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RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

WALNUT CREEK, CHAUTAUQUA COUNTY, NEW YORK

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OBG Part of Ramboll

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HIGHLAND PLANNING

RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE
WALNUT CREEK, CHAUTAUQUA COUNTY, NEW YORK

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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.

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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
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 Walnut Creek confluences with Silver Creek and has 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 Walnut 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 Walnut 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 provided by the U.S. Army Corps of Engineers (USACE 2017a) is 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 Walnut Creek watershed study areas lies within Chautauqua County. The creek flows in a general northerly direction with its headwaters at the Town of Arkwright and passes through the towns of Sheridan and Hanover and the Village of Silver Creek before its confluences with Silver Creek and empties into Lake Erie (Figure 3-1). Walnut Creek, within the Village of Silver Creek and continuing downstream to its confluence with Silver Creek, was chosen as the target 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 Walnut 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 developed for Walnut 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).

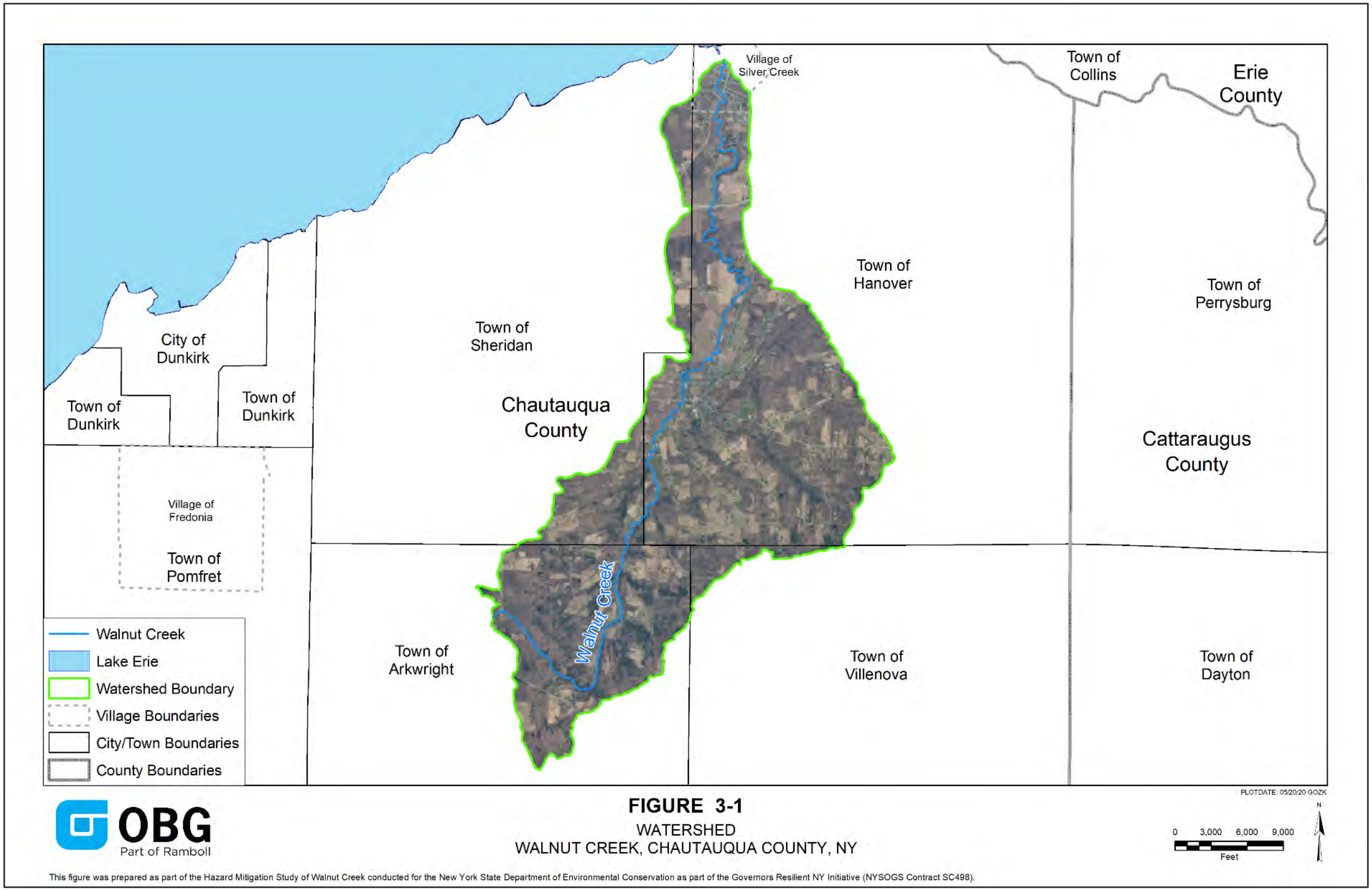

Figure 3-1. Walnut Creek Watershed, Chautauqua County, NY.

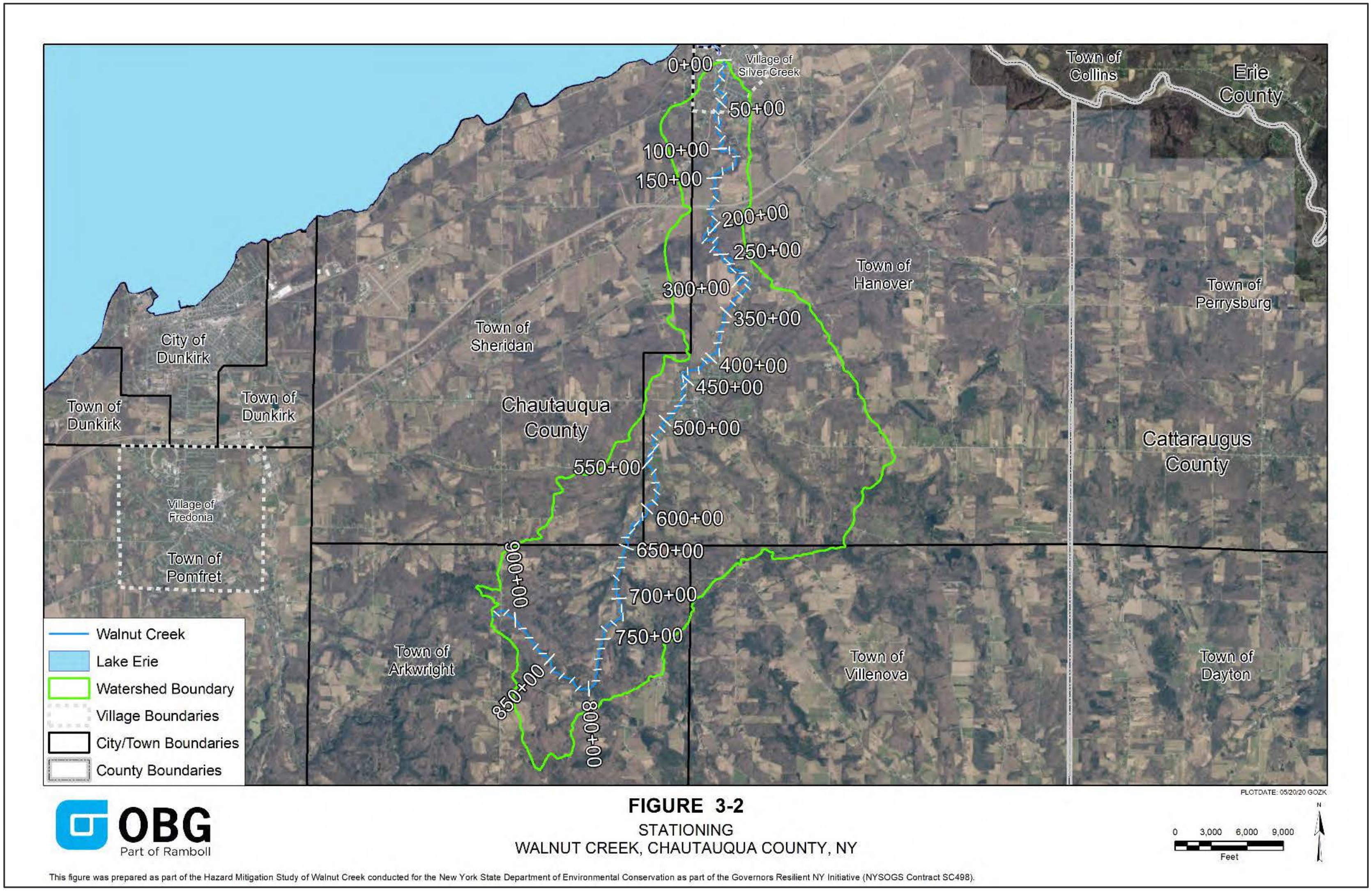

Figure 3-2. Walnut Creek Watershed Stationing, Chautauqua County, NY.

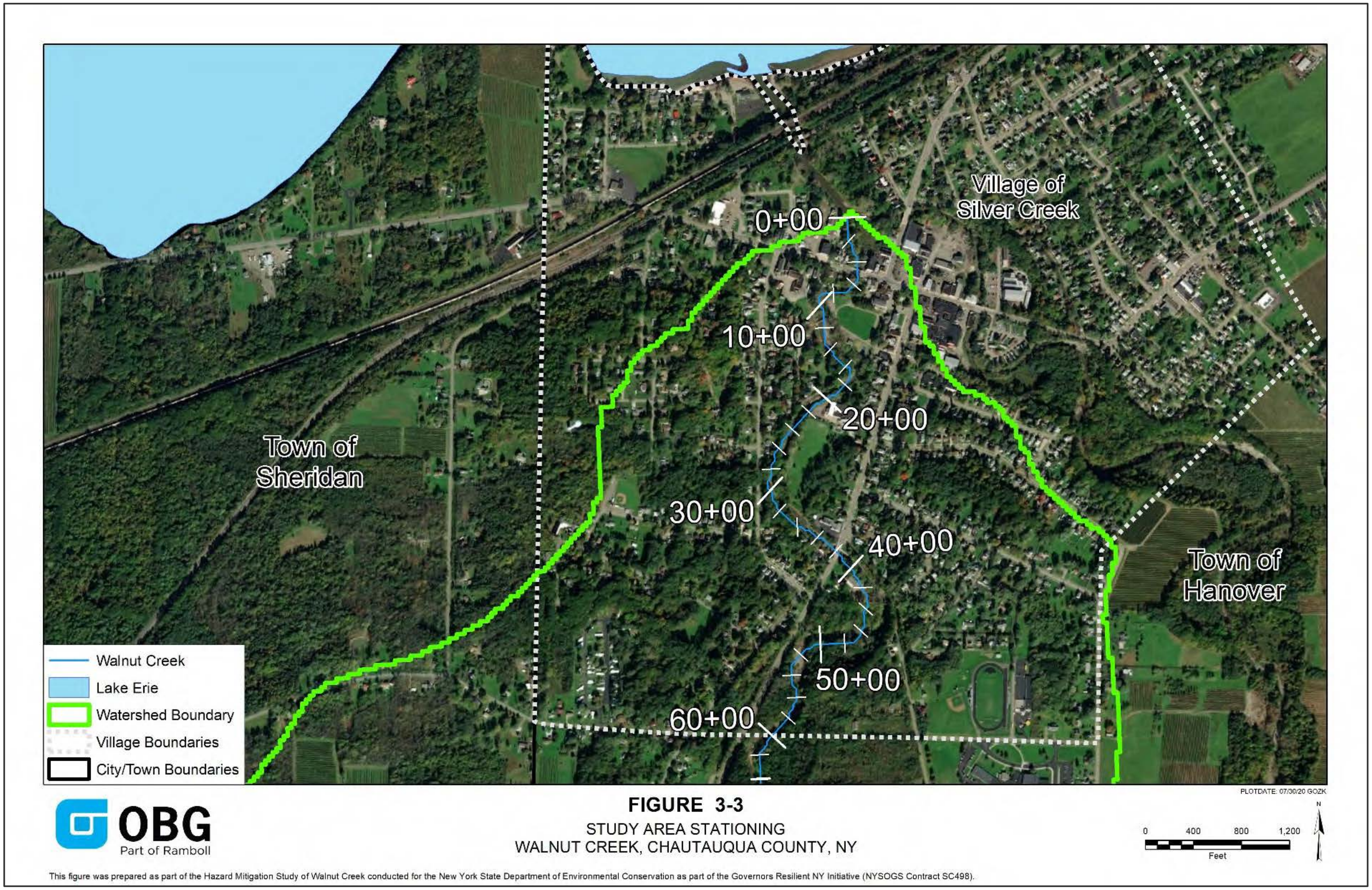

Figure 3-3. Walnut Creek Study Area Stationing, Chautauqua County, NY.

3.2 ENVIRONMENTAL CONDITIONS

An overview of the environmental and cultural resources within the Walnut 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 U.S. Fish and Wildlife Service (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 Walnut Creek watershed (Figure 3-4) (NYSDEC 2020a).

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

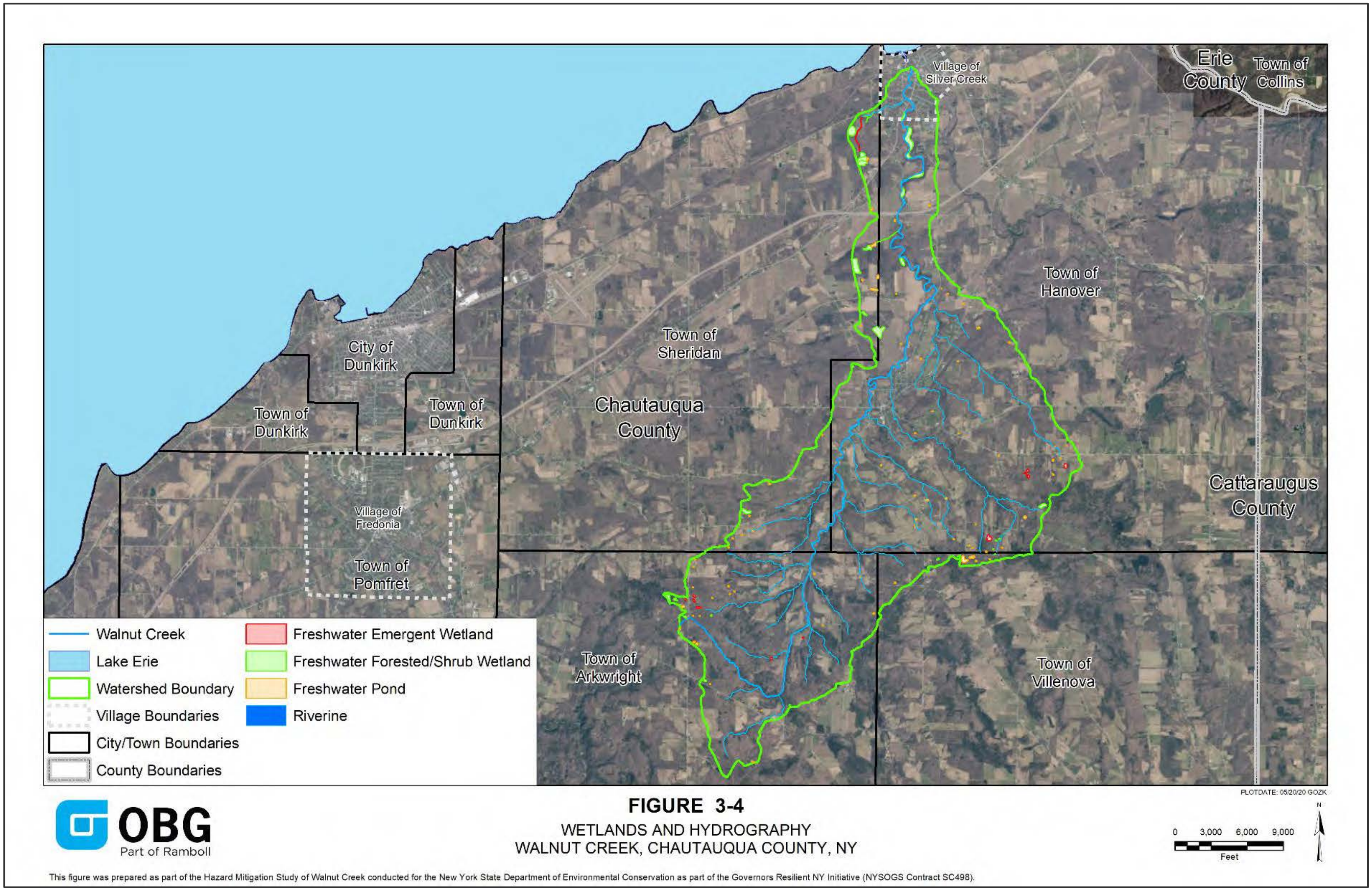

Figure 3-4. Wetlands and Hydrography, Walnut Creek, Chautauqua County, NY.

3.2.2 Sensitive Natural Resources

The Walnut 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).

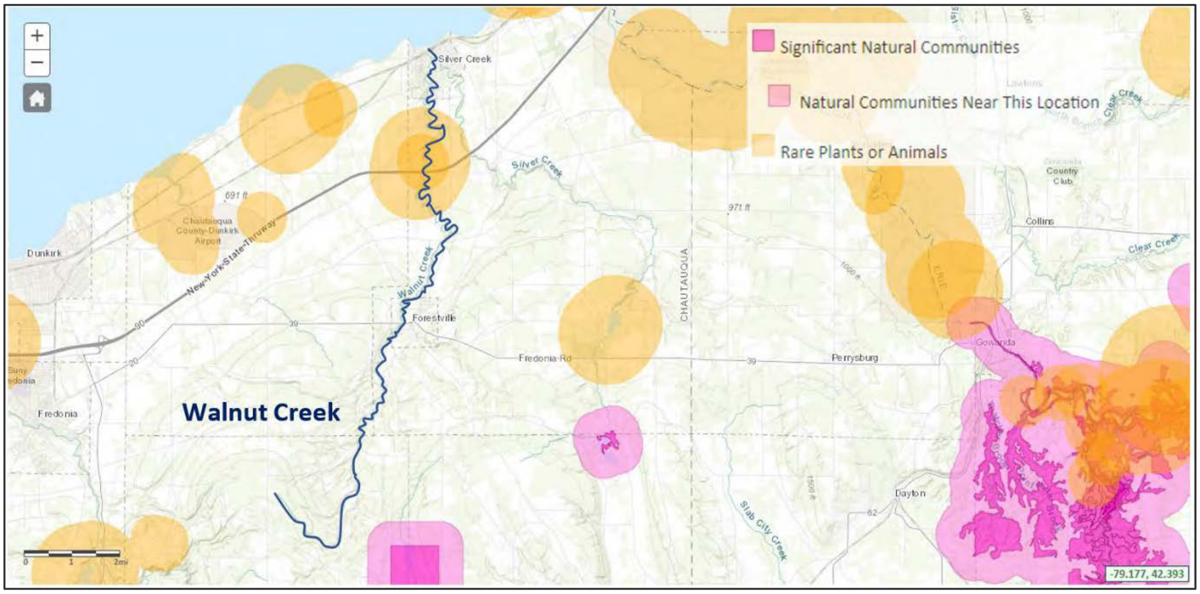

Figure 3-5. Environmental Resource Mapper - Significant Natural Communities and Rare Plants or Animals.

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 United States Fish & Wildlife Service (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

(Source: USFWS 2020)		
Common Name	**Scientific Name**	**Level of Concern**
Northern Long-eared Bat	*Myotis septentrionalis*	Threatened
Clubshell	*Pleurobema clava*	Endangered
Northern Riffleshell	*Epioblasma torulosa rangiana*	Endangered
Rayed Bean	*Villosa fabalis*	Endangered

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

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]	Breeds Sep 1 to Aug 31
Black-billed Cuckoo	*Coccyzus erythropthalmus*	BCC Rangewide (CON)[2]	Breeds May 15 to Oct 10
Bobolink	*Dolichonyx oryzivorus*	BCC Rangewide (CON)[2]	Breeds May 20 to Jul 31
Canada Warbler	*Cardellina canadensis*	BCC Rangewide (CON)[2]	Breeds May 20 to Aug 10
Lesser Yellowlegs	*Tringa flavipes*	BCC Rangewide (CON)[2]	Breeds elsewhere
Red-headed Woodpecker	*Melanerpes erythrocephalus*	BCC Rangewide (CON)[2]	Breeds May 10 to Sep 10
Snowy Owl	*Bubo scandiacus*	BCC Rangewide (CON)[2]	Breeds elsewhere
Wood Thrush	*Hylocichla mustelina*	BCC Rangewide (CON)[2]	Breeds 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. Walnut 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 (FEMA1983b; 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 Walnut 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-ft, and shown as a three-digit code on the FIRM. The flood zones indicated in the Walnut 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-ft 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% annual chance event (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 ft; 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, Walnut 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-ft 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 Walnut Creek in the Village of Silver Creek, NY (FEMA 1983a).

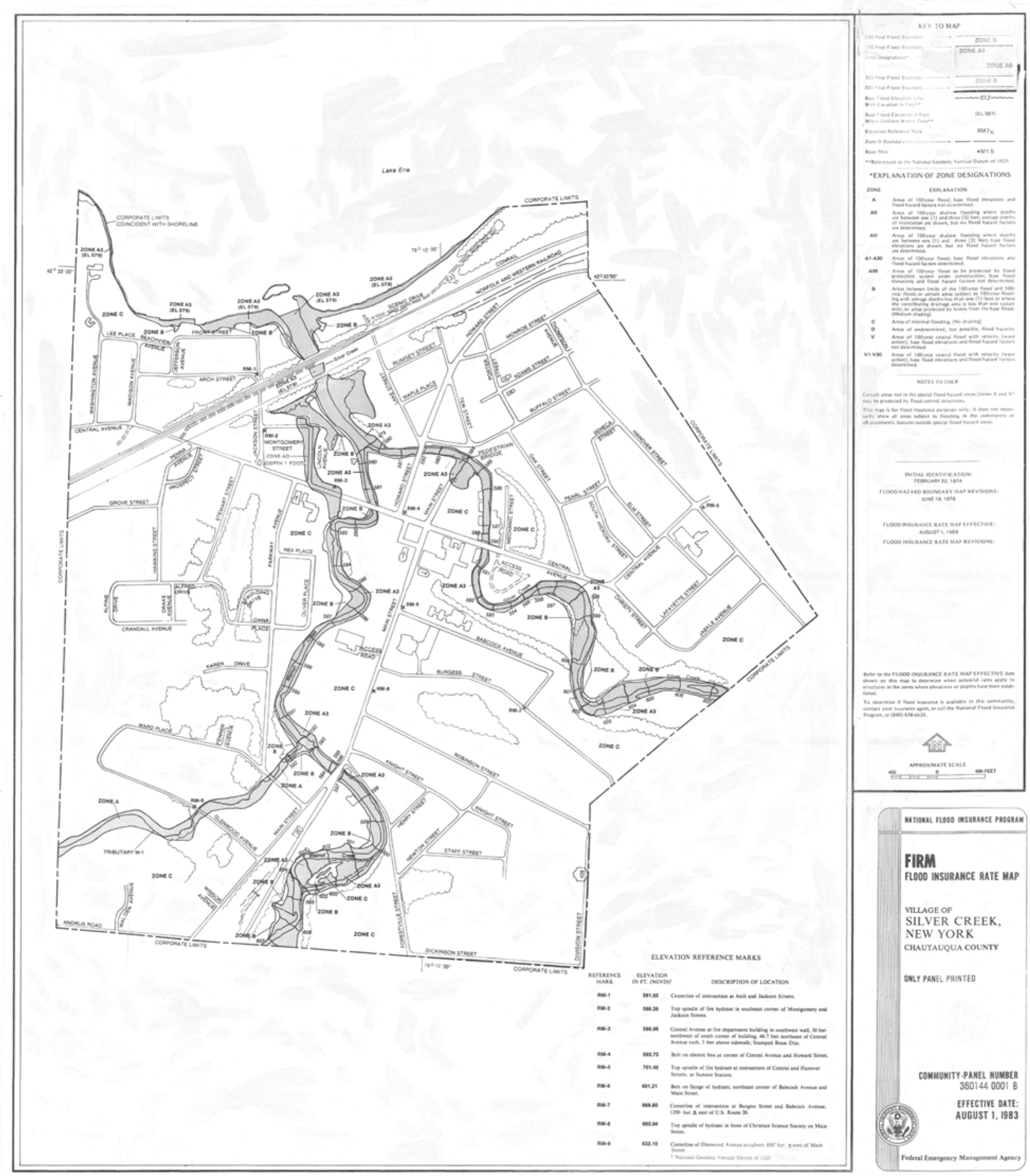

Figure 3-6. FEMA FIRM, Walnut Creek, Village of Silver Creek, Chautauqua County, NY.

3.3 WATERSHED LAND USE

The Walnut Creek stream corridor is largely comprised of forested (66%), cultivated lands / hay (19%), and grassland / pasture (6%). Of the forested lands, deciduous forests (47%) comprise the largest proportion of forest type, while other hay / non-alfalfa (9%) 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 (7%) of total land use within the Walnut Creek basin (NASS 2019).

In the Town of Hanover along Walnut Creek, development is primarily agricultural (FEMA 1984b). In the Village of Silver Creek, the Walnut Creek watershed is primarily commercial and residential 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 Walnut 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 ft 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-feet 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 ft 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 Walnut 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. Hornell silt loam 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. Busti silt loam 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 3-8 is a profile of stream bed elevation and channel distance from the confluence with Silver Creek using data from the FEMA FIS flood profiles for Walnut Creek. Walnut Creek has an average slope of 1.24% over the profile stream length. The creek's streambed lowers approximately 1,120 vertical feet over this reach from an elevation of 1,700-ft above sea level (NAVD 88) at the headwaters in the Town of Arkwright, to 580-ft above sea level at the confluence of Lake Erie in the Village of Silver Creek, NY (FEMA 1983b).

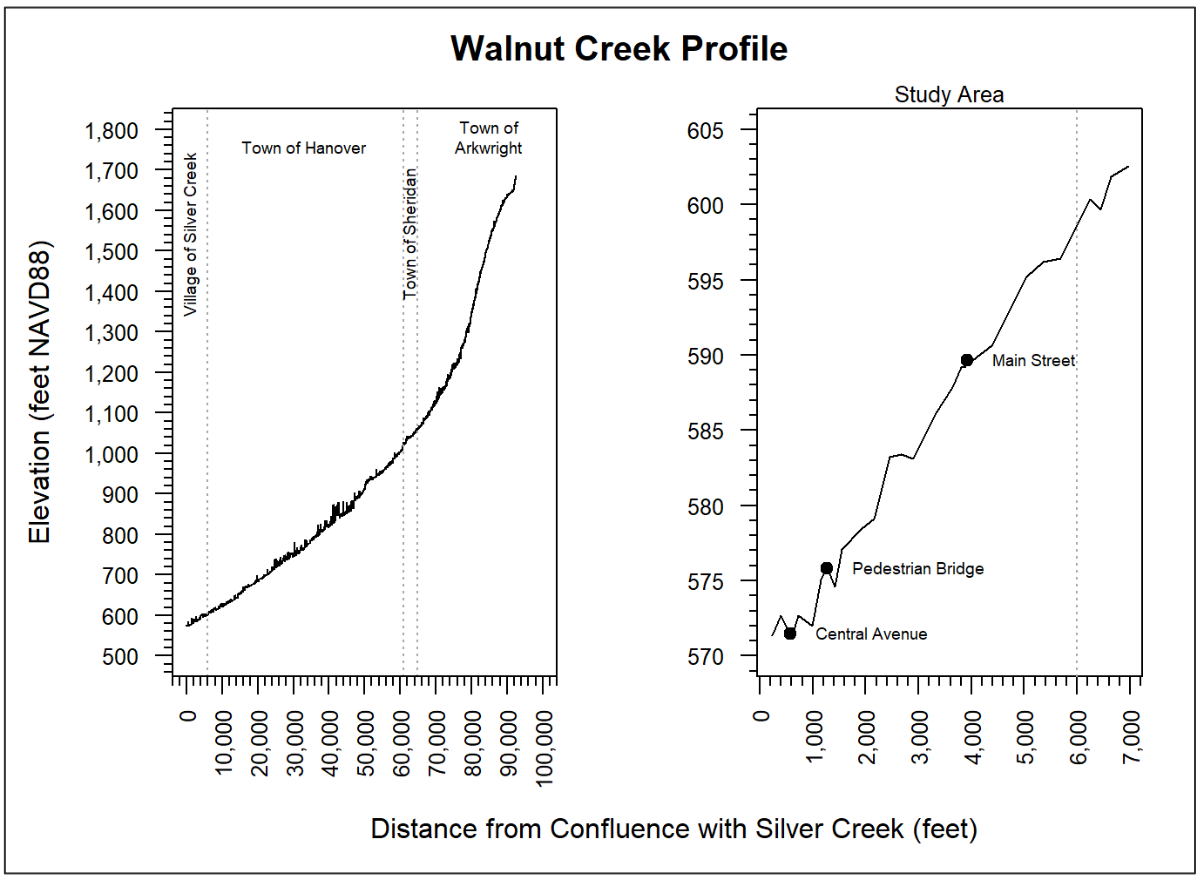

Figure 3-7. Walnut Creek Profile.

3.5 HYDROLOGY

Walnut Creek drains an area of 26.8 mi^2, is approximately 10 miles in length, and is located in the southwestern portion of New York State and in the northeastern portion of Chautauqua County, NY. Walnut 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 Silver Creek, which converges with Walnut Creek in the Village and continues downstream to Lake Erie (FEMA 1984b). Table 3 is a summary of the basin characteristic formulas and calculated values for the Walnut 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. Walnut Creek Basin Characteristics Factors

Factor	Formula	Value
Form Factor (R_F)	A / B_L^2	0.27
Circularity Ratio (R_C)	$4*\pi*A / B_P^2$	0.22
Elongation Ratio (R_E)	$2 * (A/\pi)0.5 / B_L$	0.58

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 Walnut 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 is one USGS stream gaging station on Walnut Creek, however it has less than three years' worth of data.

An effective FEMA Flood Insurance Study (FIS) for the Village of Silver Creek was issued in 1983, and for the Town of Hanover in 1984, 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 Walnut Creek (FEMA 1983b; FEMA 1984b).

Table 4. Walnut Creek Summary of FEMA FIS Peak Discharges

(Source: FEMA 1983b; FEMA 1984b)						
			Peak Discharges (cfs)			
Location[1]	**Drainage Area (sq. mi.)**	**River Station (ft)**	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
Confluence with Silver Creek	26.4	0+00	2,450	3,360	3,820	4,900
Western Village of Forestville corporate limit	13.3	495+00	1,350	1,850	2,100	2,700
1400-ft upstream of Village of Forestville corporate limit	12.1	499+00	1,220	1,670	1,900	2,450
1700-ft upstream of Village of Forestville corporate limit	11.7	502+00	1,200	1,620	1,830	2,380
900-ft upstream of Laona Road	9.6	537+00	1,000	1,370	1,560	1,950
700-ft downstream of Route 307	9.4	577+00	980	1,330	1,520	1,910
400-ft downstream of Route 307	8.6	590+00	900	1,230	1,400	1,770
Western Town of Hanover corporate limit	7.4	609+00	780	1,070	1,230	1,550

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

According to the effective FEMA FIS, for Walnut 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 Walnut 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-yr 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 Walnut 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 Walnut Creek at selected FEMA FIS profile locations.

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

(Source: FEMA 1983b; FEMA 1984b; USGS 2017)						
			Peak Discharges (cfs)			
Location	Drainage Area (sq. mi.)	River Station (ft)	10-Percent	2-Percent	1-Percent	0.2-Percent
Confluence with Silver Creek	26.4	0+00	2,730	4,350	5,100	7,080
Western Village of Forestville corporate limit	13.3	495+00	1,970	3,260	3,880	5,520
1400-ft upstream of Village of Forestville corporate limit	12.1	499+00	1,840	3,050	3,630	5,180
1700-ft upstream of Village of Forestville corporate limit	11.7	502+00	1,780	2,950	3,510	5,000
900-ft upstream of Laona Road	9.6	537+00	1,540	2,560	3,050	4,340
700-ft downstream of Route 307	9.4	577+00	1,540	2,560	3,060	4,370
400-ft downstream of Route 307	8.6	590+00	1,440	2,400	2,860	4,090
Western Town of Hanover corporate limit	7.4	609+00	1,260	2,110	2,510	3,600

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 Walnut 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 Walnut Creek as derived from the USGS *StreamStats* program (USGS 2017).

Table 7. Estimated Bankfull Discharge, Width, and Depth

(Source: FEMA 1983b; FEMA 1984b; USGS 2017)					
Location	**River Station (ft)**	**Drainage Area (sq. mi.)**	**Bankfull Depth (ft)**	**Bankfull Width (ft)**	**Bankfull Streamflow (cfs)**
Confluence with Silver Creek	0+00	26.4	2.32	67	765
Western Village of Forestville corporate limit	495+00	13.3	1.95	49.7	419
1400-ft upstream of Village of Forestville corporate limit	499+00	12.1	1.91	48	392
1700-ft upstream of Village of Forestville corporate limit	502+00	11.7	1.89	47.2	378
900-ft upstream of Laona Road	537+00	9.6	1.81	43.6	322
700-ft downstream of Route 307	577+00	9.4	1.76	41.8	296
400-ft downstream of Route 307	590+00	8.6	1.75	41.5	292
Western Town of Hanover corporate limit	609+00	7.4	1.69	39	258

3.6 INFRASTRUCTURE

Numerous infrastructure facilities cross the creek channel including bridges and dams. Table 8 lists a summary of infrastructure crossing Walnut Creek. Figure 3-8 displays the locations of the bridges and dams that cross Walnut Creek in Chautauqua County, NY (NYSDOT 2016; Ries et al. 2017).

There are five dams along Walnut Creek watershed, but only three dams interact with the flow of Walnut Creek. Of these three dams, two are purposed as “Irrigation” while the third is purposed as “Other”. The hazard classifications of the dams along Walnut Creek are negligible (class D), low (class A), and one is not rated. Table 8 lists the dams that are along Walnut Creek, including hazard codes and purpose for the dam (NYSDEC 2019).

Major bridge crossings over Walnut Creek include US Route 20 and NY Route 5 in the Village of Silver Creek, and Interstate 90 and County Routes 39 and 307 in the Town of Hanover. Bridge lengths and surface widths for NYSDOT bridges were revised as of February 2019 (NYSDOT 2016).

Table 8. Inventory of Infrastructure Crossing Walnut Creek

(Source: FEMA 1983b; FEMA 1984b; NYSDOT 2014; NYSDOT 2016; NYSDEC 2019)								
Type	**Roadway Carried or Structure Name**	**Owner**	**State ID/BIN**	**River Station (ft)**	**Length[1] (ft)**	**Width[2] (ft)**	**Height (ft)**	**Hydraulic Capacity (% Annual Chance)**
Dam	Cook Bros Silver Creek Dam	Private	006-0496	23+00	N/A	80	5	No Data Available
Dam	A C Cook Forestville Dam	Private	007-0540	386+00	N/A	100	7	No Data Available
Dam	Forestville Reservoir Dam	Village of Forestville	007-0554	529+50	N/A	5	14	No Data Available
Bridge	Central Avenue / NY-5	NYSDOT	1001290	5+00	40	87	No Data Available	0.2
Bridge	Pedestrian Bridge	N/A	N/A	11+00	N/A	N/A	No Data Available	No FIS Data Available
Bridge	Main Street / US-20	NYSDOT	1015420	37+00	40	95	No Data Available	0.2
Bridge	Interstate 90 (WB)	NYS Thruway Authority	5511511	177+00	51	259	No Data Available	No FIS Data Available
Bridge	Interstate 90 (EB)	NYS Thruway Authority	5511512	178+00	51	259	No Data Available	No FIS Data Available
Bridge	Stebbins Road / Co. Rte. 86	Chautauqua County	3324840	179+00	30	197	No Data Available	No FIS Data Available
Bridge	King Road / Co. Rte. 84	Chautauqua County	3324810	307+00	28.3	56.5	No Data Available	No FIS Data Available
Bridge	Mixer Road	Chautauqua County	2212590	400+00	22.6	73	No Data Available	No FIS Data Available
Bridge	Main Street / Co. Rte. 39	NYSDOT	1024420	473+00	37.4	64	No Data Available	No FIS Data Available
Bridge	Laona Road	Chautauqua County	3324830	527+00	24.3	53	No Data Available	0.2

(Source: FEMA 1983b; FEMA 1984b; NYSDOT 2014; NYSDOT 2016; NYSDEC 2019)								
Type	**Roadway Carried or Structure Name**	**Owner**	**State ID/BIN**	**River Station (ft)**	**Length[1] (ft)**	**Width[2] (ft)**	**Height (ft)**	**Hydraulic Capacity (% Annual Chance)**
Bridge	Walnut Creek Road / Co. Rte. 307	Chautauqua County	3324760	585+00	34.1	29	No Data Available	0.2
Bridge	Walnut Creek Road / Co. Rte. 307	Chautauqua County	3325500	635+00	25.3	71	No Data Available	No FIS Data Available
Bridge	Straight Road	Chautauqua County	3323470	660+00	25.6	84	No Data Available	No FIS Data Available
Bridge	Walnut Creek Road / Co. Rte. 85	Chautauqua County	3323410	695+00	Not Listed	22.2	No Data Available	No FIS Data Available
Bridge	Henry Rd	Town of Arkwright	N/A	715+00	N/A	N/A	No Data Available	No FIS Data Available
Bridge	Walnut Creek Road / Co. Rte. 85	Chautauqua County	3323490	736+00	Not Listed	22	No Data Available	No FIS Data Available
Bridge	Walnut Creek Road / Co. Rte. 85	Chautauqua County	N/A	743+00	N/A	N/A	No Data Available	No FIS Data Available
Bridge	Walnut Creek Road / Co. Rte. 85	Chautauqua County	N/A	792+00	N/A	N/A	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

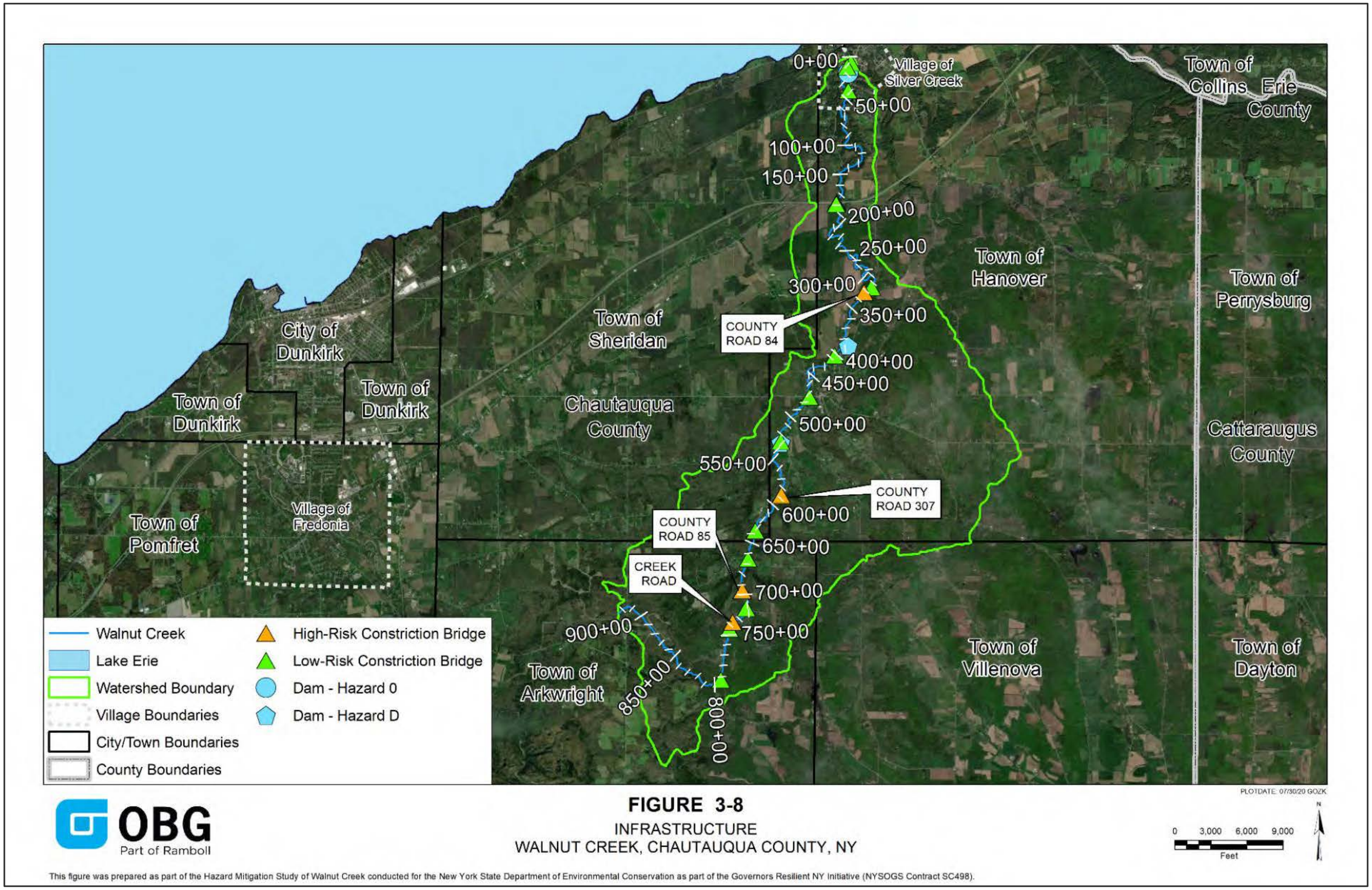

Figure 3-8. Infrastructure, Walnut Creek, Chautauqua County, NY.

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 Walnut 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 ft 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 six 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-yr 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-yr 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 three 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 Walnut Creek.

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

(Source: FEMA 1983b, 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)**
Central Avenue / NY-5	5+00	580.75	581.25	0.5
Main Street / US-20	37+00	596.0	596.5	0.5
Laona Road	527+00	Data illegible in FIS report		
County Rte. 307	585+00	Data illegible in FIS report		

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 Walnut Creek (Table 10). The bankfull widths are wider than the structure's width for the King Road (CO-84) bridge and three crossings with Walnut Creek Road (CO-307 and CO-85).

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	King Road / Co. Rte. 84	307+00	56.5	65.3	524	80-percent
Bridge	Walnut Creek Road / Co. Rte. 307	585+00	29	41.8	296	80-percent
Bridge	Walnut Creek Road / Co. Rte. 85	695+00	22.2	29.2	144	80-percent
Bridge	Walnut Creek Road / Co. Rte. 85	736+00	22	47.9	105	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 WALNUT 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 Western New York, the recommended design-flow multiplier is 10% for an end of design life of 2025-2100 (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 *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 *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 *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 *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 *FutureFlow* projected peak discharges at the FEMA FIS locations (USGS 2016).

Table 11. Walnut 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 Silver Creek	26.4	0+00	3,194	4,906	5,692	7,728
Western Village of Forestville corporate limit	13.3	496+00	2,398	3,792	4,446	6,164
1400-ft upstream of Village of Forestville corporate limit	12.1	509+00	2,246	3,548	4,164	5,774
1700-ft upstream of Village of Forestville corporate limit	11.7	513+00	2,172	3,434	4,026	5,584
700-ft upstream of Laona Road	9.6	553+00	1,896	2,998	3,516	4,876
900-ft downstream of Route 307	9.4	575+00	1,768	2,806	3,296	4,580
400-ft downstream of Route 307	8.6	588+00	1,758	2,794	3,280	4,562
Western Town of Hanover corporate limit	7.4	609+00	1,552	2,472	2,904	4,038

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-ft 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 *StreamStats* software and the mean predicted future discharge calculated using the *FutureFlow* software at each of the discharge locations included in the effective FIS.

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

(Source: USGS 2016; USGS 2017)					
Location	**Drainage Area (mi^2)**	**River Station (ft)**	**Current *StreamStats* Discharge (cfs)**	**Predicted *FutureFlow* Discharge (cfs)**	**Change (%)**
Confluence with Silver Creek	26.4	0+00	5,100	5,692	12
Western Village of Forestville corporate limit	13.3	496+00	3,880	4,446	15
1400-ft upstream of Village of Forestville corporate limit	12.1	509+00	3,630	4,164	15
1700-ft upstream of Village of Forestville corporate limit	11.7	513+00	3,510	4,026	15
700-ft upstream of Laona Road	9.6	553+00	3,050	3,516	15
900-ft downstream of Route 307	9.4	575+00	2,850	3,296	16
400-ft downstream of Route 307	8.6	588+00	2,840	3,280	15
Western Town of Hanover corporate limit	7.4	609+00	2,510	2,904	16

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. Walnut 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. Homes in the area of Rix Place and Oliver Place occurs frequently. Additional flooding occurs downstream, in part due to the 90-degree bend in Walnut Creek approximately 400-ft upstream of the Central Avenue bridge. Floodwaters impact the municipal building, fire department, emergency squad building, and residential homes in the area of Lincoln Avenue and Montgomery street. Ice jamming also frequently causes flooding along Walnut Creek in the area of the confluence with Silver Creek (NYSDEC 2020b).

FEMA FIRMs are available for Walnut 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.

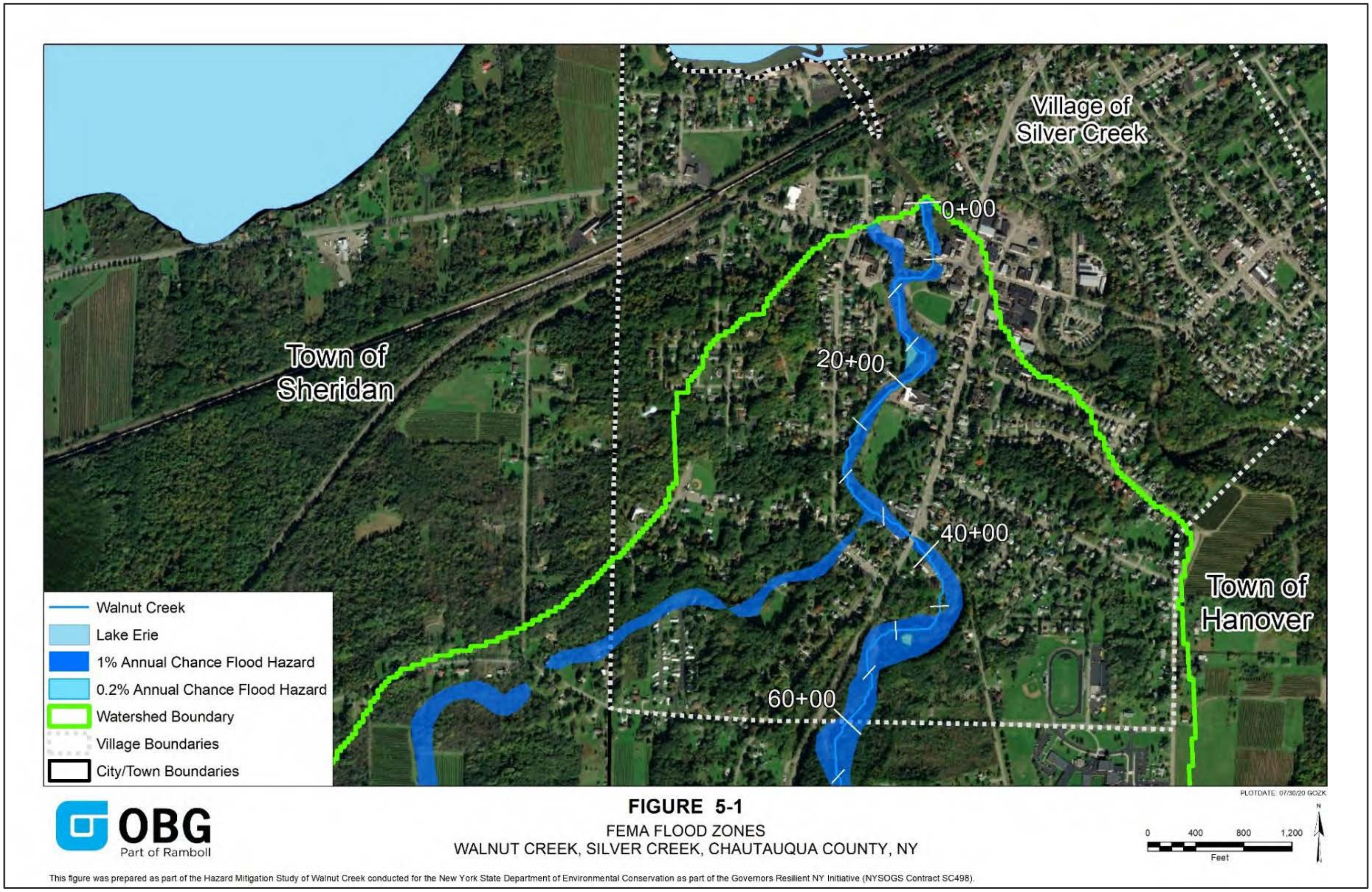

Figure 5-1. Walnut Creek, Village of Silver Creek FEMA Flood Zones, Chautauqua County, NY.

*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.

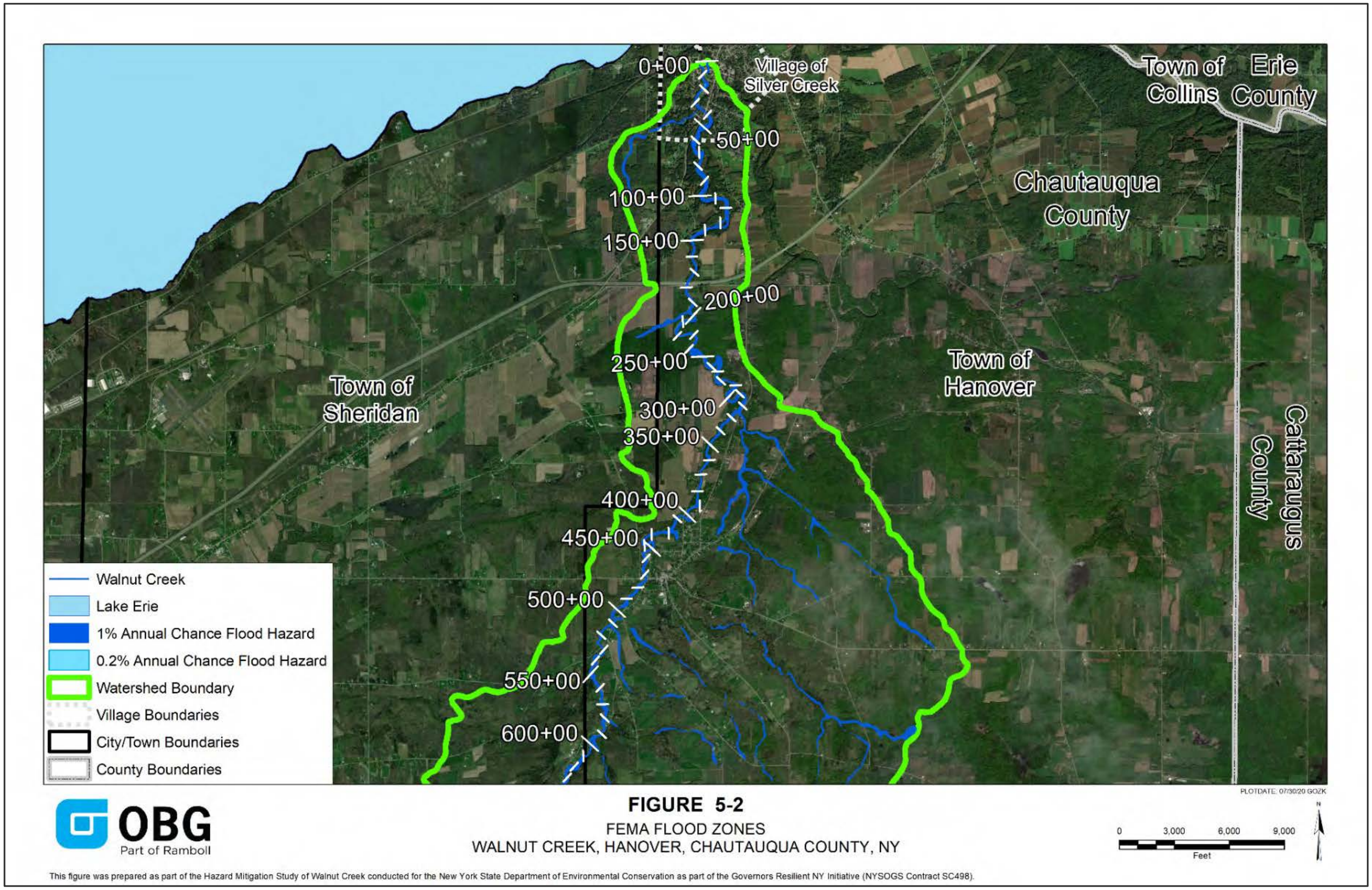

Figure 5-2. Walnut Creek, Town of Hanover FEMA Flood Zones, Chautauqua County, NY.

*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.

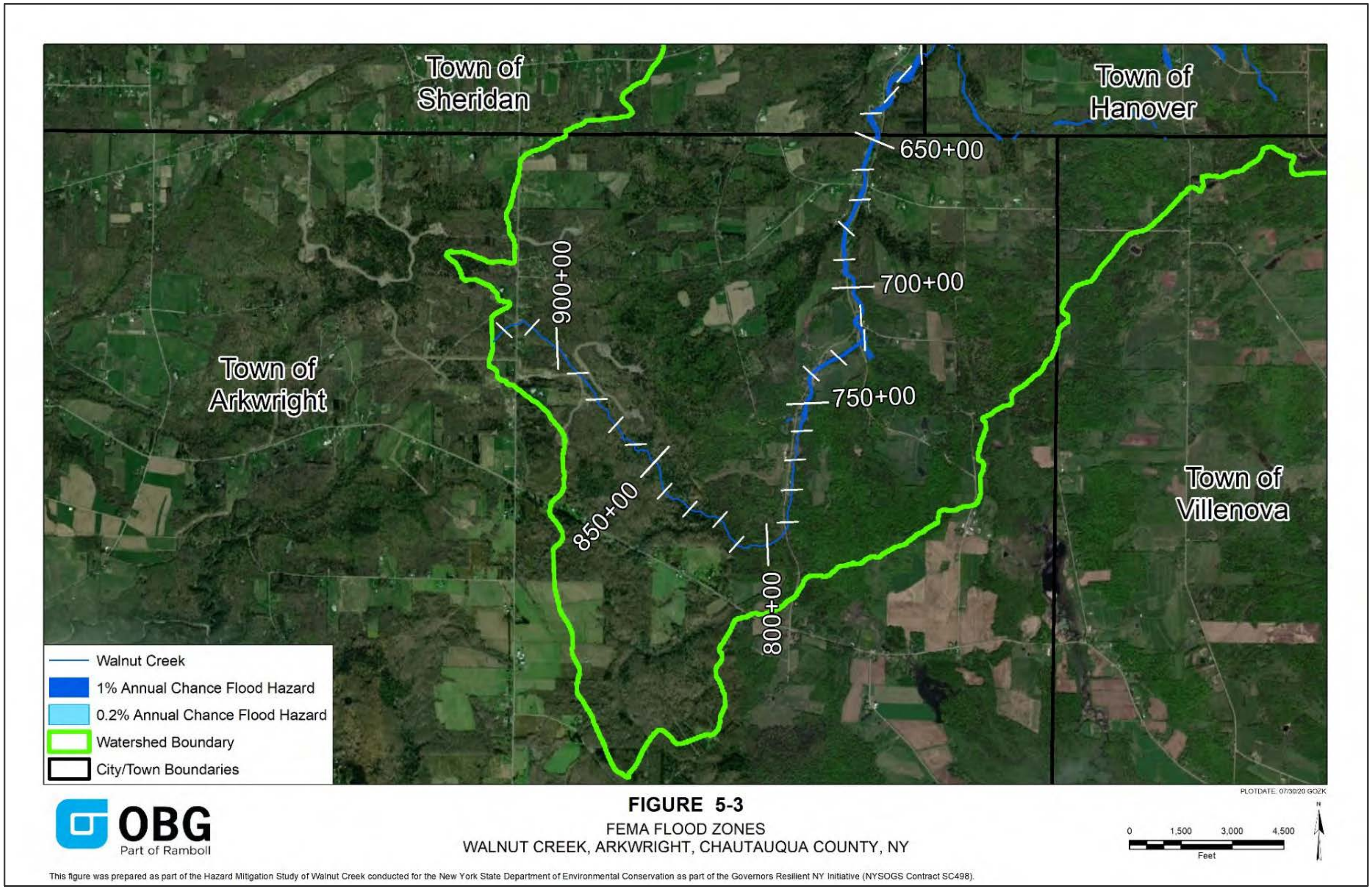

Figure 5-3. Walnut Creek, Town of Arkwright FEMA Flood Zones, Chautauqua County, NY.

*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 Walnut 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 and 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 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 Walnut Creek and Silver 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 13 scenarios were modeled to analyze potential flood mitigation strategies, with and without ice cover. Four model scenarios were selected for inclusion in Section 6 Mitigation Alternatives. The four model scenarios presented in this report include alternatives:

1-1: Flood Bench (and Ice Control Structure) at Confluence with Silver Creek

1-3: Flood Control Levees along Walnut Creek

2-1: Left Bank Levee Upstream of Main Road

3-1: Small Flood Controls Dams in the Upper Reaches of the Walnut Creek Watershed

Alternatives 1-2, 1-4 and 3-2 through 3-7 are qualitative and 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 Walnut Creek watershed is susceptible to ice jam formation and backwater flooding. Since 1941, there have been eight reported ice jam events on Walnut Creek. Since 2005, there have been six 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, which can cause ice jamming in Walnut Creek, depending on conditions. Ice jamming has occurred on Walnut Creek upstream as far as Dana Place (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, two areas along Walnut Creek were identified as high-risk flood areas in the Village of Silver Creek.

5.6.1 High-Risk Area #1: Downtown Village of Silver Creek

High-Risk Area #1 extends from downstream of the confluence of Walnut Creek with Silver Creek, upstream to Ward Place (river station 0+00 to 25+00) (Figure 5-4). This area includes a substantial portion of the downtown portion of the Village of Silver Creek. The highest-risk areas include the homes around Rix and Oliver Places, extending toward Central Avenue and further north to Lincoln Avenue and Montgomery Street. Numerous homes and business, as well as municipal services, are located in this area. Modeling shows a lack of hydraulic capacity in Walnut Creek, 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 confluence of Walnut Creek with Silver Creek is also prone to ice jamming, which can cause additional flooding on a more-frequent basis.

5.6.2 High-Risk Area #2: Upstream (East) of Main Road

High-Risk Area #2 is upstream of Main Road on the left bank of Walnut Creek (river station 35+00 to 45+00) (Figure 5-5). Flood flows leave the Walnut Creek channel at the left bank, causing some inundation in an area with private residences and a business.

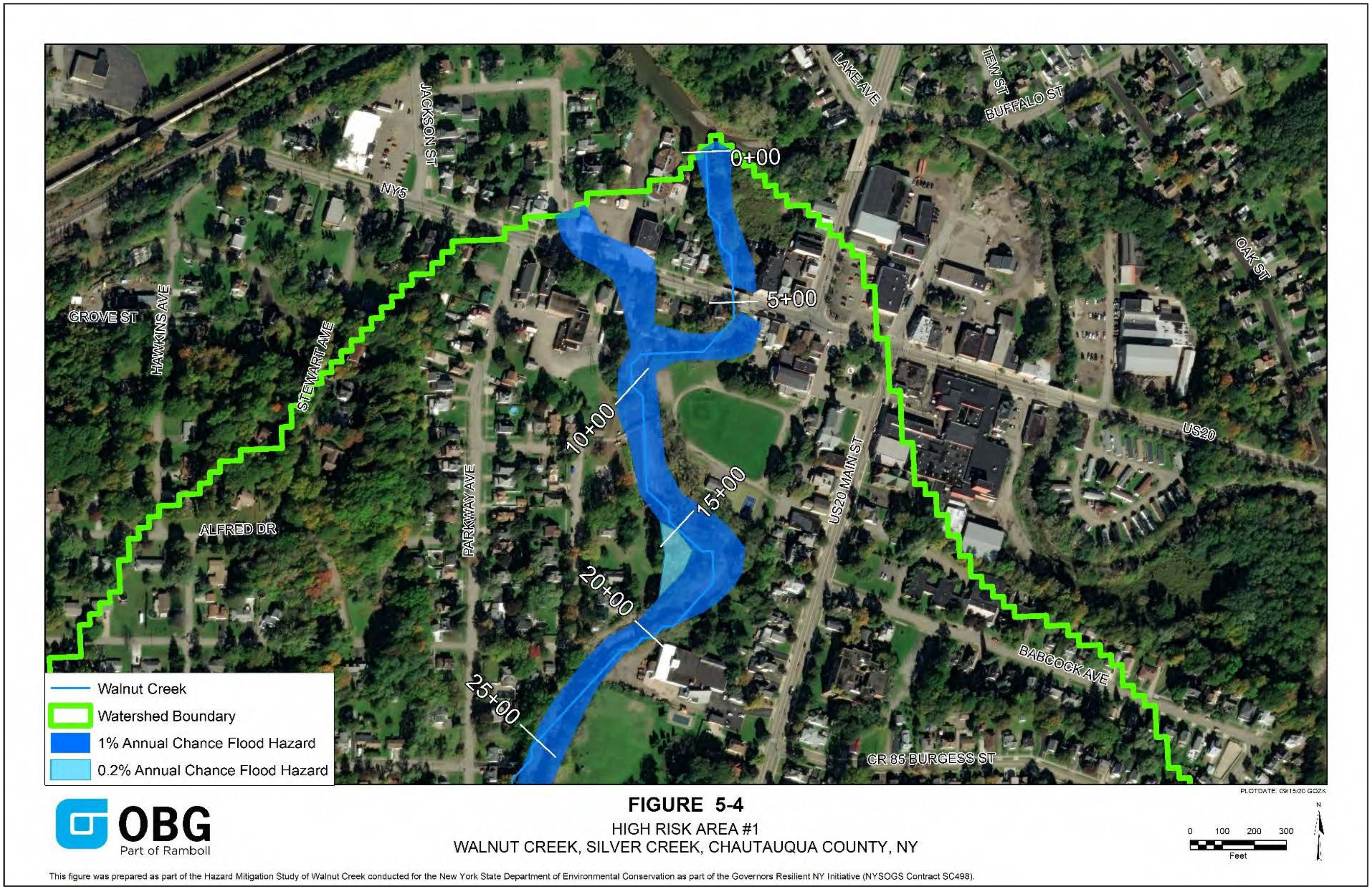

Figure 5-4. High-Risk Area #1, Walnut Creek, Village of Silver Creek, Chautauqua County, NY.

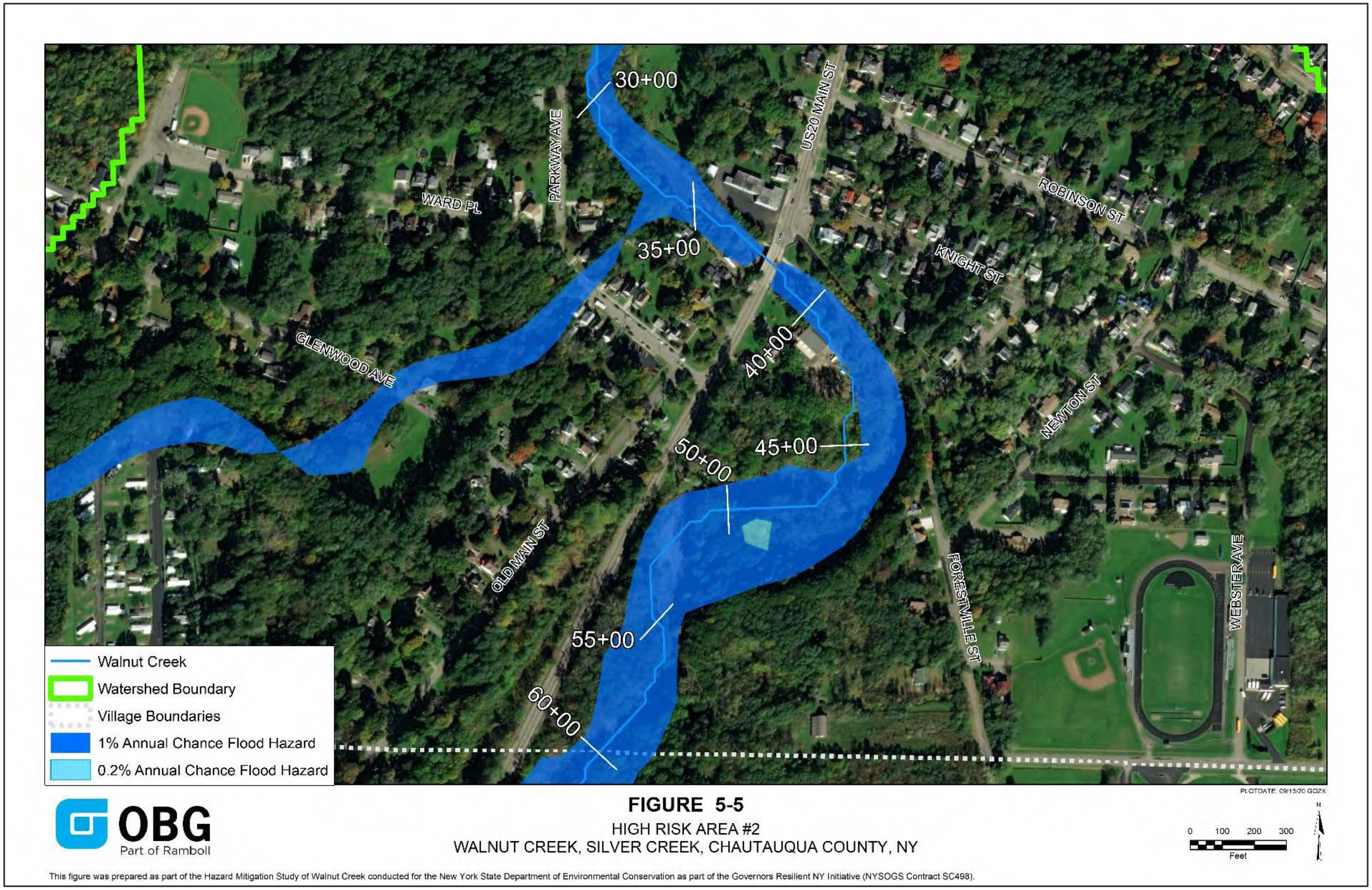

Figure 5-5. High-Risk Area #2, Walnut Creek, Village of Silver Creek, Chautauqua County, NY.

6. MITIGATION ALTERNATIVES

The following are flood mitigation alternatives that have the potential to reduce water surface elevations along high-risk areas of Walnut 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: Flood Bench (and Ice Control Structure) at Confluence with Silver Creek

The flood bench would be located at the confluence of Silver and Walnut Creeks between river stations 0+00 and 3+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 require the excavation of approximately 0.6 acres of land at an average depth of 3 feet (Figure 6-1).

The flood bench would provide addition flood protection to the residences and businesses along Central Avenue 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.

Hydraulic modeling of the flood bench estimates a decrease in water surface elevation in Walnut Creek adjacent to the flood bench of up to approximately 1.8 ft during the 1% annual chance flood event, which would likely decrease the impact of flooding but not completely mitigate it (Figures 6-2 and 6-3).

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 6-1. Location Map for Alternative #1-1: Flood Bench (and Ice Control Structure) at Confluence with Silver Creek.

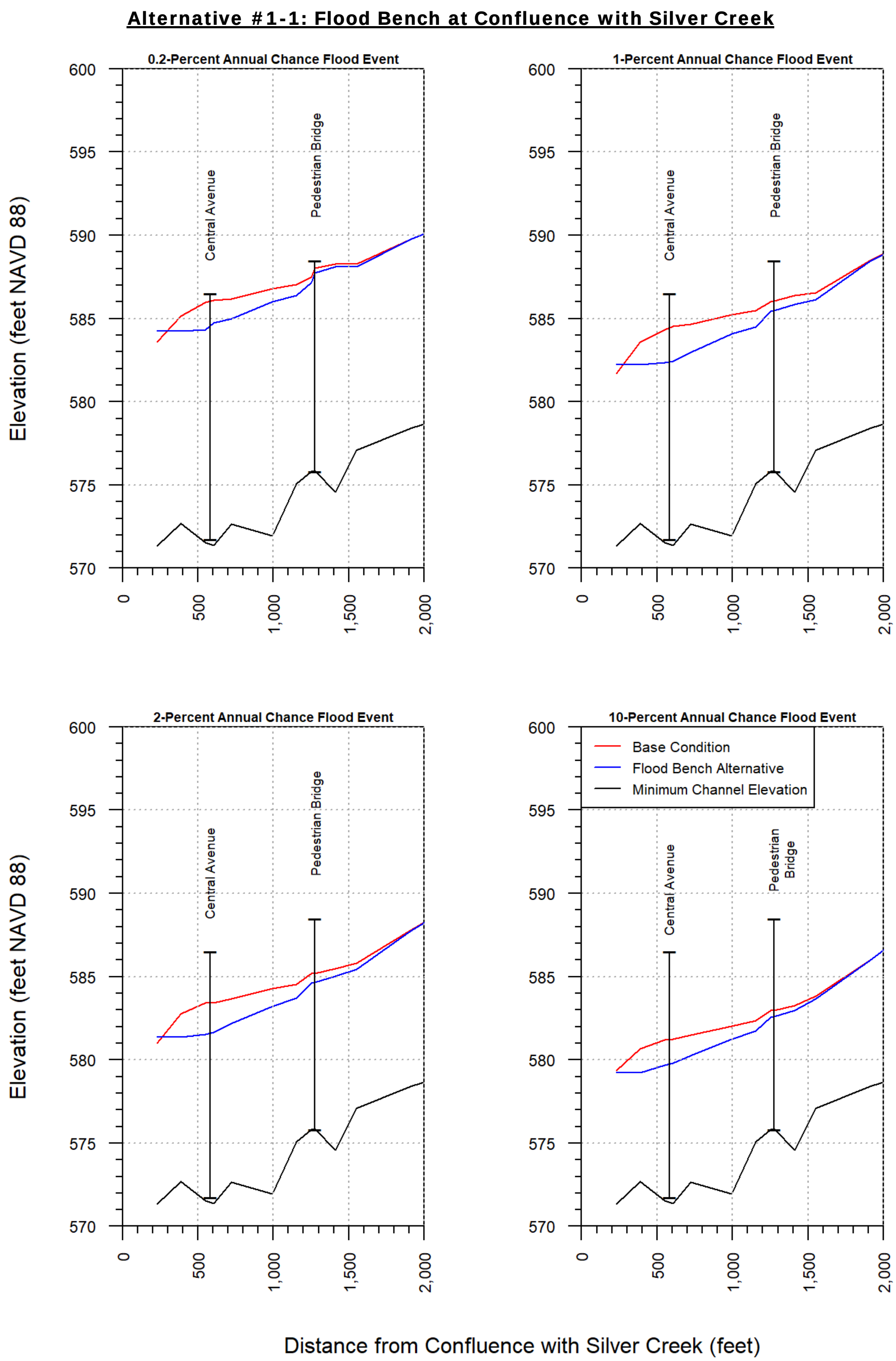

Figure 6-2. HEC-RAS proposed condition model for Alternative #1-1.

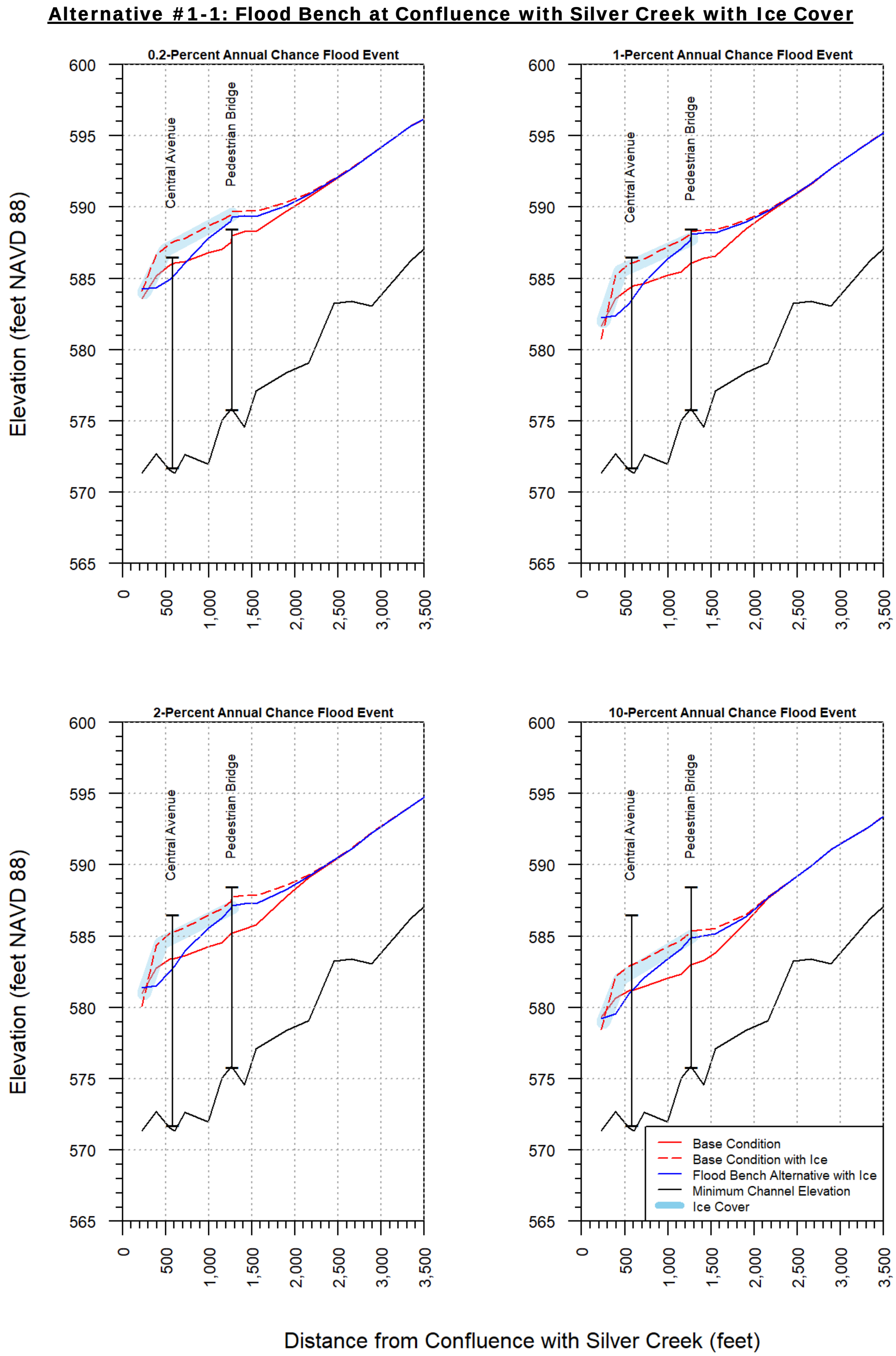

Figure 6-3. HEC-RAS proposed condition model for Alternative #1-1 with ice cover.

6.1.2 Alternative #1-2: Streambank Stabilization near Park Place Park

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 Walnut Creek streambank has severe erosion with a 10-ft cliff approximately 4-ft away from the edge of the public basketball court in the Park Place Park and has contributed roughly 700 yds or 60 truckloads of sediment to Lake Erie. The left bank along this section of creek, between river stations 9+00 and 12+00, has a concrete wall and two 90-degree bends that create ice and debris jams that impede the natural flow of the stream, which result in flooding of municipal buildings and severe erosion to the public park (Figure 6-4) (EcoStrategies 2020).

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

The proposed mitigation strategy involves the installation of large stone riprap (3-4 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 an 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: Flood-Control Levees Along Walnut Creek

This measure is intended to address flooding experienced in the Village of Silver Creek in two areas of concern. The first area, located on Walnut Creek between river stations 5+00 and 15+00, begins at the Central Avenue roadway crossing and extends upstream past the Park Place Park and includes residential and commercial buildings in the area of Parkway Street, Central Avenue, Montgomery Street, and Jackson Street. The second area, located on Walnut Creek between river stations 15+00 and 22+00, begins upstream of the pedestrian bridge and Park Place Park, extends upstream to Dana Place and the Excelco Developments, Inc. business complex, and includes the commercial and residential buildings near Dana Place, Rix Place, Oliver Place, and Main Road (Figure 6-5).

Appendix B provides mitigation renderings which illustrate a levee.

This measure includes a left bank levee and right bank levee, working in unison to prevent flood flows in Walnut Creek from exiting the channel during the 1% annual chance flood event, and during ice-cover events occurring simultaneously with the 10% annual chance event. Based on model results, the left bank levee would need to be approximately 2,100-ft long with an average height of approximately six feet. The right bank levee would need to be approximately 1,700-ft long with an average height of approximately five feet. The footprint required to construct the levee would require a combination of public and private property along Walnut Creek (Figures 6-6 and 6-7).

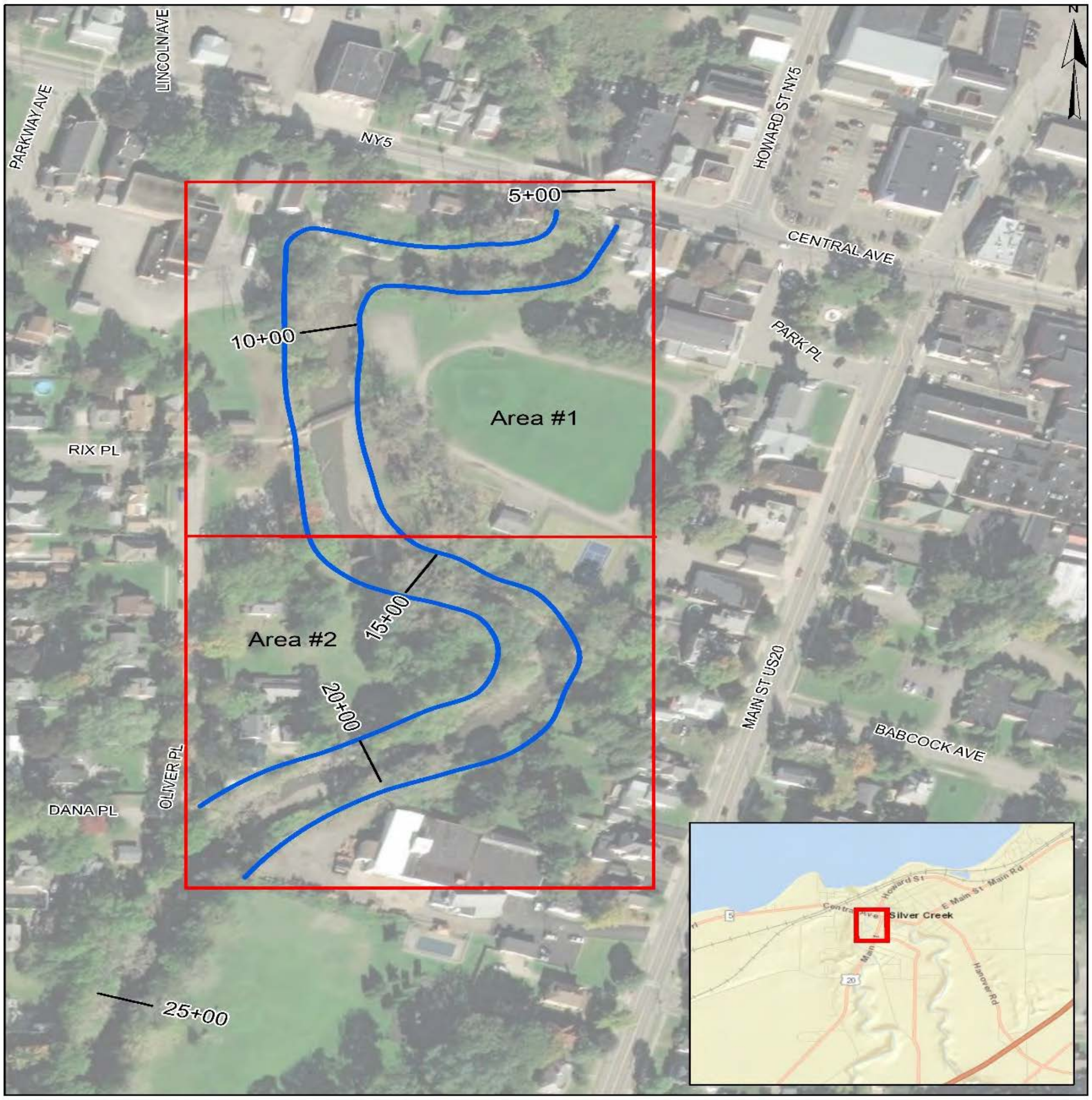

Figure 6-5. Location map for Alternative #1-3: Flood Control Levees Along Walnut Creek.

Any levee constructed in the Walnut 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 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.

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 $2,640,000, 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.

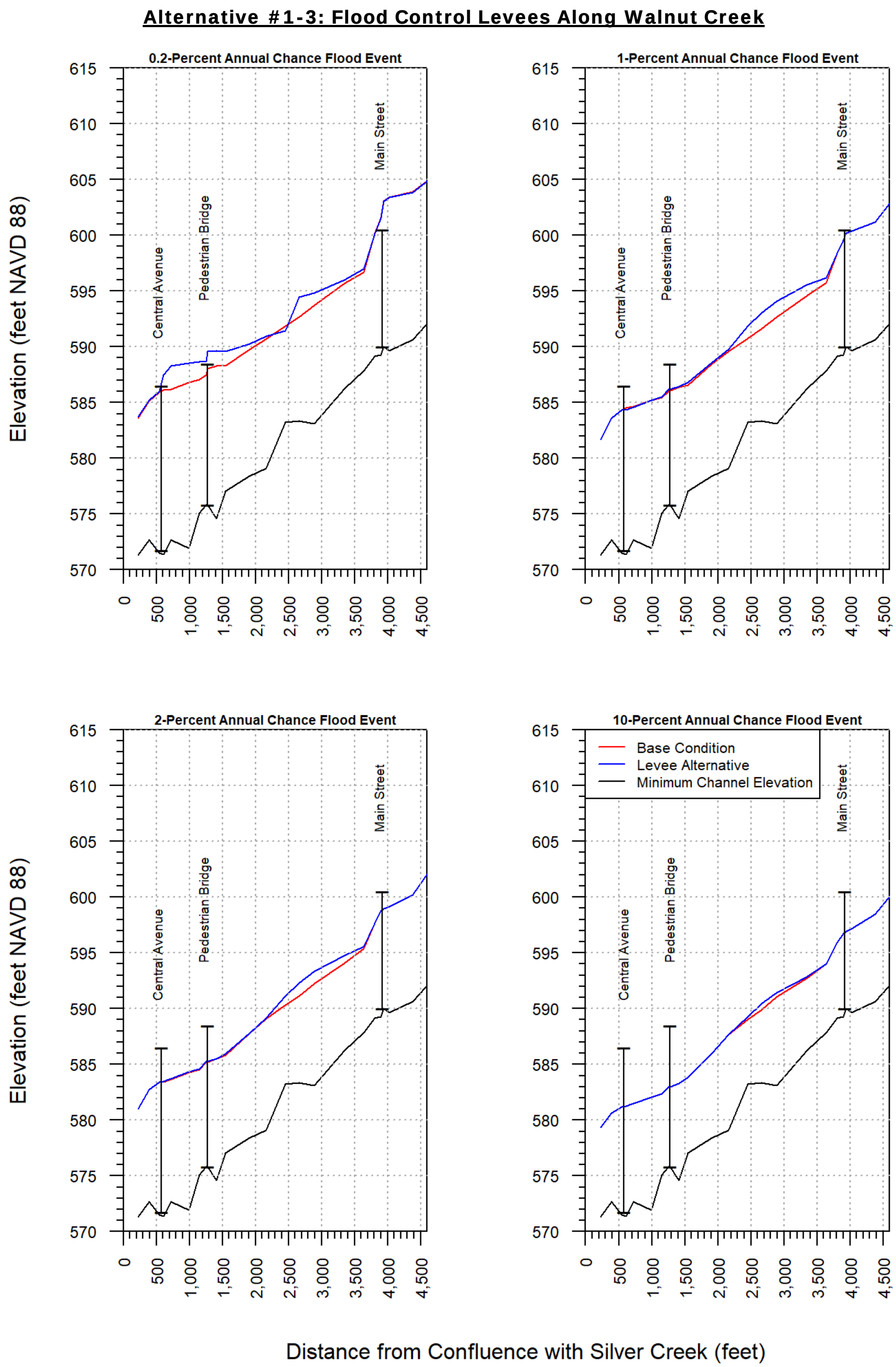

Figure 6-6. HEC-RAS proposed condition model for Alternative #1-3.

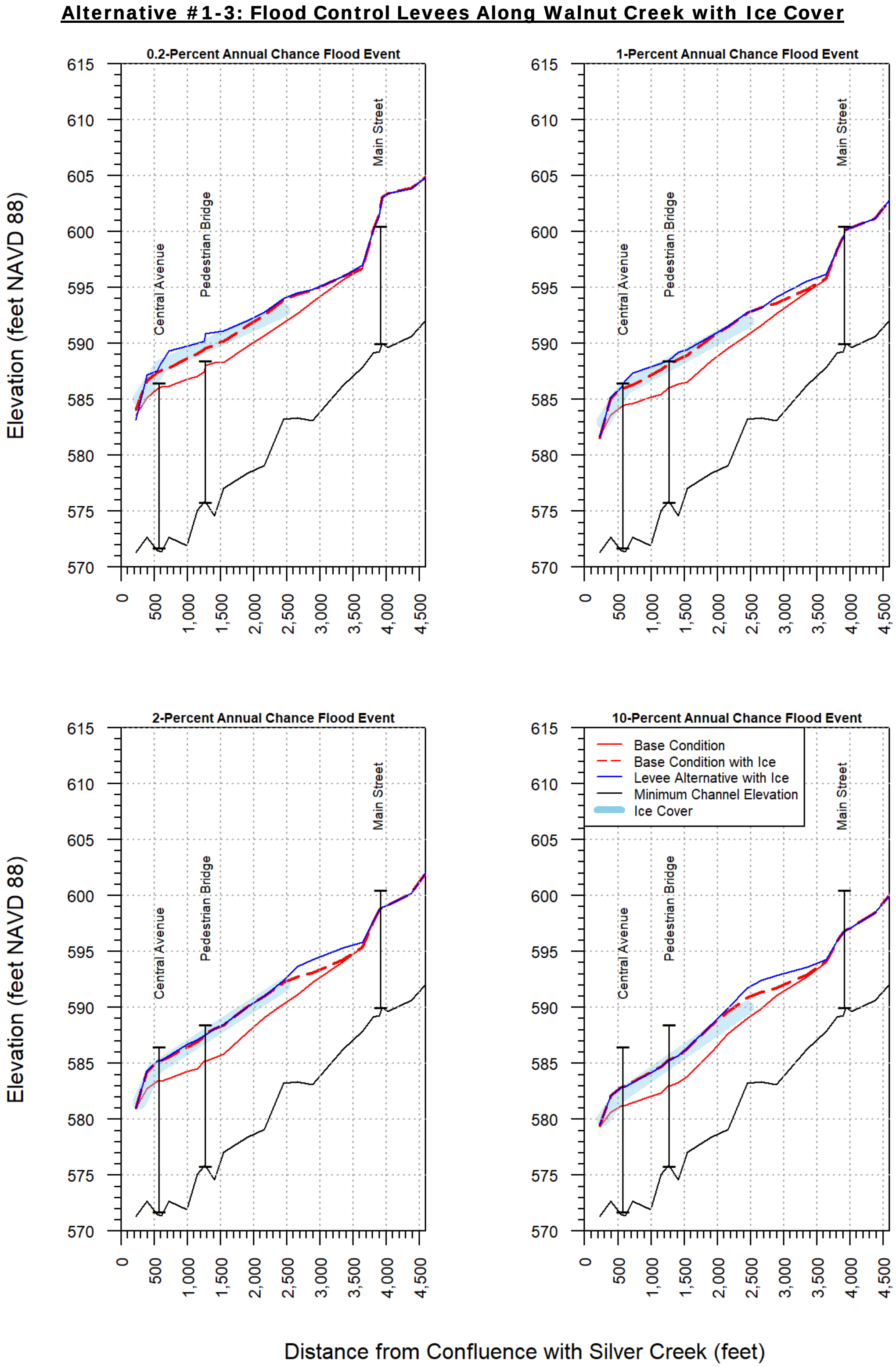

Figure 6-7. HEC-RAS proposed condition model for Alternative #1-3 with ice cover.

6.1.4 Alternative #1-4: Remove In-Channel Hydraulic Structures

This measure is intended to address sediment depositional aggradation, streambank erosion, and flooding along Walnut Creek in the Village of Silver Creek. There is an in-channel hydraulic structure at the rear of the property located at 175 Central Avenue. The structure is a concrete wall that protrudes approximately 18 ft into the Walnut Creek channel located at river station 8+50 on the left bank of Walnut Creek (Figure 6-8).

This measure would remove the 18 ft concrete wall and a portion of the earth material that extends into the Walnut Creek channel. The channel bank would be returned to a more natural geometry and then lined with stone riprap or other natural streambank stabilization material.

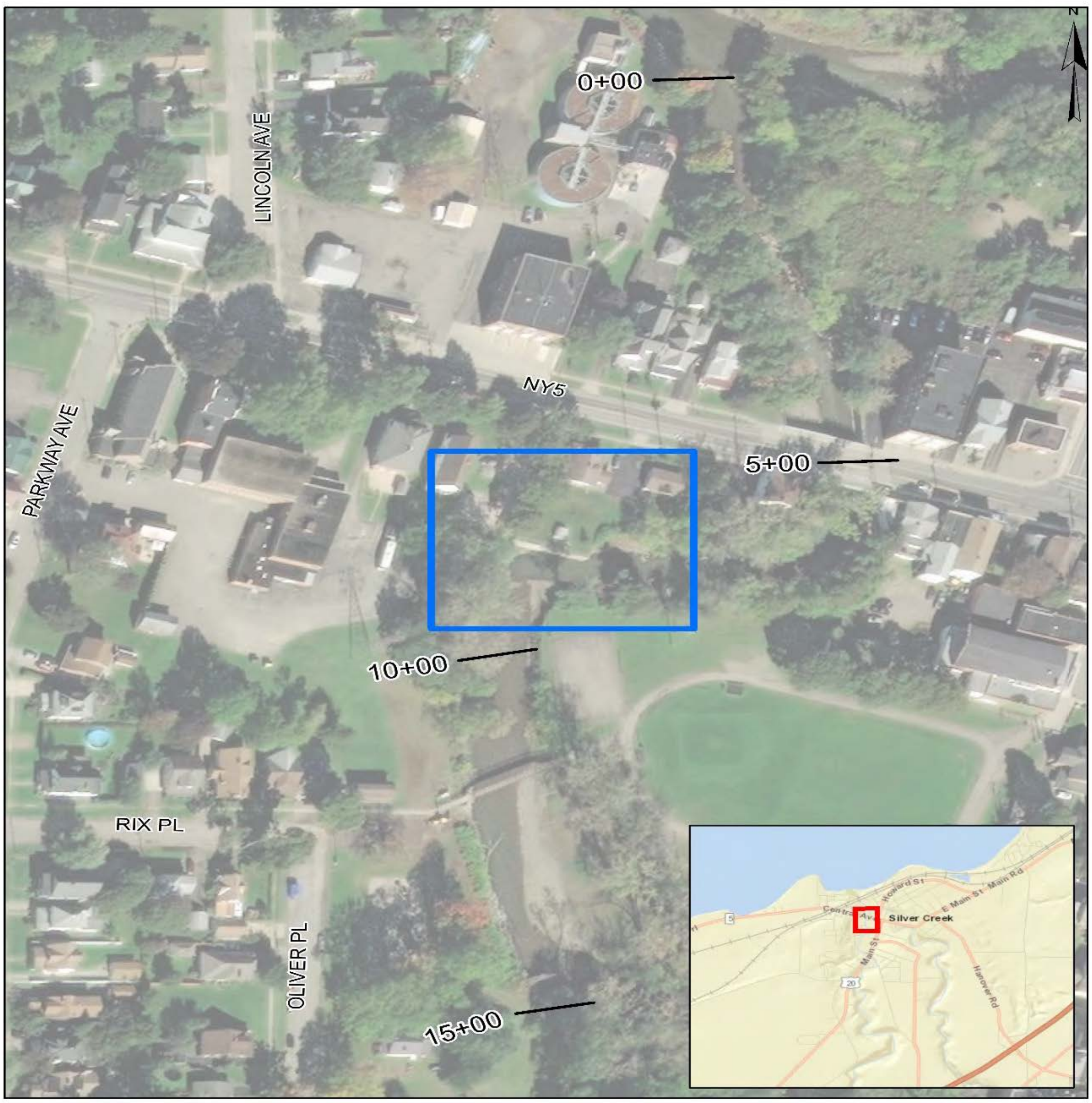

Figure 6-8. Location map for Alternative #1-4: Remove In-Channel Hydraulic Structures.

Due to the complex nature of sediment transport and channel velocity hydraulic modeling, no modeling simulations were performed for this alternative. The in-channel hydraulic constriction should be further evaluated for its hydrologic and hydraulic impacts on streamflow and debris and sediment transport prior to pursing this alternative. Any structure found to have little to no hydrologic or flooding benefits should be removed from the channel.

In addition, prior to pursuing this alternative, the construction history of this structure should be investigated. If the structure was built after August 1, 1983 then a floodplain development permit and an encroachment review would have been required. If an encroachment review that demonstrated a 0.00' rise in the BFE as a result of the project was not completed, then this would be a violation of the floodplain management regulations and mitigation would be required.

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 of the structure, respectively. Both situations can increase potential flood risk to areas adjacent to and upstream of the structure. All in-channel hydraulic structures should be evaluated periodically and if found to be a hydraulic constriction, or impediment to streamflow or sediment and debris, considered for removal from the channel.

The Rough Order Magnitude cost for this strategy is approximately $27,000, 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: Left Bank Levee Upstream of Main Road

This measure is intended to address flooding experienced in the Village of Silver Creek on the Walnut Creek left bank immediately upstream (East) of Main Road and would protect power utility infrastructure, one commercial and multiple residential properties along the left bank of Walnut Creek and Main Road (Figure 6-9). The levee would be located between river stations 39+00 and 49+00.

Appendix B provides mitigation renderings which illustrate a levee.

The left bank levee would prevent flood flows in Walnut Creek from exiting the channel during the 1% annual chance flood event, and during ice cover events occurring simultaneously with the 10% annual chance event. Based on model results, the left bank levee would need to be approximately 1,000-ft long with an average height of approximately four feet. The footprint required to construct the levee would require private property along Walnut Creek (Figures 6-10 and 6-11).

Figure 6-9. Location map for Alternative #2-1: Left Bank Levee Upstream of Main Road.

Any levee constructed in the Walnut 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 $510,000, 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.

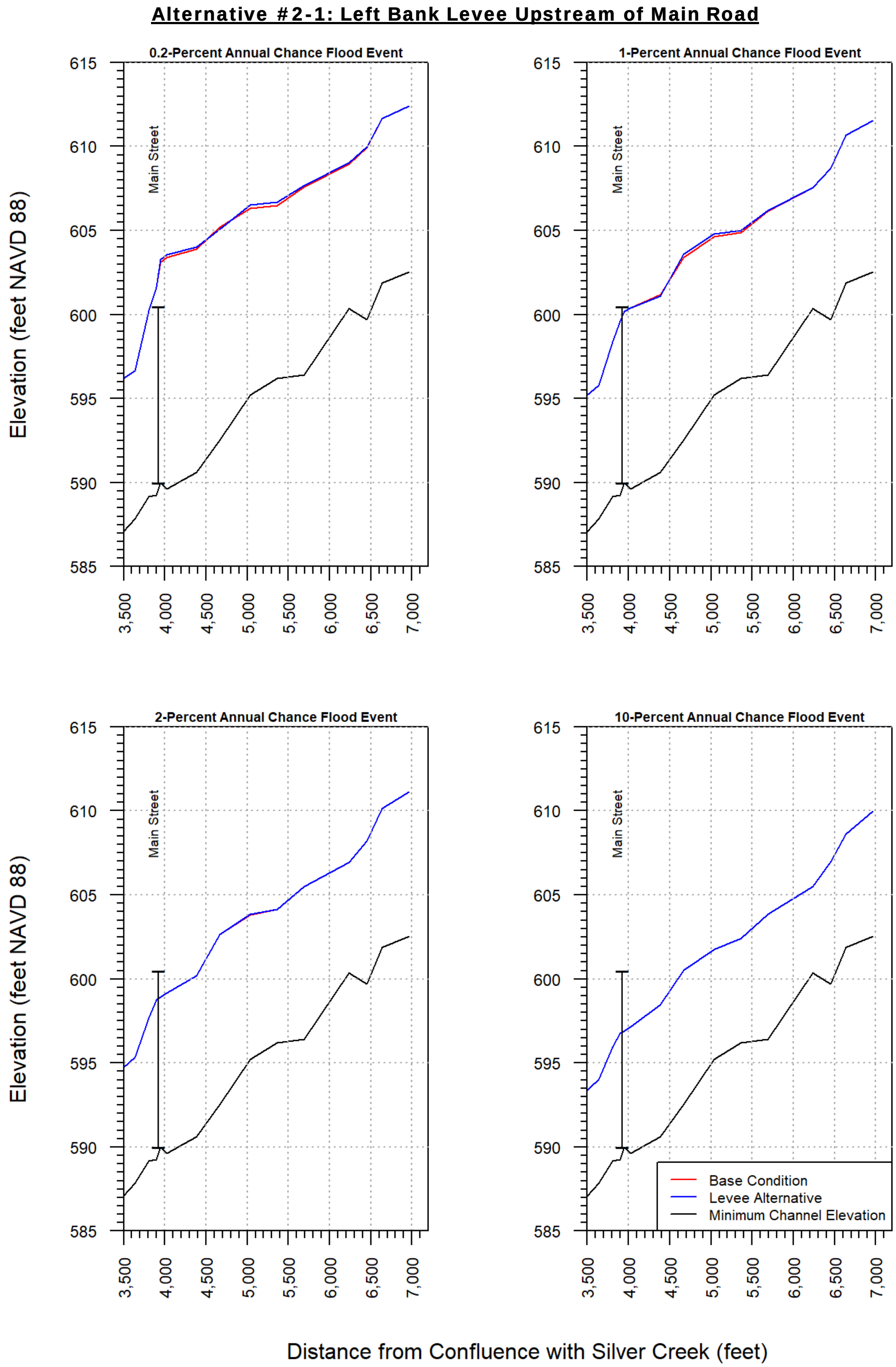

Figure 6-10. HEC-RAS proposed condition model for Alternative #2-1.

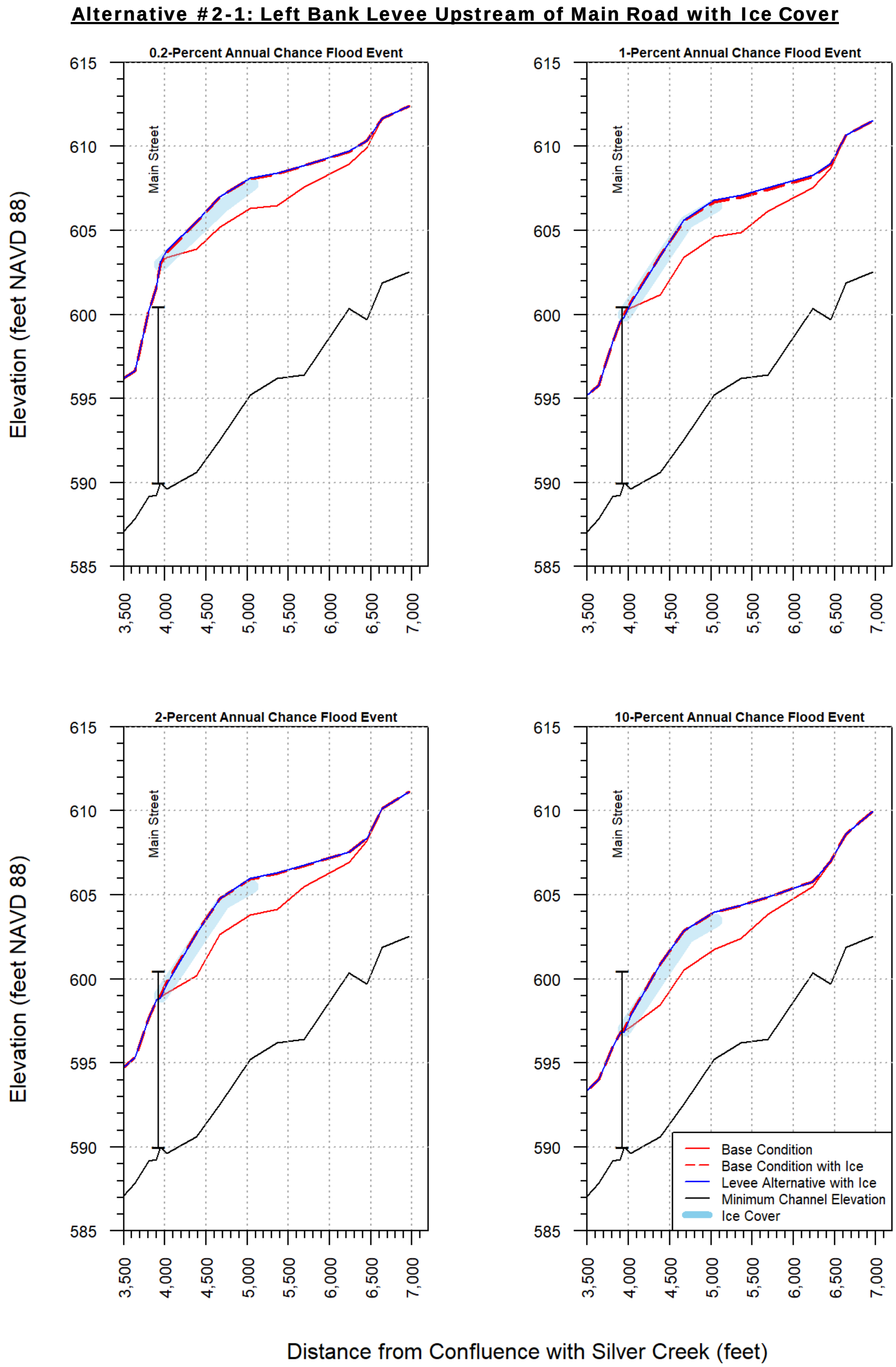

Figure 6-11. HEC-RAS proposed condition model for Alternative #2-1 with ice cover.

6.3 BASIN-WIDE MITIGATION ALTERNATIVES

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).

6.3.1 Alternative #3-1: Small Flood-Control Dams in the Upper Areas of the Walnut 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 1,100 CFS (or approximately 22%) 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 Walnut Creek below any constructed dam(s). The results of this analysis are shown in Figure 6-12.

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 Walnut 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 Walnut Creek at Dana Place. A peak-flow rate decrease of approximately 1,300 CFS (or approximately 48%) is estimated to be the minimum flow reduction required for this measure to be effective at minimizing flooding downstream for the 10% annual chance flood event with ice cover. The results of this analysis are shown in Figure 6-12.

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 #3-1: Small Flood-Control Dams in the Upper Areas of the Walnut Creek Watershed

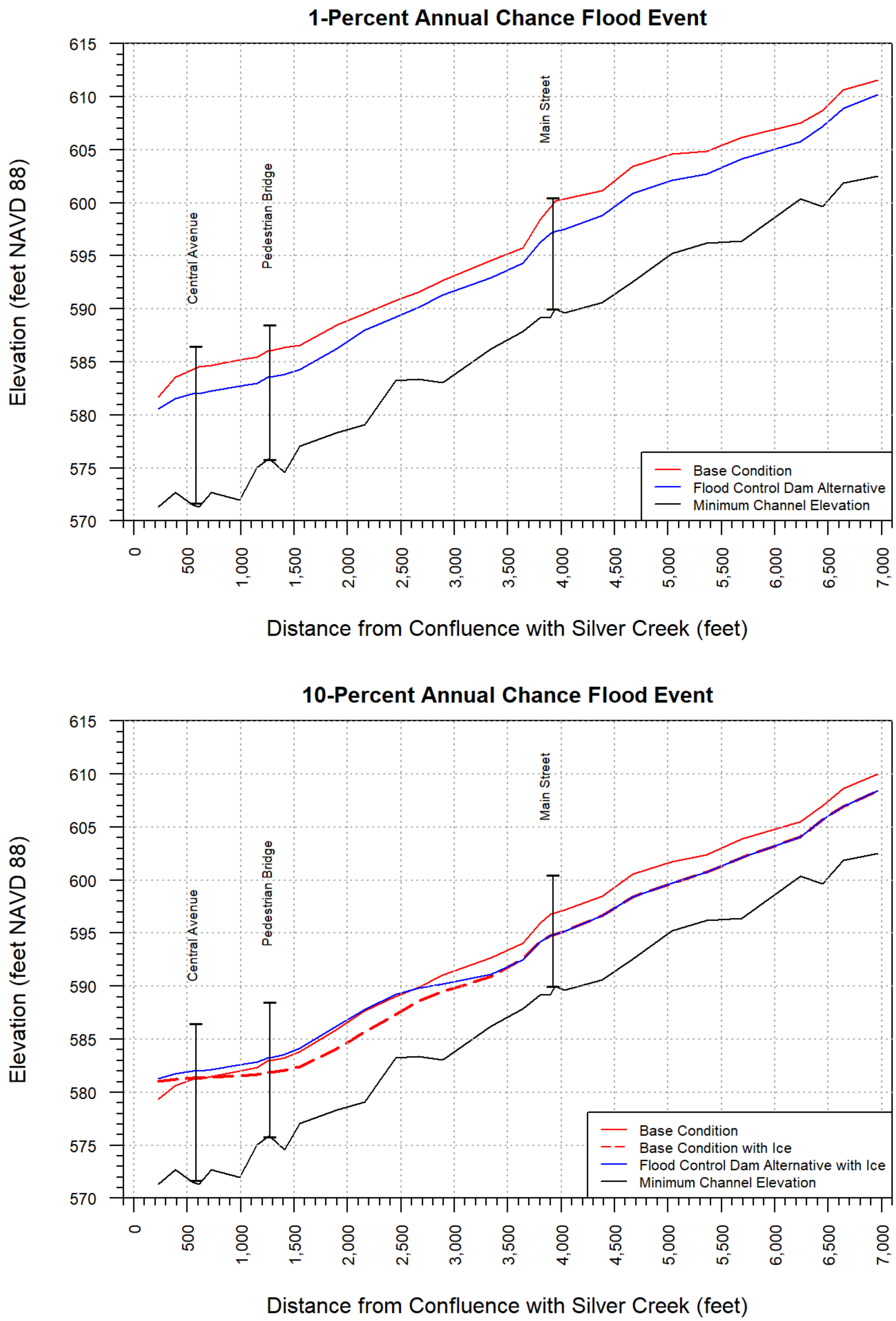

Figure 6-12. HEC-RAS proposed condition model for Alternative #3-1 at the 1% annual chance flood hazard (top) and with ice cover at the 10% annual chance flood hazard (bottom).

6.3.2 Alternative #3-2: Early-Warning Flood Detection System

Early-warning flood detection systems can be implemented which can provide communities with more advance 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. The data acquisition system performs two functions: it collects and stores real-time flood Sketch data from the pressure transducers, and initiates the notification process once predetermined flood stage conditions are met (USACE 2016a).

Another mechanism for flood warning is through a calibrated and validated hydrodynamic model simulations using the forecasted data. The National Weather Services (NWS) offer forecasted water depths, precipitation, and flow (at some specific gauge stations) for most of their gauges into several days ahead from Realtime. Therefore, the Hydrodynamic models can make use of these data to run future hydraulics conditions and identify detailed possible inundation areas ahead of time, so that the community can get prepared for the upcoming storm.

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 2016a). This method can also be supplemented by the freezing degree-day (FDD) method to forecast the ice thickness at critical locations to inform early action to control ice.

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. The 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 using 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 2016a).

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

6.3.3 Alternative #3-3: 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 Walnut 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).

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.

6.3.4 Alternative #3-4: Ice Management

This strategy is intended to control ice-jam formation by maintaining ice coverage in high-risk sections of Walnut 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 (USACE 2006)
- 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

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 annually, not including maintenance and operational costs.

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

6.3.5 Alternative #3-5: 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 more than 20 residences and businesses either within or immediately adjacent to the 1% annual chance food hazard area of Walnut Creek. In addition, there are 10 properties classified as repetitive loss properties by FEMA with the Walnut Creek watershed. There are no severe repetitive loss properties (Figure 6-13) (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. It is unlikely all the residences and businesses at risk during the 1% annual chance flood event can be bought-out or acquired without prohibitive cost and negative impact to the Village of Silver Creek. Instead, properties should be evaluated on a case-by-case basis and prioritized based on analysis of relevant metrics such as location, flood severity, etc.

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 Walnut Creek in the highest-risk flood areas and progresses outwards from there to maximize flood damage reductions. A potentially negative consequence of buyout programs is the permanent removal of properties from the floodplain, and resulting reduced tax revenue, which would have long-term implications for local governments and should be considered prior to implementing a buyout program.

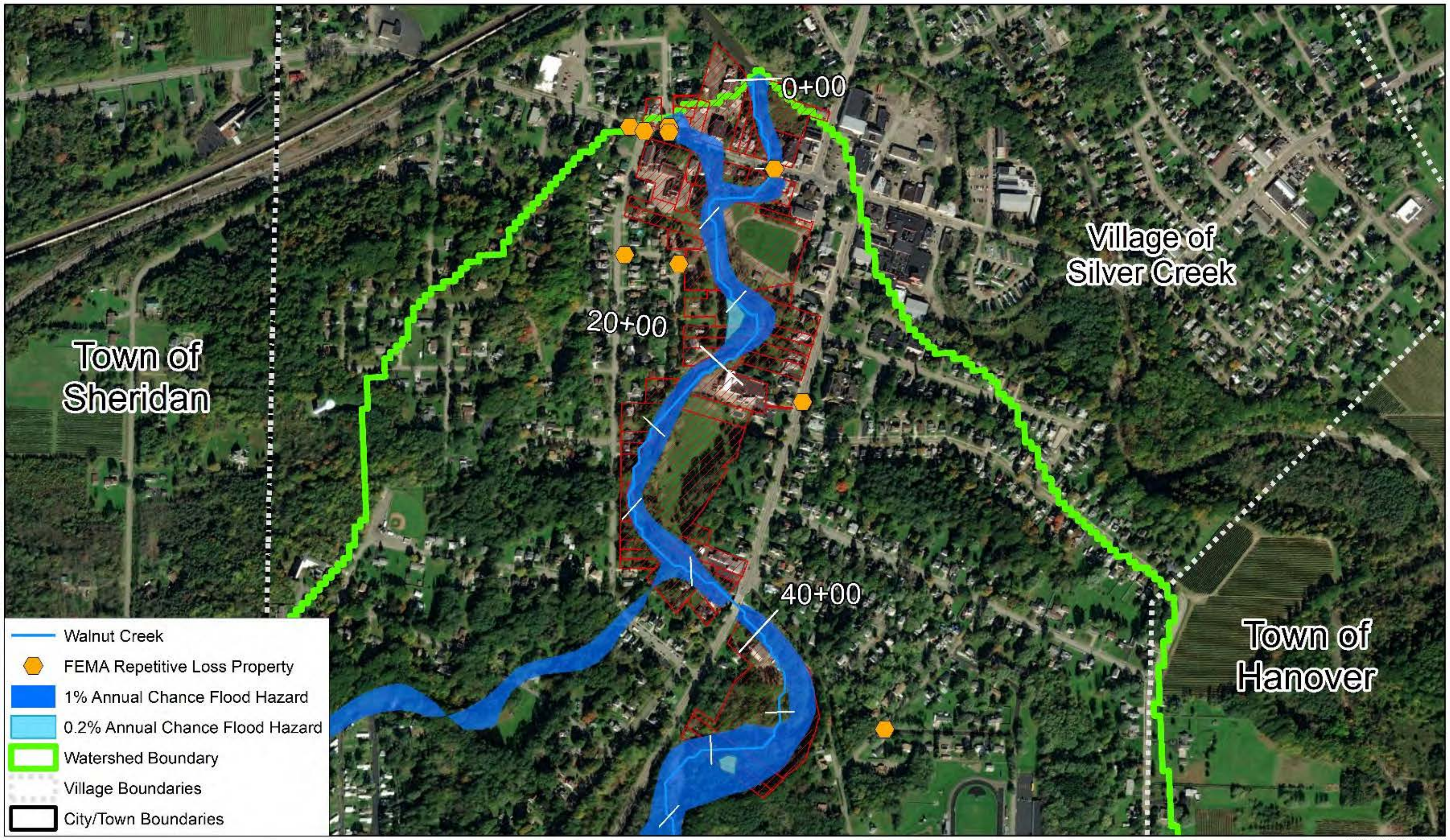

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FIGURE 6-13

TAX PARCELS WITHIN FEMA FLOOD ZONES
WALNUT CREEK, SILVER CREEK, CHAUTAUQUA COUNTY, NY

This figure was prepared as part of the Hazard Mitigation Study of Walnut Creek conducted for the New York State Department of Environmental Conservation as part of the Governors Resilient NY Initiative (NYSOGS Contract SC498).

Figure 6-13. Walnut Creek Tax Parcels within FEMA Flood Zones, Village of Silver Creek, Chautauqua County, NY.

6.3.6 Alternative #3-6: 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 involve 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 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 should be considered for the commercial properties behind the proposed levee along Main Road as an alternative flood mitigation measure.

6.3.7 Alternative #3-7: Area Preservation / Floodplain Ordinances

This alternative proposes municipalities within the Walnut 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 (NFIP), 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 Walnut 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 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 Walnut 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 Walnut 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. Other modeled lower-impact mitigation alternatives such as flood benches provided minimal benefit. Implementing multiple flood mitigation recommendations, including both structural and non-structural measures, would improve flood resiliency along Walnut Creek in the Village of Silver Creek.

The debris maintenance and sediment management would maintain the flow channel area in Walnut Creek. As sediment and debris build up at the openings of bridges and culverts and other hydraulic structures in the channel, the flow area is reduced. This can lead to potential backwater and flooding due to the inability of the creek channel to pass flows of a certain annual chance event.

Ice management to control ice buildup at critical points along Walnut 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	Flood bench (and ice control structure) at confluence with Silver Creek	Reduced model simulated water surface elevations by 1.8 ft	$870,000
1-2	Streambank stabilization near Park Place park	Controls and mitigates erosion and sedimentation downstream	$55,000
1-3	Flood-control levees along Walnut Creek	Limits flood extents and depths downstream	$2,640,000
1-4	Remove In-Channel Hydraulic Structures	Improves streamflow and sediment transport	$27,000
2-1	Left bank levee upstream of Main Road	Limits flood extents and depths downstream	$510,000
3-1	Small flood-control dams in the upper areas of the Silver Creek Watershed	Limits flood extents and depths downstream	See Note 1
3-2	Early-warning flood detection system	Early flood warning for open water and ice jam events	See Note 1
3-3	Debris maintenance and sediment management	Maintains channel flow area and reduces flood risk	$20,000
3-4	Ice management	Controls ice-jam formation and reduces flood risk from ice jams	$40,000
3-5	Flood buyouts / property acquisitions	Reduces and/or eliminates future losses	See Note 1
3-6	Floodproofing	Reduces and/or eliminates future damages	See Note 1
3-7	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 Walnut 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 Walnut 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 Walnut 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.

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APPENDICES