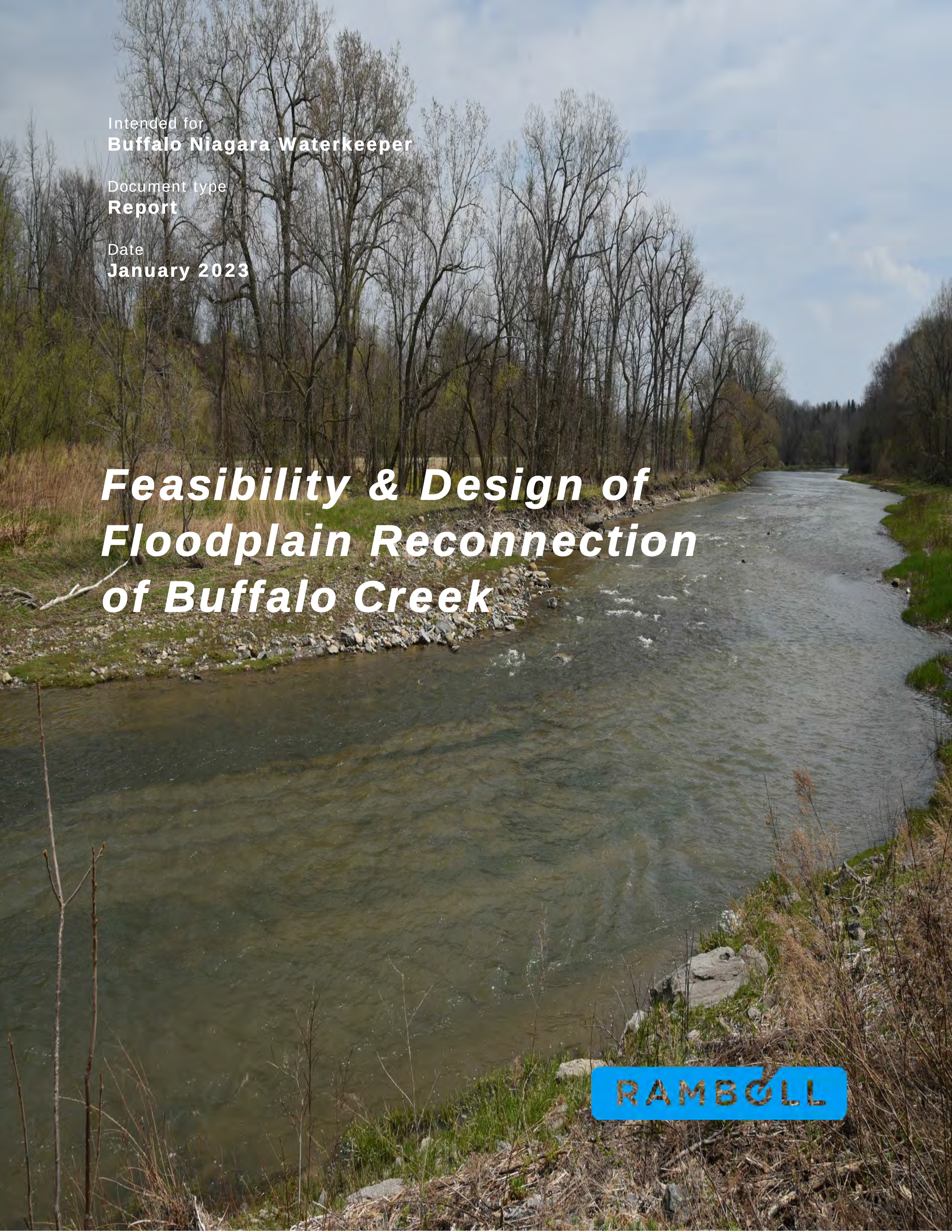

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Feasibility & Design of Floodplain Reconnection of Buffalo Creek

RAMBOLL

Feasibility & Design of Floodplain Reconnection of Buffalo Creek

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1. Introduction

1.1 Background

Buffalo Niagara Waterkeeper (Waterkeeper) is a community-based, not-for-profit organization that leads regional efforts to safeguard water resources for present and future generations and connects people to the water through education, recreation, and preservation. Funding for this project was obtained through the National Fish and Wildlife Foundation's National Coastal Resilience Fund, which works to restore, increase and strengthen natural infrastructure to protect coastal communities while also enhancing habitats for fish and wildlife.

In November 2018, New York State Governor Andrew Cuomo announced the Resilient NY Initiative in response to devastating flooding in communities across the State during the preceding years. The Buffalo Creek watershed was chosen as one of the study sites for this initiative. Overseen by the New York State Department of Environmental Conservation (NYSDEC) and the New York State Office of General Services (NYSOGS), the Resilient NY Initiative identified the causes of flooding within the Buffalo Creek watershed and developed, evaluated, and recommended effective and ecologically sustainable flood and ice jam hazard mitigation projects.

Three high risk areas for flooding were identified in the final report *Resilient NY Flood Mitigation Initiative: Buffalo Creek* (2020), including the Lexington Green Neighborhood. One of the alternatives presented in the report was the creation of a floodplain bench upstream of the Lexington Green neighborhood. The creation of a floodplain bench would increase the width (*i.e.,* cross-sectional flow) of Buffalo Creek and add storage area during times of high flows thus alleviating flooding downstream. It is important to note that this report did not identify specific parcels on which to create the floodplain bench. It also did not identify parcel ownership, parcel conditions, or the willingness of the property owners to allow for construction of a floodplain bench on their land.

1.2 Project Location

This project is located along Buffalo Creek in the Town of West Seneca, NY (Town) upstream of the union with Cayuga Creek. The Town is located just outside of Buffalo, NY and covers an area of approximately 21 square miles. It is transected by nine (9) major highways, including the NY State Thruway, which makes it an ideal location for both residential and commercial development. The Town has experienced a long history of flooding damages and impacts associated with rapid snowmelt, heavy rainfall, and ice jams. Some of the largest of these impacts are cited as occurring along the Buffalo Creek corridor.

The Lexington Green neighborhood sits along a bend in Buffalo Creek approximately 0.7 miles upstream of its union with Cayuga Creek at the Harlem Road Bridge. Buffalo Creek runs along the north and east sides of the neighborhood over a length of approximately 0.45 miles. The neighborhood was developed in the mid-1960s on top of the former Buffalo Creek channel, which was filled with gravel and excavated materials from a sediment control project. Approximately 90 homes were built within the neighborhood, all of which are still occupied as of 2022. Attachment A displays the primary and secondary project locations in the Town of West Seneca, NY.

Figure 1. Buffalo Creek in the vicinity of the Lexington Green neighborhood, West Seneca, NY.

1.3 Flood History

Flooding along Buffalo Creek generally occurs in the late winter and early spring due to rapid snowmelt and spring rains. The situation is compounded by restrictive bridges, which cause ice jams along the stream channel. In addition, continued development in the floodplain exposes a greater numbers of assets to potential flood damages. Most major floods have historically occurred during the months of January to March.

Historically, the Lexington Green neighborhood has been susceptible to flooding, particularly ice jams in the late winter to early spring. In the winter of 2014, two significant flood events occurred within 6 weeks of each other causing a combined damage estimate of $1.2 million (USACE 2016). These storms caused damage to over 70 homes and 2 dozen vehicles in the Lexington Green neighborhood. In the winter of 2019, a significant ice-jam flooding event caused the evacuation of the School Street Neighborhood. Most recently, in the winter of 2022, a severe flooding event caused emergency evacuations of several neighborhoods in the Town of West Seneca along Buffalo Creek.

The Federal Emergency Management Agency (FEMA) is responsible for flood studies and mapping in the United States. FEMA produces Flood Insurance Rate Maps (FIRMs), which are the official community maps that show special flood hazard areas (SFHAs) and the risk premium zones. For Buffalo Creek in the Town of West Seneca, NY, FIRMs were developed and updated in 2019. The current effective Flood Insurance Study (FIS) for Buffalo Creek is dated June 16, 2021. Attachment A displays the FEMA effective flood zones for Buffalo Creek in the project area.

1.4 Objectives

Ramboll was tasked with identifying opportunities for reconnecting Buffalo Creek to its floodplain to:

- Address reoccurring flooding
- Improve flood resiliency
- Develop preliminary designs of floodplain benches based on verified on-the-ground opportunities in the vicinity of the Lexington Green neighborhood.

During the last six months, Ramboll performed a preliminary analysis of the benefits of constructing flood benches along Buffalo Creek in the vicinity of the Lexington Green neighborhood. The purpose of this report is to provide a summary of the evaluated flood bench scenarios.

Based on historical flood reports and public engagement, it is understood that the Lexington Green neighborhood is susceptible to both open-water and ice-jam related flooding. A separate ice-jam analysis was performed for the flood bench alternatives to determine their effectiveness during ice-jam flooding events.

2. Methodology

2.1 Model Data

Attachment B is a technical memorandum describing the methodology used to evaluate each flood bench for this project in further detail. The following data were obtained and utilized for this project:

- FEMA peak discharges (FEMA 2021)
- USGS *StreamStats* peak discharges (USGS 2021)
- New York State Digital Ortho-Imagery Program imagery (NYSOITS 2021)
- National Land Cover Database (NLCD) data (USGS 2021)
- NYSDOT bridge data (NYSDOT 2019)
- New York State 1-meter LiDAR digital elevation model (DEM) data with vertical accuracy of 19.6-centimeters (7.7 inches) in the North American Vertical Datum of 1988 (NAVD88) (NYSOITS 2019)

To evaluate existing and proposed conditions along Buffalo Creek, it was necessary to obtain discharge data for the 10-, 2-, 1-, and 0.2- percent AEP (10, 50, 100, and 500-year recurrence) events. Hydrologic data was obtained from the USGS *StreamStats* software due to the limited available FEMA data for Buffalo Creek within the project area.

The USGS *StreamStats* v4.10.1 software is a map-based web application that provides an assortment of analytical tools. The primary purpose of *StreamStats* is to provide estimates of streamflow statistics for user-selected un-gaged sites and for USGS stream gages, which are locations where data is collected (Ries et al. 2017, USGS 2022). Table 1 displays the data obtained from *StreamStats* for Buffalo Creek at the union with Cayuga Creek.

Table 1. USGS *StreamStats* data for Buffalo Creek for the 10-, 2-, 1-, and 0.2- percent AEP events (10, 50, 100, and 500-year recurrence intervals).

Location	Drainage Area (sq miles)	River Station (ft)	Peak Discharges (cfs)			
			10-Percent	2-Percent	1-Percent	0.2-Percent
Union with Cayuga Creek	146	0+00	7,990	11,800	13,600	18,000

2.2 Effective FIS model

As part of its role, FEMA performs hydrologic & hydraulic (H&H) analyses and develops H&H models for each studied watershed within a community. These models are referred to as ***effective FIS models***. The effective FIS model for Buffalo Creek was created using the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center River Analysis System (HEC-RAS) program (USACE 2021).

According to the Flood Insurance Study (FIS) for Erie County, NY (2021), the effective FIS model for Buffalo Creek in the Town of West Seneca was completed by FEMA in 1976. It was then revised and updated in 1992. For this project, the effective FIS model was obtained for the project area, which begins at the union between Buffalo Creek and Cayuga Creek (river station 0+00) and extends upstream to the Buffalo Airfield (river station 205+00) (Figure 2). In Figure 2 below, the blue line represents the centerline of Buffalo Creek while the green lines represent the cross-sections in the effective FIS model. Additionally, the numbered labels represent the distance (in feet) along the centerline upstream from the union of Buffalo and Cayuga Creeks.

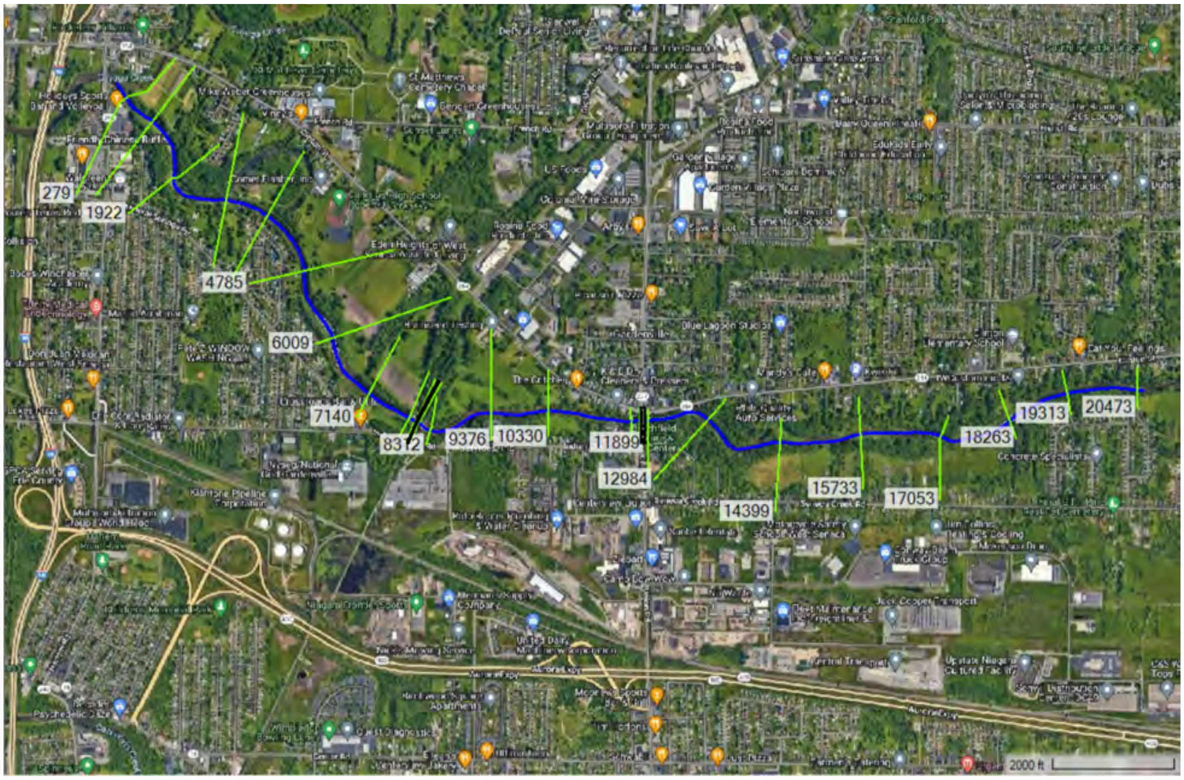

Figure 2. FEMA Effective FIS model layout for Buffalo Creek.

2.3 Existing Conditions Model

Due to the age of the effective FIS model (first developed in 1976 and updated in 1992), most of the input data used by FEMA in the model is outdated and potentially inaccurate. For the purposes of this project, updates were made to the effective FIS model data, using the latest LiDAR digital elevation model (DEM) (2019) and land cover data (2019) to modify the geometry and values used for land cover (NYSOITS 2019; USGS 2021). This updated model is referred to as the ***existing conditions model.***

Due to the water penetration limitations of the LiDAR technology, minimum channel elevations were maintained or modified to match the effective FIS model (1992) or FIS profile plot (2019).

In addition, 12 cross sections were added to the existing conditions model between river stations 36+50 and 80+00 to provide the necessary starting and ending positions for the different flood bench scenarios along the Lexington Green neighborhood. These new cross sections had their overland set to the DEM data and the minimum channel elevations were modified to match the minimum channel elevation from the effective FIS model profile plot. Figure 3 displays the existing conditions model layout for Buffalo Creek. The blue line represents the centerline of Buffalo Creek while the green lines represent the cross-sections in the existing conditions. Additionally, the numbered labels represent the distance (in feet) along the centerline upstream from the union of Buffalo and Cayuga Creeks.

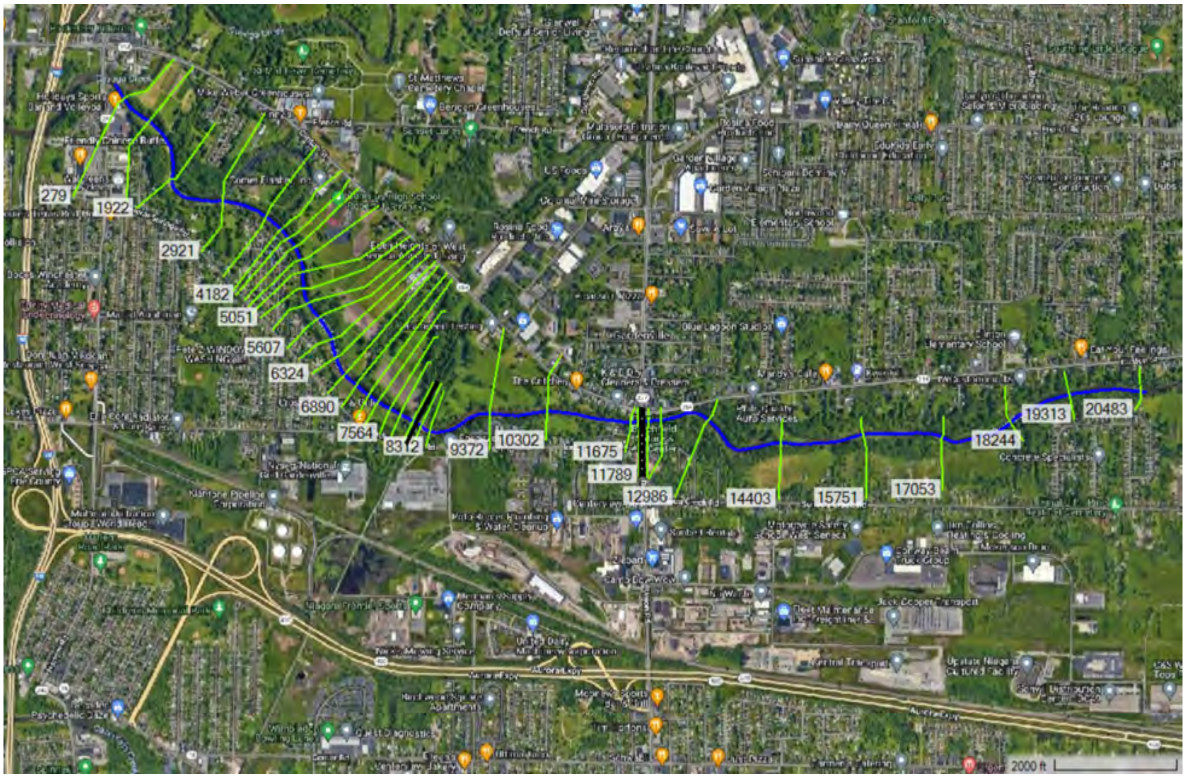

Figure 3. Existing conditions model for Buffalo Creek.

2.4 Survey Data

Field staff from Ramboll performed a site visit on November 2, 2022, where overbank and in-channel survey data and streambank assessments were performed. Four locations were surveyed due to their accessibility, close proximity to the Lexington Green neighborhood, and lack of adequate representation in the effective FIS model layout. Figure 4 displays the field survey locations along Buffalo Creek.

Figure 4. Field survey locations along Buffalo Creek.

Field surveys involved field staff using surveying and leveling equipment to measure land surface elevations perpendicularly across the creek channel from one overbank area to the other. In addition, stream bank assessments were performed at each location to identify the condition and locations of overbank zones (e.g., toe, bank, overbank, transitional, and upland zones).

This survey data was used to validate the overbank and channel elevations in the existing conditions model. In addition, survey data was incorporated into the existing conditions model where significant discrepancies were found. Attachment C contains the field notes from the field staff.

2.5 Flood Bench Scenarios

A flood bench (also referred to as a floodplain bench or bankfull bench) is a flat area adjacent to the stream at some specified elevation. Flood benches are constructed to create an area for flows to spread out, dissipate energy, and catch erosion. A flood bench is effective at reducing flood stages and velocities, improving water quality, reducing stream bank erosion, and providing stream bed stability. Attachment D contains a sectional plan view of a flood bench.

Potential flood bench locations were identified using input received from the public engagement meeting and contact with individual property owners. A public engagement meeting took place on August 22, 2022, where Ramboll discussed the project goals and potential property owner participation. Highland Planning, LLC (Highland) took the lead in contacting and engaging with property owners to gauge interest in being included in this project. Based on discussions and participation by the community and property owners, six potential flood bench configurations were identified along Buffalo Creek within the project area.

In addition, through public engagement and discussions with representatives of Canisius High School, it was identified that the school is in the process of constructing two baseball fields, a practice field, and tennis courts in the open area adjacent to Buffalo Creek. The site plans and drawings for this construction were provided to Ramboll and incorporated into the H&H model for Buffalo Creek. Attachment E contains the site plans for the development.

Table 2 summarizes the different identified flood bench locations with descriptions. Figure 5 displays the locations and extents of each flood bench, including the proposed development locations by the Canisius High School.

Table 2. Summary table of proposed flood bench locations.

Flood Bench ID	Description
1a	Western portion of the Canisius School tax parcel
1b	Western portion of the Canisius School tax parcel (outside of the proposed development area)
2	Western portion of the 1904 Union Rd tax parcel
3	Western portion of the 3099 Clinton Street tax parcel
4	Western portion of the Transmission Land (Right Bank) tax parcel
5	Western portion of the Transmission Land (Upstream – Left Bank) tax parcel
6	Western portion of the Transmission Land (Downstream - Left Bank) tax parcel

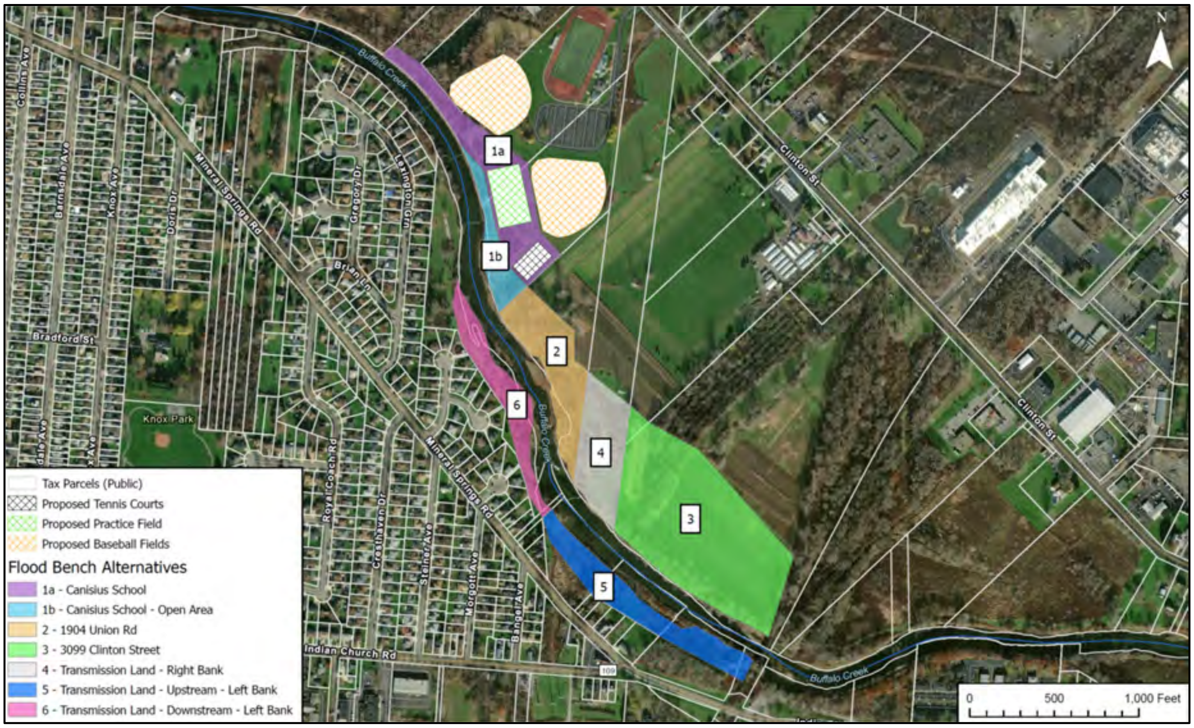

Figure 5. Map of Buffalo Creek and the proposed flood bench locations.

Based on the six identified flood bench locations, nine flood bench scenarios of different configurations were developed. Table 3 outlines the nine flood bench scenarios.

Table 3. Summary table of modeled flood bench scenarios.

Scenario ID	Flood Bench Configurations
1	1a
2	1b
3	1b + 2
4	2 & 3
5	1b + 2 + 3
6	2 + 3 + 4
7	1b + 2 + 3 + 4
8	5 + 6
9	1b + 2 + 3 + 4 + 5 + 6

2.6 Proposed Scenario Modeling

Proposed conditions models were developed for each flood bench configuration based on the existing conditions model. To model each flood bench scenario, terrain modifications were made to each cross section that intersected a proposed flood bench. Figure 6 displays an example cross section where the terrain was modified to represent a flood bench.

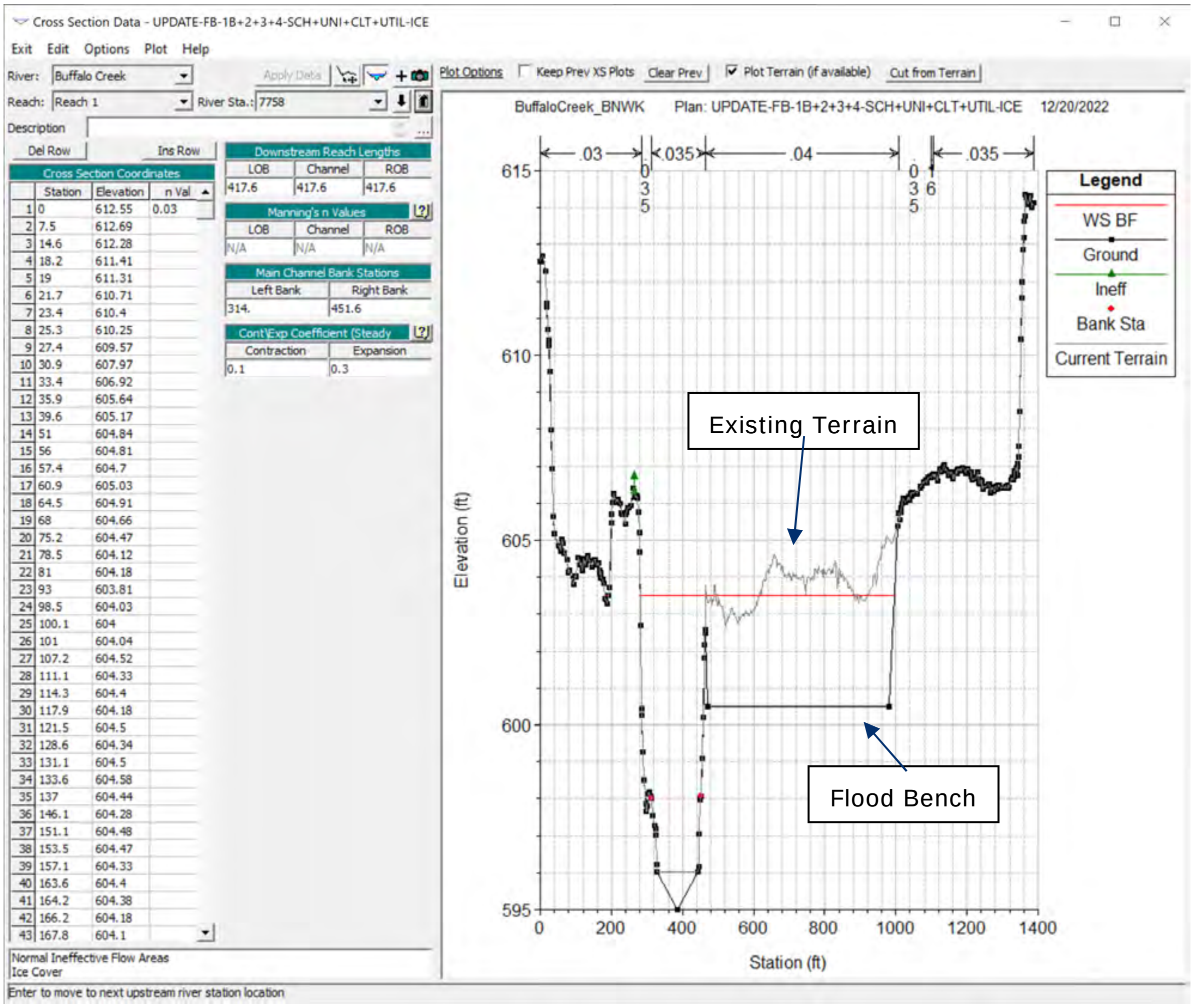

Figure 6. Example Cross-Section Depicting a Flood Bench.

2.7 Ice-Jam Analysis

An ice jam typically occurs in the late winter and early spring in ice-covered streams when ice accumulates at man-made (e.g., bridge piers, dams) or natural narrower or shallower sections or meanders of a river slowing down or blocking the incoming ice by bridging the ice across the width of the river. Ice-jam flooding presents a complex problem for scientists and engineers since the resulting flood stage can be significantly higher than the flood stage caused from streamflow alone. In other words, a relatively minor discharge of streamflow can result in a major flooding event during an ice jam (USACE 2006).

The ice jam analysis in this study used the 10% ACE (10-yr) to develop an ***existing condition with ice cover model.*** Ice-jam simulations were performed for each proposed conditions model using the built-in Ice Cover settings within the HEC-RAS model software. Based on historical ice jam data, ice cover lengths and depths were obtained and input into the model. For the ice-jam simulations, an ice cover of 1-ft thickness was used starting from the confluence with Cayuga Creek/Buffalo River (river station 0+00) upstream to the Union Road bridge (river station 118+60).

3. Results

3.1 Effective FEMA and Existing Conditions Model Results

Attachment F contains the model results for the effective FEMA and existing conditions models. Based on the modeling results, there is a difference in water surface elevations (WSELs) between the effective FIS model and the existing conditions model of up to 2.0-feet using the FEMA 1-percent AEP peak discharge. Figure 7 displays the profile plot of the effective FEMA and existing conditions model results.

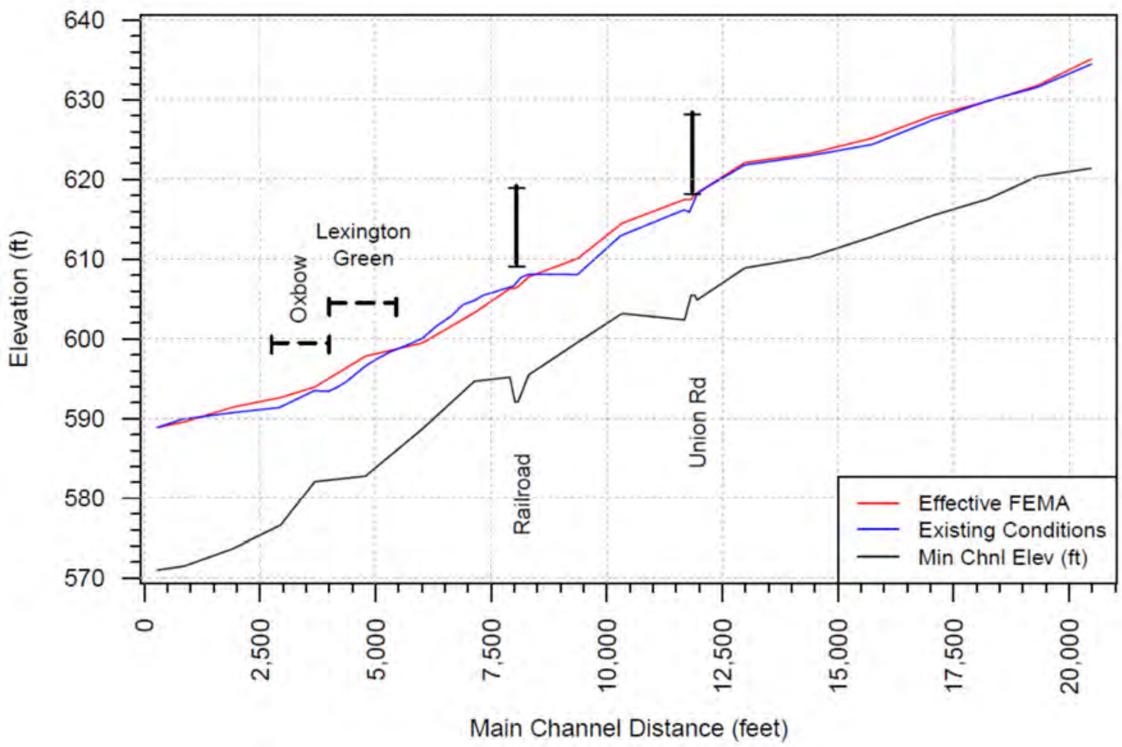

Figure 7. Effective FEMA and existing conditions profile plot using the FEMA 1-percent AEP (100-year recurrence) event peak discharge.

The difference in water surface elevations (WSELs) between the effective FIS model and the existing conditions model are a result of multiple factors, including:

- Updated geometry using the most current LiDAR DEM available
- Updated values to represent land use changes over time in the watershed
- Additional cross-sections to provide more consistent and higher resolution calculations and results
- Difference in versions of the USACE HEC-RAS modeling used for the effective FIS and the existing conditions model.

Figure 8 displays the flood extents of the effective FIS model and the existing conditions model results using the FEMA 1-percent AEP event peak discharge.

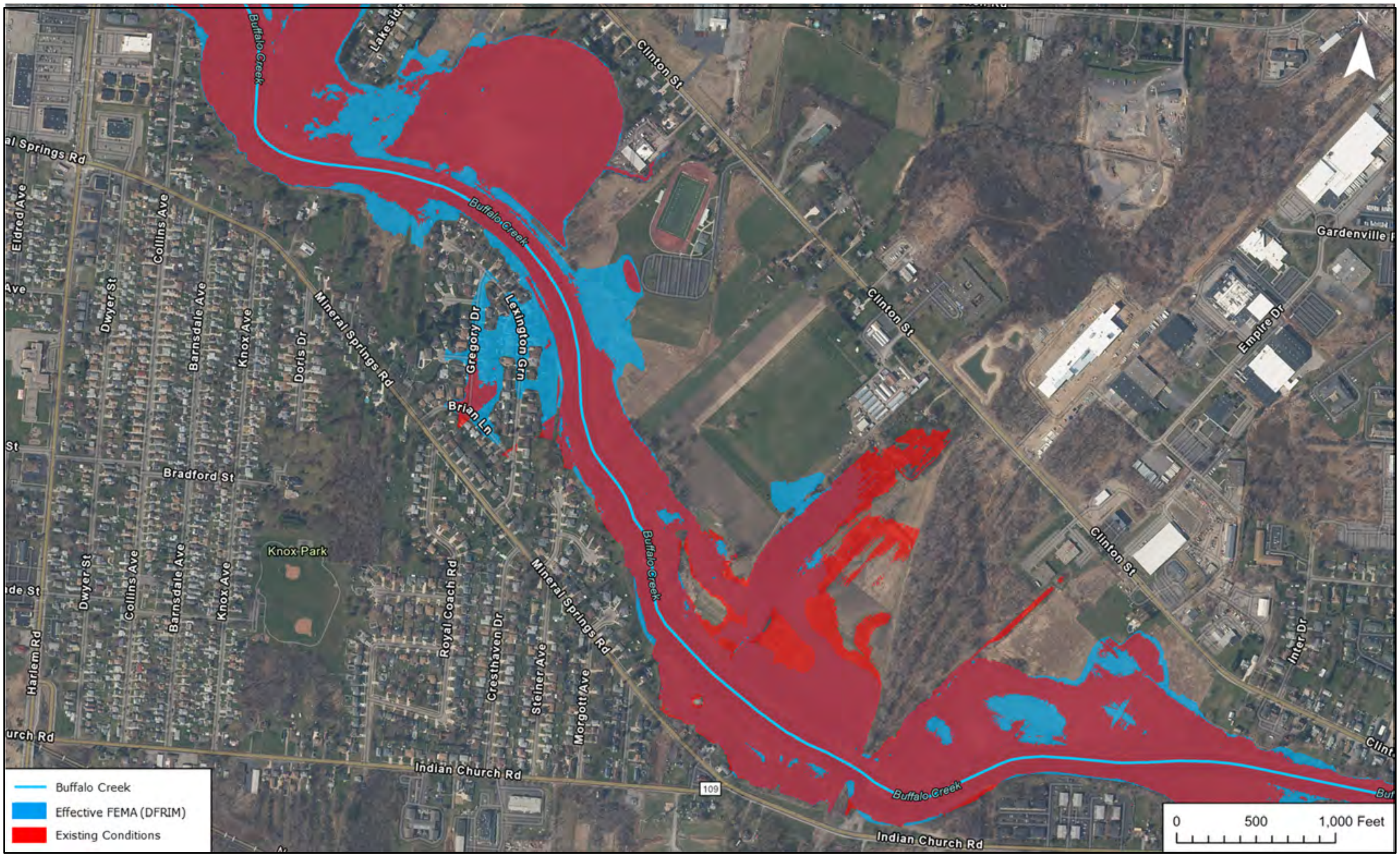

Figure 8. Flood extents for the effective FEMA (blue) and existing condition (red) model simulation results using the FEMA 1-percent AEP (100-year recurrence) event peak discharge.

The largest difference between the effective FEMA and existing conditions model simulations results occurs downstream of the Oxbow and in the vicinity of the Lexington Green neighborhood. Since the development of the effective FIS a temporary protective berm was placed to help reduce the risk of flooding in the Lexington Green neighborhood.

For regulatory and insurance purposes, the berm along the Lexington green neighborhood is not recognized as an official levee since it does not meet the minimum design standards for providing safe, reliable flood protection. The minimum design standards include design height for the specified level of protection (e.g., 1% AEP/100-year level), overtopping criteria, top width, side slopes, seepage, and stability (i.e., foundation protection, erosion and scour protection, etc.). Therefore, it was considered in the developing the effective FIRM nor this study.

3.2 Proposed Conditions Model Results

Attachment F contains the results for the existing and proposed conditions models. The model results of each proposed flood bench scenario in comparison to the existing conditions model is summarized in Table 4.

Table 4. Results of the existing and proposed conditions models for the 10-, 2-, 1-, and 0.2- percent AEP events (10, 50, 100, and 500-year recurrence intervals).

Scenario ID	Flood Bench Configurations	Reductions in Water Surface Elevations (feet NAVD88)			
		10-Percent	2-Percent	1-Percent	0.2-Percent
1	1a	1.0	1.4	1.5	1.6
2	1b	0.4	0.6	0.6	0.6
3	1b + 2	0.8	1.2	1.3	1.3
4	2 + 3	1.4	1.6	1.6	1.6
5	1b + 2 + 3	1.4	1.6	1.6	1.6
6	2 + 3 + 4	1.5	2.0	2.2	2.4
7	1b + 2 + 3 + 4	1.5	2.0	2.2	2.5
8	5 + 6	0.6	0.7	0.7	0.7
9	1b + 2 + 3 + 4 + 5 + 6	1.6	2.2	2.4	2.8

Figures 9 through 17 display the flood extents from the proposed (blue) and existing (pink) conditions model for each flood bench using the USGS *StreamStats* 1-percent AEP (100-year recurrence) event peak discharge. Where the flood extents for both the proposed and existing conditions model overlap, the flood extents will appear as purple on the figures.

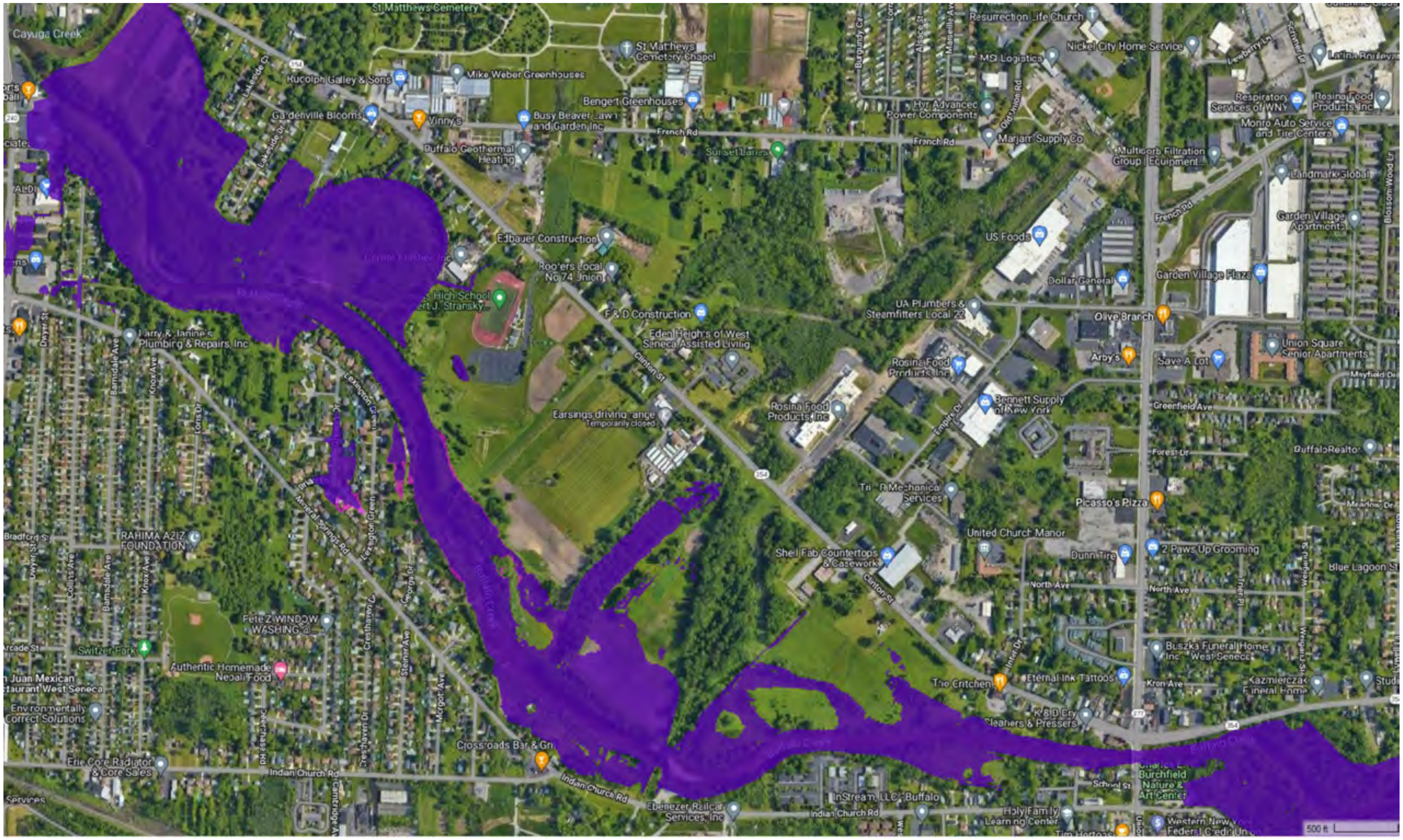

Figure 9. Scenario #1 - Flood extents for proposed conditions (blue) and existing condition (pink) model using the USGS *StreamStats* 1-percent AEP (100-year recurrence) event peak discharge.

Figure 10. Scenario #2 - Flood extents for proposed (blue) and existing conditions (pink) model using the USGS *StreamStats* 1-percent AEP (100-year recurrence) event peak discharge.

Figure 11. Scenario #3 - Flood extents for proposed (blue) and existing conditions (pink) model using the USGS *StreamStats* 1-percent AEP (100-year recurrence) event peak discharge.

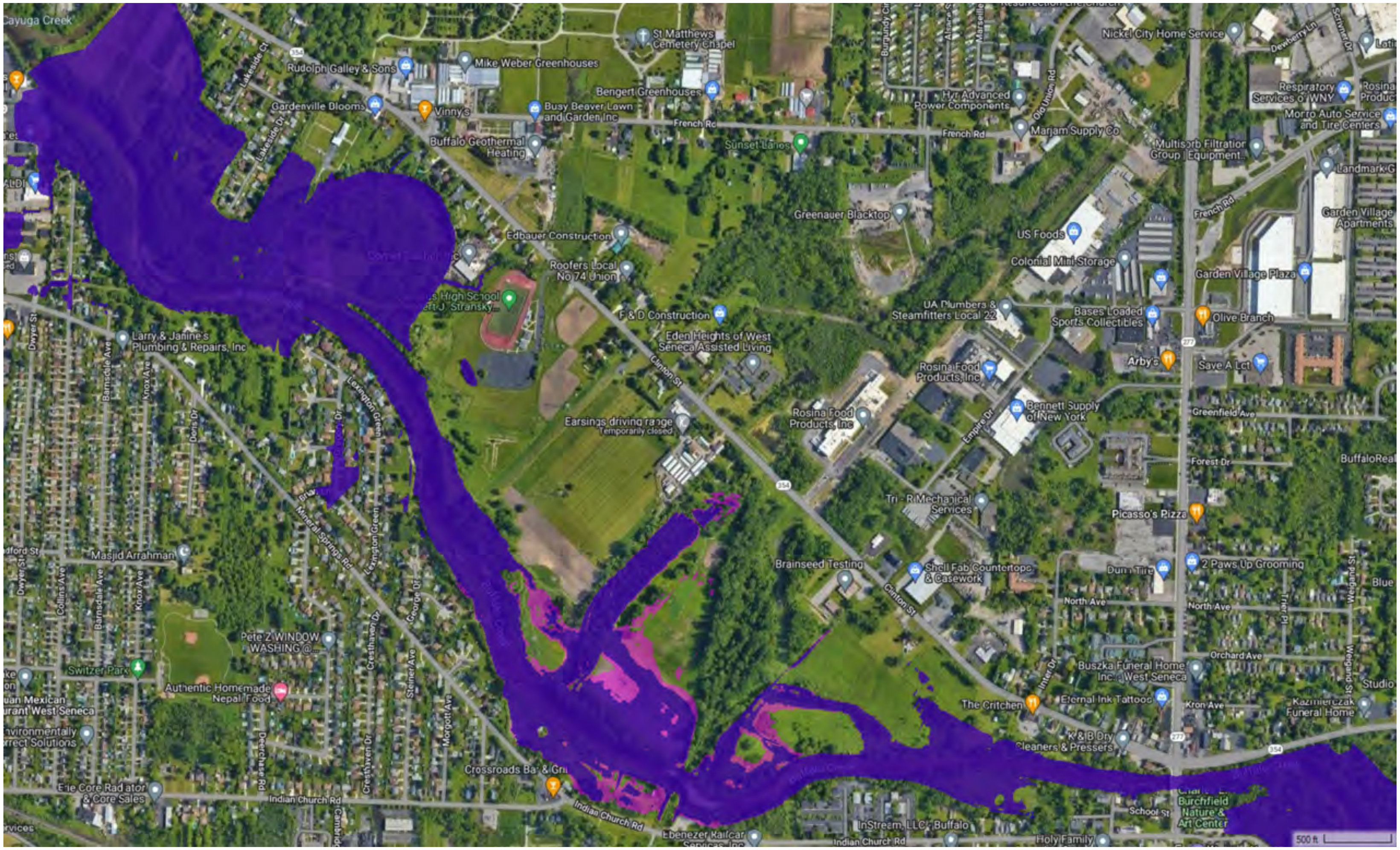

Figure 12. Scenario #4 - Flood extents for proposed (blue) and existing conditions (pink) model using the USGS *StreamStats* 1-percent AEP (100-year recurrence) event peak discharge.

Figure 13. Scenario #5 - Flood extents for proposed (blue) and existing conditions (pink) model using the USGS *StreamStats* 1-percent AEP (100-year recurrence) event peak discharge.

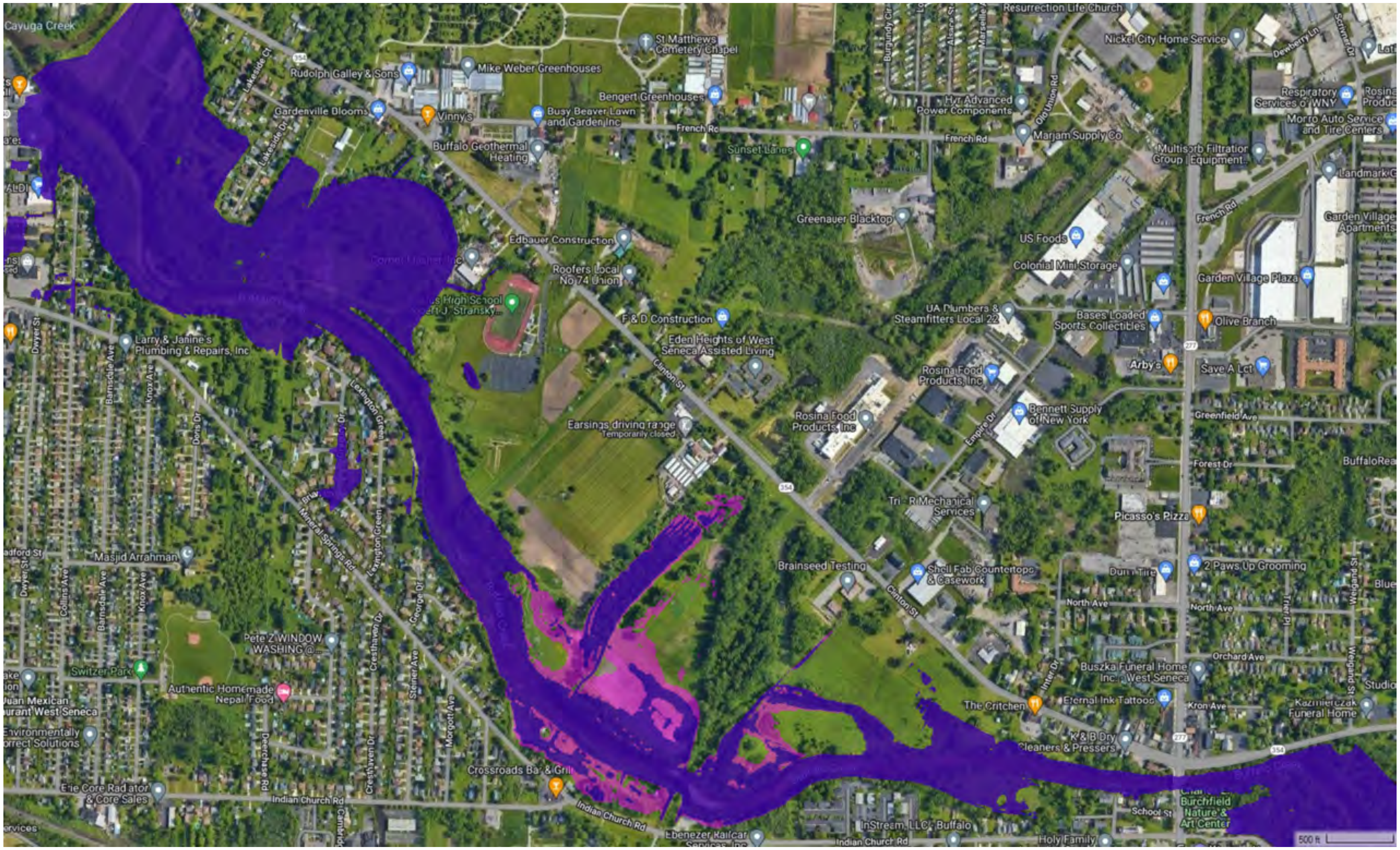

Figure 14. Scenario #6 - Flood extents for proposed (blue) and existing conditions (pink) model using the USGS *StreamStats* 1-percent AEP (100-year recurrence) event peak discharge.

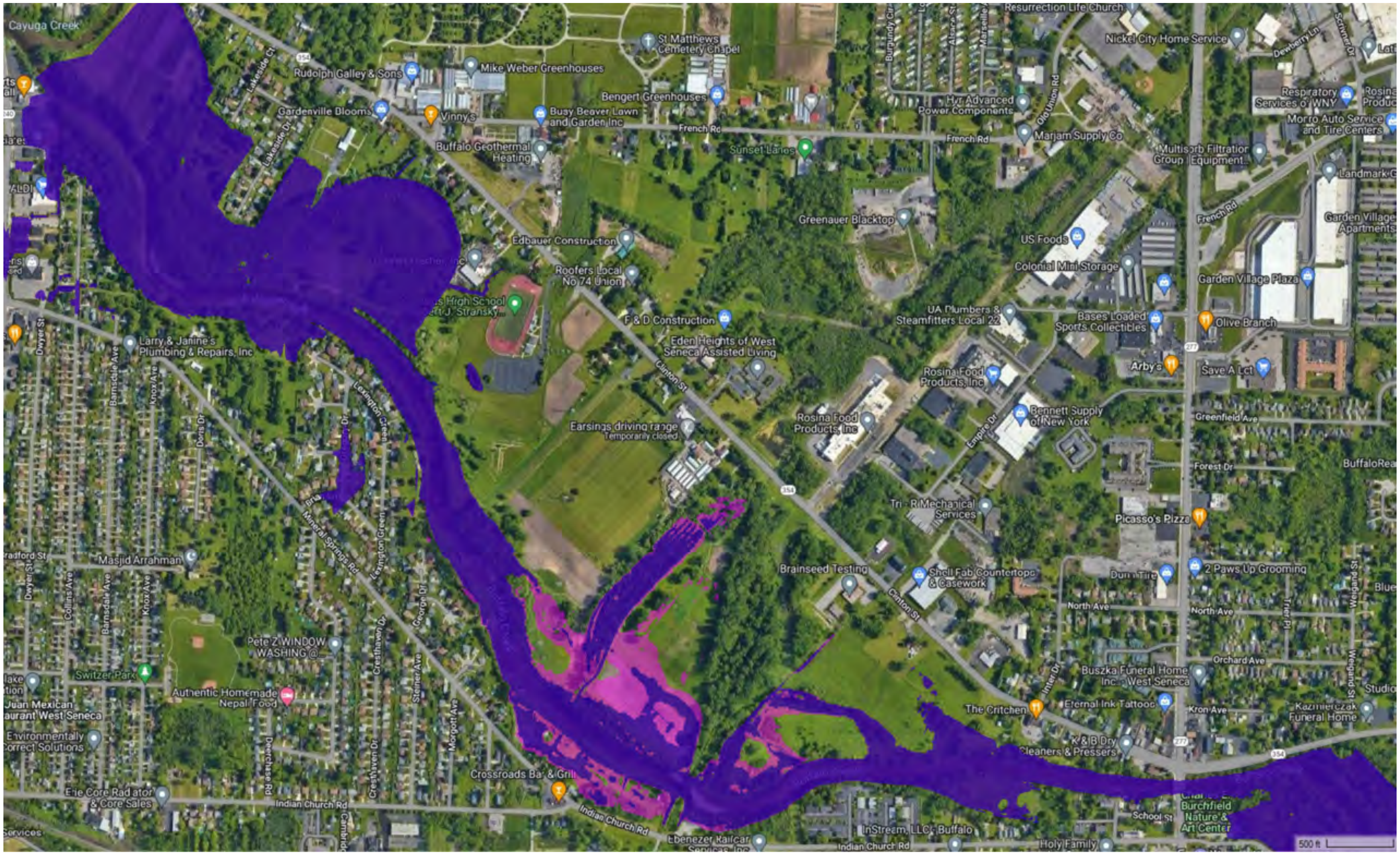

Figure 15. Scenario #7 - Flood extents for proposed (blue) and existing conditions (pink) model using the USGS *StreamStats* 1-percent AEP (100-year recurrence) event peak discharge.

Figure 16. Scenario #8 - Flood extents for proposed (blue) and existing conditions (pink) model using the USGS *StreamStats* 1-percent AEP (100-year recurrence) event peak discharge.

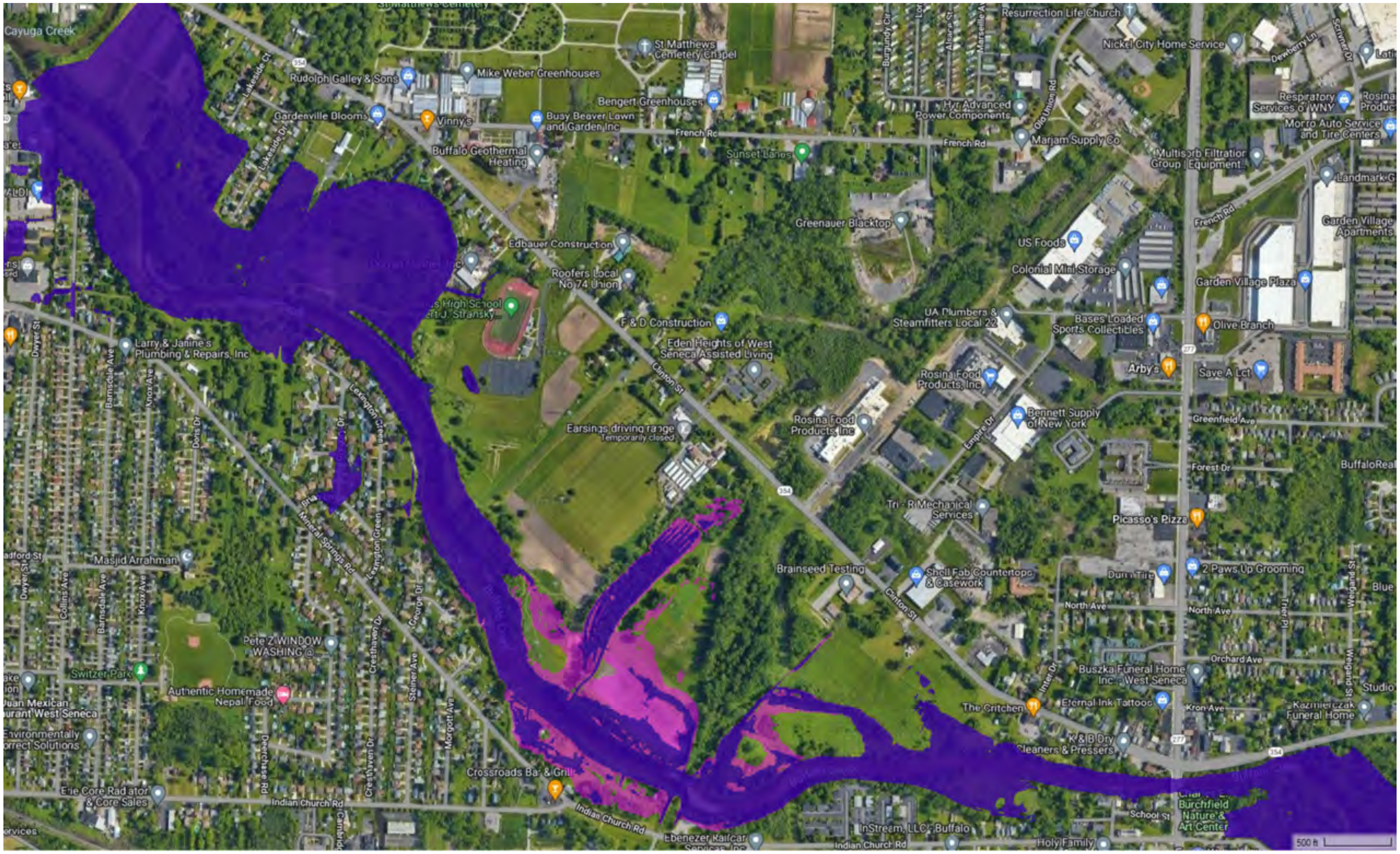

Figure 17. Scenario #9 - Flood extents for proposed (blue) and existing condition (pink) model using the USGS *StreamStats* 1-percent AEP (100-year recurrence) event peak discharge.

Table 5 summarizes the difference in WSELs between the existing and proposed conditions scenario model results for the 1-percent AEP event for the reach along the Lexington Green neighborhood (river stations 39+97 to 53+07). It should be noted positive values indicate the existing conditions WSELs are higher than the proposed scenario, while negative values indicate the existing conditions WSELs are lower than the proposed scenario. Results for events that occur more frequently (i.e., 10- and 2-percent) can be found in Attachment F.

Table 5. WSEL (feet NAVD88) differences for the existing and proposed conditions models in the vicinity of Lexington Green for the 1-percent AEP event.

	Water Surface Elevation (ft NAVD88)						
	RS 39+97	RS 41+82	RS 43+63	RS 45+82	RS 47+86	RS 50+51	RS 53+07
Scenario #1	-0.1	-0.2	-0.5	0	0.3	0.7	1.3
Scenario #2	0	0	-0.4	0	0	0	0.3
Scenario #3	0	0	-0.4	0	0	0	0.2
Scenario #4	0	0	0	0	0	0	-0.2
Scenario #5	0	0	-0.4	0	0	0	0.2
Scenario #6	0	0	0	0	0	0	-0.2
Scenario #7	0	0	-0.4	0	0	0	0.2
Scenario #8	0	0	0	0	0	0	-0.1
Scenario #9	0	0	-0.4	0	0	0	0.2

In the vicinity of the Lexington Green neighborhood, WSELs remain unchanged for most of flood bench scenarios across the majority of this reach. Scenario #1 displays the most significant benefits with WSEL reductions of up to 1.3-ft, primarily in the upstream portion of Lexington Green.

3.3 Berm Impacts

For regulatory and insurance purposes, the berm along the Lexington Green neighborhood is not recognized as an official levee since it does not meet the minimum design standards for providing safe, reliable flood protection. However, due to the existence of and flood mitigation impacts of the existing berm, the project team included the berm in the H&H analysis performed in this study. The berm elevation in the existing conditions model was set to 599.5-ft NAVD88 in line with the LiDAR DEM data. Figure 18 displays the flood extents for the existing conditions model simulation results with and without the berm.

Figure 18. Flood extents for existing with berm (pink) and existing without berm (green) conditions models using the USGS StreamStats 1-percent AEP (100-year recurrence) event peak discharge.

Table 6 summarizes the results for the 1-percent AEP event of the existing and proposed conditions modeling for the reach containing the berm along the Lexington Green neighborhood. Results for events that occur more frequently (i.e., 10- and 2-percent) can be found in Attachment F.

Table 6. Berm and WSELs (feet NAVD88) along Lexington Green for the existing and proposed conditions models for the 1-percent AEP event.

	Water Surface Elevation (ft NAVD88)		
	RS 45+82	**RS 47+86**	**RS 50+51**
Berm Elevation (ft NAVD88)	**599.5**	**599.5**	**600.5**
Existing Conditions	595.8	596.4	597.0
Scenario #1	595.8	596.1	596.3
Scenario #2	595.8	596.4	597.0
Scenario #3	595.8	596.4	597.0
Scenario #4	595.8	596.4	597.0
Scenario #5	595.8	596.4	597.0
Scenario #6	595.8	596.4	597.0
Scenario #7	595.8	596.4	597.0
Scenario #8	595.8	596.4	597.0
Scenario #9	595.8	596.4	597.0

Based on the model simulation results, only the flood bench Scenario #1 produced a reduction in WSELs in the vicinity of the berm. All of the other scenarios maintained the same WSEL as the existing conditions model.

It is important to note that since the berm was not built to USACE guidelines, the berm does not have the appropriate high-ground elevation tie-ins for the upstream and downstream ends of the berm. As a result, flood waters from high flow events can circumvent the berm causing flooding to the areas behind the berm. In addition, the probability of failure of the berm is high due to the improper construction. Once the berm fails, as any levee failure, the resulting damages can be significant and catastrophic. Further consultation with the USACE and NYSDEC regarding modifications to the berm or construction of a certified levee is recommended.

3.4 Ice-Jam Simulation Results

Attachment F contains the results for the ice-jam simulations for the existing and proposed conditions models. Figure 19 displays the flood extents for the existing conditions model under open-water (blue) and ice-jam (pink) conditions using the USGS *StreamStats* 10-percent AEP (10-year recurrence) event peak discharge. Where the flood extents for the existing conditions model under open-water and ice-jam conditions overlap, the flood extents will appear as purple on the figures.

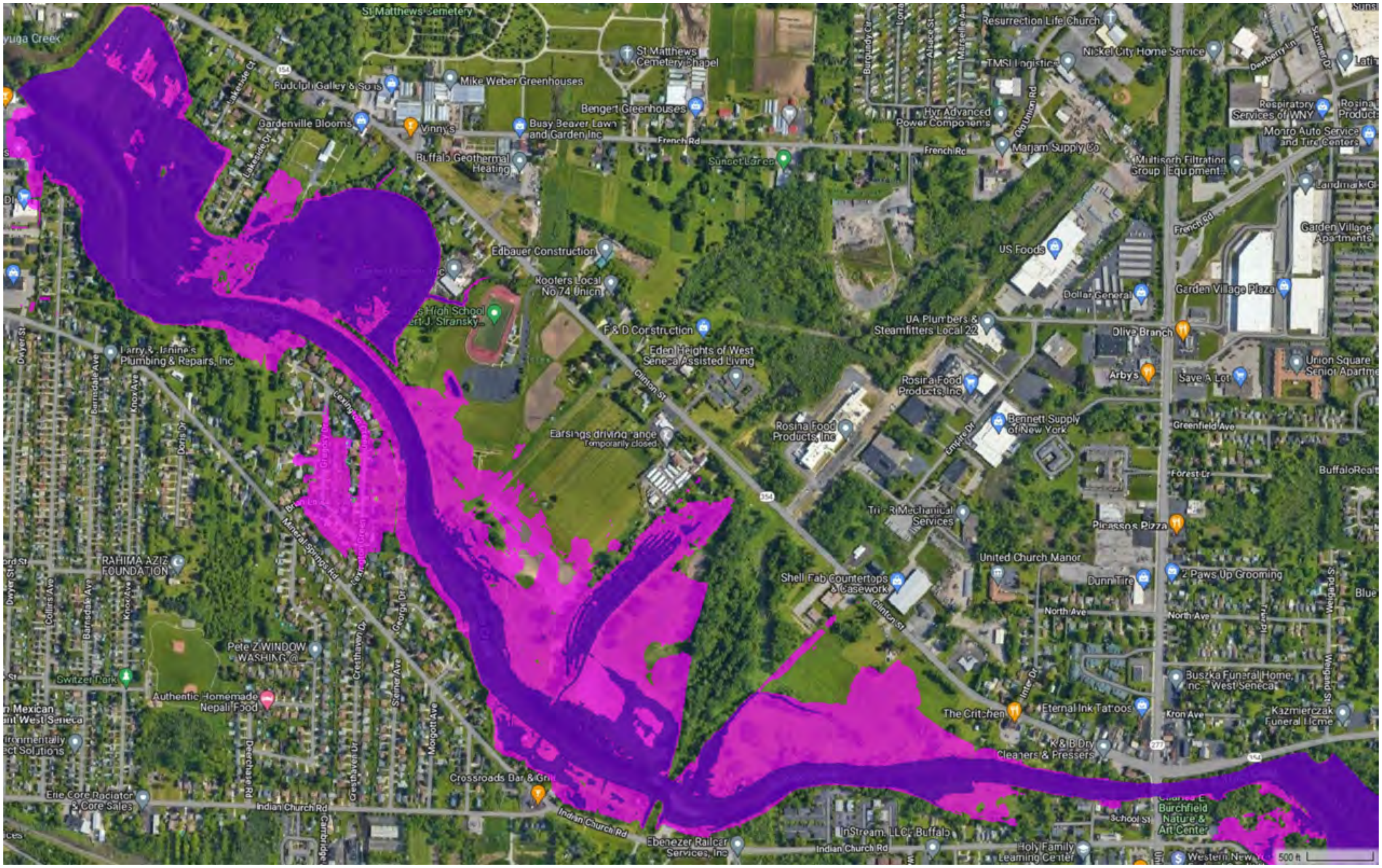

Figure 19. Flood extents for the existing conditions model under open-water (blue) and ice-jam (pink) conditions models using the USGS *StreamStats* 10-percent AEP (10-year recurrence) event peak discharge.

Table 7 summarizes the model results of each proposed flood bench scenario with an ice-jam in comparison to the existing condition with an ice-jam models.

Table 7. Results of the existing and proposed conditions models with ice-jams for the 10-, 2-, 1-, and 0.2-percent AEP events (10, 50, 100, and 500-year recurrence intervals).

Scenario ID	Flood Bench Configurations	Reductions in Water Surface Elevations (feet NAVD88)			
		10-Percent	2-Percent	1-Percent	0.2-Percent
1	1a	2.8	1.2	1.2	1.2
2	1b	1.6	0.2	0.1	0.1
3	1b + 2	1.9	1.5	0.6	0.6
4	2 + 3	1.5	1.7	1.6	1.6
5	1b + 2 + 3	1.9	1.7	1.6	1.6
6	2 + 3 + 4	3.1	2.0	1.8	1.7
7	1b + 2 + 3 + 4	3.2	2.0	1.8	1.7
8	5 + 6	1.1	0.5	0.5	0.4
9	1b + 2 + 3 + 4 + 5 + 6	3.6	2.4	2.3	2.1

Table 8 summarizes the difference in WSELs for the 10-percent AEP event of the existing and proposed conditions with ice-jam model results for the reach along the Lexington Green neighborhood (river stations 39+97 to 53+07). It should be noted positive values indicate the existing conditions WSELs are higher than the proposed scenario, while negative values indicate the existing conditions WSELs are lower than the proposed scenario. Results for higher intensity events that occur less frequently (i.e., 2-, 1- and 0.2-percent) can be found in Attachment F.

Table 8. WSEL (feet NAVD88) differences between the existing and proposed conditions with ice-jam models in the vicinity of Lexington Green for the 10-percent AEP event.

	Water Surface Elevation (ft NAVD88)						
	RS 39+97	RS 41+82	RS 43+63	RS 45+82	RS 47+86	RS 50+51	RS 53+07
Scenario #1	-0.3	-0.7	-0.6	0.7	1.7	2.4	2.8
Scenario #2	0	0	0	0	0.5	0.8	1.1
Scenario #3	0	0	-0.1	0	0.5	0.9	1.2
Scenario #4	0	0	0	0	0.1	0.2	0.5
Scenario #5	0	0	-0.1	0	0.5	0.9	1.2
Scenario #6	0	0	0	0	0.1	0.2	0.5
Scenario #7	0.1	0	0	0	0.5	0.9	1.2
Scenario #8	0	0	0	0	0.1	0.1	0.3
Scenario #9	0.1	0	0	0	0.5	0.9	1.3

Figures 20 through 28 display the flood extents from the proposed with ice-jam (blue) and existing with ice-jam (pink) conditions models for each flood bench using the USGS *StreamStats* 10-percent AEP (10-year recurrence) event peak discharge. Where the flood extents for both the proposed and existing conditions with ice-jam models overlap, the flood extents will appear as purple on the figures.

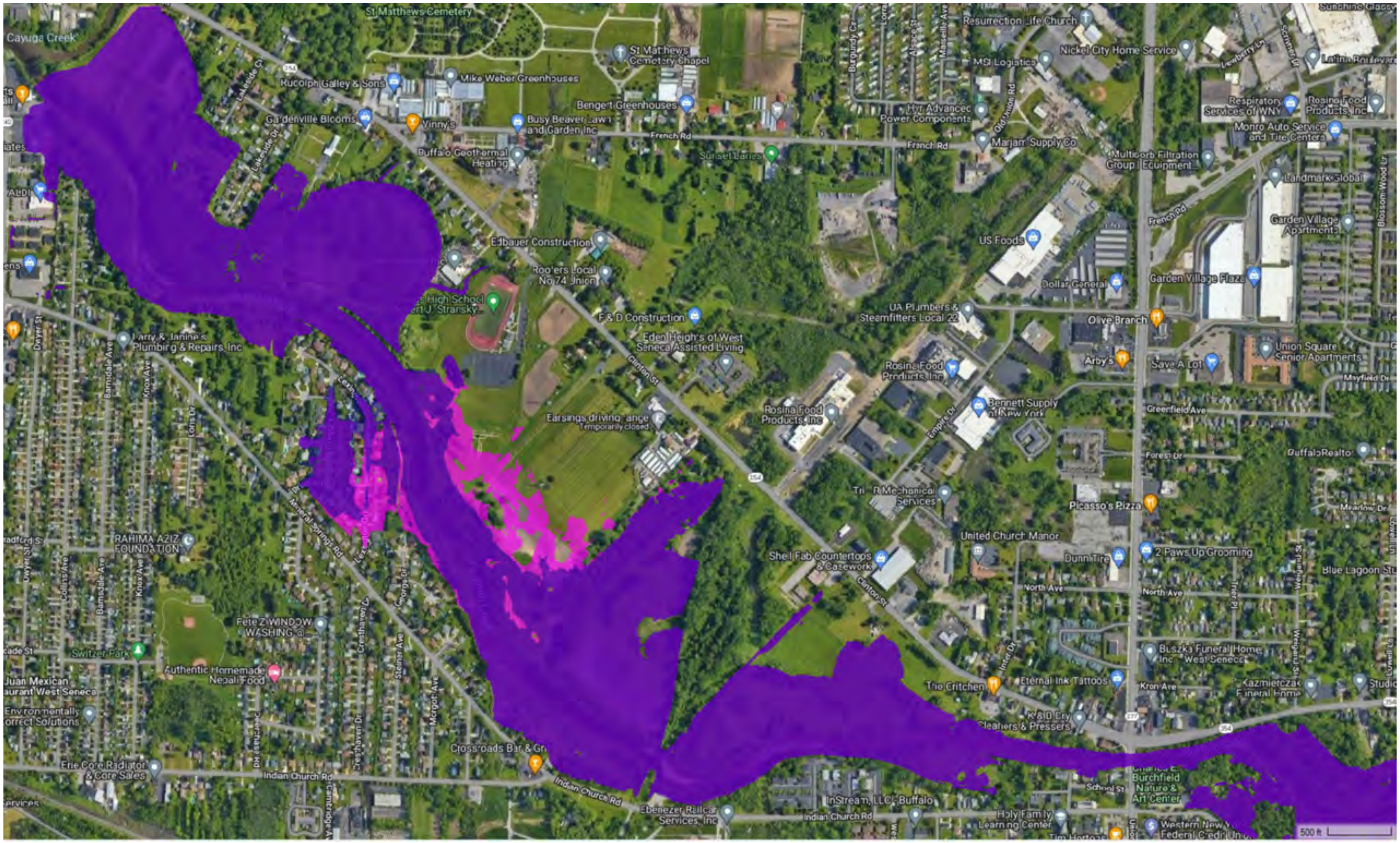

Figure 20. Scenario #1 - Flood extents for proposed (blue) and existing condition (pink) with ice-jam models using the USGS *StreamStats* 10-percent AEP (10-year recurrence) event peak discharge.

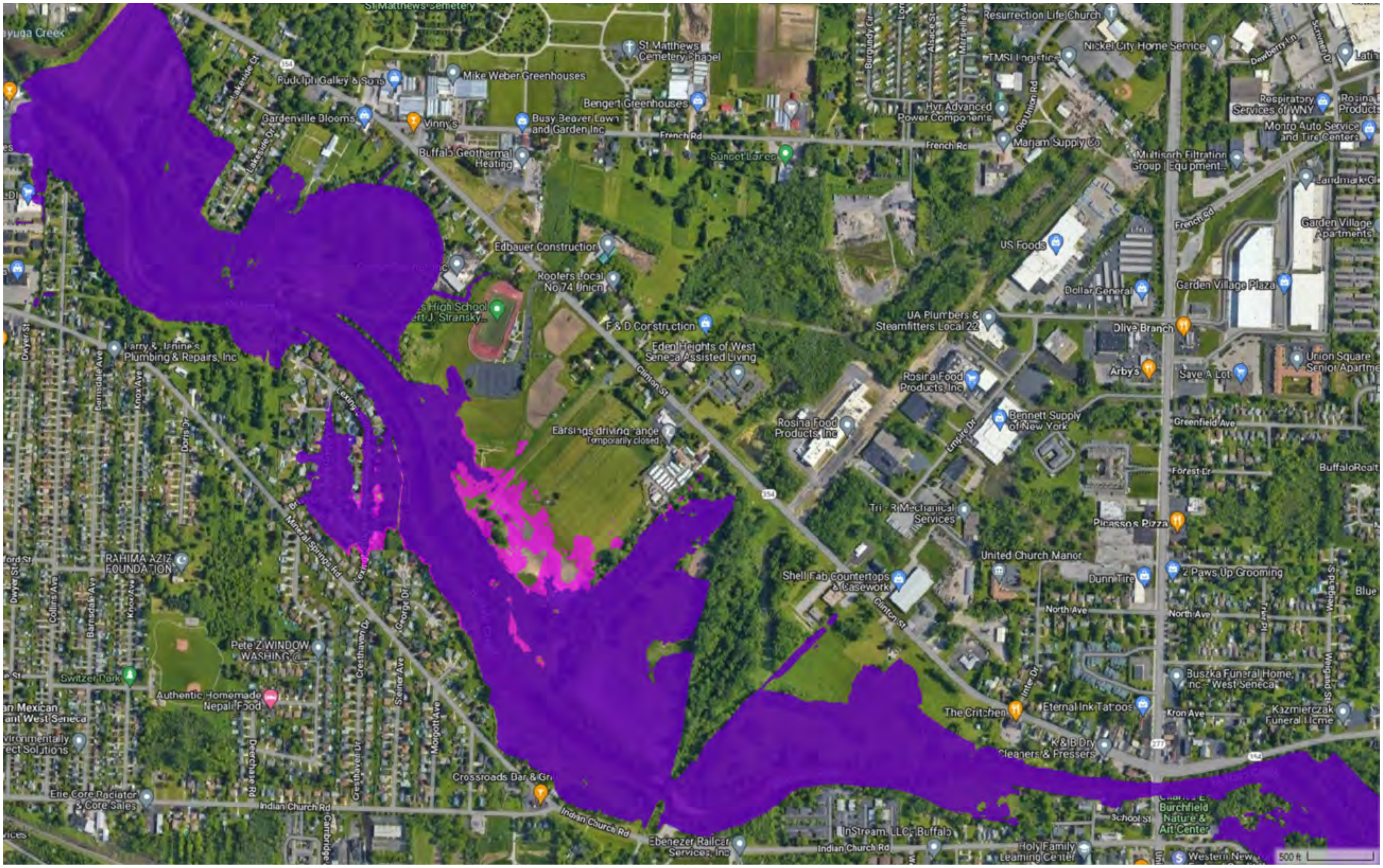

Figure 21. Scenario #2 - Flood extents for proposed (blue) and existing condition (pink) with ice-jam models using the USGS *StreamStats* 10-percent AEP (10-year recurrence) event peak discharge.

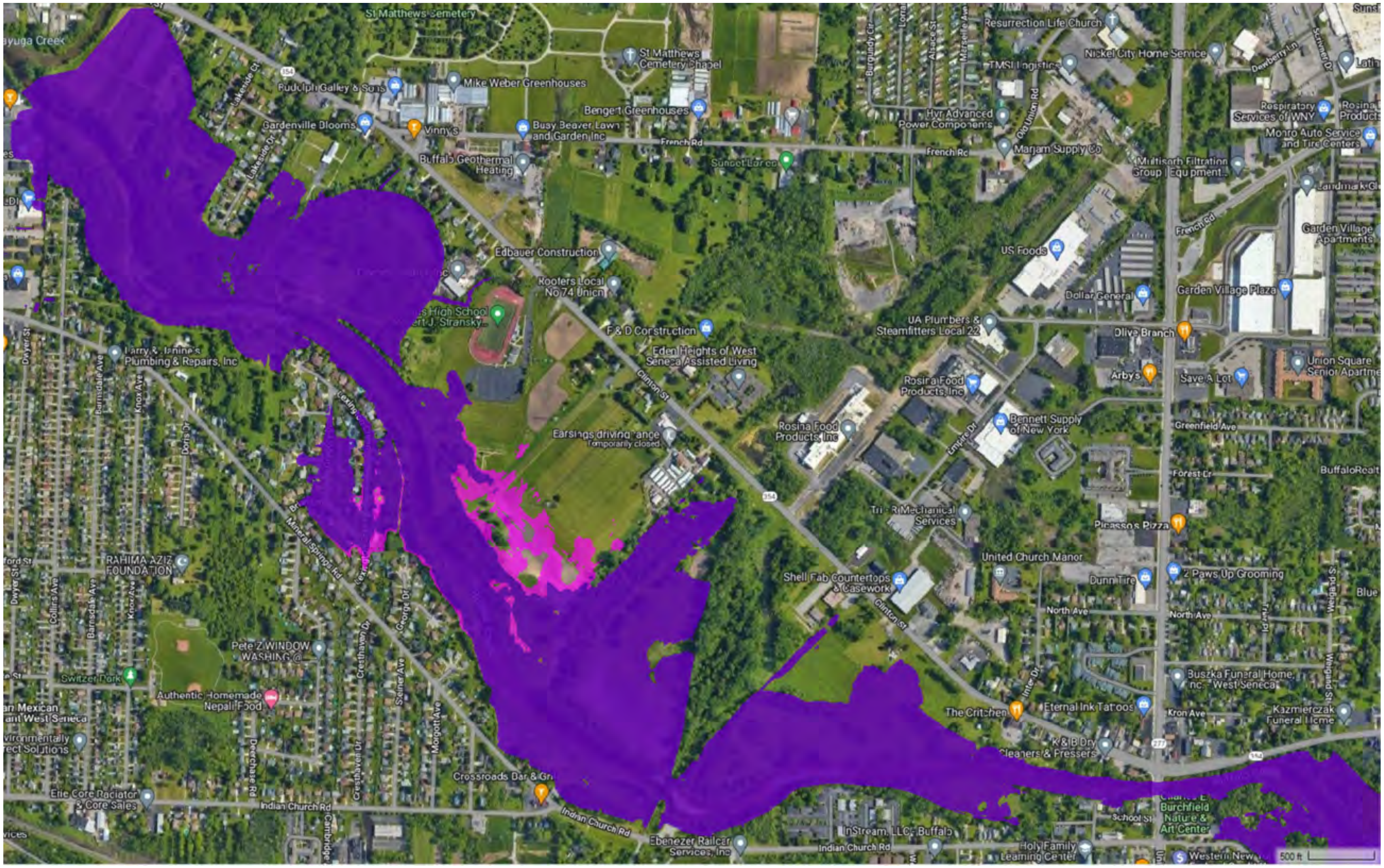

Figure 22. Scenario #3 - Flood extents for proposed (blue) and existing condition (pink) with ice-jam models using the USGS *StreamStats* 10-percent AEP (10-year recurrence) event peak discharge.

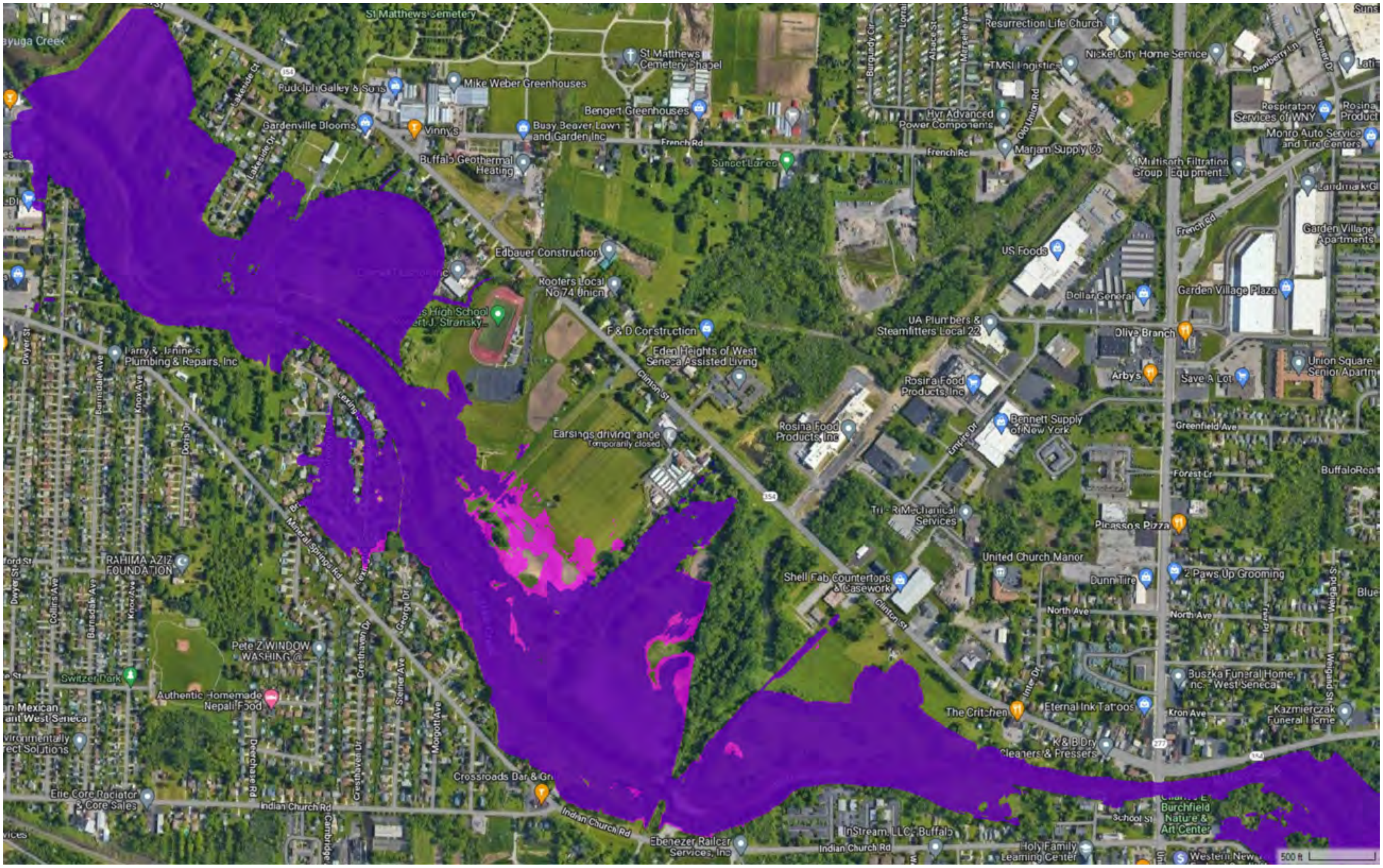

Figure 23. Scenario #4 - Flood extents for proposed (blue) and existing condition (pink) with ice-jam models using the USGS *StreamStats* 10-percent AEP (10-year recurrence) event peak discharge.

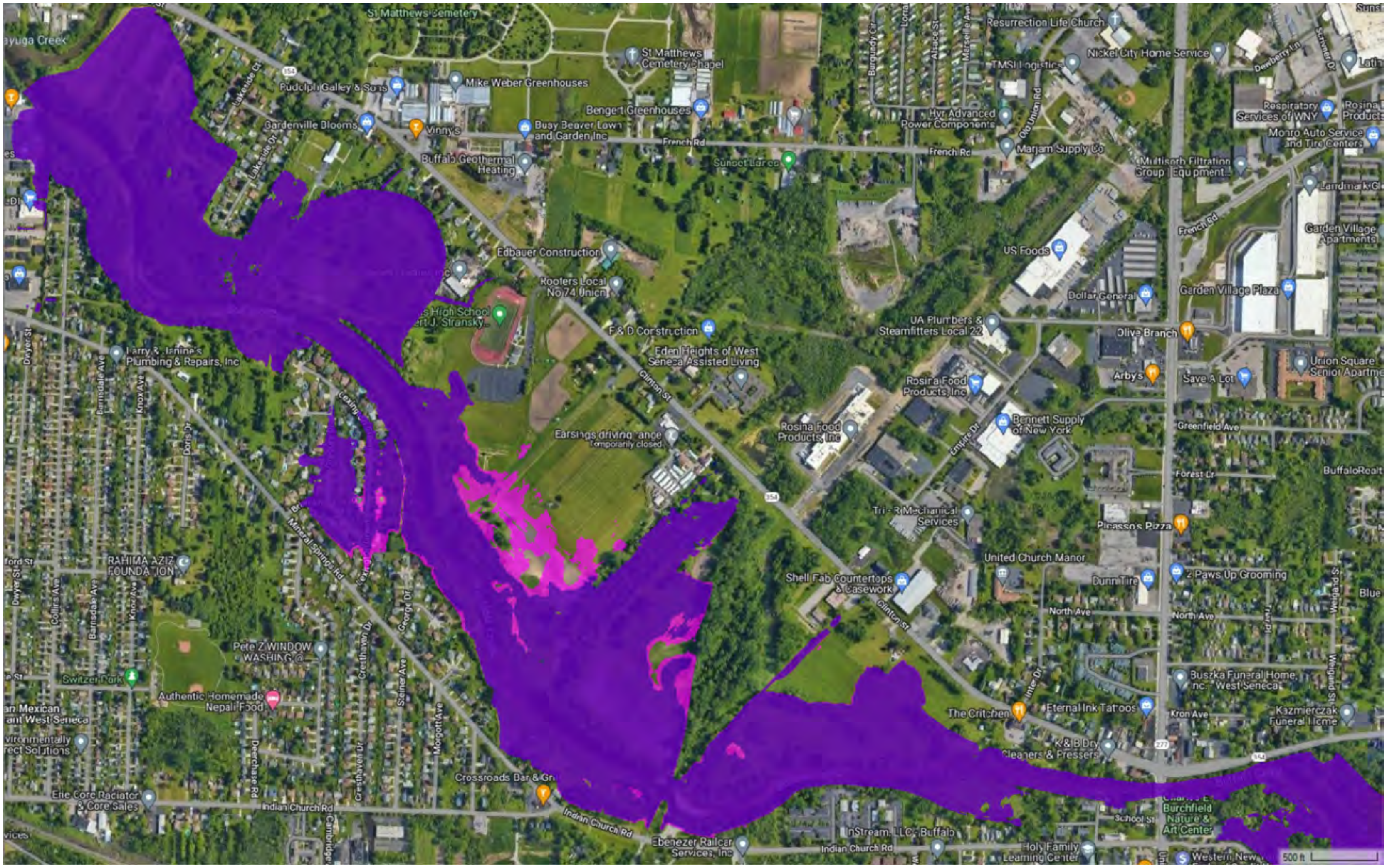

Figure 24. Scenario #5 - Flood extents for proposed (blue) and existing condition (pink) with ice-jam models using the USGS *StreamStats* 10-percent AEP (10-year recurrence) event peak discharge.

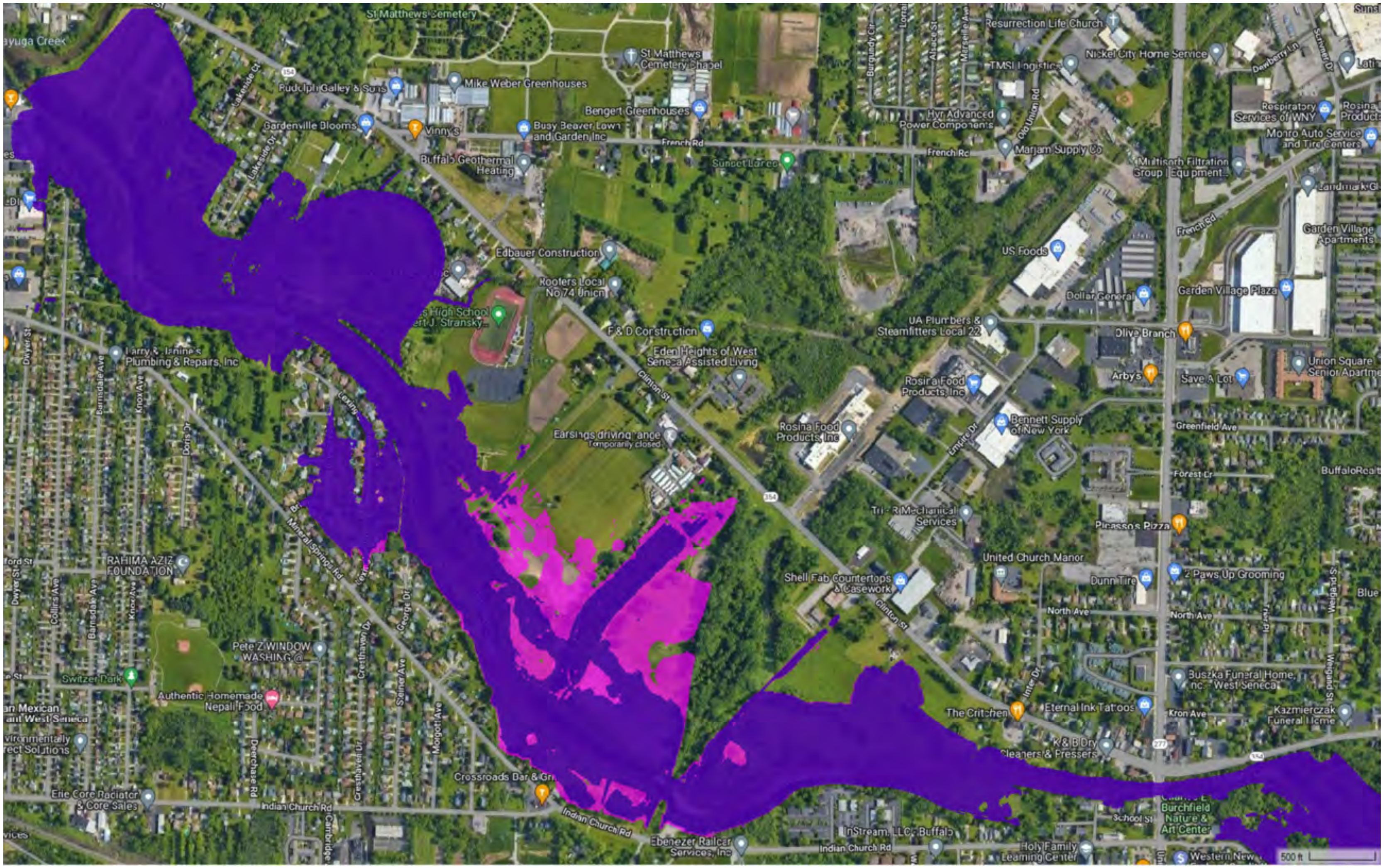

Figure 25. Scenario #6 - Flood extents for proposed (blue) and existing condition (pink) with ice-jam models using the USGS *StreamStats* 10-percent AEP (10-year recurrence) event peak discharge.

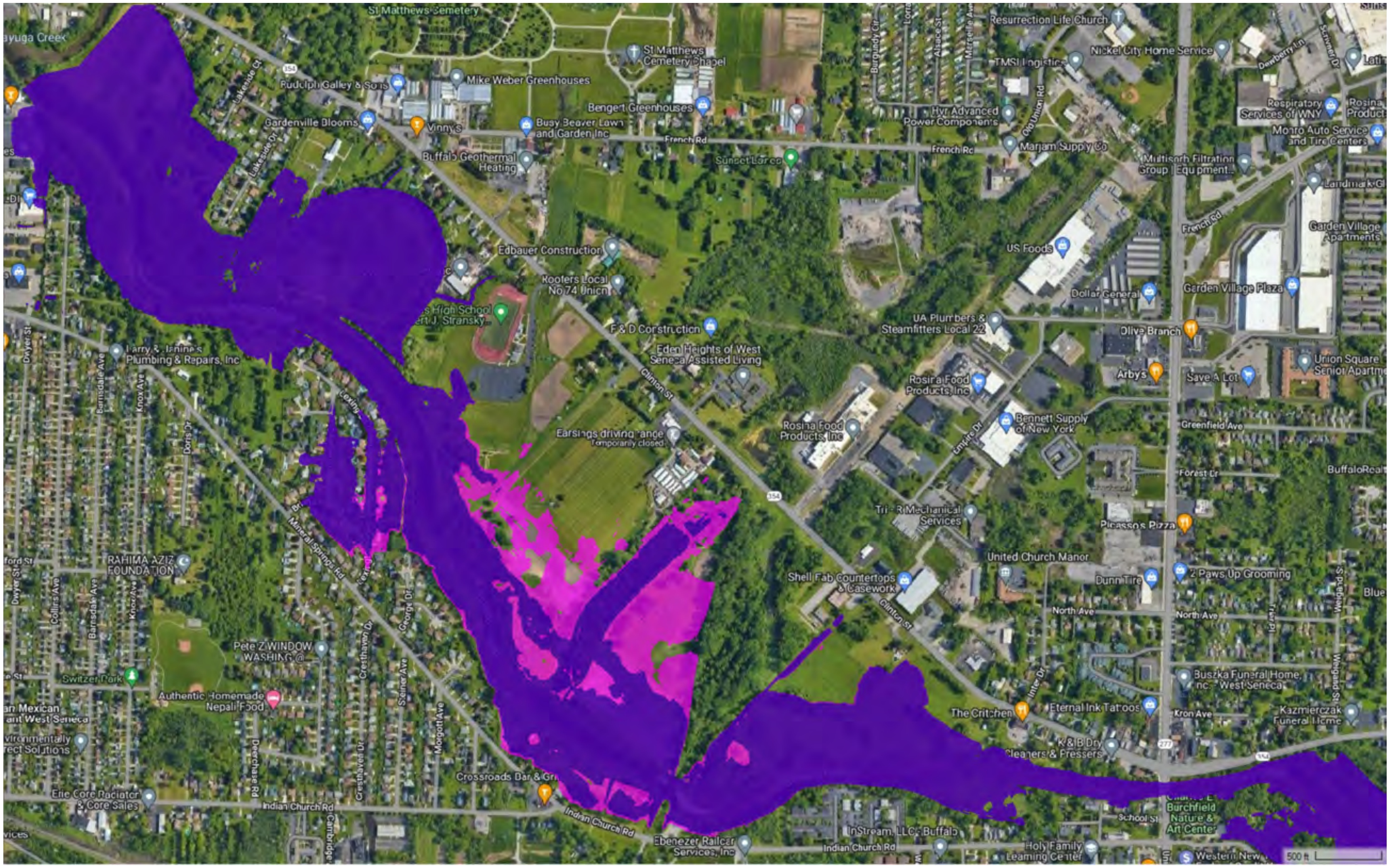

Figure 26. Scenario #7 - Flood extents for proposed (blue) and existing condition (pink) with ice-jam models using the USGS *StreamStats* 10-percent AEP (10-year recurrence) event peak discharge.

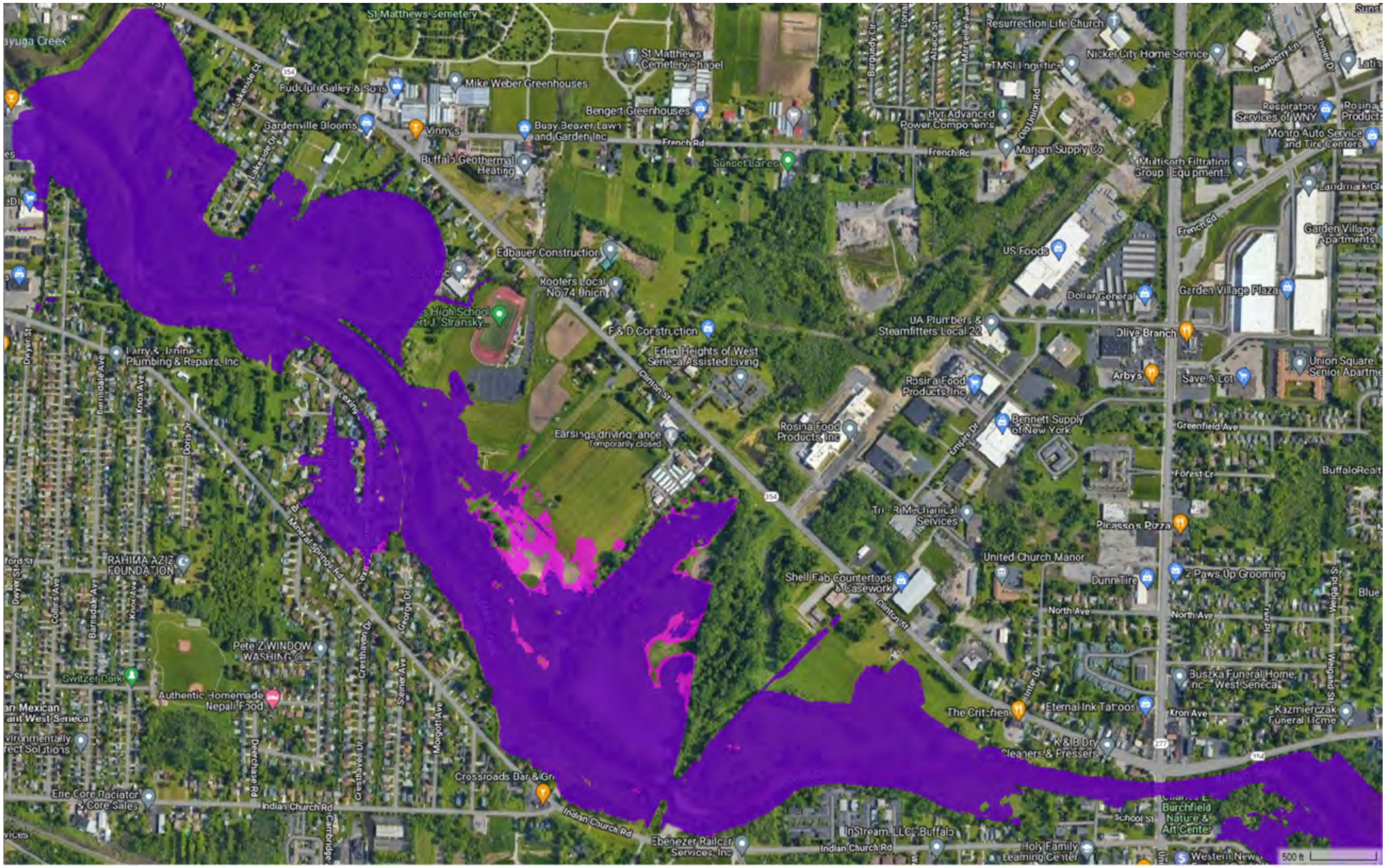

Figure 27. Scenario #8 - Flood extents for proposed (blue) and existing condition (pink) with ice-jam models using the USGS *StreamStats* 10-percent AEP (10-year recurrence) event peak discharge.

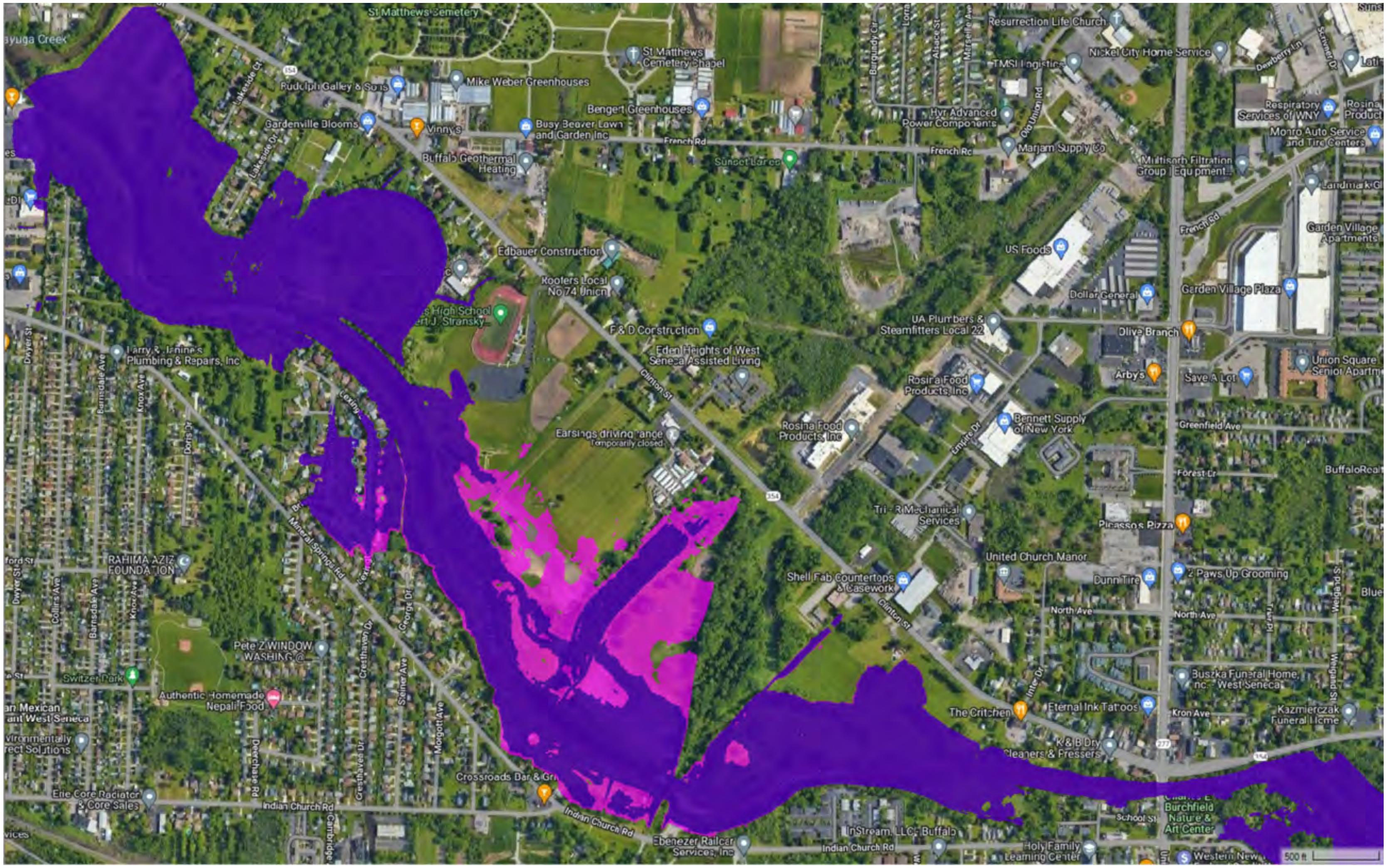

Figure 28. Scenario #9 - Flood extents for proposed (blue) and existing condition (pink) with ice-jam models using the USGS *StreamStats* 10-percent AEP (10-year recurrence) event peak discharge.

3.5 Bank and Channel Stabilization Features

Streambank erosion is a natural process that occurs when the forces of flowing water exceed the ability of the soil and vegetation to hold the banks in place. The forces that cause erosion increase during flood events, and most erosion occurs at these times. Human disturbances to watersheds that increase frequency and magnitude of runoff events also increase streambank erosion. Loss of streambank and streamside vegetation reduces the resisting forces and makes streambanks more susceptible to erosion. This is often the single greatest contributing factor to harmful or accelerated erosion on small and medium-size streams (GASWCC 2000).

Streambank stabilization measures work either by reducing the force of flowing water, by increasing the resistance of the bank to erosion, or by some combination of both. Generally speaking, there are four approaches to streambank protection: 1) the use of vegetation; 2) soil bioengineering; 3) the use of rock work in conjunction with plants; and 4) conventional bank armoring (GASWCC 2000).

Streambank stabilization can also play a vital role in flood risk management in areas located in flood prone areas. The magnitude of that risk is a function of the flood hazard, the characteristics of a particular location (i.e., elevation, proximity to the waterway, susceptibility to fast-moving flows, etc.), measures that have been taken to mitigate the potential impact of flooding, the vulnerability of people and property, and the consequences that result from a particular flood event. A flood risk management strategy identifies and implements measures that reduce the overall risk, and what remains is the residual risk. In developing the strategy, those responsible judge the costs and benefits of each measure taken and their overall impact in reducing the risk (NRC 2013).

There are two types of engineering strategies to sediment and debris management and flood mitigation: structural and non-structural. Structural adjustments involve two different approaches: hard and soft structures. Hard engineering strategies act as a barrier between the river and the surrounding land where artificial structures are used to change or disrupt natural processes. Soft engineering does not involve building artificial structures, but takes a more sustainable and natural approach to managing the potential for erosion, deposition, and flooding by enhancing or protecting a river's natural features (NRC 2013). Flood benches and streambank stabilization and protection are considered soft engineering strategies.

The purpose of non-structural flood mitigation is to change the way that people interact with the floodplain, flood risk, and also aims to move people away from flood-prone areas. More and more communities have looked for alternatives to structural flood damage reduction techniques and instead have begun to pursue nonstructural techniques used to reduce flood damages that do not disturb the environment or that can lead to environmental restoration. Non-structural flood damage reduction techniques have proven to be extremely viable in alternatives consisting of total non-structural, or a combination non-structural and structural measures (USACE 2001; NRC 2013).

Bank and channel stabilization features are dependent on two forces: velocity and shear stress. Velocity in a waterway is controlled by a number of factors, including friction slope, channel geometry, size of sediments on the stream bed, and the discharge (volume) of water passing a point in a unit of time. A stream typically reaches its greatest velocity when it is close to flooding over its banks, known as the bank-full stage. As soon as the flooding stream overtops its banks and occupies the wide area of its flood plain, the water has a much larger area to flow through and the velocity drops significantly. At this point, sediment that was being carried by the high-velocity water is deposited near the edge of the channel, forming a natural bank or levee (Earle 2019).

Shear stress is the parameter often used as a measure of the stream's ability to entrain bed material, which is created by the friction from water acting on the bed material. Generally, shear stress acts in the direction of the flow in a uniform channel as it slides along the channel bed and banks. A given particle will move only when the shear stress acting on it is greater than the resistance of the particle to movement. The resistance of the particles to movement and thus its entrainment will vary depending on its size, shape, its size relative to surrounding particles, how it is oriented and the degree to which it is embedded. The magnitude of shear stress required to move a given particle is known as the critical shear stress. When the shear stress equals the critical shear stress, the channel will likely be in equilibrium. Where shear stress is excessively greater than critical shear stress, channel degradation will likely result. Where the shear stress is less than critical shear stress, channel aggradation will likely result. Thus, the ability to calculate or measure both shear and critical shear stress is crucial in understanding channel adjustments (VTANR 2004).

Channel shear stress and velocity values were obtained from the existing conditions model simulation results (Attachment F). For the reach of Buffalo Creek that runs adjacent to the Lexington Green neighborhood between river stations 40+00 to 65+50, the maximum shear stress and velocity value was 1.3 lb/sq. ft. and 8.7 ft/s for the 1-percent AEP event.

Table 9 summarizes the bank and channel stabilization strategies that could potentially be employed along Buffalo Creek in the vicinity of the Lexington Green neighborhood (river stations 40+00 to 66+50) for the 1-percent AEP event. Attachment G summarizes the different bank and channel stabilization features discussed in Table 9. It should be noted that the identified bank and channel stabilization strategies are not intended to represent a fully comprehensive list and are based on the preliminary analysis performed in this study. Additional geomorphic research and advanced multi-dimensional open-water and ice-jam modeling is recommended to determine the most appropriate strategy for this reach of Buffalo Creek.

Table 9. Bank and channel stabilization strategies along Buffalo Creek for the 1-percent AEP event.

Measure Type	Treatment Type	Description of Measure
Brush Mattress	Staked only w/ rock riprap toe (grown)	Brush mattresses slow water velocities along the streambank and reduce erosion. The open space between the woody material allows for sediment deposition and water drainage. The build-up of sediment enhances the colonization of native plants.
Coir Geotextile Roll	Roll with Polypropylene rope mesh staked and with rock riprap toe	Coir geotextiles protect land surfaces, help with soil stabilization, promote vegetation growth in varying slopes, and provide erosion control.
Gravel / Cobble	12-inch	Cobble or gravel armor is used to protect a sloping bank against fluvial entrainment by flow in the stream or over the top of the bank.
Soil Bioengineering	Vegetated coir mat	Soil bioengineering methods have a common geotechnical benefit of providing root reinforcement in the soil and can help modify drainage patterns of the soil, help stabilize soils at steeper angles if desired, help keep grasses, and bushy vegetation in place resisting erosion, and support woody debris or other types of vegetation.
	Live brush mattress (grown)	
	Brush layering (initial/grown)	
Boulder Clusters	Small (>10-inch diameter) and larger	Boulder clusters can prevent large buildup of wood and reduce flood and bank erosion.

4. Summary

Based on the results of the proposed conditions modeling, there are multiple flood bench configurations that could provide flood mitigation benefits to the areas in the vicinity of the flood benches. The top three scenarios that produced the largest reduction of water surface elevations were:

1. Scenario #9: Up to 2.4-ft of modeled water surface elevation reductions at the 1-percent AEP (100-year recurrence) event.
2. Scenario #7: Up to 2.2-ft of modeled water surface elevation reductions at the 1-percent AEP (100-year recurrence) event.
3. Scenario #6: Up to 2.2-ft of modeled water surface elevation reductions at the 1-percent AEP (100-year recurrence) event.

Scenario #9 involved utilizing flood benches from all 6 proposed locations, while Scenario #7 involved flood benches 1b, 2, 3, and 4 and Scenario #6 involved flood benches 2, 3, and 4. None of the remaining scenarios exceeded 2-ft of water surface elevation reductions, with Scenarios #1, 2, and 8 producing the lowest water surface elevation reductions of less than 1-ft.

The common element between the top three scenarios was the involvement of flood benches 2, 3, and 4. As of November 2022, the landowners for flood benches 2 and 3 have expressed interest in pursuing flood mitigation projects on their properties, such as the proposed flood benches.

Flood bench 4 involves land owned by National Grid and contains utility equipment and transmission lines. Any flood mitigation project involving this land would require permission and coordination with National Grid. As of November 2022, the project team and Buffalo Niagara Waterkeeper were in contact with company representatives regarding potential interest in pursuing a flood mitigation project.

Flood benches 1a and 1b involve land owned by Canisius High School. As of November 2022, the school has started construction on the two new baseball fields, practice field, and tennis courts. Flood bench 1a would involve land being used for this new construction and, as such, would most likely not be supported by the school. Flood bench 1b does not involve land impacted by the new construction and may be potentially supported by the school. As of November 2022, the project team and Buffalo Niagara Waterkeeper were in discussions with school representatives regarding potential interest in pursuing a flood mitigation project, such as flood bench 1b.

Based on the analysis performed in this study, the Project Team recommends Scenario #6 be considered for advancement. Scenario #6 provided measurable flood mitigation benefits based on the H&H modeling simulations and requires the least number of property owner participants. In addition, the property owners for flood benches 2 and 3 have expressed interest in participating in the project during individual and the public engagement meeting. Figure 29 displays the location and extent of the flood benches for Scenario #6.

Figure 29. Flood bench locations and extent for Scenario #6.

The flood mitigation benefits of Scenario #6 occur predominately upstream of the Lexington Green neighborhood starting in the vicinity of George Drive/Windtree Court and extending upstream of the Railroad bridge (Figure 14). Properties in the vicinity of Mineral Springs and Indian Church Roads along the left bank of Buffalo Creek downstream of the railroad bridge would experience significant flood mitigation benefits if Scenario #6 were implemented. In addition, there is no increase in WSELs at river station 43+63 under Scenario #6, while there is an increase of up to 0.3-feet for Scenarios #7 and #9.

Based on model simulation results, Scenario #6 provides up to 0.5-feet of modeled water surface elevation reductions at the 10-percent AEP (10-year recurrence) event during an ice-jam event when compared to open-water conditions in the vicinity of the Lexington Green neighborhood. A flood bench further downstream of Scenario #6 would provide additional reductions in WSELs (i.e., reduce flood depths); however, the flood mitigation benefits would remain primarily in the upstream portion of the Lexington Green neighborhood and would not extent to the downstream portion of the neighborhood, regardless of whether an additional flood bench downstream of Scenario #6 was considered.

For the three recommended scenarios (#6, #7, and #9), there are no adverse impacts to areas upstream or downstream of the Lexington Green neighborhood, including areas in the vicinity of Canisius High School and Harlem Road bridge, according to the model simulation results.

Natural floodplains and flood benches provide flood risk reduction benefits by slowing runoff and storing flood water. They also provide other benefits of considerable economic, social, and environmental value that should be considered in local land-use decisions. Floodplains frequently contain wetlands and other important ecological areas which directly affect the quality of the local environment. Floodplain management is the operation of a community program of preventive and corrective measures to reduce the risk of current and future flooding, resulting in a more resilient community. These measures take a variety of forms, are carried out by multiple stakeholders with a vested interest in responsible floodplain management, and generally include requirements for zoning, subdivision or building codes, and special-purpose floodplain ordinances. While FEMA has minimum floodplain management standards for communities participating in the National Flood Insurance Program (NFIP), best practices demonstrate the adoption of higher standards which will lead to safer, stronger, and more resilient communities (FEMA 2006).

There are some potential constraints to Scenario #6 that should be considered by the Project Team and community moving forward. The property owner of flood bench 4 is National Grid, which has transmission line equipment and towers within the proposed flood bench area. Coordination and buy-in from National Grid, in conjunction with design plans that mitigate any impacts to their utility equipment and towers, would be necessary to progress Scenario #6. The availability of potential State and/or Federal funding through grants, loans, awards, etc. would also need to be considered. Finally, the Oxbow along Buffalo Creek downstream of the Lexington Green neighborhood is a protected wetland so coordination with the New York State Department of Environmental Conservation (NYSDEC) would be necessary for any flood mitigation project along Buffalo Creek in the project area.

5. Next Steps

Engineering studies are typically completed in a phases referred to as the 30-60-90-100% process. The analysis performed in this study represents a 30% conceptual design. A 30% conceptual design includes: advance preliminary concept sketches to develop conceptual design plans for the project area; rudimentary design sketches of plan, profile, and typical section views of proposed flood mitigation strategies; preliminary rough order of magnitude cost estimates for identified flood mitigation strategies; and a technical memorandum presenting engineering analysis and concept design basis.

The 60% preliminary design phase requires one or more flood mitigation strategies to be identified as a potential construction project. Once a flood mitigation strategy has been identified, a 60% preliminary design can be completed. The preliminary design involves advancing the conceptual design by incorporating any comments received from the 30% phase; modifying design plans with more specific engineering details; ***using multi-dimensional or variable-specific (i.e., ice cover, sediment, etc.) hydrologic and hydraulic models*** to evaluate identified flood mitigation strategies; developing additional "amenities" plans for any community identified features (i.e., walking and/or bike trails, facilities, etc.); modifying the rough order magnitude cost estimates to reflect updated engineering analyses and designs; and developing a preliminary design report presenting the updated engineering analyses and design basis.

Along with the engineering and design process, there are additional procedures that would need to be considered and potentially completed during the 60% preliminary design phase. These procedures include regulatory permitting applications; wetland delineations; rare, threatened, and endangered species identification and analyses; the Historic Preservation Review Process; preparing the Environmental Assessment Form with supporting documents to complete the State Environmental Quality Review; local permit applications; and responding to comments during the design and permit review process.

The 90% final design phase includes advanced design drawings, plans, and profiles of the construction project for both the existing and proposed conditions and construction documents with technical specifications and supporting information for the front-end specifications (i.e., bid forms, conditions of contract, forms of agreement, etc.).

The 100% final design includes the final design drawings, construction cost opinions, and contract documents signed and sealed by a licensed engineer.

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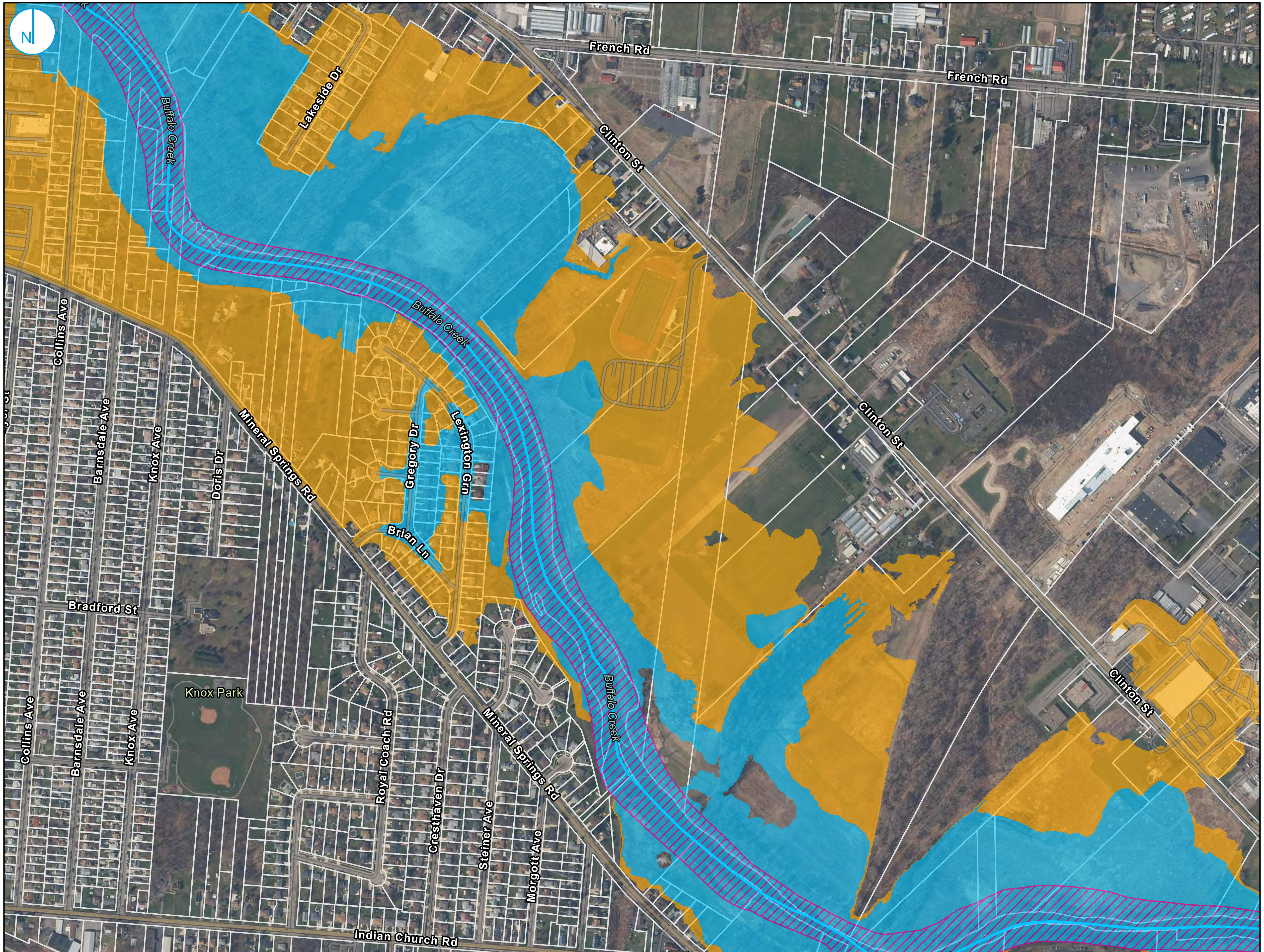
Attachment A
Project Site Maps



Legend

Special Flood Hazard Areas (SFHAs)

- Regulatory Floodway
- 1% Annual Chance Hazard
- 0.2% Annual Chance Hazard
- Buffalo Creek
- Tax Parcels (Public)

0 500 1,000 Feet

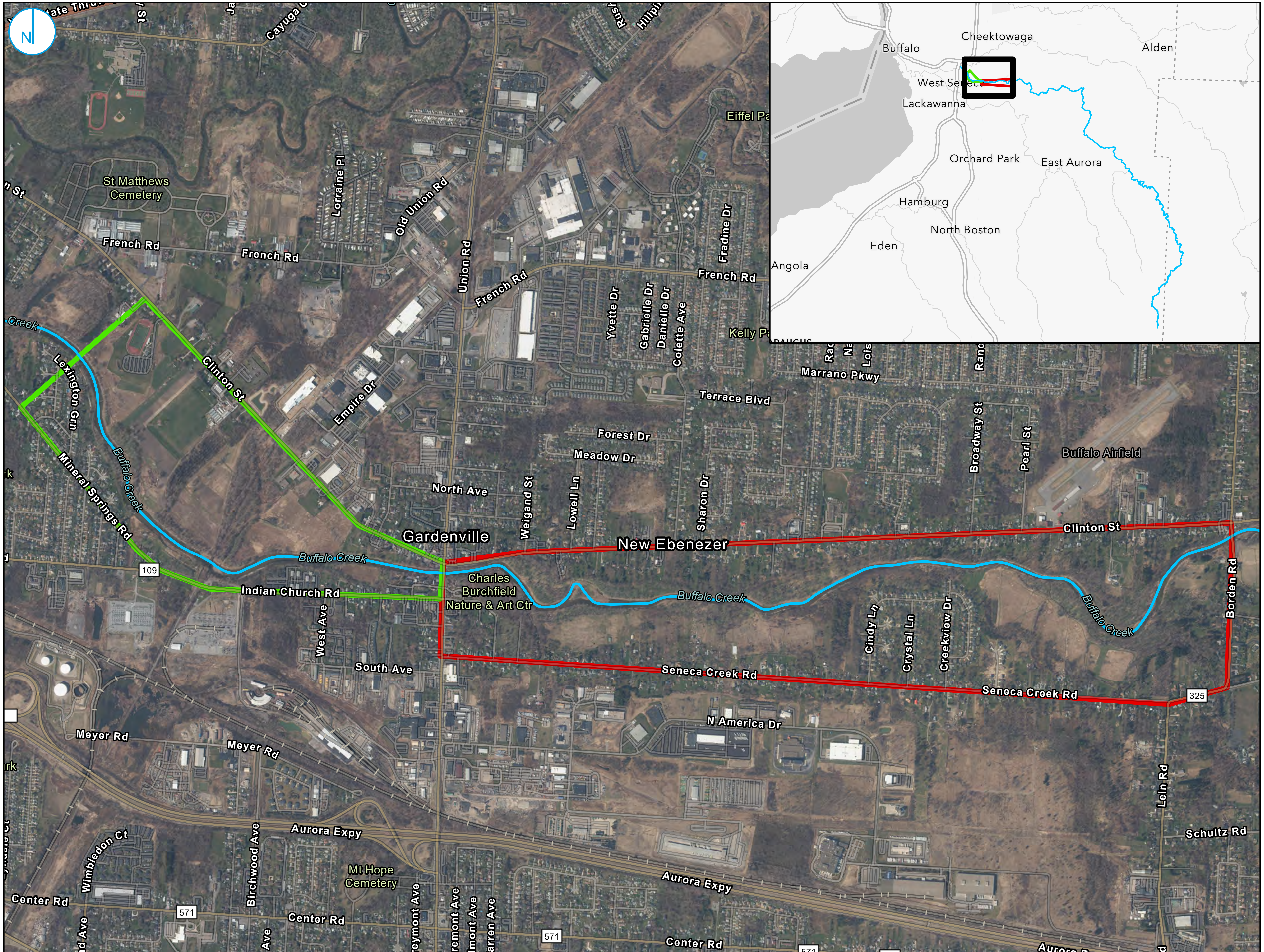
FEMA Special Flood Hazard Zones (DFRIM)

Buffalo Creek

Town of West Seneca, NY

FIGURE 1 of 2

RAMBOLL AMERICAS
ENGINEERING SOLUTIONS, INC.
A RAMBOLL COMPANY



Project Focus Areas (Primary and Secondary)

Buffalo Creek

Town of West Seneca, NY

FIGURE 2 of 2

RAMBOLL AMERICAS ENGINEERING SOLUTIONS, INC.
A RAMBOLL COMPANY

Attachment B
Hydrologic & Hydraulic Modeling Technical Memorandum

HYDROLOGIC & HYDRAULIC MODELING TECHNICAL MEMORANDUM

Project name	**Feasibility & Design of Floodplain Reconnection of Buffalo Creek**
Project no.	**1940102804**
Client	**Buffalo Niagara Waterkeeper**
Memo No.	**1**
Version	**3**
To	**Katherine Winkler, Senior Project Manager, Buffalo Niagara Waterkeeper**
From	**Ramboll Americas Engineering Solutions, Inc.**
Copy to	**Holly Kistner, Project Manager, Buffalo Niagara Waterkeeper** **Gary Dickson, Town Supervisor, Town of West Seneca** **Amelia Greenan, Deputy Supervisor, Town of West Seneca** **David Johnson, Town Engineer, Clark Patterson Lee (CPL)**
Prepared by	**Kadir Goz**
Checked by	**Shaun Gannon, P.E., D.WRE, P.H., CFM, PMP**
Approved by	**Michelle McEntire, PE**

Date: December 30, 2022

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1 Methodology

1.1 Model Input Data

The following data was obtained and utilized for the H&H modeling efforts:

- FEMA effective H&H model for Buffalo Creek (FEMA 2021)
- FEMA peak discharges (FEMA 2021)
- USGS *StreamStats* peak discharges (USGS 2021)
- New York State Digital Ortho-Imagery Program imagery (NYSOITS 2021)
- National Land Cover Database (NLCD) data (USGS 2021)
- NYSDOT bridge data (NYSDOT 2019)
- New York State 1-meter LiDAR digital elevation model (DEM) data with vertical accuracy of 19.6-centimeters (7.7 inches) in the North American Vertical Datum of 1988 (NAVD88) (NYSOITS 2019)

The hydrologic input data that was used by FEMA in the effective Flood Insurance Study (FIS) model was a peak discharge calculated using the methodology outlined in USGS Water Resources Investigations (WRI) 79-83 “Technique for Estimating Magnitude and Frequency of Flooding in Rural Unregulated Streams in New York State excluding Long Island” (USGS 1979), for un-gaged sites on gaged streams. This report is obsolete and was replaced in 2006 by Scientific Investigation Report (SIR) 2006-5112 “Magnitude and Frequency of Flood in New York.” SIR 2006-5112 forms the bases for the current method, USGS Stream Stats, for estimating peak discharges lacking stream measurement gages.

Peak discharge data for Buffalo Creek in the effective (FIS) for Erie County, NY (2021); were for the 1-percent AEP event, also referred to as the 100-year recurrence event, only, which was 16,000 cubic feet per second (cfs). To evaluate existing and proposed conditions along Buffalo Creek, it was necessary to obtain discharge data for the 50-, 20-, 10-, 2-, 1-, and 0.2- percent AEP (2, 5, 10, 50, 100, and 500-year recurrence) events. Hydrologic data was obtained from the USGS StreamStats software.

The USGS StreamStats v4.10.1 software (https://streamstats.usgs.gov/ss/) is a map-based web application that provides an assortment of analytical tools that are useful for water resources planning and management, and engineering purposes. The primary purpose of StreamStats is to provide estimates of streamflow statistics for user-selected un-gaged sites on streams and for USGS stream gages, which are locations where streamflow data are collected (Ries et al. 2017, USGS 2022). Table 1 displays the peak streamflow data obtained from StreamStats for Buffalo Creek at the confluence with Cayuga Creek.

The StreamStats peak discharge of 13,600 cfs is less than the effective FIS value of 16,000 cfs. This is attributed to StreamStats using updated equations as detailed in SIR 2006-5112.

Table 1. USGS *StreamStats* Peak Streamflow for Buffalo Creek.

Location	Drainage Area (sq miles)	River Station (ft)	Peak Discharges (cfs)			
			10-Percent	2-Percent	1-Percent	0.2-Percent
Confluence with Cayuga Creek	146	0+00	7,990	11,800	13,600	18,000

1.2 FEMA Hydrologic & Hydraulic (H&H) Model

As part of its role under the National Flood Insurance Program (NFIP), FEMA performs hydrologic & hydraulic (H&H) analyses and develops H&H models for each studied watershed within a community to establish regulatory flood insurance boundaries (i.e., effective FIS). The effective FIS for Buffalo Creek was created using the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center River Analysis System (HEC-RAS) program (USACE 2021).

According to the FIS for Erie County, NY (2021), the effective FEMA model for Buffalo Creek in the Town of West Seneca was originally completed by FEMA in 1976. It was then revised and updated in 1992. For the current effective FIS (2021) the 1992 data was remapped using Digital Elevation Models (DEM) and ortho-imagery.

For this project, the effective FEMA model was obtained for the project area, which begins at the union between Buffalo Creek and Cayuga Creek (river station 0+00) and extends upstream to the Buffalo Airfield (river station 205+00) (Figure 2). In Figure 1 below, the blue line represents the centerline of Buffalo Creek while the green lines represent the cross-sections in the effective FEMA model. Additionally, the numbered labels represent the distance (in feet) along the centerline upstream from the union of Buffalo and Cayuga Creeks.

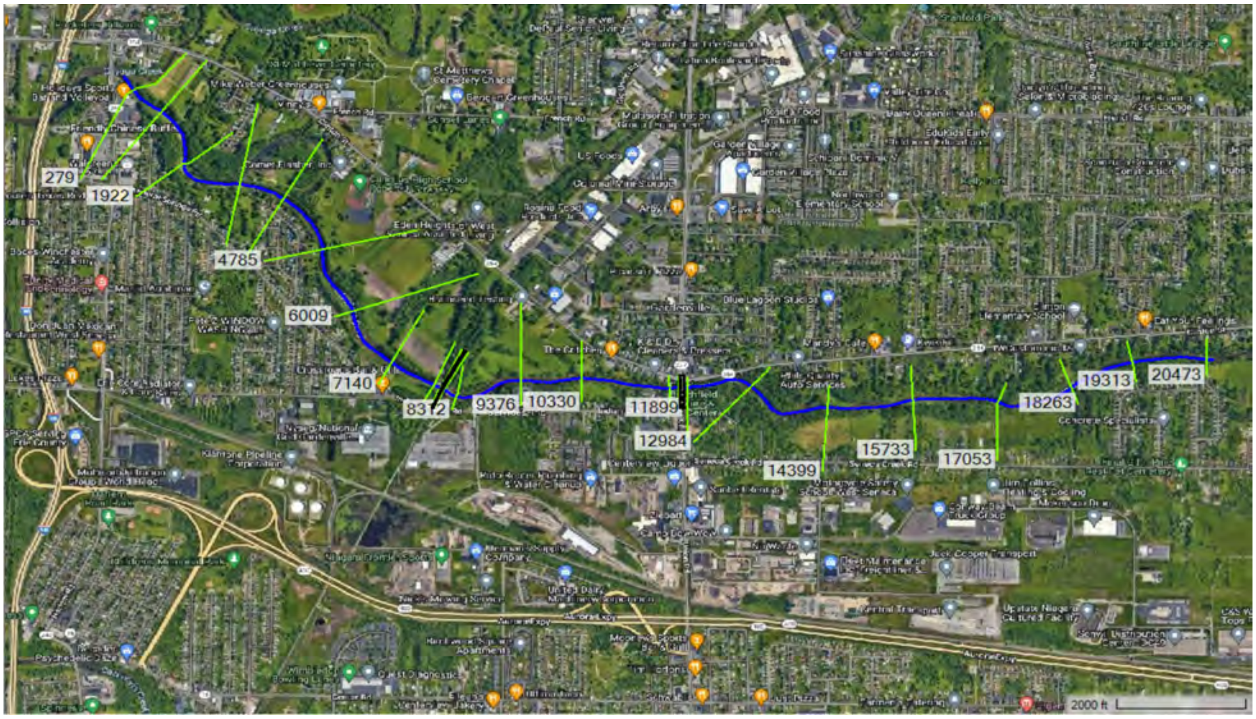

Figure 1. FEMA Effective FIS model layout for Buffalo Creek.

1.3 Existing Conditions Model

The FEMA effective H&H model was obtained by Ramboll and was one component in the development the existing conditions model. Due to the age of the effective FEMA model (first developed in 1976 and updated in 1992), most of the data used by FEMA in the model is outdated and potentially inaccurate. Therefore, the model used in this study is a combination of DEM data and the effective FIS.

Using LiDAR based DEM and land cover data (both from 2019), the geometry from each cross section in the effective FEMA model had the overland and channel geometries cut from the DEM. Manning's roughness vales were assigned based on land cover type (NYSOITS 2019; USGS 2021). Since LiDAR does not completely penetrate water and record the channel bottom, the minimum channel elevation of each cross section was modified to match the channel elevation from the effective FEMA model (1992) or FIS profile plot (2019).

In addition, 12 cross sections were added to the those in the effective FIS model between river stations 36+50 and 80+00 to provide the necessary starting and ending positions for the different flood bench scenarios along the Lexington Green neighborhood. These new cross sections had their overland set to the DEM data and the minimum channel elevations were modified to match the minimum channel elevation from the effective FIS model profile plot. This updated model is referred to as the ***existing conditions model***. Figure 2 displays the existing conditions model layout for Buffalo Creek. The blue line represents the centerline of Buffalo Creek while the green lines represent the cross-sections in the existing conditions. Additionally, the numbered labels represent the distance (in feet) along the centerline upstream from the union of Buffalo and Cayuga Creeks.

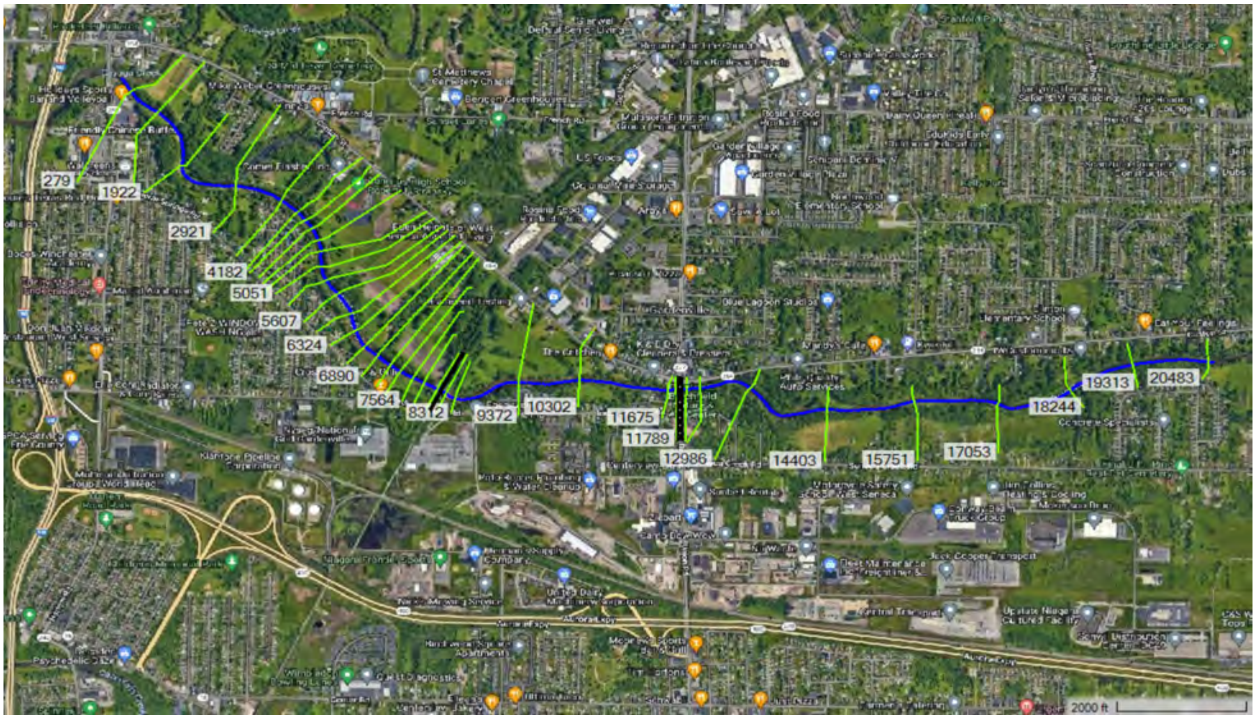

Figure 2. Existing conditions model layout from the USACE HEC-RAS model software for Buffalo Creek.

1.4 Boundary Conditions

The modeling software requires an estimate of the conditions at the downstream boundary of the study to solve for water surface elevation at each cross section. These are referred to as Boundary Conditions. The method used in the effective FIS and the existing conditions model was slope, also referred to as the normal depth method (FEMA 2021). For this model, the slope between the last three cross sections was used and calculated to be 0.00012 ft/ft.

1.5 Survey Data

Field staff from Ramboll performed a field visit on November 2, 2022, where overbank and in-channel survey data and streambank assessments were performed. Four locations were surveyed due to their accessibility, close proximity to the Lexington Green neighborhood, and lack of adequate representation in the effective FEMA model layout. Figure 3 displays the field survey locations along Buffalo Creek.

Figure 3. Field survey locations along Buffalo Creek.

Field surveys involved field staff using surveying and leveling equipment to measure land surface elevations perpendicularly across the creek channel from one overbank area to the other at the four identified locations. In addition, stream bank assessments were performed at each location to determine the condition and locations of overbank zones (e.g., toe, bank, overbank, transitional, and upland zones).

This survey data was used to validate the overbank and channel elevations in the existing conditions model and incorporated into the model where significant discrepancies were found by modifying the cross-section geometry in the existing conditions model. Attachment B contains the field notes from the field staff

1.6 Overbank Modifications

Through public engagement and a meeting with Canisius High School, it was identified that the school is in the process of constructing two baseball fields, a practice field, and tennis courts in the open area adjacent to Buffalo Creek. The site plans and drawings for this construction was provided to Ramboll and incorporated into the H&H model for Buffalo Creek.

The new construction includes the placement of fill material in overland areas adjacent to Buffalo Creek. To account for this fill the existing conditions model was modified using blocked obstructions. Blocked Obstructions simply “blockout” a portion of the cross-section area preventing water from expanding into it. Attachment B contains the site plans for the development. Figure 4 displays the HEC-RAS cross section data window where a blocked obstruction was used to represent the proposed development.

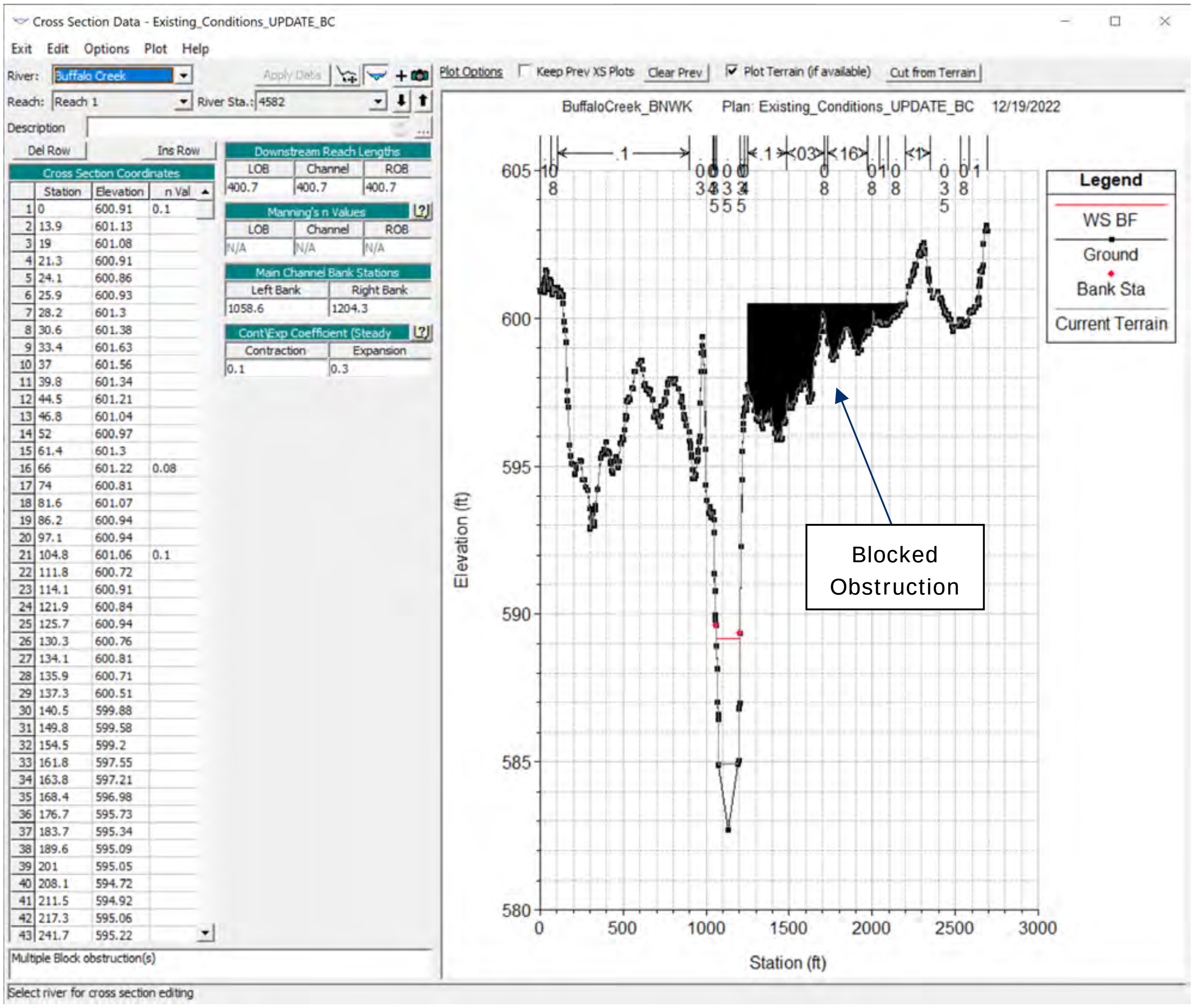

Figure 4. HEC-RAS representation of a blocked obstruction.

1.7 Flood Bench Scenarios

A flood bench (also referred to as floodplain bench or bankfull bench) is a flat area adjacent to the stream at some specified elevation constructed to both create an area for flows above a specific discharge to spread out, dissipate energy and to provide for sediment and debris deposition. A flood bench is effective for reducing flood stages and velocities, improving water quality, reducing stream bank erosion, and providing stream bed stability. Attachment C contains a sectional plan view of a flood bench.

Potential flood bench locations were identified using input received from the public engagement meeting and contact with individual property owners. Highland Planning, LLC (Highland), the public outreach and engagement sub-contractor for this project, took the lead in contacting and engaging with property owners to gauge interest in being included in this project. A public engagement meeting took place on

August 22, 2022, where project members from Ramboll discussed the project goals and potential property owner participation. Based on discussions and participation by the community and property owners, six potential flood bench configurations were identified along Buffalo Creek within the project area.

In addition, through public engagement and discussions with representatives of Canisius High School, it was identified that the school is in the process of constructing two baseball fields, a practice field, and tennis courts in the open area adjacent to Buffalo Creek. The site plans and drawings for this construction were provided to Ramboll and incorporated into the H&H model for Buffalo Creek. Attachment D contains the site plans for the development.

Table 2 summarizes the different identified flood bench configurations with descriptions. Figure 5 displays the locations and extents of each flood bench scenario, including the proposed development locations by the Canisius High School.

Table 2. Summary Table of Proposed Flood Bench Configurations

Flood Bench ID	Description
1a	Western portion of the Canisius School tax parcel
1b	Western portion of the Canisius School tax parcel (outside of proposed site plans)
2	Western portion of the 1904 Union Rd tax parcel
3	Western portion of the 3099 Clinton Street tax parcel
4	Western portion of the Transmission Land (Right Bank) tax parcel
5	Western portion of the Transmission Land (Upstream – Left Bank) tax parcel
6	Western portion of the Transmission Land (Downstream - Left Bank) tax parcel

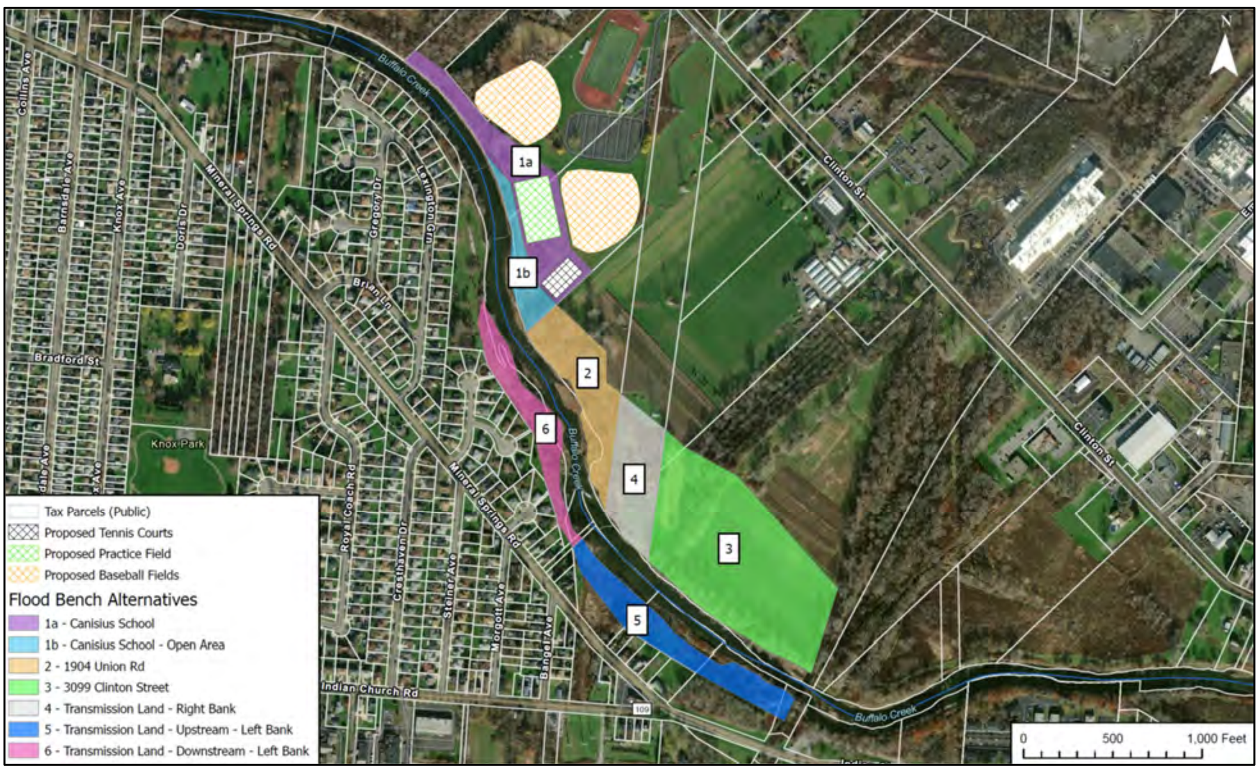

Figure 5. Location map of Buffalo Creek and the flood bench scenarios.

Based on the six identified flood bench locations, nine flood bench scenarios of different configurations were developed and modeled using the HEC-RAS modeling software. Table 3 outlines the nine flood bench scenarios.

Table 3. Summary table of modeled flood bench scenarios.

Scenario ID	Flood Bench Configurations
1	1a
2	1b
3	1b + 2
4	2 & 3
5	1b + 2 + 3
6	2 + 3 + 4
7	1b + 2 + 3 + 4
8	5 + 6
9	1b + 2 + 3 + 4 + 5 + 6

1.8 Proposed Scenario Modeling

Using the HEC-RAS modeling software, ***proposed conditions models*** were developed for each flood bench configuration based on the existing conditions model. To model each flood bench scenario, cross section, that intersected a proposed flood bench in that specified configuration, were modified by adjusting the elevation of the overland terrain. Figure 6 displays an example cross section where the overbank terrain was modified to represent a flood bench.

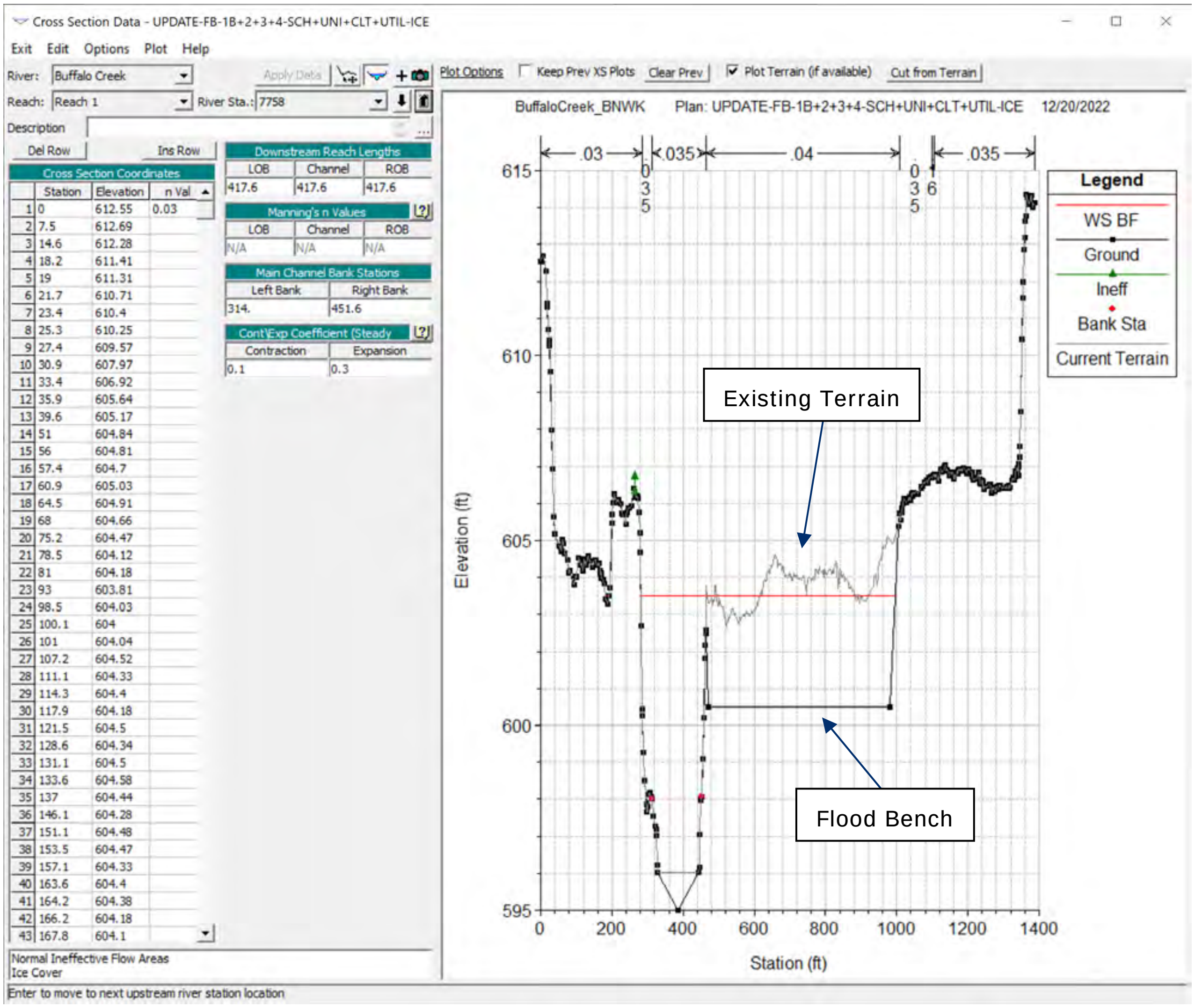

Figure 6. Example Cross-Section from HEC-RAS Depicting a Flood Bench.

1.9 Ice-Jam Analysis

An ice jam typically occurs in the late winter and early spring in ice-covered streams when ice accumulates at man-made (e.g., bridge piers, dams) or natural narrower or shallower sections or meanders of a river slowing down or blocking the incoming ice by bridging the ice across the width of the river. Ice-jam flooding presents a complex problem for scientists and engineers since the resulting flood stage can be significantly higher than the flood stage caused from streamflow alone. In other words, a relatively minor discharge of streamflow can result in a major flooding event during an ice jam (USACE 2006).

The ice jam analysis in this study used the 10% ACE (10-yr) to develop an ***existing condition with ice cover model***. Ice-jam simulations were performed for each proposed conditions model using the built-in Ice Cover settings within the HEC-RAS model software. Based on historical ice jam data, ice cover lengths and depths were obtained and input into the model. For the ice-jam simulations, an ice cover of 1-ft thickness was used starting from the confluence with Cayuga Creek/Buffalo River (river station 0+00) upstream to the Union Road bridge (river station 118+60).

2 Results

2.1 Effective FEMA versus Existing Conditions Models

Based on the modeling simulation results, there is a difference in water surface elevations (WSELs) between the effective FEMA and existing conditions models of up to 2.0-feet using the FEMA 1-percent AEP peak discharge of 16,000 cfs. Table 4 outlines the results of the effective FEMA and Existing Conditions models. Figure 7 displays the profile plot of the effective FEMA and existing conditions model results.

Table 4. HEC-RAS Model Results for the FEMA FIS 1-Percent Peak Discharge.

River Station (ft) Effective/Existing	Water Surface Elevation (ft NAVD88)		
	Effective FEMA	Existing Conditions	Difference Effective - Existing
20473/20483	635.1	634.5	0.6
19313	631.8	631.6	0.2
18263/18244	629.9	629.9	0.0
17053	628.0	627.5	0.5
15733/15751	625.2	624.4	0.8
14399/14403	623.3	623.0	0.3
12984/12986	622.1	621.8	0.3
11955/12162	618.3	619.0	-0.7
11899/11955	618.2	618.2	0.0
11850/11860	**Union Rd**		
11826/11789	617.5	615.9	1.6
11682/11675	617.5	616.2	1.3
10330/10302	614.5	613.0	1.6
9376/9372	610.1	608.1	2.0
8312	607.8	608.1	-0.3
8081/8145	606.6	607.7	-1.2
8050/8049	**Railroad Bridge**		
8016/7984	606.4	606.6	-0.3
7906	606.3	-	-
7758	-	606.3	-
7564	-	605.9	-
7340	-	605.5	-
7140/7151	603.3	604.9	-1.6
6890	-	604.3	-
6631	-	602.8	-
6324	-	601.7	-
6009/6015	599.5	600.0	-0.5

River Station (ft) Effective/Existing	**Water Surface Elevation (ft NAVD88)**		
	Effective FEMA	**Existing Conditions**	**Difference** Effective - Existing
5607	-	599.0	-
5307	-	598.3	-
5051	-	597.5	-
4785 / 4786	597.8	596.7	1.1
4582	-	595.7	-
4363	-	594.6	-
4182	-	594.0	-
3997	-	593.5	-
3686 / 3670	594.0	593.5	0.5
2949 / 2921	592.7	591.4	1.3
1922 / 1922	591.5	590.8	0.7
866 / 833	589.6	590.0	-0.4
279	588.9	588.9	0.0

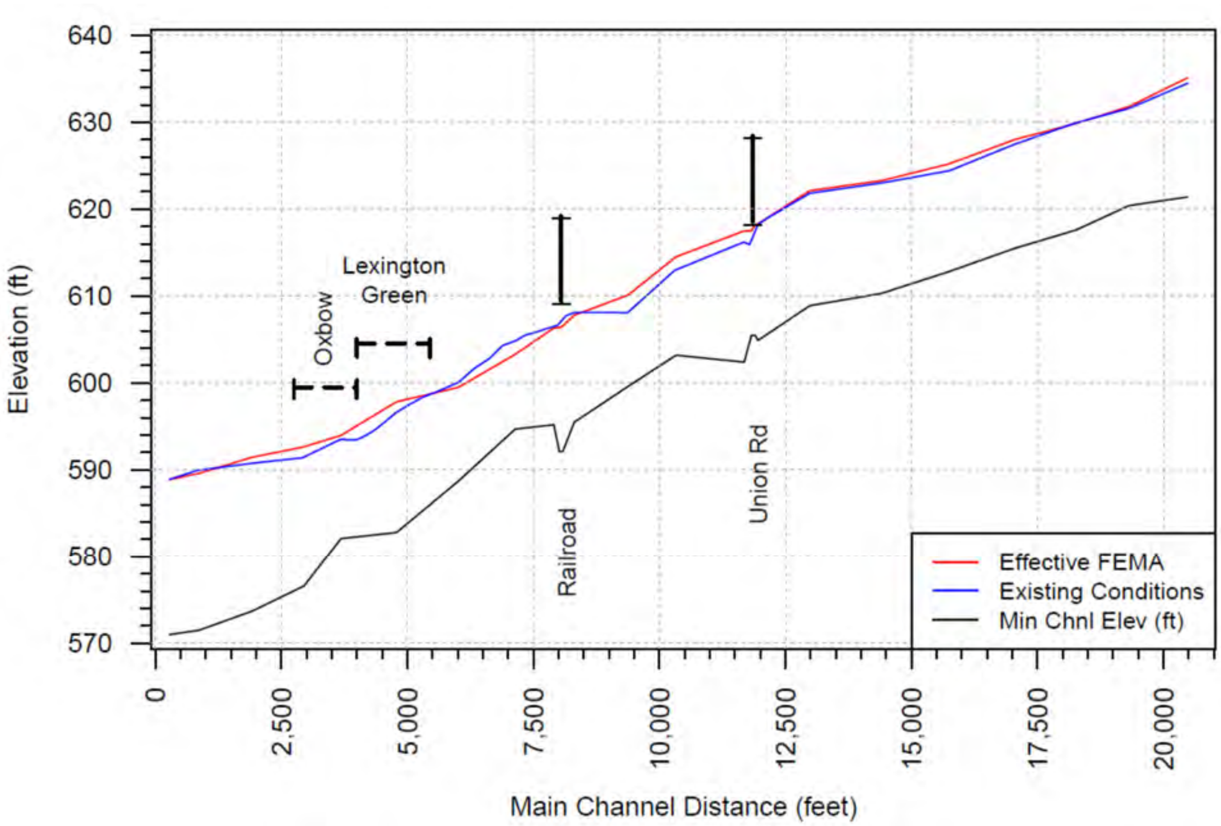

Figure 7. Effective FEMA and existing conditions profile plot using the FEMA 1-percent AEP (100-year recurrence) event peak discharge.

The differences between the effective and existing conditions models are a result of multiple factors, including:

- Updated overbank and channel geometry using the most current LiDAR DEM available
- Updated Manning's n values in the overbank areas to represent land use changes over time in the watershed
- The additional cross-sections in the project area providing more consistent and higher resolution hydraulic calculations and output data
- Difference in versions of the USACE HEC-RAS modeling used for the effective FIS and the existing conditions model.

The existing conditions model, developed for this study, was not prepared in accordance with all requirements of FEMA Guidelines and Specifications. Therefore, this model should not be considered the bases to challenge the effective Flood Insurance Rate Maps (FIRMs).

Figure 8 displays the flood extents of the effective FEMA and existing conditions model results using the FEMA 1-percent AEP event peak discharge. It should be noted that all models used in this study are 1-dimensional (1D) HEC-RAS models. The flood extent outputs from 1D models are static WSELs that are superimposed over the DEM terrain. Any terrain elevation within the model domain that is below the WSEL at a given cross-section will appear flooded regardless of the hydrological connectivity of the area to the flooding source.

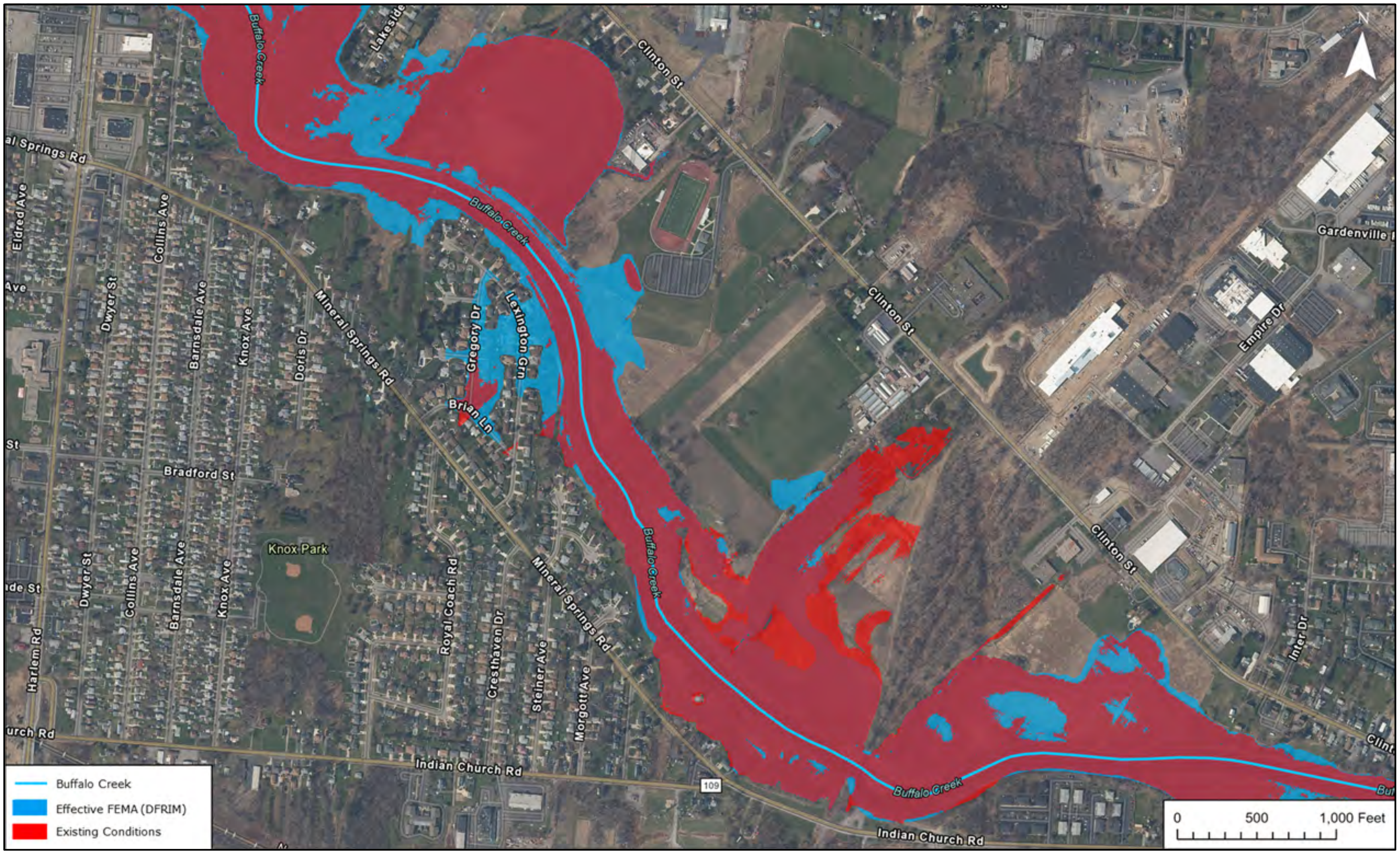

Figure 8. Flood extents for the effective FEMA (blue) and existing condition (red) model simulation results using the FEMA 1-percent AEP (100-year recurrence) event peak discharge.

The largest difference between the effective FEMA and existing conditions model simulations results occurs downstream of the Oxbow and in the vicinity of the Lexington Green neighborhood. Since the development of the effective FIS a temporary protective berm was placed to help reduce the risk of flooding in the Lexington Green neighborhood.

For regulatory and insurance purposes, the berm along the Lexington green neighborhood is not recognized as an official levee since it does not meet the minimum design standards for providing safe, reliable flood protection. The minimum design standards include design height for the specified level of protection (e.g., 1% AEP/100-year level), overtopping criteria, top width, side slopes, seepage, and stability (i.e., foundation protection, erosion and scour protection, etc.). Therefore, it was considered in the developing the effective FIRM nor this study.

2.2 Scenario Modeling Results

The results of each proposed flood bench scenario modeled in comparison to the existing conditions model is summarized in Table 5. The table represents the maximum difference in water surface elevation at any point within the study area.

Table 5. Results of the Proposed Conditions Models.

Scenario ID	Flood Bench Configurations	Reductions in Water Surface Elevations (ft NAVD88)			
		10-Percent	2-Percent	1-Percent	0.2-Percent
1	1a	1.0	1.4	1.5	1.6
2	1b	0.4	0.6	0.6	0.6
3	1b + 2	0.8	1.2	1.3	1.3
4	2 + 3	1.4	1.6	1.6	1.6
5	1b + 2 + 3	1.4	1.6	1.6	1.6
6	2 + 3 + 4	1.5	2.0	2.2	2.4
7	1b + 2 + 3 + 4	1.5	2.0	2.2	2.5
8	5 + 6	0.6	0.7	0.7	0.7
9	1b + 2 + 3 + 4 + 5 + 6	1.6	2.2	2.4	2.8

Figures 9 through 17 display the HEC-RAS profile plot results for each flood bench scenario compared to the existing conditions WSELs using the USGS *StreamStats* 10-, 2-, 1-, and 0.2-percent AEP event peak discharges.

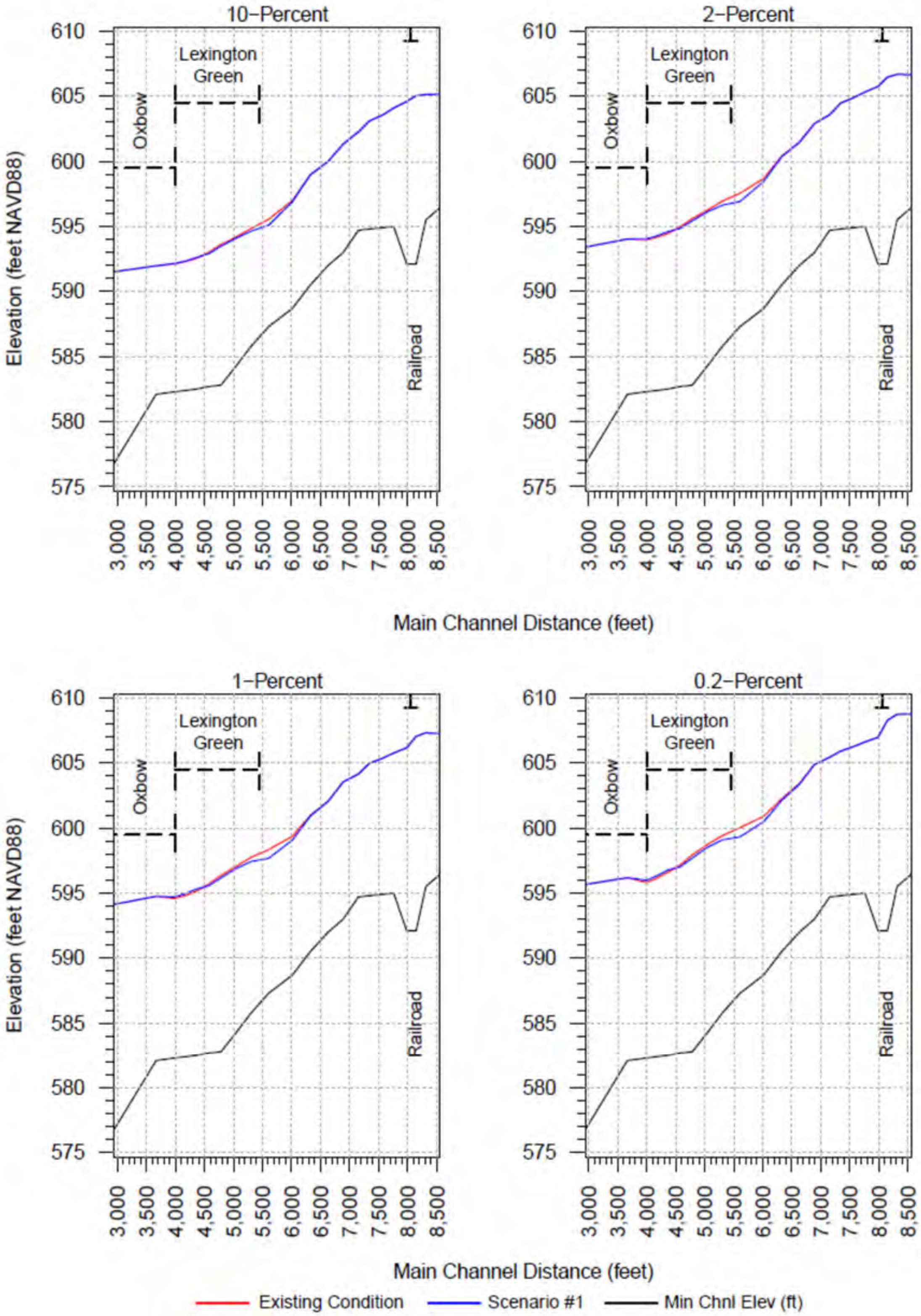

Figure 9. HEC-RAS model profile plots for Flood Bench Scenario #1.

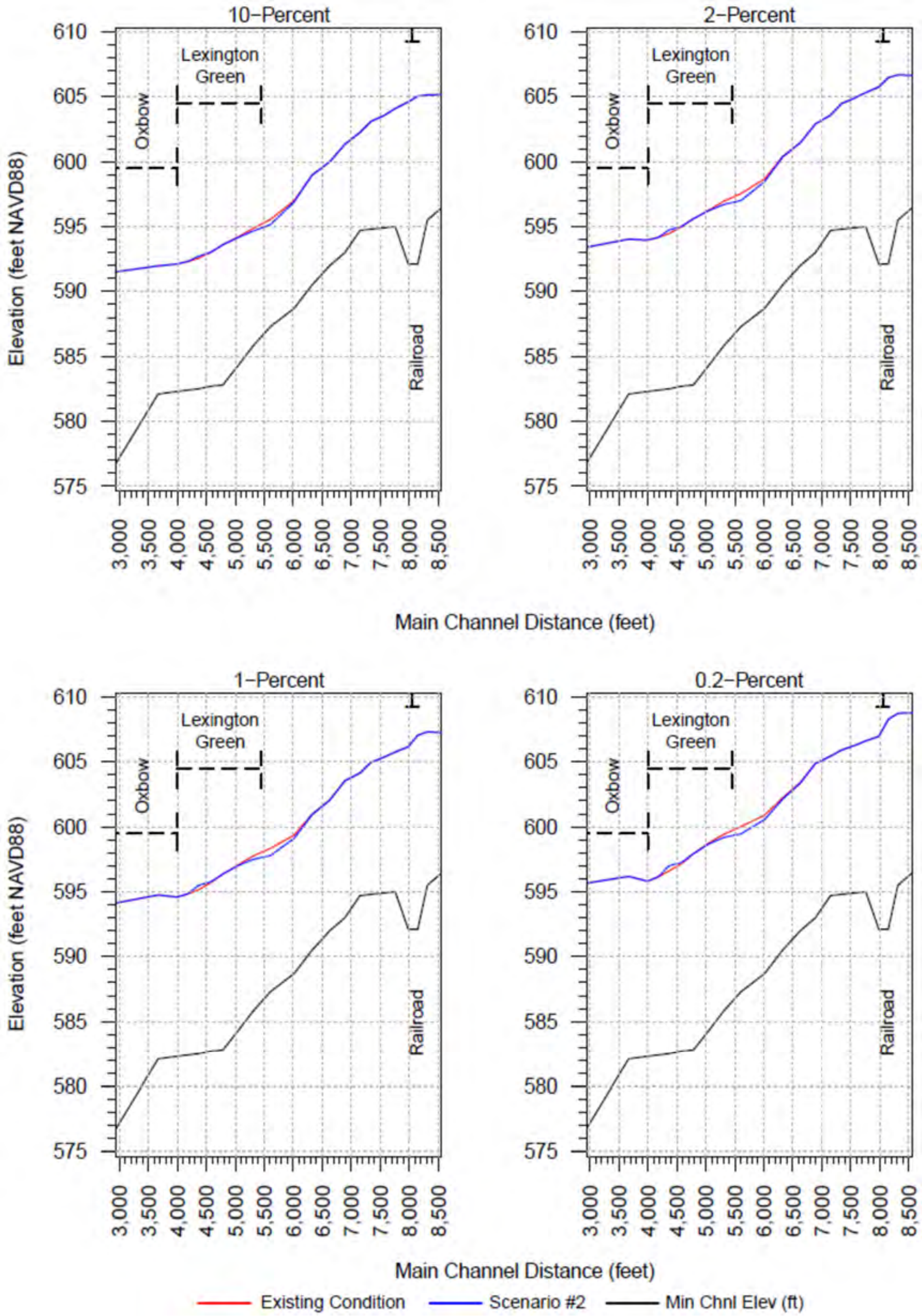

Figure 10. HEC-RAS model profile plots for Flood Bench Scenario #2.

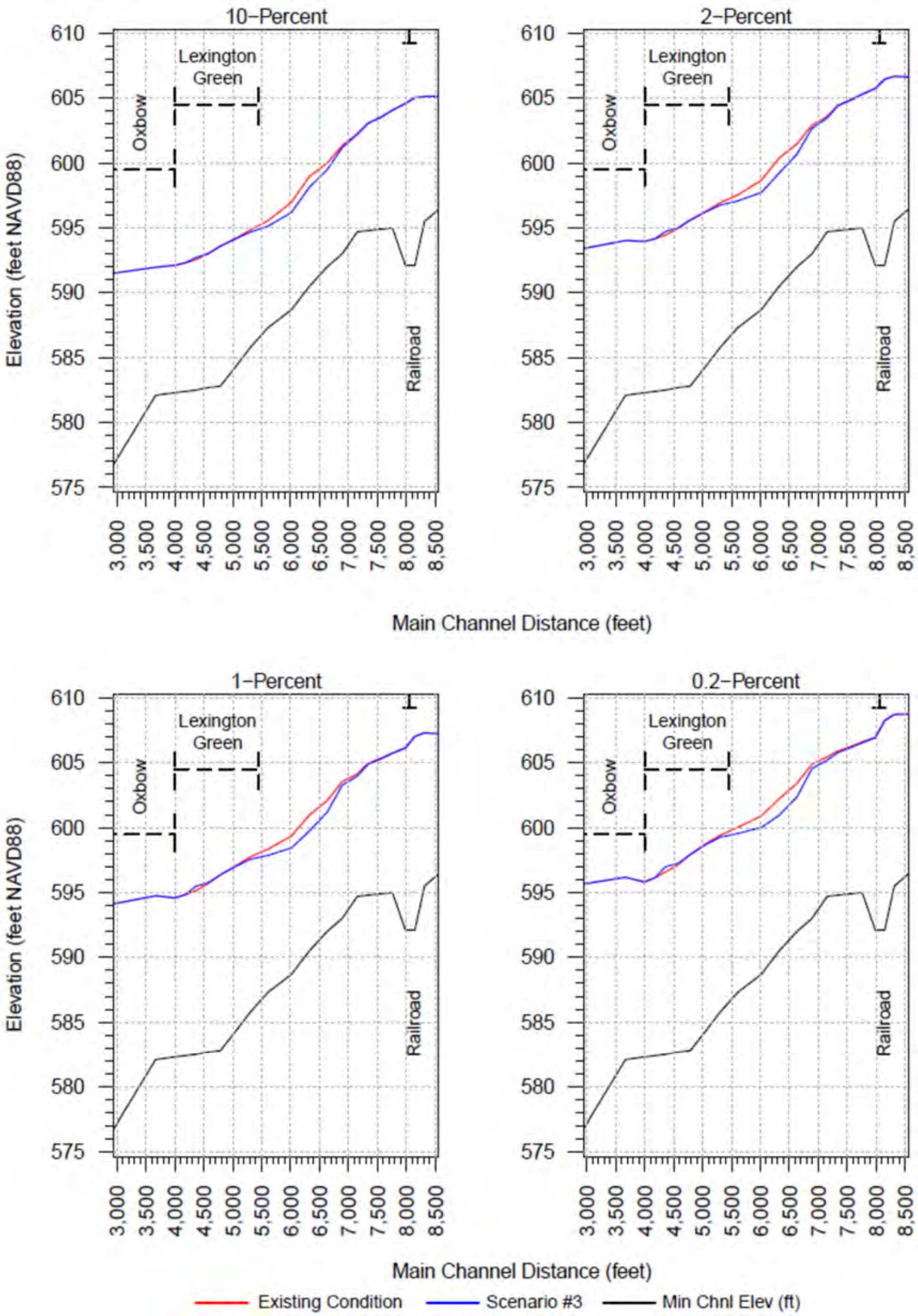

Figure 11. HEC-RAS model profile plots for Flood Bench Scenario #3.

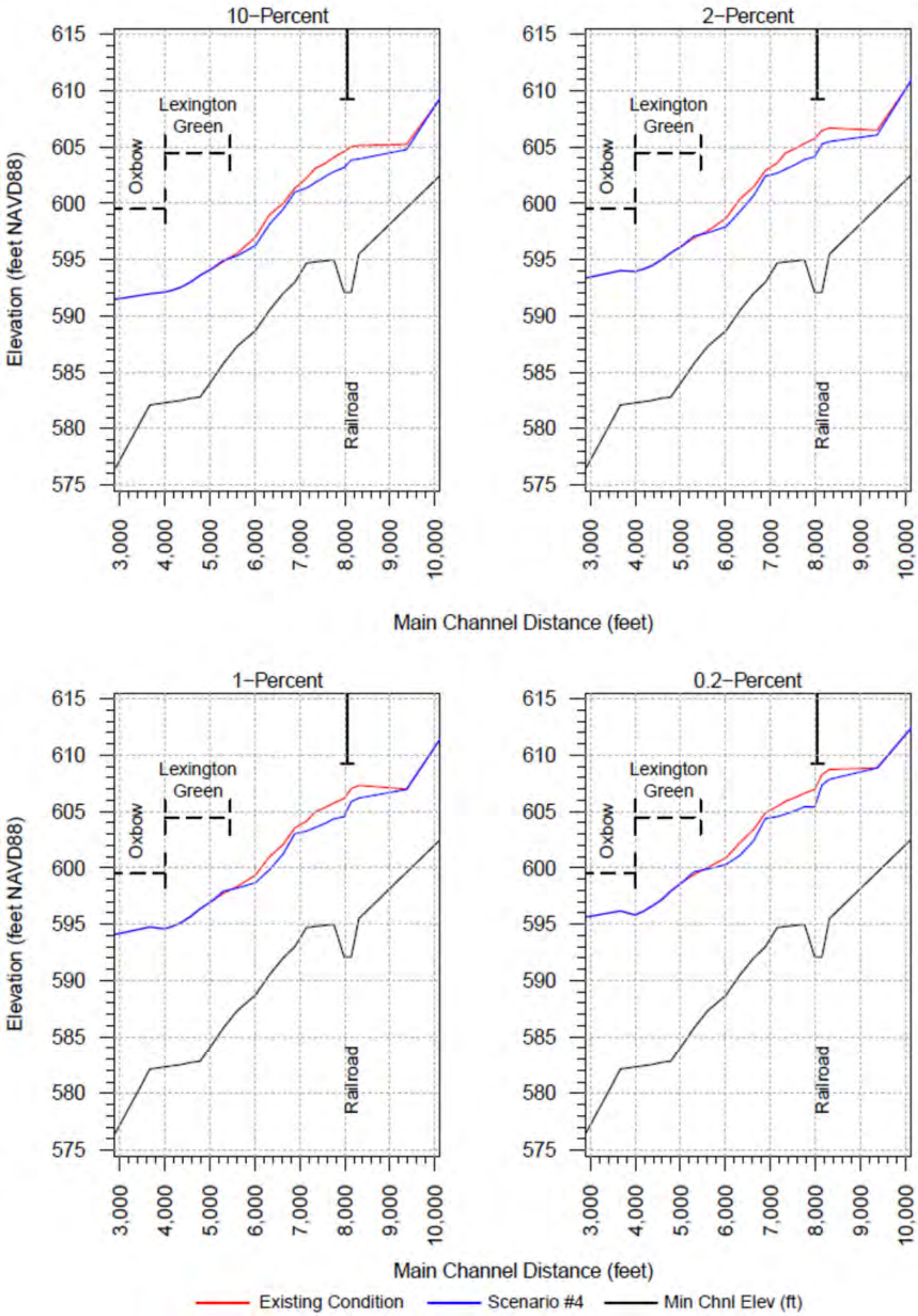

Figure 12. HEC-RAS model profile plots for Flood Bench Scenario #4.

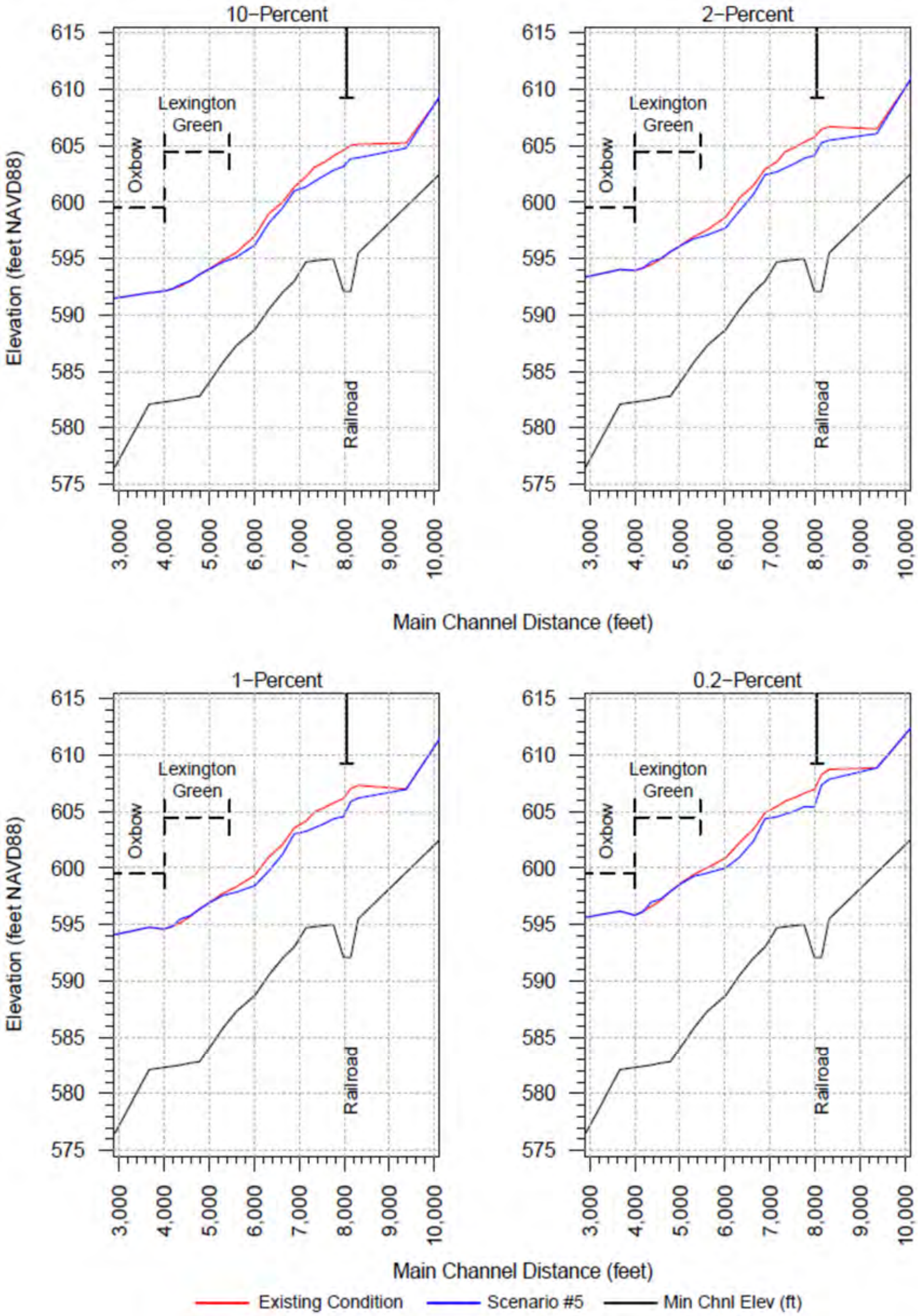

Figure 13. HEC-RAS model profile plots for Flood Bench Scenario #5 .

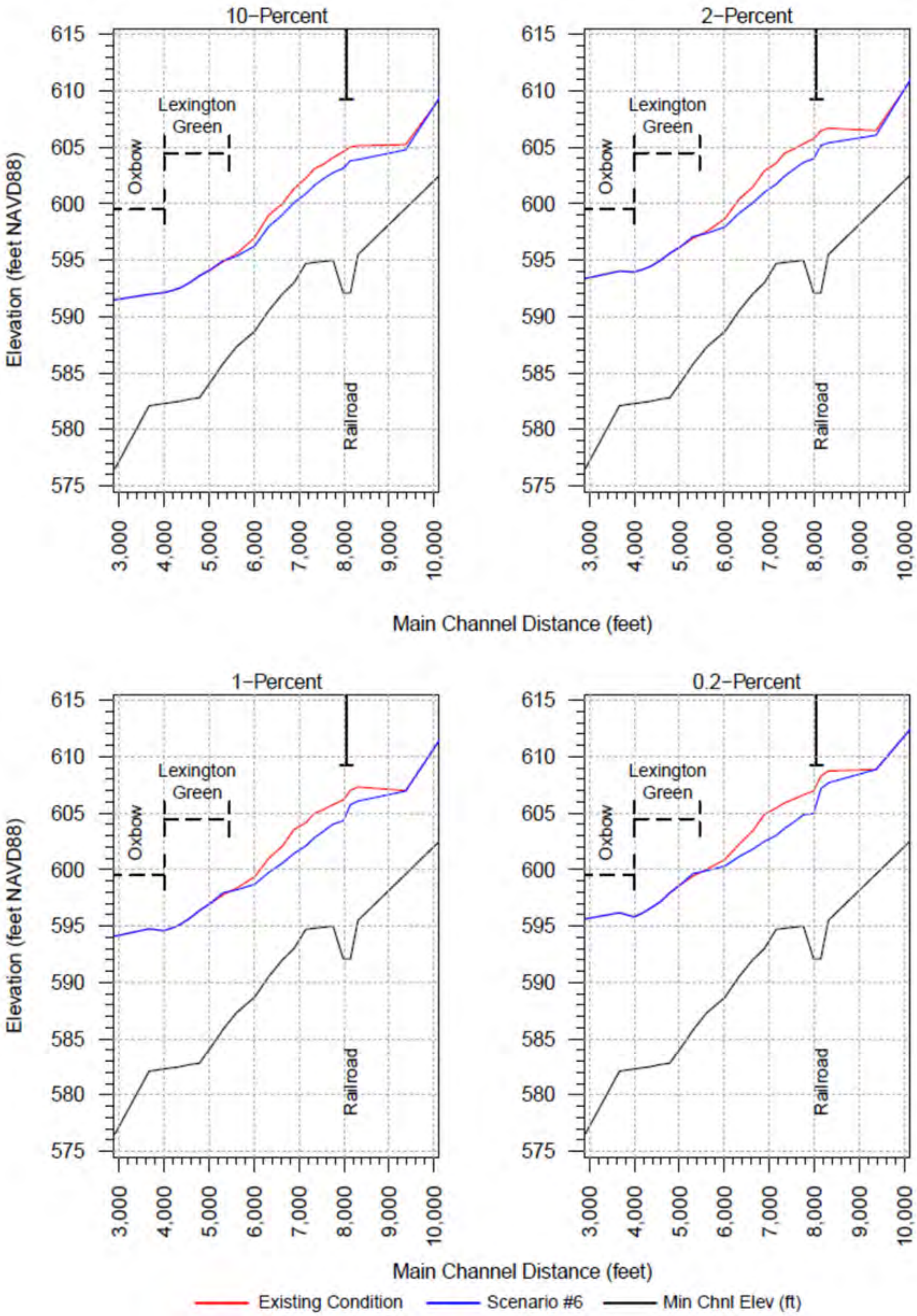

Figure 14. HEC-RAS model profile plots for Flood Bench Scenario #6.

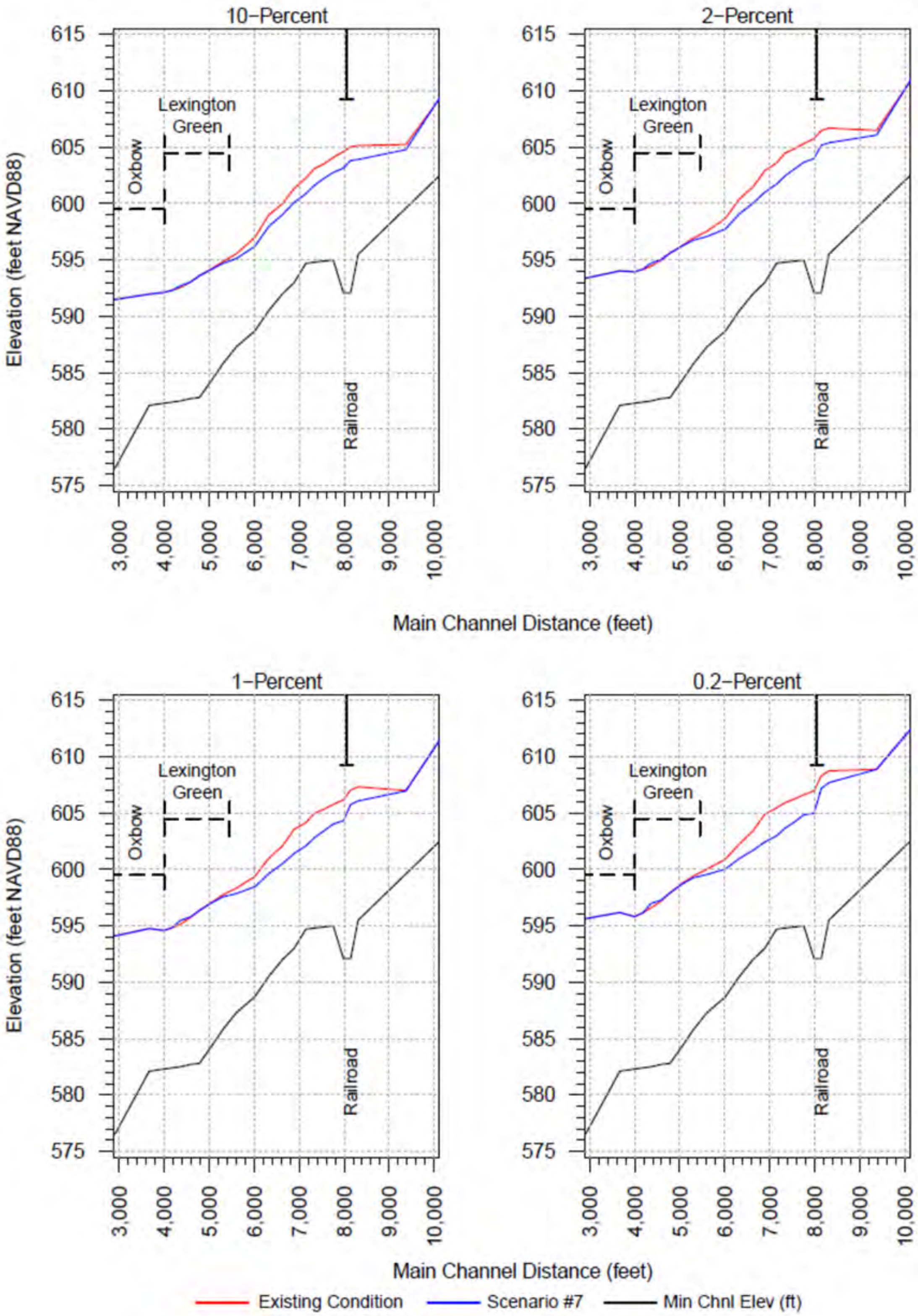

Figure 15. HEC-RAS model profile plots for Flood Bench Scenario #7.

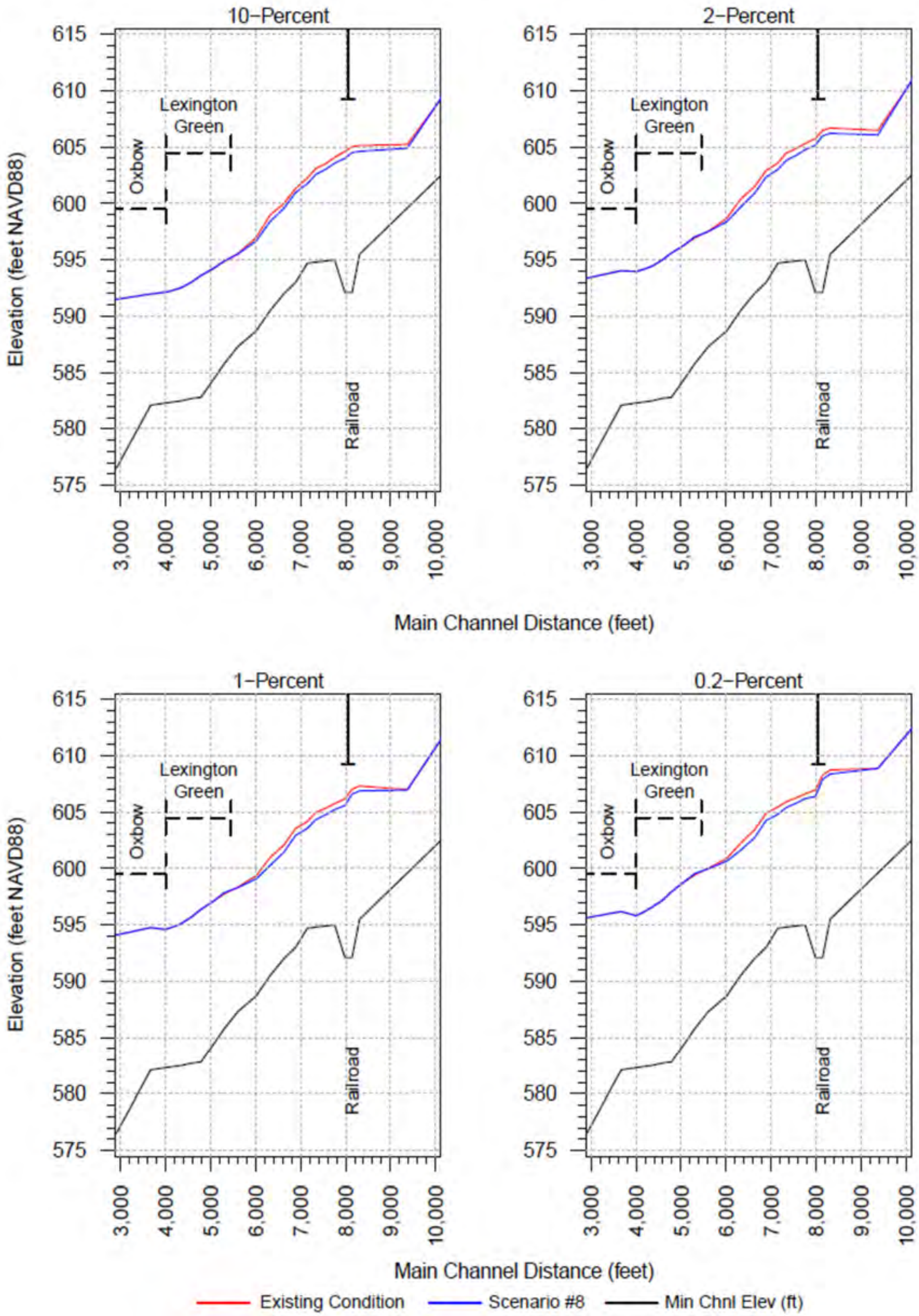

Figure 16. HEC-RAS model profile plots for Flood Bench Scenario #8.

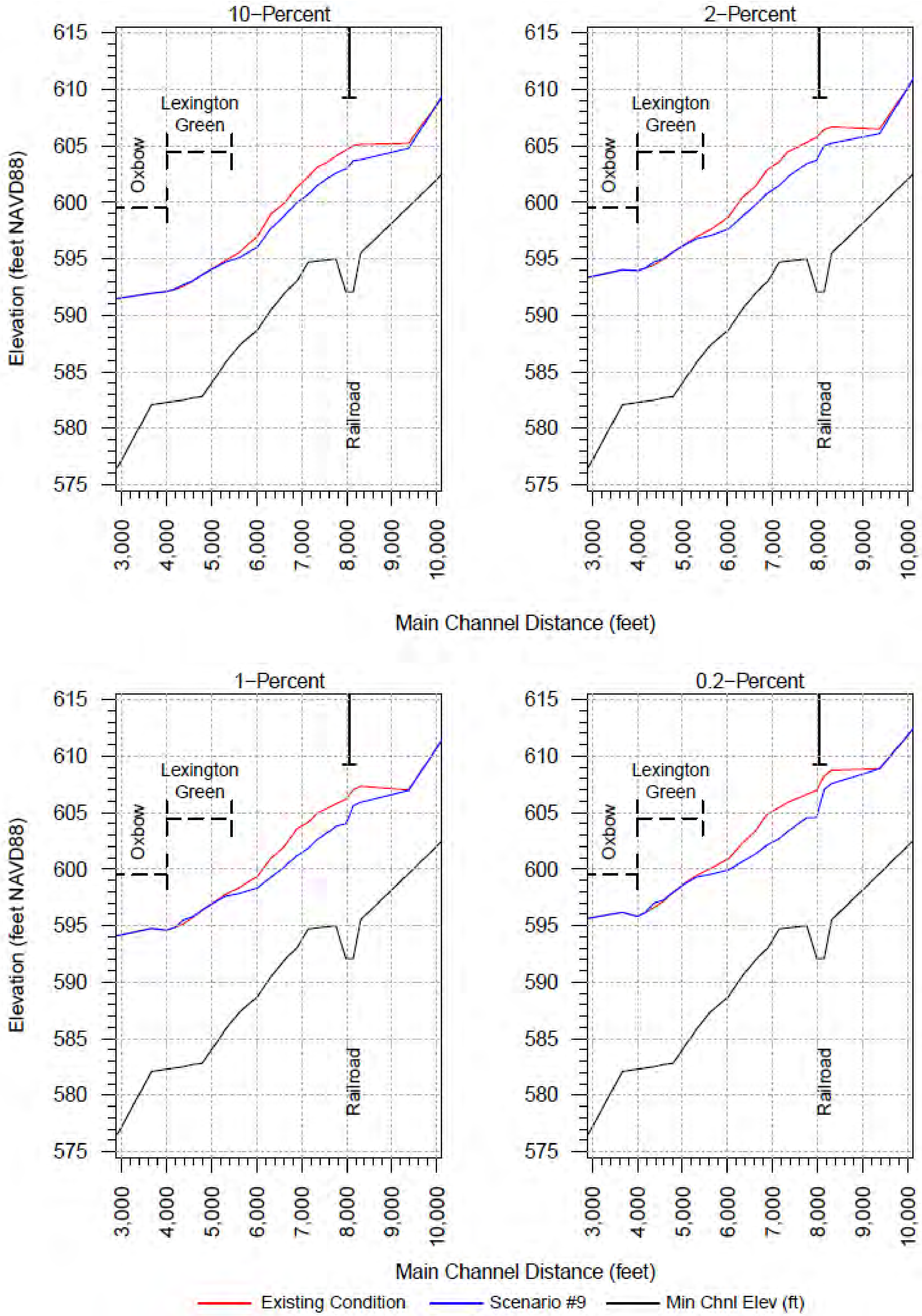

Figure 17. HEC-RAS model profile plots for Flood Bench Scenario #9.

Table 6 looks specifically at the changes in water surface elevation within the Lexington Green neighborhood (river stations 39+97 to 53+07) for the 1-percent AEP event. Results for events that occur more frequently (i.e., 10- and 2-percent) can be found in Attachment F.

Table 6. WSELs (feet NAVD88) in the vicinity of Lexington Green for the existing and proposed conditions models for the 1-percent AEP event.

	Water Surface Elevation (ft NAVD88)						
	RS 39+97	RS 41+82	RS 43+63	RS 45+82	RS 47+86	RS 50+51	RS 53+07
Existing Conditions	594.6	594.8	595.1	595.8	596.4	597.0	597.7
Scenario #1	594.7	595.0	595.6	595.8	596.1	596.3	596.4
Scenario #2	594.6	594.8	595.5	595.8	596.4	597.0	597.4
Scenario #3	594.6	594.8	595.5	595.8	596.4	597.0	597.5
Scenario #4	594.6	594.8	595.1	595.8	596.4	597.0	597.9
Scenario #5	594.6	594.8	595.5	595.8	596.4	597.0	597.5
Scenario #6	594.6	594.8	595.1	595.8	596.4	597.0	597.9
Scenario #7	594.6	594.8	595.5	595.8	596.4	597.0	597.5
Scenario #8	594.6	594.8	595.1	595.8	596.4	597.0	597.8
Scenario #9	594.6	594.8	595.5	595.8	596.4	597.0	597.5

Near the Lexington Green neighborhood, WSELs remain unchanged for most of flood bench scenarios. Scenario #1 displays the most significant benefits with WSEL reductions of up to 1.3-ft, primarily in the upstream portion of Lexington Green.

2.3 Berm Impacts

For regulatory and insurance purposes, the berm along the Lexington Green neighborhood is not recognized as an official levee since it does not meet the minimum design standards for providing safe, reliable flood protection. However, due to the existence of and flood mitigation impacts of the existing berm, the project team included the berm in the H&H analysis performed in this study. The berm elevation in the existing conditions model was set to 599.5-ft NAVD88 in line with the LiDAR DEM data. Figure 18 displays the flood extents for the existing conditions model simulation results with and without the berm.

Figure 18. Flood extents for existing with berm (pink) and existing without berm (green) conditions models using the USGS StreamStats 1-percent AEP (100-year recurrence) event peak discharge.

Table 7 summarizes the results for the 1-percent AEP event of the existing and proposed conditions modeling for the reach containing the berm along the Lexington Green neighborhood. Results for events that occur more frequently (i.e., 10- and 2-percent) can be found in Attachment F.

Table 7. WSELs (feet NAVD88) in the vicinity of the berm along Lexington Green for the existing and proposed conditions models for the 1-percent AEP event.

	Water Surface Elevation (ft NAVD88)		
	RS 45+82	RS 47+86	RS 50+51
Berm Elevation (ft NAVD88)	**599.5**	**599.5**	**600.5**
Existing Conditions	595.8	596.4	597.0
Scenario #1	595.8	596.1	596.3
Scenario #2	595.8	596.4	597.0
Scenario #3	595.8	596.4	597.0
Scenario #4	595.8	596.4	597.0
Scenario #5	595.8	596.4	597.0
Scenario #6	595.8	596.4	597.0
Scenario #7	595.8	596.4	597.0
Scenario #8	595.8	596.4	597.0
Scenario #9	595.8	596.4	597.0

It is important to note that since the berm was not built to USACE guidelines, the berm does not have the appropriate high-ground elevation tie-ins for the upstream and downstream ends of the berm. As a result, flood waters from high flow events can circumvent the berm causing flooding to the areas behind the berm. In addition, the probability of failure of the berm is high due to the improper construction. Once the berm fails, as any levee failure, the resulting damages can be significant and catastrophic. Further consultation with the USACE and NYSDEC regarding modifications to the berm or construction of a certified levee is recommended.

2.4 Ice-Jam Simulation Results

The ice jam analysis in this study used the 10% ACE (10-yr) to develop an existing condition with ice cover model simulation at each identified ice-jam susceptible location using the built-in Ice Cover settings within the HEC-RAS model software. Where ice cover was modeled in the vicinity of bridges, the Ice Jam Computation Option under the Bridge/Culvert Data editor was changed to the option "ice remains constant through the bridge" in the HEC-RAS model software (USACE 2021).

Based on historical ice jam data and public engagement, ice cover lengths and depths were obtained and input into the model. Manual calibration of the length and depth of the ice cover in the model was performed to reproduce historical flood levels caused by ice-jam events along Buffalo Creek in the vicinity of Lexington Green. The calibration determined that an ice cover of 1 ft thick and extending from the confluence with Cayuga Creek (Buffalo River) upstream to the Union Road bridge reproduced the historical flood levels.

Using the calibrated ice cover specifications, the existing condition ice-cover simulation model was used to test the effectiveness of the flood bench alternatives. Figure 19 displays the flood extents for the existing conditions model under open-water (blue) and ice-jam (pink) conditions using the USGS StreamStats 10-percent AEP (10-year recurrence) event peak discharge. Where the flood extents for the existing conditions model under open-water and ice-jam conditions overlap, the flood extents will appear as purple on the figures.

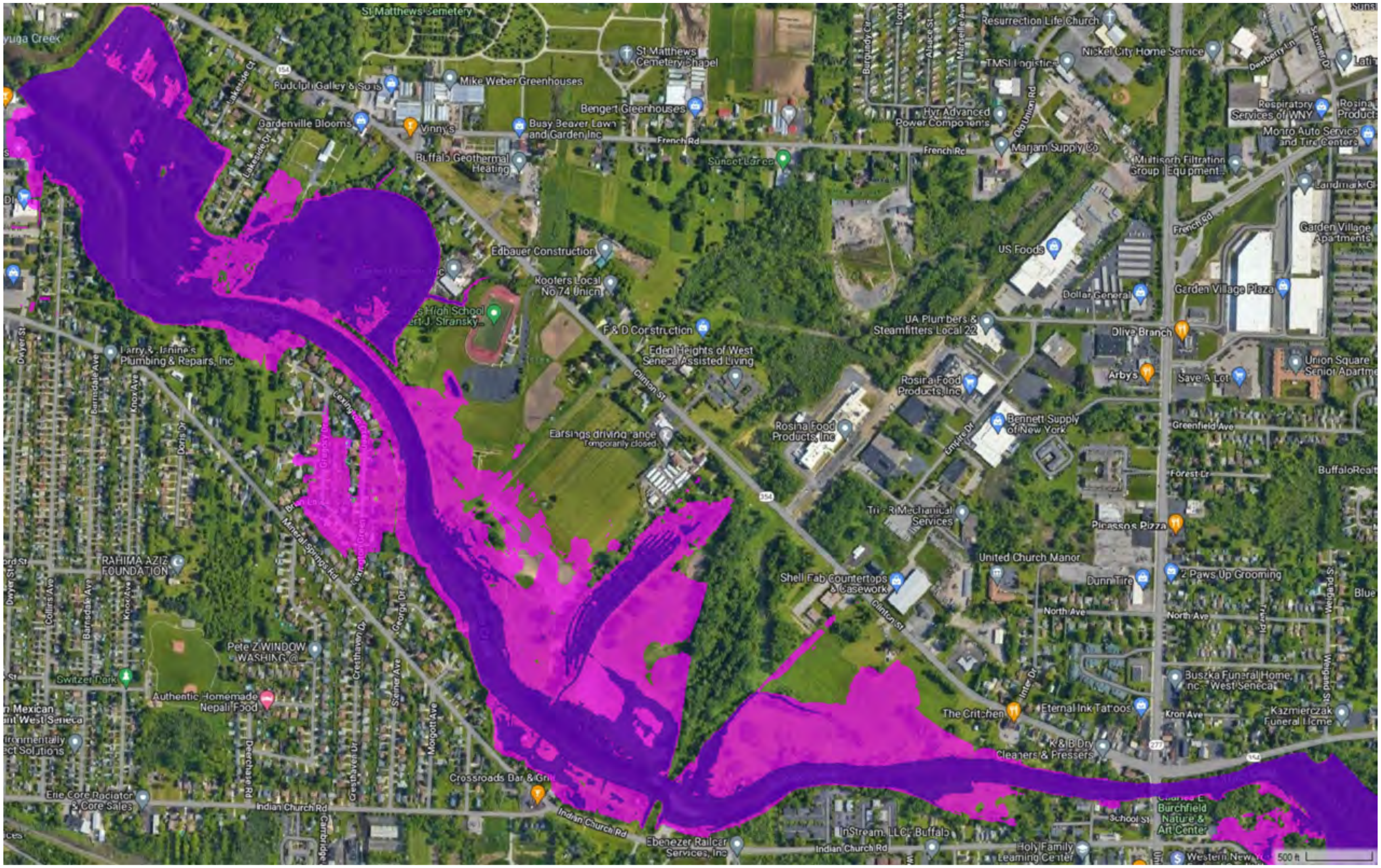

Figure 19. Flood extents for the existing conditions model under open-water (blue) and ice-jam (pink) conditions models using the USGS StreamStats 10-percent AEP (10-year recurrence) event peak discharge.

Table 8 summarizes the model results of each proposed flood bench scenario with an ice-jam in comparison to the existing condition with an ice-jam models.

Table 8. Results of the existing and proposed conditions models with ice-jams for the 10-, 2-, 1-, and 0.2-percent AEP events (10, 50, 100, and 500-year recurrence intervals).

Scenario ID	Flood Bench Configurations	Reductions in Water Surface Elevations (feet NAVD88)			
		10-Percent	2-Percent	1-Percent	0.2-Percent
1	1a	2.8	1.2	1.2	1.2
2	1b	1.6	0.2	0.1	0.1
3	1b + 2	1.9	1.5	0.6	0.6
4	2 + 3	1.5	1.7	1.6	1.6
5	1b + 2 + 3	1.9	1.7	1.6	1.6
6	2 + 3 + 4	3.1	2.0	1.8	1.7
7	1b + 2 + 3 + 4	3.2	2.0	1.8	1.7
8	5 + 6	1.1	0.5	0.5	0.4
9	1b + 2 + 3 + 4 + 5 + 6	3.6	2.4	2.3	2.1

Scenario #9 provides the greatest overall flood mitigation benefits under ice-jam conditions in the project area with WSEL reductions of up to 3.6-ft. Scenarios #7 and #6 follow with WSEL reductions of up to 3.2- and 3.1-ft, respectively. Table 9 summarizes the WSEL results for the 10-percent AEP event of the existing and proposed conditions with ice-jam models for the reach along the Lexington Green neighborhood (river stations 39+97 to 53+07). Results for higher intensity events that occur less frequently (i.e., 2-, 1- and 0.2-percent) can be found in Attachment F.

Table 9. WSELs (feet NAVD88) in the vicinity of Lexington Green for the existing and proposed conditions with ice-jam models for the 10-percent AEP event.

	Water Surface Elevation (ft NAVD88)						
	RS 39+97	RS 41+82	RS 43+63	RS 45+82	RS 47+86	RS 50+51	RS 53+07
Existing Conditions	595.6	596.0	596.5	597.9	599.1	599.9	600.5
Scenario #1	595.9	596.7	597.1	597.2	597.4	597.5	597.7
Scenario #2	595.6	596.0	596.5	597.9	598.6	599.1	599.4
Scenario #3	595.6	596.0	596.6	597.9	598.6	599.0	599.3
Scenario #4	595.6	596.0	596.5	597.9	599.0	599.7	600.0
Scenario #5	595.6	596.0	596.6	597.9	598.6	599.0	599.3
Scenario #6	595.6	596.0	596.5	597.9	599.0	599.7	600.0
Scenario #7	595.5	596.0	596.5	597.9	598.6	599.0	599.3
Scenario #8	595.6	596.0	596.5	597.9	599.0	599.8	600.2
Scenario #9	595.5	596.0	596.5	597.9	598.6	599.0	599.2

In the vicinity of Lexington Green, Scenario #1 provides the greatest flood mitigation benefits under ice-jam conditions with WSEL reductions of up to 2.8-ft, while Scenarios #9, #7, and #6 follow with reductions of up to 1.3- and 1.2-ft, respectively. Figures 20 through 28 display the HEC-RAS profile plot results for the ice-jam simulations of each flood bench scenario compared to the existing conditions WSELs using the USGS *StreamStats* 10-, 2-, 1-, and 0.2-percent AEP event peak discharges. Where the flood extents for both the proposed and existing conditions with ice-jam models overlap, the flood extents will appear as purple on the figures.

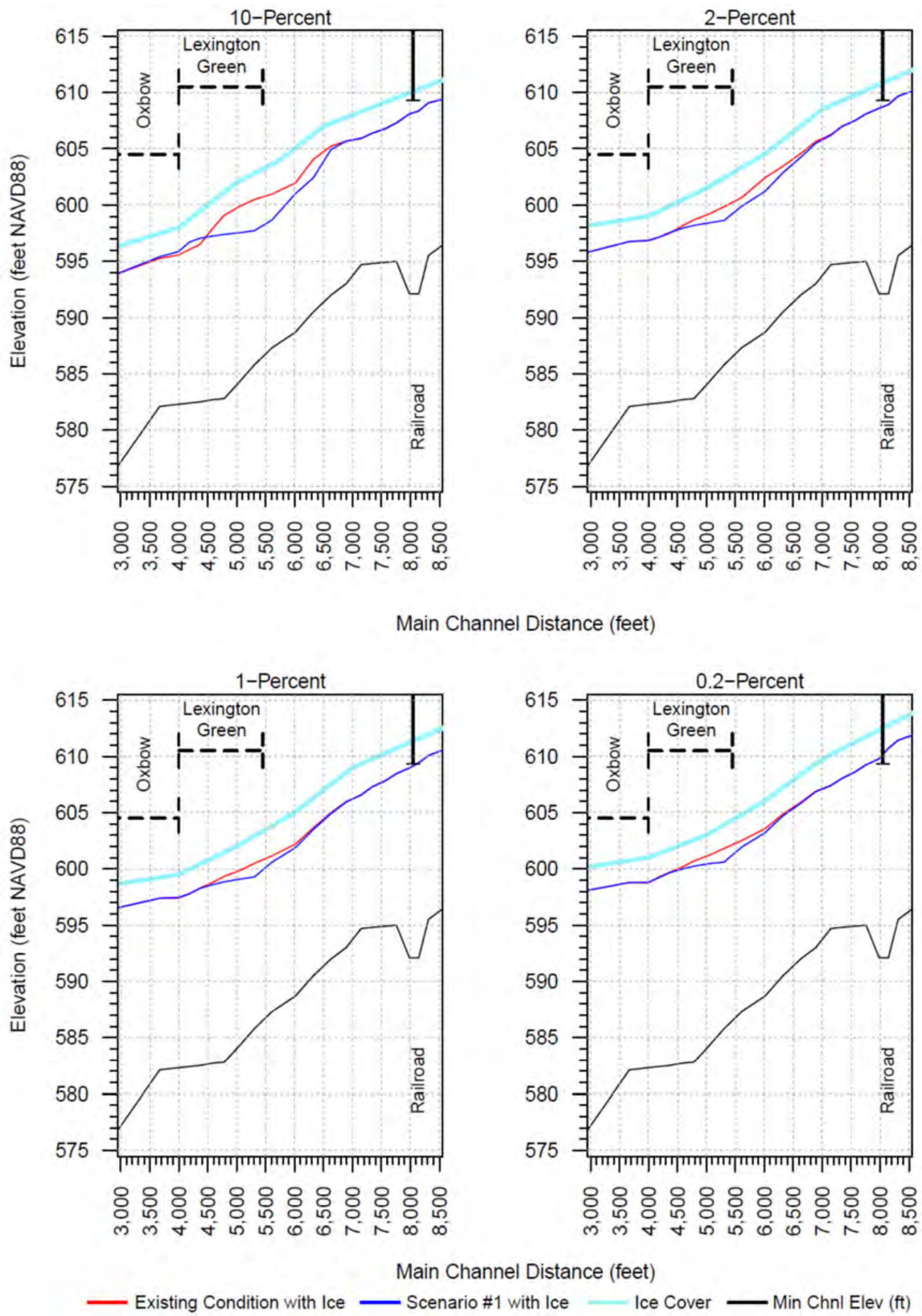

Figure 20. HEC-RAS model profile plots for Flood Bench Scenario #1 under ice cover conditions.

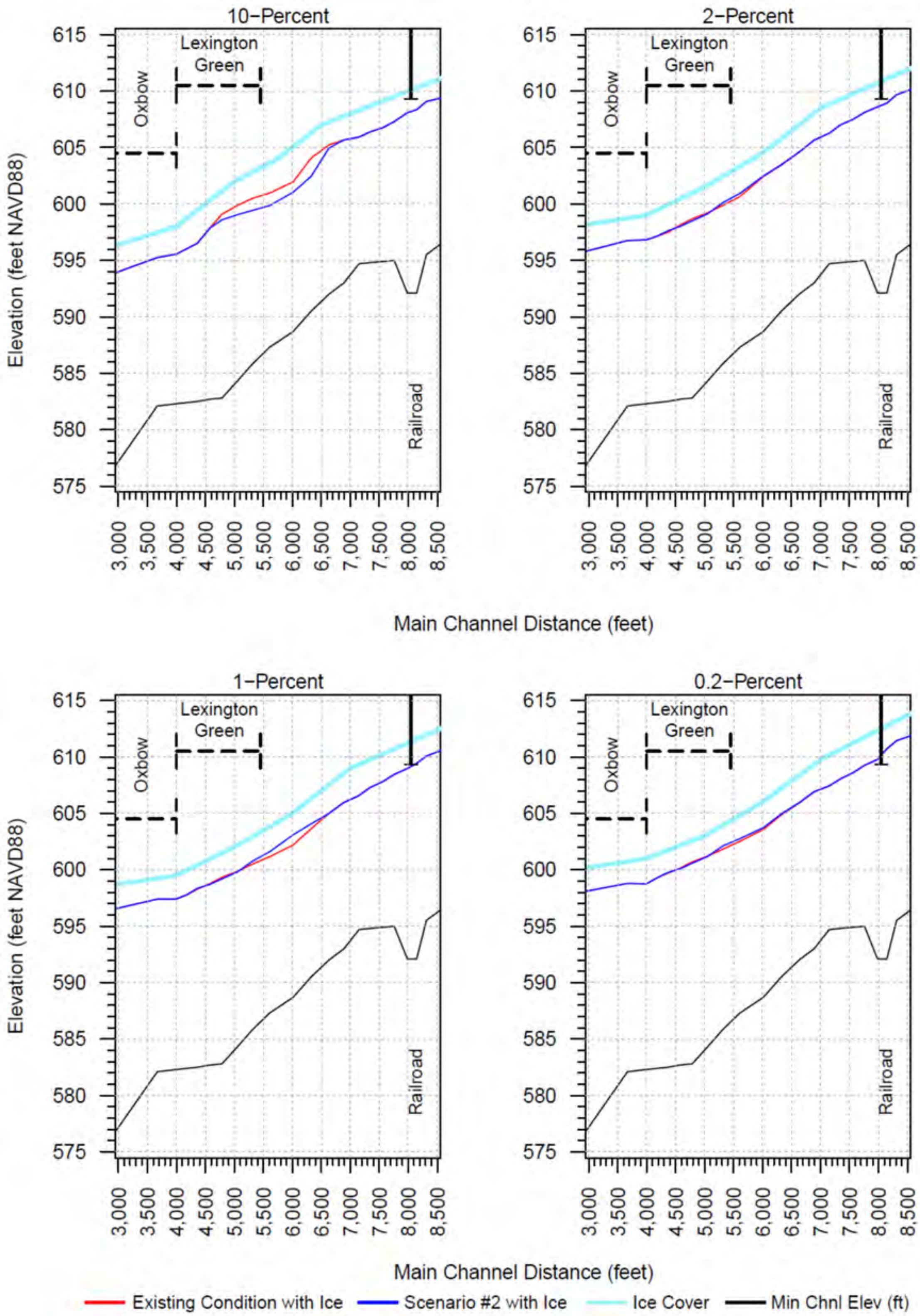

Figure 21. HEC-RAS model profile plots for Flood Bench Scenario #2 under ice cover conditions.

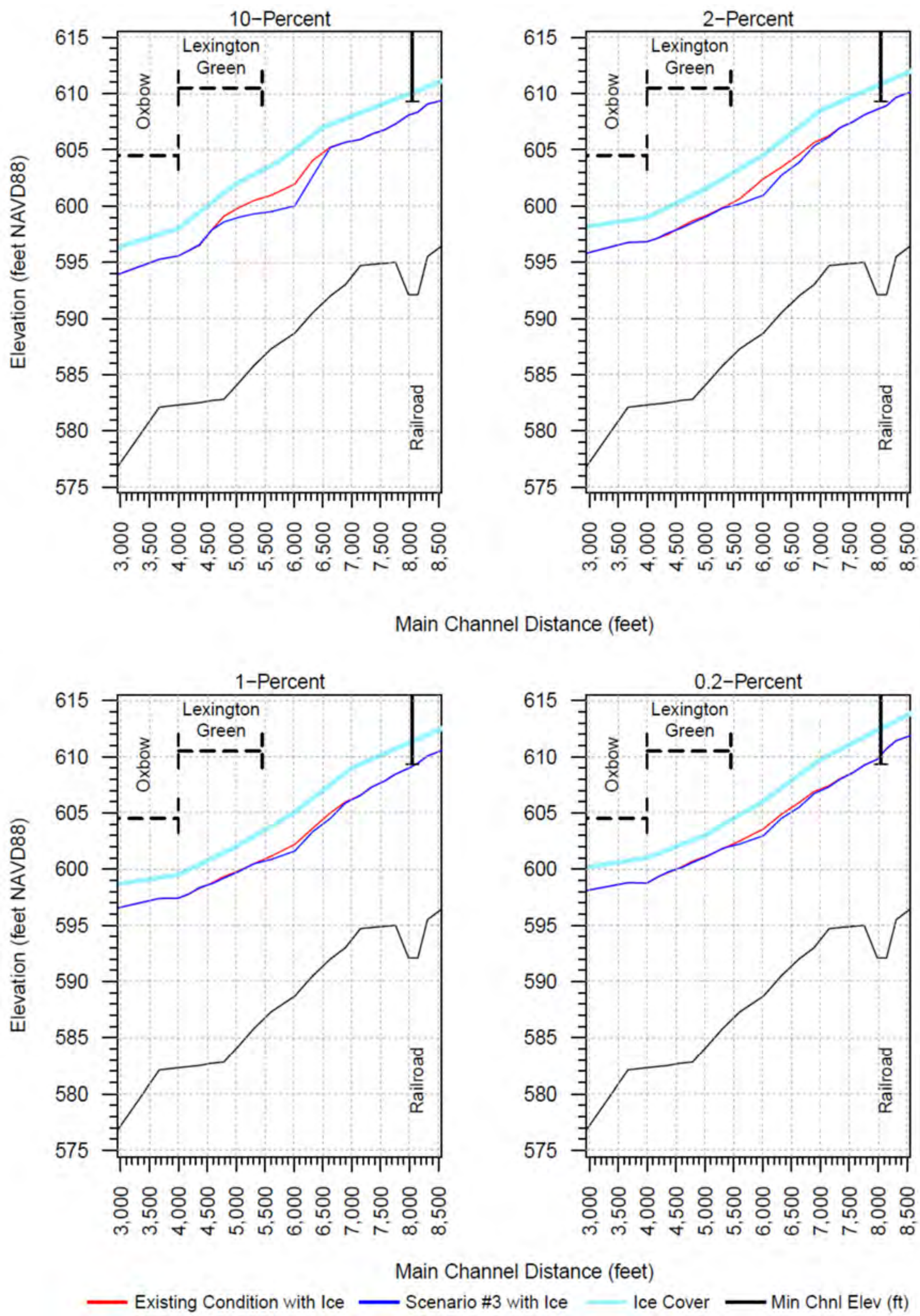

Figure 22. HEC-RAS model profile plots for Flood Bench Scenario #3 under ice cover conditions.

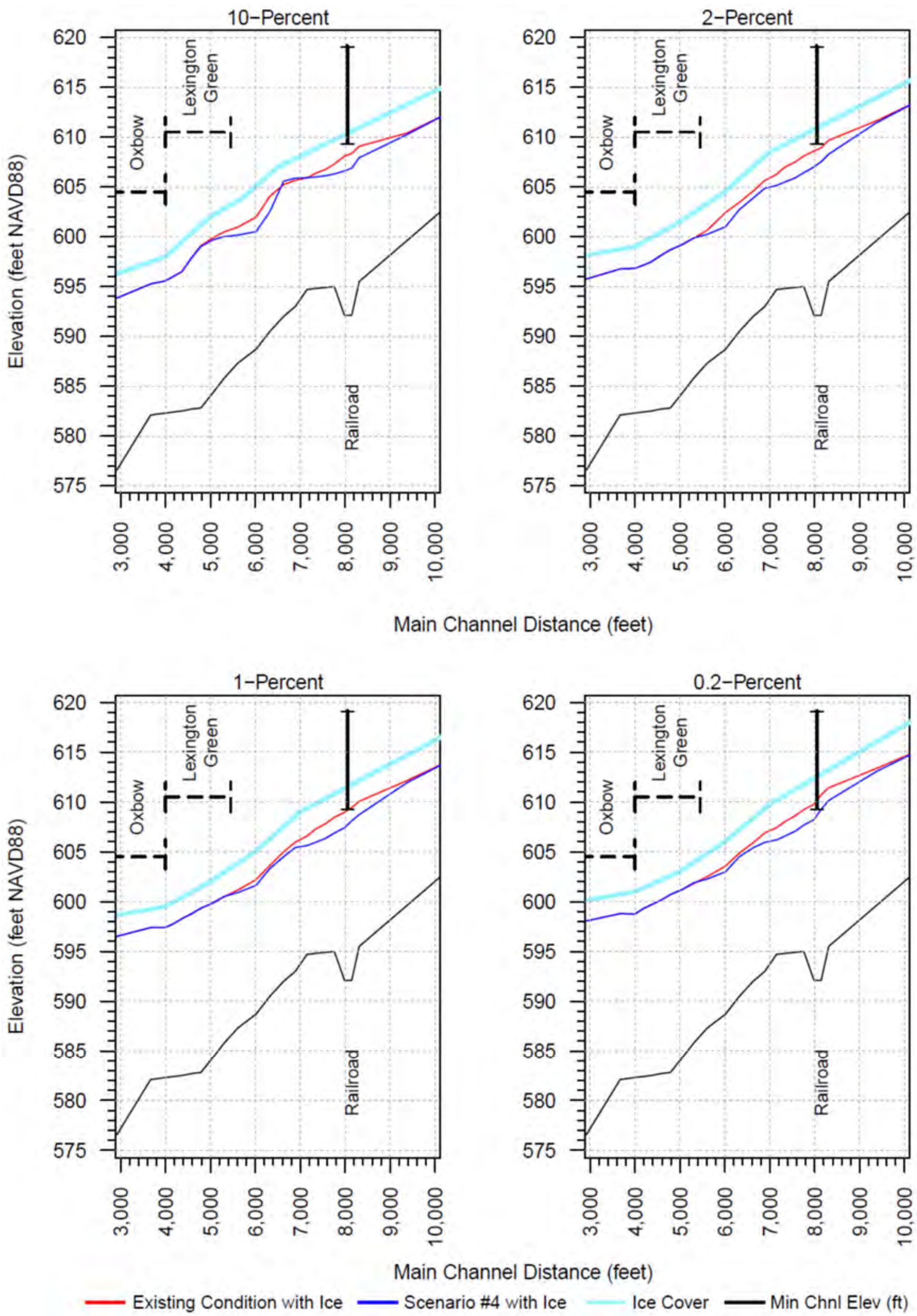

Figure 23. HEC-RAS model profile plots for Flood Bench Scenario #4 under ice cover conditions.

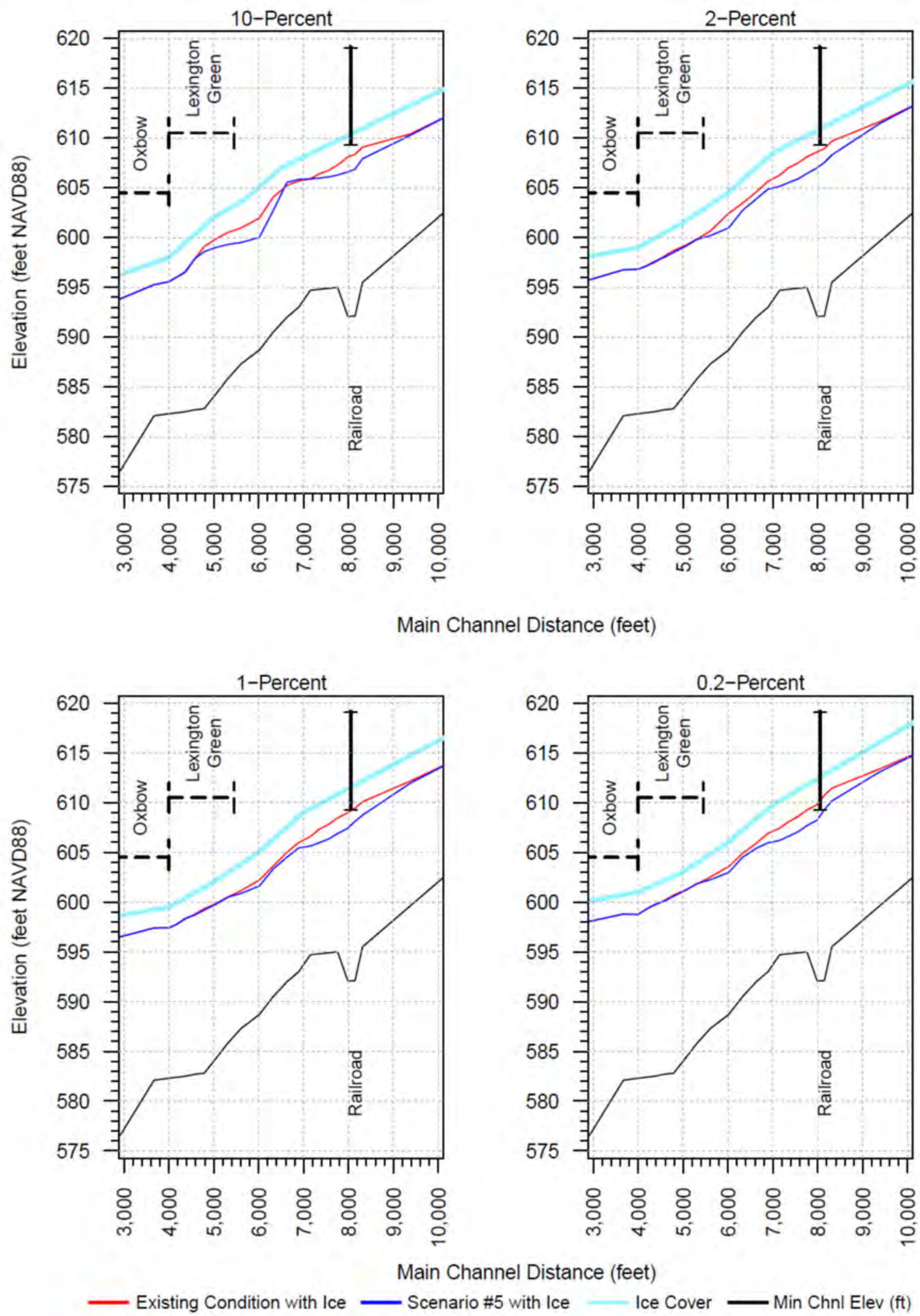

Figure 24. HEC-RAS model profile plots for Flood Bench Scenario #5 under ice cover conditions.

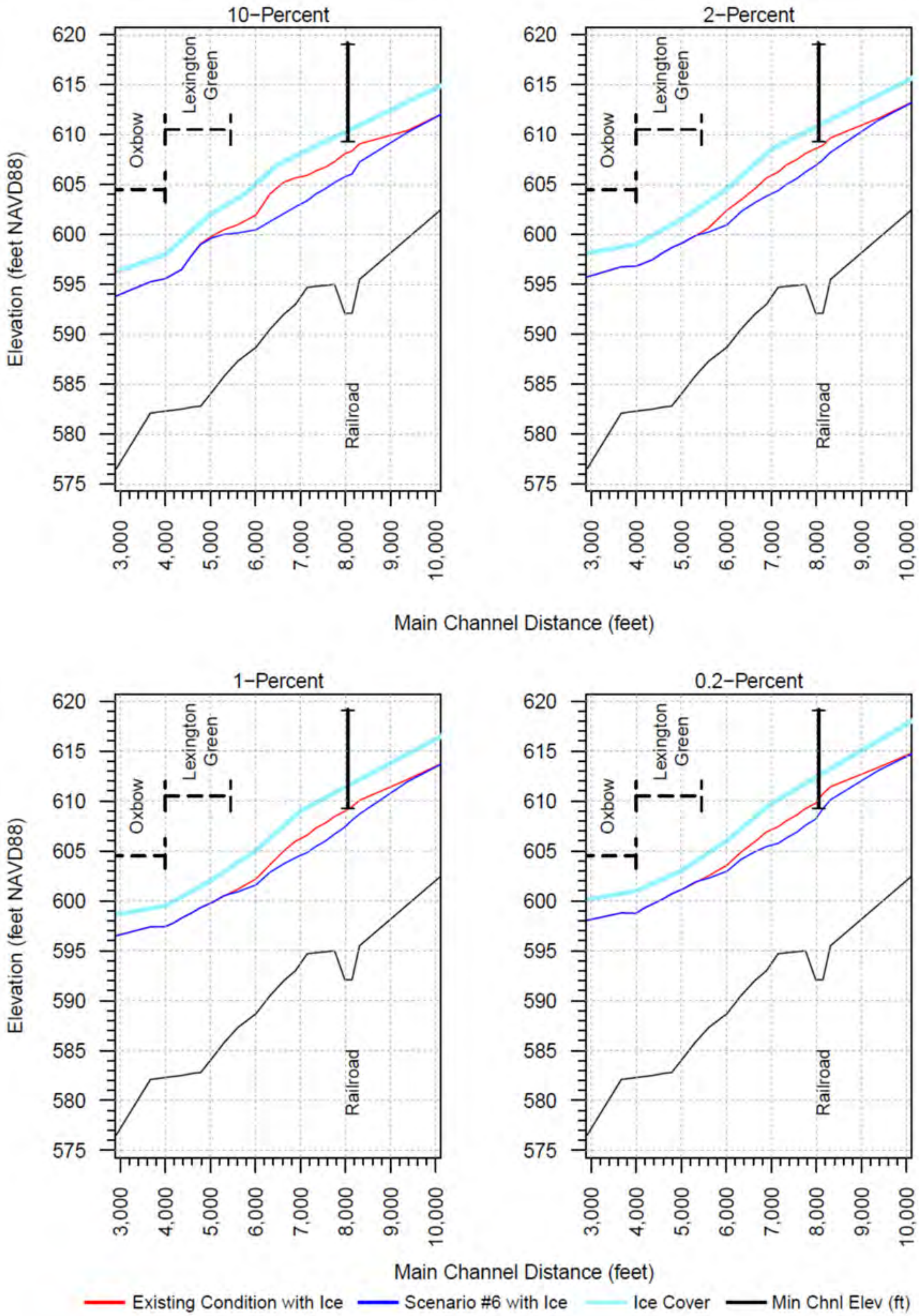

Figure 25. HEC-RAS model profile plots for Flood Bench Scenario #6 under ice cover conditions.

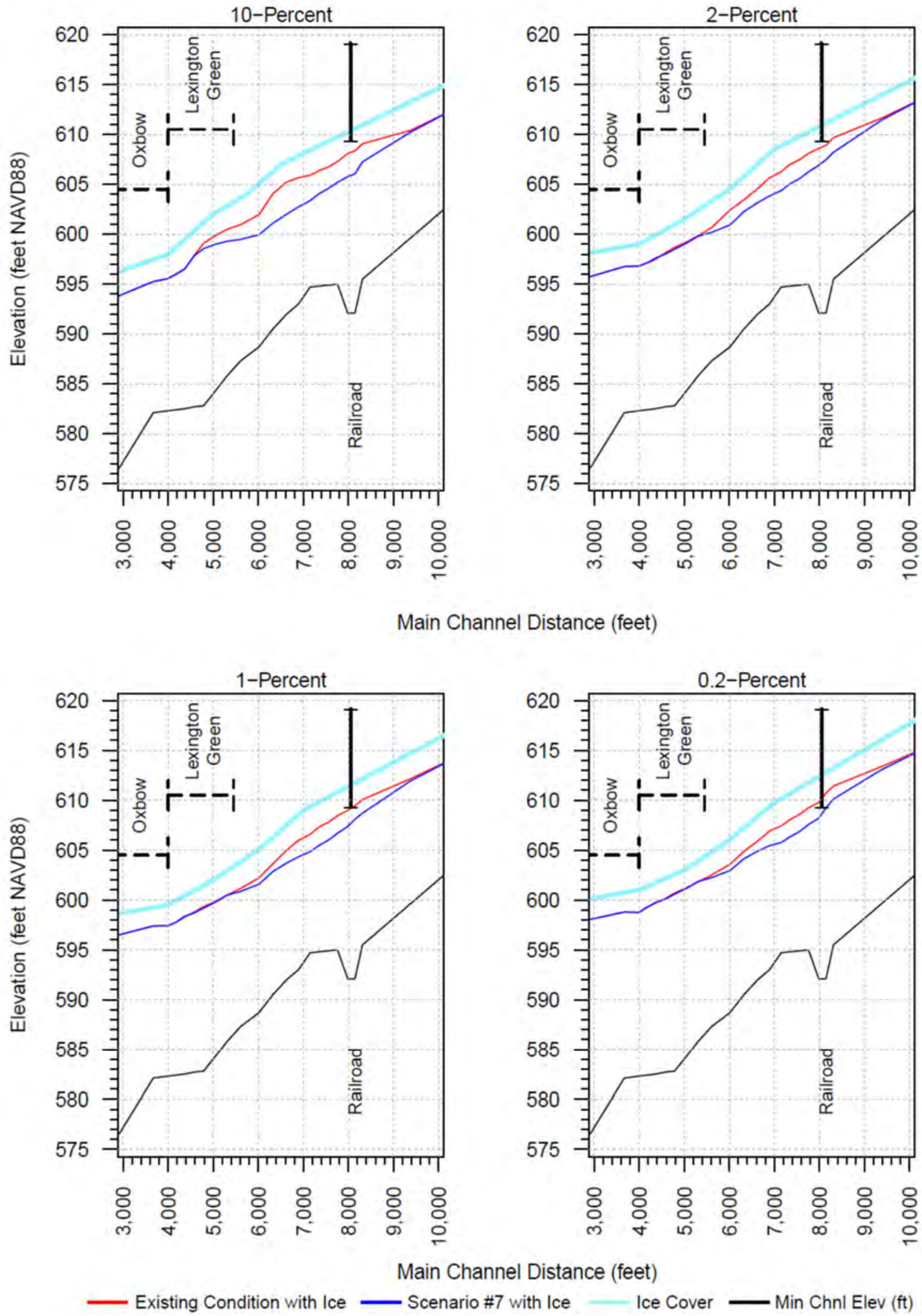

Figure 26. HEC-RAS model profile plots for Flood Bench Scenario #7 under ice cover conditions.

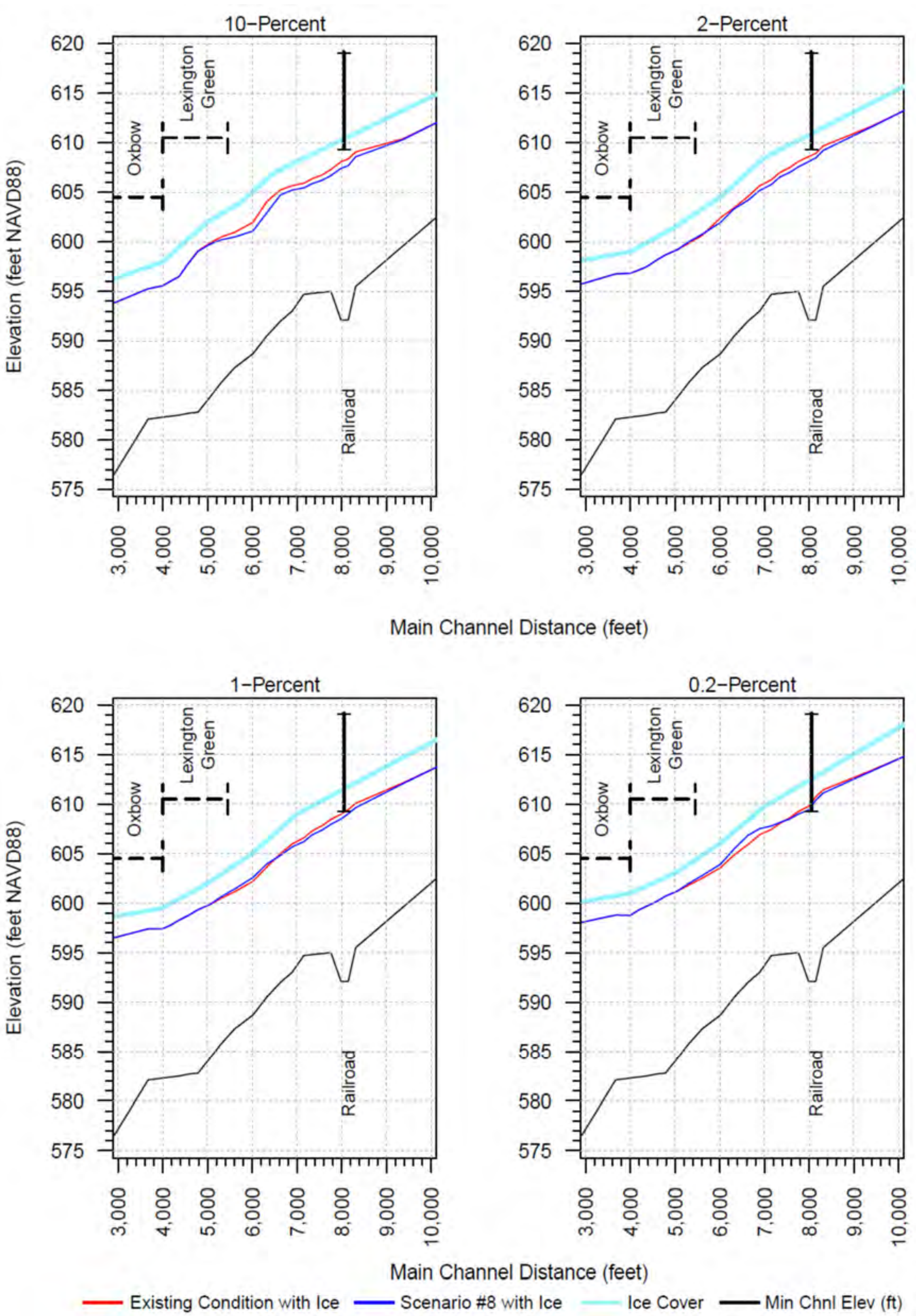

Figure 27. HEC-RAS model profile plots for Flood Bench Scenario #8 under ice cover conditions.

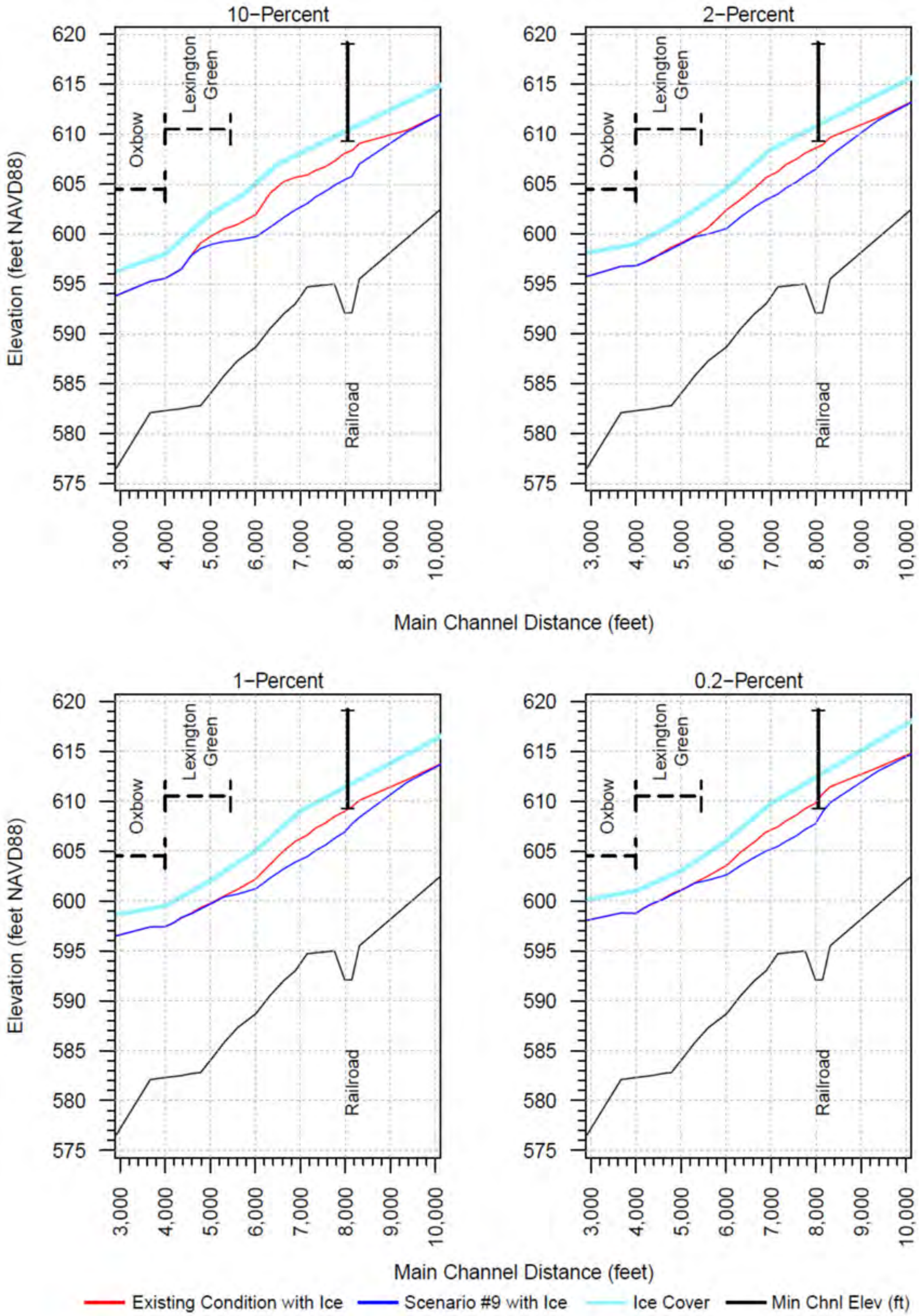

Figure 28. HEC-RAS model profile plots for Flood Bench Scenario #9 under ice cover conditions.

2.5 Bank and Channel Stabilization Features

Streambank erosion is a natural process that occurs when the forces of flowing water exceed the ability of the soil and vegetation to hold the banks in place. The forces that cause erosion increase during flood events, and most erosion occurs at these times. Human disturbances to watersheds that increase frequency and magnitude of runoff events also increase streambank erosion. Loss of streambank and streamside vegetation reduces the resisting forces and makes streambanks more susceptible to erosion. This is often the single greatest contributing factor to harmful or accelerated erosion on small and medium-size streams (GASWCC 2000).

Streambank stabilization measures work either by reducing the force of flowing water, by increasing the resistance of the bank to erosion, or by some combination of both. Generally speaking, there are four approaches to streambank protection: 1) the use of vegetation; 2) soil bioengineering; 3) the use of rock work in conjunction with plants; and 4) conventional bank armoring (GASWCC 2000).

Bank and channel stabilization features are dependent on two forces: velocity and shear stress. Velocity in a waterway is controlled by a number of factors, including friction slope, channel geometry, size of sediments on the stream bed, and the discharge (volume) of water passing a point in a unit of time. A stream typically reaches its greatest velocity when it is close to flooding over its banks, known as the bank-full stage. As soon as the flooding stream overtops its banks and occupies the wide area of its flood plain, the water has a much larger area to flow through and the velocity drops significantly. At this point, sediment that was being carried by the high-velocity water is deposited near the edge of the channel, forming a natural bank or levee (Earle 2019).

Shear stress is the parameter often used as a measure of the stream's ability to entrain bed material, which is created by the friction from water acting on the bed material. Generally, shear stress acts in the direction of the flow in a uniform channel as it slides along the channel bed and banks.

Channel shear stress and velocity values were obtained from the existing conditions model simulation results (Attachment E). For the reach of Buffalo Creek that runs adjacent to the Lexington Green neighborhood between river stations (RS) 40+00 to 65+50, the maximum shear stress and velocity value was 1.3 lb/sq ft and 8.7 ft/s for the 1-percent AEP. Table 10 displays the channel maximum shear stress (lb/sq ft) and velocity (ft/s) for the existing conditions model.

Table 10. Existing Conditions Model Results for Channel Maximum Shear Stress and Velocity.

River Station (ft)	Channel Maximum Shear Stress (lb/sq ft)				Channel Maximum Velocity (ft/s)			
	10-Percent	2-Percent	1-Percent	0.2-Percent	10-Percent	2-Percent	1-Percent	0.2-Percent
204+83	0.9	1.2	1.3	1.7	7.1	8.7	9.3	10.5
193+13	1.3	1.6	1.7	1.9	8.4	9.7	10.2	10.9
182+44	0.9	1.0	1.0	1.1	7.0	7.7	7.9	8.5
170+53	0.9	1.2	1.2	1.4	7.3	8.4	8.8	9.7
157+51	1.1	1.3	1.4	1.6	7.7	8.9	9.3	10.1

River Station (ft)	Channel Maximum Shear Stress (lb/sq ft)				Channel Maximum Velocity (ft/s)			
	10-Percent	2-Percent	1-Percent	0.2-Percent	10-Percent	2-Percent	1-Percent	0.2-Percent
144+03	0.7	0.7	0.7	0.7	6.2	6.5	6.5	6.5
129+86	0.7	0.6	0.6	0.5	6.2	6.3	6.2	6.1
121+62	1.3	1.7	1.9	2.0	8.6	10.3	11.0	11.7
119+55	1.4	1.8	2.0	2.4	9.0	10.6	11.3	12.6
117+89	1.9	2.6	3.0	4.1	10.1	12.3	13.4	15.8
116+75	0.9	1.4	1.6	2.2	7.4	9.2	10.1	12.0
103+02	1.2	1.4	1.4	1.8	7.9	8.9	9.1	10.6
93+72	2.4	3.0	3.2	2.6	10.7	12.5	13.2	12.4
83+12	0.2	0.3	0.3	0.4	3.7	4.3	4.6	5.2
81+45	0.2	0.3	0.4	0.6	3.6	4.8	5.3	6.4
79+84	0.5	0.8	0.9	1.3	5.2	6.8	7.6	9.3
77+58	0.6	0.7	0.8	0.9	6.0	6.7	7.0	7.7
75+64	0.7	0.7	0.7	0.7	6.2	6.4	6.5	6.7
73+40	0.6	0.6	0.6	0.6	5.7	6.0	6.1	6.2
71+51	0.7	0.8	0.8	0.6	6.2	6.9	6.9	6.1
68+90	0.7	0.7	0.6	0.6	6.2	6.2	6.1	6.1
66+31	0.9	1.1	1.1	1.2	6.7	7.7	8.0	8.6
63+24	0.6	0.8	0.9	1.2	5.9	7.0	7.4	8.5
60+15	1.3	1.3	1.3	1.3	8.1	8.5	8.7	9.1
56+07	0.8	0.9	0.9	0.9	6.7	7.2	7.3	7.8
53+07	0.6	0.6	0.7	0.8	5.7	6.3	6.6	7.5
50+51	0.6	0.7	0.8	0.8	5.7	6.6	6.9	7.4
47+86	0.6	0.8	0.8	0.8	6.0	7.0	7.3	7.6
45+82	0.7	0.9	0.9	1.0	6.4	7.4	7.7	8.2
43+63	0.6	0.9	1.0	1.2	6.2	7.4	7.9	8.8
41+82	0.7	0.9	1.0	1.3	6.2	7.5	8.0	9.2
39+97	0.6	0.8	1.0	1.3	6.0	7.2	7.8	9.2
36+70	0.4	0.4	0.4	0.5	5.1	5.2	5.4	5.8
29+21	0.4	0.5	0.5	0.5	4.9	5.8	6.0	6.2
19+22	0.1	0.2	0.2	0.2	3.2	3.3	3.5	3.7
8+33	0.1	0.1	0.1	0.1	2.7	2.8	2.8	3.0

River Station (ft)	Channel Maximum Shear Stress (lb/sq ft)				Channel Maximum Velocity (ft/s)			
	10-Percent	2-Percent	1-Percent	0.2-Percent	10-Percent	2-Percent	1-Percent	0.2-Percent
2+79	0.1	0.1	0.1	0.1	2.8	3.0	3.1	3.3

Table 11 summarizes the bank and channel stabilization strategies that could potentially be employed along Buffalo Creek in the vicinity of the Lexington Green neighborhood (RS 40+00 to 66+50) for the 1-percent AEP event. It should be noted that the identified bank and channel stabilization strategies are not intended to represent a fully comprehensive list and are based on the preliminary analysis performed in this study. Additional geomorphic research and advanced multi-dimensional open-water and ice-jam modeling is recommended to determine the most appropriate strategy for this reach of Buffalo Creek.

Table 11. Bank and channel stabilization strategies along Buffalo Creek for the 1-percent AEP event.

Measure Type	Treatment Type	Description of Measure
Brush Mattress	Staked only w/ rock riprap toe (grown)	Brush mattresses slow water velocities along the streambank and reduce erosion. The open space between the woody material allows for sediment deposition and water drainage. The build-up of sediment enhances the colonization of native plants.
Coir Geotextile Roll	Roll with Polypropylene rope mesh staked and with rock riprap toe	Coir geotextiles protect land surfaces, help with soil stabilization, promote vegetation growth in varying slopes, and provide erosion control.
Gravel / Cobble	12-inch	Cobble or gravel armor is used to protect a sloping bank against fluvial entrainment by flow in the stream or over the top of the bank.
Soil Bioengineering	Vegetated coir mat	Soil bioengineering methods have a common geotechnical benefit of providing root reinforcement in the soil and can help modify drainage patterns of the soil, help stabilize soils at steeper angles if desired, help keep grasses, and bushy vegetation in place resisting erosion, and support woody debris or other types of vegetation.
	Live brush mattress (grown)	
	Brush layering (initial/grown)	
Boulder Clusters	Small (>10-inch diameter) and larger	Boulder clusters can prevent large buildup of wood and reduce flood and bank erosion.

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