Appendix A – Scope of Services

NPDES Stormwater and Clintonville Blueprint Monitoring Project

The Engineer shall furnish all labor, materials, equipment, and supervision necessary to complete the wet weather monitoring requirements specified in the City's MS4 Permit and the following goals:

Task 1 - Storm Water Quantity, Quality and Public Health

1. Quantify changes in storm water flow from green infrastructure using simulated storm and actual rainfall events.
2. Quantify changes in storm water quality from green infrastructure using simulated storm and actual rainfall events.
3. Quantify reduction in storm water flow, pollutants, and microorganisms and pathogens in storm water released from areas with green infrastructure and compare to control areas without green infrastructure. Use Microbial Source Tracking to determine the origin of indicator microorganisms and pathogens (e.g. humans, domestic animals, or wildlife).
4. Predict the impact of the complete installation of green infrastructure projects as part of Blueprint Columbus-Clintonville to reduce pathogens and stormwater runoff and improve water quality.

Task 2 - Social and Economic Impacts

1. Determine whether and to what extent property values increase or decrease as a result of GI projects relative to control neighborhoods, and how these effects vary with the different attributes of green infrastructure.
2. Value other ecosystem services that are generated by the green infrastructure projects, including habitat, water quality, health and social benefits, and how the valuation of these services varies with the different attributes of green infrastructure.
3. Determine whether residents in treated neighborhoods find green infrastructure to be aesthetically pleasing and are generally satisfied with the installation of green infrastructure.
4. Determine whether and to what extent the factors listed below change and compare between the Blueprint project areas and nearby control neighborhoods.
    a. Overall well-being and specific components of well-being among individuals
    b. Social capital, community attachment, pro-sociality, and cooperation
    c. Preferences for walking and overall physical activity

d. Environmental behavior, particularly behaviors related to water use and water pollution (e.g. installing rain barrels, planting native gardens on homeowners property, reducing water use within the home, etc.).

Task 3 - Habitat Creation and Biodiversity

1. Determine the effect of green storm water infrastructure on habitat and biodiversity by analyzing the composition of insect and bird communities
2. Include these changes in economic valuation as biodiversity improvement.
3. By comparing impacts of different green infrastructure designs across the five study areas identify design differences to increase the ecological value of green infrastructure.

Incorporated to the Scope of Services by reference, and included as Appendix G, is the proposal titled *Holistic Research & Monitoring to Determine Impacts of Blueprint Columbus-Clintonville*.

In addition, the Engineer shall perform the following:

Quality Assurance Project Plan

Prior to any sampling work, the Engineer shall prepare a Quality Assurance Project Plan (QAPP), patterned after the elements provided in the U.S. EPA's *Guidance for Quality Assurance Project Plans*, that describes the activities that will be performed to complete the sampling, analytical, monitoring, and reporting tasks. The QAPP shall document the results of the project's technical planning process; provide a clear, concise, and complete plan for task performance; identify quality assurance and quality control objectives and procedures; and identify key project personnel that will be responsible for performing each task.

Procedures outlined in the QAPP shall be followed during the completion of each task and throughout the duration of the project. The City recognizes that there may be instances where procedures specified in the QAPP may require revision due to circumstances that were unknown at the beginning of the project. In stances where it is found that a procedure specified in the QAPP is impracticable, the QAPP shall be revised to incorporate an alternative procedure and justification of the change shall be provided. In no instance shall changes be made within the QAPP without prior approval by the City.

Permits and Maintenance of Traffic

The following task shall be performed to comply with City permitting requirements and to ensure the safety of the Engineer's sampling/monitoring crews and traveling public.

The Engineer shall procure the necessary right-of-way permits form the City's Transportation Division where any wet weather sampling or simulated rainfall tasks are to be performed within city right-of-way.

The Engineer shall provide for the maintenance of vehicular and pedestrian traffic to ensure that any wet weather sampling or simulated rainfall tasks are conducted safely where such tasks are to be performed in or around vehicular and pedestrian traffic.

Wet Weather Monitoring

The following tasks shall be performed to collect the necessary water quality samples, precipitation information, and flow information as required in the City's MS4 Permit. No additional compensation will be considered beyond the negotiated cost of serves for after-hours sampling.

The Engineer shall collect, maintain records of, and report on the following information for each wet weather event that is monitored at each of the outfalls that are to be monitored as part of this project.

- Date and duration (in hours) for all storm events sampled. The Engineer may use City rainfall gages to acquire this information.
- The rainfall measurements (in inches) of the storm event which generated each sampled runoff.
- The duration (in hours) between the storm event sampled and the end of the previous measurable storm event for all storm events that are sampled. A written justification for the lag time between storms that was used must be provided in the summary report.
- Total runoff volumes (in gallons) of all discharges that are sampled.

Laboratory Analysis

The following table lists the constituents and minimum detection limits for which the Engineer shall collect samples to test.

Parameter	Abbreviation	Unit of Measure	Detectible Limit
Fecal Coliform	-	# / 100 ml	1.0 / 100 ml
E. Coli	-	# / 100 ml	1.0 / 100 ml
Nitrite	NO_2	mg / l	0.05 mg / l
Total Phosphorous	-	mg / l	1.0 mg / l
Orthophosphate	-	mg / l	0.05 mg / l
Carbonaceous Biochemical Oxygen Demand	$CBOD_5$	mg / l	2.0 mg / l
Biochemical Oxygen Demand	BOD_5	mg / l	1.0 mg / l
Chemical Oxygen Demand	COD	mg / l	1.0 mg / l
Total Suspended Solids	TSS	mg / l	0.05 mg / l

Ammonia	NH_3	mg / l	0.02 mg / l
Alkalinity	-	mg / l	1.2 mg / l
Oil and Grease	-	mg / l	1.0 mg / l
Total Cyanide	-	µg / l	0.002 mg / l
Hardness (as $CaCO_3$)	-	mg / l	1.7 mg / l
Total Recoverable Cadmium	Cd	µg / l	0.00011 mg / l
Total Recoverable Chromium	Cr	µg / l	0.005 mg / l
Total Recoverable Copper	Cu	µg / l	0.00075 mg / l
Total Recoverable Lead	Pb	µg / l	0.00034 mg / l
Total Recoverable Nickel	Ni	µg / l	0.0055 mg / l
Total Recoverable Zinc	Zn	µg / l	0.001 mg / l

Data Evaluation and Report Preparation

The Engineer shall prepare and submit a report annually that summarizes the sampling, analysis, and evaluation of data collected. The summary reports shall be submitted for incorporation in the City's annual report to Ohio EPA and shall meet the requirements specified in the City's MS4 Permit. The Engineer shall perform statistical analyses of the data generated to identify any long term and short term trends in the results obtained. The Engineer shall prepare a draft report for the City's review. The final report must be submitted to the City by March 1 of each year.

Project Management

The Engineer shall provide the necessary project management to schedule, coordinate, and manage the necessary equipment and personnel to perform the services required. Project Management services shall include, but are not limited to, scheduling, invoicing, and participating in quarterly progress meetings with the City. Within thirty (30) days of contract award, the Engineer shall prepare and submit a schedule that includes all meeting and deliverable dates associated with this project. The Engineer shall participate in one kick-off meeting at the beginning of the project.

Appendix B - Estimate of Labor Hours
NPDES Stormwater and Clintonville Blueprint Monitoring Project

	professor 1	professor 2	professor 3	professor 4	graduate student	undergrad	research assoc
Task 1 - Stormwater Quantity, Quality, and Public Health							
Goal 1	176	0	0	0	1274	637	602
Goal 2	176	0	0	0	1274	637	602
Goal 3	101	0	0	448	728	364	344
Goal 4	50	0	0	0	364	182	172
Task 2 - Social and Economic Impacts							
Goal 1	63	84	0	0	455	228	0
Goal 2	63	84	0	0	455	228	0
Goal 3	63	84	0	0	455	228	0
Goal 4	63	84	0	0	455	228	0
Task 3 - Habitat Creation and Biodiversity							
Goal 1	113	0	151	0	819	410	0
Goal 2	50	0	67	0	364	182	0
Goal 3	88	0	118	0	637	319	0
total hours	1008	336	336	448	7280	3640	1720

APPENDIX C - PROJECT COST SUMMARY

NPDES Stormwater and Clintonville Blueprint Monitoring Project

1. CITY: COLUMBUS, OHIO	2. CIP NO.			3. VERSION	
DEPT. OF PUBLIC UTILITIES				YEAR 2016	
4. NAME OF CONSULTANT: The Ohio State University	PROJECT TITLE: NPDES Stormwater and Clintonville Blueprint Monitoring Project				
5. ADDRESS: 1960 Kenny Road; Columbus, OH 43210-1016				6. TYPE OF CONTRACT: DIRECT HOURLY w/MULTIPLIER	
7. DIRECT LABOR (DL)	LABOR CATEGORY		EST. HOURS	MAX HOURLY RATE	TOTALS
	prof1		144	109.67	
	prof2		48	109.05	
	prof3		48	63.75	
	prof4		64	86.69	
	Research Assoc		660	52.01	
	grad		1040	55.16	
	undergrad		520	10.71	
				DL TOTAL	126,897.24
8. HOURLY COST MULTIPLIER HCM = (1+OR+NF)					
OR = Overhead Rate	91.47	%		$116,071.10	
NF = Net Fee or Profit	8.15	%		$19,801.92	
				HCM TOTAL	$135,873.02
9.TOTAL LABOR COSTS					$262,770.26
10. Other Direct Costs				EST. COST	
a. travel				$0.00	
b. Equipment, materials, supplies					
(Consumable supplies for monitoring/sampling activities)					
			E, M &S Subtotal	$35,560.00	
c. Other					
testing lab				$7,000.00	
survey				$6,120.00	
			Other Subtotal	13,120.00	
				ODC TOTAL	$48,680.00
11. TOTAL COST (SUM OF Line 9 + Line 10)					$311,450.26
12 If Authorized	0	% of line 11			$0.00
13. CONTRACT GRAND TOTAL					**$311,450.26**

APPENDIX C - PROJECT COST SUMMARY

NPDES Stormwater and Clintonville Blueprint Monitoring Project

1. CITY: COLUMBUS, OHIO	2. CIP NO.			3. VERSION	
DEPT. OF PUBLIC UTILITIES				YEAR 2017	
4. NAME OF CONSULTANT: The Ohio State University	PROJECT TITLE: NPDES Stormwater and Clintonville Blueprint Monitoring Project				
5. ADDRESS: 1960 Kenny Road; Columbus, OH 43210-1016				6. TYPE OF CONTRACT: DIRECT HOURLY w/MULTIPLIER	
7. DIRECT LABOR (DL)	LABOR CATEGORY		EST. HOURS	MAX HOURLY RATE	TOTALS
	prof1		144	112.96	
	prof2		48	112.32	
	prof3		48	65.66	
	prof4		64	89.29	
	Research Assoc		660	53.57	
	grad		1040	56.82	
	undergrad		520	11.03	
				DL TOTAL	130,708.44
8. HOURLY COST MULTIPLIER HCM = (1+OR+NF)					
OR = Overhead Rate	91.47	%		$119,557.15	
NF = Net Fee or Profit	8.15	%		$20,396.65	
				HCM TOTAL	$139,953.80
9.TOTAL LABOR COSTS					$270,662.24
10. Other Direct Costs				EST. COST	
a. travel				$0.00	
b. Equipment, materials, supplies					
(Consumable supplies for monitoring/sampling activities)					
E, M &S Subtotal				$6,990.00	
c. Other					
testing lab				$7,140.00	
survey				$0.00	
Other Subtotal				7,140.00	
				ODC TOTAL	$14,130.00
11. TOTAL COST (SUM OF Line 9 + Line 10)					$284,792.24
12 If Authorized 0 % of line 11					$0.00
13. CONTRACT GRAND TOTAL					**$284,792.24**

APPENDIX C - PROJECT COST SUMMARY

NPDES Stormwater and Clintonville Blueprint Monitoring Project

1. CITY: COLUMBUS, OHIO	2. CIP NO.			3. VERSION	
DEPT. OF PUBLIC UTILITIES				YEAR 2018	
4. NAME OF CONSULTANT: The Ohio State University	PROJECT TITLE: NPDES Stormwater and Clintonville Blueprint Monitoring Project				
5. ADDRESS: 1960 Kenny Road; Columbus, OH 43210-1016				6. TYPE OF CONTRACT: DIRECT HOURLY w/MULTIPLIER	
7. DIRECT LABOR (DL)	LABOR CATEGORY		EST. HOURS	MAX HOURLY RATE	TOTALS
	prof1		144	116.35	
	prof2		48	115.69	
	prof3		48	67.63	
	prof4		64	91.97	
	Research Assoc		400	53.89	
	grad		1040	58.52	
	undergrad		520	11.36	
				DL TOTAL	119,763.84
8. HOURLY COST MULTIPLIER HCM = (1+OR+NF)					
OR = Overhead Rate	91.47	%		$109,546.28	
NF = Net Fee or Profit	8.15	%		$18,688.78	
				HCM TOTAL	$128,235.06
9.TOTAL LABOR COSTS					$247,998.90
10. Other Direct Costs				EST. COST	
	a. travel			$0.00	
	b. Equipment, materials, supplies				
	(Consumable supplies for monitoring/sampling activities)				
			E, M &S Subtotal	$250.00	
	c. Other				
	testing lab			$7,282.80	
	survey			$6,493.00	
			Other Subtotal	13,775.80	
				ODC TOTAL	$14,025.80
11. TOTAL COST (SUM OF Line 9 + Line 10)					$262,024.70
12 If Authorized	0	% of line 11			$0.00
13. CONTRACT GRAND TOTAL					**$262,024.70**

APPENDIX C - PROJECT COST SUMMARY

NPDES Stormwater and Clintonville Blueprint Monitoring Project

1. CITY: COLUMBUS, OHIO	2. CIP NO.			3. VERSION	
DEPT. OF PUBLIC UTILITIES				YEAR 2019	
4. NAME OF CONSULTANT: The Ohio State University	PROJECT TITLE: NPDES Stormwater and Clintonville Blueprint Monitoring Project				
5. ADDRESS: 1960 Kenny Road; Columbus, OH 43210-1016				6. TYPE OF CONTRACT: DIRECT HOURLY w/MULTIPLIER	
7. DIRECT LABOR (DL)	LABOR CATEGORY		EST. HOURS	MAX HOURLY RATE	TOTALS
	prof1		144	119.84	
	prof2		48	119.16	
	prof3		48	69.66	
	prof4		64	94.72	
	Research Assoc		0	0.00	
	grad		1040	60.28	
	undergrad		520	11.70	
				DL TOTAL	101,157.60
8. HOURLY COST MULTIPLIER HCM = (1+OR+NF)					
OR = Overhead Rate	91.47	%		$92,527.42	
NF = Net Fee or Profit	8.15	%		$15,785.33	
				HCM TOTAL	$108,312.75
9.TOTAL LABOR COSTS					$209,470.35
10. Other Direct Costs				EST. COST	
a. travel				$0.00	
b. Equipment, materials, supplies					
(Consumable supplies for monitoring/sampling activities)					
			E, M &S Subtotal	$6,950.00	
c. Other					
testing lab				$7,428.46	
survey				$0.00	
			Other Subtotal	7,428.46	
				ODC TOTAL	$14,378.46
11. TOTAL COST (SUM OF Line 9 + Line 10)					$223,848.81
12 If Authorized	0	% of line 11			$0.00
13. **CONTRACT GRAND TOTAL**					**$223,848.81**

APPENDIX C - PROJECT COST SUMMARY

NPDES Stormwater and Clintonville Blueprint Monitoring Project

1. CITY: COLUMBUS, OHIO	2. CIP NO.			3. VERSION	
DEPT. OF PUBLIC UTILITIES				YEAR 2020	
4. NAME OF CONSULTANT: The Ohio State University	PROJECT TITLE: NPDES Stormwater and Clintonville Blueprint Monitoring Project				
5. ADDRESS: 1960 Kenny Road; Columbus, OH 43210-1016				6. TYPE OF CONTRACT: DIRECT HOURLY w/MULTIPLIER	
7. DIRECT LABOR (DL)	LABOR CATEGORY		EST. HOURS	MAX HOURLY RATE	TOTALS
	prof1		144	123.44	
	prof2		48	122.74	
	prof3		48	71.75	
	prof4		64	97.57	
	Research Assoc		0	0.00	
	grad		1040	62.09	
	undergrad		520	12.06	
				DL TOTAL	104,200.16
8. HOURLY COST MULTIPLIER HCM = (1+OR+NF)					
OR = Overhead Rate	91.47	%		$95,310.41	
NF = Net Fee or Profit	8.15	%		$16,260.11	
				HCM TOTAL	$111,570.52
9.TOTAL LABOR COSTS					$215,770.68
10. Other Direct Costs				EST. COST	
a. travel				$0.00	
b. Equipment, materials, supplies					
(Consumable supplies for monitoring/sampling activities)					
			E, M &S Subtotal	$250.00	
c. Other					
testing lab				$7,577.03	
survey				$0.00	
			Other Subtotal	7,577.03	
				ODC TOTAL	$7,827.03
11. TOTAL COST (SUM OF Line 9 + Line 10)					$223,597.71
12 If Authorized	0	% of line 11			$0.00
13. CONTRACT GRAND TOTAL					**$223,597.71**

APPENDIX C - PROJECT COST SUMMARY

NPDES Stormwater and Clintonville Blueprint Monitoring Project

1. CITY: COLUMBUS, OHIO	2. CIP NO.			3. VERSION	
DEPT. OF PUBLIC UTILITIES				YEAR 2021	
4. NAME OF CONSULTANT: The Ohio State University	PROJECT TITLE: NPDES Stormwater and Clintonville Blueprint Monitoring Project				
5. ADDRESS: 1960 Kenny Road; Columbus, OH 43210-1016				6. TYPE OF CONTRACT: DIRECT HOURLY w/MULTIPLIER	
7. DIRECT LABOR (DL)	LABOR CATEGORY		EST. HOURS	MAX HOURLY RATE	TOTALS
	prof1		144	127.14	
	prof2		48	126.42	
	prof3		48	73.90	
	prof4		64	100.49	
	Research Assoc		0	0.00	
	grad		1040	63.95	
	undergrad		520	12.42	
				DL TOTAL	107,321.28
8. HOURLY COST MULTIPLIER HCM = (1+OR+NF)					
OR = Overhead Rate	91.47	%		$98,165.25	
NF = Net Fee or Profit	8.15	%		$16,747.16	
				HCM TOTAL	$114,912.41
9.TOTAL LABOR COSTS					$222,233.69
10. Other Direct Costs				EST. COST	
a. travel				$0.00	
b. Equipment, materials, supplies					
(Consumable supplies for monitoring/sampling activities)					
			E, M &S Subtotal	$1,250.00	
c. Other					
testing lab				$7,728.57	
survey				$7,308.00	
			Other Subtotal	15,036.57	
				ODC TOTAL	$16,286.57
11. TOTAL COST (SUM OF Line 9 + Line 10)					$238,520.26
12 If Authorized	0	% of line 11			$0.00
13. **CONTRACT GRAND TOTAL**					**$238,520.26**

APPENDIX C - PROJECT COST SUMMARY

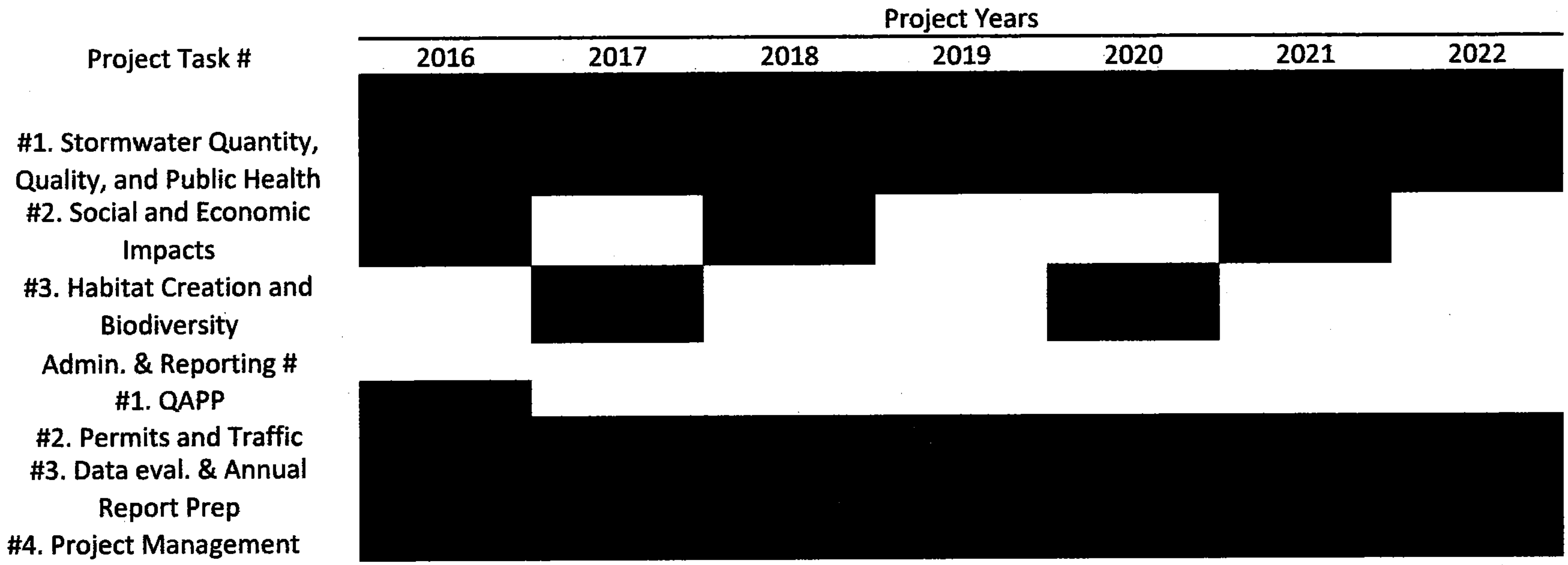
NPDES Stormwater and Clintonville Blueprint Monitoring Project

1. CITY: COLUMBUS, OHIO	2. CIP NO.			3. VERSION	
DEPT. OF PUBLIC UTILITIES				YEAR 2022	
4. NAME OF CONSULTANT: The Ohio State University	PROJECT TITLE: NPDES Stormwater and Clintonville Blueprint Monitoring Project				
5. ADDRESS: 1960 Kenny Road; Columbus, OH 43210-1016				6. TYPE OF CONTRACT: DIRECT HOURLY w/MULTIPLIER	
7. DIRECT LABOR (DL)	LABOR CATEGORY		EST. HOURS	MAX HOURLY RATE	TOTALS
	prof1		144	130.95	
	prof2		48	130.21	
	prof3		48	76.12	
	prof4		64	103.51	
	Research Assoc		0	0.00	
	grad		1040	65.87	
	undergrad		520	12.79	
				DL TOTAL	110,540.88
8. HOURLY COST MULTIPLIER HCM = (1+OR+NF)					
OR = Overhead Rate	91.47	%		$101,110.17	
NF = Net Fee or Profit	8.15	%		$17,249.56	
				HCM TOTAL	$118,359.73
9.TOTAL LABOR COSTS					$228,900.61
10. Other Direct Costs				EST. COST	
	a. travel			$0.00	
	b. Equipment, materials, supplies				
	(Consumable supplies for monitoring/sampling activities)				
			E, M &S Subtotal	$250.00	
	c. Other				
	testing lab			$7,883.14	
	survey			$0.00	
			Other Subtotal	7,883.14	
				ODC TOTAL	$8,133.14
11. TOTAL COST (SUM OF Line 9 + Line 10)					$237,033.75
12 If Authorized	0	% of line 11			$0.00
13. CONTRACT GRAND TOTAL					**$237,033.75**

Appendix D - Maximum Hourly Rate Schedule
NPDES Stormwater and Clintonville Blueprint Monitoring Project

	2016	2017	2018	2019	2020	2021	2022
professor 1	$ 109.67	$ 112.96	$ 116.35	$ 119.84	$ 123.44	$ 127.14	$ 130.95
professor 2	$ 109.05	$ 112.32	$ 115.69	$ 119.16	$ 122.74	$ 126.42	$ 130.21
professor 3	$ 63.75	$ 65.66	$ 67.63	$ 69.66	$ 71.75	$ 73.90	$ 76.12
professor 4	$ 86.69	$ 89.29	$ 91.97	$ 94.72	$ 97.57	$ 100.49	$ 103.51
graduate student	$ 55.16	$ 56.82	$ 58.52	$ 60.28	$ 62.09	$ 63.95	$ 65.87
undergrad	$ 10.71	$ 11.03	$ 11.36	$ 11.70	$ 12.06	$ 12.42	$ 12.79
research assoc	$ 52.01	$ 53.57	$ 53.89	$ 60.28	$ 62.09	$ 63.95	$ 65.87

Appendix E - Project Time Schedule
NPDES Stormwater and Clintonville Blueprint Monitoring Project



Appendix F – Local Workforce Breakdown

Provide a detailed self evaluation of staff and subconsultant utilization estimated for this project in accordance with the Evaluation Criteria. The local workforce information requested shall be detailed enough to enable the City to complete its own evaluation to validate the stated breakdown.

Identify the percentage of the Team paying Columbus income tax on the date the proposal is submitted and the percentage of the Team that is located within Franklin County, but outside Columbus corporate limits. Use this information to determine scoring as stated in the evaluation criteria.

Offeror: _______Ohio State University________________________________
Team % - (Cols. Income Tax/Within Franklin Co.) ___73%_______/______91%_____
Provide office location of team members and indicate whether or not they pay Columbus income tax.:
All team members are employed at Ohio State University, Main Campus, and will pay Columbus income tax related to work location. The percentages above reflect the locations of residences of team members.

Proposed Subcontractor: ____________________________
Contract $ Amount: _________________________
Team % - (Cols. Income Tax/Within Franklin Co.) ___________/___________
Provide office location of team members and indicate whether or not they pay Columbus income tax:

Proposed Subcontractor: ____________________________
Contract $ Amount: _________________________
Team % - (Cols. Income Tax/Within Franklin Co.) ___________/___________
Provide office location of team members and indicate whether or not they pay Columbus income tax:

Proposed Subcontractor: ____________________________
Contract $ Amount: _________________________
Team % - (Cols. Income Tax/Within Franklin Co.) ___________/___________
Provide office location of team members and indicate whether or not they pay Columbus income tax:

Proposed Subcontractor: ____________________________
Contract $ Amount: _________________________
Team % - (Cols. Income Tax/Within Franklin Co.) ___________/___________

Appendix F – Local Workforce Breakdown

Provide office location of team members and indicate whether or not they pay Columbus income tax:

Holistic Research & Monitoring to Determine Impacts of Blueprint Columbus-Clintonville

A Partnership Between:

The City of Columbus **and** **The Ohio State University**

Prepared and Submitted by:

Dr. Jay Martin Dept. of Food, Agricultural & Biological Engineering

Dr. Jeremy Brooks School of Environment and Natural Resources

Dr. Elena Irwin Dept. Agricultural, Environ. & Developmental Econ.

Dr. Jiyoung Lee School of Public Health

Blueprint Columbus represents an unprecedented effort by the City of Columbus to install a network of green infrastructure across the city to address numerous goals. In addition to reducing sanitary sewer overflows, it is hoped that the green infrastructure will improve water quality, provide habitat, improve property values, and help stabilize neighborhoods (Blueprint Columbus website). As shown by the Triple Bottom Line assessment, however, few of these goals have been well-quantified: of those just listed, only housing values appears in the assessment, and this relies on data from other cities, which could differ significantly from Columbus in their response to green infrastructure installation. The research pursued by the OSU team in Clintonville will provide important information to determine impacts of Blueprint Columbus on storm water reduction, water quality improvement, habitat creation, property values, and the stabilization of neighborhoods. This will inform future decisions about infrastructure installation, allowing the city to consider a more accurate and comprehensive cost-benefit analysis. It will also strengthen the case that will be made to the USEPA for supporting Blueprint to fulfill the city's consent order.

Our team at Ohio State is well positioned to collect and analyze the information required to determine if the project goals are being met. We have a group of engineers, ecologists, economists, social scientists, and public health practitioners that are accustomed to working in an interdisciplinary environment, and on projects with a wide scope. Given the opportunity, we can help the City reach its goals and advance our understanding of the benefits of Green Infrastructure. Because of the lengthy timeline of this project, through 2022, we will work with the city on amendments or additions to the project that could arise in future years as needs change.

The proposed research program will address three areas of benefits of green infrastructure, with each lead by faculty members at OSU. Dr. Martin will oversee the project and insure that the results are relevant to the city's needs:

1. Storm Water Quantity, Quality & Public Health (Dr. Martin, Dept. of Food, Agricultural & Biological Engineering and Dr. Jiyoung Lee, College of Public Health, Division of Environmental Health Sciences)
2. Social and Economic Impacts (Dr. Elena Irwin, Dept. of Agricultural, Environmental & Developmental Economics and Dr. Jeremy Brooks, School of Environment & Natural Resources)
3. Habitat Creation and Biodiversity (Dr. Martin, Dept. of Food, Agricultural & Biological Engineering)

1. Storm Water Quantity, Quality and Public Health

Goals:

1. Quantify changes in storm water flow from green infrastructure using simulated storm events.
2. Quantify changes in storm water quality from green infrastructure using simulated storm events.
3. Quantify reduction in storm water flow, pollutants, and microorganisms and pathogens in storm water released from areas with green infrastructure and compare to control areas without green infrastructure. Use Microbial Source Tracking to determine the origin of indicator microorganisms and pathogens (e.g. humans, domestic animals, or wildlife).
4. Predict the impact of the complete installation of green infrastructure projects as part of Blueprint Columbus-Clintonville to reduce pathogens and stormwater runoff and improve water quality.

Approach:

Goals #1 and 2: Two simulated storm events will be completed annually to determine reductions in flow, nitrogen (TN, NO_3, NH_4), phosphorus (TP, PO_4) and sediment (TSS) produced by three green infrastructure installations in each of the six project zones. These events have been successfully used to evaluate the performance of past green infrastructure systems (Hatt *et al.* 2009; Carpenter and Hallam 2010, Schlea *et. al* 2014). The 18 specific sites were selected based on hydrology and piping configurations to permit flow measurements and sample collection (Figure 1). Additional considerations were the inclusion of various types of installations within each of the six project zones, as well as geographic distribution within each project zone (Table 1). For each event we will know the amount of water and nutrients that entered each system, and can compare this with the amount of water and nutrients leaving each system. One piezometer will also be installed in each system with a data logger to record changes in water level. This information along with soil characteristics (i.e. porosity) will allow the calculation of the volume of water within the system. In this manner, we will construct mass balances around each system to determine impacts on water quantity and quality. The volume of water and inflow rate will be selected to mimic common storm events, and experiments will be performed across a range of antecedent moisture conditions. Water quality samples will be analyzed by the DPU water quality lab following standard procedures.

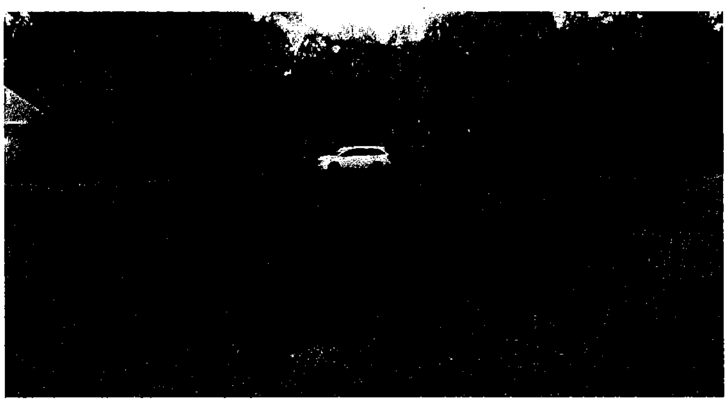


Figure 1. Site of bioinfiltration system at Glenmount Place and Canyon Drive where simulated storm events will be performed to determined reductions in storm water and improvement in water quality. "A-16" on Location Map.

Goal #3: Instrumentation will be installed to quantify the impacts of green infrastructure upon storm water quantity, quality and pathogen levels across three catchments in the Clintonville project area. Three catchments will be identified for monitoring using a mixture of GIS and field-reconnaissance. The monitoring design will target varied intensity of green infrastructure implementation; for example, the research team would identify catchments where 30%, 50%, and 70% of the impervious surfaces will be treated by green infrastructure. Furthermore, the outlet of each catchment (Figure 2) will be checked for "monitorability", ensuring that high-quality hydrologic data sets will be obtained (i.e. no backwater conditions, no mixing with other outfalls, etc.). A fourth nearby catchment will also be identified for monitoring; this catchment will not have SCMs installed, and will therefore serve as a control in the statistical design. This will allow the research team to discern changes in hydrology and water quality due to green infrastructure implementation in the treatment catchments.

Figure 2. Catchment outfalls at Blenheim Rd. and High St. (left) and Overbrook Dr. and Canyon Dr. (right) that will likely be fitted with monitoring equipment for continuous flow measurements and collection of water samples during storm events. Existing gauges deployed by the city (CL 0334 and CL 0394, Location Map) have collected past data at each site.

Following the winter of 2016, monitoring equipment installation will begin at the outlet of each catchment. A flow monitoring structure (flume or weir) in combination with a pressure transducer will be used to *continuously* monitor flows from each catchment. A Doppler-velocity flow meter will be used only if placement of a flume or weir is not possible. Rainfall events will be separated during post-processing to determine the effects of green infrastructure implementation on hydrologic variables of interest (e.g. normalized total flow volume, flow duration, peak flow rate, time to peak). The flow measurement device will be utilized to trigger flow proportional, composite samples from each of the four watersheds with an ISCO autosampler. A minimum of 18 samples from from each storm at each catchment will be targeted to allow for statistical analysis of the data from at least four storm events per year. Samples will be analyzed at the DPU water quality lab for nutrients (N and P forms), total suspended solids (TSS), and heavy metals (minimum Cd, Cu, Pb, and Zn). Comparisons among the treatment and control watersheds will be made for both pollutant concentrations and loading. Both hydrologic and water quality parameters for the retrofitted catchments will be compared against the control catchment to determine statistical significance of trends in the data using methods similar to those in Clausen and Spooner (1993), Page et al (2015a), and Page et al. (2015b). Pre-installation data gathered by the City will complement discharge and water quality data from this project to better establish baseline conditions to compare the results after installation. Relevant weather information (i.e. previous 24-h and 48-h precipitation data, and storm characteristics) will be collected from an existing weather station located at the Park or Roses.

Storm water samples collected from project areas and the control area will also be analyzed to determine differences in *E. coli,* and pathogen levels due to the Blueprint project. *E. coli* will be measured with modified-mTEC method and microbial source tracking and antibiotic resistance will be determined with quantitative PCR (targeting dog, human, avian wildlife markers) at the OSU College of Public Health Laboratory (Biosafety Level 2).

Goal #4: Results from goals #1, #2, and #3 will be extrapolated with total flow data estimated by existing flow meters to determine the overall improvements in water quality and reductions in pathogens due to the Blue Print-Clintonville project. By choosing representative installations for goal #1 these results can be multiplied by the number of systems in each project area, on an areal basis, to estimate an overall water quality and quantity improvement for each project area. Comparing these results with differences identified by the catchment gauges will yield robust estimates of the impact of the Blueprint project across various areas. By combining across project areas, a grand total of water quantity and quality improvements will be estimated for the entire Blueprint Clintonville area.

2. Social and Economic Impacts:

Background and Justification:

Increased property values are often hypothesized to be a direct economic benefit of Green Infrastructure (GI). People commonly value green space, and studies have shown positive relationships between proximity to green areas and housing values (Irwin 2002). However, the specific attributes of Green Infrastructure projects matter in ways that are sometimes unexpected. For example, recent work in Maryland reveals a negative impact of stormwater basins on housing values in some suburban neighborhoods (Irwin *et al.* 2015). For the city of Columbus, we will quantify the marginal values that households have for the different attributes of GI—e.g., the type of vegetative cover and the degree of maintenance that is required. In addition, we will collect data on housing transactions before and after the installation of GI projects to examine the changes in property values near newly-installed GI and to identify the features that are the most and least highly valued. We will also be able to better value the other benefits outlined in this proposal (i.e. biodiversity), contributing to a more accurate comparison of the costs and benefits associated with GI versus conventional approaches.

Importantly, the benefits of well-designed and constructed GI may go beyond increased property values. There are a number of social, psychological and physical benefits that can result from GI. For instance, the psychological benefits of contact with nature include reduced stress and mental fatigue and an increase in positive emotions (Luck *et al.* 2011; Russell *et al.*, 2012),Tzoulas et l. 2007). In terms of physical health, there is evidence that the state of the local natural environment can influence levels of walking and other forms of activity (Humpel *et al.* 2002). Further, local environmental and social conditions are thought to influence levels of pro-social behavior and collective action (Wilson 2011). Natural features in one's neighborhood can enhance community satisfaction and feelings of attachment to one's community, increase social interactions and social involvement, and strengthen community identity (Tzoulas *et al.* 2007, Kim and Kaplan 2004). Importantly, each of these psychological, social, and physical benefits are thought to be important for increasing overall well-being (King *et al.* 2014). For this reason, GI has been viewed as a component of neighborhood revitalization and as an important contributor to higher quality of life (Barton 2007).

However, as with property values, the potential psychological, social and physical benefits of GI depend on the type and quality of the natural features that are installed. Natural areas that are overgrown and aesthetically unpleasing may actually increase levels of stress and decrease social interactions, community pride, and, subsequently, overall levels of well-being (Kuo *et al.* 1998). The proposed research will investigate the potential economic, psychological and social benefits of GI by using surveys that are distributed before and after installation of specific GI projects to households in the Blueprint project area as well as households from "control" neighborhoods that are very similar to the treated neighborhoods, but have not had GI projects installed.

Goals (numbers in parentheses indicate the years in which data will be collected for each objective):

1. Determine whether and to what extent property values increase or decrease as a result of GI projects relative to control neighborhoods, and how these effects vary with the different attributes of GI. (2016-2021)
2. Value other ecosystem services that are generated by the GI projects, including habitat, water quality, health and social benefits, and how the valuation of these services varies with the different attributes of GI (2016, 2018, 2021)
3. Determine whether residents in treated neighborhoods find GI to be aesthetically pleasing and are generally satisfied with the installation of GI. (2018, 2021)
4. Determine whether and to what extent the factors listed below change and compare between the Blueprint project areas and nearby control neighborhoods (2016, 2018, 2021)
    - Overall well-being and specific components of well-being among individuals
    - Social capital, community attachment, pro-sociality, and cooperation
    - Preferences for walking and overall physical activity
    - Environmental behavior, particularly behaviors related to water use and water pollution (e.g. installing rain barrels, planting native gardens on homeowners property, reducing water use within the home, etc.).

Approach:

For objective 1, changes in property values due to bioretention basins will be estimated using a first-stage hedonic regression, which as been used in the past to determine impacts of stormwater retention basins on housing values in Baltimore, MD (Irwin et al. 2015). Housing sales from the study area retrieved from the auditors website, will be combined with the distance of each exchanged property from individual basins following the methods in the previous study. Using empirical methods, impacts of other variables, such as square footage and date of construction, impacting sales prices will be assigned to other variables, so changes due to the bioinfiltration basins can be identified.

To meet objectives 2, 3, and 4, surveys will be mailed to a random sample of households in the sections of Clintonville targeted by BluePrint Columbus as well as sections of Clintonville that are adjacent to the targeted areas and that share the same demographic profile. We will follow the standard approach outlined by Dillman (2000) for maximizing response rates for mailed surveys. We will mail a total of 2000 surveys (1000 in the treatment area and 1000 in the control area) with the goal of receiving approximately 500 total responses (250 from each sampling area). These estimates are based on a conservative expectation of a 25% response rate (Kaplowitz *et al.* 2004).

Data collection will begin in spring 2016, or as soon as possible afterwards, to establish baseline levels for important social, cultural and economic factors. Follow up surveys will be distributed one year after GI installation to capture immediate changes. A second set of follow up surveys will be distributed two and five years after installation to explore the durability of any immediate changes as well as changes that emerge over time with the maturity of the GI features.

3. Habitat Creation and Biodiversity

Background and Justification:

Cities generally have degraded natural ecosystems, and there is a strong interest in restoring urban ecosystems for both human and environmental benefit. Advocates for green infrastructure note increases in the biodiversity of urban areas associated with green infrastructures, and support them as a way to increase and improve the natural environment within cities. However, this claim is not always borne out by the evidence (Hostetler *et. al* 2011; Williams *et. al* 2014). While many studies have looked at the effects of remnant green spaces and of parks on biodiversity, few have focused on the biodiversity impacts of green infrastructure storm water systems. Rain gardens, in particular, create small habitat patches but in a network could provide suitable habitat for rare, endangered, or charismatic insects and birds as well as plants. The proposed research project will inventory species diversity before and after construction, focusing especially on the spatial arrangement of rain gardens as a factor in biodiversity promotion. Finding that stormwater retention structures improve biodiversity will make them more appealing to a broad spectrum of stakeholders, increasing support for these projects.

Goals:

1. Determine the effect of green storm water infrastructure on habitat and biodiversity by analyzing the composition of insect and bird communities
2. Include these changes in economic valuation as biodiversity improvement.
3. By comparing impacts of different green infrastructure designs across the five study areas identify design differences to increase the ecological value of green infrastructure.

Approach:

Insect traps and acoustic sampling for birds will be used within the blueprint project area and nearby control neighborhoods to detect differences in habitat and biodiversity due to installation of green infrastructure (Hobson *et al.* 2002). Approximately 4 insect traps and acoustic sensors will be installed and monitored in each of the six study areas and control areas. Three will be deployed in the same sites used for Objective One, with one additional sampling site in each sub-area. Control sites will include similar settings in adjacent Clintonville neighborhoods, as well as locations at Whetstone Park to establish more "natural" background levels. Sampling will be completed twice in spring, summer and fall of 2016 to establish baseline populations prior to, or just after installation for both the project and control areas. Subsequent sampling will take place in the spring and fall of 2017, 2019 and 2021. These traps and sensors will be analyzed and the presence of different species will be recorded and diversity indices computed. By comparing the values from the Blueprint-Clintonville area to values from control areas impacts of green infrastructure on habitat and diversity will be identified. These differences will be noted in later surveys to determine how much economic value residents would place on these changes. By comparing differences among the five study areas, design recommendations will be made to increase habitat and biodiversity associated with future green infrastructure installations.

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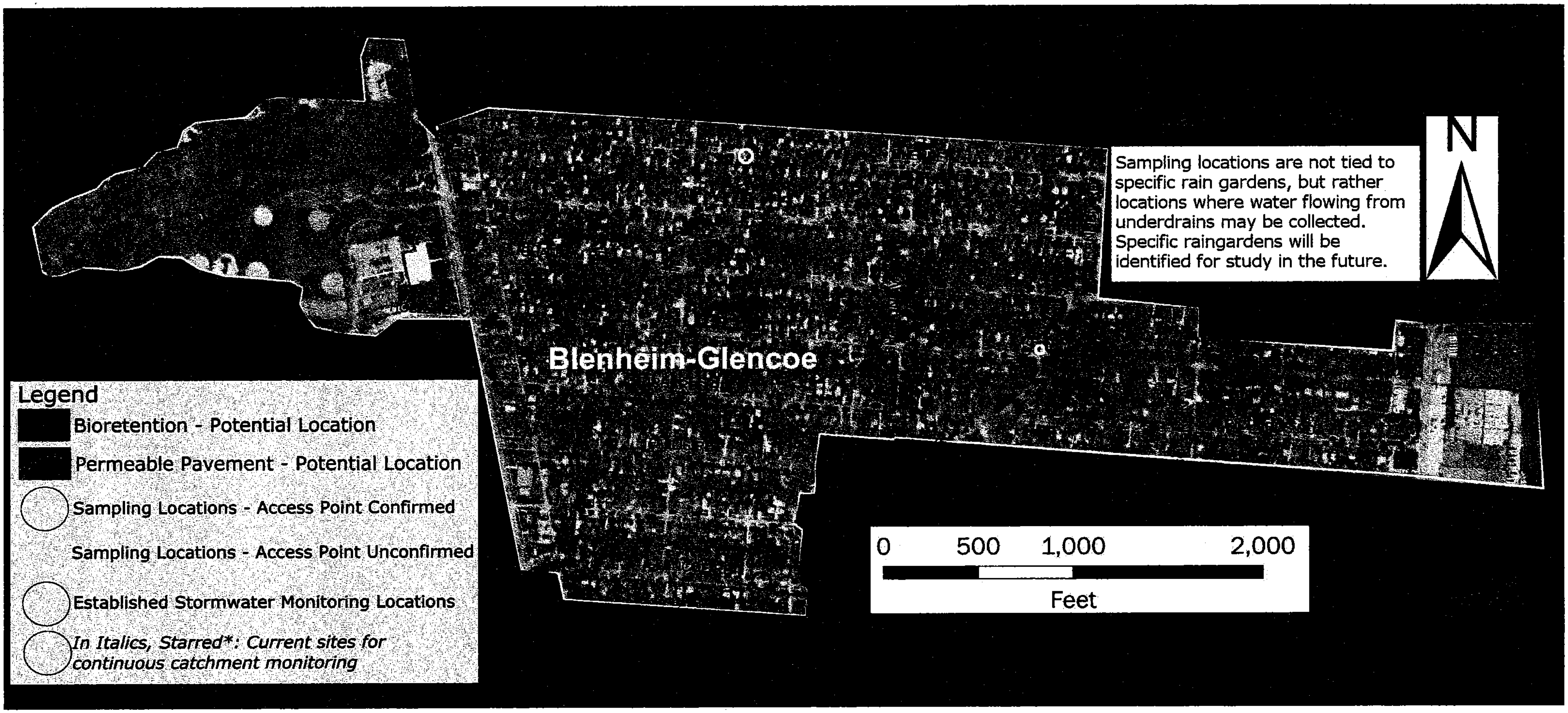
Legend
Bioretention - Potential Location
Permeable Pavement - Potential Location
Sampling Locations - Access Point Confirmed
Sampling Locations - Access Point Unconfirmed
Established Stormwater Monitoring Locations
In Italics, Starred: Current sites for continuous catchment monitoring*
Blenheim-Glencoe
Sampling locations are not tied to specific rain gardens, but rather locations where water flowing from underdrains may be collected. Specific raingardens will be identified for study in the future.
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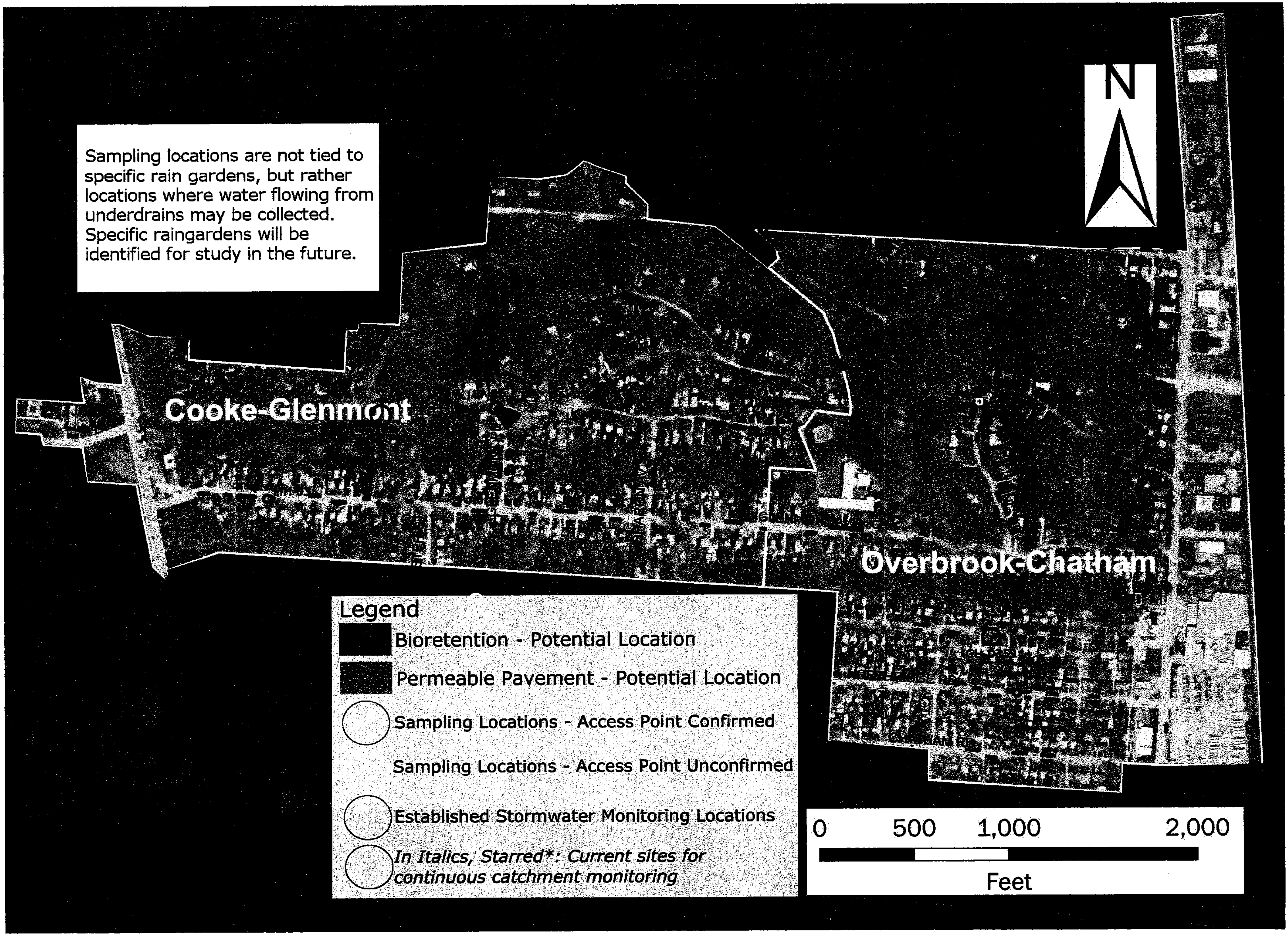
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Cooke-Glenmont
Overbrook-Chatham
Legend
Bioretention - Potential Location
Permeable Pavement - Potential Location
Sampling Locations - Access Point Confirmed
Sampling Locations - Access Point Unconfirmed
Established Stormwater Monitoring Locations
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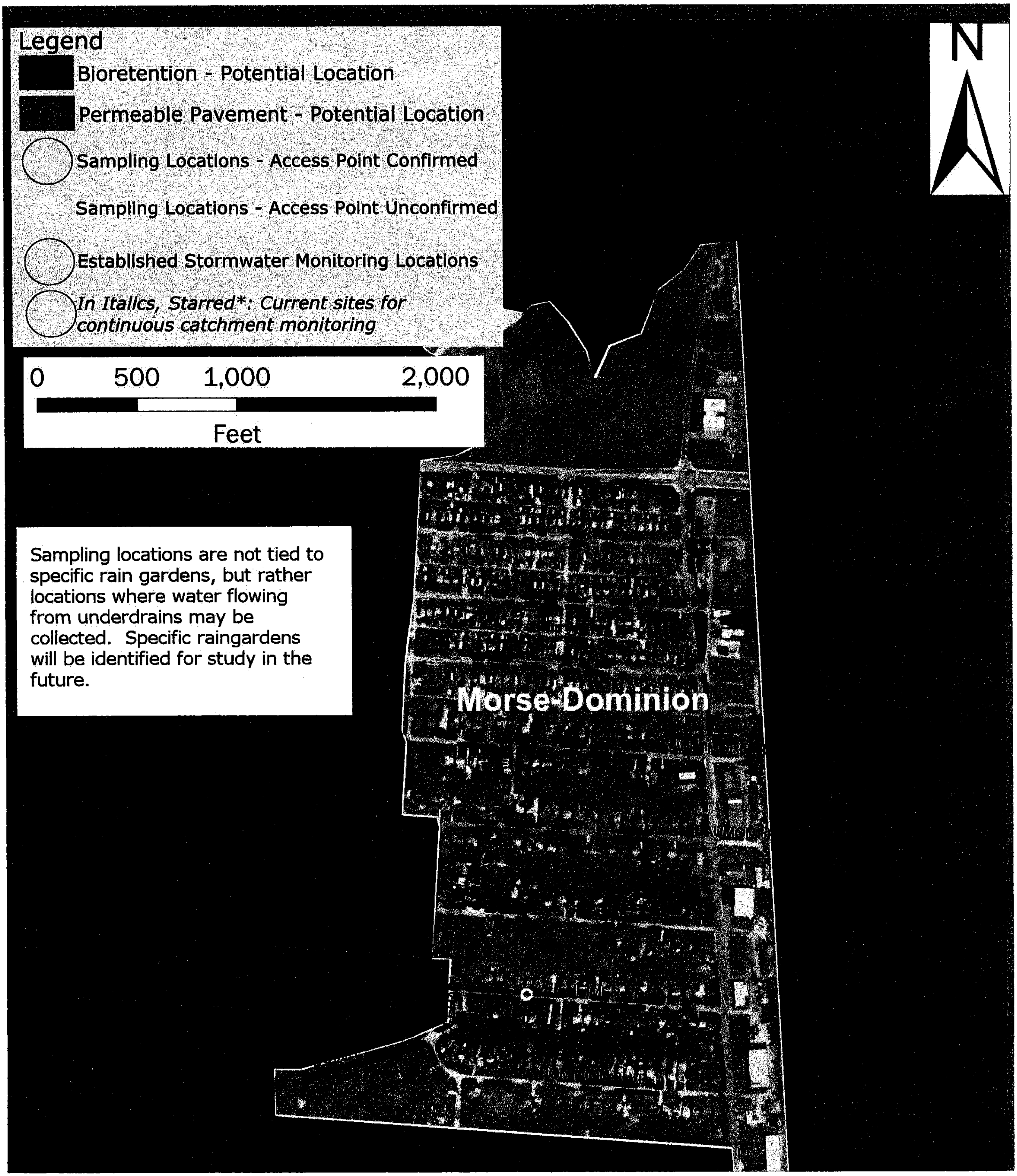
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Established Stormwater Monitoring Locations
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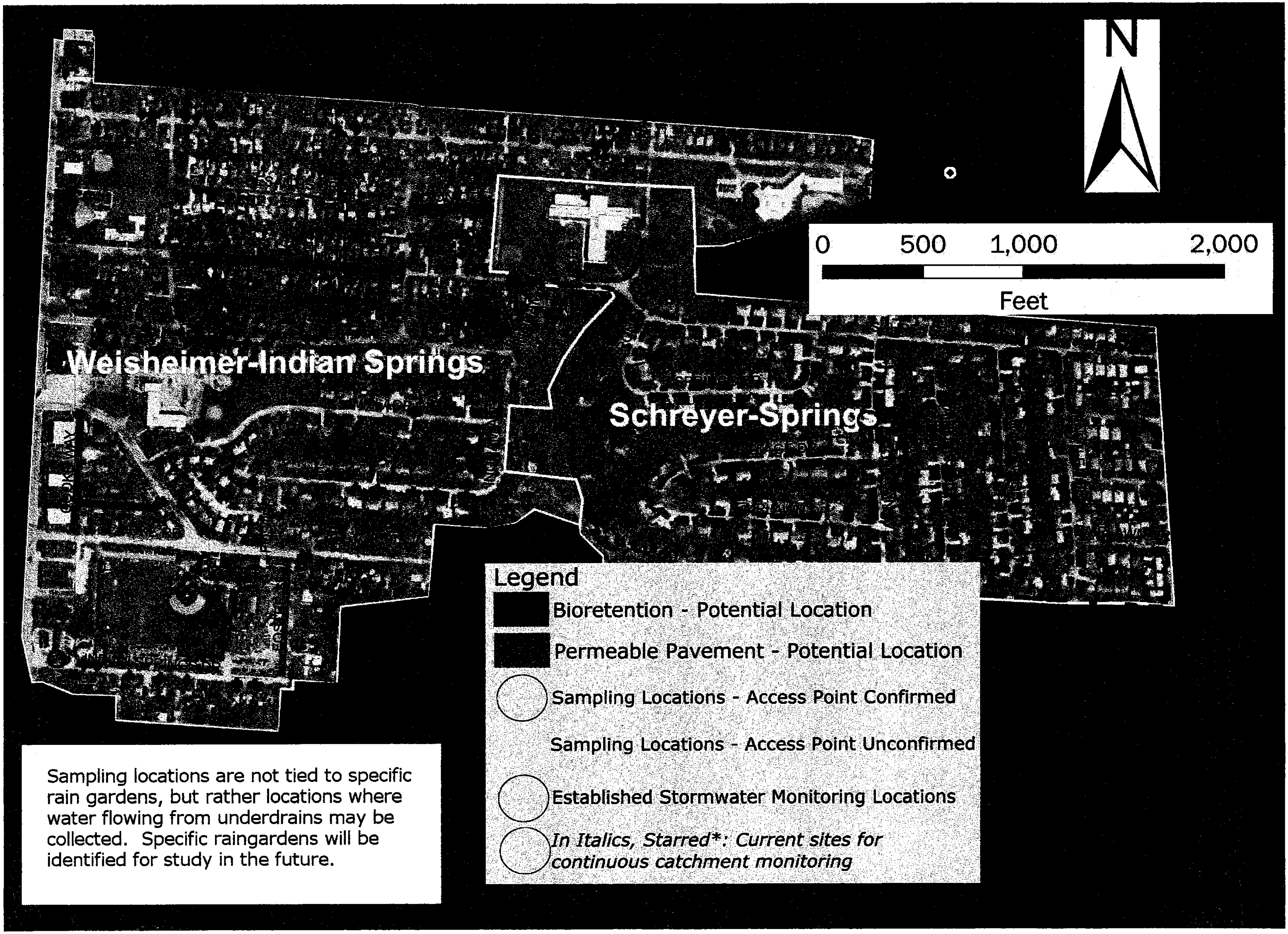
Sampling locations are not tied to specific rain gardens, but rather locations where water flowing from underdrains may be collected. Specific raingardens will be identified for study in the future.
Morse-Dominion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Weisheimer-Indian Springs
Schreyer-Springs
Legend
Bioretention - Potential Location
Permeable Pavement - Potential Location
Sampling Locations - Access Point Confirmed
Sampling Locations - Access Point Unconfirmed
Established Stormwater Monitoring Locations
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