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# HYDROLOGY & HYDRAULIC MODELING AND FLOODPLAIN MANAGEMENT ANALYSIS

## EASTON COMMERCE CENTER

FOR EASTON WOOD AVE. PROPCO, LLC

CITY OF EASTON, PALMER TOWNSHIP, AND WILSON BOROUGH
NORTHAMPTON COUNTY
PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
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**Date:** May 2023

Revised: -
September 2024

PROJECT: 2022-528

**HYDROLOGY & HYDRAULIC MODELING AND FLOODPLAIN MANAGEMENT ANALYSIS NARRATIVE**

**EASTON COMMERCE CENTER**

SCANNELL PROPERTIES

CITY OF EASTON, PLAMER TOWNSHIP, AND WILSON BOROUGH

NORTHAMPTON COUNTY

PENNSYLVANIA

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TABLE OF CONTENTS



APPENDICES

Appendix A: StreamStats Report

Appendix B: HEC-RAS Outputs for Existing Condition

Appendix C: HEC-RAS Outputs for Proposed Condition

Appendix D: Maintenance Plan

Appendix E: FEMA Map and Report

Appendix F: 50-Year Flood Modeling

## SITE HISTORY AND CONDITIONS

The site is partially developed with majority of undeveloped portions covered with dirt, grass, and woods. There is one perennial creek as well as an intermittent stream within and adjacent to the site. Bushkill Creek flows from north to south in the eastern side of the project site and the end discharge point is Delaware River. Bushkill Creek is labelled as Bushkill Creek Reach 1 in the FEMA flood map (42095C0278E; revised on July 16, 2014) and FIS (42095CV001A; revised on July 16, 2014). In FEMA documents, the flooding data were studied based on statistical analysis of stage-discharge records of a USGS station. The records were assessed by reginal regression equations developed to estimate different frequency flood flows. The 100-year flood flow is calculated to be 8,100 cfs in this reach of Bushkill Creek. An unnamed tributary to Bushkill Creek, labelled as UNT in this report, is shown as Zone A of the Bushkill Creek floodway (i.e., floodplain without base flood elevation determined) on FEMA flood map. There is no separate study on this stream. It should be noted that the confluence of UNT and Bushkill Creek is located almost 1.34 miles upgradient of where Bushkill Creek discharges into Delaware River. Generally, from the historical records, areas within the City of Easton, Borough of Wilson, and Palmer Township are subject to flooding in all seasons and after tropical storms, rapid melting of snow, and infiltration losses due to frozen ground. Major flooding in the area have been associated with the flooding in Delaware River, however, some within-basin (i.e., related to tributaries of Delaware River) had occurred by cold-front (intense rain followed by cold weather) and warm-front (rainfall on winter snow) storms. Major floods of the Delaware River adjacent to project site have occurred in October 1903, March 1936, May 1942, and August 1955. Since the Bushkill Creek is tributary of the River and project is beyond 1.3 miles away from the River, the magnitude of flooding has been less severe. Similarly, the flooding in UNT is less sever than Bushkill Creek.

Major portions of the stream banks within and adjacent to project site are undeveloped and can provide natural flood storage capacity. Currently, there are a few structural flood protection measures that may mitigate the flooding along the Bushkill Creek. There will be no modifications or disturbance to Bushkill Creek in the post-construction conditions that would potentially change the flow patterns in streams. The UNT would be relocated to provide construction site, and the channel would pass through a culvert that is installed under a proposed access driveway. It should be noted that the current path of UNT also passes through an underground tunnel. The proposed UNT obstruction will be replaced with a proposed relocated channel. The relocation made it feasible to improve the channel condition when comparing with the existing conditions by designing a stable channel with adequate capacity that can safely pass the 100-year flow. The stormwater in the post-construction condition is managed to lower the release rates compared to the existing condition via employing stormwater MRC BMPs, etc. Such stormwater management measures would assist in mitigating and controlling the flooding in the streams in the post-construction conditions.

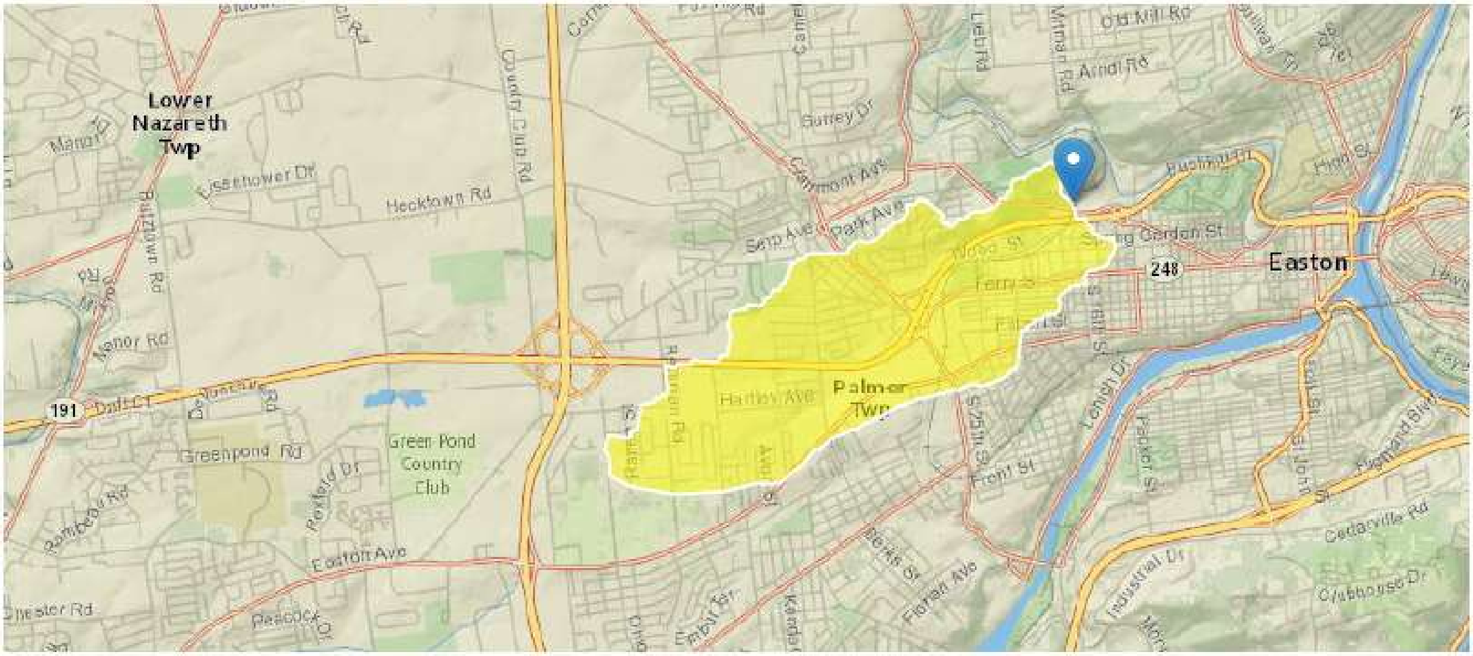
## HYDROLOGY

The 100-year flow was used to model the pre- and post-construction floodplain boundaries, flood elevations, and flood flow velocities. Additionally, bank-full and base flow conditions were also modeled to simulate the normal stream condition. As mentioned before, the Bushkill is completely undisturbed and out of limit of disturbance in this project, while UNT is proposed to be relocated. The UNT is not listed and shown in the FEMA map and report, therefore, this stream was studied separately through available hydrological tools such as StreamStats and USGS stations. The 100-year flow data, extracted from StreamStats of 621 cfs is reported for the point at which the relocation is proposed (i.e., the common upstream of existing and proposed creeks), while bank-full and mean annual flows are reported 12.5 cfs and 3.43 cfs, respectively. As depicted below the drainage area associated with this point is estimated to be 2.32 sq.miles. The StreamStats report is presented in Appendix A of this document. In addition to abovementioned steady flow data, the stable channel design needed employing unsteady flow data to properly model the fluctuations in high and low flows and how the cycles of ups and downs in flow would impact sediment transport and as a result deposition and erosion patterns. To do so, the nearest USGS gauge to the site was identified and then the daily flow data for the last 15 years were extracted. Project specific flows were then estimated by adjusting the measured flows (USGS station) by drainage area. Known daily flow rate data from USGS station #01446776 Bushkill Creek at Tatamy, PA (almost 3.5 miles upstream of project site) was sourced from the USGS National Water Information System. The drainage area associated with this gauge is 31.2 sq.miles, while it is 2.3 sq.mile for the point of interest, therefore, the reported flows can be estimated from below conversion factor:

Conversion Factor = $\frac{2.3}{31.2} 0.074$

## Bushkill Tributary

**Region ID:** PA
**Workspace ID:** PA20230515123543682000
**Clicked Point (Latitude, Longitude):** 40.69561, -75.23498
**Time:** 2023-05-15 08:36:06 -0400




Collapse All

### Basin Characteristics

| Parameter Code | Parameter Description | Value | Unit |
|---|---|---|---|
| CARBON | Percentage of area of carbonate rock | 93.03 | percent |
| DRNAREA | Area that drains to a point on a stream | 2.32 | square miles |
| ELEV | Mean Basin Elevation | 360 | feet |
| FOREST | Percentage of area covered by forest | 8.9887 | percent |
| PRECIP | Mean Annual Precipitation | 45 | inches |
| ROCKDEP | Depth to rock | 5.4 | feet |
| STRDEN | Stream Density -- total length of streams divided by drainage area | 0 | miles per square mile |
| URBAN | Percentage of basin with urban development | 67.0411 | percent |

**HYDRAULIC ANALYSIS**

The UNT in the needed to be modeled to determine the flood boundaries and elevations for pre- and post-construction conditions. It is only Bushkill Creek that is delineated for floodway and reported by FEMA, owing to its larger drainage area, and the other existing UNT within the project site have been considered as tributaries of Bushkill Creek and of a less concern because their flooding does not have floodway delineation. Nonetheless, the hydraulic modeling of the floods in UNT was performed because the project proposes a channel relocation as well as additions of a culvert for necessary stream crossings. As a result of the proposed development, a comparison basis for pre- versus post-construction flood characteristics was needed to show compliance with the chapter 105 requirements for stream obstruction/replacement.

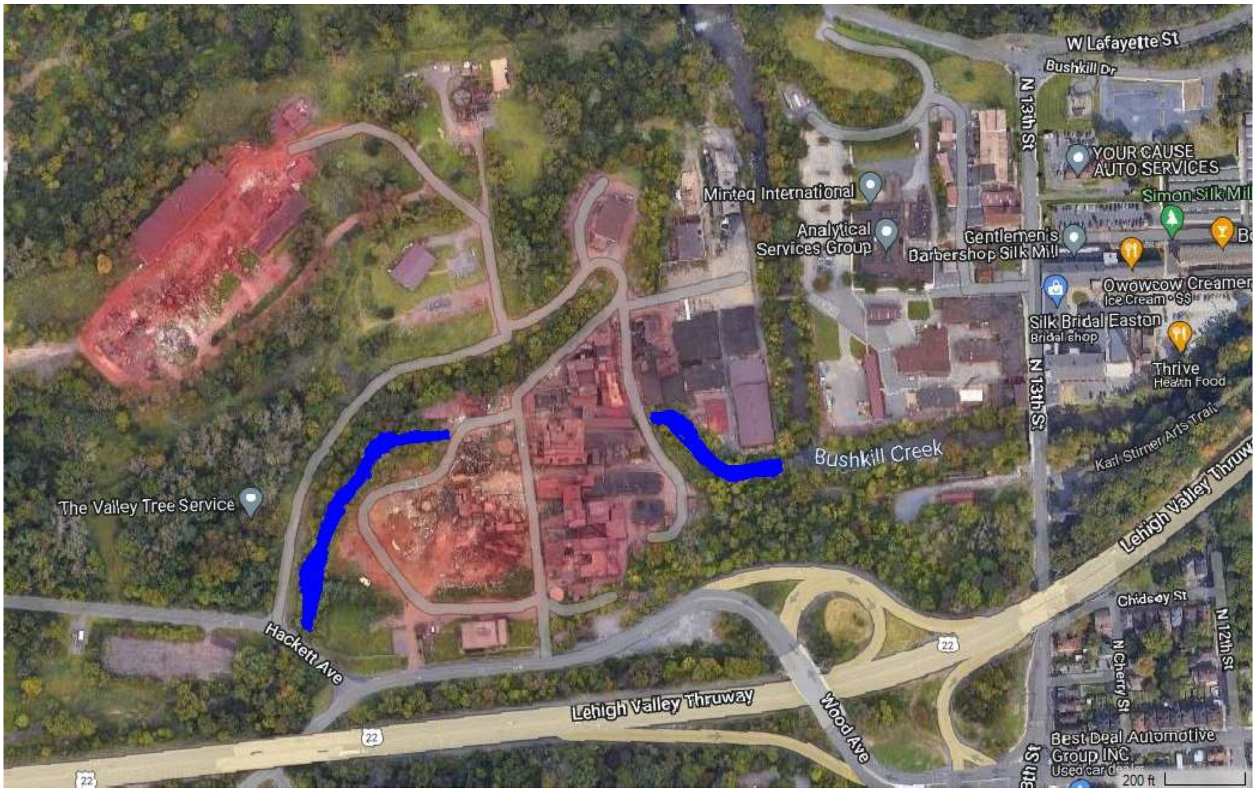
Hydraulic modeling had three parts:

- Modeling 100-year flood for the existing condition
- Modeling 100-year flood for the proposed condition
- Design of the relocated channel as a stable channel

The hydraulic modeling was performed by employing HEC-RAS. The hydrological input to HEC-RAS was provided by the hydrological studies that were described in the previous section. Geometry of the project site as well as offsite locations (to evaluate impacts of proposed development on upstream, downstream, and adjacent properties) was defined based on the site survey. The terrain in the HEC-RAS was generated by exporting the corresponding surfaces from Civil 3D. There is one spot at which the tributary streams of UNT discharges into Bushkill Creek, therefore, 1d hydraulic simulation was adopted to study the proposed project. The basis for flow simulation was Manning's equation and backwater analysis.

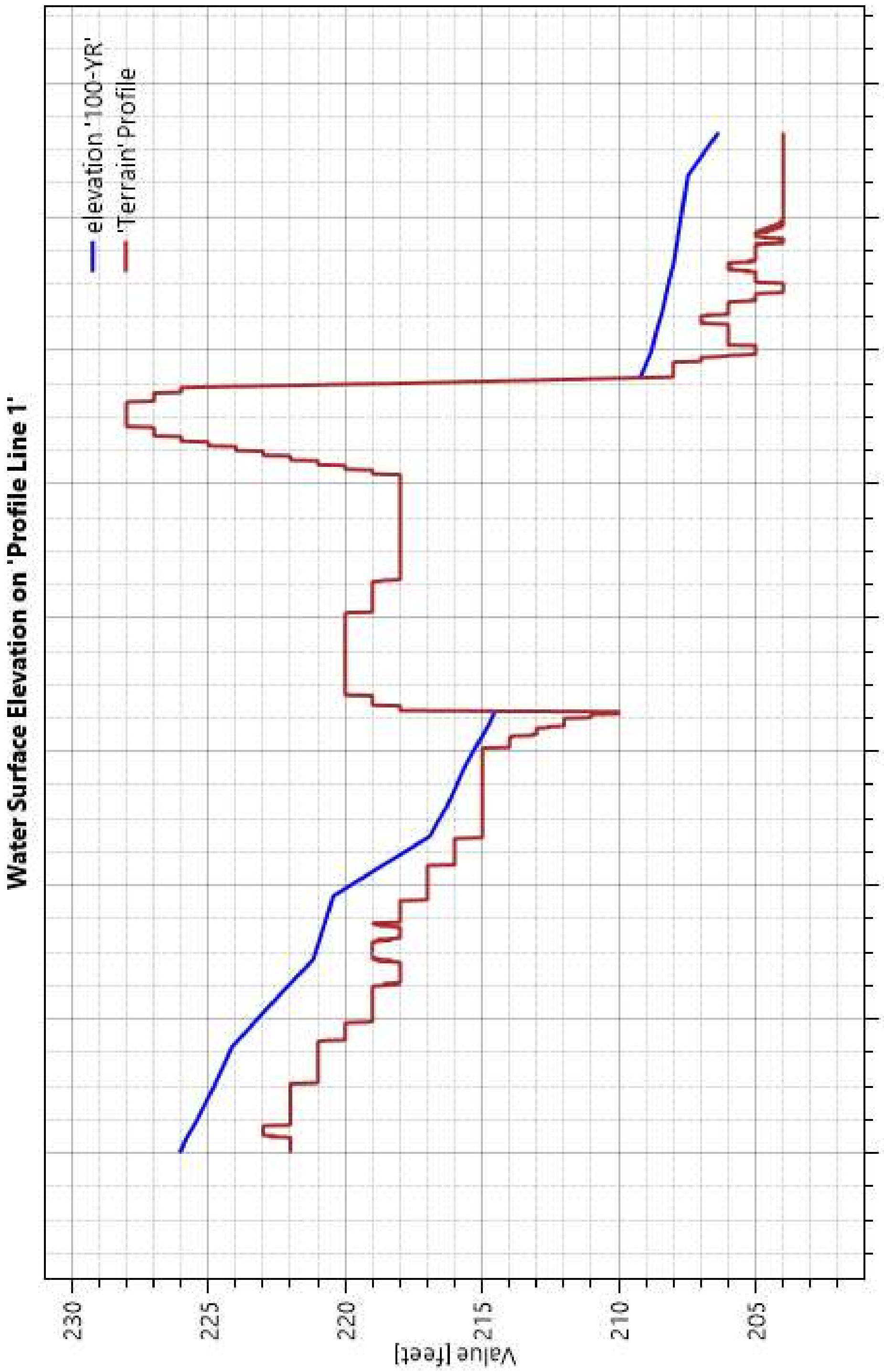
The results from the hydraulic flood modeling using HEC-RAS for the pre- and post-development conditions are presented here. First, the floodplain is delineated for both conditions by showing inundation boundary associated with 100-year flood flow. In the next step, the water surface elevations and flow velocities (velocity at water pool) are shown, and finally the cross-sectional views of pre- and post- construction water surface for each of the sections have depicted the impacts of the development on the flood elevation (reported in Appendices B and C). It should be noted that there is only FEMA flood elevations determined for Bushkill Creek that shows floodway and floodplain associated with Bushkill Creek, and there is no delineated floodway or determined flood elevation for the studied UNT.

- Existing condition results

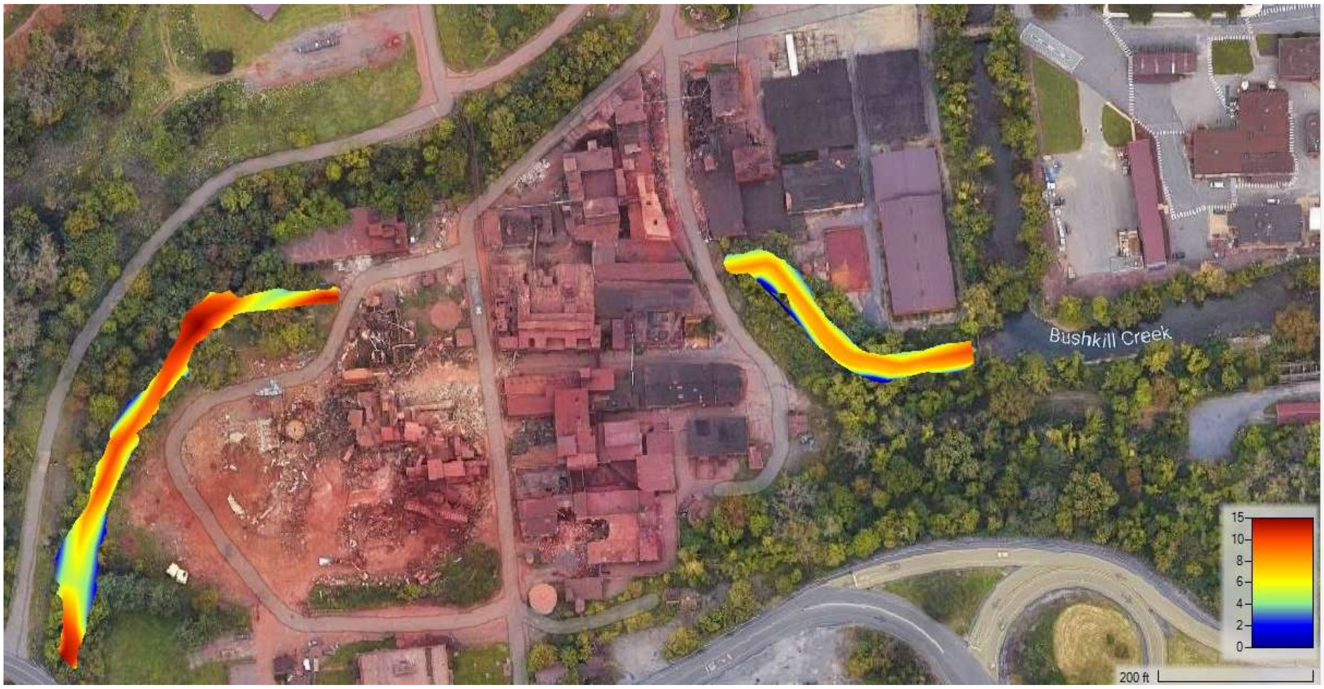



*Inundation boundary of 100-year flood for the pre-development condition.*


*Water surface elevation (ft; NAVD 88) of 100-year flood for the pre-development condition.*



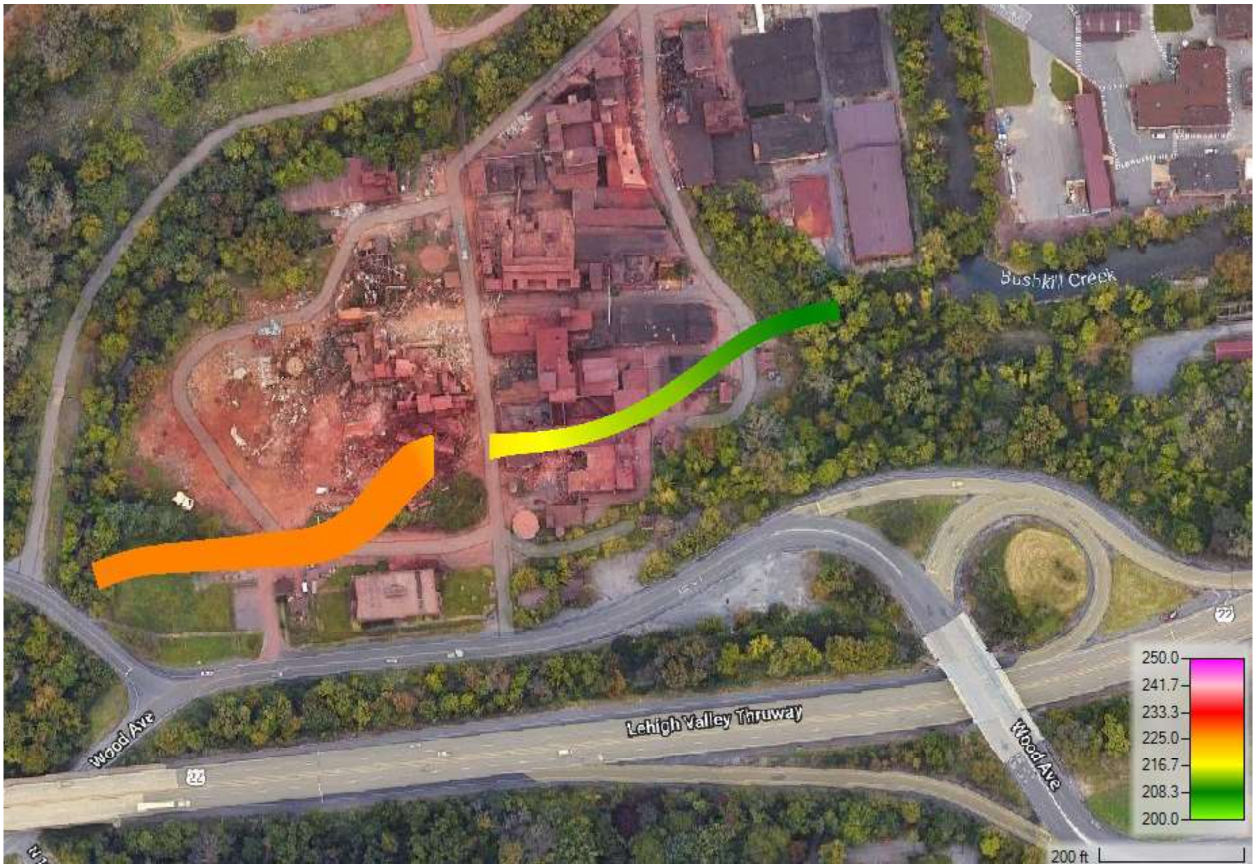

*Existing channel profile view of water surface elevation (ft; NAVD 88) for 100-year flood in the pre-development condition.*



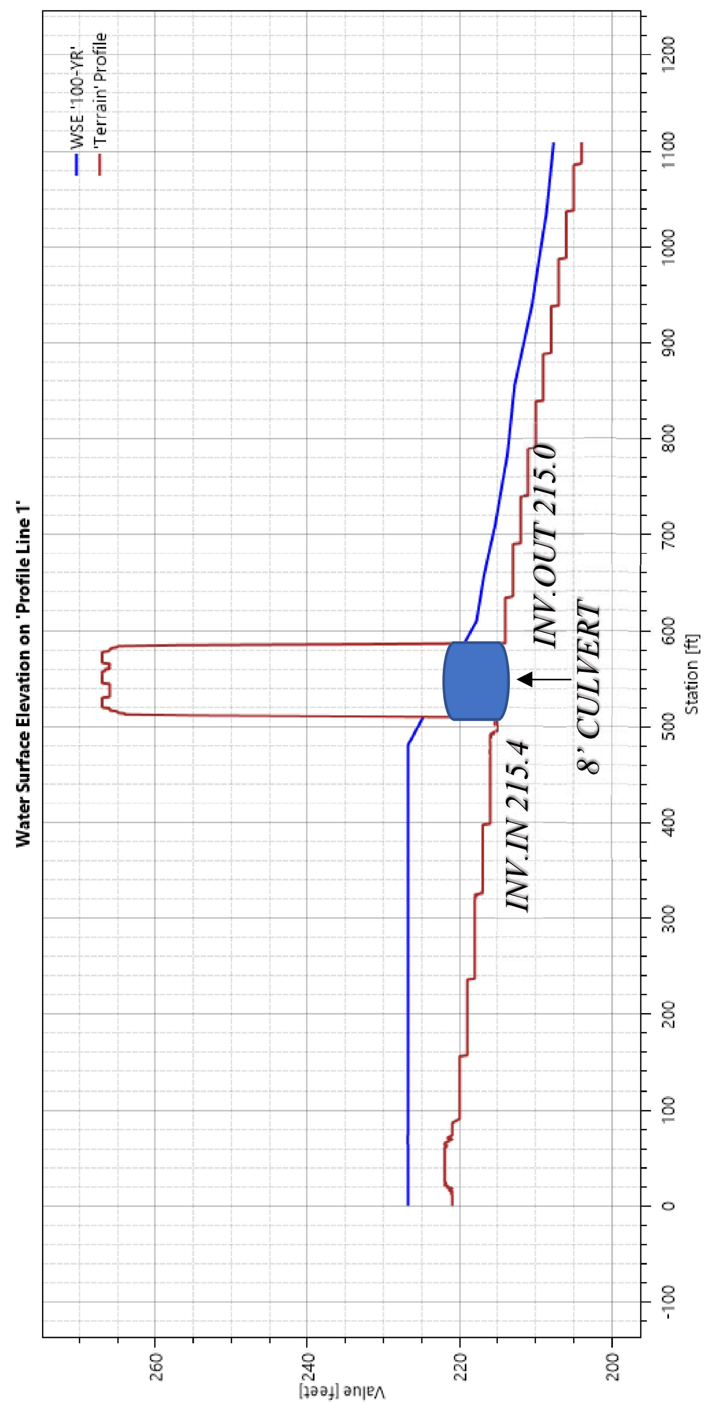

*Maximum flow velocity (ft/s; at water pool) of 100-year flood for the pre-development condition.*

➢ Proposed condition results

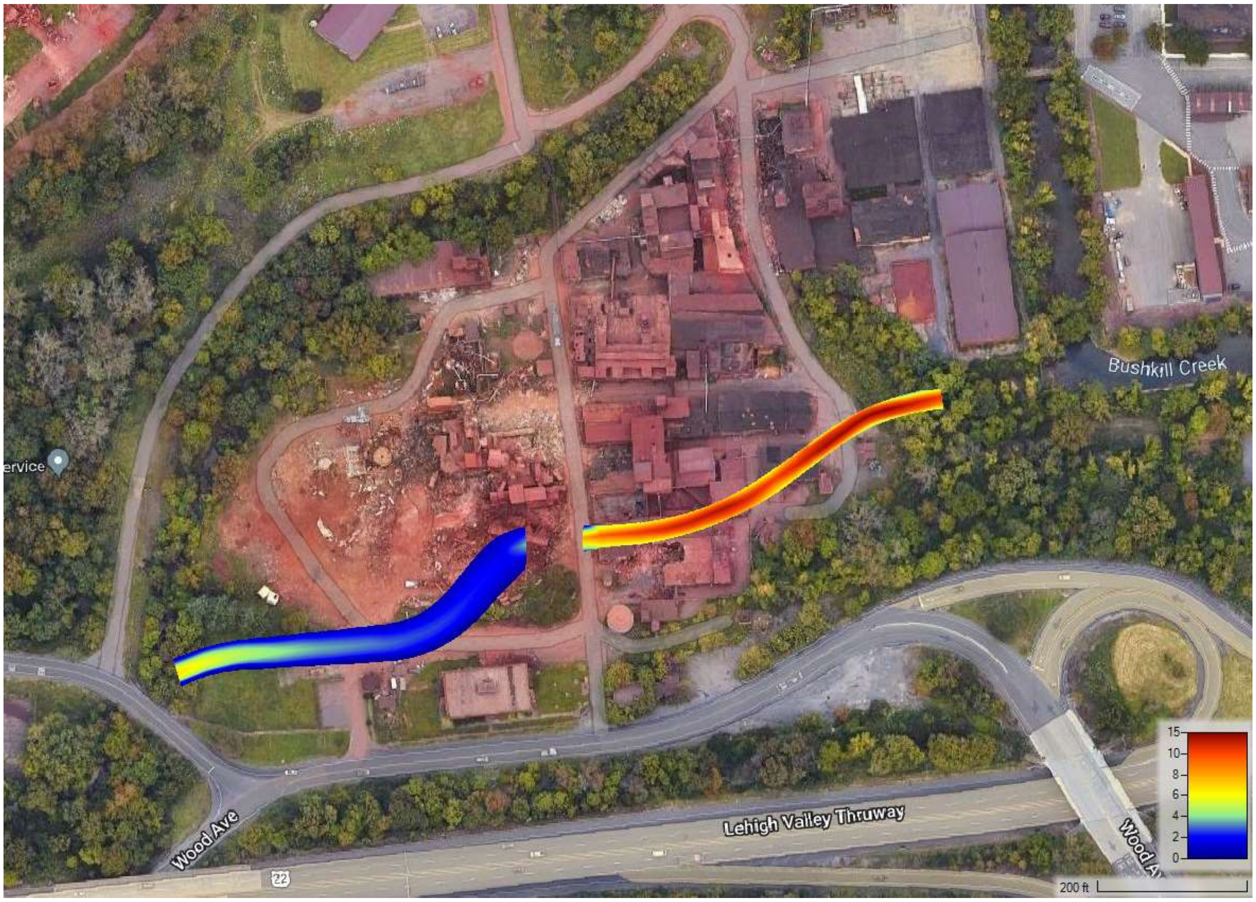

*Inundation boundary of 100-year flood for the post-development condition.*




*Water surface elevation (ft; NAVD 88) of 100-year flood for the post-development condition.*




*Relocated channel profile view of water surface elevation (ft; NAVD 88) for 100-year flood in the post-development condition.*




*Maximum flow velocity (ft/s; at water pool) of 100-year flood for the post-development condition.*

In summary, the major changes of the relocated stream in the post-construction condition are:

- Installing one 8' concrete pipe culvert (#1) along UNT with total length of 76', upstream invert elevation of 215.4', and downstream invert elevation of 215.0'

As can be seen through the presented graphical results, the following stream crossing criteria are met by employing culverts with adequate hydraulic capacity:

- The floodplain boundaries of pre- and post-construction conditions of existing and proposed UNT are similar and none result in overflow from the banks.
- The post-construction increase in flood elevations in the flood areas delineated by FEMA map is less than 1', and many sections the post-development water surface is lower.

- The flow velocities in the pre- and post-construction condition as well as in the upstream and downstream of the culverts in the post-construction condition of UNT have improved compared to the pre-development condition.

In addition to the improvement in the flood management in the relocated channel, principles of stable channel design were employed to enhance the current conditions of the channel.

The proposed channel was designed based on the following criteria:

- Mimic the existing upstream cross section and modify cross sections where needed
- Safely convey the 100-year discharge
- Selection of bed material size to minimize the potential cross-sectional morphologic changes over time (i.e., limit scouring to protect downgradient streams)

Relocation of the channel reduces the floodplain dimension as well as mitigates the stream velocity. However, since the stream velocity in the post-development condition was still high and could pose erosive potential, the sediment transport through the channel was modeled. Based on the results from the sediment transport, the bed and bank material size was designed to impede erosion and therefore protect the downgradient stream. The sediment transport model was done by HEC-RAS and used flow data as explained in the Hydrology section of this document. Total suspended solid (TSS) data were extracted from USGS Gauge and based on that two concentrations each corresponding to minimum and maximum flow were determined.

A typical suspended solid size distribution in the stormwater for low flow conditions (TSS of 10 mg/L when the flow is 1.92 cfs), presented below, was employed as the incoming sediment into the channel:

Clay (0.002 mm to 0.004 mm): 15 %

VFM (0.004 mm to 0.008 mm): 20 %

FM (0.008 mm to 0.016 mm): 25 %

MM (0.016 mm to 0.032 mm): 25 %

CM (0.032 mm to 0.0625 mm): 10 %

VFS (0.0625 mm to 0.125 mm): 5 %

A typical suspended solid size distribution in the stormwater for high flow conditions (TSS of 20 mg/L when the flow is 191.54 cfs), presented below, was employed as the incoming sediment into the channel:

Clay (0.002 mm to 0.004 mm): 15 %

VFM (0.004 mm to 0.008 mm): 15 %

FM (0.008 mm to 0.016 mm): 15 %

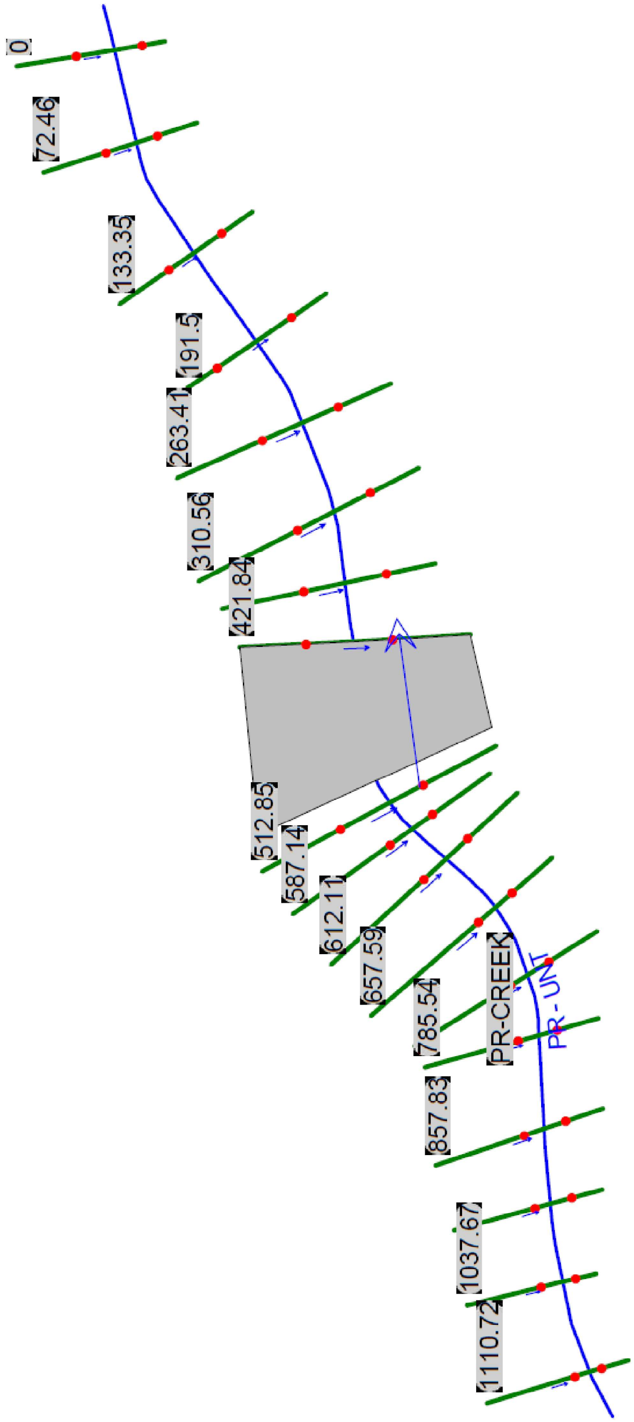
MM (0.016 mm to 0.032 mm): 10 %

CM (0.032 mm to 0.0625 mm): 20 %

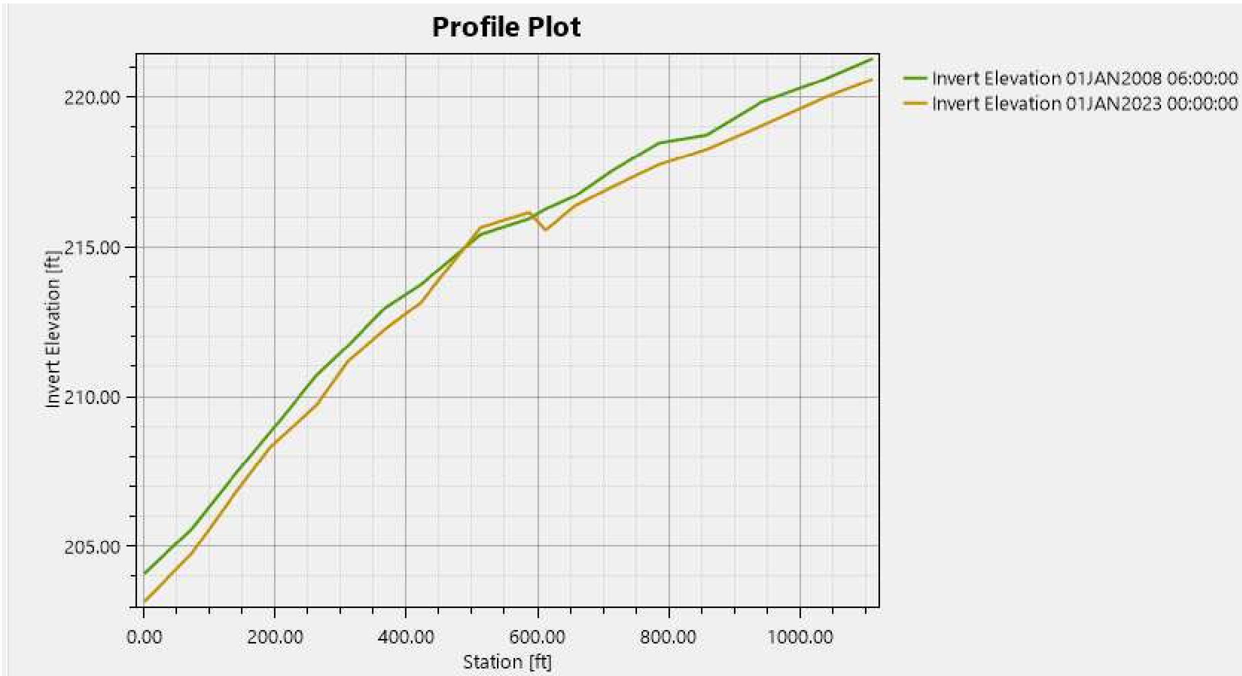
VFS (0.0625 mm to 0.125 mm): 20 %

FS (0.125 mm to 0.250 mm): 5 %

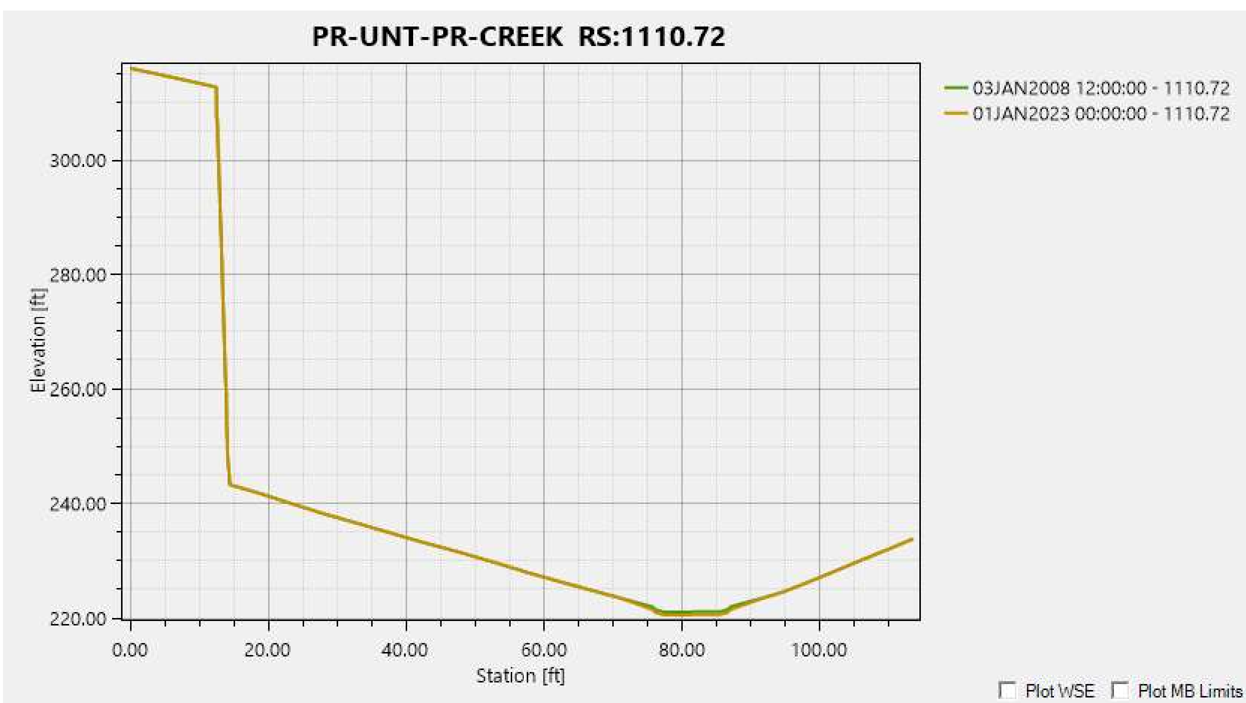
The bed and bank material size distribution was determined by iterations in a way that the changes in the cross-section morphology (i.e., erosion/deposition) would be minimal. The upstream boundary condition of sediment transport model was flow data, while it was the normal depth (i.e., in form of slope) for the downstream end. The sediment transport simulation employed backwater analysis for the hydraulic part. A maximum moveable bed of 1' was assumed for the simulation, and the moveable bed was considered at bed as well as at banks up to the main channel elevation. Laursen, Copeland, and Rubey were selected as transport function, sorting method, and settlement velocity method, respectively. An annual average temperature of 55 $^{o}$F was adopted to estimate water characteristics such as viscosity etc. The flow data was introduced on a daily basis, while the transport model computation increment was set to 6 hours to increase the resolution and accuracy of the simulation. The highlights from the results of 15 years of simulation are summarized in the following figures to illustrate the adequacy of the selected bed gradation.



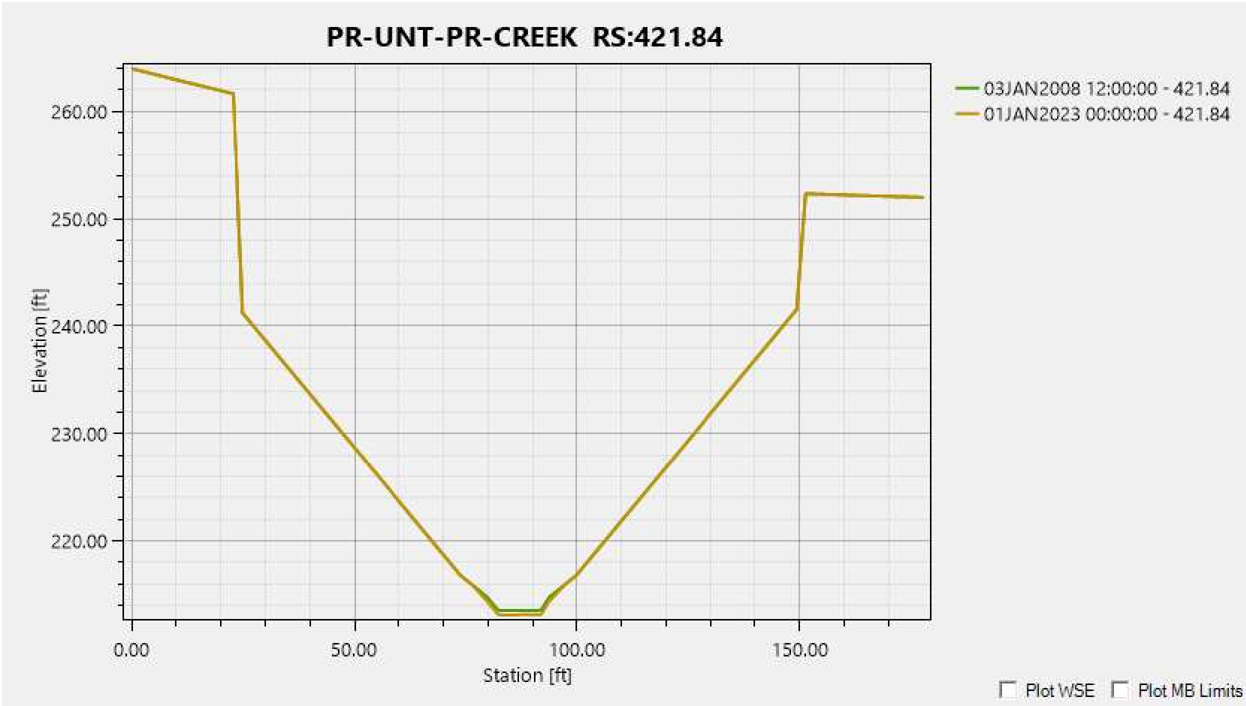

*Plan of relocated channel and cross section labels.*



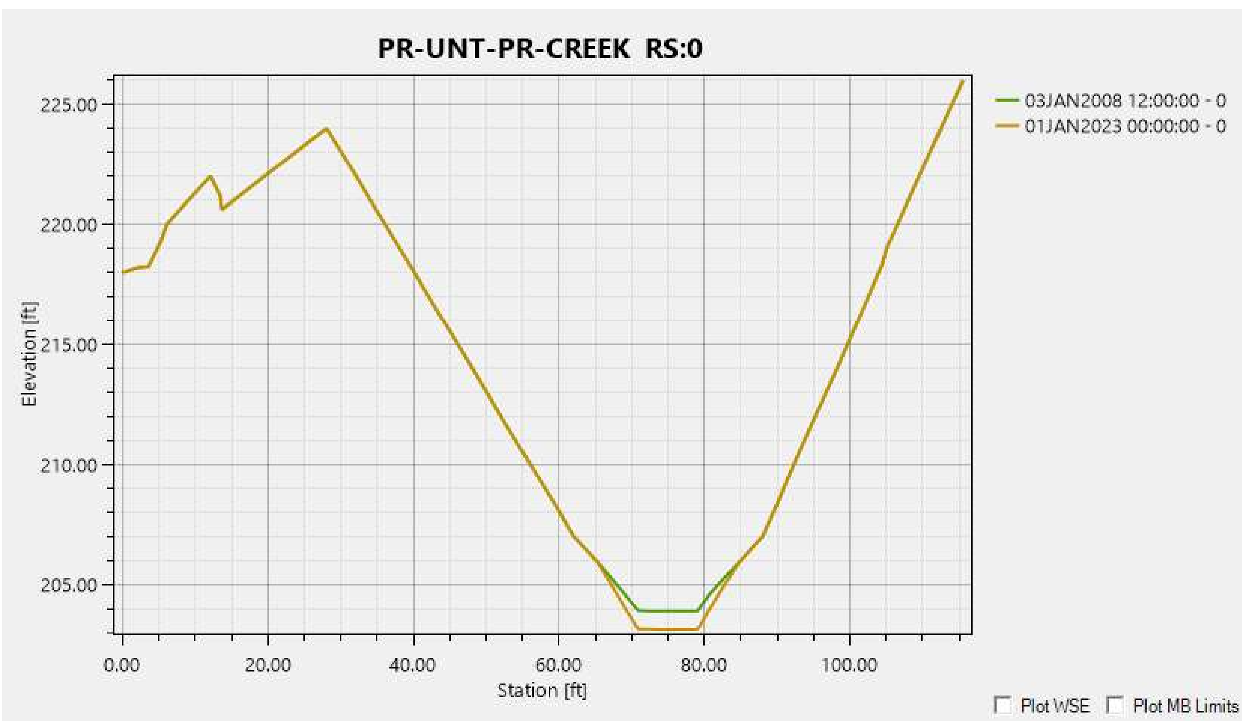

*Profile view of the Invert elevations at the beginning and end of sediment transport simulation.*



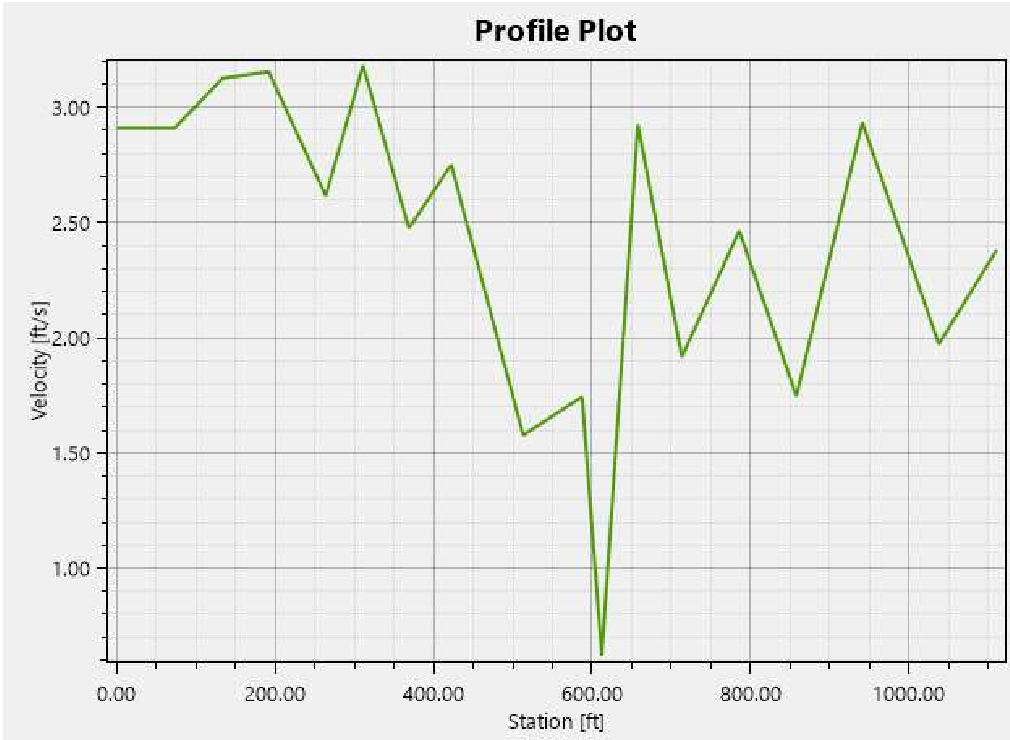

*Upstream section view of the Invert elevations at the beginning and end of sediment transport simulation.*



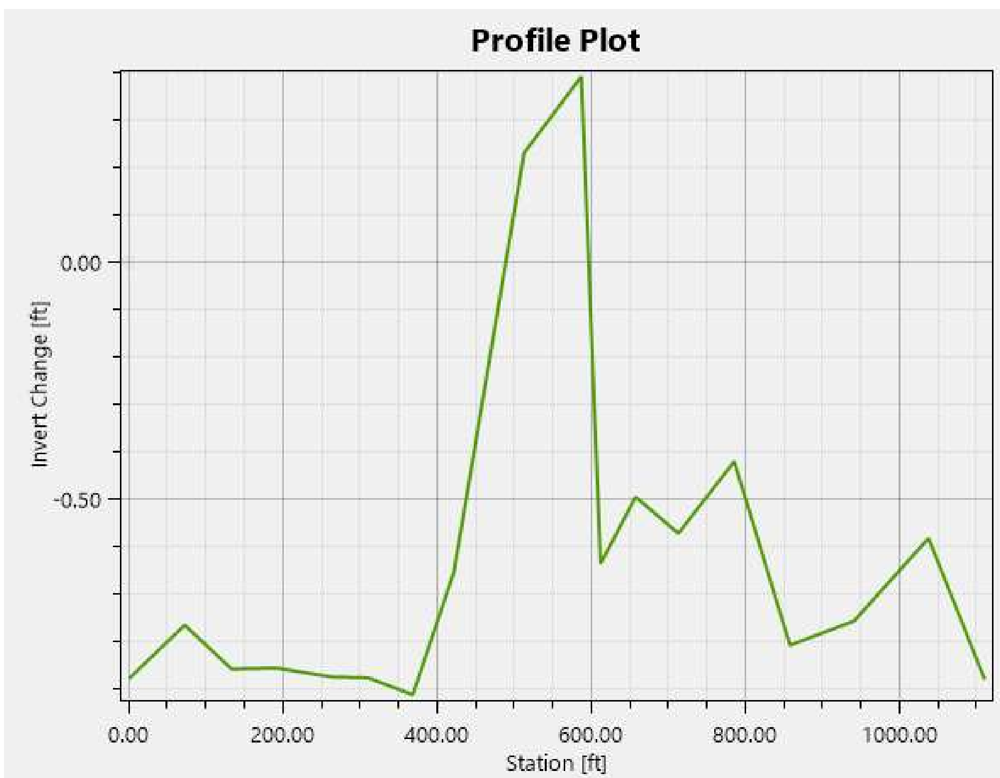

*Immediately downgradient of culvert Invert elevations at the beginning and end of sediment transport simulation.*




*Downstream section view of the Invert elevations at the beginning and end of sediment transport simulation.*

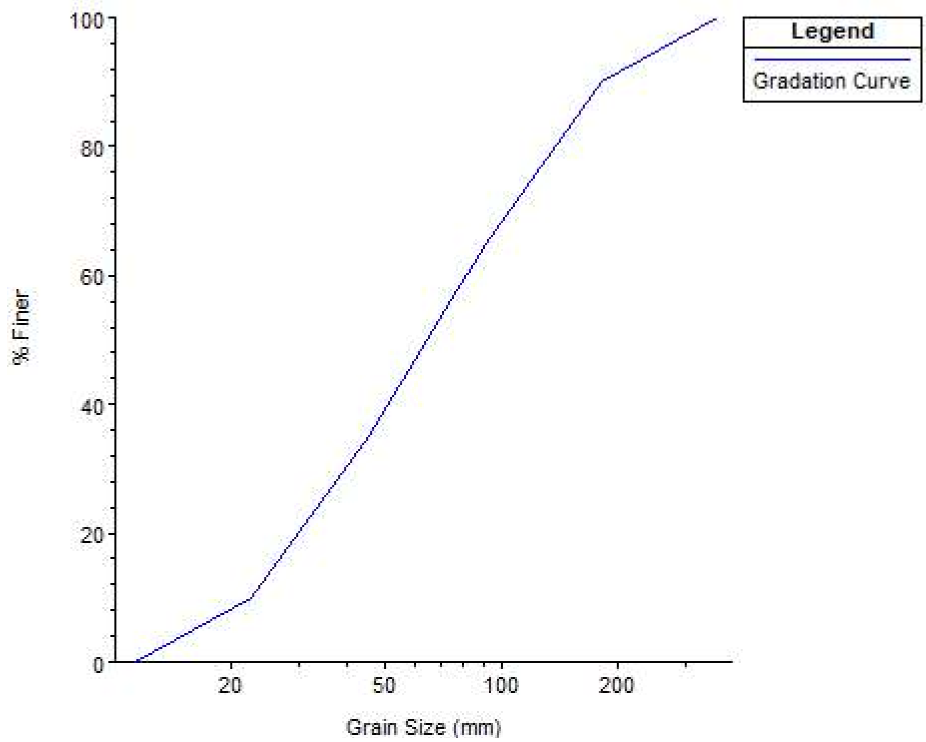



*Profile view of the stream maximum velocities at bed elevation.*




*Profile view of the invert changes after 15 years of simulation.*

As can be seen through the figures, the elevation change after 15 years of simulation is minimal and is mostly less than 1' scouring. Moreover, the stream velocity profiles at bed elevation indicated that the velocities do not exceed 6.5 ft/s. Table 8-12 of PENNDOT publication 584 (chapter 8; 2010 edition) has reported permissible velocities for various linings. The relocated channel is considered stable because the simulated velocities are below the lowest permissible velocities listed for the riprap lining. It should be noted that the proposed bed material is boulder with a d50 of ~ 60mm (2.4") and the following size distribution.




*Size distribution of the proposed bed and banks material (the chart is in mm; 25.4 mm = 1 inch).*