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Memorandum

To: Bryan T. Healy [Village of Croton-on-Hudson]

From: David Stahl [AKRF]

Date: 07/03/2025

Re: Croton-Harmon Train Station Parking Lot – Shoreline Resiliency and Flood Mitigation

cc: Dan O'Connor, Frank Balbi [Village of Croton-on-Hudson]; Patrick Parault, Justin Seeney, Nora Schmidt [AKRF]

Introduction

The Metro-North Railroad (MTA) Croton Harmon Train Station in the Village of Croton on Hudson (Village) has experienced significant flooding conditions at Parking Lot I (site). The flooding is caused by high tides that enter the site from the adjacent Hudson River. These flooding conditions reduce parking capacity and increase the risk of vehicular and property damage.

The Village contracted AKRF to evaluate existing flooding and future flooding conditions from projected sea level rise, to identify alternatives to mitigate this risk, and propose a recommendation to advance to potential design and funding procurement. AKRF performed a desktop analysis of current and projected future flood conditions, visited the site during a flood condition, identified possible design flood elevations (DFE) to protect the site with varying levels of risk mitigation, selected a singular DFE to design to that would protect the site through 2080, developed three alternatives in consultation with the Village, and developed a recommendation to construct a 1,200-foot-long, 2-to-3-foot-high knee wall to provide flood protection up to elevation 6.0, along with a new stormwater collection system and pump.

Due Diligence

To understand the site's characteristics, historical information, including site surveys, as-built plans, and historical flooding event photos provided by the Village were reviewed. Westchester County GIS and LiDAR data were obtained to supplement the files provided by the Village. Based on a review of historical imagery, the parking lot was constructed between 1953 and 1974 over assumed marshland. The parking lot was retrofitted in 2009/2010 to raise its elevation to 4.9 feet based on the rim elevations of the inlets.

To determine the elevations that cause the parking lot to flood, AKRF established a relationship between the tide gauges and elevations within the site. AKRF analyzed the tide gauges located closest to the site: (i) The NOAA gauge at the Battery is approximately 30 miles south of the site, and (ii) USGS has a gauge at Piermont, NY approximately 5 miles south of the site. The USGS gauge has a smaller record period, so a correlation between the two sites' water surface elevation levels (WSEL) was calculated. It was determined that the max WSEL difference between the two sites was 0.25 feet, meaning that the elevation at the Battery was on average 0.25 feet higher than the elevation at the Piermont station. Using this, AKRF calculated the approximate water elevations for historical storms shared by the Village. See Table 1 for a summary of historical flooding events. Summary photos from these historical events were shared by the Village and are included in Figure 1. It was found that the primary cause of flooding was due to high tidal water levels that occur because of lunar tides. Sometimes, rain coincides with high water levels and compounds onsite flooding. Storms that coincide with higher tide can increase the predicted tides because of the storm surge caused by the storm system.

Table 1. Historical Flood Events at Project Site

Date	Est. Flood Depth (based on photos)	Hudson Water Level (Piermont Station) – FT NAVD88	Max Flood Time (Piermont Station)	Last Rain Amount (in)	Days from Last Rain Event	Days to/from Full/New Moon
12/23/2022[1]	24-30"	5.68	9:12	0.84	0	0
9/30/2023[1]	6"	4.01	10:42	1.77	1	1
12/28/2023[1]	6-10"	4.10	11:00	1.80	0	2
1/13/2024[1]	30-40"	5.58	11:42	2.38	3	2
9/20/2024[2]	4-8"	3.73	11:30	0.35	11	3

1) Photos from these events were provided by the Village and included in Figure 1.

2) Photos from this event were taken by AKRF as part of this project and are included in Figure 2.

12.23.22 9:23 AM

9.30.23 12:36 PM

12.28.23 11:17 AM

1.13.24 11:55 AM

Figure 1. Photos taken during historical flooding events.

AKRF performed a site visit on 9/20/2024. The peak high tide was observed around 12:30 pm which coincides with the photo time stamps. Only 4-8 inches of flooding was observed. This flooding is described as “nuisance flooding” and would not cause damage to personal property and vehicles. Based on observations, the water entered the site from the marsh on the eastern side of the parking lot. It was observed that water entered the parking lot through the existing drainage system as seen in Photo D, in

Figure 2. The original site plans for the 2009 upgrade included duck bill tide gates; however, based on discussions with the Village, it was understood that these tide gates were not installed. The missing tide gates allow tidal water to back up through the storm sewer system causing the surcharging inlets as observed. The amount of flooding during this event was higher than expected based on site elevations, and AKRF calculated that settling had occurred which is described in the next section.

Photo A

Photo B

Photo C

Photo D

Figure 2. Photos taken during site visit on 9/20/2024 by AKRF.

Site Settling Analysis

Based on the elevations provided in the as-builts and Westchester County LiDAR, the site was experiencing more flooding than expected. AKRF predicted that settling at the site was the cause of the increased flooding and calculated this by using 1 foot contour data from 2019 (NYS Contour Download App) for the Town of Cortland and the as-built contours from the 2009 parking lot retrofit. AKRF calculated the site was about 0.8 feet lower than the design elevations from 2009. This was further verified by Value.Space, a third-party contractor, who performed an aerial movement analysis using imagery from 2016-2024. They also determined that the site is subsiding. Value Space's report indicates that the rate of subsistence in Lot I has decreased over time: up to 37 mm/yr from 2016-2018, up to 34 mm/y from 2018-2021, and up to 24 mm/yr from 2021-2024. There is not enough information to predict if or when the site will stop settling. Using the lowest setting rate from 2021-2024 (24 mm/yr), AKRF projected that approximately 1.2 feet of settling has occurred in Lot I from 2009-2024.

Exposure Screening and Vulnerability Analysis

AKRF analyzed the known flood events to determine the cause of flooding within the parking lot. The tides, lunar cycles, and past precipitation were analyzed to determine if overland (stormwater runoff) or tidal fluctuations were the main cause of flooding in the parking lot. Based on the analysis the primary cause of flooding was the tidal and lunar cycle, with more flooding occurring during a high tide that was closer to a new or full moon, when tides are highest. Water levels may be higher during events where both rain and a high tide impact the site.

To evaluate the effects of various tidal conditions on the site, AKRF mapped out various water level datums such as the current FEMA Limit of Moderate Wave Action (LiMWA), Mean Higher High Water (MHHW), 100-year, and 500-year floodplains. The site is fully within the 500-year and 100-year floodplains and ARKF recommended to not size an intervention to these levels due to the significant disturbance and anticipated. The Village acknowledged that any intervention was not going to elevate or eliminate the site above the 100- or 500-year floodplains.

To determine the impact of projected sea level rise on flooding of the parking lot, AKRF applied sea level rise adjustment factors from the New York City Panel on Climate Change to the LiMWA and MHHW elevations. Table 2 shows the elevations and impacts to the site on parking and structures for MHHW and LiMWA for existing, projected 2020, 2050, and 2080 Sea Level Rise (SLR) conditions. Figure 3 graphically shows these existing and projected elevations on the site map with present day elevations (no further settlement). The observed flooding event on 9/20/24 and historical flood elevations were all above the existing MHHW and MHHW with SLR. The LiMWA elevations consider wave action due to storms. AKRF utilized the historical flood information with the predicted amount of parking spaces lost, and discussions with the Village to set the DFE at the projected 2080 LiMWA elevation of 5.9 ft (NAVD88).

Table 2. Parking and Structures Impacted Based on Flood Elevations

		Elev (ft - NAVD88)	Parking Spaces Impacted	Structures / Buildings Impacted
9/20/2024 Event		3.73	149	0
MHHW	**Existing**	2.07	0	0
	2020 SLR	2.57	0	0
	2050 SLR	3.40	27	0
	2080 SLR	4.40	134	0
LiMWA	**Existing**	3.57	32	0
	2020 SLR	4.07	70	0
	2050 SLR	4.90	227	0
	2080 SLR[1]	5.90	712	2

1) Selected DFE for Flood Mitigation Alternatives

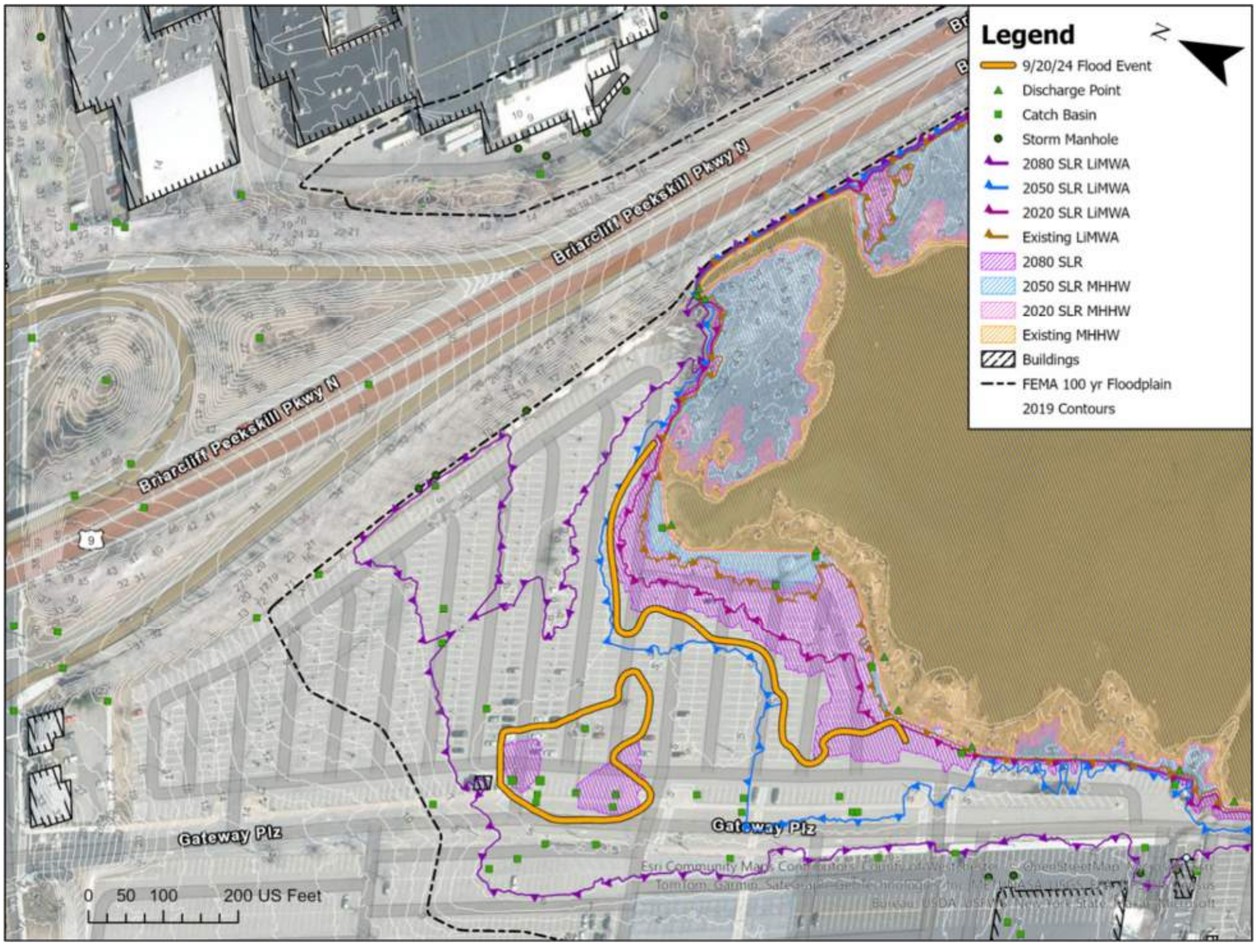


Figure 3: MHHW and LiMWA for existing conditions and 2020, 2050, & 2080 SLR

Flood Mitigation Alternatives

After determining a DFE, AKRF developed three alternatives to mitigate the flooding: 1) non-construction measures focusing on operational strategies, 2) raise the parking lot elevation to reduce flood risk, and 3) knee wall installation for structural flood protection. These options are described below and in Table 3.

Option 1- Non-Construction Measures Focused on Operational Strategies ("Do-Nothing")

The do-nothing approach represents no significant capital improvements to mitigate flooding at the site in the short term before an option with significant capital investment is needed. AKRF recommends this approach only in the short term while the recommended solution is designed and constructed. Signs and barriers would be deployed to restrict access to areas of the parking lot temporarily, prior to anticipated flooding events, or permanently. By the end of the 2020's, approximately 70 parking spaces would be impacted by LiMWA elevations. The do-nothing/non-construction option includes deploying signage and barriers before high tide events and permanently abandoning 32 parking spaces that are currently in the existing LiMWA area. Sites closer to the marsh at lower elevations should be the priority in closing prior to projected flooding. This option is easy to implement, with low costs, but requires active monitoring of water levels in the Hudson. The Battery has a predictive tide gauge, so the Village would use that as a prediction tool.

Option 2 - Raise Parking lot with Fill

Option 2 would raise the elevation of the entire parking lot to the prosed DFE. Option 2 would raise the elevation of the parking lot using traditional fill, like what was completed in 2009. The drainage system would need to be evaluated and potentially elevated to ensure that the site can properly drain during high tide events. While this option is comparatively simpler than other options, it does not address the settling issue that resulted from the 2009 improvements. The site will be designed for a 2080 DFE, settling would likely continue to occur and reduce the effectiveness of the design and increase the risk of nuisance flooding over time.

Another alternative that addresses the site setting is to replace some of the existing soil with lightweight fill to raise the elevation of the parking lot to the proposed DFE. Light weight fill is more expensive than standard fill. Because the lightweight fill is less dense than the existing soil, it would impart a reduced load from the current conditions. This will require testing of excavated soils for contamination before being. Settling at the site would likely still occur, but not at the rate expected with standard fill. Using light weight fill would be more complicated as lightweight fill will need to be designed to counteract buoyancy and wrapped in a geotextile to prevent siltation overtime.

Both options would require wetland permitting. Permitting is needed due to the physical disturbance of land within the 100’ buffer of a freshwater wetland. The impervious area within the wetland buffer will be reduced for both options by adding a stabilized embankment at the edge (currently gabion baskets). This would reduce parking by approximately 100 spaces. Since the parking lot and the stormwater system are being elevated, the revised stormwater design will be retrofitted with water quality treatment devices to improve the water quality leaving the site. These improvements to the design would help facilitate an easier permitting approval process.

For construction, both options would require a thoughtful construction phasing approach to minimize the disruption and access to parking spaces at a given time. This can be done by breaking the project limits into 3 to 4 stages where only portions of the 10 acres are excavated at a time. However, there would still be major disturbances to parking during construction. To help with the permitting process, the 100’ wetland buffer could be staged separately to mitigate potential issues.

Option 3 – Knee Wall

Option 3 presents a proactive and resilient flood mitigation strategy that includes the construction of a knee wall along the parking lot's perimeter. On average, the knee wall would be 2 ft high (based on the existing pavement elevation) and have a total length of approximately 1,200 ft. The knee wall would terminate at points along the shoreline that are equal to the DFE, such that there is a contiguous barrier to prevent flooding of the parking lot. To ensure long-term stability, the wall would be supported by deep foundations (e.g. piles, steel sheeting, etc.) to minimize potential settling. The drainage system would mostly stay the same; however, the outfalls below the knee wall would require protection or resetting during construction. For rain events that occur in the future, flooding could still occur on the site if the storm event coincides with a high tide event. To further enhance the site’s resilience, a new pumping system will be required to manage stormwater during high tide events.

While more complex than Options 1 and 2, the construction and design of knee wall offers a robust and long-term flood protection solution. This approach includes structural design support for the deep foundations and knee wall as well as the inclusion of multiple pumping stations with additional piping and structures. Construction of this option involves limited closures of portions of Lot I along the lot perimeter to excavate the edge of the parking lot, install deep foundations to support the knee wall, install the structural concrete knee wall, install the pumping stations, and install associated piping to connect the existing drainage network to the stormwater pumps. Although some parking spaces will be temporarily unavailable during construction, the number of spots impacted is expected to be significantly lower than in Option 2 and will ultimately depend on final design details and staging requirements.

This option will require wetland permits due to the knee wall's location within the freshwater wetland buffer. However, by driving the piles from the parking lot side, additional permitting for in-wetland work can be avoided, helping to streamline the approval process.

Table 3. Comparison of Flood Mitigation Options

Criteria	Option 1- "Do Nothing"	Option 2- Normal Fill	Option 3- Knee Wall
Loss of Permanent Parking	High	None	None
Risk Reduction	Low	Medium	Medium
Impact to Operations During Construction	None	High	Medium
Environmental/ Permitting Requirements	None	Medium	Medium
Maintenance	Low	Medium	Medium
Capital Costs	Low	High	Medium

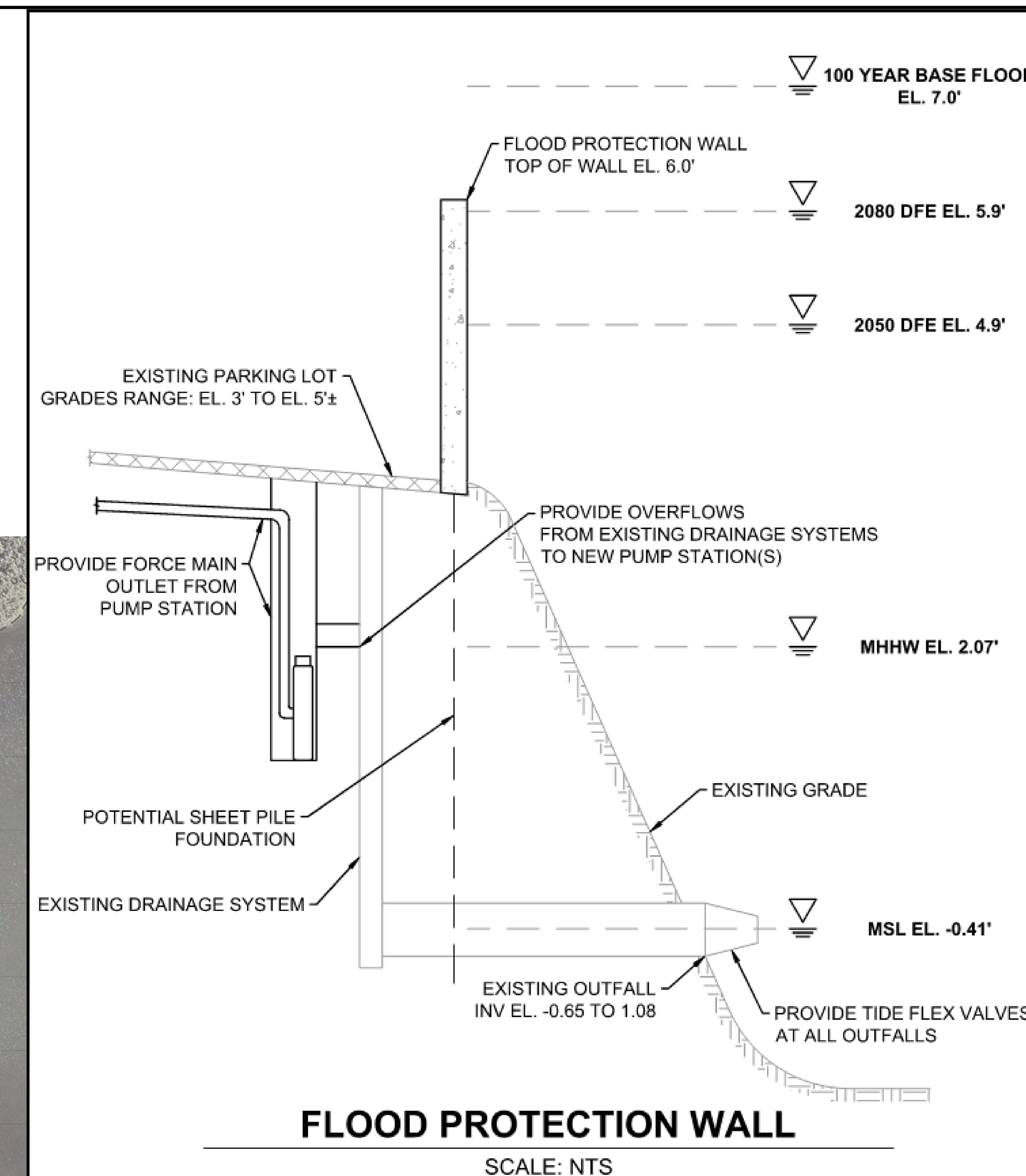
Preferred Alternative

Based on the previously described options and discussions with the Village, Option 3 was selected as the preferred alternative (Appendix A). It provides effective protection against future tidal flooding while minimizing disturbance to the existing parking lot. An additional concept—construction of a five-story parking garage with elevated entrances above the 100-year floodplain—was also discussed but not advanced for further analysis. This concept is included for reference in Appendix B.

A rough order of magnitude estimate of the Option 3 alternative is provided below.

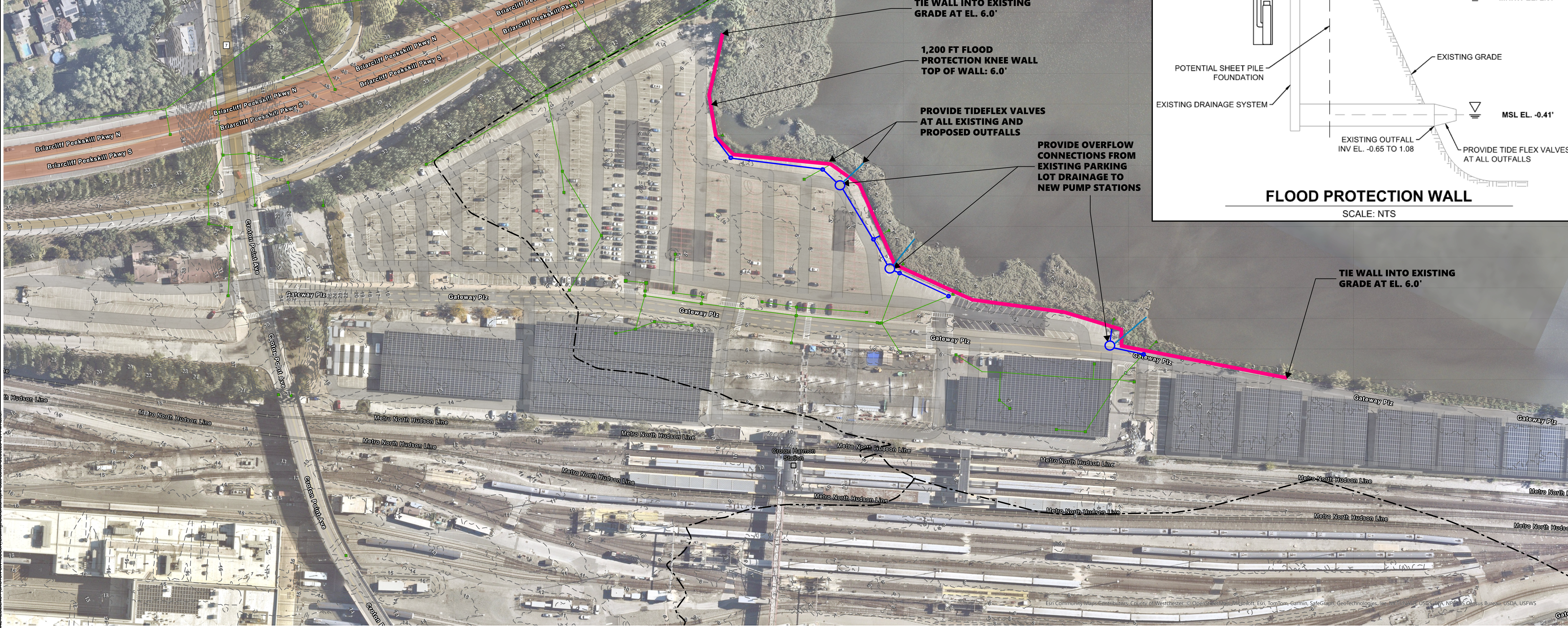
Item	Quantity	Unit	Unit Price	Total	Notes
Knee Wall					
Steel Sheeting	60,000	SF	$ 60	$ 3,600,000	50' Deep for 1,200 LF
Concrete Wall	300	CY	$ 800	$ 240,000	7'H x 1'D x 1,200' L
Drainage Improvments					
Manholes	8	EA	$ 7,000	$ 56,000	
Overflow Piping	800	LF	$ 300	$ 240,000	
Tideflex Valves	5	EA	$ 7,000	$ 35,000	
Pump Stations	3	EA	$ 100,000	$ 300,000	
			Subtotal	**$ 4,471,000**	
			Design & Permitting (15%)	$ 670,650	
			Contingency (40%)	$ 1,788,400.0	
			Order of Magnitude Total	**$ 6,930,050**	

APPENDIX A



FLOOD PROTECTION WALL

SCALE: NTS



FLOOD WALL OPTION

LEGEND

- Storm Pipe
- Discharge Point
- Catch Basin
- FEMA 100-yr Floodplain
- 2019 Contours

0 37.5 75 150 225 300 Feet

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CROTON-HARMON TRAIN STATION PARKING LOT SHORELINE RESILIENCY AND FLOOD MITIGATION STUDY

VILLAGE OF CROTON-ON-HARMON
1 Van Wyck Street, Croton-On-Hudson, NY, 10520

DATE
3/27/2025

PROJECT NO.
240624

FIGURE
SK-2

APPENDIX B

PARKING GARAGE OPTION

LEGEND

—·— FEMA 100-yr Floodplain

- - - 2019 Contours

0 37.5 75 150 225 300 Feet

34 South Broadway, Suite 300, White Plains, NY 10601

CROTON-HARMON TRAIN STATION PARKING LOT SHORELINE RESILIENCY AND FLOOD MITIGATION STUDY

VILLAGE OF CROTON-ON-HARMON

1 Van Wyck Street, Croton-On-Hudson, NY, 10520

DATE
3/27/2025

PROJECT NO.
240624

FIGURE
SK-3