City of Alexandria, Virginia
Waterfront Implementation

Technical Memorandum 4
PARKSPACE AND STREETSCAPE STORMWATER ATTENUATION SOLUTIONS

FINAL | February 2023

COMMONWEALTH OF VIRGINIA
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Abbreviations

BMP	best management practice
Carollo	Carollo Engineers
CF	detention volume
CIP	Capital Improvements Plan
City	City of Alexandria
DEQ	Department of Environmental Quality
ft	feet
GDM	Geotechnical Design Memorandum
HGL	hydraulic grade line
IR	isolator row
M	million
MG	million gallons
MSWMP	Master Storm Water Management Plan
NOAA	National Oceanic and Atmospheric Administration
O&M	Operations and Maintenance
OA	Owner's Advisor
Project	Waterfront Implementation Project
PS	pump station
PS1	Southern Pump Station
PS2	Northern Pump Station
ROW GI	right-of-way green infrastructure
SAP	Small Area Plan
T&ES	City of Alexandria's Department of Transportation and Environmental Services
TM	technical memorandum
VDEQ	Virginia Department of Environmental Quality
VRRM	Virginia Runoff Reduction Method

Technical Memorandum 4

PARKSPACE AND STREETSCAPE STORMWATER ATTENUATION SOLUTIONS

1.1 Purpose

In January 2015, the City of Alexandria's City Council adopted a "Core Area Phasing Priority Plan" for the Small Area Plan. The plan identified flood mitigation as the top priority which was carried forward into the Waterfront Implementation Project (Project). Preliminary engineering efforts from 2016 – 2019 resulted in a mainly "grey" suite of engineering solutions to mitigate flooding caused by storms (up to and including the design storm as defined in Technical Memorandum 1 (TM 1) (Carollo 2022) within the "core area". The "core area" is located between Union Street and the Waterfront from Duke Street to Queen Street. The Master Storm Water Management Plan (MSWMP) recommended design proposed placing new inlets, upsizing the pipes within the "core area", and routing the sewers through two distinctive drainage areas (Stantec 2018). Each drainage area discharges into a proposed pump station, one at the Waterfront Park (PS1) and other located at the east end of Thompsons Alley (PS2)[1]. Collectively, these investments constitute the stormwater flood mitigation system for the baseline project (Baseline Project).

This memorandum introduces and evaluates state-of-the-art green solutions for integration into the Baseline Project to improve the system's resilience while aiming to reduce the overall project cost. The memorandum is organized into three main sections: streetscape best management practices (BMPs), parkspace stormwater attenuation solutions, and cost.

1. *Streetscape Stormwater Attenuation Solutions* introduces various BMPs and offers two opportunities where it can be explored and incorporated into the Project.
    a. In the right-of-way (ROW) along specific city blocks upstream of the proposed storm sewer improvements that produce excess stormwater runoff and contribute to "core area" flooding during design storm conditions.
    b. On King Street between Union and Lee Street as part of the King Street Pedestrianization Pilot Study/Concept.
2. *Parkspace Stormwater Attenuation Solutions* identifies Waterfront Park and Founders Park as usable areas for both underground detention and above ground bioretention. Each of these parks offer an opportunity to intercept and attenuate stormwater runoff prior to entering the downstream pumping station. Regulatory implications, project risks, and community stakeholder feedback are discussed.
3. *Cost* summarizes the Class 4 Construction Estimate for the *Parkspace Stormwater Attenuation Solution* components including underground stormwater detention chambers and bioretention.

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[1] Stormwater pumping station nomenclature for Waterfront Park Pump Station (PS1) and Thompsons Alley Park Pump Station (PS2) is specific to the Baseline Project as documented in the 2018 Stantec MSWMP. However, for the purposes of this TM and to be consistent with the Design-Builder Request for Proposal (February 2023), all future references to stormwater pumping stations are as follows: Southern Pump Station (PS1) and Northern Pump Station (PS2).

1.2 Streetscape Stormwater Attenuation

The primary goal of streetscape or right-of-way green infrastructure (ROW GI) is to intercept stormwater runoff to provide relief on the storm sewer infrastructure. Relief could be achieved either through infiltration to underlying soils or temporarily storing runoff before discharging back into the storm sewer; the extent of relief achieved is primarily dependent upon subsurface conditions, which will be investigated and analyzed in the Geotechnical Data Report (MRCE 2022) and Geotechnical Design Memorandum (MRCE 2022), respectively.

This section explores various Virginia Department of Environmental Quality (VDEQ) approved BMPs and offers solutions to mitigate "core area" flooding. These solutions are sited outside of the "core area" because this is where excess stormwater runoff originates, and then runoff travels overland to the "core area". Second, this section suggests how the King Street Pedestrianization Pilot Study/Concept may incorporate some BMPs into their overall plan. Carollo Engineers (Carollo) will continue to coordinate with the King Street Pedestrianization Project as any modifications to the existing topography including impervious area will affect the Project improvements.

1.3 Integrating Stormwater BMPs Upstream of Core Area

Carollo explored VDEQ approved BMPs including bioretention, infiltration practices, permeable pavements, and stormwater planters. Overall, these BMPs can provide some hydrologic benefits to the Project, most notably during smaller storm events up to one inch in rainfall since that is the standard treatment volume per VDOT BMP Design Manual of Practice. For larger sized storms these BMPs can capture some of the stormwater runoff (up to one inch) and excess runoff will enter the stormwater conveyance system. But more importantly, since the Baseline Project was approved, a new regulatory climate has emerged including enhanced nutrient management under the Virginia Stormwater Plan. BMPs can help satisfy the total phosphorus capture requirements for new and redevelopment projects. Since Old Town is a densely urban area Carollo opted for BMPs that could be integrated into the existing area without disrupting or changing its use, e.g., permeable pavements and infiltration basins since they do not require additional space at either a new development or developed site.

1.3.1 Siting

According to the *Alexandria Waterfront Historic Shorelines*, all streets due east of Lee Street within the "core area" were infilled between 1749 and present day. Per Virginia Best Management Practices Clearinghouse requirements, a BMP cannot be infiltration-based if it is sited above fill soils.

Figure 1 shows a snapshot of the XPSWMM stormwater model predicted flooding under design storm conditions with Baseline Project proposed improvements. According to Figure 1 there is up to 8 inches of flooding in the "core area". A timestep series of the model demonstrated that the flooding originates upstream of the "core area" and the stormwater runoff continues to travel downstream until there sufficient capacity in the storm sewer system and allows water to enter. The locations of proposed permeable pavements and infiltration basins locations are shown in red (Figure 1) which target and intercept stormwater runoff to relieve the storm sewer network and mitigate downstream or "core area" flooding.

In addition, Clearinghouse requirements dictate a minimum soil infiltration rate of 0.5 inches per hour for infiltration-based practices. To verify acceptable subsurface conditions, geotechnical field investigations performed in-situ infiltration testing at select locations. Some general field investigation results are discussed later in this TM; the complete subsurface data is documented in the Geotechnical Data Report submitted under a separate cover.

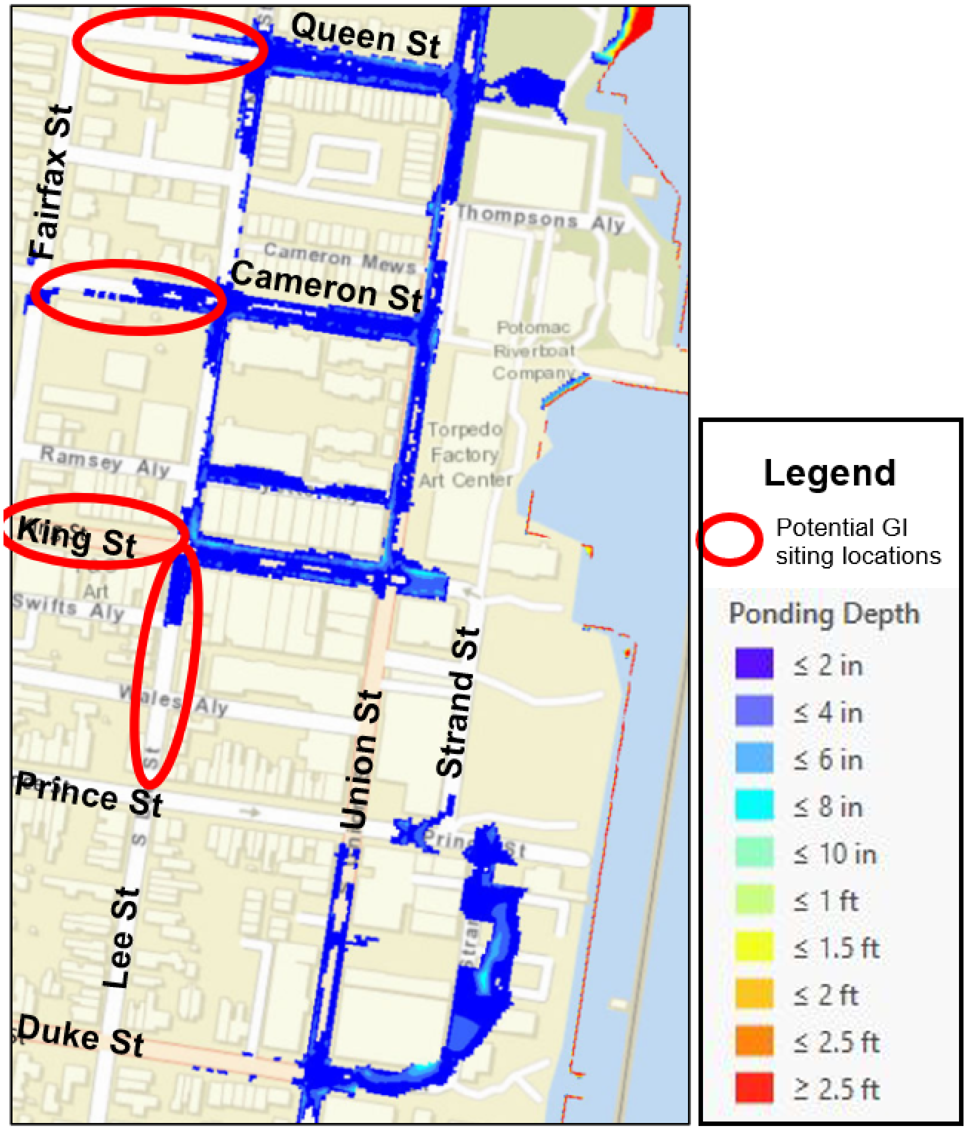

Figure 1 Potential Siting for ROW GI in City of Alexandria Upstream of "Core Area"

1.3.2 Design Parameters for Permeable Pavements and Infiltration Basins

For preliminary sizing and cost, Carollo assumed the following design parameters.

- Uniform base and bedding coarse stone with a 5-feet depth and 40 percent porosity.
- Standard 5-feet width.
- Proprietary equipment cost on average is $20 per cubic foot of stormwater detention volume (per conversations with various BMP manufacturers)2.
- Saturate installation(s) along entire roadway width.

[2] Carollo corresponded with Storm-Crete and Pavedrain via email. Storm-Crete suggested using $35-$40/sq. feet which is equal to $20/cf stormwater volume assuming 40 percent stone porosity. Pavedrain suggested using $10/sq. feet which is equal to $5.88/cf stormwater volume assuming 35 percent stone porosity. For planning and high-level budgeting purposes, Carollo opted for the more conservative cost.

- The stone reservoir can completely drain within 48 hours.
- There is no external drainage contributing area and the underlying soil has a minimum of 0.5 inch/hour infiltration rate, such that no underdrain is required.

Table 1 summarizes the estimated detention volume (CF) per unit block and total direct cost based on preliminary siting of each BMP.

Table 1 Summary of Streetscape BMP Recommendations by Detention Volume (CF) and Total Direct Cost ($)

BMP	Location		Detention Volume	Total Direct Costs(1)
	Street	Cross-Streets	CF	$
Permeable Pavement(2)	Queen St	Fairfax and Lee	4,600	$700,000
Permeable Pavement	Cameron St	Fairfax and Lee	4,600	
Permeable Pavement	Lee (West)	Prince and King	3,700	
Infiltration Basin(3)	Lee (East)	Prince and King	2,830	$620,000
Infiltration Basin(3)	King Street	Fairfax and Lee	4,800	
Total			**20,530**	**$1,320,000**

Notes:
(1) Cost does not reflect the Total Construction Cost or the Total Project Cost. Therefore, it does not include costs for General Conditions, contractor overhead, profit and risk, sales tax, design development contingency, pricing contingency, and bonds and insurance. Moreover, it does not include additional costs for engineering, change orders, and legal and administrative fees.
(2) Permeable pavement is proposed to replace the existing parking lane(s).
(3) Infiltration basin is proposed when there is no parking lane and to avoid any interferences with the King St Trolley.

Under design storm conditions, the stormwater model calculates approximately 300,000 CF and 200,000 CF of runoff into PS1 and PS2, respectively. Therefore, the proposed BMPs may not provide significant hydrologic improvement under design storm conditions, nor will it help reduce PS sizing capacity or building footprint.

1.3.3 Upstream Stormwater BMP Recommendations

Carollo recommends further evaluation for streetscape GI for the following reasons:

- Provides some hydrologic benefit for storms particularly for those up to one inch. According to the National Oceanic and Atmospheric Administration (NOAA) National Airport Data from 1948 – 2019, 90 percent of annual storms in Alexandria are less than one inch.
- Can help the Project meet the total phosphorus requirements per the Virginia Stormwater Management Program.
- Total Project Cost is projected to be less than $3 million, i.e., less than 3 percent of the total project budget (assuming a $102 million Capital Improvements Plan (CIP) budget).

1.4 King Street Pedestrianization

There may be an opportunity to identify project synergies between the King Street Pedestrianization Pilot Study/Concept and the Waterfront Project. While many Waterfront Project investments focus on flood mitigation strategies, it also seeks to enhance the connection to and from the downtown and Waterfront, much like the King Street Pedestrianization. Additionally, the Department of Environmental Quality (DEQ) approved BMPs may be able to provide some hydrologic benefit and contribute to the King Street Pedestrianization goals.

Olin's 2019 King Street Pedestrianization Pilot Study/Design Concept is intended to achieve the following goals:

1. Enhance pedestrian streetscape experience.
2. Enhance connection to the Waterfront.
3. Integrate public art.
4. Expand outdoor dining opportunities.
5. Extend retail capacity.

Figure 2 illustrates Carollo's understanding of the current proposed plan per the March 2020 City Council Update and email communications between City Department of Project Implementation Project Manager and Division Chief of Mobility Services for City's Department of Transportation and Environmental Services (T&ES). In this plan vehicular traffic is completely blocked along the 100-block of King Street and the King Street Trolley is rerouted away from this block. The Plan allocates 22 feet for pedestrians to walk and 20 feet for seating in the sidewalk and parking lane on either side of the street.

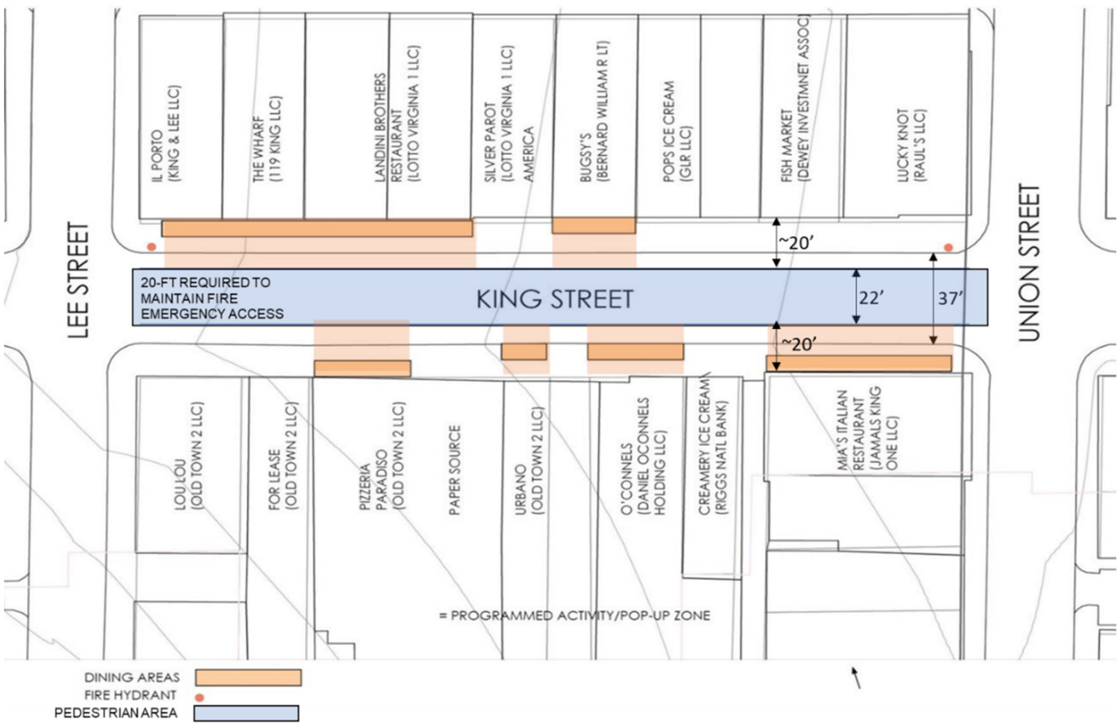

Figure 2 King Street Pedestrianization Plan as of March 2020

Based on this plan Carollo recommends investing in VDEQ approved BMPs to improve stormwater management and embrace a greener City. Since the 100-block of King Street is sited above fill soils, all BMPs must include an underdrain which will temporarily store and delay the stormwater runoff before it enters the storm sewer system.

In the ROW, Carollo recommends urban bioretention, e.g., stormwater curb extension or expanded tree pits. The block has already allocated space to several tree pits, however, there is an opportunity to expand the green space and capture stormwater runoff directly from the adjacent impervious surfaces, e.g., sidewalk, street, and rooftops. Both strategies be a detectable barrier between the sidewalk and any outdoor dining areas along with proposed planters or bollards. However, these green elements may impose on the available sidewalk or roadway (assuming restaurant owners intend to maximize outdoor seating areas).

Additionally, Carollo recommends a pervious paving material coupled with underground stormwater detention as part of the streetscape pedestrianization approach. For example, Invisible Storage Solutions' GravelPave material mimics impervious asphalt but is comprised of a plastic ring-on-grid structure overlaid with stone and a binder material. The product is intended to withstand high foot-traffic, as demonstrated by previous project implementation at the Pentagon Memorial Garden and walking trails outside of the National Arboretum and is commonly used in emergency fire lanes[3]. Pervious surfaces can be integrated with subsurface detention, e.g., stone reservoir, ADS StormTech chambers Invisible Storage Solutions RainStore and ACF R-Tank, among other products. Work will require excavation along the entire City block and relocation of utilities to accommodate the subsurface detention, which will disrupt business-as-usual activities.

1.5 Parkspace Stormwater Attenuation

Parkspace stormwater attenuation is comprised of underground (hidden) stormwater detention chambers and bioretention. Underground chambers sited in Waterfront Park and Founders Park, and configured in-line with PS1 and PS2, respectively, offer the only opportunity to increase (temporary) stormwater storage capacity that can result in a smaller pumping capacity. Note that all other attenuation solutions – streetscape and bioretention – are significantly smaller in size and will have little to no effect on PS capacity calculations. Thus, any aboveground modifications to the park are in addition to underground detention and can be justified by water quality benefits and new educational programming opportunities for the community. Utilization of Waterfront and Founders Park are contingent upon field investigation data and analysis as well as stakeholder input and approval.

1.6 Underground Park Detention

Carollo investigated various subsurface detention systems that could be incorporated into the Project for a more sustainable and resilient stormwater management solution. Subsurface systems are typically situated under parking lots, greenspaces, or used in conjunction with green infrastructure; these can be configured as either retention or detention systems depending on existing site conditions. Underground park detention was reviewed, evaluated, and summarized as follows:

1. Stormwater Chamber Siting.
2. Stormwater Detention Volume.
3. Benefits.
4. System Features.
5. Operations and Maintenance (O&M).

Carollo coordinated with Advanced Drainage Systems' StormTech stormwater chambers and the MC-7200 model, but major discussion points reflect general benefits, features, challenges, etc.

[3] Permeable pavements may be unable to accept the high loadings imposed by fire trucks and are not recommended in the emergency access lane.

1.6.1 Siting

Based on Stantec's 2018 MSWMP's preliminary design for the Baseline Project, Carollo identified the following hydraulically favorable locations for underground stormwater chamber siting. In this manner, the siting of the underground chambers could intercept the runoff conveyed by the storm sewer system and then, discharge to the downstream pumping station (PS1 or PS2):

- Waterfront Park, including street end of King Street, for PS1 King Street stormwater conduit. The Waterfront Park stormwater chambers could intercept the King Street stormwater conduit, and then, discharge downstream to PS1.
- Parking Garage at the intersection of Prince Street and Strand Street for the PS1 Prince Street stormwater conduit. The Parking Garage stormwater chambers could intercept the Prince Street stormwater conduit, and then, discharge downstream to PS1.
- Founders Park. The Founders Park stormwater chamber could intercept the Queen Street stormwater conduit, and then, discharge downstream to PS2.

The Prince/Strand Street parking garage is privately owned, and therefore was not considered as a possible siting location for the Project. Therefore, only City-owned land at existing greenspaces was carried forward for preliminary design and stakeholder outreach.

1.6.2 Volume

Preliminary engineering efforts sought to maximize the underground detention while preserving critical site constraints. Figures 3 and 4 outline the proposed stormwater chamber locations at Waterfront Park and Founders Park, respectively. Waterfront Park chambers are coordinated with the existing waterfront alignment, the *Master Utility Plan* (Stantec 2019) inclusive of storm sewer improvements and park amenities, and Olin (who provided feedback on existing park elements and proposed utilities that required protection or allowed for rerouting). In this manner, the stormwater detention chambers could be implemented whether a Cost-Based or Performance-Based Alternative was selected based on available project funding, i.e., receipt of award for external funding. The Founders Park locations are sketched on the *Carollo Topographic Survey* drawing to maximize subsurface storage while preserving "the grove" and other mature trees throughout the park based on stakeholder feedback.

Figures 3 and 4 were correlated with the detention volumes shown in Table 2. Chambers can capture up to 88,000 CF (0.66 million gallons (MG)) and 230,000 CF (1.7 MG) in Waterfront and Founders Park, respectively. The bottom of chamber elevation, per Table 3, reflects the maximum elevation of the chambers as recommended in *Collection System Upgrades Memorandum* (Carollo 2022). The storm pipe immediately upstream of the chamber and stormwater hydraulic grade line (HGL), as predicted by the XPSWMM stormwater model, must be higher than bottom of the chamber so that the chamber can fill by gravity.

Additionally, Carollo confirmed that siting of the chamber satisfies the maximum 7-foot cover height and accommodates anticipated loadings, including vehicular traffic and the interactive water jet feature at King Street Square per the 2014 Small Area Plan (SAP). For reference, the MC-7200 chambers inclusive of 12-inch stone fill above chamber is 6 feet high; assuming an average Waterfront Park grade of El. +5 feet, there is approximately 4 feet of fill above each chamber at Waterfront Park and an average Founders Park grade of El. +8 feet, there is approximately 7 feet at Founders Park excluding bioretention at all locations.

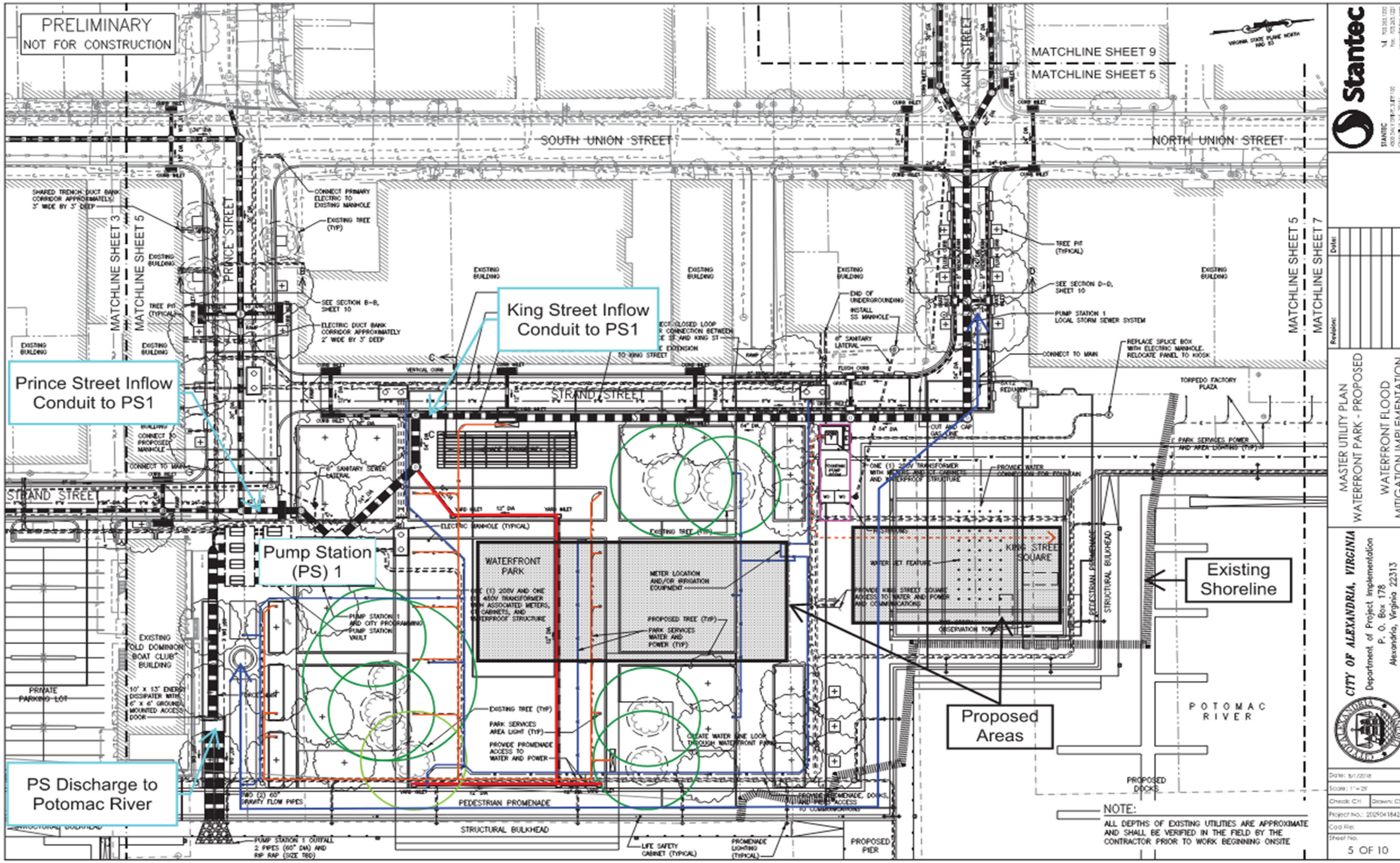

Figure 3 ADS StormTech Chamber Locations at Waterfront Park

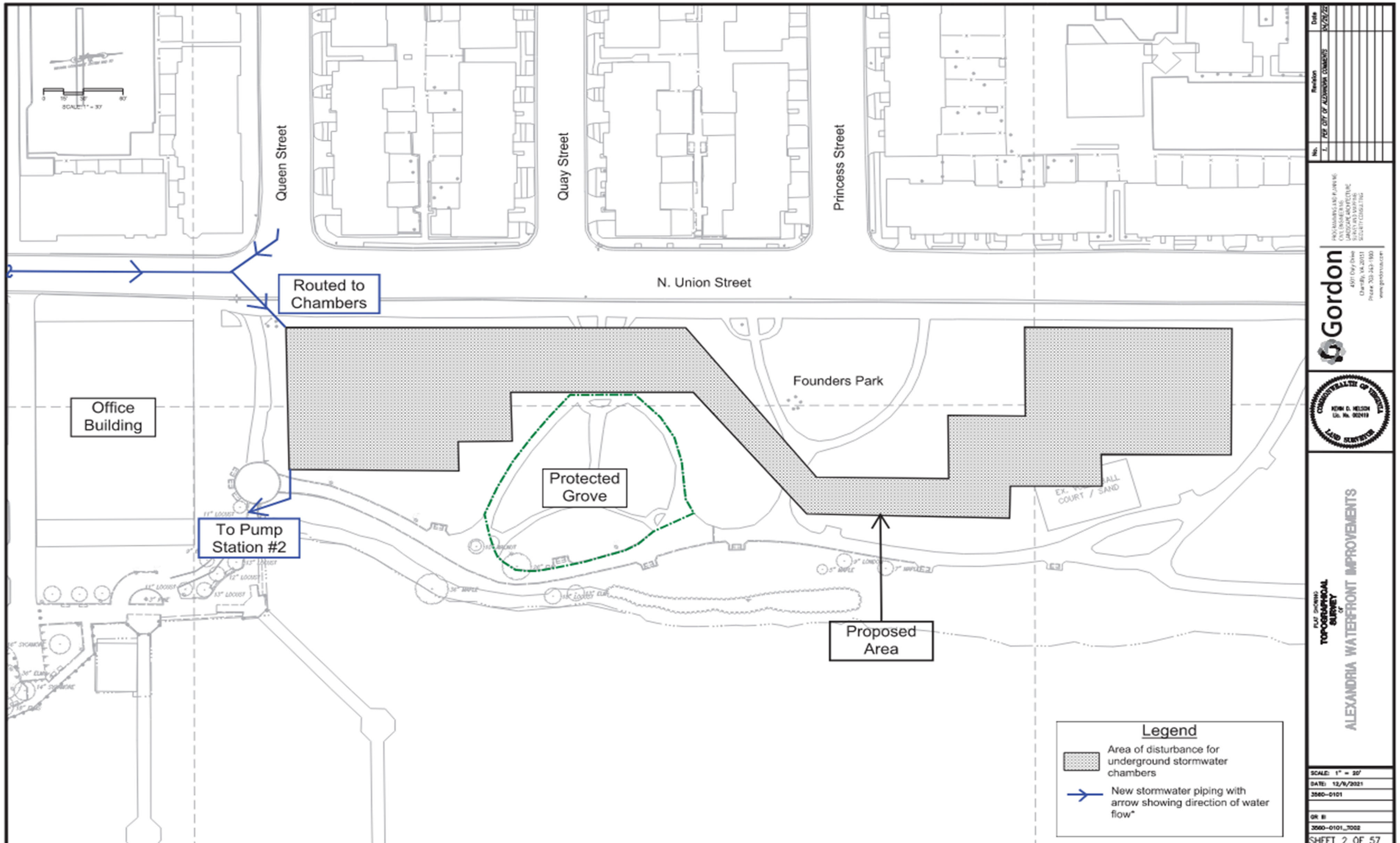

Figure 4 ADS StormTech Chamber Location in Founders Park

Table 2 Summary of the ADS StormTech Chamber Detention Volume and Sizing Configuration

Location	Volume (CF)	Volume (MG)	Bottom of Chamber Elevation (ft)(1)
Waterfront Park for PS1 Volume Attenuation	88,000	0.66	-5.3'
Founders Park for PS2 Volume Attenuation	230,000	1.7	-5.7'

Note:
(1) This elevation reflects the bottom of stormwater detention. The total depth of excavation will deepen to accommodate the foundational structure.

For each stormwater pumping station, there are two inflow conduits. Given there is only one chamber location per PS, chambers are only capable of intercepting and attenuating one of the incoming flows. For PS1, the Waterfront Park chambers' detention volume, per Table 2, represents about 50 percent of the total King Street conduit inflow volume; when also accounting for the second conduit, from Prince Street, the detention volume represents about 40 percent of the total PS1 inflow volume. For PS2, over 99 percent of the total inflow volume is conveyed via the Queen Street conduit with the remaining flow from the Chart House area. The Founders Park chambers' detention volume is more than 100 percent of the Queen Street conduit inflow volume. Thus, the chambers are capable of temporarily storing more than 99 percent of the total inflow volume.

A comparison of inflow volume and chamber detention volume suggests that the chambers can reduce the pumping capacity of both pump stations. While PS1 capacity can be reduced to handle a lower incoming peak flow, PS2 can be resized to operate as a dewatering pumping station. Refer to TM 6 *Pump Station Sizing and Capacity* for further information regarding pump station sizing and design details.

1.6.3 Benefits

Following preliminary design efforts, the team continued to explore *how* the subsurface detention chambers could provide multi-benefits to the Waterfront Implementation Project. In doing so, Carollo looked to previous StormTech chamber success both in Virginia and nationwide along with site-specific benefits that could be realized by proceeding with this approach. Collectively the team identified four main benefits – hydrologic, water quality, improved stormwater resilience, and improved park conditions.

1.6.3.1 Hydrologic

Under some project conditions the StormTech chambers can capture the entire inflow volume such that pumping stations are sized for dewatering pumping only. As documented in TM6, proceeding with the Founders Park chamber configuration per Figure 4 offers an opportunity to resize PS2 as a dewatering pumping station.

Under other project conditions the StormTech chambers can capture some of the total inflow, and thus, reduce the pump station rated capacity based on a lower incoming peak flow to the pumping station. As documented in TM6, proceeding with the Waterfront Park chamber configuration per Figure 3 offers an opportunity to reduce PS1 rated capacity by approximately 50 percent.

1.6.3.2 Water Quality

Water quality compliance for this project is required per Part IIB Technical Criteria of the Virginia Stormwater Management Program (9VAC25-870-63). The regulatory requirement for total phosphorus removal is calculated using the Virginia Runoff Reduction Method (VRRM) spreadsheet for redeveloped sites. Overall, a higher disturbed area footprint will result in a higher regulatory TP (pounds per year) requirement.

In alignment with the City's environmental initiatives, e.g., Eco-City Alexandria, Green Building Policy, and Environmental Action Plan 2040, the Project is exploring opportunities to incorporate VDEQ approved BMPs to achieve (or exceed) the regulatory requirement. The chambers can be easily retrofitted to include an Isolator Row; when added, 40 percent TP removal can be manually added into the VRRM spreadsheet. Preliminary calculations demonstrate that the Isolator Row can exceed the project regulatory requirement when applying the chamber configurations per Figures 3 and 4.

The Commonwealth of Virginia allows urban stormwater to be included in sectors that may trade nutrient credits to meet reduction requirements, and nutrient credit purchase is available in accordance with Alexandria Zoning Ordinance 13-109.8.b. However, nutrient trading credits are market-based and dependent on availability and supply/demand/scarcity. Given the estimated $15M in direct costs for stormwater chambers, as shown in Section 1.9 of this TM, the purchasing of nutrient credits is likely to have a lower price tag. As of 2021, the current market rate was about $35,000 per pound of TP removed. To date, the City's policy has been to not purchase nutrient credits because it does not contribute to improving local water quality, and implementation of BMPs or other VDEQ approved products offers an opportunity for the City to lead by example when it comes to its environmental and sustainability commitments.

1.6.3.3 Improved Stormwater Resilience

Incorporating chambers will reduce reliance on pumping at peak times with a more flexible operating schedule. Mechanical equipment and moving components are more at-risk for failure. Given that the subsurface detention chambers are passively operated, it minimizes the potential for failure mechanisms and number of failure points especially during peak flows.

Chamber implementation also improves stormwater management resilience because the pumps will operate at a lower rate for a longer duration, which in turn, reduces peak energy demand.

1.6.3.4 Improved Park Conditions

While subsurface detention in Founders Park will impact the usability of the space during construction, it could offer an opportunity to improve existing subsurface conditions. It is likely that geotechnical analysis will recommend disposal of any excavated soil; since current fill soil is not conducive to infiltration, it is expected that imported soil will have improved hydraulic conditions and better manage stormwater.

Any impact to Founders Park will be restored to existing condition. This may slightly improve the condition of existing greenspaces and/or walkways but will not provide a significant aesthetic improvement from existing conditions.

1.6.4 System Features

In general, the stormwater chambers work in tandem with the upgraded storm sewer network and new pumping stations, and therefore, implementation of the chambers does not eliminate the requirement to continue investments in an upgraded storm newer network and new pumping stations. Since the chambers are intended to fill and drain by gravity, the bottom of the chamber, and thus, the depth of excavation is based upon the storm sewer design; however, due to the high groundwater table, the chambers will drain via gravity to the stormwater pumping station whereby it is discharged to the Potomac via pumping.

Table 3 identifies two operational modes for the chamber configuration and the potential for challenging site conditions. ADS StormTech provided project examples to demonstrate if/when a system feature has been integrated into a previous job.

Table 3 Project-Specific Criteria and Risks for ADS StormTech Chambers and Previous Project Examples

Project Criteria	Project Explanation of Possible Risk	StormTech Project Examples
Chambers may work in tandem with the new stormwater pumping stations in one of two ways: 1. Chambers may function as an extended wet well for the pumping stations whereby water is continuously fed into the pump station during a wet weather event. **OR** 2. Chambers may function as an isolated temporary storage unit whereby a gate valve will direct stormwater runoff into and out of chambers downstream to pump station.	Complete draining of the chambers is dependent upon stormwater pumping due to the relatively high groundwater levels. Therefore, if stormwater pumps do not turn on at the intended time, the chambers may not be empty in time for the next wet weather event. This operational failure of the pumps may result in upstream flooding that would otherwise be avoided. Both scenarios will likely require automatic controls for the pump station operation (Criteria 1) and/or gate valves (Criteria 2). To mitigate a potential operational failure, it may be important to include manual overrides or other back-up contingency measures.	Project examples with in-line pumping are using the HP Storm Pipe at Eaton Elementary in Washington DC and WMATA Bus Garage in Prince George's County, among others.
Stormwater chambers will be sited in challenging site conditions. Challenging site conditions include chambers partially or fully sited below the groundwater table and/or on fill soils.	It is possible that integration of the chambers will not reduce overall project costs to satisfy budgetary constraints. Cost increases include but are not limited to: **Foundations**: While typical StormTech chamber installations account for a 6 to 12-inch stone foundation, a chamber system partially or fully below the groundwater table will require a more substantial foundation, e.g., a concrete pad and anchors, to withstand buoyant forces. **Thermoplastic Liner Product:** StormTech chamber system requires a thermoplastic liner to fully enclose the system and isolate entirely from the surrounding area to prevent groundwater intrusion. **Complex Construction Activities:** It is assumed that dewatering, sheeting and shoring, and importing/hauling of new backfill will be required during construction.	**Below Groundwater** Tidewater Virginia projects including Sentara Cancer Center in Norfolk VA, Priority Ford in Norfolk, VA, and a 7-Eleven on Laskin Road in the City of Virginia Beach. **Concrete Foundation** Millipore Building Expansion in Jaffrey, New Hampshire and the Insulet Manufacturing Facility in Acton, Massachusetts

The subsurface conditions will be confirmed and documented in the Geotechnical Data Report. Refer to the Geotechnical Design Memorandum (GDM), a separate submittal document, for an analysis of the groundwater field investigatory findings and implications on design and construction risks, considerations, and recommendations.

1.6.5 Operations and Maintenance

Table 4 summarizes the high-level O&M activities anticipated for the stormwater chambers. Activities are categorized with respect to a wet weather event or routine maintenance.

Table 4 Operations and Maintenance for Subsurface Stormwater Chambers

Category	Occurrence	Description
Significant Wet Weather Event	Before Storm	Maintenance staff should visit each pump station and stormwater chamber access points to ensure valves, sensors, and pumps are in place and functional.
	During Storm	Staff to confirm upstream operational structure and associated instrumentation devices are operating properly based on cumulative inflow volume and total detention capacity of stormwater chambers. Staff to confirm chamber outlet valve is providing a controlled release of flow from the chambers to the downstream pumping station(s)[(1)].
	After Storm	Staff to open the chamber outlet valve and provide a controlled release of flow from the chamber to downstream pumping station(s)[(1)].
Routine	Monthly	Visit to each pump station and chamber access points to verify functionality of equipment and controls.
	Bi-Annually	Inspect Isolator Row (IR) bi-annually (with one inspection occurring in early spring after the winter loading of salt and sand) via standard manholes and inspection ports sited along the length of the IR; other chamber rows do not require maintenance since it is only intended for stormwater detention.
	3 to 6 years	Interval depends on sediment loading. When approximately 3 inches of sediment has accumulated throughout the length of the Isolator Row, system shall be cleaned with a JetVac.

Note:

(1) The chamber outlet valve maintenance will be further discussed in TM 6 *Pump Station Sizing and Capacity* as O&M Staff may elect to operate chamber as an extended wet well, i.e., controlled release of stormwater to pumping station during the event, or as an isolated, temporary storage chamber, i.e., controlled release after the event. Predicted upstream flooding implications for each operational scenario will be discussed in TM6.

It is critical to consider the O&M needs for the integrated stormwater management system rather than each component because the operability of one will affect another. For instance, installed and well-maintained upstream pretreatment devices(s) will improve chamber operations. By capturing debris and sediment at each contributing inlet structure or a centralized capture device, e.g., hydrodynamic separator, an upstream pretreatment device will keep unwanted debris out of the chamber.

Therefore, a comprehensive and robust maintenance schedule shall be developed and executed based on manufacturer recommendations, site-specific conditions, and input from T&ES.

1.7 Above Ground Bioretention

While bioretention cannot replace underground detention, it can be incorporated into the overall stormwater management solution. The quantity of stormwater detention is at least an order of magnitude less than the chambers, and thus will not significantly affect the stormwater pumping station sizing.

In general, bioretention provides water quality benefits and educational programming to the City. If underground stormwater chambers are not incorporated in the project, then, bioretention could fulfill the water quality objectives and regulatory requirements; for clarity, the discussion included herein is specific to the integration of bioretention with the stormwater chambers.

Bioretention siting was considered in areas above the proposed chambers. By siting bioretention above the chambers the two systems could be hydraulically connected such that water could flow from the bioretention to the underground chambers. The renderings show the proposed locations for bioretention in Waterfront Park (Figure 5) and Founders Park (Figure 6). Figure 5 is oriented due north in Waterfront Park; Figure 6 illustrates how a continuous bioretention area could be sited in Founders Park above the proposed chamber configuration, however, the final siting is flexible. Walking paths are proposed over the depressed vegetation areas to preserve the movement and mobility through the park and to the Waterfront.

Table 5 summarizes the total detention volume at Waterfront and Founders Park, inclusive of underground stormwater chambers and bioretention.

Table 5 Summary of ADS StormTech Chambers and Bioretention Stormwater Detention Capacity (CF)

Location	Underground Chamber Volume (CF)	Bioretention Volume (CF)	Total Detention Volume (CF)	Relative Volume Increase (%)
Waterfront Park for PS1 Volume Attenuation	88,000	8,000	96,000	9%
Founders Park for PS2 Volume Attenuation	230,000	32,000	262,000	Not Applicable(1)

Note:

(1) The relative volume increase (%) for Founders Park is labeled Not Applicable because the underground chamber volume already exceeds the projected inflow volume under design storm conditions. Therefore, any additional detention volume provided by bioretention does not provide hydrologic benefits under design storm conditions.

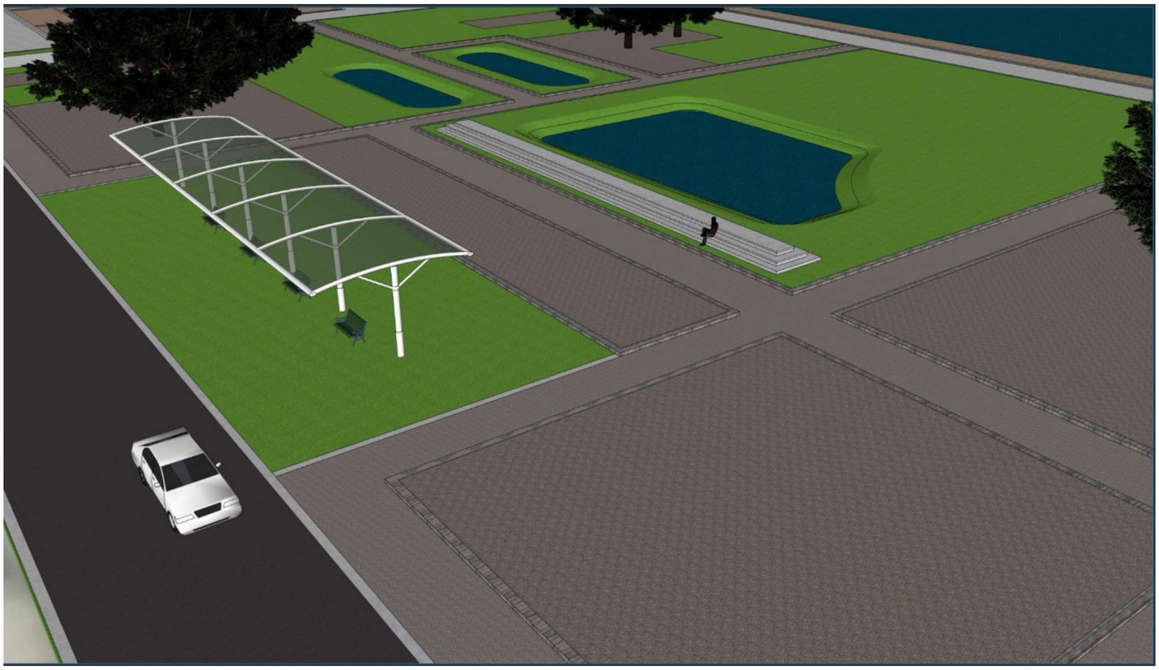

Figure 5 Sketch-Up Drawing Shows Proposed Locations for Bioretention at Waterfront Park

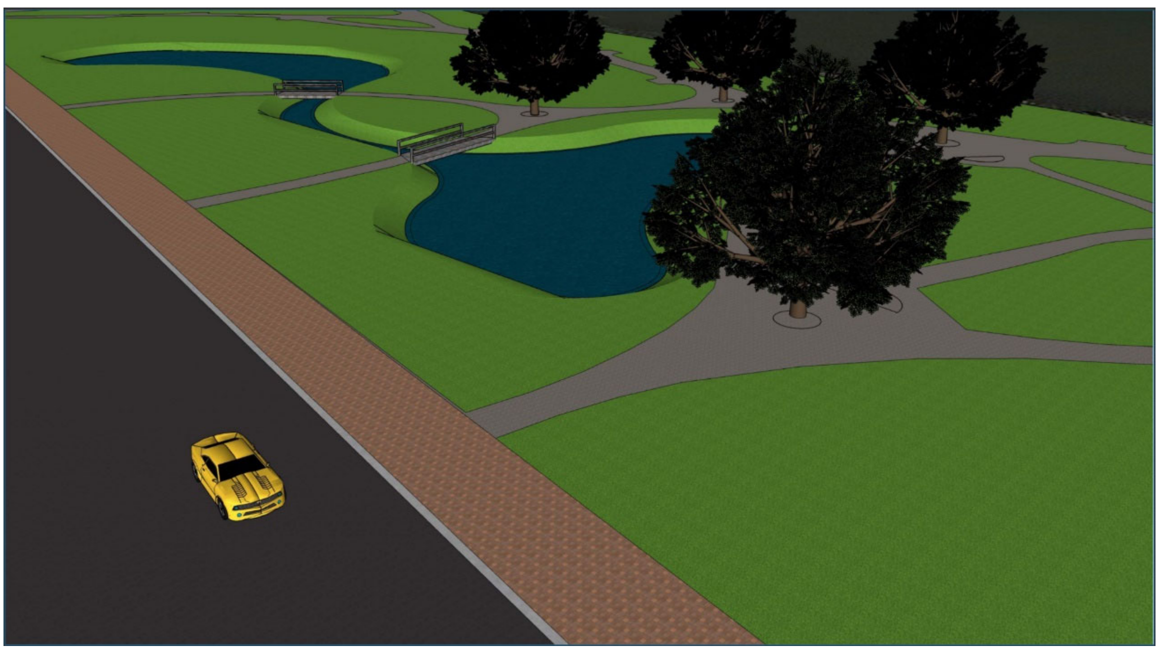

Figure 6 Sketch-Up Drawing Shows Proposed Locations for Bioretention at Founders Park

In summary, the addition of bioretention did not provide significant hydraulic improvements to the overall stormwater management system. For PS1. Adding bioretention increased the total detention volume by about 9 percent and a negligible impact on PS1 rated capacity. There is no change in the volume capture percentages reported for PS2 with the addition of bioretention because subsurface storage already exceeds the total inflow volume.

Despite the lack of hydraulic improvements, the project team presented a collective bioretention and subsurface chamber solution to various community groups for input and feedback. The project team highlighted the educational benefits, opportunity for improved/new aboveground features, and demonstration of the City's good faith efforts to pursue investments in alignment with City environmental goals.

1.8 Community Engagement and Feedback

The project team facilitated various community engagement meetings with the Parks and Recreation Committee, the Flood Mitigation Subcommittee of the Waterfront Commission, and the Founders Park Community Association. These meetings coupled with email exchanges have afforded the team an opportunity to solicit feedback and understand community goals, concerns, and priorities.

Generally, community members agree that the waterfront would benefit from flood mitigation investments and want to be good stewards of the environment. At the same time many members also voiced concerns related to cost and/or impact of investment.

With regards to cost, members expressed a preference to allocate funds to both flood mitigation as well as other community priorities, i.e., those that would enhance the experience and programming functionality of the existing parks. In other words, community members were concerned that the sustainable stormwater practices discussed herein would ultimately eliminate the opportunity for other community priority investments.

Community impact concerns refer to temporary construction impacts and long-term functionality of parks. Specifically, the proposed Founders Park configuration would likely necessitate up to one year of construction; during this time at least part of the park would be unavailable to the public. Construction activities include but are not limited to excavation, sheeting and shoring, dewatering, backfilling, and landscape restoration. Many community members use this park daily and prefer to maintain its passive use, so both a one-year construction period and installation of aboveground surface features, e.g., bioretention, are of utmost concern.

Regarding long-term impacts, some questioned whether the subsurface stormwater chambers may negatively affect the park's ability to manage stormwater along North Union Street and/or overland flow in Founders Park. Others voiced concern that construction activities will necessitate the removal of mature trees. Lastly, the waterfront has a rich industrial past; therefore, it is possible that the soil and/or groundwater may be contaminated. To this end, some individuals are concerned that construction activities in Founders Park may release such into the air and/or water which could compromise public health and safety.

Collectively to address community concerns, the project team has committed to the following:

1. The Waterfront Implementation Project will be delivered via progressive design build. Carollo, as the Owner's Advisor (OA), is responsible for recommending a project scope and defining design criteria with support from the City. Therefore, the subsurface stormwater chambers as presented in the current Project Design Alternative, are not fixed (or required) scoping elements. Rather, the chambers are part of the team's recommended solution to mitigate flooding. Also, the current Project Design Alternative does not include aboveground bioretention in either park based on community feedback received.

2. The OA may revise the chamber configuration based on the subsurface findings and engineering recommendations published in the GDM. Collectively the GDM will re-evaluate the feasibility of construction and installation and refine the configuration based on geotechnical, environmental, and geo-archaeological data collection. Therefore, the configuration included herein may be superseded by a Conceptual Design Report (to be released at a later date).
3. The Design Builder will be responsible for performing a cost-benefit analysis of the stormwater chambers and sharing the findings with the community prior to proceeding with any design efforts. Given the project delivery method, the team hopes to leverage the creativity and innovation of the Design Builder, which may further revise the Project Design Alternative.
4. Forthcoming project documents will define requirements for construction in Founders Park including protection of key surface features, e.g., the "Grove" and other mature trees, and restoration of the park.
5. Construction contract documents will define construction safety procedures and protocols to protect public health and safety. The Environmental Site Assessment Phase 2 Report, published under a separate cover, identifies some construction best practices and recommends some project-specific protocols.

1.9 Cost

Table 6 summarizes the costs for underground stormwater detention and bioretention at a Class 4 Level (+20 percent, -15 percent).

Table 6 Summary of the Total Direct Costs(1) for ADS StormTech Chambers and Bioretention in Parks

Location	Stormwater Chambers(1)	Stormwater Chambers and Biroetention(2)
Founders Park	$14.3M	$14.8M
Waterfront Park	$5.2M	$5.3M
Total	**$19.5M**	**$20.1M**

Notes:
(1) The Total Direct Cost is based on unit costs. It does not include costs for General Conditions, contractor overhead, profit and risk, sales tax, design development contingency, pricing contingency, and bonds and insurance. Moreover, it does not include additional costs for engineering, change orders, and legal and administrative fees.
(2) The cost associated with the columns titled Stormwater Chambers refers to the optimized chamber sizing and configuration per Table 2. The Stormwater Chambers and Bioretention refers to the sizing and configuration per Table 5.

Table 7 summarizes the anticipated 20-year O&M associated with the underground detention chambers and aboveground bioretention. Over this period, two categories of O&M expenditures were estimated for each proposed element:

- Regular O&M activities are the routine O&M activities required on an annual or more frequently (e.g., daily, weekly, monthly, quarterly).
- Intermittent O&M activities are the less routine O&M activities required less frequently than annually.

Table 7 Summary of O&M Costs

<table>
<tr><th>Description</th><th>Annual Cost for Regular O&M Activities[1,2]</th><th>20-Year Total of Regular O&M Activities[1,3]</th><th>20-Year Total of Intermittent O&M Activities[1,4]</th><th>Total 20-Year Cost[1,5]</th></tr>
<tr><td>Waterfront Park
Cleaning Isolator Row</td><td>$0</td><td>$0</td><td>$11,000</td><td>$11,000</td></tr>
<tr><td>Founders Park
Cleaning Isolator Row</td><td>$0</td><td>$0</td><td>$0</td><td rowspan="2">$345,000</td></tr>
<tr><td>Founders Park
General Park Maintenance</td><td>$15,000</td><td>$300,000</td><td>$30,000</td></tr>
<tr><td>**TOTAL**</td><td></td><td></td><td></td><td>**$356,000**</td></tr>
</table>

Notes:
(1) All costs are in 2021 dollars.
(2) Annual cost of regular (annual or less frequent) maintenance and operations costs.
(3) Total cost of regular maintenance and operations cost over 20-year life cycle.
(4) Total cost of intermittent (less frequent than annual) maintenance costs over 20-year life cycle.
(5) Total O&M cost over 20-year life cycle.

Key assumptions driving the O&M costs are as follows:

- Isolator Row requires cleaning every six years. Underground chambers do not require any additional maintenance. Costs includes a vacuum truck rental, operator and labor cost, and debris disposal.
- General Park Maintenance is performed on a weekly basis for eight hours per week. This includes vegetation maintenance, grass cutting, and trash removal.

While the addition of chambers can support a smaller rated PS1 and PS2, the costs presented in Table 6 do not demonstrate an overall financial benefit. Both scenarios in Table 6 assume the PS2 footprint is reduced and PS2 is relocated to the foot end of Queen Street; by doing so, the direct costs do not include dredging and/or infilling the Potomac. The reduced jurisdictional impacts were not quantified in the TM but are an important added benefit to the project.

1.10 Conclusions and Recommendations

Based on the evaluation presented, the following are recommended:

- Prepare and finalize the GDM for field investigation findings, including geotechnical, environmental, and geoarchaeological work. The GDM, in part, will document the feasibility of parkspace and streetscape attenuation solutions as well as provide recommendations for foundation design and siting constraints. This report will inform any modifications to the current Project Design Alternative and aid in the preparation of an OPCC Level 3 cost estimate.
- Prepare documentation and communicate expectations to prospective Design Builders regarding the implementation of subsurface stormwater detention chambers. A Design Builder will be asked to perform a cost-benefit analysis and communicate the findings to the community. They are also expected to offer creative and innovative stormwater management solutions, protect key Founders Park surface features during construction as well as restore the park following construction.
- Coordinate with stormwater pumping station design following finalization of the GDM.
- Continued coordination with stakeholders to keep apprised of ongoing preliminary design development and procurement timeline and documentation.

- Continued use of the 2D XPSWMM stormwater model following refinements to the current Project Design Alternative per the GDM.
- Continued coordination with the King Street Pedestrianization Pilot to review opportunities for BMP integration into the plan and identify stormwater benefits to this Project.
- Continued coordination with local, state, and federal regulatory stakeholders. This includes but is not limited to T&ES and demonstration of compliance with Article 13 of the City of Alexandria's Zoning Code as well as VDEQ for stormwater nutrient credits.

1.11 References

City of Alexandria Stormwater Model Documentation:

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8. City of Alexandria Department of Planning and Zoning. "Alexandria Waterfront Historic Shorelines". Image, Alexandria, Virginia, June 25, 2009.
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