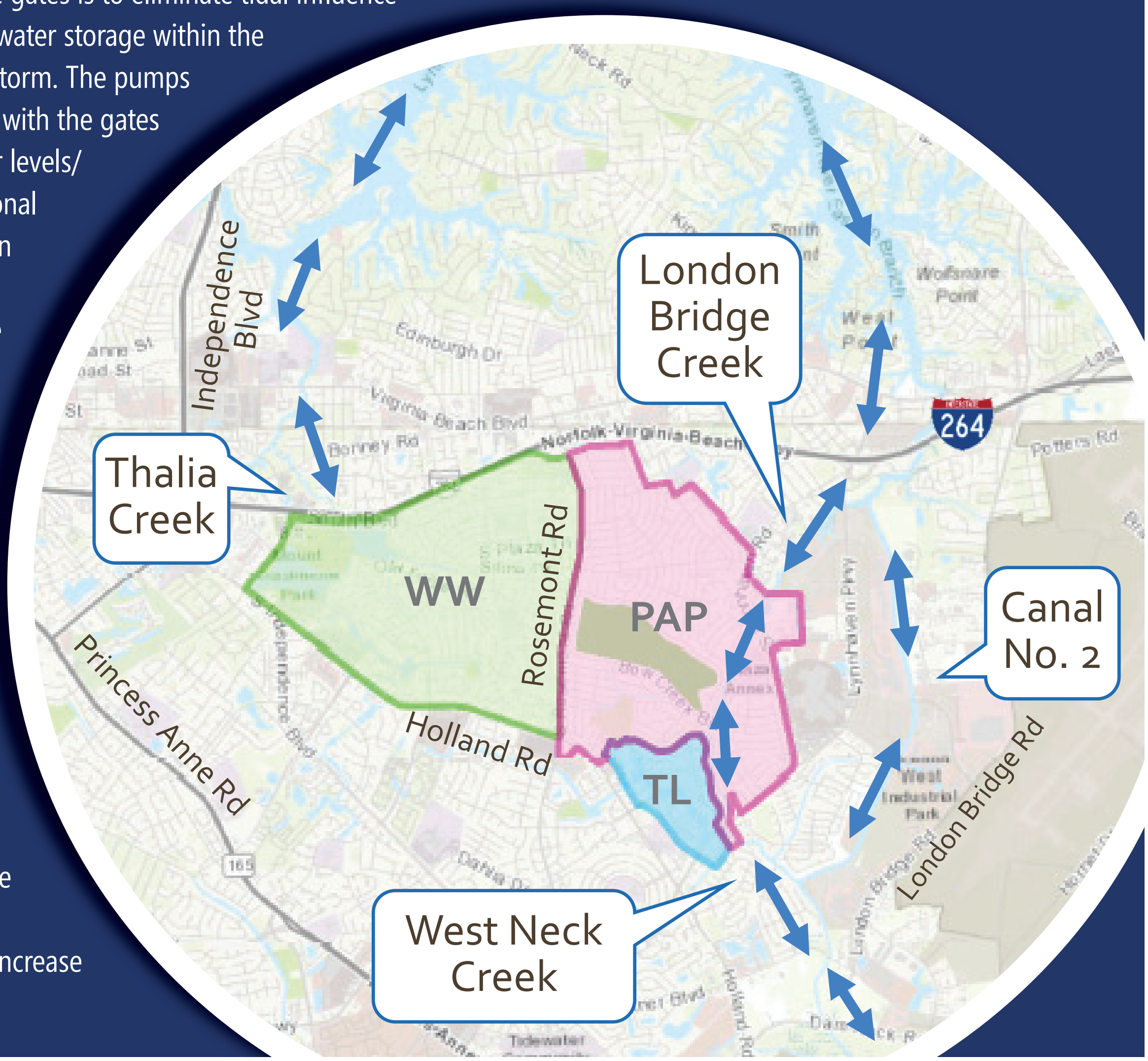
AUGUST 2020

City of Virginia Beach

The Lakes, Princess Anne Plaza & Windsor Woods Drainage Improvements

DOWNSTREAM CONSIDERATIONS

To mitigate flooding issues within The Lakes, Princess Anne Plaza, and Windsor Woods areas of the City, several different types of storm drainage improvements are required. Major improvements include tide gates, pump stations, and stormwater storage creation. The purpose of the gates is to eliminate tidal influence and create additional stormwater storage within the drainage system prior to a storm. The pumps will be used in combination with the gates to lower and maintain water levels/storage volume. This additional storage plays a critical role in mitigating the flooding by allowing the City to manage the stormwater and slowly discharge it downstream. The tide gate and pumps will be used prior to and during an extreme storm event. Otherwise, the natural ebb and flow of the tide will occur. While the gate and pumps are in use, water levels will continually be monitored both downstream and upstream to ensure there are no adverse impacts. Project implementation WILL NOT increase flooding downstream.

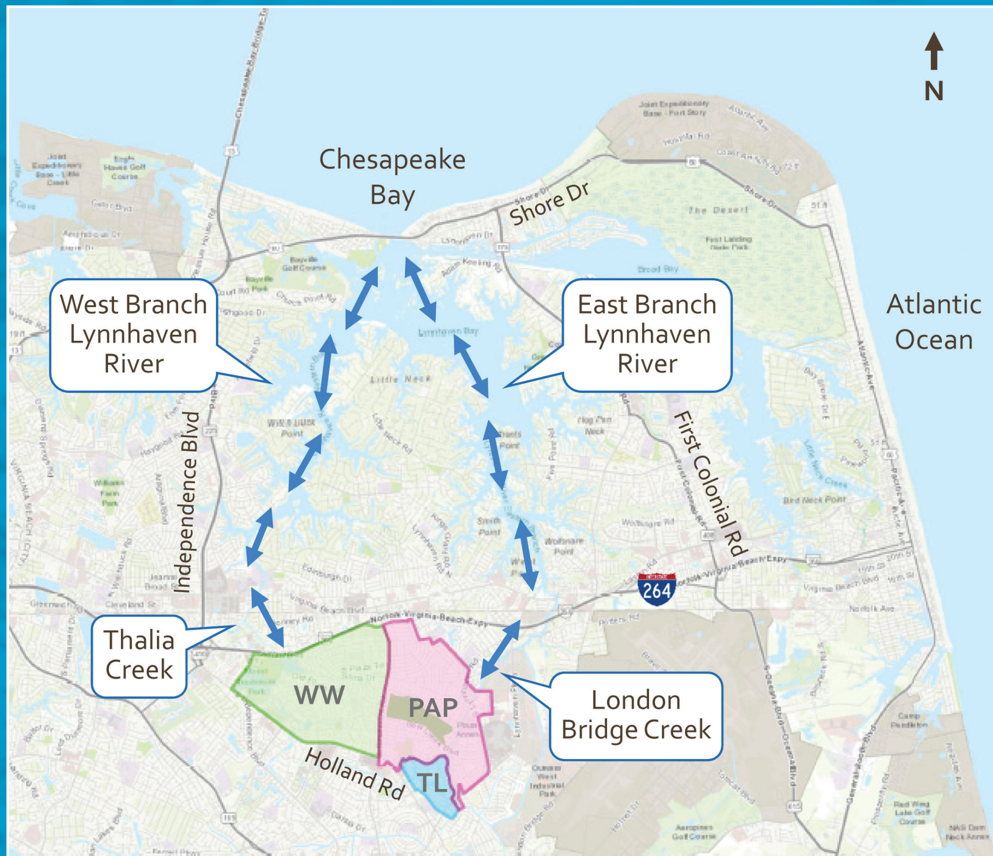


The proposed tide gates and pump stations DO NOT increase flooding downstream:

1. Understanding Tidal Impacts and Water Surface Elevation:

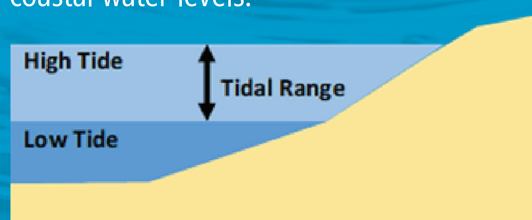
THALIA CREEK AND LONDON BRIDGE CREEK

The water surface elevations of Thalia Creek and London Bridge Creek are directly tied to that of the Chesapeake Bay and Atlantic Ocean. There are two low-tides and two high-tides daily due to the gravitational forces of the earth, moon, and sun. The water surface elevation varies throughout the day as a result of this tide cycle with an average range of 2 to 2.5 feet. Water levels are dependent upon a number of outside influences and a much larger, controlling body of water.



Below is a summary of the many factors influencing downstream and coastal water levels:

- **Tide:** This area experiences two high and two low tides per day, which is referred to as a semi-diurnal (daily) tide cycle. Water levels are continually fluctuating based on this varying tide cycle.



- **Atmospheric/Storm Surge:** On top of regular tide levels, storm surges are the water level changes that result from a combination of air pressures and winds. Local wind and weather patterns, water depth, size/type of water body, and coastal topography all contribute to water levels. In this area, wind speed and direction plays a major role due to the unique geography in that the rivers run south to north. When the wind blows from the north, water can be pushed from the Chesapeake Bay inland up the Lynnhaven Watershed making the water and tide levels higher than normal. Often, these wind and/or storm events can last for several days, which allows water to pile up along the coastline and into the rivers and creeks, creating higher than normal water levels, since the water is unable to drain out. This is referred to as **tidal stacking**. Conversely, a southern wind assists in pushing the water out into the Bay, which reduces internal water levels. Overall, the Lynnhaven Watershed is relatively flat, with little downhill slope or current, which allows its water level to be easily influenced by the wind and/or storm surges.

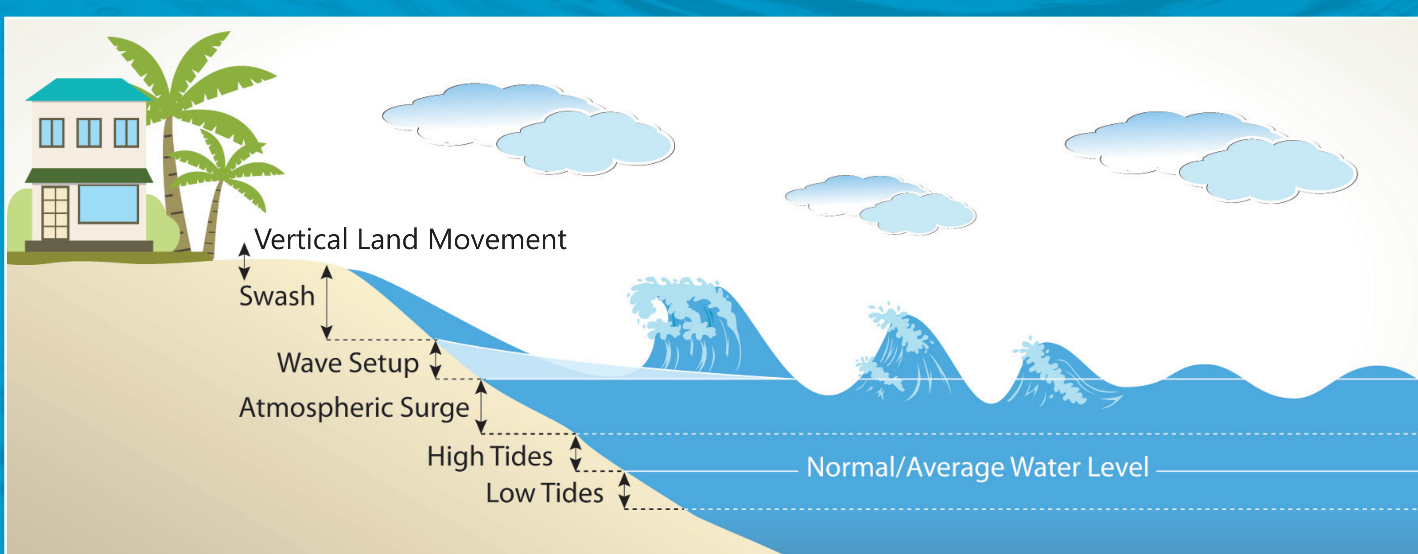
Storm intensity, forward speed, pressure, and angle of approach to the coastline all influence storm surge, as does the shape of the existing coastline, bays, watersheds, and rivers. A large storm with strong winds and low pressure will produce a high storm surge as will a fast-moving storm on an open coast. However, a slow-moving storm will increase surge in bays, sounds, and other enclosed bodies of water. Coastal areas with a steeply sloped bottom/coastal shelf will experience less surge than areas adjacent to a wider, shallower sloped shelf.

- **Waves:** Waves breaking along the coastline result in coastal erosion, the evolution of shorelines, and increased water levels. Wind driven waves contribute to raising water levels through wave runup and wave setup. **Wave runup,** which consists of a combination of **wave setup** and **swash,** occurs when a wave breaks near the shore and water is propelled onto the upper reaches of the beach. The **swash** is the runup from the wave breaking/collapsing onto the shoreline. **Wave setup** results when waves continually break onshore and the runup piles up along the coastline increasing water levels. During an extreme event, such as a hurricane, the waves become larger allowing more water to be pushed ashore further raising sea levels. Generally, wave setup or swash only pertain to coastlines abutting major bodies of water (such as the Chesapeake Bay or Atlantic Ocean).

- **Vertical Land Movement:** This refers to land subsidence, which is defined as the sinking and/or lowering of the ground elevation measured relative to the center of the Earth. There are numerous causes of vertical land movement, such as groundwater depletion, land settlement, melting of the glaciers, and tectonics to name a few. Vertical land motion contributes to relative sea level change observed by tide gauges across the coast, as the seas are rising the ground is lowering. Overall this is small factor in water levels at present day but will play a larger role in years to come in estimated sea level rise approximations.

- **Dampening of Impacts:** Water levels in estuaries, rivers, creeks, and streams are further impacted by channel widths, depths, bends, and restrictions along the waterway such as culverts, road and bridge crossings. All assist in dampening (lessening) impacts from waves and storm surges when compared to adjacent coastal areas. Traditionally, inland river areas are more protected than wide-open coastlines. This is evidenced by local fisherman and boaters moving their vessels inland prior to major storm events for protection.

  The restrictions (such as culverts and bridges) and channel geometry also plays a role in controlling water elevations upstream of the coastline as evidenced in Section 3, which shows existing water elevations rising along Thalia Creek from Virginia Beach Boulevard to Lake Windsor.



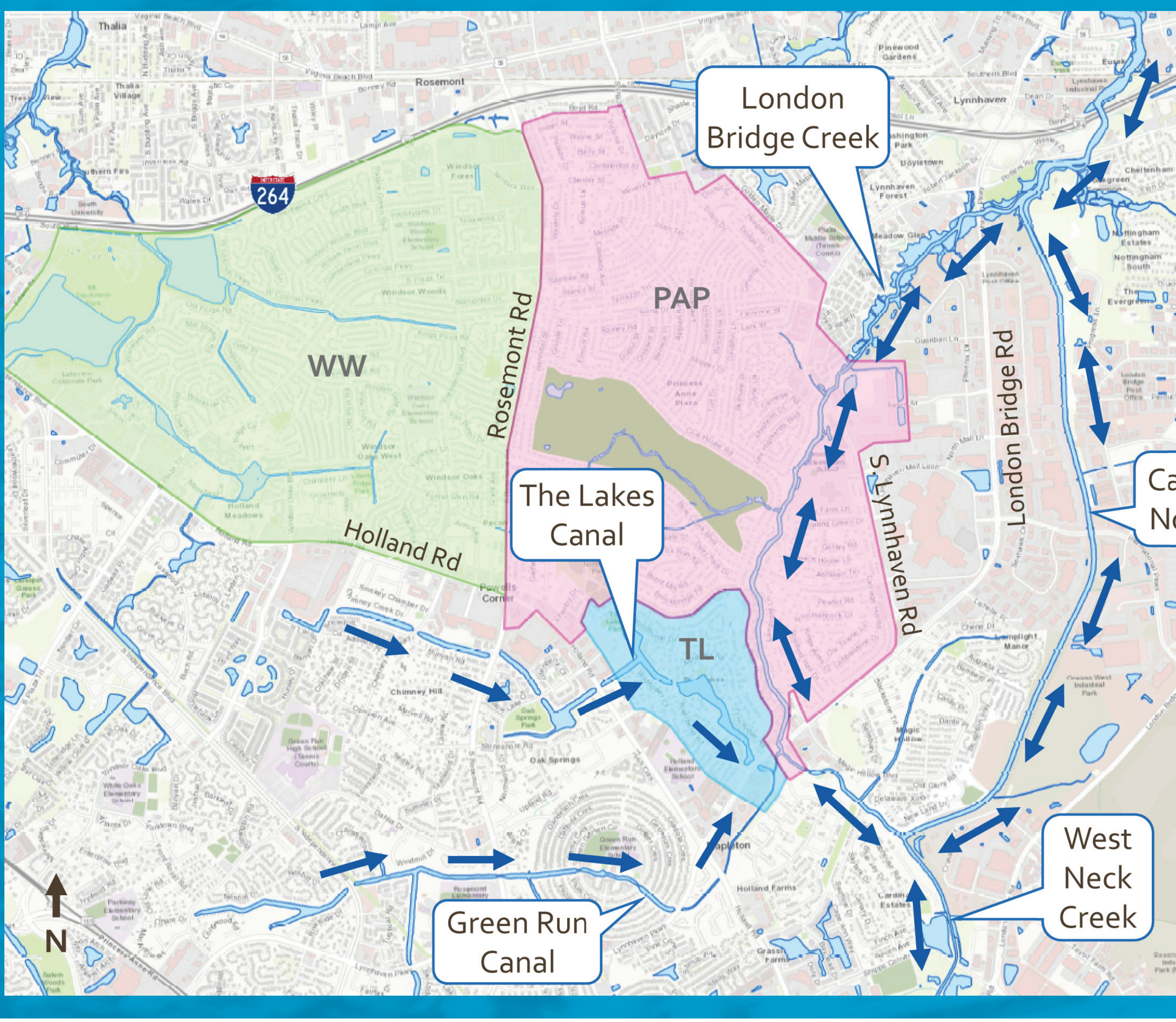
Factors Impacting Sea Levels along the Coast

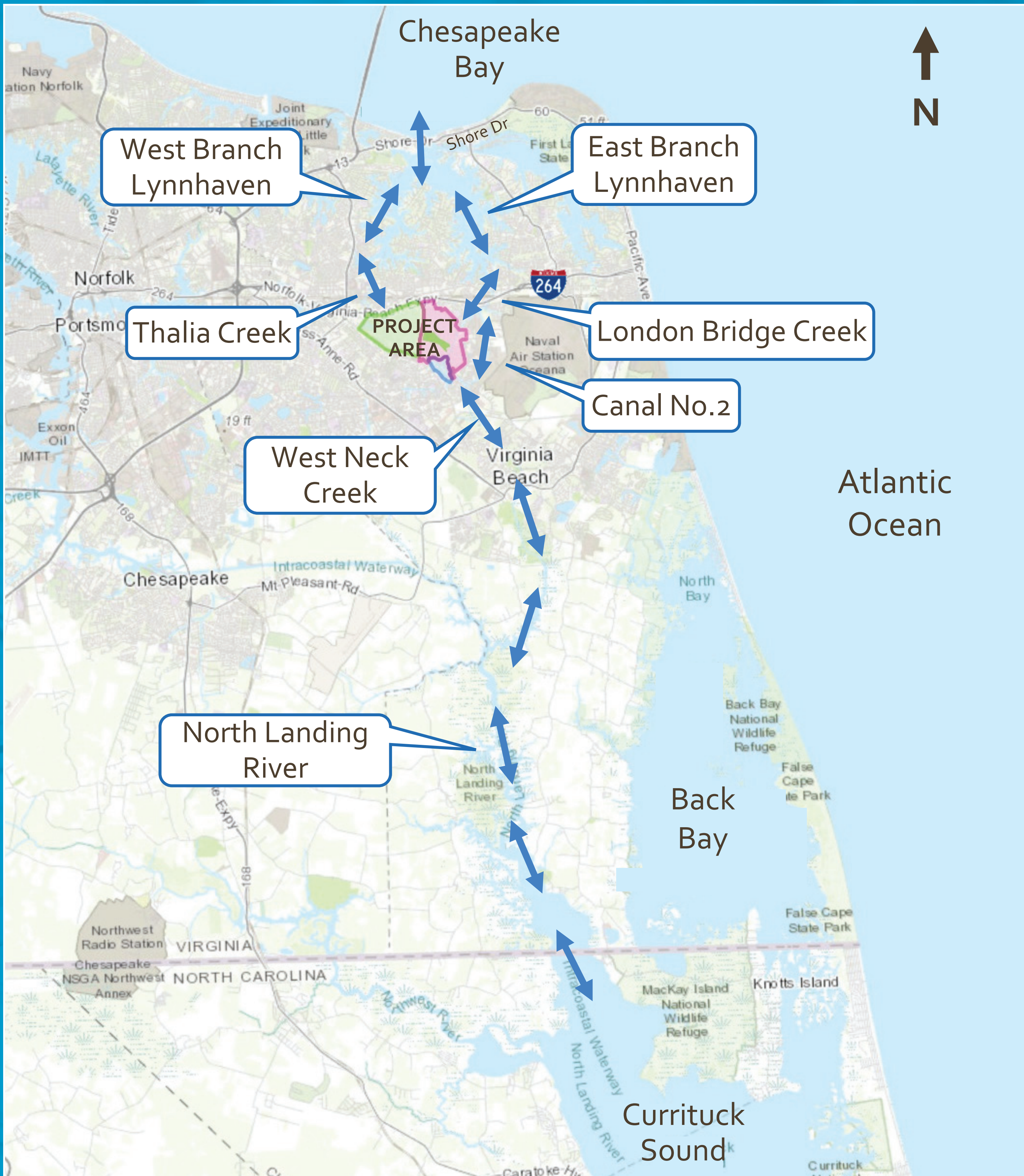
WEST NECK CREEK

In addition to the items discussed in relation to Thalia and London Bridge Creeks, the water surface elevation of West Neck Creek is impacted by additional factors. As shown in the map below, West Neck Creek, The Lakes Canal, and the Green Run Canals all converge near London Bridge Road. To the east is Canal No. 2, which was built by the US Army Corps back in the 1980s to provide drainage relief to this area. Canal No. 2 outlets to London Bridge Creek, which transitions to the East Branch of the Lynnhaven River and ultimately connects to the Chesapeake Bay. Like London Bridge Creek, Canal No. 2 is tidally impacted.

The flow patterns in this area are unique and depend on such factors as water levels, wind/tide patterns, and the time of year. Generally, the flow from the Lakes tends to head north up West Neck Creek to London Bridge Creek. The flow from Green Run typically heads east along West Neck Creek until it reaches Canal No. 2, where it either heads north up Canal No. 2 or continues south along West Neck Creek. West Neck Creek heads south and ties into North Landing River, which ultimately connects to the Currituck Sound near the North Carolina border. See the map on the next page.

The City's Southern Watershed is especially susceptible to wind tides that push water up into the rivers, bays, and inlets. These wind tides can often last for several days causing the water to rise (i.e., "stack"), which leads to flooding in low-lying areas. In extreme circumstances these southern wind tides can impact the drainage along West Neck Creek and subsequently, the The Lakes and Princess Anne Plaza Areas by increasing water levels and/or preventing drainage to the south along West Neck Creek.





Chesapeake Bay
West Branch Lynnhaven
East Branch Lynnhaven
N
Thalia Creek
PROJECT AREA
London Bridge Creek
Canal No.2
West Neck Creek
Atlantic Ocean
North Landing River
Back Bay
Currituck Sound
Norfolk
Virginia Beach
Chesapeake
VIRGINIA
NORTH CAROLINA

2. Recommended Storm Drainage Improvements:

Recommended improvements consist of:

- Tide Gates & Barriers (in 3 locations)
- Stormwater Pump Stations (in 2 locations)
- Creation of Stormwater Storage
- Storm Drain Pipe Improvements

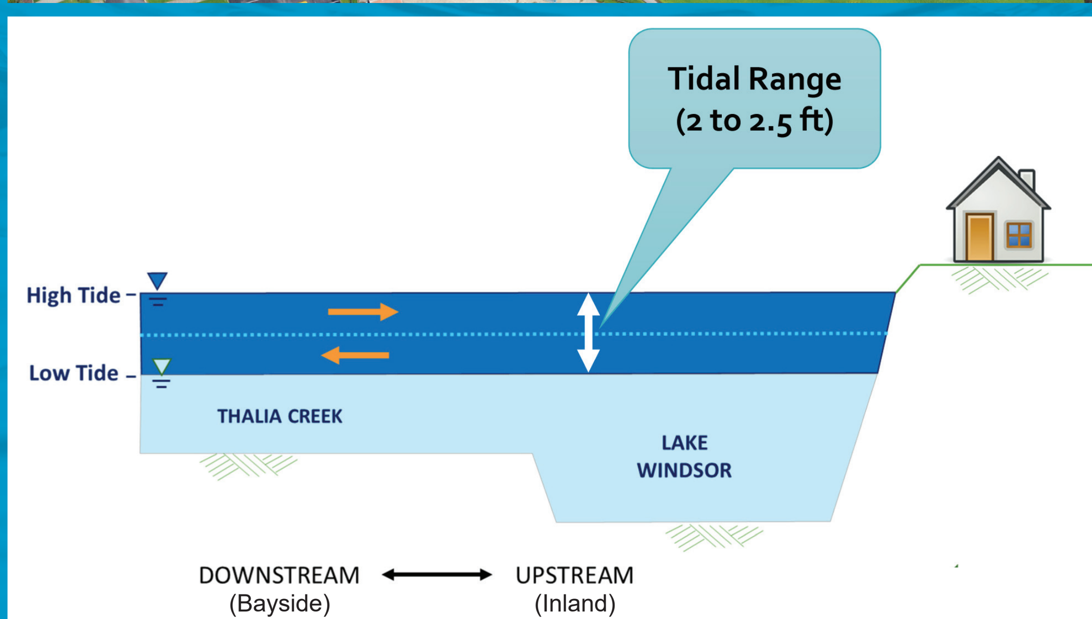
The locations of the major improvements are shown in the Exhibit below. Tide gates and pump stations are proposed in the northwest corner along Thalia Creek and the northeast corner along London Bridge Creek. A tide gate is also proposed at the southwest corner across West Neck Creek along with channel improvements to separate and manage The Lakes and Green Run flows. Stormwater storage within the Windsor Woods area will predominately occur within the existing lakes (Lake Windsor and Lake Trashmore). Storage creation for The Lakes and Princess Anne Plaza areas is proposed to be accomplished through the conversion of the Bow Creek Golf Course into a Stormwater Park.

For more information on the overall improvements please see the "Combined Drainage Improvements" brochure.

3. **Tide Gate and Pump Station Purpose:** The purpose of the gates is to block the incoming tide from entering the project area and filling up the available storage within the storm drainage system which consists of lakes, canals, and pipes. By eliminating the influence of the tidal waters prior to a storm event, storage capacity is created in the drainage system so that the stormwater can be collected, stored, and more effectively managed to mitigate flooding. The pump stations serve dual purposes: 1) to draw down water levels prior to a storm event to increase storage capacity and, 2) to maintain water levels below flood stage behind the gate during a storm event. The gates and pump stations will be utilized prior to and during major storm events.

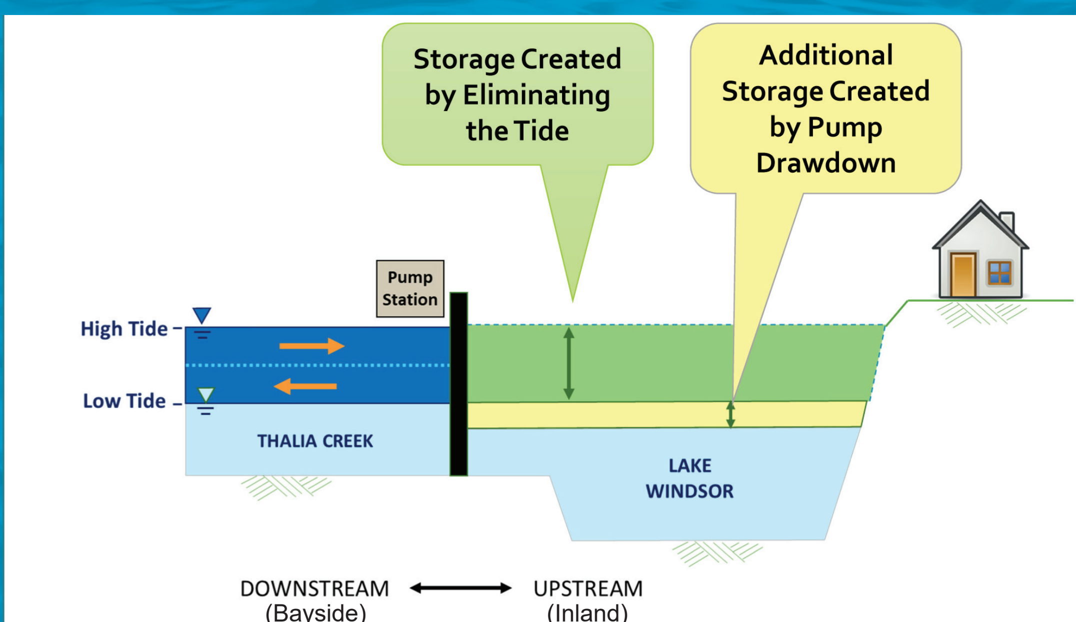
   The tide gate and pump station proposed as part of the Windsor Woods Project along Thalia Creek is illustrated below to demonstrate how these improvements work together to increase stormwater storage capacity and manage water levels to mitigate flooding. This same concept also applies to the proposed tide gate and pump station along London Bridge Creek in the northeast corner of the Princess Anne Plaza Area and the gate/channelization across West Neck Creek at the southeast corner of The Lakes Area. The only difference being there is not a pump station associated with the gate along West Neck Creek. Since West Neck and London Bridge Creeks are interconnected (as discussed on page 4), the pump station proposed along London Bridge is able to serve both areas.

   The exhibits below illustrate current (i.e., today's) conditions prior to the installation of the proposed tide gate and pump station. The top exhibit is an aerial view of Thalia Creek at Lake Windsor just south of I-264. The second exhibit is a cross-section of this same area through Thalia Creek and Lake Windsor demonstrating how the water levels are influenced by tide levels.



The exhibits below illustrate conditions after the installation of the proposed Windsor Woods Tide Gate and Pump Station (i.e., after project implementation). The top is rendering of proposed tide gate across Thalia Creek and pump station at Lake Windsor. The second exhibit is a profile view through this same area showing how the gate will be utilized to block the incoming tide to create storage in the lake behind the gate (shown in green) and how the pumps will be used to drawdown water levels creating storage (shown in yellow). Prior to a major storm or high tide event, the gate will be closed at low tide, which frees up storage in the lake that is normally taken up by tidal waters. The pumps will be used to further drawdown water levels (to increase storage capacity within the system) prior to the storm event. The additional storage capacity allows the stormwater that currently causes flooding to be controlled and managed, which is the key to flood mitigation for this area. The stormwater will be collected and detained within the additional storage areas prior to being slowly released downstream. The increased storage capacity behind the gate allows the peak flows to be decreased downstream. See Section 3 for more details on downstream modeling results.

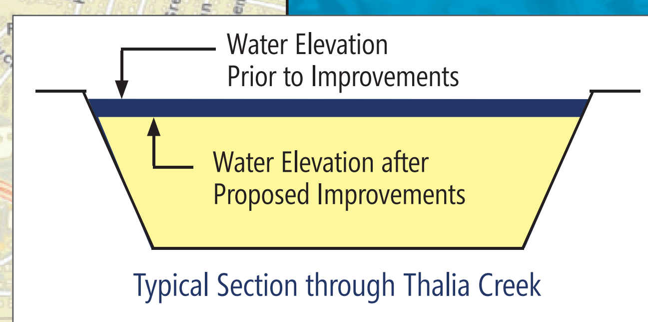
The gate closure and pump station will be designed so there is NO increase in water levels over the conditions that existed prior to project implementation (i.e. water levels after improvements will be equal or less than before). Pump operation will be controlled and monitored to ensure that existing stream capacity, flow velocity, and the normal high-water surface elevations are not exceeded. Downstream water levels will NOT increase as a result of the gate or pump operation. Water sensors will be placed both upstream and downstream in multiple locations along Thalia Creek, London Bridge Creek, and West Neck Creek to continually monitor water levels. The tide gate and pump station are being designed to handle a 100-year design storm, which has a 1% chance of occurring in any given year.



4. **Downstream Stormwater Modeling:** Extensive hydraulic modeling has been performed to evaluate conditions prior to and after project implementation downstream of the tide gates and pump stations along Thalia Creek, London Bridge Creek, and West Neck Creek. Model results demonstrate that downstream water surface elevations are <u>equal to (or below)</u> existing elevations as a result of the proposed drainage improvements. By creating additional stormwater storage capacity upstream of the tide gates within the project area and using the pump station to control the release of the stormwater into the downstream system, we can ensure that downstream water levels are not impacted.

   The following exhibits show the downstream locations along Thalia Creek, London Bridge Creek, and West Neck Creek evaluated with the conditions prior to project implementation and resulting water surface elevations after the installation of the recommended improvements (i.e., before and after). As shown in the tables and graphs, the proposed water surface elevations after improvements are <u>less than or equal to</u> prior water levels, demonstrating the proposed improvements <u>are not</u> increasing downstream water levels or flooding.

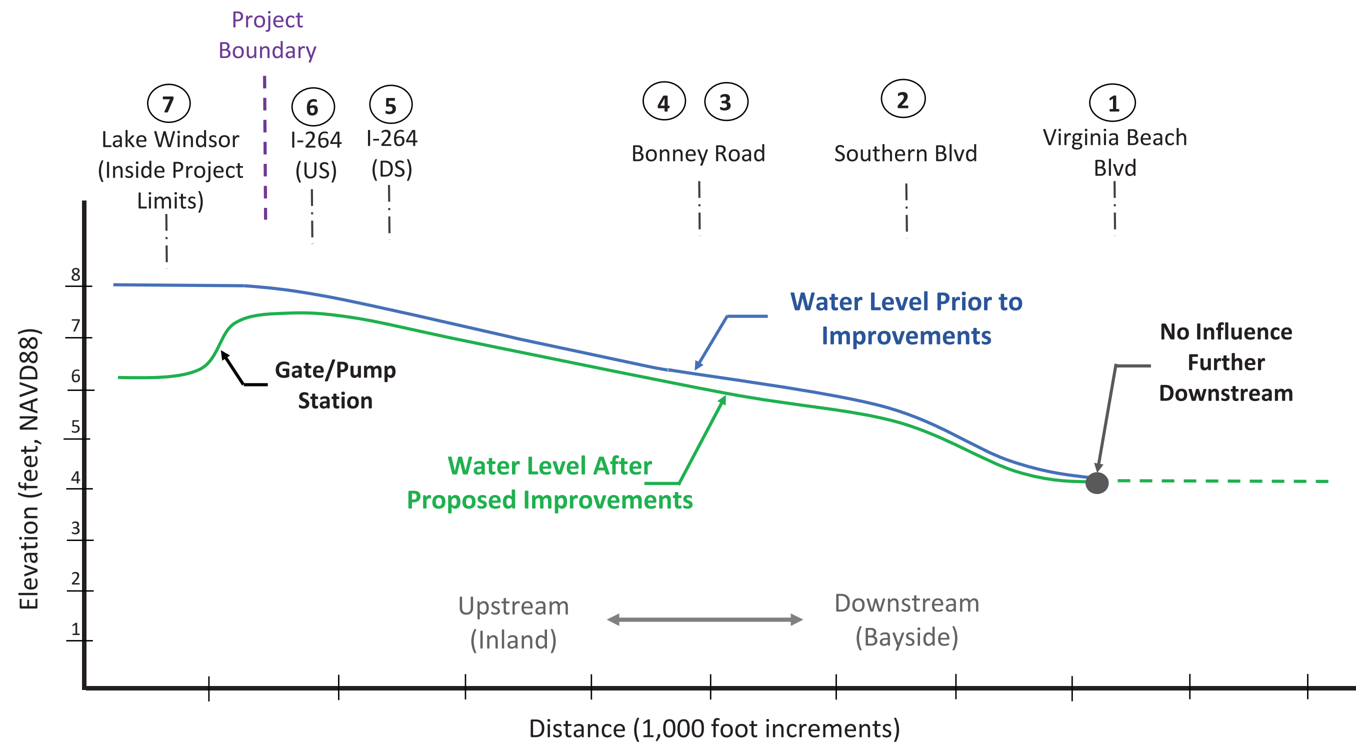
   Thalia Creek Results:



Typical Section through Thalia Creek

Thalia Creek 100-Year Design Storm Results		
Location	Water Elevation (feet)*	
	Prior to Improvements**	After Proposed Improvements
1. Virginia Beach Blvd	3.7	3.7
2. Southern Blvd	5.5	5.4
3. Bonney Road Culvert (Downstream)	6.1	5.9
4. Bonney Road Culvert (Upstream)	6.2	6.0
5. I-264 (Downstream)	6.8	6.7
6. I-264 (Upstream)	7.6	7.3
7. Lake Windsor (Inside Project Limits)	7.8	6.5

* All Elevations = NAVD 88
** The water elevation increase from Location 1 to 7 is a result of existing conditions along the channel. Reductions in channel widths/depths, restrictions due to culverts or bridge crossings, and thick floodway grasses all impede stream flow and velocity resulting in increased water levels (i.e., hydraulic grades lines).



Water Level Along Thalia Creek - Before/After Improvements (100-year Design Storm)

The table and graph above shows the model results for the water levels along Thalia Creek prior to and after proposed improvements. As shown, water levels after project implementation are less than or equal to today's water levels demonstrating that the proposed improvements are not causing adverse downstream impacts. In fact, project implementation improves (i.e., lowers) water levels up to Virginia Beach Boulevard at which point the proposed improvements have no influence on water levels downstream. This is the point where Thalia Creek becomes the Lynnhaven River and the downstream channel width/area increases significantly.

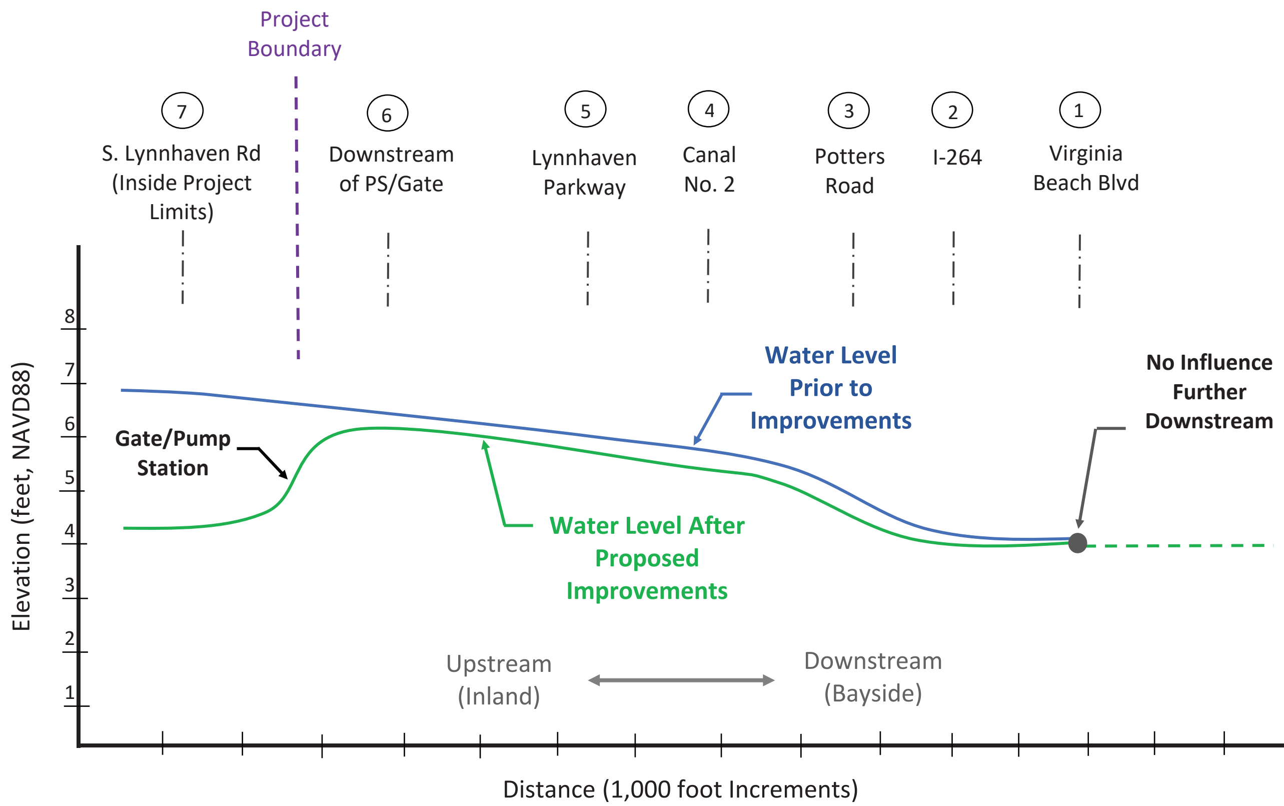
The graph also illustrates how the proposed tide gates and pump stations work together to lower water levels behind (i.e., upstream/inland) of the project boundary. This is evidenced by the drop in water levels between locations 6 and 7 after the proposed improvements are in place (i.e., green line). As discussed in the previous section, it is the tide gate, pump station, and increased storage capacity that allows the stormwater to be managed and slowly released downstream. This management reduces water levels within the project area, which results in flood mitigation. The lower the water level, the less flooding will occur. This same concept is illustrated in the graphs for London Bridge and West Neck Creeks on the following pages. Water levels upstream/inland of the improvements are significantly reduced from water levels prior to improvements. This is demonstrated by the drop in the water levels shown in the graphs near the project boundary after improvements (i.e., green line).

London Bridge Creek Results:

London Bridge Creek 100-Year Design Storm Results		
Location	Water Elevation (feet)*	
	Prior to Improvements**	After Proposed Improvements
1. Virginia Beach Blvd	3.6	3.6
2. I-264	4.9	4.8
3. Potters Road	5.5	5.4
4. Canal No. 2	5.8	5.7
5. Lynnhaven Parkway	5.9	5.8
6. Downstream of Pump Station/Gate (Bay Side - Outside Project Limits)	6.4	6.2
7. S. Lynnhaven Road (Behind Pump Station/ Gate - Inside Project Limits)	6.6	4.8

* All Elevations = NAVD 88

** The water elevation increase from Location 1 to 7 is a result of existing conditions along the channel. Reductions in channel widths/depths, restrictions due to culverts or bridge crossings, and thick floodway grasses all impede stream flow and velocity resulting in increased water levels (i.e., hydraulic grades lines).



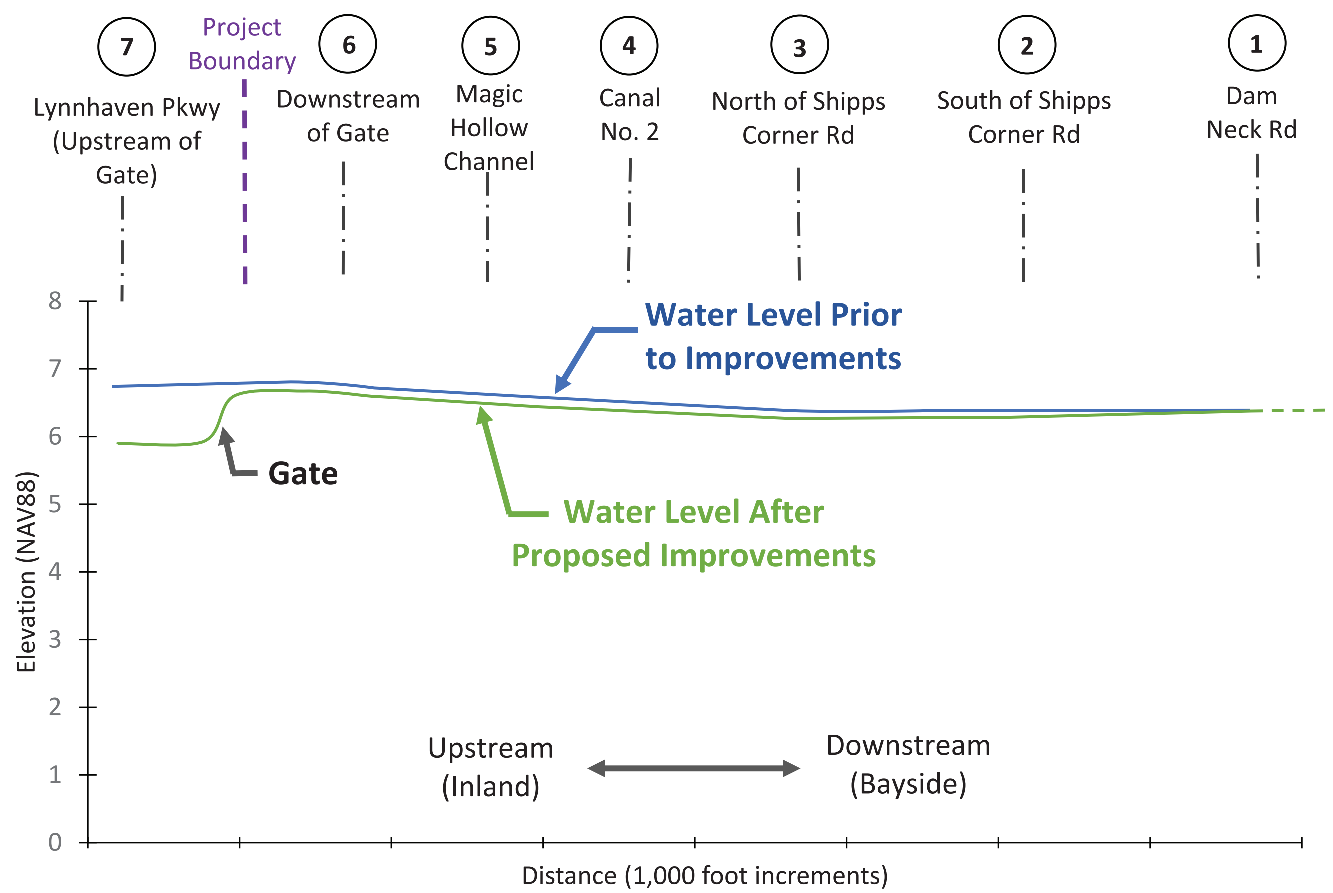
Water Level Along London Bridge Creek - Before/After Improvements (100-year Design Storm)

Similar to the results for Thalia Creek, the proposed improvements have no influence on water levels downstream of Virginia Beach Boulevard (the point where London Bridge Creek becomes the East Branch of the Lynnhaven River and the downstream channel width/area increases significantly).

West Neck Creek Results:

West Neck Creek 100-Year Design Storm Results		
Location	Water Elevation (feet)*	
	Prior to Improvements**	After Proposed Improvements
1. Dam Neck Road	6.4	6.3
2. South of Shipps Corner Road	6.3	6.3
3. North of Shipps Corner Road	6.3	6.3
4. Canal No. 2	6.5	6.5
5. Magic Hollow Channel	6.6	6.6
6. Downstream of Gate (Outside Project Limits)	6.7	6.6
7. Lynnhaven Parkway Upstream of Gate (Behind Gate - Inside Project Limits)	6.9	5.5

* All Elevations = NAVD 88



Water Level Along West Neck Creek Before/After Improvements (100-year Design Storm)

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For more information, hover over the QR code with your smartphone camera.