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RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

GRANNIS CREEK, ERIE COUNTY, NEW YORK

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OBG Part of Ramboll

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Highland Planning

RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

GRANNIS CREEK, ERIE COUNTY, NEW YORK

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

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ACRONYMS/ABBREVIATIONS

1-D	1-Dimensional
2-D	2-Dimensional
BFE	Base Flood Elevation
BSOR	Buffalo Southern Railroad
CDBG	Community Development Block Grants
CFA	Consolidated Funding Applications
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second (ft3/s)
CRRA	Community Risk and Resiliency Act
CSC	Climate Smart Communities
DEM	Digital Elevation Model
DHS	Department of Homeland Security

ECDHSES	Erie County Department of Homeland Security and Emergency Services
ECIDA	Erie County Industrial Development Agency
EPA	Environmental Protection Agency
EWP	Emergency Watershed Protection
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIA	Federal Insurance Administration
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
FT	Feet
FT^2	Square Feet
GIS	Geographic Information System
GSE	Gomez & Sullivan Engineers
H&H	Hydrologic and Hydraulic
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HMA	Hazard Mitigation Assistance
HSGP	Homeland Security Grant Program
HUD	Department of Housing and Urban Development
IPaC	Information for Planning and Consultation
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light Detection and Ranging
LOMR	Letter of Map Revision
NAVD 88	North American Vertical Datum of 1988
NCEI	National Centers for Environmental Information
NFIP	National Flood Insurance Program
NFHL	National Flood Hazard Layer
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NWI	National Wetlands Inventory
NWS	National Weather Service
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDHSES	New York State Division of Homeland Security and Emergency Services
NYSDOT	New York State Department of Transportation
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	OBG, Part of Ramboll
PDM	Pre-Disaster Mitigation
RC	Circularity Ratio
RCP	Representative Concentration Pathway
RE	Elongation Ratio
RF	Form Factor
RF	Radio Frequency

RL	Repetitive Loss
ROM	Rough Order of Magnitude
SCS	Soil Conservation Service
SFHA	Special Flood Hazard Area
SQ MI	Square Miles (mi2)
SRL	Severe Repetitive Loss
US	United States
USACE	United States Army Corps of Engineers
USDHS	United States Department of Homeland Security
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Service
USSCS	United States Soil Conservation Service
WQIP	Water Quality Improvement Project
WRI	Water Resources Investigations

1. INTRODUCTION

1.1 HISTORICAL INITIATIVES

Flood mitigation has historically been an initiative in western New York and in the Grannis Creek watershed. In response to periodic and repetitive flood losses in the Village of Gowanda, local, state, and federal agencies have constructed flood mitigation structures along Thatcher Brook, Cattaraugus Creek, and Grannis Creek between 1940 and 1973.

On Thatcher Brook, the John and Chapel Street bridges were raised, and debris was cleared out in 1940; a weir was built to allow high velocity debris to settle out, preventing jamming at the bridges downstream; levees and concrete and sheet pile retaining walls have been built along multiple portions of the stream for bank protection; and a maintenance program for clearing out debris in the settling basin north of Hill Street was implemented (FIA 1976).

On Cattaraugus Creek, a section of the power dam upstream of the railroad was removed in 1953; a new channel was dredged between the Erie Railroad and Main Street bridges in 1956; a retaining wall was constructed in 1957 at the intersection of Commercial Street and South Water Street; a new channel was cut for Cattaraugus Creek downstream of Thatcher Brook by the Town of Perrysburg, Cattaraugus County, and the Gowanda Central School District in 1958; a new Main Street bridge was constructed by the State in 1962; and in 1964, the Village of Gowanda and New York State (NYS) had bank protection constructed between the Main Street and Aldrich Street bridges (USACE 1968).

On Grannis Creek and Thatcher Brook, the United States Soil Conservation Service (USSCS) completed flood damage repair and improvements in the channels after Tropical Storm Agnes in 1972 (Sergel 1973).

1.2 FLOODPLAIN DEVELOPMENT

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

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

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

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

1.3 RESILIENT NY INITIATIVE

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

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

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

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

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

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

The flood mitigation and resiliency study for Grannis Creek began in March of 2019 and is planned to be completed in mid-2020.

2. DATA COLLECTION

2.1 INITIAL DATA COLLECTION

Hydrological and meteorological data were obtained from readily available state and federal government databases, including ortho-imagery, flood zone maps, streamflow, precipitation, and 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 *StreamStats* v4.3.11 (Ries et al. 2017) software were used to develop current and future potential discharges, and bankfull widths and depths, at various points along the stream channel. Hydrologic and hydraulic (H&H) modeling was performed previously, as part of the 1976 FEMA Flood Insurance Study (FIS) for the Village of Gowanda, NY.

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 determine water stage at current and potential future levels for high risk areas and to evaluate the effectiveness of proposed 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.

2.2 PUBLIC OUTREACH

An initial project kickoff meeting was held on September 19, 2019, with representatives of the NYSDEC, NYSOGS, OBG, Part of Ramboll (OBG), Gomez & Sullivan Engineers (GSE), Highland Planning, LLC, Erie County Department of Homeland Security & Emergency Services (ECDHSES), Town of Collins, Village of Gowanda, and Cattaraugus County Division of Public Works (CCDPW) (Appendix D). Discussions included a variety of topics, including:

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

This outreach effort assisted in the identification of current high-risk areas to focus on during the flood risk assessment tasks.

2.3 FIELD ASSESSMENT

Following the initial data gathering and agency meetings, field staff from OBG undertook field data collection efforts with special attention given to high-risk areas in the Town of Collins and Village of Gowanda as identified in the initial data collection process. Initial field assessments of Grannis Creek were conducted in May 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 B is a copy of the Stream Channel Classification Form, Field Observation Form for the inspection of bridges and culverts, and Wolman Pebble Count Form, as well as a location map of where field work was completed. Appendix C is a photo log of select locations within the creek 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.

3. WATERSHED CHARACTERISTICS

3.1 STUDY AREA

The Grannis Creek watershed lies entirely within Erie County, NY. The creek flows in a westerly direction with its headwaters beginning in the Town of Collins and traveling through the Village of Gowanda until it reaches the confluence with the Cattaraugus Creek (Figure 3-1). Grannis Creek and Thatcher Brook are the two main tributaries that make up the Cattaraugus Creek basin within the Village. Cattaraugus Creek is the major stream within the corporate limits of the Village of Gowanda and flows in a northwesterly direction through the Village. All three streams, Grannis Creek, Thatcher Brook, and Cattaraugus Creek contribute to local flood problems for the Village of Gowanda and the Town of Collins in Erie County, NY (FIA 1976). Within the Grannis Creek watershed, the Village of Gowanda was chosen as the target area due to historical flood records and the hydrologic conditions of the creek in this area. Figures 3-2 and 3-3 depict the stream stationing along Grannis Creek in Erie County, NY, and the study area in the Village of Gowanda, NY, respectively.

3.2 ENVIRONMENTAL CONDITIONS

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

- **Environmental Resource Mapper** – The Environmental Resource Mapper is a tool used to identify mapped federal and state wetlands, state designated significant natural communities, and plants and animals identified as endangered or threatened by the NYSDEC (https://gisservices.dec.ny.gov/gis/erm/) (NYSDEC 2020).
- **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 deepwater habitats" (NYSDEC 2020).
- **Information for Planning and Consultation (IPaC)** – The IPaC database provides information about endangered/threatened species and migratory birds regulated by the United States Fish and Wildlife Service (USFWS) (USFWS 2020).
- **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).

3.2.1 Wetlands

The State Regulated Freshwater Wetlands database shows the approximate location of wetlands regulated by New York State. The check zone is a 100-foot buffer zone around the wetland in which the actual wetland may occur. No state-regulated freshwater wetlands were mapped within the watershed (NYSDEC 2020).

The National Wetlands Inventory was reviewed to identify national wetlands and surface waters within the Grannis Creek watershed (Figure 3-4). Riverine habitats, several freshwater ponds, freshwater emergent wetlands, and freshwater forested/shrub wetlands were found within the Grannis Creek watershed in the NWI (NYSDEC 2020).

3.2.2 Sensitive Natural Resources

Areas designated as significant natural communities by the NYSDEC were mapped in the Grannis Creek watershed. The natural communities identified included Hemlock-northern hardwood forests, which are classified as forested uplands (NYSDEC 2020).

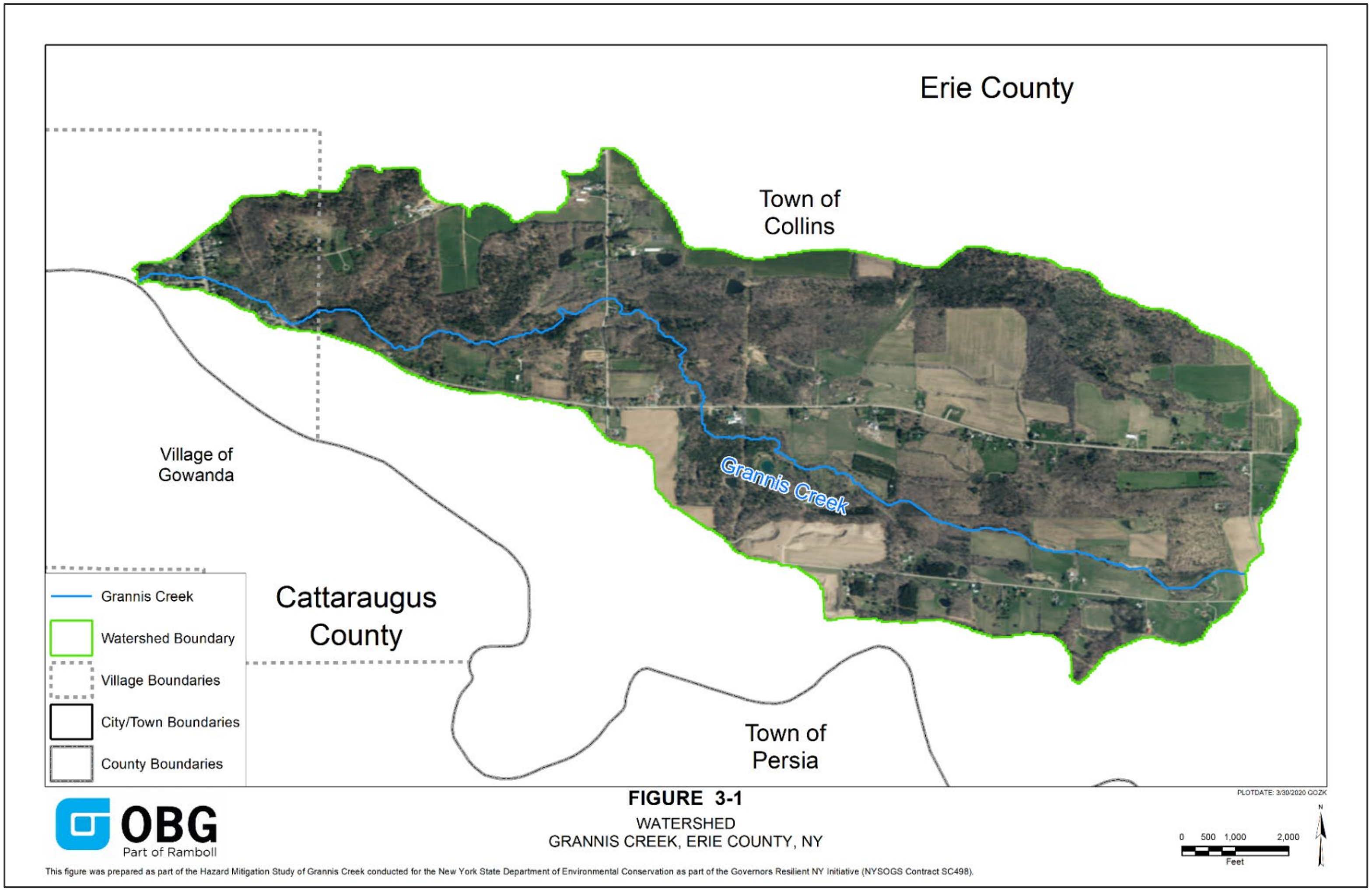


Figure 3-1. Grannis Creek Watershed, Erie County, NY.

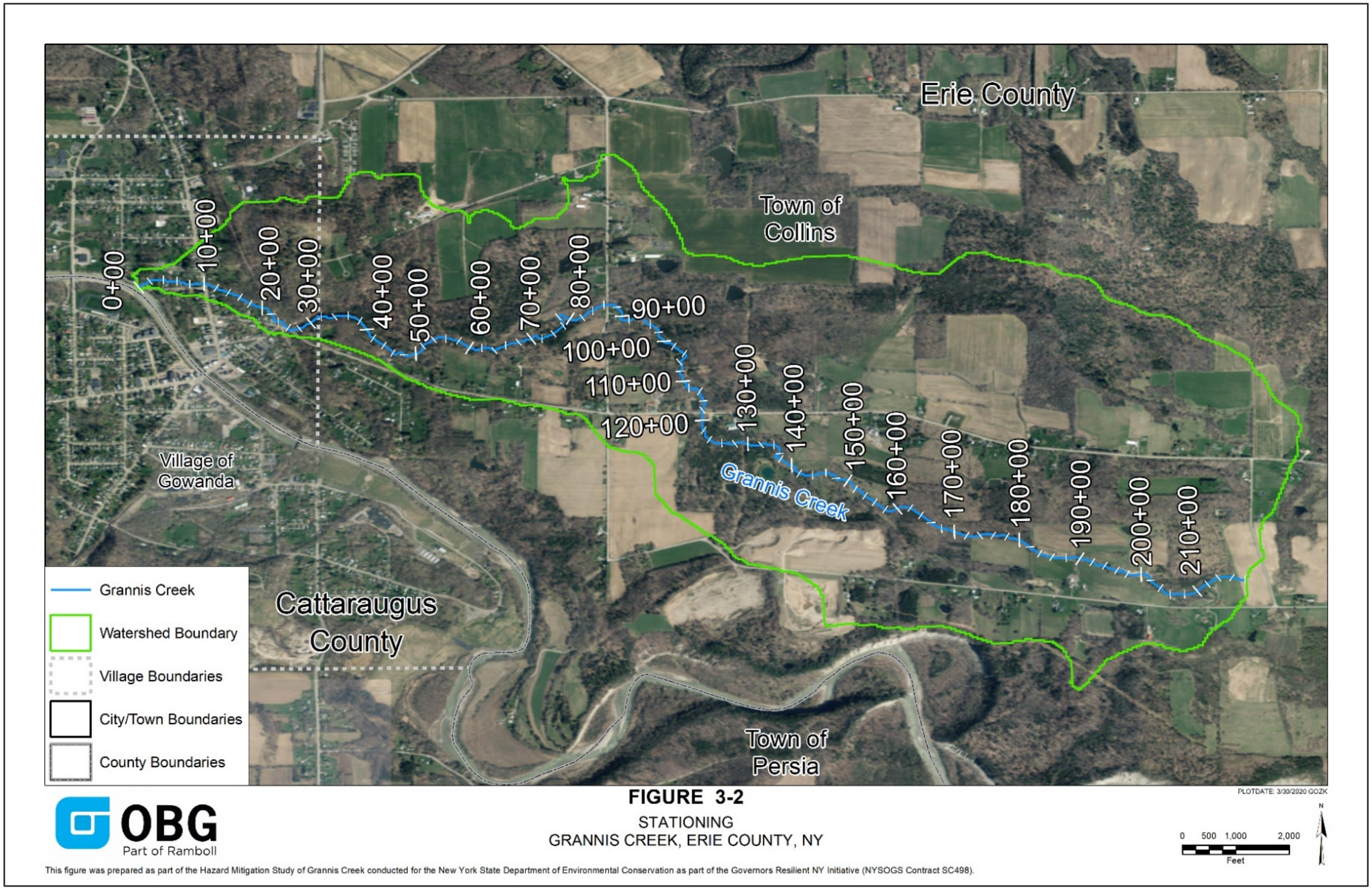


Figure 3-2. Grannis Creek Stationing, Erie County, NY.

Figure 3-3. Grannis Creek Study Area Stationing, Village of Gowanda, NY.

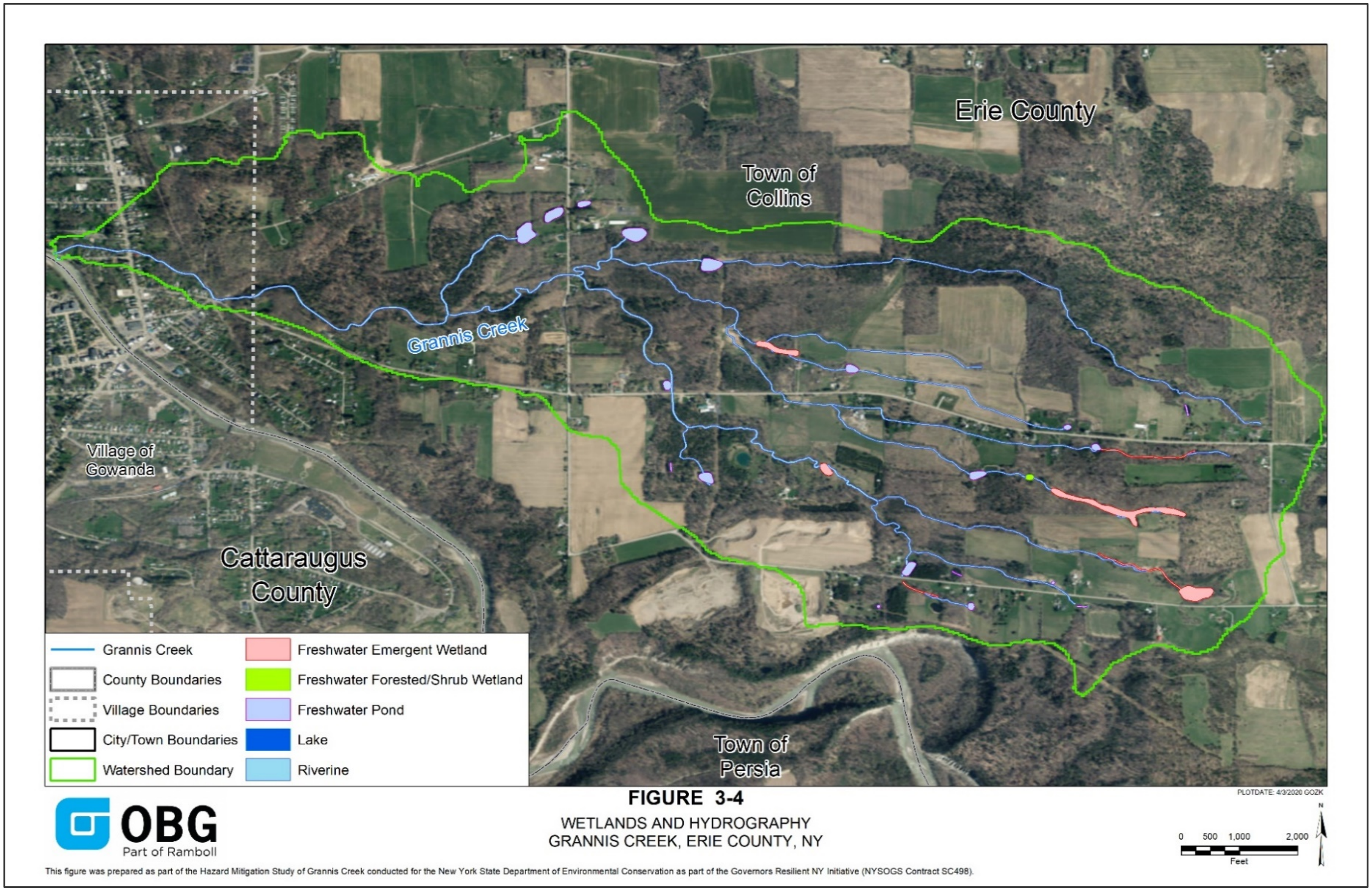


Figure 3-4. Grannis Creek Wetlands and Hydrography, Erie County, NY.

3.2.3 Endangered or Threatened Species

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

The Information for Planning and Consultation results for the project area list one threatened species, the Northern Long-eared Bat (*Myotis septentrionalis*). No critical habitat has been designated for the species at this location (USFWS 2020) (https://ecos.fws.gov/ipac/).

The migratory bird species listed in Table 1 are transient species that may pass over but are not known to nest within the project area.

Table 1. USFWS IPaC Listed Migratory Bird Species

Source: (USFWS 2020)			
Common Name	**Scientific Name**	**Level of Concern**	**Breeding Season**
Bald Eagle	*Haliaeetus leucocephalus*	Non-BCC Vulnerable[1]	Breeds Sep 1 to Aug 31
Bobolink	*Dolichonyx oryzivorus*	BCC Rangewide (CON)[2]	Breeds May 20 to Jul 31
Wood Thrush	*Hylocichla mustelina*	BCC Rangewide (CON)[2]	Breeds May 10 to Aug 31

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

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

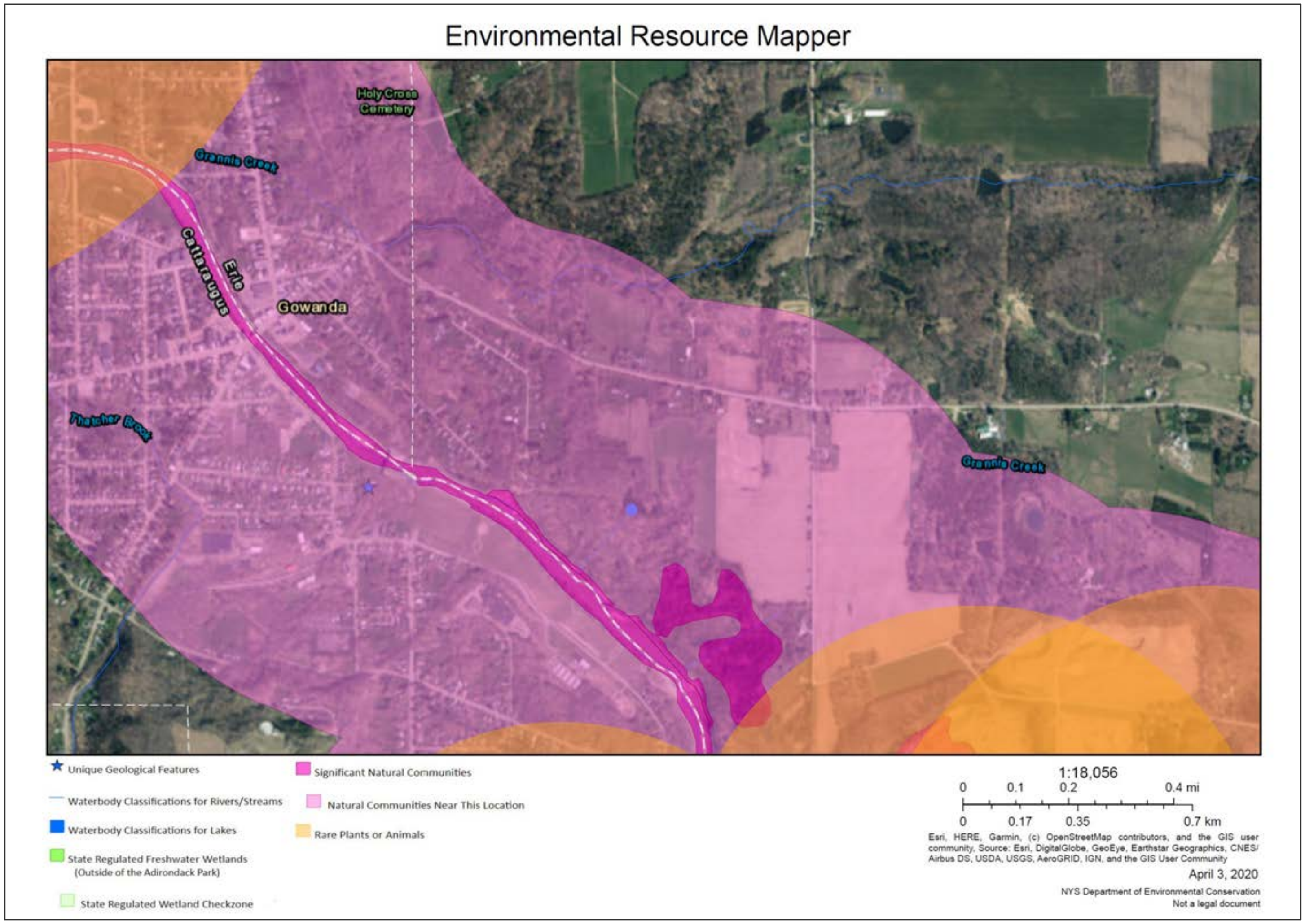


Figure 3-5. Significant Natural Communities and Rare Plants or Animals, Grannis Creek Watershed, Erie County, NY.

3.2.4 Cultural Resources

No facilities listed on the National Register of Historic Places were found within the project area. Consultation with New York State Office of Parks, Recreation, and Historic Places (NYSOPRHP) should be performed to identify the potential presence of archeological resources and the subsequent need to perform a cultural resource investigation (NPS 2014).

3.2.5 Floodplain Location

The FEMA National Flood Hazard Layer (NFHL) (https://hazards-fema.maps.arcgis.com/) is a tool that allows users to generate Flood Insurance Rate Maps (FIRMs) for a selected area. The generated FIRM for the Grannis Creek watershed indicate Special Flood Hazard Areas (SFHAs), which are land areas covered by the floodwaters of the 1% annual chance base flood, are found primarily near the mouth of Grannis Creek at the confluence with Cattaraugus Creek (Figure 3-6) (FEMA 2019c). According to the effective FEMA FIS, the hydrologic and hydraulic analyses completed for Grannis Creek were a re-delineation of the original FEMA H&H study completed in 1976 (FEMA 2019b).

Redelineation is the method of updating effective flood hazard boundaries to match updated topographic data based on the computed water surface elevations from 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).

Cattaraugus Creek is a Regulatory Floodway, which is defined the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than 1-foot over the 1% annual chance flood hazard water surface elevation, 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 discharge. The floodway is the area that needs to be kept free of encroachment in order to convey the base flood. Development in the portions of the floodplain beyond the floodway, referred to as the floodway fringe, is allowed as long as it does not increase the BFE more than 1.0 ft. (FEMA 2000).

For streams and other watercourses where FEMA has provided BFEs, but no floodway has been designated, such as Grannis Creek, 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 Grannis Creek watershed are Zone AE and Zone AO, where mandatory flood insurance purchase requirements apply within these areas. AE Zones are areas that have a 1% annual chance of flooding where BFEs are provided by FEMA. AO zones are shallow flooding areas where FEMA provides a base flood depth, which indicates the depth of water above highest adjacent grade resulting from a flood that has a 1% annual chance of equaling or exceeding that level. FEMA does not provide a BFE for Zone AO's (FEMA 2000).

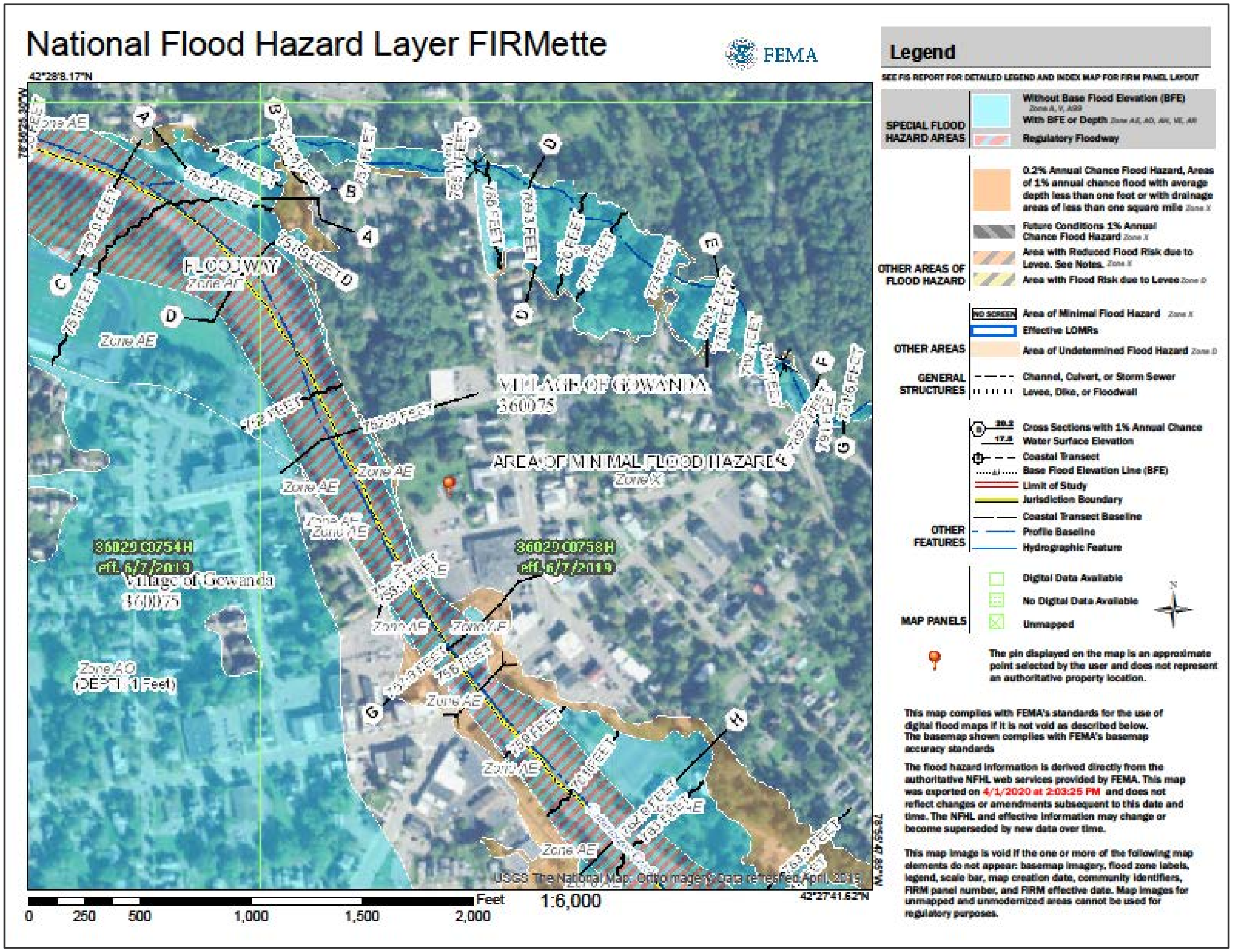


Figure 3-6. National Flood Hazard Layer FIRMette Map, Village of Gowanda, NY.

3.3 WATERSHED LAND USE

The Grannis Creek stream corridor is largely comprised of forested lands (55%) and cultivated (37%) within the basin. Of the forested lands, deciduous forests (46%) comprise the largest proportion of forest type, while corn (10%) encompasses the largest percentage of cultivated land (NASS 2019).

The upper and middle reaches of the basin is primarily cultivated and forested lands. As the creek approaches the confluence with Cattaraugus Creek, the corridor is mainly comprised of forested land, with very little developed land (6%) throughout the basin (NASS 2019).

3.4 GEOMORPHOLOGY

The bedrock geology in the area is of the Canadaway Group, which consists of shales, sandstones, and siltstones. This group is the youngest geologic feature in Erie County and encompasses the southern portion of the County, including the Town of Collins and Village of Gowanda. The bedrock under the county is fairly flat but dips or tilts approximately 50 feet a mile to the southwest. The rocks have retained much of the form they had when they were deposited as silts and sands in the ancient seas that covered this area approximately 300 million years ago (USSCS 1986; Dicken et al. 2008).

Prehistoric advances and retreats of glacial ice during the last ice age beginning approximately 300,000 years ago and ending 10,000 years ago affected the bedrock and soil composition of Erie County, NY. Soil material and pieces of bedrock would be carried and redeposited by moving glacial sheets creating unconsolidated materials of various sizes, shapes, and mineral content. Because the deposited materials were variable, different soils formed in them. Erosion and sedimentation have been at work since the ice retreated and, as a result, steep, fan- shaped alluvial deposits accumulated at the mouths of streams where the velocity of the water slowed, and the sand and gravel dropped out of suspension (USSCS 1986).

Within the Grannis Creek watershed basin, the most predominant soil types are Fluvaquents and Udifluvents (Fu), Langford channery silt loam (LfB), and Chenango gravelly loam (CkB) (NRCS 2019). Fluvaquents and Udifluvents make up the largest proportion of soil type by total acreage within the Grannis Creek basin and are subject to frequent overflow from adjacent streams. These soils commonly shift from place to place during flood due to periods stream cutting and lateral erosion. Fluvaquents are somewhat poorly drained or poorly drained and the Udifluvents are well drained or moderately well drained. Permeability, available water capacity, content of small stones, and acidity are quite variable in these soils (USSCS 1986).

The Grannis Creek channel has cut deep valleys in the upper and lower reaches of the watershed from the headwaters in the Town of Collins down to the Village of Gowanda. As a result, the upper and middle reaches have a narrow floodplain with high banks on both sides of the creek. After entering the Village limits, the floodplain broadens and the creek meanders through the Village towards the confluence with Cattaraugus Creek. The banks of Grannis Creek within the Village are highly developed with residential and commercial properties (FIA 1976).

Figure 3-7 is a stream bed elevation and channel distance from the confluence with Cattaraugus Creek profile using 1-meter light detection and ranging (LiDAR) data from FEMA and the FIS flood profiles for Grannis Creek. Grannis Creek has an average slope of 2.2% over the profile stream length. The creek's streambed lowers approximately 471 vertical feet over this reach from an elevation of 1,205-feet above sea level (NAVD 88) at the headwaters in the Town of Collins to 734-feet above sea level at the confluence of Cattaraugus Creek in the Village of Gowanda, NY (FEMA 2019a; NYSDEC 2008).

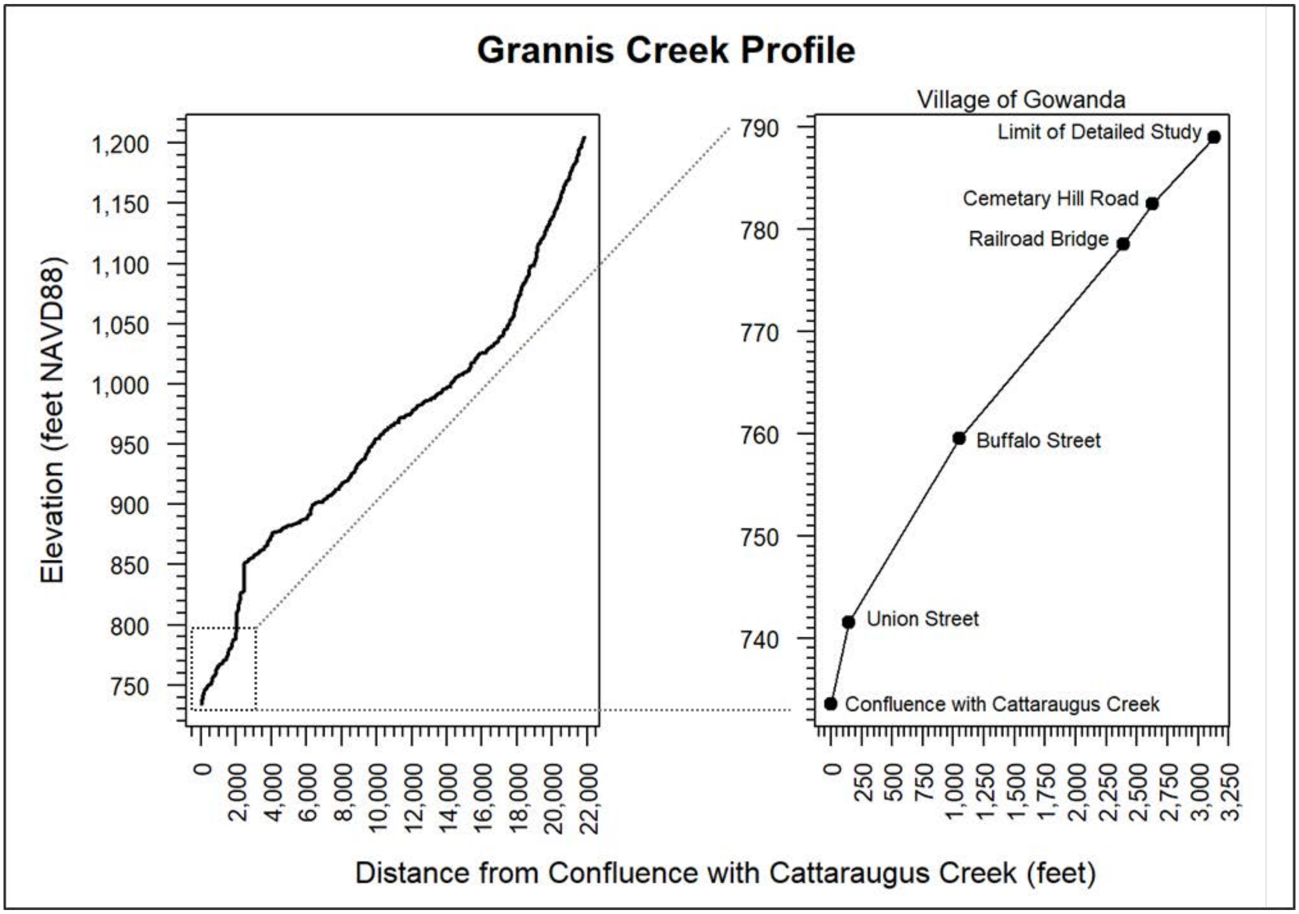


Figure 3-7. Grannis Creek profile of stream bed elevation and channel distance from the confluence with Cattaraugus Creek.

The slope of Grannis Creek is not uniform throughout its flow path. The upstream portion of the creek, from the headwaters to the corporate limits of the Village, has an average slope of 1.9%, while the lower reach, from the Village limits to the confluence with Cattaraugus Creek, has an average slope of 3.7%. The difference in slope contributes to channel bank erosion in the upstream and concentrates runoff and sediment deposition in the lower reaches (FEMA 2019a; NYSDEC 2008).

3.5 HYDROLOGY

Grannis Creek drains an area of 2.7 square miles, is approximately 4 miles in length, and is located in the southwestern portion of New York State and Erie County. Grannis Creek is one of several tributaries of the Cattaraugus Creek and flows in a general westerly direction through the Village of Gowanda, NY. Cattaraugus Creek flows through the Village in a deeply entrenched channel that can handle flows greater than the 0.2-percent annual chance flood hazard without overtopping its banks. However, there are problems with overbank flow at the confluence of Cattaraugus Creek and Grannis Creek (FIA 1976).

Thatcher Brook and Grannis Creek create major flood problems in their lower reaches. The main channels of these streams, as they pass through more developed sections of the Village of Gowanda, have been formed so that when the water level exceeds bankfull, flow is lost over the left bank on Grannis Creek and over the right bank on Thatcher Brook. Areas that receive this overbank flow are generally heavily developed areas where flood damages tend to be extensive (FIA 1976).

Table 2 is a summary of the basin characteristic formulas and calculated values for the Grannis Creek watershed, where A is the drainage area of the basin in square miles (sq. mi.), B_L is the basin length in miles, and B_P is the basin perimeter in miles (Waikar and Nilawar 2014).

Table 2. Grannis Creek Basin Characteristics Factors

(Source: USGS 1978)		
Factor	**Formula**	**Value**
Form Factor (R_F)	A / B_L^2	0.28
Circularity Ratio (R_C)	$4*pi*A / B_P^2$	0.28
Elongation Ratio (R_E)	$2 * (A/pi)^{0.5} / B_L$	0.60

Form Factor (RF) 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 (RC) 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 (RE) gives an indication of ground slope where values less than 0.7 correlate to steeper ground slopes and elongated basin shapes. Based on the basin characteristics factors, the Grannis Creek watershed can be characterized as an elongated basin with lower peak discharges of longer durations, high relief topography with structural controls on drainage, and steep ground slopes (Waikar and Nilawar 2014).

There are no United States Geologic Survey (USGS) stream gaging stations on Grannis Creek. An effective FEMA FIS for Erie County was issued on June 7, 2019 and included drainage area and discharge information for Grannis Creek. Table 3 lists the FEMA FIS drainage area and peak discharges, in cubic feet per second (cfs), for Grannis Creek (FEMA 2019a).

Table 3. Grannis Creek FEMA FIS Peak Discharges

(Source: FEMA 2019a)						
			Peak Discharges (cfs)			
Location	**Drainage Area (sq. mi.)**	**River Station (ft)**	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
Grannis Creek	2.7*	0+00	1,050*	1,550*	1,700*	2,050*
* Values interpolated from FEMA FIS Frequency-Discharge, Drainage Area Curve for Grannis Creek						

The FEMA FIS flood-frequency discharges for Grannis Creek in the Village of Gowanda, NY were developed using a rainfall-runoff relationship determined by the USSCS (Kent 1973). The rainfall frequency was developed by the National Weather Service (NWS) and extends through the 1-percent annual chance interval, while the 0.2-percent annual chance interval was determined using straight-line extrapolation. The FEMA FIS methodology was based on the USDA Soil Conservation Service (SCS) method contained in Technical Release No. 55 (TR-55), peak rate of discharge (graphical method), hydrographs (tabular method), and storage volumes (quick manual method) to convert rainfall into runoff (FEMA 2019a).

A general limitation of the FEMA FIS methodology is that flow is based on open and unconfined flow over land or in channels. Since the SCS method relied heavily on rainfall depths, the outdated rainfall depths used in the FEMA FIS do not accurately reflect the current runoff in the watershed (USSCS 1975).

USGS *StreamStats* v4.3.11 software (https://streamstats.usgs.gov/ss/) is a map-based web application that provides an assortment of analytical tools that are useful for water-resources planning and management, and engineering purposes. Developed by the USGS, the primary purpose of *StreamStats* is to provide estimates of streamflow statistics for user selected ungaged sites on streams and for USGS stream gages, which are locations where streamflow data are collected (Ries et al. 2017).

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

For ungaged sites, such as Grannis Creek, *StreamStats* relies on regional regression equations that were developed by statistically relating the streamflow statistics to the basin characteristics for a group of stream gages within a region. Estimates of streamflow statistics for an ungaged site can then be obtained by measuring its basin characteristics and inserting them into the regression equations (Ries et al. 2017).

For example, the equation for estimating the 100-year flood for ungaged sites within one hydrologic region in New York is:

$$Q_{100} = 1.91 * (A)^{0.980} * (SL)^{0.636} * (P)^{0.590}$$

Where

A is the drainage area in square miles;

SL is the main channel slope in feet per mile; and

P is the mean annual precipitation, in inches (Lumia et al. 2006).

StreamStats delineates the drainage basin boundary for a selected site by use of an evenly spaced grid of land-surface elevations, also referred to 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-percent annual chance interval discharge when compared to the drainage-area only regression equation (Ries et al. 2017).

However, when one or more of the basin characteristics for an ungaged site are outside the given ranges then the estimates are extrapolated. *StreamStats* provides warnings when extrapolation occurs. Although *StreamStats* does provide estimates of streamflow statistics in these circumstances, no error indicators are provided with them, as the errors associated with these estimates are unknown and may be very large (Ries et al. 2017).

In addition, estimates of streamflow statistics that are obtained from regression equations are based on the assumption of natural flow conditions at the ungaged site unless the reports that document the equations state otherwise. If human activities such as dam regulation and water withdrawals substantially affect the timing, magnitude, or duration of flows at a selected site, the regression-equation estimates provided by *StreamStats* should be adjusted by the user to account for those activities (Ries et al. 2017). Table 4 is the summary output of peak discharges calculated by the USGS *StreamStats* software for Grannis Creek at selected FEMA FIS profile locations.

Table 4. USGS *StreamStats* Peak Discharge for Grannis Creek at the FEMA FIS Locations

Source: (Ries et al. 2017)						
			Peak Discharges (cfs)			
Location	Drainage Area (sq. mi.)	River Station (ft)	10-Percent	2-Percent	1-Percent	0.2-Percent
Confluence with Cattaraugus Creek	2.7	0+00	509	823	970	1,360
Union Street	2.7	1+50	509	823	970	1,360
Buffalo Street	2.58	10+50	483	780	919	1,280
Railroad Bridge	2.48	23+90	465	750	884	1,230
Cemetery Hill Road	2.48	26+30	465	750	884	1,230
Limit of Detailed Study	2.46	31+30	465	750	884	1,230
South Quaker Street	1.97	85+00	383	619	730	1,020
Gowanda Zoar Rd/Co. Rd. 74	0.69	114+00	152	246	290	404

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-percent annual chance flood hazards were determined. Standard error gives an indication of how accurate the calculated peak discharges are when compared to the actual peak discharges since about two-thirds (68.3-percent) of the calculated peak discharges would be within one standard error of the actual peak discharge, 95.4-percent would be within two standard errors, and almost all (99.7-percent) would be within three standard errors (McDonald 2014). Table 5 is a summary table of the USGS *StreamStats* standard errors at each percent annual chance flood hazard.

Table 5. USGS *StreamStats* standard errors for full regression equations

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

Based on the *StreamStats* standard error calculations, the FEMA FIS peak discharges were determined to be outside of the acceptable range (95% confidence interval). For this study, to maintain consistency in the modeling outputs with the FEMA models and to develop a conservative analysis of flood risk in the Grannis Creek watershed, the effective FIS peak discharges were used in the HEC-RAS modeling software simulations.

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

Bankfull discharge is defined as the flow that reaches the transition between the channel and its flood plain. This regionally specific model of calculating bankfull statistics was determined to be more accurate when compared to a statewide (or pooled) model (Mulvihill et al. 2009). The bankfull width and depth of Grannis 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 and Silvey 1996). Table 6 lists the estimated bankfull discharge, width, and depth at select locations along Grannis Creek as derived from the USGS *StreamStats* program (Ries et al. 2017).

Table 6. Estimated Bankfull Discharge, Width, and Depth

Source: (Ries et al. 2017)					
Location	**Drainage Area (sq. mi.)**	**River Station (ft)**	**Discharge (cfs)**	**Bankfull Width (ft)**	**Bankfull Depth (ft)**
Confluence w/ Cattaraugus Creek	2.7	0+00	111	25.6	1.33
Union Street	2.7	1+50	111	25.6	1.33
Buffalo Street	2.58	10+50	107	25.1	1.31
Railroad Bridge	2.48	23+90	103	24.7	1.3
Cemetery Hill Road	2.48	26+30	103	24.7	1.3
Limit of Detailed Study	2.46	31+30	102	24.6	1.3
South Quaker Street	1.97	85+00	85	22.5	1.23
Gowanda Zoar Rd / Co. Rd. 74	0.69	114+00	35.1	14.5	0.95

3.6 INFRASTRUCTURE

Due to the small size of the Grannis Creek watershed, there are few infrastructure features that cross the creek channel. There are no dams along Grannis Creek; however, there is a secondary recreation/water supply dam along one of the creek's tributaries. The Capella Brothers farm pond dam is in the Town of Collins and is located approximately 0.5 miles northeast the junction of Gowanda Zoar and South Quaker Roads. The dam has a hazard rating of Class 0, which indicates it is a "negligible or no hazard" dam (NYSDEC 2019b).

There are numerous crossings over Grannis Creek where culverts of various sizes can be found, but there is only one NYSDOT owned large culvert at Buffalo Street (BIN #C540053) in the Village of Gowanda, NY. The remaining culverts at Union Street and Cemetery Hill Road are owned and maintained by the Village of Gowanda (NYSDOT 2014). A culvert of great significance, but not found in the NYSDOT database, is the culvert underneath Cemetery Hill Road. This culvert was the location where debris accumulated and caused water in the creek to overtop the banks causing flooding in the Village in 2009 (NYSDEC 2019a).

There is an active railroad track and bridge that crosses the creek in the Village that is owned by the Erie County Industrial Development Agency (ECIDA) and operated by Buffalo Southern Railroad (BSOR) (NYSDOT 2013). Construction of the railroad bridge led to the altering of the creek path. To minimize track and bridge lengths, the creek was re-directed at two near 90^{o} angles underneath the railroad bridge (NYSDEC 2019a).

Figure 3-8 displays the locations of infrastructure that cross Grannis Creek in the Village of Gowanda and Town of Collins, NY. Table 7 summarizes the infrastructure data for bridges and culverts that cross Grannis Creek in the Village of Gowanda, NY with bankfull widths from the USGS *StreamStats* program and hydraulic capacities from the FEMA FIS (NYSDOT 2014; OBG 2019; Ries et al. 2017).

Table 7. Summary of Infrastructure Crossing Grannis Creek

Source: (NYSDOT 2014; OBG 2019; Ries et al. 2017; FEMA 2019a)						
Type	**Roadway Carried**	**River Station (ft)**	**Length[1] (ft)**	**Width[2] (ft)**	**Height (ft)**	**Hydraulic Capacity (% Annual Chance)**
Box Culvert	Union Street	1+50	32	12.5	10.5	N/A
Box Culvert	Buffalo Street (NY-39/US-62)	10+50	83	16	6	Greater than 10
Railroad Bridge	Railroad Tracks	23+90	15	10.3	13.9	0.2
Box Culvert	Cemetery Hill Road	26+30	31	10	8	Greater than 10

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

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

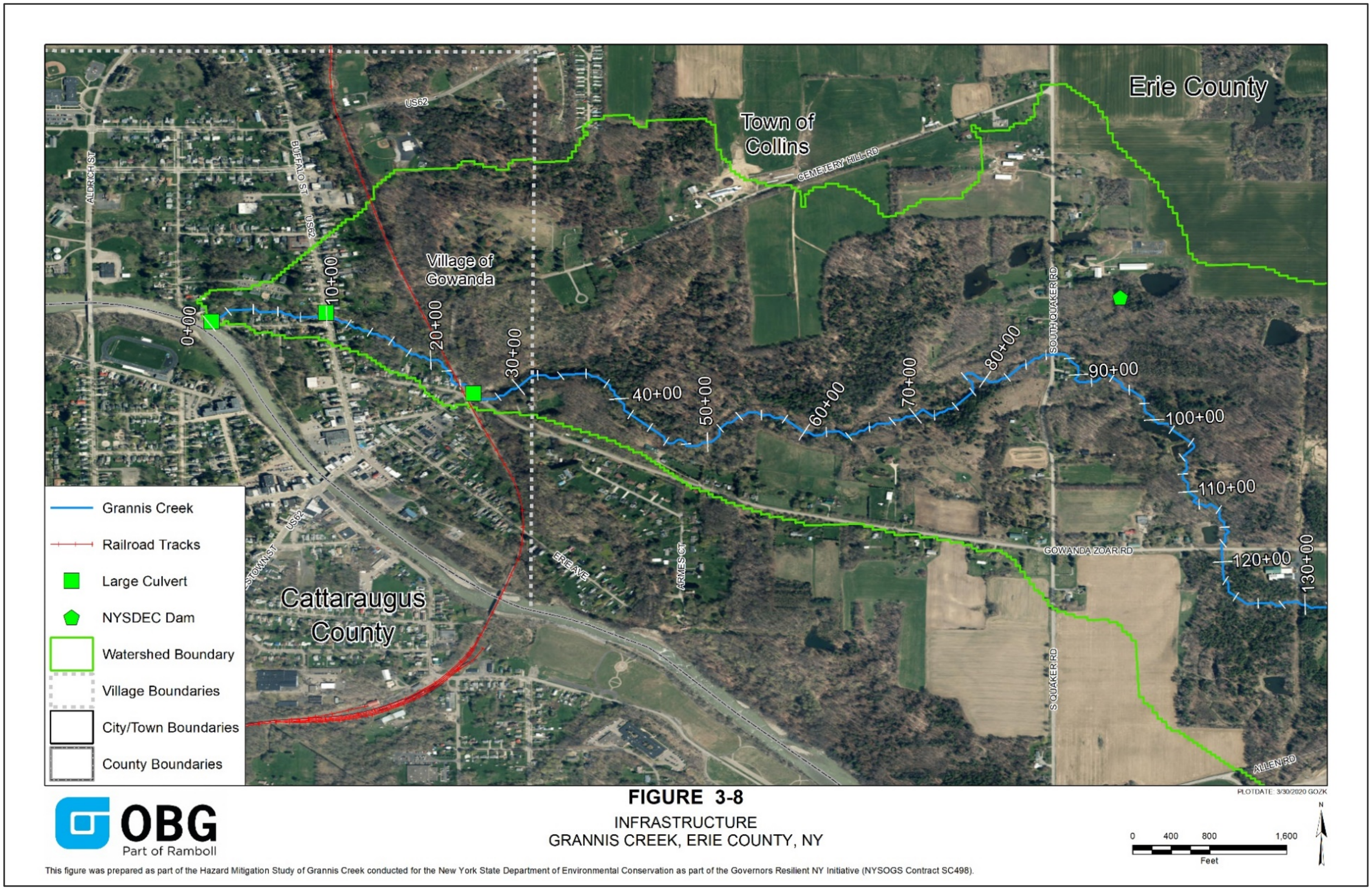


Figure 3-8. Grannis Creek Infrastructure, Erie and Cattaraugus Counties, NY.

Hydraulic capacity is the measure of the amount of water that can pass through a structure or watercourse. Hydraulic design is an essential function of structures in watersheds. Exceeding the capacity can result in damages or flooding to surrounding areas and infrastructure (Zevenbergen et al. 2012).

In 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 peak flows shall be increased to account for future projected peak flows based on the USGS StreamStats tool where current 2% peak flows shall be increased by 10% in Region 5. For critical culverts, the minimum hydraulic design criteria is 3-feet of freeboard over the 2% 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 (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 8 displays the 2% and 1% annual chance flood levels and their calculated difference at FEMA FIS infrastructure locations using the FIS profile for Grannis Creek.

Table 8. 2 and 1-percent Annual Chance Flood Hazard Levels with Differences at Infrastructure Locations

Source: (FEMA 2019a)				
Bridge Crossing	**River Station (ft)**	**2-Percent Water Surface Elevation (ft NAVD88)**	**1-Percent Water Surface Elevation (ft NAVD88)**	**Difference in Water Surface Elevations (ft NAVD88)**
Union Street[1]	1+50	N/A	N/A	N/A
Buffalo Street	10+50	768.5	768.75	0.25
Railroad Tracks	23+90	788.5	789	0.5
Cemetery Hill Road	26+30	790.75	791	0.25

[1] Water surface elevations at the Union Street culvert incorporate backwater from Cattaraugus Creek in the FEMA FIS profile and were not included in the table.

In assessing hydraulic capacity of the high-risk constriction point culverts and bridge along Grannis Creek, the FEMA FIS profile of Grannis Creek was used to determine the highest annual chance flood elevation to flow under the low chord of a bridge or culvert (Table 7). According to the FEMA FIS profiles, the Union Street box culvert is not displayed due to the backwater effect of Cattaraugus Creek, and both the Buffalo Street and Cemetery Hill Road culverts are overtopped by annual chance flood events of less than the 10% flood hazard level (FEMA 2019a).

In addition, the USGS *StreamStats* tool was used to calculate the bankfull widths and discharges for each structure in the Village of Gowanda. Table 9 indicates that the bankfull widths are wider than the structure's width for each structure except for the Cemetery Hill Road culvert.

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

Table 9. Infrastructure Width and Bankfull Width and Discharge of High-Risk Constriction Point Infrastructure

Source: (NYSDOT 2014; OBG 2019; Ries et al. 2017; FEMA 2019a)						
Infrastructure Type	**Roadway Carried**	**River Station (ft)**	**Structure Width (ft)**	**Bankfull Width (ft)**	**Bankfull Discharge (cfs)**	**Annual Chance Flood Event Equivalent**
Box Culvert	Union Street	1+50	12.5	25.6	111	80-percent
Box Culvert	Buffalo Street	10+50	16	25.1	107	80-percent
Railroad Bridge	Railroad Tracks	23+90	10.3	24.7	103	80-percent
Box Culvert	Cemetery Hill Road	26+30	10	24.7	103	80-percent

4. CLIMATE CHANGE IMPLICATIONS

4.1 FUTURE PROJECTED STREAMFLOW IN GRANNIS 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) (Rosenzweig et al. 2011). 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).

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

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* was developed by the USGS in partnership with the New York State Department of Transportation. 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, termed “Representative Concentration Pathways” (RCP): 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 et al. 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 cannot provide accurate results for basins that extend across more than one hydrologic region in New York (NYSDEC 2018). The Grannis Creek watershed does not extend across multiple hydrologic regions. It is located within hydrologic region 5 in New York State (Lumia et al. 2006).

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 can 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-percent increased flow for an end of design life of 2025-2100 (NYSDEC 2018). Table 10 provides a summary of the projected future peak stream flows using the FEMA FIS peak discharges and 10-percent CRRA design multiplier and the associated change in water surface elevations at the confluence of Grannis and Cattaraugus Creeks.

Table 10. Current and Projected Future Discharge in Grannis Creek at the Confluence with Cattaraugus Creek

Source: (Ries et al. 2017; NYSDEC 2018)			
Annual Chance Flood Event	**Current Effective FIS Discharge (cfs)**	**Projected CRRA Future Discharge (cfs)**	**Change in Water Surface Elevation (ft)**
10-Percent	1,050	1,155	+ 0.6
2-Percent	1,550	1,705	+ 0.8
1-Percent	1,700	1,870	+ 0.8
0.2-Percent	2,050	2,255	+ 0.8

Appendix F contains the HEC-RAS simulation summary sheets for the proposed and future condition simulations. The HEC-RAS model simulation results for the future condition model parameters using the future projected discharge values are similar to the base condition model output with the only difference being future projected water surface elevations are up to 0.8 feet higher due to the increased discharges. Table 11 displays the change in water surface elevations for each annual chance flood event at select locations along Grannis Creek using the HEC-RAS base and future condition simulations. Positive water surface elevation changes indicate the future condition simulations projected higher water surface elevations when compared to the current base condition simulations.

Table 11. Change in Water Surface Elevations at Select Locations Using HEC-RAS Base and Future Condition Simulations

		Change in Water Surface Elevation (ft)			
Location	**River Station (ft)**	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
Confluence with Cattaraugus Creek	0+00	+ 0.6	+ 0.8	+ 0.8	+ 0.8
Union Street	1+50	+ 0.5	+ 0.3	+ 0.3	+ 0.4
Buffalo Street	10+50	+ 0.1	+ 0.1	+ 0.1	+ 0.1
Cemetery Hill Road	26+30	+ 0.2	+ 0.2	+ 0.2	+ 0.2

5. FLOODING CHARACTERISTICS

5.1 FLOODING HISTORY

Flooding along Grannis Creek generally occurs in the late spring and summer months due to heavy rain or rain on saturated soil events. The situation is compounded by the accumulation of debris and sediment at the upstream face of culverts that can potentially clog the openings and cause backwater flooding. The heavily developed lower reaches of Grannis Creek, primarily in the Village of Gowanda, are at considerable risk of flood damages due to the close proximity of residential and commercial properties to the creek banks and topography of the floodplain in the Village.

According to FEMA severe repetitive loss and repetitive loss data, there are 10 properties identified as repetitive loss and no severe repetitive loss properties within the Village of Gowanda. None of the repetitive loss properties are located within the Grannis Creek watershed. A Repetitive Loss (RL) property is any insurable building for which two or more claims of more than $1,000 were paid by the NFIP within any rolling ten-year period, since 1978. A Severe Repetitive Loss (SRL) property is any insurable building for which four or more claims of more than $5,000 (or cumulative amount exceeding $20,000) were paid by the NFIP or at least two separate claims payments have been made with the cumulative amount of exceeding the fair market value of the insured building on the day before each loss within any rolling ten-year period, since 1978 (FEMA 2019d; FEMA 2020).

Most recorded major flood events have occurred during the months of May to August. The greatest flood of historical record occurred on August 9, 2009, while other damaging floods have occurred in June 1998, May 2014, and November 2017 (NCEI 2019).

The August 9, 2009 flood is considered to be the maximum flood of record. During the night of August 9, 2009, two storm systems intersected over western New York and produced torrential rain and rainfall rates of nearly 6 inches of rain in 1.5 hours as recorded by a National Weather Service weather observer in Perrysburg, NY. In the Village of Gowanda, Cattaraugus Creek was not the primary source of flooding; instead, Thatcher Brook and Grannis Creek overwhelmed culverts and bridges, overtopping roadways and washing out culverts. Debris accumulation around culverts and the topography of the Village exacerbated the flooding due to the modest gradient and lack of confining valleys around the smaller tributaries entering the Village. As a result, sheet-flow flooding impacted residential and commercial areas outside of the FEMA recognized 1 and 0.2-percent flood zones. Many people were evacuated or rescued in the Village of Gowanda and one death occurred during the flood. The water supplies of the Village were compromised by damages to reservoirs and water-transmission infrastructures. Water and mud damage to residential and commercial properties was extensive. The combined total estimate of damages from the flash floods was greater than $90 million (USGS 2010).

Though there is no USGS gage on Grannis Creek, the nearby USGS gage 04213500 on Cattaraugus Creek at Gowanda, New York recorded a flow of 32,300 cfs, which is the highest flow ever recorded for that gage. The storm intensity had an annual chance flood recurrence of less than 0.2-percent (500-year recurrence interval). Flood elevations exceeded previously defined 0.2-percent annual exceedance probability (500-year recurrence interval) elevations by 2 to 4 feet in the Village. High-water marks surveyed by the USGS were used in indirect hydraulic computations to estimate peak flows for Grannis Creek. The peak flow in Grannis Creek was computed, using the slope-area method, to be 1,400 cfs, which would be greater than the current 0.2-percent annual chance event according to the USGS *StreamStats* (USGS 2010).

More recently, on May 13, 2014, a stalled warm front over the southern tier of Western NY brought heavy rainfall and thunderstorms with rainfall rates of up to 3 inches over a few hours. The rain intensity caused flash flooding across the region washing out roads and culverts and requiring evacuations and high-water rescues in the Village of Gowanda. State Disaster Declarations were made for the affected areas and reported property damages of approximately $5 million were incurred (NCEI 2019).

FEMA FIRMs are available for Grannis Creek from FEMA. Figure 5-1 displays the floodway and 1- and 0.2-percent annual chance flood event boundaries for Grannis Creek as determined by FEMA for the Village of Gowanda, NY. The maps indicate that flooding generally occurs in the downstream portions of Grannis Creek, primarily in the neighborhoods adjacent to Perry and Buffalo Streets and downstream near Union Street (FEMA 2019a).

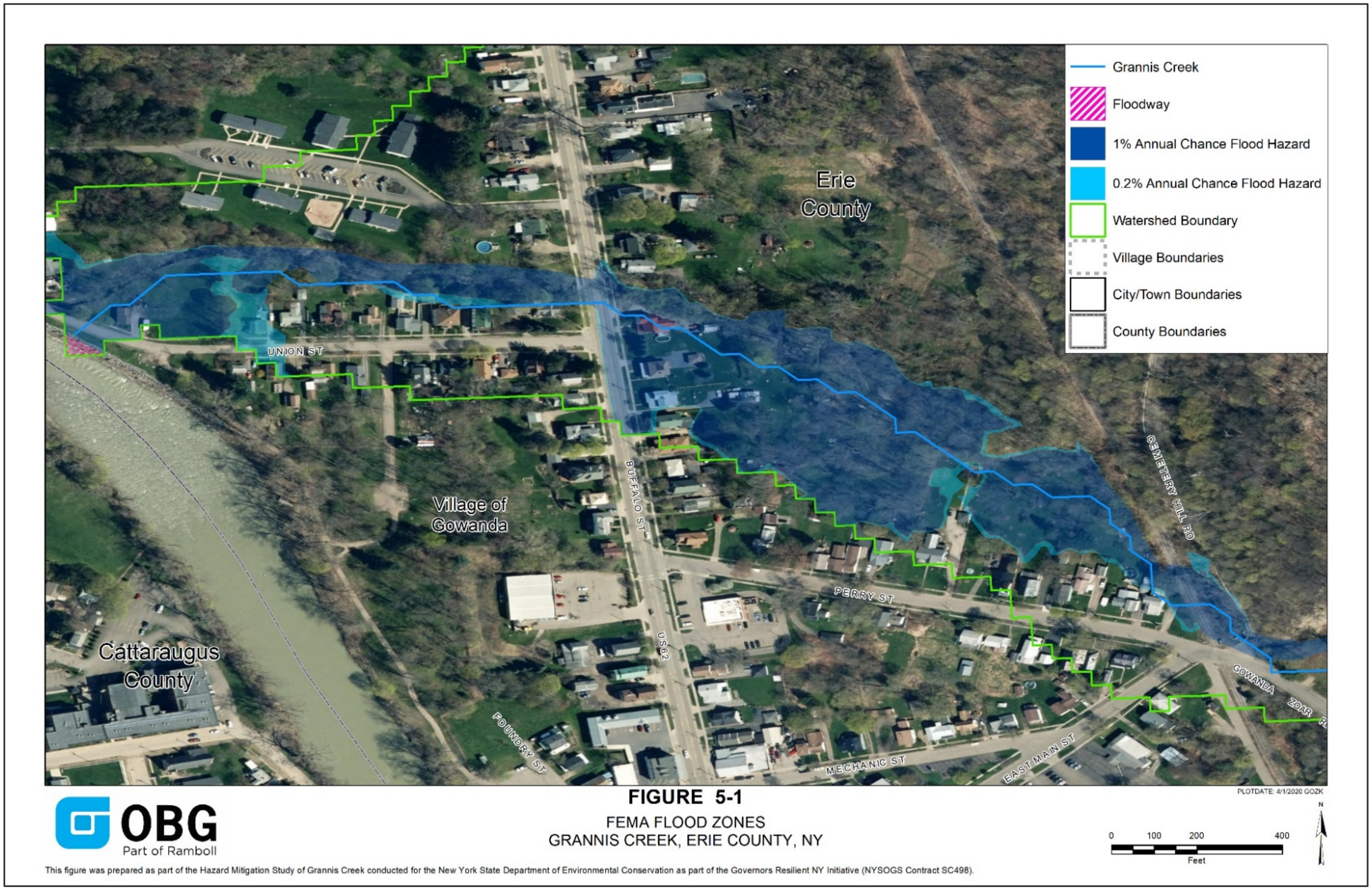


Figure 5-1. Grannis Creek FEMA flood zones, Village of Gowanda, NY

6. FLOOD RISK ASSESSMENT

6.1 FLOOD MITIGATION ANALYSIS

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

Hydraulic modeling of Grannis Creek in the Village of Gowanda and Town of Collins was completed by FEMA in 1976. Due to the age and format of the 1976 study, an updated 2-Dimensional (2-D) HEC-RAS model was developed for this study using a 1-meter LiDAR DEM (NYSDEC 2008), Autodesk's AutoCAD 2018 (Autodesk, Inc. 2017), and ESRI ArcMap 10.7 (ESRI 2019) GIS software. The hydraulics model was developed for Grannis Creek beginning at the confluence with Cattaraugus Creek (river station 0+00) and extending upstream to the limits of the FEMA detailed study upstream the Cemetery Hill Road crossing (river station 31+30).

A base condition model was developed using a 2-D computational mesh, which was generated with the available tools within the HEC-RAS software. The mesh was comprised of 20 x 20 feet base elements with required refinements to best represent the topography of the Grannis Creek watershed. Flow breaklines were also added to force alignment of the computational elements and to implement flow breaks in the 2-D computational domain. The 2-D computational mesh consists of approximately 10,000 cells with an average area of 370 ft^2/cell, which when joined form a mesh that encompasses the entire Grannis Creek watershed. Each cell of the mesh represents an individual solution to a hydraulic equation, which when combined over the entire mesh, produces a solution for the entire model area.

The riverine mesh elements are used to calculate energy losses in the entire system through friction. Frictional losses are typically derived through Manning's equation and the use of a Manning n-value for roughness. Manning's n value is highly variable and depends on a number of factors, including size and shape of the channel, stage and discharge, seasonal changes, surface roughness, vegetation, channel irregularities, temperature, channel alignment, obstructions, scour and deposition, and suspended material and bedload. A Manning's roughness of 0.035 for the creek, 0.032 for roads and impervious surfaces, and 0.055 for vegetation were used and the rest of the computational domain was assigned values through a 2-D coverage shapefile (USACE 2010).

The 2-D computational model incorporated LiDAR DEM data and structural data of bridges and culverts along Grannis Creek to model the existing floodplain conditions (USACE 2010). The model was given upstream constant flow and downstream normal depth of 0.015 boundary conditions. A time step of 2 seconds was used for all the flow scenarios for a sufficiently long time to arrive at steady state conditions. The computational mesh was refined, so that further regiments of the mesh didn't give different results with the selected time step.

The base condition model was then compared to the effective FEMA FIS water surface elevation profiles, FIRM, and past flood events with known water surface elevations to validate the model. After the base condition model was verified, it was then used to develop proposed condition models to simulate potential flood mitigation strategies. The simulation results of the proposed conditions were evaluated based on their reduction in water surface elevations. The flood mitigation measures modeled were:

- Increase Size of Cemetery Hill Road Box Culvert
- Increase Size of Buffalo Street Box Culvert
- Increase Size of Union Street Box Culvert
- Increase Width of Railroad Bridge Opening
- Levee Behind Perry Street Neighborhood
- Flood Bench Downstream Railroad Bridge

6.2 COST ESTIMATE ANALYSIS

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

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

For mitigation alternatives where increases in culvert sizes were recommended, culvert size increases were initially analyzed based on 2-feet freeboard over the Base Flood Elevation for a 1-percent annual chance flood event. Once these optimal sizes were determined, further analysis was completed including site constraints and constructability. Due to these additional constraints, often the size necessary to meet the freeboard requirement was not feasible. Cost estimates were performed based on projects determined to be constructible and practical.

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

6.3 ICE JAM ANALYSIS

According to the USACE Cold Regions Research and Engineering Laboratory (CRREL) ice jam database, National Centers for Environmental Information (NCEI) storm events database, the FEMA FIS, and the stakeholder engagement meeting, there have been no reported or observed ice jam events on Grannis Creek (CRREL 2020; FEMA 2019b, NYSDEC 2019a). Therefore, ice jam flooding was determined not to be a driving factor of flood risk in the Village of Gowanda.

6.4 HIGH RISK AREAS

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

6.4.1 High Risk Area #1: Union Street Culvert

High risk area #1 is the box culvert underneath the Union Street crossing over Grannis Creek immediately upstream of the confluence with Cattaraugus Creek in the Village of Gowanda (river station 1+50) (Figure 6-1). The effective FEMA FIRM shows that the culvert under Union Street constricts flow causing backwater flooding upstream of the culvert. There is no available data from the FIS water surface profile regarding the hydraulic capacity of the culvert. The water surface elevations in this reach are also influenced by backwater from Cattaraugus Creek due to the close proximity of the culvert to the confluence. The backwater effect from Cattaraugus Creek extends approximately 400-feet upstream of Grannis Creek for the 1% annual chance flood hazard, according to the FEMA FIS profiles (FEMA 2019b).

6.4.2 High Risk Area #2: Buffalo Street Culvert

High risk area #2 is the box culvert underneath the Buffalo Street crossing over Grannis Creek in the Village of Gowanda (river station 10+50) (Figure 6-1). The effective FEMA FIRM shows that the Buffalo Street culvert constricts flow causing backwater flooding approximately 750-feet upstream of the culvert (FEMA 2019b). The FEMA FIS water surface elevation profiles for the Buffalo Street crossing indicates the box culvert is unable to pass annual chance flood events below 10-percent (FEMA 2019a). The susceptibility of the Buffalo Street crossing to flooding is an important issue not only for nearby residential and commercial properties, but also for infrastructure and emergency response since Buffalo Street is a major route into and out of the Village of Gowanda.

Buffalo Street is an important thoroughfare in the Village of Gowanda. Numerous businesses and residences reside along Buffalo Street and depend on its traffic and access for business. It is one of only two major United States (US) routes through the

Village. If Buffalo Street were to become impassible, there would be only one alternative route, Aldrich Street (County Highway 84), within the Village to cross Cattaraugus Creek. According to the NYSDOT Functional Class Viewer (https://gis.dot.ny.gov/html5viewer/?viewer=FC), Buffalo Street is classified is a Principal Arterial Other, which is defined as a connected rural network of continuous routes that serves corridor movement and has trip length and travel density characteristics indicative of substantial statewide or interstate travel; and provides an integrated network without stub connections except where unusual geographic or traffic flow conditions dictate otherwise (e.g. international boundary connections and connections to coastal cities). Based on the functional classification for Buffalo Street and the NYSDOT definition of critical infrastructure, the Buffalo Street culvert was determined to be a critical culvert in this study (NYSDOT 2016).

6.4.3 High Risk Area #3: Railroad Bridge Crossing

High risk area #3 is the channelization of Grannis Creek for the railroad bridge crossing downstream of the Cemetery Hill Road box culvert (river station 23+90) (Figure 6-1). The FEMA FIS water surface elevation profiles for the railroad bridge indicate that the bridge is of sufficient height for all annual chance flood events up to 0.2-percent (FEMA 2019a).

Based on field measurements the railroad bridge opening across Grannis Creek is 14-ft high by 15-ft wide. USGS *StreamStats* calculated the bankfull width of the bridge to be 24.7-ft. This indicates the railroad bridge opening is nearly 10-ft too narrow to allow bankfull discharge to pass under the bridge, which causes water velocities to slow and contract and water surfaces to rise upstream. The effective FEMA FIRM shows that the railroad bridge, and the two 90^{o} bends in the channel constructed to accommodate the railroad tracks, act to constrict and slow flow causing backwater flooding upstream of the railroad crossing. The influence of the railroad bridge crossing and the channelization of Grannis Creek underneath the railroad bridge extends upstream approximately 240-ft to the Cemetery Hill Road culvert. Any flood mitigation measures aimed at improving the Cemetery Hill Road culvert would need to address the water flow effects of the channelized creek that pass under the railroad bridge (FEMA 2019b).

6.4.4 High Risk Area #4: Cemetery Hill Road Culvert

High risk area #4 is the box culvert underneath the Cemetery Hill Road crossing over Grannis Creek in the Village of Gowanda (river station 26+30) (Figure 6-1). The effective FEMA FIRM indicates that the Cemetery Hill Road culvert does not cause backwater upstream of the culvert (FEMA 2019b). This is due to the fact that the left bank elevation is 792-ft NAVD88, while the BFE in the FIRM is 791-ft NAVD88 upstream of the culvert. Once water surface elevations exceed the 1% annual chance flood hazard level, water overtops the banks and floods adjacent areas as sheet flow. There is little to no backwater as a result (NYSDEC 2008). The FEMA FIS water surface elevation profiles for the Cemetery Hill Road crossing indicate that the box culvert is unable to pass annual chance flood events below 10-percent (FEMA 2019a).

The Cemetery Hill Road culvert was identified as an area for debris accumulation, which increases the potential for backwater and flooding in the vicinity of the culvert. Also, this location was determined to be the primary location for flood waters overtopping the Grannis Creek banks and causing sheet-flow flooding in the Village during the August 9, 2009 flood event. Eyewitness accounts describe water overtopping the creek banks at Cemetery Hill Road and flowing down East Main Street towards Cattaraugus Creek, damaging residential and commercial properties in the process (NYSDEC 2019a).

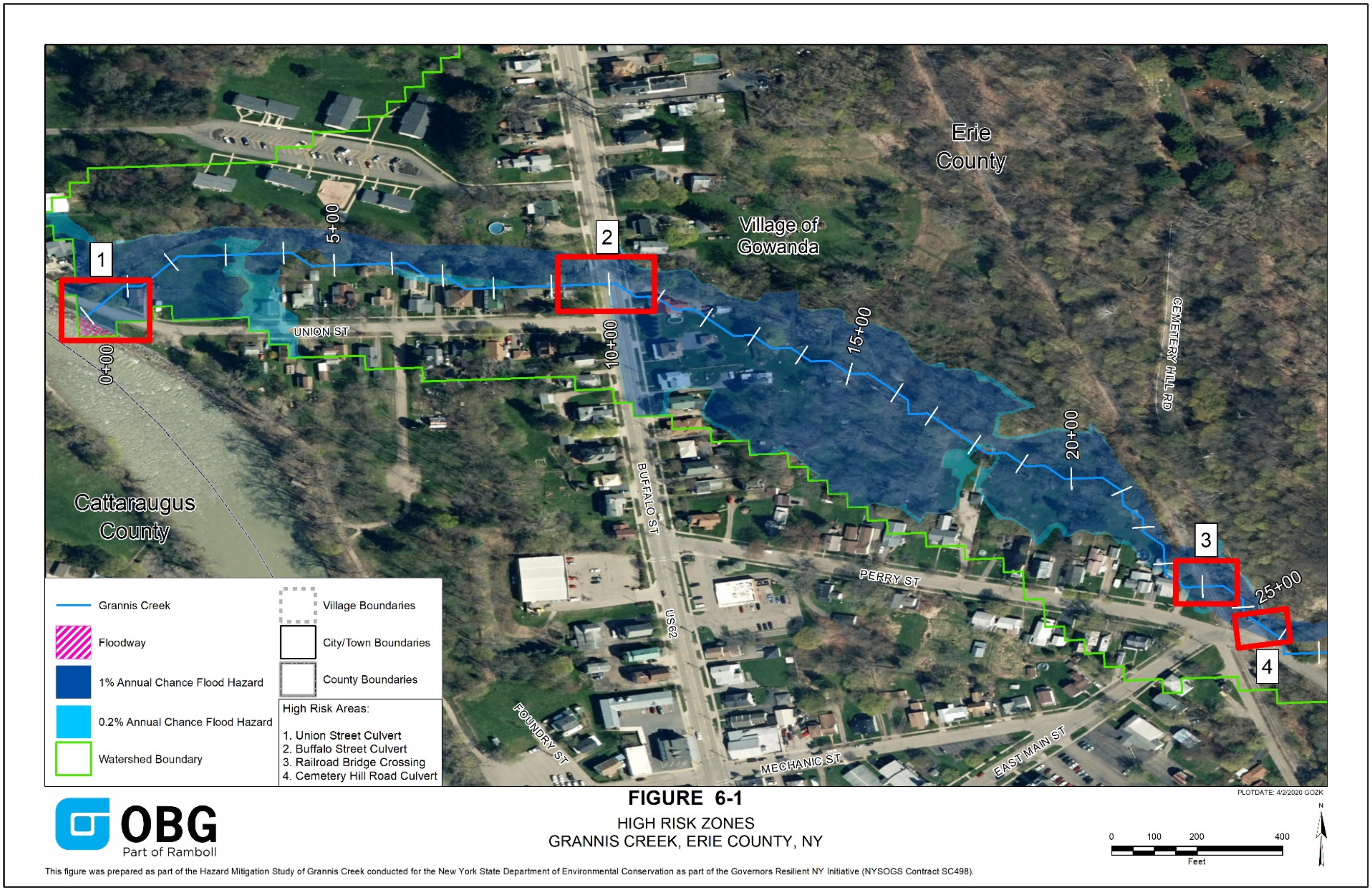


Figure 6-1. Grannis Creek high risk areas, Village of Gowanda, NY.

7. MITIGATION RECOMMENDATIONS

7.1 ALTERNATIVE #1: INCREASE SIZE OF UNION STREET BOX CULVERT

This measure is intended to increase the cross-sectional flow area of the channel by increasing the width of the Union Street box culvert opening located at river station 1+50. The Union Street box culvert is 12.5-ft by 10.5-ft and has an opening of approximately 131 ft^2 for water to flow through. According to the HEC-RAS base condition model, the Union Street box culvert is unable to pass discharges at the 1-percent annual chance flood water surface elevation (Figure 7-1).

Figure 7-1. Alternative #1 location map

The proposed condition modeling confirmed that the Union Street box culvert is a constriction point along Grannis Creek. The model simulation results indicate that after removing the backwater effects of Cattaraugus Creek, the Union Street culvert can successfully pass the 10-, 2-, 1-, and 0.2-percent annual chance flood hazard discharges with minimal backwater effects upstream. Three different widening scenarios were modeled to assess the effectiveness of increasing the culvert opening on water surface elevations. The widening scenarios increased the cross-sectional flow area of the culvert by approximately 60%, 140%, and 220% of the current flow area. The cross-sectional flow area was increased by increasing the horizontal width (i.e. span) of the culvert opening. Table 12 is a summary of the model simulation results for water surface elevation change by percent increase in cross-sectional area at the 1-percent annual chance flood event.

Table 12.Union Street Culvert Water Surface Reductions by Flow Area (1-Percent Annual Chance)

Proposed Bridge Span (ft)	Cross-Sectional Area (ft^2)	Percent Increase (%)	Water Surface Elevation Reduction (ft)
20	210	60	0.8
30	315	140	1.5
40	420	220	1.8

The proposed condition modeling simulation results indicated water surface reductions of up to 1.8-ft for the 1-percent annual chance flood event immediately upstream of the Union Street culvert (Figure 7-2). The modeling output for future conditions displayed similar results with water surface elevations up to 0.8-ft higher for the 1-percent annual chance flood event immediately upstream of the Union Street culvert due to the increased discharges associated with predicted future flows in Grannis Creek.

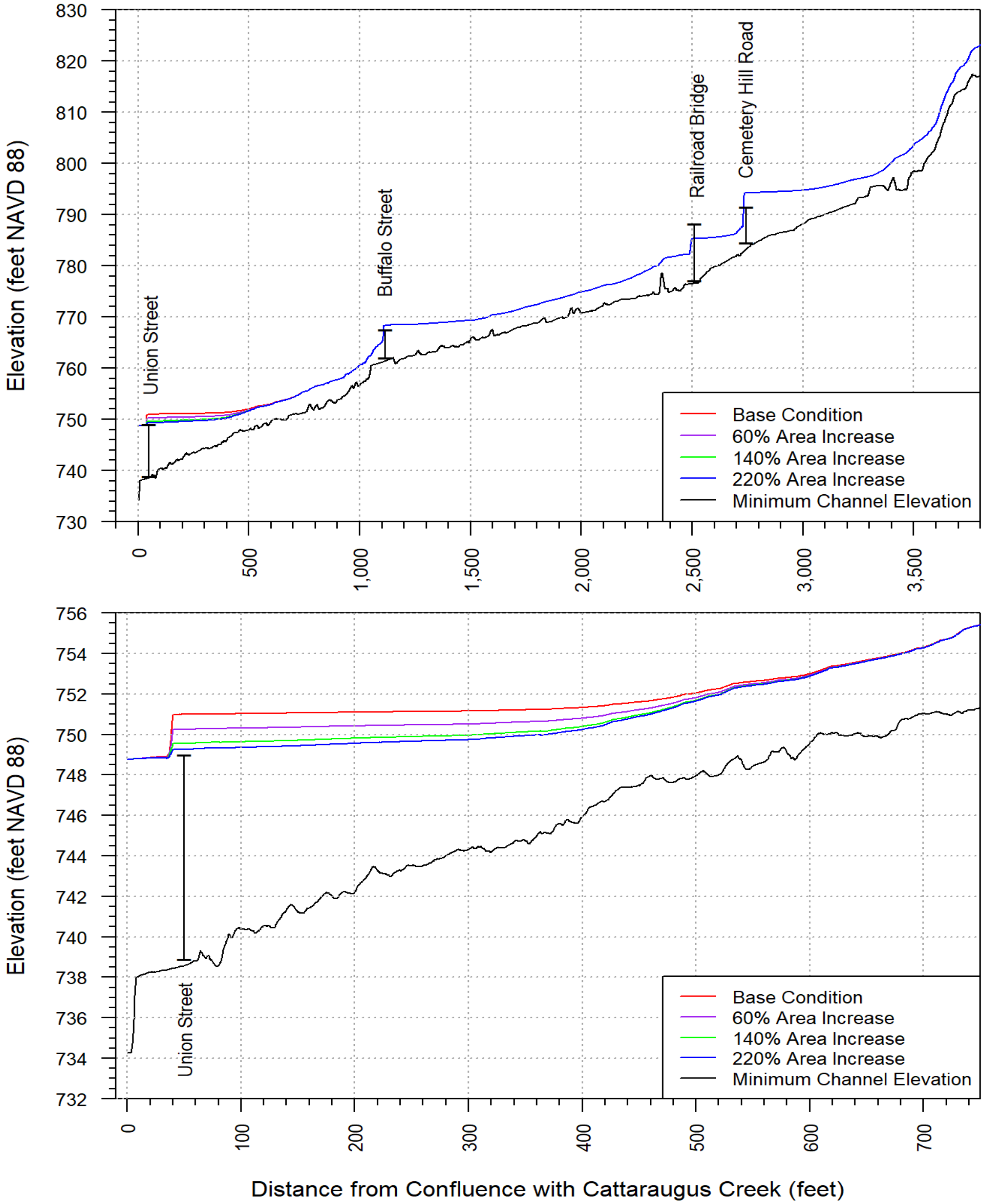


Figure 7-2. HEC-RAS model simulation output results for alternative #1 at the 1-percent annual chance flood event.

Culvert size increases were initially analyzed based on 2-feet freeboard over the base flood elevation for a 1-percent annual chance flood event. Once these optimal sizes were determined, further analysis was completed including site constraints and constructability. Due to these additional constraints, often the size necessary to meet the freeboard requirement was not feasible. Cost estimates were performed based on projects determined to be constructible and practical.

Based on field measurements and verified using FEMA FIS H&H data, the low chord elevation of the Union Street road deck is approximately 749-ft NAVD88. In order to achieve the NYSDOT standard of 2-ft of freeboard over the 2-percent annual chance water surface elevation plus a 10% increase for climate change, the water surface elevations passing through the culvert would need to be 747-ft NAVD88 or lower. Based on the HEC-RAS v5.0.7 model simulations, the current 2-percent water surface elevation at the opening of the culvert is 751-ft NAVD88, while the future 2-percent water surface elevation at the opening of the culvert is 751.3-ft NAVD88. Neither scenario meets the recommended 2-ft of freeboard. The culvert would need to be widened to a minimum cross-sectional area of greater than the modeled 420-ft^2 in order to meet the required 2-ft of freeboard over the 2-percent annual chance water surface plus the 10% climate change factor.

The Rough Order Magnitude cost for this measure is $750,000 not including land acquisition costs for survey, appraisal, and engineering coordination for the properties located at 81 and 85 Union Street.

7.2 ALTERNATIVE #2: INCREASE SIZE OF BUFFALO STREET BOX CULVERT

This measure is intended to increase the cross-sectional flow area of the channel by increasing the width of the Buffalo Street box culvert opening located at river station 10+50. The Buffalo Street box culvert is 16-ft by 6-ft and has an opening of approximately 96 ft^2 for water to flow through. According to the HEC-RAS base condition model, the Buffalo Street box culvert is unable to pass discharges at the 1-percent annual chance flood water surface elevation (Figure 7-3). The effective FEMA FIRM shows that the Buffalo Street culvert constricts flow causing backwater flooding approximately 750-feet upstream of the culvert (FEMA 2019b). The FEMA FIS water surface elevation profiles for the Buffalo Street crossing indicate the box culvert is unable to pass annual chance flood events below 10-percent (FEMA 2019a).

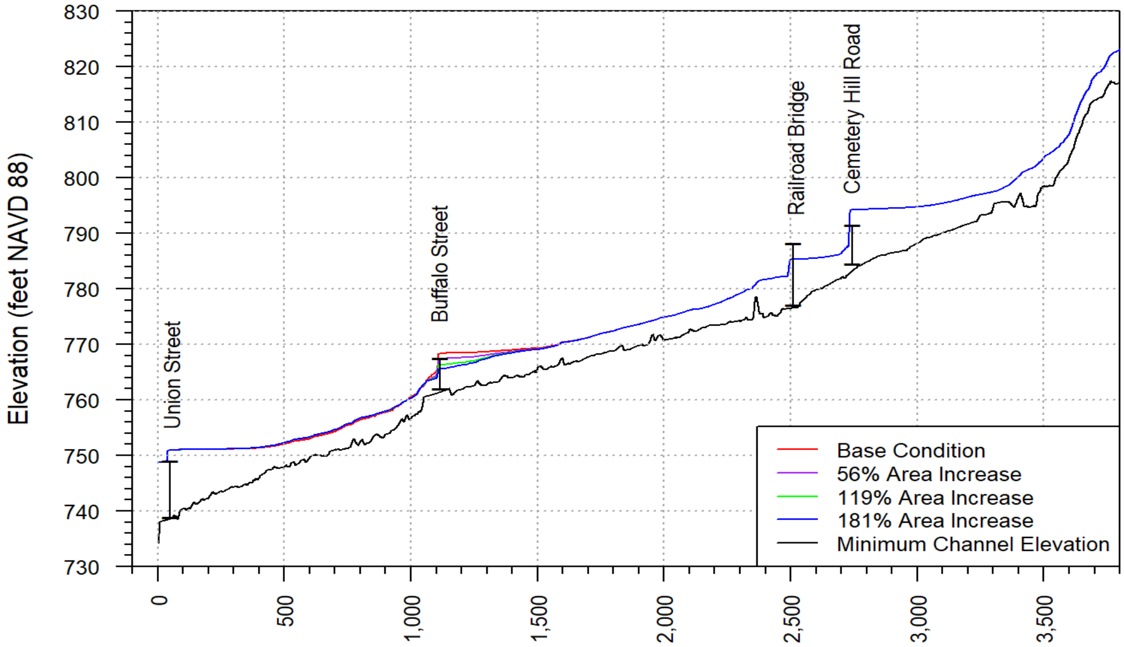
Figure 7-3. Alternative #2 location map.

The proposed condition modeling confirmed that the Buffalo Street box culvert is a constriction point along Grannis Creek. Three different widening scenarios were modeled to assess the effectiveness of increasing the culvert opening on water surface elevations. The widening scenarios increased the cross-sectional flow area by approximately 56%, 119%, and 181% of the current flow area. The cross-sectional flow area was increased by increasing the horizontal width (i.e. span) of the culvert opening. Table 13 is a summary of the model simulation results for water surface elevation change by percent increase in cross-sectional area at the 1-percent annual chance flood event.

Table 13.Buffalo Street Culvert Water Surface Reductions by Flow Area

Proposed Bridge Span (ft)	Cross-Sectional Area (ft^2)	Percent Increase (%)	Water Surface Elevation Reduction (ft)
25	150	56	1.0
35	210	119	2.0
45	270	181	2.6

The proposed condition modeling simulation results indicated water surface reductions of up to 2.6-feet for the 1-percent annual chance flood event immediately upstream of the Buffalo Street culvert (Figure 7-4). The modeling output for future conditions displayed similar results with water surface elevations up to 0.2-ft higher for the 1-percent annual chance flood event immediately upstream of the Buffalo Street culvert due to the increased discharges associated with predicted future flows in Grannis Creek.



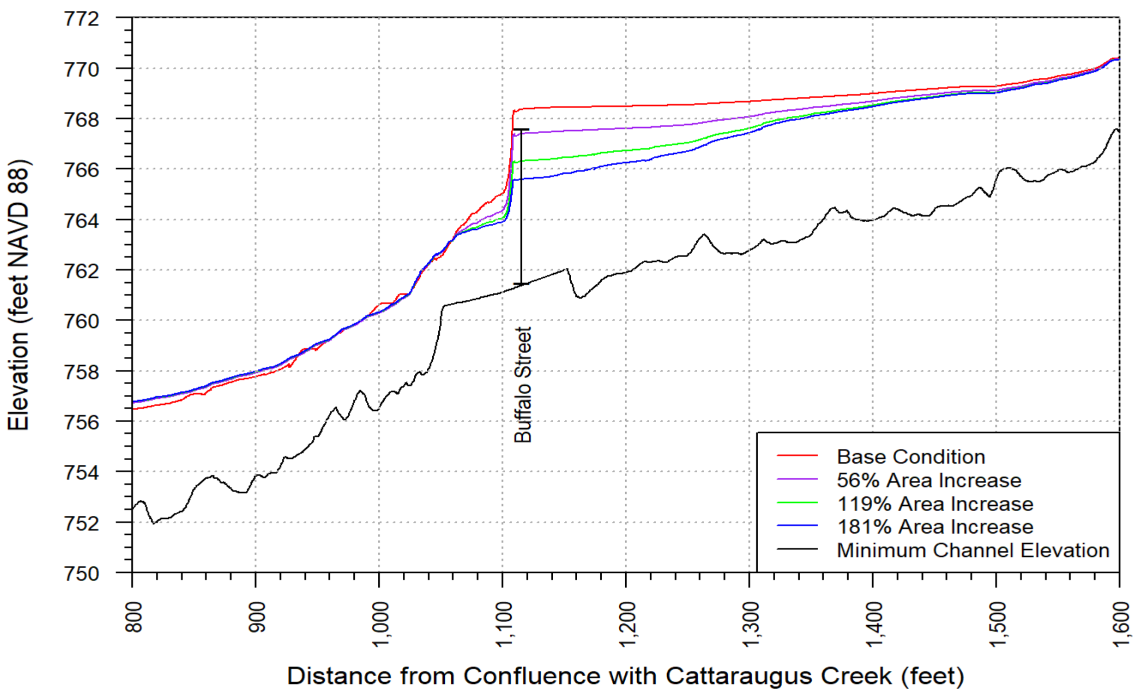


Figure 7-4. HEC-RAS model simulation output results for alternative #2 at the 1-percent annual chance flood event.

The Buffalo Street box culvert is located on the primary transportation route and commercial hub for the Village of Gowanda, so its significance to the Village and its residents is substantial. Grannis Creek in the vicinity of the Buffalo Street culvert is bounded by residential and commercial properties on both the right and left banks, and upstream and downstream in close proximity to the creek channel. In order to complete the widening of the culvert opening, there is the potential need for property acquisition around the creek banks. Partial or complete property acquisition of residences located at 133, 140, 145, and 160 Buffalo Street would be required in order to complete a culvert widening project.

This strategy would introduce additional project costs and potential objections to this mitigation alternative; however, the benefit to neighboring properties and communities upstream of the Buffalo Street culvert affected by flooding cannot be overlooked. Widening the culvert can increase the cross-sectional area of the creek channel in the vicinity of Union Street, allowing more water to flow downstream and potentially reducing the risk of flooding. The potential benefits of the culvert upsizing are immediately upstream and in the vicinity of the culvert at river stations 10+00 and 16+00.

Culvert size increases were initially analyzed based on 2-ft freeboard over the base flood elevation for a 1-percent annual chance flood event. Once these optimal sizes were determined, further analysis was completed including site constraints and constructability. Due to these additional constraints, often the size necessary to meet the freeboard requirement was not feasible. Cost estimates were performed based on projects determined to be constructible and practical.

Based on the FEMA FIS profile plot for Grannis Creek, the low chord elevation of the Buffalo Street road deck is approximately 764-ft NAVD88. In order to achieve the NYSDOT standard of 2-ft of freeboard over the 2-percent annual chance water surface elevation plus a 10% climate change factor, the water surface elevations passing through the culvert would need to be 762-ft NAVD88 or lower. Based on the HEC-RAS current base and future condition model simulations, none of the culvert opening scenarios modeled met the required 2-ft of freeboard. The culvert would need to be widened to a cross-sectional area greater than the modeled 270-ft^2 in order to meet the required 2-ft of freeboard over the 2-percent annual chance water surface.

The Rough Order Magnitude cost for this measure is $1.3 million, not including land acquisition costs for survey, appraisal, and engineering coordination.

7.3 ALTERNATIVE #3: INCREASE SIZE OF CEMETERY HILL ROAD BOX CULVERT

This measure is intended to increase the cross-sectional flow area of the channel by increasing the width of the Cemetery Hill Road box culvert opening located at river station 26+30. The Cemetery Hill Road box culvert is 10-ft by 8-ft and has an opening of approximately 80 ft^2 for water to flow through. According to the FEMA FIS, the Cemetery Hill Road box culvert is unable to pass flows below the 10-percent annual chance flood (FEMA 2019b). The HEC-RAS base condition model and USGS *Flash Floods of August 10, 2009, in the Villages of Gowanda and Silver Creek, New York* (USGS

2010) report identified the Cemetery Hill Road box culvert as a major source of flooding in the Village due to water overtopping the creek banks upstream the culvert (Figure 7-5).

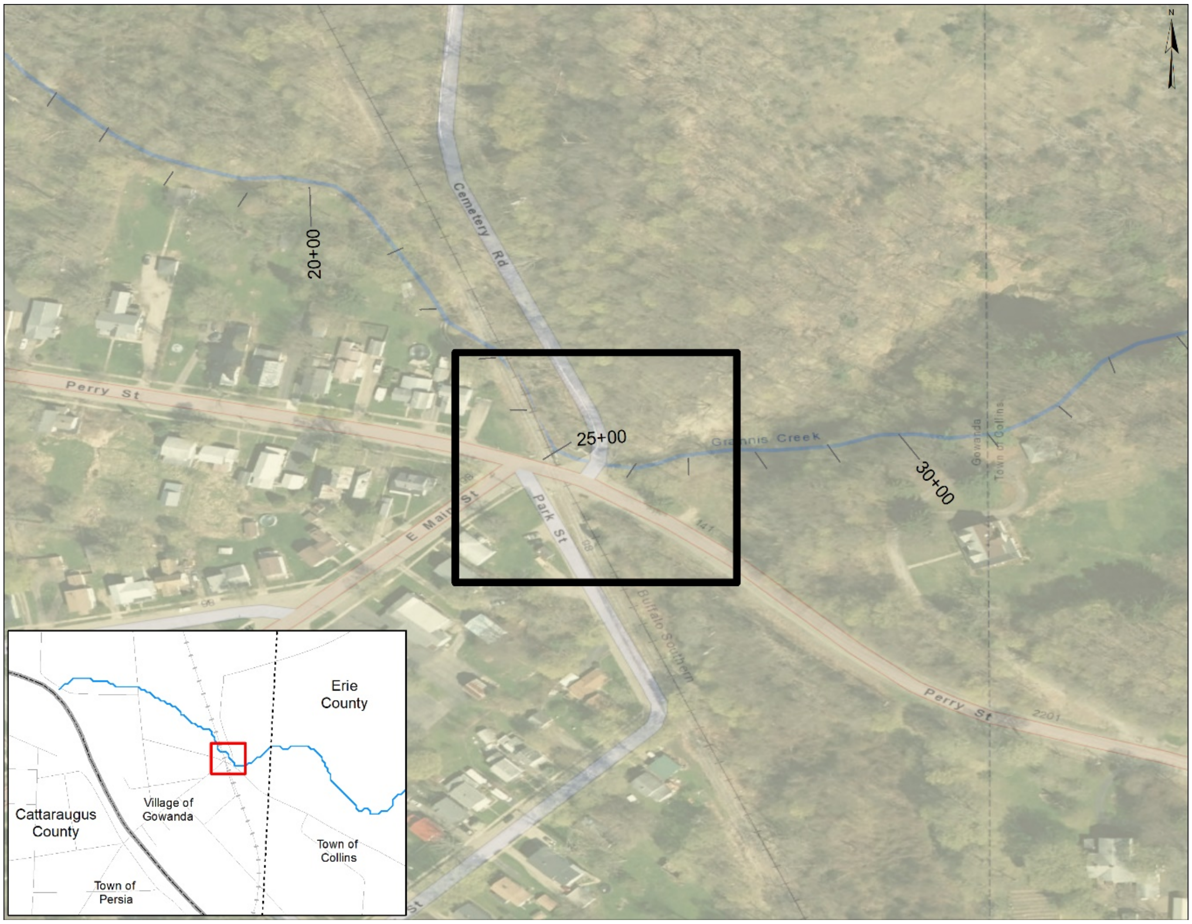


Figure 7-5. Alternative #3 location map.

The proposed condition modeling confirmed that the Cemetery Hill Road box culvert is a constriction point along Grannis Creek. Three different widening scenarios were modeled to assess the effectiveness of increasing the culvert opening on water surface elevations. The widening scenarios increased the cross-sectional flow area of the culvert by approximately 100%, 200%, and 300% of the current flow area. The cross-sectional flow area was increased by increasing the horizontal width (i.e. span) of the culvert opening. Table 14 is a summary of the model simulation results for water surface elevation change by percent increase in cross-sectional area at the 1-percent annual chance flood event.

Table 14. Cemetery Hill Road Culvert Water Surface Reductions by Flow Area

Proposed Bridge Span (ft)	Cross-Sectional Area Increase (ft^2)	Percent Increase (%)	Water Surface Elevation Reduction (ft)
20	160	100	1.1
30	240	200	2.4
40	320	300	3.0

The proposed condition modeling simulation results indicated water surface reductions of up to 3.0-ft for the 1-percent annual chance flood event immediately upstream of the Cemetery Hill Road culvert (Figure 7-6). The modeling output for future conditions displayed similar results with water surface elevations up to 0.5-ft higher for the 1-percent annual chance flood event immediately upstream of the Cemetery Hill Road culvert due to the increased discharges associated with predicted future flows in Grannis Creek.

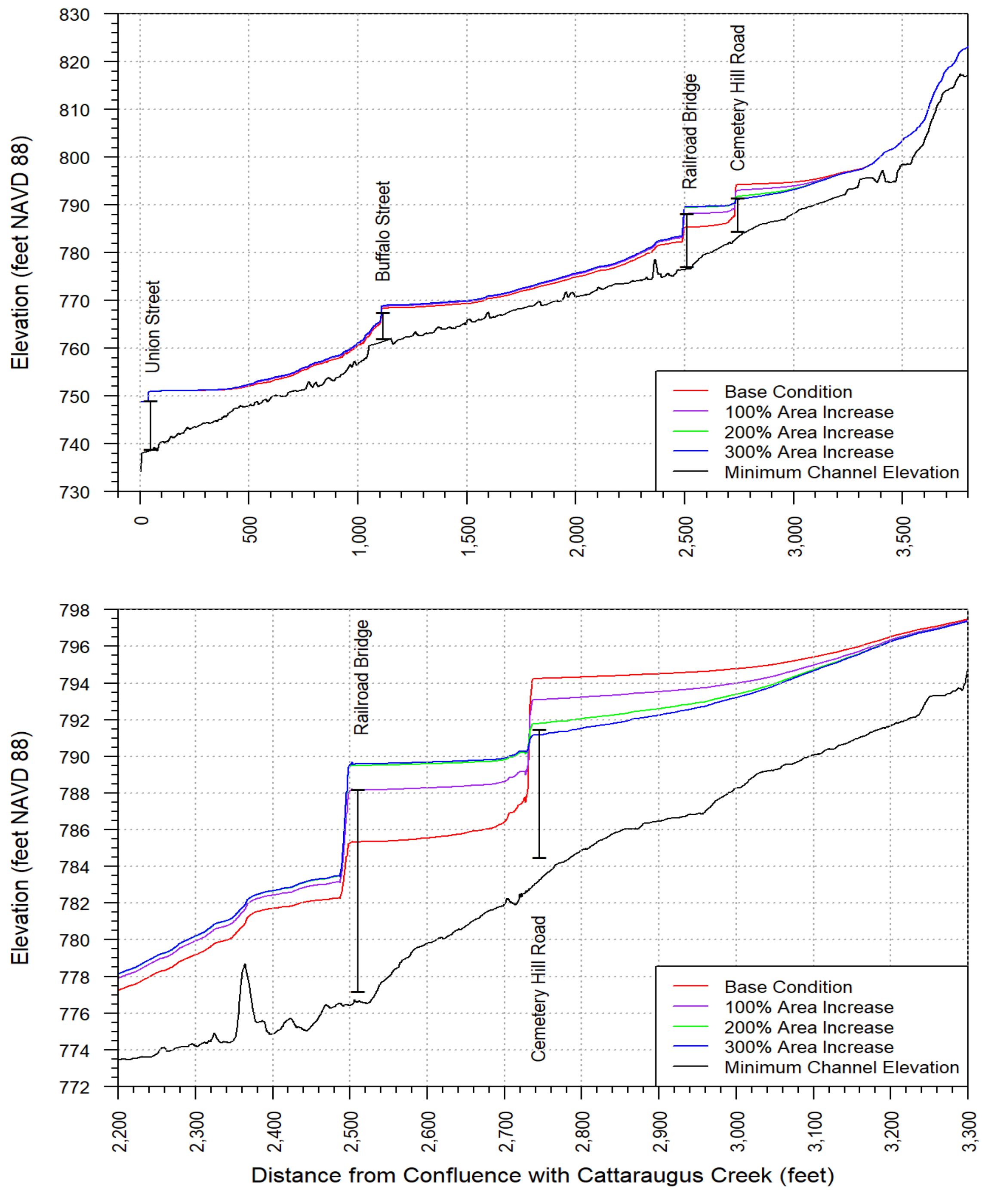


Figure 7-6. HEC-RAS model simulation output results for alternative #3 at the 1-percent annual chance flood event.

The Cemetery Hill Road is the intersection point between Grannis Creek, Gowanda Zoar Road, East Main Street, the railroad bridge, and three smaller town roads in the Village of Gowanda. Cemetery Hill Road is an important transportation interchange in the Village and crossing point for the railroad company, so its significance to the Village and its residents is very high. Grannis Creek in the vicinity of the Cemetery Hill Road culvert is bounded by the ECIDA railroad tracks and Gowanda Zoar Road on the left bank, and Cemetery Hill Road and steep valley banks on the right bank in this reach.

In order to complete the widening of the culvert opening, there is the likely need for relocation of Gowanda Zoar and Cemetery Hill Roads and the railroad tracks. This strategy would introduce additional project costs and potential objections to this mitigation alternative; however, the benefit to the entire Village of Gowanda downstream of the Cemetery Hill Road culvert affected by the 2009 flooding cannot be overlooked. Widening the culvert can increase the cross-sectional area of the creek channel in the vicinity of Cemetery Hill Road, allowing more water to flow downstream and potentially reducing the risk of flooding. The potential benefits of the culvert upsizing are immediately upstream and in the vicinity of the culvert at river stations 25+50 to 27+00.

Based on the FEMA FIS profile plot for Grannis Creek, the low chord elevation of the Cemetery Hill Road deck is approximately 788-ft NAVD88. In order to achieve the NYSDOT standard 2-ft of freeboard over the 2-percent annual chance water surface elevation, the water surface elevations passing through the culvert would need to be 786-ft NAVD88 or lower. Based on the HEC-RAS v5.0.7 current base and future condition model simulations, none of the culvert opening scenarios modeled met the recommended 2-ft of freeboard. The culvert would need to be widened to a cross-sectional area greater than the modeled 320-ft^2 in order to meet the required 2-ft of freeboard over the 1-percent annual chance water surface.

The Rough Order Magnitude cost for this measure is $430,000, not including land acquisition costs for survey, appraisal, and engineering coordination for the properties located at 120 Perry Street or railroad operational and/or track costs.

7.4 ALTERNATIVE #4: INCREASE WIDTH OF RAILROAD BRIDGE OPENING

This measure is intended to increase the cross-sectional flow area of the channel by increasing the opening of the railroad bridge opening located at river station 23+90. The railroad bridge opening is approximately 14.5-ft by 11.7-ft, or 170 ft^2, with a utility pipe running parallel to the bridge roughly 0.5-ft below the bridge deck. According to the HEC-RAS base condition model, the railroad bridge allows discharges at the 1-percent annual chance flood water surface elevation to pass (Figure 7-7).

Increasing the railroad bridge opening would reduce the hydraulic jump that occurs immediately downstream of the bridge, which causes water to overtop the banks and flood the Perry Street neighborhood. According to the FEMA FIRM, the BFE downstream of the railroad bridge is approximately 784-ft NAVD88 (FEMA 2019b). The maximum elevation of the left bank downstream of the bridge is 784-ft NAVD88 (NYSDEC 2008). By widening the railroad bridge opening, water velocities can maintain their speed through the bridge potentially keeping water surface elevations upstream lower. In addition, widening the bridge opening can reduce the effects of the contraction and expansion of water as it passes under the bridge, which in turn, can reduce the hydraulic jump immediately downstream of the bridge and potentially mitigate the flooding issues in the Perry Street neighborhood.

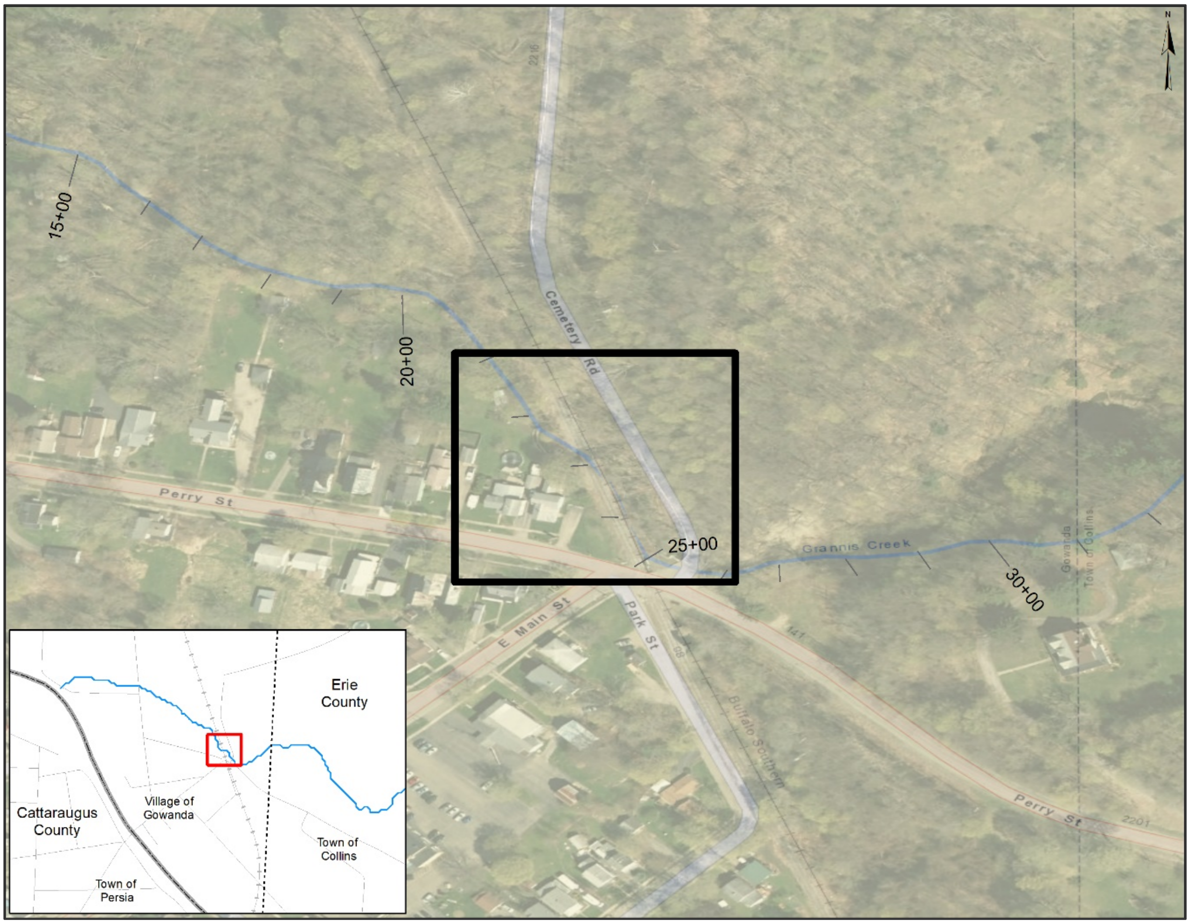


Figure 7-7. Alternative #4 location map.

The proposed condition modeling confirmed that the railroad bridge is a constriction point along Grannis Creek. Three different widening scenarios were modeled to assess the effectiveness of increasing the bridge opening on water surface elevations. The widening scenarios increased the cross-sectional flow area of the culvert by approximately 72%, 141%, and 244% of the current flow area. The cross-sectional flow area was increased by increasing the horizontal width (i.e. span) of the bridge opening. Table 15 is a summary of the model simulation results for water surface elevation change by percent increase in cross-sectional area at the 1-percent annual chance flood event.

Table 15. Railroad Bridge Water Surface Reductions by Flow Area

Proposed Bridge Span (ft)	Cross-Sectional Area Increase (ft^2)	Percent Increase (%)	Water Surface Elevation Reduction (ft)
25	292.5	72	2.0
35	409.5	141	2.5
50	585	244	2.6

The proposed condition modeling simulation results indicated water surface reductions of up to 2.6-ft for the 1-percent annual chance flood event immediately upstream of the railroad bridge (Figure 14). The modeling output for future conditions displayed similar results with water surface elevations up to 0.2-ft higher for the 1-percent annual chance flood event immediately upstream of the railroad bridge due to the increased discharges associated with predicted future flows in Grannis Creek (Figure 7-8).

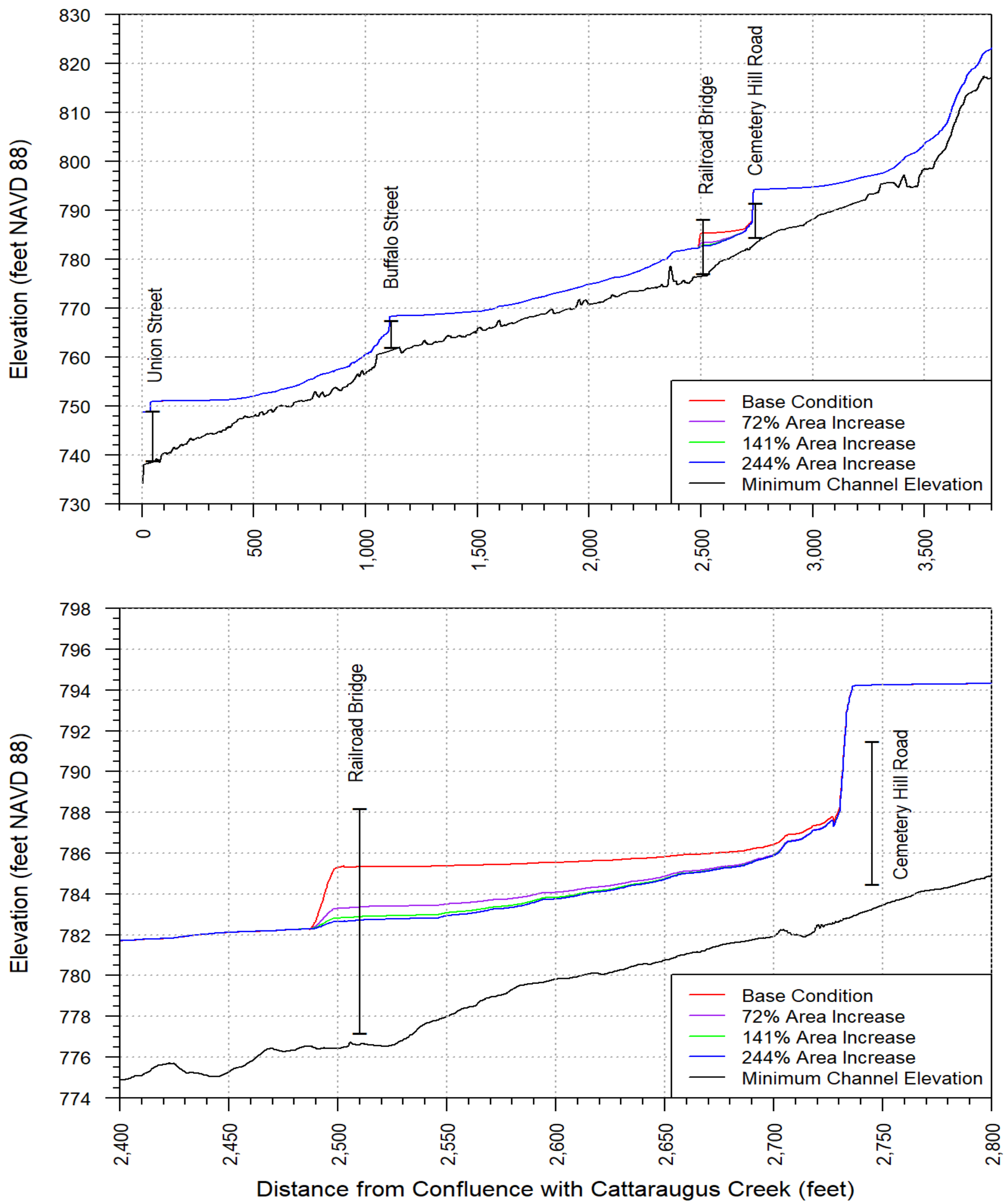


Figure 7-8. HEC-RAS model simulation output results for alternative #4 at the 1-percent annual chance flood event.

The railroad line through the Village of Gowanda is currently active and owned by ECIDA and operated by BSOR. To limit the cost of construction, Grannis Creek was channelized and re-oriented under the bridge at two near 90º angles when the railroad tracks and bridge were laid. As a result, water flow in this area is restricted causing backwater flooding upstream and overtopping of banks downstream during high flow events. Widening the bridge opening can increase the cross-sectional area of the creek channel in the vicinity of the railroad bridge and Cemetery Hill Road, allowing more water to flow downstream and potentially reducing the risk of flooding. The potential benefits of the bridge opening widening are immediately upstream and in the vicinity of the railroad and Cemetery Hill Road at river stations 23+50 and 27+00.

Based on the FEMA FIS profile plot for Grannis Creek, the low chord elevation of the railroad bridge deck is approximately 788-ft NAVD88. In order to achieve the NYSDOT standard 2-ft of freeboard over the 2-percent annual chance water surface elevation plus a 10% climate change factor, the water surface elevations passing through the culvert would need to be 786-ft NAVD88 or lower. Based on the model simulations, all of the culvert opening scenarios modeled met the recommended 2-ft of freeboard However, this can be attributed to the downstream top of bank land elevations being less than or equal to 784-ft NAVD88. As a result, during high flow events, water will overtop the banks creating a new discharge point off of Grannis Creek that would reduce in-channel water surface elevations.

No cost estimates were prepared for this alternative, as extensive coordination with the ECIDA/BSOR will be needed to determine what, if any projects can be completed under the rail line. The railroad through Gowanda is a single track, main line to the City of Buffalo, and thus it will likely not be feasible to stop train traffic for a long enough duration to perform any cross-sectional area widening project requiring the use of open-cut techniques. Trenchless methods, such as jack and bore, direct jack, or micro tunneling of culverts is a possible alternative, and should be analyzed and discussed with the railroad for feasibility. In addition, there would most likely be the need for partial or complete property acquisition of the residence of 86 Perry Street, which is adjacent to Grannis Creek and the railroad tracks.

7.5 ALTERNATIVE #5: LEVEE BEHIND PERRY STREET NEIGHBORHOOD

This strategy is intended to restrict high-flow events from overtopping channel banks and flooding homes, properties, etc. in the high-risk area of the Perry Street neighborhood by constructing a permanent levee along the neighborhood. The levee would be approximately 1,250-ft long with a height of two feet above the future flood flow stage for the projected 1-percent annual chance flood elevation (770.5 - 785 ft NAVD 88) and located along river stations 11+00 to 23+50. Compaction and the possibility of using cut material as fill has not been accounted for at this point. Downstream and opposite bank effects of the levee were modelled, and the levee was determined to have no measurable effects on upstream or downstream water surface elevations (Figure 7-9).

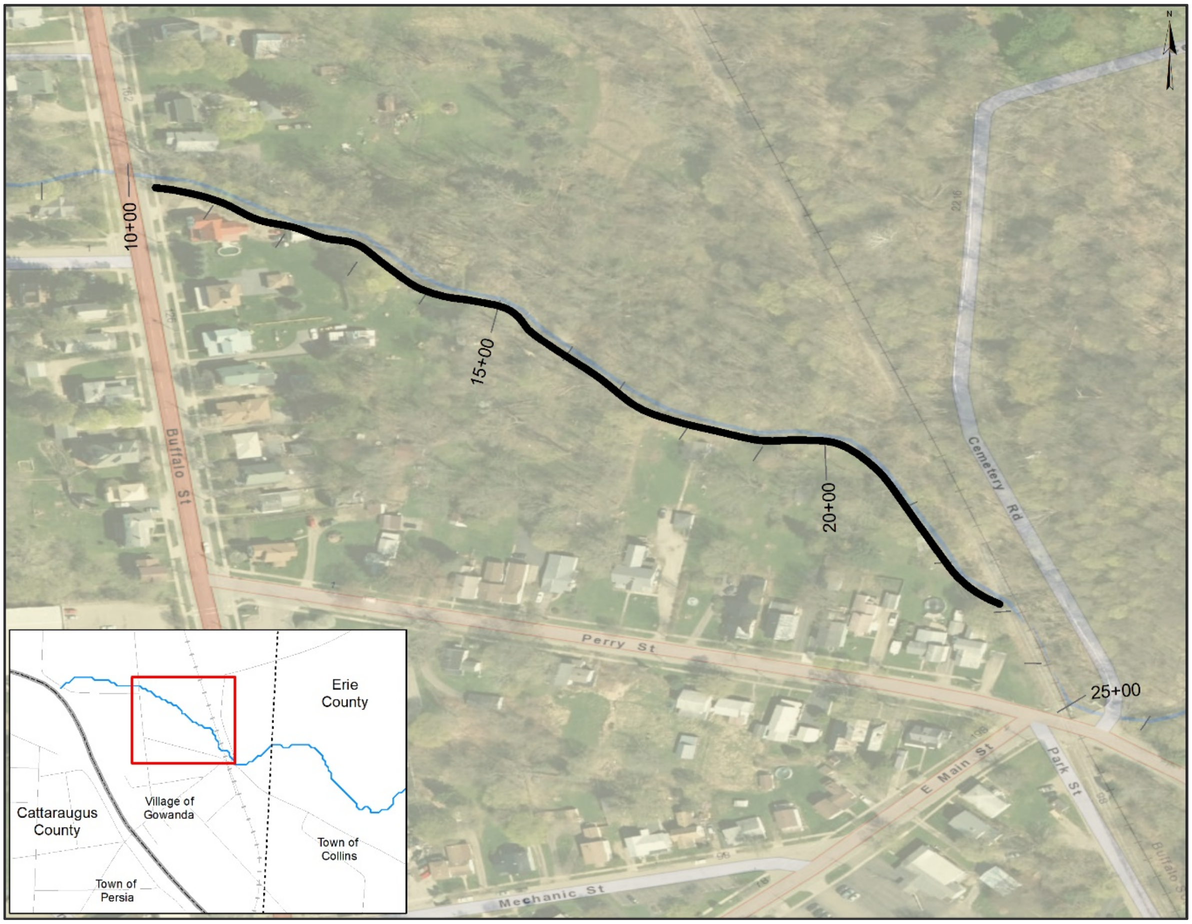


Figure 7-9. Alternative #5 location map.

The proposed and future hydraulic modeling confirmed that constructing a levee along Grannis Creek in the reach adjacent to the Perry Street neighborhood would decrease the flood risk of the neighborhood, while leaving the flood potential of downstream and opposite bank areas unaffected (Figure 7-10).

The proposed condition model simulation results indicated that water surface elevations for the levee behind Perry Street would increase due to the greater volume of water being passed through the creek channel. Without the levee, a 1-percent annual chance flood event would overtop the channel banks downstream of the railroad bridge and near river station 15+00 inundating the Perry and Buffalo Street neighborhoods and impacting numerous buildings and properties. The average inundation depth is approximately 0.5-ft of water for the 1-percent annual chance flood event.

With the levee, model simulation results indicated this water would remain in the channel and flow downstream causing water surface elevations to increase without impairing the adjacent neighborhood. However, according to the HEC-RAS model simulation results, backwater occurs at the railroad bridge upstream of the Cemetery Hill Road culvert. This results in increased flooding when high flows overtop the Cemetery Hill Road culvert. In addition, due to the low road deck elevation of Buffalo

Street there is still flooding upstream of Buffalo Street according to the model results, but the extent and depth of inundation is reduced by approximately 50%.

The modeling output for the future conditions produced similar results to the proposed condition simulation. The significant difference between the two models was increased flooding in the vicinity of Union Street and the confluence with Cattaraugus Creek in the future condition model. This is due to the increase volume of water being passed through the Union Street culvert because of the increased stream flow and levee containing more water within the channel. As a result, the areas in the vicinity of Union and Buffalo Street and the Railroad Bridge, would experience higher water surface elevations and inundation for a future 1-percent annual chance flood event.

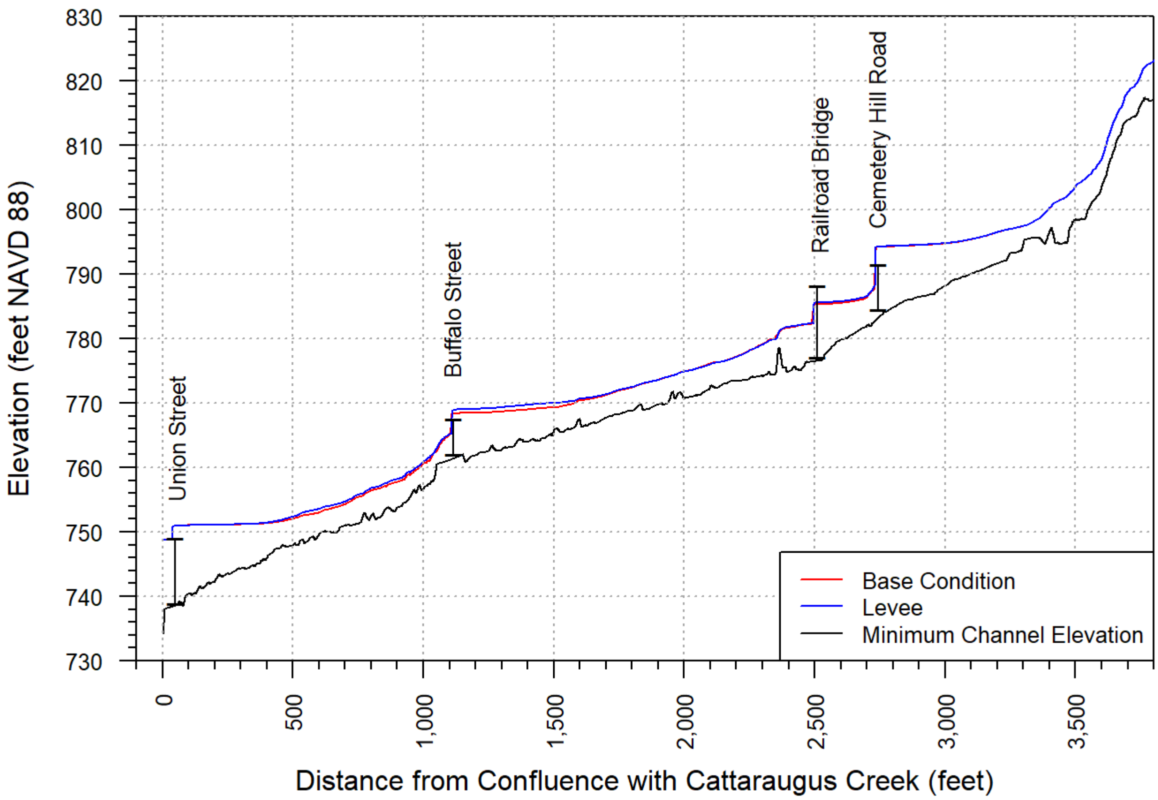


Figure 7-10. HEC-RAS model simulation output results for alternative #5 at the 1-percent annual chance flood event.

The levee system behind the Perry Street neighborhood would be beneficial for the residents along the left bank of Grannis Creek from the railroad bridge up to the Buffalo Street junction. However, due to the elevation of the Buffalo Street road deck, high flows would overtop the roadway and inundate residences along Buffalo and Union Streets causing higher flood damages in these areas, while reducing flood damages along Perry Street. Additional levee structures downstream of Buffalo Street and increasing the elevation of the Buffalo Street roadway crossing Grannis Creek, would need to be considered in order to construct a levee system that could reduce the risk of all residents within the Village of Gowanda. Due to the additional costs associated with a project of this scale, only a levee along the Perry Street neighborhood was analyzed in this study. The potential benefits of this alternative are immediately upstream and in the vicinity of the levees at river stations 10+00 to 24+00.

Additional hydrologic and hydraulic modeling, coupled with an engineering review, would be necessary to determine the full scale, design criteria, and costs associated with a large-scale levee system throughout the Village that complies with FEMA flood plain management criteria. In addition, the levee would not remove areas from the FEMA mapped floodplain but would only provide additional flood protection for a certain level of annual chance flood event. Homeowners and businesses behind the levee would still be required to purchase flood insurance if they are within any FEMA designated flood zones (FEMA 2000).

The Rough Order Magnitude cost for this strategy is approximately $2.8 Million, not including annual maintenance or land acquisition costs for survey, appraisal, and engineering coordination for the properties located adjacent to Grannis Creek along the levee, which includes 38, 46, 60, 64, 68, 72, 80, and 86 Perry Street, and 115, 123, and 133 Buffalo Street.

7.6 ALTERNATIVE #6: DEBRIS MAINTENANCE AROUND CULVERTS/BRIDGES

Debris, such as trees, branches and stumps, are an important feature of natural and healthy stream systems. In a healthy stream network, woody debris help 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 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).

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

The Rough Order Magnitude cost for this strategy is approximately $20,000 annually (estimated six days for labor/equipment costs).

7.7 ALTERNATIVE #7: EARLY FLOOD-WARNING DETECTION SYSTEM

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 2016).

Early flood-warning detection systems can be implemented which can provide communities with more advance warning of potential flood conditions. Early forecast and warning involve the identification of imminent flooding, implementation of a plan to warn the public, and assistance in evacuating persons and some personal property. A typical low-cost early flood-warning system consists of commercially available off-the-shelf-components. The major components of an early-flood warning system are a sensor connected to a data acquisition device with built-in power supply or backup; some type of notification or warning equipment; and a means of communication. The 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 2016).

The system can be powered from an alternating current source via landline or by batteries that are rechargeable 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 2016).

The Rough Order Magnitude cost for this strategy is approximately $100,000.

7.8 ALTERNATIVE #8: FLOOD BENCH

Installing a flood bench would provide additional storage and floodplain width, which could potentially reduce damages in the event of flooding and address issues within the Village of Gowanda. Due to the limited availability of open land along the banks of Grannis Creek, there is only one suitable location for a flood bench within the Village. The flood bench would be located downstream the railroad bridge at river station 20+50 and extend downstream to river station 13+00 upstream the Buffalo Street culvert. The total acreage of the flood bench would be 2.5 acres. The flood bench is located on the right bank of Grannis Creek and is within the FEMA designated Special Flood Hazard Area, Zone AE, which is an area subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods where base flood elevations are shown and mandatory flood insurance purchase requirements and floodplain management standards apply (Figure 7-11).

Figure 7-11. Alternative #8 location map.

The proposed condition modeling confirmed that the flood bench would reduce water surface elevations by up to 1.3-feet for a 1-percent annual chance flood event in the vicinity of and immediately downstream and upstream of the flood bench; however, water surface elevations in the remaining reaches of Grannis Creek remain unaffected. The modeling output for future conditions displayed similar results with water surface elevations up to 0.1-ft higher for the 1-percent annual chance flood event in the vicinity of and immediately downstream and upstream of the flood bench due to the increased discharges associated with predicted future flows in Grannis Creek (Figure 7-12).

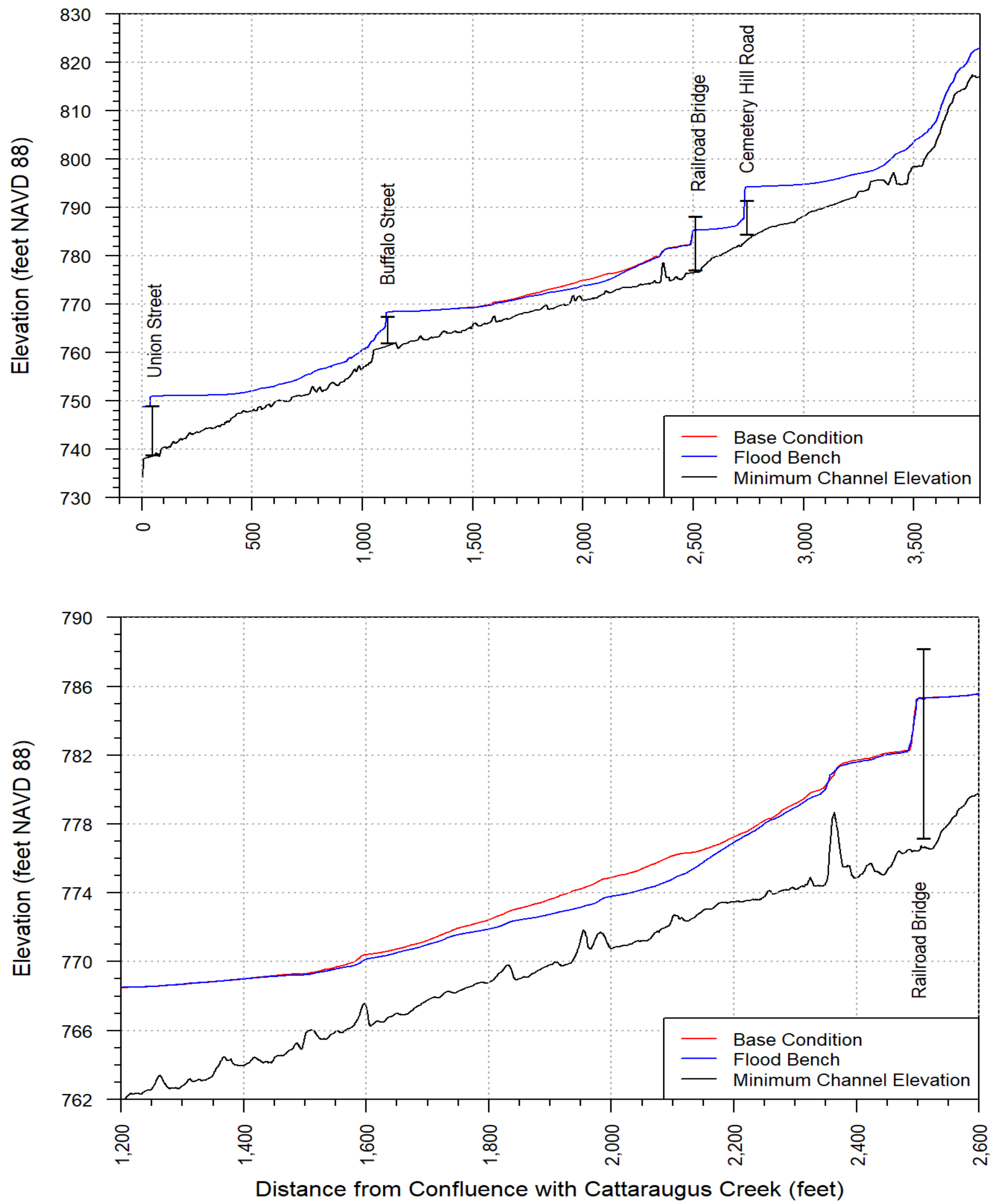


Figure 7-12. HEC-RAS model simulation output results for alternative #8 at the 1-percent annual chance flood event.

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

The ROM cost for this measure was determined to be approximately $1 Million, which does not include land acquisition costs for survey, appraisal, and engineering coordination for the properties located at 38, 46, 60, 64, and 68 Perry Street and 115 and 165 Buffalo Street and potentially land owned by the ECIDA/BSOR railroad company.

7.9 ALTERNATIVE #9: FLOOD BUYOUTS/PROPERTY ACQUISITION

Buyouts and acquisitions allow state and municipal agencies the ability to purchase developed properties within areas vulnerable to flooding from willing owners. Buyouts and acquisitions are effective management tools in response to natural disasters to reduce or eliminate future losses of vulnerable or repetitive loss properties. The terms buyout and acquisition are often used interchangeably, but they are distinct and serve distinct purposes (Siders 2013).

Acquisition is the general term and refers to the purchase of private property by government for public use. It is not confined to a particular purpose or end use for the property. Buyout programs, on the other hand, are a specific subset of acquisition in which private lands are purchased, existing structures demolished, and the land maintained in an undeveloped state for public use in perpetuity. Both buyout and acquisition programs can be conducted without the consent of the landowners by using eminent domain, but most often they are conducted with voluntary sales from landowners who have recently experienced a natural disaster (Siders 2013).

Acquisition programs can be designed for many purposes. Most often, following a disaster, they are intended to purchase damaged parcels from homeowners who are unwilling or unable to rebuild, thereby granting the homeowners the financial resources to relocate to a less vulnerable area. The parcels are then re-sold to a developer, who is held to stricter building requirements to make the new structure more resilient to natural threats. Acquisition programs designed in this way are intended to maintain similar amounts of housing and a similar local tax base in the affected community. Such programs may also improve the resilience of the community, by requiring developers to meet more stringent mitigation standards, but they will be no more resilient than communities where the original homeowners undertake mitigation programs. The main benefit is to the homeowner who is enabled to relocate (Siders 2013).

Buyout programs, on the other hand, are designed to permanently remove built structures and replace them with public space or natural buffers. Buyout programs not only assist individual homeowners but are also intended to improve the resiliency of the entire community in the following ways:

- 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. Acquisition programs do not produce the same results because the newly-built homes, even if built to be more resilient, are still vulnerable and may still suffer damage during subsequent events (Siders 2013).

In order to achieve these goals, buyouts need to acquire a continuous swatch of land, rather than individual homes in isolated areas, or only some of the homes within flood-prone areas. Acquisition programs can be effective even if they purchase individual isolated homes, but buyout programs will be most effective when they purchase entire streets or neighborhoods (Siders 2013).

Acquisition and buyout programs can be funded entirely through state or local funds, but most often such programs occur after a nationally recognized disaster and use a combination of federal and state funds. The Federal Emergency Management Agency (FEMA) administers programs to help with buyouts under the Stafford Disaster Act, and the Department of Housing and Urban Development (HUD) administers another program through Community Development Block Grants (CDBG). These funding sources can reduce the economic burden on the local community. However, these funds also come with guidelines and regulations that may constrain policy makers' options on whether to pursue an acquisition or buyout strategy and how to shape their programs. FEMA funds may be used to cover 75-percent of the expenses, but the remaining 25-percent 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).

In the Village of Gowanda, there are approximately 42 residences within the FEMA 1-percent annual chance food hazard area of Grannis Creek (Figure 7-12). Table 16 summarizes the number of residences and their total assessed and market retail values (NYSGPO 2019).

Table 16. Residences within FEMA 1-percent Flood Zone

Number of Residences	**Total Assessed Value (AV)**	**Total Retail Market Value** (AV * 1.2)
42	$1,604,700	$1,925,640

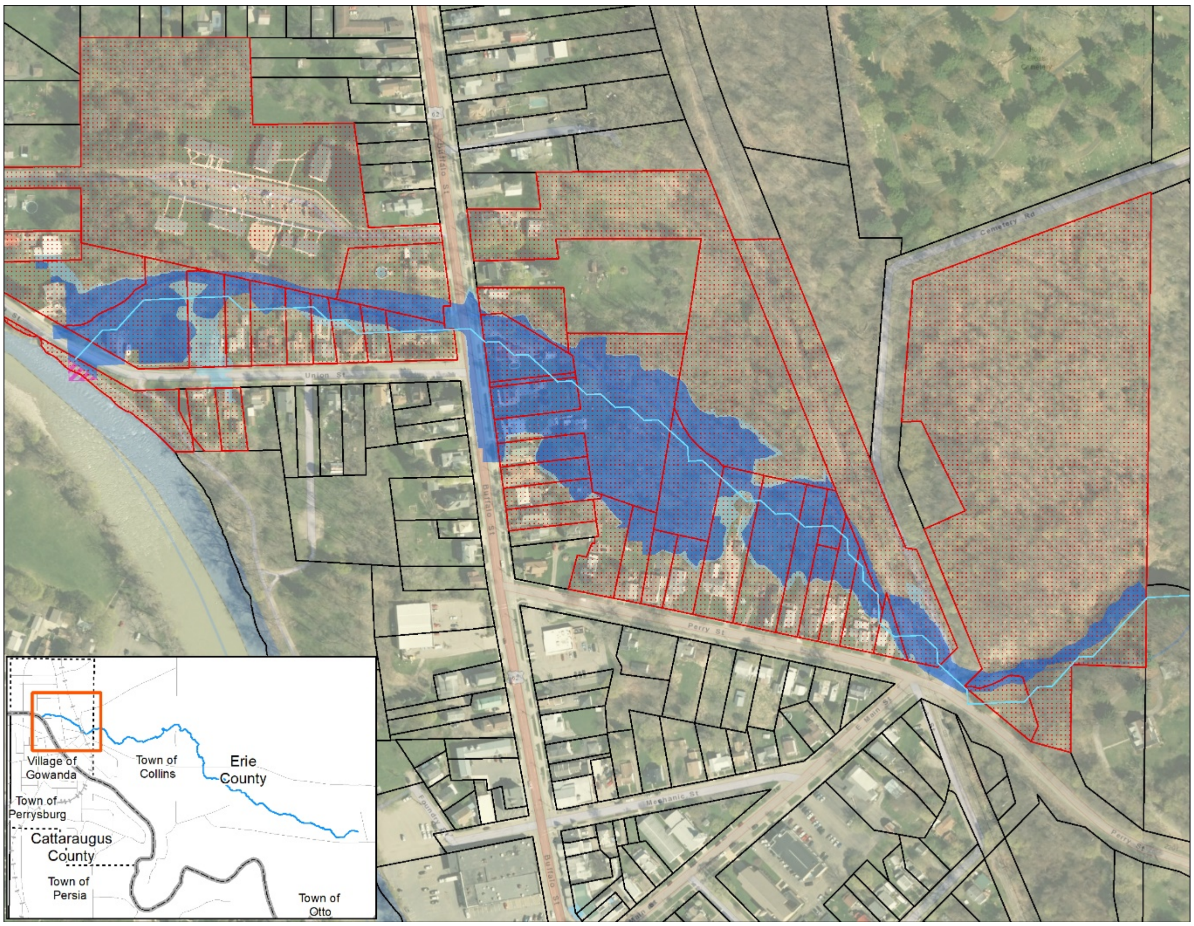


Figure 7-13. Alternative #9 tax parcels within FEMA 1-percent flood zone.

Due to the variable nature of buyout or acquisition programs, no ROM cost estimate was produced for this study. It is recommended that any buyout or acquisition program begin with a cost-benefit analysis for each property. After a substantial benefit has been established, a buyout or acquisition strategy study should be performed that focuses on properties closest to Grannis Creek in the highest risk flood areas and progresses outwards from there to maximize flood damage 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.

7.10 ALTERNATIVE #10: FLOOD PROOFING

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

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

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

For communities that have been provided an exception by FEMA, the CFR allows for the floodproofing of residential basements as outlined in 44 CFR 60.6 (c) “a permit can be obtained to floodproof a residential building basement, if it can demonstrate an adequate warning time under a flood depth less than 5 feet and a velocity less than 5 fps.” Floodproofing residential basements should be considered during the design phase of a structure prior to construction. For existing structures, floodproofing residential basements can be a difficult, complex, and expensive measure to achieve. Instead, residential structures should be raised above the BFE in accordance with local regulations. Floodproofing is allowed for non-residential structures, with design guidelines outlined in FEMA P-936 – Floodproofing Non-Residential Structures (FEMA 2000; FEMA 2013). The local floodplain administrator should carefully review local ordinances, the CFR and available design guidelines perform issuing a permit for structural flood proofing. Floodproofing strategies include:

Interior Modification/Retrofit Measures

Interior modification and retrofitting involves making changes to an existing building to protect it from flood damage. When the mitigation is properly completed in accordance with NFIP floodplain management requirements, interior modification/retrofit measures could achieve the 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 alone may not provide protection to the BFE or, where applicable, the locally required freeboard elevation (FEMA 2015b).

Examples include:

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

Dry floodproofing

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

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

Examples include:

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

Wet floodproofing

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

Examples include:

- *Flood Openings*: This measure involves installing openings in foundation and enclosure walls located below the BFE that allow automatic entry and exit of floodwaters to prevent collapse from the pressures of standing water
- *Elevate Building Utilities*: This measure involves elevating all building utility systems and associated equipment (e.g., furnaces, septic tanks, and electric and gas meters) to protect utilities from damage or loss of function from flooding

- *Floodproof Building Utilities*: This measure involves floodproofing all building utility systems and associated equipment to protect it from damage or loss of function from flooding
- *Flood Damage-Resistant Materials*: This measure involves the use of flood damage-resistant materials such as non-paper-faced gypsum board and terrazzo tile flooring for building materials and furnishings located below the BFE to reduce structural and nonstructural damage and post-flood event cleanup

Barrier Measures

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

- Consult a registered design professional (i.e. architect or engineer) who is qualified to deal with the specifics of a flood mitigation project
- Check your community's floodplain management ordinances

- Contact your insurance agent to find out how your flood insurance premium may be affected
- Check what financial assistance might be available
- Hire a qualified contractor
- Contact the local building department to learn about development and permit requirements and to obtain a building permit
- Determine whether the mitigation project will trigger a Substantial Improvement declaration
- See the project through to completion
- Obtain an elevation certificate and an engineering certificate (if necessary)

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

8. NEXT STEPS

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

8.1 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-Dimensional (1-D) steady flow simulations.

8.2 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 Office of Emergency Management (NYSOEM)
- Consolidated Funding Applications (CFA)
- Natural Resources Conservation Services (NRCS) Emergency Watershed Protection (EWP) Program
- FEMA's Unified Hazard Mitigation Assistance (HMA) Program

8.2.1 NYS Office of Emergency Management (NYSOEM)

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

8.2.2 Consolidated Funding Applications (CFA)

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

Water Quality Improvement Project (WQIP) Program

The Water Quality Improvement Project Program, administered through the NYSDEC, is a statewide reimbursement grant program to address documented water quality impairments. Eligible parties include local governments and not-for-profit corporations.

Funding is available for construction/implementation projects; projects exclusively for planning are not eligible. Match for WQIP is a percentage of the award amount, not the total project cost. Deadlines are in accordance with the CFA application cycle.

Climate Smart Communities (CSC) Grant Program

The Climate Smart Communities 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 NYSDEC 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.

8.3 NRCS EMERGENCY WATERSHED PROTECTION (EWP) PROGRAM

Through the Emergency Watershed Protection (EWP) Program, the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) can assist communities in addressing watershed impairments that pose imminent threats to lives and property. Most EWP projects involve the protection of threatened infrastructure from continued stream erosion. 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 percent), and performing any necessary operation and maintenance for a ten-year period. Through EWP, the NRCS may pay up to 75 percent of the construction costs of emergency measures, with up to 90 percent 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.

8.4 FEMA UNIFIED HAZARD MITIGATION ASSISTANCE (HMA) PROGRAM

The FEMA Unified Hazard Mitigation Assistance Program, offered by the New York State Division of Homeland Security and Emergency Services (NYSDHSES), provides funding for creating/updating hazard mitigation plans and implementing hazard mitigation projects. The HMA program consolidates the application process for FEMA's annual mitigation grant programs not tied to a State's Presidential disaster declaration. Funds are available under the Pre-Disaster Mitigation (PDM) Program and the Flood Mitigation Assistance (FMA) Program.

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.

8.4.1 Pre-Disaster Mitigation (PDM) Program

The Pre-Disaster Mitigation (PDM) Grant Program provides resources to reduce overall risk to the population and structures from future hazard events, while also reducing reliance on federal funding from future disasters. Federal funding is available for up to 75 percent of eligible activity costs. The PDM project funding categories include Advance Assistance (up to $200,000 total of federal share funding), Resilient Infrastructure (up to $10 million total of federal share funding), and Projects (up to $4 million per project).

8.4.2 Flood Mitigation Assistance Program

The Flood Mitigation Assistance Program provides resources to reduce or eliminate long-term risk of flood damage to structures insured under the National Flood Insurance Program (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 percent of the eligible activity costs. FEMA may contribute up to 100 percent federal cost share for severe repetitive loss properties, and up to 90 percent 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 facilities
- Floodplain and stream restoration
- Water and sanitary sewer system protective measures

9. SUMMARY

The Village of Gowanda, NY has had a short, but extensive history of flooding events along Grannis Creek. Flooding along Grannis Creek generally occurs in the late spring and summer months due to heavy rain, or rain on saturated soil events. The situation is compounded by the accumulation of debris and sediment at the upstream face of culverts, which can potentially cause backwater flooding. The heavily developed lower reaches of Grannis Creek, primarily in the Village of Gowanda, are at considerable risk of flood damages due to the close proximity of residential and commercial properties to the creek banks, and topography of the floodplain in the Village. In response to catastrophic flooding in recent years, the State of New York in conjunction with the Village of Gowanda and Erie County are studying, addressing, and recommending potential flood mitigation projects for Grannis Creek as part of the Resilient NY Initiative.

This report analyzed the historical and present day causes of flooding in the Grannis 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 Grannis 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 Grannis 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 the culvert upsizing recommendations for Union and Buffalo Streets and the flood bench. The most cost effective of these alternatives would be the culvert upsizing of the Cemetery Hill Road Culvert; however, there would be an overall greater effect in water surface elevations if multiple culvert upsizing alternatives were built along Grannis Creek in different phases, rather than one large single upsizing project. In addition, the flood bench measure only reduced water surface elevations in the vicinity of and immediately upstream and downstream the bench location and did not provide significant flood risk reduction to high risk areas downstream.

Other alternatives that should be considered are the early flood-warning detection system and debris maintenance around the culverts and/or bridges. The early flood-warning system can provide valuable preparation and evacuation time for residents within flood-prone areas prior to a flooding event. Debris maintenance around the culvert and/or bridges in the Village can reduce and possibly prevent flood risk and damages in the event of a flood by increasing the cross-sectional area for water flow through the culverts/bridges.

The levee system behind the Perry Street neighborhood would be beneficial for the residents along the left bank of Grannis Creek from the railroad bridge up to the Buffalo Street junction. Due to the elevation of Buffalo Street, high flows would overtop the roadway and inundate residences along Buffalo and Union Streets causing higher flood damages in these areas, while reducing flood damages along Perry Street. Additional levee structures downstream, and increasing the elevation of the Buffalo Street roadway, would need to be considered in order to construct a levee system that could reduce the risk of all residents within the Village of Gowanda. Additional hydrologic and hydraulic modeling would be necessary to determine the full scale and costs associated with a large-scale levee system throughout the Village.

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-percent 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 future flood damages remain. A benefit to floodproofing versus buyouts is that properties remain in the Village and the tax base for the local municipality remains intact. Table 17 is a summary of the proposed flood mitigation measures, including modeled water surface elevation reductions and estimated ROM costs.

Table 17. Summary of Flood Mitigation Measures

Alternative No.	Description	Current Water Surface Elevation Reductions (ft)	ROM cost (U.S. dollars)
1	Increase Size of Union Street Box Culvert	Up to 1.8-ft	$750,000 (not including property acquisition costs)
2	Increase Size of Buffalo Street Box Culvert	Up to 2.6-ft	$1.3 Million (not including property acquisition costs)
3	Increase Size of Cemetery Hill Road Box Culvert	Up to 3.0-ft	$430,000 (not including property acquisition costs)
4	Increase Size of Railroad Bridge Opening	Up to 2.6-ft	Further Analysis Needed Due to Complications with Railroad Coordination Costs
5	Levee Behind Perry Street Neighborhood	N/A	$2.8 Million (not including property acquisition costs)
6	Debris Maintenance Around Culverts/Bridges	N/A	$20,000
7	Early Flood Warning Detection System	N/A	$100,000
8	Flood Bench	Up to 1.3-ft	$1 Million (not including property acquisition costs)
9	Flood Buyouts/Property Acquisitions	N/A	Variable (case-by-case)
10	Floodproofing	N/A	Variable (case-by-case)

10. CONCLUSION

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

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

1. Obtain stakeholder and public input to assess the feasibility and public support of each mitigation strategy presented in this report.
2. Complete any additional data collection and modeling efforts to assess the effectiveness of the proposed flood mitigation strategies.
3. Develop a list of final flood mitigation strategies based on the additional data collection and modeling results.
4. Select a final flood mitigation strategy or series of strategies to be completed for Grannis 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

Summary of Data and Reports Collected			NYSOGS Project # SC498
Resilient New York Flood Mitigation Initiative			**OBG Project # SC800**
Grannis Creek - Erie County, New York			**March 9, 2020**
Year	Data Type	Document Title	Author
1968	Report	Flood Plain Information, Cattaraugus Creek and Thatcher Brook, Irving, Sunset Bay and Gowanda, N.Y.	United States Army Corps of Engineers (USACE)
1973	Report	Emergency treatment assistance, Thatcher Brook and Grannis Creek	United States Soil Conservation Service (USSCS)
1975	Report	Urban Hydrology for Small Watersheds: TR-55	United States Soil Conservation Service (USSCS)
1976	Report	Flood Insurance Study (FIS), Village of Gowanda, Cattaraugus County and Erie County, New York	Federal Insurance Administration (FIA)
1986	Report	Soil Survey of Erie County, New York	United States Soil Conservation Service (USSCS)
2006	Report	Magnitude and Frequency of Floods in New York	United States Geological Survey (USGS)
2009	Report	Bankfull discharge and channel characteristics of streams in New York State	United States Geological Survey (USGS)
2010	Report	Flash Floods of August 10, 2009, in the Villages of Gowanda and Silver Creek, New York	United States Geological Survey (USGS)
2010	Report	HEC-RAS River Analysis System, Hydraulic Reference Manual Version 4.1	United States Army Corps of Engineers (USACE)
2011	Report	Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation	New York State Energy Research and Development Authority (NYSERDA)
2012	Report	Hydraulic Design of Safe Bridges	Federal Highway Administration (FHA)
2015	Report	Erie County, New York Multi-Jurisdictional Hazard Mitigation Plan Update	URS Engineering (AECOM)
2016	Report	HEC-RAS River Analysis System User's Manual Version 5.0	United States Geological Survey (USGS) Hydrologic Engineering Center (HEC)
2018	Report	[DRAFT] New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act	New York State Department of Environmental Conservation (NYSDEC)
2019	Report	Flood Insurance Study (FIS), Erie County	Federal Emergency Management Agency (FEMA)
2008	Data	Erie County, NY -LiDAR Terrain Elevation	New York State Department of Environmental Conservation (NYSDEC)
2013	Data	Railroads	New York State Department of Transportation (NYSDOT)

2014	Data	Culverts	New York State Department of Transportation (NYSDOT)
2018	Data	A New Generation of the United States National Land Cover Database: Requirements, Research Priorities, Design, and Implementation Strategies	United States Geological Survey (USGS) Multi-Resolution Land Characteristics (MRLC)
2019	Data	City/Town Boundaries, County Boundaries	New York State Office of Information Technology Services (NYSOITS)
2019	Data	Cropland	United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS)
2019	Data	Dams, Hydrography	New York State Department of Environmental Conservation (NYSDEC)
2019	Data	Development of flood regressions and climate change scenarios to explore estimates of future peak flows	United States Geological Survey (USGS)
2019	Data	FIRM Flood Insurance Rate Map Erie County, NY (All Jurisdictions)	Federal Emergency Management Agency (FEMA)
2019	Data	Ice Jam Database	United States Geological Survey (USGS) Cold Regions Research and Engineering Laboratory (CRREL)
2019	Data	National Flood Hazard Layer: Erie County, NY	Federal Emergency Management Agency (FEMA)
2019	Data	RSMeans CostWorks 2019, version 16.03	Gordian, Inc.
2019	Data	Soils	United States Geological Survey (USGS)
2019	Data	Storm Events Database: Erie County, NY	National Centers for Environmental Information (NCEI)
2019	Data	StreamStats, version 4.3.8	United States Geological Survey (USGS)
2019	Data	Streets	New York State Department of Transportation (NYSDOT)
2019	Data	Tax Parcels, Parks, Public Schools, Sheriff Stations	New York State Office of Real Property Tax Services (NYSORPTS)

APPENDIX B
FIELD DATA COLLECTION FORM EXAMPLES

Stream Channel Classification (Level II)

Wisconsin Job Sheet 811

U.S. Department of Agriculture
Natural Resources Conservation Service

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.

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

Mean Depth (d_{bkf}):	_________ ft.	_________ ft.	_________ ft.	0.00 ft.

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 (A_{bkf}):	_________ sq. ft.	_________ sq. ft.	_________ sq. ft.	0.00 sq. ft.

Area of the stream channel cross section, at bankfull stage elevation, in a riffle section.

Width / Depth Ratio (W_{bkf}/d_{bkf}):	_________ ft.	_________ ft.	_________ ft.	0.00 ft.

Bankfull width divided by bankfull mean depth, in a riffle section.

Maximum Depth (d_{mbkf}):	_________ ft.	_________ ft.	_________ ft.	0.00 ft.

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 (W_{fpa}):	_________ ft.	_________ ft.	_________ ft.	0.00 ft.

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

Entrenchment Ratio (ER):	_________ ft.	_________ ft.	_________ ft.	0.00 ft.

The ratio of flood-prone area width divided by bankfull channel width. (W_{fpa}/W_{bdf}) (riffle section)

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

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

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

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

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: ______________________________

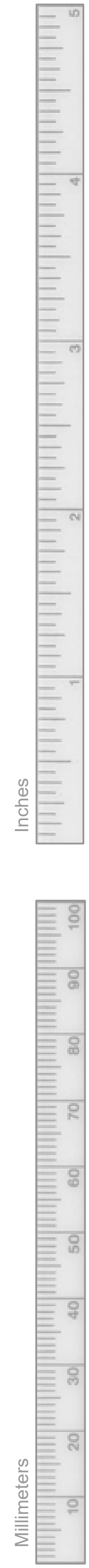
Horizontal Datum: NAD ________ Projection: ☐Transverse Mercator ☐Lambert Conformal Conical

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 #	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				



OBG
Part of Ramboll

Field Observation Form

By:______________________ Date: ____________________ Project Name: _______________________________
Project Number: ______________________________

Location/Description

____

____

____

____

____

Sketches (Include flow depth, channel bed material, Manning values, flow direction, etc.)

Plan View:

Section View:

Structure Data

☐ Bridge ☐ Culvert

Height: _____________ Width: ____________ ☐ Box # Sides: _____ ☐ Pipe ☐ Arch ☐ Other

Length in direction of flow: _______________ Manning Value Top: ____________ Bottom: _____________

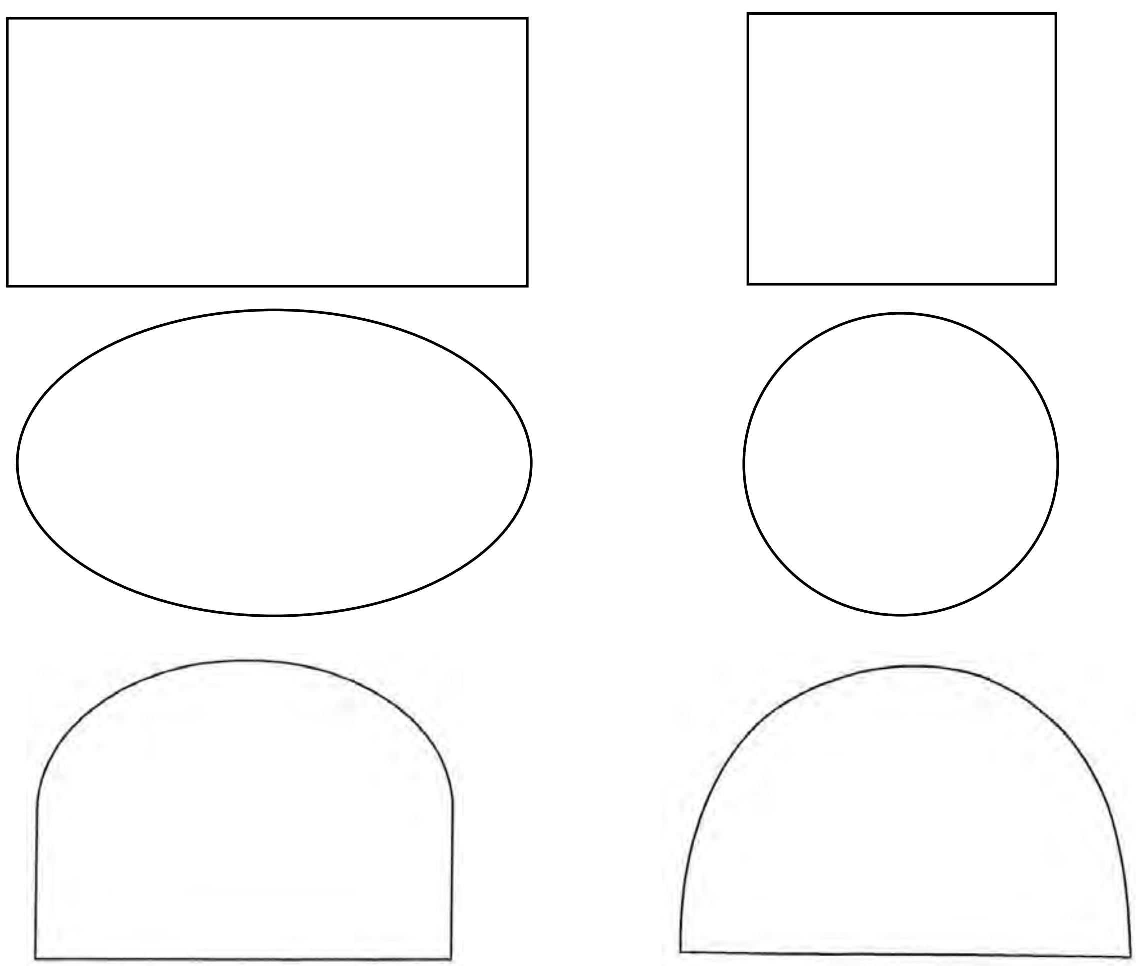
Description:

____

____

____

Typical Culvert Shapes (fill in dimensions)



APPENDIX C
PHOTO LOGS

PHOTO LOG	
Photo log of select locations within the river corridor.	
Photo No. 1 **Description:** Facing downstream at the Union Street culvert looking at the confluence with Cattaraugus Creek.	
Photo No. 2 **Description:** Facing upstream at the Union Street culvert.	

Photo No. 3 **Description:** Union Street culvert road deck.		
Photo No. 4 **Description:** Upstream of the Buffalo Street culvert facing downstream.		

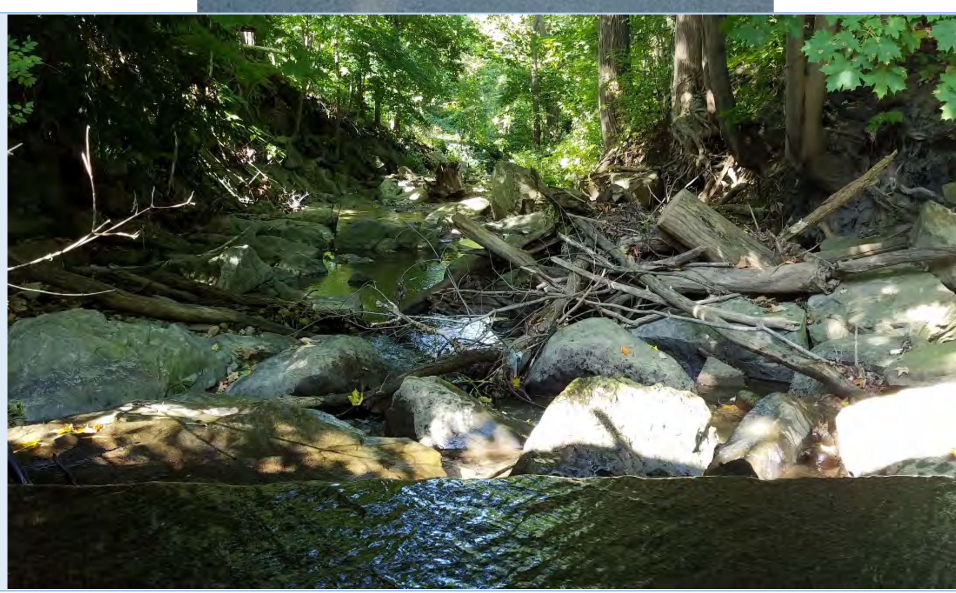
Photo No. 5 **Description:** Facing downstream standing atop the Buffalo Street culvert road deck.	
Photo No. 6 **Description:** Inside the Buffalo Street culvert facing downstream.	

Photo No. 7 **Description:** Facing upstream standing atop the railroad bridge.	
Photo No. 8 **Description:** Facing downstream standing atop the railroad bridge.	

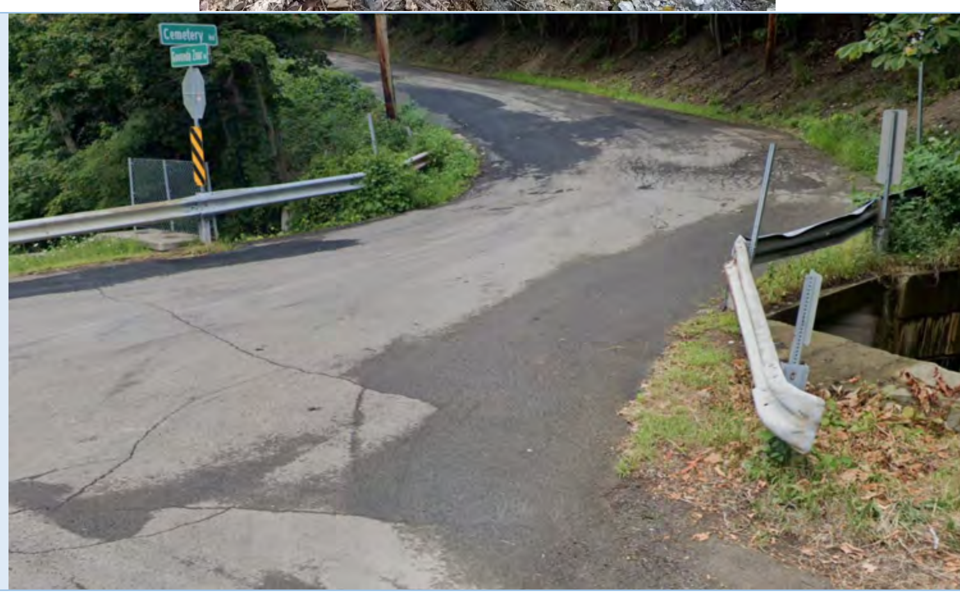
Photo No. 9 **Description:** Standing atop the railroad bridge.	
Photo No. 10 **Description:** Cemetery Hill Road culvert road deck.	

Photo No. 11 **Description:** Facing downstream standing atop the Cemetery Hill Road culvert.	
Photo No. 12 **Description:** Facing downstream at the Cemetery Hill Road culvert.	

Photo No. 13 **Description:** Facing downstream at the South Quaker Road culvert.	
Photo No. 14 **Description:** Standing atop the South Quaker Road culvert.	

APPENDIX D

AGENCY AND STAKEHOLDER MEETING SIGN-IN SHEET

Sign in

Grannis 9/19

Name	Affiliation	Phone	Email
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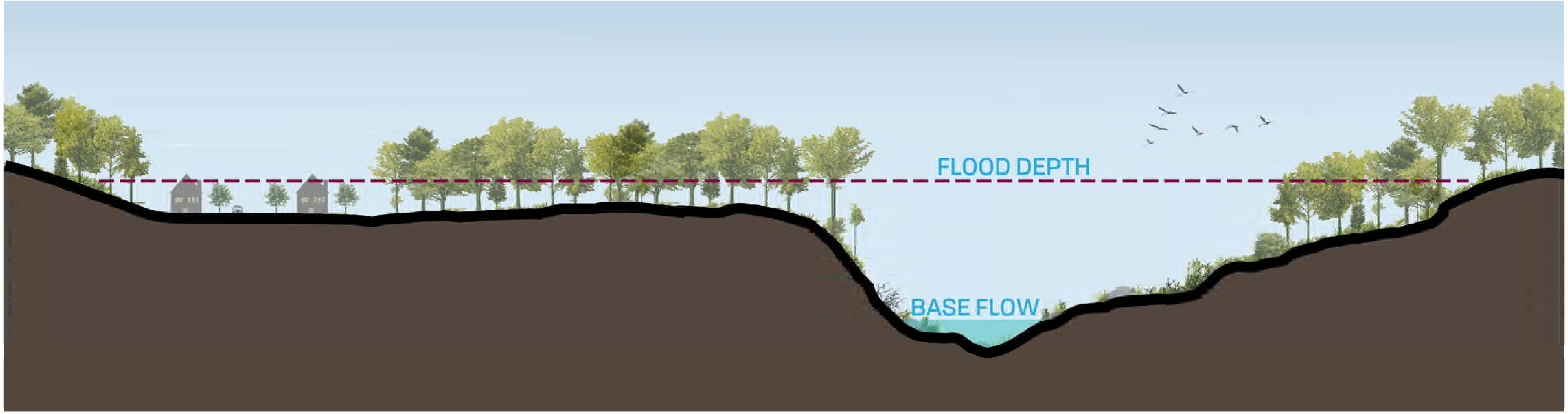
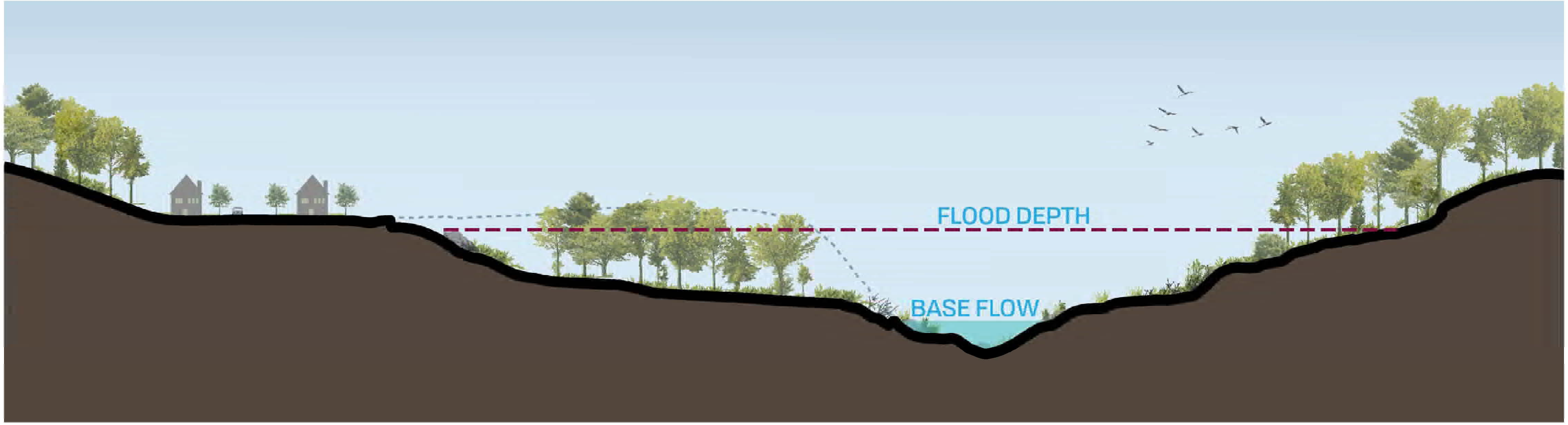
Mark C Burr	Catt Co DPW	716-938-2431	mcburr@ Catt Co.org

APPENDIX E

MITIGATION RENDERINGS



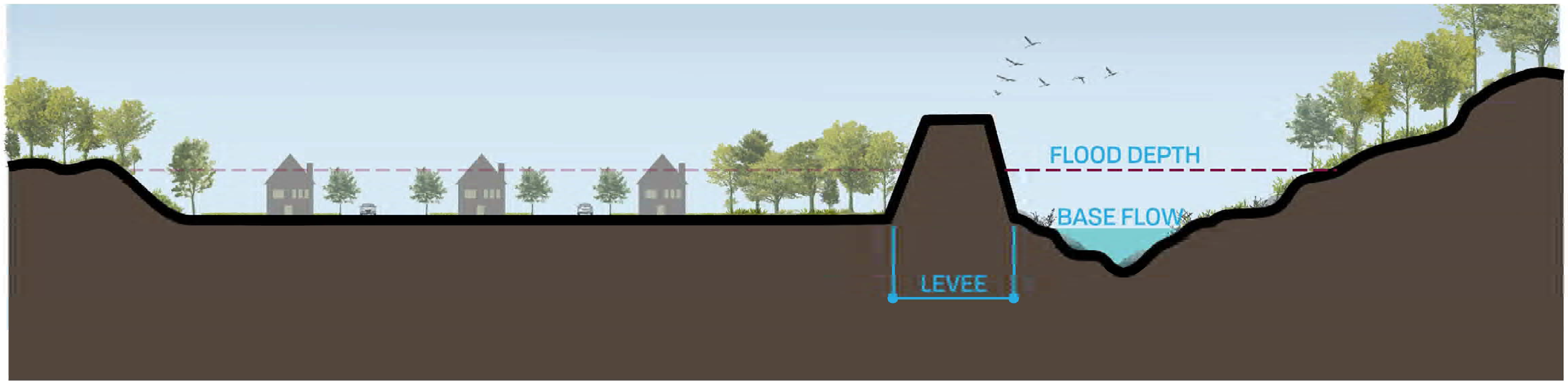
Existing Condition



Future Condition

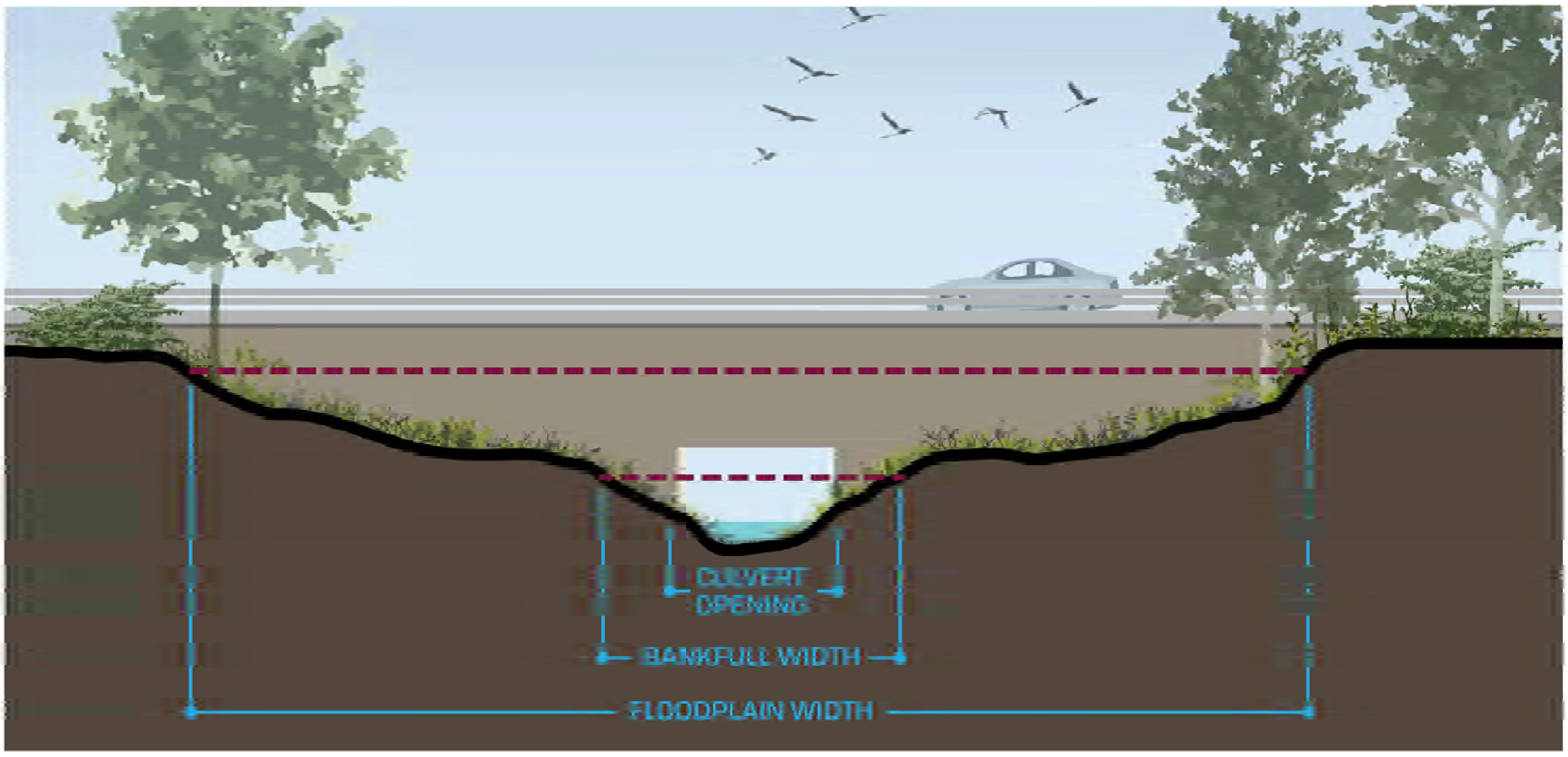
FLOODPLAIN BENCH

Existing Condition

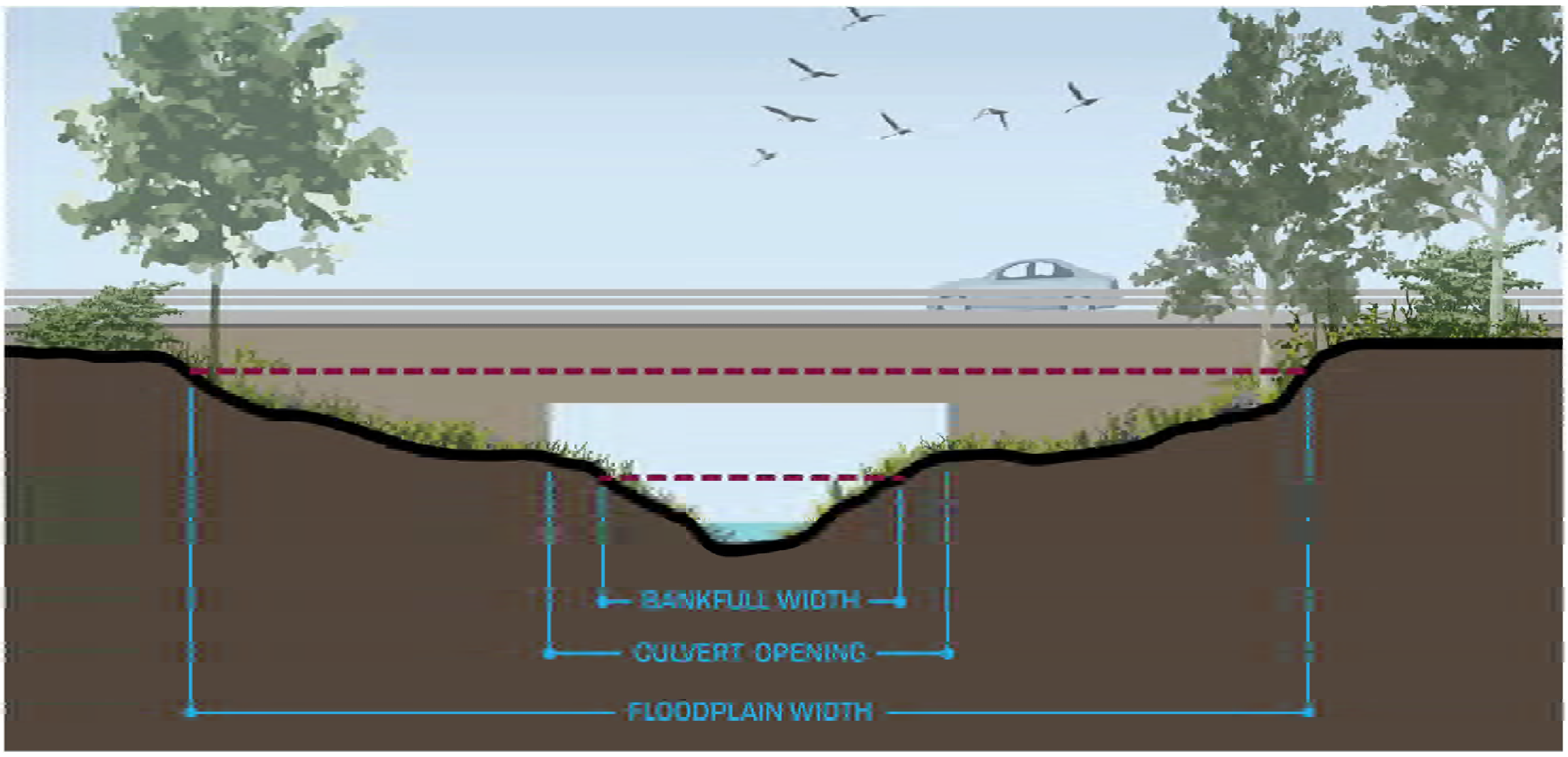


Future Condition

PROTECTIVE LEVEE



Existing Condition



Future Condition

RIGHT SIZING CULVERTS