Intended for

**New York State Department of Environmental Conservation**

**625 Broadway**

**Albany, New York 12233**

Document type

**Report**

Date

**April 2021**

# RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

# SILVER CREEK, CHAUTAUQUA COUNTY, NEW YORK

Prepared for:

New York State Office of General Services

New York State Department of Environmental Conservation

Project Team:

OBG Part of Ramboll

Gomez and Sullivan Engineers

Highland Planning

# RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE
# SILVER CREEK, CHAUTAUQUA COUNTY, NEW YORK

| | |
|---|---|
| Project name | **Resilient New York Flood Mitigation Initiative – Silver Creek, Chautauqua County, New York** |
| Project no. | **SD121** |
| Recipient | **New York State Office of General Services** |
| Document type | **Report** |
| Version | **Final** |
| Date | **December 2, 2020** |
| Prepared by | **Kevin Grim, P.E.** |
| Checked by | **Kadir Goz, Margaret Reilly, P.E., Ahintha Kandamby, Ph.D., P.E., CFM** |
| Approved by | **Shaun B. Gannon, P.E., D.WRE, P.H., CFM** |


Ramboll
101 First Street
4th Floor
Utica, NY 13501
USA

T 315-956-6950
F 315-790-5434
https://ramboll.com

**IN NOVEMBER 2018, NEW YORK STATE GOVERNOR ANDREW CUOMO COMMITTED FUNDING TO UNDERTAKE ADVANCED MODELING TECHNIQUES AND FIELD ASSESSMENTS OF 48 FLOOD PRONE STREAMS TO IDENTIFY PRIORITY PROJECTS AND ACTIONS TO REDUCE COMMUNITY FLOOD AND ICE JAM RISKS, WHILE IMPROVING HABITAT. THE OVERALL GOAL OF THE PROGRAM IS TO MAKE NEW YORK STATE MORE RESILIENT TO FUTURE FLOODING.**

Ramboll
101 First Street
4th Floor
Utica, NY 13501
USA

T 315-956-6950
F 315-790-5434
https://ramboll.com

# TABLE OF CONTENTS

## TABLE OF TABLES

## TABLE OF FIGURES

## APPENDICES

Appendix A: Summary of Data and Reports

Appendix B: Mitigation Renderings

Appendix C: Ice-Jam Mitigation Strategies

Appendix D: Virtual Meeting Attendee List

Appendix E: HEC-RAS Simulation Output

## ACRONYMS/ABBREVIATIONS

| | |
|---|---|
| 1-D | 1-Dimensional |
| 2-D | 2-Dimensional |
| ACE | Annual Chance Flood Event |
| BCA | Benefit-Cost Analysis |
| BCR | Benefit-Cost Ratio |
| BFE | Base Flood Elevation |
| BRIC | Building Resilient Infrastructure and Communities |
| CCSWD | Chautauqua County Soil and Water Conservation District |
| CDBG | Community Development Block Grant |
| CEHA | Coastal Erosion Hazard Area |
| CFA | Consolidated Funding Applications |
| CFS | Cubic Feet per Second ($ft^3/s$) |
| CMIP5 | 5th Phase of the Coupled Model Intercomparison Project |
| CRISSP | Comprehensive River Ice Simulation System |
| CRRA | Community Risk and Resiliency Act |
| CRREL | Cold Regions Research and Engineering Laboratory |
| CRS | Community Rating System |
| CSC | Climate Smart Communities |
| CWSRF | Clean Water State Revolving Fund |
| DEM | Digital Elevation Model |
| DHS | United States Department of Homeland Security |
| DRRA | Disaster Recovery Reform Act of 2018 |
| EPA | Environmental Protection Agency |
| EPG | Engineering Planning Grant |
| ESD | Empire State Development Corporation |
| ESRI | Environmental Systems Research Institute |
| EWP | Emergency Watershed Protection |
| FCA | Flood Control Act |
| FDD | Freezing Degree-Day |
| FEMA | Federal Emergency Management Agency |
| FHF | Flood Hazard Factor |
| FIRM | Flood Insurance Rate Map |
| FIS | Flood Insurance Study |
| FMA | Flood Mitigation Assistance |
| FT | Feet |
| GIS | Geographic Information System |
| GLS | Generalized Least Squares |
| GSE | Gomez & Sullivan Engineers |

| | |
|---|---|
| H&H | Hydrologic and Hydraulic |
| HEC | Hydrologic Engineering Center |
| HEC-RAS | Hydrologic Engineering Center's River Analysis System |
| HMA | Hazard Mitigation Assistance |
| HSGP | Homeland Security Grant Program |
| HUD | United States Department of Housing and Urban Development |
| IPaC | Information for Planning and Consulting |
| LOMR | Letter of Map Revision |
| LP3 | Log-Pearson Type III |
| NAVD 88 | North American Vertical Datum of 1988 |
| NCEI | National Center for Environmental Information |
| NFIP | National Flood Insurance Program |
| NPFA | Natural Protective Feature Area |
| NRCS | Natural Resources Conservation Service |
| NWI | National Wetlands Inventory |
| NWS | National Weather Service |
| NYS | New York State |
| NYSDEC | New York State Department of Environmental Conservation |
| NYSDHSES | New York State Division of Homeland Security and Emergency Services |
| NYSDOT | New York State Department of Transportation |
| NYSEFC | New York State Environmental Facilities Corporation |
| NYSOEM | New York State Office of Emergency Management |
| NYSOGS | New York State Office of General Services |
| NYSOPRHP | New York State Office of Parks, Recreation, and Historic Places |
| RAMBOLL | OBG, Part of Ramboll |
| PA | Pennsylvania |
| PDM | Pre-Disaster Mitigation |
| RC | Circularity Ratio |
| RE | Elongation Ratio |
| RF | Form Factor |
| RF | Radio Frequency |
| RICEN | River Ice Simulation Model |
| RL | Repetitive Loss |
| ROM | Rough Order of Magnitude |
| SFHA | Special Flood Hazard Area |
| SFHE | Special Flood Hazard Evaluation |
| SHA | Structural Hazard Area |
| SIR | Scientific Investigations Report |
| SQ MI | Square Miles ($mi^2$) |
| SRL | Severe Repetitive Loss |
| TOGS | Technical & Operational Guidance Series |
| USACE | United States Army Corps of Engineers |
| USFWS | United States Fish & Wildlife Service |
| USGS | United States Geologic Service |
| USSCS | United States Soil Conservation Service |
| WCRP | World Climate Research Programme |
| WGCM | Working Group Coupled Modelling |
| WQIP | Water Quality Improvement Project |
| WRI | Water Resources Investigations |

# 1. INTRODUCTION

## 1.1 HISTORICAL INITIATIVES

Flood mitigation has been an initiative in western New York and in the Silver Creek watershed, where the Silver Creek and its tributary, Walnut Creek, have historically caused significant flooding in the Village of Silver Creek. Flooding most frequently occurs during ice-jam events, which can happen as often as every spring. In addition, flooding can occur during high-flow events unrelated to ice jamming. Two notable events include flooding during rainfall associated with Hurricane Agnes in 1972 (FEMA 1983b), and more recently during an isolated precipitation event in 2009 (USACE 2017b).

There are no existing large-scale flood-mitigation projects in the Village of Silver Creek (USACE 2017b). The Village of Silver Creek typically relies on mechanical methods to break up ice cover and alleviate ice jams in the village (Alexander 2018). In response to flooding damage due to the 2009 flooding events, $35 million in grant funding was released by the Federal Emergency Management Agency (FEMA) for repairs. A portion of the grant money was allocated for measures such as replacing and raising mobile homes impacted by flooding, and to perform small-scale flood protection measures on waterways in the village (Goshgarin 2019).

Multiple studies have been performed on the Silver Creek watershed including two FEMA Flood Insurance Studies (FIS), released in 1983 and 1984, a United States Geologic Survey (USGS) Scientific Investigations Report (SIR) on the 2009 flooding, and a United States Army Corps of Engineers (USACE) Special Flood Hazard Evaluation (SFHE) in 2017 (FEMA 1983b; FEMA 1984b; USGS 2010; USACE 2017b).

## 1.2 FLOODPLAIN DEVELOPMENT

General recommendations for high-risk floodplain development follow three basic strategies:

1. Remove the flood prone facilities from the floodplain
2. Adapt the facilities to be flood resilient under repetitive inundation scenarios
3. Develop nature-based mitigation measures (e.g., floodplain benches, constructed wetlands, etc.) to lower flood stages in effected areas
4. Up-size bridges and culverts to be more resilient to ice jams, high flow events, and projected future flood flows due to climate change in effected areas

In order to effectively mitigate flooding along substantial lengths of a watercourse corridor, floodplain management should restrict the encroachment on natural floodplain areas. Floodplains act to convey floodwaters downstream, mitigate damaging velocities, and provide areas for sediment to accumulate safely. The reduction in floodplain width of one reach of a stream, often leads to the increase in flooding upstream or downstream. During a flood event, a finite amount of water with an unchanging volume must be conveyed and, as certain conveyance areas are encroached upon, floodwaters will often expand into other sensitive areas.

A critical evaluation of existing floodplain law and policies should be undertaken to evaluate the effectiveness of current practices and requirements within this watershed. Local floodplain regulations should be consistent with the National Flood Insurance Program (NFIP) and FEMA regulations since the Village of Silver Creek is a participating community in the NFIP and should involve a floodplain coordinator and a site plan review process for all proposed developments. This review should be in accordance with local regulations and the NFIP requirements, which require the community to determine if any future proposed development could adversely impact the floodplain or floodway resulting in higher flood stages and sequentially greater economic losses to the community (FEMA 2019).

## 1.3 RESILIENT NY INITIATIVE

In November of 2018, New York State (NYS) Governor Andrew Cuomo announced the Resilient NY program in response to devastating flooding in communities across the State in the preceding years. A total of 48 high-priority flood prone watersheds across New York State are being addressed through the Resilient NY program. Flood mitigation studies were commissioned using advanced modeling techniques and field assessments to identify priority projects in these 48 flood-prone watersheds, develop state-of-the-art studies to reduce flooding and ice jams, and to improve ecological habitats in the watersheds (NYSGPO 2018). The Silver Creek watershed was chosen as a study site for this initiative.

The New York State Department of Environmental Conservation (NYSDEC) is responsible for implementing the Resilient NY program with contractual assistance from the New York State Office of General Services (NYSOGS). High-priority watersheds were selected based on several factors, such as frequency and severity of flooding and ice jams, extent of previous flood damage, and susceptibility to future flooding and ice-jam formations (NYSGPO 2018).

The Resilient NY flood studies will identify the causes of flooding within each watershed and develop, evaluate, and recommend effective and ecologically sustainable flood and ice-jam hazard mitigation projects. Proposed flood mitigation measures will be identified and evaluated using hydrologic and hydraulic modeling to quantitatively determine flood mitigation recommendations that would result in the greatest flood reductions benefits. In addition, the flood mitigation studies incorporate the latest climate change forecasts and assess ice-jam hazards where jams have been identified as a threat to public health and safety.

This report is not intended to address detailed design considerations for individual flood mitigation alternatives. The mitigation alternatives discussed are conceptual projects that have been initially developed and evaluated to determine their flood mitigation benefits. A more in-depth engineering design study would still be required for any mitigation alternative chosen to further define the engineering project details. However, the information contained within this study can inform such in-depth engineering design studies and be used in the application of state and federal funding and/or grant programs.

***The goals of the Resilient NY Program are to:***

1. Perform comprehensive flood and ice jam studies to identify known and potential flood risks in flood-prone watersheds
2. Incorporate climate change predictions into future flood models
3. Develop and evaluate flood hazard mitigation alternatives for each flood-prone stream area, with a focus on ice-jam hazards

The overarching purpose of the initiative is to recommend a suite of flood and ice-jam mitigation projects that local municipalities can undertake to make their community more resilient to future floods. The projects should be affordable, attainable through grant funding programs, able to be implemented either individually or in combination in phases over the course of several years, achieve measurable improvement at the completion of each phase, and fit with the community way of life.

The flood mitigation and resiliency study for Silver Creek began in February of 2020 and a final flood study report was issued in November of 2020.

# 2. DATA COLLECTION

## 2.1 INITIAL DATA COLLECTION

Hydrological and meteorological data were obtained from readily available state and federal government databases, including ortho-imagery, flood zone maps, streamflow, precipitation, flooding and ice jam reports. Historical flood reports, newspaper articles, social media posts, community engagement meeting notes, and geographic information system (GIS) mapping were used to identify stakeholder concerns, produce watershed maps, and identify current high-risk areas. New York State Community Risk and Resiliency Act (CRRA) draft guidelines (NYSDEC 2018), New York State Department of Transportation (NYSDOT) bridge and culvert standards, and USGS *FutureFlow Explorer* v1.5 (USGS 2016) and *StreamStats* v4.3.11 (USGS 2017) software were used to develop current and future potential discharges and bankfull widths and depths at various points along the stream channel. Hydrologic and hydraulic (H&H) modeling was performed previously, as part of the 1983 FEMA FIS for the Village of Silver Creek.

Updated H&H modeling was performed as part of a USACE Special Flood Hazard Evaluation using the USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 5.0.7 software (USACE 2019) to determine 1% and 0.2% annual chance flood hazard flood zones. The USACE HEC-RAS model was adapted for use in this study. These studies and data sources were obtained and used, all or in part, as part of this effort. Appendix A is a summary listing of data and reports collected.

## 2.2 PUBLIC OUTREACH

A series of virtual initial project kickoff meetings were held in April 2020, with representatives of OBG, Part of Ramboll (Ramboll), Chautauqua County Soil and Water Conservation District (CCSWD), NYSDOT, Village of Silver Creek, Cattaraugus County, Chautauqua County, and Highland Planning, LLC (Appendix D). At the project kickoff meetings project specifics including background, purpose, funding, roles, and timelines were discussed. Discussions included a variety of topics, including:

- Firsthand accounts of past flooding events
- Identification of specific areas that flooded in each community, and the extent and severity of flood damage
- Information on post-flood efforts, such as temporary floodwalls

This outreach effort assisted in the identification of current high-risk areas to focus on during the future flood risk assessments. Additional project meetings will be planned to include a summary of study procedures, recommended flood mitigation measures, and the results of H&H modeling.

## 2.3 FIELD ASSESSMENT

In-person field data collection efforts were not performed for this report due to travel restrictions and potential health risks to field crews associated with the 2020 Coronavirus pandemic in New York State. Instead, satellite imagery, photographs, maps, and street-level views from multiple sources were used. Additionally, the base model was provided by the U.S. Army Corps of Engineers (USACE 2017a) based on high-quality and field-surveyed data, and therefore contains much of the information which ordinarily would have been collected by in-person field assessment.

All references to “right bank” and “left bank” in this report refer to "river right" and "river left," meaning the orientation assumes that the reader is looking downstream.

# 3. WATERSHED CHARACTERISTICS

## 3.1 STUDY AREA

The Silver Creek watershed study areas lies primarily within Chautauqua County with a small portion of the watershed extending into Cattaraugus County. The creek flows in a general north / northwest direction with its headwaters at East Mud Lake in the Town of Villenova, and passes through the Town of Hanover and the Village of Silver Creek before it confluences with Walnut Creek and then empties into Lake Erie (Figure 3-1). Silver Creek, within the Village of Silver Creek and continuing downstream to its outlet at Lake Erie, was chosen as the study area due to historical flooding issues and the hydrologic conditions of the creek. Figure 3-2 and Figure 3-3 depict the stream stationing along Silver Creek in Chautauqua County, and the study area in the Village of Silver Creek and upstream, respectively. Note the stationing was developed by Ramboll and may differ from stationing shown in FEMA Flood Insurance Studies (FIS) developed for Silver Creek. Stationing may differ due to differences in data sources and methodologies. The stationing used in this report was calculated using the Environmental Systems Research Institute's (ESRI) ArcMap version 10.7.1 software package (ESRI 2019).

The Village of Silver Creek is located in the northeastern portion of Chautauqua County in western New York State. The Village occupies 1.3 $mi^2$ (square miles) and is situated approximately 28 miles southwest of the City of Buffalo, NY and 55 miles northeast of the City of Erie, Pennsylvania (PA). Incorporated in 1848, the Village is bordered by Lake Erie to the north, the Town of Hanover to the east and south, and the Town of Sheridan to the west. The predominant hydrologic feature of the Village is Lake Erie, where all streams that flow through the Village ultimately flow. The lake shoreline is relatively flat with primarily residential development (FEMA 1983b).

The Silver Creek watershed presents a unique challenge in terms of flood mitigation. The outlet of Silver Creek into Lake Erie is affected by both riverine and coastal processes. Due to the relatively calm waters of Lake Erie, when streamflow from Silver Creek reaches the outlet, the water column loses the required energy to maintain suspended sediment and debris and causes deposition and aggradation at the outlet. In addition, littoral drift of sand and sediment through wave action along the shoreline of Lake Erie deposits sediment into the outlet further restricting in-channel flow.

During the winter months, ice jam events can be caused by two incidents: wind driven ice being forced upstream Silver Creek and ice cover break up events in the upper reaches of Silver Creek flowing downstream and catching at meanders or infrastructure crossing the waterway. The situation is compounded by the two railroad track bridge crossings over Silver Creek immediately upstream the outlet. The railroad bridge central piers restrict in-channel flow, act as catch points for downstream ice floes, and actively trap ice floes driven upstream from winds off of Lake Erie.

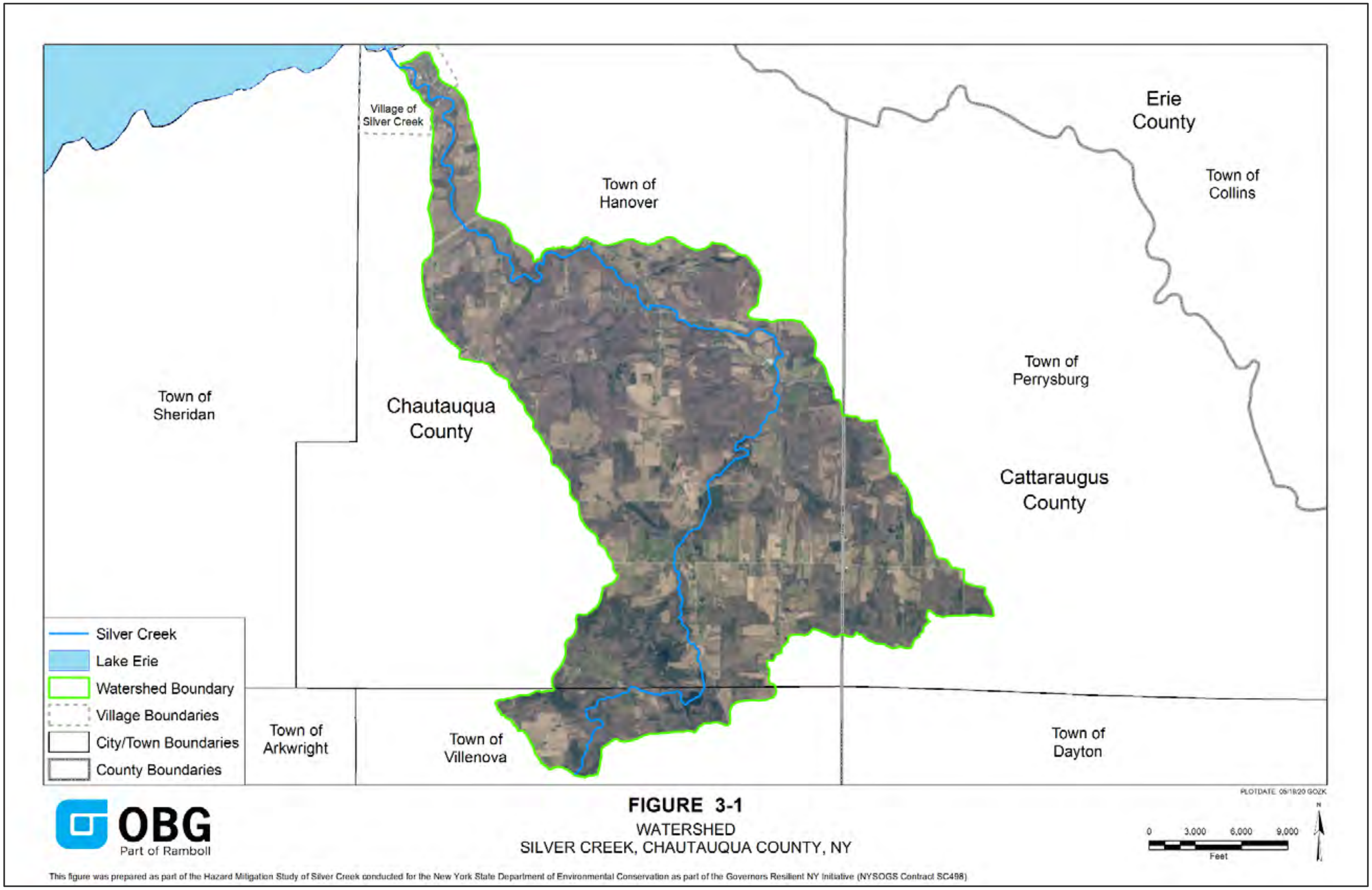



**Figure 3-1. Silver Creek Watershed, Chautauqua County, NY.**

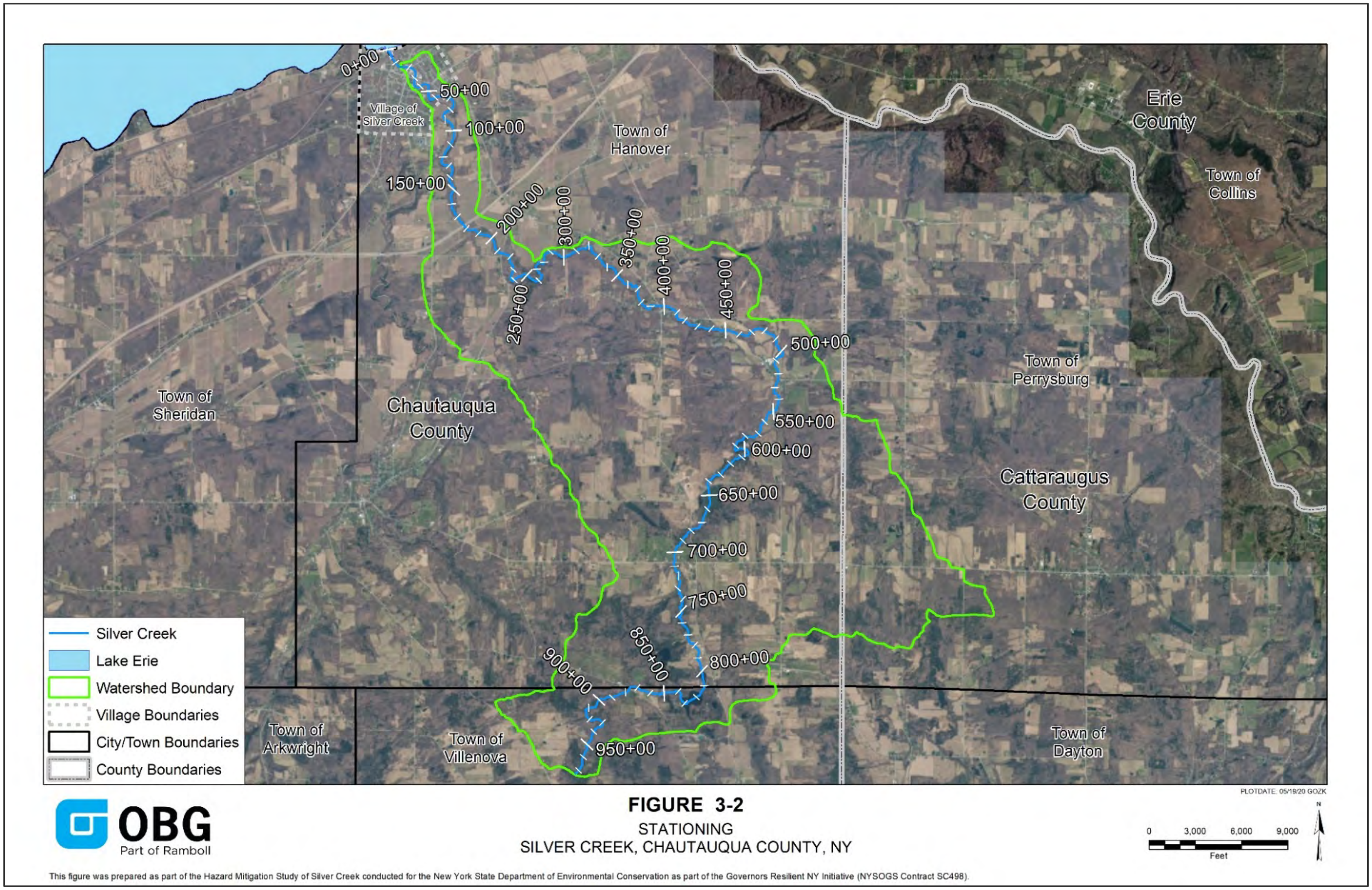



**Figure 3-2. Silver Creek Watershed Stationing, Chautauqua County, NY.**


**Figure 3-3. Silver Creek Study Area Stationing, Chautauqua County, NY.**

## 3.2 ENVIRONMENTAL CONDITIONS

An overview of the environmental and cultural resources within the Silver Creek watershed was compiled using the following online tools:

- **Environmental Resource Mapper** – The Environmental Resource Mapper is a tool used to identify mapped federal and state wetlands, state designated significant natural communities, and plants and animals identified as endangered or threatened by the NYSDEC (NYSDEC 2020a) (https://gisservices.dec.ny.gov/gis/erm/).
- **National Wetlands Inventory (NWI)** – The NWI is a digital map database available on the Environmental Resource Mapper that provides information on the "status, extent, characteristics and functions of wetlands, riparian, and deep-water habitats" (NYSDEC 2020a).
- **Information for Planning and Consultation (IPaC)** – The IPaC database provides information about endangered/threatened species and migratory birds regulated by the United States Fish and Wildlife Service (USFWS) (USFWS 2020) (https://ecos.fws.gov/ipac/).
- **National Register of Historic Places** – The National Register of Historic Places lists historic places worthy of preservation, as authorized by the National Historic Preservation Act of 1966 (NPS 2014) (https://www.nps.gov/maps/full.html?mapId=7ad17cc9-b808-4ff8-a2f9-a99909164466).

### 3.2.1 Wetlands

The State Regulated Freshwater Wetlands database shows the approximate location of wetlands regulated by New York State. The check zone is a 100-ft buffer zone around the wetland in which the actual wetland may occur. Several state-regulated freshwater wetlands are located within the Silver Creek watershed (Figure 3-4) (NYSDEC 2020a).

The National Wetlands Inventory (NWI) was reviewed to identify national wetlands and surface waters (Figure 3-4). The Silver Creek watershed includes riverine habitats, freshwater emergent wetlands, freshwater forested / shrub wetlands, freshwater pond, and lake habitats (NYSDEC 2020a).

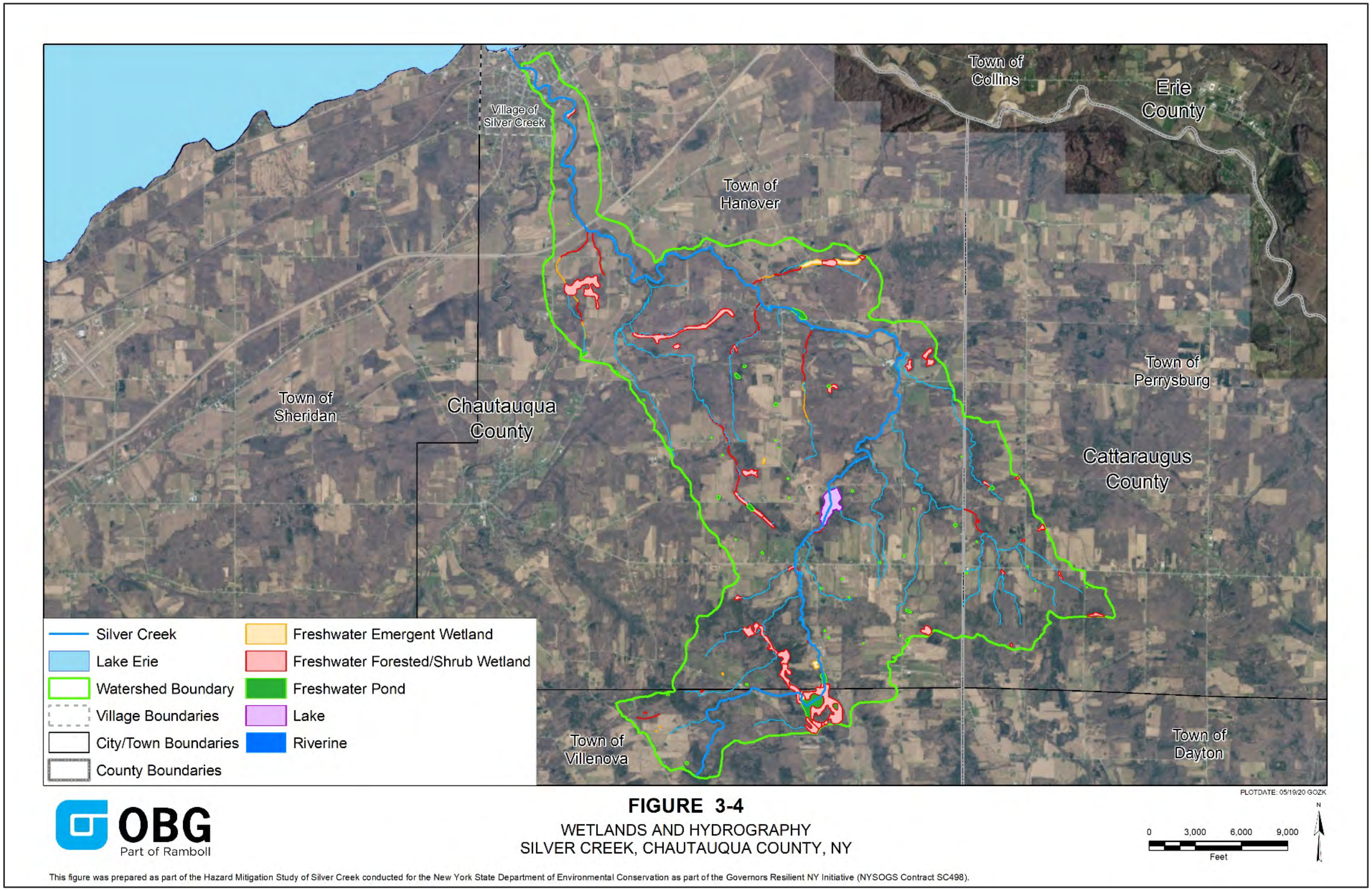



**Figure 3-4. Wetlands and Hydrography, Silver Creek, Chautauqua County, NY.**

### 3.2.2 Sensitive Natural Resources

The Silver Creek watershed contains a significant natural community, as mapped by the Environmental Resource Mapper. The significant natural community identified is East Mud Lake, which is classified as a Shrub Swamp in the ecological system Freshwater Nontidal Wetlands (NYSDEC 2020a).

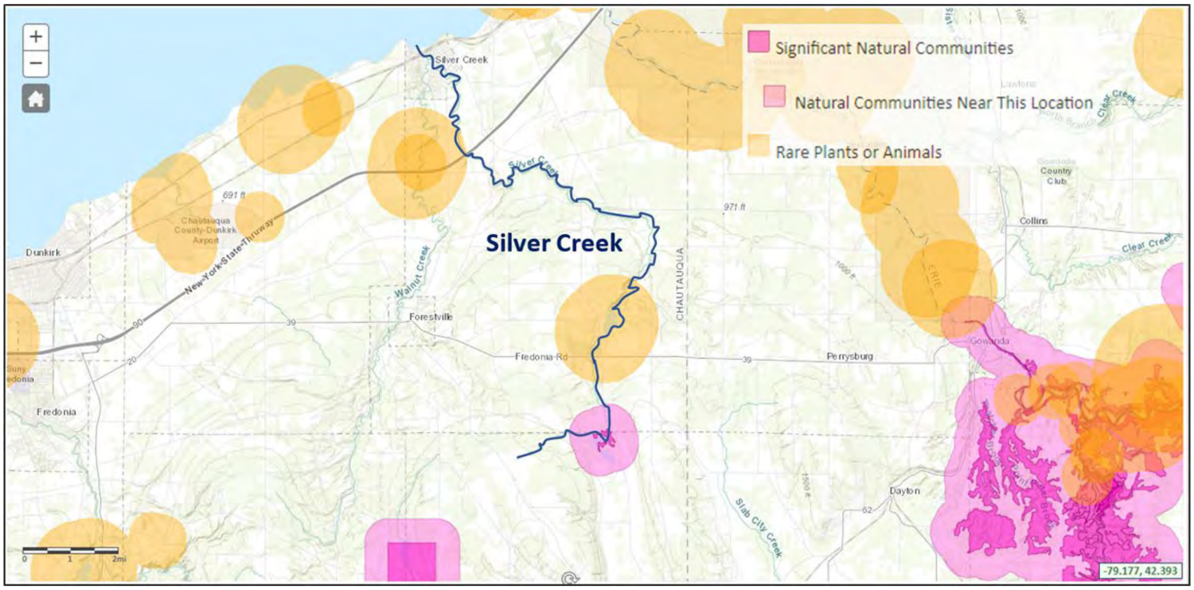



Figure 3-5. Environmental Resource Mapper - Significant Natural Communities and Rare Plants or Animals.

### 3.2.3 Endangered or Threatened Species

The Environmental Resource Mapper shows that the watershed basin is within the vicinity of Animals Listed as Endangered or Threatened by the NYSDEC (Figure 3-5). The NYSDEC Regional Office should be contacted to determine the potential presence of the species identified (NYSDEC 2020a).

The USFWS Information for Planning and Consultation (IPaC) results for the watershed basin list the following threatened and endangered species (Table 1). No critical habitat has been designated for the species at this location (USFWS 2020) (https://ecos.fws.gov/ipac/).

**Table 1. USFWS IPaC Listed Threatened and Endangered Species**

| | | |
|---|---|---|
| **Common Name** | **Scientific Name** | |
| **Northern Long-eared Bat** | *Myotis septentrionalis* | |
| **Clubshell** | *Pleurobema clava* | |
| **Northern Riffleshell** | *Epioblasma torulosa rangiana* | |
| **Rayed Bean** | *Villosa fabalis* | |

The migratory bird species listed in Table 2 are transient species that may pass over but are not known to nest within the watershed basin.

**Table 2. USFWS IPaC Listed Migratory Bird Species**

**(Source: USFWS 2020)**

| Common Name | Scientific Name | Level of Concern | Breeding Season |
|---|---|---|---|
| **American Golden-plover** | *Pluvialis dominica* | BCC Rangewide (CON)[2] | Breeds elsewhere |
| **Bald Eagle** | *Haliaeetus leucocephalus* | Non-BCC Vulnerable[1] | Sep 1 to Aug 31 |
| **Black-billed Cuckoo** | *Coccyzus erythropthalmus* | BCC Rangewide (CON)[2] | May 15 to Oct 10 |
| **Bobolink** | *Dolichonyx oryzivorus* | BCC Rangewide (CON)[2] | May 20 to Jul 31 |
| **Canada Warbler** | *Cardellina canadensis* | BCC Rangewide (CON)[2] | May 20 to Aug 10 |
| **Lesser Yellowlegs** | *Tringa flavipes* | BCC Rangewide (CON)[2] | Breeds elsewhere |
| **Red-headed Woodpecker** | *Melanerpes erythrocephalus* | BCC Rangewide (CON)[2] | May 10 to Sep 10 |
| **Snowy Owl** | *Bubo scandiacus* | BCC Rangewide (CON)[2] | Breeds elsewhere |
| **Wood Thrush** | *Hylocichla mustelina* | BCC Rangewide (CON)[2] | May 10 to Aug 31 |
| **American Golden-plover** | *Pluvialis dominica* | BCC Rangewide (CON)[2] | Breeds elsewhere |
| **Bald Eagle** | *Haliaeetus leucocephalus* | Non-BCC Vulnerable[1] | Sep 1 to Aug 31 |
| **Black-billed Cuckoo** | *Coccyzus erythropthalmus* | BCC Rangewide (CON)[2] | May 15 to Oct 10 |
| **Bobolink** | *Dolichonyx oryzivorus* | BCC Rangewide (CON)[2] | May 20 to Jul 31 |
| **Canada Warbler** | *Cardellina canadensis* | BCC Rangewide (CON)[2] | May 20 to Aug 10 |
| **Lesser Yellowlegs** | *Tringa flavipes* | BCC Rangewide (CON)[2] | Breeds elsewhere |
| **Red-headed Woodpecker** | *Melanerpes erythrocephalus* | BCC Rangewide (CON)[2] | May 10 to Sep 10 |
| **Snowy Owl** | *Bubo scandiacus* | BCC Rangewide (CON)[2] | Breeds elsewhere |
| **Wood Thrush** | *Hylocichla mustelina* | BCC Rangewide (CON)[2] | May 10 to Aug 31 |

1. This is not a Bird of Conservation Concern (BCC) in this area but warrants attention because of the Eagle Act or for potential susceptibilities in offshore areas from certain types of development or activities.

2. This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska (CON).

### 3.2.4 Cultural Resources

The National Register of Historic Places lists historic places worthy of preservation, as authorized by the National Historic Preservation Act of 1966. Silver Creek is not located near any historic places listed by the National Register of Historic Places. Consultation with New York State Office of Parks, Recreation, and Historic Places (NYSOPRHP) should be performed to identify the potential presence of archeological resources and the subsequent need to perform a cultural resource investigation (NPS 2014).

### 3.2.5 FEMA Mapping and Flood Zones

The FEMA Flood Map Service Center (https://msc.fema.gov/portal/home) is a nationwide database that contains FEMA Flood Insurance Rate Maps (FIRMs) for areas that have had FEMA flood insurance studies completed throughout the United States. For the Village of Silver Creek, the current effective FEMA FIS is dated February 1, 1983. According to the FIS, the hydrologic and hydraulic analyses for Silver and Walnut Creeks were completed using detailed methods (FEMA 1983b; FEMA 2020).

For a detailed study, FEMA can perform a limited detailed or detailed study. For both methods, semiautomated hydrologic, hydraulic, and mapping tools, coupled with digital elevation data, are used to predict floodplain limits, especially in lower-risk areas. If the tools are used with some data collected in the field (e.g. sketches of bridges to determine the clear opening) then the study is considered a limited detailed study. Limited detailed analysis sometimes results in the publishing of the Base Flood Elevations (BFEs), which is defined as the elevation of surface water resulting from a flood that has a 1% chance of equaling or exceeding that level in any given year, on the maps. The decision to place BFEs on a limited detailed study analysis is based on the desire of the community for the BFEs to be shown, plus the accuracy of the elevation data and the data on bridges, dams, and culverts that may impede flow on the flooding source. A study performed using these same tools and the same underlying map, with the addition of field-surveyed cross sections, field surveys of bridges, culverts, and dams, along with a more rigorous analysis including products such as floodways, new calibrations for hydrologic and hydraulic models, and the modeling of additional frequencies, is a detailed study. Detailed studies provide BFE information and flood profiles and usually a floodway, whereas approximate studies do not (NRC 2007). According to the FIS, a detailed study for Silver Creek was performed in the Village of Silver Creek, NY.

The FIRM for the Village of Silver Creek indicates Special Flood Hazard Areas (SFHAs), which are land areas covered by the floodwaters of the 1 or 0.2% annual chance flood events (ACE), along the banks of the creek (FEMA 1983b). In the Village of Silver Creek FIS, Flood Hazard Factors (FHFs) were used by the FIA to correlate flood information with insurance rate tables. The FHF for a reach is the average weighted difference between the 10 and 1% annual chance flood hazard (10- and 100-year flood) water-surface elevations expressed to the nearest 0.5-foot, and shown as a three-digit code on the FIRM. The flood zones indicated in the Silver Creek study area are Zones AO, A3, B and C. AO Zones are SFHAs subject to inundation by the 1% annual chance flood event as a result of shallow flooding where depths are between 1.0 to 3.0-feet where depths are shown on the map, but no FHFs are determined. Zone A3 are SFHAs subject to inundation by the 1% annual chance flood event determined by detailed methods with BFEs shown and zones subdivided according to FHF. B Zones are areas between the SFHAs and the limits of the 0.2% ACE (500-year) flood, including areas of the 0.2% flood plain that are protected from the 1% flood by dike, levee, or other water control structure. B Zones also include areas subject to certain types of 1% annual chance event shallow flooding where depths are less than 1.0 foot; and areas subject to 1% annual chance event flooding from sources with drainage areas less than 1 square mile. Zone B have no BFEs and are not subdivided by FHF. C Zones are areas of minimal flooding (FEMA 1983b).

In addition, Silver Creek is a Regulatory Floodway, which is defined the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than 1-foot over the 1% annual chance flood hazard water surface elevation (e.g. BFE). In the regulatory floodway, communities must regulate encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway and demonstrate through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not increase flood levels within the community during the occurrence of the base flood discharge. The floodway is the area that needs to be kept free of encroachment in order to convey the base flood. Development in the portions of the floodplain beyond the floodway, referred to as the floodway fringe, is allowed as long as it does not increase the BFE more than 1.0 ft (FEMA 2000). The regulatory floodway is depicted by a white section with dashed lines in the center of the creek on the current effective FIRMs.

For streams and other watercourses where FEMA has provided BFEs, but no floodway has been designated, or where FEMA has not provided BFEs, the community must review floodplain development on a case-by-case basis to ensure that increases in water surface elevations do not occur or identify the need to adopt a floodway if adequate information is available (FEMA 2000). Figure 3-6 is the FIRM of Silver Creek in the Village of Silver Creek, NY (FEMA 1983a).

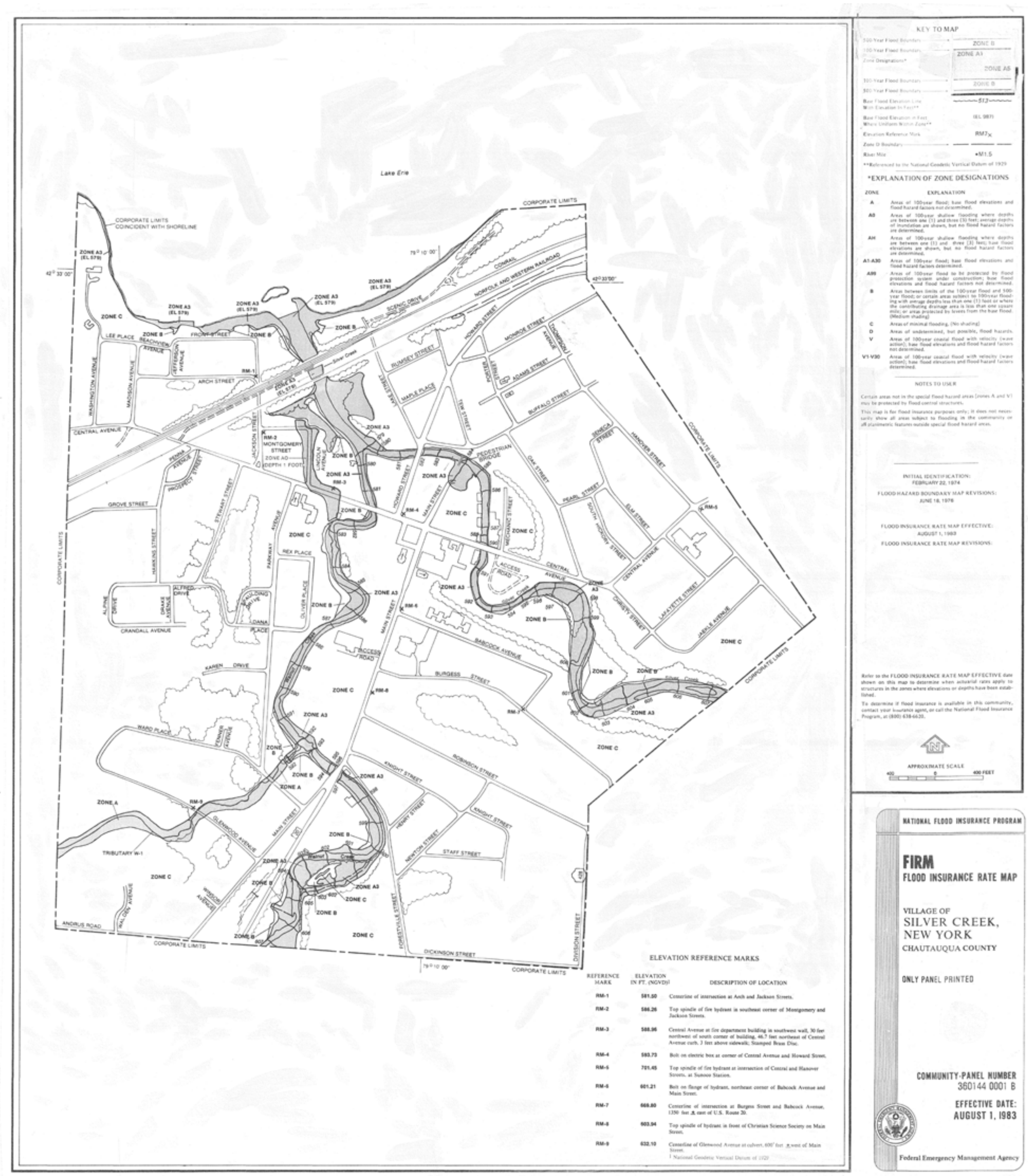



**Figure 3-6. FEMA FIRM, Village of Silver Creek, Chautauqua County, NY.**

## 3.3 WATERSHED LAND USE

The Silver Creek stream corridor is largely comprised of forested (62%), cultivated lands / hay (24%), and grassland / pasture (7%). Of the forested lands, deciduous forests (43%) comprise the largest proportion of forest type, while other hay / non-alfalfa (14%) and grapes (5%) encompasses the largest percentages of cultivated land. Developed lands, including high, medium, and low-intensity development and open developed space, comprise a small proportion (5%) of total land use within the Silver Creek basin (NASS 2019).

In the Town of Hanover, along Silver Creek development is primarily agricultural (FEMA 1984b). In the Village of Silver Creek, the Silver Creek watershed is primarily residential with one industrial complex located near the creek within village limits (FEMA 1983b).

## 3.4 GEOMORPHOLOGY

The geologic history of Chautauqua County dates back 300-million years to the Upper Devonian. The various formations of rock, particularly those near Lake Erie, occur in bands that have an east-west orientation. They also possess very gentle regional dips that have a south-southeast orientation. The oldest rocks in Chautauqua County are largely the black and gray shales that occur along Lake Erie. The age of the rocks is progressively younger toward the southeastern part of the county (Tesmer 1954; USSCS 1994).

Chautauqua County experienced several advances and retreats of glacial ice during the Pleistocene ice age. The ice age began about 300,000-years ago, and ended during the late Wisconsin glaciation, about 14,000-years ago. With each southern movement, the ice picked up soil material and pieces of bedrock and ultimately redeposited a mixture of unconsolidated material of varying size, shape, and mineral content. The last advance stripped earlier deposits and laid down the mantle in which most of the present-day soils formed (Muller 1963; USSCS 1994).

The bedrock and geology of the Silver Creek watershed is primarily made up of the Canadaway Group, which is a succession of black and gray shales that include some thin siltstone layers. In Chautauqua County, the Canadaway Group averages about 1,050 feet in thickness and is subdivided into seven members. The oldest of these is the black Dunkirk Shale, which is about 85-ft thick and extends eastward along Walnut and Silver Creeks until it reaches a point south of the village of Silver Creek. Overlying the Dunkirk Shale is a dominantly gray shale named South Wales Shale, which is about 50-ft thick. The South Wales exposures extend along Canadaway, Walnut, and Silver Creeks and then proceed eastward along Cattaraugus Creek. Above the South Wales Shale is the Gowanda Member, which consists of 280 feet of mainly gray shale that has thin bands of black shale and gray siltstone. This member is also exposed along Silver Creek, south of the Village of Silver Creek (USSCS 1994).

Within the Silver Creek watershed basin, the most predominant soil types are Fremont silt loam (FmB), Hornell silt loam (HrB), and Busti silt loam (BsB). FmB is gently sloping, very deep, and somewhat poorly drained. It is on broad hilltops and valley sides that receive a considerable amount of runoff from the higher adjacent soils. Individual areas are oblong or rectangular. They commonly are 5 to 75 acres in size but range from 10 to several hundred acres. HrB is gently sloping, moderately deep, and somewhat poorly drained. It is on broad flats and side slopes in areas where the topography is influenced by the underlying bedrock. Soft shale bedrock is at a depth of 20 to 40 inches. Individual areas are oblong and range from 10 to 50 acres in size. BsB is gently sloping, very deep, and somewhat poorly drained. It is in convex areas on uplands, on side slopes, and in concave areas on foot slopes that receive runoff from the higher adjacent soils. Individual areas are irregularly shaped or rectangular. Most range from 10 to 75 acres in size but some are as large as 100 acres or more (USSCS 1994).

Figure 3-7 is a profile of stream bed elevation and channel distance from the confluence with Walnut Creek using data from the FEMA FIS flood profiles for Silver Creek. Silver Creek has an average slope of 1.03% over the profile stream length. The creek's streambed lowers approximately 1,030 vertical feet over this reach from an elevation of 1,700-ft above sea level (NAVD 88) at the headwaters in the Town of Villenova to 670-ft above sea level at the confluence of Lake Erie in the Village of Silver Creek, NY (FEMA 1983b).

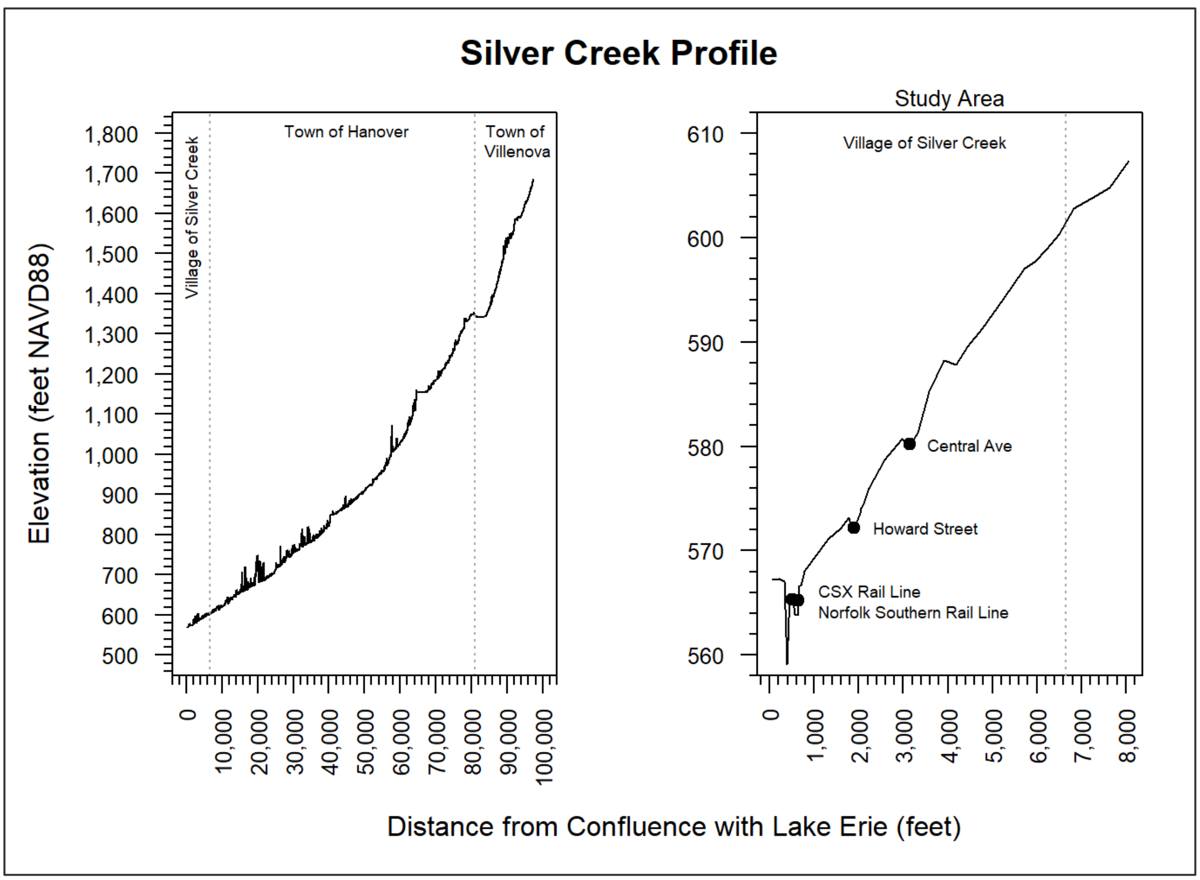



**Figure 3-7. Silver Creek Profile.**

## 3.5 HYDROLOGY

Silver Creek drains an area of 52.2 $mi^2$, which includes Walnut Creek, is approximately 14.2 miles in length, and is located in the southwestern portion of New York State and in the northeastern portion of Chautauqua County, NY. Excluding the Walnut Creek drainage area, Silver Creek drains an area of 25.2 $mi^2$. Silver Creek is one of the four major streams that flows through the Town of Hanover, and one of the two major streams that flows through the Village of Silver Creek. The other major stream in the Village is Walnut Creek, which converges with Silver Creek in the Village and continues downstream to Lake Erie (FEMA 1983b, FEMA 1984b). Table 3 is a summary of the basin characteristic formulas and calculated values for the Silver Creek watershed, where A is the drainage area of the basin in square miles, $B_L$ is the basin length in miles, and $B_P$ is the basin perimeter in miles (USGS 1978).

**Table 3. Silver Creek Basin Characteristics Factors**

| Factor | Formula | Value |
|---|---|---|
| **Form Factor ($R_F$)** | A / $B_L$2 | 0.18 |
| **Circularity Ratio ($R_C$)** | 4*п*A / $B_P$2 | 0.20 |
| **Elongation Ratio ($R_E$)** | 2 * (A/п)0.5 / $B_L$ | 0.47 |

Form Factor ($R_F$) describes the shape of the basin (e.g., circular or elongated) and the intensity of peak discharges over a given duration of time. Circularity Ratio ($R_C$) gives an indication of topography where the higher the circularity ratio, the lower the relief and less disturbance to drainage systems by structures within the channel. Elongation Ratio ($R_E$) gives an indication of ground slope where values less than 0.7 correlate to steeper ground slopes and elongated basin shapes. Based on the basin characteristics factors, the Silver Creek watershed can be characterized as an elongated basin with lower peak discharges of longer durations, high relief topography with structural controls on drainage, and steep ground slopes (Waikar and Nilawar 2014).

There are three USGS stream gaging stations on Silver Creek; however, none of the gages have recorded data for longer than three years. A minimum of at least 50-years of data is required to do an accurate log-Pearson III (LP3) analysis.

**Two effective FEMA FIS reports for Silver Creek were issued in 1983 for the Village of Silver Creek and 1984 for the Town of Hanover, which included drainage area and peak discharge information, in cubic feet per second (cfs).**

Table 4 summarizes the FEMA FIS drainage area and peak discharges for Silver Creek (FEMA 1983b; FEMA 1984b).

**Table 4. Silver Creek Summary of FEMA FIS Peak Discharges**

| (Source: FEMA 1983b; FEMA 1984b) | | | | | | |
|---|---|---|---|---|---|---|
| | | | Peak Discharges (cfs) | | | |
| Location[1] | Drainage Area (Sq. Miles) | River Station (ft) | 10-Percent | 2-Percent | 1-Percent | 0.2-Percent |
| Confluence with Lake Erie | 52.2 | 0+00 | 4,450 | 6,100 | 7,000 | 9,000 |
| Upstream of Corporate Limits | 25 | 67+00 | 2,350 | 3,200 | 3,650 | 4,700 |
| Dam at Smith Mills | 15.9 | 405+00 | 1,600 | 2,150 | 2,450 | 3,200 |
| 1600-ft upstream of King Road | 14.6 | 437+50 | 1,470 | 2,000 | 2,300 | 3,000 |
| 1600-ft downstream of Mackinaw Road | 13.7 | 473+00 | 1,380 | 1,870 | 2,150 | 2,800 |
| 1300-ft downstream of Mackinaw Road | 12.2 | 505+00 | 1,280 | 1,750 | 2,000 | 2,550 |
| 3200-ft upstream of Mackinaw Road | 11.9 | 535+00 | 1,220 | 1,670 | 1,900 | 2,450 |

[1] Location names are from FEMA FIS reports for naming convention consistency

According to the effective FEMA FIS, for Silver Creek in both the Village of Silver Creek and Town of Hanover, peak discharges were based on an adaptation of regional flood-frequency curves determined by Goodkind and O'Dea, Inc., Consulting Engineers (Goodkind and O'Dea, Inc. 1978). The peak discharge-frequency relationship of nine USGS gaging stations outside the Tonawanda Creek basin were established, using the standard LP3 method, without the influence of expected probability adjustments. The regional skew value of 0.0 was a computed weighted average considering the natural skews and years of record for each gage. A set of regional curves was then derived, which graphically correlated peak discharge and drainage area for the selected return periods. These curves were extrapolated to smaller drainage areas based on studies used in Hydraulic Engineering Circular No. 4 (USDC 1963).

USGS *StreamStats* v4.3.11 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. Developed by the USGS, the primary purpose of *StreamStats* is to provide estimates of streamflow statistics for user selected ungaged sites on streams and for USGS stream gages, which are locations where streamflow data are collected (Ries et al. 2017; USGS 2017).

Methods for computing a peak discharge estimate for a selected recurrence interval at a specific site depend on whether the site is gaged or ungaged, and whether the drainage area lies within a single hydrologic region, or crosses into an adjacent hydrologic region or State. Hydrologic regions refer to areas in which streamflow-gaging stations indicate a similarity of peak-discharge response that differs from the peak-discharge response in adjacent regions. These similarities and differences are defined by the regression residuals, which are the differences between the peak discharges calculated from station records and the values computed through the regression equation. There are currently six hydrologic regions in New York State (Lumia 1991; Lumia et al. 2006).

For gaged sites, such as Silver Creek in hydrologic region 5 of New York State, the generalized least-squares (GLS) regional-regression equations are used to improve streamflow-gaging-station estimates (based on LP3 flood-frequency analysis of the gaged annual peak-discharge record) by using a weighted average of the two estimates (regression and gaged). Incorporating the regression estimate into the weighted average tends to decrease time sampling errors that result for sites with short periods of record. The weighted-average discharges are generally the most reliable and are computed from the equation:

$$Q_{T(w)} = Q_{T(g)}(N) + Q_{T(r)}(E) / N + E$$

where

$Q_{T(w)}$ is weighted peak discharge at the gaged site, in cubic feet per second, for the T-year recurrence interval;

$Q_{T(g)}$ is peak discharge at gage, in cubic feet per second, calculated through log-Pearson Type III frequency analysis of the station’s peak discharge record, for the T-year recurrence interval;

N is number of years of annual peak-discharge record used to calculate $Q_{T(g)}$ at the gaging station;

$Q_{T(r)}$ is regional regression estimate of the peak discharge at the gaged site, in cubic feet per second, for the T-year recurrence interval; and

E is average equivalent years of record associated with the regression equation that was used to calculate $Q_{T(r)}$ (Lumia et al. 2006).

*StreamStats* delineates the drainage basin boundary for a selected site by use of an evenly spaced grid of land-surface elevations, known as a Digital Elevation Model (DEM), and a digital representation of the stream network. Using this data, the application calculates multiple basin characteristics, including drainage area, main channel slope, and mean annual precipitation. By using these characteristics in the calculation, the peak discharge values have increased accuracy and decreased standard errors by approximately 10% for a 1% annual chance interval (100-year recurrence) discharge when compared to the drainage-area only regression equation (Lumia et al. 2006; Ries et al. 2017).

When *StreamStats* is used to obtain estimates of streamflow statistics for USGS stream gages, users should be aware that there are errors associated with estimates determined from available data for the stations as well as estimates determined from regression equations, and some disagreement between the two sets of estimates is expected. If the flows at the stations are affected by human activities, then users should not assume that the differences between the databased estimates and the regression equation estimates are equivalent to the effects of human activities on streamflow at the stations (Ries et al. 2017).

*StreamStats* was used to calculate the current peak discharges for Silver Creek and compared with the effective FIS peak discharges. Table 5 is the summary output of peak discharges calculated by the USGS *StreamStats* software for Silver Creek at selected FEMA FIS profile locations.

**Table 5. Silver Creek USGS *StreamStats* Summary of Peak Discharges at FEMA FIS Locations**

| (Source: USGS 2017) | | | | | | |
|---|---|---|---|---|---|---|
| | | | Peak Discharges (cfs) | | | |
| Location | Drainage Area ($Mi^2$) | River Station (ft) | 10-Percent | 2-Percent | 1-Percent | 0.2-Percent |
| Confluence with Lake Erie | 52.2 | 0+00 | 5,200 | 8,320 | 9,790 | 13,600 |
| Upstream of Corporate Limits | 25 | 67+00 | 2,650 | 4,220 | 4,950 | 6,870 |
| Dam at Smith Mills | 15.9 | 405+00 | 2,080 | 3,360 | 3,970 | 5,560 |
| 1600-ft upstream of King Road | 14.6 | 437+50 | 1,970 | 3,190 | 3,770 | 5,290 |
| 1600-ft downstream of Mackinaw Road | 13.7 | 473+00 | 1,900 | 3,100 | 3,660 | 5,150 |
| 1300-ft downstream of Mackinaw Road | 12.2 | 505+00 | 1,740 | 2,830 | 3,350 | 4,710 |
| 3200-ft upstream of Mackinaw Road | 11.9 | 535+00 | 1,670 | 2,710 | 3,210 | 4,500 |

Using the standard error calculations from the regression equation analysis in *StreamStats*, an acceptable range at the 95% confidence interval for peak discharge values at the 10, 2, 1, and 0.2% annual chance flood hazards were determined. Standard error gives an indication of how accurate the calculated peak discharges are when compared to the actual peak discharges since approximately two-thirds (68.3%) of the calculated peak discharges would be within one standard error of the actual peak discharge, 95.4% would be within two standard errors, and almost all (99.7%) would be within three standard errors (McDonald 2014). Table 6 is a summary table of the USGS *StreamStats* standard errors at each percent annual chance flood hazard for Region 5 in New York State.

**Table 6. USGS *StreamStats* Standard Errors for Full Regression Equations**

| Source: (Lumia et al. 2006) | | | | |
|---|---|---|---|---|
| | Peak Discharges (cfs) | | | |
| | 10-Percent | 2-Percent | 1- Percent | 0.2- Percent |
| Standard Error | 36.1 | 37.5 | 38.7 | 42.6 |

FEMA FIS peak discharges were determined to be outside an acceptable range (95% confidence interval) based on the *StreamStats* standard error calculations, and the *StreamStats* peak discharges are higher. As a result, the *StreamStats* peak discharge values were used in the hydraulic and hydrologic model simulations for this study because they are more conservative estimates.

In addition to peak discharges, the *StreamStats* software also calculates bankfull statistics by using stream survey data and discharge records from 281 cross-sections at 82 streamflow-gaging stations in a linear regression analyses to relate drainage area to bankfull discharge and bankfull-channel width, depth, and cross-sectional area for streams across New York state. These equations are intended to serve as a guide for streams in areas of the same hydrologic region, which contain similar hydrologic, climatic, and physiographic conditions (Mulvihill et al. 2009).

Bankfull discharge is defined as the flow that reaches the transition between the channel and its flood plain. Bankfull discharge is considered to be the most effective flow for moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphological characteristics of channels (Mulvihill et al. 2009). The bankfull width and depth of Silver Creek is important in understanding the distribution of available energy within the channel, and the ability of various discharges occurring within the channel to erode, deposit, and move sediment (Rosgen and Silvey 1996). Table 7 lists the estimated bankfull discharge, width, and depth at the FEMA FIS locations along Silver Creek as derived from the USGS *StreamStats* program (USGS 2017).

**Table 7. Silver Creek Estimated Bankfull Discharge, Width, and Depth using USGS *StreamStats***

| (Source: USGS 2017) | | | | | |
|---|---|---|---|---|---|
| **Location** | **River Station (ft)** | **Drainage Area ($Mi^2$)** | **Bankfull Depth (ft)** | **Bankfull Width (ft)** | **Bankfull Streamflow (cfs)** |
| **Confluence with Lake Erie** | 0+00 | 52.2 | 2.7 | 88.6 | 1,340 |
| **Upstream of Corporate Limits** | 67+00 | 25 | 2.3 | 65.1 | 722 |
| **Dam at Smith Mills** | 405+00 | 15.9 | 2.0 | 53.9 | 493 |
| **1600-ft upstream of King Road** | 437+50 | 14.6 | 2.0 | 52 | 459 |
| **1600-ft downstream of Mackinaw Road** | 473+00 | 13.7 | 2.0 | 50.6 | 435 |
| **1300-ft downstream of Mackinaw Road** | 505+00 | 12.2 | 1.9 | 48.2 | 394 |
| **3200-ft upstream of Mackinaw Road** | 535+00 | 11.9 | 1.9 | 47.7 | 386 |

## 3.6 INFRASTRUCTURE

Numerous infrastructure facilities cross the creek channel including bridges and dams. Table 8 lists a summary of infrastructure crossing Silver Creek. Figure 3-8 displays the locations of the bridges and dams that cross Silver Creek in Chautauqua County, NY (NYSDOT 2016; NYSDEC 2019).

There are seven dams within the Silver Creek watershed, but only four dams interact with the flow of Silver Creek. Of these four dams, two are purposed as "Water Supply – Secondary," while the other two are "Other" purpose dams. The hazard classifications of the dams along Silver Creek include negligible (class D), low (class A), and two intermediate (class B) hazard dams (NYSDEC 2019). Smith Mills Reservoir dam is in the planning stage for eventual decommissioning and removal as part of the *Smith Mills Reservoir Dam (State ID: 006-0516) Demolition & Creek Restoration Project*. The change in flows in Silver Creek is expected to be negligible (EcoStrategies 2019), and therefore is unlikely to result in any changes to flows in Silver Creek and flooding downstream due to Smith Mills Reservoir Dam.

Major bridge crossings over Silver Creek include US Route 20 and NY Route 5 in the Village of Silver Creek, and Interstate 90 and County Routes 89 and 93 in the Town of Hanover. Bridge lengths and surface widths for NYSDOT bridges were revised as of February 2019 (NYSDOT 2016).

**Table 8. Summary of Infrastructure Crossing Silver Creek**

(Source: FEMA 1983b; FEMA 1984b; NYSDOT 2014; NYSDOT 2016; NYSDEC 2019)

| Type | Roadway Carried or Structure Name | Owner | State Highway Number | River Station (ft) | Length[1] (ft) | Width[2] (ft) | Height (ft) | Hydraulic Capacity (% Annual Chance) |
|---|---|---|---|---|---|---|---|---|
| **Dam** | Old Silver Creek Reservoir Dam | Private | N/A | 312+00 | N/A | 200 | 3 | No Data Available |
| **Dam** | Smith Mills Reservoir Dam | Private | N/A | 405+00 | N/A | 90 | 19 | No Data Available |
| **Dam** | Silver Creek Reservoir Dam | Private | N/A | 645+50 | N/A | 2000 | 35 | No Data Available |
| **Dam** | Edwin Butcher Wildlife Pond Dam #1 | Private | N/A | 800+00 | N/A | 225 | 6 | No Data Available |
| **Railroad Bridge** | CSX Railroad | Private | N/A | 5+00 | 68 | 148 | No Data Available | No Data Available |
| **Railroad Bridge** | Norfolk Southern Railroad | Private | N/A | 6+00 | 28 | 145 | No Data Available | No Data Available |
| **Bridge** | Howard Street (NY-5) | State | 52-4 | 18+00 | 44 | 105 | No Data Available | 0.2 |
| **Bridge** | Central Avenue (US-20) | State | 5452 | 31+00 | 40 | 67 | No Data Available | 0.2 |
| **Bridge** | Interstate 90/ NYS Thruway (WB) | State | 55013 | 177+25 | 51 | 288 | No Data Available | No FIS Data Available |
| **Bridge** | Interstate 90/ NYS Thruway 90 (EB) | State | 55013 | 177+75 | 53.2 | 286 | No Data Available | No FIS Data Available |

| (Source: FEMA 1983b; FEMA 1984b; NYSDOT 2014; NYSDOT 2016; NYSDEC 2019) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Type** | **Roadway Carried or Structure Name** | **Owner** | **State Highway Number** | **River Station (ft)** | **Length[1] (ft)** | **Width[2] (ft)** | **Height (ft)** | **Hydraulic Capacity (% Annual Chance)** |
| **Bridge** | Angell Road (Co. Rte. 89) | Local | N/A | 212+00 | 26 | 216 | No Data Available | No FIS Data Available |
| **Bridge** | Hanover Road (Co. Rte. 93) | Local | N/A | 397+00 | 29 | 162 | No Data Available | No FIS Data Available |
| **Bridge** | King Road | Local | N/A | 413+00 | 24 | 53 | No Data Available | 0.2 |
| **Bridge** | Alleghany Road | Local | N/A | 448+50 | 30.3 | 36 | No Data Available | 0.2 |
| **Bridge** | Alleghany Road | Local | N/A | 523+00 | 25.3 | 47 | No Data Available | 0.2 |
| **Culvert** | Hopper Road | Local | N/A | 645+50 | 22.8 | 26 | No Data Available | No FIS Data Available |

[1] Length refers to measured distance of a structure in parallel direction to stream flow

[2] Width refers to measured distance of structure in perpendicular direction to stream flow

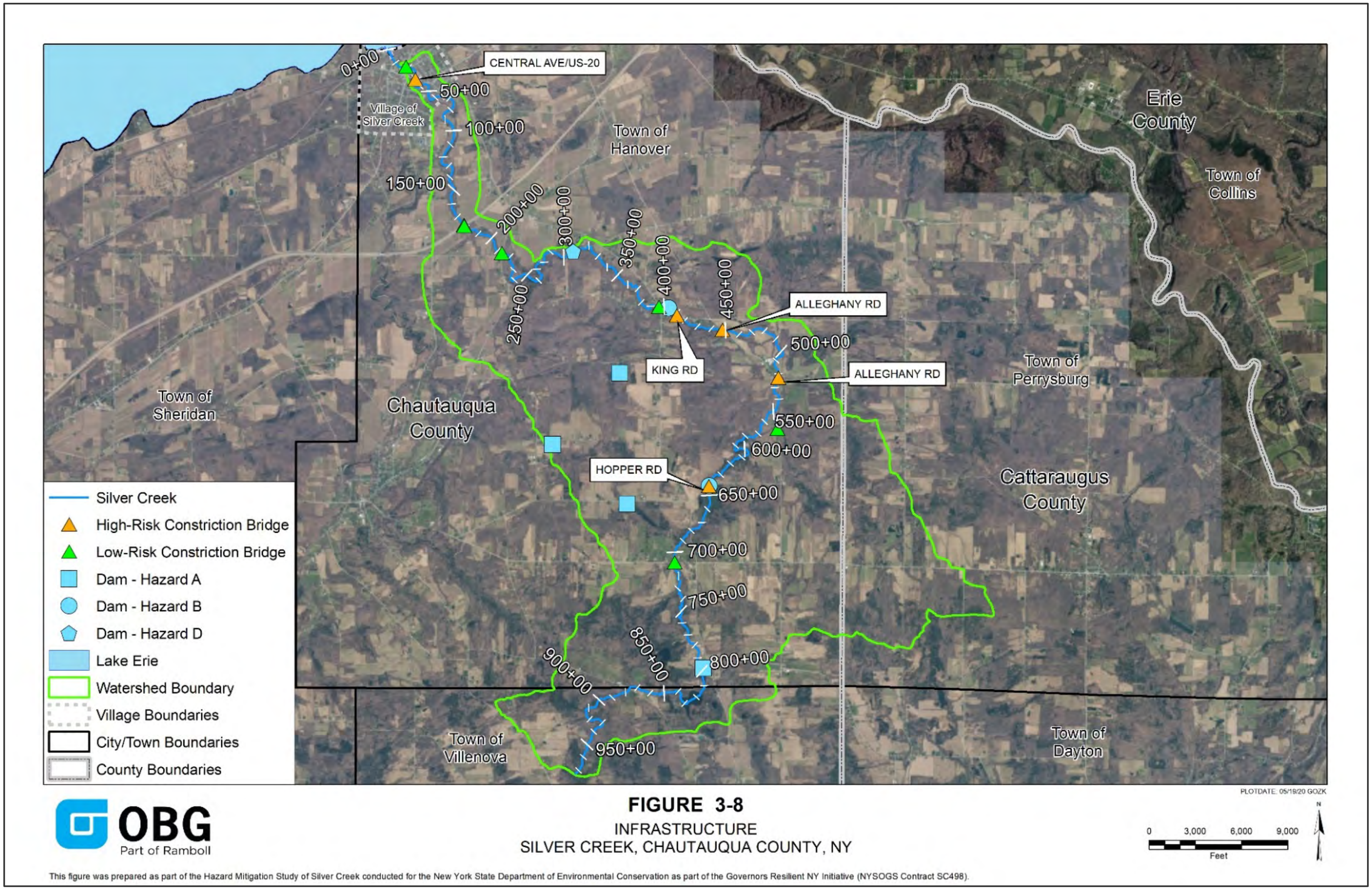



**Figure 3-8. Infrastructure, Silver Creek, Chautauqua County, NY.**

### 3.7 HYDRAULIC CAPACITY

Hydraulic capacity is the measure of the amount of water that can pass through a structure or watercourse. Hydraulic design is an essential function of structures in watersheds. Exceeding the capacity can result in damages or flooding to surrounding areas and infrastructure (Zevenbergen et al. 2012). In assessing hydraulic capacity of the high-risk constriction point culverts and bridges along Silver Creek, the FEMA FIS profiles were used to determine the lowest annual chance flood elevation to flow under a culvert and the low chord of a bridge, without causing an appreciable backwater condition upstream (Table 8).

In New York State, hydraulic and hydrologic regulations for bridges were developed by the NYSDOT. The NYSDOT guidelines require a factor of safety for bridges that cross waterways, known as freeboard. Freeboard is the additional capacity, usually expressed as a distance in feet, in a waterway above the calculated capacity required for a specified flood level, usually the base flood elevation. Freeboard compensates for the many unknown factors that could contribute to flood heights being greater than calculated, such as wave action, minor silt and debris deposits, the hydrological effect of urbanization of the watershed, etc. However, freeboard is not intended to compensate for higher floods expected under future climatic conditions, such as those due to sea-level rise or more extreme precipitation events (NYSDEC 2018).

The term “bridge” shall apply to any structure whether single or multiple span construction with a clear span in excess of 20 feet when measurement is made horizontally along the center line of roadway from face to face of abutments or sidewalls immediately below the copings or fillets; or, if there are no copings or fillets, at 6 inches below the bridge seats or immediately under the top slab, in the case of frame structures. In the case of arches, the span shall be measured from spring line to spring line. All measurements shall include the widths of intervening piers or division walls, as well as the width of copings or fillets. (NYSDOT 2020)

According to the NYSDOT bridge manual (2019) for Region 5, which includes Niagara, Erie, Chautauqua, and Cattaraugus Counties, new and replacement bridges are required to meet certain standards, which include (NYSDOT 2019):

- The structure will not raise the water surface elevations anywhere when compared to the existing conditions for both the 2 and 1% annual chance event (50 and 100-year flood) flows.
- The proposed low chord shall not be lower than the existing low chord.
- A minimum of 2’-0” of freeboard for the projected 2% annual chance event (50-year flood) is required for the proposed structure. The freeboard shall be measured at the lowest point of the superstructure between the two edges of the bottom angle for all structures.
- The projected 1% annual chance event (100-year flood) flow shall pass below the proposed low chord without touching it.
- The maximum skew of the pier to the flow shall not exceed 10 degrees.

In addition, current peak flows shall be increased to account for future projected peak flows based on the USGS *StreamStats* tool where current 2% peak flows shall be increased by 10% in Region 5. For critical bridges, the minimum hydraulic design criteria is 3-feet of freeboard over the 2% annual chance flood elevation. A critical bridge is considered to be vital infrastructure that the incapacity or destruction of such would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters (NYSDOT 2019; USDHS 2010).

Table 9 displays the 2% and 1% annual chance flood levels and their calculated difference at FEMA FIS infrastructure locations using the FIS profile for Silver Creek.

**Table 9. 2% and 1% Annual Chance Flood Levels with Differences at FEMA FIS Bridge Locations**

| (Source: FEMA 1983b; FEMA 1984b) | | | | |
|---|---|---|---|---|
| **Bridge Crossing** | **River Station (ft)** | **2-Percent Water Surface Elevation (ft NAVD88)** | **1-Percent Water Surface Elevation (ft NAVD88)** | **Difference in Water Surface Elevations (ft NAVD88)** |
| **CSX Railroad Bridge** | 5+00 | 578.2 | 578.6 | 0.4 |
| **Norfolk Southern Railroad Bridge** | 6+00 | 578.2 | 578.6 | 0.4 |
| **Howard Street/NY-5** | 18+00 | 581.5 | 582.2 | 0.7 |
| **Central Avenue/US-20** | 31+00 | 590.0 | 590.8 | 0.8 |
| **King Road** | 413+00 | Data illegible in FIS report | | |
| **Alleghany Road** | 448+50 | Data illegible in FIS report | | |
| **Alleghany Road** | 523+00 | Data illegible in FIS report | | |

According to the FEMA FIS profiles, the King Road bridge does not meet the NYSDOT guidelines for 2-feet of freeboard over the 2% annual chance flood. In addition, this bridge does not meet the new draft CRRA climate change infrastructure guidelines as described above. However, the low chord elevation is above the 0.2% annual chance flood event (FEMA 1983b; FEMA 1984b). Even though these structures may have hydraulic capacity restraints, the NYSDOT has to balance both physical constraints along with cost versus benefit of replacing existing bridges to meet the current NYSDOT or new draft CRRA guidelines.

In addition, the USGS *StreamStats* tool was used to calculate the bankfull widths and discharges for each structure in the Village of Silver Creek along Silver Creek (Table 10). The bankfull widths are wider than the structure's width for the Central Avenue / US-20, King Road, and Hopper Road bridges, and for two Allegany Road bridges.

The structures with bankfull widths that are wider than or close to the structures width indicate that water velocities have to slow and contract in order to pass through the structures, which can cause sediment depositional aggradation and the accumulation of sediment and debris. Aggradation can lead to the development of sediment and sand bars, which can cause upstream water surfaces to rise, increasing the potential for overtopping banks or backwater flooding. Since the bankfull discharge required for water surface elevations to reach the bankfull width is low (e.g. 80% annual chance event), the likelihood of relatively low flow events causing backwater and potential flooding upstream of these structures is fairly high.

**Table 10. Infrastructure Width and Bankfull Width with Discharge of High-risk Constriction Point Infrastructure**

| **Source: (NYSDOT 2016; USGS 2017)** | | | | | | |
|---|---|---|---|---|---|---|
| **Infrastructure Type** | **Roadway Carried** | **River Station (ft)** | **Structure Width (ft)** | **Bankfull Width (ft)** | **Bankfull Discharge (cfs)** | **Annual Chance Flood Event Equivalent[1]** |
| **Bridge** | Central Avenue/US-20 | 31+00 | 67 | 65.3 | 726 | 80-percent |
| **Bridge** | King Road | 413+00 | 53 | 53.9 | 493 | 80-percent |
| **Bridge** | Alleghany Road | 448+50 | 36 | 51.5 | 451 | 80-percent |
| **Bridge** | Alleghany Road | 523+00 | 47 | 47.9 | 389 | 80-percent |
| **Culvert** | Hopper Road | 645+50 | 26 | 36.8 | 229 | 80-Percent |

[1] Annual Chance Flood Event Equivalent describes the equivalent annual chance flood event for the given bankfull discharge as calculated by the USGS *StreamStats* application. The 80% annual chance flood event is equal to a 1.25-year recurrence interval.

# 4. CLIMATE CHANGE IMPLICATIONS

## 4.1 FUTURE PROJECTED STREAMFLOW IN SILVER CREEK

In an effort to improve flood resiliency of infrastructure in light of future climate change, New York state passed the Community Risk and Resiliency Act in 2014. In accordance with the guidelines of the CRRA, the NYSDEC released the *New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act* (2018) draft report. In the report, two methods for estimating projected future discharges were discussed: an end of design life multiplier, and the USGS *FutureFlow* Explorer map-based web application (NYSDEC 2018).

In addition, the NYSDEC recommended flood risk management guidelines for transportations infrastructure in the draft guidelines report. For non-critical bridges, the CRRA recommended increasing peak flows for future conditions by multiplying relevant peak-flow parameters, currently used in hydraulic analysis (e.g. 2% annual chance or 50-year flood) by a factor specific to the expected service life of the structure and the geographic location of the project and increases consideration of freeboard for critical infrastructure by 1-ft (NYSDEC 2018).

The end of design life multiplier is described as an adjustment to current peak-flow values by multiplying relevant peak-flow parameters by a factor specific to the expected service life of the structure and geographic location of the project to estimate future peak-flow conditions. For Silver Creek, the recommended design-flow multiplier is 10% for an end of design life for a structure between 2025 and 2100 (NYSDEC 2018).

The USGS *FutureFlow* software is an extension of the *StreamStats* software where regionally specific peak-flow regression equations are used to estimate the magnitude of future floods for any stream or river in New York State (excluding Long Island) and the Lake Champlain basin in Vermont. The *FutureFlow* software substitutes a new climate variable (either precipitation or runoff) to the peak-flow regression equations. This climate variable is obtained from five climate models that were reviewed by the World Climate Research Programme's (WCRP) Working Group Coupled Modelling (WGCM) team during the 5th Phase of the Coupled Model Intercomparison Project (CMIP5). These five climate models were chosen because they best represent past trends in precipitation for the region (Burns et al. 2015).

With the USGS *FutureFlow* software, climate variable data is evaluated under two future scenarios, termed "Representative Concentration Pathways" (RCP) in CMIP5, that provide estimates of the extent to which greenhouse-gas concentrations in the atmosphere are likely to change through the 21st-century. RCP refers to potential future emissions trajectories of greenhouse gases, such as carbon dioxide. Two scenarios, RCP 4.5 and RCP 8.5, were evaluated for each climate model in CMIP5. RCP 4.5 is considered a midrange-emissions scenario, and RCP 8.5 is a high-emissions scenario (Taylor et al. 2011).

Results of the climate models and the RCPs are averaged for three future periods, from 2025 to 2049, 2050 to 2074, and 2075 to 2099. The downscaled climate data for each model and the RCP scenario averaged over these 25-year periods were obtained from the developers of the USGS *Climate Change Viewer* (https://www.fs.usda.gov/ccrc/tools/national-climate-change-viewer) (USGS 2019). The USGS *FutureFlow* software calculates results based on all five climate models for any of the two greenhouse-gas scenarios, and the three time periods. These available results are meant to reflect a range of variation predicted from among the five models, and two greenhouse-gas scenarios (Alder & Hostetler 2017). The predictions of future mean annual runoff, obtained from the USGS *FutureFlow* software were used with the USGS regional regression equations and the computed basin characteristics, described in previous sections, to compute the expected future peak flows. The USGS *FutureFlow* software provides five estimates of the mean annual runoff for each RCP and future time period, one corresponding to each of the five climate models used. Future flows were computed for each of the five models corresponding to RCP 8.5 and the 2075 to 2099 time period, and the mean computed from the five results are displayed. Table 11 is a summary of the USGS *FutureFlow* projected peak discharges at the FEMA FIS locations (USGS 2016).

**Table 11. Silver Creek Projected Peak Discharges using USGS *FutureFlow* software**

| (Source: USGS 2016) | | | | | | |
|---|---|---|---|---|---|---|
| | | | Peak Discharges (cfs) | | | |
| **Location** | **Drainage Area ($Mi^2$)** | **River Station (ft)** | **10-Percent** | **2-Percent** | **1-Percent** | **0.2-Percent** |
| **Confluence with Lake Erie** | 52.2 | 0+00 | 6,130 | 9,440 | 10,970 | 14,950 |
| **Upstream Corporate Limits** | 25 | 67+00 | 3,090 | 4,760 | 5,540 | 7,530 |
| **Dam at Smith Mills** | 15.9 | 405+00 | 2,400 | 3,750 | 4,380 | 6,020 |
| **1600-ft upstream King Road** | 14.6 | 437+50 | 2,260 | 3,550 | 4,150 | 5,710 |
| **1600-ft downstream Mackinaw Road** | 13.7 | 473+00 | 2,200 | 3,460 | 4,050 | 5,590 |
| **1300-ft downstream Mackinaw Road** | 12.2 | 505+00 | 2,020 | 3,170 | 3,710 | 5,120 |
| **3200-ft upstream Mackinaw Road** | 11.9 | 535+00 | 1,970 | 3,100 | 3,620 | 5,000 |

Appendix E contains the HEC-RAS simulation summary sheets for the proposed and future condition simulations. The HEC-RAS model simulation results for the future condition model parameters using the future projected discharge values are similar to the base condition model output with future projected water surface elevations increasing approximately 0.8-feet higher for the 1% annual change peak stream flow due to the increased discharges. Table 12 provides a comparison of the current 1% annual change peak stream flows calculated using the USGS *StreamStats* software (USGS 2017) and the mean predicted future discharge calculated using the USGS *FutureFlow* software (USGS 2016) at each of the discharge locations included in the effective FIS.

**Table 12. Comparison of 1% Annual Chance Current and Future Discharges at Silver Creek**

| (Source: USGS 2016; USGS 2017) | | | | | |
|---|---|---|---|---|---|
| **Location** | **Drainage Area ($Mi^2$)** | **River Station (ft)** | **Current *StreamStats* Discharge (cfs)** | **Predicted *FutureFlow* Discharge (cfs)** | **Change (Percent)** |
| **Confluence with Lake Erie** | 52.2 | 0+00 | 9,790 | 10,970 | 12 |
| **Upstream of Corporate Limits** | 25 | 67+00 | 4,950 | 5,540 | 12 |
| **Dam at Smith Mills** | 15.9 | 405+00 | 3,970 | 4,380 | 10 |
| **1600-ft upstream of King Road** | 14.6 | 437+50 | 3,770 | 4,150 | 10 |
| **1600-ft downstream of Mackinaw Road** | 13.7 | 473+00 | 3,660 | 4,050 | 11 |
| **1300-ft downstream of Mackinaw Road** | 12.2 | 505+00 | 3,350 | 3,710 | 11 |
| **3200-ft upstream of Mackinaw Road** | 11.9 | 535+00 | 3,210 | 3,620 | 13 |

The USGS recommends using the *FutureFlow* application as a tool in an exploratory manner and to consider the results along with other sources of information to decide how future climate change may affect peak-flow magnitudes. The field of climate change investigations is evolving rapidly. This study utilized *FutureFlow* projected discharge values in the assessment of flood mitigation alternatives to maintain consistency with the use of *StreamStats* peak discharges and to develop the most conservative assessment of the flood mitigation alternatives since the *FutureFlow* discharges are greater than the 10% design life multiplier recommended by the CRRA (Burns et al. 2015).

# 5. FLOODING CHARACTERISTICS

## 5.1 FLOODING HISTORY

In the Village of Silver Creek, flooding occurs almost annually along Lake Erie and Walnut Creek in the late winter and early spring season due to rapid thawing of snow and ice cover, often accelerated by rainfall and ice jams. Silver Creek experiences relatively little flooding due to high banks within the village limits (FEMA 1983b). Floods of record in the Village of Silver Creek include Hurricane Agnes in June 1972 and an August 2009 localized storm event (NYSDEC 2020b).

Hurricane Agnes caused major flooding along both Silver and Walnut Creeks and along Lake Erie. No damage estimate or peak discharge rate has been determined for this event; however, it is estimated that approximately 50% of the village was affected in some way (FEMA 1983b).

The August 2009 flooding was caused by nearly 6 inches of rainfall in a span of 1.5 hours near the Village of Silver Creek. Severe damage occurred in the Silver Creek and Walnut Creek watersheds with many roadway culverts were washed away and/or destroyed resulting in significant damage to commercial and residential properties. Two fatalities were reported in the Village of Gowanda, located approximately 12 miles southeast of the Village of Silver Creek. Flood damage estimates totaled greater than $90 million in the three counties, including Chautauqua County, as a result of this storm event. The previously estimated 0.2% exceedance storm water depths in the Village of Silver Creek were exceeded by an estimated 6 to 8 feet (USGS 2010).

Three flood events in the Village of Silver Creek have caused damage since 2000. On August 15, 2000, a thunderstorm along the Lake Erie shoreline produced torrential rains. Residents notified local law enforcement of roadway and basement flooding in the village. On May 13, 2014, a stalled warm front brought heavy rain showers and embedded thunderstorms which trained across the western Southern Tier of New York State. Rainfall amounts of one to three inches in just a few hours resulted in flash flooding across the region. Roadways and culverts were washed out along with numerous roadways being water-covered and closed. Evacuations took place in the Village of Silver Creek. States of Emergency were declared in Cattaraugus and Chautauqua Counties. The resulting damages were enough to warrant a State Disaster Declaration (NCEI 2020).

Feedback from the virtual project kickoff meetings and public outreach provided additional insight into flooding issues in the Village of Silver Creek. The mobile home park located on the southern side of Main Road (County Route 20) was severely impacted during the 2009 flooding. It is located very close to Silver Creek and several homes are close to the right bank, making them especially susceptible to future flooding. Sediment buildup at the confluence of Silver Creek with Lake Erie limits flow capacity which can cause higher flows immediately upstream, impacting the Silver Creek Firemen’s Association property. Ice jamming also frequently causes flooding along Silver Creek from the confluence with Walnut Creek downstream to the confluence with Lake Erie (NYSDEC 2020b).

FEMA FIRMs are available for Silver Creek from FEMA. Figure 5-1, Figure 5-2, and Figure 5-3 display the 1 and 0.2% annual chance flood event boundaries for Silver Creek as determined by FEMA for the Village of Silver Creek and the Towns of Hanover and Villenova, respectively. The maps were derived by scanning the existing FIRM hardcopy and capturing a thematic overlay of flood risks, which can often distort map features that are georeferenced over large areas. The FEMA Digital Q3 Flood Data files used to develop these figures contain only certain features from the FIRM hardcopy in effect at the time of scanning and do not replace the existing FIRM hardcopy maps (FEMA 1983a; FEMA 1984a; FEMA 1996).

Figures 5-1, 5-2, and 5-3 should be considered an advisory tool for general hazard awareness, education, and flood plain management and are not official and may not be used for regulatory purposes. The maps indicate that flooding generally occurs near the lake and railroad bridges upstream in the Village of Silver Creek and in Smith Hills in the vicinity of the dam in the Town of Hanover.


**Figure 5-1. Silver Creek, Village of Silver Creek FEMA Flood Zones, Chautauqua County, NY.**

*Note: This map was created using FIRMs georeferenced to the earth's surface. This figure is not official and may not be used for regulatory purposes.

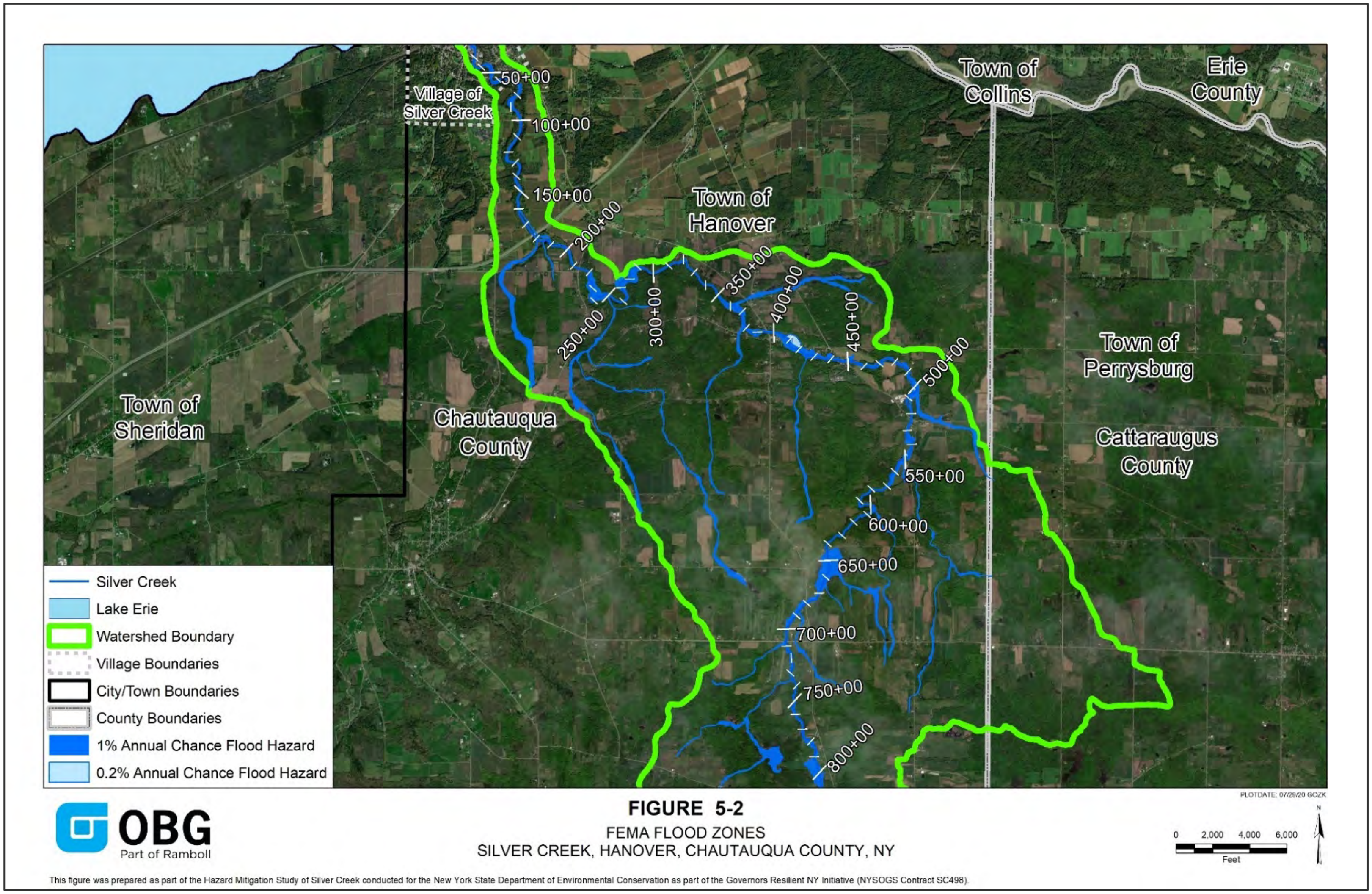



**Figure 5-2. Silver Creek, Town of Hanover FEMA Flood Zones, Chautauqua County, NY.**

*Note: This map was created using FIRMs georeferenced to the earth's surface. This figure is not official and may not be used for regulatory purposes.

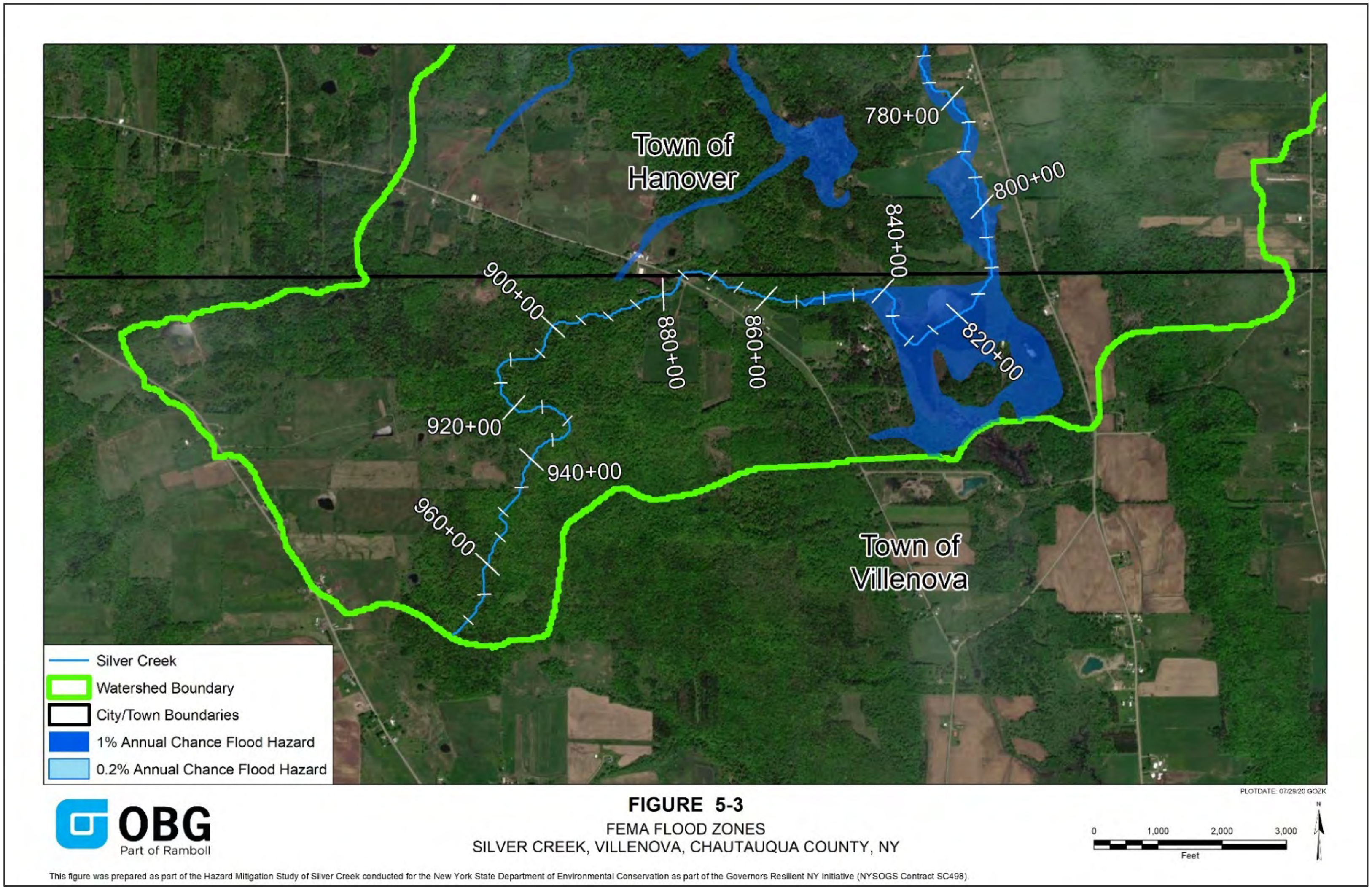



**Figure 5-3. Silver Creek, Town of Villenova FEMA Flood Zones, Chautauqua County, NY.**

*Note: This map was created using FIRMs georeferenced to the earth's surface. This figure is not official and may not be used for regulatory purposes.

## 5.2 FLOOD MITIGATION ANALYSIS

Hydraulic analysis of Silver Creek was conducted using the HEC-RAS computer program. The HEC-RAS computer program was written by the USACE Hydrologic Engineering Center (HEC) and is considered to be the industry standard for riverine flood analysis. The model is used to compute water surface profiles for one-dimensional, steady-state, or time-varied flow. Water surface profiles are computed from one cross section to the next by solving the one-dimensional energy equation with an iterative procedure (i.e. standard step backwater method). Energy losses are evaluated by friction (Manning's Equation) and the contraction / expansion of flow through the channel. The momentum equation is used in situations where the water surface profile is rapidly varied, such as hydraulic jumps, mixed-flow regime calculations, hydraulics of dams and bridges, and evaluating profiles at a river confluence. HEC-RAS version 5.0.7 was used in this study (USACE 2016a).

## 5.3 HEC-RAS MODEL DEVELOPMENT

The base condition model by the USACE (USACE 2017a) was reviewed by Ramboll, then used to develop proposed condition models to simulate potential flood-mitigation strategies. The general model domain was reviewed to verify it contained the study area. Cross sections were checked for appropriate elevation data, roughness parameters, buildings, and the inclusion of ineffective flow areas. The original model results were analyzed to verify that the results appeared reasonable and accurate for use in this study. The original steady flow parameters were verified against USGS *StreamStats* v4.3.11 software. Based on the review, the USACE model appears to be high-quality and accurate, and did not require modification for modeling the existing conditions. Note, modeling for both Silver Creek and Walnut Creek (provided under separate cover) was performed using one HEC-RAS model due to the interrelation between both creeks.

The simulation results of the proposed conditions were evaluated based on their reduction in water surface elevations. A total of 17 scenarios were modeled to analyze potential flood mitigation strategies, with and without ice cover. Six model scenarios were selected for inclusion in Section 6: MITIGATION . The modeled alternatives presented in this report include:

- 1-1: Jetty at Silver Creek Confluence with Lake Erie
- 2-1: Flood Bench Upstream Railroad Bridges
- 2-2: Flood Bench (and Ice Control Structure) at Confluence with Walnut Creek
- 2-3: Levee at Main Street
- 3-1: Levee at Mobile Home Park
- 3-2: Flood Bench Upstream of Mobile Home Park
- 4-1: Small Flood Controls Dams in the Upper Reaches of the Silver Creek Watershed

Alternatives #1-2, #1-3 and #4-2 through #4-6 are either qualitative in nature or did not require modeling.

## 5.4 COST ESTIMATE ANALYSIS

Rough order of magnitude (ROM) cost estimates were prepared for each mitigation alternative. In order to reflect current construction market conditions, a semi-analogous cost estimating procedure was used by considering costs of a recently completed, similar scope construction project performed in Upstate New York. Phase I of the Sauquoit Creek Channel and Floodplain Restoration Project in Whitestown, NY contained many elements similar to those found in the proposed mitigation alternatives.

Where recent construction cost data was not readily available, RSMeans CostWorks 2019 was used to determine accurate and timely information (RSMeans Data Online 2019). Costs were adjusted for inflation and verified against current market conditions and trends.

Infrastructure and hydrologic modifications will require permits and applications to the NYS and / or FEMA, including construction and environmental permits from the State and accreditation, Letter of Map Revision (LOMR), etc. applications to FEMA. Application and permit costs were not incorporated in the ROM costs estimates.

## 5.5 ICE-JAM FORMATION

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.

As the air temperature drops, the water temperature reaches freezing temperatures and starts to form frazil ice crystals in the water column. These ice crystals travel in the water column (suspended ice) with the river currents, growing in concentration, and losing heat while traveling. They float on the surface (surface ice), and as the crystals grow in size, they form surface frazil ice. As the air temperature continues to drop, temperature losses from the water and frazil ice create more surface ice, and thicken the existing surface frazil ice, increasing the surface ice concentrations on the river as it approaches colder winter temperatures. The presence of surface and suspended frazil ice increases resistance to the flow, thus increasing the water levels of rivers in the wintertime. Increasing concentrations of surface and suspended frazil ice increase the potential for ice jam formation, which can inhibit the flow of water in the channel, affecting both upstream and downstream water levels.

An existing ice jam can break-up and travel downstream along with larger ice particles with the higher flows of a flash flood and accumulate at a constricted downstream location creating another break-up ice jam, or damage downstream riverbanks or downstream infrastructures severely. 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 1966).

### 5.5.1 Ice-Jam Prone Areas

According to the USACE Cold Regions Research and Engineering Laboratory (CRREL) ice-jam database (https://icejam.sec.usace.army.mil/ords/f?p=101:7), National Centers for Environmental Information (NCEI) storm events database, the FEMA FIS, and the stakeholder engagement meeting, the Silver Creek watershed is susceptible to ice jam formation and backwater flooding. Since 1939, there have been seven reported ice-jam events on Silver Creek. Since 2010, there have been four ice-jam flooding events (CRREL 2020; NCEI 2020). Ice jamming and associated flooding frequently happens at the confluence of Silver Creek and Walnut Creek. Additionally, when Lake Erie freezes, ice jamming occurs at the confluence of Silver Creek at Lake Erie, and from Lake Erie ice being pushed upstream into Silver Creek depending on conditions. Ice jamming has occurred on Silver Creek upstream as far as Howard Avenue (Highway 5) (CRREL 2020).

### 5.5.2 Ice-Jam Flooding Mitigation Alternatives

There are several widely accepted and practiced standards for ice-jam controls to mitigate the ice-jam related flooding. These are referred to as ice-jam mitigation strategies, and each strategy is very much site dependent. A strategy that works for a certain reach of a river may not work for another reach in the same river due to river morphology and hydrodynamics. Therefore, each of these strategies need to be analyzed with numerical modeling and simulations to check if they work for a considered area / reach of a river before implementing or recommending with the previous observational experience alone. The standard strategies that are widely accepted and practiced in cold-region engineering, such as in Western New York, are listed below with greater detail provided in Appendix C:

- Ice booms
- Ice breaking using explosives
- Ice breaking using ice-breaker ferries and cutters
- Installing inflatable dams (Obermeyer Spillways)
- Mixing heated effluent into the cold water
- Removal of bridge piers, heated bridge piers, or heated riverbank dikes
- Ice retention structures
- Ice forecasting systems and ice management

Ramboll suggests performing a freeze-up or a break-up ice model simulation study prior to implementing any of the above discussed strategies. The basic data needs and steps involved in an ice simulation analysis are also outlined in Appendix C.

## 5.6 HIGH-RISK AREAS

Based on the FEMA FIS, NCEI storm events database, historical flood reports, and stakeholder engagement meeting notes, three areas along Silver Creek were identified as high-risk flood areas in the Village of Silver Creek.

### 5.6.1 High-Risk Area #1: Silver Creek Outlet

High-Risk Area #1 is the confluence of Silver Creek with Lake Erie (river station 0+00 to 4+00) (Figure 5-4). Modeling shows a constriction due to sediment build up and littoral currents (i.e. longshore) in Lake Erie limit the hydraulic capacity of Silver Creek at its outlet, causing backwater conditions which raise water surface elevations for large storm events, including the 1% annual chance flood event and the 0.2% chance annual flood event. The constriction also inhibits ice flow out of Silver Creek, which can cause jamming to extend upstream, toward the confluence of Silver Creek and Walnut Creek, which can cause additional flooding in the Village of Silver Creek.

Various soft (i.e. natural) and hard (i.e. constructed) structures were assessed as mitigation alternatives to the sediment build up at the outlet of Silver Creek into Lake Erie. Soft structures, such as beach nourishment, dredging, beach scraping, and sand fencing, were determined to be ineffective strategies for reducing sediment build up due to the littoral current off of Lake Erie at the outlet of Silver Creek. Multiple hard structures were analyzed and are discussed in the mitigation alternatives section below.

### 5.6.2 High-Risk Area #2: Northern End of Main Street

High-Risk Area #2 is the northern end of Main Street on the south side of Silver Creek (river station 25+00) (Figure 5-4). Flood flows leave the Silver Creek channel at the left bank, causing some inundation of the area on the northern end of Main Street.

### 5.6.3 High-Risk Area #3: Mobile Home Park

High-Risk Area #3 is at the mobile home park located on the southern side of Main Road (County Route 20) (river station 35+00 to 42+00) (Figure 5-4). This area has previously flooded, most notable in 2009, and remains at risk according to modeling performed in this study. Water surfaces during the 1% annual chance event and the 0.2% annual chance event are predicted to impact the mobile home park.

According to FEMA guidelines, the NFIP requires that manufactured homes placed or substantially improved in Zones A1-30, AH, or AE on the community's FIRM on sites:

(i) Outside of a manufactured home park or subdivision,
(ii) In a new manufactured home park or subdivision,
(iii) In an expansion to an existing manufactured home park or subdivision, or
(iv) In an existing manufactured home park or subdivision on which a manufactured home has incurred substantial damage as the result of a flood,

be elevated on a permanent foundation such that the lowest floor of the manufactured home is elevated to or above the base flood elevation and be securely anchored to an adequately anchored foundation system to resist flotation, collapse and lateral movement. Methods of anchoring may include, but are not limited to, the use of over-the-top frame ties to ground anchors. This requirement is in addition to applicable State and local anchoring requirements for resisting wind forces (FEMA 2000; FEMA 2009).

The NFIP allows for a limited exemption to elevating to the BFE by allowing elevating to no less than 36 inches in height above grade for lots in existing manufactured home parks in Zones A1-30, AE, or AH on the community's FIRM. A manufactured home placed in an existing manufactured home park must meet either of the following requirements:

1) The lowest floor of the manufactured home is at or above the base flood elevation; or
2) The manufactured home chassis is supported by reinforced piers or other foundation elements of at least equivalent strength that are no less than 36 inches in height above grade and be securely anchored to an adequately anchored foundation system to resist flotation, collapse, and lateral movement (FEMA 2000; FEMA 2009).

The elevation requirements above apply in existing manufactured home parks or subdivisions established before the date of the community's initial floodplain management regulations when:

1) A manufactured home is being placed or replaced with a new model in an existing community or subdivision, or
2) A manufactured home is being replaced in an existing manufactured home park or subdivision when the previous home had sustained substantial damage due to reasons other than a flood (FEMA 2009).

An inspection of the current mobile home park structures would need to be performed to determine whether the mobile home structures are in compliance with FEMA, NFIP, State, and local requirements.

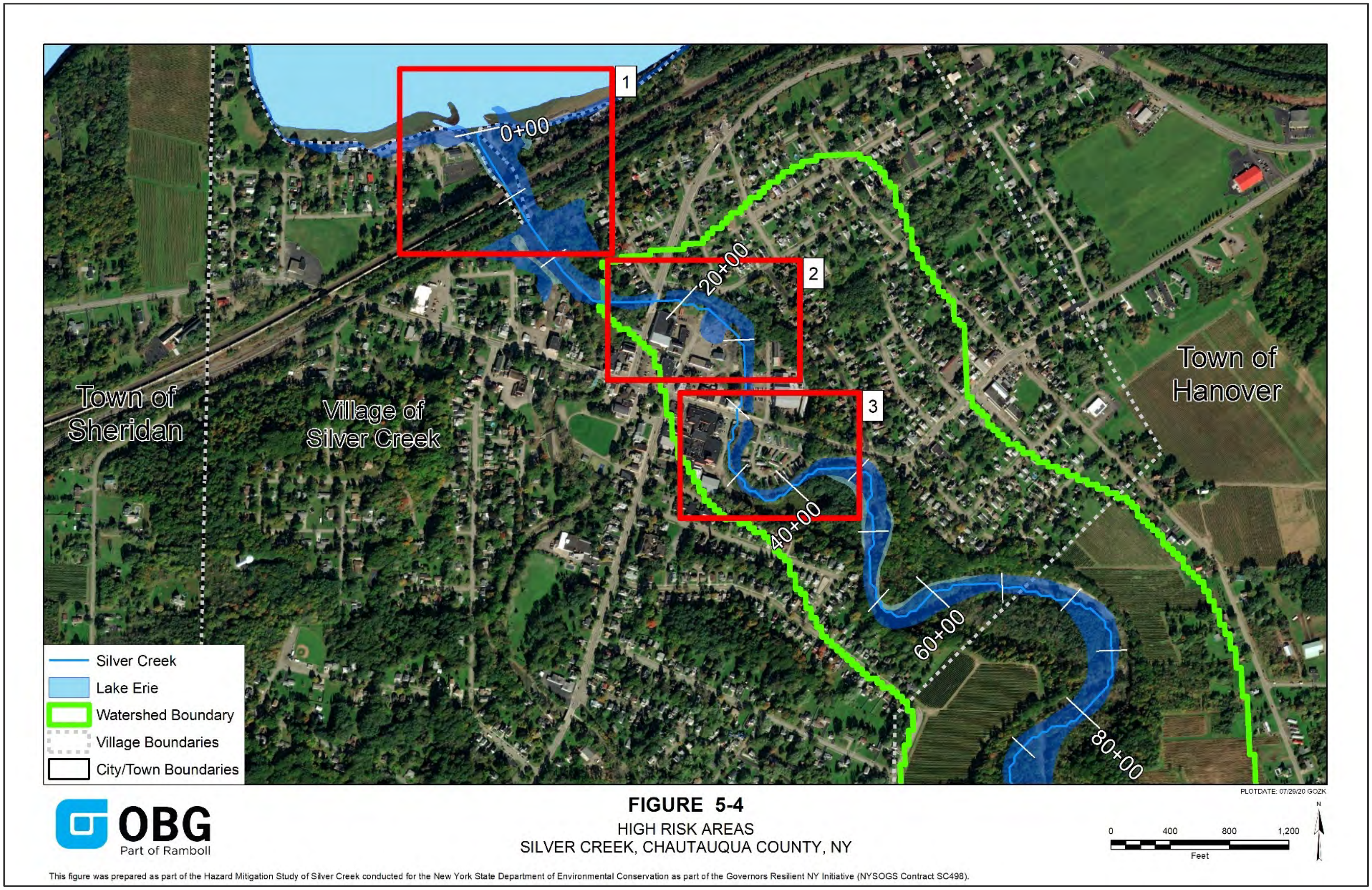



**Figure 5-4. Silver Creek High-risk Areas, Village of Silver Creek, Chautauqua County, NY.**

# 6. MITIGATION ALTERNATIVES

The following are flood mitigation alternatives that have the potential to reduce water surface elevations along high-risk areas of Silver Creek. These alternatives could potentially reduce flood related damages in areas adjacent to the creek. Local and State officials and stakeholders should evaluate each alternative before pursuing them further.

## 6.1 HIGH-RISK AREA #1

### 6.1.1 Alternative #1-1: Jetty at Silver Creek Confluence with Lake Erie

This measure is a jetty intended to address sediment buildup at the confluence of Silver Creek with Lake Erie (river station 0+00), which would increase flow conveyance and decrease flow depths in this area downstream of the Norfolk Southern and CSX railroad bridges. A jetty is a structure, often made of large riprap, which projects into a waterbody, helping to limit sediment buildup. In this case, the jetty would project into Lake Erie on each side of Silver Creek, helping to limit sediment buildup due to flows in Lake Erie, and to encourage free discharge of flows in Silver Creek. Feedback from public outreach conducted for this report indicates that silt buildup can vary seasonally, with summertime buildup reducing the channel outlet to only a few feet wide.

Silver Creek at the confluence with Lake Erie is within a mapped Coastal Erosion Hazard Area (CEHA), specifically a Natural Protective Feature Area (NPFA) and Structural Hazard Area (SHA) as indicated by the Coastal Erosion Hazard Area Map for the Village of Silver Creek. For a Coastal Erosion Management permit to be issued, the NYSDEC would need significant justification for the project and it would require an alternative analysis be completed. Before a jetty can be permitted, the community would need to demonstrate that it is the least impactful alternative that will mitigate their flooding issue, which is typically done through additional modeling. In addition, USACE permits and a New York State Department of State (NYSDOS) Coastal Consistency review would be required if the jetty required fill below the ordinary high water, which would be likely.

Prior to pursuing this alternative, for a coastal management project to be considered a feasible alternative, additional extensive hydrologic and hydraulic modeling, NYSDEC and USACE permitting, and a significant proposal justification, including only viable alternative and greatest benefit with least amount of impact, would be required. In addition, it is NYSDEC policy that non-structural (i.e. natural) solutions be considered before structural mitigation strategies are considered reasonable and necessary. For a structural mitigation strategy, the NYSDEC would require the following information:

- How the alternative will alleviate flooding and the effectiveness at various flood levels?
- What, if any, impacts there will be to sediment transport? How will any impacts be mitigated?
- What, if any, impacts will there be to adjacent areas (private properties, wetlands, nearshore)?

- Will the alternative cause increased erosion or flooding impacts to adjacent areas?
- What, if any, are the long-term maintenance requirements?


**Figure 6-1. Location map for Alternative #1-1: Jetty at Silver Creek confluence with Lake Erie.**

Hydraulic modeling of this measure estimates a decrease in water surface elevation at the outlet of up to approximately 1.5 ft during the 1% annual chance flood event from 576-ft NAVD88 to 574.5-ft NAVD88. The water surface elevation decrease would continue upstream approximately to the Norfolk Southern and CSX railroad bridges (Figure 6-2). The Silver Creek Firemen's Association building and parking area would be less likely to flood during high-flow events. The jetty would also help prevent sediment build-up due to littoral currents at the outlet, and encourage higher velocities which inhibit new sediment build-up due to bed load sediment carried in Silver Creek from the contributing drainage area.

Removal of sediments at the confluence, by dredging or excavation, would likely produce similar results to those shown in modeling, but would provide only temporary relief until sediments inevitably build up again. The sediment movement is seasonally cyclical, due to the lake's tidal effects. A jetty would encourage hydraulic conditions which would provide a more sustainable method to preventing sediment buildup. Additional hydraulic modeling including 2-Dimensional coastal analyses would be required to further determine potential impacts and design for the jetty.

This measure would also likely aid in decreasing ice jamming due to sediment obstructing ice cover from exiting Silver Creek. The decrease in water surface elevation during the 10% annual chance flood event with ice cover can be seen in Figure 6-3. A jetty would likely not provide benefits during ice-jam events when Lake Erie is ice-covered.

The disadvantages of a jetty is that the structure is designed to interrupt long-shore sediment transport, preventing sediment accumulation in an inlet or river mouth. Consequently, sediment accumulation typically occurs on their updrift side, and sediment starvation on their down-drift side. Furthermore, the formation of rip currents in the adjacent area should be expected. Due to the typical length of a jetty, it can be expected that there would be greater sediment loss to deep water during storm events when compared to similar areas without a jetty (Masselink and Hughes 2003; Appelquist et al. 2016).

When implementing jetties, long-shore sediment transport is therefore a critical design parameter. Considering this, it may be necessary to combine jetty construction with a sediment bypassing scheme, where sediment trapped by the jetty is dredged from its updrift side and deposited on the downdrift side of the tidal inlet / river mouth. This would maintain a degree of longshore sediment supply and could be implemented alongside channel dredging which is likely to be required for the maintenance (Appelquist et al. 2016).

USACE has the authority to construct small flood risk reduction projects that are engineeringly feasibly, structurally sound and cost efficient through the authority provided under Section 205 of the 1948 Flood Control Act (FCA), as amended. Coordination should also occur with NYSDEC as they need to be the non-Federal sponsor on these types of projects.

In addition, a FEMA Benefit-Cost Analysis (BCA) would need to be performed to determine the cost-effectiveness of the alternative prior to applying for FEMA mitigation grant programs funding. The BCA is the method by which the future benefits of a mitigation project are determined and compared to its cost. The end result is a Benefit-Cost Ratio (BCR), which is derived from a project's total net benefits divided by its total project cost. The BCR is a numerical expression of the cost effectiveness of a project. A project is considered to be cost effective when the BCR is 1.0 or greater.

The Rough Order Magnitude cost for this strategy is approximately $499,000. This estimate only addresses construction of the jetty and does not include the additional engineering, modeling, and permitting requirements or maintenance costs.

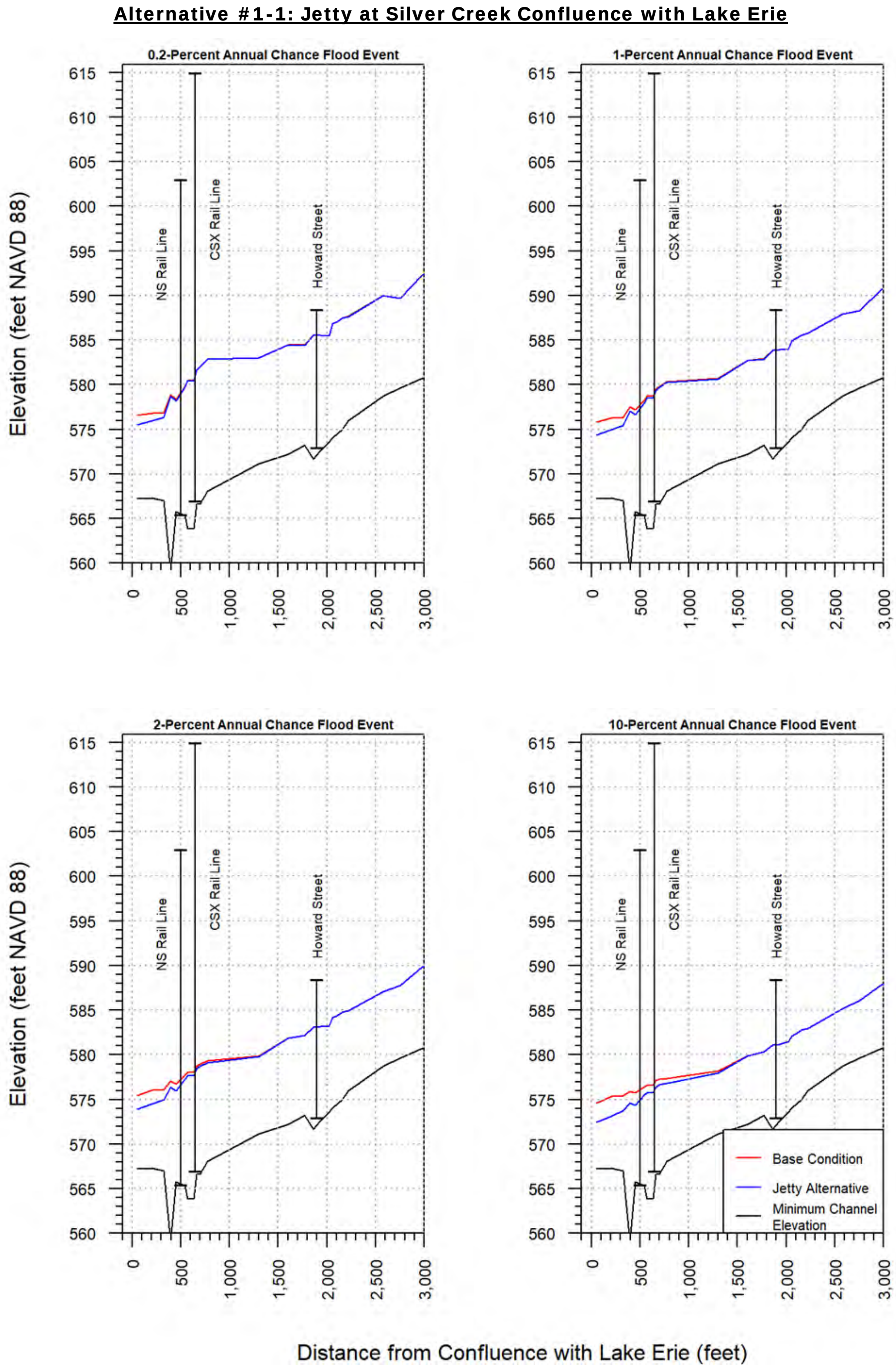



Figure 6-2. HEC-RAS proposed condition model for Alternative #1-1.

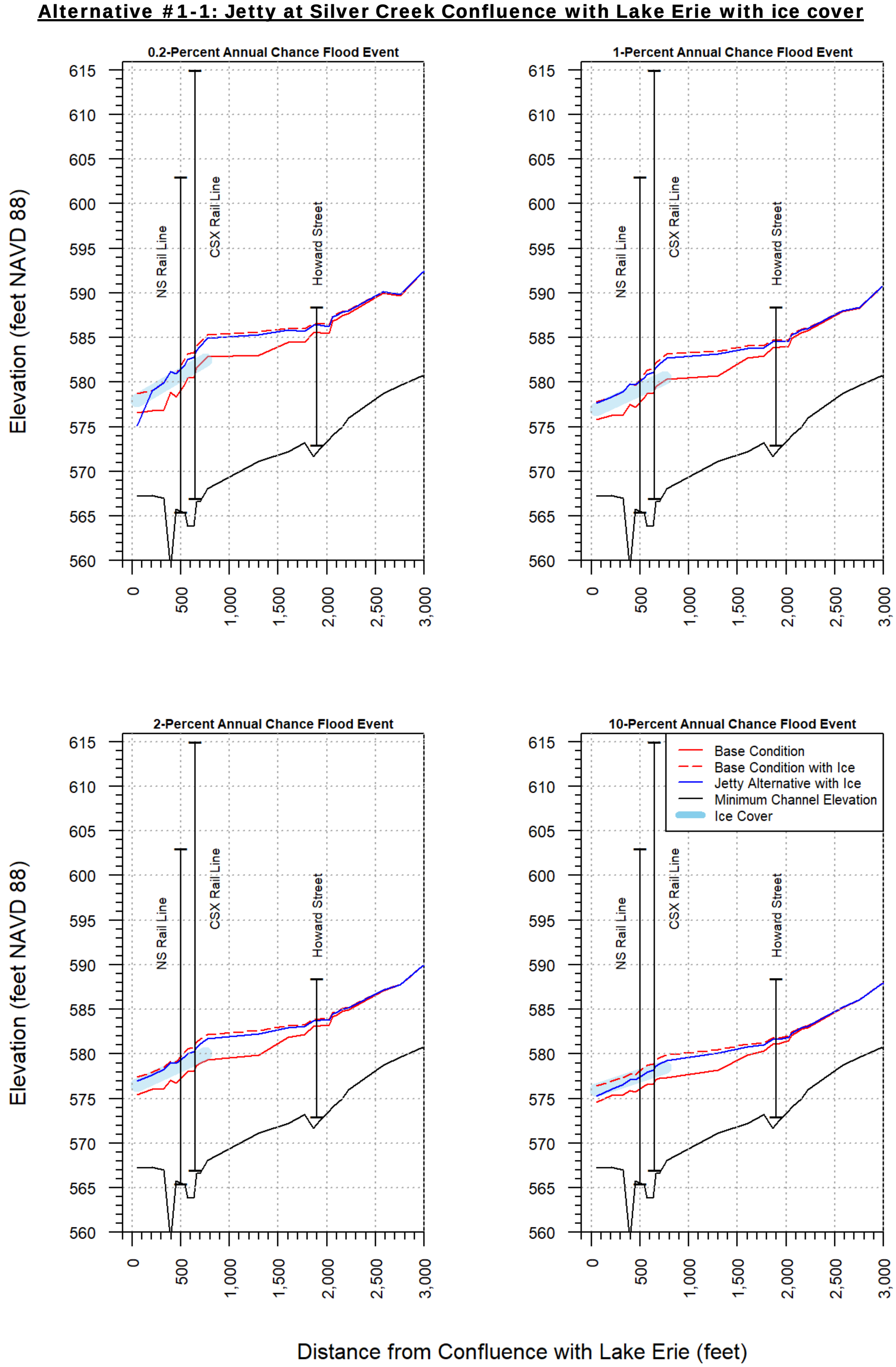



**Figure 6-3. HEC-RAS proposed condition model for Alternative #1-1 with ice cover.**

### 6.1.2 Alternative #1-2: Streambank Stabilization near Outlet

This mitigation alternative is currently being proposed and considered by the Town of Hanover under the 2021 2% Occupancy Tax Application Grant Program for Lakes and Waterways in Chautauqua County, NY. The proposal was submitted by EcoStrategies Engineering & Surveying, PLLC. The Silver Creek left bank is being eroded between river stations 1+00 and 3+00, which is creating a safety hazard for users of the publicly accessible parking lot at George Borrello Park, and is a source of sedimentation (over 200-yds or 20 truckloads) and nutrients to Lake Erie (Figure 6-4) (EcoStrategies 2020).


**Figure 6-4. Location map for Alternative #1-2: Streambank Stabilization near outlet.**

The proposed mitigation strategy involves the installation of large stone riprap (3 to 4-ft diameter) to stabilize the creek bed and banks with toe protection, rock vanes, bendway weirs, etc. along the right bank of Walnut Creek. The project incorporates simple, low-cost solutions that include sloping back and re-shaping existing eroded banks with and excavator, installing live stakes (willows or dogwood), installing native seed mix and / or hydroseeding, and using erosion control blankets. Excess creek gravel at the project locations will also be removed to help rebuild portions of the eroded bank and around the large stone riprap for proper bedding and backside drainage (EcoStrategies 2020).

This project will improve water quality to the lake by controlling erosion / sedimentation and filtering pollutants upstream; the bio-engineering, live stakes and native seed will improve riparian buffer, ecology, wildlife habitat and aesthetics; both sites are visible and open to the public and will serve as a demonstration site; and finally, the project will help mitigate the sediment build-up problem at the lake and flooding to municipal buildings (EcoStrategies 2020).

The Rough Order Magnitude cost for this strategy is approximately $55,000.

### 6.1.3 Alternative #1-3: Sediment Management at Outlet to Lake Erie

This measure is intended to the remove deposited sediment at the outlet of Silver Creek with Lake Erie that has aggraded the creek channel (Figure 6-5). Sediment sources at the outlet are driven by both costal and riverine processes, including littoral drift along the shoreline of Lake Erie and the natural sediment transport and streambank erosion that occurs along Silver Creek. As the sediment aggrades at the outlet, the channel geometry is altered and the in-channel flow area is reduced. This, in turn, reduces the volume of water that can be transported safely within the channel without overtopping the banks.

A sediment management strategy that involves removing sediment from the channel, such as dredging, requires extensive environmental and modeling studies, application, sampling, testing, certification, permitting, operational and maintenance plans with proof of financial viability, and a significant proposal justification, including only viable alternative and greatest benefit with least amount of impact. The NYSDEC *Technical & Operations Guidance Series (TOGS) 5.1.9 In-Water and Riparian Management of Sediment and Dredged Material* (2004) should be used to determine the procedure and necessary steps in order to develop a sediment removal strategy.

There are a number of federal, state and local regulatory controls in place which apply to in-water and riparian sediment management projects. The applicability of these controls to each project depends on the particular circumstances of each case, such as the sediment classification and the intended use or management of the removed material (NYSDEC 2004).


**Figure 6-5. Location Map for Alternative #1-3: Sediment Management at outlet to Lake Erie.**

Some or all of the following New York State and Federal Permits may be required: Use and Protection of Waters Permit; Freshwater Wetlands Permit; Tidal Wetlands Permit; State Pollutant Discharge Elimination System Permit; Clean Water Act § 401 Water Quality Certification and § 404 Permit and Rivers and Harbors Act § 10 Permits, issued by the USACE. An antidegradation review and Wild, Scenic and Recreational Rivers Program permits may also be required (NYSDEC 2004).

The basic steps involved in the application process and technical review of a sediment assessment and management plan involves the following:

1. A pre-application meeting with the NYSDEC to discuss all application, permitting, and information needs
2. A sampling plan to determine sampling requirements for proper characterization of proposed sediments and material to be removed
3. Laboratory analysis of sampled material
4. Evaluation of laboratory results
5. Determination of appropriate management options based on sediment class

6. Development of permit conditions for the process of removing sediments and materials and the management of the removed materials
7. Maintenance and monitoring of operations for the management plan (NYSDEC 2004)

Due to the complex nature of sediment transport during both coastal and riverine processes, no modeling simulations were performed for this alternative.

Sediment management at the outlet can improve water quality of both Lake Erie and Silver Creek, and in-channel flow area and, thereby, reduce flood risk for areas in the vicinity of the outlet. However, the process of removing sediment can also fundamentally change the composition of aquatic habitats and potentially release pollutants into the water column that were previously secured in the channel sediments.

USACE has the authority to construct small flood risk reduction projects that are engineeringly feasibly, structurally sound and cost efficient through the authority provided under Section 205 of the 1948 FCA, as amended. Coordination should also occur with NYSDEC as they need to be the non-Federal sponsor on these types of projects. In addition, a FEMA Benefit-Cost Analysis (BCA) would need to be performed to determine the cost-effectiveness of the alternative prior to applying for FEMA mitigation grant programs funding.

The Rough Order Magnitude cost for this strategy is approximately $506,000, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

## 6.2 HIGH-RISK AREA #2

### 6.2.1 Alternative #2-1: Flood Bench Upstream Railroad Bridges

The flood bench would be located on the right bank of Silver Creek between river stations 7+00 and 15+00. The addition of a flood bench increases the water storage volume to the river, decreasing water depths during large flow events. This measure would be located immediately upstream the railroad bridges and would require the excavation of approximately three acres of land at an average depth of four feet (Figure 6-6).

The flood bench would provide addition flood protection to the residences along Lake Avenue on the right bank and Montgomery Street and Lincoln Avenue on the left bank of Silver Creek. In addition, the railroad bridges are a known ice jam location. A flood bench upstream the railroad bridges would provide additional water and ice storage during ice-jam events, which could potentially reduce flood risk and damages.

Appendix B provides mitigation renderings which illustrate a flood bench.


**Figure 6-6. Location Map for Alternative #2-1: Flood Bench upstream of railroad bridges.**

Hydraulic modeling of the flood bench estimates a decrease in water surface elevation in Silver Creek adjacent to the flood bench of up to approximately 1.2 ft during the 1% annual chance flood event, which would likely decrease the impact of flooding but not completely mitigate it (Figures 6-7 and 6-8).

Flood benches generally provide flood protection for localized areas in the vicinity of and immediately upstream and downstream of the bench. Based on the analysis of high-risk areas, a flood bench located upstream the railroad bridges would provide some protection to the properties adjacent to the bench, but high flood-risk areas downstream would not benefit from the bench.

The Rough Order Magnitude cost for this strategy is approximately $1,500,000, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

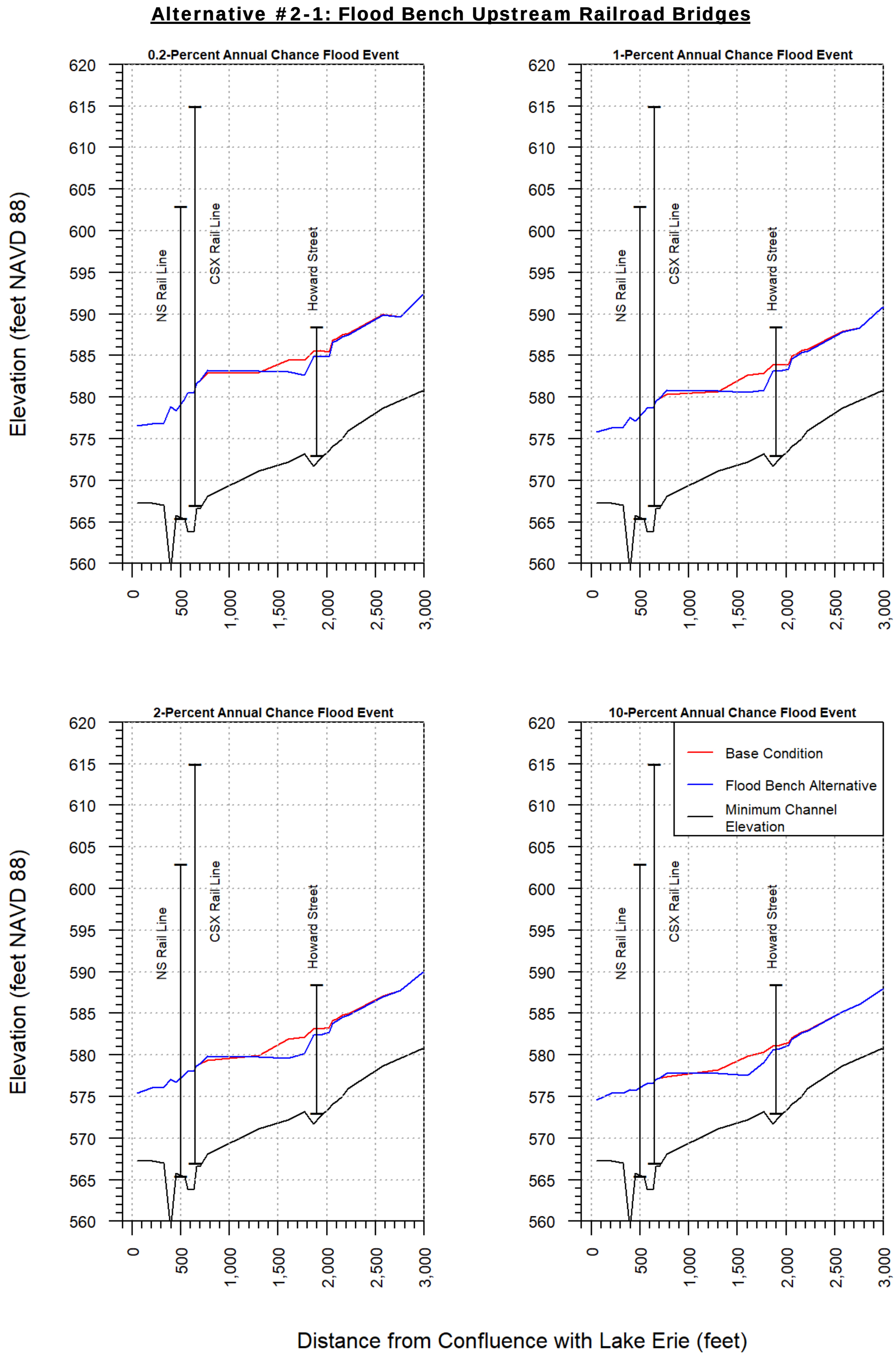



**Figure 6-7. HEC-RAS proposed condition model for Alternative #2-1.**

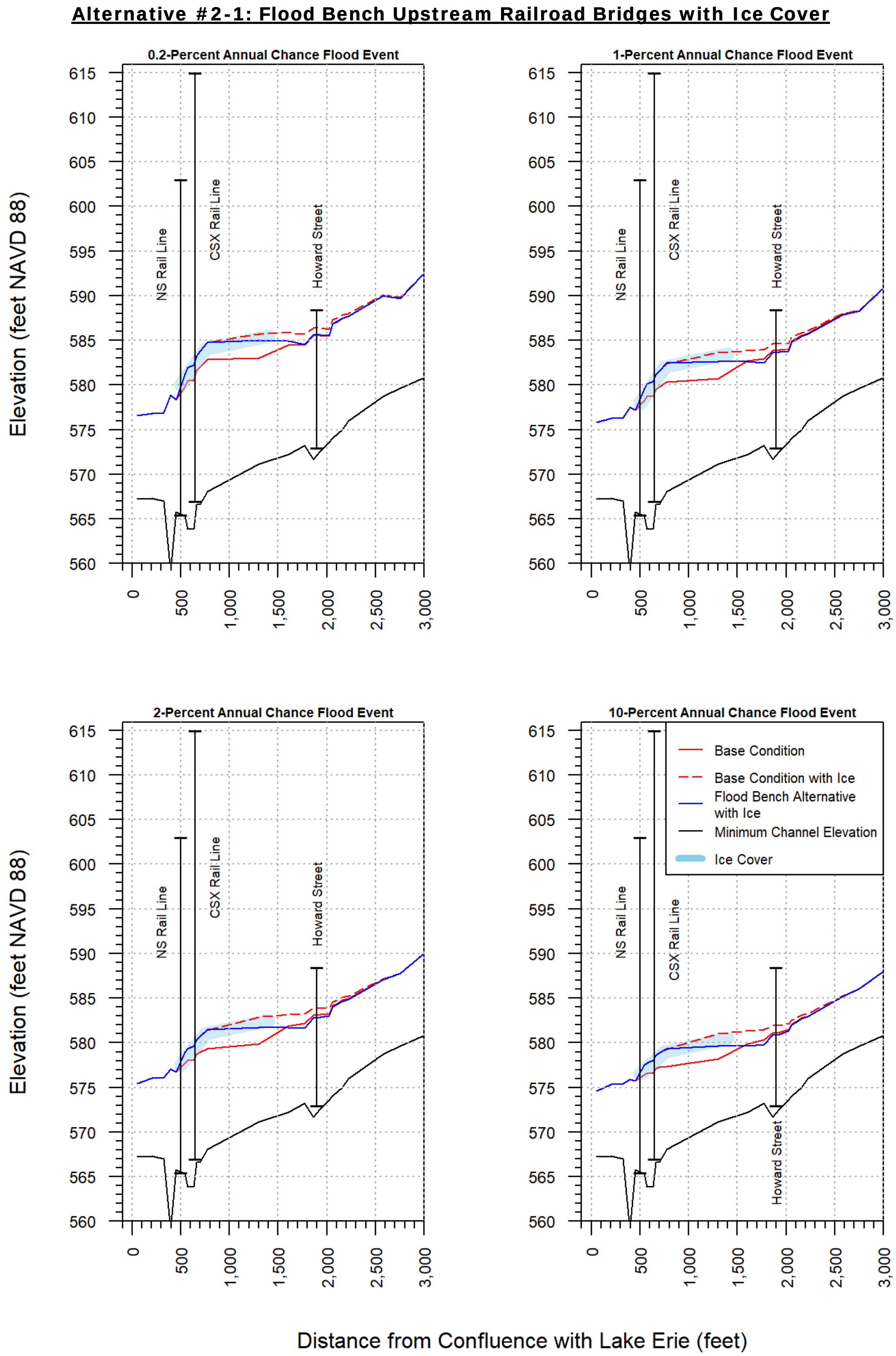



**Figure 6-8. HEC-RAS proposed condition model for Alternative #2-1 with ice cover.**

### 6.2.2 Alternative #2-2: Flood Bench (and Ice Control Structure) at Confluence with Walnut Creek

The flood bench would be located at the confluence of Silver and Walnut Creeks between river stations 13+00 and 15+50. The addition of a flood bench increases the water storage volume to the river, decreasing water depths during large flow events. This measure would require the excavation of approximately 0.6 acres of land at an average depth of 3 ft (Figure 6-9).

The flood bench would provide addition flood protection to the residences and businesses along Central Ave and Howards Street along the banks of both Silver and Walnut Creeks. In addition, the confluence is a known ice jam location. A flood bench at the confluence with an ice control structure, such as ice piers, would provide additional water and ice storage during ice-jam events, which could potentially reduce flood risk and damages.

Appendix B provides mitigation renderings which illustrate a flood bench.


**Figure 6-9. Location Map for Alternative #2-2: Flood Bench (and Ice Control Structure) at confluence with Walnut Creek.**

Hydraulic modeling of the flood bench estimates a decrease in water surface elevation in Silver Creek adjacent to the flood bench of up to approximately 0.4 ft during the 1% annual chance flood event, which would likely decrease the impact of flooding but not completely mitigate it (Figures 6-10 and 6-11).

Flood benches generally provide flood protection for localized areas in the vicinity of and immediately upstream and downstream of the bench. Based on the analysis of high-risk areas, a flood bench located at the confluence with Walnut Creek would provide some protection to the properties adjacent to the bench, but high flood-risk areas downstream would not benefit from the bench.

Ice control structures require careful consideration due to the fact that the right conditions have to be in place for them to be effective. Additional hydrologic, hydraulic, and ice modeling simulations need to be performed to determine the effective distance of the damage area, and provide a place to trap the ice (gorge location) and allow floodwater to pass by without causing further damage (undeveloped floodplain). Flowage easements have to be secured upstream to mitigate increases in water surface elevations due to trapped ice. In addition, ice control structures can trap a lot of debris, requiring a high level of annual maintenance.

The Rough Order Magnitude cost for this strategy is approximately $870,000, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

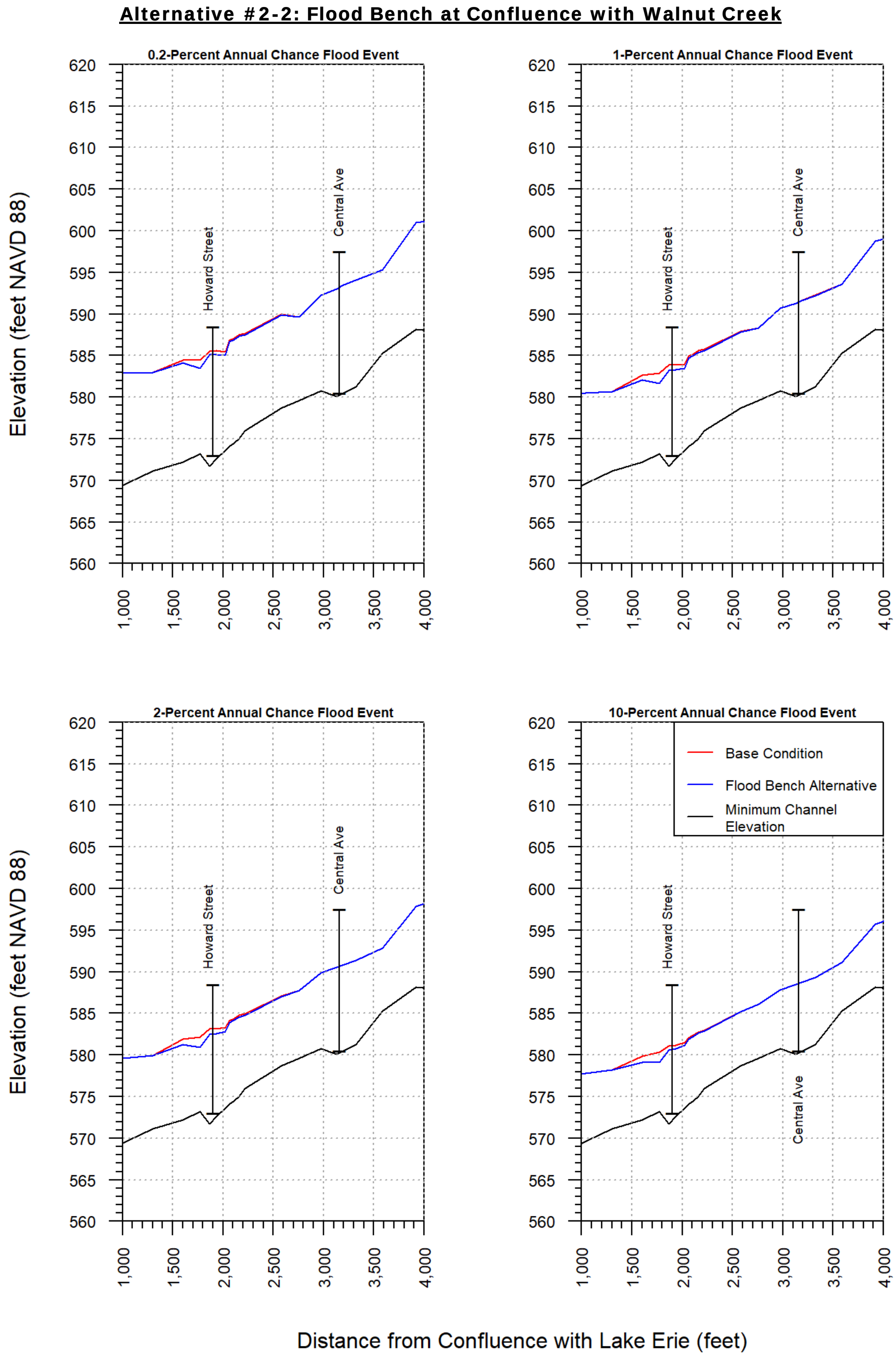



Figure 6-10. HEC-RAS proposed condition model for Alternative #2-2.

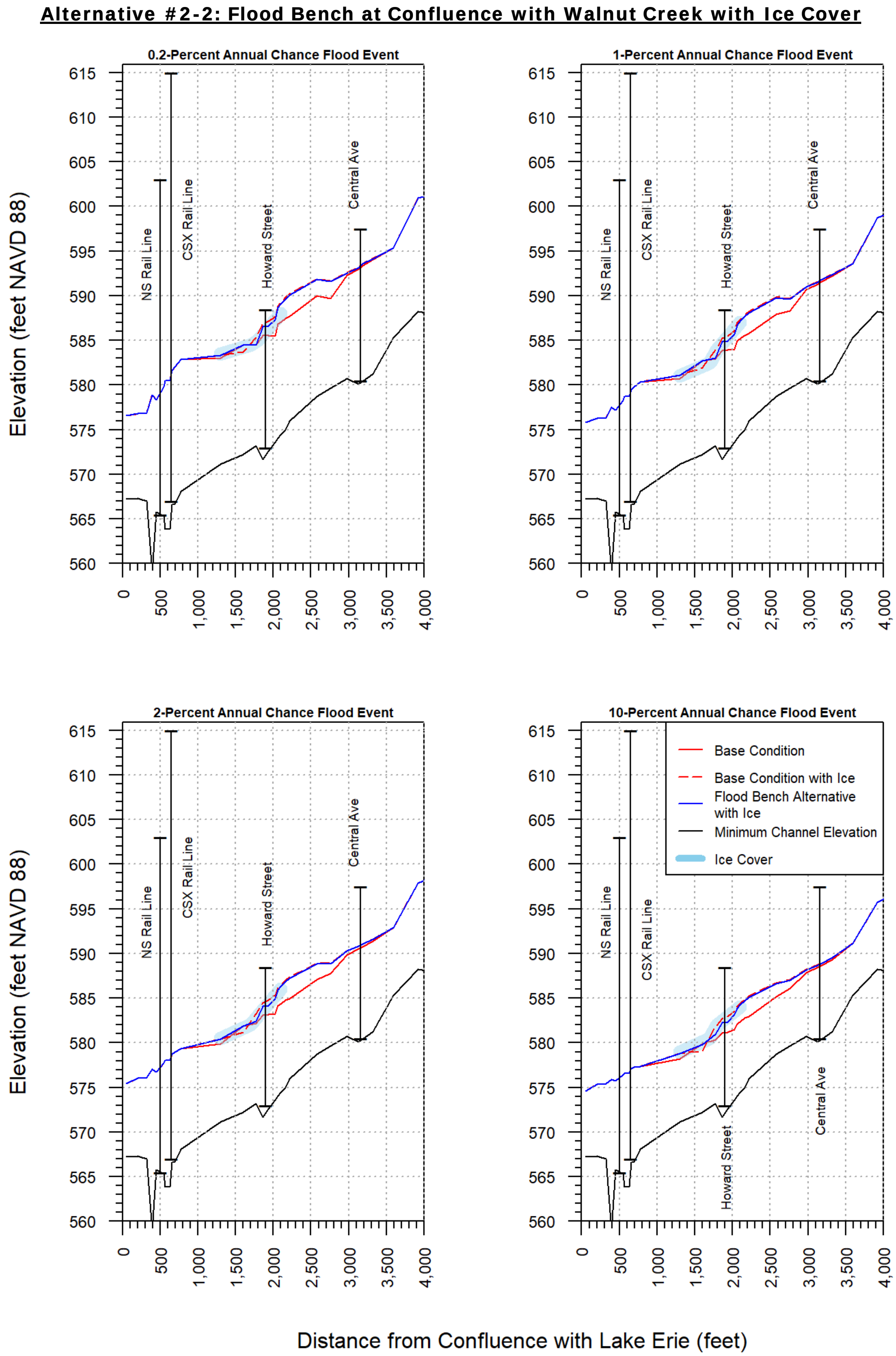



Figure 6-11. HEC-RAS proposed condition model for Alternative #2-2 with ice cover.

### 6.2.3 Alternative #2-3: Levee at Main Street

This measure is intended to address minor flooding experienced at the northern end of Main Street on the south side of Silver Creek. This area includes both private and public structures at risk of flood damages, including the V.F.W. Post 6472 and Village Division of Public Works facilities and equipment. A left-bank levee located between river stations 22+00 and 27+00, approximately 500-ft long and 5-ft high, would help prevent Silver Creek from leaving the stream channel during flow events up to and including the 1% annual chance flood event. There were no effects on right bank water surface elevations according to the model simulation results (Figure 6-12).

Appendix B provides mitigation renderings which illustrate a levee structure.


**Figure 6-12. Location map for Alternative #2-3: Levee at Main Street.**

Modeling indicates minor flooding would occur during the 1% annual chance flood event. In addition to preventing flooding during open-water storm events, modeling estimates that a levee would provide similar flood prevention benefits during a 10% annual chance flood event occurring with ice cover 1-ft thick (Figures 6-13 and 6-14).

Any levee constructed in the Silver Creek watershed would need to follow the USACE *Design and Construction of Levees* EM 1110-2-1913 guidelines, including obtaining the required individual, regional, and nationwide permits for design, construction, and maintenance of a levee (USACE 2000).

USACE has the authority to construct small flood risk reduction projects that are engineeringly feasibly, structurally sound and cost efficient through the authority provided under Section 205 of the 1948 FCA, as amended. Coordination should also occur with NYSDEC as they need to be the non-Federal sponsor on these types of projects. In addition, a FEMA Benefit-Cost Analysis (BCA) would need to be performed to determine the cost-effectiveness of the alternative prior to applying for FEMA mitigation grant programs funding.

A levee would require significant engineering, construction, and maintenance efforts throughout its lifespan, resulting in a relatively high cost burden. Levees should be placed as far away from the creek channel as possible to maximize the capacity of the natural floodplain to convey floodwaters and designed and constructed in a manner that does not cause flooding downstream of the structure. Furthermore, strict requirements would need to be met to comply with NFIP requirements (44 CFR §65.10) to affect a building's flood insurance rating.

The Rough Order Magnitude cost for this strategy is approximately $352,000, which does not include permitting, annual maintenance or land acquisition costs for survey, appraisal, and engineering coordination. This ROM estimate assumes suitable clay material for levee fill that meets USACE requirements is readily available and nearby the Village of Silver Creek.

In addition, closure structures, tie-ins and pump stations were not discussed as these structures should be considered on an as needed basis to address interior drainage. As such, the ROM cost for this alternative did not include the associated costs for these structures.

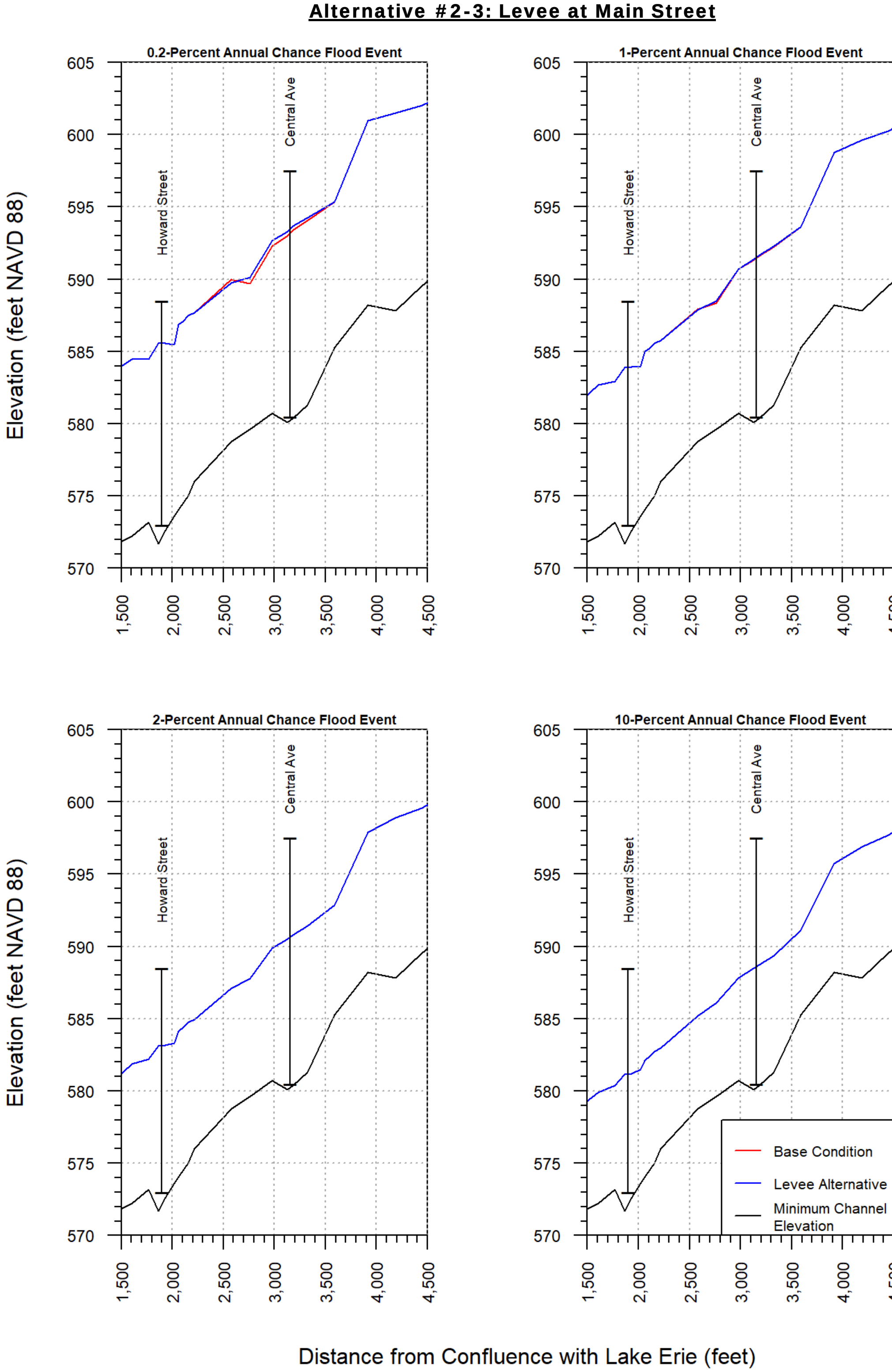



**Figure 6-13. HEC-RAS proposed condition model for Alternative #2-3.**

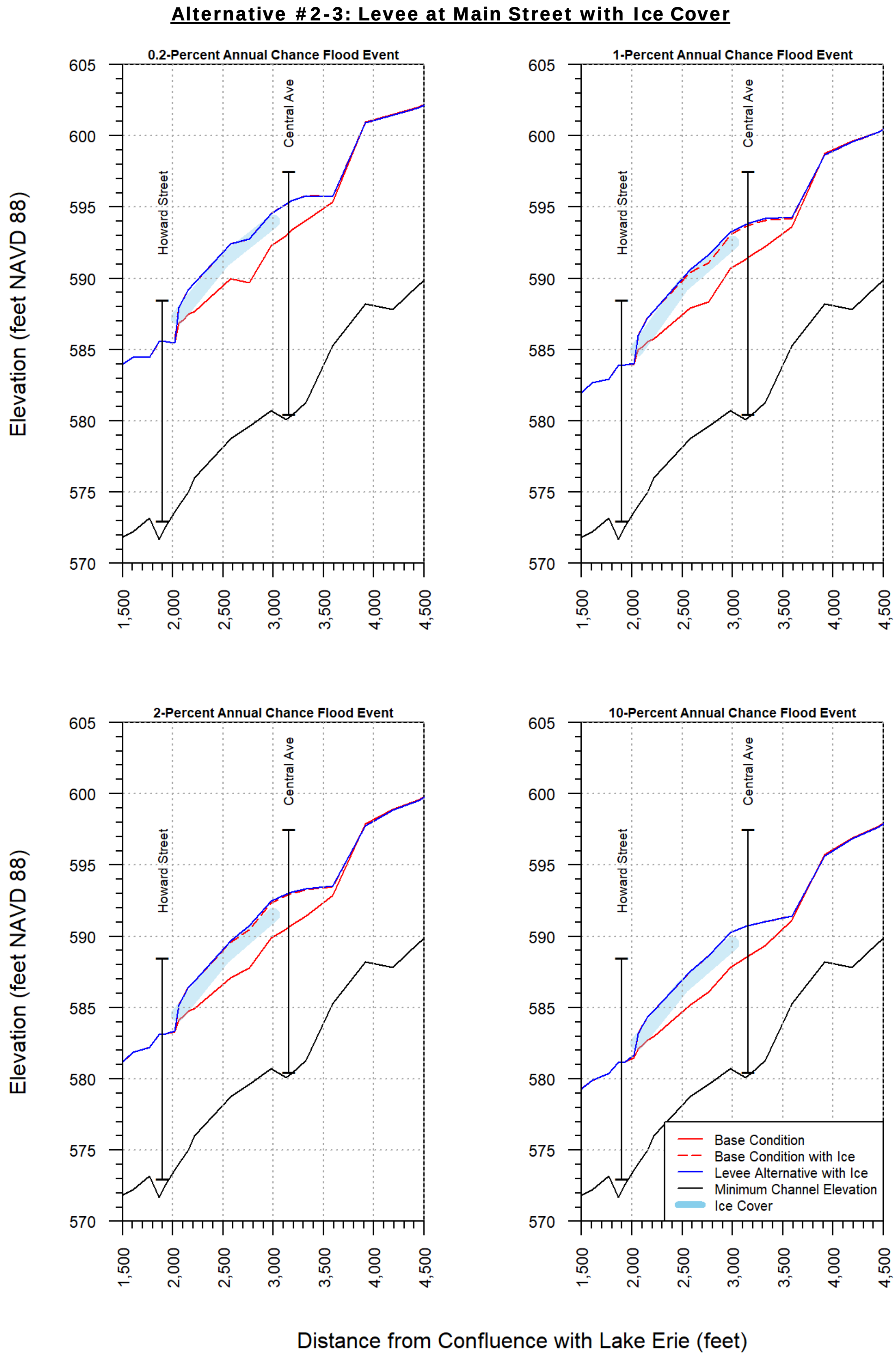



Figure 6-14. HEC-RAS proposed condition model for Alternative #2-3 with ice cover.

## 6.3 HIGH-RISK AREA #3

### 6.3.1 Alternative #3-1: Levee at Mobile Home Park

This measure is intended to address flooding experienced at the mobile home park located on the southern side of Main Road (County Route 20). A right-bank levee located between river stations 36+00 and 41+00, approximately 500-ft long and 6-ft high, would help prevent Silver Creek from leaving the stream channel during flow events up to and including the 1% annual chance flood event. The footprint required to construct the levee would require property along the Silver Creek in the mobile home park (Figure 6-15).


**Figure 6-15. Location map for Alternative #3-1: Levee at mobile home park.**

Any levee constructed in the Silver Creek watershed would need to follow the USACE *Design and Construction of Levees* EM 1110-2-1913 guidelines, including obtaining the required individual, regional, and nationwide permits for design, construction, and maintenance of a levee (USACE 2000). USACE has the authority to construct small flood risk reduction projects that are engineeringly feasibly, structurally sound and cost efficient through the authority provided under Section 205 of the 1948 FCA, as amended. Coordination should also occur with NYSDEC as they need to be the non-

Federal sponsor on these types of projects. In addition, a FEMA Benefit-Cost Analysis (BCA) would need to be performed to determine the cost-effectiveness of the alternative prior to applying for FEMA mitigation grant programs funding.

A levee would require significant engineering, construction, and maintenance efforts throughout its lifespan, resulting in a relatively high cost burden. Levees should be placed as far away from the creek channel as possible to maximize the capacity of the natural floodplain to convey floodwaters and designed and constructed in a manner that does not cause flooding downstream of the structure. In addition, strict requirements would need to be met to comply with NFIP requirements (44 CFR §65.10) to affect a building's flood insurance rating.

The Rough Order Magnitude cost for this strategy is approximately $417,000, which does not include permitting, annual maintenance or land acquisition costs for survey, appraisal, and engineering coordination. In addition, this ROM estimate assumes suitable clay material for levee fill that meets USACE requirements is readily available and nearby the Village of Silver Creek.

In addition, closure structures, tie-ins and pump stations were not discussed as these structures should be considered on an as needed basis to address interior drainage. As such, the ROM cost for this alternative did not include the associated costs for these structures.

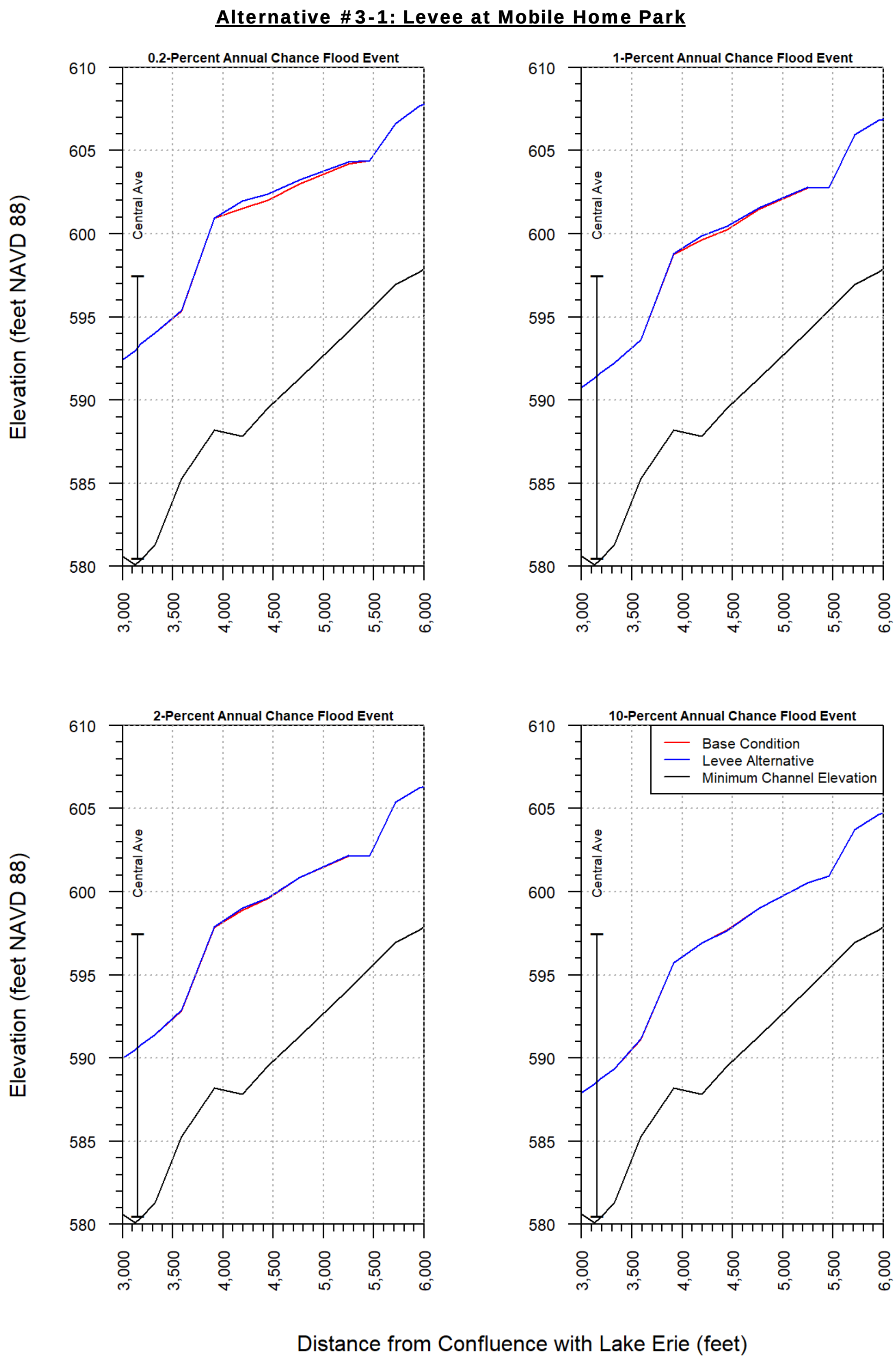



**Figure 6-16. HEC-RAS proposed condition model for Alternative #3-1.**

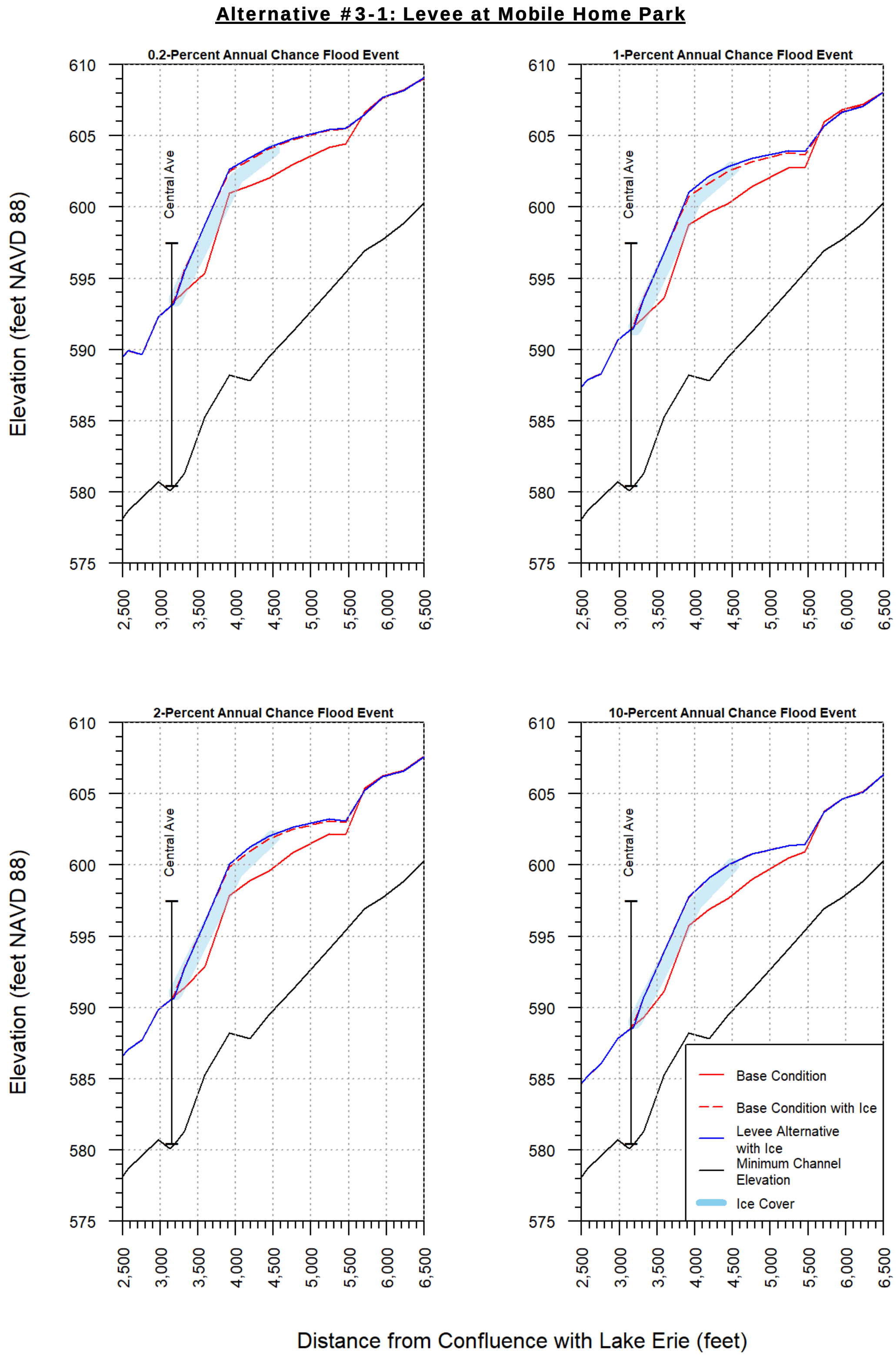



**Figure 6-17. HEC-RAS proposed condition model for Alternative #3-1 with ice cover.**

### 6.3.2 Alternative #3-2: Flood Bench Upstream Mobile Home Park

The flood bench would be located on the left bank of Silver creek between river stations 38+00 and 50+00. The addition of a flood bench increases the water storage volume to the river, decreasing water depths during large flow events. This measure would be located immediately upstream and on the opposite bank (left bank) from the mobile home park, and would require the excavation of approximately four acres of land at an average depth of 5 ft (Figure 6-18).

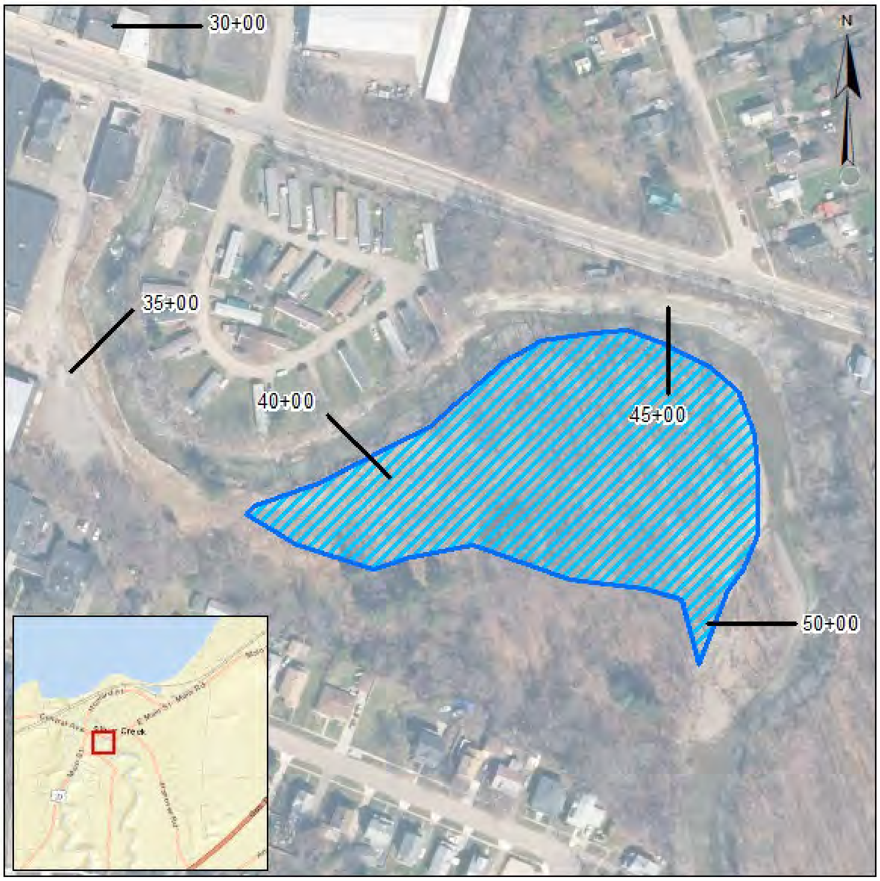



**Figure 6-18. Location map for Alternative #3-2: Flood Bench upstream of mobile home park.**

Hydraulic modeling of the flood bench estimates a decrease in water surface elevations in Silver Creek adjacent to and immediately upstream of the mobile home park of up to approximately 0.8 ft and 2.5 ft during the 1% annual chance flood event, respectively. This water surface elevation reduction would likely decrease the impact of flooding in this area, but not completely mitigate it. Appendix B provides mitigation renderings which illustrate a flood bench (Figures 6-19 and 6-20).

Flood benches generally provide flood protection for localized areas in the vicinity of and immediately upstream and downstream of the bench. Based on the analysis of high-risk areas, a flood bench located adjacent to the mobile home park would provide some protection to the properties adjacent to the bench, but high flood-risk areas downstream would not benefit from the bench.

The Rough Order Magnitude cost for this strategy is approximately $1,954,000, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

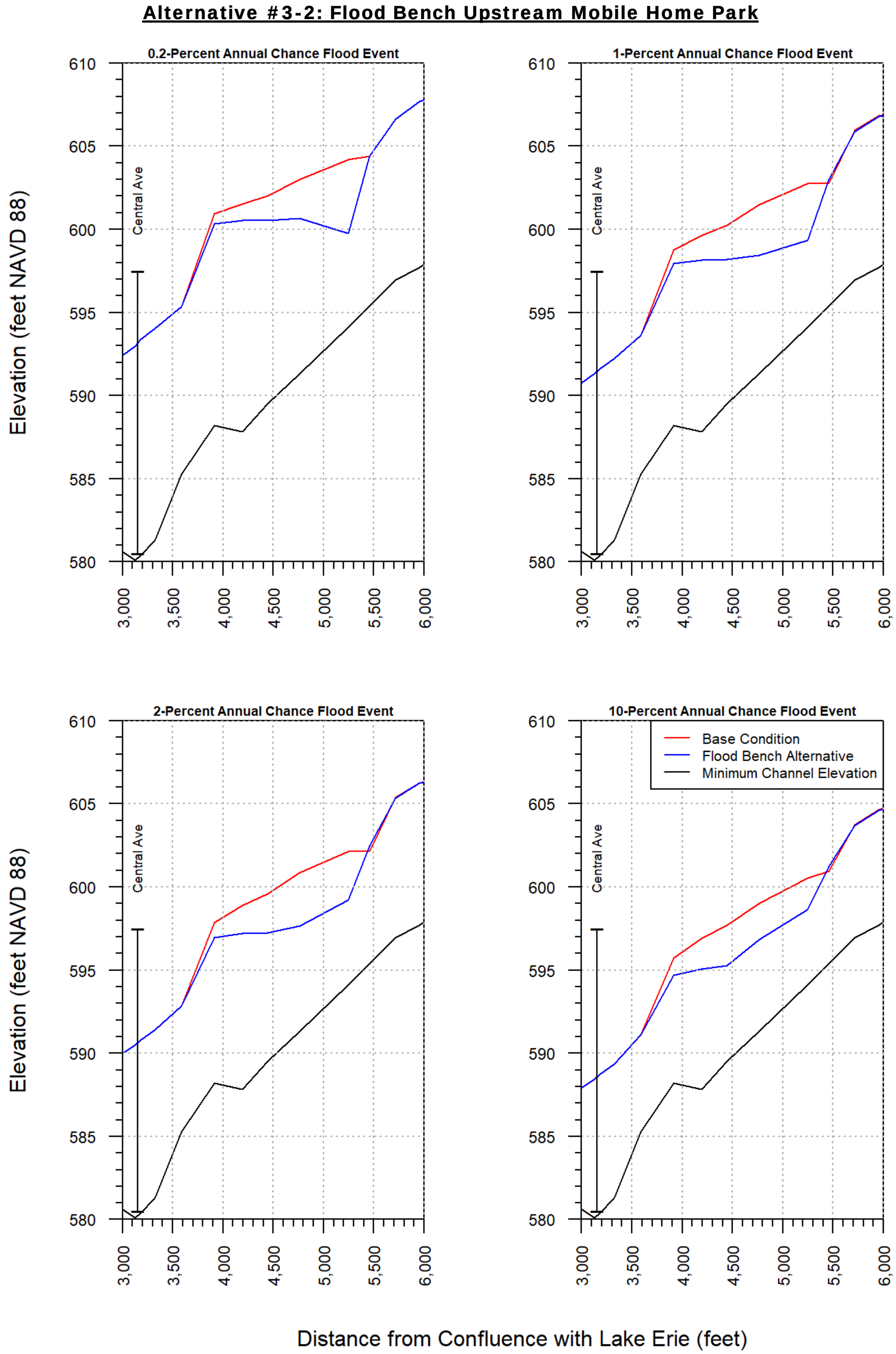



**Figure 6-19. HEC-RAS proposed condition model for Alternative #3-2.**

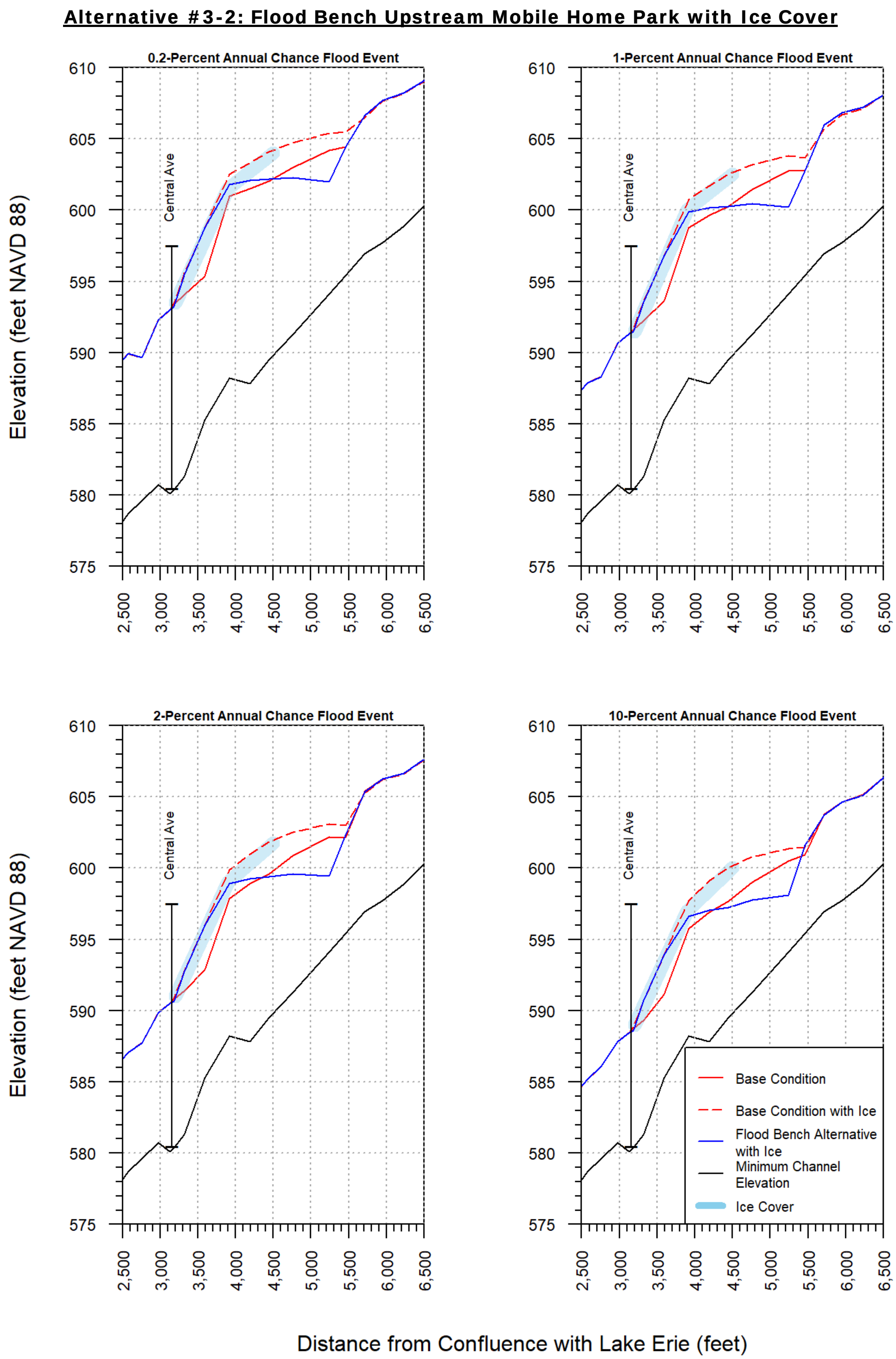



**Figure 6-20. HEC-RAS proposed condition model for Alternative #3-2 with ice cover.**

## 6.4 BASIN-WIDE MITIGATION ALTERNATIVES

Structural flood mitigation measures attempt to reduce or avoid flood damages by constructing structures, such as levees, dams, flood benches, etc., to protect properties or reduce water surface elevations within the floodplain. Non-structural measures attempt to avoid flood damages by modifying or removing properties currently located within flood-prone areas. These measures do not affect the frequency or level of flooding within the floodplain; rather, they affect floodplain activities. In considering the range of non-structural measures, the community needs to assess the type of flooding which occurs (depth of water, velocity, duration) prior to determining which measure best suits its needs (USACE 2016b).

### 6.4.1 Alternative #4-1: Small Flood-Control Dams in the Upper Reaches of the Silver Creek Watershed

The construction of small flood-control dams in the headwaters and tributaries of flood-prone streams has proven successful at preventing flood damage in small towns throughout the United States (Helms 1986). These dams are traditionally located in rural areas in agricultural fields and undeveloped land. Many maintain little to no permanent pool and are designed to detain water during larger flow events, decreasing peak-flow water surface elevations and minimizing flooding further downstream in developed areas.

A rough conceptual analysis was performed to determine the approximate reduction in peak-flow rate during the 1% chance annual storm event which would be required to minimize flooding in the Village of Silver Creek, when not used in addition to other measures. A peak-flow rate decrease of approximately 1,200 CFS (or approximately 25%) is estimated to be the minimum flow reduction required for this measure to be effective at minimizing flooding downstream for the 1% annual chance flood event. This alternative would provide flood mitigation benefits along the full reach of Silver Creek below any constructed dam(s). The results of this analysis are shown in Figure 6-21.

Further analysis was performed to determine the approximate reduction in peak-flow rate during the 10% chance annual storm event which would be required to minimize flooding along the full length of Silver Creek in the Village of Silver Creek during an ice-cover event. Ice cover was modeled based on the Ice Jam Database published by the USACE Ice Engineering Group (CRREL 2020), which shows the farthest-upstream extent of ice cover on Silver Creek at the Howard Street / Highway 5 bridge. This analysis showed flooding during this event is minimal and may not require reduction in flow by small flood control dam(s) to mitigate flooding. The results of this analysis are shown in Figure 6-21.

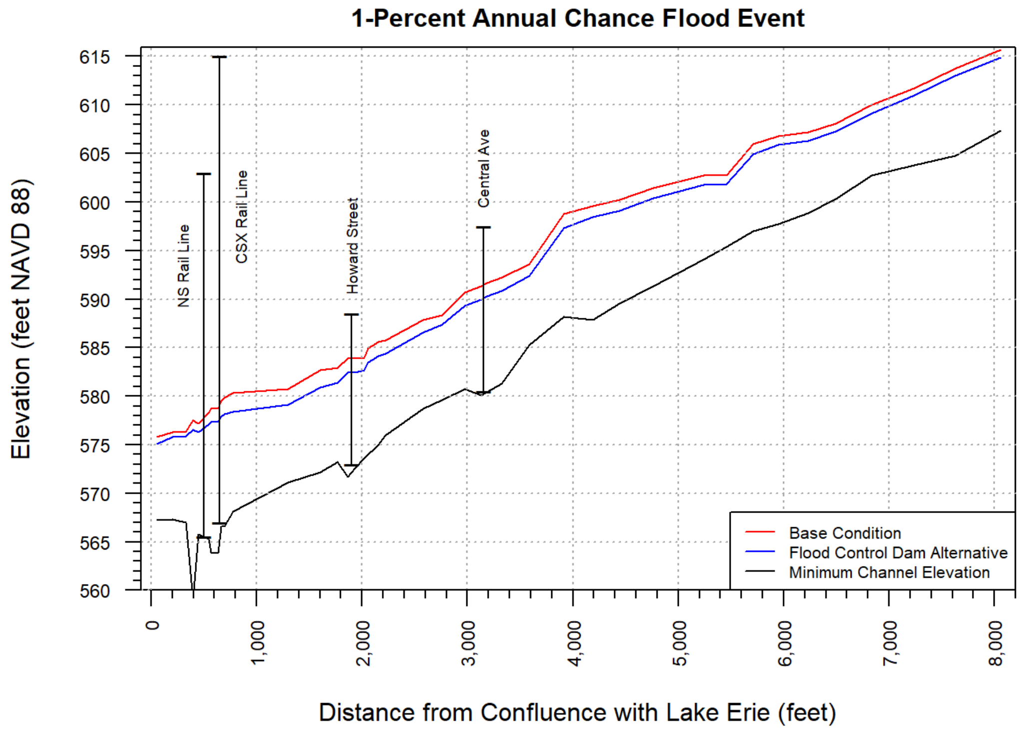
In New York State, a joint permit application from the NYSDEC and USACE may be required in order to construct, reconstruct or repair a dam or other impoundment. The NYSDEC is entrusted with the regulatory power to oversee dam safety. To protect people from the loss of life and property due to flooding and / or dam failure, the NYSDEC Dam Safety Section, in cooperation with the USACE, reviews proposed dam construction and / or modifications, conducts dam safety inspections, and monitors projects for compliance with dam safety criteria.

To acquire a permit for the construction, reconstruction, or repair of a dam or other impoundment, a developer must submit an application to the NYSDEC for an Article 15 Dam Construction Permit, along with the USACE Joint Application Form that, if approved, would allow activities affecting waters within the state.

USACE has the authority to construct small flood risk reduction projects that are engineeringly feasibly, structurally sound and cost efficient through the authority provided under Section 205 of the 1948 FCA, as amended. Coordination should also occur with NYSDEC as they need to be the non-Federal sponsor on these types of projects. In addition, a FEMA Benefit-Cost Analysis (BCA) would need to be performed to determine the cost-effectiveness of the alternative prior to applying for FEMA mitigation grant programs funding.

Due to the conceptual nature of this measure, and significant amount of data required to produce a reasonable rough-order-of-magnitude cost, it is not feasible to quantify the costs of this measure without further engineering analysis and modeling. However, the cost of designing, permitting, constructing, and maintaining one or more flood-control dams in the headwaters of the Silver Creek watershed are expected to be significant.

**Alternative #4-1: Small Flood Control Dams in Upper Areas of the Silver Creek Watershed**



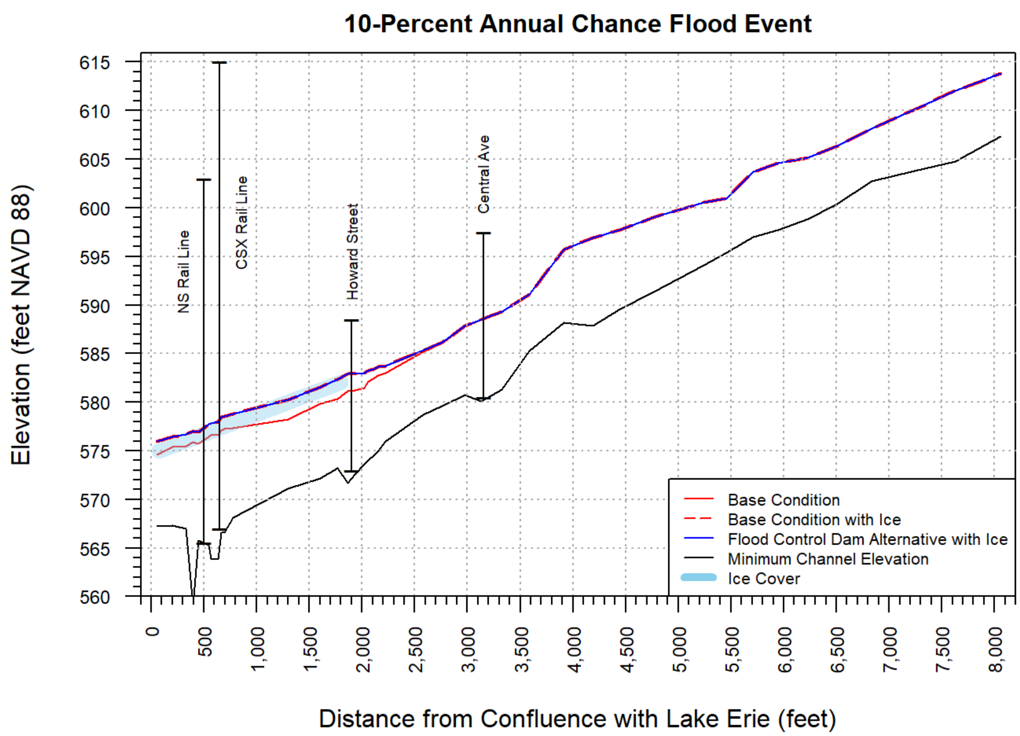




**Figure 6-21. HEC-RAS proposed condition model for Alternative #4-1 at the 1% annual chance flood hazard (top) and with ice cover at the 10% annual chance flood hazard (bottom).**

### 6.4.2 Alternative #4-2: Early-Warning Flood Detection System

Early-warning flood detection systems can be implemented, which can provide communities with more advanced warning of potential flood conditions. Early forecast and warning involve the identification of imminent flooding, implementation of a plan to warn the public, and assistance in evacuating persons and some personal property. A typical low-cost early-warning flood detection system consists of commercially available off-the-shelf-components. The major components of an early-warning flood detection system are a sensor connected to a data acquisition device with built-in power supply or backup, some type of notification or warning equipment, and a means of communication.

For ice-jam warning systems, condition is generally monitored using a pressure transducer. The data acquisition system performs two functions: it collects and stores real-time flood stage data from the pressure transducer, and initiates the notification process once predetermined flood-stage conditions are met (USACE 2016b).

This method can also be supplemented by an ice-jam predicting calculation procedure using the freezing degree-day (FDD) method to forecast the ice thickness at critical locations to inform early action to control ice (Shen and Yapa 2011). The method involves a small computer tool that goes through all the ice calculations and gives the output in a graphical format of the predicted ice thickness with time. This can be quickly implemented and can be a very good solution due to its low cost, and low labor and maintenance requirements. The method needs only the forecasted air temperature and current water level at the critical location. During severe winter conditions, the ice thickness prediction can be used to help prepare and coordinate resources needed for a potential ice-jam event and consequential flooding. For regular winter conditions, the tool can be used as a quick ice-thickness monitoring mechanism.

The pressure transducer system can be powered from an alternating current source via landline or by batteries that are recharged by solar panels. The notification process can incorporate standard telephone or cellular telephone. Transfer of data from the system can be achieved using standard or cellular telephone, radio frequency (RF) telemetry, wireless internet, or satellite transceivers. Emergency management notification techniques can be implemented through the use of radio, siren, individual notification, or a reverse 911 system. More elaborate means include remote sensors that detect water levels and automatically warn residents. These measures normally serve to reduce flood hazards to life, and damage to portable personal property (USACE 2016b).

The Rough Order Magnitude cost for this strategy is approximately $120,000, not including annual maintenance and operational costs.

### 6.4.3 Alternative #4-3: Debris Maintenance and Sediment Management

Debris, such as trees, branches and stumps, are an important feature of natural and healthy stream systems. In a healthy stream network, woody debris helps to stabilize the stream and its banks, reduce sediment erosion, and slow storm-induced high streamflow events. Fallen trees and brush also form the basis for the entire aquatic ecosystem by providing food, shelter, and other benefits to fish and wildlife. In the headwaters of many streams, woody debris influences flooding events by increasing channel roughness, dissipating energy, and slowing floodwaters, which can potentially reduce flood damages in the downstream reaches. Any woody debris that does not pose a hazard to infrastructure or property should be left in place and undisturbed, thereby saving time and money for more critical work at other locations (NYSDEC 2013).

However, in some instances, significant sediment and debris can impact flows by blocking bridge and culvert openings and accumulating along the stream path at meanders, contraction / expansion points, etc., which can divert stream flow and cause backwater and bank erosion. When debris poses a risk to infrastructure, such as bridges or homes, it should be removed. Provided fallen trees, limbs, debris and trash can be pulled, cabled or otherwise removed from a stream or stream bank without significant disruption of the stream bed and banks, a permit from the NYSDEC is not required. Woody debris and trash can be removed from a stream without the need for a permit under the following guidelines:

- Fallen trees and debris may be pulled from the stream by vehicles and motorized equipment operating from the top of the streambanks using winches, chains and or cables.
- Hand-held tools, such as chainsaws, axes, handsaws, etc., may be used to cut up the debris into manageable sized pieces.
- Downed trees that are still attached to the banks should be cut off near the stump. Do not grub (pull out) tree stumps from the bank; stumps hold the bank from eroding.
- All trees, brush, and trash that is removed from the channel should not be left on the floodplain. Trash should be properly disposed of at a waste management facility. Trees and brush can be utilized as firewood. To prevent the spread of invasive species, such as Emerald Ash Borer, firewood cannot be moved more than 50 miles from its point of origin.
- Equipment may not be operated in the water, and any increase in stream turbidity from the removal must be avoided (NYSDEC 2013).

Any work that will disturb the bed or banks of a protected stream (gravel removal, stream restoration, bank stabilization, installation, repair, replacements of culverts or bridges, objects embedded in the stream that require digging out, etc.) will require an Article 15 permit from the NYSDEC. Projects that will require disturbance of the stream bed or banks, such as excavating sand and gravel, digging embedded debris from the streambed or the use of motorized, vehicular equipment, such as a tractor, backhoe, bulldozer, log skidder, four-wheel drive truck, etc. (any heavy equipment), in the stream channel, or anywhere below the top of banks, will require either a Protection of Waters or Excavation or Fill in Navigable Waters Permit (NYSDEC 2013).

Sediment control basins along Silver Creek could be established to reduce watercourse and gully erosion, trap sediment, reduce and manage runoff near and downstream of the basin, and to improve downstream water quality. A sediment control basin is an earth embankment or a combination ridge and channel generally constructed across the slope and minor watercourses to form a sediment trap and water detention basin. The basin should be configured to enhance sediment deposition by using flow deflectors, inlet and outlet selection, or by adjusting the length to width ratio of the creek channel.

Additional hydrologic and hydraulic studies should be performed to identify the optimal locations for the sediment control basins. Operation and maintenance costs to maintain the embankment, design capacity, vegetative cover, and outlet of the basin should be considered (NRCS 2002).

In-channel hydraulic constrictions, such as dams, concrete structures, etc., should be evaluated for their hydrologic and hydraulic impacts on streamflow and debris and sediment transport. Any structures found to have little to no hydrologic or flooding benefits should be removed from the channel. Hydraulic constrictions can reduce a waterways ability to adequately convey water and transport sediment downstream, which can lead to backwater and bedload to aggrade upstream the structure, respectively. Both situations can increase potential flood risk to areas adjacent to and upstream of the structure.

Consultation with the NYSDEC can help determine if, when and how sediment and debris should be managed and whether a permit will be required.

The Rough Order Magnitude cost for this strategy is up to $20,000 annually, not including maintenance, operational costs, and removal and disposal costs.

### 6.4.4 Alternative #4-4: Ice Management

This strategy is intended to control ice-jam formation by maintaining ice coverage in high-risk sections of Silver Creek. Ice management strategies include various methods of preventing ice jams by breaking ice using various ice cutting patterns and techniques, as well as various equipment and personnel. Suggested locations for ice-cutting operations would be provided based on anticipated effectiveness, site accessibility, and historical occurrences of ice jams. Criteria and scheduling would be provided by county and / or state agencies and determined based on environmental conditions (e.g. temperature, ice thickness, weather forecast) (USACE 2016b).

Possible ice management strategies would include:

- Ice cutting – cut ice free from banks or cross-cut ice to hasten the release of ice in order to prevent ice-jam formations
- Trenchers and special design trenching equipment – used to dig ditches customarily, but can be used to cut ice to hasten release downstream
- Channeling plow – plow mounted to a sledge drawn by a tractor that breaks and clears ice from channel
- Water jet and thermal cutting – supersonic water streams and thermal cutting tools to separate the ice and move it downstream
- Hole cutting – drill large holes into the ice to reduce the integrity of the ice cover and curtail ice formation
- Air bubbler and flow systems – release air bubbles and warm water from the water bottom to suppress ice growth
- Ice breakup using amphibious excavators - separating ice pack and moving ice pieces downstream is highly effective at preventing ice jams and potential flooding

at key infrastructure points by separating ice pack and moving ice pieces downstream (USACE 2006)

Generally, the FDD method, as previously discussed, is a good technique to first predict the ice thickness at critical locations, such as bridges or any flow constriction structures using the forecasted air temperature. This method will let the community officers know the severity of any possible ice jams based on future air temperature, allowing for time to get equipment and labor ready for the forthcoming ice jam. A small computer program could be used to do the iterative calculations faster, so that any non-technical user can use it to foresee the ice jam (Shen and Yapa 2011).

Another technique is maintaining a calibrated ice model to predict possible ice jam locations using forecasted air temperature and flow. This will be a comprehensive 2-D river ice simulation model (RICEN) (Shen et al. 1995) or Comprehensive River Ice Simulation System (CRISSP 2D) (CEATI 2005) that predicts the fate of ice evolution from fall to spring.

The Rough Order Magnitude cost for this measure is $40,000, not including annual maintenance and operational costs.

Additional discussion of ice management options is included in Appendix C.

### 6.4.5 Alternative #4-5: Flood Buyout Program

Buyouts allow state and municipal agencies the ability to purchase developed properties within areas vulnerable to flooding from willing owners. Buyouts are effective management tools in response to natural disasters to reduce or eliminate future losses of vulnerable or repetitive loss properties. Buyout programs include the acquisition of private property, demolition of existing structures, and conversion of land into public space or natural buffers. The land is maintained in an undeveloped state for public use in perpetuity. Buyout programs not only assist individual homeowners, but are also intended to improve the resiliency of the entire community in the following ways (Siders 2013):

- Reduce exposure by limiting the people and infrastructure located in vulnerable areas
- Reduce future disaster response costs and flood insurance payments
- Restore natural buffers such as wetlands in order to reduce future flooding levels
- Reduce or eliminate the need to maintain and repair flood control structures
- Reduce or eliminate the need for public expenditures on emergency response, garbage collection and other municipal services in the area
- Provide open space for the community

Resilience achieved through buyouts can have real economic consequences in addition to improved social resilience. According to FEMA, voluntary buyouts cost $1 for every $2 saved in future insurance claims, an estimate which does not include money saved on flood recovery and response actions, such as local flood fighting, evacuation, and rescue, and recovery expenses that will not be incurred in the future. In order to achieve these goals, buyouts need to acquire a continuous swatch of land, rather than individual homes in isolated areas, or only some of the homes within flood-prone areas (Siders 2013).

Buyout programs can be funded through a combination of federal, state or local funds, and are generally made available following a nationally recognized disaster. FEMA administers programs to help with buyouts under the Stafford Disaster Act, and the Department of Housing and Urban Development (HUD) administers another program through Community Development Block Grants (CDBG). These funding sources can reduce the economic burden on the local community. However, these funds also come with guidelines and regulations that may constrain policy makers' options on whether to pursue a buyout strategy, and how to shape their programs. FEMA funds may be used to cover 75% of the expenses, but the remaining 25% must come from another non-federal source. In most cases, the buyout must be a cost-effective measure that will substantially reduce the risk of future flooding damage (Siders 2013).

For homes in the SFHA, FEMA has developed precalculated benefits for property acquisition and structure elevation of buildings. Based on a national analysis that derived the average benefits for acquisition and elevation projects, FEMA has determined that acquisition projects that cost $276,000 or less, or elevation projects that costs $175,000 or less, and which are located in the 1% annual chance event (i.e. 100-year recurrence interval) floodplain are considered cost-effective and do not require a separate benefit-cost analysis. For projects that contain multiple structures, the average cost of all structures in the project must meet the stated criteria. If the cost to acquire or elevate a structure exceeds the amount of benefits listed above, then a traditional FEMA approved benefits-cost analysis must be completed (FEMA 2015a).

In the Village of Silver Creek there are approximately 18 residences either within or immediately adjacent to the 1% annual chance food hazard area of Silver Creek (Figure 6-22) in the mobile home park located on the south side of Main Road. In addition, there is one property classified as a repetitive loss property by FEMA within the Silver Creek watershed in the Town of Hanover. There are no severe repetitive loss properties (FEMA 2019; NYSGPO 2019).

Results of the modeling performed for this study were used to determine possible acquisition locations instead of the FEMA FIS data due to the age of the FEMA FIS reports at this location. The acquisition of all the mobile homes located in the park is recommended for consideration because of uncertainties which are inherent to the hydrologic and hydraulic methods used in this study, and the potential increase in flood elevations due to climate change.

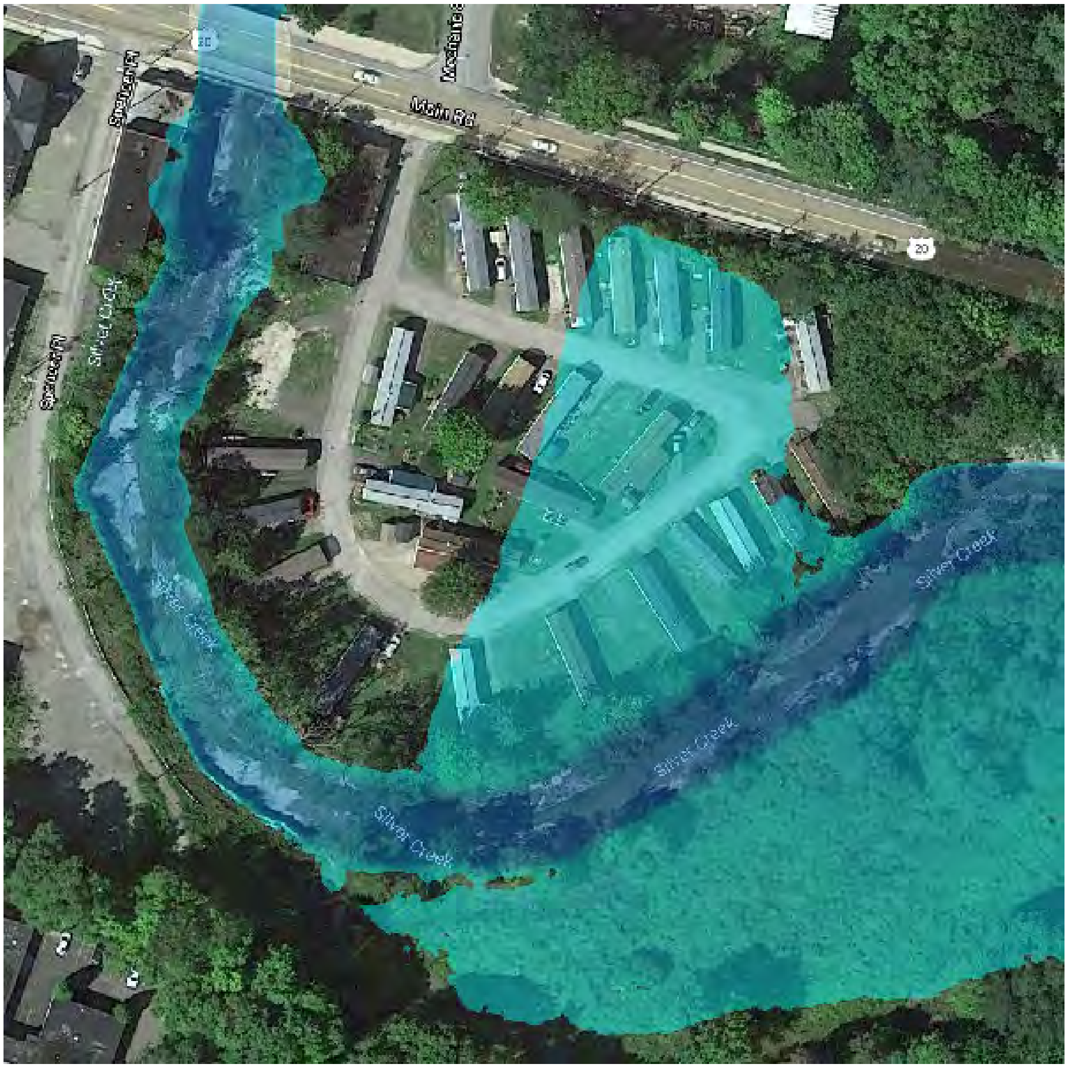



**Figure 6-22. Mobile Home Park 1% Annual Chance Inundation Zone.**

Due to the variable nature of buyout or acquisition programs, no ROM cost estimate was produced for this study. It is recommended that any buyout or acquisition program begin with a cost-benefit analysis for each property. After a substantial benefit has been established, a buyout or acquisition strategy study should be developed that focuses on properties closest to Silver Creek in the highest-risk flood areas, and progresses outwards from there to maximize flood damage reductions. The mobile home park should be considered for any buyout program due to the high flood risk and historical flood damages associated with the area. If the mobile home park was purchased under a flood buyout program, it would be recommended that the area be developed using a flood mitigation strategy, such as a flood bench.

A potential negative consequence of buyout programs is the permanent removal of properties from the floodplain, and resulting tax revenue, which would have long-term implications for local governments, and should be considered prior to implementing a buyout program.

### 6.4.6 Alternative #4-6: Floodproofing

Floodproofing is defined as any combination of structural or nonstructural adjustments, changes, or actions that reduce or eliminate flood damage to a building, contents, and attendant utilities and equipment (FEMA 2000). Floodproofing can prevent damage to existing buildings and can be used to meet compliance requirements for new construction of residential and non-residential buildings.

The most effective flood mitigation methods are relocation (i.e. moving a home to higher ground outside of a high-risk flood area) and elevation (i.e. raising the entire structure above BFE). The relationship between the BFE and a structure's elevation determines the flood insurance premium. Buildings that are situated at or above the level of the BFE have lower flood risk than buildings below BFE and tend to have lower insurance premiums than buildings situated below the BFE (FEMA 2015b).

In some communities, where non-structural flood mitigation alternatives are not feasible, structural alternatives such as flood proofing may be a viable alternative. The National Flood Insurance Program has specific rules related to flood proofing for residential and non-residential structures. These can be found in the Code of Federal Regulations (CFR) 44 CFR 60.3 (FEMA 2000).

For existing residential structures, structures should be raised above the BFE in accordance with local regulations. Floodproofing is allowed for non-residential structures, with design guidelines outlined in FEMA P-936 – Floodproofing Non-Residential Structures (FEMA 2000; FEMA 2013). The local floodplain administrator should carefully review local ordinances, the CFR and available design guidelines perform issuing a permit for structural flood proofing. Floodproofing strategies include:

**Interior Modification / Retrofit Measures**

Interior modification and retrofitting involves making changes to an existing building to protect it from flood damage. When the mitigation is properly completed in accordance with NFIP floodplain management requirements, interior modification / retrofit measures could achieve somewhat similar results as elevating a home above the BFE. Keep in mind, in areas where expected base flood depths are high, the flood protection techniques below may not provide protection on their own to the BFE or, where applicable, the locally required freeboard elevation (FEMA 2015b).

Examples include:

- *Basement Infill*: This measure involves filling a basement located below the BFE to grade (ground level)
- *Abandon Lowest Floor*: This measure involves abandoning the lowest floor of a two or more story slab-on-grade residential building
- *Elevate Lowest Interior Floor*: This measure involves elevating the lowest interior floor within a residential building with high ceilings

### Dry Floodproofing

A combination of measures that results in a structure, including the attendant utilities and equipment, being watertight with all elements substantially impermeable to the entrance of floodwater and with structural components having the capacity to resist flood loads (FEMA 2015b).

Although NFIP regulations require non-residential buildings to be watertight and protected only to the BFE for floodplain management purposes (to meet NFIP regulations), protection to a higher level is necessary for dry floodproofing measures to be considered for NFIP flood insurance rating purposes. Because of the additional risk associated with dry floodproofed buildings, to receive an insurance rating based on 1% annual-chance (100-year) flood protection, a building must be dry floodproofed to an elevation at least 1-ft above the BFE (FEMA 2013). In New York State, the requirement is a minimum of 2-ft above BFE.

Examples include:

- *Passive Dry Floodproofing System:* This measure involves installing a passive (works automatically without human assistance) dry floodproofing system around a home to protect the building from flood damage
- *Elevation:* This measure involves raising an entire residential or non-residential building structure above BFE

### Wet Floodproofing

The use of flood-damage-resistant materials and construction techniques to minimize flood damage to areas below the flood protection level of a structure, which is intentionally allowed to flood (FEMA 2015b).

Examples include:

- *Flood Openings:* This measure involves installing openings in foundation and enclosure walls located below the BFE that allow automatic entry and exit of floodwaters to prevent collapse from the pressures of standing water
- *Elevate Building Utilities:* This measure involves elevating all building utility systems and associated equipment (e.g., furnaces, septic tanks, and electric and gas meters) to protect utilities from damage or loss of function from flooding
- *Floodproof Building Utilities:* This measure involves floodproofing all building utility systems and associated equipment to protect it from damage or loss of function from flooding
- *Flood Damage-Resistant Materials:* This measure involves the use of flood damage-resistant materials such as non-paper-faced gypsum board and terrazzo tile flooring for building materials and furnishings located below the BFE to reduce structural and nonstructural damage and post-flood event cleanup

### Barrier Measures

Barriers, such as floodwalls and levees, can be built around single or multiple residential and non-residential buildings to contain or control floodwaters (FEMA 2015b). Although floodwalls or levees can be used to keep floodwaters away from buildings, implementing these measures will not affect a building's flood insurance rating unless the flood control structure is accredited in accordance NFIP requirements (44 CFR §65.10) and provides protection from at least the 1% annual chance (100-year) flood. In addition, floodwalls or levees as a retrofit measure will not bring the building into compliance with NFIP requirements for Substantial Improvement / Damage (FEMA 2013).

- *Floodwall with Gates and Floodwall without Gates:* These two measures involve installing a reinforced concrete floodwall, which works automatically without human assistance, constructed to a maximum of four feet above grade (ground level). The floodwall with gates is built with passive flood gates that are designed to open or close automatically due to the hydrostatic pressure caused by the floodwater. The floodwall without gates is built using vehicle ramps or pedestrian stairs to avoid the need for passive flood gates.
- *Levee with Gates and Levee without Gates:* These two measures involve installing an earthen levee around a home, which works automatically without human assistance, with a clay or concrete core constructed to a maximum of six feet above grade (ground level). The levee with gates is built with passive flood gates that are designed to open or close automatically due to hydrostatic pressure caused by the floodwater. The levee without gates is built using vehicle access ramps to avoid the need for passive flood gates.

Modifying a residential or non-residential building to protect it from flood damage requires extreme care, will require permits, and may also require complex, engineered designs. Therefore, the following process is recommended to ensure proper and timely completing of any floodproofing project (FEMA 2015b):

- Consult a registered design professional (i.e. architect or engineer) who is qualified to deal with the specifics of a flood-mitigation project
- Check your community's floodplain management ordinances
- Contact your insurance agent to find out how your flood insurance premium may be affected
- Check what financial assistance might be available
- Hire a qualified contractor
- Contact the local building department to learn about development and permit requirements and to obtain a building permit
- Determine whether the mitigation project will trigger a Substantial Improvement declaration
- See the project through to completion
- Obtain an elevation certificate and an engineering certificate (if necessary)

No cost estimates were prepared for this alternative due to the variable and case-by-case nature of the flood mitigation strategy. Local municipal leaders should contact residential and non-residential building owners that are currently at a high flood risk to inform them about floodproofing measures, the recommended process to complete a floodproofing project, and the associated costs and benefits.

Floodproofing would be an effective flood mitigation strategy for the mobile home park located on the south side of Main Road in High-Risk Area #3. Ensuring that the structures are properly elevated and meet the current floodplain management regulations and, if not, requiring the structures to be complaint would be an effective way to reduce the flood risk and potential damages in this area.

### 6.4.7 Alternative #4-7: Area Preservation / Floodplain Ordinances

This alternative proposes municipalities within the Silver Creek watershed consider watershed and floodplain management practices such as preservation and / or conservation of areas along with land use ordinances that could minimize future development of sensitive areas such as wetlands, forests, riparian areas, and other open spaces. It could also include areas in the floodplain that are currently free from development and providing floodplain storage.

A watershed approach to planning and management is an important part of water protection and restoration efforts. New York State’s watersheds are the basis for management, monitoring, and assessment activities. The NYS Open Space Conservation Plan, NYSDEC Smart Growth initiative and the Climate Smart Communities Program address land use within a watershed (NYSDEC [date unknown]).

Natural floodplains 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, building codes and special-purpose floodplain ordinances. While FEMA has minimum floodplain management standards for communities participating in the National Flood Insurance Program, best practices demonstrate the adoption of higher standards which will lead to safer, stronger, and more resilient communities (FEMA 2006).

For floodplain ordinances, the NYSDEC has a sample of regulatory requirements for floodplain management that a community can adopt within their local flood damage prevention ordinance. If a community is interested in updating their local law to include regulatory language promoting floodplain management, it is recommended that they reach out to the NYSDEC through floodplain@dec.ny.gov or (518) 402-8185 for more information.

In addition, the Community Rating System (CRS) program through FEMA is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. Participating communities are able to get discounted rates on the flood insurance premiums for residents in the community. Adopting these enhanced requirements and preserving open space for floodplain storage earns points in the CRS program, which can lead to discounted flood insurance premiums.

Further hydrology and hydraulic model scenarios could be performed to illustrate how future watershed and floodplain management techniques could benefit the communities within the Silver Creek watershed.

# 7. NEXT STEPS

Before selecting a flood mitigation strategy, securing funding or commencing an engineering design phase, Ramboll recommends that additional modeling simulations and wetland investigations be performed.

## 7.1 ADDITIONAL DATA MODELING

Additional data modeling would be necessary to more precisely model water surface elevations and the extent of potential flooding in overbank areas and the floodplain. 2-D unsteady flow modeling using the HEC-RAS program would incorporate additional spatial information in model simulations producing more robust results with a higher degree of confidence than the currently modeled 1-D steady flow simulations.

## 7.2 STATE / FEDERAL WETLANDS INVESTIGATION

Any flood mitigation strategy that proposes using the oxbow lake in any capacity needs to be evaluated based on federal and state wetland criteria before that mitigation strategy can be recommended for final consideration.

## 7.3 ICE EVALUATION

Due to the complex interaction of ice jams and water flow through a river, it is difficult to draw conclusions regarding proposed flood-mitigation strategies and ice-jam formations based on observational data alone. The river bathymetry and channel meanders can complicate the ice dynamics and freeze-up jams. Spring runoff is affected by multiple environmental factors, including:

- Available moisture
- Air temperature
- Land cover
- Precipitation
- Snowmelt intensity

The impact of these factors will be amplified by climate change. Projected increases in precipitation across New York State, indicates the potential for increases in spring runoff, which in turn would increase water levels and velocities in nearby streams and rivers (Rosenzweig et al. 2011). In theory, the increased velocities would move ice blocks and frazil ice down the river channel quicker, possibility preventing ice-jam formations. However, due to the limited available research in this area, additional data collection and modeling needs to be performed before a recommendation can be made regarding a flood mitigation strategy and its specific influence on ice-jam formations.

## 7.4 EXAMPLE FUNDING SOURCES

There are numerous potential funding programs and grants for flood mitigation projects that may be used to offset municipal financing, including:

- NYS Division of Homeland Security and Emergency Services (NYSDHSES)

- Regional Economic Development Councils/Consolidated Funding Applications (CFA)
- Natural Resources Conservation Service (NRCS) Emergency Watershed Protection (EWP) Program
- FEMA Hazard Mitigation Assistance (HMA) Grants
- Chautauqua County 2% Occupancy Tax Grant Program for Lakes and Waterways

### 7.4.1 NYS Division of Homeland Security and Emergency Services (NYSDHSES)

The NYS Division of Homeland Security and Emergency Services (NYSDHSES), through the U.S. Department of Homeland Security (DHS), offers several funding opportunities under the State Homeland Security Program (SHSP). The priority for these programs is to provide resources to strengthen national preparedness for catastrophic events. These include improvements to cybersecurity, economic recovery, housing, infrastructure systems, natural and cultural resources, and supply chain integrity and security. In 2018, there was no cost share or match requirement.

### 7.4.2 Consolidated Funding Applications (CFA)

The Consolidated Funding Application is a single application for state economic development resources from numerous state agencies. The ninth round of the CFA was offered in 2019. As of the writing of this report, the tenth round of CFAs in 2020 was postponed due to the financial uncertainties surrounding the COVID-19 outbreak.

#### 7.4.2.1 Water Quality Improvement Project (WQIP) Program

The Water Quality Improvement Project Program, administered through the NYSDEC, is a statewide reimbursement grant program to address documented water quality impairments. Eligible parties include local governments and not-for-profit corporations. Funding is available for construction/implementation projects; projects exclusively for planning are not eligible. Match for WQIP is a percentage of the award amount, not the total project cost. Deadlines are in accordance with the CFA application cycle.

#### 7.4.2.2 Climate Smart Communities Grant Program

The Climate Smart Communities (CSC) Grant Program is a 50/50 matching grant program for municipalities under the New York State Environmental Protection Fund, offered through the CFA by the NYS Office of Climate Change. The purpose of the program is to fund climate change adaptation and mitigation projects and includes support for projects that are part of a strategy to become a Certified Climate Smart Community. The eligible project types that may be relevant include the following:

- The construction of natural resiliency measures, conservation or restoration of riparian areas and tidal marsh migration areas
- Nature-based solutions such as wetland protections to address physical climate risk due to water level rise, and / or storm surges and / or flooding

Relocation or retrofit of facilities to address physical climate risk due to water level rise, and / or storm surges and / or flooding

- Flood risk reduction
- Climate change adaptation planning and supporting studies

Eligible projects include implementation and certification projects. Deadlines are in accordance with the CFA cycle.

### 7.4.3 NRCS Emergency Watershed Protection (EWP) Program

Through the Emergency Watershed Protection (EWP) Program, the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) can assist communities in addressing watershed impairments that pose imminent threats to lives and property. Most EWP projects involve the protection of threatened infrastructure from continued stream erosion, but also include: removal of debris from stream channels, road culverts and bridges; correcting damaged or destroyed drainage facilities; establishing vegetative cover on critically eroding lands; repairing levees and structures; and repairing conservation practices.

Projects must have a project sponsor, defined as a legal subdivision of the State, such as a city, county, general improvement district, or conservation district, or an Indian Tribe or Tribal organization. Sponsors are responsible for providing land rights to do repair work, securing the necessary permits, furnishing the local cost share (25%), and performing any necessary operation and maintenance for a ten-year period. The NRCS may pay up to 75% of the construction costs of emergency measures, with up to 90% paid for projects in limited-resource areas.

### 7.4.4 FEMA Hazard Mitigation Grant Program (HMGP)

The Federal Emergency Management Agency's Hazard Mitigation Grant Program (HMGP), offered by the New York State Division of Homeland Security and Emergency Services (NYSDHSES), provides funding for creating / updating hazard mitigation plans and implementing hazard mitigation projects. The HMA program consolidates the application process for FEMA's annual mitigation grant programs not tied to a State's Presidential disaster declaration. Funds are available under the Building Resilient Infrastructure and Communities (BRIC) and the Flood Mitigation Assistance (FMA) Programs.

For flood mitigation measures that are being considered for funding through FEMA grant programs, a benefit-to-cost analysis will be required. In order to qualify for FEMA grants and / or funding, the benefit to cost ratio must be greater than one.

#### 7.4.4.1 Building Resilient Infrastructure and Communities (BRIC)

Beginning in 2020, the Building Resilient Infrastructure and Communities (BRIC) grant program, which was created as part of Disaster Recovery Reform Act of 2018 (DRRA), replaced the existing Pre-Disaster Mitigation (PDM) program and is funded by a 6% set-aside from federal post-disaster grant expenditures. BRIC will support states, local communities, tribes and territories as they undertake hazard mitigation projects, reducing the risks they face from disasters and natural hazards. BRIC aims to categorically shift the federal focus away from reactive disaster spending and toward research-supported, proactive investment in community resilience. Through BRIC, FEMA will invest in a wide variety of mitigation activities, including community-wide public infrastructure projects. Moreover, FEMA anticipates BRIC will fund projects that demonstrate innovative approaches to partnerships, such as shared funding mechanisms and/or project design.

#### 7.4.4.2 Flood Mitigation Assistance (FMA) Program

The Flood Mitigation Assistance Program provides resources to reduce or eliminate long-term risk of flood damage to structures insured under the National Flood Insurance Program. The FMA project funding categories include Community Flood Mitigation – Advance Assistance (up to $200,000 total federal share funding) and Community Flood Mitigation Projects (up to $10 million total). Federal funding is available for up to 75% of the eligible activity costs. FEMA may contribute up to 100% federal cost share for severe repetitive loss (SRL) properties, and up to 90% cost share for repetitive loss (RL) properties. Eligible project activities include the following:

- Infrastructure protective measures
- Floodwater storage and diversion
- Utility protective measures
- Stormwater management
- Wetland restoration/creation
- Aquifer storage and recovery
- Localized flood control to protect critical facility
- Floodplain and stream restoration
- Water and sanitary sewer system protective measures

### 7.4.5 Chautauqua County 2% Occupancy Tax Grant Program for Lakes and Waterways

Chautauqua County collects a 2% occupancy tax to collect revenue to fund projects in the county which provide water quality benefits. Grants are available in amounts ranging from $500 to $40,000. Grant funding has been used for roadway drainage, agriculture, stormwater, streambank, and lakeshore projects. An application for an erosion control project along Village Park in the village of Silver Creek is currently under review, with construction scheduled to begin in 2021 (Chautauqua County 2019).

# 8. SUMMARY

This report analyzed the historical and present day causes of flooding in the Silver Creek watershed. Hydraulic and hydrologic data was used to model potential flood mitigation measures. The model simulation results indicated that there are flood mitigation measures that have the potential to reduce water surface elevations along high-risk areas of Silver Creek, which could potentially reduce flood related damages in areas adjacent to the creek.

Based on the flood mitigation analyses performed in this report, the mitigation measures that provided the single greatest reductions in water surface elevations in floodplain areas were the levee alternatives. Lower-impact mitigation alternatives such as channel sediment clearing and increasing floodplain conveyance through brush clearing proved to be ineffective at providing significant flood control benefits. Implementing multiple flood mitigation recommendations, including both structural and non-structural measures, would improve flood resiliency along Silver Creek in the Village of Silver Creek.

Ice management to control ice buildup at critical points along Silver Creek would be highly recommended for areas upstream of known flood-prone zones. An ice prediction method using the FDD would be a good starting point to monitor and mitigate any ice related flooding before it actually occurs. For example, planning, preparation, equipment and labor management for ice break-up using amphibious excavators is highly effective at preventing ice jams and potential flooding at key infrastructure points. Therefore, good prediction of possible ice jams enables municipalities to have the appropriate equipment available at the right time and place. This will reduce indirect costs and inconvenience. To alleviate costs of equipment purchase, operation, and maintenance, the County and local Townships could share ownership. Recurring maintenance and staffing required in order to operate the equipment should be factored into any cost analysis.

For flood mitigation measures that are being considered for funding through FEMA grant programs, a benefit-to-cost analysis will be required. In order to qualify for FEMA grants and / or funding, the benefit to cost ratio must be greater than one. Flood buyouts / property acquisitions can qualify for FEMA grant programs with a 75% match of funds. The remaining 25% of funds is the responsibility of state, county, and local governments. The case-by-case nature of buyouts and acquisitions requires widespread property owner participation to maximize flood risk reductions. An unintended consequence of buyout programs is the permanent removal of properties from the floodplain, including tax revenue, which would have long-term implications for local governments and should be considered prior to implementing a buyout program.

Floodproofing is an effective mitigation measure but requires a large financial investment in individual residential and non-residential buildings. Floodproofing can reduce the future risk and flood damage potential but leaves buildings in flood risk areas so that future flood damages remain. A benefit to floodproofing versus buyouts is that properties remain in the Village and the tax base for the local municipality remains intact.

Table 13 provides a summary of the flood mitigation alternatives, their modeled influence on water surface elevations, and associated ROM costs.

**Table 13. Summary of Flood Mitigation Measures**

| Alternative No. | Description | Benefits Related to Alternative | ROM cost ($U.S. dollars) |
|---|---|---|---|
| **1-1** | Jetty at confluence with Lake Erie | Reduced model simulated water surface elevations by 1.5 ft | $499,000 |
| **1-2** | Streambank stabilization near outlet | Controls and mitigates erosion and sedimentation downstream | $55,000 |
| **1-3** | Sediment Management at Outlet to Lake Erie | Improves water quality and increases channel flow area | $506,000 |
| **2-1** | Flood bench upstream railroad bridges | Reduced model simulated water surface elevations by 1.2 ft | $1,500,000 |
| **2-2** | Flood bench (and ice control structure) at confluence with Walnut Creek | Reduced model simulated water surface elevations by 0.4 ft | $870,000 |
| **2-3** | Levee at Main Street | Limits flood extents and depths downstream | $352,000 |
| **3-1** | Levee at mobile home park | Limits flood extents and depths downstream | $417,000 |
| **3-2** | Flood bench upstream of mobile home park | Reduced model simulated water surface elevations by 0.8 ft | $1,950,000 |
| **4-1** | Small flood control dams in the upper areas of the Silver Creek Watershed | Limits flood extents and depths downstream | See Note 1 |
| **4-2** | Early flood warning detection system | Early flood warning for open water and ice-jam events | $120,000 |
| **4-3** | Debris maintenance and sediment management | Maintains channel flow area and reduces flood risk | $20,000 |
| **4-4** | Ice management | Controls ice-jam formation and reduces flood risk from ice jams | $40,000 |
| **4-5** | Flood buyouts/property acquisitions | Reduces and/or eliminates future losses | See Note 1 |
| **4-6** | Flood proofing | Reduces and/or eliminates future damages | See Note 1 |
| **4-7** | Area Preservation / Floodplain Ordinances | Reduces and/or eliminates future losses | See Note 1 |

Notes:

1- Rough order magnitude cost not calculated due to uncertainty; if alternative is pursued, a more detailed analysis will need to be performed

# 9. CONCLUSION

Municipalities affected by flooding along Silver Creek can use this report to support flood mitigation initiatives within their communities. This report is intended to be a high-level overview of proposed flood mitigation strategies and their potential impacts on water surface elevations in Silver Creek. The research and analysis that went into each proposed strategy should be considered preliminary, and additional research, field observations, and modeling are recommended before final mitigation strategies are chosen.

In order to implement the flood mitigation strategies proposed in this report, communities should engage in a process that follows the following steps:

1. Obtain stakeholder and public input to assess the feasibility and public support of each mitigation strategy presented in this report.
2. Complete additional data collection and modeling efforts to assess the effectiveness of the proposed flood mitigation strategies.
3. Develop a list of final flood mitigation strategies based on the additional data collection and modeling results.
4. Select a final flood mitigation strategy or series of strategies to be completed for Silver Creek based on feasibility, permitting, effectiveness, and available funding.
5. Develop a preliminary engineering design report and cost estimate for each selected mitigation strategy.
6. Assess funding sources for the selected flood mitigation strategy.

Once funding has been secured and the engineering design has been completed for the final mitigation strategy, construction and / or implementation of the measure should begin.

# 10. REFERENCES


Alder JR and Hostetler SW. 2017. USGS National Climate Change Viewer. US Geological Survey. Reston (VA): U.S. Department of the Interior. Available from: https://www2.usgs.gov/climate_landuse/clu_rd/nccv.asp doi:10.5066/F7W9575T.

Alexander, K. 2018. Village, county, and state crews respond to Silver Creek ice jams. Buffalo (NY): WIVB / WNLO-TV. [accessed 2020 June 25]. Available from: https://www.wivb.com/news/village-county-and-state-crews-respond-to-silver-creek-ice-jams/.

Appelquist LR, Halsnaes K. 2015. The Coastal Hazard Wheel System for Coastal Multi-Hazard Assessment & Management in a Changing Climate. Journal of Coastal Conservation 19(2): pp 157-179.

Appelquist LR, Balstrom T, Halsnaes K. 2016. Managing Climate Change Hazards in Coastal Areas: The Coastal Hazard Wheel Decision-Support System, Catalogue of Hazard Management Options. Nairobi (KE): United Nations Environment Programme. Available from: https://www.coastalhazardwheel.org/media/1217/main-manual-coastal-hazard-wheel.pdf.

Burns DA, Smith MJ, Freehafer DA. 2015. Development of flood regressions and climate change scenarios to explore estimates of future peak flows. Reston (VA): U.S. Geological Survey (USGS). Report No.: 2015–1235. Available from: http://dx.doi.org/10.3133/ofr20151235.

Chautauqua County. 2019. Applications Available in January for Chautauqua County Occupancy Tax Grant Program for Lakes and Waterways. Mayville (NY): Chautauqua County. Available from: https://chqgov.com/county-executive/news/applications-available-january-chautauqua-county-occupancy-tax-grant-program.

Centre for Energy Advancement through Technological Innovation (CEATI). 2005. Comprehensive River Ice Simulation System Project (CRISSP). [computer software]. Version 1.0. Montreal (QC): Centre for Energy Advancement through Technological Innovation (CEATI).

[CRREL] Cold Regions Research and Engineering Laboratory. [Internet]. 2020. Ice Jam Database. Hanover (NH): United States Geologic Survey (USGS); [updated 2020 July 28; cited 2020 July 28]. Available from: https://icejam.sec.usace.army.mil/ords/f?p=101:7::::::.

EcoStrategies Engineering and Surveying, PLLC (EcoStrategies). 2019. Engineering Report – Smith Mills Reservoir Dam Demolition & Creek Restoration Project. Ellicott (NY): Chautauqua County Soil and Water Conservation District (CCSWD). Available from: Chautauqua County Soil and Water Conservation District (CCSWD).

EcoStrategies Engineering and Surveying, PLLC (EcoStrategies). 2020. Chautauqua County 2021 Occupancy/Bed Tax Application – Lakes and Waterways Version. Ellicott (NY): Chautauqua County Water Quality Task Force (CCWQTF). Available from: Chautauqua County Water Quality Task Force (CCWQTF).

Environmental Systems Research Institute (ESRI). 2019. ArcGIS for Desktop 10. [computer software]. Version 10.7.1. Redlands (CA): Environmental Systems Research Institute (ESRI).

Federal Emergency Management Agency (FEMA). 1983a. FIRM Flood Insurance Rate Map, Village of Silver Creek, New York, Chautauqua County. Washington, D.C. (US): United States Department of Homeland Security. Available from: FEMA.

Federal Emergency Management Agency (FEMA). 1983b. Flood Insurance Study Village of Silver Creek, New York, Chautauqua County. Washington, D.C. (US): United States Department of Homeland Security. Report No.: 360144. Available from: FEMA.

Federal Emergency Management Agency (FEMA). 1984a. FIRM Flood Insurance Rate Map, Town of Hanover, New York, Chautauqua County. Washington, D.C. (US): United States Department of Homeland Security. Available from: FEMA.

Federal Emergency Management Agency (FEMA). 1984b. Flood Insurance Study Town of Hanover, New York, Chautauqua County. Washington, D.C. (US): United States Department of Homeland Security. Report No.: 365336. Available from: FEMA.

Federal Emergency Management Agency (FEMA). 1996. Q3 Flood Data, Chautauqua County, New York. Washington, D.C. (US): United States Department of Homeland Security. Report No.: 365336. Available from: http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=246.

Federal Emergency Management Agency (FEMA). 2000. Title 44 Emergency Management and Assistance Chapter I Federal Emergency Management Agency Department of Homeland Security Subchapter B Insurance and Hazard Mitigation. Washington DC (US): United States Department of Homeland Security (USDHS). Available from: https://www.govinfo.gov/content/pkg/CFR-2002-title44-vol1/pdf/CFR-2002-title44-vol1-chapI.pdf.

Federal Emergency Management Agency (FEMA). 2006. Floodplain Management Requirements: A Study Guide and Desk Reference for Local Officials. Washington DC (US): United States Department of Homeland Security (USDHS). Available from: https://www.fema.gov/media-library-data/20130726-1539-20490-9157/nfip_sg_full.pdf.

Federal Emergency Management Agency (FEMA). 2009. Protecting Manufactured Homes from Floods and Other Hazards. Washington DC (US): United States Department of Homeland Security (USDHS). Report No.: FEMA P-85. Available from: https://www.fema.gov/media-library-data/20130726-1502-20490-8377/fema_p85.pdf.

Federal Emergency Management Agency (FEMA). 2013. Floodproofing Non-Residential Buildings. Washington DC (US): United States Department of Homeland Security (USDHS). FEMA P-936. Available from: https://www.fema.gov/media-library/assets/documents/34270.

Federal Emergency Management Agency (FEMA). 2015a. Hazard Mitigation Assistance Program Digest, September 2015. Washington DC (US): United States Department of Homeland Security (USDHS). Available from: https://www.fema.gov/media-library-data/1444240033001-518cdc8d447ef79a1360763e3145d17e/HMA_Program_Digest_508.pdf.

Federal Emergency Management Agency (FEMA). 2015b. Reducing Flood Risk to Residential Buildings That Cannot Be Elevated. Washington DC (US): United States Department of Homeland Security (USDHS). FEMA P-1037. Available from: https://www.fema.gov/media-library/assets/documents/109669.

Federal Emergency Management Agency (FEMA). 2019. The National Flood Insurance Program Community Status Book. Washington, D.C. (US): United States Department of Homeland Security; [updated 2019 September 24; cited 2020 May 28]. Available from: https://hazards-fema.maps.arcgis.com/.

[FEMA] Federal Emergency Management Agency. [Internet]. 2020. FEMA Flood Map Service Center. Washington DC (US): United States Department of Homeland Security (USDHS); [updated 2020 Sept 4; cited 2020 Sept 12]. Available from: https://msc.fema.gov/portal/home.

Goodkind and O'Dea, Inc. 1978. Preliminary Hydrological Data for Western New York, Frequency-Discharge, Drainage Area Curves, All Drainage Basins Except Tonawanda Creek Basin.

Goshgarin, M. 2019. Community Reflects on 10-Year Anniversary of Devastating Silver Creek Flooding. Buffalo (NY): Spectrum News. [accessed 2020 June 25]. Available from: https://spectrumlocalnews.com/nys/buffalo/news/2019/08/14/community-reflects-on-10-year-anniversary-of-devastating-silver-creek-flooding.

Hartloff, R. 2015. Ice Jam at Silver Creek NY 3 14 15 Drone Video. Silver Creek (NY): YouTube. [accessed 2020 June 25]. Available from: https://www.youtube.com/watch?v=FXAGdeXGHT0.

Helms, D. 1986. Legacy of the Flood Control Act of 1936. In: Rosen H, Reuss M, editors. The Flood Control Challenge: Past, Present, and Future: Proceedings of a National Symposium, 1988. Chicago (IL): Public Works Historical Society, pp. 67-88. Available from: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/about/history/?&cid=nrcs143_010953.

Lumia R. 1991. Regionalization of flood discharges for rural unregulated streams in New York excluding Long Island. Albany (NY): United States Geologic Survey (USGS). WRI 90-4197. Available from: https://pubs.usgs.gov/wri/1990/4197/report.pdf.

Lumia R, Freehafer DA, Smith MJ. 2006. Magnitude and Frequency of Floods in New York. Troy (NY): United States Geologic Survey (USGS). Report No.: SIR2006-5112. Available from: https://pubs.usgs.gov/sir/2006/5112/.

Masselink G, Hughes MG. 2003. Introduction to Coastal Processes and Geomorphology. Oxford (UK): Oxford University Press. pp. 354.

McDonald JH. 2014. Handbook of Biological Statistics, 3rd ed. Baltimore (MD): Sparky House Publishing. pp. 299.

Muller EH. 1963. Geology of Chautauqua County, New York, part II, Pleistocene Geology. Albany (NY): The University of the State of New York, The State Education Department. New York State Museum and Science Service, Bulletin Number 392. Available from: https://nysl.ptfs.com/data/Library1/06042012/77490.PDF.

Mulvihill CI, Baldigo BP, Miller SJ, DeKoskie D, DuBois J. 2009. Bankfull discharge and channel characteristics of streams in New York State. Troy (NY): United States Geological Survey (USGS). Report No.: SIR 2009–5144. Available from: http://pubs.usgs.gov/sir/2009/5144/.

[NASS] National Agricultural Statistics Service. [Internet]. 2019. 2018 New York Cropland Data Layer. Washington D.C. (US): United States Department of Agriculture (USDA). [updated 2019 Feb 15; cited 2020 Jan 23]. Available from: https://nassgeodata.gmu.edu/CropScape/.

[NCEI] National Centers for Environmental Information. [Internet]. 2020. Storm Events Database: Chautauqua County, NY. Asheville (NC): National Oceanic and Atmospheric Administration (NOAA); [updated 2020 June 31; cited 2020 July 24]. Available from: https://www.ncdc.noaa.gov/.

[NPS] National Park Service [software]. 2014. National Register of Historic Places. Washington, D.C. (US): United States Department of the Interior [updated 2014 April; cited 2020 March 25]. Available from https://www.nps.gov/maps/full.html?mapId=7ad17cc9-b808-4ff8-a2f9-a99909164466.

National Research Council (NRC). 2007. Elevation Data for Floodplain Mapping. Washington, DC (US): The National Academies Press, Committee on Floodplain Mapping Technologies. Available from: https://www.nap.edu/catalog/11829/elevation-data-for-floodplain-mapping. ISBN: 0-309-66807-7.

Natural Resources Conservation Service (NRCS). 2002. Water and Sediment Control Basin (No.) CODE 638. Lincoln (NE): United States Department of Agriculture (USDA). Report No.: 638-1. Available from: NRCS.

[NYSDEC] New York State Department of Environmental Conservation. [Internet]. [date unknown]. Watershed Management. New York State Department of Environmental Conservation (NYSDEC) web site. [accessed 2020 June 24]. Available from: https://www.dec.ny.gov/lands/25563.html.

New York State Department of Environmental Conservation (NYSDEC). 2004. Technical & Operational Guidance Series (TOGS) 5.1.9 In-Water and Riparian Management of Sediment and Dredged Material. Albany (NY): New York State Department of Environmental Conservation. Available from: https://www.dec.ny.gov/docs/water_pdf/togs519.pdf.

New York State Department of Environmental Conservation (NYSDEC). 2013. Removal of Woody Debris and Trash from Rivers and Streams. Albany (NY): New York State Department of Environmental Conservation. Available from: https://www.dec.ny.gov/docs/permits_ej_operations_pdf/woodydebrisfact.pdf.

New York State Department of Environmental Conservation (NYSDEC). 2018. DRAFT New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act. Albany (NY): New York State Department of Environmental Conservation. Available from: https://www.dec.ny.gov/docs/administration_pdf/frmgpublic.pdf.

[NYSDEC] New York State Department of Environmental Conservation. [Internet]. 2019. Inventory of Dams - New York State (NYSDEC). Albany (NY): New York State Department of Environmental Conservation, Division of Water, Dam Safety Section; [updated 2019 Mar 6; cited 2019 Oct 25]. Available from http://gis.ny.gov/.

New York State Department of Environmental Conservation (NYSDEC) [software]. 2020a. Environmental Resource Mapper. Albany, NY: New York State Department of Environmental Conservation (NYSDEC); [cited 2020 March 25]. Available from https://gisservices.dec.ny.gov/gis/erm/.

New York State Department of Environmental Conservation (NYSDEC). 2020b. Flooding in Silver & Walnut Creek. Resilient NY – OGS Project No. SD121 Silver Creek/SD123 Walnut Creek. Albany (NY): Highland Planning, LLC.

[NYSDOT] New York State Department of Transportation. [Internet]. 2014. Culvert Point Locations & Select Attributes - New York State Department of Transportation. Albany (NY): New York State Department of Transportation, GIS Coordinator; [updated 2019 February 1; cited 2020 June 22]. Available from: https://gis.ny.gov/gisdata/inventories/details.cfm?DSID=1255.

[NYSDOT] New York State Department of Transportation. [Internet]. 2016. Bridge Point Locations & Select Attributes - New York State Department of Transportation. Albany (NY): New York State Department of Transportation, Structures Division; [updated 2019 February 1; cited 2020 June 22]. Available from: https://gis.ny.gov/gisdata/inventories/details.cfm?DSID=397.

New York State Department of Transportation (NYSDOT). 2019. Bridge Manual. Albany (NY): New York State Department of Transportation (NYSDOT) Structures Division. Available from: https://www.dot.ny.gov/divisions/engineering/structures/manuals/bridge-manual-usc.

New York State Department of Transportation (NYSDOT). 2020. Standard Specifications (US Customary Units), Volume 1. Albany (NY): New York State Department of Transportation (NYSDOT) Engineering Division. Available from: https://www.dot.ny.gov/main/business-center/engineering/specifications/updated-standard-specifications-us.

[NYSGPO] New York State Governor's Press Office. [Internet]. 2018 Nov 5. Governor Cuomo Announces $3 Million for Studies to Reduce Community Flood Risk. New York State Governor's Press Office. Available from: https://www.governor.ny.gov/news/governor-cuomo-announces-3-million-studies-reduce-community-flood-risk.

[NYSGPO] New York State Office of Information Technology Services GIS Program Office, New York State Department of Taxation and Finance's Office of Real Property Tax Services (ORPTS), Chautauqua County Real Property Tax Services (ECRPTS). [Internet]. 2019. NYS Statewide 2018 Parcels for Public Use. Albany (NY): New York State Office of Information Technology Services (NYSOITS); [updated 2020 August; cited 2020 September 15]. Available from: http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=1300.

Ries KG III, Newson JK, Smith MJ, Guthrie JD, Steeves PA, Haluska TL, Kolb KR, Thompson RF, Santoro RD, Vraga HW. 2017. StreamStats, version 4.3.8: U.S. Geological Survey Fact Sheet 2017–3046. Reston (VA): United States Department of the Interior (USDOI); [updated 2019 Mar 4; cited 2020 July 24]. Available from: https://streamstats.usgs.gov/ss/.

Rosenzweig C, Solecki W, DeGaetano A, O'Grady M, Hassol S, Grabhorn P, editors. 2011. Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation. Albany (NY): New York State Energy Research and Development Authority (NYSERDA). Available from: www.nyserda.ny.gov.

Rosgen DL, Silvey HL. 1996. Applied River Morphology. 2nd edition. Fort Collins (CO): Wildland Hydrology Books. 378 p.

RSMeans Data Online [Software]. 2019. RS Means CostWorks 2019 Version 16.03. Rockland (MA): Gordian, Inc.; [updated 2019; cited 2020 June 22]. Available from: https://www.rsmeans.com/products/online.aspx.

Shen HT, Wang DS, Wasantha Lal AM. 1995. Numerical Simulation of River Ice Processes. Reston (VA): Journal of Cold Region Engineering. 9(3): 107-118. Available from: https://doi.org/10.1061/(ASCE)0887-381X(1995)9:3(107).

Shen HT, Yapa P. 2011. A Unified Degree-Day Method for River Ice Cover Thickness Simulation. Montreal (QC): Canadian Journal of Civil Engineering. 12 (1): 54-62. DOI: 10.1139/l85-006.

Siders AR. 2013. Anatomy of a Buyout – New York Post-Superstorm Sandy. In: The 16th Annual Conference Litigating Takings Challenges to Land Use and Environmental Regulations. New York (NY): New York University School of Law. Available from: https://www.researchgate.net/publication/308518538_Anatomy_of_a_Buyout_Program_--_New_York_Post-Superstorm_Sandy.

Taylor KE, Stouffer RJ, and Meehl GA 2011. An Overview of CMIP5 and the Experiment Design. Bulletin of the American Meteorological Society (BAMS) [Internet]. [cited 2019 Nov 21]; 93(4): 485-498. Available from: https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-11-00094.1.

Tesmer, IH. 1954. Part II of Geology of Chautauqua County, New York. In: Muller EH. 1963. Geology of Chautauqua County, New York: Pleistocene Geology. Bulletin 392. Albany (NY): University of the State of New York, State Education Department.

United States Army Corps of Engineers (USACE). 1966. Flood Plain Information Buffalo Creek, New York in the Towns of Elma and West Seneca. Buffalo (NY): United States Army Corps of Engineers (USACE), Buffalo District. Available from: USACE.

United States Army Corps of Engineers (USACE). 2000. Engineering and Design – DESIGN AND CONSTRUCTION OF LEVEES. Washington D.C. (US). United States Department of the Army. Report No.: EM 1110-2-1913. Available from: USACE, https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1913.pdf?ver=2013-09-04-072924-963.

United States Army Corps of Engineers (USACE). 2006. Engineering and Design - ICE ENGINEERING. Washington D.C. (US). United States Department of the Army. Report No.: EM 1110-2-1612. Available from: USACE, https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1612.pdf.

United States Army Corps of Engineers (USACE). 2016a. HEC-RAS River Analysis System User's Manual Version 5.0. Davis (CA): United States Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC). Report No.: CPD-68. Available from: USACE.

United States Army Corps of Engineers (USACE). 2016b. Lexington Green – Section 205 of the 1948 Flood Control Act – Flood Risk Management. Buffalo (NY): United States Army Corps of Engineers (USACE) Buffalo District. P2#443918. Available from: http://www.westseneca.net/sites/default/files/Buffalo%20Creek%20Lexington%20Green%20West%20Seneca%20NY%20-%20Determination%20of%20Federal%20Interest%20-%20Final%20(5-24)(1).pdf.

United States Army Corps of Engineers (USACE). 2017a. HEC-RAS River Analysis System: Silver Creek Floodplain Management Services (FPMS) model. [computer software]. Version 5.0.7. Buffalo (NY): United States Army Corps of Engineers (USACE), Buffalo District.

United States Army Corps of Engineers (USACE). 2017b. Special Flood Hazard Evaluation Silver Creek, Silver Creek, Chautauqua County, New York. Buffalo (NY): United States Army Corps of Engineers (USACE), Buffalo District. Available from: USACE.

United States Army Corps of Engineers (USACE). 2019. HEC-RAS River Analysis System. [computer software]. Version 5.0.7. Davis (CA): United States Army Corps of Engineers (USACE), Hydrologic Engineering Center (HEC).

United States Department of Commerce (USDC). 1963. Hydraulic Engineering Circular No. 4, Peak Rates of Runoff from Small Watersheds. Washington DC (US): United States Department of Commerce (USDC).

United States Department of Homeland Security (USDHS). 2010. DHS Risk Lexicon – 2010 Edition. Washington DC (US): United States Department of Homeland Security (USDHS). Available from: http://www.dhs.gov/xlibrary/assets/dhs-risk-lexicon-2010.pdf.

United States Fish and Wildlife Service (USFWS) [software]. 2020. Information for Planning and Consultation (IPaC). Washington, D.C. (US): Environmental Conservation Online System (ECOS); [cited 2020 March 25]. Available from https://ecos.fws.gov/ipac/.

United States Geologic Survey (USGS). 1978. Chapter 7: Physical basin characteristics from hydrologic analysis. In: National Handbook of Recommended Methods for Water-Data Acquisition. Reston (VA): U.S. Geologic Survey, Office of Water Data Coordination. Available from: USGS.

United States Geologic Survey (USGS). 2010. Flash Floods of August 10, 2009 in the Villages of Gowanda and Silver Creek, New York. Reston (VA): United States Geologic Survey (USGS). Report No.: SIR 2010-5259. Available from: https://pubs.usgs.gov/sir/2010/5259/pdf/SIR%202010-5259.pdf.

[USGS] United States Geologic Survey. [Internet]. 2016. Application of Flood Regressions and Climate Change Scenarios to Explore Estimates of Future Peak Flows, version 1.5. Reston (VA): United States Geologic Survey (USGS); [updated 2016 May 19; cited 2020 July 8]. Available from: https://streamstats.usgs.gov/ss/.

[USGS] United States Geologic Survey. [Internet]. 2017. StreamStats, version 4.3.8. Reston (VA): United States Geologic Survey (USGS); [updated 2020 February 6; cited 2020 June 24]. Available from: https://streamstats.usgs.gov/ss/.

[USGS] United States Geologic Survey. [Internet]. 2019. National Climate Change Viewer. Reston (VA): United States Geologic Survey (USGS); [updated 2019 April 26; cited 2020 June 24]. Available from: https://www2.usgs.gov/landresources/lcs/nccv/viewer.asp.

United States Soil Conservation Service (USSCS). 1994. Soil Survey of Chautauqua County, New York. Mayville (NY): United States Department of Agriculture (USDOA). Available from https://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/new_york/NY013/0/chautauqua.pdf.

Waikar ML, Nilawar AP. 2014. Morphometric Analysis of a Drainage Basin using Geographic Information System: A Case Study. International Journal of Multidisciplinary and Current Research. 2 (Jan/Feb): 179-184. ISSN: 2321-3124.

Zevenbergen LW, Ameson LA, Hunt JH, Miller AC. 2012. Hydraulic Design of Safe Bridges. Washington D.C. (US): United States Department of Transportation, Federal Highway Administration. Report No.: FHWA-HIF-12-018, HDS-7. Available from: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif12018.pdf.

# APPENDICES