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RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE
ELLICOTT CREEK, NEW YORK

Prepared for:

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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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LIST OF ABBREVIATIONS

1-D	one-dimensional
2-D	two-dimensional
ACE	annual chance flood event
BFE	base flood elevation
BIN	Bridge Identification Number
BRIC	Building Resilient Infrastructure and Communities
CDBG	Community Development Block Grants
CFA	Consolidated Funding Applications
CFR	Code of Federal Regulations
cfs	cubic feet per second
CIN	Culvert Identification Number
CMIP	Coupled Model Intercomparison Project
CRISSP	Comprehensive River Ice Simulation System Project
CRRA	Community Risk and Resiliency Act
CRREL	Cold Regions Research and Engineering Laboratory
CRS	Community Rating System
CSC	Climate Smart Communities
DEM	Digital Elevation Model
EWP	Emergency Watershed Protection
FDD	freezing degree-day
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
ft	feet
GIS	Geographic Information Systems
GLS	Generalized Least-Squares
GSE	Gomez and Sullivan Engineers, D.P.C.
H&H	Hydrologic and Hydraulic
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center's River Analysis System
Highland Planning	Highland Planning, LLC
HMGP	Hazard Mitigation Grant Program
IPaC	Information for Planning and Consultation
LiDAR	Light Detection and Ranging
LOMR	Letter of Map Revision
LP3	Log-Pearson III
mi^2	square miles
MSC	Map Service Center
NAVD88	North American Vertical Datum of 1988
NCEI	National Centers for Environmental Information
NFIP	National Flood Insurance Program
NLCD	National Land Cover Database
NRCS	Natural Resources Conservation Service

NWI	National Wetlands Inventory
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
NYSERDA	New York State Energy Research and Development Authority
NYSGOSR	New York State Governors Office of Storm Recovery
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
OBG	O'Brien and Gere, Part of Ramboll
PDM	Pre-Disaster Mitigation
RCP	Representative Concentration Pathways
RAMBOLL	OBG, Part of Ramboll
R_c	Circularity Ratio
R_E	Elongation Ratio
R_F	Form Factor
RF	Radio Frequency
RICEN	River Ice Simulation Model
RL	Repetitive Loss
ROM	Rough Order of Magnitude
SFHA	Special Flood Hazard Area
SRL	Severe Repetitive Loss
USACE	United States Army Corps of Engineers
USDHS	United States Department of Homeland Security
USDOT	United States Department of Transportation
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WCRP	World Climate Research Programme
WGCM	Working Group Coupled Modelling
WQIP	Water Quality Improvement Project

Introduction

Historical Initiatives

Flood mitigation has historically been an initiative in western New York and in the Ellicott Creek watershed. In 1929, a new 1,100-foot long channel and gate controlled dam was constructed in the Village of Williamsville upstream of Glen Falls. Upstream of the new channel, Ellicott Creek was also cleaned, deepened, and widened for a distance of 1,400 feet. In 1932, a 2,800 feet length of Ellicott Creek was cleaned, deepened and widened just upstream of the Village of Williamsville. Six miles of the creek were cleared and snagged by the USACE in 1958-1959 from Sheridan Drive to 2,700 feet downstream of Sweet Home Road. A diversion channel was constructed along the downstream end of Ellicott Creek by Erie County in 1965 (FEMA, 2019).

Development in the Ellicott Creek floodplain is restricted by zoning ordinances and building codes in the Town of Cheektowaga (FEMA, 2019). Since 1977, the Town of Amherst floodplain regulations have required that all new construction be flood proofed to the elevation of the 1% annual chance flood event (ACE), commonly referred to as the 100-year flood (FEMA, 1992).

A 2011 flood mitigation report for the Town of Amherst recommended various measures including flood-proofing structures to two feet above the base flood elevation, implementation of a flood early warning system, open space and farmland conservation, purchase of repetitive loss structures, channel maintenance, updating town ordinances, developing a flood awareness/education program, and floodproofing evacuation routes (URS, 2011).

Floodplain Development

General recommendations for high risk floodplain development follow four 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 Federal Emergency Management Agency (FEMA) regulations since the Town of Amherst, Village of

Williamsville, Town of Lancaster, and Town of Cheektowaga are participating communities 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.

Resilient NY Initiative

In November of 2018, New York State 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 improve ecological habitats in the watersheds (NYSGPO, 2018). The Ellicott 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 effective and ecologically sustainable flood and ice-jam hazard mitigation projects. Potential flood mitigation measures will be evaluated using hydrologic and hydraulic (H&H) modeling to quantitatively determine flood mitigation strategies that would result in the greatest flood reduction benefits. In addition, the flood mitigation studies incorporate the latest climate change forecasts and assess open water and ice-jam hazards where future flood risks have been identified.

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 for 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

RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

The overarching purpose of the initiative is to evaluate 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 information developed under this initiative is intended to provide the community with a basis for assessing and selecting flood mitigation strategies to pursue; no recommendations are made as to which strategies the community should pursue.

The flood mitigation and resiliency study for Ellicott Creek began in July of 2019 and a final flood study report was issued in June of 2021.

Data Collection

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 (NYSDEC, 2018) draft guidelines, New York State Department of Transportation (NYSDOT) bridge and culvert standards, and United States Geologic Service (USGS) *FutureFlow Explorer* v1.5 (USGS, 2016) and *StreamStats* v4.4.0 (USGS, 2020) software were used to develop current and future potential discharges and bankfull widths and depths at various points along the stream channel. H&H modeling was performed previously, as part of the 2019 FEMA Flood Insurance Study (FIS) for Erie County within the Town of Amherst. H&H modeling was also performed in pre-countywide analyses for the 2001 revision of the FEMA FIS for the Town of Lancaster and for the 1984 FEMA FIS for the Town of Cheektowaga.

Updated H&H modeling was performed in this study using the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis System (HEC-RAS) v5.0.7 (USACE, 2019) software to compute water stage at current and potential future levels for high risk areas and to evaluate the effectiveness of potential flood mitigation strategies. These studies and data were obtained and used, all or in part, as part of this effort. Appendix A is a summary listing of data and reports collected for this study.

Public Outreach

An initial project kickoff meeting was held on July 16, 2019, with representatives of the NYSDEC, NYSOGS, OBG, Part of Ramboll (Ramboll), Gomez & Sullivan Engineers, D.P.C. (GSE), Highland Planning, USACE, NYSDOT, NYSOEM, Erie County Department of Environment and Planning, Erie County Soil and Water Conservation District, Erie County Department of Homeland Security and Emergency Services, Lake Erie Watershed Protection Alliance Town of Concord, Town of West Seneca, Town of Amherst, and Buffalo Niagara Waterkeeper (Appendix B). At the project kickoff meeting, 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 mitigation 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.

Field Assessment

Following the initial data gathering and agency meetings, field staff from GSE undertook field data collection efforts with special attention given to high risk areas in the Town of Amherst, Town of Lancaster, and Town of Cheektowaga as identified in the initial data collection process. Initial field assessments of Ellicott Creek were conducted in July 2019. Information collected during field investigations included the following:

- Rapid "windshield" river corridor inspection
- Photo documentation of inspected areas
- Measurement and rapid hydraulic assessment of bridges, culverts, and dams
- Geomorphic classification and assessment, including measurement of bankfull channel widths and depths at key cross sections
- Field identification of potential flood storage areas
- Wolman pebble counts
- Characterization of key stream bank failures, head cuts, bed erosion, aggradation areas, and other unstable stream channel features
- Preliminary identification of potential flood hazard mitigation alternatives, including those requiring further analysis

Included in Appendix C is a copy of the Stream Channel Classification Form, Field Observation Form for the inspection of bridges and culverts, and Wolman Pebble Count Form. Appendix D is a photo log of select locations within the river corridor. The collected field data was categorized, summarized, indexed, and geographically located within a GIS database. This GIS database will be made available to the NYSDEC and NYSOGS upon completion of the project.

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 standing in the river looking downstream.

Watershed Characteristics

Study Area

The Ellicott Creek Watershed has a total drainage area of approximately 120 square miles at its confluence with Tonawanda Creek (Erie Canal), and is primarily located in Erie County, NY, with a portion of the headwaters located in Genessee and Wyoming Counties. The watershed lies within the Towns of Darien, Alden, Lancaster, Cheektowaga, Amherst, Bennington, Pembroke, Newstead, Clarence, and the Cities of Tonawanda and Buffalo. The creek originates near Darien Lakes State Park northeast of the intersection of South Alleghany Road (Route 77) and Broadway Road (Route 20) in the Town of Darien, and generally flows from southeast to northwest into Tonawanda Creek (Erie Canal) in the City of Tonawanda. Figure 1 depicts the location of the Ellicott Creek watershed.

Within the watershed, the Towns of Amherst, Cheektowaga, and Lancaster and the Village of Williamsville were chosen as the target study area due to the history of flooding in and along the creek and the amount of development along the creek. Figure 2 depicts the stationing of the creek for the watershed and identifies the study area. Figure 3 depicts the stationing along Ellicott Creek within the study area, as well as the locations where field data were collected for this study.

Figure 1. Ellicott Creek Watershed, Erie, Genessee, and Wyoming Counties, NY

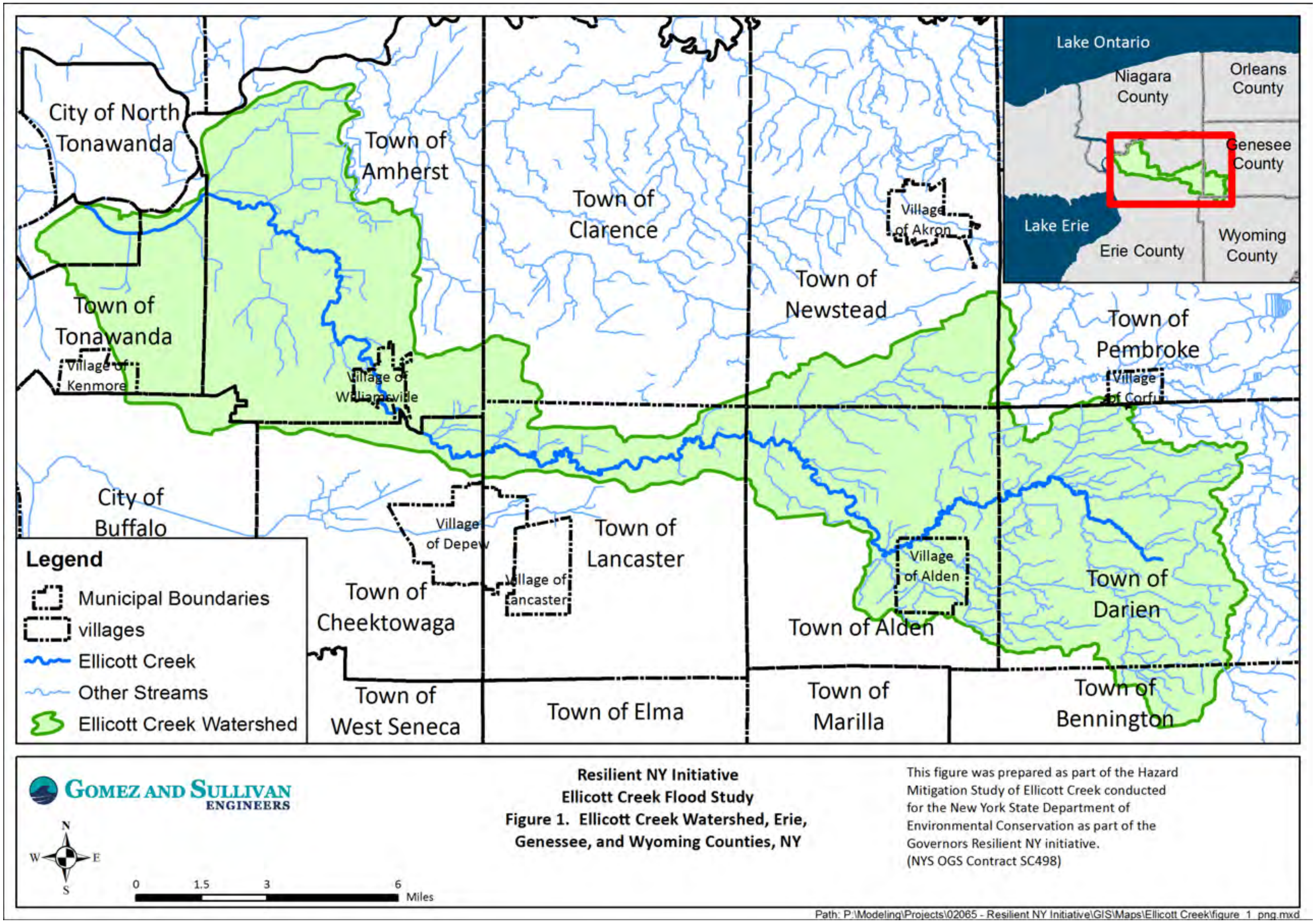


Figure 2. Ellicott Creek Stationing, Erie, Genessee, and Wyoming Counties, NY

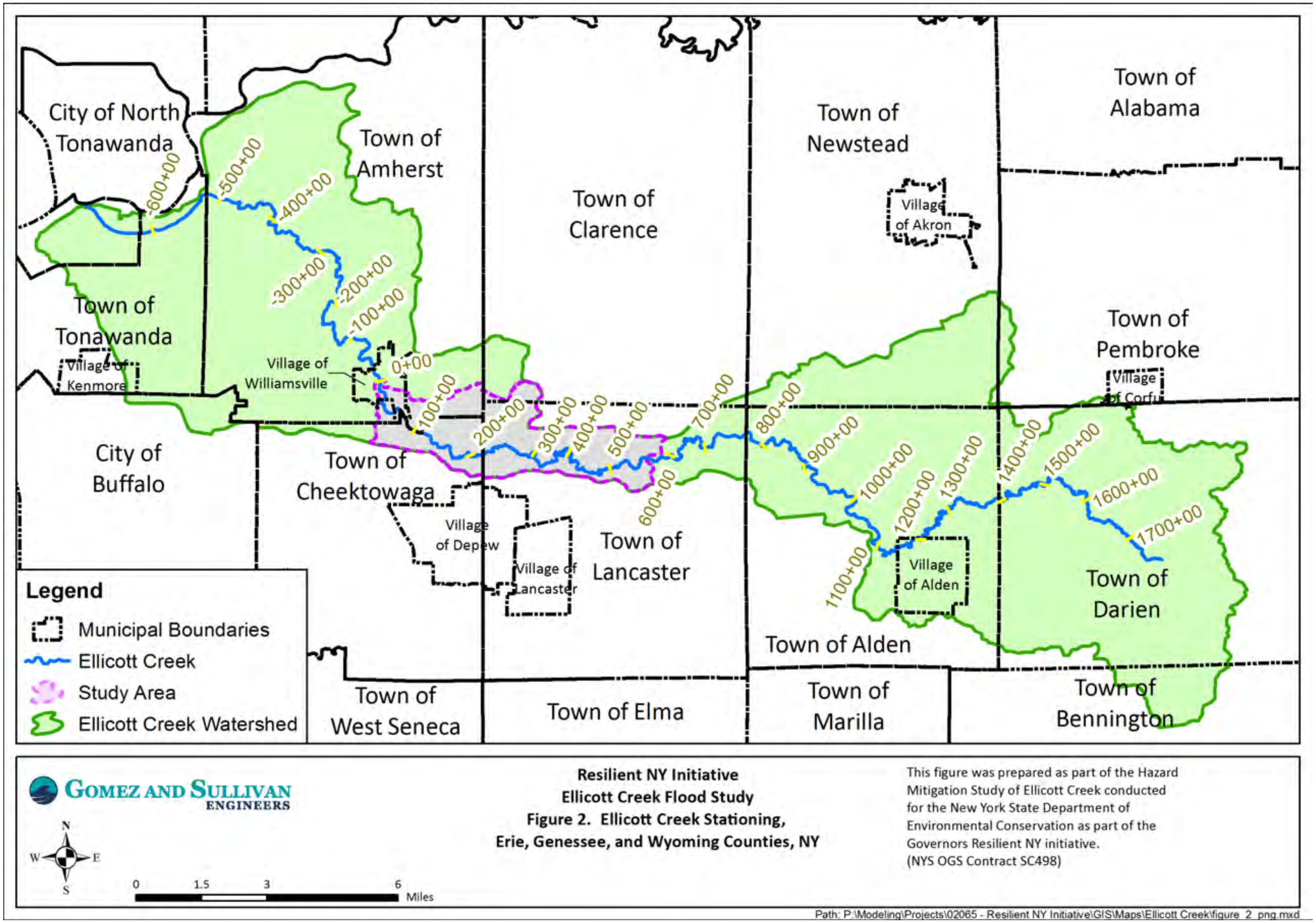
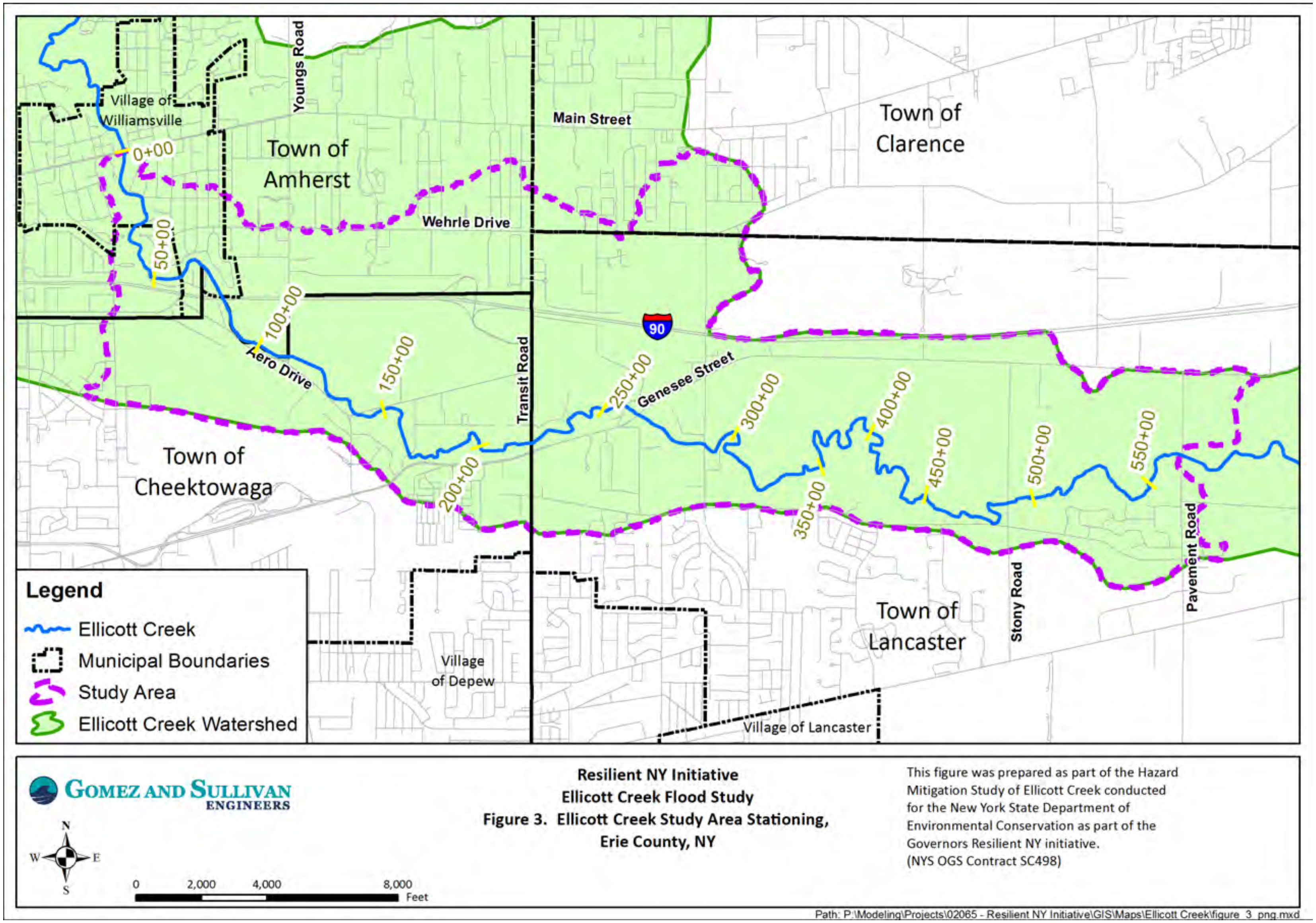


Figure 3. Ellicott Creek Study Area Stationing, Erie County, NY



Environmental Conditions

An overview of the environmental and cultural resources within the Ellicott Creek study area 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, 2021) (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, 2021)
Information for Planning and Consultation (IPaC): The IPaC database provides information about endangered/threatened species and migratory birds regulated by the United States Fish and Wildlife Service (USFWS, 2021) (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-a999091644466)

Wetlands

The State-Regulated Freshwater Wetlands database shows the approximate location of wetlands regulated by New York State. The check zone is a 100-foot buffer zone around the wetland in which the actual wetland may occur. According to the Environmental Resource Mapper, there are ten NYSDEC-regulated wetlands within the study area (NYSDEC, 2021).

The NWI was reviewed to identify national wetlands and surface waters (Figure 4). The Ellicott Creek study area includes 160 NWI wetlands, separate from Ellicott Creek (USFWS, 2021). There are 80 freshwater forested/shrub wetlands, 55 freshwater ponds, 21 freshwater emergent wetlands, and four lakes.

Sensitive Natural Resources

No areas designated as significant natural communities by the NYSDEC were mapped in the Ellicott Creek study area (Figure 5). (The pink polygon shown in Figure 5 is the Harris Hill oak openings, which are north of the Ellicott Creek study area) (NYSDEC, 2021).

Endangered or Threatened Species

The Environmental Resource Mapper shows that rare plants and animals have been documented in the vicinity of the study area (Figure 5) (NYSDEC, 2021). The NYSDEC Regional Office should be contacted to determine the potential presence of the species identified (NYSDEC, 2021).

The USFWS Information for Planning and Consultation (IPaC) results for the study area list northern long-eared bat. No critical habitat has been designated for any species within the study area (USFWS, 2021).

The migratory bird species listed in Table 1 are are birds of conservation concern (BCC) and vulnerable species that may pass over or nest within the study area.

Table 1. USFWS IPaC Listed Migratory Bird Species

Common Name	Scientific Name	Level of Concern	Breeding Season
Bald Eagle	*Haliaeetus leucocephalus*	Non-BBC Vulnerable	Dec 1 to Aug 31
Black-billed Cuckoo	*Coccyzus erythrophthalmus*	BCC	May 15 to Oct 10
Bobolink	*Dolichonyx oryzivorus*	BCC	May 20 to Jul 31
Canada Warbler	*Cardellina canadensis*	BCC	May 20 to Aug 10
Golden-winged Warbler	*Vermivora chrysoptera*	BCC	May 1 to Jul 20
Lesser Yellowlegs	*Tringa flavipes*	BCC	Breeds elsewhere
Red-headed Woodpecker	*Melanerpes erythrocephalus*	BCC	May 10 to Sep 10
Semipalmated Sandpiper	*Calidris pusilla*	BCC	Breeds elsewhere
Short-billed Dowitcher	*Limnodromus griseus*	BCC	Breeds elsewhere
Snowy Owl	*Bubo scandiacus*	BCC	Breeds elsewhere
Wood Thrush	*Hylocichla mustelina*	BCC	May 10 to Aug 31

Source: (USFWS, 2021)

Cultural Resources

According to the National Register of Historic Places (National Parks Service, 2020), the only historic place point within the study area is Garrison Cemetery, south of Aero Drive.

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 resources investigation (NPS, 2014).

Figure 4. Ellicott Creek Study Area Wetlands and Hydrography, Erie County, NY

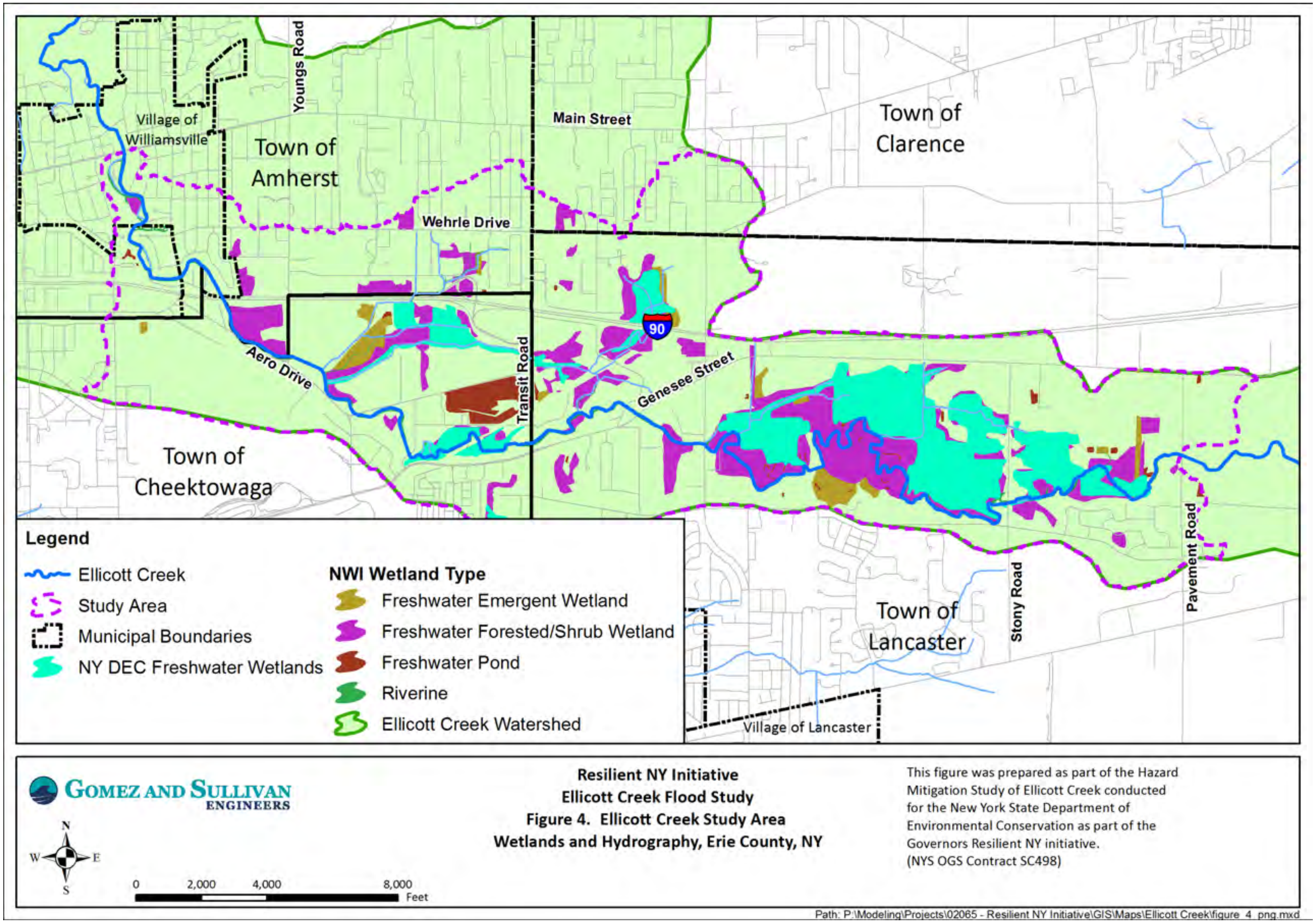
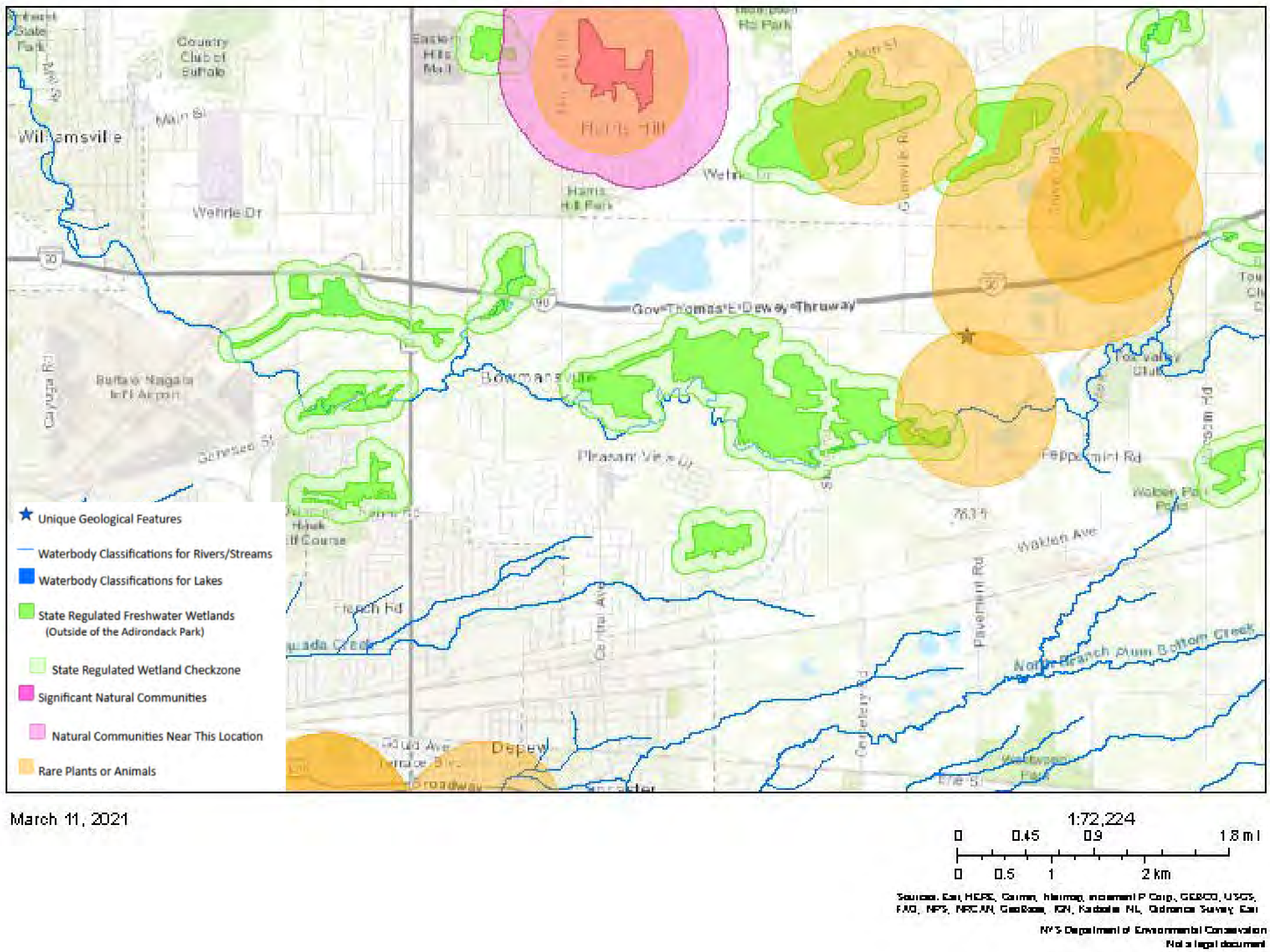


Figure 5. Significant Natural Communities and Rare Plants or Animals, Ellicott Creek Study Area, Erie County, NY

NYSDEC Environmental Resource Mapper - Ellicott Creek



Floodplain Location

The FEMA Flood Map Service Center (MSC) (https://msc.fema.gov/portal/home) is a 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 Towns of Amherst, Cheektowaga, and Lancaster and the Village of Williamsville, the current effective FEMA FIS was completed on June 7, 2019. According to the FIS, the hydrologic and hydraulic analyses completed included re-delineation of the original FEMA H&H studies and updated new detailed studies from the original H&H studies. The FEMA FIS included Ellicott Creek as a new detailed study within the Town of Amherst and Village of Williamsville and a re-delineation study in the Towns of Cheektowaga and Lancaster (FEMA, 2019).

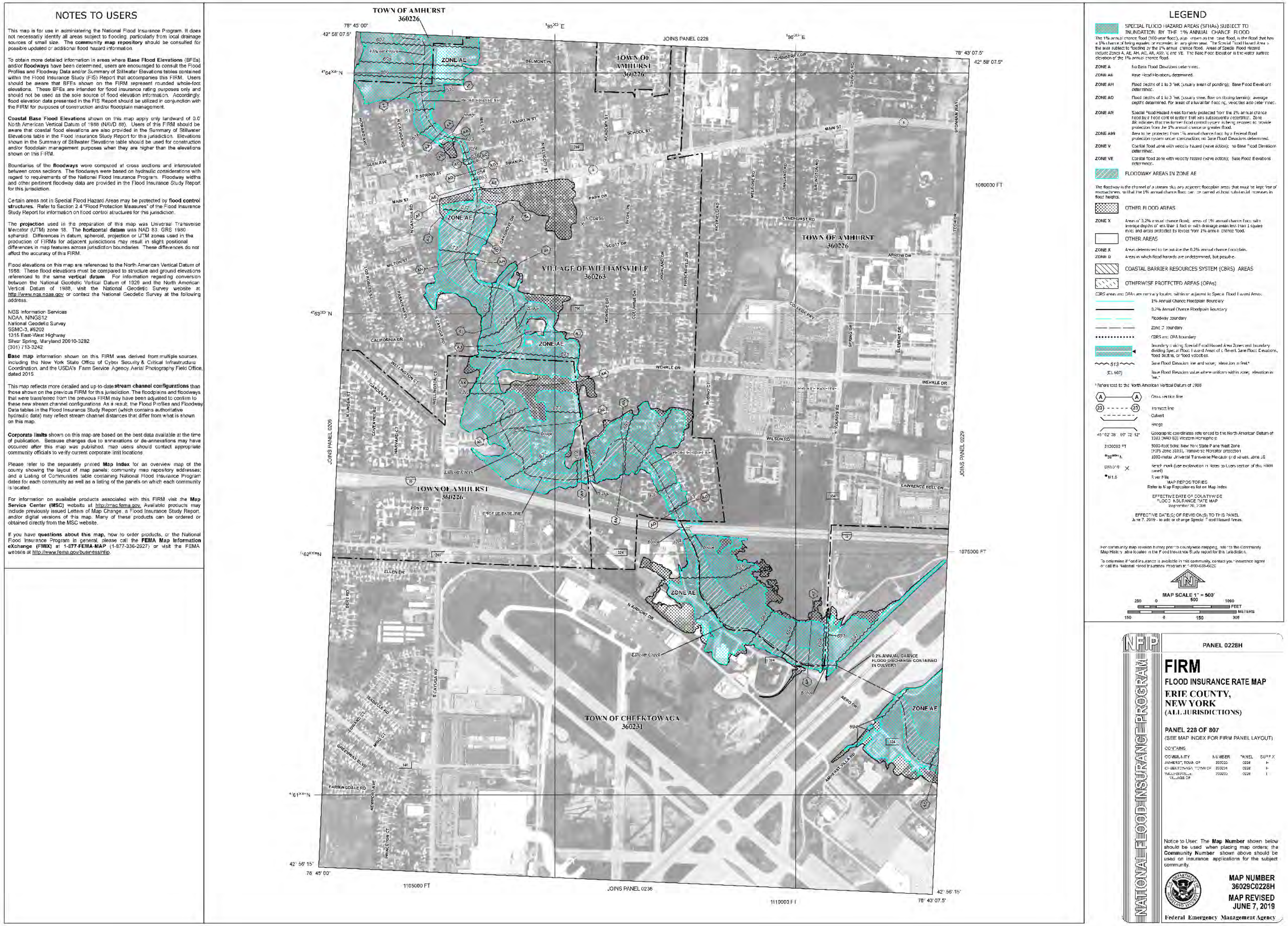
Redelineation is the method of updating effective flood hazard boundaries to match current topographic data based on the computed water surface elevations from FEMA effective models. The results of a redelineation update are more accurate floodplain boundaries when compared to current ground conditions. Redelineation of floodplain boundaries can be applied to both riverine and coastal studies. No new engineering analyses are performed as part of the redelineation methodology; however, redelineation can be paired with new engineering studies as part of a larger update. For riverine studies, effective flood profiles and data tables from the Flood Insurance Study (FIS) report, Base Flood Elevations (BFEs) from the Flood Insurance Rate Maps (FIRMs), and supporting hydrologic and hydraulic analyses are used in conjunction with the updated topographic data to formulate new floodplain boundaries. The coastal redelineation method also typically involves no new analyses. This method combines effective information from the FIRM and FIS Report and the supporting analyses with new, more detailed, or more up to-date topographic data to redelineate coastal high hazard areas (FEMA, 2015a).

For a new 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 BFEs 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).

The FIRM for Ellicott Creek indicates Special Flood Hazard Areas (SFHAs), which are land areas covered by floodwaters during the 1% annual chance flood event (ACE), along the banks of the creek, for almost the entire length of the creek (FEMA, 2019). Ellicott Creek is a Regulatory Floodway, which is defined as the watercourse channel and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than 1-foot over the 1% annual chance flood hazard water surface elevation, referred to as the Base Flood Elevation (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. 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 foot (FEMA, 2000).

For 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. The flood zones indicated in the Ellicott Creek study area are Zones A and AE, where mandatory flood insurance purchase requirements apply. A Zones are areas subject to inundation by the 1% ACE. Where detailed hydraulic analyses have not been performed, no BFEs or flood depths are shown. AE Zones are areas that have a 1% annual chance of flooding where BFEs are provided by FEMA (FEMA 2000). Figure 6 is a FIRM that includes a portion of Ellicott Creek in the Village of Williamsville and the Towns of Amherst, Cheektowaga, and Lancaster, NY (FEMA, Effective FIRM).

Figure 6. FEMA FIRM, Ellicott Creek, Village of Williamsville and Towns of Amherst and Cheektowaga, Erie County, NY



Study Area Land Use

The National Land Cover Database (MRLC, 2019) shows that, within the study area, the Woody Wetland land use cover type makes up 25% of the study area. All developed land cover types total 50% of the study area and all agriculture cover types total 11%. Further details of the distribution of land cover within the watershed are shown on Table 2. The Woody Wetland land use cover type is located mostly in the central and eastern portion of the study area. Developed land use cover types are dominant in the northern and western portion of the study area, in the Towns of Amherst, Cheektowaga, and Clarence, and Village of Williamsville. Agriculture is present throughout the eastern portions of the study area in the Town of Lancaster.

Table 2. Land Use Cover Types in the Ellicott Creek Study Area

Land Use Cover Type	Acres	Percentage
Woody Wetlands	1433.3	25%
Developed, Low Intensity	950.3	16%
Developed, Open Space	949.4	16%
Developed, Medium Intensity	726.0	12%
Pasture/Hay	500.2	9%
Deciduous Forest	320.2	6%
Developed High Intensity	306.6	5%
Mixed Forest	161.2	3%
Emergent Herbaceous Wetlands	153.2	3%
Cultivated Crops	115.7	2%
Barren Land (Rock/Sand/Clay)	96.7	2%
Grassland/Herbaceous	70.9	1%
Open Water	25.9	<1%
Shrub/Scrub	8.1	<1%
Evergreen Forest	1.6	<1%
Total	**5819.3**	**100%**

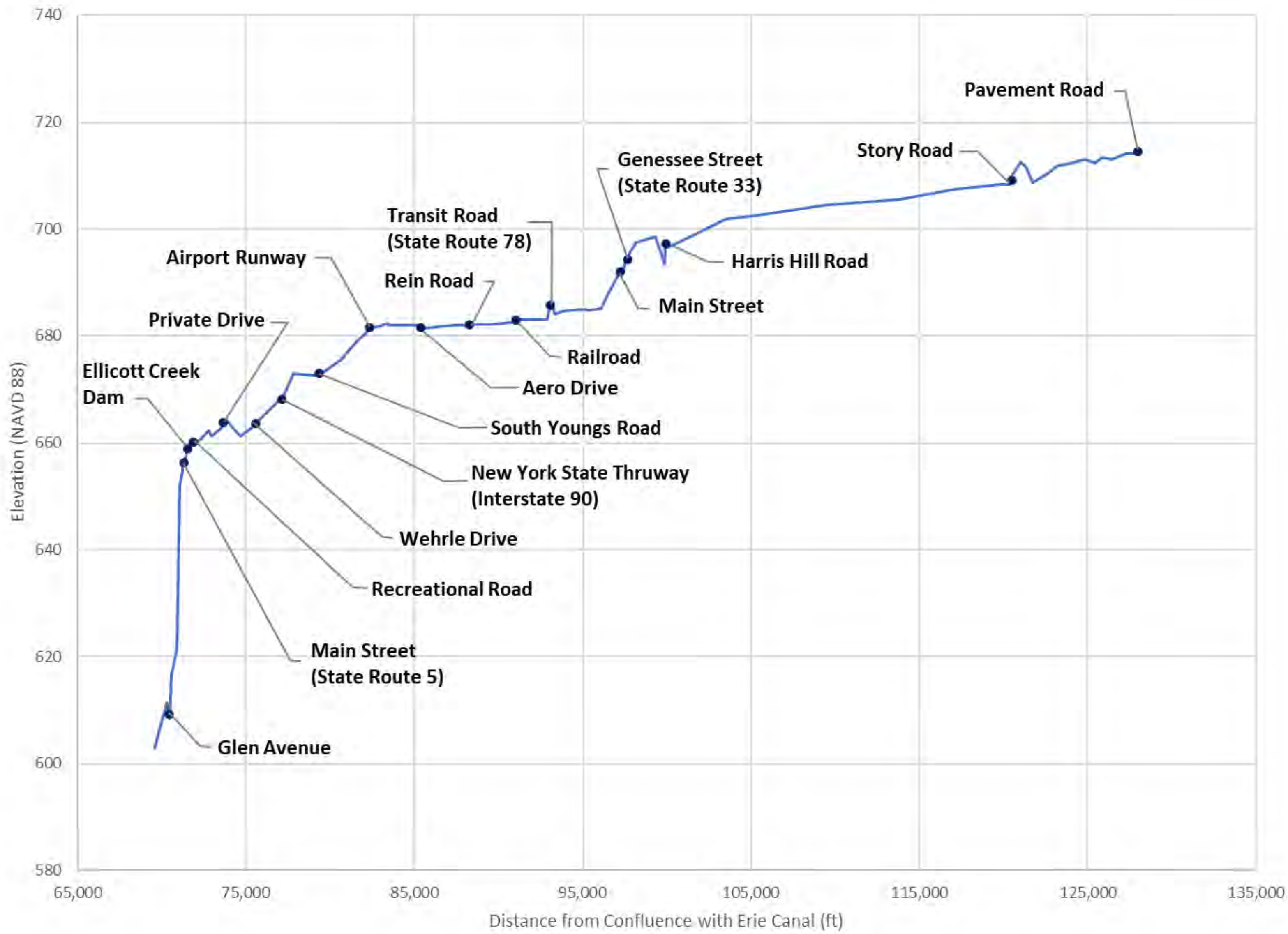
Source: (MRLC, 2019)

Geomorphology

Ellicott Creek resides in the Erie-Ontario Lowland physiographic province. The surficial geology in the headwaters consists of till moraine, lacustrine silt and clay, and lacustrine beach. Further downstream Ellicott Creek traverses till, outwash sand and gravel followed by till moraine and lacustrine silt and clay in the lower reaches of the creek. The presence of lacustrine silt and clay and lacustrine beach deposits suggests the presence of a proglacial lake in the lower and upper reaches of Ellicott Creek. Surficial geology in the study area primarily consists of outwash sand and gravel and glacial till which is shallow to bedrock in some areas (New York State Museum, 1991). There are several locations where bedrock controls the grade in the Village of Williamsville and the Town of Cheektowaga, particularly at Glen Falls in the Village of Williamsville. For most of the study area, bedrock geology consists of Onondaga Limestone, which is resistant to erosion and creates an escarpment which runs east-west across Western New York. Glen Falls is located at the transition from the Onondaga escarpment to the Tonawanda Plain geologic area, which is relatively flat and poorly drained (Buffalo Society of Natural Science, 1963); (Amherst State Park, 2020). The soils along Ellicott Creek in the study area are generally silt loam to loamy fine sand, with the exception of urban-land complex where Ellicott Creek flows through the Buffalo Niagara International Airport and the Village of Williamsville (USDA, 2020).

Figure 7 is a profile of stream bed elevation and channel distance within the study area based on the hydraulic model used for this study. The figure includes the location of all stream crossings included within the hydraulic model.

Figure 7. Ellicott Creek Study Area Profile of Stream Bed Elevation and Channel Distance



Hydrology

Ellicott Creek is approximately 52.7 miles long and its watershed covers approximately 120 square miles (76,800 acres) beginning with groundwater in the Town of Darien. The creek generally flows northwest and empties into the Erie Canal/Tonawanda Creek just upstream of the confluence with the Niagara River. Ellicott Creek has several significant tributaries in the upstream portion of the watershed, including Crooked Creek, Elevenmile Creek, and Spring Creek. The only significant tributary within the study area outfalls to Ellicott Creek just upstream of the culvert which flows under the Buffalo Niagara International Airport runway, this tributary is 2.3 miles long and has a drainage area of approximately 0.8 square miles (USGS, 2020).

Table 3 is a summary of the basin characteristic formulas and calculated values for the Ellicott Creek watershed, where A is the drainage area of the basin in square miles (mi^2), B_L is the basin length in miles, and B_P is the basin perimeter in miles (USGS, 1978).

Table 3. Ellicott Creek Basin Characteristics Factors

Factor	Formula	Value
Form Factor (R_F)	A/B_L^2	0.04
Circularity Ratio (R_C)	$4\pi A/B_P^2$	0.11
Elongation Ratio (R_E)	$2(A/\pi)^{0.5}/B_L$	0.23

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 characteristic factors, the Ellicott Creek basin would be categorized as a more elongated basin being more susceptible to erosion, and which would be expected to have lower peak discharges and longer duration high flow events than less elongated basins would (Parveen, Kumar, & Singh, 2012). The drainage system within the basin would be expected to be more influenced by structural disturbances and have high relief topography (Waikar & Nilawar, 2014).

There are three USGS stream gaging stations (one active and two historic) on Ellicott Creek. These gages are: USGS Gage 04218518 Ellicott Creek below Williamsville, NY with a period of record from October 1972 to current; USGS Gage 04218500 Ellicott Creek at Williamsville, NY with a period of record from October 1955 to September 1972; and USGS Gage 04218450 Ellicott Creek at Millgrove, NY with a period of record from March 1963 to September 1968.

An effective FEMA Flood Insurance Study (FIS) for Erie County was issued on June 7, 2019, which included a new detailed study for Ellicott Creek within the Town of Amherst and Village of Williamsville and a re-delineation study in the Towns of Cheektowaga and Lancaster, and included drainage area and discharge information for the portions of Ellicott Creek included in this study. Table 4 summarizes the FEMA FIS drainage area and peak discharges, in cubic feet per second (cfs), for Ellicott Creek within the study area (FEMA, 2019). The flows reported in the 2019 FEMA FIS differed from the flows used in the hydraulic model used for the most recent FEMA FIS detailed hydraulic study for Ellicott Creek within the Town of Amherst and the Village of Williamsville. The updated flows from this study are shown in Table 4 and were used for this study.

Table 4. Ellicott Creek FEMA FIS Peak Discharges

Flooding Source and Location	Drainage Area (mi^2)	River Station (ft)	Peak Discharge (cfs)			
			10%	2%	1%	0.2 %
At Stoney Rd	67.4	491+26	3630	5580	6470	8620
At Wehrle Dr	72.4	57+90	3810	5870	6790	9060
At Island Park	72.8	5+84	4420	6150	7150	8420
At Sheridan Dr	77.6	-131+77	4500	6235	7245	8520

Source: (FEMA, 2019)

According to the effective FEMA FIS, for Ellicott Creek in Lancaster, peak discharges were obtained from a 1978 USACE report. Beard-type statistical discharge-frequency curves were developed in 1968 using discharge records for Ellicott Creek at the Williamsville gage (04218500) in addition to three other western New York streams with similar watershed characteristics (FEMA, 2019). For Ellicott Creek in the Village of Williamsville, peak discharges were calculated using regional regression equations following methodology in the USGS publication Water-Resources Investigations Report 94-4002 [(USGS, 1994) ; (FEMA, 2019)].

General limitations of the FEMA FIS methodology are the age of the effective FIS H&H analysis and the age of the methodology. The hydrologic analysis for Ellicott Creek in the Town of Lancaster was completed in 1968 using the Beard-type discharge-frequency curve methodology, and the hydrologic analysis for Ellicott Creek in the Village of Williamsville was completed in 2008 using regional regression equations. The age of the Town of Lancaster study suggests that more recent data is available for inclusion in a regional regression analysis.

StreamStats v4.4.0 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 [(USGS, 2017); (USGS, 2020)].

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 [(USGS, 1991); (USGS, 2006)].

For gaged sites, such as Ellicott Creek in hydrologic region 6 of New York State, the generalized least-squares (GLS) regional-regression equations are used to improve streamflow-gaging-station estimates (based on log-Pearson type III (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 $Q_{T(r)}$ (USGS, 2006).

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

StreamStats was used to calculate the current peak discharges for Ellicott Creek, and the results were weighted with a frequency analysis of the gaged peaks performed by the USGS (USGS, 2014). The results of the weighted peak analysis were then compared with the effective FIS peak discharges. Table 5 is the summary output of peak discharges calculated by the weighted peak method for Ellicott Creek at the same locations as the FEMA FIS peak discharges.

Table 5. USGS *StreamStats* Peak Discharge for Ellicott Creek at the FEMA FIS Locations

Flooding Source and Location	Drainage Area (mi^2)	River Station (ft)	Peak Discharge (cfs)			
			10%	2%	1%	0.2%
At Stoney Road	64.9	491+26	2,380	3,117	3,402	4,118
At Wehrle Drive	72.5	57+90	2,554	3,322	3,617	4,350
At Island Park	72.8	5+84	2,564	3,334	3,630	4,364
At Sheridan Drive	79.7	-131+77	2,828	3,672	3,993	4,795

Source: (USGS, 2020); (USGS, 2014)

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 was 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 6 in New York State.

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

Parameter	Annual Chance of Exceedance (%)			
	10%	2%	1%	0.2%
Standard Error of Peak Discharge (%)	32.9	35.8	37.2	41.4

Source: (USGS, 2006)

FEMA FIS peak discharges are greater than *StreamStats* peak discharges. As a result, the FEMA FIS peak discharge values were used in the hydraulic model simulations for this study to maintain consistency between the modeling outputs and the FEMA models.

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 analysis 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 (USGS, 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 (USGS, 2009). The bankfull width and depth of Ellicott Creek is important in understanding the distribution of available energy within the stream channel and the ability of various discharges occurring within the channel to erode, deposit, and move sediment (Rosgen & Silvey, 1996). Table 9 lists the estimated drainage area, bankfull discharge, width, and depth at select locations along Ellicott Creek as derived from the USGS *StreamStats* program.

Table 7. USGS *StreamStats* Estimated Drainage Area, Bankfull Discharge, Width, and Depth

Flooding Source and Location	Drainage Area (mi^2)	River Station (ft)	Bankfull Depth (ft)	Bankfull Width (ft)	Bankfull Streamflow (cfs)
At Stoney Rd	67.4	491+26	2.94	94.2	1520
At Wehrle Dr	72.4	57+90	3.01	99.3	1680
At Island Park	72.8	5+84	3.01	99.3	1690
At Sheridan Dr	77.6	-131+77	3.08	103	1830

Source: (USGS, 2020)

Infrastructure

Table 8 provides a summary of the dams located on Ellicott Creek within the study area. Table 9 summarizes pertinent information about the three NYSDOT owned bridges and culverts crossing Ellicott Creek within the study area. In addition to the NYSDOT infrastructure, Ellicott Creek is crossed by 15 structures within the study area, which are owned and maintained by Erie County, local municipalities, and private owners as summarized in Table 10. 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 (USDOT, 2012). In assessing hydraulic capacity of the culverts and bridges along Ellicott Creek, the FEMA FIS profile of Ellicott Creek was used to determine the lowest annual chance flood elevation to flow under a culvert or the low chord of a bridge, without causing an appreciable backwater condition upstream (Table 9, Table 10). Figure 8 depicts the location of the infrastructure crossing Ellicott Creek within the study area.

Table 8. Inventory of Dams along Ellicott Creek

Municipality	Dam Name	River Station (ft)	Hazard Code	Purpose
Village of Williamsville	Williamsville Dam	2+94	A	Flood Control and Storm Water Management
Village of Williamsville	Ellicott Creek Dam	2+94	D	Recreation

Source: (NYSDEC, 2020b)

Table 9. NYSDOT Bridges/Culverts Crossing Ellicott Creek

Roadway Carried (NY/US Route)	NYSDOT BIN/CIN	River Station (ft)	Bridge Length (ft)	Surface Width[1] (ft)	Hydraulic Capacity (% Annual Chance)
Main Street (State Route 5)	1001650	0+00	91	58	>10%
Transit Road (State Route 78)	1030250	217+87	127	76	10%
Genesee Street (State Route 33)	1022920	263+11	151	38	0.2%

Notes:
1. Surface Width is measured parallel to creek flow and refers to the curb-to-curb width, which is the minimum distance between the curbs or the bridge railings (if there are no curbs), to the nearest 30 mm or tenth of a foot (NYSDOT, 2006).

Source: (NYSDOT, 2019a); (FEMA, 2019)

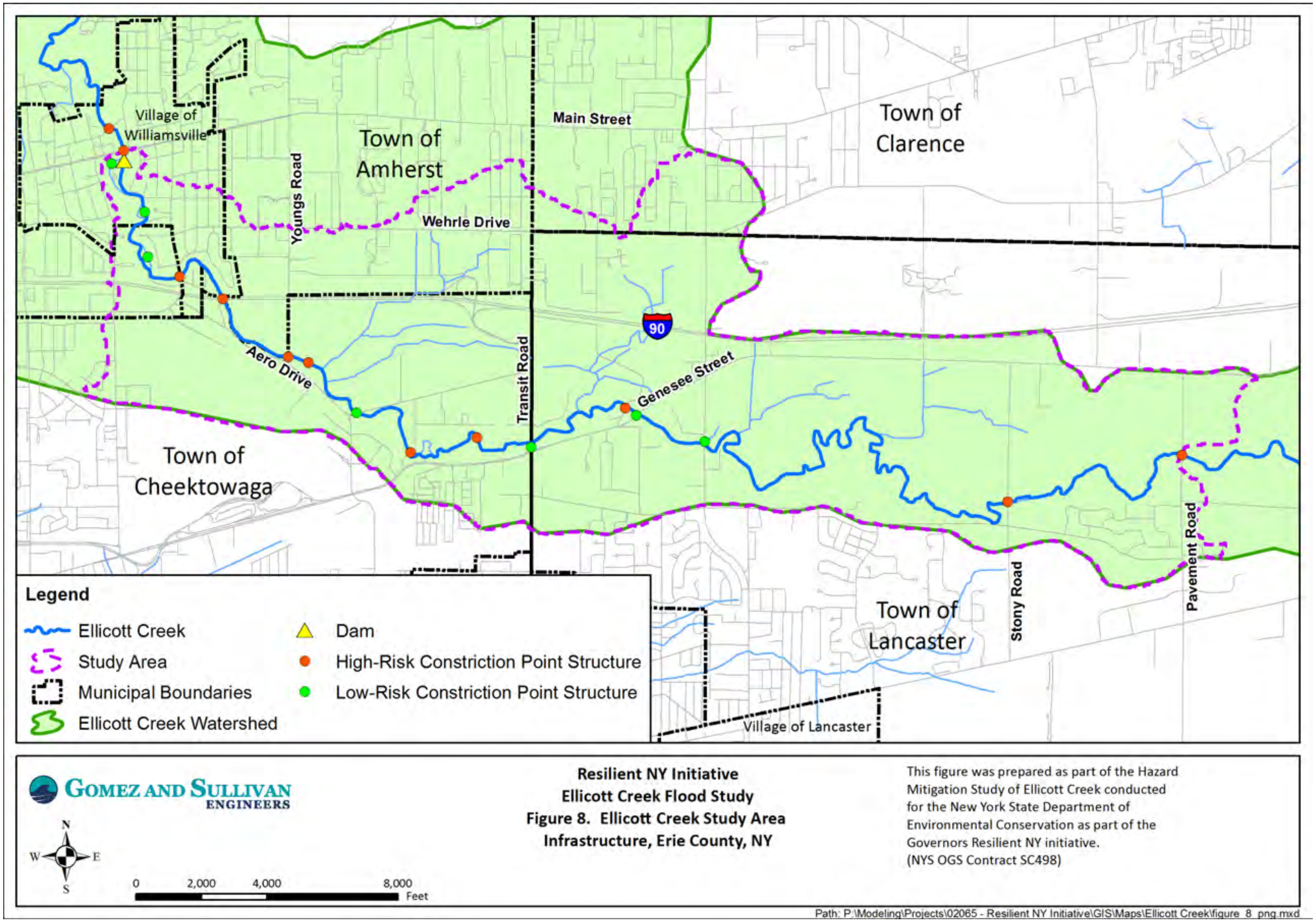
Table 10.Non-NYSDOT Bridges/Culverts Crossing Ellicott Creek

Roadway Carried	BIN/CIN	River Station (ft)	Owner	Bridge Length (ft)	Surface Width (ft)	Hydraulic Capacity (% Annual Chance)
Glen Avenue	3328860	-8+95	Erie County	96	27.9	0.2%
Recreational Road (Williamsville Park)	2260770	5+84	Village of Williamsville	52	8.4	10%
Private Drive	--	23+21	Private	--	--	>10%
Pedestrian Bridge	--	42+86	Private	--	--	2%
Wehrle Drive	3327130	57+90	Erie County	102.2	42	>10%
NYS Thruway (Interstate 90)	5511919	80+35	NYS Thruway Authority	124	107	0.2%

Roadway Carried	BIN/CIN	River Station (ft)	Owner	Bridge Length (ft)	Surface Width (ft)	Hydraulic Capacity (% Annual Chance)
South Youngs Road	2212850	110+03	Erie County	86	41	>10%
Airport Runway	--	116+70	BUF Airport	--	--	>10%
Aero Drive	3327230	140+65	Erie County	87	24	>10%
Rein Road	2212970	169+36	Town of Cheektowaga	85	24	>10%
Railroad	--	197+31	--	--	--	>10%
Main Street	2213280	258+85	Town of Lancaster	132	29.4	10%
Harris Hill Road	3326910	286+51	Erie County	144	30	0.2%
Stoney Road	3328720	491+26	Erie County	109.8	33	>10%
Pavement Road	3326940	566+37	Erie County	86	34	10%

Source: (NYSDOT, 2019a); (FEMA, 2019)

Figure 8. Ellicott Creek Study Area Infrastructure, Erie County, NY



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

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

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

- The structure will not raise the water surface elevations anywhere when compared to the existing conditions for both the 2 and 1% ACE (50- and 100-year flood) flows.
- The proposed low chord shall not be lower than the existing low chord.
- A minimum of 2'-0" of freeboard for the projected 2% ACE (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 current 1% ACE (100-year flood), based on peak streamflow from the USGS *StreamStats* plus a 10% increase in 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% ACE peak flows shall be increased by 10% in Region 5. For critical bridges, the minimum hydraulic design criteria is 3-feet of freeboard over the 2% annual chance flood elevation. A critical bridge is considered to be vital infrastructure that the incapacity or destruction of such would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters [(NYSDOT, 2019b); (USDHS, 2010)].

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 (CRRA) 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, the NYSDEC outlined infrastructure guidelines, most notably that the new freeboard recommendation for normal bridges is 2-feet of freeboard over the elevation of a flood with a 1%

chance of being equaled or exceeded in a given year (i.e. base flood elevation) and 3-feet for a critical structure (NYSDEC, 2018). When compared to current guidelines, the new CRRA climate change recommended freeboard is based on the 1% ACE water surface elevation, while the previous guidelines were based on the 2% ACE. This is a higher standard for freeboard. Table 13 displays the 2% and 1% annual chance flood levels and their calculated difference at FEMA FIS infrastructure locations using the FIS profile for Ellicott Creek.

In New York State, hydraulic and hydrologic regulations for culverts were developed by the NYSDOT. The NYSDOT guidelines require culverts to be designed based upon an assessment of the likely damage to the highway and adjacent landowners from a given flow and the costs of the drainage facility. The design flood frequency for drainage structures and channels is typically the 2% (50-year) annual chance flood hazard for Interstates and other Freeways, Principal Arterials, and Minor Arterials, Collectors, Local Roads, and Streets. If the proposed highway is in an established regulatory floodway or floodplain then the 1% (100 year) annual chance flood hazard requirement must be checked (NYSDOT, 2018).

The term “culvert” is defined as any structure, whether of single- or multiple-span construction, with an interior width of 20 ft. or less when the measurement is made horizontally along the center line of the roadway from face-to-face of abutments or sidewalls (NYSDOT, 2020).

In assessing the hydraulic capacity of culverts, NYSDOT highway drainage standards require the determination of a design discharge (e.g. 50-year flood) through the use of flood frequencies. The design flood frequency is the recurrence interval that is expected to be accommodated without exceeding the design criteria for the culvert. There are four recommended methodologies: the Rational Method, the Modified Soil Cover Complex Method, historical data, and the regression equations. Each method should be assessed and the most appropriate method for the specific site should be used to calculate the design flood frequency and discharge (NYSDOT, 2018).

In addition, current NYSDOT standards require peak flows to 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. According to the draft CRRA guidelines, for culverts the minimum hydraulic design criteria is 2-feet of freeboard over the 2% annual chance flood elevation. For critical culverts, the CRRA guidelines recommend 3-feet of freeboard over the 1% annual chance flood elevation. A critical culvert 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 [(NYSDEC, 2018); (NYSDOT, 2018); (USDHS, 2010)].

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 (CRRA) 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, the NYSDEC outlined infrastructure guidelines, most notably the recommendation that culverts be able to fully pass the design flood without increasing headwater and that they provide at least 2-feet of roadway freeboard above the projected 1% (100-year) annual chance flood hazard. An additional 1-foot of roadway freeboard should be considered for culverts on critical roadways (NYSDEC, 2018). When compared to current guidelines, the new CRRA climate change recommendation of freeboard for culverts encourages building more flood resilient infrastructure. Table 13 displays the 2% and 1% annual chance flood levels and their calculated difference at FEMA FIS infrastructure locations using the FIS profile for Ellicott Creek.

Table 11.FEMA FIS Profile 2 and 1% Annual Chance Flood Hazard Levels with Differences at Infrastructure Locations

Bridge Crossing	River Station (ft)	2% Water Surface Elevation (ft NAVD88)	1% Water Surface Elevation (ft NAVD88)	Difference in Water Surface Elevations (ft NAVD88)
Glen Avenue	-8+95	620.71	621.59	0.88
Main Street (State Route 5)	0+00	666.63	667.92	1.29
Recreational Road (Williamsville Park)	5+84	671.89	672.18	0.29
Private Drive	23+21	673.99	674.59	0.6
Pedestrian Bridge	42+86	676.37	676.98	0.61
Wehrle Drive	57+90	679.04	679.75	0.71
NYS Thruway (Interstate 90)	80+35	683.22	683.65	0.43
South Youngs Road	110+03	690.64	690.66	0.02
Airport Runway (Culvert)	116+70	692.57	693.24	0.67
Aero Drive	140+65	696.08	697.05	0.97
Rein Road	169+36	697.12	697.99	0.87
Railroad	197+31	698.8	699.62	0.82
Transit Road (State Route 78)	217+87	699.44	700.39	0.95
Main Street	258+85	701.55	702.31	0.76
Genesee Street (State Route 33)	263+11	701.9	702.56	0.66
Harris Hill Road	286+51	707.91	708.4	0.49
Stoney Road	491+26	719.67	720.22	0.55
Pavement Road	566+37	726.81	729.4	2.59

Source: (FEMA, 2019)

In assessing hydraulic capacity of the bridges and culvert located in the identified high-risk areas along Ellicott Creek, the FEMA FIS profile was used to determine the lowest annual chance flood elevation to flow under the low chord of a bridge, without causing a significant backwater condition upstream (Table 9, Table 10). According to the FEMA FIS profiles, two structures within the identified high-risk areas do not meet the NYSDOT guidelines for 2-feet of freeboard for bridges: Wehrle Drive and the Railroad Bridge. In addition, these structures do not meet the new draft CRRA climate change infrastructure guidelines as described above. Their low chord elevations are below the 0.2% ACE (for Wehrle Drive) and 10% ACE (for the Railroad) and they do not provide the recommended hydraulic capacity (FEMA, 2019). 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 new draft CRRA guidelines.

The Wehrle Drive Bridge is located in the urban area of the Village of Williamsville and causes flood waters to rise by 2-3 feet upstream of the bridge as shown on the effective FEMA FIS flood profiles for the 10%, 2%, 1%, and 0.2% ACE (FEMA, 2019). The raised water surface elevations upstream of Wehrle Drive Bridge impacts residential areas and streets, including the Cadman Drive neighborhood. The Railroad Bridge is located upstream of the Greater Buffalo International Airport Runway which spans the Ellicott Creek floodplain. The Railroad is affected by backwater from the hydraulic constriction at the Airport Runway and its low chord is submerged during the 10%, 2%, 1%, and 0.2% ACE. The Railroad also serves as a significant hydraulic constriction for floodwaters which causes raised water surface elevations upstream of the bridge by up to one foot for all modeled discharges as shown on the effective FEMA FIS flood profiles (FEMA, 2019). The raised water surface elevations upstream of the Railroad impacts commercial properties and streets including along Transit Road upstream of the Railroad.

In addition to comparing the annual chance flood elevations and low chords for bridges and culverts that cross Ellicott Creek, the structure width and bankfull width were compared for each of these structures. The USGS *StreamStats* tool was used to calculate the bankfull widths and discharge for each structure along Ellicott Creek. Table 14 indicates that in Erie County, NY, there are 9 bridges within the study area that cross Ellicott Creek that have bridge openings that are smaller than the bankfull widths: Glen Avenue, Main Street (Route 5), NYS Thruway (Interstate 90), South Youngs Road, Airport Runway, Rein Road, Rairoad, Main Street, Pavement Road. In addition, there is one bridge with an opening that is very close (within 5 feet) of bankfull width: Wehrle Drive, which is also an area of concern since it also does not meet the NYSDOT guidelines for 2-feet of freeboard above the 2% ACE or the draft CRRA guidelines for 2-feet of freeboard above the 1% ACE. Of the bridges listed in Table 14, 7 are within the identified high risk areas: Main Street (Route 5), Wehrle Drive, Rein Road, Railroad, Main Street, Stoney Road, and Pavement Road.

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. 34% ACE), the likelihood of relatively low flow events causing backwater and potential flooding upstream of these structures is fairly high. Therefore, structures with widths less than or within five feet of the bankfull width are considered high-risk constriction point structures, as depicted in Figure 8.

Table 12.Hydraulic Capacity of Potential Constriction Point Bridges Crossing Ellicott Creek

Roadway Carried	Structure Type	River Station (ft)	Structure Width (ft)	Bankfull Width (ft)	Bankfull Discharge (cfs)	ACE Equivalent[1]
Glen Avenue	Bridge	-8+95	69	100	1830	31%
Main Street (State Route 5)	Bridge	0+00	76	100	1830	31%
Wehrle Drive	Bridge	57+90	101	99	1690	34%
NYS Thruway (Interstate 90)	Bridge	80+35	95	99	1680	34%
South Youngs Road	Bridge	110+03	80	99	1680	34%
Airport Runway	Culvert	116+70	60	99	1680	34%
Rein Road	Bridge	169+36	82	98	1680	34%
Railroad	Bridge	197+31	88	98	1680	34%
Main Street	Bridge	258+85	92	97	1680	34%
Pavement Road	Bridge	566+37	81	93	1520	45%

Notes:

1. ACE Equivalent describes the equivalent ACE for the given bankfull discharge as calculated by the USGS *StreamStats* application. The 34% ACE is equal to a 2.9-year recurrence interval.

Source: (NYSDOT, 2019a); (USGS, 2020); (FEMA, 2019)

Climate Change Implications

Future Projected Stream Flow in Ellicott Creek

In New York State, climate change is expected to exacerbate flooding due to projected increases of 1-8% in total annual precipitation coupled with increases in the frequency, intensity, and duration of extreme precipitation events (events with more than 1, 2, or 4 inches of rainfall) (NYSERDA, 2011). In response to these projected changes in climate, New York State passed the Community Risk and Resiliency Act (CRRA) 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).

USGS *FutureFlow Explorer* v1.5 (https://ny.water.usgs.gov/maps/floodfreq-climate/) is discussed as a potential tool to project peak flows under various climate scenarios into the future. *FutureFlow* Explorer was developed by the USGS in partnership with the NYSDOT. This application is an extension for the USGS *StreamStats* map-based web application and projects future stream flows in New York State. The USGS team examined 33 global climate models and selected five that best predicted past precipitation trends in the region. The results were then downscaled to apply to all six hydrologic regions of New York State. Three time periods can be examined: 2024-2049, 2050-2074 and 2075-2099, as well as two Intergovernmental Panel on Climate Change (IPCC) greenhouse gas emission scenarios: RCP 4.5 and RCP 8.5. RCP 4.5 is considered a midrange-emissions scenario, and RCP 8.5 is a high-emissions scenario [(Taylor, Stouffer, & Meehi, 2011); (NYSDEC, 2018)].

In general, climate models are better at forecasting temperature than precipitation and contain some level of uncertainty with their calculations and results. The USGS recommends using *FutureFlow* projections as qualitative guidance to see likely trends within any watershed and as an exploratory tool to inform selection of appropriate design flow. Current future flood projection models will not provide accurate results for basins that extend across more than one hydrologic region in New York (NYSDEC, 2018).

Based on the current future flood projection models, flood magnitudes are expected to increase in nearly all cases in New York State, but the magnitudes vary among regions. While the *FutureFlow* application is still being upgraded, it can be used with appropriate caution. Climate model forecasts are expected to improve and as they do, the existing regression approach will be tested and refined further (NYSDEC, 2018).

The NYSDEC recommends that future peak flow conditions should be adjusted by multiplying relevant peak flow parameters by a factor specific to the expected service life of the structure and geographic location of the project. For Western New York, the recommended design-flow multiplier is 10% increased flow for an end of design life of 2025-2100 (NYSDEC, 2018). Table 15 provides a summary of the projected future peak stream flows using the FEMA FIS peak discharges and 10% CRRA design multiplier.

Table 13.Ellicott Creek Projected Peak Discharges

Flooding Source and Location	Drainage Area (mi^2)	River Station (ft)	Peak Discharge (cfs)			
			10%	2%	1%	0.2 %
At Stoney Rd	67.4	491+26	3993	6138	7117	9482
At Wehrle Dr	72.4	57+90	4191	6457	7469	9966
At Island Park	72.8	5+84	4862	6765	7865	9262
At Sheridan Dr	77.6	-131+77	4950	6858.5	7969.5	9372

Source: (NYSDEC, 2018)

Appendix E contains the HEC-RAS simulation summary sheets for the current and projected future flow 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 the only difference being future projected water surface elevations are up to 2.9-feet higher at specific locations within the study area, generally upstream of bridges due to backwater, as a result of the increased discharges.

Table 16 provides a comparison of HEC-RAS base condition modeled water surface elevations at the FIS discharge locations, using the effective FEMA FIS flows, and future condition, using the 10% CRRA design multiplier flows.

Table 14.HEC-RAS Current and Projected Future Flow Water Surface Elevation Comparison

Flooding Source and Location	Drainage Area (mi^2)	River Station (ft)	Water Surface Elevation Change (ft)[1]			
			10%	2%	1%	0.2%
At Stoney Rd	67.4	491+26	0.5	0.2	0.2	0.4
At Wehrle Dr	72.4	57+90	0.1	1.6	0.2	0.1
At Island Park	72.8	5+84	0.4	0.4	0.3	0.3

Notes:

1. Positive changes in water surface elevation indicate the future conditions water surface elevation is higher than the base condition.

Source: : (FEMA, 2019); (NYSDEC, 2018); (USACE, 2019)

Flooding Characteristics

Flooding History

A storm in November 2014 produced up to six feet of snow and was followed by temperatures in the sixties, which led to flooding of Ellicott Creek in the Village of Williamsville. A major flood occurred in March 1960, with the most severe flooding on Ellicott Creek located downstream of the study area. This flood was estimated to be similar to a 5% annual chance flood event and had a flow at the Williamsville gage of 4,860 cfs. Another major flood occurred before the installation of the gage in March 1936, which had an estimated flow of 6,800 cfs in Williamsville and was estimated to approximate a 2% annual chance flood event. Flooding of Ellicott Creek in the Village of Williamsville and the Towns of Cheektowaga, Lancaster, and Amherst also occurred in March 1916, January 1929, March 1936, June 1937, March 1940, March 1954, March 1956, January 1959, and March 1963. Low-lying areas of the Village of Williamsville are subject to frequent flooding in late winter/early spring (FEMA, 2019).

FEMA FIRMs are available for Ellicott Creek, depicting the extent of the expected floodplain. Figure 9 and Figure 10 display the floodway and 1% and 0.2% ACE boundaries for Ellicott Creek as determined by FEMA for the Village of Williamsville and the Towns of Amherst, Cheektowaga, and Lancaster (FEMA, 2019).

Figure 9. Ellicott Creek, FEMA Flood Zones, Town of Lancaster, Erie County, NY

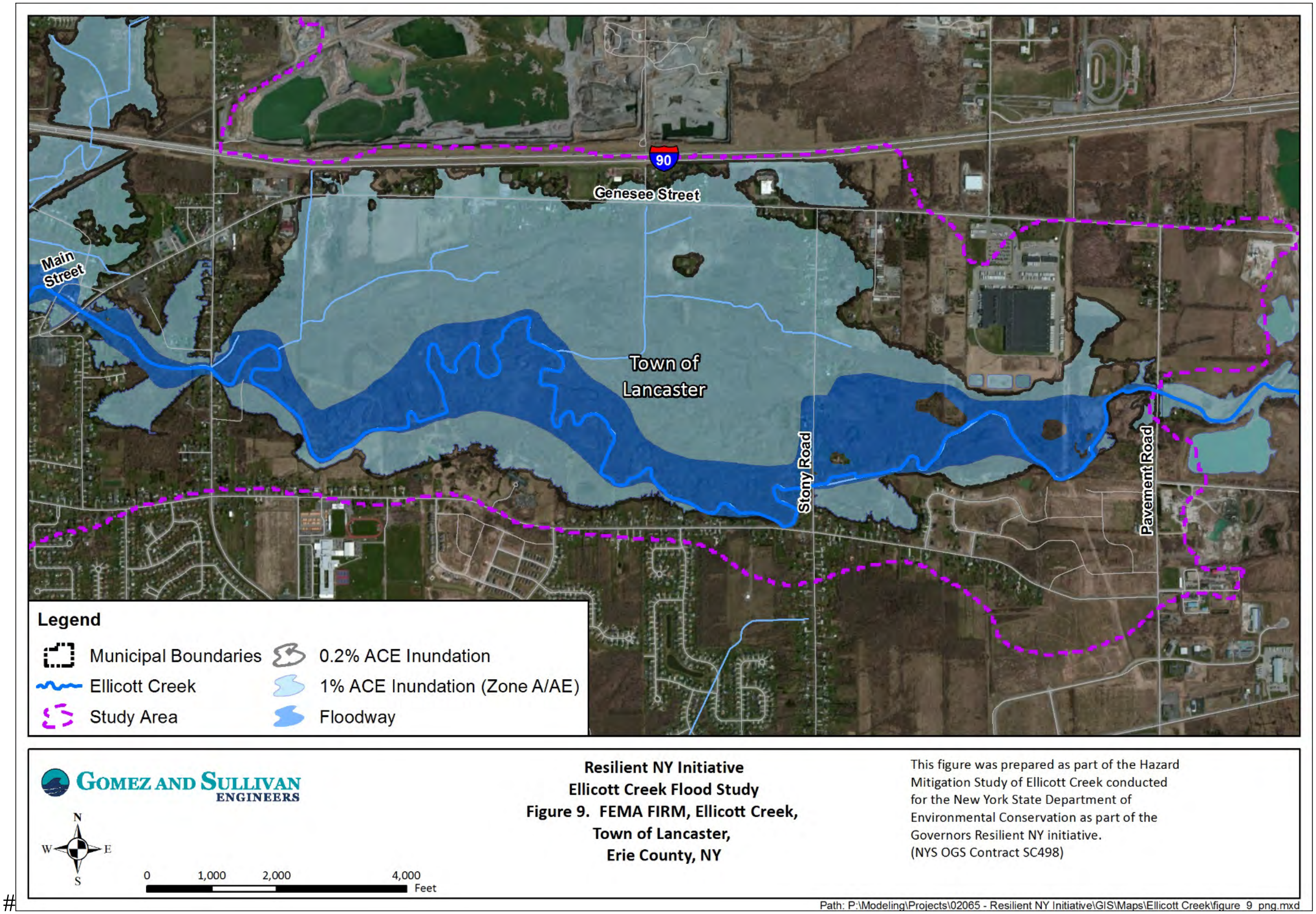
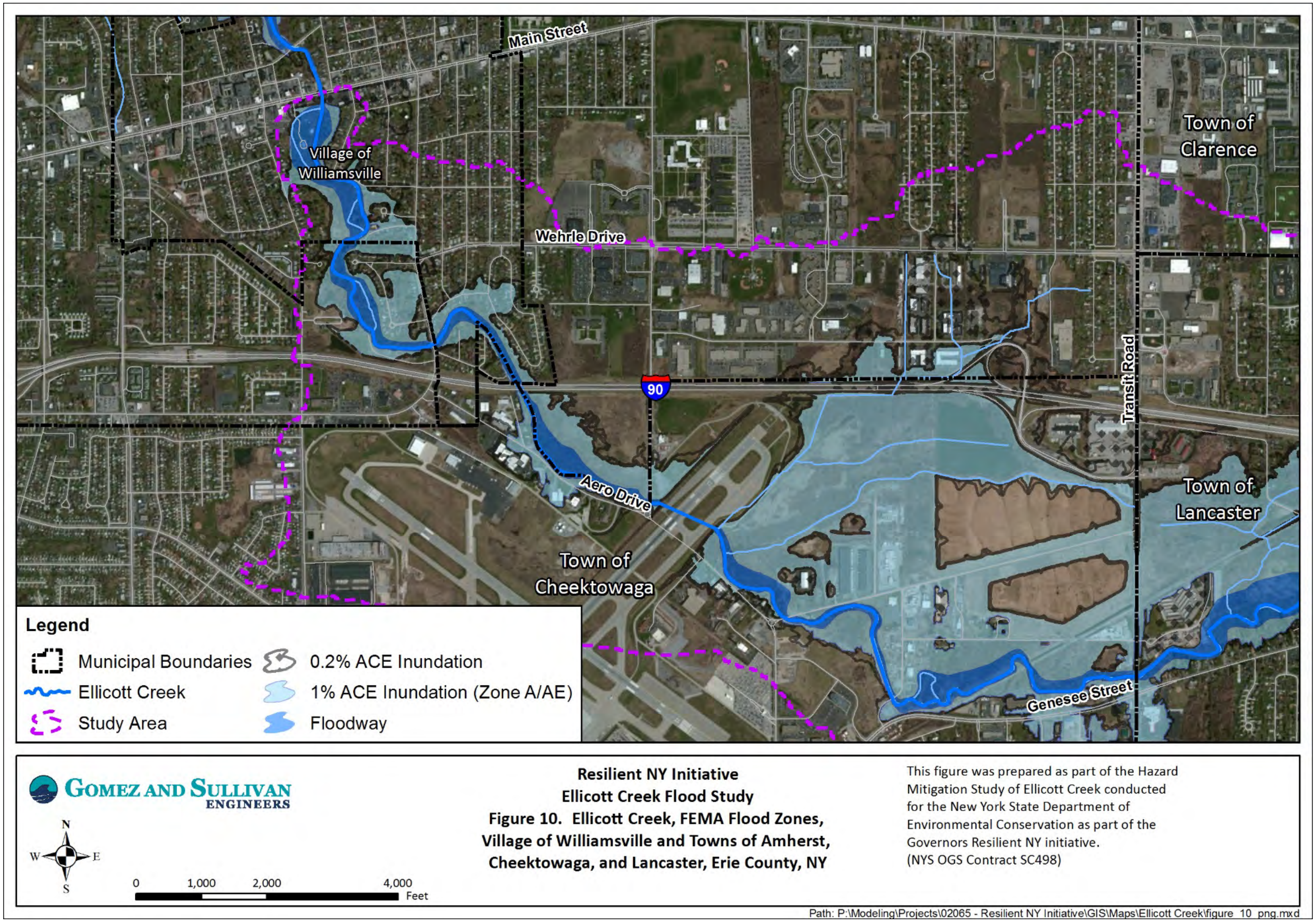


Figure 10. Ellicott Creek, FEMA Flood Zones, Village of Williamsville and Towns of Amherst, Cheektowaga, and Lancaster, Erie County, NY



Flood Mitigation Analysis

For this study of Ellicott Creek, standard hydrologic and hydraulic study methods were used to determine and evaluate flood hazard data. Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10%, 2%, 1%, and 0.2% chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. The analyses reported herein reflect flooding potentials based on conditions existing in the county at the time of completion of the effective FIS (FEMA, 2019).

Hydraulic analysis of Ellicott Creek was conducted using the HEC-RAS v5.0.7 program (USACE, 2019). 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- and two-Dimensional (2-D), steady-state, or time-varied (unsteady) flow. In one-dimensional (1-D) solutions, the water surface profiles are computed from one cross section to the next by solving the one-dimensional St. Venant equations 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 (USACE, 2016a).

Hydraulic and Hydrologic modeling of Ellicott Creek in the Village of Williamsville and the Towns of Cheektowaga and Lancaster was completed by FEMA in 2019, 1977, and 1998, respectively. Due to the age and format of the FIS study, an updated 1-D HEC-RAS model was developed using the following data and software:

- Erie County, NY 1.4-meter LiDAR DEM data (Sanborn Map Company, Inc, 2008)
- New York State Digital Ortho-imagery Program imagery for Erie County (NYSOITS, 2017)
- National Land Cover Database (NLCD) data (MRLC, 2019)
- USGS *StreamStats* peak discharge data (USGS, 2020)
- RAS Mapper extension in HEC-RAS software
- ESRI ArcMap 10.7 with the HEC-GeoRAS extension GIS software (ESRI, 2019)

The hydraulic model was developed for Ellicott Creek beginning 800 ft downstream of Glen Avenue (river station -17+18) and extending upstream to 68 ft upstream of Pavement Road (river station 567+23).

Methodology of HEC-RAS Model Development

Hydraulic modeling of Ellicott Creek in the Town of Cheektowaga was completed using HEC-2 software in 1977. The Town of Cheektowaga analysis extended from Island Park in the Village of

Williamsville to just upstream of Stoney Road in the Town of Lancaster. Hydraulic modeling of Ellicott Creek in the Town of Lancaster was completed using HEC-2 software in 1998 as two separate models "Lancaster East" and "Lancaster West". The Lancaster East analysis extended from just downstream of Stoney Road to just upstream of Pavement Road. The Lancaster West analysis extended from just downstream of Transit Road to just upstream of Harris Hill Road. Hydraulic modeling of Ellicott Creek in the Village of Williamsville and the Town of Amherst was completed using HEC-RAS software in 2019. The Village of Williamsville analysis extended from 800 feet downstream of Glen Avenue to just downstream of the NYS Thruway (Interstate 90).

Using the LiDAR DEM data, orthoimagery, land cover data, and the RAS Mapper extension in the HEC-RAS software, a base condition hydraulic model was developed from the effective FEMA hydraulic models using the following methodology:

- HEC-2 models were imported and elevations were converted from NGVD29 to NAVD88 (NAVD88 = NVGD29 – 0.5 feet)
- The Village of Williamsville HEC-RAS model was imported
- Georeferenced stream centerline and cross sections using geographic information systems (GIS)
- Revised reach lengths between cross sections using RAS Mapper
- Adjusted cross-section geometry for areas outside the stream channel throughout the model using LiDAR data
- Updated Manning's n values to better reflect channel, bank, and floodplain roughness, based on field observations and ortho-imagery
- Updated structure geometry and channel elevations based on as-built drawings and field measurements for critical structures within high risk areas
- Adjusted ineffective flow areas to account for floodplain expansion and contraction at structures and due to terrain
- Revised expansion and contraction coefficients to correspond with hydraulic conditions near structures
- Adjusted left and right bank stations based on the adjusted cross section geometry and bankfull discharge
- Performed a 1-D steady flow simulation using the effective FEMA FIS discharges in addition to future projected discharges

The base condition model water surface elevation results were then compared to the FEMA FIS water surface profiles, and the effective FEMA FIS streambed elevation profiles to validate the model. A major discrepancy between the effective FIS and baseline conditions models was observed in the area between Harris Hill Road and Stoney Road in the Town of Lancaster. The effective FEMA HEC-2 model for this area was completed in 1977 and had the following differences from the baseline conditions model: Manning's n values which were much higher than those typically used, narrower cross sections which did not span the entire floodplain, and large differences in overbank terrain compared to LiDAR data. After the base condition model was verified, it was then used to develop alternative condition models to simulate potential flood mitigation strategies. Generic renderings of various potential flood mitigation strategies are provided in Appendix F. The simulation results of the alternative conditions were evaluated based on their reduction in water surface elevations. As the potential flood mitigation strategies are, at this point, preliminary, inundation mapping was not developed from the computed water surface profiles for each potential mitigation alternative. Inundation shown on figures within this report reflects that of the effective FEMA FIS for the Village of Williamsville and the Towns of Amherst, Cheektowaga, and Lancaster. The effectiveness of each potential mitigation strategy was evaluated based on reduction in water surface elevations. In addition to reduced water surface elevations at the inundated structures, some structures may be removed from the inundation area for a given annual chance exceedance (ACE) event by implementing the mitigation strategies.

The flood mitigation strategies that were modeled were:

Alternative #1-1: Modify Wehrle Drive Bridge (Station 57+90)
Alternative #1-2: Flood Bench Creation Between Island Park and Wehrle Drive (Station 14+75 to 33+62)
Alternative #1-3: Modify Wehrle Drive Bridge and Flood Bench Creation Between Island Park and Wehrle Drive (Station 14+75 to 57+90)
Alternative #2-1: Modify Railroad Bridge (Station 197+31)
Alternative #2-2: Flood Bench Creation Between Rein and Transit Roads (Station 198+65 to 217+23)
Alternative #2-3: Flood Bench Creation Between Transit Road and Main Street (Station 237+86 to 257+95)
Alternative #2-4: Modify Airport Runway Culverts (Station 116+70)
Alternative #3-1: Flood Bench Creation Between Harris Hill and Stoney Roads (Station 287+69 to 490+90)
Alternative #3-2: Flood Bench Creation Between Stoney and Pavement Roads (Station 514+81 to 565+53)

Stationing references for the flood mitigation measures are based on the NYSDEC hydrography GIS data for Ellicott Creek, which differs from the FEMA FIS stationing values.

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 potential mitigation alternatives.

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

For mitigation alternatives where increases in bridge sizes were evaluated, bridge size increases were initially analyzed based on 2-feet freeboard over the base flood elevation for a 1% ACE. Once these optimal sizes were determined, further analysis was completed including site constraints and constructability. Due to these additional constraints, for some mitigation measures the size necessary to meet the freeboard requirement was not feasible. Cost estimates were only performed for projects determined to be constructible and practical.

Infrastructure and hydrologic modifications will require permits and applications to the New York State 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.

Ice Jam Formation

An ice jam typically occurs in the late winter and/or 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).

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 or reach of a river before pursuing or implementing 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 G:

- 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

Gomez and Sullivan 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 G.

Ice-Jam Prone Areas

According to the USACE Cold Regions Research and Engineering Laboratory (CRREL) ice jam database and the effective FEMA FIS, there have been no recorded ice jam events on Ellicott Creek [(USACE, 2020); (FEMA, 2019)]. However, according to the National Centers for Environmental Information (NCEI) storm events database and the stakeholder engagement meeting for Ellicott Creek, there have historically been ice jam issues at the Stoney Road Bridge crossing (NCEI, 2021). The Stoney Road Bridge was recently replaced in 2018 with a larger sized opening which likely lessened the chance of future ice jam events.

In order to determine the most appropriate mitigation measures to address ice jam flooding along Ellicott Creek, additional hydraulic and hydrologic modeling using ice simulation models and ice jam specific mitigation measures, as outlined in Appendix G, is recommended for each ice jam prone area.

High Risk Areas

Based on the FEMA FIS, NCEI storm events database, historical flood reports, and stakeholder input from engagement meetings, 3 areas along Ellicott Creek were identified as high-risk flood areas in the Village of Wiliamsville and the Towns of Amherst, Cheektowaga, and Lancaster.

High Risk Area #1: Main Street (Route 5) to NYS Thruway (I-90) (Station 0+00 to 77+71)

High Risk Area #1 extends along Ellicott Creek from upstream of Main Street (Route 5) in the Village of Williamsville to downstream of the NYS Thruway (I-90). A review of the effective FIRM for this area indicates that residential and street flooding occurs in this area, and in particular the Lehn Springs Drive and Cadman Drive Neighborhoods are both located within the 1% and 0.2% ACE floodplains. There is one structure in the vicinity of this high risk area that has been identified as a repetitive loss structure. The Wehrle Drive Bridge was identified as a High-Risk Potential Constriction Point Structure and does not meet the NYSDOT or draft CRRA guidelines for 2 feet of freeboard above the 2% and 1% ACE respectively. The Wehrle Drive Bridge is owned and maintained by Erie County (BIN 3327130). Within this risk area, water surface elevations can be impacted by the Williamsville Dam just upstream of Main Street. The dam was constructed to provide flood control, therefore changes to the structure or its operations were not considered in the mitigation alternatives.

Figure 11 depicts the extent of flooding within the risk area, while Figure 12 shows the water surface profiles within the risk area.

Figure 11. High Risk Area #1: Main Street (Route 5) to NYS Thruway (I-90) (Station 0+00 to 77+71)

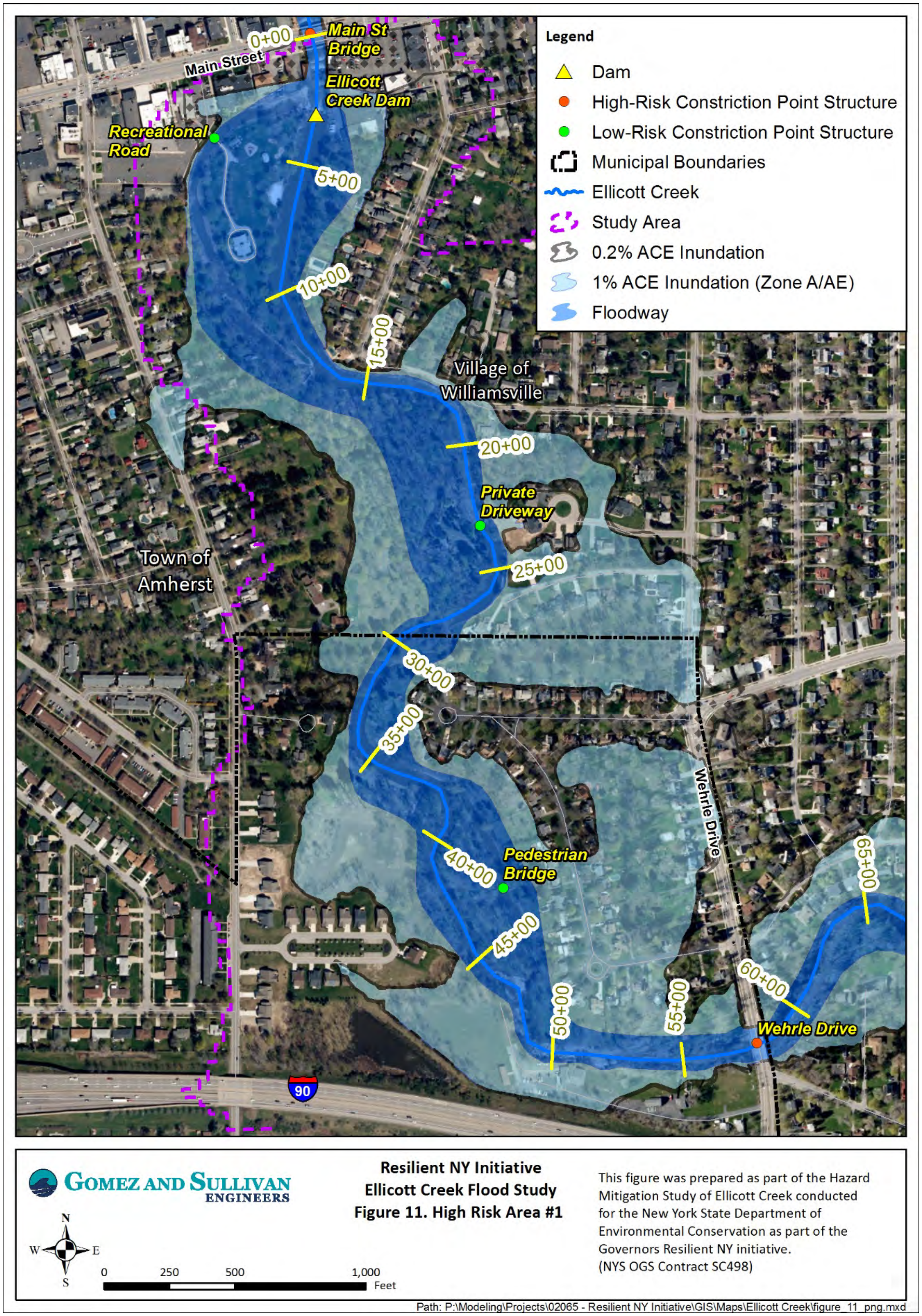
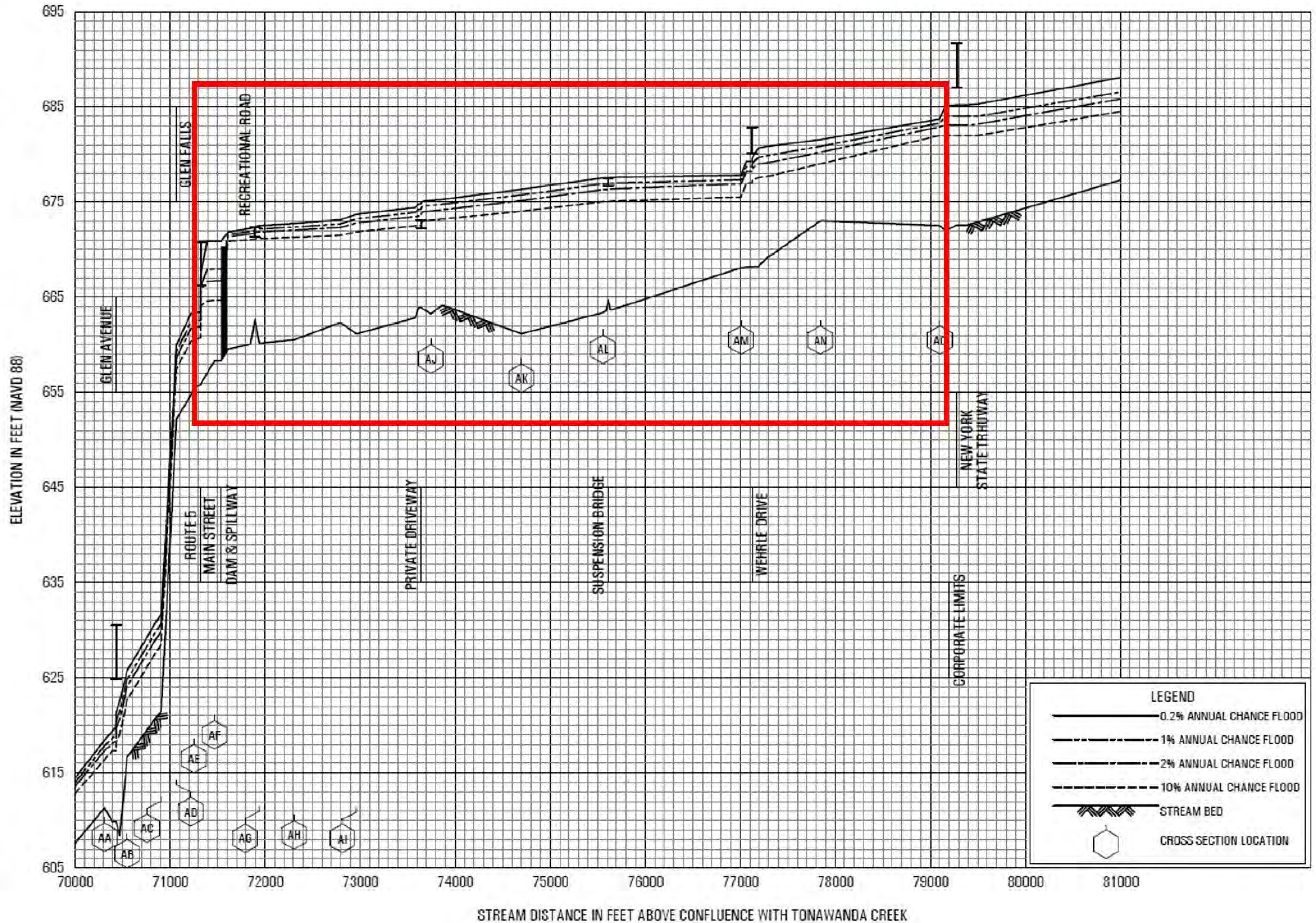


Figure 12. FEMA FIS Profile for Ellicott Creek in the Vicinity of High Risk Area #1



High Risk Area #2: Greater Buffalo International Airport Runway to Genesee Street (Station 141+34 to 262+71)

High Risk Area #2 extends along Ellicott Creek from the culverts under the Greater Buffalo International Airport Runway in the Town of Cheektowaga to Genesee Street in the Town of Lancaster. Review of the effective FIRM identified commercial properties throughout this area which are inundated during the 1% and 0.2% ACE. In addition, the Bowmansville Fire House is also located within the 1% ACE floodplain, which is consistent with comments made during public outreach. Within this high risk area one repetitive loss and one severe repetitive loss structures have been identified. The Greater Buffalo International Airport Runway at the downstream end of High Risk Area #2 extends across the floodplain for Ellicott Creek, with three culverts for passage of flow. The constriction caused by the runway serves as a significant hydraulic control for high flow events on Ellicott Creek, as evidenced by the effective FEMA profile, which shows a rise in water surface elevations of greater than 3 feet for the 0.2% ACE and 2-3 feet for the 10%, 2%, and 1% ACE. The Airport Runway culverts are owned and maintained by Greater Buffalo International Airport. Undersized stream crossings and development of the floodplain also exacerbate flooding impacts within this risk area.

Figure 13 depicts the extent of flooding within the risk area, while Figure 14 shows the water surface profiles within the risk area.

Figure 13. High Risk Area #2: Greater Buffalo International Airport Runway to Genesee Street (Station 141+34 to 262+71)

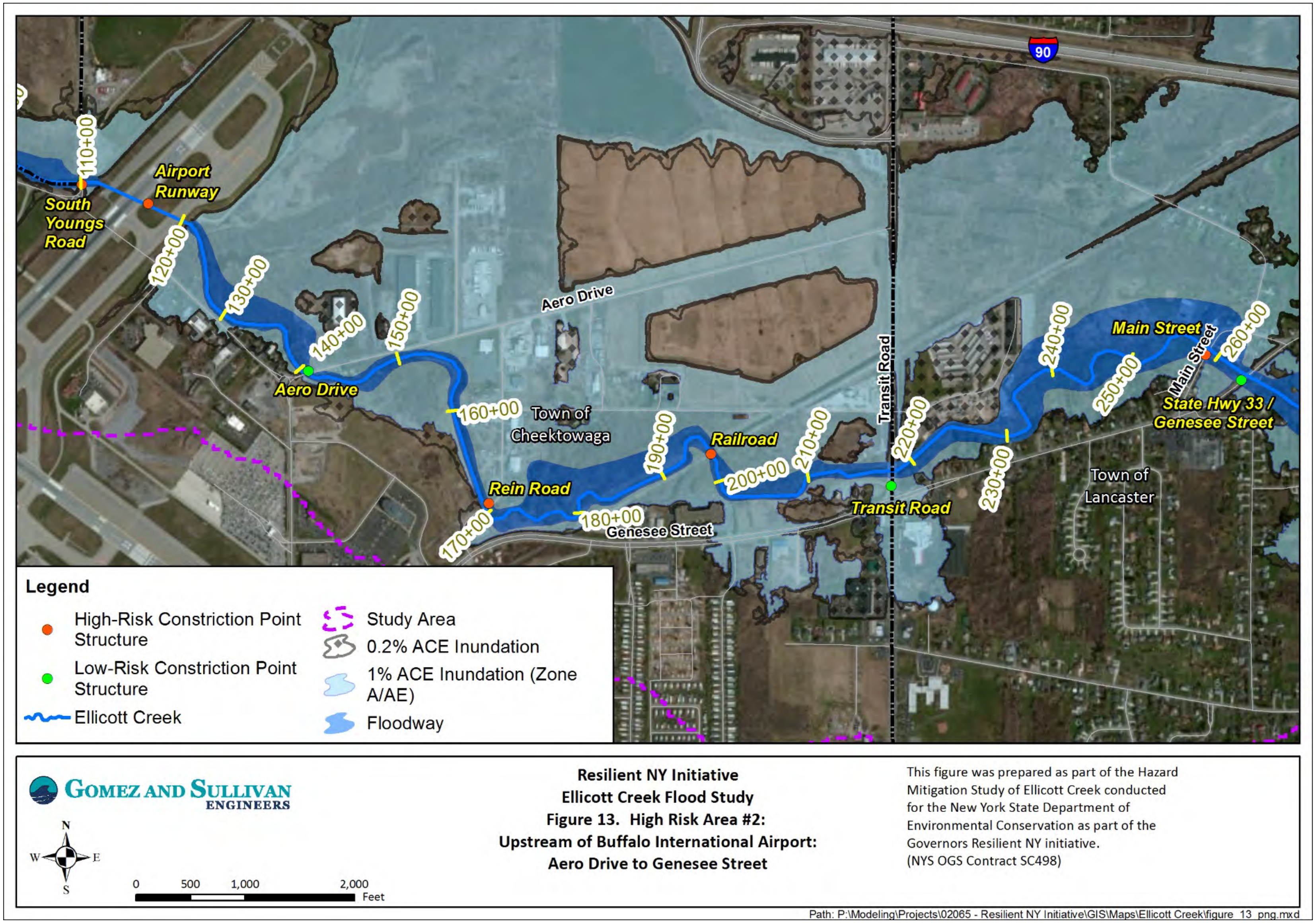
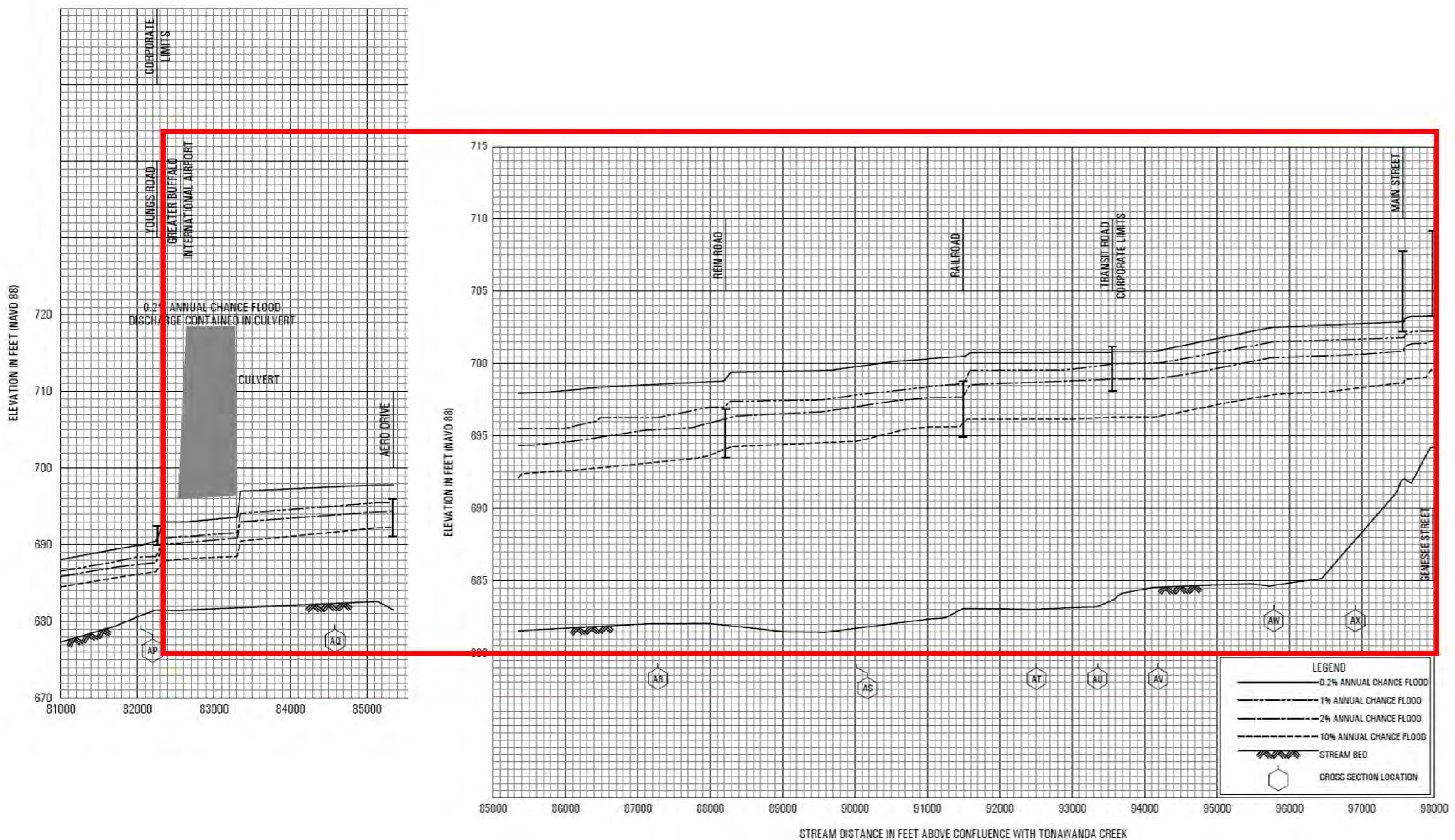


Figure 14. FEMA FIS Profile for Ellicott Creek in the Vicinity of High Risk Area #2



High Risk Area #3: Stoney Road in The Town of Lancaster (Station 458+18 to 566+04)

High Risk Area #3 extends from Stoney Road to Pavement Road in the Town of Lancaster. In reviewing the effective FIRM, it was noted that multiple houses along Stony Road are impacted by the 1% ACE. During the public outreach meeting, participants mentioned that few homes have flooding issues in this area, but that there are new residential developments in this area just south of Ellicott Creek. There is one structure in the vicinity of this high risk area that has been identified as a repetitive loss structure. It was also noted that there were historically ice jam issues at Stoney Road but that the bridge had recently been replaced. Updated dimensions from as-built plans for the new Stoney Road bridge were incorporated into the corrected baseline model.

Within this High Risk Area, debris in the stream channel was noted as a flooding concern, with Emerald Ash Borers leading to increased debris loading. Debris management benefits were considered in evaluating mitigation alternatives for this High Risk Area; debris management itself was evaluated as a basin-wide mitigation alternative that could be pursued in various areas.

Figure 15 depicts the extent of flooding within the risk area, while Figure 16 shows the water surface profiles within the risk area.

Figure 15. High Risk Area #3: Stoney Road in The Town of Lancaster (Station 458+18 to 566+04)

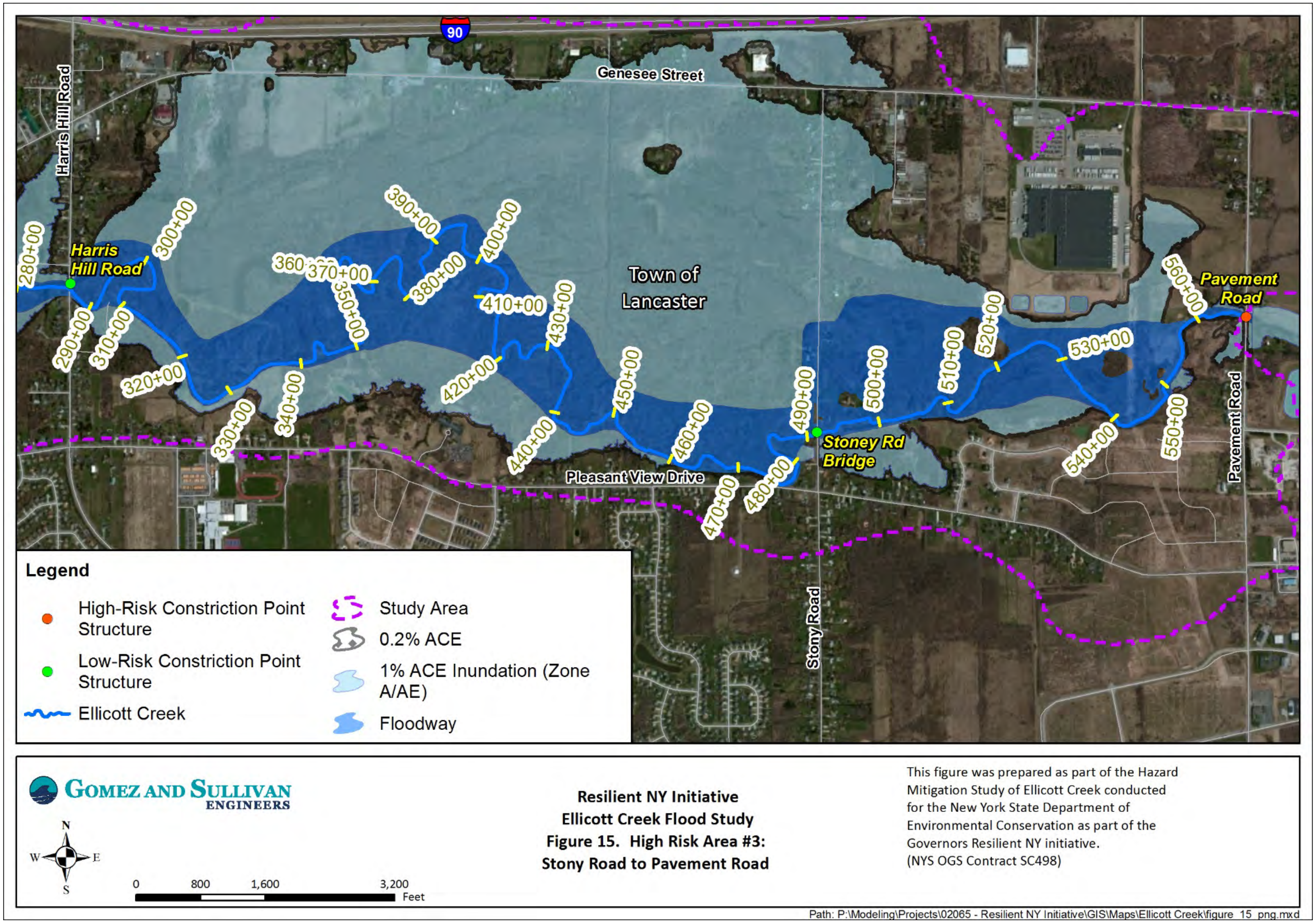
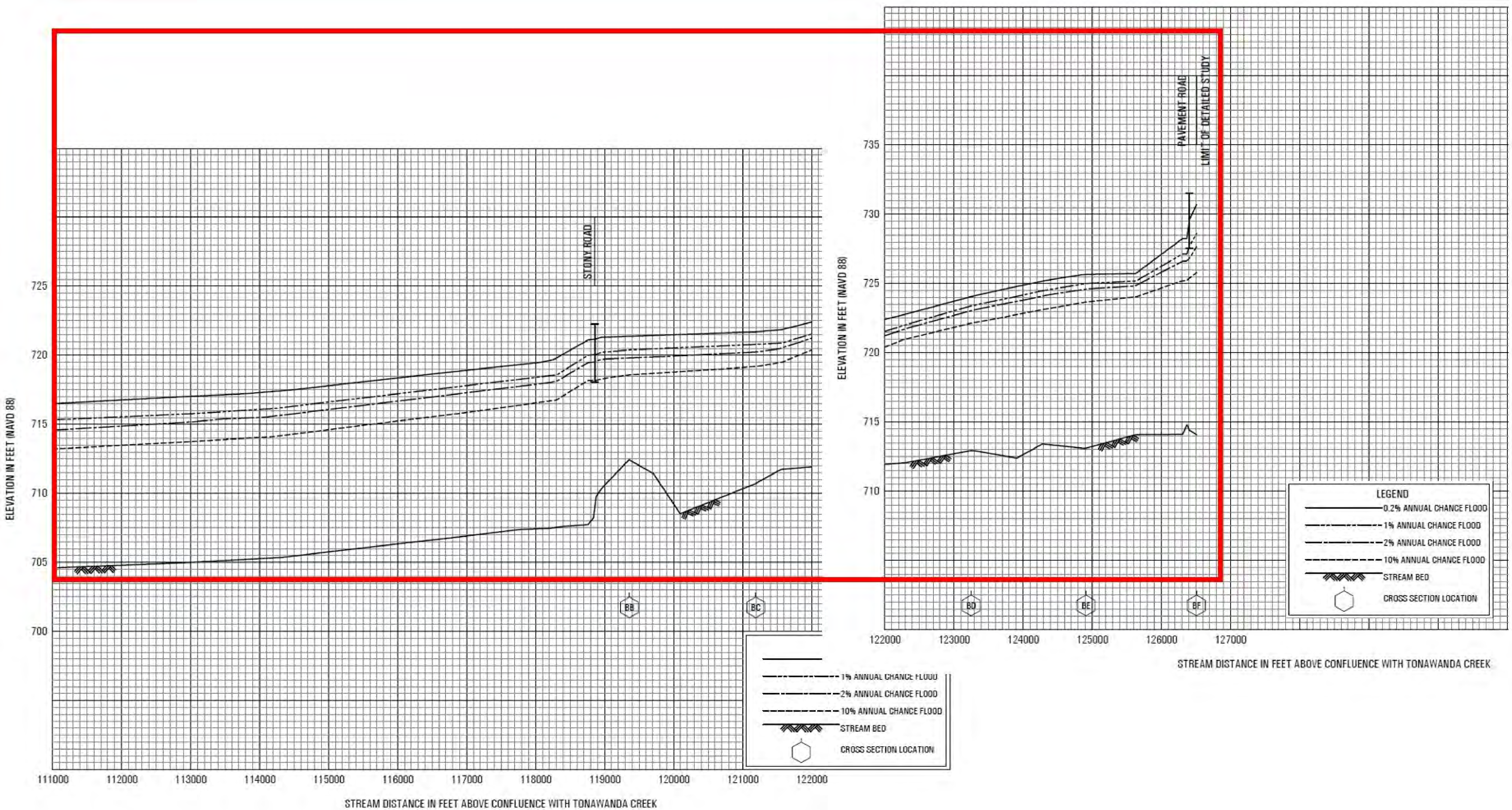


Figure 16. FEMA FIS Profile for Ellicott Creek in the Vicinity of High Risk Area #3



Mitigation Alternatives

The following flood mitigation alternatives that have the potential to reduce water surface elevations were evaluated for the identified high-risk areas along Ellicott Creek. These alternatives could potentially reduce flood related damages in areas adjacent to the creek. The Village of Williamsville and the Towns of Amherst, Cheektowaga and Lancaster should evaluate each alternative and consider the potential effects to the community and the level of community buy-in for each before pursuing them further.

High Risk Area #1: Main Street (Route 5) to NYS Thruway (I-90) (Station 0+00 to 77+71)

Alternative #1-1: Modify Wehrle Drive Bridge (Station 57+90)

The water surface profiles for the effective FEMA FIS indicate that the Wehrle Drive Bridge causes an increase in water surface elevations upstream of the road for all the modeled discharges. In addition, the effective FIRM indicates extensive residential and street flooding in this area. The hydraulic width of the existing bridge is within five feet of of the bankfull width, according to *StreamStats*.

This potential flood mitigation alternative is intended to provide additional flow area through the bridge opening by widening the bridge by 50 feet and raising the low chord by 2 feet. The proposed bridge would extend the opening to the north (right of bank). In order to facilitate flow through the new bridge opening, a small flood bench would be constructed, extending from 60 feet upstream of the upstream face of the bridge to 100 feet downstream of the downstream face of the bridge. The existing topography was lowered by approximately 2 feet for a width of approximately 50 feet on the right overbank, resulting in the removal of approximately 660 cubic yards of material. Figure 17 depicts the conceptual extents of this alternative.

Figure 18 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #1-1 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in water surface elevation reductions extending from the Wehrle Drive Bridge to approximately 260 feet downstream of the NYS Thruway (Interstate 90). Water surface elevation reductions under current discharges are computed to be as much as 0.1 ft for the 10% ACE discharge, 0.2 ft for the 2% ACE discharge, 1.2 ft for the 1% ACE discharge, and 0.8 ft for the 0.2% ACE discharge. Similar results, relative to the extent and magnitude of water surface elevation reductions, were found under this alternative for the projected future discharges. Reductions under projected future discharges are computed to be as much as 0.1 ft for the 10% ACE discharge, 1.3 ft for the 2% ACE discharge, 1.0 ft for the 1% ACE discharges, and 0.5 ft for the 0.2% ACE discharge.

The Rough Order Magnitude cost is $6 million, which does not include land acquisition costs other than survey, appraisal, and engineering coordination.

Figure 17. Location Map for Alternative #1-1

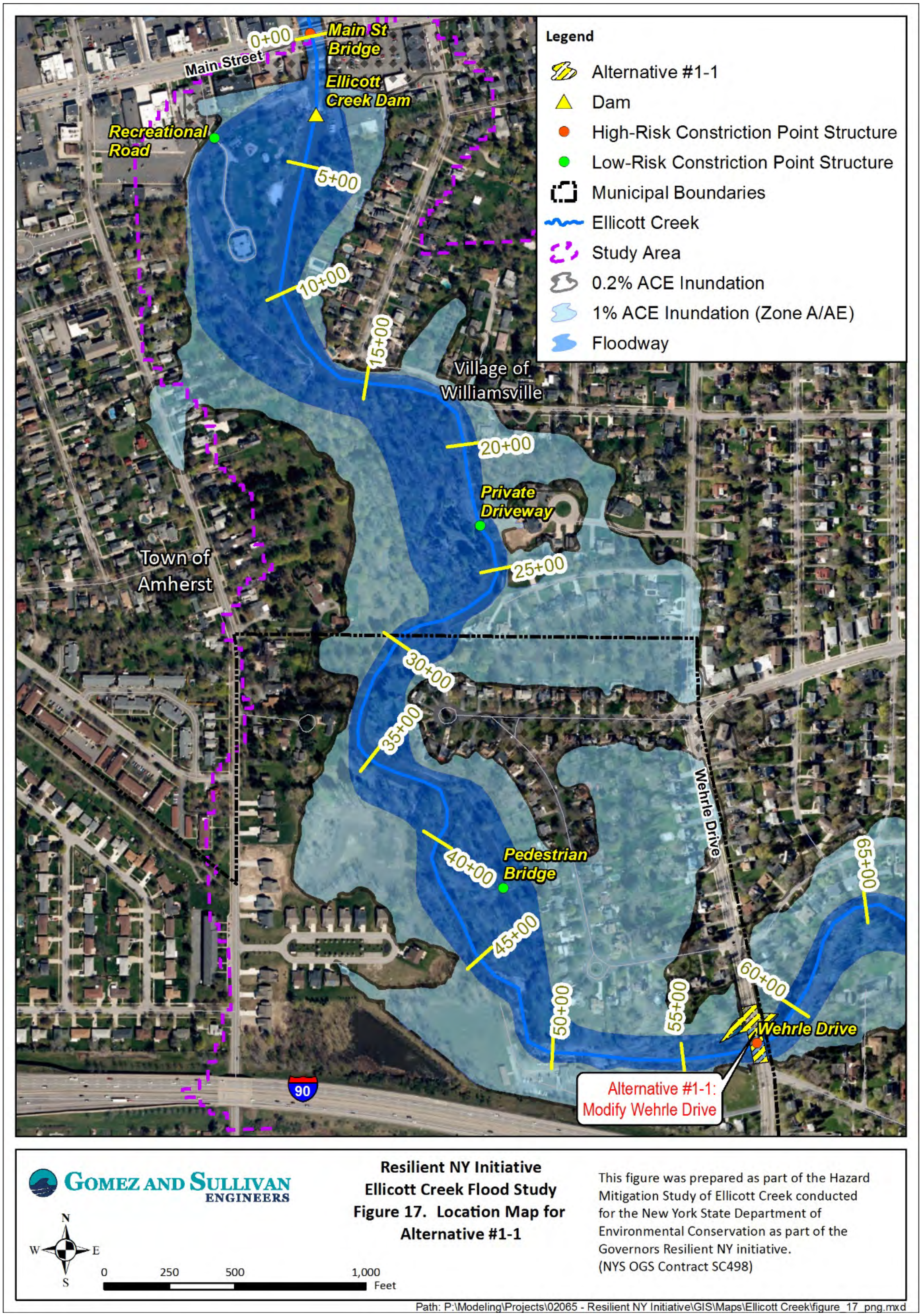
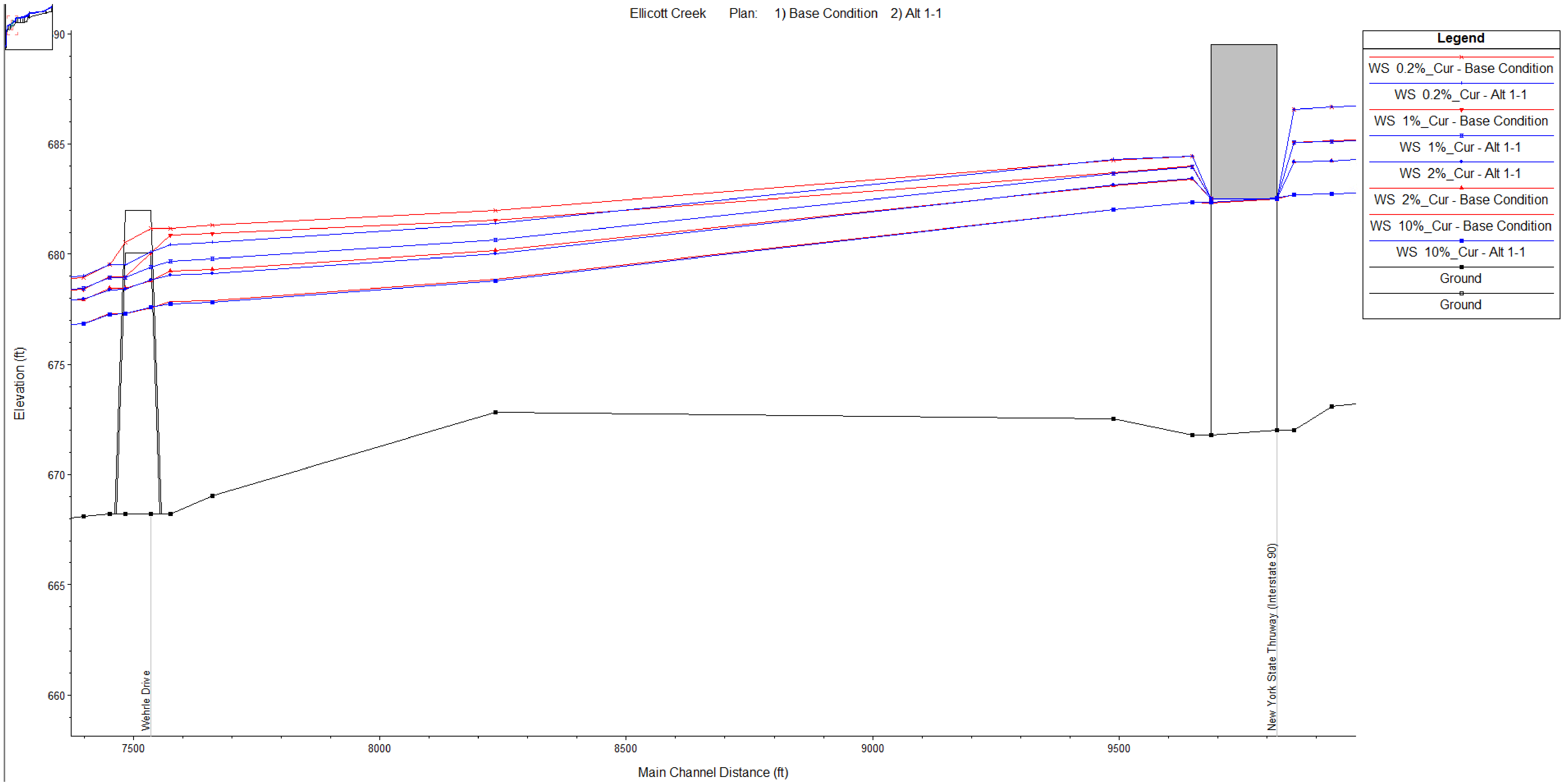


Figure 18. HEC-RAS Model Simulation Output Results for Alternative #1-1



Alternative #1-2: Flood Bench Creation Between Island Park and Wehrle Drive (Station 14+75 to 33+62)

The inundation extents for the effective FEMA FIRM indicates extensive residential and street flooding along Ellicott Creek in the Village of Williamsville upstream of the Main Street (Route 5) Bridge, particularly in the Lehn Springs Drive and Cadman Drive Neighborhoods. The floodplain corridor through this area has been encroached upon by urban development, which has reduced the capacity of the floodplain to contain flood waters. In addition, the Ellicott Creek Dam just upstream of Main Street (Route 5) serves as a significant hydraulic control, backing up flow during high and low flow events. During public outreach, it was noted that debris jams were an issue in this area.

This potential flood mitigation alternative is intended to provide additional flow area in the overbank, through construction of multiple flood benches extending approximately 2,000 feet from just upstream of Island Park. For this alternative, the left overbank just upstream of Island Park was lowered by approximately two feet for a width of up to 180 feet and a length of approximately 870 feet. In addition, approximately 1,650 feet upstream of Island Park the right overbank was lowered by approximately two feet for a width of up to 155 feet and a length of approximately 330 feet. Flood bench creation for this alternative would result in the removal of approximately 16,400 cubic yards of material. Figure 19 depicts the conceptual extents of this alternative.

Figure 20 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #1-2 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in water surface elevation reductions extending from approximately 400 feet upstream of Island Park to just upstream of the NYS Thruway (Interstate 90). Water surface elevation reductions under current discharges are computed to be as much as 0.8 ft for the 10% and 2% ACE discharges, 0.7 ft for the 1% ACE discharge, and 0.6 ft for the 0.2% ACE discharge. Similar results, relative to the extent and magnitude of water surface elevation reductions, were found under this alternative for the projected future discharges. Reductions under projected future discharges are computed to be as much as 0.8 ft for the 10% ACE discharge, 1.3 ft for the 2% ACE discharge, 0.7 ft for the 1% ACE discharge, and 0.6 ft for the 0.2% ACE discharge.

The Rough Order Magnitude cost is $1.8 million, which does not include land acquisition costs other than survey, appraisal, and engineering coordination.

Figure 19. Location Map for Alternative #1-2

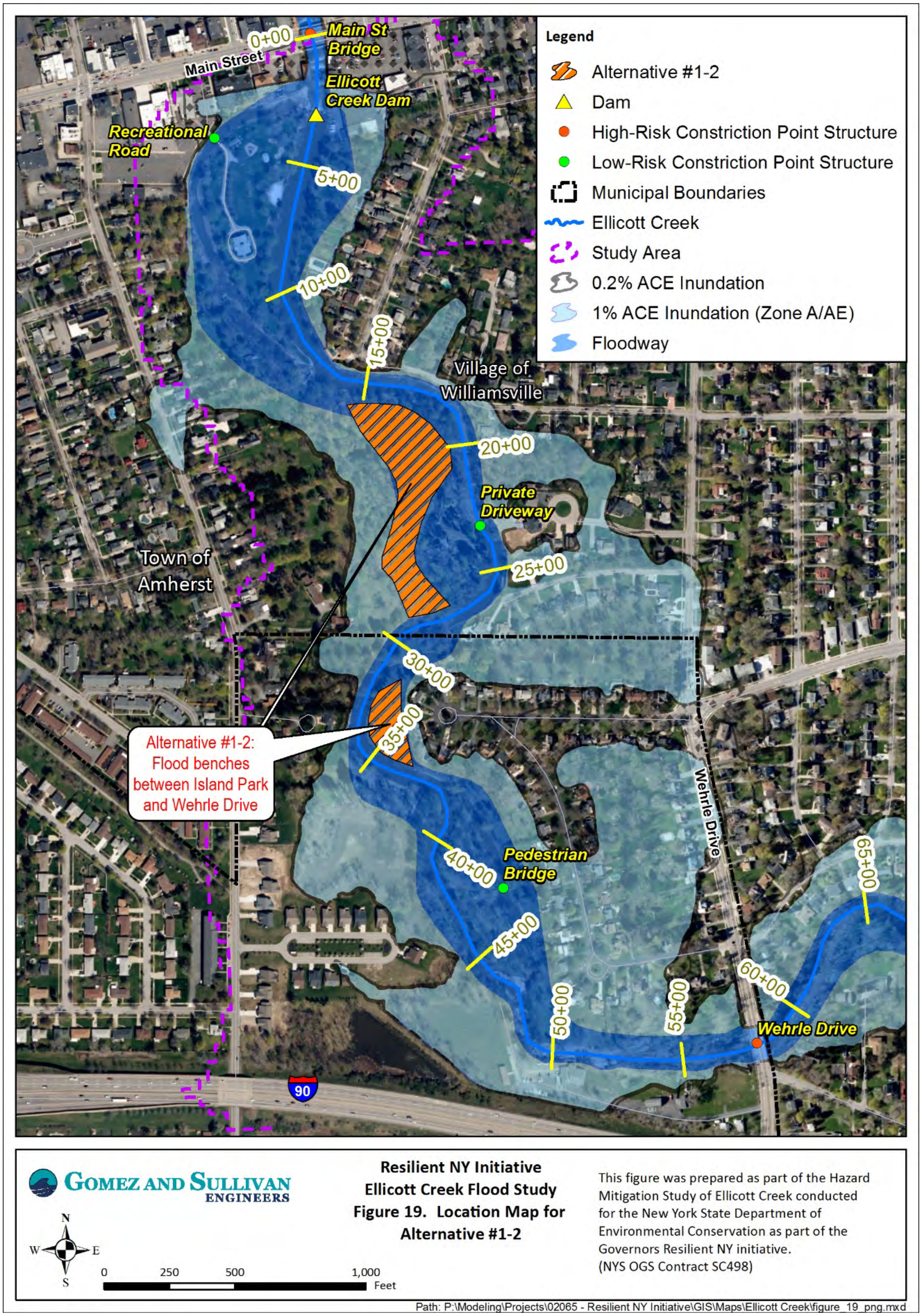
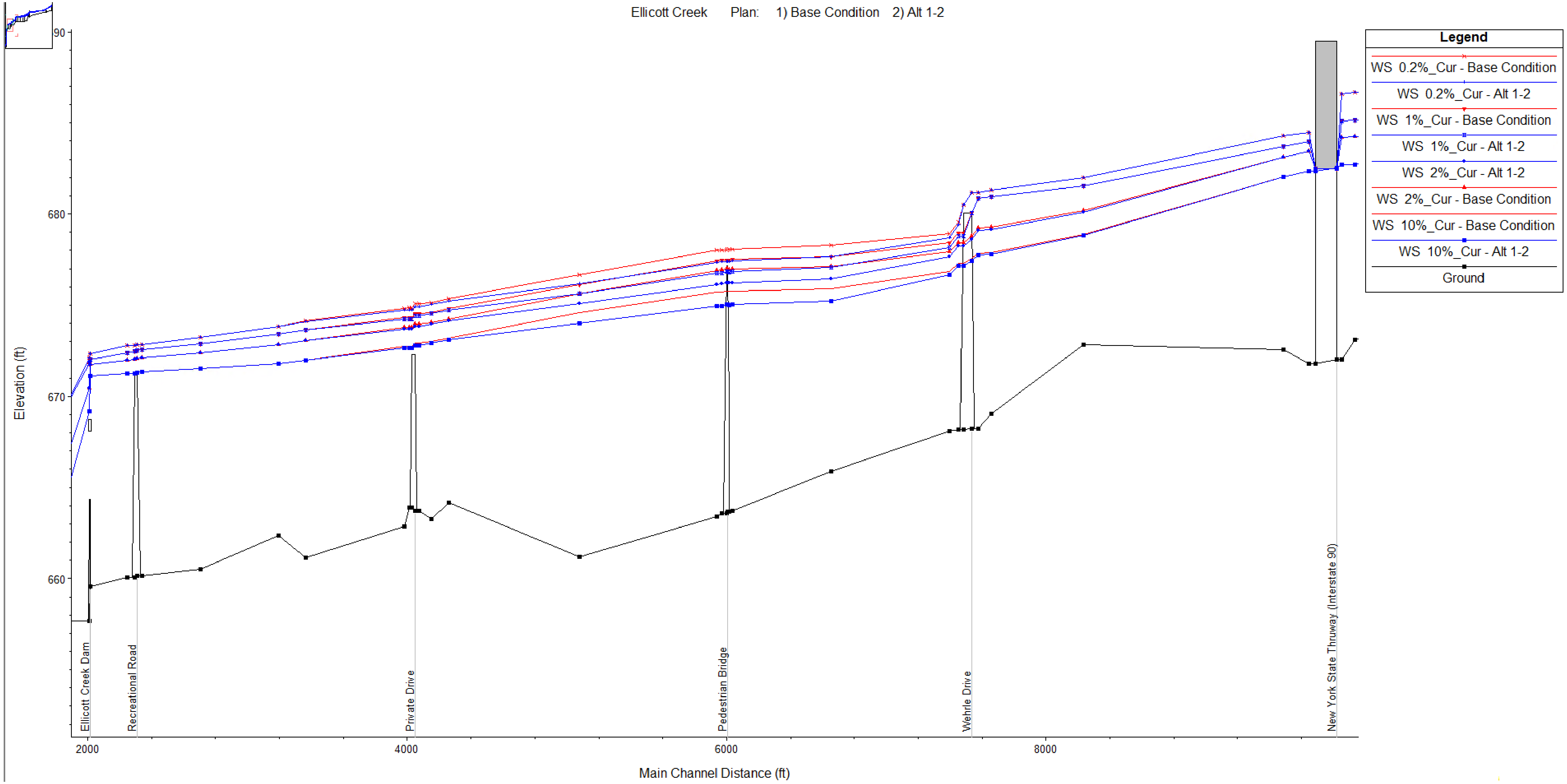


Figure 20. HEC-RAS Model Simulation Output Results for Alternative #1-2



Alternative #1-3: Modify Wehrle Drive Bridge and Flood Bench Creation Between Island Park and Wehrle Drive (Station 14+75 to 57+90)

In order to evaluate the potential cumulative effects of instituting both Alternative 1-1 and 1-2, the two previous alternatives were combined for this alternative.

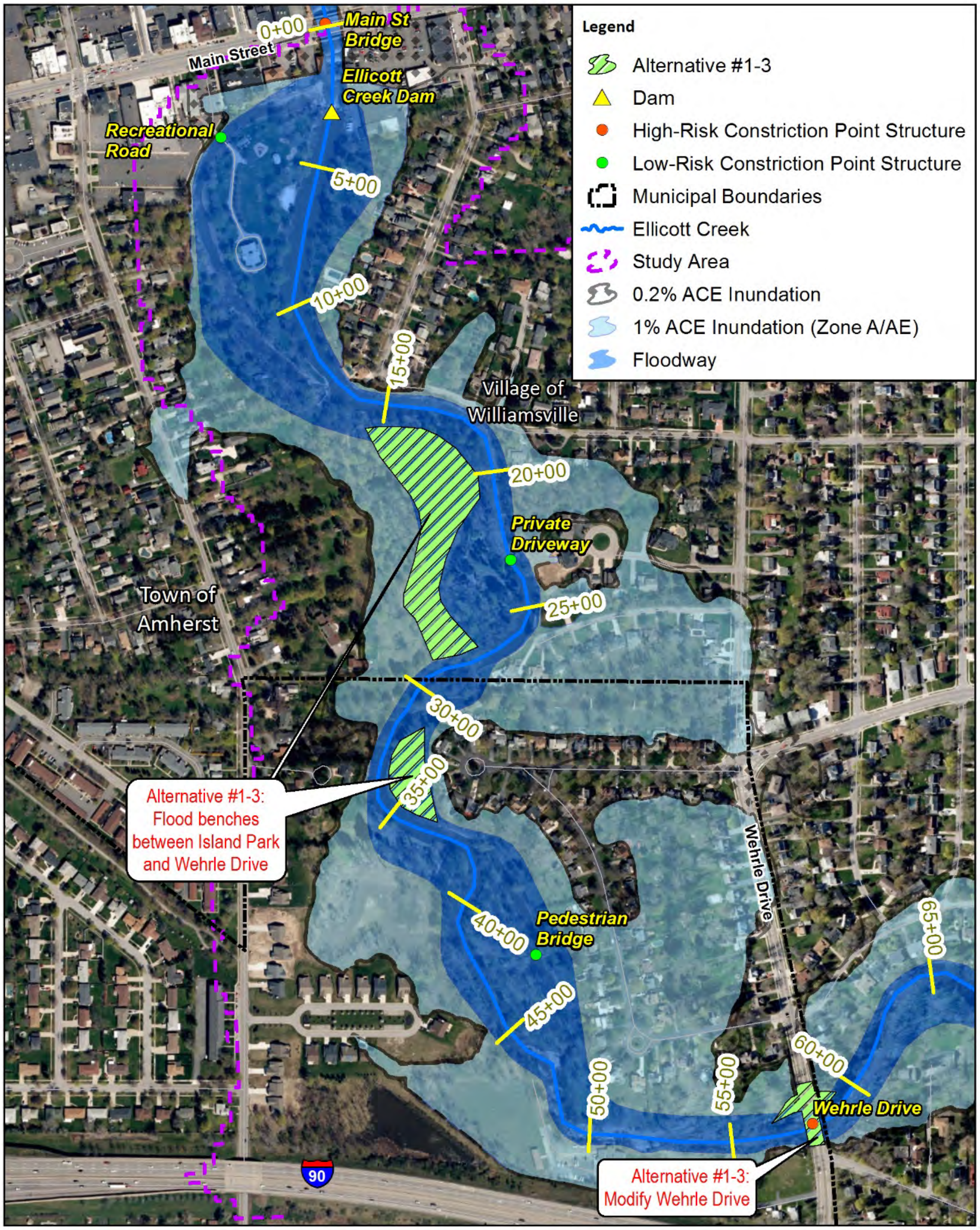
This potential flood mitigation alternative is intended to provide additional flow area through the Wherle Drive Bridge by widening the bridge by 50 feet and raising the low chord by 2 feet. The proposed bridge would extend the opening to the north (right of bank). In order to facilitate flow through the new bridge opening, a small flood bench would be constructed, extending from 60 feet upstream of the upstream face of the bridge to 100 feet downstream of the downstream face of the bridge. The existing topography was lowered by approximately 2 feet for a width of approximately 50 feet on the right overbank.

In addition to the Werhle Drive modifications, this alternative is intended to provide additional flow area in the overbank through construction of multiple flood benches extending approximately 2,000 feet from just upstream of Island Park. For this alternative, the left overbank just upstream of Island Park was lowered by approximately two feet for a width of up to 180 feet and a length of approximately 870 feet. In addition, approximately 1,650 feet upstream of Island Park the right overbank was lowered by approximately two feet for a width of up to 155 feet and a length of approximately 330 feet. Flood bench creation for this alternative would result in the removal of approximately 16,400 cubic yards of material. Figure 21 depicts the conceptual extents of this alternative.

Figure 22 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #1-3 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in water surface elevation reductions extending approximately 400 feet upstream of Island Park to approximately 260 feet downstream of the NYS Thruway (Interstate 90). Water surface elevation reductions under current discharges are computed to be as much as 0.8 ft for the 10% and 2% ACE discharges, 1.3 ft for the 1% ACE discharge, and 0.9 ft for the 0.2% ACE discharge. Similar results, relative to the extent and magnitude of water surface elevation reductions, were found under this alternative for the projected future discharges. Reductions under projected future discharges are computed to be as much as 0.8 ft for the 10% ACE discharge, 1.5 ft for the 2% ACE discharge, 1.1 ft for the 1% ACE discharge, and 0.6 ft for the 0.2% ACE discharge.

The Rough Order Magnitude cost is $7.8 million, which does not include land acquisition costs other than survey, appraisal, and engineering coordination.

Figure 21. Location Map for Alternative #1-3



GOMEZ AND SULLIVAN ENGINEERS

N E S W

0 250 500 1,000 Feet

Resilient NY Initiative
Ellicott Creek Flood Study
Figure 21. Location Map for Alternative #1-3

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

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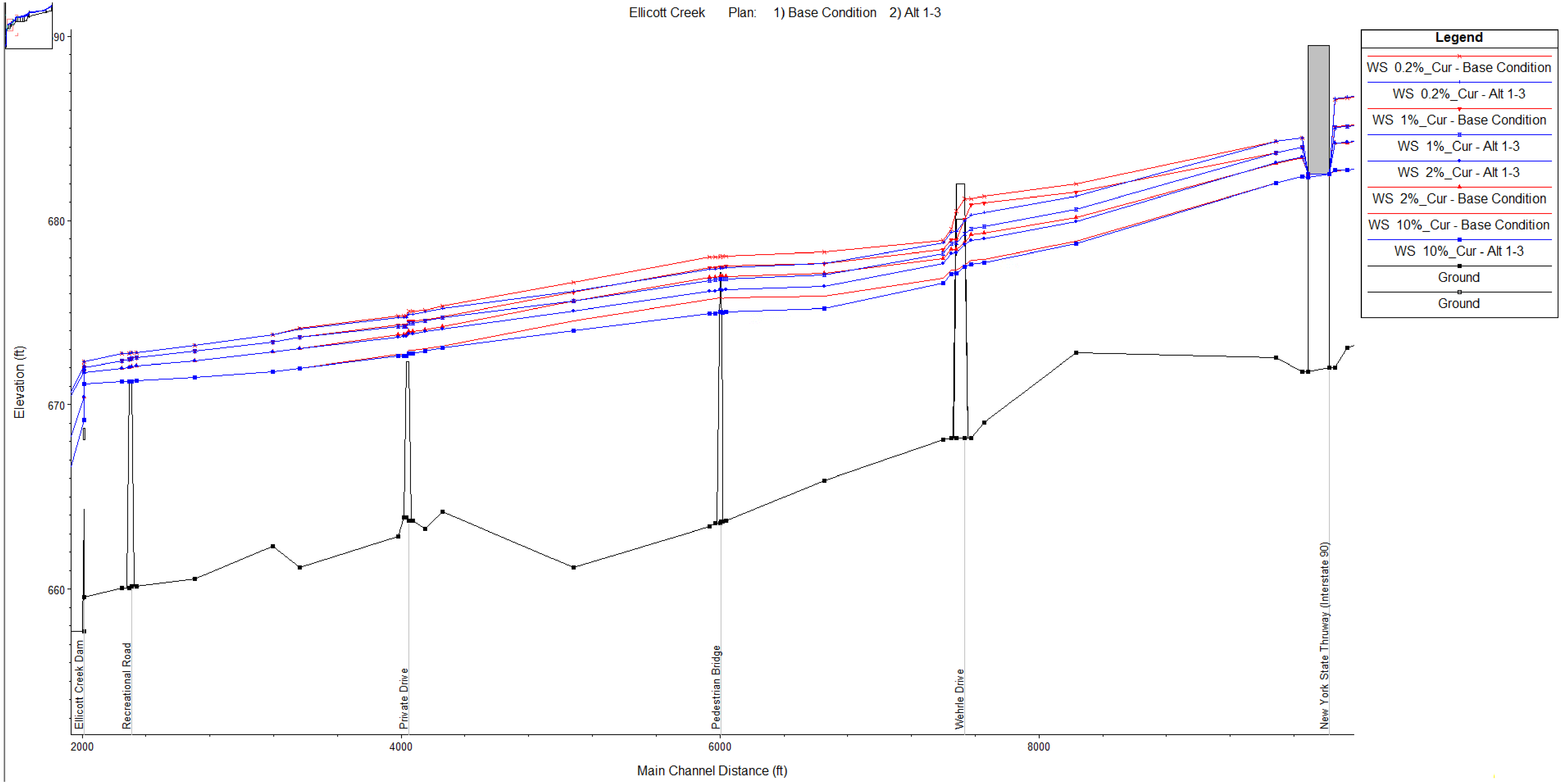
Figure 22. HEC-RAS Model Simulation Output Results for Alternative #1-3



High Risk Area #2: Upstream of Greater Buffalo International Airport (Station 141+34 to 262+71)

Alternative #2-1: Modify Railroad Bridge (Station 197+31)

The water surface profiles for the effective FEMA FIS indicates that the Railroad Bridge at Station 197+31 causes an increase in water surface elevations of 2-3 feet upstream of the bridge for all the modeled discharges. The existing bridge opening is 88 feet, which is significantly less than the bankfull width of around 99 feet, according to *StreamStats*. The railway embankment extends across approximately 1,300 feet of the Ellicott Creek floodplain, as observed from LiDAR ground elevation data. In addition, it appears that a length of approximately 780 feet of the channel was formerly straightened for construction of the railway bridge and embankment. The Railroad is no longer an active railway and has been converted to a pedestrian trail.

This potential flood mitigation alternative is intended to provide additional flow area through the bridge by widening the bridge from 88 to 150 feet, and by raising the low chord by three feet. As part of the bridge replacement, a portion of the railway embankment would also be removed in order to create a small floodplain bench at elevation 688 ft (NAVD88) under the extended bridge opening, on the left overbank. The flood bench would be up to 80 feet wide and 230 feet long, resulting in the removal of approximately 2,250 cubic yards of material. Figure 23 depicts the conceptual extents of this alternative.

Figure 24 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #2-1 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in water surface elevation reductions extending from just downstream of the Railroad Bridge to approximately 450 feet upstream of Genesee Street (State Route 33). Water surface elevation reductions under current discharges are computed to be as much as 0.2 ft for the 10% ACE discharge, 0.5 ft for the 2% ACE discharge, 0.8 ft for the 1% ACE discharge, and 0.4 ft for the 0.2% ACE discharge. Similar results, relative to the extent and magnitude of water surface elevation reductions, were found under this alternative for the projected future discharges. Reductions under projected future discharges are computed to be as much as 0.2 ft for the 10% ACE discharge, 0.7 ft for the 2% ACE discharge, 0.6 ft for the 1% ACE discharge, and 0.4 ft for the 0.2% ACE discharge.

The Rough Order Magnitude cost $1.1 million, which does not include land acquisition costs other than survey, appraisal, and engineering coordination.

Figure 23. Location Map for Alternative #2-1

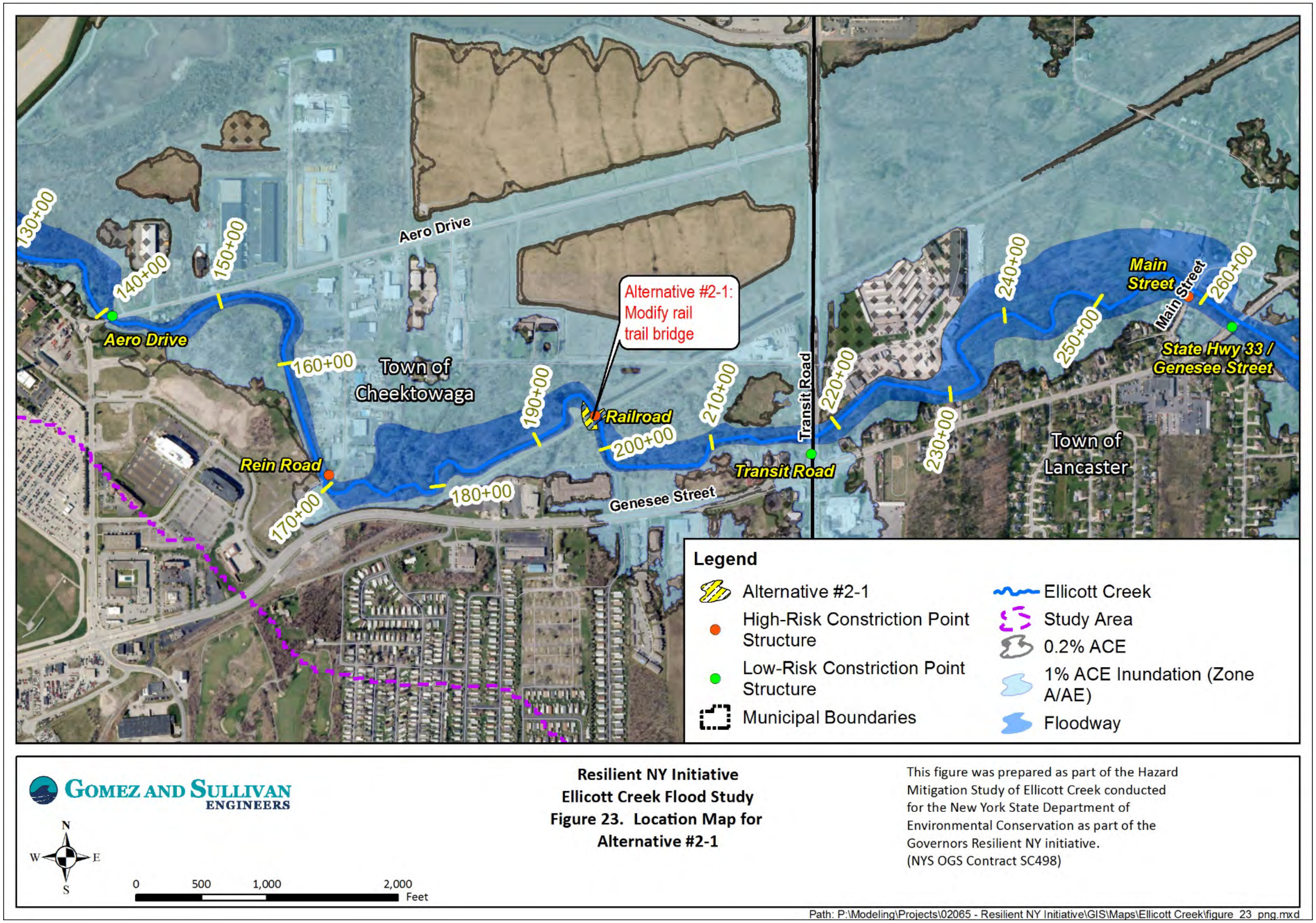
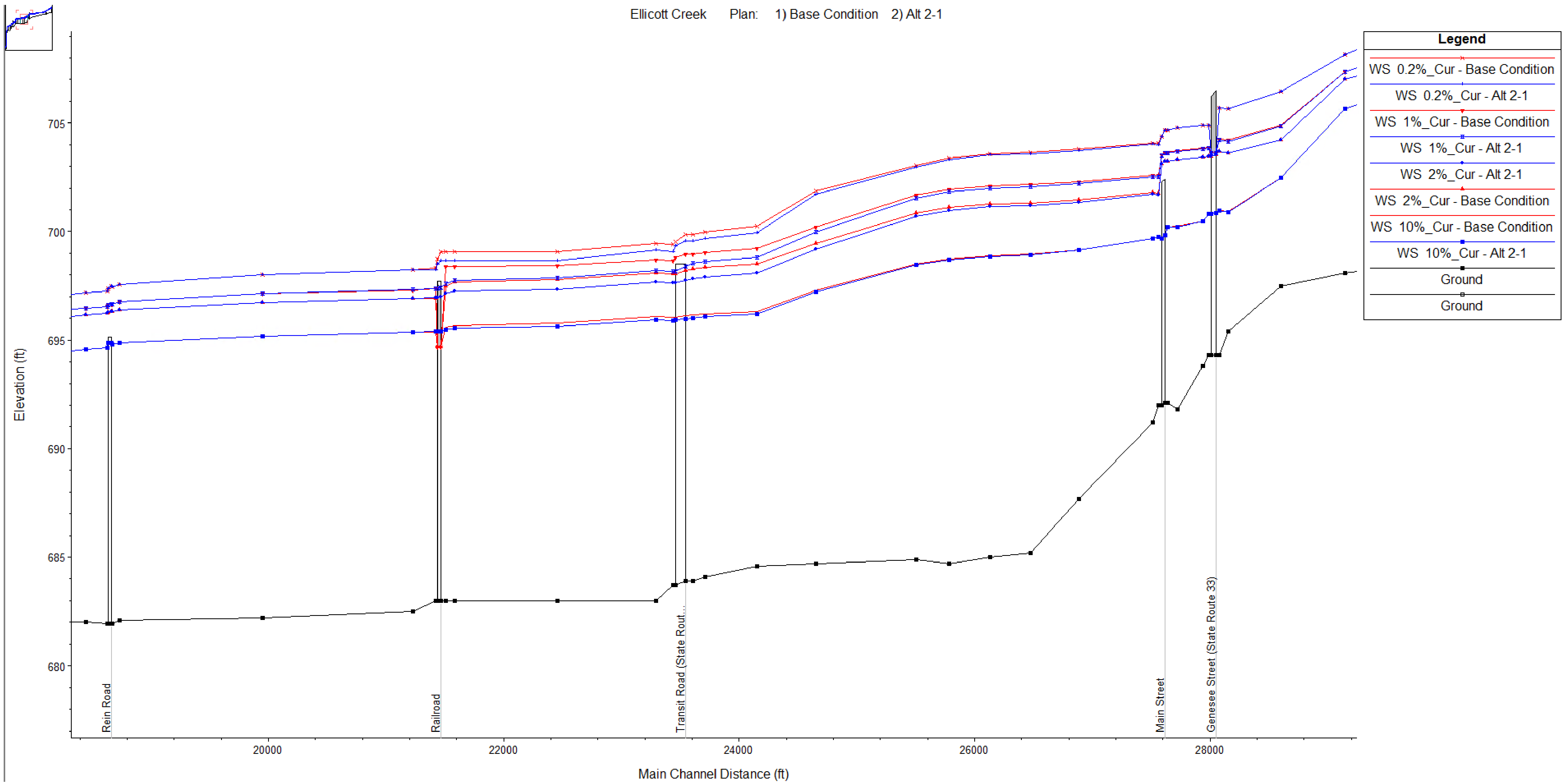


Figure 24. HEC-RAS Model Simulation Output Results for Alternative #2-1



Alternative #2-2: Flood Bench Creation Between Rein and Transit Roads (Station 198+65 to 217+23)

The inundation extents for the effective FEMA FIRM indicates extensive flooding of commercial properties and streets in the area between Rein Road and Transit Road in the Town of Cheektowaga. Review of LiDAR ground elevation data for this area shows encroachment of the Ellicott Creek floodplain downstream and upstream of the Transit Road Bridge, which causes a significant constriction for flood waters. Downstream of Transit Road, due to past development, the channel has no access to the floodplain for a length of approximately 600 feet along Ellicott Creek.

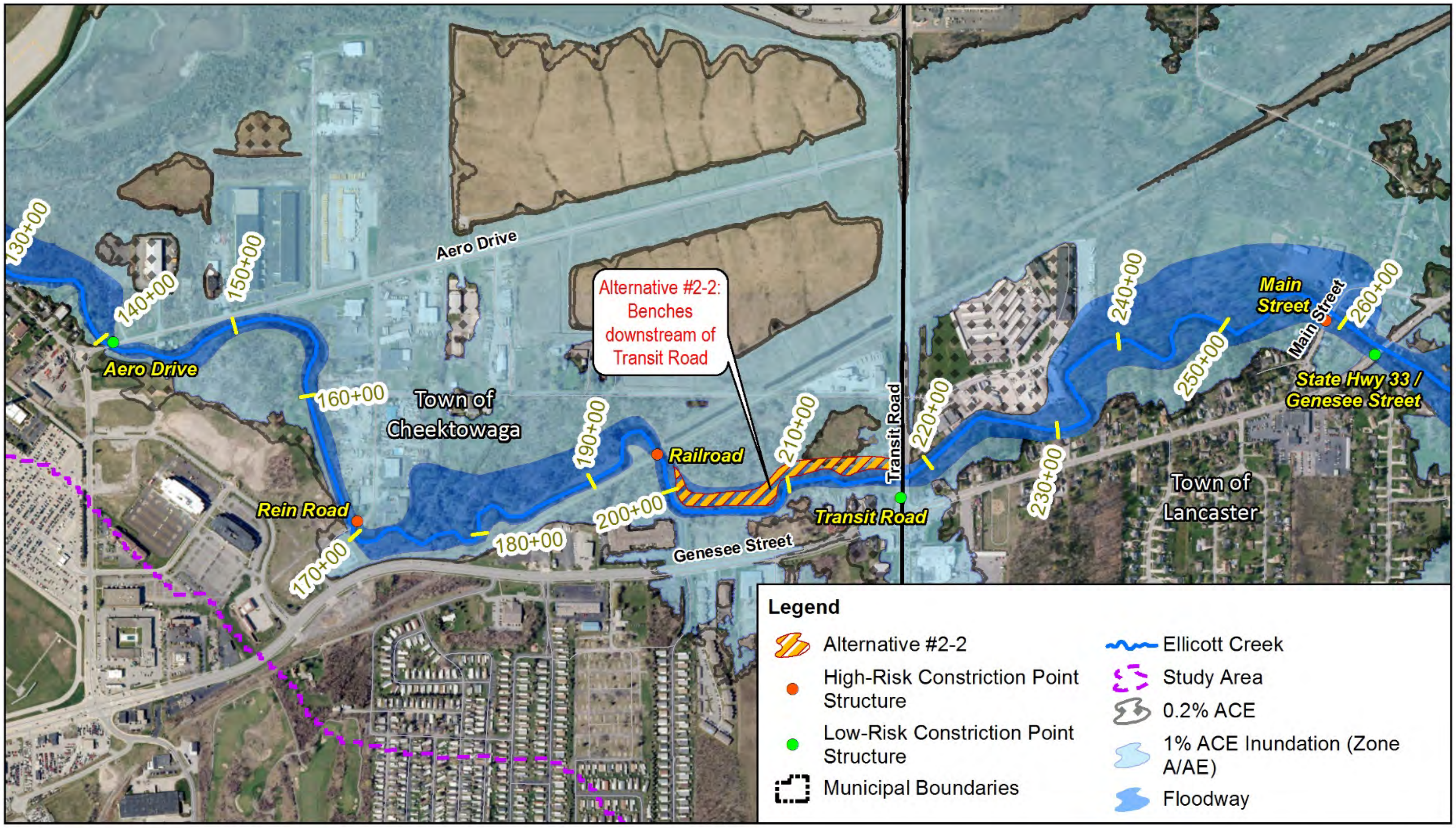
This potential flood mitigation alternative is intended to provide flow area in the overbank through construction of a flood bench in the right (north) overbank along 1,900 feet of Ellicott Creek. The existing topography was lowered by approximately 1.5 to 7 feet for this alternative to an elevation between approximate bankfull and 10% ACE water surface elevations, resulting in the removal of approximately 15,900 cubic yards of material. Figure 25 depicts the conceptual extents of this alternative.

Figure 26 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #2-2 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in water surface elevation reductions extending from approximately 50 feet downstream of the Railroad Bridge to approximately 550 feet upstream of Transit Road (State Route 78). Water surface elevation reductions under current discharges are computed to be as much as 0.1 ft for the 2% and 1% ACE discharges, no water surface reductions were computed for the other ACE discharges. Similar results, relative to the extent and magnitude of water surface elevation reductions, were found under this alternative for the projected future discharges. Reductions under projected future discharges are computed to be as much as 0.1 ft for the 10% and 2% ACE discharges, no water surface reductions were computed for the 1% and 0.2% ACE discharges.

This strategy is not recommended because the modeled water surface elevation reductions were small (0.1 ft or less for all modeled discharges) and therefore the benefits do not justify the costs of this alternative.

The Rough Order Magnitude cost is $1.5 million, which does not include land acquisition costs other than survey, appraisal, and engineering coordination.

Figure 25. Location Map for Alternative #2-2



GOMEZ AND SULLIVAN ENGINEERS

N W E S

0 500 1,000 2,000 Feet

Resilient NY Initiative
Ellicott Creek Flood Study
Figure 25. Location Map for Alternative #2-2

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

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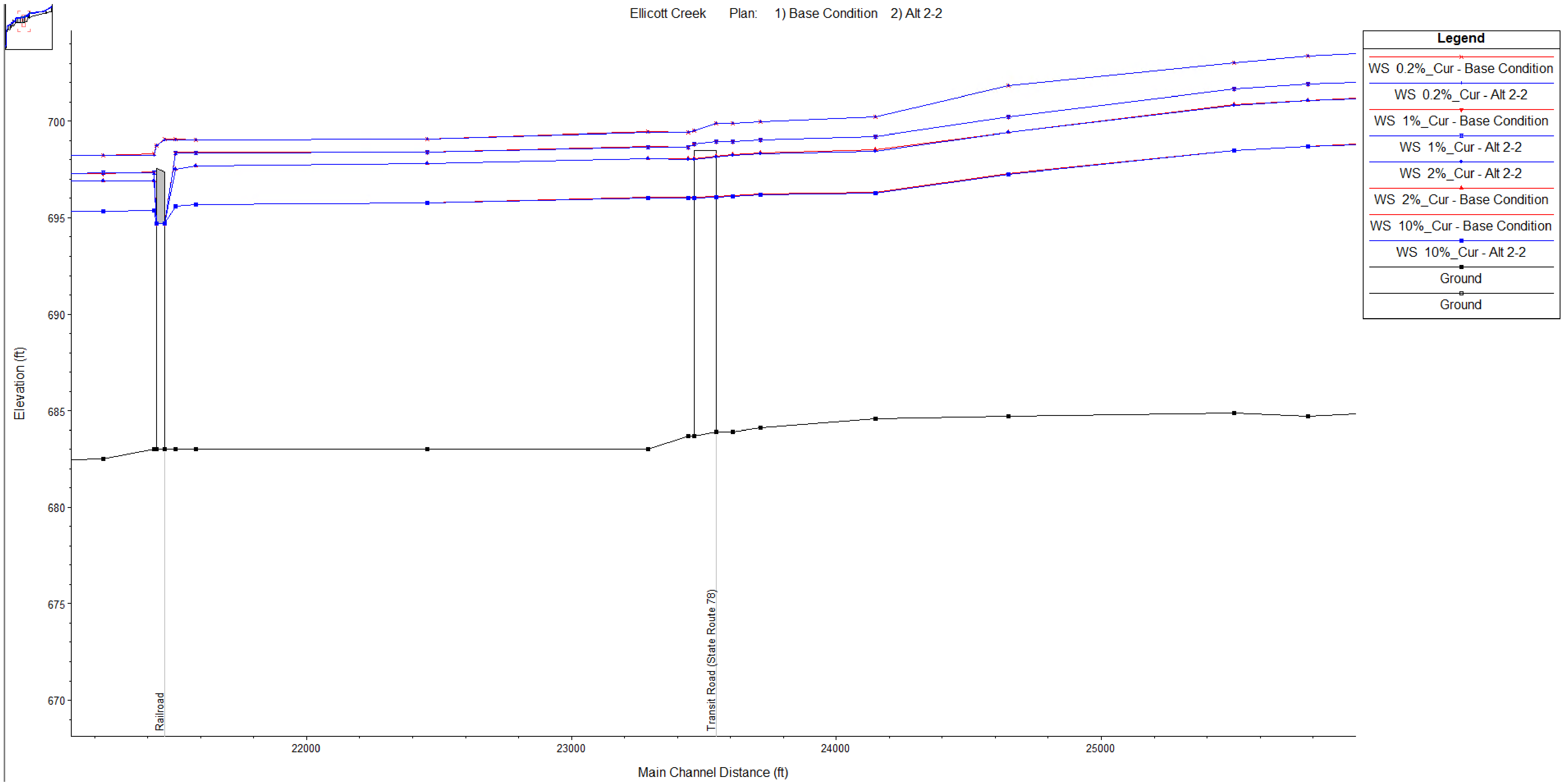
Figure 26. HEC-RAS Model Simulation Output Results for Alternative #2-2



Alternative #2-3: Flood Bench Creation Between Transit Road and Main Street (Bowmansville) (Station 237+86 to 257+95)

The inundation extents for the effective FEMA FIRM indicates extensive flooding of commercial and residential properties and streets between Transit Road and Genesee Street in the Town of Lancaster. In addition, the Bowmansville Fire Station is located within the 1% ACE floodplain.

This potential flood mitigation alternative is intended to provide additional flow area in the overbanks through construction of multiple flood benches along approximately 1,900 feet of Ellicott Creek just downstream of Main Street. The existing topography was lowered by approximately one to three feet for a width of up to 300 feet on the left and right overbanks, resulting in the removal of approximately 47,700 cubic yards of material. Figure 27 depicts the conceptual extents of this alternative.

Figure 28 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #2-3 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in water surface elevation reductions extending from approximately 50 feet downstream of the Railroad Bridge to approximately 450 feet upstream of Genesee Street (State Route 33). Water surface elevation reductions under current discharges are computed to be as much as 0.4 ft for the 10% and 1% ACE discharges and 0.3 ft for the 2% and 0.2% ACE discharges. Similar results, relative to the extent and magnitude of water surface elevation reductions, were found under this alternative for the projected future discharges. Reductions under projected future discharges are computed to be as much as 0.4 ft for the 10% and 2% ACE discharges and 0.3 ft for the 1% and 0.2% ACE discharges.

The Rough Order Magnitude cost is $3.7 million, which does not include land acquisition costs other than survey, appraisal, and engineering coordination.

Figure 27. Location Map for Alternative #2-3

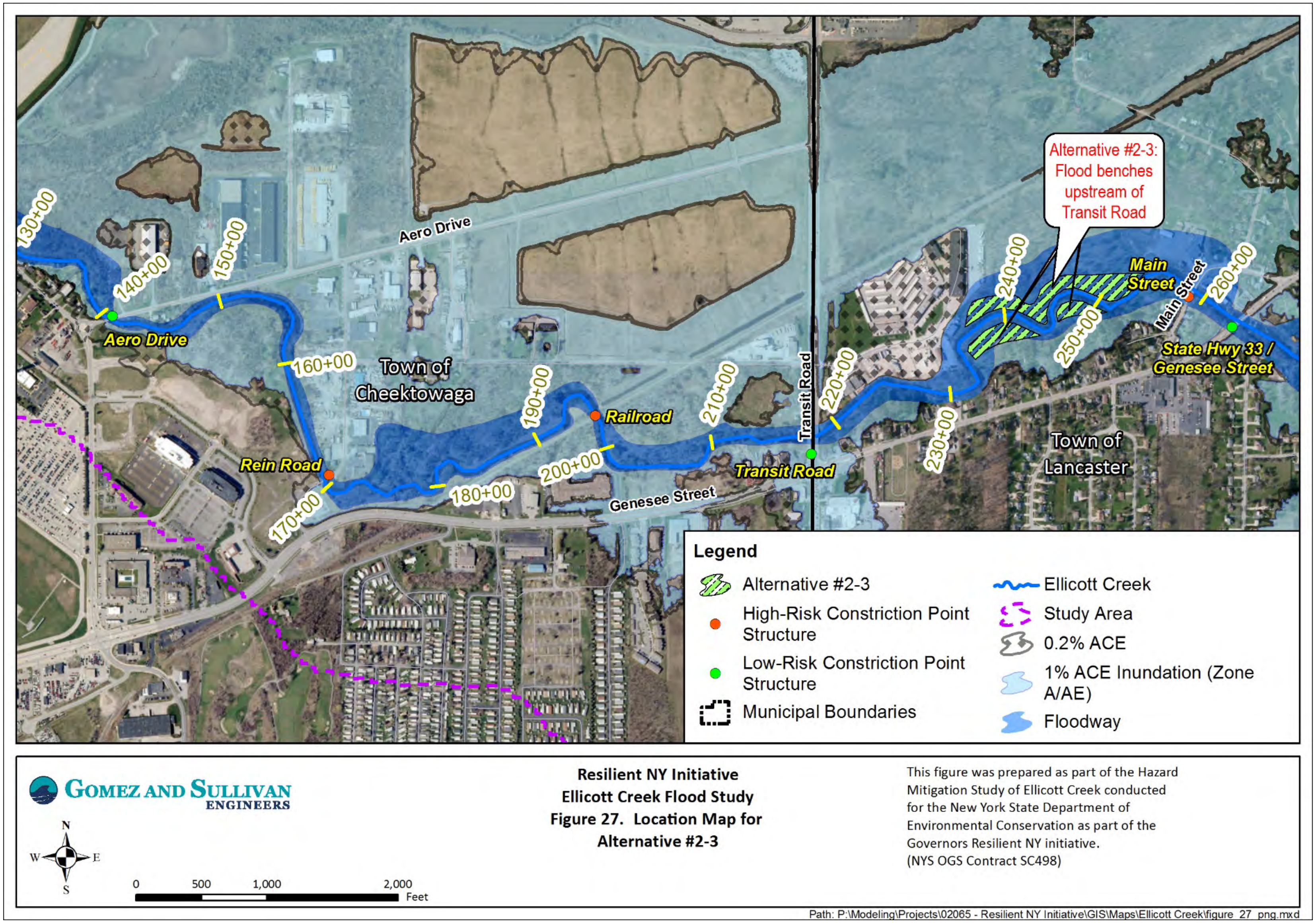
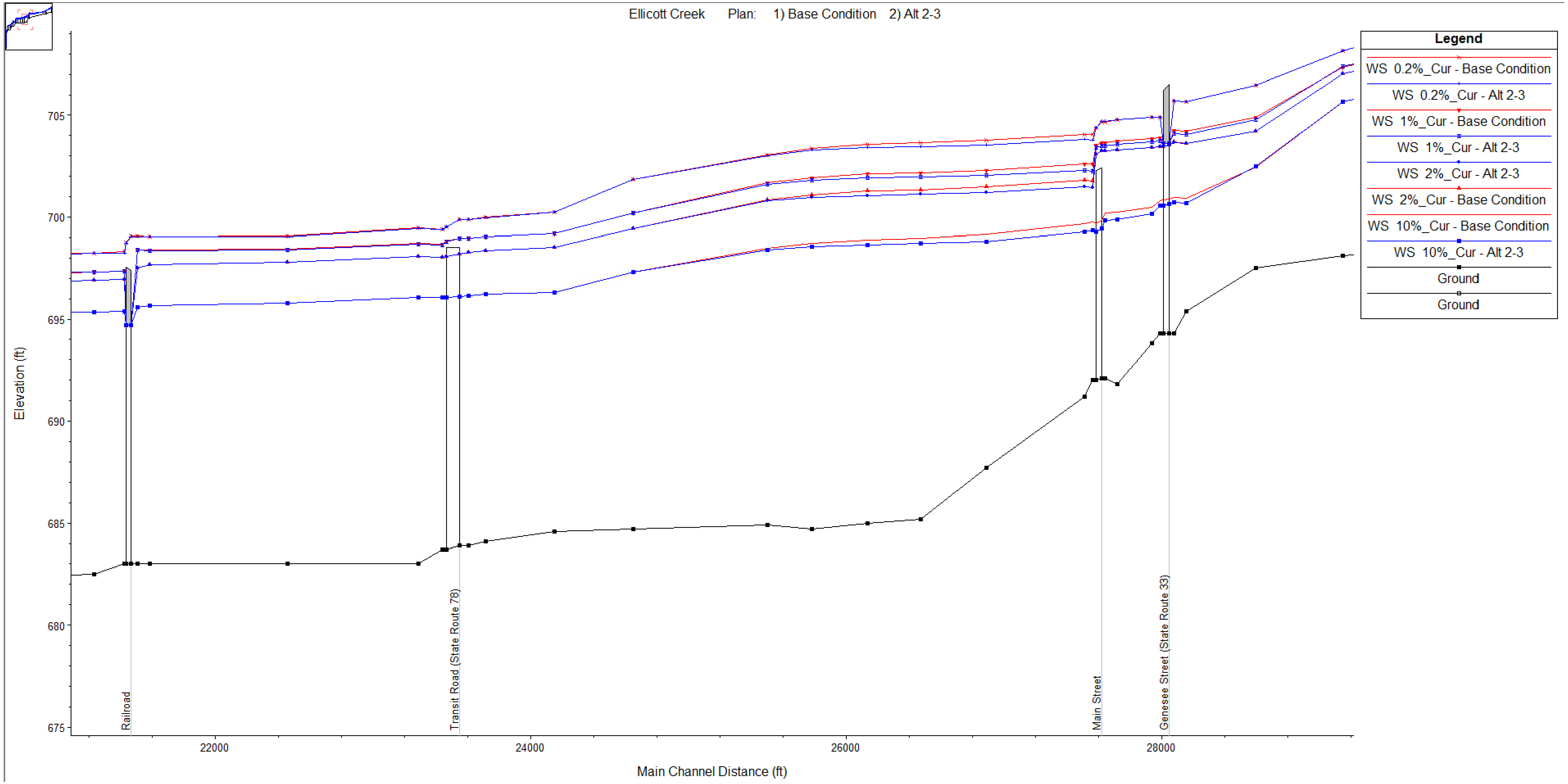


Figure 28. HEC-RAS Model Simulation Output Results for Alternative #2-3



Alternative #2-4: Modify Airport Runway Culverts (Station 116+70)

Ellicott Creek passes under on of the runways of the Buffalo Niagara International Airport through three equal sized arch culverts. The water surface profiles for the effective FEMA FIS indicate that the flow capacity of the three culverts causes an increase in water surface elevations of 2-3 feet upstream for all the modeled discharges, and the inundation extents for the effective FEMA FIRM indicate that extensive commercial and street flooding occurs upstream of the constriction caused by the Airport Runway. The hydraulic width of the culverts, approximately 60 feet in total, is much less than the bankfull width of around 99 feet, according to *StreamStats*.

The Airport Runway extends more than 3,000 feet across the entire floodplain of Ellicott Creek, and serves as a significant hydraulic control on Ellicott Creek, backing up floodwaters through the Risk Area and spreading flood waters to a signicantly greater width as compared to downstream of the culverts. Up-sizing the culverts to greater than the bankfull width of approximately 99 feet would help to reduce flooding upstream significantly. However, due to the cost necessary to modify the structure and the resulting disturbance to airport operations, this alternative is considered unfeasible and was not evaluated further.

Figure 29 depicts the conceptual extents of this alternative.

Figure 29. Location Map for Alternative #2-4

GOMEZ AND SULLIVAN ENGINEERS

N W E S

0 500 1,000 2,000 Feet

Resilient NY Initiative
Ellicott Creek Flood Study
Figure 29. Location Map for Alternative #2-4

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

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High Risk Area #3: Stoney Road in The Town of Lancaster (Station 458+18 to 566+04)

Alternative #3-1: Flood Bench Creation Between Harris Hill and Stoney Roads (Station 287+69 to 490+90)

The inundation extents for the effective FEMA FIRM indicates residential and street flooding between Harris Hill and Stoney Roads in the Town of Lancaster. An extensive forested wetland floodplain already exists through this area, which is up to 3,500 feet wide along over 20,000 feet of Ellicott Creek. There is a natural constriction at Harris Hill Road just downstream of the extensive wooded floodplain, and the bridge at Harris Hill Road further constricts flood waters down to 138 feet wide. At the upstream end of the extensive wooded wetland, Stoney Road runs north-south through a low-lying area adjacent to the wetlands. The Stoney Road Bridge was recently replaced in 2018 with a larger-sized opening bridge, however the baseline condition model with the new Stoney Road Bridge incorporated indicated that all of the modeled flows overtop Stoney Road to the north of the bridge opening, flooding residences along Stoney Road.

This potential flood mitigation alternative is intended to facilitate flow through the constriction at Stoney Road by providing additional flow area in the overbanks downstream of the crossing. In addition, the lower floodplain elevation would provide a location for debris to safely collect during high flow events. For this alternative, multiple flood benches would be created from the downstream face of the Stoney Road Bridge to approximately 3,800 feet downstream of the bridge. The maximum width of the new flood benches would be around 280 feet and would lower the existing topography by approximately one foot. In addition, a second, lower elevation bench would be created by lowering existing topography an additional 1-1.5 feet for a width of around 30 to 50 feet. The lower elevation bench would serve to provide a smoother transition in flow area downstream of the bridge. Construction of the flood benches downstream of Stoney Road would result in the removal of approximately 58,100 cubic yards of material. Figure 30 depicts the conceptual extents of this alternative.

Figure 31 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #3-1 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in water surface elevation reductions extending from approximately 600 feet downstream of Stoney Road to approximately 1,250 feet upstream of Stoney Road. Water surface elevation reductions under current discharges are computed to be as much as 0.1 ft for the 10%, 2%, 1%, and 0.2% ACE discharges. Similar results, relative to the extent and magnitude of water surface elevation reductions, were found under this alternative for the projected future discharges. Reductions under projected future discharges are computed to be as much as 0.1 ft for the 10%, 2%, 1%, and 0.2% ACE discharges.

This strategy is not recommended because the modeled water surface elevation reductions were small (0.1 feet for all modeled discharges) and therefore the benefits do not justify the costs of this alternative.

The Rough Order Magnitude cost is $5.7 million, which does not include land acquisition costs other than survey, appraisal, and engineering coordination.

Figure 30. Location Map for Alternative #3-1

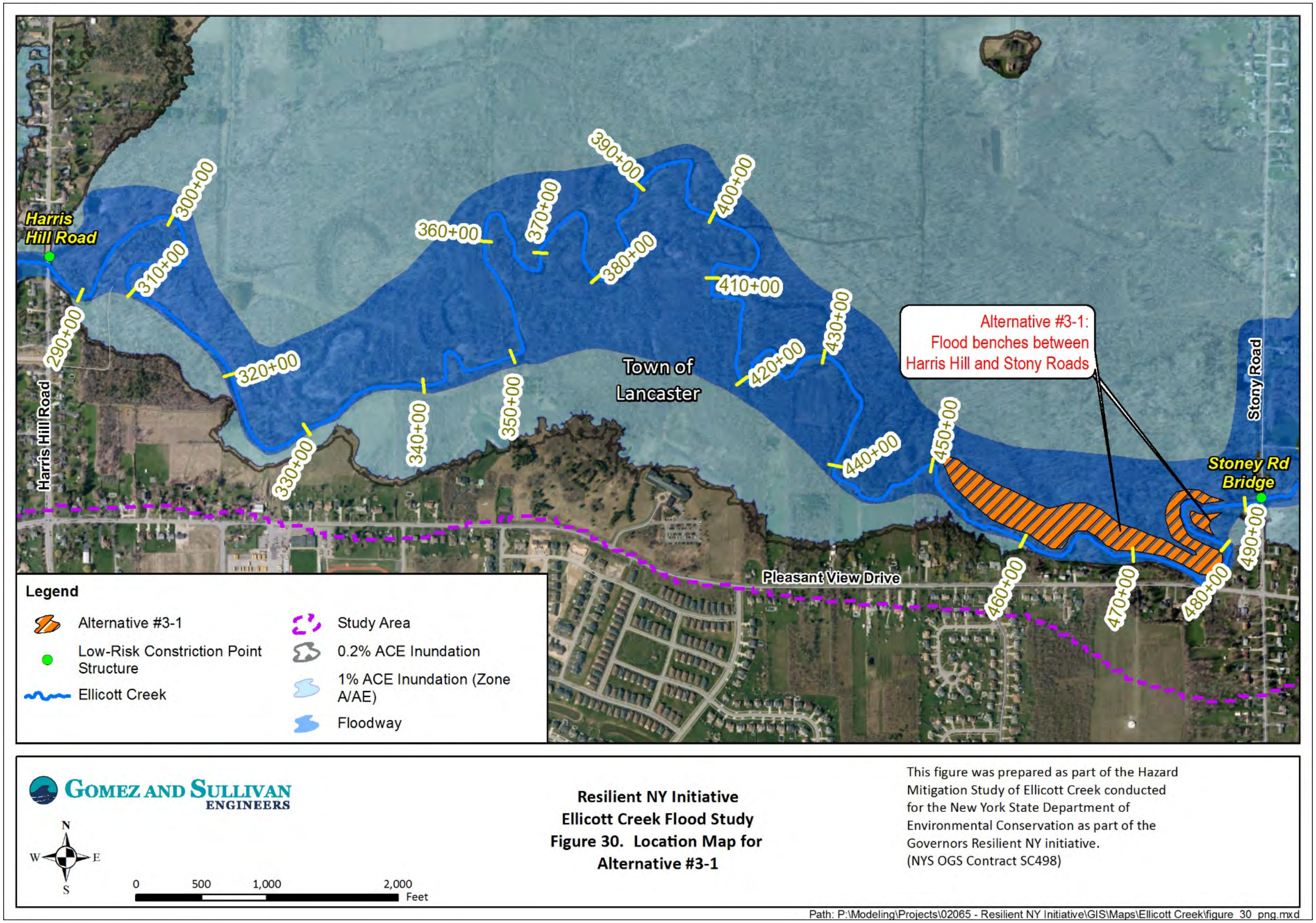
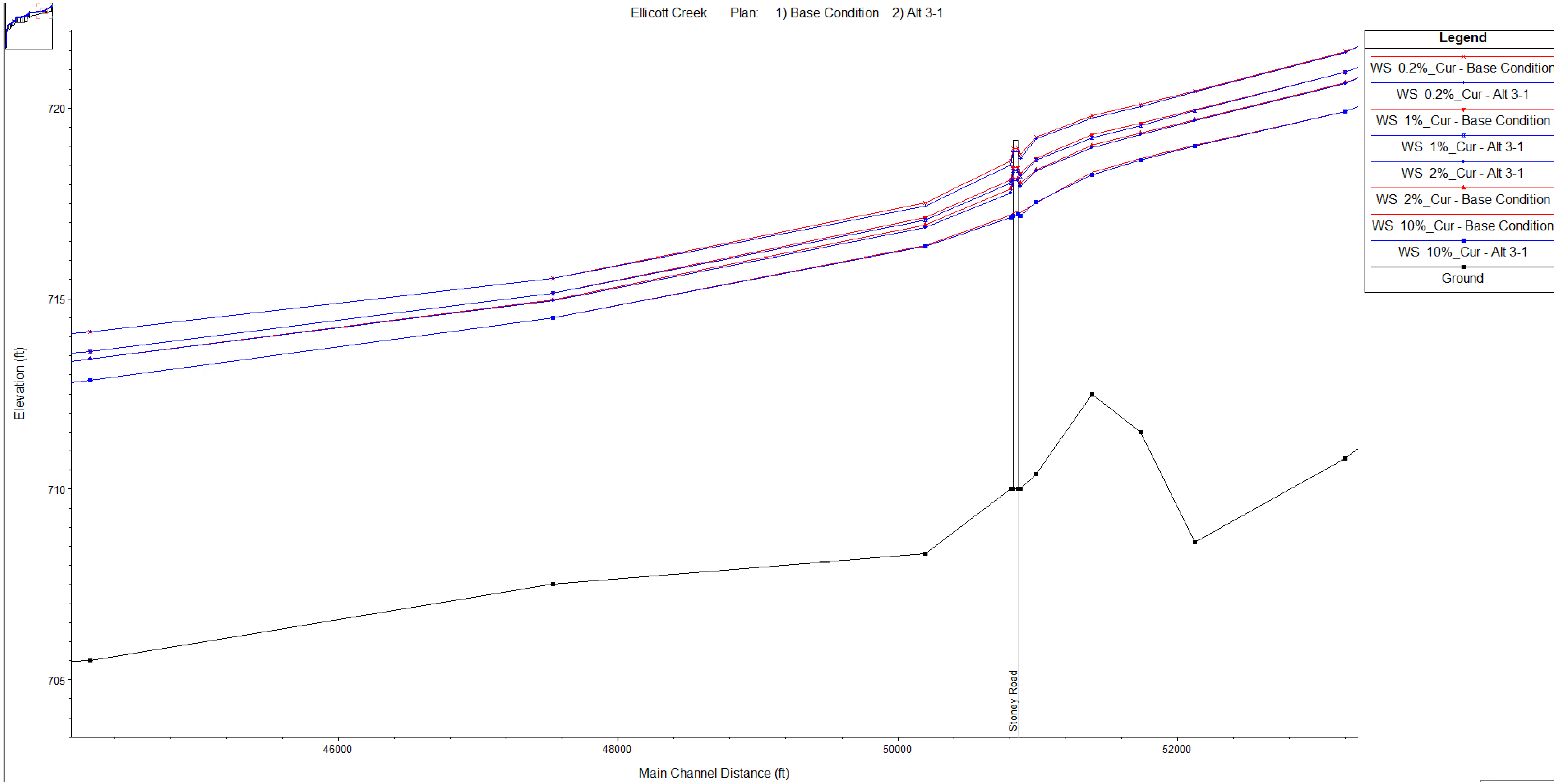


Figure 31. HEC-RAS Model Simulation Output Results for Alternative #3-1



Alternative #3-2: Flood Bench Creation Between Stoney and Pavement Roads (Station 514+81 to 565+53)

The inundation extents for the effective FEMA FIRM indicates residential and street flooding between Stoney Road and Pavement Road in the Town of Lancaster. New developments are located just south of Ellicott Creek, which are generally outside the 1% ACE floodplain but may be impacted by the 0.2% ACE. The stream appears to be entrenched in this area, with a channel depth of between seven and ten feet, compared to the bankfull depth of around three feet according to *StreamStats*. Additionally, during the community meeting, ice jamming was identified as an issue in the area of Stoney Road.

This potential flood mitigation alternative is intended to provide additional flow area in the overbanks through construction of multiple flood benches extending from just downstream of the Pavement Road Bridge to approximately 5,00 feet downstream of Pavement Road. The existing topography was lowered by two to three feet to create benches up to 250 feet wide on the left and right overbanks, resulting in the removal of approximately 87,500 cubic yards of material. Figure 32 depicts the conceptual extents of this alternative. This alternative would also provide area for shelving of ice during breakup events, reducing the potential for ice jamming downstream and would provide a location for debris to safely collect during high flow events.

Figure 33 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #3-2 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in water surface elevation reductions extending from approximately 4,750 feet downstream of Pavement Road to at least 50 feet upstream of Pavement Road (limit of detailed study). Water surface elevation reductions under current discharges are computed to be as much as 0.6 ft for the 10% ACE discharge, 1.2 ft for the 2% ACE discharge, and 0.6 ft for the 1% and 0.2% ACE discharges. Similar results, relative to the extent and magnitude of water surface elevation reductions, were found under this alternative for the projected future discharges. Reductions under projected future discharges are computed to be as much as 0.6 ft for the 10% and 2% ACE discharges, 0.7 ft for the 1% ACE discharge, and 0.6 ft for the 0.2% ACE discharge.

The Rough Order Magnitude cost is $7.3 million, which does not include land acquisition costs other than survey, appraisal, and engineering coordination.

Figure 32. Location Map for Alternative #3-2

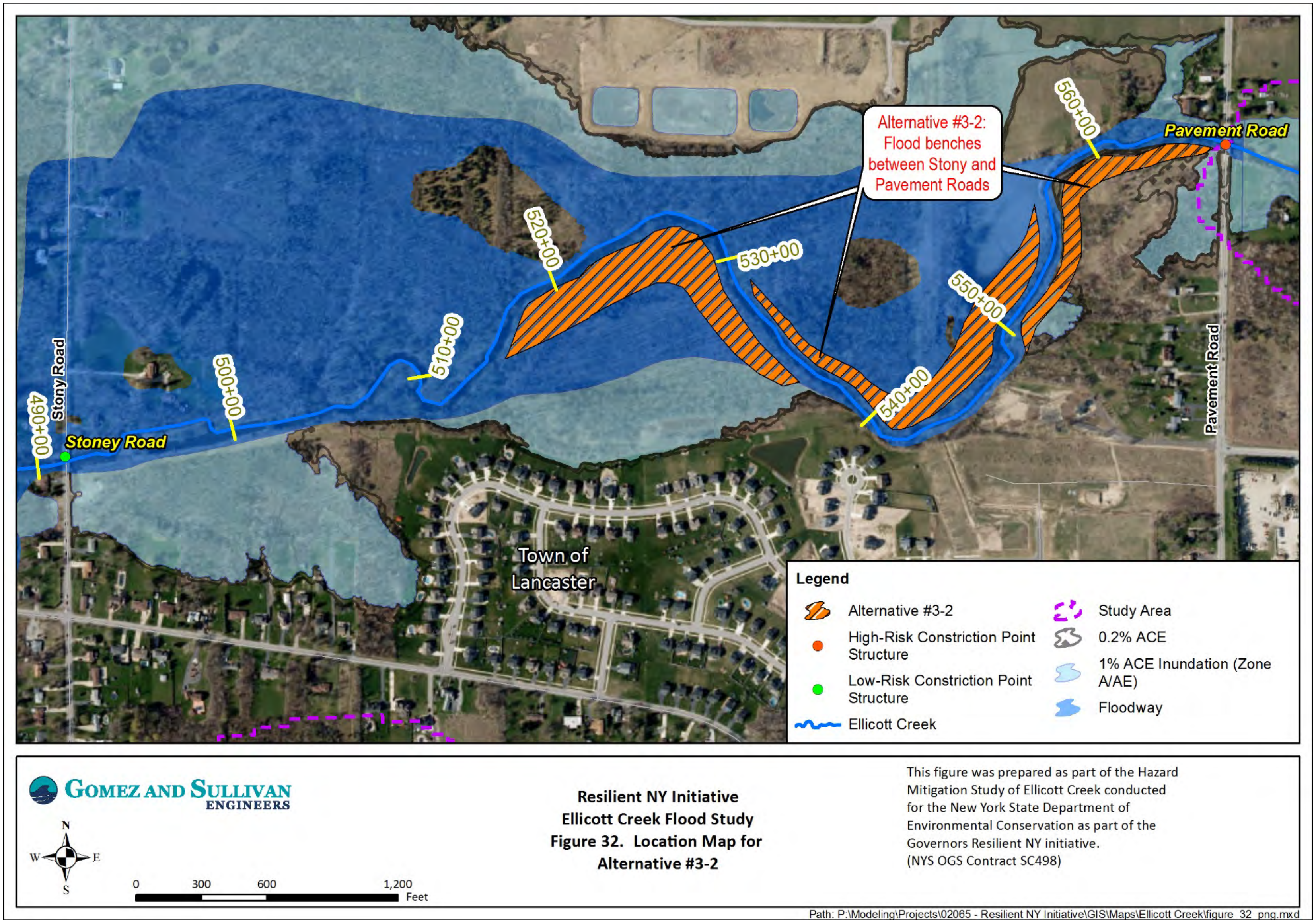
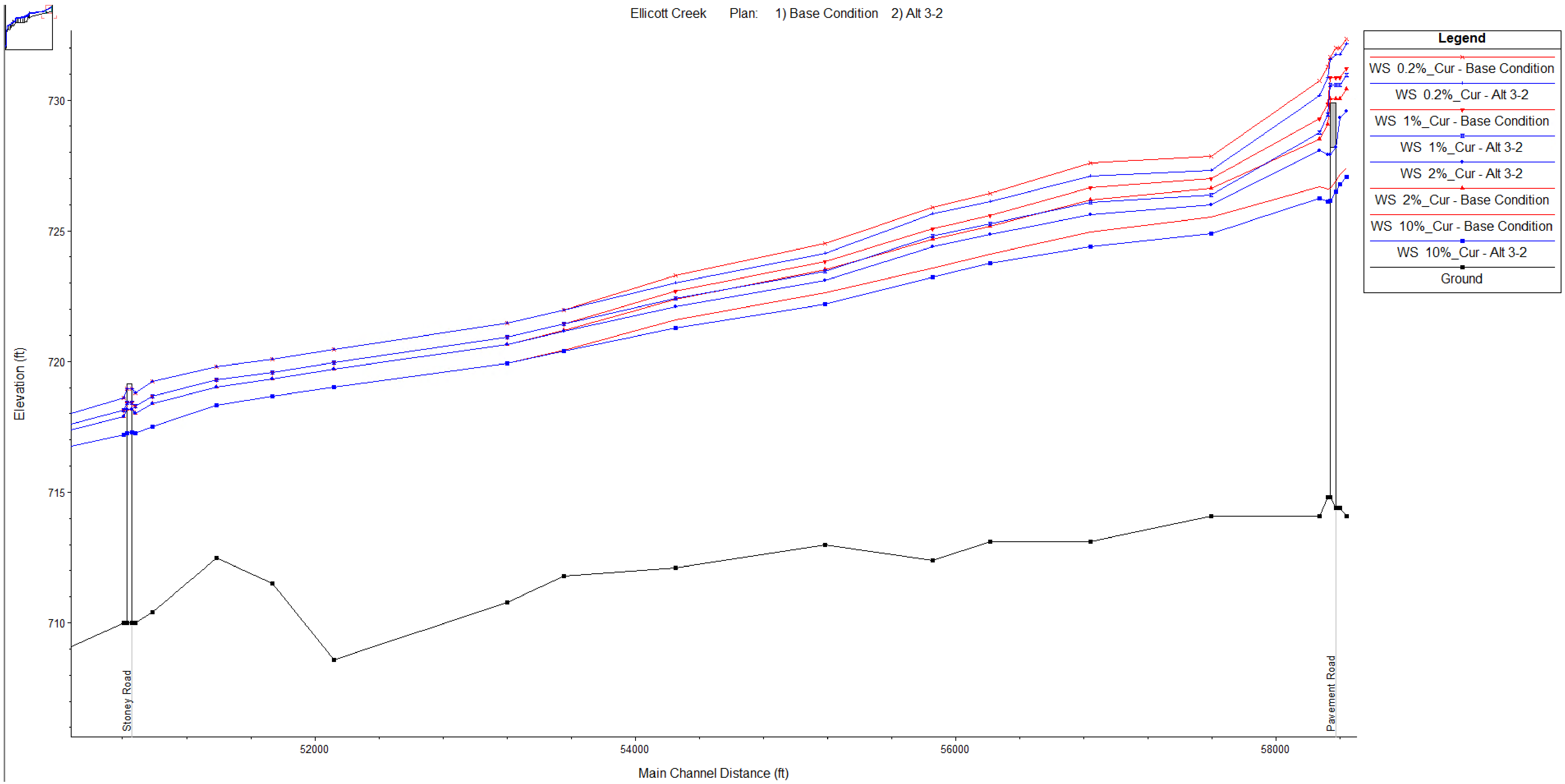


Figure 33. HEC-RAS Model Simulation Output Results for Alternative #3-2



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).

Alternative #4-1: Early Warning Flood Detection System

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

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

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

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

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

Alternative #4-2: Debris Maintenance around Bridges/Culverts

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).

In addition, sediment control basins along Ellicott 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, not including annual maintenance and operational costs.

Alternative #4-3: Flood Buyout Programs

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 swath of land, rather than individual homes in isolated areas, or only some of the homes within flood-prone areas (Siders, 2013).

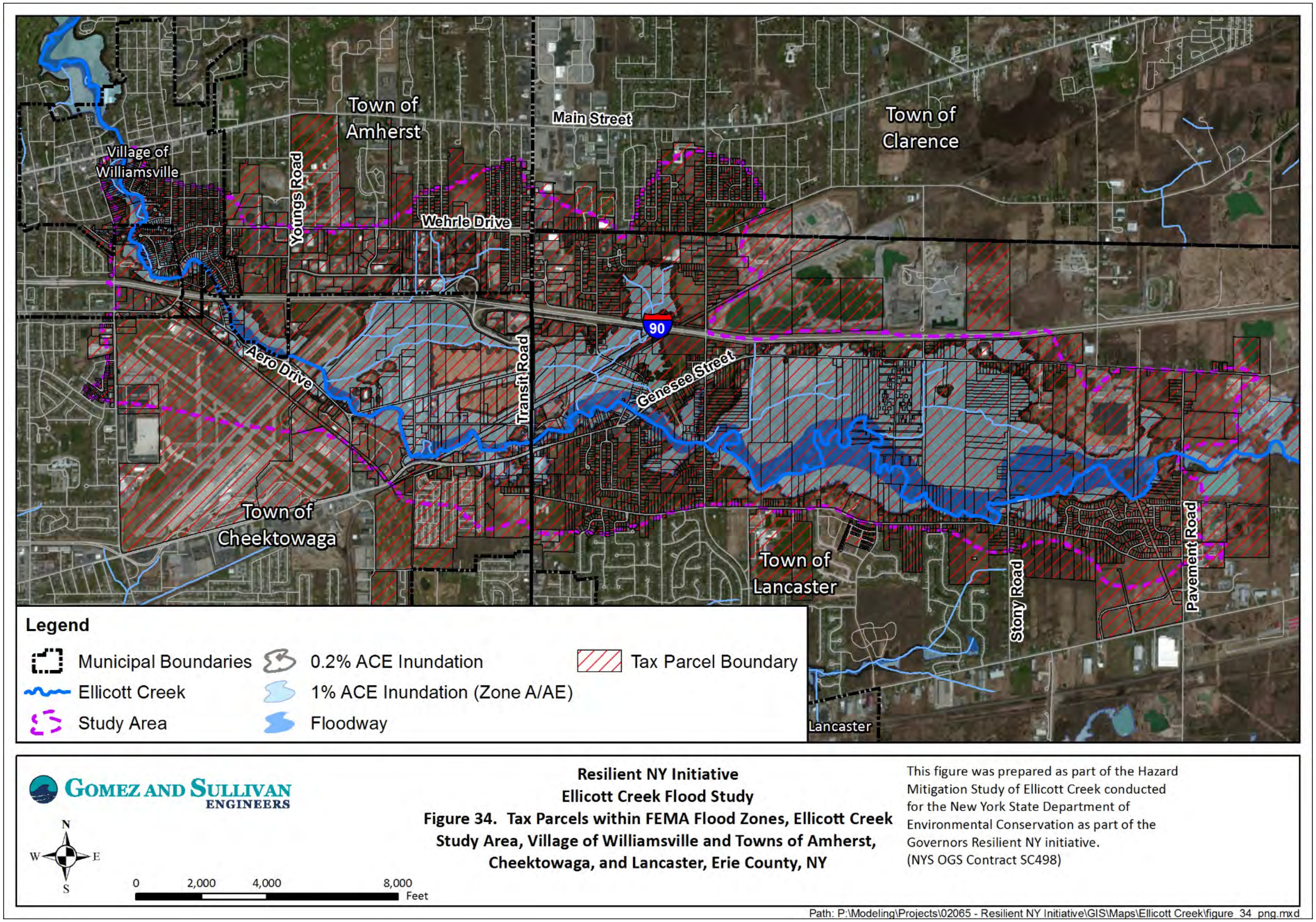
Buyout programs can be funded through a combination of federal, state or local funds, and are generally made available following a nationally recognized disaster. FEMA administers programs to help with buyouts under the Stafford Disaster Act, and the Department of Housing and Urban Development (HUD) administers another program through Community Development Block Grants (CDBG) [(FEMA, 2020), (NYSGOSR, 2019)]. 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 special flood hazard area (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% ACE (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, 2015b).

In the study area, there are approximately 1,500 residences within the FEMA 1% and 0.2% annual chance flood hazard zones (Figure 34). Within Erie County, there are 22 FEMA Repetitive Loss (RL) and 2 Severe Repetitive Loss (SRL) properties located within the Ellicott Creek watershed.

Due to the variable nature of buyout programs, no ROM cost estimate was produced for this study. It is recommended that any buyout program begin with a cost-benefit analysis for each property. After a substantial benefit has been established, a buyout strategy study should be developed that focuses on properties closest to Ellicott Creek in the highest-risk flood areas and progresses outwards from there to maximize flood damage reductions. In addition, structures located adjacent to flood prone infrastructure (i.e. bridges, culverts, etc.) should also be considered high-risk and prioritized in any buyout program strategy. A potential negative consequence of buyout programs is the permanent removal of properties from the floodplain, and resulting tax revenue, which would have long-term implications for local governments, and should be considered prior to implementing a buyout program.

Figure 34. Tax Parcels within FEMA Flood Zones, Ellicott Creek Study Area, Village of Williamsville and Towns of Amherst, Cheektowaga, and Lancaster, Erie County, NY



Alternative #4-4: 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, 2015c).

In some communities, where non-structural flood mitigation alternatives are not feasible, structural alternatives such as flood proofing may be a viable alternative. The NFIP 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 or above the freeboard required by 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 before 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, 2015c).

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, 2015c).

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-foot above the BFE (FEMA, 2013).

In New York State, only non-residential buildings are allowed to be dry floodproofed and the building must be dry floodproofed to an elevation of at least 2 feet above the BFE. New York State has higher freeboard standards than federal regulations at 44 CFR Part 60.3. Care must be taken to check the New York State Building Code for more stringent guidelines.

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 the BFE or above the freeboard required by local regulations.

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, 2015c).

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, 2015c). 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 with NFIP requirements (44 CFR §65.10) and provides protection from at least the 1% annual chance (100-year) flood. Furthermore, floodwalls or levees as a retrofit measure will not bring the building into compliance with NFIP requirements for Substantial Improvement/Damage (FEMA, 2013). Barrier measures require ongoing maintenance (i.e. mowing, etc.) which should be factored into any cost analysis. In addition, barrier measures tend to create a false sense of security for the property owners and residents that are protected by them. If a barrier structure is not properly constructed or maintained and fails, catastrophic damages to surrounding areas can occur.

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 completion of any floodproofing project (FEMA, 2015c):

- 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.

Alternative #4-5: Area Preservation / Floodplain Ordinances

This alternative proposes that municipalities within the Ellicott 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 are 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 New York State Open Space Conservation Plan, NYSDEC's 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 NFIP, best practices demonstrate that the adoption of higher standards 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 Ellicott Creek watershed.

Alternative #4-6: Ice Management

This strategy is intended to control ice-jam formation by maintaining ice coverage in high-risk sections of Ellicott 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, 2016a).

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 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

Ice breakers: ships, hovercrafts, amphibious hydraulic excavators, construction equipment, and blasting techniques designed to breakup ice and move ice downstream

Air bubbler and flow systems: release air bubbles and warm water from the water bottom to suppress ice growth (USACE, 2002)

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 officials 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 & Yapa, A Unified Degree-Day Method for River Ice Cover Thickness Simulation, 2011).

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

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

Next Steps

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

Additional Data Modeling

Additional data collection and 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. 2-D ice simulations are highly recommended to access the wintery condition with the suggested alternatives to evaluate the water level rises due to presence of ice, ice-jam or break-up ice jam conditions.

State/Federal Wetlands Investigation

Any flood mitigation strategy that proposes using wetlands in any capacity, needs to be evaluated based on federal and state wetland criteria before that mitigation strategy can be pursued for consideration.

Ice Evaluation

Due to the complex interaction of ice formation and water flow through a river, it is difficult to draw conclusions regarding potential 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:

- Air temperature
- Water temperature
- Snow and ice melt intensity
- Upstream flow
- Upstream ice concentration
- Land cover
- Precipitation

Therefore, river reaches with potential ice jams should be analyzed using more comprehensive ice studies, possibly a 2-D ice dynamic study, to better understand the nature of the flooding, and the potential mitigation strategies. Ice-jam flooding is very different compared to regular flooding due to the presence of solid and frazil ice. The transportation of frazil ice and solid ice in a river constantly changes the hydrodynamics of the flow, and even at low flows can still raise water levels high enough to cause flooding. The growth of single-layer ice jams can create conditions that change low flood hazards, to high flood hazards, even at low flow conditions.

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 (NYSERDA, 2011). In theory, the increased velocities would move solid ice and frazil ice down the river channel more quickly, possibly 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.

Example Funding Sources

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

- New York State Division of Homeland Security and Emergency Services (NYSDHSES)
- Regional Economic Development Councils/Consolidated Funding Applications (CFA)
- Natural Resources Conservation Services (NRCS) Emergency Watershed Protection (EWP) Program
- FEMA Hazard Mitigation Grant Program (HMGP)
- New York State Department of Transportation (NYSDOT) BRIDGE NY Program

New York State Division of Homeland Security and Emergency Services (NYSDHSES)

The New York State Office of Emergency Management (NYSOEM), which is a part of the NYSDHSES, in conjunction with the United States Department of Homeland Security (USDHS) and FEMA, offers several funding opportunities through federal grant programs. Two primary programs are available through FEMA's Hazard Mitigation Grant Program (HMGP): Public Assistance, which includes post-disaster recovery grants enabled by Presidential declaration to reimburse for the emergency protective measures and the repair of eligible public facilities and infrastructure; and Hazard Mitigation, which includes pre-disaster project grants to eligible government sub-applicants to avoid or reduce the loss of life and property in future events. The NYSOEM would be the primary point of contact for all aspects of these programs.

Regional Economic Development Councils/Consolidated Funding Applications (CFA)

The CFA is a single application for state economic development resources from numerous state agencies. The ninth round of the CFA was offered in 2019.

Water Quality Improvement Project (WQIP) Program

The WQIP 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.

Climate Smart Communities (CSC) Grant Program

The 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 New York State 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.

NRCS Emergency Watershed Protection (EWP) Program

Through the EWP Program, the United States Department of Agriculture's (USDA) 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. 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. Through EWP, 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. The remaining costs must come from local services. Eligible projects include, but are not limited to, debris-clogged stream channels, undermined and unstable streambanks, and jeopardized water control structures and public infrastructures.

FEMA Hazard Mitigation Grant Program (HMGP)

The HMGP, offered by FEMA and administered by the NYSDHSES, provides funding for creating/updating hazard mitigation plans and implementing hazard mitigation projects. The HMGP 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 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.

Building Resilient Infrastructure and Communities (BRIC) Program

Beginning in 2020, the 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.

Flood Mitigation Assistance (FMA) Program

The FMA Program provides resources to reduce or eliminate long-term risk of flood damage to structures insured under the NFIP. 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 properties, and up to 90% cost share for repetitive loss 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

New York State Department of Transportation (NYSDOT) BRIDGE NY Program

The BRIDGE NY program from the NYSDOT is intended to provide assistance to local governments for rehabilitation and replacement of bridges and culverts, that otyherwise would not be completed. At least $200 million in funding is expected to be awarded for fiscal years 2020-21 and 2021-22, with awards considered for projects costing as little as $250,000 and a maximum award amount of $5.0 million. The program is specifically intended for locally owned structures on public roadways. The program can cover up to 95% of the authorized project costs, and can cover all project costs including design/engineering, right-or-way, construction and inspection. The ranking criteria to be used in selecting projects includes risk and resiliency; this report can support the application to support the necessity of increasing the structure opening size.

Summary

The Village of Williamsville and the Towns of Amherst, Cheektowaga, and Lancaster have had a history of flooding events along Ellicott Creek. Flooding in the Village of Williamsville and the Towns of Amherst, Cheektowaga, and Lancaster primarily occurs during the summer and spring months due to heavy rains by convective systems and snowmelt, however ice jam flooding has also been historically an issue near Stoney Road. In response to persistent flooding, the State of New York in conjunction with the Village of Williamsville and the Towns of Amherst, Cheektowaga, and Lancaster, and Erie County, are studying and evaluating potential flood mitigation projects for Ellicott Creek as part of the Resilient NY Initiative.

This study analyzed the historical and present day causes of flooding in the Ellicott 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 Ellicott Creek, which could potentially reduce flood related damages in areas adjacent to the creek. Constructing multiple flood mitigation measures would increase the overall flood reduction potential along Ellicott Creek by combining the reduction potential of the mitigation measures being constructed.

Based on the flood mitigation analyses performed in this report, the mitigation measures that provided the greatest reductions in water surface elevations were:

Alternative #1-1: Modify Wehrle Drive Bridge (Station 57+90)
Alternative #1-2: Flood Bench Creation Between Island Park and Wehrle Drive (Station 14+75 to 33+62)
Alternative #1-3: Modify Wehrle Drive Bridge and Flood Bench Creation Between Island Park and Wehrle Drive (Station 14+75 to 57+90)
Alternative #2-1: Modify Railroad Bridge (Station 197+31)
Alternative #2-3: Flood Bench Creation Between Transit Road and Main Street (Station 237+86 to 257+95)
Alternative #2-4: Modify Airport Runway Culverts (Station 116+70)
Alternative #3-2: Flood Bench Creation Between Stoney and Pavement Roads (Station 514+81 to 565+53)

There would be an overall greater effect in water surface elevations if multiple alternatives were built along Ellicott Creek in different phases, rather than a single mitigation project. For example, building multiple flood benches along a single reach would compound the flood mitigation benefits of each bench.

Based on the analysis of the bridge widening simulations, the Wehrle Drive and Railroad bridge crossings benefited from increased bridge openings. The benefits of the measures in their respective reaches should be balanced with the associated costs of each bridge widening measure to determine if it would be feasible to move a bridge widening measure forward. In addition, other complications, such as traffic re-routing, should be taken into account when considering any of the bridge widening measures.

The debris maintenance alternatives around culverts / bridges would maintain the flow channel area in Ellicott Creek. As sediment and debris build up at the openings of bridges and culverts, the channel flow area is reduced. This can lead to potential backwater and flooding due to the inability of the creek channel to pass stream flows of the same annual chance event.

Ice management to control ice buildup at critical points along Ellicott Creek should be considered 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 the potential for future flood damages remain. A benefit to floodproofing versus buyouts is that properties remain in the community and the tax base for the local municipality remains intact. Table 18 is a summary of the potential flood mitigation measures, including modeled water surface elevation reductions and estimated ROM costs.

Table 15.Summary of Flood Mitigation Measures

Alternative No.	Description	Change in Water Surface Elevation (ft)		ROM cost ($U.S. dollars)
		Current Flows	Projected Flows	
1-1	Modify Wehrle Drive Bridge	0.1 – 1.2	0.1 – 1.3	$6.0 million
1-2	Flood Bench Creation Between Island Park and Wehrle Drive	0.6 – 0.8	0.6 – 1.3	$1.8 million
1-3	Combined Alternative 1-1 and 1-2	0.8 – 1.3	0.6 – 1.5	$7.8 million
2-1	Modify Railroad Bridge	0.2 – 0.8	0.2 – 0.7	$1.1 million
2-2	Flood Bench Creation Between Rein and Transit Roads	0.0 – 0.1	0.0 – 0.1	$1.5 million
2-3	Flood Bench Creation Between Transit Road and Main Street	0.3 – 0.4	0.3 – 0.4	$3.7 million
3-1	Flood Bench Creation Between Harris Hill and Stoney Roads	0.1	0.1	$5.7 million
3-2	Flood Bench Creation Between Stoney and Pavement Roads	0.6 – 1.2	0.6 – 0.7	$7.3 million
4-1	Early Flood Warning Detection System	N/A	N/A	$120,000 (not including annual operational costs)
4-2	Debris Maintenance Around Bridges/Culverts	N/A	N/A	$20,000 (not including annual operational costs)
4-3	Flood Buyouts Program	N/A	N/A	Variable (case-by-case)
4-4	Floodproofing	N/A	N/A	Variable (case-by-case)
4-5	Area Preservation/Floodplain Ordinances	N/A	N/A	Variable (case-by-case)
4-6	Ice Management	N/A	N/A	$40,000 (not including annual operational costs)

Conclusion

Municipalities affected by flooding along Ellicott Creek can use this report to support flood mitigation initiatives within their communities. This report is intended to be a high-level overview of potential flood mitigation strategies, their impacts on water surface elevations, and the associated ROM cost for each mitigation strategy. The research and analysis that went into each potential 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 presented 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 potential 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 Ellicott 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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Appendix A. Summary of Data and Reports Collected

Year	Type	Document Title	Author	Publisher
1966	Report	Flood Plain Information: Buffalo Creek, New York in the Towns of Elma and West Seneca	Buffalo District	USACE
1963	Website	Geology of Erie County, New York		USGS
1978	Report	National Handbook of Recommended Methods for Water-Data Acquisition	Office of Water Data Coordination	USGS
1991	Report	Regionalization of Flood Discharges for Rural, Unregulated Streams in New York, Excluding Long Island	Richard Lumia	USGS
1991	Report	Surficial Geologic Map of New York		USGS
1992	Report	Flood Insurance Study: Town of Amherst, New York – Erie County		FEMA
1995	Article	Numerical Simulation of River Ice Processes	H. T. Shen, D. S. Wang, and L. A. Wasantha,	Journal of Cold Region Engineering
1996	Book	Applied River Morphology, 2nd Edition	D. L. Rosgen and H. L. Silvey	Wildland Hydrology Books
2000	Code	Title 44: Emergency Management and Assistance, Chapter 1		FEMA
2002	Standard	National Conservation Practice Standard No. 638: Water and Sediment Control Basin		NRCS
2002	Report	Engineering Manual 1110-2-1612: Engineering and Design – Ice Engineering		USACE

Year	Type	Document Title	Author	Publisher
2005	Software	Comprehensive River Ice Simulation System Project (CRISSP)		CEATI
2006	Report	Floodplain Management Requirements: A Study Guide and Desk Reference for Local Officials		FEMA
2006	Report	Bridge Inventory Manual		NYSDOT
2006	Report	Magnitude and Frequency of Floods in New York	Richard Lumia, Douglas A. Freehafer, and Martyn J. Smith	USGS
2007	Book	Elevation Data for Floodplain Mapping		NRC
2008	Data	Erie County, NY LiDAR Terrain Elevation	Sanborn Map Company, Inc.	FEMA
2009	Report	Bankfull Discharge and Channel Characteristics of Streams in New York State	Christiane I. Mulvihill, Barry P. Baldigo, Sarah J. Miller, Douglas DeKoskie, and Joel DuBois	USGS
2010	Report	DHS Risk Lexicon		USDHS
2011	Report	Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation in New York State, Final Report		NYSERDA
2011	Article	A Unified Degree-Day Method for River Ice Cover Thickness Simulation	H. T. Shen and P. Yapa	Canadian Journal of Civil Engineering
2011	Article	An Overview of CMIP5 and the Experiment Design	K. E. Taylor, R. J. Stouffer, and G. A. Meehi	Bulletin of the American Meteorological Society
2011	Report	Town of Amherst Flood Mitigation Plan Report	URS Corporation	Erie County
2012	Report	Hydraulic Design of Safe Bridges	L. W. Zevenbergen, L. A. Arneson, J.H. Hunt, and A.C. Miller	USDOT

Year	Type	Document Title	Author	Publisher
2012	Article	Geomorphic Characterization of Upper South Koel Basin, Jharkhand: A Remove Sensing and GIS Approach	R. Parveen, U. Kumar, and V. K. Singh	Journal of Water Resource and Protection, 1042-1050
2013	Report	Floodproofing Non-Residential Buildings		FEMA
2013	Report	Removal of Woody Debris and Trash from Rivers and Streams		NYSDEC
2013	Article	Anatomy of a Buyout Program – New York Post-Superstorm Sandy	A. R. Siders	Vermont Law School
2014	Book	Handbook of Biological Statistics, 3rd Edition	J. H. McDonald	Sparky House Publishing
2014	Report	National Register of Historical Places and National Historic Landmarks Program Records for New York State		NPS
2014	Article	Morphometric Analysis of a Drainage Basin Using Geographical Information System: A Case Study	M. L. Waikar and A. P. Nilawar	International Journal of Multidisciplinary and Current Research
2014	Report	Maximum Known Stages and Discharges of New York Streams and Their Annual Exceedance Probabilities Through September 2011	G. R. Wall, P. M. Murray, R. Lumia, and T. P. Suro	USGS
2015	Report	Guidance for Flood Risk Analysis and Mapping: Redelineation Guidance		FEMA
2015	Report	Hazard Mitigation Assistance Program Digest, September 2015		FEMA
2015	Report	Reducing Flood Risk to Residential Buildings That Cannot Be Elevated		FEMA

Year	Type	Document Title	Author	Publisher
2015	Article	Influence of Aggradation and Degradation on River Channels: A Review	U. R. Mugade and J. B. Sapkale	International Journal of Engineering and Technical Research
2015	Report	Development of Flood Regressions and Climate Change Scenarios to Explore Estimates of Future Peak Flows	Douglas A. Burns, Martyn J. Smith, and Douglas A. Freehafer	USGS
2016	Report	HEC-RAS: River Analysis System User's Manual, Version 5.0	HEC	USACE
2016	Report	Lexington Greene – Section 2015 of the 1948 Flood Control Act – Flood Risk Management	Buffalo District	USACE
2016	Software	Application of Flood Regressions and Climate Change Scenarios to Explore Estimates of Future Peak Flows, Version 1.5 Web Application		USGS
2017	Data	New York State Digital Ortho-Imagery Program	GIS Program Office	NYSOITS
2017	Report	Fact Sheet 2017-3046: *StreamStats*, Version 4	Kernell G. Ries III, Jeremy K. Newsom, Martyn J. Smith, John D. Guthrie, Peter A. Steeves, Tiana L Haluska, Katharine R. Kolb, Ryan F. Thompson, Richard D. Santoro, and Hans W. Vraga	USGS
2018	Report	DRAFT New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act		NYSDEC
2018	Report	Highway Design Manual	Engineering Division, Office of Design	NYSDOT

Year	Type	Document Title	Author	Publisher
2018	Article	Governor Cuomo Announces $3 Million for Studies to Reduce Community Flood Risk		NYSGPO
2019	Report	Flood Insurancy Study, Erie County, NY		FEMA
2019	Software	ArcGIS for Desktop 10		ESRI
2019	Data	2016 Land Cover: Conterminous United States	NLCD	MRLC
2019	Data	Bridge Point Locations and Select Attributes	Structures Division	NYSDOT
2019	Report	Bridge Manual	Structures Division	NYSDOT
2019	Data	CostsWorks 2019	RS Means Data Online	Gordian, Inc.
2019	Software	Hydrologic Engineering Center’s River Analysis System, Version 5.0.7	HEC	USACE
2019	Report	Policy Manual: NY Rising Buyout and Acquisition Program, Version 7.0		NYSGOSR
2020	Data	Storm Events Database	NCEI	NOAA
2020	Software	Environmental Resource Mapper Web Application		NYSDEC
2020	Data	Inventory of Dams – New York State		NYSDEC
2020	Standard	Standard Specifications (US Customary Units), Volume 1	Engineering Division	NYSDOT
2020	Data	Ice Jam Database	CRREL	USACE
2020	Software	Information for Planning and Consultation Web Application	ECOS	USFWS

Year	Type	Document Title	Author	Publisher
2020	Software	*StreamStats*, Version 4.4.0 Web Application		USGS
2020	Website	Hazard Mitigation Grant Program (HMGP)		FEMA
2020	Website	Geologic History of Amherst State Park		Amherst State Park
2020	Data	National Register of Historic Places		National Parks Service
2021	Data	Environmental Resource Mapper Web Application		NYSDEC
2021	Data	Information for Planning and Consultation (IPaC) Web Application		USFWS
2021	Data	National Wetlands Inventory		USFWS
Unk	Article	Watershed Management		NYSDEC

Appendix B. Agency and Stakeholder Meeting Attendees List

Initial Project Kickoff Meeting: July 16, 2019

Attendees	Affiliation
Jeff Szatkowki	Amherst, Town of
Laura Ortiz	Army Corps
Katherine Winkler	Buffalo Niagara Waterkeeper
Clyde Drake	Concord, Town of
Joanna Panasiewicz	ECDEP/LEWPA
Joe Fiegl	ECDEP-DSM
David Hall	Erie County DEP
JT Glass	Erie County DHSES
Mark Gaston	Erie County SWCD
Matt Deno	Gomez and Sullivan
Susan Hopkins	Highland Planning
Jen Topa	Highland Planning
Ted Myers	NYSDEC
Thomas R. Snow, Jr.	NYSDEC
Ryan Tomko	NYSDEC
Don Zelazny	NYSDEC
Kerrie O'Keefe	NYSDEC R9
SAMUEL BATT	NYSDOT R5
Garnell Whitfield	NYSOEM
Shaun Gannon	OBG
Kadir Goz	OBG
Ryan Hastings	OBG
Gene Hart	West Seneca, Town of
Dave Johnson	West Seneca, Town of
Steve Tanner	West Seneca, Town of

Appendix C. Field Data Collection Forms

NRCS
U.S. Department of Agriculture
Natural Resources Conservation Service

Stream Channel Classification (Level II)

Wisconsin Job Sheet 811

Natural Resources Conservation Service (NRCS) **Wisconsin**

Project: ______________________ Date: ______________________

County: ______________________ Stream: ______________________

Reach No.: ______________________ Logged By: ______________________

Horizontal Datum: NAD ________ Projection: ☐ Transverse Mercator ☐ Lambert Conformal Conical

Coordinate System: ☐ __________ County Coordinates ☐ WTM ☐ State Plane Coordinates ☐ UTM

Units: ☐ Meters ☐ Feet Horizontal Control: N or Lat. __________ E or Long. __________

Elevation: __________ ☐ Assumed ☐ DOT ☐ NAVD (29 / 88) Units: ☐ Meters ☐ Feet

Fluvial Geomorphology Features (3 Cross Sections) for Stream Classification

				Average
Bankfull Width (W_{bkf}):	________ ft.	________ ft.	________ ft.	0.00 ft.
Mean Depth (d_{bkf}):	________ ft.	________ ft.	________ ft.	0.00 ft.
Bankfull X-Section Area (A_{bkf}):	________ sq. ft.	________ sq. ft.	________ sq. ft.	0.00 sq. ft.
Width / Depth Ratio (W_{bkf}/d_{bkf}):	________ ft.	________ ft.	________ ft.	0.00 ft.
Maximum Depth (d_{mbkf}):	________ ft.	________ ft.	________ ft.	0.00 ft.
Width of Flood-Prone Area (W_{fpa}):	________ ft.	________ ft.	________ ft.	0.00 ft.
Entrenchment Ratio (ER):	________ ft.	________ ft.	________ ft.	0.00 ft.

Bankfull Width: *Width of the stream channel, at bankfull stage elevation, in a riffle section.*

Mean Depth: *Mean depth of the stream channel cross section, at bankfull stage elevation, in a riffle section. ($d_{bkf}=A_{bkf}/W_{bkf}$)*

Bankfull X-Section Area: *Area of the stream channel cross section, at bankfull stage elevation, in a riffle section.*

Width / Depth Ratio: *Bankfull width divided by bankfull mean depth, in a riffle section.*

Maximum Depth: *Maximum depth of the Bankfull channel cross section, or distance between the bankfull stage and thalweg elevations, in a riffle section.*

Width of Flood-Prone Area: *Twice maximum depth, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area width is determined (riffle section).*

Entrenchment Ratio: *The ratio of flood-prone area width divided by bankfull channel width. (W_{fpa}/W_{bkf}) (riffle section)*

USDA-NRCS **January 2009** **Wisconsin Job Sheet 811**

Reach Characteristics

Channel Materials (Particle Size Index) D50: _________ mm

The D50 particle size index represents the median diameter of channel materials, as sampled from the channel surface, between the bankfull stage and thalweg elevations.

Water Surface Slope (S): ________________ ft./ft.

Channel slope = "rise" over "run" for a reach approximately 20-30 bankfull channel widths in length, with the "riffle to riffle" water surface slope representing the gradient at bankfull stage.

Channel Sinuosity (K): ________________.

Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL/VL); or estimated from a ratio of valley slope divided by channel slope (VS/S).

Distance to Up-Stream Structures: _____________________________.

Stream Type: _____________________ (For reference, note Stream Type Chart and Classification Key)

Dominant Channel Soils at an Eroding Bank Location

Bed Material: __________________________ Left Bank: ___________ Right Bank: ___________

Description of Soil Profiles (from base of bank to top):

Left: ____

____

Right: ____

____

Riparian Vegetation at an Eroding Bank Location

Left Bank: _____________________________ Right Bank: ____________________________

Percent Total Area (Mass): Left: __________________ Right: ___________________________

Percent Total Height with Roots: Left: __________________ Right: _____________________

Other Bank Features at an Eroding Bank Location

Actual Bank Height: _______________________ Bankfull Height: _________________________

Bank Slope (Horizontal to Vertical):

Left:
- ☐ 0-20° (flat)
- ☐ 21-60° (moderate)
- ☐ 61-80° (steep)
- ☐ 81-90° (vertical)
- ☐ 90°+ (undercut)

Right:
- ☐ 0-20° (flat)
- ☐ 21-60° (moderate)
- ☐ 61-80° (steep)
- ☐ 81-90° (vertical)
- ☐ 90°+ (undercut)

Visible Seepage in Bank? ☐ Yes ☐ No Where? _________________________________

Thalweg Location: ☐ Near 1/3 ☐ Mid 1/3 ☐ Far 1/3

NRCS
U.S. Department of Agriculture
Natural Resources Conservation Service

Pebble Count (Data Collection)

Wisconsin Job Sheet 810

Natural Resources Conservation Service (NRCS) **Wisconsin**

Project: ______________ Date: ______________

County: ______________ Stream: ______________

Reach No.: ______________ Logged By: ______________

Horizontal Datum: NAD ________ Projection: ☐ Transverse Mercator ☐ Lambert Conformal Conical

Coordinate System: ☐ ________ County Coordinates ☐ WTM ☐ State Plane Coordinates ☐ UTM

Units: ☐ Meters ☐ Feet Horizontal Control: N or Lat. ________ E or Long. ________

Elevation: ________ ☐ Assumed ☐ DOT ☐ NAVD (29 / 88) Units: ☐ Meters ☐ Feet

Inches	Millimeters	Particle	Particle Count 1	Total #	Particle Count 2	Total #
<.002	<.062	Silt/Clay				
.002 - .005	.062 - .125	Very Fine Sand				
.005 - .01	.125 - .25	Fine Sand				
.01 - .02	.25 - .50	Medium Sand				
.02 - .04	.50 - 1.0	Coarse Sand				
.04 - .08	1.0 - 2	Very Coarse Sand				
.08 - .16	2 - 4	Very Fine Gravel				
.16 - .22	4 - 5.7	Fine Gravel				
.22 - .31	5.7 - 8	Fine Gravel				
.31 - .44	8 - 11.3	Medium Gravel				
.44 - .63	11.3 - 16	Medium Gravel				
.63 - .89	16 - 22.6	Coarse Gravel				
.89 - 1.26	22.6 - 32	Coarse Gravel				
1.26 - 1.77	32 - 45	Very Coarse Gravel				
1.77 - 2.5	45 - 64	Very Coarse Gravel				
2.5 - 3.5	64 - 90	Small Cobbles				
3.5 - 5.0	90 - 128	Small Cobbles				
5.0 - 7.1	128 - 180	Large Cobbles				
7.1 - 10.1	180 - 256	Large Cobbles				
10.1 - 14.3	256 - 362	Small Boulders				
14.3 - 20	362 - 512	Small Boulders				
20 - 40	512 - 1024	Medium Boulders				
40 - 80	1024 - 2048	Large-Very Large Boulders				
		Bedrock				

DRAFT

Inches

Millimeters

GOMEZ AND SULLIVAN ENGINEERS

Resilient New York

Date:

Field crew:

Stream:

Road crossing:

Structure data: ☐ Bridge

Height at edge[1]: _____ Width at top of opening: _____

Height at deepest point: _____ Bank slope: Rise: _____ Run: _____

Piers _____ Pier shape: round triangle square

Span between piers: _____ Width of piers: _____

☐ Culvert (see data below)

Length in direction of flow:

Manning value: Top: Bottom:

Deck thickness:

Height of rail:

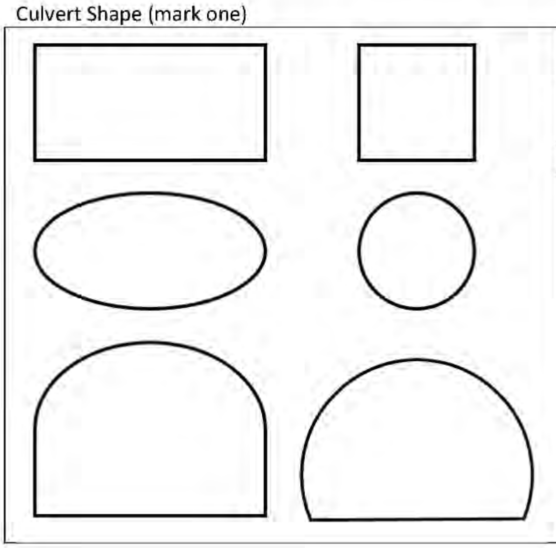
Type of rail:

Structure material:

Bottom substrate:

Description:

Culvert Shape (mark one)



Depth from top of opening to bottom of stream

at edge: _____

at deepest location: _____

Opening width: _____

[1] All measurements should be taken to 0.1 feet

P:\2065 - Resilient NY Initiative\Field Data Collections\Field_Template.docx

Appendix D. Photo Log

List of Additional Field Photos

Photo D-1. *Wehrle Drive looking downstream at right (north) bank*

Photo D-2. *Wehrle Drive looking downstream*

Photo D-3. *Wehrle Drive looking upstream*

Photo D-4. *Wehrle Drive looking at upstream right (north) bank*

Photo D-5. *Rein Road looking at right (east) bank*

Photo D-6. *Transit Road looking downstream*

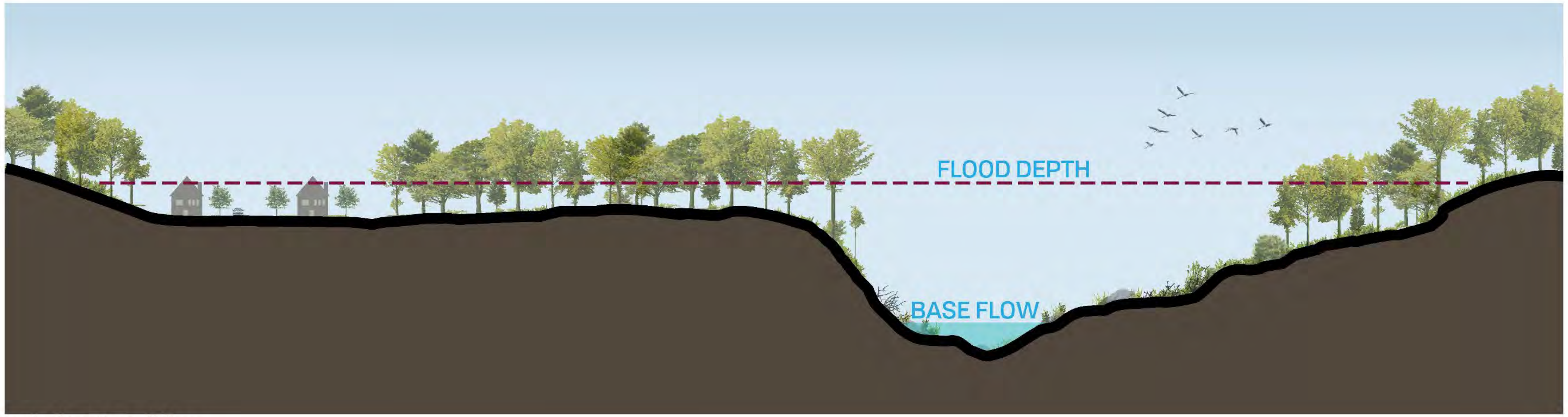
Photo D-7. *Genesse Street (State Route 33) looking downstream towards Main Street*

Photo D-8. *Genesse Street (State Route 33) looking upstream*

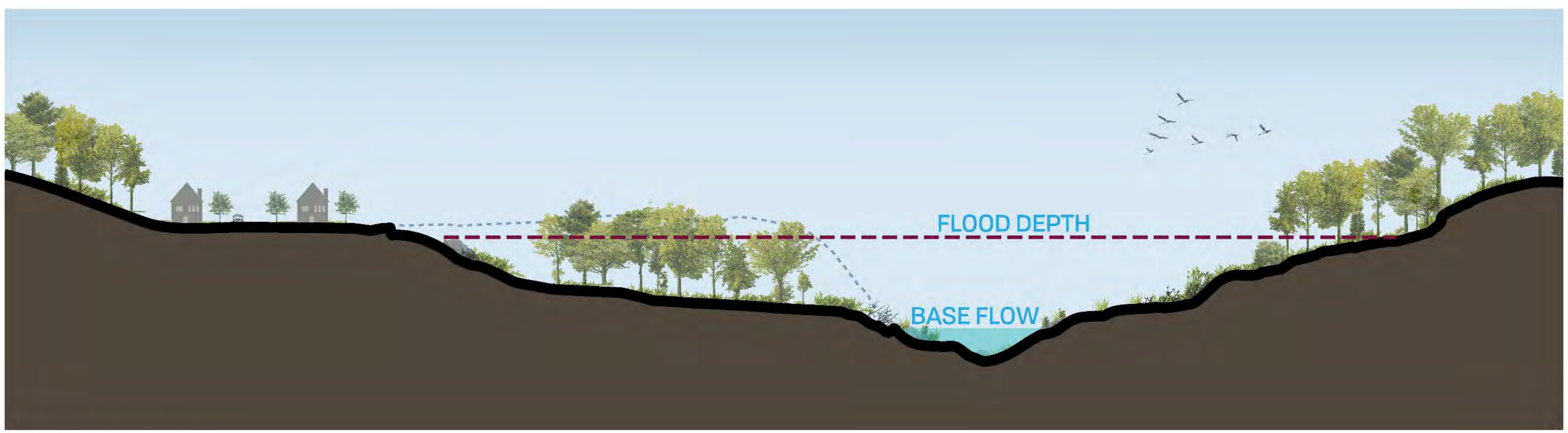
Photo D-9. *New Stoney Road Bridge*

Photo D-10. *Stoney Road looking upstream at right (north) bank*

Appendix E. HEC-RAS Simulation Output

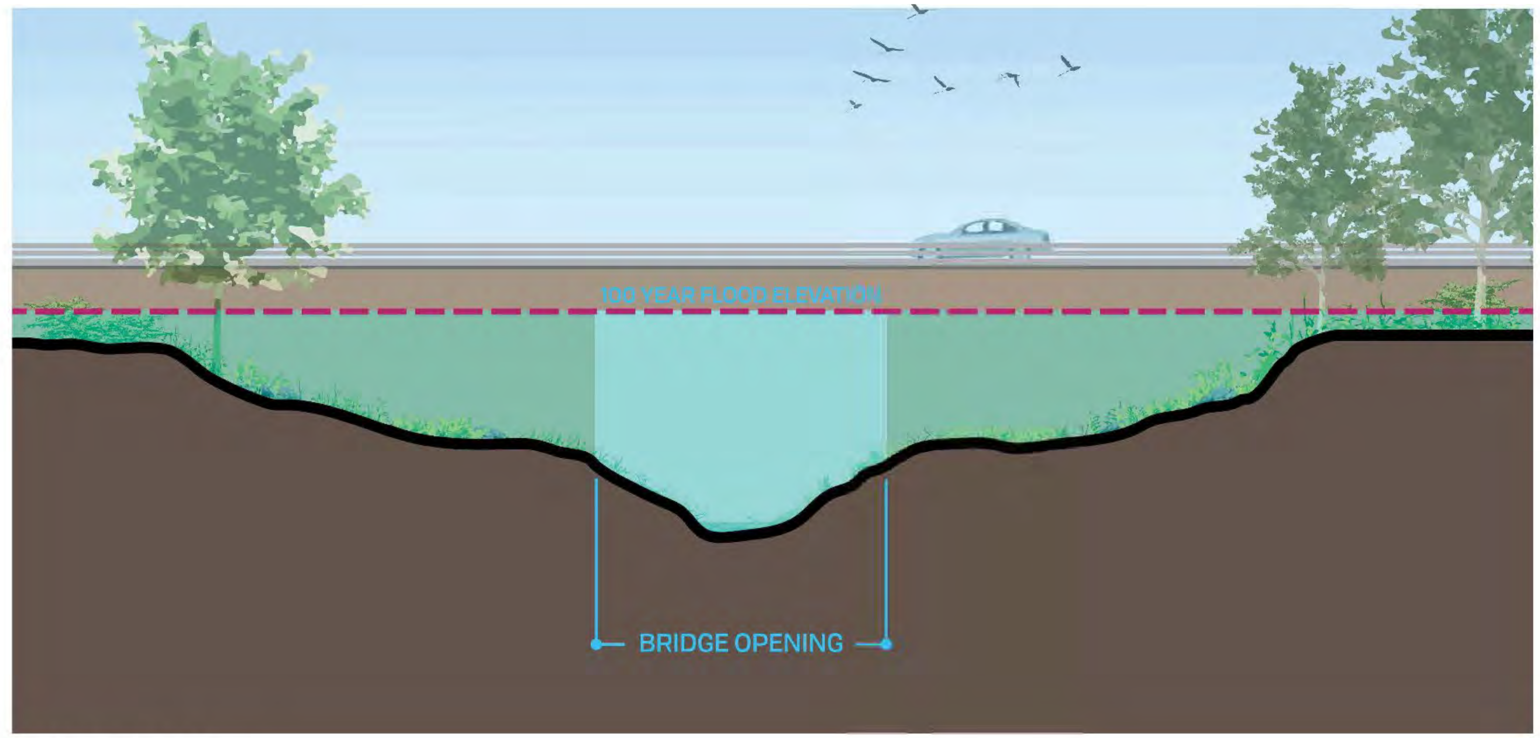


Existing Condition

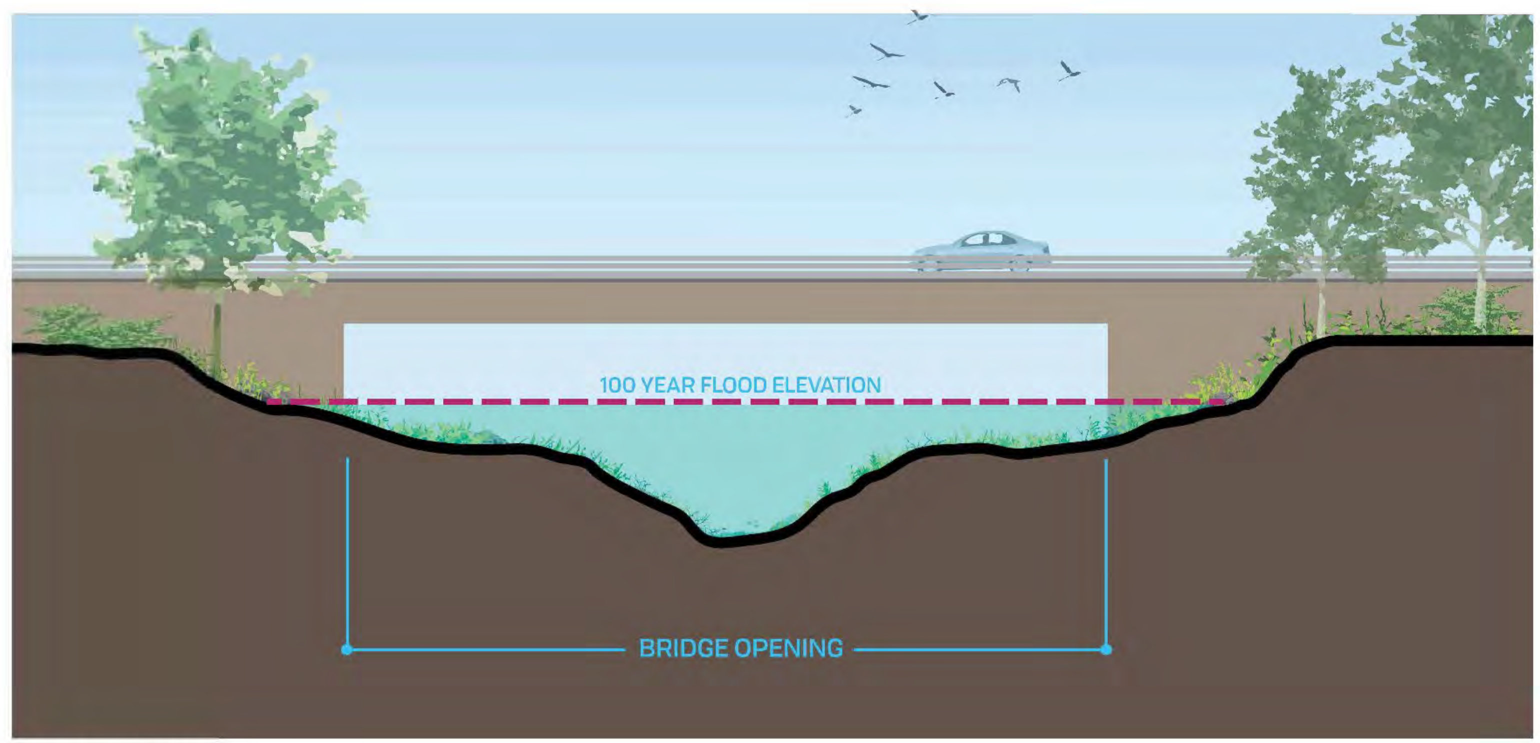


Future Condition

FLOODPLAIN BENCH

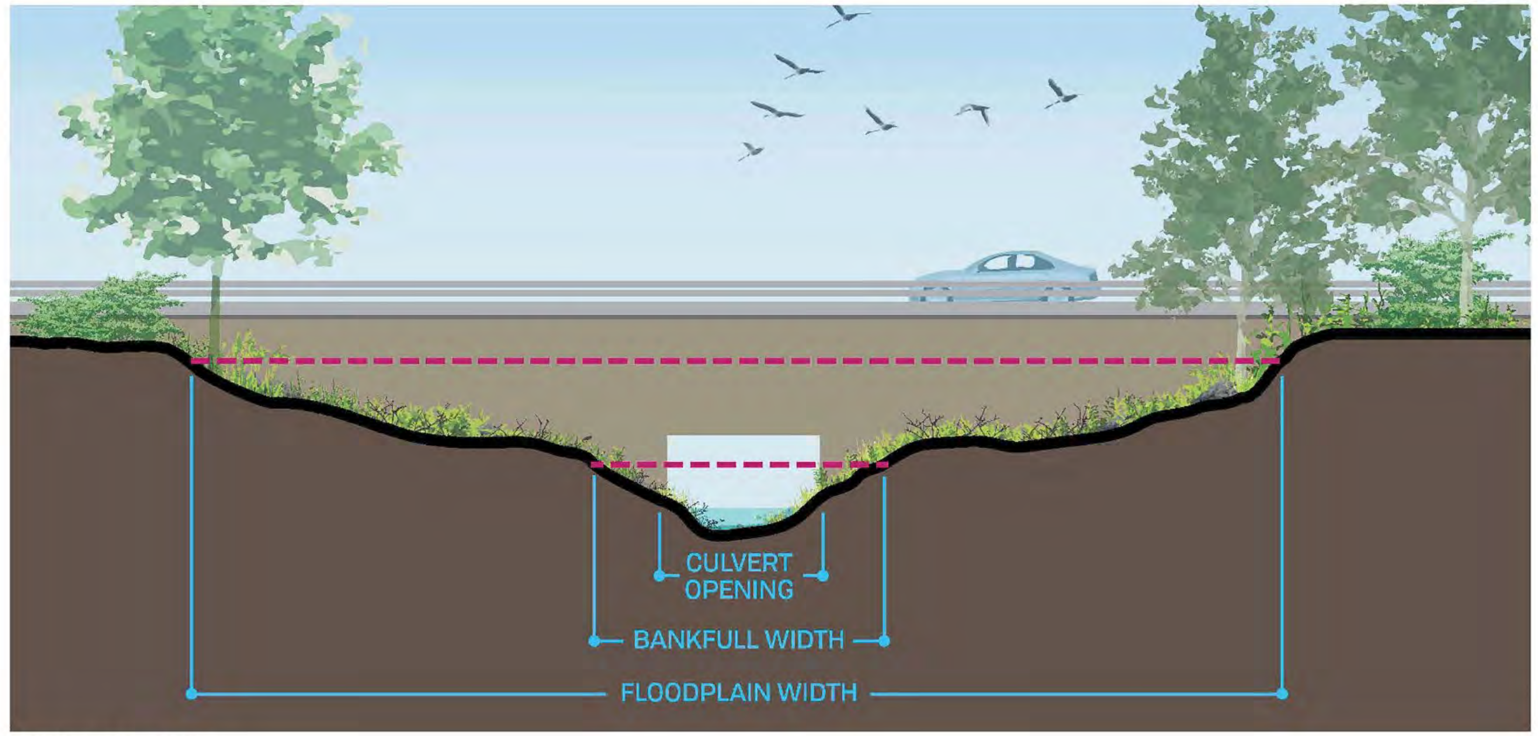


Existing Condition

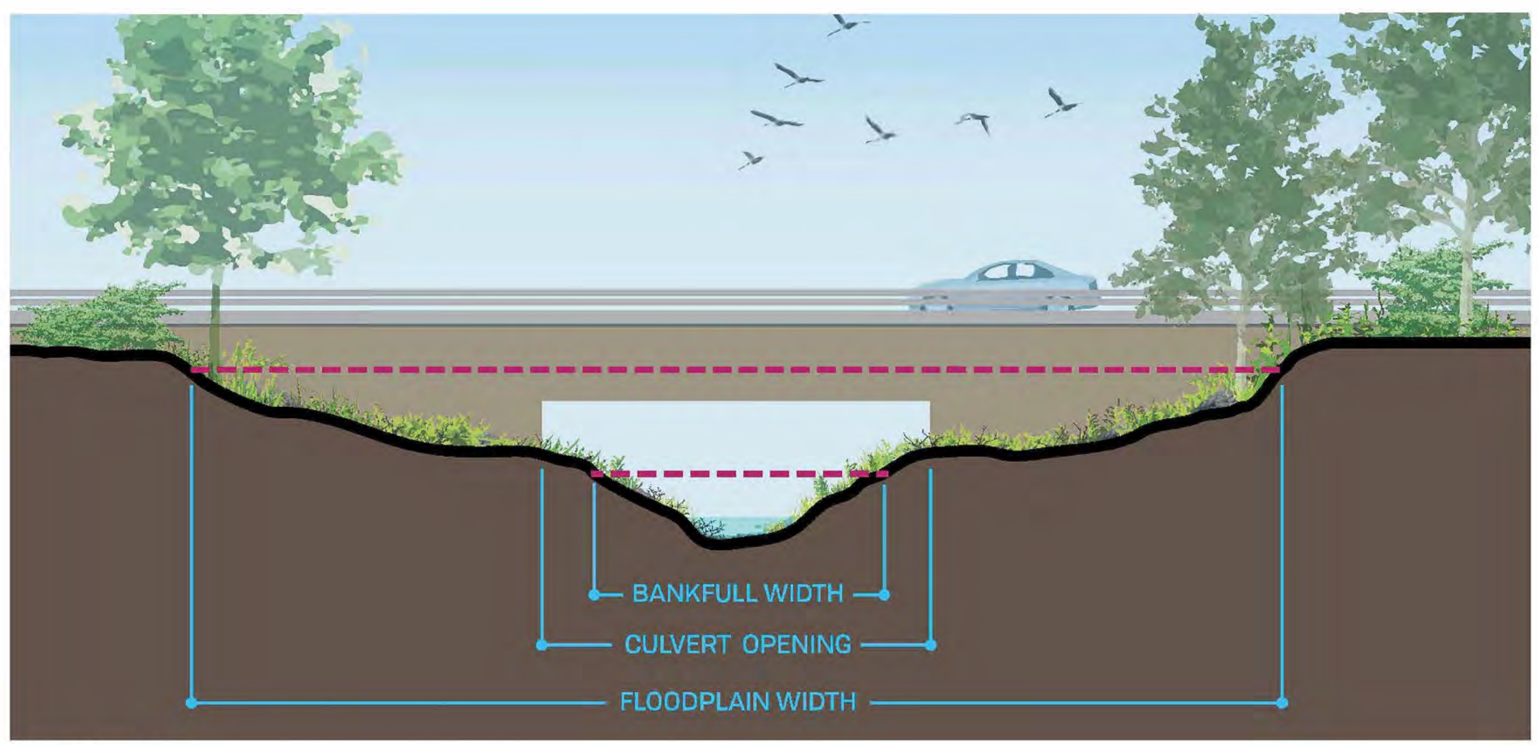


Future Condition

EXPANDED BRIDGE OPENING



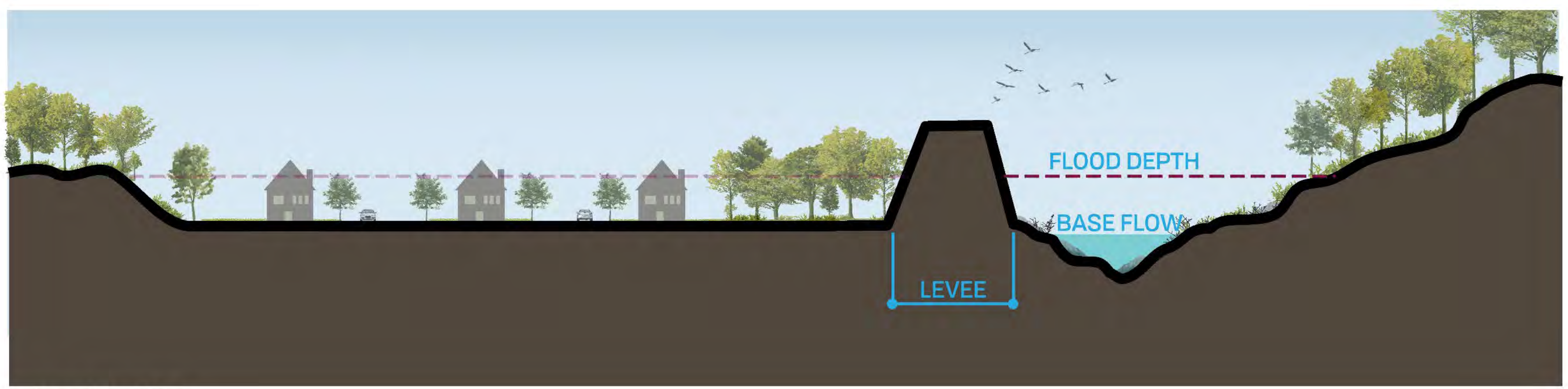
Existing Condition



Future Condition

EXPANDED CULVERT OPENING

Existing Condition



Future Condition

PROTECTIVE LEVEE

Appendix G. Ice-Jam Mitigation Strategies

Ice Jam Flooding Mitigation Strategies

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 wouldn't 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 are:

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

Ice Booms

Ice booms are the most widely used ice jam control strategy to control ice movement and minimizes surface ice transport. They can be both permanent and temporary structures depending on the emergency measure in high-risk situations. They mainly consist of a series of timber beams or pontoons connected and strung across a river. Once the ice disappears, the booms can be removed if needed and transported elsewhere for storage during the summer months. Ice booms are flexible and can be designed to release ice gradually when overloaded. They can be a relatively cost-effective intervention and can be placed seasonally to reduce potential negative environmental impacts. Ice booms can also be deployed relatively rapidly, rendering them effective as an emergency response measure.

However, the removal of ice booms can be costly since the components of each boom must be disconnected, cleaned, transported and stored until their next deployment. Ice booms can also be ineffective given that ice jams have the potential to circumvent the booms by moving underneath them. Ice booms do not suit all river environments and require low river flow velocity and adequate upstream ice storage capacity.

Ice Breaking Using Explosives

Thermally grown ice is relatively easy to break up by blasting, while frazil ice is more difficult because it absorbs much of the blast energy. Ice blasting using dynamite is being widely used in rivers where very thick ice jams are formed. It is a very efficient method that can be performed within minutes. It is easily transported to remote locations and does not require any maintenance. Holes are drilled in the ice and dynamite is inserted to blow the ice apart. The most effective results can be achieved by placing the charges underneath the ice surface.

Using dynamite to clear ice can, however, be harmful to the environment. It is also a dangerous method to employ with potentially fatal consequences. Dynamite is not a sustainable solution and can require multiple treatments during extreme cold. It also requires the containment of large areas, which might have to be repeated several times.

Ice Breaking using Ice-Breaker Ferries and Cutters

Ice breakers are specialized vessels designed to break ice jams in wide rivers. They represent a non-structural ice jam mitigation method that is used internationally, in lakes, wide rivers, and oceans. Ice breakers are generally operated when temperatures start to rise, before it reaches the peak cold. They are most suitable for ice sheet breaking (juxtaposed type ice jams), as there are limitations for the ice thickness that they are capable of breaking.

Cutting thick ice covers can also mechanically weaken the ice jams and help relive the internal pressure of an ice-covered channel due to the thick ice cover. A thick ice cover increases the resistance to flow and slowdown the discharge under the ice covers and increase the backwater effects upstream. By cutting the ice cover this pressure can be relieved and the backwater effects can be minimized to reduce upstream flooding potentials. This can also help to control the ice jam breakup and control large ice pieces release from the break-up.

Ice breakers can typically break thick ice covers of up to three to ten feet. Ice breakers have proven to be effective tools for breaking up ice cover on rivers. There are multiple types of ice breakers and, being a mobile solution, they can be flexibly targeted at areas with the most need. Operating ice breakers requires a highly skilled command and crew and are not suitable in all environments. Transporting ice breakers is also relatively difficult, making it a time-consuming and potentially cost-intensive solution.

Installing Inflatable Dams (Obermeyer Spillways)

Removing permanent run-of-river low head dams that are prone to ice jams and replacing them with floatable dams can be a good solution for flow control for all seasons. Since the crest elevation can altered, they allow for a control release of incoming ice, allowing it to spillover without jamming. Also, in case of a sudden freeze-up jam that lead to an overnight thick jam can also be broken by frequent or oscillatory movement of lowering and raising the crest to break or weaken the ice jam. Obermeyer Spillway gates are recommended in areas where it is more prone to ice accumulation and flow control is still essential during all seasons.

Obermeyer Spillway Gates consist of a row of steel gate panels installed either at the top of dams or as free-standing structures. The system utilizes a combination of metal flap-gate panels supported by multiple small inflatable “bladders” that adjust the panels’ angle and elevation. By controlling the pressure in the bladders, the water flow can be infinitely adjusted within the system control range. Panels can also be designed to include heated abutment plates to prevent ice formation.

Mixing Heated Effluent to the Cold Water

The release of warm water waves into a river from a nearby treatment plants or additions of heated water mixing can help mitigate ice jam formations where the above mentioned alternatives won’t work. Provided that the effluent is added to the river prior to ice jam formation, the additional water volume can increase the river flow velocities and prevent ice jam creation in the first place. The wastewater can also be used for the thermal control of ice, as the released warm water can melt or thin ice jams.

Removal of Bridge Piers or Heated Bridge Piers or Heated Riverbank Dikes

Bridge piers are a hotspot for capturing surface and suspended frazil ice. When surface ice floes are adhered to the bridge piers and abutments the lateral growth of ice rapidly increase thus snagging more ice on the surface creating an ice bridge across the river. When there are more piers across the river the potential of ice bridging between piers increase due to a series of small ice bridging between two piers can be rapidly form than between longer between the longer pier spans.

Removing bridge piers can lead to high cost construction projects with inconvenience to the daily traffic through the bridge and the structural integrity. Therefore, heated bridge piers can be a good alternative to the existing piers that are prone to more ice cohesion and that can lead to high cost of removing the piers. This will limit the ice adhesion to the bridge and pass through the surface and suspended ice without encouraging snagging, capturing and flocculation of surface ice at bridge piers avoiding the possible ice jams.

Also, the heating of piers can heat the surrounding water and mix with the ambient cold water that will lead to the melt existing surface and suspended ice in the water. This reduces any extra ice generation in the water column.

However, heating bridge piers involves carful installation of the wiring and maintenance of the heating elements and energy costs. More frequent inspections of the bridge piers are also needed since the temperature can affect the concrete composition or special treatment for the concrete is needed.

Ice Retention Structures

Ice retention structures are used to control ice jams by actively initiating jams in more suitable locations where they are less damaging. Ice is captured and retained upstream of residential areas.

Ice retention structures are cost-effective, installation methods are simple, however the design is highly customizable according to the site. A retention structure can be associated with a flood bench so that increased water levels due to ice accumulation can be compromised be allowing more storage in the flood bench. The retention structures don’t increase the water level during normal flows.

However, the structures do require ongoing maintenance to remove debris. Channel bed scour is a concern for these structures, therefore, a scour analysis needed to perform in the vicinity of the structure to make sure the ice mitigation strategy will not adversely affect the normal river flow.

Ice Forecasting Systems and Ice Management

Visual monitoring of the ice formation, and ice cover progressions and water levels are good elements of monitoring the ice conditions of a river during the wintertime, but not sufficient to accurately predict the upstream back water effects or ice jam formations or ice jam break-ups. Ice condition and ice jam monitoring system is a useful tool for emergency ice management but limited in ice forecasting ability.

Ice long-term forecasting and short-term freeze-up and ice jam breakup predictions is a complicated process and challenging due to several reasons. Ice forecasting needs geomorphological, meteorological, coupled thermodynamics and hydrodynamics to identify the factors effecting an ice jam condition.

Therefore, an ice forecasting simulation will not be able to be carried out in a timely manner to help making emergency decisions. Therefore, a good forecasting system that will recommend an ice management plan would and customized ice monitoring strategy would be the most appropriate alternative to follow. An annual ice jam simulation with that accounts for forecasted meteorological and hydrological conditions and simulated ice control strategy that is suitable for the upcoming winter can identify the flood prone areas and enable to calculate the associate risk beforehand. These annual studies can also suggest the type of monitoring that is needed in different reaches or areas. For example, if an area needed to visually monitor the ice formation and ice transport through webcams or need to perform a calculation procedure such as "Freezing-Degree-Day" (FDD) method to predict the thickness of an ice jam to break to make decision when to start breaking. This will help officials to manager the resources and order the equipment and staff available before an emergency occur.

Gomez and Sullivan suggests performing a freeze-up or a break-up ice simulation study before implementing or recommending any of the above discussed strategies. The basic data needs and steps involved in an ice simulation analysis is also outlined below.

Ice Forecasting Model Simulations

Freeze-up ice simulation is a complex simulation carried out to predict ice generation, movement and coagulation with the change of air temperature, water temperature and water flow over a period of time. Usually these simulations and carried out for a two to three-month time period. A calibration and validation is also needed to ensure accuracy. A freeze-up or ice jam simulation needs the following input data:

- Accurate river bathymetry created from LiDAR survey or hydro-corrected bathymetric data from the state agencies.
- Weather data such as air temperature, wind condition, cloud cover, snowfall and precipitation data.
- Flow conditions, from gauge data or measured data. (e.g. upstream discharge and downstream water level data).
- Ice conditions data, such as water temperature data, incoming ice concentration, and initial ice cover thickness or initial ice floe concertation's and ice floe thickness.
- Visual observation data that are useful to calibrate the model, such as ice cover leading edge propagation locations, water temperature and ice thickness measurements.

The results of such a simulation, when the results are in agreement with observational data, can lead to a better understanding of ice behavior and associated ice jam flooding in the simulated areas that will aid officials and emergency responders in developing better ice management plans.