requires specialized cleaning materials/paint remover requiring specialized training in use and disposal.
Water	Daily (first 2 weeks after installation) Regularly (during first year after installation)* As needed (during extended periods of drought)*	*as dictated by species and weather
Prune	As needed	Within formal BMPs, prune to maintain aesthetic (plant form and habit). Within informal BMPs, prune to maintain plant condition.
Weed*	As needed	Within formal BMPs weeding should be performed regularly. Within informal BMPs, weed growth may be less visible due to the high diversity within the practice, however weeding should be performed on a regular basis to ensure successful establishment. *avoid machinery, such as mowers, that will compact soil
Treat diseased species	As needed or annually*	*according to specifications
Replace dead or diseased species	As needed	
Reseed bare soil	As needed	
Repair or replace no-mow, no trampling, or educational signage	As needed	
Storage Volume Depression:		
Stabilize and/or repair damaged or eroded areas	As needed	
Replace the top few inches of the planting media	As needed*	*when water ponds within the practice for more than 48 hours
Remove debris	As needed	Within formal practices, remove organic matter and trash. Within informal practices, remove trash but leave and organic matter (unless sourced from diseased plants).
Remove sediment	As needed*	*when sediment depth exceeds 1”
Repair damage from sinkholes, subsidence, or soil loss	As needed	
Mulch:		
Add mulch	As needed*	*to maintain as-built condition
Replace mulch	As needed*	*annually, at minimum, for practices treating areas with high concentrations of heavy metals (e.g. parking lots)
Edge:		
Supplement, repair or replace edge*	As needed	*to aesthetic standard

Establishment Phase Maintenance

The establishment phase is the period of 2-3 years when the plants within a vegetated stormwater BMP (i.e., rain garden, micro-bioretention practice, meadow, forest, or green roof) are taking root, maturing, and/or spreading. Often, the original planting density is developed to account for the development and growth of vegetation during the establishment phase. For example, green roof plants will spread and mature during the first two years, filling bare soil areas left in anticipation of this establishment process. In some cases, specimens are planted in higher densities than those expected of the mature design in anticipation that a portion of the plants will not survive. Additional or more frequent maintenance activities are usually required during this period.

Newly installed vegetated stormwater BMPs require more intensive, and often more frequent maintenance during establishment than in later years. Adequate watering is the most important maintenance activity after initial planting and throughout the first year of establishment to ensure plant survival. This is especially true for tree and shrub survival during the entire first year of growth. Even when using native plants, adequate watering during the first year of establishment is necessary.

Plants require special care during transport and storage to ensure survival. Detailed planting specifications should be included within final plan sets or may be obtained from the supplying nursery. The specifications include proper methods for plant transport, watering, and covering and maximum on-site storage times prior to planting. Establishment success is best for plants installed during the spring or fall; planting during hot summer months should be avoided. Maintaining moist soil conditions for 2-3 weeks after planting or seeding herbaceous meadows is important to maximize plant survival. Because of this, watering regimes should respond to the amount of rainfall during the time of planting and initial establishment. Fertilizer should not be used within stormwater BMPs, to maintain water quality, as well as deter non-target weed growth.

Special Maintenance Visits

While the maintenance program is structured on routine visits, additional visits are required periodically when:

- Rainfall event of one (1) inch or more occurs;
- Maintenance activities or repairs are beyond the scope of routine work; or
- Maintenance activities are more frequent than routine visits.

Storm Event Maintenance

In addition to inspection and maintenance at pre-defined intervals, a storm event inspection and maintenance visit (storm event visit) should be completed following rainfall events of 1 inch or greater. The procedure for storm event visits is to identify and implement maintenance activities that are of emergency nature and cannot wait until the next routine visit to address. Conditions that pose an imminent hazard to life or property and cannot be accomplished during the storm inspection should be either visually marked or blocked-off (e.g., temporary fencing) or repaired immediately. Approval for follow-on maintenance required as a result of damage from storm events should be obtained and scheduled immediately or during the next routine maintenance event, as necessary.

Follow-on Maintenance

Follow–on maintenance includes activities that cannot be performed during routine visits, due to materials or labor requirements or because prior authorizations are required. Follow-on maintenance tasks are identified by the crews during routine or storm event visits and entered into the work flow system for approval and scheduling. Follow-on work may be completed during an upcoming routine visit or a specially scheduled visit (follow-on visit). Tasks that may require follow-on approval or a follow-on visit include, but are not limited to:

- Major repairs sinkhole or slumping or subsidence or settling;
- Shrub and/or tree replacement;
- Grading storage volume depression (to maintain designed capacity);
- Specialized herbicide applications;
- Major repair or replacement of structures;
- Major repair due to slumping or settling;
- Tree root aeration; and
- Cistern draining (within 48 to 72 hours after major rain event to ensure availability of storage for another storm).

Special Maintenance

Special maintenance activities are those activities that are anticipated or repetitive and require more frequent visits than routine inspection and maintenance tasks. Special visits may be scheduled and approved in advance to create an efficient, cost-effective workflow. Tasks included in special visits may include, but are not limited to:

- Daily watering during establishment phase; and
- Regular applications of herbicide or disease treatments.

Maintenance Tracking

The JHU Maintenance Coordinator will maintain records of each routine, follow-on, and special maintenance visit completed for the maintenance program. Data collection and tracking for the maintenance program will be accomplished through JHU's existing work flow tracking system and supplemented with additions to the HCSMS or a separate database, as necessary. Maintenance will be tracked on both the stormwater BMP and Feature levels, where features are individual components of stormwater BMPs, such as planting areas, structures, and trees.

Inspection and Maintenance Documentation

Maintenance crews are responsible for providing a record of each inspection and maintenance event to the JHU Maintenance Coordinator for filing.

Written documentation of inspections and maintenance events should include the following for each maintenance cycle:

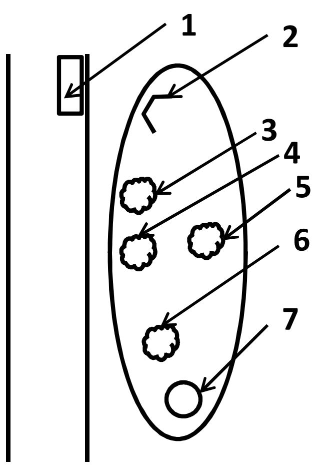
- Date;
- Inspector;
- Maintenance Crew;

- Type of visit (routine, follow-on, rain event);
- Condition of stormwater BMP features (including vegetation and structures);
- Record of completed maintenance activities;
- Record of follow-on maintenance activities recommended; and
- Record of any photographs taken during visit.

Stormwater BMP and Stormwater BMP Feature Coding

Prior to implementing the maintenance program on a particular stormwater BMP, the stormwater BMP and its features should be assigned a unique numerical identifier. Whenever possible these IDs should correlate with those in the HCSM BMP and Infrastructure Geodatabases. All inspection and maintenance documentation should use this nomenclature to refer to stormwater BMPs and stormwater BMP features. The JHU GIS Coordinator should develop a feature map for each stormwater BMP after completion of project construction so that crews can easily identify stormwater BMP elements in the field.

BMP ID. Example



BMP ID. Example

Date: ______

Weather: ______

Inspector: ______

Crew: ______

Feature ID	Feature	Condition	Maintenance Completed	Follow-on Maintenance Suggested
A.1	Inlet			
A.2	Endwall			
A.3	Tree			
A.4	Tree			
A.5	Tree			
A.6	Tree			
A.7	Outlet			

Comments

Inspection and Maintenance Task Coding

A consistent nomenclature or coding system for inspection and maintenance tasks and feature conditions should be implemented on all inspection and maintenance documentation. Whenever possible, this nomenclature or coding system should be synched with the Stormwater Infrastructure Geodatabase to simplify record keeping.

Photo Documentation

Maintenance crews should take digital photographs before and/or after maintenance activities to record reoccurring or unusual issues and measure taken to fix the issue. Digital photographs should be organized by date, stormwater BMP ID, and Feature ID and stored within JHU's servers. Digital photographs should be hyperlinked to maintenance records for convenient retrieval.

Chapter 9

References

Chapter 9: References

AKRF, Inc. (AKRF). 2012. Johns Hopkins University 2012 Homewood Campus Stormwater Management Master Plan. Concept Plan Design and Computations. April 2012.

Baltimore City. 2009. The Baltimore Sustainability Plan. April 2009.

Brown, Harkness and Johnston. 1998. Eco-Revelatory Design: Nature Constructed/Nature Revealed. Landscape Journal - Special Issue.

Center for Watershed Protection (CWP). 2008. Lower Jones Falls Watershed Small Watershed Action Plan. October 2008.

Clark, C. 2005. Optimization of Green Roofs for Air Pollution Mitigation. Greening Rooftops for Sustainable Communities: Washington DC. Green Roofs for Healthy Cities.

Echols, Stuart and Eliza Pennypacker. Stormwater as Amenity: The Application of Artful Rainwater Design. Department of Landscape Architecture, Pennsylvania State University: University Park.

Engineering New Report (ENR). 2012. Construction Cost Index History. http://www.enr.com/features/conEco/costIndexes/constIndexHist.asp

Engineering Technologies Associates, Inc. (ETA). 2003. Baltimore City Stormwater Management Manual. Baltimore City Department of Public Works. Baltimore, MD

Fairfax County LID BMP Fact Sheet—Permeable/Porous Pavements. Fairfax County, Virginia. February 28, 2005

Forman, Richard T.T. 1997. Land Mosaics: The Ecology of Landscapes and Regions. University Press: Cambridge.

Johns Hopkins University (JHU). 2001. Homewood Campus Plan. May 2001.

Johns Hopkins University (JHU). 2004. Johns Hopkins University Homewood Campus Open Space Implementation – Phase I Materials and Products Palette. January 2004.

Johns Hopkins University (JHU). 2009. 2008 Homewood Campus Plan Update. February 2009.

LID Urban Design Tools, Permeable Pavers. Low Impact Development Center, Inc. Http://www.lid-stormwater.net/permpaver_costs.htm

Maryland Department of the Environment (MDE). 1983. Modeling Infiltration Practices Using the TR-20 Hydrologic Program (1983). Maryland Department of the Environment. Baltimore, MD.

Maryland Department of the Environment (MDE). 2010a. Environmental Site Design (ESD) Process & Computations July 2010. Maryland Department of the Environment. Baltimore, MD.

Maryland Department of the Environment (MDE). 2010b. Environmental Site Design (ESD) Redevelopment Examples October 2010. Maryland Department of the Environment. Baltimore, MD.

Maryland Department of the Environment (MDE). 2000-2010. Maryland Stormwater Design Manual. Maryland Department of the Environment. Baltimore, MD.

Muller, Brook. 2007. Continuity of Singularities: Urban Architectures, Ecology and the Aesthetics of Restorative Orders. Department of Architecture, University of Oregon: Eugene.

Nassauer, J.I. 1995. Messy Ecosystems, Orderly Frames. Landscape Journal. 14:2, pp. 161-170.

Niu, H., C. Clark, J. Zhou, and P. Adriaens. 2010. Scaling of Economic Benefits from Green Roof Implementation in Washington, DC. Environ. Sci. Technol., 44, 4302-4208.

RSMeans Site Work & Landscape Cost Data 26th Annual Addition 2010. Reed Construction Data Inc.

Rummel, Klepper & Kahl, LLP (RK&K). 2001. Stormwater Management Report—Johns Hopkins University Homewood Campus Master Plan. May 2001.

Schueler, T., D. Hirschman, M. Novotney, and J. Zielinski, P.E. 2007. Urban Stormwater Retrofit Practices Version 1.0. Urban Subwatershed Restoration Manual Series Manual 3. Center for Watershed Protection, Ellicot City, MD.

Selvakumar, A. 2004. BMP Costs. Chapter 6 in: The Use of Best Management Practices (BMPs) in Urban Watersheds EPA/600/R-04/184.

Soil Conservation Service. 1986. Urban Hydrology for Small Watersheds. 2nd ed. Technical Release 55, U.S. Department of Agriculture.

State of Maryland Department of Natural Resources (DNR). 2003. A Comprehensive Forest Conservation Plan for Long-term Watershed Protection on the City of Baltimore's Reservoirs. January 2003.

Vanaskie, M., D. Myers, A. Signarovitz. 2008. LTCPU Land Based Stormwater Controls Cost Estimates. Memorandum from CDM to PWD Office of Watersheds.

Whitney, Bailey, Cox & Magnani, LLP. 1999. Student Arts Center Stormwater Management Analysis. May 1999.

Appendix A

Peak Flow Regulatory Compliance Methods and Results

Appendix A: Peak Flow Regulatory Plan Compliance Methods and Results

Under proposed conditions, the peak discharge rates of runoff, analyzed at a common downstream point of interest (POI), must be less than or equal to those of existing conditions (ETA 2003, Section 2.4.1 [6] and COMAR 26.17.02.06[C]). Hydrologic modeling of the Regulatory Site was performed to determine peak flows for regulated storm events through the build-out period based on campus expansion plans outlined in the 2008 Homewood Campus Plan Update. Campus areas east of North Charles Street were not included in the modeling effort and campus expansion in these areas will require independent modeling and regulatory approval. Similarly, campus expansion project within the Regulatory Plan Boundary not included in the 2008 Homewood Campus Plan Update may require independent or additional modeling and regulatory approval. Modeling results show that peak flows for all regulated storm events are reduced from existing conditions (2012) over the course of the twenty-year build-out. Accordingly, the construction of quantity control facilities is not proposed within the Regulatory Plan. A detailed description of modeling methods and findings is presented in the following sections.

Methods

The software package WinTR-20 v.1.11, developed by the USDA Natural Resources Conservation Service, was used to model the existing and 2032 (proposed) hydrologic conditions for the campus. Analysis of the rainfall simulations to estimate the resultant stormwater runoff was completed using this methodology. Time of concentration for each campus sub-area was calculated using the NRCS Segmental Approach presented in USDA NRCS Technical Release 55 (TR-55).

Drainage Area Delineations

Peak flows were analyzed at two major Points of Interest (POI) and at the points where stormwater from each contributing campus drainage area exit the JHU property and/or the study area. Campus drainage patterns are driven by a topographic break or ridge that runs northeast to southwest across the site. Campus drainage areas 1, 2, and 7 drain in a westerly direction and ultimately enter Stoney Run (Figure 26). Point of Interest West (POI-West) was defined at the downstream interaction of campus drainage areas 1, 2, and 7 and represents the combined peak flow from campus drainage areas 1, 2, and 7. Campus drainage areas 3, 4, and 5 drain in an easterly direction and ultimately enter the Baltimore City storm sewer system in North Charles Street. Point of Interest East (POI-East) was defined at the downstream interaction of campus drainage areas 3, 4, and 5 and represents the combined peak flow from campus drainage areas 3, 4, and 5. POI-East is within the Baltimore City storm sewer which is located beneath the North Charles Street public Right-of-Way.

The combined peak flows to either POI-West or POI-East represent simple hydrograph addition computed within the WinTR-20 model. This method disregards any potential peak attenuation that might occur if the discharge from each separate campus drainage area were to enter the actual drainage networks (Stoney Run or the Charles Street storm sewer system) at discrete points along each drainage network. Therefore this method is considered a conservative method of peak flow comparison.

Small portions of the property owned by JHU (Block-Lot: 3690-001) and draining to POI-3 and POI-4(1) were not included in the TR-20 analysis because they are located outside the potential area of disturbance. Therefore, conditions in these areas will remain unchanged in 2032 from existing conditions and will not impact the peak flow analysis. The property between POI-3 and POI-4(1) is associated with the Museum of Art and owned by the Baltimore City Mayor and City Council (Block-Lot: 3690-001A).

Land grading during the construction of certain build-out projects could result in slight modifications to campus drainage area boundaries. As these changes are likely to be minor and to some degree unpredictable until final designs are developed, identical campus drainage area boundaries were used for existing conditions and build-out phase modeling.

Precipitation Input Data

The HEC-HMS model was used to evaluate hydrologic conditions for the Type II – 24 hr frequency storms for the 1, 2, 10, and 100-yr rainfall events, which are associated with rainfall depths of 2.6, 3.2, 5.1, and 7.1 inches respectively, as provided in the Manual.

Weighted Curve Number (CN) Development

Rainfall runoff was determined using the NRCS curve number method for the WinTR-20 model. This method requires the development of weighted CNs that express the degree to which precipitation encountering the watershed land surface becomes surface runoff. Weighted CN values for each campus drainage area were determined through methods outlined in NRCS Technical Reference 55 (TR-55). Land cover polygons required for CN calculations were digitized from existing aerial photographs, engineering plans, and mapping from the 2008 Homewood Campus Plan Update. Land cover mapping for the build-out condition (2032) incorporated changes in cover related to proposed BMPs, the conversion of lawns and landscaped areas to natural areas, and improved condition of pervious areas associated with campus expansion. Initial land cover polygon coverages for the existing condition were then field verified by AKRF staff. Hydrologic conditions for pervious land cover polygons were determined in the field by AKRF staff.

Weighted CN values were then determined for each of the campus drainage areas. When land cover types did not match CN categories provided in the TR-55 guidance, best professional judgment was used to select the most appropriate CN number. Based on USGS data, soils within the campus belong to HSGs B, C, and D. For the purpose of determining CN values, however, HSG C was assumed for all campus soils. Using HSG C is a conservative approach that accounts for the effects of soil compaction within developed areas, and facilitates comparison with previous model results presented by RK&K (2001). Weighted CNs were developed using the CN value guidance found in Technical Report 55 (TR-55), which also mimics the NRCS method of hydrology calculation. Time of concentration paths were obtained from RK&K (2001) and modified, as needed, using desktop analysis to reflect existing conditions. Time of concentration paths are shown on Figure 26, and time of concentration calculations provided in Appendix A of the Regulatory Plan were computed manually using the NRCS segmental approach. Time of concentration calculations were not computed using

WinTR-20 or WinTR-55 because of model limitations, i.e., the models did not allow more than one sheet flow segment as in the case of some campus drainage areas.

Existing Stormwater Management Facilities

Two stormwater management facilities are located within the Homewood campus. Both facilities were included in the hydrologic modeling for the campus. An existing stormwater quantity control basin (SWM 2) is located within campus drainage area 2 on the western side of campus, just north of Olin Hall. This facility has a storage volume of approximately 21.39 ac-ft and manages the runoff from all of campus drainage area 2. POI-West reflects the peak discharge for campus drainage areas 1, 2 and 7 combined, and includes the hydrologic routing of SWM 2. Elevation storage-discharge relationships were obtained from the RK&K (2001) report.

An existing subsurface stormwater quality facility (SWM 1) is located beneath the Mattin Center along the eastern side of campus, within campus drainage area 4. This facility has a storage volume of approximately 0.34 ac-ft and manages runoff from a portion of campus drainage area 4. For modeling, campus drainage area 4 was subdivided into campus drainage areas 4(1) and 4(2), with campus drainage area 4(2) defined as the catchment area for the facility SWM 1. POI-East reflects the peak discharge for campus drainage areas 3, 4(1), 4(2), and 5 combined, and includes the hydrologic routing of SWM 1. Elevation-storage-discharge relationships were obtained from the Whitney, Bailey, Cox & Magnani, LLP (1999) Student Arts Center Stormwater Report.

Reduction in Curve Numbers Due to Modeling Infiltration Practices

The Regulatory Plan achieves peak flow compliance for areas of campus west of North Charles Street by demonstrating that the proposed condition peak discharge at each campus drainage area POI is less than or equal to the existing condition peak discharge. In all campus drainage areas except DA3, peak flow compliance can be attributed to the decrease of Curve Numbers due to proposed land cover changes such as conversion of impervious cover to natural areas, installation of alternative surfaces, and implementation of nonstructural and micro-scale BMPs. In those campus drainage areas, TR-20 modeling did not account for the runoff volume stored within the BMPs. In campus drainage area DA3, a net increase in impervious surfaces resulted in an increased proposed condition Curve Number, and a net peak discharge increase. Therefore, in order to demonstrate compliance, the TR-20 model for DA3 was modified to account for the runoff volume stored by four proposed infiltration practices (see LOD D and F in Appendix B).

Guidance for modeling infiltration practices in TR-20 was obtained from the MDE (1983), and was based on Method 1 – Change in Curve Number Method. This method was used to develop a reduced Curve Number, CN*, given by the following equation:

$$CN^{*} = \frac{200}{(P+2\Delta Q+2)-\sqrt{5P\Delta Q+4\Delta Q^{2}}}$$

Where P = design rainfall depth in inches

ΔQ = after development runoff depth minus the runoff depth stored by the infiltration practices in inches

The ΔQ term in the equation represents runoff depth (in inches) over the entire campus drainage area DA3 that is captured and treated by proposed infiltration practices. In order to compute this value, it was first necessary to determine the drainage area (DA) and managed runoff depth (Q_E) for each individual practice. Then, the weighted managed runoff depth Q_E over campus drainage area DA3 was calculated by summing the product of DA and Q_E for each practice, then dividing that term by the total area of campus drainage area 3, represented by the following equation:

$$Q_E\,(watershed\ DA3) = \frac{\sum_{i=1}^{n}(Q_{Ei}\ x\ DAi)}{\mathrm{DA3}}$$

The runoff depth managed by the infiltration practices in DA3 was then calculated as:

$\Delta Q = Q_{post} - Q_E$

Where Q_{post} represents the unmanaged runoff depth in inches from the proposed condition TR-20 model, and Q_E was calculated as shown above. Because the reduced Curve Number equation requires the design rainfall depth P, a separate reduced Curve Number was calculated for each design storm event. Supplemental TR-20 models for campus drainage area 3 using the reduced Curve Number were developed for each storm event. The proposed condition hydrograph computed by TR-20 with the revised Curve Number is the downstream hydrograph that accounts for infiltration storage. Table 21 summarizes the peak flow compliance modeling including the effect of infiltration storage within DA3. Appendix A includes the reduced Curve Number calculations for DA3 as well as supplemental TR-20 model output sheets for the 1-year, 2-year, 10-year, and 100-year design storms.

Findings

The results indicate that peak discharge rates analyzed at the downstream points of interest at Stoney Run (POI-West) and North Charles Street (POI-East) decreased in the proposed build-out phase (2032) when compared to peak flows associated with existing conditions (Table 21) even though proposed BMP were not factored into the model (Table 21). Unlike the peak discharge at other POIs, peak discharge at POI-3 increased from existing to 2032 conditions when land cover changes alone were considered. However, when stormwater managed within proposed micro-bioretention and rain garden practices were factored into the model, there was a decrease in peak discharge from existing to proposed conditions during all design storms at POI-3 (Table 21). The results thus indicate that the BMPs and land cover conversions proposed throughout the build-out are sufficient to meet Maryland's stormwater quantity management requirements of providing zero net increase of peak discharge rates between existing and proposed conditions in the Regulatory Site. Therefore, no additional stormwater quantity management facilities are proposed.

Table 21

Hydrologic Modeling Results

	Comparison of Existing and Proposed (2032) Estimated Peak Flow Discharge for the 2-Year, 10-Year, and 100-Year Recurrance Interval Flow Events (cfs)											
	1-year			2-Year			10-year			100-year		
Sub-Watershed	**Existing**	**2032**	**% Change**	**Existing**	**2032**	**% Change**	**Existing**	**2032**	**% Change**	**Existing**	**2032**	**% Change**
1	100.6	99.8	-0.8%	144.4	143.7	-0.5%	292.7	292.3	-0.1%	453.8	453.0	-0.2%
2 (without SWM)	11.6	10.8	-6.9%	17.2	16.3	-5.2%	37.1	35.9	-3.2%	59.0	57.8	-2.0%
2 (with SWM)	0.0	0.0	0.0%	0.0	0.0	0.0%	2.8	2.6	-7.1%	5.9	5.7	-3.4%
7	22.3	20.2	-9.4%	29.7	27.4	-7.7%	53.3	51.0	-4.3%	77.9	75.8	-2.7%
A (West)-Stoney Run*	**108.6**	**107.0**	**-1.5%**	**155.6**	**153.9**	**-1.1%**	**314.2**	**312.4**	**-0.6%**	**486.6**	**484.6**	**-0.4%**
3	16.6	17.3	4.2%	23.4	24.2	3.4%	46.2	47.2	2.2%	70.7	71.6	1.3%
4(1)	28.8	28.2	-2.1%	39.3	38.7	-1.5%	73.4	72.8	-0.8%	109.4	108.9	-0.5%
4(2) without SWM	4.0	4.0	0.0%	5.1	5.1	0.0%	8.5	8.5	0.0%	12.0	12.0	0.0%
4(2) with SWM	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	2.2	2.2	0.0%
5	2.6	2.6	0.0%	3.9	3.9	0.0%	8.4	8.3	-1.2%	13.3	13.3	0.0%
B (East)-Baltimore Sewer *	**41.5**	**41.4**	**-0.2%**	**57.6**	**57.5**	**-0.2%**	**110.7**	**110.5**	**-0.2%**	**168.2**	**168.1**	**-0.1%**
3**	**16.6**	**10.8**	**-34.9%**	**23.4**	**18.0**	**-23.1%**	**46.2**	**43.9**	**-5.0%**	**70.7**	**69.5**	**-1.7%**

* Modeled with the effects of existing stormwater management facility

**Modeled with the effects of proposed stormwater management facilities

Appendix B

Environmental Site Design Computations

Appendix B: Environmental Site Design Computations

Calculation of the Required A_T, ESD_v, and Re_V

The required A_T, ESD_v and Re_V were calculated for each LOD and summed to provide campus-wide targets. As described earlier, six (6) LODs were delineated to include demolition, new construction and other areas likely to be impacted by planned future construction staging and layout. LOD A, C, and F include construction activities proposed during multiple build-out phases. Regulatory requirements for LOD B are included in the SWMMP; however campus expansion in this area (east of North Charles Street) was not included in the Regulatory Plan and will require independent approvals from Baltimore City DPW.

The required A_T was calculated for the *new* (the net IA increase) and *redevelopment* (50% of the existing IA less any decrease in imperviousness) portions of the IA. The total area and IA within each LOD was obtained from GIS-based cover maps. These data were used to calculate the percent increase in IA for each LOD (Table 22). The total required A_T was calculated as the sum of the *new* and *redevelopment* portions of the A_T. The *new* portion consists of the increase in IA between proposed (2032) and existing conditions. For LODs where the IA decreased (e.g., pervious area resulting from demolition is greater than impervious area resulting from construction), there were no *new* development requirements. The *redevelopment* portion consists of 50% of the existing IA acreage. This value is then reduced by any net decrease in IA over the build-out period. The campus-wide target A_T for the twenty-year build-out is the sum of the total required A_T for each LOD. The WQ_V requirement is met when a minimum treatment volume equivalent to one inch over the A_T is provided.

The required ESD_V for *new* and *redevelopment* portions of IA in an LOD were calculated differently, as described below. For the *new* portions, the target rainfall (P_E) was calculated as a weighted average based on the proportion of the LOD underlain by each mapped HSG (NRCS Soil Data Mart) following examples from MDE ESD Process & Computations (MDE 2010a). For *redevelopment* portions a P_E equal to one was used (MDE 2010b). The campus-wide target ESD_V for the twenty-year build-out is the sum of the total required ESD_V for each LOD.

The required Re_V for the *new* portions of IA in an LOD were calculated based on the predevelopment HSG and the soil specific recharge factor (S) using the "percent volume method" (Section 2.2, MDE 2000-2010). The *redevelopment* portion of the IA has no Re_V requirement. The campus-wide target Re_V for the twenty-year build-out is the sum of the total required Re_V for each LOD.

Per discussion with Baltimore City DPW during the June 15, 2011 meeting and subsequent email correspondence dated June 17, 2011, JHU will be permitted to run a cumulative ESD_V and/or A_T deficit of no more than 10% during any point in the campus expansion period for the Regulatory Site (not including areas of campus east of North Charles Street). The interim deficit provision does not change JHU's commitment to meet the full ESD treatment requirements by the end of the build out period in 2032. This interim 10% allowance will be computed on a Regulatory Site-wide basis. During the build out period, JHU will carry a cumulative ESD_V and/or A_T deficit for no more than two (2) consecutive years before implementing additional ESD practices to erase the deficit. The anticipated frequency of project implementation during the build out period should allow for deficits, should they be incurred, to be effectively mitigated within a two (2) year period.

Definition of Terms

A_{LOD} = Area of LOD

A_{HSG-B} = Area of LOD underlain by HSG B

A_{HSG-C} = Area of LOD underlain by HSG C

A_{HSG-D} = Area of LOD underlain by HSG D

A_{Tredev} = *Redevelopment* impervious treatment area

ESD_{Vredev} = *Redevelopment* Environmental Site Design volume

A_{redev} = Total area of LOD

$'I'_{redev}$ = Percent IA within LOD

A_{Tnew} = *New* impervious treatment area

ESD_{Vnew} = *New* Environmental Site Design volume

A_{new} = Net increase in IA from existing to proposed conditions

$'I'_{new}$ = Percent impervious area for new IA

P_E = Rainfall target based on 'I' obtained from Table 5.3 in the Maryland Stormwater Design Manual

R_v = The dimensionless volumetric runoff coefficient

S = Soil specific recharge factor based on HSG (Section 2.2., MDE 2000-2010)

IA_{pr} = Proposed IA within LOD

IA_{ex} = Existing IA within LOD

A_T = Total impervious treatment area

ESD_V = Total Environmental Site Design volume

Re_V = Recharge volume

Calculation of the Redevelopment Portion of A_T, ESD_V, and Re_V

Water quality treatment or impervious area reduction must be provided for 50% of the existing LOD impervious area. The *redevelopment* portion of the IA has no Re_V requirement. The *redevelopment* portion of the A_T and ESD_v were calculated using the following method:

A_{Tredev} (acres) = 0.5 x IA_{ex} (acres)*

ESD_{Vredev} (cubic feet) = P_E (inches) x R_v x A_{redev} (acres) x (43,560 square feet / 1 acre) x (1 foot / 12 inches) where,

$'I'_{redev}$ (%) = A_{Tredev} (acres) / A_{redev} (acres) x 100; and

R_{Vredev} = 0.05 + 0.009 x 'I'$_{redev}$ (%)

*In cases where there was a net impervious area reduction from existing to proposed conditions, the calculated A_{Tredev} is reduced by the net impervious area reduction.

Calculation of the New Development Portion of A_T, ESD_V, and Re_V

ESD treatment must be provided for any net increase in LOD impervious cover. For LODs comprised of more than one HSG, a weighted P_E and S were substituted for the P_E and S specific to a single HSG. The *new* development portions of the A_T, ESD_v, and Re_V were calculated using the following method:

A_{Tnew} (acres) = IA_{pr} (acres) - IA_{ex} (acres)

ESD_{Vnew} (cubic feet) = P_E (inches) x R_v x A_{new} (acres) x (43,560 square feet / 1 acre) x (1 foot / 12 inches)

Re_V (cubic feet) = S x R_{Vnew} x A_{new} (acres) x (1 foot / 12 inches) x (43,560 square feet / 1 acre) where

A_{new} (acres) = A_{Tnew} (acres)

'I'$_{new}$ (%) = A_{Tnew} (acres) / A_{new} (acres) x 100; 100%;

R_{vnew} = 0.05 + 0.009 x 'I'$_{new}$ (%)

Weighted P_E (inches) = {(P_{E_HSG-B} [inches] x A_{HSG-B} [acres]) + (P_{E_HSG-C} [inches] x A_{HSG-C} [acres]) + (P_{E_HSG-D} [inches] x A_{HSG-D} [acres])} / A_{LOD} (acres])

Weighted S = {(S_{HSG-B} x A_{HSG-B} [acres]) + (S_{HSG-C} x A_{HSG-C} [acres]) + (S_{HSG-D} x A_{HSG-D} [acres])} / A_{LOD} (acres])

Calculation of Required A_T, ESD_V, and Re_V

The A_T, ESD_V, and Re_V were calculated for each LOD according to the methods described. The approved Regulatory Plan requires treatment of 13.83 acres of IA and capture of 67,471.53 cubic feet of stormwater, of which 1,661.83 cubic feet must be treated in a practice that provides groundwater recharge. In addition, campus expansion activities east of North Charles Street (LOD B) require treatment of 1.13 acres of IA and capture of 5,514.14 cubic feet of stormwater, of which 98.97 cubic feet must be treated in a practice that provides groundwater recharge.

Table 22

Required Environmental Site Design Treatment Calculations

Limit of Disturbance (LOD)	Total Area (ac)	Impervious Area (ac)		Net Impervious Area Increase		Area by HSG (ac)			Required A_T (ac)		
		Existing	2031	(ac)	(%)	*B*	*C*	D	*Redevelopment*[3]	*New*[4]	Total
A - University Parkway	24.77	11.24	12.93	1.69	15%	13.16	8.67	2.94	5.62	1.69	**7.31**
C - Wyman Park	12.78	7.07	6.86	-0.21	-3%	5.11	0.00	7.67	3.33	0.00	**3.33**
D - Gilman	5.89	2.31	1.89	-0.42	-18%	5.84	0.00	0.05	0.74	0.00	**0.74**
E - Whitehead	1.92	1.15	1.07	-0.08	-7%	1.92	0.00	0.00	0.50	0.00	**0.50**
F - Decker	9.75	2.55	3.22	0.67	26%	8.95	0.00	0.80	1.28	0.67	**1.95**
Regulatory Plan[1] LOD Totals	55.11	24.32	25.97	1.65		34.98	8.67	11.46	11.47	2.36	**13.83**
B - St. Paul[2]	1.84	1.43	1.84	0.41	29%	0.00	0.00	1.84	0.72	0.41	**1.13**

Limit of Disturbance	I (%)		R_V		P_E (inches)		S	Required ESD_V (cf)			Required Re_V (cf)
	Redevelopment[5]	*New*[6]	*Redevelopment*	*New*	*Redevelopment*	*New*		*Redevelopment*[7]	*New*[8]	Total	*New*[9]
A - University Parkway	22.69	100.00	0.2542	0.9500	1.0	2.4	0.19	22,856.42	13,987.12	**36,843.53**	**1,107.31**
C - Wyman Park	26.06	100.00	0.2845	0.9500	1.0	2.2	0.15	13,198.35	-	**13,198.35**	**-**
D - Gilman	12.56	100.00	0.1631	0.9500	1.0	2.6	0.26	3,487.19	-	**3,487.19**	**-**
E - Whitehead	26.04	100.00	0.2844	0.9500	1.0	2.6	0.26	1,982.15	-	**1,982.15**	**-**
F - Decker	13.13	100.00	0.1682	0.9500	1.0	2.6	0.24	5,953.02	6,007.29	**11,960.31**	**554.52**
Regulatory Plan[1] LOD Totals								47,477.14	19,994.40	**67,471.53**	**1,661.83**
B - St. Paul[2]	39.13	100.00	0.4022	0.9500	1.0	2.0	0.07	2,686.37	2,827.77	**5,514.14**	**98.97**

[1]Excludes campus expansion activities east of North Charles Street (LOD B)

[2]LOD B - St. Paul is not included in the 2012 Johns Hopkins University Homewood Campus SWMMP Concept Plan Design and Computations ("the Regulatory Plan"). Stormwater best management practices to treat campus expansion activities occuring outside the Baltimore City DPW-approved LODs (i.e., A, C, D, E, F) must be submitted to Balitmore City DPW for concept plan approval independent of the Regulatory Plan.

[3]*Redevelopment* A_T (ac) = 0.5 x Existing Impervious Area (ac); this value is reduced by any net decrease in impervious area

[4]*New* A_T (ac) = Impervious Area in 2031 (ac) - Existing Impervious Area (ac); New A_T does not apply when there is a net decrease in impervious area

[5]*Redevelopment I = Redevelopment* A_T *(ac) / Total LOD Area (ac) x 100*

[6]*New* I = 100%

[7]*Redevelopment* ESD_V (cf) = P_E (in) x R_V x Total LOD Area (ac) x (43560 sf / 1 ac) x (1 ft / 12 in)

[8]*New* ESD_V (cf) = P_E (in) x R_V x *New* Required A_T (ac) x (43560 sf / 1 ac) x (1 ft / 12 in)

[9]Recharge is only required for *New* A_T and is calculated as Re_V (cf) = S x R_V x *New* Required A_T (ac) x (1 ft / 12 in) x (43560 sf / 1 ac)

Compliance Calculations for the A_T, ESD_v, and Re_V

Proposed conditions under the Regulatory Plan achieve compliance with stormwater management quality requirements within the Regulatory Site (excluding LOD B) by 2032 using ESD. Through the proposed conversion of impervious cover to natural areas, installation of alternative surfaces, and implementation of micro-scale practices, the required A_T and ESD_v is met on a Regulatory-Site wide basis and where possible within each LOD. Compliance with WQ_V requirements is ensured by applying a minimum treatment depth of one inch (P_E = 1 inch) for in all ESD practices and therefore over the entire provided A_T. Compliance with Re_V requirements, which are addressed within the ESD_V, will be attained using micro-bioretention and rain garden practices. In some cases either A_T and ESD_v could not be met within individual LODs. In these cases, additional A_T and/or ESD_v was provided in other LODs within the Regulatory Site to offset the deficit. As previously discussed with Baltimore City DPW during the June 15, 2011 meeting and subsequent email correspondence dated June 17, 2011, Baltimore City DPW will allow JHU to meet project-specific volume and A_T requirements by providing treatment both within the LOD in which the project is located and/or elsewhere within the Regulatory Site. The SWMMP also proposes BMPs within areas east of North Charles Street (LOD B) that achieve A_T and ESD_v requirements; however independent concept approval from Baltimore City DPW will be required for these practices.

Within each LOD, A_T and ESD_v requirements were addressed by campus drainage area. If only a small portion of a campus drainage area (less than 5% of the LOD area) was encompassed within an LOD, the proportion of the ESD_v and A_T requirement attributed to that campus drainage area was treated within other campus drainage areas within the same LOD to the MEP. In all cases where this occurs, no direct disturbance is planned within a campus drainage area that is less than 5% of the LOD area. If the required ESD_v or A_T could not be treated within the LOD, the balance was treated within another LOD. For each BMP, the characteristics of the BMP drainage area (total area and impervious area) were used to determine the provided A_T and captured ESD_v for that practice. Due to site constraints, some BMPs were oversized (i.e., management of more than the required ESD_v for the BMP treatment drainage area) to manage the required ESD_v for each LOD. All BMPs were sized to capture no more than the runoff from the 1-year 24-hour storm (Q_E) and no less than the WQ_V. These limits were calculated by ensuring that a P_E of no more than 2.8 inches and no less than 1.0 inches were routed to any practice.

Grading of the property during construction of build-out plan will result in slight drainage area modifications. Therefore, there are instances of stormwater BMPs or stormwater BMP drainage areas occurring in multiple campus drainage areas. For consistency in the hydrologic modeling throughout the build-out phases, campus drainage areas were held constant at each build-out phase.

Impervious Area Reduction

The campus offers modest opportunity for impervious cover reduction. Surface parking and roadways within the core areas have been largely removed during previous redevelopment efforts and remaining impervious areas consist primarily of roofs and pathways. Within these constraints, the SWMMP minimizes new impervious areas and removes unnecessary existing impervious surfaces where practicable. Impervious cover at the twenty-year build-out is reduced relative to existing conditions for LOD C Wyman Park, LOD D Gilman, and LOD E Whitehead. In addition, the following impervious areas were replaced with naturalized cover:

- The parking lot adjacent to the greenhouse (LOD D); and

- The tennis courts adjacent to Charles Street (LOD A).

Alternative Surfaces

The SWMMP incorporates alternative surfaces where practicable. In addition to alternative surfaces described within the Maryland Stormwater Design Manual, the SWMMP proposes to convert lawn or landscaped land to woodland or meadow. These land cover conversions will improve the infiltration rate of the existing pervious areas and reduce the volume of stormwater runoff from the campus in aggregate.

Porous Pavements

Porous pavements are not proposed in the SWMMP because they require soils with a HSG type A, B or C. Because the campus is largely underlain with compacted urban fill soils or soils compacted from previous redevelopment and campus expansion projects, porous pavement practices were not proposed. If on-site soil testing reveals suitable soil conditions, porous pavement may be considered at later phases in the design process.

Green Roofs

Green roofs are proposed within LODs A, B, and E. ESD_V for green roofs was calculated using equivalent ESD_V per BMP footprint ratio provided in Table 1 on page 6 of the ESD Process and Computations document (MDE 2010a). This ratio is a depth that, when multiplied by the BMP footprint, equals the captured ESD_V for the practice. Using the equivalent ESD_V per BMP footprint ratio, the treated ESD_V was calculated for a green roof of a specified media depth (i.e., 4 inches for green roofs in LOD A and B and 6 inches for green roofs in LOD E), as follows:

ESD_V per BMP footprint ratio for green roof with 4 inch media depth = 0.077 feet

ESD_V per BMP footprint ratio for green roof with 6 inch media depth = 0.095 feet

A_f = BMP footprint (square feet)

ESD_V (cubic feet) = ESD_V per BMP footprint ratio (feet) x A_f (square feet)

When final design of the buildings and BMPs are completed, the green roof media depth must be a minimum of that specified in these concept plans.

Nonstructural and Micro-scale Best Management Practices

Nonstructural practices such as sheet flow to conservation areas and rooftop disconnection were considered but not included in the SWMMP for the following reasons:

- Potential conservation areas were located on or adjacent to steep slopes;
- Directing runoff to pervious areas would occur across campus open spaces resulting in undesirable conditions in these multi-use areas; and
- Given the likelihood that installation sites are underlain with soils compacted from previous redevelopment and campus expansion projects or urban fill soils, nonstructural practices would likely require significant soil amendments, making micro-scale practices a more attractive alternative.

Micro-scale BMPs, including micro-bioretention systems, rain gardens, and cisterns, are the primary ESD technologies proposed in the SWMMP. Practices limited to infiltration (e.g., landscape infiltration) were considered, but not recommended, because of the likely presence of widespread soil compaction within the campus. Should on-site soil tests show that soils suitable for infiltration occur within a BMP footprint, infiltrating practices may be substituted for filtration practices at later phases of the design process. Landscape infiltration practices can often be substituted for rain gardens and micro-bioretention practices with minimal changes in practice location and layout. By providing a minimum P_E of one inch for all practices, the soil specific recharge factor will always be exceeded, thus providing the required groundwater recharge (MDE 2000-2010). In addition, where infiltration is poor or not possible due to soil conditions, enhanced filters will be a component of the micro-bioretention and rain garden practices to ensure achievement of the required Re_V.

The methods of determining ESD_v for each micro-scale practice followed design guidance in the Maryland Stormwater Design Manual.

Micro-bioretention

The treated ESD_v for micro-bioretention practices was calculated using Equation 5.2 (page 5.98) of the Maryland Stormwater Design Manual:

ESD_v (cubic feet) = P_E (inches) x R_V x DA (square feet) x (1 foot / 12 inches) where:

DA = Drainage area to BMP (square feet);

P_E (inches) = 15 inches x A_f (square feet) / DA (square feet);

A_f = BMP footprint (square feet); and

R_v = 0.05 + 0.009 x (IA [square feet] / DA [square feet]) x 100 where:

IA is the impervious portion DA.

This method of calculations provides a conservative (maximum) footprint for the practice because it assumes the minimum treatment depth. During later design phases, practices may be designed with smaller footprints, where appropriate, and should include enhanced filters to promote groundwater recharge. Planter boxes were a common micro-bioretention practice proposed in the SWMMP. Planter boxes were proposed when locations were constrained by size or a structured aesthetic was preferred. When located in close proximity to a building, these practices must be lined with an impermeable membrane to avoid impact to the building structure. Micro-bioretention practices not specified as planter boxes are identified as ‘standard’.

Rain Garden

The treated ESD_v for rain garden practices was calculated using Equation 5.3 (page 5.105) of the Maryland Stormwater Design Manual:

ESD_v (cubic feet) = P_E (inches) x R_V x DA (square feet) x (1 foot / 12 inches) where:

DA = Drainage area to BMP (square feet);

P_E (inches) = 10 inches x A_f (square feet) / DA (square feet);

A_f = BMP footprint (square feet); and

R_v = 0.05 + 0.009 x (IA [square feet]/ DA [square feet] x 100) where:

IA is the impervious portion of DA.

This method of calculations provides a conservative (maximum) footprint for the practice because it assumes the minimum treatment depth. During later design phases, practices may be designed with smaller footprints, where appropriate, and should include enhanced filters to promote groundwater recharge.

Rainwater Harvesting—Cistern

Rainwater harvested from cisterns will be used to supplement the campus landscape irrigation system. The treated ESD_v for cisterns was assumed to be the captured runoff volume. Cisterns do not provide Re_V. The P_E was based on the volume captured applied to the contributing roof area as described on page 5.72 of the Maryland Stormwater Design Manual. All cisterns were designed to capture a minimum of 0.2 inches of rainfall from the BMP drainage area (DA). The stated volume for commercially available cisterns was used to size the proposed practices. Typical commercially available cisterns used during sizing included:

- 3,200 gallon capacity with 7.92 foot diameter and 9.33 foot height;
- 4,000 gallon capacity with 7.90 foot diameter and 11.67 foot height;
- 5,000 gallon capacity with 8.50 foot diameter and 12.80 foot height;
- 6,800 gallon capacity with 10.0 foot diameter and 12.50 foot height; and
- 10,000 gallon capacity with 11.75 foot diameter and 13.33 foot height.

Proposed cistern configurations capturing more than 10,000 gallon were calculated as multiple cisterns in series by summing the capture capacity for multiple structures. During later design phases, cisterns in series or custom-made structures may be acceptable.

ESD_v (cubic feet) = $V_{cistern}$ (gallons) x (1 cubic foot / 7.4805 gallons)* where:

$V_{cistern}$ = engineer's best estimate of a feasible cistern size based on commercially available cisterns.

P_E (inches) = ESD_v (cubic feet) / DA (square feet) x (12 inches / 1 foot) where:

DA = the BMP drainage area which is assumed to be 100% impervious.

*The stated capacity of the cisterns (provided in gallons), rather than the dimensions of the structure, was used to compute the ESD_V.

Regulatory Plan Compliance

ESD to the MEP criteria were implemented within each LOD included in the Regulatory Plan. Where full achievement of A_T and ESD_V targets was not possible within an LOD, additional treatment was added within other LODs. The Regulatory Plan provides total A_T = 13.83 acres and total ESD_V = 67,641.42 cubic feet. Therefore, all A_T, ESD_V, and Re_V targets were met within the Regulatory Site. In addition, A_T = 1.80 acres and ESD_V = 6,036.03 cubic feet were provided in LOD B, which was outside the Regulatory Site and not included in the approved Regulatory Plan.

BMPs were located within the LODs to largely avoid areas with K_f values higher than 0.35 with a few exceptions. Micro-bioretention practices R16 and R17 within LOD A and Micro-bioretention R44 and Rain garden R48 within LOD C overlap with the eastern extent of the Manor loam polygon (21 E), which has a K_f value of 0.37. Within LOD F, a portion of Micro-bioretention - Planter box R69 overlaps with the western extent of the Beltsville-Urban land complex (2UB) polygon, which has a K_f value of 0.43, and a portion of Micro-bioretention R66 overlaps with the Mattapex-Urban land complex, which has a K_f value of 0.43. The rationale for the placement of ESD practices within soil areas possessing K_f values higher than 0.35 includes the following: (1) the overflow discharging from each BMP shall be designed in accordance with the ESD criteria, which states "runoff shall enter, flow through, and exit micro-bioretention practices in a safe and non-erosive manner" (MDE 2000-2010 Section 5.4.3, page 5.97 and 5.105). In addition, turf to meadow conversion is proposed directly adjacent to Planter Box R69 and Micro-bioretention R66, further decreasing potential for soil erosion within these areas of the campus, which have the highest K_f values at 0.43. NRCS data provide an overview of probable soils on a site. Typically, soil borings are performed during later design phases to accurately determine soil types at a specific site.

Appendix C

Stormwater BMP Cost Development

Appendix C: Stormwater BMP Cost Development

Unit Costs

Unit costs ($/cubic foot treated) for stormwater BMP construction (materials and labor) were obtained from recent literature, design guidance, or line item estimates using RSMeans when other reliable sources were not available. The majority of unit costs were derived from documents available through the Center for Watershed Protection, Ellicott City, MD (Schueler *et al.* 2007). This resource provides 'retrofit' costs for stormwater BMPs that account for the constrained nature of urban site development. Porous pavement unit costs were derived from a document available through the Low Impact Development Center, Inc. (Urban Design 2002). Green roof costs for installation on a new building were obtained from a recent study by Niu et al. (2010).

Stormwater BMP costs can be highly variable (ranging by an order-of-magnitude) even for the same type of stormwater BMP. Two cost categories were developed for each type of stormwater BMP to allow cost adjustments depending on stormwater BMP complexity. Four categories of micro-bioretention were included as this was the flexible practice—applications of this practice range from simple vegetated depressions to planter boxes. Some instances where complexity and cost increase include: extensive conveyance; formal plantings; poor access for construction; utility conflicts; structures in close proximity; and pavement removal. Stormwater BMPs installed as part of a new building construction project are inherently less expensive than retrofit installations because mobilization and other costs are absorbed by the larger project. The design professional used best professional judgment to determine the appropriate cost category for each stormwater BMP when the practice was sized.

The stormwater BMP unit costs were adjusted to account for inflation and regional variations. Costs were adjusted for inflation from the year in which the costs were published to the first quarter of 2012 using the ENR construction cost index history data (Selvakumar 2004, ENR 2012). Costs were then adjusted for regional differences. The Baltimore Regional Factor was calculated based on methods in Selvakumar (2004). The unit cost was multiplied by a twenty city index factor. The twenty city index factor is the average monthly ENR Baltimore Construction Cost Index (CCI) for the first quarter of 2012 (6542.387) divided by the average monthly USA National CCI for the first quarter of 2012 (9214.000) resulting in a regional factor of 0.710048. This factor was multiplied by the 2012 value of the stormwater BMP construction cost. Costs were then adjusted for regional rainfall bias, as suggested in Selvakumar (2004). Baltimore is located within EPA rainfall Region 2. The rainfall adjustment factor for Region 2 is 0.90. The construction cost, adjusted for inflation and region was divided by the rainfall adjustment factor.

Total stormwater BMP unit costs were adjusted to include a 32% mark-up for design and engineering (D&E) and a 50% contingency factor to account for uncertainty in cost estimation and unforeseen design and construction issues. The D & E factor includes permitting and erosion and sediment control costs. D & E factors can vary depending on the complexity of the stormwater BMP type (Schueler *et al.* 2007); however we assumed that this factor was constant across stormwater BMPs. Items such as major utility line replacements and hazardous material remediation, which are not typical components of stormwater BMP installation, were not accounted for.

Annual unit costs ($/square foot of stormwater BMP footprint) for O&M were determined for stormwater BMPs and existing ground cover. The incremental O&M cost for a stormwater BMP over that of the replaced cover type were calculated. Most O&M values were obtained from a study in Philadelphia (Vanaskie et al. 2008) or actual maintenance costs of stormwater BMPs in Philadelphia. Meadow and forest O&M costs were derived from CWP and EPA documents (Schueler *et al.* 2007 and Selvakumar 2004). Green roof O&M costs were derived from a green roof conference paper (Clark 2005). Cistern O&M costs were derived from a stormwater BMP factsheet (Fairfax Co 2004). Annual O&M costs were adjusted for inflation.

Scenario Costs

The total cost and cost by stormwater BMP type were calculated for both scenarios (Table 11). The unit cost for each stormwater BMP type was multiplied by the stormwater BMP volume. To be conservative, the stormwater BMP volume used in cost estimation ("cost volume") was greater than the ESD volume. The stormwater BMP cost volume was calculated using the length, width, and depth of the practice, accounting for side slopes, freeboard, and pore space of filter media. In contrast, the ESD volume was based on the drainage area size and imperviousness and the stormwater BMP footprint.

Net Present Value

The Net Present Value (NPV) of all cost and expenses over a 40-year period was calculated for each scenario. NPV is defined as the total present value of cash flows minus the initial investment. It is a standard method for using the time value of money to appraise long-term projects. Cash flows are discounted using a discount rate that represents the opportunity cost of making the investment. The analysis assumes that 80% of the stormwater BMP installation costs (total cost per scenario) are financed, with an interest rate of 6%, over a term of 40 years. Capital investments are depreciated using straight-line depreciation over 39-year period. Fees and O&M cost are escalated at an annual rate of 3% to account for inflation.

Table 23
Stormwater BMP Unit Costs

Practice	BMP Installation Unit Cost ($/cf)	Annual O&M Unit Cost ($/sf)
Cover Conversion		
Impervious to Meadow	32.20	0.06
Impervious to Forest	32.20	0.06
Turf to Meadow	11.92	0.06
Turf to Forest	11.92	0.06
Alternate Surfaces		
Green Roof-simple	373.20	0.10
Green Roof-complex	439.06	0.10
Green Roof-new construction	94.73	0.10
Porous Pavement-new construction	0.00	0.06
Permeable Pavement-asphalt	16.05	0.06
Permeable Pavement-concrete	90.94	0.06
Reinforced Turf	78.46	0.06
Nonstructural		
Rooftop disconnection-simple	2.93	0.10
Rooftop disconnection-complex	17.56	1.20
Non-rooftop disconnection-simple	7.32	1.20
Non-rooftop disconnectio-complex	14.64	1.20
Sheetflow to conservation area-simple	0.00	0.00
Sheetflow to conservation area-complex	7.32	1.05
Micro-scale practices		
Rainwater harvesting-cistern-simple	21.95	4.19
Rainwater harvesting-cistern-complex	36.59	4.19
Rainwater harvesting-rain barrel-simple	36.59	4.19
Rainwater harvesting-rain barrel-complex	58.54	4.19
Landscape infiltration-simple	21.95	0.84
Landscape infiltration-complex	33.66	0.84
Submerged Gravel Wetland-simple	25.25	0.84
Submerged Gravel Wetland-complex	43.91	0.84
Dry well-simple	17.56	1.10
Dry well-complex	19.76	1.10
Micro-bioretention-simple	15.37	0.84
Micro-bioretention-moderate	25.25	0.84
Mircro-bioretention-complex	43.91	0.84
Micro-bioretention-highlycomplex	58.54	0.84
Rain garden-simple	10.98	0.84
Rain garden-complex	14.64	0.84
Swale-simple	18.29	0.84
Swale-complex	32.20	0.84
Structural		
Pond retrofits-simple	4.39	0.84
Pond retrofits-complex	14.64	0.84
Pond new-simple	7.82	0.84
Pond new-complex	12.91	0.84
Existing		
Turf		0.63
Roof		0.06
Pavement		0.06
Landscaped		0.84

Appendix D

Scenario Weighted Score Methods

Appendix D: Scenario Weighted Score Methods

Weighted scoring was developed to provide a numeric comparison between scenarios. The total scenario score (weighted score) was determined using the percent achievement of each metric weighted relative to the goal rank developed from the prioritization matrix. A goal weight was assigned to each of the final goals (Table 10) based on both internal JHU and external planning document prioritizations. The fourteen final metrics were calculated for both the Regulatory Compliance and SWMMP Scenarios. Percent achievement was calculated and normalized by goal. Normalizing the metric ensured that each goal had equal weight within the total scenario score regardless of the number of contributing metrics. The normalized percent achievement value was then multiplied by the goal weight to produce a weighted score for each metric. The total scenario score was the sum of weighted scores for all metrics, where 260 was a perfect score.

Appendix E

Stormwater BMP Master List

Appendix E: Stormwater BMP Master List

The stormwater BMP master list is a complete list of practices included in the campus scenarios. The table includes the following items:

- A unique identification that begins with a letter (where "R" represents practices approved by Baltimore City DPW and required for regulatory compliance and "V" represents voluntary practices, which are included as part of the SWMMP Scenario ONLY and have not been approved by Baltimore City DPW) and ends with a number. Listed stormwater BMPs include micro-scale ESD practices and those that naturalize impervious or turf areas (the latter are included at the end of the list).
- A reference to the corresponding figure;
- The type of stormwater BMP and anticipated complexity of installation;
- The drainage area to the stormwater BMP;
- Design comments;
- Stormwater BMP aesthetic;
- Year of implementation phase;
- A_T provided;
- ESD_V provided;
- Cost volume;
- Rainwater Harvested;
- The footprint of the stormwater BMP; and
- A binary indicator of whether or not a practice contributes to a campus goal, where 1 is 'Yes' and 0 is 'No'.

Stormwater BMP Master List

Feature ID	Figure #	Drainage Area to BMP (sf)	BMP Type and Complexity	Design Comments	BMP Aesthetic	Year	A_T (sf)	ESDv (cf)	COSTv (cf)	Rainwater Harvest (gallons)	BMP Footprint (sf)	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	11*	12*	13*	14*
R1	21	14,800	Microbioretention - simple		Formal	2017	7,450	1,116.66	1,470	0	1,820	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R2	21	17,260	Microbioretention - simple		Formal	2017	6,860	586.41	830	0	1,200	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R3	21	11,770	Microbioretention - simple		Formal	2017	7,590	1,112.97	1,350	0	1,430	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R4	21	11,190	Microbioretention - simple		Formal	2017	4,990	462.10	640	0	800	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R5	21	11,120	Microbioretention - simple		Formal	2017	9,860	1,414.46	1,620	0	1,360	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R6	21	20,000	Microbioretention - simple		Formal	2017	14,230	1,265.73	1,550	0	1,500	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R7	21	15,140	Microbioretention - simple		Formal	2017	6,310	589.97	800	0	1,110	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R8	21	20,000	Microbioretention - simple		Formal	2017	11,950	1,077.63	1,350	0	1,500	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R9	21	19,580	Microbioretention - simple		Formal	2017	7,240	999.36	1,340	0	2,100	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R10	21	13,080	Microbioretention - moderate		Informal Juxtaposition	2032	9,150	740.76	900	0	900	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R11	21	8,320	Microbioretention - highly complex	Planter box	Informal Juxtaposition	2032	6,800	980.43	1,200	0	1,020	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R12	21	4,870	Microbioretention - highly complex	Planter box	Informal Juxtaposition	2032	4,220	606.24	730	0	590	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R13	21	5,680	Microbioretention - highly complex	Planter box	Informal Juxtaposition	2032	4,880	701.37	840	0	700	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R14	21	8,120	Microbioretention - highly complex	Planter box	Informal Juxtaposition	2032	6,890	991.09	1,200	0	990	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R15	21	13,700	Microbioretention - highly complex	Planter box	Informal Juxtaposition	2032	11,950	953.29	1,150	0	900	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R16	21	19,850	Microbioretention - highly complex	Planter box	Informal Juxtaposition	2032	17,070	2,044.55	2,460	0	1,950	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R17	21	9,240	Microbioretention - simple		Informal	2032	6,970	954.13	1,160	0	1,050	0	1	0	0	0	1	0	0	0	0	0	0	0	0
R18	21	20,000	Microbioretention - simple		Formal	2032	16,000	1,540.00	1,810	0	1,600	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R19	21	19,600	Microbioretention - highly complex	Planter box	Formal	2032	17,370	2,353.50	2,820	0	2,240	1	1	0	0	0	0	0	0	1	0	0	0	0	0
R20	21	20,000	Microbioretention - complex		Informal	2032	11,000	1,362.50	1,769	0	2,000	0	1	0	0	0	1	1	0	0	0	0	0	0	0
R21	21	7,550	Microbioretention - moderate		Formal	2032	3,790	568.29	740	0	900	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R22	21	6,680	Microbioretention - moderate		Formal	2032	3,630	540.18	690	0	800	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R23	22	7,840	Raingarden - complex		Formal	2017	5,490	799.92	308	0	1,440	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R24	22	4,140	Raingarden - complex		Formal	2017	2,740	400.98	540	0	760	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R25	21	7,540	Microbioretention - moderate		Informal Juxtaposition	2017	5,100	745.10	890	0	910	1	1	0	0	0	0	0	0	0	1	0	0	0	0
R26	21	14,200	Microbioretention - moderate		Informal Juxtaposition	2017	9,980	1,453.73	1,780	0	1,710	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R27	21	22,170	Microbioretention - moderate		Informal Juxtaposition	2017	5,310	588.84	910	0	1,800	0	1	0	1	0	0	0	0	0	1	0	0	0	1
R28	21	2,000	Greenroof - simple		NA	2017	2,000	154.00	150	0	2,000	0	1	0	0	0	0	0	0	1	0	0	0	0	1
R29	21	2,000	Greenroof - simple		NA	2017	2,000	154.00	150	0	2,000	0	1	0	0	0	0	0	0	1	0	0	0	0	1
R30	21	6,940	Raingarden - simple		Formal	2017	1,410	134.69	320	0	700	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R31	21	15,410	Microbioretention - highlycomplex		Formal	2032	13,900	1,660.04	2,000	0	1,490	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R32	21	19,880	Microbioretention - highlycomplex		Formal	2032	17,540	2,517.11	3,000	0	2,350	0	1	0	1	0	0	0	0	0	0	0	0	0	1
R33	21	16,310	Cistern - complex		NA	2032	16,310	2,680.00	2,680	402,620	280	0	1	1	0	0	0	0	0	0	0	0	0	0	0
R34	21	26,400	Cistern - complex		NA	2032	26,400	2,680.00	4,450	651,700	280	0	1	1	0	0	0	0	0	0	0	0	0	0	0

*** Goals and Performance Metrics**
1* - Reduction of impervious area (IA)
2* - Treatment of IA
3* - Reuse of Stormw ater
4* - Reduction in landscape energy use (kWh/yr)
5* - Creation of natural habitat (forest, shrub/brush, meadow)
6* - Creation of natural habitat adjacent to w oodlands or w oodland finger (forest, shrub/brush, meadow)
7* - Treatment of IA w ithin gully DA
8* - Conversion of landscape trouble spots to BMP
9*- Conversion of hardscape converted to BMP
10* - BMP as trail access point to forested areas
11* - Interpretive BMP
12* - Show case or artistic BMP
13* - Educational BMP
14* - Treatment of IA w ithin flood prone DA

Note: This summary w as derived from the BMP attribute table w ithin the GIS geodatabase that w as created for the 2012 SWMMP. The **Feature ID** column correlates to the stormw ater BMP as it is labeled on the SWMMP Scenario Figures (Figures 20-25). Feature ID prefix "R" indicates that a stormw ater BMPs is necessary to meet regulations and has concept approval from Baltimore City DPW. Feature ID prefix "V" indicate a voluntary stormw ater BMPs. The **Drainage Area to BMP** column is the contributing area of runoff for each practice. The **BMP Type and Complexity** column lists the type of stormw ater BMP and the degree of complexity anticipated for installation for each. The **Design Comments** column lists specific stormw ater BMP design information that w as considered during conceptual design. The **BMP Aesthetic** column refers to the degree of formality or informality of the stormw ater BMP as it relates to the campus precincts and design considerations outlined in Chapter 7: Building, Site, and Stormw ater Design Guidance. The **Year** column is the anticipated year of construction completion for each stormw ater BMP. The $\mathbf{A_T}$ column is the area of impervious cover treated per stormw ater BMP. The $\mathbf{ESD_V}$ is the treatment volume per stormw ater BMP. The $\mathbf{COST_V}$ column w as used to estimate order of magnitude costs per stormw ater BMP. The **Rainwater Harvest** column lists the gallons of w ater storage per each cistern. The **BMP Footprint** is the estimated surface area of each stormw ater BMP. Columns 1* - 14* identifies metrics to w hich the practice contributes or, for metrics 11-13, presents an opportunity to contribute.

Stormwater BMP Master List Continued

Feature ID	Figure #	Drainage Area to BMP (sf)	BMP Type and Complexity	Design Comments	BMP Aesthetic	Year	A_T (sf)	ESDv (cf)	COSTv (cf)	Rainwater Harvest (gallons)	BMP Footprint (sf)	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	11*	12*	13*	14*
R35	25	20,000	Microbioretention - simple		Informal Juxtaposition	2022	12,300	1,005.83	1,280	0	1,350	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R36	25	19,140	Microbioretention - simple		Informal Juxtaposition	2022	11,500	942.33	1,190	0	1,280	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R37	25	12,820	Microbioretention - simple		Informal Juxtaposition	2032	8,430	685.66	830	0	840	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R38	25	14,250	Microbioretention - simple		Informal Juxtaposition	2032	9,600	779.36	980	0	990	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R39	25	9,600	Microbioretention - moderate		Informal Juxtaposition	2022	5,460	449.52	540	0	610	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R40	25	6,800	Raingarden - simple		Informal Juxtaposition	2022	3,330	278.06	420	0	675	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R41	25	7,150	Raingarden - simple		Informal Juxtaposition	2022	4,160	341.77	530	0	750	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R42	25	17,650	Microbioretention - moderate		Informal Juxtaposition	2027	11,250	917.36	1,120	0	1,200	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R43	25	4,480	Microbioretention - complex	Planter box	Informal Juxtaposition	2027	3,930	313.41	370	0	290	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R44	25	19,030	Microbioretention - moderate		Informal Juxtaposition	2027	10,400	859.36	1,130	0	1,320	0	1	0	1	0	0	1	0	0	0	1	1	1	0
R45	25	20,000	Microbioretention - moderate		Informal Juxtaposition	2027	15,000	1,450.00	1,730	0	1,600	0	1	0	1	0	0	1	0	0	0	1	1	1	0
R46	25	3,930	Raingarden - simple		Informal Juxtaposition	2027	1,700	143.87	230	0	400	0	1	0	1	0	0	0	0	0	0	1	1	1	0
R47	25	9,380	Raingarden - simple		Informal Juxtaposition	2027	5,500	451.57	620	0	930	0	1	0	1	0	0	0	0	0	0	1	1	1	0
R48	25	9,990	Raingarden - simple		Informal	2027	5,810	572.83	820	0	1,200	0	1	0	0	0	1	0	0	0	0	1	1	1	0
R49	25	19,900	Microbioretention - moderate		Formal	2032	13,600	1,102.96	2,560	0	1,340	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R50	25	17,360	Microbioretention - complex	Planter box	Informal Juxtaposition	2027	16,010	1,273.07	1,310	0	1,100	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R51	25	20,000	Microbioretention - highly complex		Informal Juxtaposition	2032	18,040	1,436.33	1,600	0	1,330	0	1	0	0	0	0	0	0	1	0	0	0	0	0
R52	25	18,460	Microbioretention - complex	Planter box	Informal Juxtaposition	2027	17,110	1,360.19	1,550	0	1,250	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R53	25	4,510	Cistern - simple		NA	2027	4,510	430.00	400	111,330	50	0	1	1	0	0	0	0	0	0	0	0	0	0	0
R54	25	4,460	Cistern - simple		NA	2027	4,460	430.00	400	110,100	50	0	1	1	0	0	0	0	0	0	0	0	0	0	0
R55	25	5,720	Microbioretention - complex		Formal	2032	4,180	337.34	400	0	400	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R56	22	9,110	Microbioretention_simple		Informal Juxtaposition	2027	3,220	279.45	400	0	600	0	1	0	1	0	1	1	0	0	0	1	0	1	0
R57	22	17,430	Microbioretention_simple		Informal Juxtaposition	2027	6,930	947.73	1,300	0	1,840	0	1	0	1	0	1	1	0	0	1	1	0	1	0
R58	22	5,270	Raingarden - complex		Formal	2027	2,800	324.75	460	0	750	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R59	22	19,730	Raingarden - complex		Formal	2027	15,040	1,452.33	1,720	0	1,630	0	1	0	0	0	0	1	0	0	1	0	0	1	0
R60	22	9,940	Raingarden - simple		Formal	2027	800	202.78	480	0	2,000	0	1	0	1	0	0	1	1	0	0	0	0	0	1
R61	22	4,310	Microbioretention - moderate		Formal	2027	4,310	375.33	400	0	310	1	1	0	0	0	1	1	0	1	0	0	0	0	0
R62	24	18,130	Microbioretention - moderate		Formal	2017	7,250	1,238.58	1,690	0	2,450	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R63	24	3,920	Cistern - complex		NA	2017	3,920	530.00	790	96,770	70	0	1	1	0	0	0	0	0	0	0	0	0	0	0
R64	24	2,950	Greenroof_simple		NA	2017	2,950	280.25	280	0	2,950	0	1	0	0	0	0	0	0	1	0	0	0	0	0
R65	25	12,790	Microbioretention - moderate		Informal	2027	8,910	1,298.82	1,600	0	1,560	0	1	0	0	1	1	1	0	0	0	0	0	0	0
R66	25	20,000	Microbioretention - simple		Informal Juxtaposition	2022	13,100	1,918.50	2,340	0	2,340	0	1	0	1	0	1	0	1	0	0	0	0	0	0
R67	24	19,980	Microbioretention - moderate		Formal	2017	16,250	2,343.65	2,240	0	2,360	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R68	24	8,400	Microbioretention - complex		Formal	2017	5,900	859.45	3,200	0	990	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R69	24	7,750	Microbioretention - complex	Planter Box	Formal	2022	4,680	728.27	580	0	980	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R70	24	6,470	Microbioretention - complex		Formal	2022	3,880	604.10	770	0	800	0	1	0	1	0	0	0	0	0	0	0	0	0	0
R71	24	19,020	Microbioretention - moderate		Formal	2022	12,030	1,766.58	2,200	0	2,240	0	1	0	1	0	0	0	0	0	0	0	1	0	0

*** Goals and Performance Metrics**

1* - Reduction of impervious area (IA)
2* - Treatment of IA
3* - Reuse of Stormwater
4* - Reduction in landscape energy use (kWh/yr)
5* - Creation of natural habitat (forest, shrub/brush, meadow)
6* - Creation of natural habitat adjacent to woodlands or woodland finger (forest, shrub/brush, meadow)
7* - Treatment of IA within gully DA
8* - Conversion of landscape trouble spots to BMP
9*- Conversion of hardscape converted to BMP
10* - BMP as trail access point to forested areas
11* - Interpretive BMP
12* - Showcase or artistic BMP
13* - Educational BMP
14* - Treatment of IA within flood prone DA

Note: This summary was derived from the BMP attribute table within the GIS geodatabase that was created for the 2012 SWMMP. The **Feature ID** column correlates to the stormwater BMP as it is labeled on the SWMMP Scenario Figures (Figures 20-25). Feature ID prefix "R" indicates that a stormwater BMPs is necessary to meet regulations and has concept approval from Baltimore City DPW. Feature ID prefix "V" indicate a voluntary stormwater BMPs. The **Drainage Area to BMP** column is the contributing area of runoff for each practice. The **BMP Type and Complexity** column lists the type of stormwater BMP and the degree of complexity anticipated for installation for each. The **Design Comments** column lists specific stormwater BMP design information that was considered during conceptual design. The **BMP Aesthetic** column refers to the degree of formality or informality of the stormwater BMP as it relates to the campus precincts and design considerations outlined in Chapter 7: Building, Site, and Stormwater Design Guidance. The **Year** column is the anticipated year of construction completion for each stormwater BMP. The **A_T** column is the area of impervious cover treated per stormwater BMP. The **ESD_V** is the treatment volume per stormwater BMP. The **$COST_V$** column was used to estimate order of magnitude costs per stormwater BMP. The **Rainwater Harvest** column lists the gallons of water storage per each cistern. The **BMP Footprint** is the estimated surface area of each stormwater BMP. Columns 1* - 14* identifies metrics to which the practice contributes or, for metrics 11-13, presents an opportunity to contribute.

Stormwater BMP Master List Continued

Feature ID	Figure #	Drainage Area to BMP (sf)	BMP Type and Complexity	Design Comments	BMP Aesthetic	Year	A_T (sf)	ESDv (cf)	COSTv (cf)	Rainwater Harvest (gallons)	BMP Footprint (sf)	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	11*	12*	13*	14*
V1	24	27,340	Greenroof - complex		NA	2022	27,340	2,105.18	2,110	0	27,340	0	1	0	0	0	0	0	0	1	0	1	0	1	0
V2	24	51,050	Greenroof - complex		NA	2022	51,050	3,930.85	3,930	0	51,050	0	1	0	0	0	0	0	0	1	0	1	0	1	0
V3	24	3,260	Raingarden - complex		Formal	2032	2,180	320.00	440	0	600	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V4	24	2,970	Raingarden - complex		Formal	2032	2,200	340.00	410	0	550	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V5	24	3,290	Raingarden - complex		Formal	2032	2,280	330.00	460	0	600	0	1	0	1	0	0	0	0	0	0	0	0	0	0
V6	24	3,450	Raingarden - complex		Formal	2032	2,470	380.00	480	0	640	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V7	24	4,250	Microbioretention - complex		Formal	2032	3,300	530.00	620	0	580	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V8	24	1,510	Raingarden - complex		Formal	2032	800	130.00	190	0	290	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V9	24	10,030	Microbioretention - complex		Formal	2027	7,430	1,070.00	1,190	0	1,200	0	1	0	0	0	0	1	0	0	0	0	0	0	0
V10	22	4,250	Microbioretention - moderate		Formal	2027	1,550	260.00	310	0	540	0	1	0	1	0	0	1	0	0	0	0	0	0	0
V11	24	9,810	Raingarden - complex		Formal	2032	5,190	780.00	1,150	0	1,780	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V12	22	14,960	Microbioretention - complex		Formal	2022	7,730	1,170.00	1,630	0	1,820	0	1	0	1	0	0	0	0	0	0	0	0	0	1
V13	24	4,510	Raingarden - complex		Formal	2032	3,130	450.00	540	0	830	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V14	24	2,130	Raingarden - complex		Formal	2032	1,120	190.00	270	0	410	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V15	24	2,890	Microbioretention - highly complex		Formal	2032	1,960	300.00	330	0	360	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V16	24	2,630	Microbioretention - highly complex		Formal	2032	1,790	300.00	320	0	360	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V17	24	12,380	Microbioretention - complex		Formal	2017	9,700	1,100.00	1,250	0	1,120	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V18	24	12,170	Cistern - complex		Formal	2027	12,170	1,000.00	1,000	300,500	100	0	1	1	0	0	0	0	0	0	0	1	1	1	0
V19	21	13,880	Microbioretention - complex		Informal Juxtaposition	2032	11,530	1,800.00	2,070	0	1,800	0	1	0	1	0	0	0	0	0	0	1	0	0	0
V20	21	15,330	Microbioretention - complex		Informal Juxtaposition	2032	12,140	1,840.00	2,120	0	1,900	0	1	0	1	0	0	0	0	0	0	1	0	0	0
V21	21	11,000	Microbioretention - complex		Informal Juxtaposition	2032	7,430	1,210.00	1,520	0	1,500	0	1	0	1	0	0	0	0	0	0	0	0	0	0
V22	23	6,980	Microbioretention - moderate		Formal	2032	3,720	590.00	930	0	940	0	1	0	1	0	0	0	0	0	0	0	0	0	1
V23	24	7,270	Microbioretention - highly complex	Planter box	Formal	2032	7,270	1,210.00	1,460	0	1,000	1	1	0	0	0	0	0	0	1	0	0	0	0	0
V24	24	7,490	Microbioretention - highly complex	Planter box	Formal	2032	7,490	1,190.00	1,400	0	1,000	1	1	0	0	0	0	0	0	1	0	0	0	0	0
V25	22	6,440	Microbioretention - moderate		Formal	2027	2,500	340.00	620	0	700	0	1	0	1	0	0	1	0	0	0	0	1	0	0
V26	22	9,890	Microbioretention - moderate		Formal	2027	7,370	770.00	890	0	870	0	1	0	1	0	0	1	0	0	0	0	1	0	0
V27	23	3,580	Microbioretention - highly complex	Planter box	Formal	2032	3,080	490.00	630	0	480	1	1	0	0	0	0	0	0	0	0	0	0	0	1
V28	24	15,060	Microbioretention - complex		Informal Juxtaposition	2027	10,760	1,560.00	1,860	0	1,820	0	1	0	1	0	0	0	0	0	0	1	1	1	0

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Stormwater BMP Master List Continued

Feature ID	Figure #	Drainage Area to BMP (sf)	BMP Type and Complexity	Design Comments	BMP Aesthetic	Year	A_T (sf)	ESDv (cf)	COSTv (cf)	Rainwater Harvest (gallons)	BMP Footprint (sf)	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	11*	12*	13*	14*
V29	23	6,980	Cistern - complex		NA	2017	6,980	670.00	670	172,310	60	0	1	1	0	0	0	0	0	0	0	0	0	0	1
V30	22	6,000	Cistern - complex		NA	2022	6,000	530.00	530	148,110	50	0	1	1	0	0	0	0	0	0	0	1	1	1	1
V31	22	5,010	Cistern - complex		NA	2022	5,010	400.00	400	123,680	50	0	1	1	0	0	0	0	0	0	0	0	0	0	1
V32	22	5,130	Cistern - complex		NA	2032	5,130	400.00	400	126,640	50	0	1	1	0	0	0	1	0	0	0	1	1	1	0
V33	22	16,570	Microbioretention - moderate		Informal Juxtaposition	2017	14,320	2,060.00	2,720	0	1,940	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V34	22	23,920	Cistern - complex		NA	2017	23,920	910.00	910	590,480	80	0	1	1	0	0	0	0	0	0	0	0	0	0	0
V35	22	see G39_1	Cistern - complex		NA	2017	:e G39_1	910.00	910	see G39_1	80	0	1	1	0	0	0	0	0	0	0	0	0	0	0
V36	22	5,920	Cistern - complex		NA	2022	5,920	530.00	530	145,890	50	0	1	1	0	0	0	0	0	0	0	1	1	1	1
V37	22	5,860	Cistern - complex		NA	2022	5,860	530.00	530	144,660	50	0	1	1	0	0	0	0	0	0	0	1	1	1	1
V38	22	14,060	Microbioretention - complex		Formal	2022	8,840	1,310.00	1,540	0	1,720	0	1	0	1	0	0	0	0	0	0	0	0	0	1
V39	22	13,280	Microbioretention - complex		Formal	2022	8,110	1,200.00	1,540	0	1,600	0	1	0	1	0	0	0	0	0	0	0	0	0	1
V40	22	3,740	Raingarden - complex		Formal	2022	2,240	330.00	520	0	680	0	1	0	1	0	0	0	0	0	0	0	0	0	1
V41	22	5,860	Cistern - complex		NA	2022	5,860	530.00	530	144,660	50	0	1	1	0	0	0	0	0	0	0	1	1	1	1
V42	22	16,410	Microbioretention - complex		Formal	2022	12,770	1,860.00	2,210	0	1,980	0	1	0	1	0	0	0	0	0	0	0	0	0	1
V43	22	15,890	Microbioretention - complex		Formal	2022	12,290	1,790.00	2,150	0	1,940	0	1	0	1	0	0	0	0	0	0	0	0	0	1
V44	22	4,770	Cistern - complex		NA	2032	4,770	400.00	400	117,750	50	0	1	1	0	0	0	1	0	0	0	1	1	1	0
V45	22	4,550	Cistern - complex		NA	2032	4,550	400.00	400	112,320	50	0	1	1	0	0	0	1	0	0	0	1	1	1	0
V46	22	4,860	Cistern - complex		NA	2032	4,860	400.00	400	119,970	50	0	1	1	0	0	0	1	0	0	0	1	1	1	0
V47	22	3,900	Raingarden - complex		Formal	2022	2,370	350.00	470	0	720	0	1	0	1	0	0	0	0	0	0	0	0	0	1
V48	22	1,830	Raingarden - simple		Formal	2022	700	100.00	170	0	300	0	1	0	1	0	0	0	0	0	0	0	0	0	1
V49	23	3,020	Cistern - complex		NA	2017	3,020	280.00	280	74,300	40	0	1	1	0	0	0	0	0	0	0	0	0	0	1
V50	23	4,150	Cistern - complex		NA	2017	4,150	400.00	400	102,450	50	0	1	1	0	0	0	0	0	0	0	0	0	0	1
V51	23	3,950	Cistern - complex		NA	2017	3,950	400.00	400	98,740	50	0	1	1	0	0	0	0	0	0	0	0	0	0	1
V52	25	7,490	Cistern - simple		NA	2027	7,490	670.00	670	184,900	60	0	1	1	0	0	0	0	0	0	0	0	0	0	0
V53	23	12,260	Microbioretention - complex		Formal	2027	8,000	1,180.00	1,440	0	1,500	0	1	0	1	0	0	0	0	0	0	0	0	0	0
V54	23	14,560	Microbioretention - complex		Formal	2027	10,500	1,530.00	1,850	0	1,770	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V55	24	13,990	Microbioretention - complex		Formal	2022	10,770	1,550.00	1,880	0	1,680	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V56	24	12,620	Microbioretention - complex		Formal	2022	7,840	1,150.00	1,440	0	1,550	0	1	0	0	0	0	0	0	0	0	0	0	0	0
V57	21	2,100	Raingarden - complex		Informal Juxtaposition	2032	1,350	200.00	270	0	380	0	1	0	1	0	0	0	1	0	0	0	0	0	0
V58	21	3,430	Raingarden - complex		Informal Juxtaposition	2032	2,470	360.00	470	0	630	0	1	0	1	0	0	0	1	0	0	0	0	0	0
V59	21	3,570	Raingarden - complex		Informal Juxtaposition	2027	2,700	390.00	500	0	650	0	1	0	1	0	0	0	1	0	0	0	0	0	0

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Stormwater BMP Master List Continued

Feature ID	Figure #	Drainage Area to BMP (sf)	BMP Type and Complexity	Design Comments	BMP Aesthetic	Year	A_T (sf)	ESDv (cf)	COSTv (cf)	Rainwater Harvest (gallons)	BMP Footprint (sf)	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	11*	12*	13*	14*
R72	21	NA	Turf to Meadow Conversion		Informal Juxtaposition	2032	NA	0	340	0	4,130	0	0	0	1	1	1	0	0	0	0	0	0	0	0
R73	21	NA	Turf to Meadow Conversion		Informal Juxtaposition	2032	NA	0	1,021	0	12,250	0	1	0	1	1	1	0	0	0	1	0	0	0	0
R74	21	NA	Turf to Meadow Conversion		Informal Juxtaposition	2032	NA	0	270	0	3,180	0	0	0	1	1	1	1	0	0	0	0	0	0	0
R75	21	NA	Turf to Meadow Conversion		Informal Juxtaposition	2017	NA	0	2,460	0	28,200	0	0	0	1	1	0	0	0	0	0	0	0	0	1
R76	21	NA	Impervious to Forest Conversion		Informal Juxtaposition	2017	NA	0	1,640	0	19,650	1	1	0	0	1	0	0	0	0	0	0	0	0	1
R77	21	NA	Turf to Meadow Conversion		Formal	2032	NA	0	740	0	8,930	0	0	0	1	1	1	0	0	0	0	0	0	0	0
R78	21	NA	Turf to Meadow Conversion		Formal	2032	NA	0	560	0	6,740	0	0	0	1	1	1	0	0	0	0	0	0	0	0
R79	25	NA	Turf to Meadow Conversion		Informal Juxtaposition	2027	NA	0	720	0	8,650	0	0	0	1	1	0	0	0	0	0	0	0	0	0
R80	25	NA	Turf to Forest Conversion		Informal Juxtaposition	2032	NA	0	890	0	10,690	0	0	0	1	1	1	0	0	0	0	0	0	0	0
R81	25	NA	Turf to Forest Conversion		Informal Juxtaposition	2022	NA	0	560	0	6,730	0	0	0	1	1	1	0	0	0	0	0	0	0	0
R82	25	NA	Turf to Forest Conversion		Informal Juxtaposition	2027	NA	0	1,460	0	17,510	0	0	0	1	1	1	0	0	0	0	0	0	0	0
R83	25	NA	Turf to Forest Conversion		Informal Juxtaposition	2022	NA	0	540	0	6,530	0	0	0	1	1	1	0	0	0	0	0	0	0	0
R84	22	NA	ImperviousForest		Informal	2027	NA	0	570	0	6,810	1	1	0	0	1	1	1	0	0	0	0	0	0	0
R85	24	NA	Turf to Meadow Conversion		Informal Juxtaposition	2017	NA	0	40	0	520	0	0	0	1	1	0	0	0	0	0	0	0	0	0
R86	24	NA	Turf to Meadow Conversion		Informal Juxtaposition	2017	NA	0	210	0	2,530	0	0	0	1	1	0	0	0	0	0	0	0	0	0
R87	24	NA	Turf to Meadow Conversion		Informal	2017	NA	0	690	0	8,250	0	0	0	1	1	0	0	0	0	0	0	0	0	0
R88	24	NA	Turf to Forest Conversion		Formal	2022	NA	0	150	0	1,750	0	0	0	1	1	1	0	1	0	0	0	0	0	0
R89	24	NA	Turf to Forest Conversion		Formal	2022	NA	0	460	0	5,480	0	0	0	1	1	1	0	1	0	0	0	0	0	0
R90	24	NA	Turf to Forest Conversion		Formal	2022	NA	0	320	0	3,820	0	0	0	1	1	1	0	0	0	0	0	0	0	0
R91	24	NA	Turf to Meadow Conversion		Informal Juxtaposition	2022	NA	0	100	0	1,180	0	0	0	1	1	1	0	0	0	0	0	0	0	0
R92	24	NA	Turf to Meadow Conversion		Informal Juxtaposition	2022	NA	0	190	0	2,310	0	0	0	1	1	1	0	0	0	0	0	0	0	0
R93	24	NA	Turf to Meadow Conversion		Formal	2022	NA	0	453	0	5,110	0	0	0	1	1	1	0	0	0	0	0	0	0	0
R94	24	NA	Turf to Meadow Conversion		Formal	2022	NA	0	550	0	6,560	0	0	0	1	1	0	0	0	0	0	0	0	0	0
R95	24	NA	Turf to Meadow Conversion		Formal	2022	NA	0	580	0	6,930	0	0	0	1	1	0	0	0	0	0	0	0	0	0
V60	22	NA	Turf to Forest Conversion		Formal	2027	NA	0	690	0	8,250	0	0	0	1	1	1	0	0	0	0	0	0	0	0
V61	21	NA	Turf to Forest Conversion		Informal	2027	NA	0	1,540	0	18,450	0	0	0	1	1	1	0	0	0	0	0	0	0	0
V62	22	NA	Turf to Meadow Conversion		Informal	2032	NA	0	800	0	9,650	0	0	0	1	1	1	0	1	0	1	0	0	0	1
V63	22	NA	Turf to Meadow Conversion		Informal	2032	NA	0	1,900	0	22,780	0	0	0	1	1	1	0	1	0	0	0	0	0	1
V64	22	NA	Turf to Meadow Conversion		Informal	2032	NA	0	120	0	1,440	0	0	0	1	1	1	0	0	0	0	0	0	0	1
V65	24	NA	Turf to Meadow Conversion		Informal Juxtaposition	2017	NA	0	1,100	0	13,160	0	0	0	1	1	0	0	1	0	0	0	0	0	0
V66	24	NA	Turf to Meadow Conversion		Formal	2017	NA	0	160	0	1,950	0	0	0	1	1	0	0	1	0	0	0	0	0	0
V67	24	NA	Turf to Meadow Conversion		Formal	2017	NA	0	250	0	2,950	0	0	0	1	1	0	0	1	0	0	0	0	0	0
V68	22	NA	Turf to Meadow Conversion		Formal	2017	NA	0	590	0	7,110	0	0	0	1	1	0	0	0	0	0	0	0	0	1

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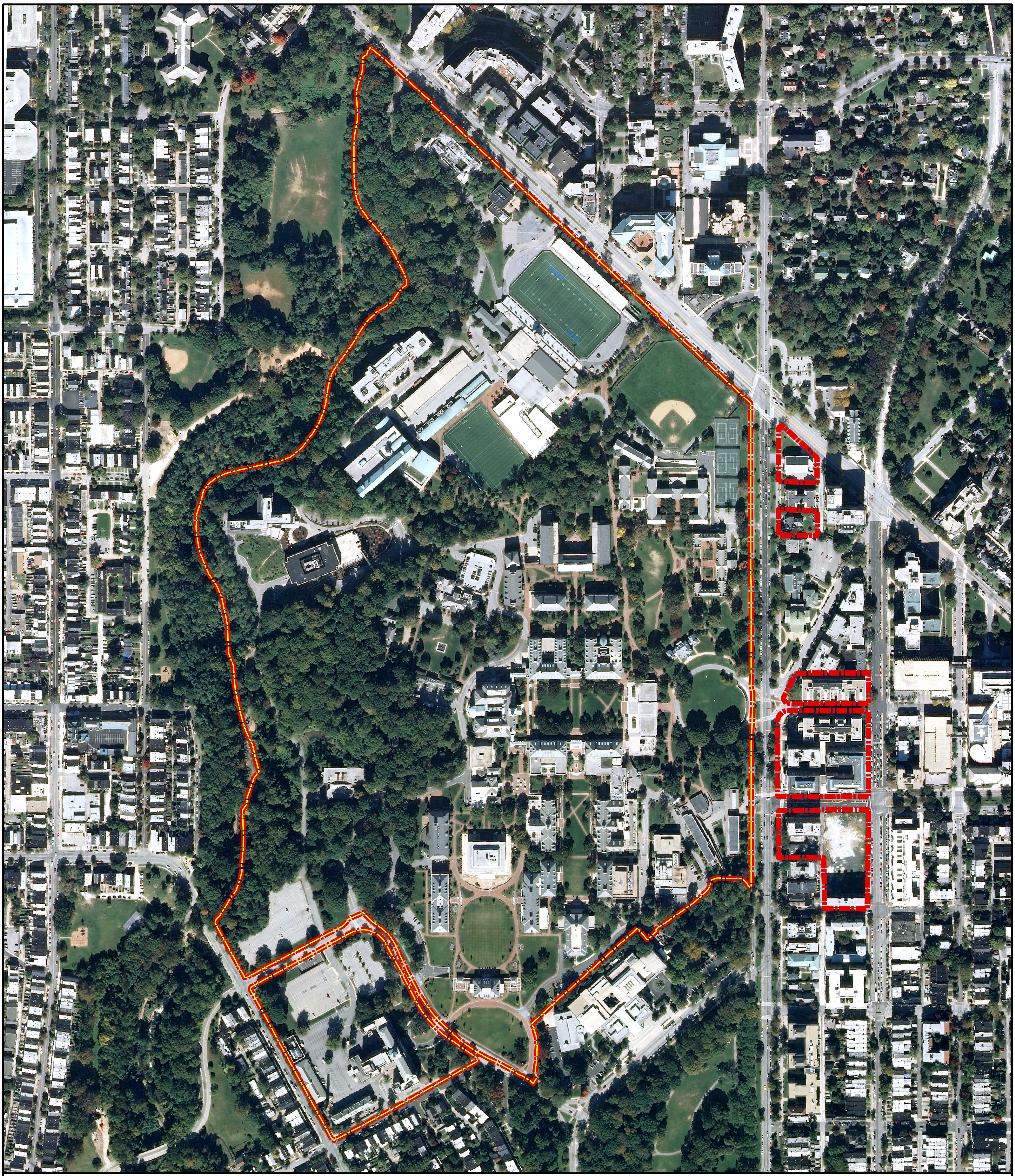
13* - Educational BMP
14* - Treatment of IA within flood prone DA

Note: This summary was derived from the BMP attribute table within the GIS geodatabase that was created for the 2012 SWMMP. The **Feature ID** column correlates to the stormwater BMP as it is labeled on the SWMMP Scenario Figures (Figures 20-25). Feature ID prefix "R" indicates that a stormwater BMPs is necessary to meet regulations and has concept approval from Baltimore City DPW. Feature ID prefix "V" indicate a voluntary stormwater BMPs. The **Drainage Area to BMP** column is the contributing area of runoff for each practice. The **BMP Type and Complexity** column lists the type of stormwater BMP and the degree of complexity anticipated for installation for each. The **Design Comments** column lists specific stormwater BMP design information that was considered during conceptual design. The **BMP Aesthetic** column refers to the degree of formality or informality of the stormwater BMP as it relates to the campus precincts and design considerations outlined in Chapter 7: Building, Site, and Stormwater Design Guidance. The **Year** column is the anticipated year of construction completion for each stormwater BMP. The **A_T** column is the area of impervious cover treated per stormwater BMP. The **ESD_V** is the treatment volume per stormwater BMP. The **$COST_V$** column was used to estimate order of magnitude costs per stormwater BMP. The **Rainwater Harvest** column lists the gallons of water storage per each cistern. The **BMP Footprint** is the estimated surface area of each stormwater BMP. Columns 1* - 14* identifies metrics to which the practice contributes or, for metrics 11-13, presents an opportunity to contribute.

Figures

Project 51110.0001



Stormwater Management Master Plan
Johns Hopkins University

Homewood Campus
3400 North Charles Street
Baltimore, Maryland 21218

SWMMP Extent

1 Inch = 400 Feet

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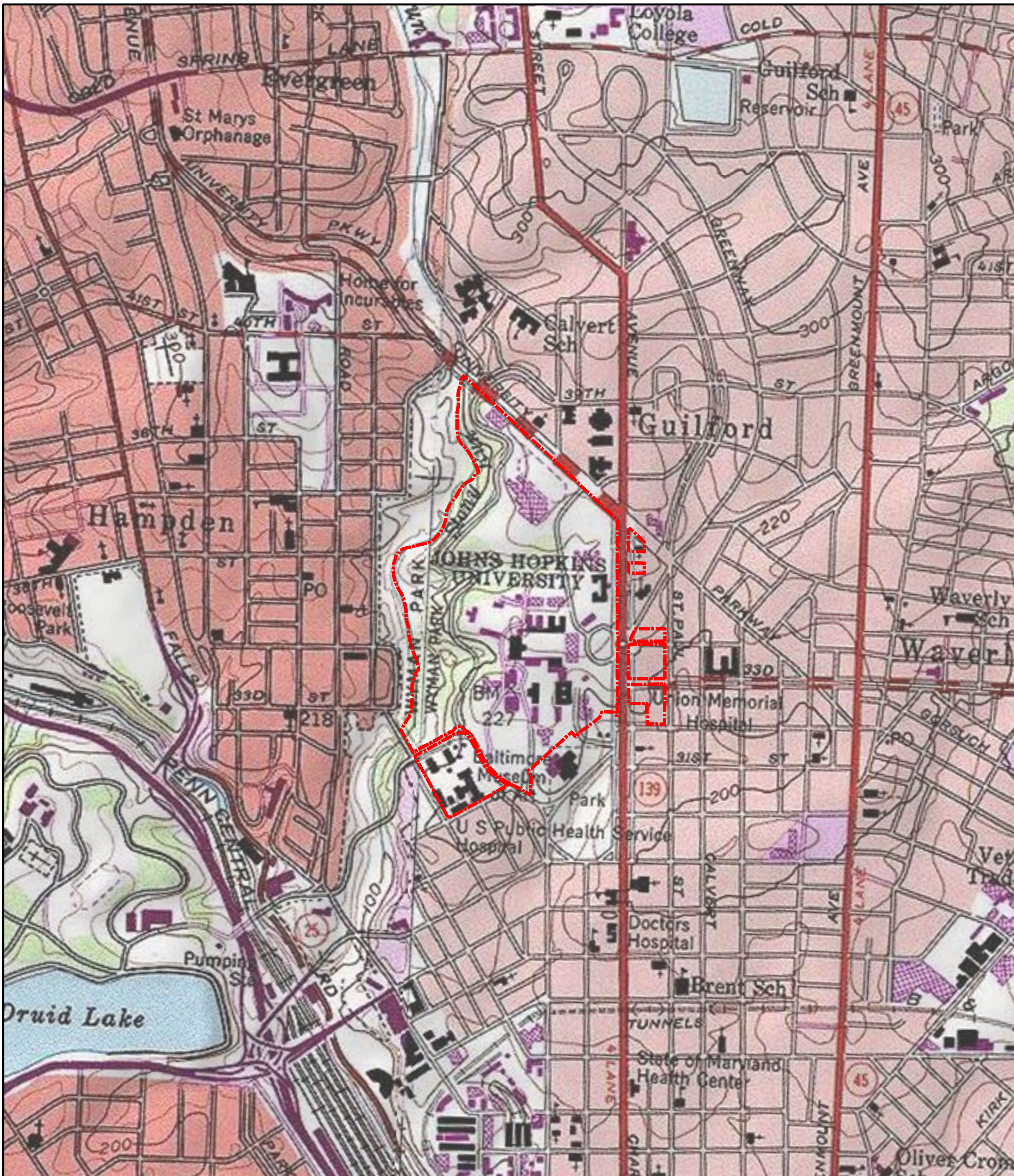
Figure 1



Approximate coordinates of Project Site:
39° 19' 45" N, 76° 37' 17" W

USGS 7.5 Minute Topographic Map - Baltimore West and Baltimore East Quads

SWMMP Boundary

1,000 Feet

N

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Baltimore, Maryland 21218

Location

1 Inch = 400 Feet

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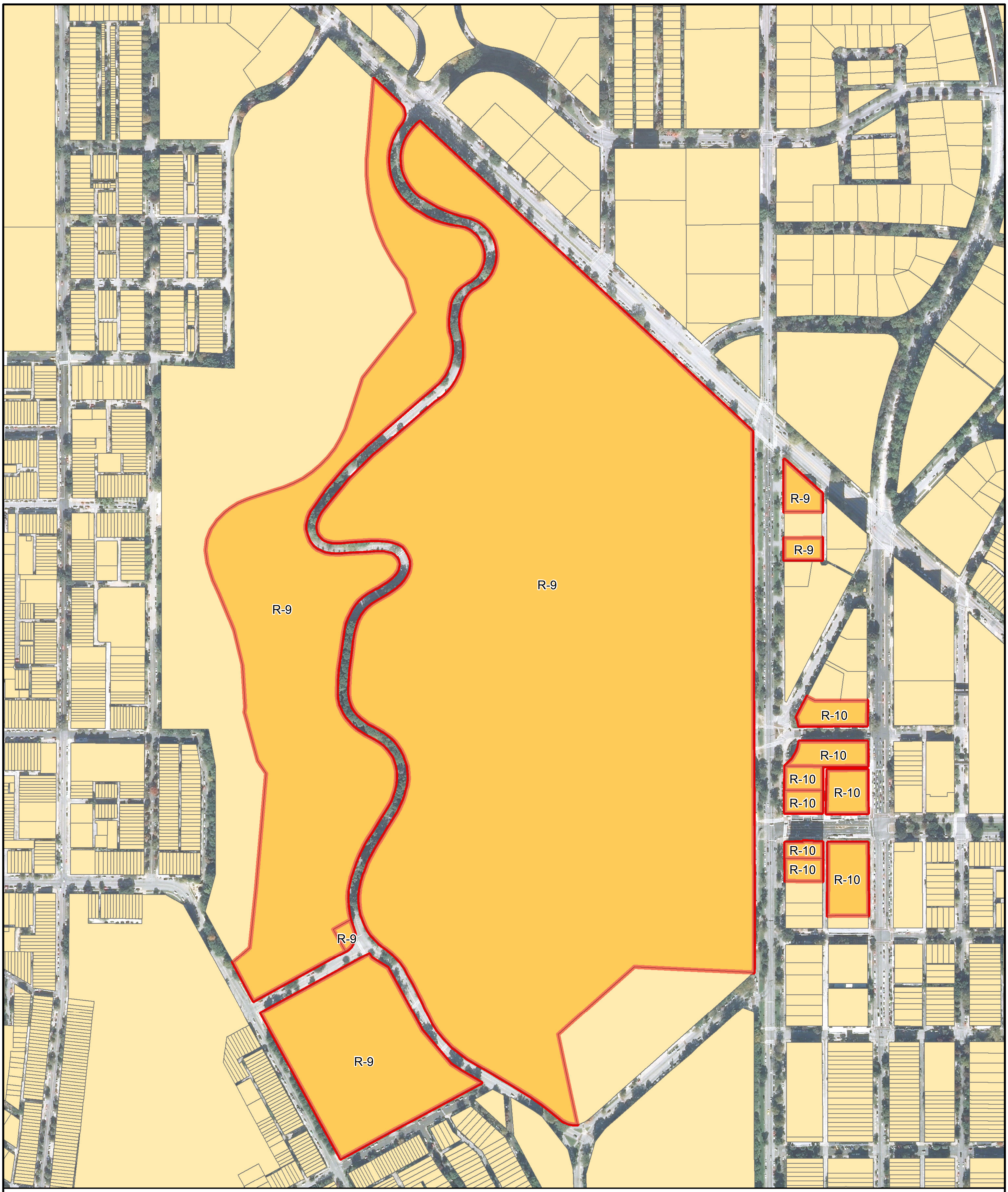
Figure 2

Project 51110.0001



Parcel data obtained from the City of Balitmore GIS department.
R-9 - Multi-Family Residential Zoning District
R-10 - High Density Multi-Family Residential Zoning District

Parcel
SWMMP Parcels

400
Feet
N

Stormwater Management Master Plan
Johns Hopkins University

SWMMP Parcels
1 Inch = 400 Feet

Homewood Campus
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Baltimore, Maryland 21218

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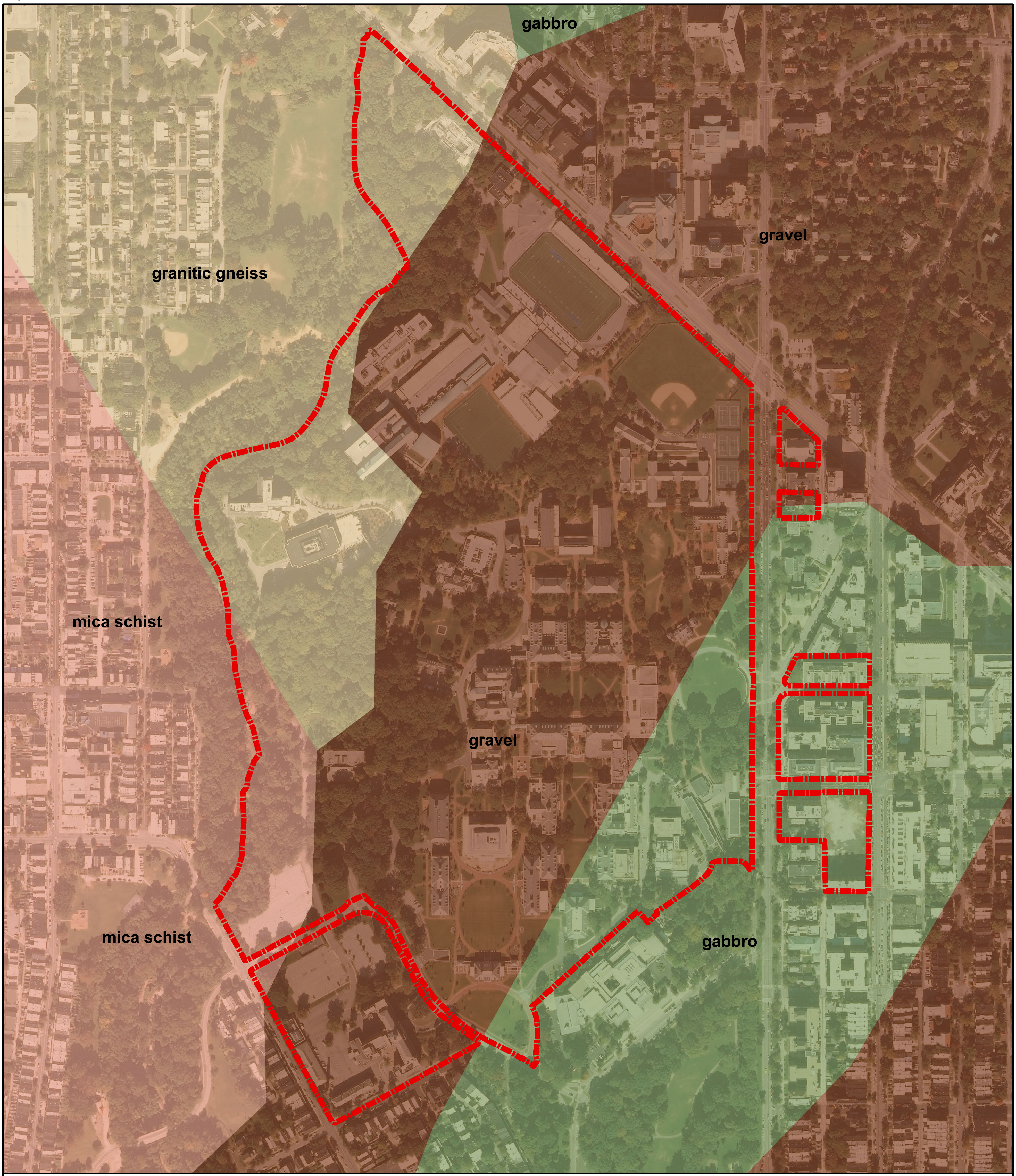
Figure 3



The Homewood Campus is located west of the fall line, in the Northeast Piedmont Region, where the coastal plain meets the piedmont's distinct topographic and geologic formations. The underlying geology of the campus is a mix of schist and sandy gravels, characteristic of the wider region. Geologic data was gathered from the Natural Resource Conservation Service's Geospatial Data Gateway.

- SWMMP Boundary
- gabbro
- granitic gneiss
- gravel
- mica schist

400 Feet

N

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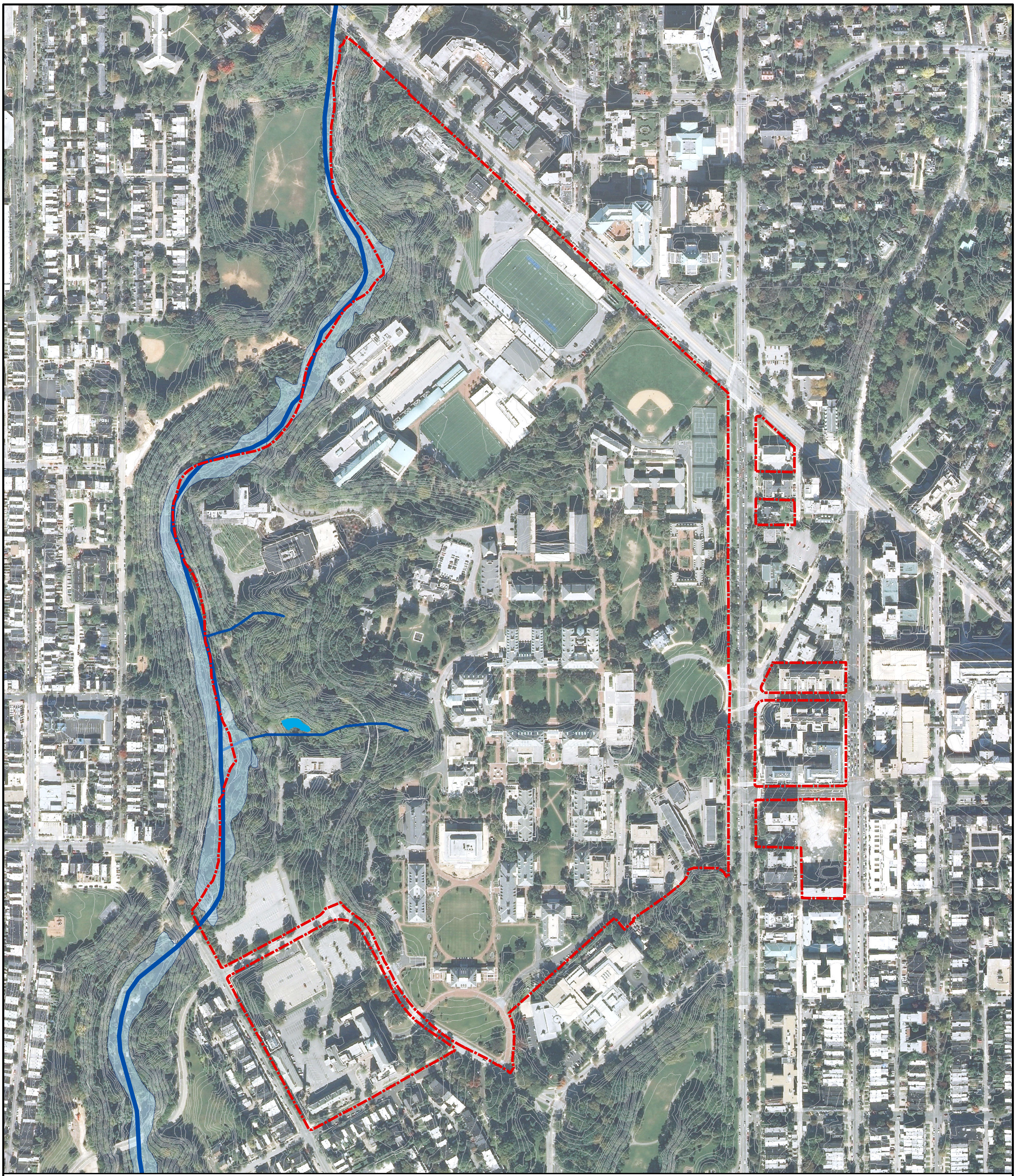
Geology

1 Inch = 400 Feet

Figure 4

Project 51110.0001



The Homewood Campus is located within the Patapsco River watershed, which drains into the Chesapeake Bay. Generally, the Campus drains from east to west towards Stoney Run, a small tributary to the Patapsco River that forms the Campus's western boundary and drains south and into the City of Baltimore. Drainage within developed portions of Campus occurs largely via subsurface stormwater pipe networks, which empty into a series of small, ephemeral surface drainage ways to Stoney Run, or directly to Stoney Run. Stream data pictured here was gathered from the Maryland Department of Natural Resources Geospatial Data Bank and from field observation. Floodplain data was gathered from the FEMA Map Service Center. The topographic data was obtained from the City of Baltimore GIS department.

SWMMP Boundary
Existing Basin
Stoney Run
Floodplain
Drainageways
2 Ft Contour Interval

N

400 Feet

Stormwater Management Master Plan
Johns Hopkins University

Hydrology
1 Inch = 400 Feet

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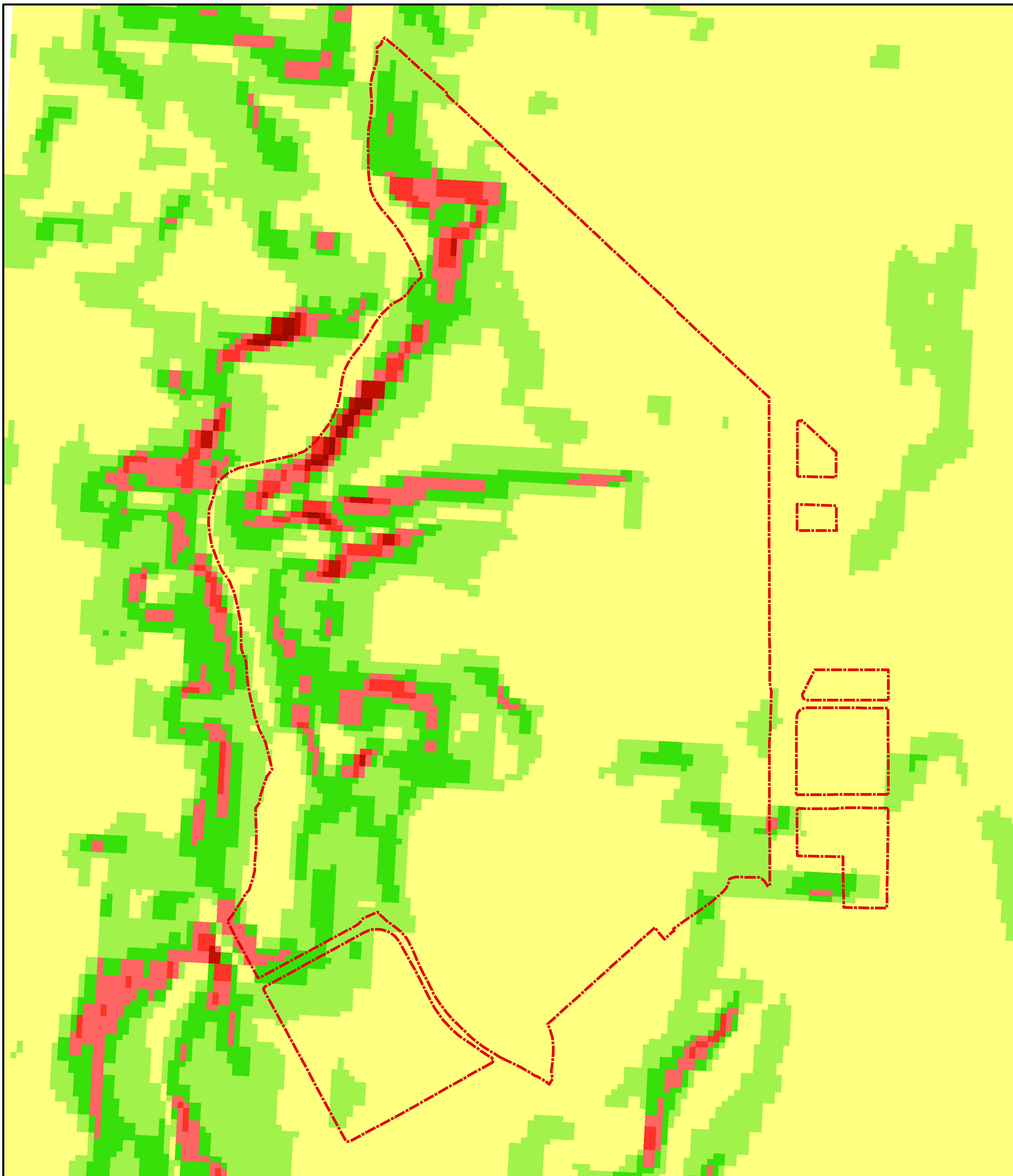
Figure 5



Steep slopes of 20% or greater are found along the western edge of campus, particularly along the Stoney Run valley. Others are found at the southeastern edge of campus, along North Charles Street. The campus itself slopes from north to south, with an elevation loss of over 100 feet between Homewood Field and Olin Hall. Slopes were calculated from a digital elevation model supplied by GeoCommunity (www.geocomm.com).

- SWMMP Boundary
- 0 - 5 %
- 5 - 10 %
- 10 - 15 %
- 15 - 20 %
- 20 - 25 %
- 25 - 30 %
- 30 % +

400 Feet

N

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Slope

1 Inch = 400 Feet

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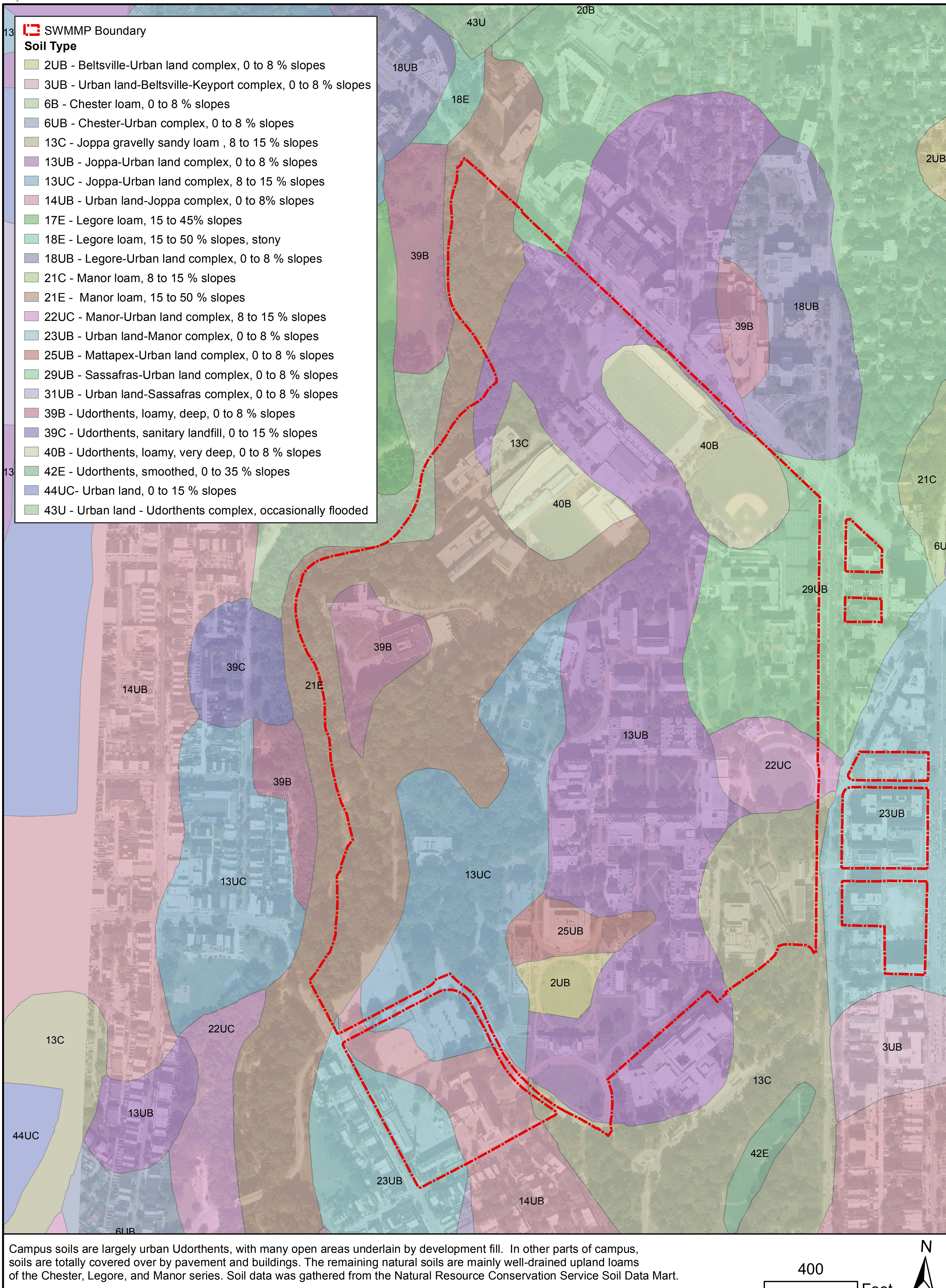
Figure 6

Project 51110.0001



Campus soils are largely urban Udorthents, with many open areas underlain by development fill. In other parts of campus, soils are totally covered over by pavement and buildings. The remaining natural soils are mainly well-drained upland loams of the Chester, Legore, and Manor series. Soil data was gathered from the Natural Resource Conservation Service Soil Data Mart.

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Soils

1 Inch = 400 Feet

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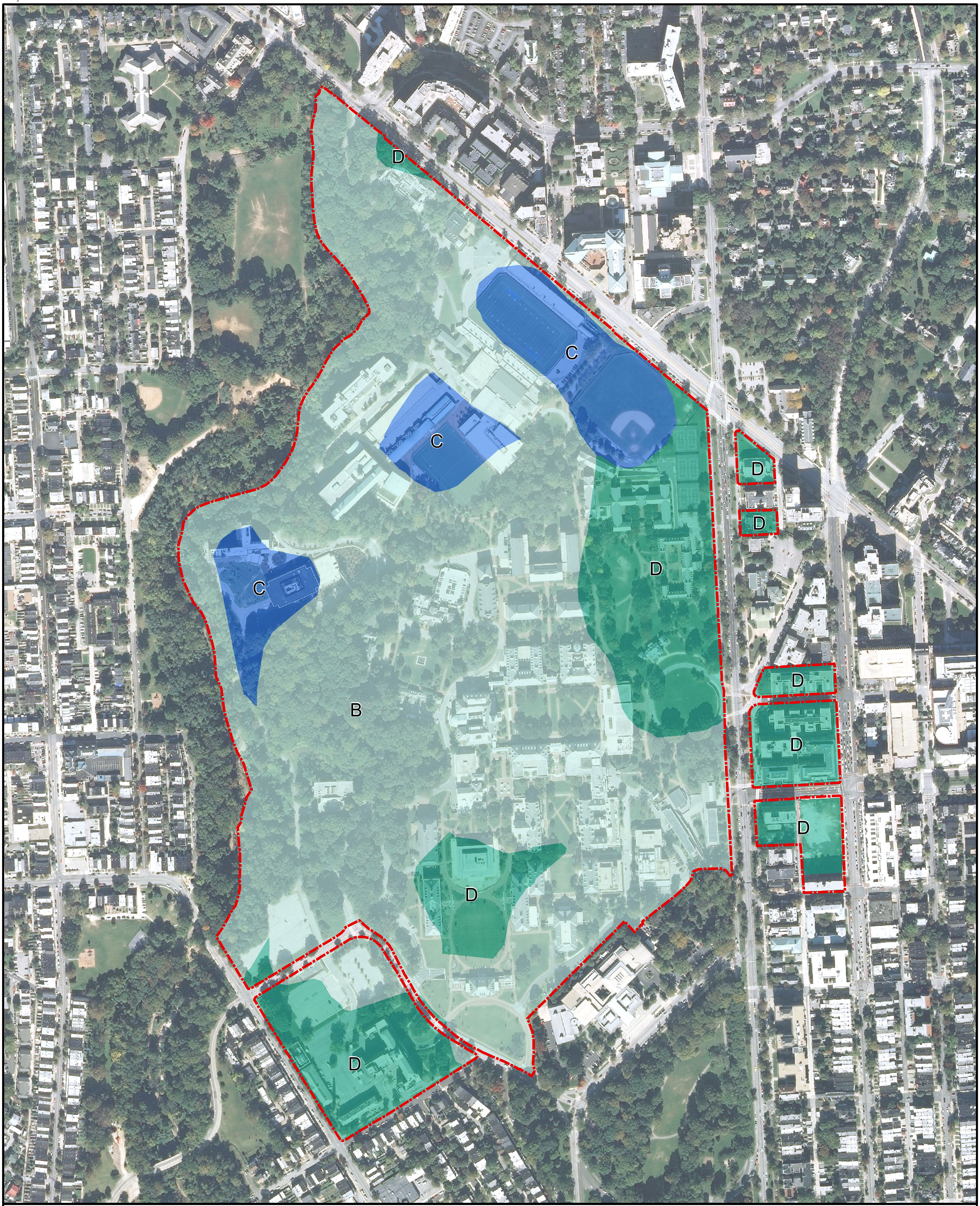
Figure 7



Soil data was gathered from the Natural Resource Conservation Service Soil Data Mart.

SWMMP Boundary
B - 68% of project area
C - 10% of project area
D - 22% of project area

400 Feet

N

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Hydrologic Soils Group

1 Inch = 400 Feet

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Figure 8

The Homewood campus is largely characterized by a mosaic of campus buildings and paved pathways interspersed with expansive, open lawns and smaller, vegetated landscaping beds. Roadways and surface parking areas are mostly absent within the core campus. The Homewood campus's western edge is characterized by increasing forest cover and less intensive development. A twenty-acre Forest Conservation Zone lies in this corridor. Cover type data was collected using aerial photography, engineering design plans, and field verification. The legend contains the percent coverage of each of the different landcovers within the Homewood campus.

- SWMMP Boundary
- Buildings - 17%
- Dirt or Gravel - 1%
- Other impervious areas - 0.04%
- Roads, parking and other vehicular ways - 14%
- Sidewalks, paths and other pedestrian ways - 11%
- Athletic fields - 5%
- Brush, shrubs, and thickets - 0.2%
- Forest - 22%
- Landscaped areas - 3%
- Lawns - 22%
- Meadows and fields - 1%
- Ponds, streams, etc. - 0.05%
- Woods-Grass, Orchards, etc. - 4%

400 Feet

N

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Existing Land Cover

1 Inch = 400 Feet

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Figure 9

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Existing Conditions - 2012
Impervious and Pervious Coverage

1 Inch = 400 Feet

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Figure 10

- LOD
- Existing Buildings
- 2017 (5 year build out)
- 2022 (10 year build out)
- 2027 (15 year build out)
- 2032 (20 year build out)
- SWMMP Boundary
- Mature Tree Grove - Formal
- BMP
- Meadow - Formal
- Meadow - Informal
- Other Impervious Surface
- Proposed Buildings
- Athletic fields
- Brush, shrubs, and thickets
- Forest
- Landscaped areas
- Lawns
- Meadows and fields
- Ponds, streams, etc.
- Woods-Grass, Orchards, etc.

LOD A—UNIVERSITY PARKWAY
2017 – (1) Freshman Housing Plan, (2) Lacrosse Building, (3) Mudd Hall addition

2032 – (4) University Parkway Building A, (5) University Parkway Building B, (6) Athletic Recreation Plan

LOD B—ST. PAUL
2022 – (7) St. Paul Housing

LOD C—WYMAN PARK
2022 – (8) Wyman Park building C & (9) Wyman Park building D

2027 – (10) Wyman Park building A, (11) Wyman Park building B, (12) Wyman Park building E & Wyman Parking Garage

2032 – (13) Wyman Park Building F & (14) Wyman Park Building G

LOD D—GILMAN
2027 – (15) New Levering Hall

LOD E—WHITEHEAD
2017 – (16) Whitehead Hall addition

LOD F—DECKER
2017 – (17) Decker Building C

2022 – (18) Decker Building A & (19) Decker Building B

400 Feet

N

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Build-out Conditions - 2032

Impervious and Pervious Coverage

1 Inch = 400 Feet

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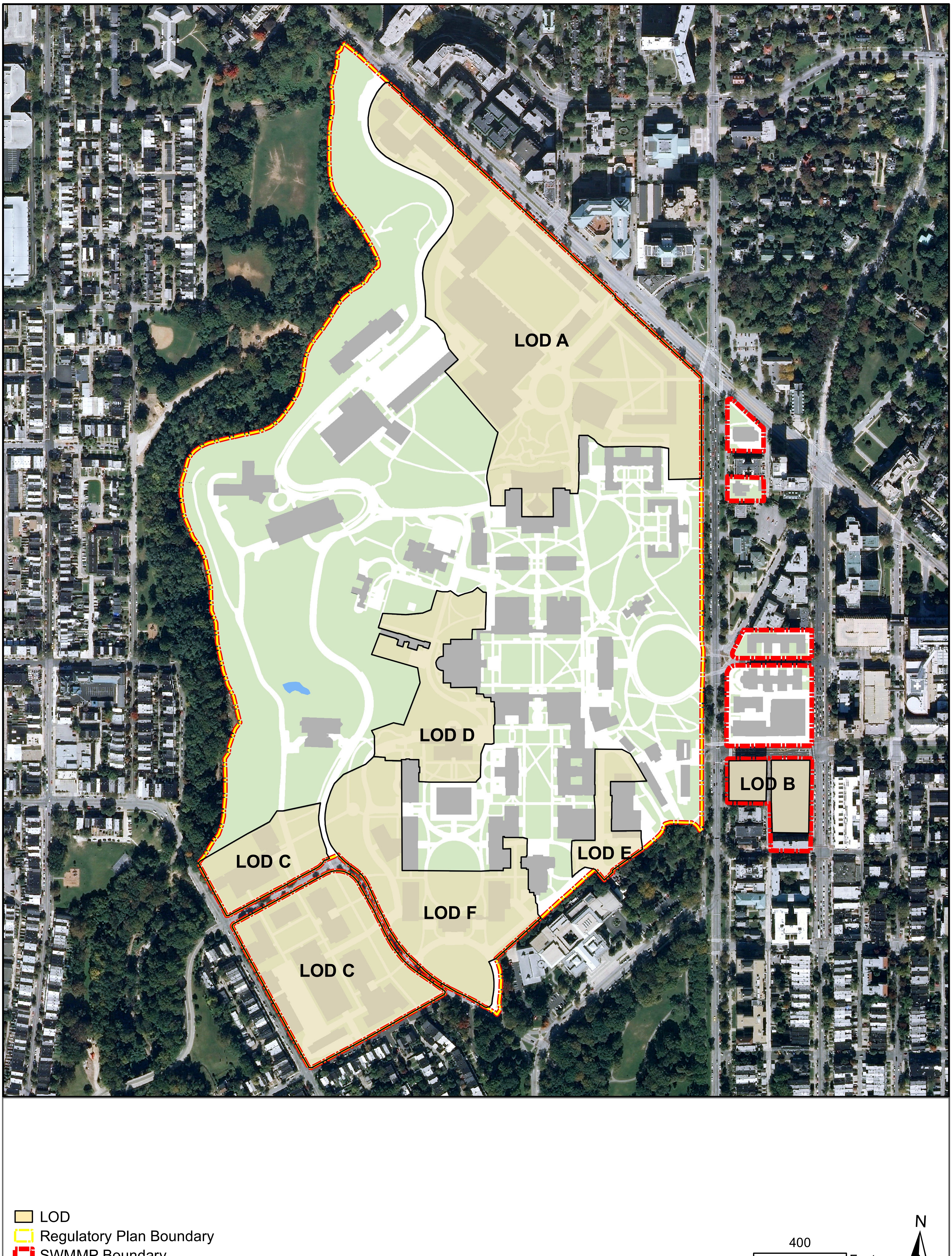
Figure 11



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Homewood Campus
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Limit of Disturbance (LOD) Boundaries

1 Inch = 400 Feet

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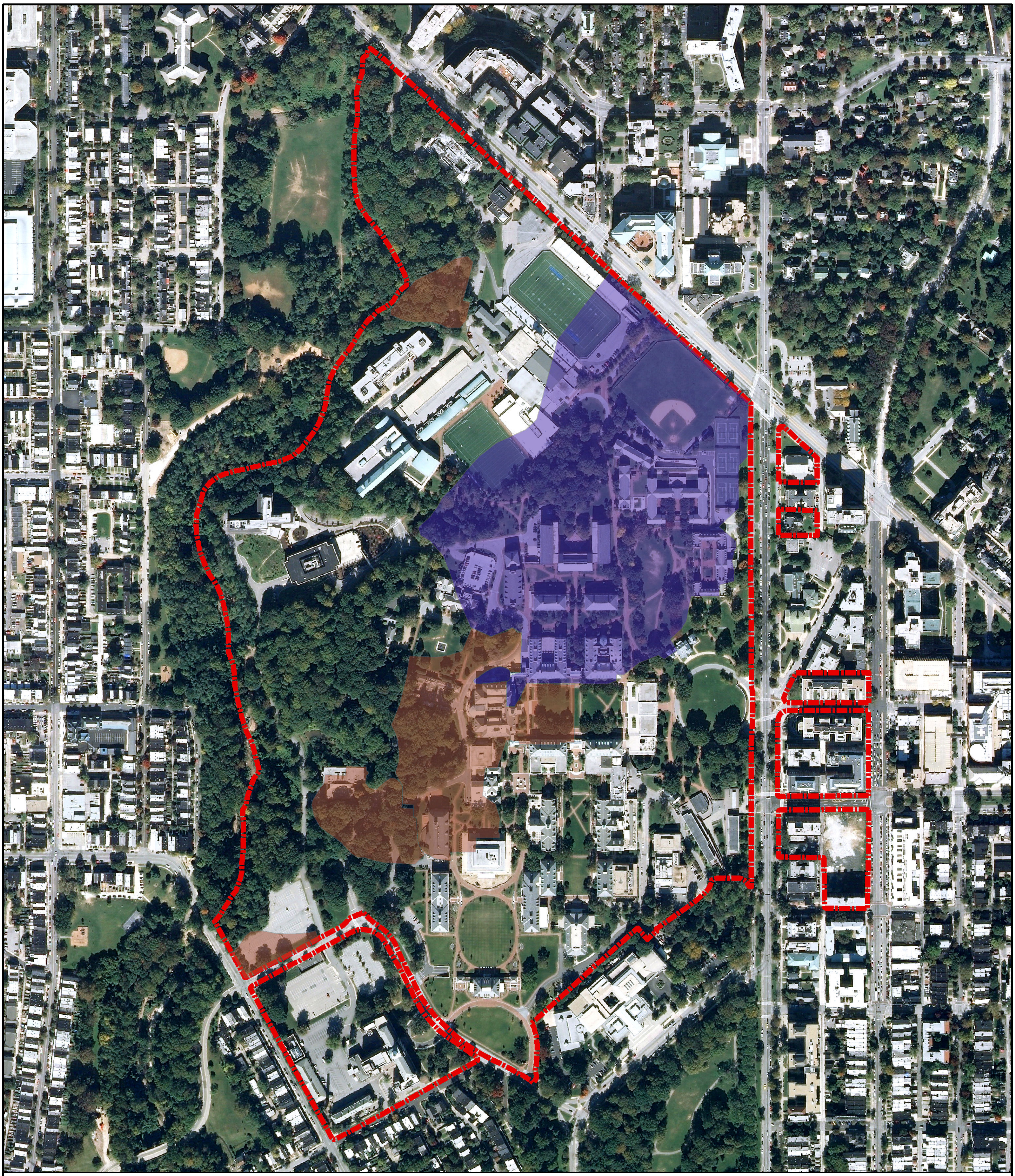
Figure 12

Project 51110.0001



Drainage to Flood-Prone Areas

Drainage to Gullied Areas

SWMMP Boundary

400 Feet

N

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Drainage to Problem Areas

1 Inch = 400 Feet

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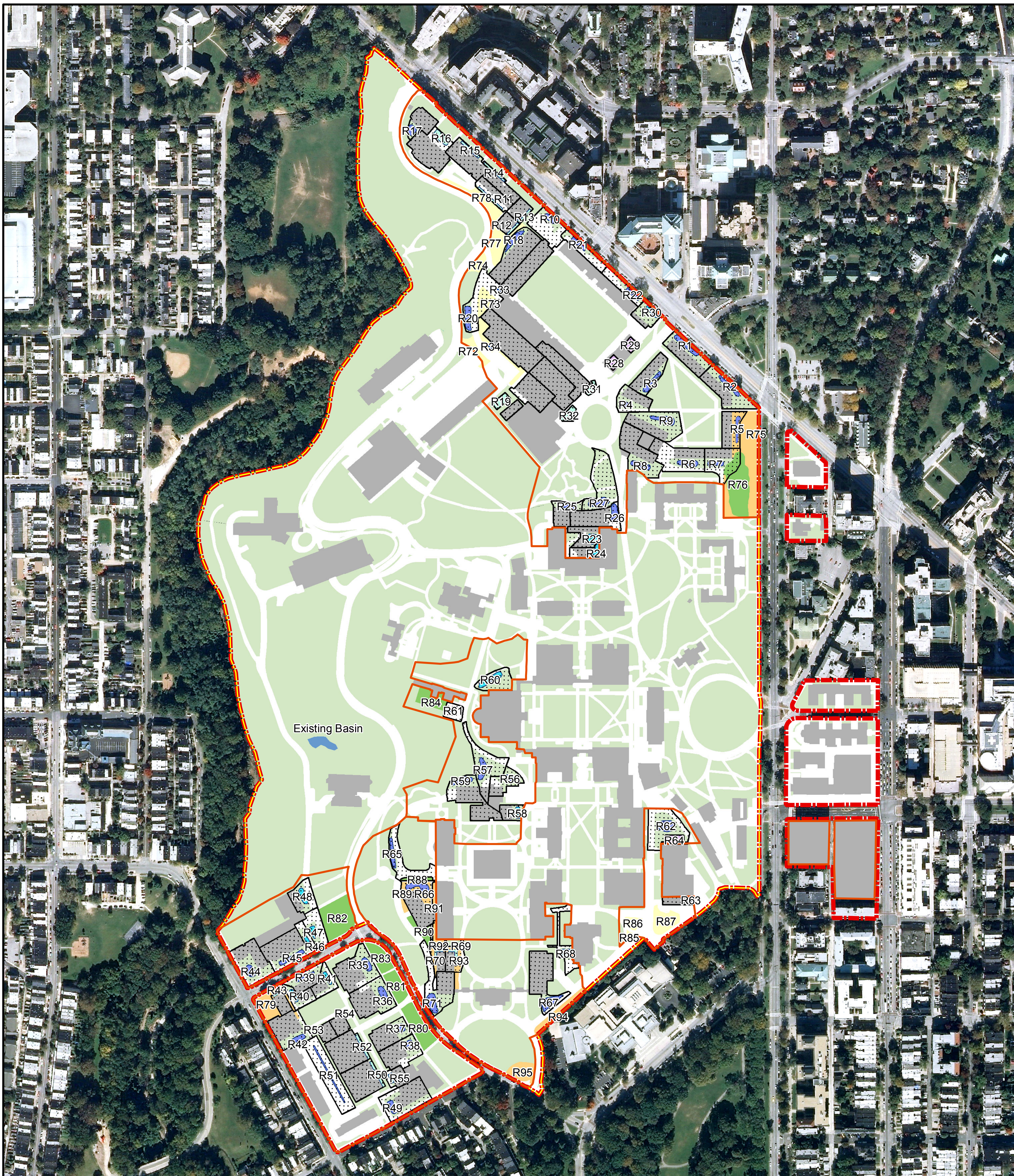
Figure 13

Project 51110.0001



- Cistern
- Mature Tree Grove - Formal
- Green Roof
- Microbioretention
- Meadow - Formal
- Meadow - Informal
- Planter Box
- Raingarden
- Other Impervious Surface
- Buildings
- Pervious Area
- Existing Basin
- Treatment Drainage Areas
- LOD
- SWMMP Boundary
- Regulatory Plan Boundary

400 Feet

N

Stormwater Management Master Plan
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Homewood Campus
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BMP Campus Layout
Regulatory Compliance Scenario

per ESD Volume Requirements within each LOD

1 Inch = 400 Feet

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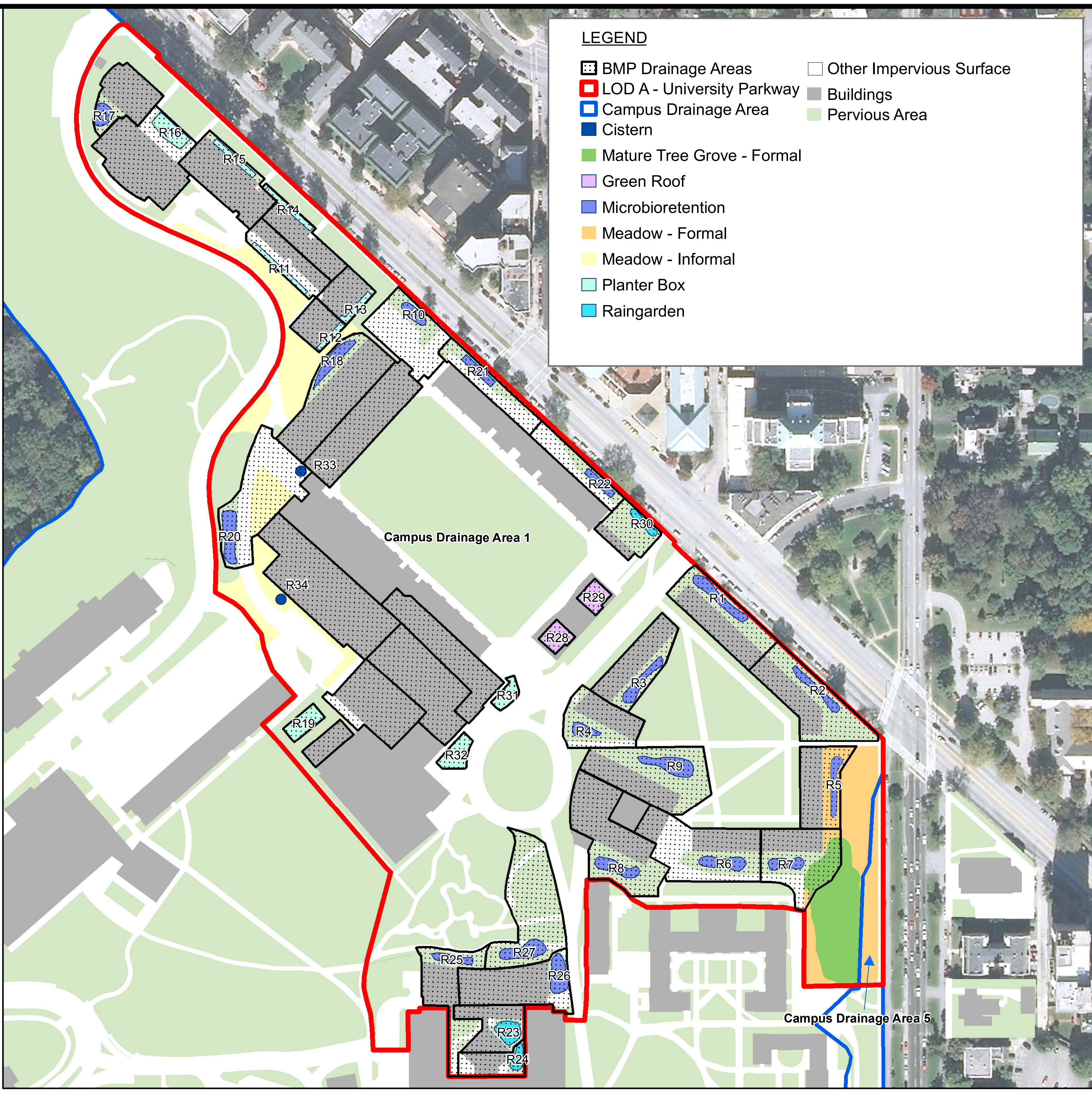
Figure 14



Johns Hopkins Homewood Campus - LOD A **1 Inch = 200 Feet**

N

200 Feet

Table A-1

LOD A--University Parkway
Best Management Practices

BMP ID	Type of BMP	Year	Footprint (sf)	Drainage Area to BMP (sf)	Impervious Area in BMP Drainage Area (sf)	R_v	P_E (in)	Captured ESD_v (cf)
Campus Drainage Area 1								
R1	Microbioretention	2017	1,820	14,800	7,450	0.5030	1.8	1,116.66
R2	Microbioretention	2017	1,200	17,260	6,860	0.4077	1.0	586.41
R3	Microbioretention	2017	1,430	11,770	7,590	0.6304	1.8	1,112.97
R4	Microbioretention	2017	800	11,190	4,990	0.4505	1.1	462.10
R5	Microbioretention	2017	1,360	11,120	9,860	0.8480	1.8	1,414.46
R6	Microbioretention	2017	1,500	20,000	14,230	0.6904	1.1	1,265.73
R7	Microbioretention	2017	1,110	15,140	6,310	0.4251	1.1	589.97
R8	Microbioretention	2017	1,500	20,000	11,950	0.5878	1.1	1,077.63
R9	Microbioretention	2017	2,100	19,580	7,240	0.3828	1.6	999.36
R10	Microbioretention	2032	900	13,080	9,150	0.6796	1.0	740.76
R11	Microbioretention - Planter box	2032	1,020	8,320	6,800	0.7856	1.8	980.43
R12	Microbioretention - Planter box	2032	590	4,870	4,220	0.8299	1.8	606.24
R13	Microbioretention - Planter box	2032	700	5,680	4,880	0.8232	1.8	701.37
R14	Microbioretention - Planter box	2032	990	8,120	6,890	0.8137	1.8	991.09
R15	Microbioretention - Planter box	2032	900	13,700	11,950	0.8350	1.0	953.29
R16	Microbioretention - Planter box	2032	1,950	19,850	17,070	0.8240	1.5	2,044.55
R17	Microbioretention	2032	1,050	9,240	6,970	0.7289	1.7	954.13
R18	Microbioretention	2032	1,600	20,000	16,000	0.7700	1.2	1,540.00
R19	Microbioretention - Planter box	2032	2,240	19,600	17,370	0.8476	1.7	2,353.50
R20	Microbioretention	2032	2,000	20,000	11,000	0.5450	1.5	1,362.50
R21	Microbioretention	2032	900	7,550	3,790	0.5018	1.8	568.29
R22	Microbioretention	2032	800	6,680	3,630	0.5391	1.8	540.18
R23	Raingarden	2017	1,440	7,840	5,490	0.6802	1.8	799.92
R24	Raingarden	2017	760	4,140	2,740	0.6457	1.8	400.98
R25	Microbioretention	2017	910	7,540	5,100	0.6588	1.8	745.10
R26	Microbioretention	2017	1,710	14,200	9,980	0.6825	1.8	1,453.73
R27	Microbioretention	2017	1,800	22,170	5,310	0.2656	1.2	588.84
R28	Greenroof	2017	2,000	2,000	2,000	0.9500	1.0	154.00
R29	Greenroof	2017	2,000	2,000	2,000	0.9500	1.0	154.00
R30	Raingarden	2017	700	6,940	1,410	0.2329	1.0	134.69
R31	Microbioretention - Planter box	2032	1,490	15,410	13,900	0.8618	1.5	1,660.04
R32	Microbioretention - Planter box	2032	2,350	19,880	17,540	0.8441	1.8	2,517.11
R33	Cistern	2032	280	16,310	16,310	0.9500	2.0	2,680.00
R34	Cistern	2032	280	26,400	26,400	0.9500	1.2	2,680.00
				Total Provided A_T (sf)	**304,380**	**Total Provided ESD_v (cf)**		**36,930.03**

NOTE: Treated Environmental Site Design Volume (ESD_v) Calculations

ESD_v for microbioretention and raingarden practices is calculated using the following equation:

$ESD_v = P_E$ (inches) x R_V x DA (square feet) x (1 foot / 12 inches) where:

R_v = 0.05 + 0.009 x (IA [square feet] / DA [square feet]) x 100, where IA is the impervious portion of the BMP drainage area (DA); and

P_E = 10 (inches) x A_f (square feet) / DA (square feet) for raingarden, and

P_E = 15 (inches) x A_f (square feet) / DA (square feet) for microbioretention, where

A_f is the BMP footprint

ESD_v for cisterns is the captured volume of runoff.

Cisterns are designed to capture a minimum of 0.2 inches of rainfall from the contributing rooftop area (DA).

P_E = ESD_v (cubic feet) / DA (square feet) x (12 [inches] / 1 [foot])

ESD_v for greenroofs is calculated from the ESD_v / DA ratio.

ESD_v = 0.077 (feet) x A_f (square feet), for roof thickness = 4” (as applied to greenroofs in LOD A and LOD B)

ESD_v = 0.095 (feet) x A_f (square feet), for roof thickness = 6” (as applied to greenroofs in LOD E)

Table A-2

LOD A - University Parkway
Campus Drainage Area Information

Campus Drainage (DA)	Total LOD Area (sf)	% Area of LOD	Required A_T (sf)	Required A_T (ac)	Provided A_T (sf)	Provided A_T (ac)	Required ESD_v (cf)	Provided ESD_v (cf)
1	1,067,800	99%	315,239	7.24	304,380	6.99	36,475.09	36,930.03
5	11,300	1%	3,184	0.07	0	0.00	368.44	0.00
Totals	1,079,100	100%	318,424	7.31	304,380	6.99	**36,843.53**	**36,930.03**

ESD_V requirements have been met. Re_V requirements are provided for in the ESD_V within micro-bioretention and rain garden practices. An additional ESD_V = 86.50 cf is provided to make up for deficits within other LODs. A_T provided is 0.32 less than the A_T requirements. The balance is made up within other LODs.

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Proposed Environmental Site Design
Limit of Disturbance (LOD) A - University Parkway

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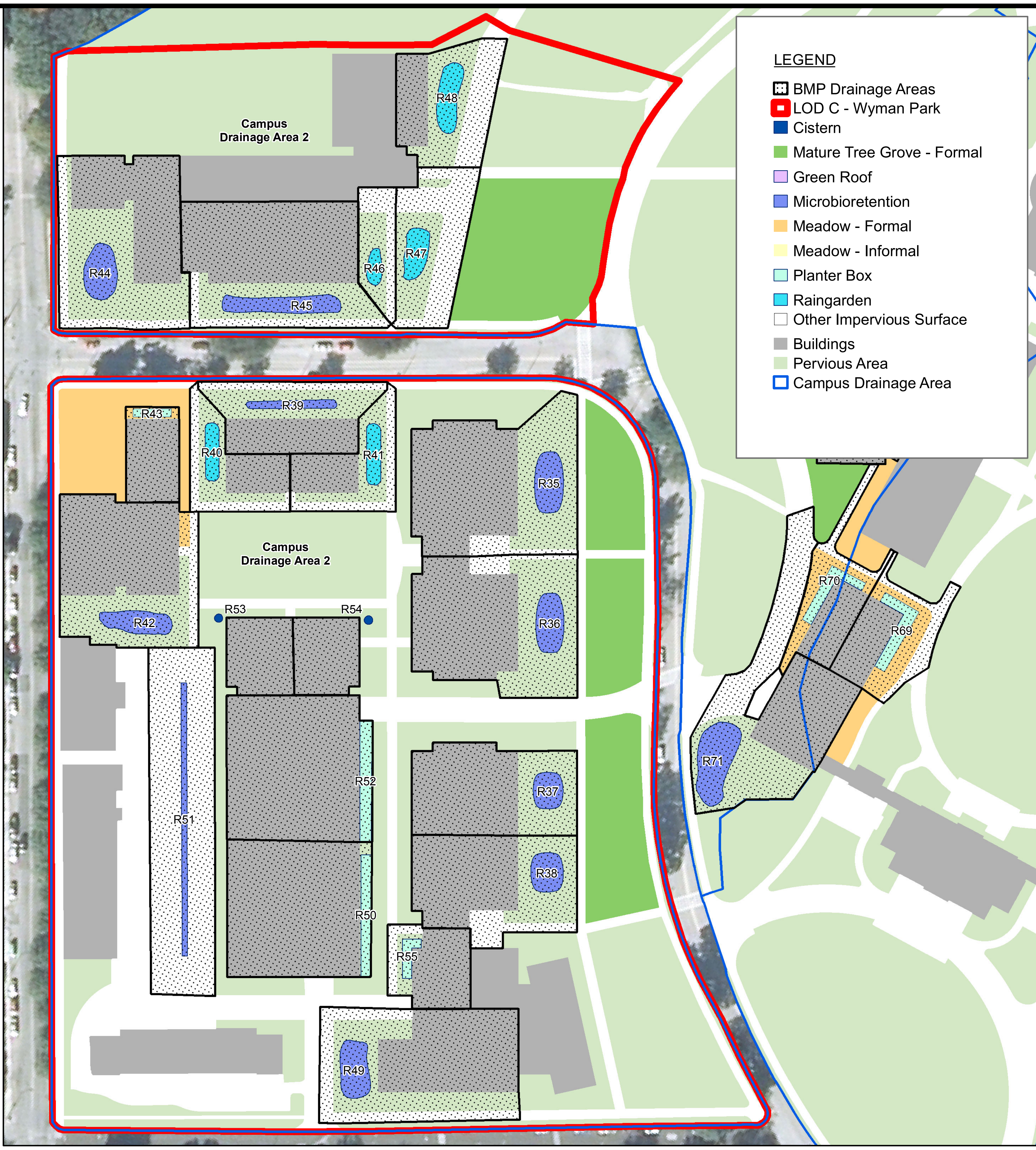
Figure 15



Johns Hopkins Homewood Campus - LOD C **1 Inch = 100 Feet**

Table C-1

LOD C--Wyman Park

Best Management Practices

BMP ID	Type of BMP	Year	Footprint (sf)	BMP Drainage Area (sf)	Impervious Area in BMP Drainage Area (sf)	R_v	P_E (in)	Captured ESD_v (cf)
Campus Drainage Area 1								
R44	Microbioretention	2027	1,320	19,030	10,400	0.5419	1.0	859.36
R45	Microbioretention	2027	1,600	20,000	15,000	0.7250	1.2	1,450.00
R46	Raingarden	2027	400	3,930	1,700	0.4393	1.0	143.87
R47	Raingarden	2027	930	9,380	5,500	0.5777	1.0	451.57
R48	Raingarden	2027	1,200	9,990	5,810	0.5734	1.2	572.83
				Total A_T	**38,410**		**Total ESD_v**	**3,477.63**
Campus Drainage Area 7								
R35	Microbioretention	2022	1,350	20,000	12,300	0.6035	1.0	1,005.83
R36	Microbioretention	2022	1,280	19,140	11,500	0.5908	1.0	942.33
R37	Microbioretention	2032	840	12,820	8,430	0.6418	1.0	685.66
R38	Microbioretention	2032	990	14,250	9,600	0.6563	1.0	779.36
R39	Microbioretention	2022	610	9,600	5,460	0.5619	1.0	449.52
R40	Raingarden	2022	675	6,800	3,330	0.4907	1.0	278.06
R41	Raingarden	2022	750	7,150	4,160	0.5736	1.0	341.77
R42	Microbioretention	2027	1,200	17,650	11,250	0.6237	1.0	917.36
R43	Microbioretention-Planter box	2027	290	4,480	3,930	0.8395	1.0	313.41
R49	Microbioretention	2032	1,340	19,900	13,600	0.6651	1.0	1,102.96
R50	Microbioretention-Planter box	2027	1,100	17,360	16,010	0.8800	1.0	1,273.07
R51	Microbioretention	2032	1,330	20,000	18,040	0.8618	1.0	1,436.33
R52	Microbioretention-Planter box	2027	1,250	18,460	17,110	0.8842	1.0	1,360.19
R53	Cistern	2027	50	4,510	4,510	0.9500	1.1	430.00
R54	Cistern	2027	50	4,460	4,460	0.9500	1.2	430.00
R55	Microbioretention-Planter box	2032	400	5,720	4,180	0.7077	1.0	337.34
				Total A_T	**147,870**		**Total ESD_v**	**12,083.19**
				Total Provided A_T in LOD	**186,280**		**Total Provided ESD_v in LOD**	**15,560.82**

NOTE: Treated Environmental Site Design Volume (ESD_v) Calculations

ESD_v for microbioretention and raingarden practices is calculated using the following equation:

$ESD_v = P_E$ (inches) x R_V x DA (square feet) x (1 foot / 12 inches) where:

R_v = 0.05 + 0.009 x (IA [square feet] / DA [square feet]) x 100, where IA is the impervious portion of the BMP drainage area (DA); and

P_E = 10 (inches) x A_f (square feet) / DA (square feet) for raingarden, and

P_E = 15 (inches) x A_f (square feet) / DA (square feet) for microbioretention, where

A_f is the BMP footprint

ESD_v for cisterns is the captured volume of runoff.

Cisterns are designed to capture a minimum of 0.2 inches of rainfall from the contributing rooftop area (DA).

$P_E = ESD_v$ (cubic feet) / DA (square feet) x (12 [inches] / 1 [foot])

ESD_v for greenroofs is calculated from the ESD_v / DA ratio.

ESD_v = 0.077 (feet) x A_f (square feet), for roof thickness = 4" (as applied to greenroofs in LOD A and LOD B)

ESD_v = 0.095 (feet) x A_f (square feet), for roof thickness = 6" (as applied to greenroofs in LOD E)

Table C-2

LOD C - Wyman Park

Campus Drainage Area Information

Campus Drainage (DA)	Area within LOD (sf)	% Area of LOD	Required A_T (sf)	Required A_T (ac)	Provided A_T (sf)	Provided A_T (ac)	Required ESD_v (cf)	Provided ESD_v (cf)
1	145,100	26%	37,808	0.87	38,410	0.88	3,431.57	3,477.63
7	411,600	74%	107,247	2.46	147,870	3.39	9,766.78	12,083.19
Totals	556,700	100%	**145,055**	**3.33**	**186,280**	**4.27**	**13,198.35**	**15,560.82**

ESD_V and A_T requirements have been met within each Campus Drainage Area. An additional ESD_V = 2,362.47 cf and A_T = 0.94 ac are provided to make up for deficits within other LODs.

Stormwater Management Master Plan
Johns Hopkins University

Proposed Environmental Site Design
Limit of Disturbance (LOD) C - Wyman Park

Homewood Campus
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Baltimore, Maryland 21218

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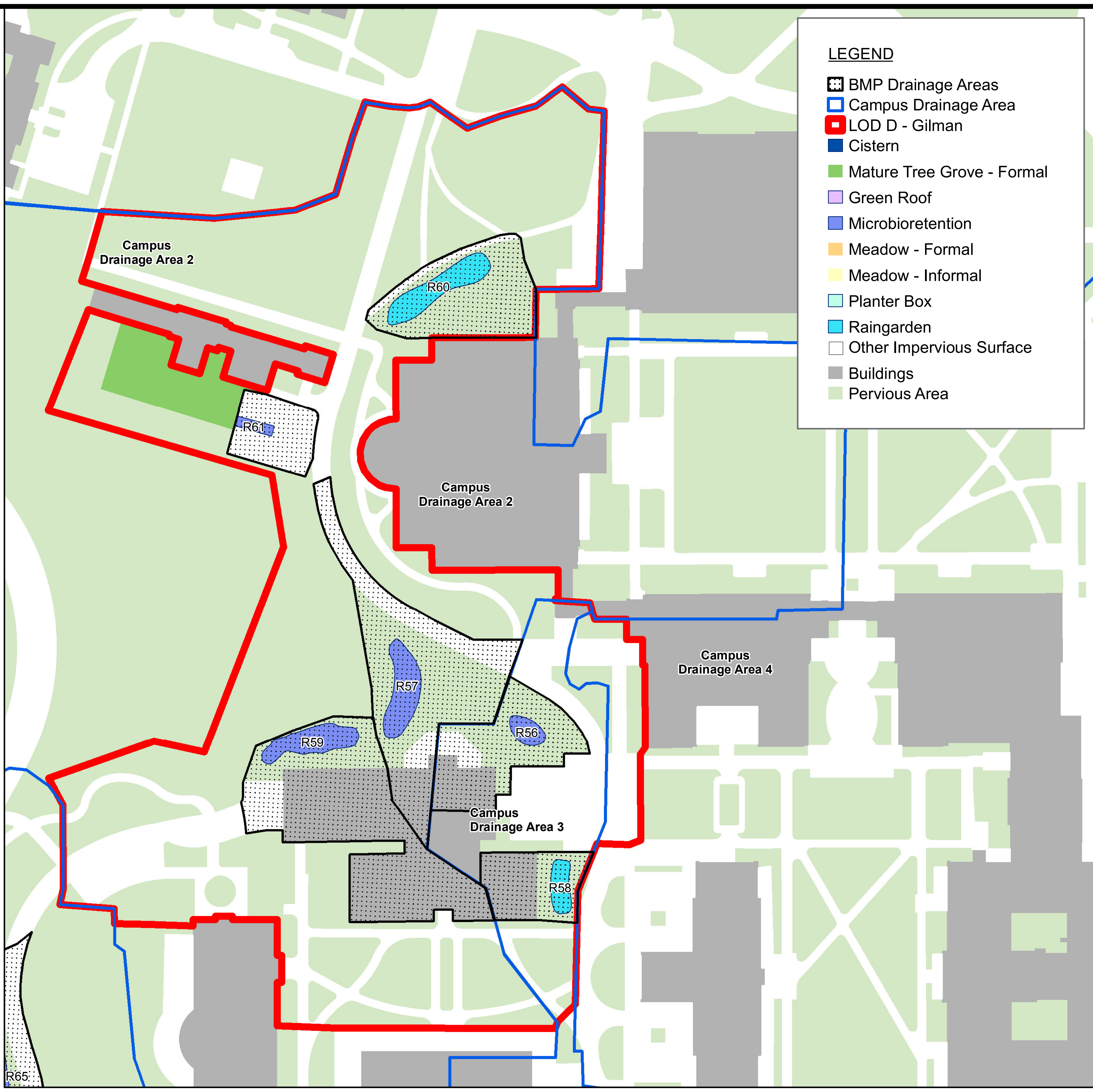
Figure 16



Johns Hopkins Homewood Campus - LOD D 1 Inch = 100 Feet

100 Feet

N

NOTE: Treated Environmental Site Design Volume (ESD_v) Calculations

ESD_v for microbioretention and raingarden practices is calculated using the following equation:

ESD_v = P_E (inches) x R_V x DA (square feet) x (1 foot / 12 inches) where:

R_v = 0.05 + 0.009 x (IA [square feet] / DA [square feet]) x 100, where IA is the impervious portion of the BMP drainage area (DA); and

P_E = 10 (inches) x A_f (square feet) / DA (square feet) for raingarden, and

P_E = 15 (inches) x A_f (square feet) / DA (square feet) for microbioretention, where

A_f is the BMP footprint

ESD_v for cisterns is the captured volume of runoff.

Cisterns are designed to capture a minimum of 0.2 inches of rainfall from the contributing rooftop area (DA).

P_E = ESD_v (cubic feet) / DA (square feet) x (12 [inches] / 1 [foot])

ESD_v for greenroofs is calculated from the ESD_v / DA ratio.

ESD_v = 0.077 (feet) x A_f (square feet), for roof thickness = 4" (as applied to greenroofs in LOD A and LOD B)

ESD_v = 0.095 (feet) x A_f (square feet), for roof thickness = 6" (as applied to greenroofs in LOD E)

Table D-1

LOD D--Gilman

Best Management Practices

BMP ID	Type of BMP	Year	Footprint (sf)	Drainage Area to BMP (sf)	Impervious Area in BMP Drainage Area (sf)	R_v	P_E (in)	Captured ESD_v (cf)
Campus Drainage Area 2								
R57	Microbioretention	2027	1,840	17,430	6,930	0.4078	1.6	947.73
R59	Microbioretention	2027	1,630	19,730	15,040	0.7361	1.2	1,452.33
R60	Raingarden	2027	2,000	9,940	800	0.1224	2.0	202.78
R61	Microbioretention	2027	310	4,310	4,310	0.9500	1.1	375.33
				Total A_T	**27,080**		**Total ESD_V**	**2,978.16**
Campus Drainage Area 3								
R56	Microbioretention	2027	600	9,110	3,220	0.3681	1.0	279.45
R58	Raingarden	2027	750	5,270	2,800	0.5282	1.4	324.75
				Total A_T	**6,020**		**Total ESD_V**	**604.20**
				Total Provided A_T in LOD	**33,100**		**Total Provided ESD_v in LOD**	**3,582.36**

Table D-2

LOD D - Gilman

Campus Drainage Area Information

Campus Drainage (DA)	Area within LOD (sf)	% Area of LOD	Required A_T (sf)	Required A_T (ac)	Provided A_T (sf)	Provided A_T (ac)	Required ESD_v (cf)	Provided ESD_v (cf)
2	213,890	84%	27,080	0.62	27,080	0.62	2,929.24	2,978.16
3	34,650	13%	4,190	0.10	6,020	0.14	453.33	604.20
4 (1)	8,160	3%	970	0.02	0	0.00	104.62	0.00
Totals	256,700	100%	**32,240**	**0.74**	**33,100**	**0.76**	**3,487.19**	**3,582.36**

ESD_V and A_T requirements have been met within each Campus Drainage Area. An additional ESD_V = 95.17 cf and A_T = 0.02 ac are provided to make up for deficits within other LODs.

Stormwater Management Master Plan
Johns Hopkins University

Proposed Environmental Site Design
Limit of Disturbance (LOD) D - Gilman

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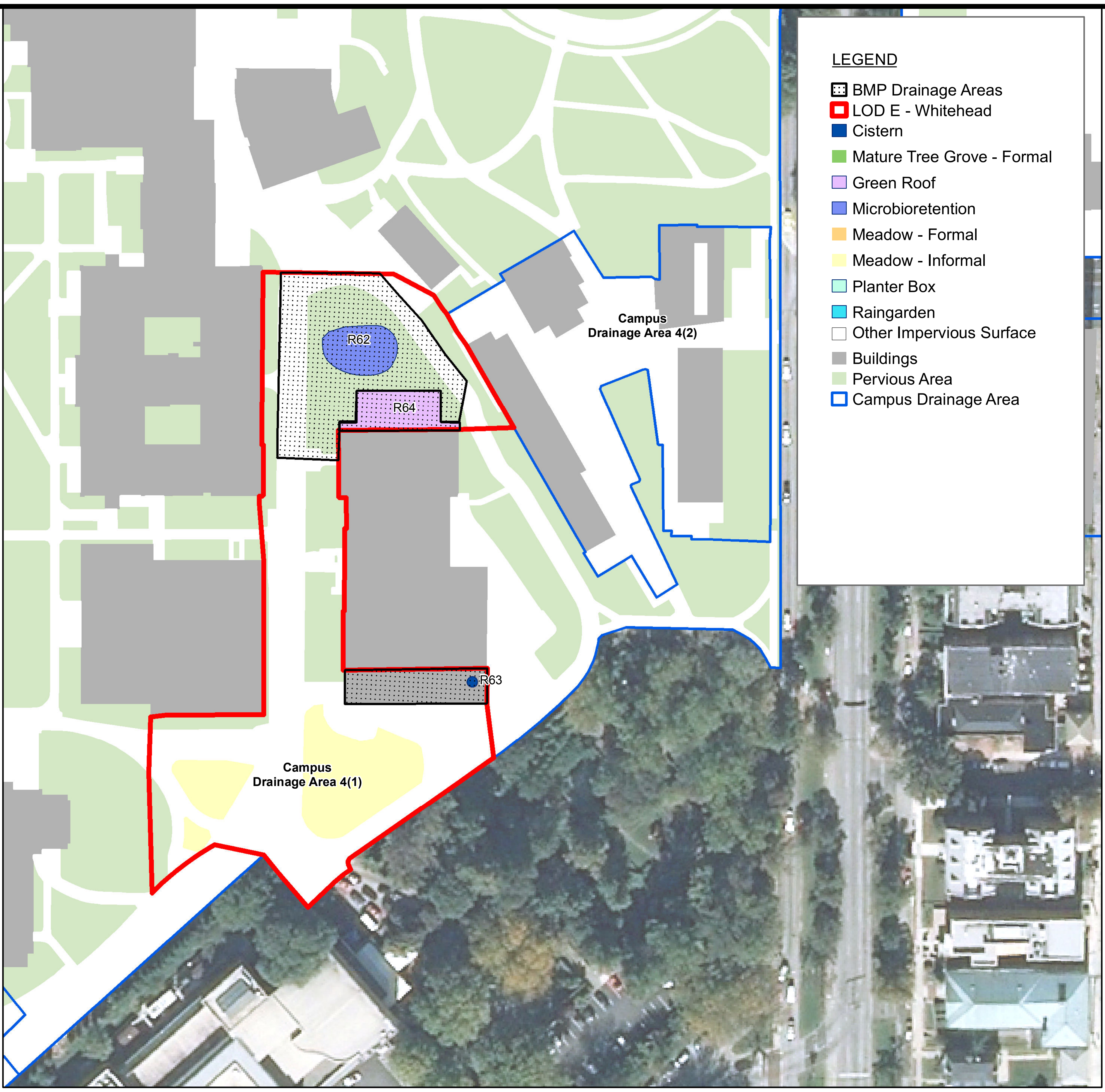
Figure 17



Johns Hopkins Homewood Campus - LOD E 1 Inch = 100 Feet

N 100 Feet

NOTE: Treated Environmental Site Design Volume (ESD_V) Calculations

ESD_v for microbioretention and raingarden practices is calculated using the following equation:

ESD_v = P_E (inches) x R_V x DA (square feet) x (1 foot / 12 inches) where:

R_v = 0.05 + 0.009 x (IA [square feet] / DA [square feet]) x 100, where IA is the impervious portion of the BMP drainage area (DA); and

P_E = 10 (inches) x A_f (square feet) / DA (square feet) for raingarden, and

P_E = 15 (inches) x A_f (square feet) / DA (square feet) for microbioretention, where

A_f is the BMP footprint

ESD_v for cisterns is the captured volume of runoff.

Cisterns are designed to capture a minimum of 0.2 inches of rainfall from the contributing rooftop area (DA).

P_E = ESD_v (cubic feet) / DA (square feet) x (12 [inches] / 1 [foot])

ESD_v for greenroofs is calculated from the ESD_v / DA ratio.

ESD_v = 0.077 (feet) x A_f (square feet), for roof thickness = 4" (as applied to greenroofs in LOD A and LOD B)

ESD_v = 0.095 (feet) x A_f (square feet), for roof thickness = 6" (as applied to greenroofs in LOD E)

Table E-1
LOD E--Whitehead
Best Management Practices

BMP ID	Type of BMP	Year	Footprint (sf)	Drainage Area to BMP (sf)	Impervious Area in BMP Drainage Area (sf)	R_v	P_E (in)	Captured ESD_v (cf)
Campus Drainage Area 4 (1)								
R62	Microbioretention	2017	2,450	18,130	7,250	0.4099	2.0	1,238.58
R63	Cistern	2017	70	3,920	3,920	0.9500	1.6	530.00
R64	Greenroof	2017	2,950	2,950	2,950	NA	1.2	280.25
				Total Provided A_T in LOD	**14,120**	**Total Provided ESD_v in LOD**		**2,048.83**

Table E-2
LOD E - Whitehead
Campus Drainage Area Information

Campus Drainage (DA)	Area within LOD (sf)	% Area of LOD	Required A_T (sf)	Required A_T (ac)	Provided A_T (sf)	Provided A_T (ac)	Required ESD_v (cf)	Provided ESD_v (cf)
4 (1)	83,780	100%	21,780	0.50	14,120	0.32	1,982.15	2,048.83
Totals	83,780	100%	21,780	0.50	14,120	0.32	**1,982.15**	**2,048.83**

ESD_V requirements have been met. An additional ESD_V = 66.68 cf is provided to make up for deficits within other LODs.
Provided A_T is 0.18 ac less than required. The balance is made up within other LODs.

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Proposed Environmental Site Design
Limit of Disturbance (LOD) E - Whitehead

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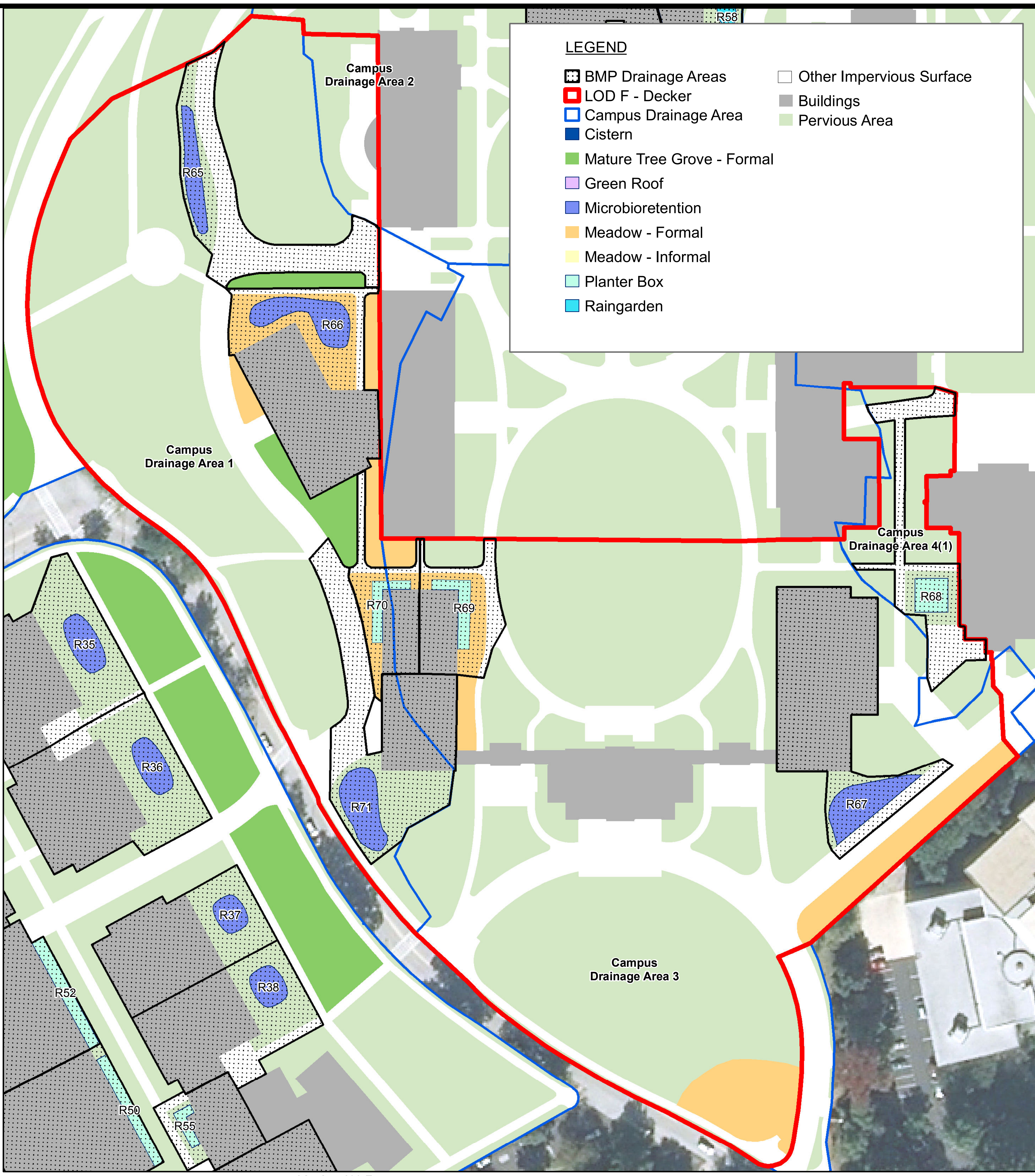

Johns Hopkins Homewood Campus - LOD F

1 Inch = 100 Feet

100 Feet

N

NOTE: Treated Environmental Site Design Volume (ESD_v) Calculations

ESD_v for microbioretention and raingarden practices is calculated using the following equation:

$ESD_v = P_E$ (inches) x R_V x DA (square feet) x (1 foot / 12 inches) where:

R_v = 0.05 + 0.009 x (IA [square feet] / DA [square feet]) x 100, where IA is the impervious portion of the BMP drainage area (DA); and

P_E = 10 (inches) x A_f (square feet) / DA (square feet) for raingarden, and

P_E = 15 (inches) x A_f (square feet) / DA (square feet) for microbioretention, where

A_f is the BMP footprint

ESD_v for cisterns is the captured volume of runoff.

Cisterns are designed to capture a minimum of 0.2 inches of rainfall from the contributing rooftop area (DA).

$P_E = ESD_v$ (cubic feet) / DA (square feet) x (12 [inches] / 1 [foot])

ESD_v for greenroofs is calculated from the ESD_v / DA ratio.

ESD_v = 0.077 (feet) x A_f (square feet), for roof thickness = 4" (as applied to greenroofs in LOD A and LOD B)

ESD_v = 0.095 (feet) x A_f (square feet), for roof thickness = 6" (as applied to greenroofs in LOD E)

Table F-1

LOD F--Decker

Best Management Practices

BMP ID	Type of BMP	Year	Footprint (sf)	BMP Drainage Area (sf)	Impervious Area in BMP Drainage Area (sf)	R_v	P_E (in)	Captured ESD_v (cf)
Campus Drainage Area 1								
R65	Microbioretention	2027	1,560	12,790	8,910	0.6770	1.8	1,298.82
R66	Microbioretention	2022	2,340	20,000	13,100	0.6395	1.8	1,918.50
R70	Microbioretention - Planter box	2022	800	6,470	3,880	0.5897	1.9	604.10
R71	Microbioretention	2022	2,240	19,020	12,030	0.6192	1.8	1,766.58
				Total A_T	37,920		**Total ESD_V**	5,588.00
Campus Drainage Area 3								
R67	Microbioretention	2017	2,360	19,980	16,250	0.7820	1.8	2,343.65
R69	Microbioretention - Planter box	2022	980	7,750	4,680	0.5935	1.9	728.27
				Total A_T	20,930		**Total ESD_V**	3,071.93
Campus Drainage Area 4 (1)								
R68	Microbioretention - Planter box	2017	990	8,400	5,900	0.6821	1.8	859.45
				Total A_T	5,900		**Total ESD_V**	859.45
				Total Provided A_T in LOD (sf)	**64,750**		**Total Provided ESD_v in LOD**	**9,519.38**

Table F-2

LOD F -Decker

Campus Drainage Area Information

Campus Drainage (DA)	Area within LOD (sf)	% Area of LOD	Required A_T (sf)	Required A_T (ac)	Provided A_T (sf)	Provided A_T (ac)	Required ESD_v (cf)	Provided ESD_v (cf)
1	168,490	40%	33,980	0.78	37,920	0.87	4,784.12	5,588.00
2	9,430	2%	1,700	0.04	0	0.00	239.21	0.00
3	226,070	53%	45,020	1.03	20,930	0.48	6,338.96	3,071.93
4 (1)	20,830	5%	4,250	0.10	5,900	0.14	598.02	859.45
Totals	424,820	100%	**84,950**	**1.95**	**64,750**	**1.49**	**11,960.31**	**9,519.38**

ESD practices were proposed to the maximum extent practicable to meet ESD_V, Re_V, and A_T requirements. The required Re_V (554.52 cf) is provided for in micro-bioretention practices. Provided ESD_V is 2,440.93 cf less than required. Provided A_T is 0.46 ac less than required. The balance of both is made up within other LODs.

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Johns Hopkins University

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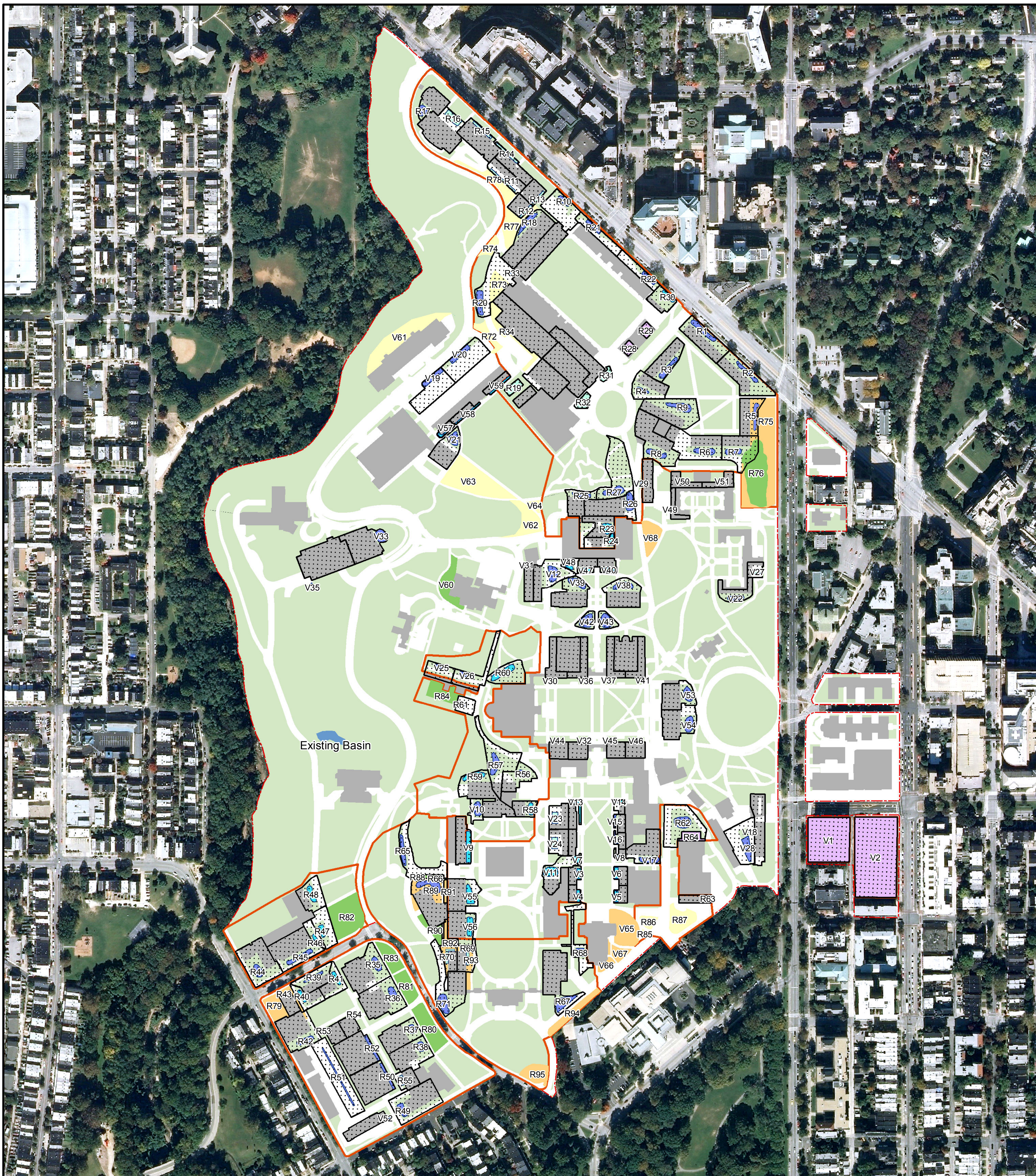
Proposed Environmental Site Design
Limit of Disturbance (LOD) F - Decker

Figure 19

Project 51110.0001



- Cistern
- Mature Tree Grove - Formal
- Green Roof
- Microbioretention
- Meadow - Formal
- Meadow - Informal
- Planter Box
- Raingarden
- Other Impervious Surface
- Buildings
- Pervious Area
- Existing Basin
- BMP Drainage Areas
- LOD
- SWMMP Boundary

400 Feet

N

Stormwater Management Master Plan
Johns Hopkins University

Homewood Campus
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Baltimore, Maryland 21218

BMP Campus Layout
SWMMP Scenario

1 Inch = 400 Feet

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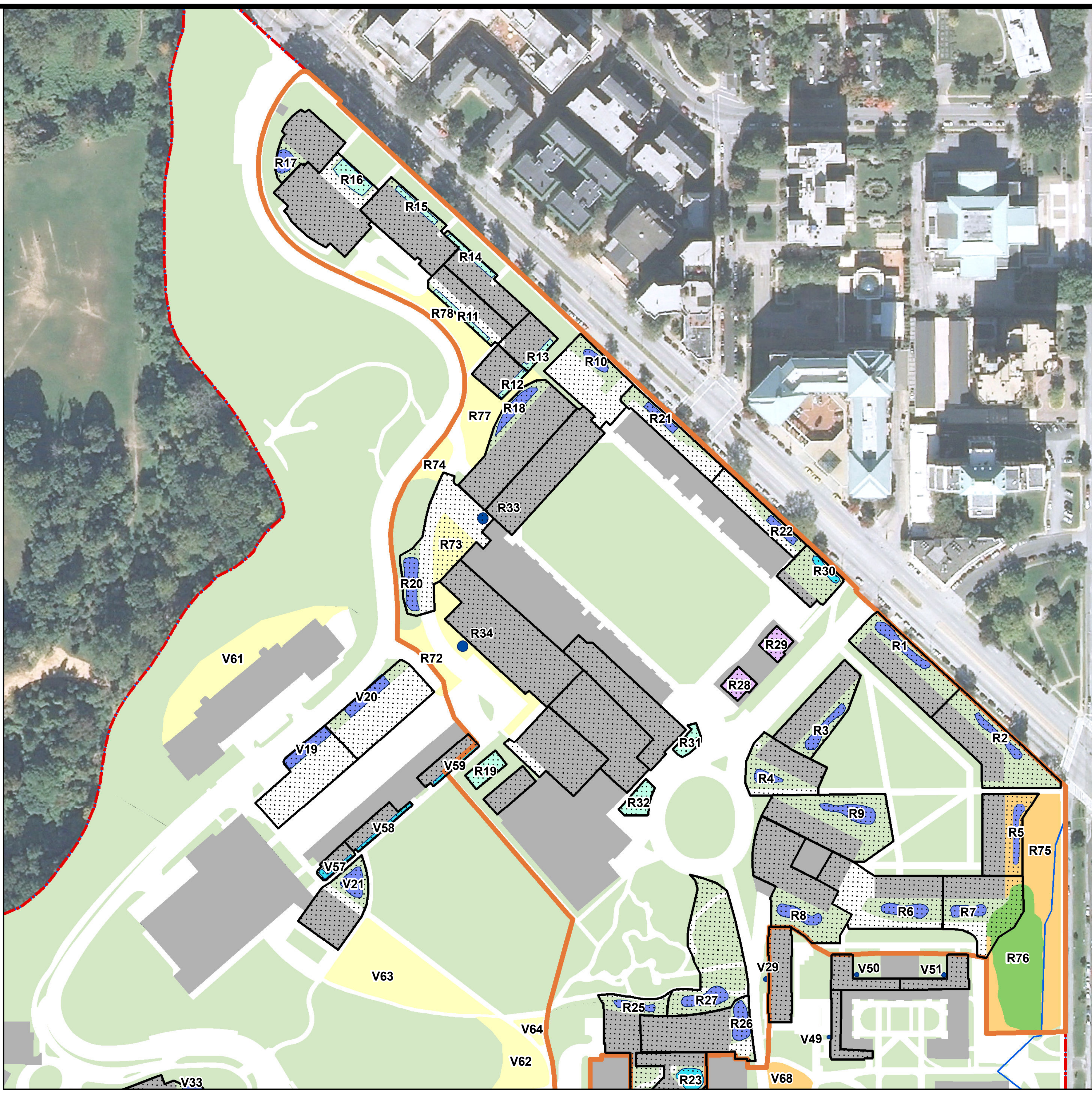
Figure 20

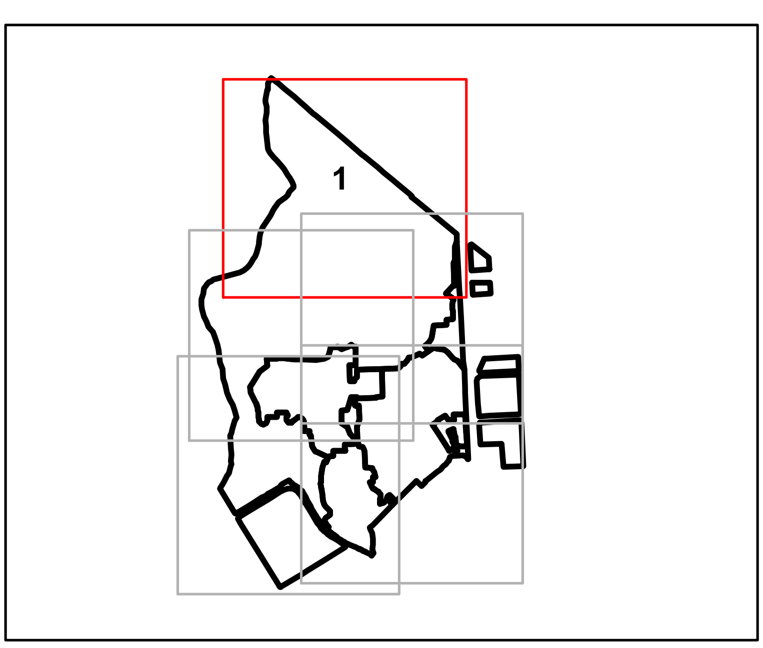


Johns Hopkins Homewood Campus - SWMMP Scenario, Area 1

1 Inch = 200 Feet

200 Feet

N



LEGEND

- BMP Drainage Areas
- LOD A - University Parkway
- Campus Drainage Area
- Cistern
- Mature Tree Grove - Formal
- Green Roof
- Microbioretention
- Meadow - Formal
- Meadow - Informal
- Planter Box
- Raingarden
- Other Impervious Surface
- Buildings
- Pervious Area
- SWMMP Boundary

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Johns Hopkins University

Homewood Campus
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Proposed Stormwater Best Management Practices
SWMMP Scenario
Area 1

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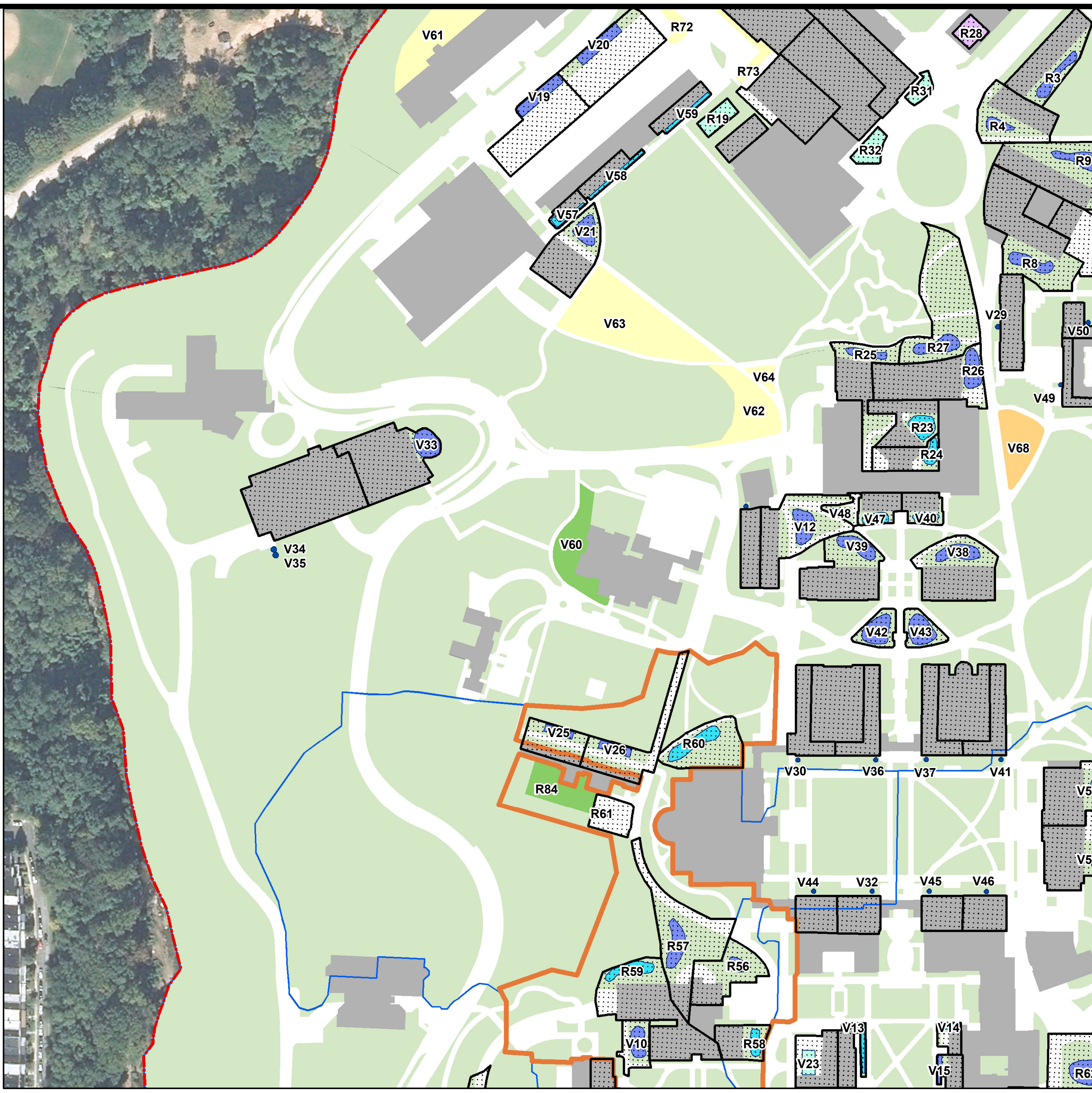
Figure 21

Project 51110.0001

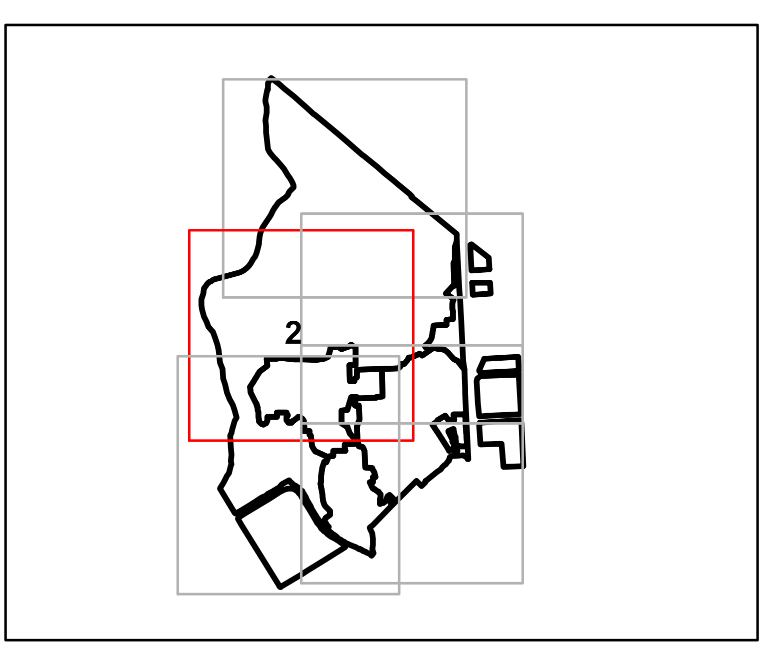


Johns Hopkins Homewood Campus - SWMMP Scenario, Area 2

1 Inch = 200 Feet

200 Feet

N



LEGEND

- BMP Drainage Areas
- LOD D - Gilman
- Campus Drainage Area
- Cistern
- Mature Tree Grove - Formal
- Green Roof
- Microbioretention
- Meadow - Formal
- Meadow - Informal
- Planter Box
- Raingarden
- Other Impervious Surface
- Buildings
- Pervious Area
- SWMMP Boundary

Stormwater Management Master Plan
Johns Hopkins University

Homewood Campus
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Proposed Stormwater Best Management Practices
SWMMP Scenario
Area 2

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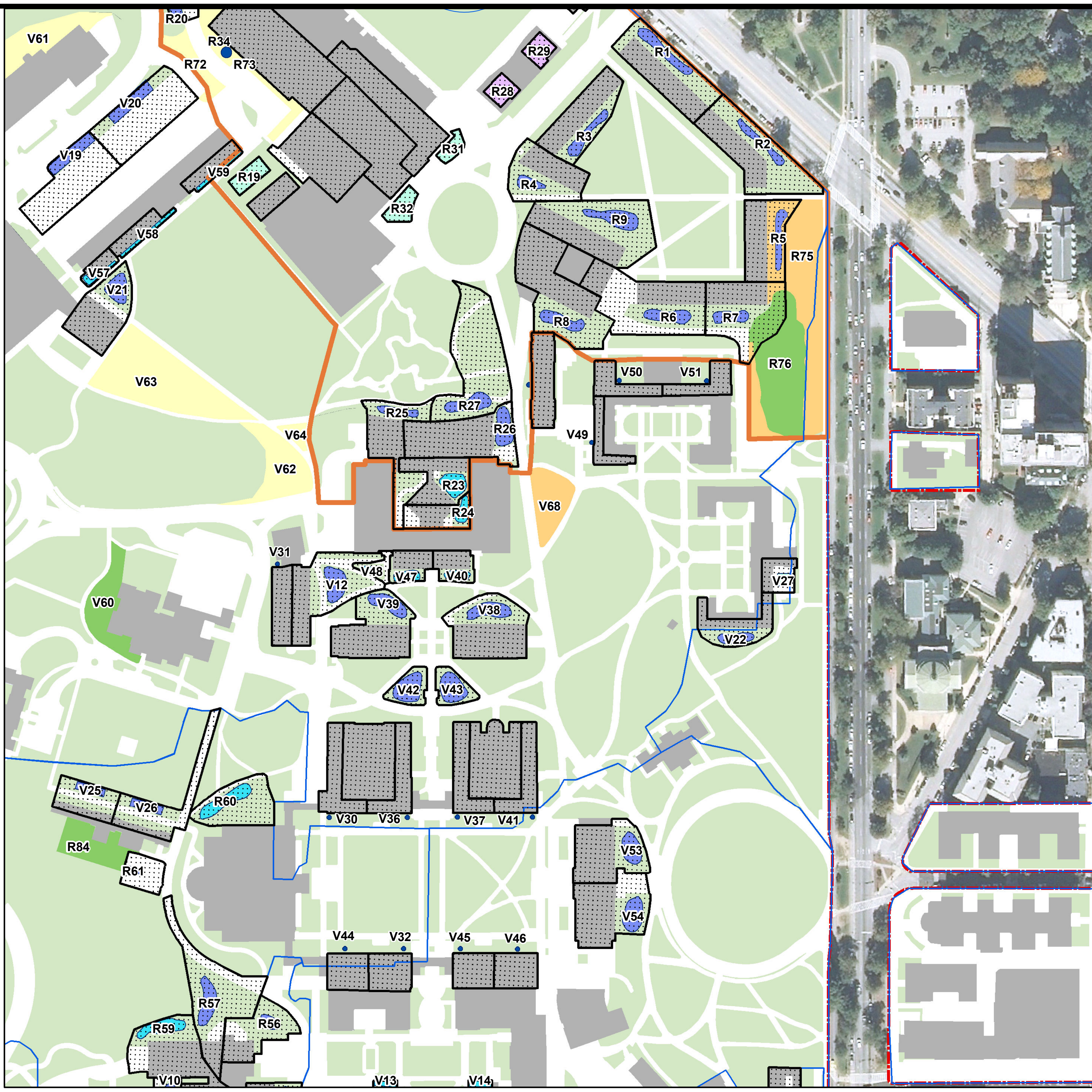
Figure 22

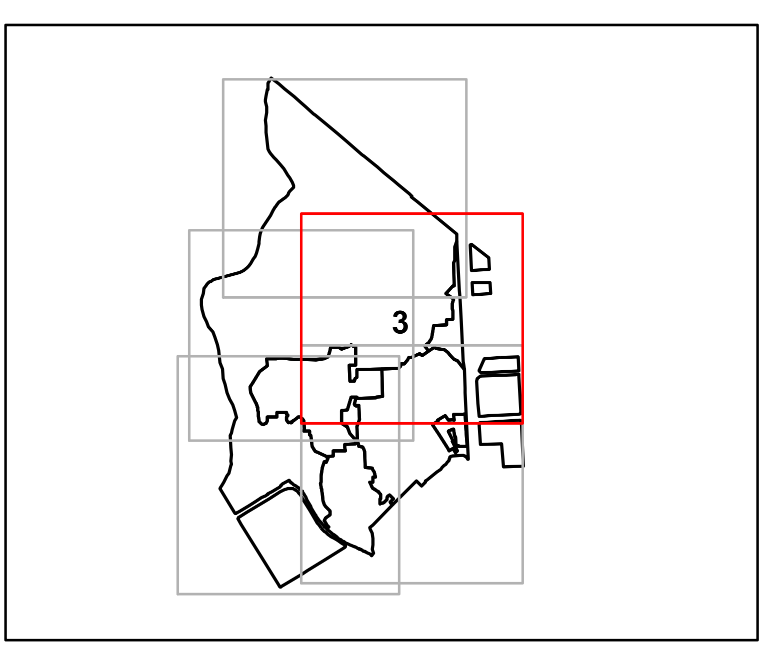


Johns Hopkins Homewood Campus - SWMMP Scenario, Area 3

1 Inch = 200 Feet

200 Feet

N



LEGEND

- BMP Drainage Areas
- DrainageArea
- LOD A - University Parkway
- Cistern
- Mature Tree Grove - Formal
- Green Roof
- Microbioretention
- Meadow - Formal
- Meadow - Informal
- Planter Box
- Raingarden
- Other Impervious Surface
- Buildings
- Pervious Area
- SWMMP Boundary

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Johns Hopkins University

Homewood Campus
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Proposed Stormwater Best Management Practices
SWMMP Scenario
Area 3

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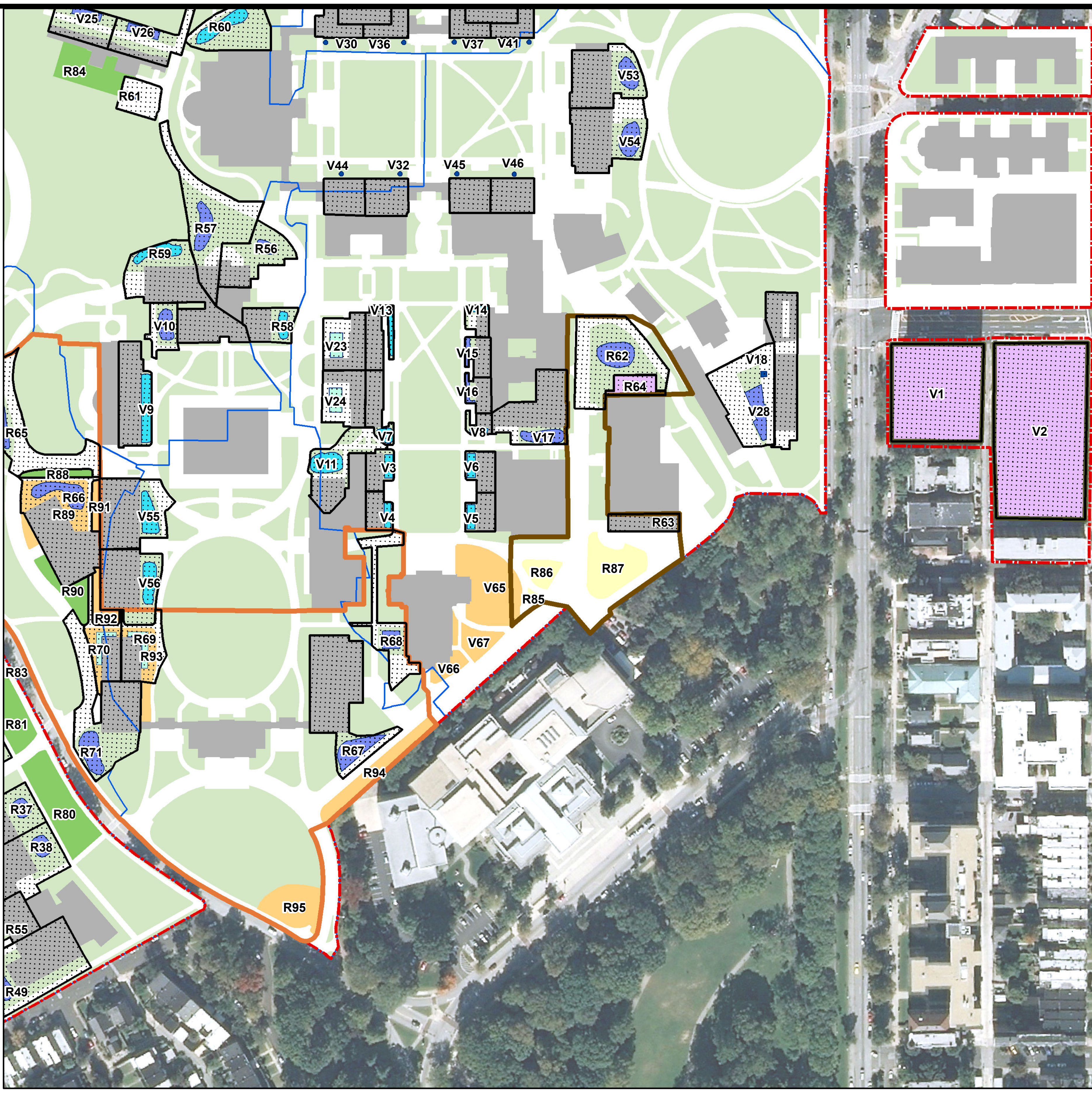
Figure 23

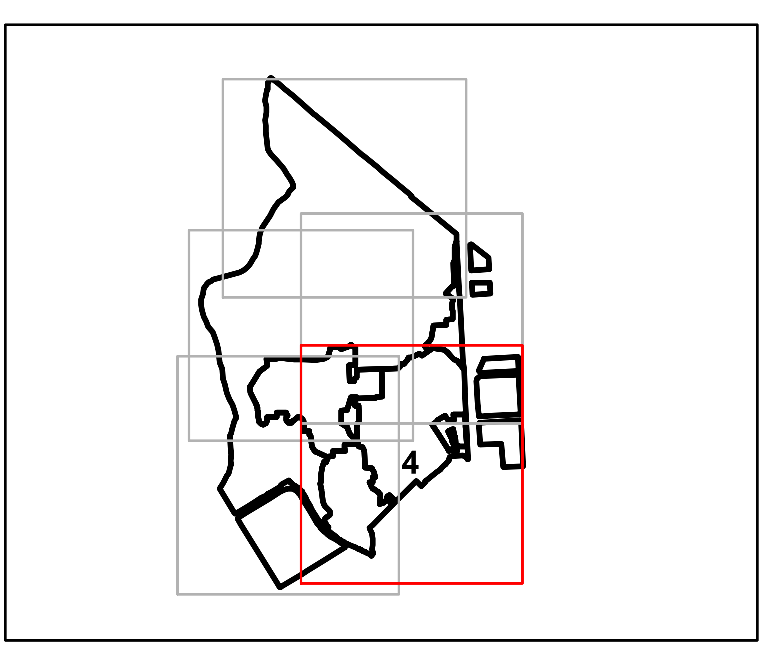


Johns Hopkins Homewood Campus - SWMMP Scenario, Area 4

1 Inch = 200 Feet

200 Feet

N



LEGEND

- BMP Drainage Areas
- LOD F - Decker
- LOD E - Whitehead
- LOD B - St. Paul
- Campus Drainage Area
- Cistern
- Mature Tree Grove - Formal
- Green Roof
- Microbioretention
- Meadow - Formal
- Meadow - Informal
- Planter Box
- Raingarden
- Other Impervious Surface
- Buildings
- Pervious Area
- SWMMP Boundary

Stormwater Management Master Plan
Johns Hopkins University

Homewood Campus
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Proposed Stormwater Best Management Practices
SWMMP Scenario
Area 4

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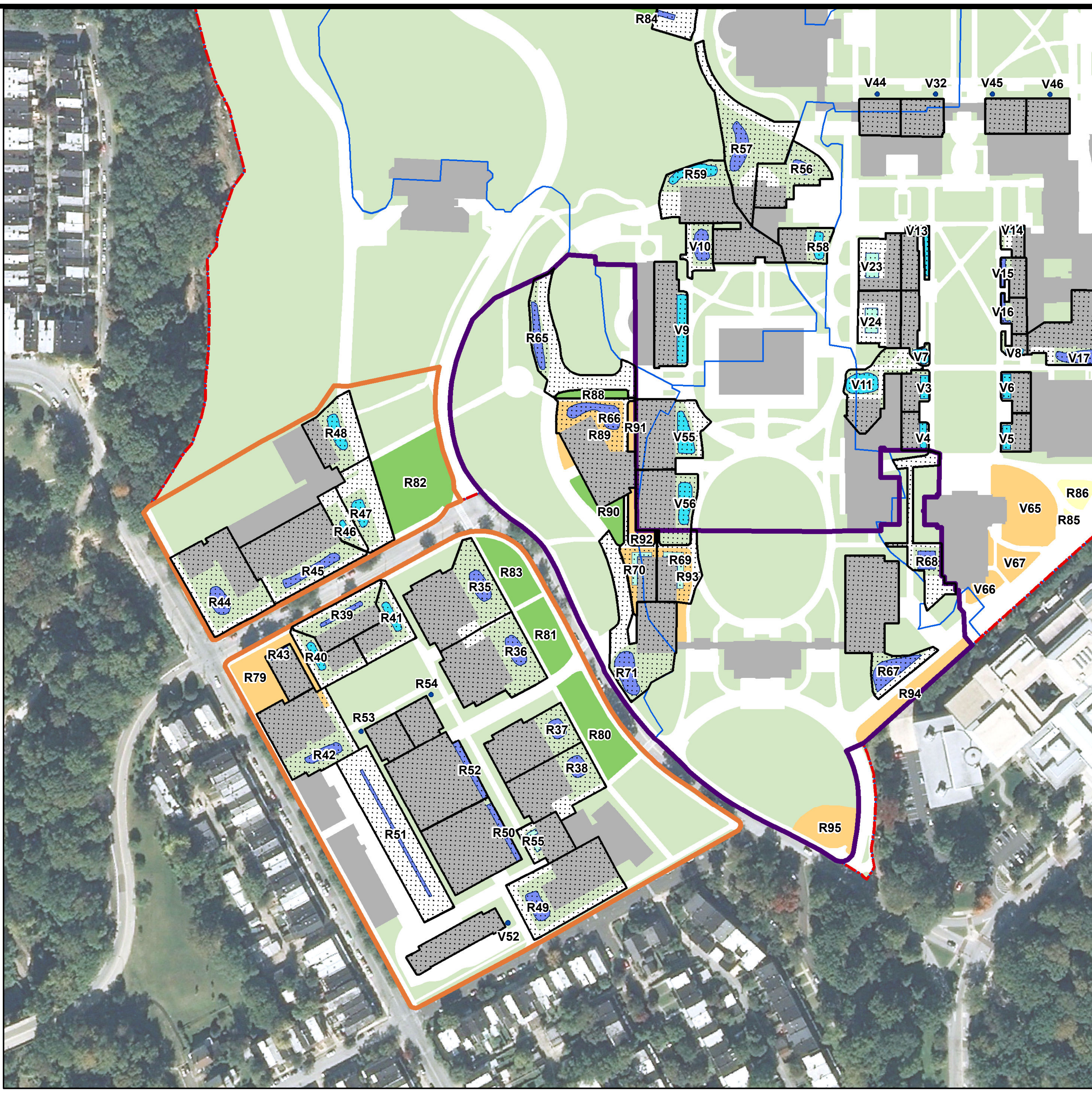
Figure 24

Project 51110.0001

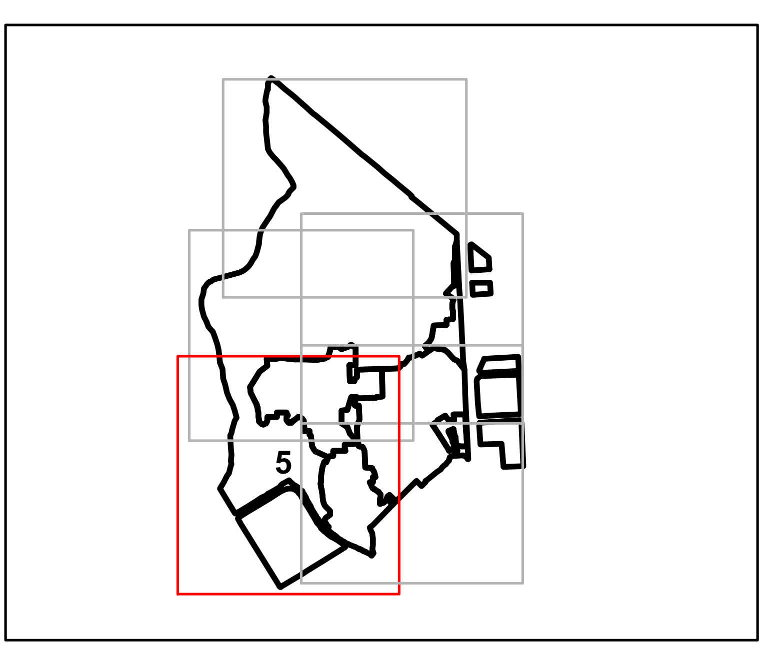


Johns Hopkins Homewood Campus - SWMMP Scenario, Area 5

1 Inch = 200 Feet

200 Feet

N



LEGEND

- BMP Drainage Areas
- LOD F - Decker
- LOD C - Wyman Park
- Campus Drainage Area
- Cistern
- Mature Tree Grove - Formal
- Green Roof
- Microbioretention
- Meadow - Formal
- Meadow - Informal
- Planter Box
- Raingarden
- Other Impervious Surface
- Buildings
- Pervious Area

Stormwater Management Master Plan
Johns Hopkins University

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Proposed Stormwater Best Management Practices
SWMMP Scenario
Area 5

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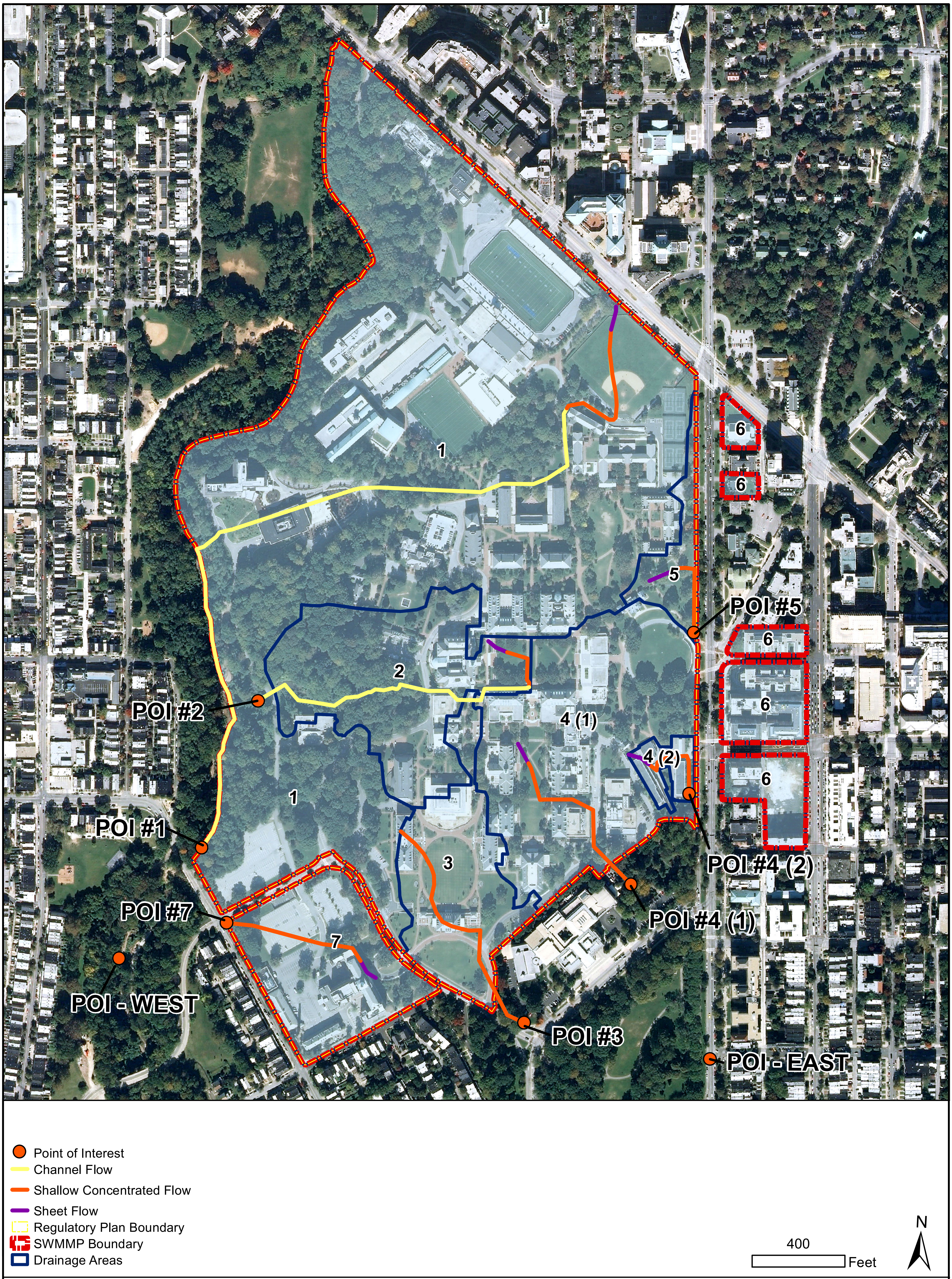
Figure 25

Project 51110.0001



Stormwater Management Master Plan
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Drainage Areas

1 Inch = 400 Feet

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Figure 26