FINAL REPORT
The Lakes and Princess Anne Plaza Drainage Improvements Preliminary Engineering Report

Report Summary
Preliminary Engineering Report
Report Summary
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PRELIMINARY ENGINEERING REPORT SUMMARY

RS1. CHAPTER 1 – INTRODUCTION & BACKGROUND

RS1.1 The Lakes

The Lakes (TL) project area is generally bounded by Holland Road to the west, Plaza Northgate Park and Lakecrest Road to the north, London Bridge Creek to the east and Lynnhaven Parkway to the south and contains approximate 185 acres (See Figure RS1-1).

Land use is primarily medium-density residential and most residences were constructed from the early 1970s to the early 1980s. Residences are a combination of single-family attached housing, townhouses, and apartments. Apartment buildings are located along the east side of South Club House Road and in Green Lakes Circle area (See Figure RS3-1 for the location of the apartment district).

All homes are concrete slab on grade construction and most have finished floors less than one foot above top of curb. Elevations range from EL 5.0 to EL 12.0 feet NAVD88. Based on FRIM Map 5155310112G, a substantial portion of the neighborhood is in Flood Zone AE with a base flood elevation (100-year storm) of EL 7.0 feet NAVD88.

RS1.2 Princess Anne Plaza

The Princess Anne Plaza (PAP) project area is generally bounded by Rosemont Road on the west, I-264 to the north, Hospital Drive and South Lynnhaven Road to the east, and Holland Road, Lakecrest Road, Lamplight Lane and Lynnhaven Parkway to the south. The project area does not include the Lynnhaven Woods, Lynnhaven Forest, Doyletown, or Washington Park areas. The PAP project area is approximately 1,077 acres and is shown in Figure RS1-1.

Land use consists primarily of medium-density single family detached residential, with some commercial development along major roads. Most of the residences were constructed from the early 1960s to the early 1970s. Homes are mostly concrete slab on grade and with some crawl space construction. The majority of homes have finished floors less than one foot above top of curb. Elevations in the project area range from EL 5.0 to EL 14.0 feet NAVD88.

Based on FIRM Map 5155310104G, the northern portion of the project area (above Silina Drive) is in Flood Zone X, areas determined to be outside the 0.2% annual chance (500-year) floodplain. However, the southern portion of PAP and along London Bridge Creek is in Flood Zone AE with a base flood elevation (100-Year Storm) of EL 7.0 feet NAVD88.
Figure RS1-1: The Lakes and Princess Anne Plaza Project Area
RS1.3 Historical Development of The Lakes and Princess Anne Plaza

Figure RS1-2 is a 1949 aerial map of the TL-PAP area showing land use at the time consisted of agricultural fields and wooded areas. It is assumed the wooded or natural areas were not cultivated because they were too wet or low lying, making them susceptible to flooding.

Figure RS1-3 overlays the growth which has occurred in the TL-PAP project area on Figure RS1-2. The blue areas on Figure RS1-3 represent the water ways providing drainage relief in the project area. Figure RS1-3 shows development has not just occurred over the farm lands, but also in the wooded areas.

After development, a large portion of the TL-PAP project area remains low-lying and susceptible to flooding. Figure RS1-4 shows flood levels based on ground surface elevation (NAVD88). The pink areas represent areas located within the one percent (1%) chance of flooding in any year (100-year flood) and the light orange areas represent the 0.2 percent (0.2%) chance of flooding in any year (500-year flood). The green shaded areas are areas where no base flood elevation has been determined. The unshaded areas represent areas outside of the FEMA Flood Zones. However, the residences and roads adjacent to low-lying areas are still vulnerable to flooding.
Figure RS-3: 1949 Aerial Overlaid with Development and Drainage Relief
Figure RS-4: 2015 FEMA Flood Zones
RS1.4 History of Flooding in The Lakes and Princess Anne Plaza

The TL-PAP project area covers approximately 1,262 acres (2.0 square miles) and is part of the London Bridge Creek tributary area, which is in the City’s Watershed 6. Watershed 6 (WS6) covers approximately 8,332 acres (13.0 square miles) and is primarily located west of Naval Air Station (NAS) Oceana, north of Dam Neck and Princess Anne Roads, east of Windsor Oaks Boulevard and South Rosemont Road and south of Virginia Beach Boulevard. London Bridge Creek and Canal #2 are the primary drainage channels running north/south through the center of WS6. Figure RS1-5 shows the project areas in relation to WS6.

![Figure RS1-5: Watershed 6](image-url)

The TL-PAP project area has experienced repeated flooding issues mainly due to its low-lying topography, tidal influence and lack of storm water storage. Table RS1-1 presents the Sewell’s Point NOAA station data for major storm events providing a general overview of the frequency and intensity of the storm events to affect the TL-PAP project area.
Table RS1-1: Historical Storm Events and Tidal Elevations at NOAA Sewell’s Point

<table>
<thead>
<tr>
<th>Storm Event</th>
<th>Date (Year)</th>
<th>Maximum Water Level (NAVD88, feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hurricane Floyd</td>
<td>1999</td>
<td>4.36</td>
</tr>
<tr>
<td>Nor’ida (Nor’easter)</td>
<td>2009</td>
<td>6.12</td>
</tr>
<tr>
<td>Hurricane Irene</td>
<td>2011</td>
<td>5.94</td>
</tr>
<tr>
<td>Hurricane Sandy</td>
<td>2012</td>
<td>5.18</td>
</tr>
<tr>
<td>Hurricane Hermine</td>
<td>2016</td>
<td>4.53</td>
</tr>
<tr>
<td>Tropical Storm Julia</td>
<td>2016</td>
<td>2.56</td>
</tr>
<tr>
<td>Hurricane Matthew</td>
<td>2016</td>
<td>4.11</td>
</tr>
</tbody>
</table>

RS2. CHAPTER 2 – PROBLEM IDENTIFICATION

Chapter 2 identifies and discusses the flooding problems in the project area based on the conclusions of the TL-PAP Mitigation Plan. In Chapter 2, the types, the effects and other factors contributing to the flooding problem are discussed. Significant rainfall events and storm surge from hurricanes and northeasters are the major flooding sources. The base flood water surface elevation of London Bridge Creek is EL 7.0 feet NAVD88 based on the FEMA 100-year (1% chance of occurrence) storm.

Modeling performed showed, under existing conditions, 116 road intersections are impacted by flooding issues during a simulated 10-year design rainfall. The most severe road flooding occurs in the Northgate and East Northgate areas. Specific road locations are Club House Road, Garrison Place, Hannibal Street, Bethune Drive, Lark Street, Northgate Drive, Forest Trail, Lamplight Lane and Burnt Mill Road.

RS2.1 Hurricane Matthew Damage in the TL-PAP Project Area

As previously noted, the FEMA 100-year flood elevation in the TL-PAP project area is EL 7.0 feet NAVD88. Hurricane Matthew exceeded this flood elevation level and was classified between a 100-year and 500-year storm.

Some of the most significant flooding occurred in the East Northgate area - east of Plaza Northgate Park, west of South Club House Road, south of Bow Creek Boulevard and north of Holland Road/Lynnhaven Parkway as shown in Figure RS2-1. Along the streets in this area, the existing ground surface elevation can be EL 6.0 feet NAVD88 or less, which makes these areas

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especially prone to the flooding. The areas most prone to structure flooding are further identified as follows (See Figure RS2-1):

- The Lakes Neighborhood
- Northgate Area of Princess Anne Plaza
- Hannibal Street
- Carriage Hill Area near London Bridge Creek
- Bethune Drive east of Lee Highlands Boulevard
- Pecan Gardens Neighborhood
- Princess Anne Plaza Neighborhood

As a result of the flooding from Hurricane Matthew, the City commissioned a study for this area entitled the **TL-PAP Mitigation Plan**.

**RS3. CHAPTER 3 - ANALYSIS METHODOLOGY**

Chapter 3 explains the hydraulic and hydrologic (H&H) model used to develop improvement recommendations in the **TL-PAP Mitigation Plan** and the refinements to the proposed improvements as performed for this PER.

The H&H model was developed to mimic existing stormwater conditions using PCSWMM Version 7.0 by Computational Hydraulics International. Model development used the City’s GIS data for storm drain pipes 24-inch and above to create the base stormwater management system. Topographic data was added using the City’s Digital Terrain Model. Finally, hydrologic parameters were assigned to each sub-basin. This constituted the “Base Model”.

The Base Model was then run against known storms and the results compared to recorded, observed conditions. The base model was calibrated by varying the model parameters until the results matched the real world observed conditions. The calibrated model was then used on an iterative basis to develop a recommended drainage improvements solution. For additional information on the H&H model refer to Chapter 3.
Figure RS3-1: Hurricane Matthew Damage in the TL-PAP Drainage Area
RS4. CHAPTER 4 - ALTERNATIVES EVALUATION

Multiple alternatives were evaluated to find the recommended solutions for flood mitigation in the project area. The “Establishment Alternatives” were identified in the TL-PAP Mitigation Plan. Chapter 4 explains the “Establishment Alternatives” and investigates other “Outside the Box” infrastructure alternatives.

The improvements recommended in TL-PAP Mitigation Plan’s Alternative 3 are presented in Table RS4-1. The recommended alternatives follow the “BERM-POND-PUMP” scenario. For the TL-PAP Project, this scenario includes installing tide gates, increasing the available storage capacity within the system, and ultimately using pumps to drawdown water levels and maintain them below flood stage. In addition to these three main concepts, the stormwater must be transported to appropriate storage areas. This will be accomplished by improving project area storm drain pipes, canals and ditches.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berm</td>
<td>Tide Gates and Flood Barriers at the northern and southern limits of London Bridge Creek</td>
</tr>
<tr>
<td>Pond</td>
<td>Bow Creek Golf Course Storage&lt;br&gt;Plaza Northgate Park Storage&lt;br&gt;Green Run Storage: Green Run Park and Green Run East</td>
</tr>
<tr>
<td>Pump</td>
<td>1,000 cfs Northern Pump Station&lt;br&gt;600 cfs Southern Pump Station</td>
</tr>
<tr>
<td>Storm Drain Pipe Improvements</td>
<td>Approximately 33,000 Lin. Ft. of storm drain pipe improvements</td>
</tr>
</tbody>
</table>

RS4.1 Potential Improvements Evaluations

Design Charrettes and other meetings were held to identify potential improvements other than the “Establishment Alternatives”. Chapter 4 identifies and examines the “Outside the Box” improvement alternatives identified during these efforts. Table RS4-2 summarizes the potential “Outside the Box” alternate improvements evaluated. For more detailed information on the improvement alternatives refer to Chapter 4.
Table RS4-2: Potential Improvements Evaluated

<table>
<thead>
<tr>
<th>Potential Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fines for Dumping into Neighborhood Ditches</td>
</tr>
<tr>
<td>Connecting Windsor Woods Canal with Bow Creek</td>
</tr>
<tr>
<td>Dedicated Funding for Canal Dredging in the Capital Improvement Plan</td>
</tr>
<tr>
<td>Accelerate the City’s Ditch Maintenance Program</td>
</tr>
<tr>
<td>Redevelopment to Raise Structures Alternative</td>
</tr>
<tr>
<td>Property Buyouts of Low Lying Structures</td>
</tr>
<tr>
<td>Additional Interconnectivity Between WW and TL-PAP</td>
</tr>
<tr>
<td>Underground Stormwater Retention</td>
</tr>
<tr>
<td>Deep Tunnel Storage</td>
</tr>
<tr>
<td>Out-of-Basin Storage</td>
</tr>
<tr>
<td>Invert Road Sections for Additional Storage</td>
</tr>
<tr>
<td>Temporary Pumps at Bow Creek Golf Course</td>
</tr>
<tr>
<td>Reducing the Level of Service</td>
</tr>
<tr>
<td>Utilize I-264 as a Barrier</td>
</tr>
<tr>
<td>Reduced Level of Service</td>
</tr>
</tbody>
</table>

RS4.2 Conclusions and Recommendations

Multiple alternate flood mitigation improvements were considered for the TL-PAP project area. Several of the alternatives were not engineering solutions but require policy decisions or changes on the part of the City. Other alternatives were determined to be too expensive or impractical and eliminated from consideration. Three alternatives: 1) Interconnecting the Windsor Woods (WW) and TL-PAP project areas, 2) providing temporary pumps at Bow Creek Golf Course and 3) Out-of-Basin Storage were identified for additional investigation. Interconnecting the WW and TL-PAP project areas was modeled and is addressed in Chapter 4, Section 4.3.5. Providing temporary pumps at the Bow Creek Golf Course and Out-of-Basin storage are evaluated in Chapter 11.

Based on evaluation of the Alternative improvements, the TL-PAP Mitigation Plan Alternative 3 infrastructure improvements formed the basis of the improvements for the project area.

Non-engineering policy decisions recommended to be considered by the City include:

- Fines for Dumping into Neighborhood Ditches;
- Dedicated Funding for Canal Dredging in the Capital Improvement Plan (CIP); and
- Accelerate the City’s Ditch Maintenance Program.
Policy related decisions relying more heavily on engineering recommendations that were considered include:

- Redevelopment to Raise Structures Alternative;
- Property Buyouts of Low Lying Structures; and
- Reducing the Level of Service.

The recommended infrastructure improvements are intended to mitigate flooding up to the 100-year storm event. However, even when fully implemented, the recommended improvements will not prevent all structures in the project area from flooding.

The TL-PAP Mitigation Plan recommended improvements and this PER are based on the following Level of Service (LOS):

- Limiting peak flood stages to 3 inches or less above road crowns for the 10-year design storm; and
- Preventing flooding of structures for the 100-year design storm.

This LOS is a reduction from the City’s current standard design requirements for new development. Reducing the LOS even further would result in additional structure flooding.

**RS5. CHAPTER 5 – RECOMMENDED SOLUTIONS AND PHASING**

**RS5.1 The Lakes and Princess Anne Plaza Drainage Area Flood Mitigation Strategy**

The PER Recommended Improvements for the TL-PAP basin lies in the “BERM-POND-PUMP” concept, which includes tide gates and flood barriers at the northern and southern limits of London Bridge Creek, increased stormwater storage, a pump station, and storm drain pipe improvements. Due to funding constraints and the magnitude of the required improvements, a conceptual phasing plan was developed (refer to Chapter 5). However, due to the overall Program cost, a separate Execution & Implementation Plan is under development to prioritize projects based on funding and flood mitigation benefits.

**RS5.1.1 BERM**

Creating additional storage will be accomplished in two steps: 1) building tide gates at the northern and southern limits of London Bridge Creek to eliminate tidal influence in the TL-PAP basin and 2) by creating flood barriers extending from the tide gates. Once the tidal influence is eliminated, the existing creeks and various neighborhood ditches can be used as dedicated stormwater retention areas.
This does not mean the tide gates and flood barriers need to be constructed simultaneously. Significant benefits are gained from the tide gates alone. The full benefit of the flood barriers is not realized until additional storage is constructed in the TL-PAP project area. Therefore, it is recommended the tide gates be designed and constructed first. Due to the time period required to construct the additional storage, design and construction of the barriers would be delayed until a later stage.

RS5.1.2 POND

The existing creeks, ditches, ponds and lakes in the TL-PAP basin do not have sufficient storage capacity to adequately contain runoff and mitigate flooding. The TL-PAP Mitigation Plan recommends an additional 433 acre-feet (ac-ft) of stormwater retention for the 100-year storm and an additional 125 ac-ft for the 10-year storm. Additional storage will be created by the construction of stormwater retention ponds on the Bow Creek Golf Course (Golf Course) and the Plaza Northgate Park and installing a tide gate on the culvert under Holland Road (See Chapter 11 for more details). The recommended second program element of the TL-PAP flood mitigation is construction of a stormwater retention pond on the Golf Course.

It is recommended the Golf Course be developed first as it has the greatest potential storage capacity. Due to the cost and scope of the work, it is proposed to develop the Golf Course storage in Sections (See Figure RS5-1). It is recommended Golf Course storage begin concurrently with the Tide Gates. It is recommended construction start with Section I because it is closest to London Bridge Creek.

Due to funding limitations, the remaining storage creation – Golf Course Sections II and III, Holland Road Flood Gate and Plaza Northgate Park - was placed in future stages. After the Golf Course Section I, the recommended development order for the remaining storage projects is:

1. Bow Creek Golf Course Section II;
2. Holland Road Flood Gate and associated infrastructure projects;
3. Plaza Northgate Park; and
4. Bow Creek Golf Course Section III.

The Plaza Northgate Park and Bow Creek Golf Course Section III will only be investigated if, after detailed design of the Golf Course and Holland Road Flood Gate storage, it is determined additional stormwater storage is required.
Figure RS5-1: Bow Creek Golf Course Development Plan
RS5.1.3 PUMP

Closing the tide gates at low tide prevents the incoming tide from filling available storage – existing or created. It is proposed to use the pump station to draw down the retention area water levels to EL 0.0 feet NAVD88 prior to a storm event to maximize storage capacity. Analysis showed lowering the water levels to EL -1.0 feet NAVD88 resulted in no change in structure flooding mitigation due to the low volume available below EL 0.0 feet NAVD88.

Pumping will continue during a storm event to maintain water levels as low as possible for as long as feasible in order to prevent the storm drain pipes, lakes, canals and ditches from overflowing and flooding the project area.

The recommended improvements include a proposed 1,200 cfs capacity Pump Station (PS) at the northern project limits on London Bridge Creek. The pump station includes a Control/Generator Building for monitoring, controlling and powering the pumps. The Control/Generator Building will be provided with facilities to maintain a crew during the storm event. Level sensors and monitors will be located upstream and downstream of the PS to monitor water levels, control pumping and ensure pumping does not create downstream conditions worse than existing.

After storage creation, the pump station is the second most expensive portion of the PER Recommended Improvements.

RS5.1.4 Storm Drain Pipe Network

The existing storm drain piping in the TL-PAP project area is undersized or non-existent. Where it exists, it is generally in poor condition – structural failures or years of silt accumulation which reduce flow capacity. Therefore, in addition to the three major program elements (i.e. “BERM-POND-PUMP”), storm drain pipe improvements are also proposed to provide an efficient and appropriately sized network to convey the runoff to London Bridge Creek. The storm drain pipe improvement projects involve: installing new storm drain pipes in areas without piping; constructing storm drain pipes to parallel existing pipes; replacing existing storm drain pipes with new larger pipes; and cleaning or rehabilitating ditches to restore the original design capacity.

Due to limited available funding, it was decided to first focus drainage improvements on mitigating structure flooding because it was the most disruption in residents lives and the most expensive to repair. Therefore, it is recommended to place the storm drain piping improvements last in the construction staging because modeling showed the improvement principally mitigate roadway flooding and not structure flooding.
The first proposed stormwater pipe projects will be in the Northgate area as it is the most prone to flooding and has experienced the most structure flooding. Subsequent recommended projects will expand out from this area first addressing areas experiencing structure flooding and then addressing roadway flooding.

Some of the recommended storm pipe improvements are located in the northern portion of PAP where there is no structure flooding. It is recommended these projects be scheduled near the end of construction due to funding constraints.

Principal neighborhood ditches in the project area are Northgate Ditch and Bethune Drive Ditch. It is recommended these waterways be rehabilitated to restore their original (design) capacity.

RS5.15 PER Recommended Improvements

The Tide Gates, Flood Barriers, Pump Station and storm drain pipe improvements described above constitute the PER Recommended Improvements. Table RS5-1 summarizes the PER Recommended Improvements and their associated estimated cost.

<table>
<thead>
<tr>
<th>Recommended Drainage Improvement</th>
<th>Estimated Project Cost ($ x Mil.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faraday Lane Drainage Improvements</td>
<td>$ 0.81</td>
</tr>
<tr>
<td>Northern Tide Gates</td>
<td>$ 7.83</td>
</tr>
<tr>
<td>Southern Tide Gates</td>
<td>$ 13.09</td>
</tr>
<tr>
<td>Northern Pump Station</td>
<td>$ 56.03</td>
</tr>
<tr>
<td>Flood Barriers</td>
<td>$ 5.65</td>
</tr>
<tr>
<td>Bow Creek Golf Course Storage Section I</td>
<td>$ 23.23</td>
</tr>
<tr>
<td>Complete Bow Creek GC Conversion</td>
<td>$ 29.87</td>
</tr>
<tr>
<td>Bow Creek Park Amenities</td>
<td>$ 14.15</td>
</tr>
<tr>
<td>Plaza Northgate Park Storage</td>
<td>$ 10.03</td>
</tr>
<tr>
<td>Holland Road Flood Gate</td>
<td>$ 8.06</td>
</tr>
<tr>
<td>PER Recommended Storm Drain Pipe Improvements</td>
<td>$ 43.88</td>
</tr>
<tr>
<td>Ditch Improvements</td>
<td>$ 2.92</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$ 215.55</td>
</tr>
</tbody>
</table>

1 - Cells 1, 2 and 3, off-site disposal of excavated material, does not include park amenities associated with Section I. Park Amenities are listed separately.
2 - Section II (Cells 4, 5, & 6), Section III (Cell 7)
3 - Includes relocation of Ballfields
Figure RS5-2
PER Recommended Flood Mitigation Improvements

Legend
- Gated Control System
- Drainage Improvements Segments
- Ditch Rehabilitation
- TL-PAP Project Limits
- Water Bodies

Northern Tide Gates & Pump Station
Northern Flood Barriers
Southern Flood Barriers
Southern Tide Gates & Channels
Bow Creek Golf Course Storage
Plaza Northgate Storage
Holland Road Flood Gate

0 1,500 3,000 Feet

Water Bodies

Legend
Gated Control System
Drainage Improvements Segments
Ditch Rehabilitation
TL-PAP Project Limits
Water Bodies
RS5.1.6 Combination of Solutions

The PER Recommended Improvements provides the general concept for flood mitigation in TL-PAP. However, to physically implement such infrastructure improvements will require extensive engineering and construction time, budget, and planning. The estimated costs of the PER Recommended Improvements are greater than budgeted in the FY2019-2032 CIP. PER Chapter 5 provides a high-level overview of the significant projects proposed to implement the BERM-POND-PUMP concept to mitigate flooding in the TL-PAP project area. However, due to the overall cost of the PER Recommended Improvements a separate Execution & Implementation Plan is under development to prioritize projects based on funding and flood mitigation benefit.

RS6. CHAPTER 6 - DESIGN SUPPORT

The PER Recommended Improvements include incremental implementation of tide gates, additional stormwater retention, a pump station, flood barriers, and storm drain pipe improvement projects. Chapter 6 discusses the information gathered to further the planning and design of these projects. Available GIS data, property deed research, field visits and reconnaissance data was obtained and reviewed to ensure proposed development was feasible or to verify existing conditions of the site (i.e. pump station site, tide gate site or conveyances project sites). For structural design and site planning, future geotechnical and environmental investigations will need to be conducted.

Throughout all activities, constant coordination with permitting agencies, the City of Virginia Beach Department of Public Works, and multiple subcontractors was conducted.

Based on the general site characteristics and coordination with multiple parties, options for proposed gate locations were refined (refer to Chapter 8 for more information). In addition, a preliminary pump station location report was completed based on the best available data to-date (refer to Chapter 7 for more information). Although surveys have not been completed for the proposed storm drain pipe improvements, City GIS data and field visits facilitated preliminary recommendations for storm drain pipe improvements (refer to Chapter 10).

RS7. CHAPTER 7 - PUMPING STATION

The Draft Assessment Brief - Determination of Barrier and Pump Station Locations Along London Bridge Creek (PS Location Assessment) (September 2019) was prepared to identify and evaluate recommended sites for the pump stations. During the PS Location Assessment data analysis, it was determined a single, 1,400 cfs capacity pump station, located at the northern project limits of London Bridge Creek and not serving Green Run flows, could adequately serve the TL-PAP project area. This was designated the “1 PS Option”. The 1 PS Option still requires
southern tide gates and barriers to prevent tidal intrusion into the storm retention areas via Canal #2.

The **PS Location Assessment** evaluated eleven PS sites at the northern and southern project limits. The pumping stations, tide gates and barriers are integral to each other. The selection of the pump station site determined the sites for the tide gates and barriers. Therefore, included in the evaluation criteria of the PS sites was the length of the barriers associated with the site.

**RS7.1 London Bridge Creek North Stormwater Pump Station**

PS Site 6 with Barrier Alternative A (See Figure 7A-1, Appendix 7A) is recommended as the site for the Northern Pump Station (NPS) in the 1 PS Option.

Site 6 (NPS site) is located on a portion of three commercial parcels along London Bridge Creek east of Cox Bridge on South Lynnhaven Road. The concept plan is to relocate the existing stormwater retention pond to allow construction of the forebay for the PS and discharge facilities. During final design, further investigation will be performed to determine if the forebay can also be used as a retention facility to reduce the impacts to the site.

Barrier Alternate A extends the northern barrier approximately 480 feet to the northwest from the tide gate structure between two apartment properties. The southern barrier extends approximately 580 feet east from the tide gate structure on the north side of the existing drainage channel for the Walmart (657 Phoenix Drive) stormwater retention pond. The stormwater retention pond will discharge into the forebay.

Figure RS7-1 provides a site plan of the proposed stormwater pump station.
FIGURE RS7-1: Proposed London Bridge Creek Northern Pump Station Site Layout

Note: This is a preliminary concept plan.
RS7.4 Pump Selection

Selected pumps will to provide high flow at a low head. Four pump styles were evaluated including submersible axial flow, vertical turbine, horizontal split case, and screw pump (See Table RS7-1). Regardless of style, all pumps will be required to meet the high capacity/low head conditions.

<table>
<thead>
<tr>
<th>Pump Type</th>
<th>Submersible Axial Flow</th>
<th>Vertical Turbine</th>
<th>Horizontal Split Case</th>
<th>Screw Pumps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>Flygt, Sulzer</td>
<td>Patterson, Fairbanks Morse, Flygt</td>
<td>Flygt</td>
<td>EPIC</td>
</tr>
<tr>
<td>Motor Size (HP)</td>
<td>385</td>
<td>355-395</td>
<td>585</td>
<td>450</td>
</tr>
<tr>
<td>Intake Diameter (in)</td>
<td>55</td>
<td>48-84</td>
<td>54</td>
<td>136</td>
</tr>
<tr>
<td>Dry Well Requirement</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Pre-Screening Requirement</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Advantages</td>
<td>• Motor Size</td>
<td>• Motor Size</td>
<td>• Reliability</td>
<td>• Low Maintenance</td>
</tr>
<tr>
<td></td>
<td>• Low Maintenance</td>
<td>• Smaller Intake</td>
<td></td>
<td>• Easy Access</td>
</tr>
<tr>
<td></td>
<td>• Easy Access</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disadvantages</td>
<td>• Large Wet Well Footprint</td>
<td>• Maintenance Requires Disassembly</td>
<td>• Motor Size</td>
<td>• Large Footprint</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Additional Piping</td>
<td></td>
</tr>
</tbody>
</table>

Chapter 7 also evaluated using the same size pumps proposed for the Windsor Woods Pump Station to simplify maintenance and require less parts inventory for City maintenance personnel to manage. However, due to the increased capacity required for the TL-PAP pump station, this is not feasible.

RS7.5 Pump Station Capacity

RS7.5.1 Capacity Alone

The PS Location Assessment recommended a capacity of 1,400 cfs based on the modeled maximum flow in London Bridge Creek during a 100-year storm event. During the PER analysis, H&H sensitivity modeling was performed to compare the impact of the considered PS capacities (i.e., 400, 600, 800, 1,000, 1,200 and 1,400 cfs) on predicted flood levels and resulting
mitigation benefits. Based on the modeling, the 600 and 1,400 cfs pump station capacities were eliminated due to poor Cost/Benefit ratios.

The purpose of the PS is to draw down water levels in the storage prior to a storm event to maximize available storage and pump during the storm event to maintain storage as long as possible. Evaluation of draw down times and storage refill rates showed a 400 cfs pump station to be in sufficient to meet the station requirements.

Pump station size impacts cost, the larger the capacity the larger the building, pipes, number of pumps, etc. Therefore, preliminary cost estimates were developed for the various PS sizes. These costs were combined with the results of the sensitivity modeling to obtain Cost/Benefit values for the different PS capacities. For the remaining potential capacities (800-cfs, 1,000-cfs and 1,200-cfs) Cost/Benefit values were obtained by dividing the estimated PS construction cost plus the cost of acquiring non-mitigated flooded structures by the length of mitigated roadway flooding or number of flooded structures mitigated. The 1,000 cfs capacity pump station had the lowest Cost/Benefit ratio.

RS7.5.2 Capacity Plus Storage Volume

The previous analysis only considered PS capacity. However, capacity can also be impacted by the amount of storage available (i.e., the more storage the less pumping capacity required). Therefore, pump station capacity was also evaluated with different storage volumes. Five storage scenarios were developed to be evaluated:

- Scenario 1 - Bow Creek Golf Course Sections I & II (275 ac-ft);
- Scenario 2 – Scenario 1 plus Holland Road Flood Gate (359 ac-ft);
- Scenario 3 – Scenario 2 plus Bow Creek Section III (403 ac-ft);
- Scenario 4 – Scenario 3 plus Plaza Northgate Park (476 ac-ft); and
- Scenario 5 – Scenario 4 minus Bow Creek Section III (432 ac-ft).

The 800, 1,000 and 1,200 cfs pump stations were modeled with each storage scenario. The modeling showed relatively little difference between Storage Scenarios 2, 3, 4 and 5 regardless of station capacity. Flood mitigation benefit percentages were all above a 90% reduction with the largest difference being 5%.

A Cost/Benefit analysis was performed to further refine the pump station capacity and storage volume. Cost/Benefit ratios were derived by dividing the total project cost of the storage scenario plus the pump station plus the cost of acquiring non-mitigated simulated flooded structures by the simulated benefit.
Based on the flood mitigation percentage reduction, the overall cost, and the Cost/Benefit Ratio, a 1,200 cfs capacity pump station is recommended.

RS8. CHAPTER 8 – GATES

RS8.1 Gates and Barriers for The Lakes and Princess Anne Drainage Area

Table RS 8-1 presents the recommended design elevations for the top elevation for the tide gates and flood barriers. Project design will be based on the Present Day, 100-year storm without consideration of Sea Level Rise (SLR). Due to existing topography and cost constraints, it is not feasible to construct a gate and barrier system addressing SLR. SLR concerns are being addressed separately by the City on an overall City-wide basis; however, these improvements will compliment and enhance the City’s SLR efforts.

Table RS8-1: Tide Gates and Barriers Design Flood Elevations

<table>
<thead>
<tr>
<th></th>
<th>Present Day (feet)</th>
<th>Future 100-year Storm (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10-year Storm</td>
<td>100-year Storm</td>
</tr>
<tr>
<td></td>
<td>No SLR</td>
<td>No SLR</td>
</tr>
<tr>
<td>Surge-Stillwater Elevation (SWEL) (1)</td>
<td>5.1</td>
<td>6.9</td>
</tr>
<tr>
<td>Correction Height (2)</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Corrected Surge-Stillwater Elevation = Subtotal of Row Values (above) (3)</td>
<td>5.7</td>
<td>7.5</td>
</tr>
<tr>
<td>Sea Level Rise (SLR)</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>Subtotal =</td>
<td>5.7</td>
<td>9.0</td>
</tr>
<tr>
<td>Maximum allowance for local wave height regeneration, due to expanding flooding (4)</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>Freeboard (5)</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>7.7</td>
<td>12.0</td>
</tr>
<tr>
<td>DESIGN FLOOD ELEVATION (DFE) for Barrier more than 100’ away from major structures (i.e. Pump Station &amp; Control Gate Structure(s) where flow is constricted)</td>
<td>7.5</td>
<td>9.5 (6)</td>
</tr>
<tr>
<td>Additional Freeboard at Pump Station &amp; Control Gate Structure(s) (7)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>8.5</td>
<td>13.0</td>
</tr>
<tr>
<td>DESIGN FLOOD ELEVATION (DFE) within 100’ of major structures (i.e. Pump Station &amp; Control Gate Structure(s) where flow is constricted)</td>
<td>8.5</td>
<td>10.5 (7)</td>
</tr>
</tbody>
</table>
Note 1. The reported Stillwater Elevation (SWEL) is based on the reported elevations (NAVD88) for the entire shoreline of the Lynnhaven River (within the community), which is reported in the Flood Insurance Study (FIS) for the City of Virginia Beach, Virginia, revised January 16, 2015. The FIS indicates these elevations reflect the Stillwater elevations due to tidal and wind setup effects.

Note 2. Correction height based on Sea Level Rise Recurrent Flood Study (SLRRFS) recommendation presented in a draft Technical Memorandum prepared by the City's Sea Level Rise study consultant dated April 27, 2018.

Note 3. Corrected Surge-Stillwater Elevation is based on increasing the FIS SWEL by the correction height listed above. See Note 2.

Note 4. Local-wave heights are based on that recommended by the City's Sea Level Rise study consultant (see Note 2 above). Apply these local-wave heights to scenarios that involve future Sea Level Rise (SLR) due to expanding flooding for future condition scenarios.

Note 5. It is understood the City desires to construct barriers to eventually qualify as viable flood protection structures under the National Flood Insurance Program (NFIP) based on 44 CFR § 65.10. For conceptual design, it was assumed wave runup is not critical and wave height under a 1%-chance event will be less than 2' (e.g., less significant than storm surge above the SWEL). It is assumed changes in discharge relationships, and source, potential and magnitude of debris/sediment accumulation are not critical to determine the Design Flood Elevation (e.g., top of barrier). For coastal barriers, 44 CFR § 65.10 requires a minimum freeboard that extends 1 foot above the height of the 1 percent wave or maximum wave runup (whichever is greater). Based on engineering judgement, a freeboard of 2 feet was used for the future 100-year storm to be conservative.

Note 6. 44 CFR § 65.10 requires the DFE to be no less than 2 feet above the 100-year SWEL for a flood protection structure under the National Flood Insurance Program (NFIP).

Note 7. 44 CFR § 65.10 requires one additional foot of freeboard within 100 feet on either side of major structures (such as a pump station or gate control structure) where flow is constricted.

Note 8. Recommended Design Flood Elevations

RS8.2 Tide Gate Operation

RS8.2.1 Tide Gate Without Pump Station

Under sunny day conditions (non-rainfall event), the tide gates will be open and tidal flows will proceed unobstructed up and down London Bridge Creek, Green Run Canal, The Lakes Canal and Canal #2.

Prior to a heavy rainfall or extreme high tide event, the tide gates will be closed at low tide to conserve storage by preventing tidal flows from entering the TL-PAP drainage basin and filling available stormwater retention areas.

During the event, the tide gates will remain closed until water levels in the TL-PAP drainage basin exceed the water levels downstream of the tide gates. When upstream levels exceed
downstream levels, the tide gates will be opened to release water from the TL-PAP basin. This includes low tide periods during the storm events. Under these conditions, the tide gates will be opened gradually to prevent an outrush of water which could impact downstream water levels or create scouring or erosion.

After the event, the tide gates will be opened to operate as during “Sunny Day” conditions.

RS8.2.2 Tide Gate With Pump Station

Under sunny day conditions (non-rainfall event), the tide gates will be open and tidal flows will proceed unobstructed up and down London Bridge Creek, Green Run Canal, The Lakes Canal and Canal #2. The North Pump Station (NPS) Forebay Gates will be closed to prevent tidal flows from entering the forebay to minimize sediment accumulation and reduce maintenance.

Prior to a heavy rainfall or extreme high tide event, the tide gates will be closed at low tide to conserve storage by preventing tidal flows from entering the TL-PAP drainage basin and filling available stormwater retention areas. The Forebay Gates will be opened to allow water from London Bridge Creek to supply the NPS. The NPS will be used to draw down water levels in the TL-PAP basin to EL. 0.0 feet NAVD88 to maximize storage volume.

During the event, the NPS will operate to maintain low water levels for as long as possible. When the NPS is operating, the tide gates and Forebay Gates will remain closed. If water levels in the TL-PAP drainage basin exceed the water levels downstream of the tide gates, the NPS will be stopped and the tide gates will be opened to release water from the TL-PAP basin. This includes low tide periods during the storm events. Under these conditions, the tide gates will be opened gradually to prevent an outrush of water which could impact downstream water levels or create scouring or erosion.

RS8.3 Gate Type Selection

Six types of gates were evaluated based on ability to control flow, control tidal influence, aesthetics, and maintenance. The gate types included: swing gates (miter gates), flap gates, slide gates, Tainter gates, crest gates (tilting weir gates), and roller gates. A detailed evaluation of gates is included in Chapter 8.

Based on the evaluation criteria, self-contained slide (sluice) gates are recommended for the forebay and tide gates at the London Bridge Creek NPS and London Bridge Creek Southern Gates sites due to ease of maintenance, economy, and aptitude for use in tidal applications.

The slide gates will be installed in slots cast into the concrete gate structures. The gate structures will also be provided with stop log slots. The stop logs will be installed upstream and
downstream of the gates to allow the structure to be dewatered for maintenance or replacement. Since the gates will be self-contained, replacement will be simplified.

A preliminary conceptual site plan for the London Bridge Creek Southern Tide Gates is shown in Figure RS8-1.

RS9. CHAPTER 9 – FLOOD BARRIERS

RS9.1 Flood Barriers

Flood Barriers are needed to stop runoff, high tides and surge from spilling into the TL-PAP basin and are an artificial ridge line between mitigated and non-mitigated areas. Flood barriers will be created by raising the existing grade to the Design Flood Elevation (DFE). Flood barriers will start at the tide gates and extend outward until a natural tie-in location of similar elevation is reached.

The DFE for flood barriers more than 100-foot away from major structures is EL 9.5 feet NAVD88. For flood barriers closer than 100-feet, the DFE is EL 10.5 feet NAVD88.

Types of barriers used will include: earthen berms; concrete and sheet pile retaining walls; and movable roadway flood barriers. The type of barrier utilized will change along the barrier length depending on the height required and available space conditions.

RS9.1.1 Flood Barrier Types

The principal flood barrier types evaluated are defined by their construction material: concrete, earthen, and sheet pile.

A. Concrete Barriers

There are four main types of concrete barriers: gravity walls; cantilever walls; buttresses (pilasters); and counterforts. In general, the advantages of concrete barriers are a smaller footprint and relatively low maintenance. Disadvantages include cost of materials, excavation requirements, foundation soil requirements, and aesthetics.

B. Earthen Berms

Earthen berms consist of constructing a mound of earth over existing grade to reach the required elevation. Advantages of earthen berms include: the availability of fill materials; ease of handling fill materials; contractor familiarity with construction techniques; low construction costs, and they are aesthetically pleasing as they are grassed green space. Earth berms are also suitable for use where soils may not support a concrete barrier.
FIGURE RS8-1: Proposed London Bridge Creek Southern Gates Site Layout

Note: This is a draft preliminary concept plan.
Disadvantages include: a larger footprint; structural fill materials may not be readily available on site; and higher maintenance costs due to mowing needs. Earth berms require increased protection against scour for flood depths greater than 7 feet and velocities exceeding 8 feet per second.

C. Sheet Piles

Sheet piling is a form of driven piling using thin interlocking sheets to obtain a continuous barrier in the ground. The pile transfers pressure from the high side of the wall to the soil in front of the wall.

Sheet piling can be installed with vibratory or vibration-free equipment. The method of installation will be dependent on soil data and proximity to and type of existing structures. Based on the TL-PAP Preliminary Soil Survey, it is expected vibration free installation could be used at the northern and southern sites. The Contractor will be required to perform vibration monitoring before and during construction to ensure work is not exceeding allowable thresholds.

RS9.1.2 Flood Barrier Type Conclusions and Recommendation

Table RS9-2 presents the advantages and disadvantages of the various barrier materials.

<table>
<thead>
<tr>
<th>Barrier Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>• Smaller Footprint Compared to Berms&lt;br&gt;• Minimal Maintenance&lt;br&gt;• Familiar Techniques</td>
<td>• Expensive&lt;br&gt;• Excavation&lt;br&gt;• Suitable Soil Strength&lt;br&gt;• Aesthetics</td>
</tr>
<tr>
<td>Earthen Berm</td>
<td>• Inexpensive&lt;br&gt;• Aesthetics&lt;br&gt;• Familiar Techniques</td>
<td>• Larger/Wider Footprints&lt;br&gt;• Maintenance/Care&lt;br&gt;• Suitable Fill Available&lt;br&gt;• Bank Protection</td>
</tr>
<tr>
<td>Sheet Pile</td>
<td>• Noncorrosive – Fiberglass Reinforced Polymer&lt;br&gt;• Smallest Easement&lt;br&gt;• Accommodates Elevation Difference</td>
<td>• Expensive&lt;br&gt;• Vibration Concerns&lt;br&gt;• Corrosion - Steel</td>
</tr>
</tbody>
</table>

It is recommended earthen berms be used where adequate space is available. For earthen barriers, the lower cost fiberglass reinforced polymer sheet piles may be installed to prevent seepage, if required.

Sheet piling or concrete retaining walls are recommended where space is limited. Sheet piling is also recommended at locations where significant elevation differences will be experienced.
on opposite sides of the wall. An example of where retaining walls are required is along London Bridge Creek at the Southern Tide Gate and Northern PS influent bay.

A concrete barrier wall is recommended for the northern barrier and an earthen berm is recommended for the southern barrier at the Northern PS.

RS9.2 Flood Barrier Locations

RS9.2.1 Northern Barriers

At the NPS, two Flood Barrier options (Alternate A and Alternate B) were evaluated. The complete evaluation is presented in the PS Location Assessment. Flood Barrier Alternate A is recommended due to the lower costs, wetlands impacts, and roadway impacts.

RS9.2.2 Southern Flood Barriers

The southern Flood Barriers use Lynnhaven Parkway as the alignment. West of London Bridge Creek, an earthen berm is proposed along the east bound lane in the existing road right-of-way. Existing sidewalks will be removed and replaced. Four business entrances will have to be reprofiled or have movable flood barriers installed.

East of London Bridge Creek, the existing earthen berm on the north side of the road will be utilized. A retaining wall will be required on 1045 Lynnhaven Parkway due to limited space to obtain the proper elevation. A movable flood barrier will be installed at the property’s Lynnhaven Parkway access (See Figure RS9-2).

Movable roadway flood barriers are proposed at Lamplight Lane and Kings Arms Drive. The type of barrier will be determined during final design.

The southern Flood Barriers will not impact any wetlands based on the locations shown on the National Wetlands Inventory (NWI) Map in Appendix 9A.
For the BERM-POND-PUMP concept to effectively mitigate flooding, runoff must be efficiently moved through the TL-PAP project area. The existing storm drain pipe network is undersized or non-existent. Therefore, a major component of flood mitigation is to improve the storm drain pipe network and existing ditches and creeks. Restoration and cleaning of existing ditches and canals will be identified and scheduled through the Department of Public Works Operations - Maintenance Division; therefore, these costs are not included in this evaluation.

Storm drain pipe improvements are based on the TL-PAP Mitigation Plan recommendations. Each storm drain pipe improvement project was evaluated for constructability and easement/acquisition requirements and a preliminary project cost developed.

An evaluation matrix was prepared to rank the recommended storm drain piping improvements. Each evaluation criterion was ranked from 1 to 10, with 1 being the lowest and 10 being the highest (i.e. the best). A weighting factor (i.e. a percentage) was applied to each criterion based on the importance of the evaluation criteria. The highest score a project could receive was 10.0. Table RS10-1 presents the Total Score and Project Ranking for each project. Project rankings were developed to recommend an order of construction.
The Garrison Place, Lark Street, Elmont Road and Dillon Drive projects are in northern PAP which only experiences road flooding. These projects should be delayed until projects in more flood prone areas are addressed. It is recommended to concentrate first on projects in areas with structure flooding and secondly on projects in area with only roadway flooding.

Bancroft Drive, Forest Glen Road, Presidential Boulevard, South Pine Grove Road, Sandy Springs Lane, Holland Road I, Holland Road II and Meadowood Drive projects are outside the project limits and are also in areas only experiencing road flooding. It is recommended these projects be delayed until projects in more flood prone areas are addressed. The Holland Road I, Holland Road II and Meadowood Drive projects are in the Windsor Woods CIP project area, but discharge to Northgate Ditch, and could be transferred to the Windsor Woods project.

The remaining projects (shown in bold and italicized in Table RS10-1) are in the project limits and in areas prone to structure flooding. It is recommended these projects be constructed roughly in the order of ranking. Exceptions could be made for funding consideration for the more expensive projects. Total estimated cost of the projects is $14,125,900, which is approximately 37% of the total estimated storm drain pipe improvements cost and 40% of the total length of proposed pipe.

Table RS10-1: Storm Drain Pipe Improvement Project Overall Rankings

<table>
<thead>
<tr>
<th>Project</th>
<th>Total Score</th>
<th>Project Ranking</th>
<th>Project</th>
<th>Total Score</th>
<th>Project Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faraday Lane</td>
<td>8.55</td>
<td>1</td>
<td>Ashaway Road</td>
<td>6.95</td>
<td>18</td>
</tr>
<tr>
<td>Plainsman Court</td>
<td>8.20</td>
<td>2</td>
<td>S. Pine Grove Rd.</td>
<td>6.85</td>
<td>19</td>
</tr>
<tr>
<td>Bancroft Drive</td>
<td>8.05</td>
<td>3</td>
<td>Dauphin Lane</td>
<td>6.80</td>
<td>20</td>
</tr>
<tr>
<td>Forest Trail</td>
<td>7.85</td>
<td>4</td>
<td>Sandy Springs Ln.</td>
<td>6.75</td>
<td>21</td>
</tr>
<tr>
<td>Bow Creek Blvd.</td>
<td>7.70</td>
<td>5</td>
<td>Ole Towne Lane</td>
<td>6.40</td>
<td>22</td>
</tr>
<tr>
<td>Kings Arms Drive</td>
<td>7.65</td>
<td>6</td>
<td>Burnt Mill/Lakecrest</td>
<td>6.25</td>
<td>23</td>
</tr>
<tr>
<td>John Hancock Dr.</td>
<td>7.50</td>
<td>7</td>
<td>Coach House Ln.</td>
<td>6.20</td>
<td>24</td>
</tr>
<tr>
<td>Plainsman Circle</td>
<td>7.50</td>
<td>7</td>
<td>Holland Road I</td>
<td>5.55</td>
<td>25</td>
</tr>
<tr>
<td>Stoneshore Road</td>
<td>7.45</td>
<td>9</td>
<td>Holland Road II</td>
<td>5.55</td>
<td>25</td>
</tr>
<tr>
<td>Forest Glen Road</td>
<td>7.35</td>
<td>10</td>
<td>Waltham Circle</td>
<td>5.50</td>
<td>27</td>
</tr>
<tr>
<td>Forrester Lane</td>
<td>7.35</td>
<td>10</td>
<td>South Lynnhaven Rd.</td>
<td>5.45</td>
<td>28</td>
</tr>
<tr>
<td>Woodburne Drive</td>
<td>7.30</td>
<td>12</td>
<td>Meadowood Dr.</td>
<td>4.85</td>
<td>29</td>
</tr>
<tr>
<td>Plainsman Trail II</td>
<td>7.20</td>
<td>13</td>
<td>Garrison Place</td>
<td>4.45</td>
<td>30</td>
</tr>
<tr>
<td>Plainsman Trail I</td>
<td>7.10</td>
<td>14</td>
<td>Lark Street</td>
<td>3.00</td>
<td>31</td>
</tr>
<tr>
<td>Lee Highlands Blvd.</td>
<td>7.10</td>
<td>14</td>
<td>Elmont Road</td>
<td>2.80</td>
<td>32</td>
</tr>
<tr>
<td>Northgate Drive</td>
<td>7.05</td>
<td>16</td>
<td>Dillon Drive</td>
<td>2.60</td>
<td>33</td>
</tr>
<tr>
<td>Presidential Blvd.</td>
<td>7.00</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RS11. CHAPTER 11 - ADDITIONAL STORMWATER RETENTION

RS11.1 Candidate Additional Retention Areas

The main PAP drainage channels are London Bridge Creek, Bow Creek and the Northgate Ditch. London Bridge Creek and Bow Creek are tidally influenced. The lowest reaches of Northgate Ditch are also tidally influenced. However, the upper reaches, in the Pecan Gardens and Windsor Oaks neighborhoods, are above the tidal zone.

The main drainage channel in The Lakes are The Lakes/Chimney Hills Canals. Minimum water levels in The Lakes/Chimney Hills Canals are maintained at EL 1.0 feet NAVD88 by a weir. However, normal high tides range up to EL 3.0 feet NAVD88; therefore, The Lakes is also tidally influenced.

To counter tidal influence, tide gates and flood barriers are proposed (See Chapters 8 and 9). H&H modeling showed these measures alone will not provide sufficient stormwater storage. Therefore, additional stormwater retention will be required (See Chapter 11). The required additional storage for the 100-year storm event is 433 acre-ft and 125 acre-ft for the 10-year storm event. This required storage is in addition to the existing TL-PAP storage.

Multiple candidate stormwater retention sites were evaluated (See Figure RS11-1). See Chapter 11 for a full description and evaluation of each candidate site. Development of additional storage is recommended on the Bow Creek Golf Course and Plaza Northgate Park.

It is also proposed to create storage by installing a flood gate on the box culvert under Holland Road connecting the Chimney Hill and The Lakes to take advantage of high ground elevations in the Chimney Hill area to store water to a higher elevation and increase storage volume. Modeling showed the area could contain 100% of the runoff up to the 10-year storm. However, the modeling also showed a minor increase in road flooding in the Chimney Hill area due to higher tailwater conditions. Therefore, the flood gate will have to be combined with storm pipe improvements to mitigate this minor street flooding.

Combined, the Bow Creek Golf Course, Plaza Northgate Park and the Holland Road Flood Gate, create a potential additional storage volume of 476 acre-ft. The 10% surplus of additional storage allows for a contingency in case actual conditions differ from the assumed preliminary conditions. Table RS11-1 summarizes the estimated additional storage volumes at each location. Table RS11-1 also contains estimated storage costs.
Figure RS 11-1
Stormwater Retention Candidate Sites Location Map
Table RS11-1: Potential Additional Storage

<table>
<thead>
<tr>
<th>Location</th>
<th>Storage Volume (Acre-ft)</th>
<th>Surplus 1</th>
<th>Project Cost 2, 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bow Creek Golf Course</td>
<td>319</td>
<td></td>
<td>$67,245,300</td>
</tr>
<tr>
<td>Plaza Northgate Park 4</td>
<td>73</td>
<td></td>
<td>$6,200,400</td>
</tr>
<tr>
<td>Holland Rd. Flood Gate</td>
<td>84</td>
<td></td>
<td>$8,056,500</td>
</tr>
<tr>
<td>Total</td>
<td>476</td>
<td>43</td>
<td>$81,502,200</td>
</tr>
</tbody>
</table>

1 – From TL-PAP Mitigation Plan recommended 433 acre-ft
2 – Bow Creek Golf Course cost includes park amenities
3 – Holland Road Flood Gate includes required storm pipe improvements
4 – Cost of relocating Ballfields not included

The TL-PAP Mitigation Plan assumes existing and proposed stormwater retention areas will be drawn down to EL. 0.0 feet NAVD88 prior to a rainfall event. Based on the projected storage volumes, the water surface elevation in the retention areas will be approximately EL. 5.0 feet NAVD88 for a 100-year storm event. This elevation is below all street and finished floor elevations in the TL-PAP project area (based on the best available information), exact elevations will be determined during detailed design.

RS11.2 Storage Without Bow Creek Golf Course

Creating the needed additional storage without using the Bow Creek Golf Course (Golf Course) was also investigated. If the Golf Course is not utilized, the Northgate area of PAP, specifically Upper Northgate and East Northgate (See Figure RS11-2), offers the best location for additional storage as the area is low lying and in the heart of the most flood prone area.

Approximately 374 parcels would have to be acquired from these neighborhoods to equal the area available on the Golf Course. Acquisition costs were estimated at over $120 million and based on the average 2018/2019 assessed value times 1.5 with an allowance for relocation and demolition. For additional information refer to Section 11.6 of Chapter 11.

This cost is above and beyond the cost of creating the storage. Excavation in the neighborhoods would be more expensive than on the Golf Course due to removal of roads and existing utilities and relocation of key utilities. Due to the significantly higher cost, impact on residents and time delay associated with acquiring the needed properties, creating the required additional storage without the Bow Creek Golf Course is not recommended.
RS12. CHAPTER 12 – SITE DEVELOPMENT

RS12.1 Property Acquisition

Proposed projects were evaluated in relation to potential permanent or temporary easements. Each project was evaluated based on existing and proposed pipe sizes, parallel utilities, and required easement widths. More information can be found in Appendix 12A.

RS12.1.1 Utility Relocation Coordination

Numerous existing utility lines, public and private, reside within the project area. For each utility company within the project area, common steps will be taken to ensure implementation of the storm drain pipe projects go as smoothly as possible. Coordination with each utility company will be necessary from design through completion of construction. During the early stages of
the design period, design drawings will be provided to each utility for their input. Additionally, a
private (franchise) utility coordination meeting to discuss the overall program strategy has
been held to begin this process.

RS12.1.2 Restoration

All disturbed areas during construction will be stabilized and restored as required by the
Stormwater Pollution Prevention Plan permit package for each construction project. Existing
facilities disturbed/removed during the installation of conveyance segments will be restored to
existing condition or better following construction. Site work including temporary access roads
and laydown areas will be restored to pre-development conditions. Seeding and general
vegetation selection will be determined in collaboration with the necessary stakeholders.

RS12.1.3 Water Quality and Quantity Enhancements

All projects will be designed in accordance with the Virginia Stormwater Management Program
(VSMP) regulations. Further coordination with the City of Virginia Beach’s Stormwater
Management Group will be needed as the design of each proposed project in this PER evaluates
the required stormwater management requirements for each conveyance segment and pump
station. See Chapter 12 for further discussion on this coordination.

RS13. CHAPTER 13 - STAKEHOLDERS/PERMITTING

RS13.1 Environmental Regulatory Assessment

To assess potential jurisdictional areas within the TL-PAP project area, the National Wetland
Inventory wetland classifications were reviewed, and brief site visits were conducted to
observe key project features. All project areas contain water features which have been
historically altered making the determination of jurisdictional status difficult. A wetland
delineation with U.S. Army Corps of Engineers (USACE) confirmation will be required to
determine the precise jurisdictional nature of all on-site features and to provide an accurate
estimate of wetland and stream impacts and potential mitigation costs.

Several different types of wetlands and Waters of the U.S. (WOUS) are found at each candidate
pump station location (Chapter 7) which are within the jurisdiction of the permitting agencies.
These jurisdictional features are shown in Appendix 6C.

The Pump Station and Tide Gate locations will require impacts to jurisdictional wetlands and
WOUS, all will require permits from the USACE, Virginia Department of Environmental Quality
(DEQ), and the Virginia Marine Resource Commission (VMRC). Since these are City projects,
authorization from the Virginia Beach Local Wetlands Board (LWB) is not anticipated.
Construction at the pump station and tide gate locations will require impacts to tidal wetlands. These impacts will require Individual Permits from the USACE and DEQ and a Habitat Permit from the VMRC. General Permits are not available from the DEQ for impacts to tidal wetlands and Nationwide Permits are not appropriate for projects of this scale.

Regulatory concerns for each of the locations evaluated are similar except for the extent of impacts to wetlands and WOUS which will be required.

Additional information will be found in Chapter 13 of the Draft-Preliminary Engineering Report.

RS14. CHAPTER 14 - CONCLUSIONS

RS14.1 Final PER Recommendations

It is recommended the City proceed with all recommended drainage improvements – Tide Gates, Flood Barriers, Pump Station, Storm Pipe Improvements and Ditch Maintenance - to provide the maximum flood mitigation in the TL-PAP project area. Table RS14-1 presents a summary of the PER Recommended Improvements. The PER Recommended Improvements are shown in Figure RS5-2 (See page RS-18).

<table>
<thead>
<tr>
<th>PER Recommended Improvements</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>London Bridge Creek Tide Gates (North and South)</td>
<td>Top of Gate – EL 10.5 Feet</td>
</tr>
<tr>
<td>Barriers at Northern PS and Southern Tide Gate</td>
<td>Top of Barrier: at Tide Gate – EL 10.5 Feet</td>
</tr>
<tr>
<td></td>
<td>At Tie-In to Grade – EL 9.5 Feet</td>
</tr>
<tr>
<td>Permanent Pump Station</td>
<td>1,200 cfs</td>
</tr>
<tr>
<td>Additional Stormwater Retention</td>
<td>Bow Creek Golf Course Sections I and II and</td>
</tr>
<tr>
<td></td>
<td>Holland Road Flood Gate (359 ac-ft total)</td>
</tr>
<tr>
<td>Storm Drain Improvements</td>
<td>31,700 Lin. Feet</td>
</tr>
<tr>
<td>Drainage Ditch Improvements</td>
<td>10,500 Lin. Feet</td>
</tr>
</tbody>
</table>

It is recognized it may not be possible to implement all the recommended improvements within the proposed 15-year project period due to funding and construction impact constraints.

Table RS14-2 lists the recommended TL-PAP infrastructure improvements along with their cumulative cost. Also, included is the incremental benefit in terms of street and structural flood mitigation projected to be achieved with the construction of each major infrastructure improvement along with the current conditions as a baseline. Currently, it is estimated approximately 41,690 linear feet of streets flood during a 10-year design storm and 601
structures flood during a 100-year event in the project area. After construction of the PER Recommended Improvements, the street flooding is reduced to approximately 5,200 linear feet and structure flooding to 18.

Table RS14-2 shows the major infrastructure improvements (i.e., - tide gate, pump station, and additional storage) provide the greatest structure flooding mitigation benefit. As a result, these items are recommended to be constructed first (Phase IA) followed by the remaining additional storage (Phase IB) and the storm drain pipe projects (Phase II). A separate Execution and Implementation Plan is under development which further outlines this phasing approach. Please see this document for further details.

The “PER Recommended Improvements” relieve the most flooding for the lowest estimated cost. While full flood mitigation (100% reduction) is not economically feasible for the project area, the “PER Recommended Improvements” address a substantial portion of the flooding issues for the project area. Roadway flooding is reduced by 87% (from 41,690 LF to 5,230 LF) during the 10-year design storm and structural flooding by 97% (from 601 to 18 structures) during the 100-year design storm. See Table RS14-3 for existing and proposed flooding data.
### Table RS14-2: Phase I & Phase II Incremental Improvements

<table>
<thead>
<tr>
<th>Major Stormwater Improvement Projects (Cumulative)</th>
<th>Cumulative Cost ($ x Million)</th>
<th>Street Flooding (10-yr Storm)</th>
<th>Structure Flooding (100-yr Storm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Conditions (No Improvements)</td>
<td>$0</td>
<td>41,690 ft</td>
<td>601</td>
</tr>
<tr>
<td>Tide Gates</td>
<td>$21.0</td>
<td>28,490 ft</td>
<td>531</td>
</tr>
<tr>
<td>Bow Creek Golf Course Storage Section I w/ Amenities</td>
<td>$50.2</td>
<td>22,740 ft</td>
<td>382</td>
</tr>
<tr>
<td>1,200-cfs Pump Station and Barriers</td>
<td>$111.9</td>
<td>21,160 ft</td>
<td>236</td>
</tr>
<tr>
<td>Bow Creek Golf Course Section II w/ Amenities</td>
<td>$133.7</td>
<td>19,890 ft</td>
<td>90</td>
</tr>
<tr>
<td>Bow Creek Golf Course Section III Amenities</td>
<td>$138.2</td>
<td>19,890 ft</td>
<td>90</td>
</tr>
<tr>
<td>Holland Road Flood Gate</td>
<td>$146.3</td>
<td>19,780 ft</td>
<td>82</td>
</tr>
<tr>
<td>Storm Drain Pipe Improve. &amp; Additional Storage</td>
<td>$216.0</td>
<td>5,230 ft</td>
<td>18</td>
</tr>
</tbody>
</table>

### Table RS14-3: Flood Mitigation Benefit

<table>
<thead>
<tr>
<th>Condition/Scenario</th>
<th>Length of Road Flooding (10-yr Design Storm)</th>
<th>Structure Flooding (100-yr Design Storm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing (Current)</td>
<td>41,690 LF</td>
<td>601</td>
</tr>
<tr>
<td>PER Recommended Improvements</td>
<td>5,230 LF</td>
<td>18</td>
</tr>
<tr>
<td>Flood Mitigation Benefit (% Reduction)</td>
<td>87%</td>
<td>97%</td>
</tr>
</tbody>
</table>

### RS14.2 Opinion of Probable Construction Cost

The planning-level opinions of probable project cost presented in this PER are Class 4 (Study or Feasibility) as defined by the AACEI (formerly American Association of Cost Engineering). The estimates are typical for projects at the concept or feasibility level of the project. The expected accuracy can range between -30% to 50%.

Unit costs were developed from: major stormwater projects in the southeast; local stormwater projects; roadway construction bid tabulations; manufacturer’s quotes for similar equipment; and the 2017 RS Means Data Site Work and Landscaping Costs. Unit costs from the RS Means were inflated at 5% per year to reflect 2019 prices. The actual construction costs are largely market driven and can significantly vary from the costs presented in this PER.
Table RS14-4 presents the PER recommended improvements estimated cost. For brevity, all of the storm drain pipe improvement projects have been lumped into a single cost.

Table RS14-4: PER Recommended Improvement Estimated Cost

<table>
<thead>
<tr>
<th>Recommended Drainage Improvement</th>
<th>Estimated Project Cost ($ x Mil.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Tide Gates</td>
<td>$ 7.83</td>
</tr>
<tr>
<td>Southern Tide Gates</td>
<td>$ 13.09</td>
</tr>
<tr>
<td>Northern Pump Station</td>
<td>$ 56.03</td>
</tr>
<tr>
<td>Flood Barriers</td>
<td>$ 5.65</td>
</tr>
<tr>
<td>Bow Creek Golf Course Storage Phase I ¹</td>
<td>$ 23.23</td>
</tr>
<tr>
<td>Complete Bow Creek GC Conversion ²</td>
<td>$ 29.87</td>
</tr>
<tr>
<td>Bow Creek Park Amenities</td>
<td>$ 14.15</td>
</tr>
<tr>
<td>Plaza Northgate Park Storage ³</td>
<td>$ 10.03</td>
</tr>
<tr>
<td>Holland Road Flood Gate</td>
<td>$ 8.06</td>
</tr>
<tr>
<td>PER Recommended Storm Drain Pipe Improvements</td>
<td>$ 44.69</td>
</tr>
<tr>
<td>Ditch Improvements</td>
<td>$ 2.92</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$ 215.55</td>
</tr>
</tbody>
</table>