Apalachin Creek Background Report

SUBMITTED TO
Tioga County Soil and Water Conservation District

DECEMBER 2019

Apalachin Creek
Background Report

SUBMITTED TO
Tioga County Soil and Water Conservation District
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1. Introduction

The Susquehanna River is a nationally important river as one of the longest rivers on the east coast and a major source of freshwater to Chesapeake Bay. It flows for approximately 460 miles through three states, beginning in upstate New York. The Upper Susquehanna watershed is located in the Allegheny Plateau region and encompasses approximately 7,500 square miles, including Tioga and Broome Counties. Primary tributaries include the Chenango River in Broome County and Owego Creek and Catatonk Creek in Tioga County.

The Regional Susquehanna River Initiative project was conceptualized through the New York Rising Community Reconstruction (NYRCR) Tioga community planning process following widespread flood devastation along the Susquehanna River and its tributaries in 2011. The area was affected by both Tropical Storm Irene and, shortly after, Tropical Storm Lee which delivered intense rainfall onto the already saturated watershed. Costly impacts included loss and damage of homes and businesses, loss and damage of utility infrastructure, road closures and washouts, and stream bank erosion affecting agricultural productivity.

The Tioga County Soil and Water Conservation District (TCSWCD) has secured U.S Department of Housing and Urban Development (HUD) Community Development Block Grant-Disaster Recover (CDBG-DR) funding, administered through the NY Rising Community Reconstruction (NYRCR) Program of the New York State Governor's Office of Storm Recovery (GOSR), to identify sustainable flood mitigation measures for six priority watersheds within Tioga and Broome Counties.

This report focuses on the Apalachin Creek watershed and has been developed by the Inter-Fluve Engineering team, including partners Fuss & O'Neill and Integrated Aquatic Sciences. The purpose of this report is to summarize our assessment of current conditions, describe flood-related vulnerabilities, and identify opportunities for both infrastructure and natural systems options for mitigating flood impacts and increasing community resilience while maintaining or improving aquatic habitat.

1.1 CLIMATE CHANGE IN NEW YORK

Since the turn of the century, global annual-average temperature has increased by 1.8°F with most of that change occurring since the 1980s (USGCRP 2017). The global scientific community agrees that human activities and the accelerated release of greenhouse gases since industrialization are the primary drivers of recently observed global temperature rise. This rise in temperatures has occurred more quickly than any time in the past 1,700 years, and additional warming is predicted even if greenhouse gas emissions are immediately substantially reduced. Globally, the impacts of climate change on sea level, water resources, agricultural productivity, weather patterns, energy use, ecology, and human health are already being realized with significant consequences.

In New York State, increasing flood risk is one of the major climate change concerns. As reported in the recent Draft New York State Flood Risk Management Guidance (NYS DEC 2018), there were 3,312 individual flood event occurrences reported in New York between 1960 and 2012 with property damage exceeding $3.8 billion. The period between 2010 and 2012 in particular was one of concentrated incidents with 287 reported flood events affecting 48 out of 62 counties and resulting in $1.1 billion in property damage. The latter does not include all losses associated with Hurricanes Sandy and Irene which caused many billions of dollars of damages and in the case of Sandy, resulted in the loss of 53 lives in the state (CDC 2013).

Studies have anticipated a shift toward more extreme precipitation events and higher peak flood flows in the years to come. In the Northeast, the amount of precipitation falling in the heaviest storm events increased by over 70% between 1958 and 2010 (Horton et al. 2014). Flash flooding is an ongoing problem in Tioga County with impacts felt as recently as August 15, 2018 when as much four inches of rain fell within a 24-hour period (NWS 2018). Under current climate change projections, flooding and flood-related impacts in the County are likely to intensify. Adaptation is necessary to avoid increasingly significant impacts.

1.2 APALACHIN CREEK WATERSHED

The Apalachin Creek watershed encompasses 43 square miles in southern New York and northern Pennsylvania (Figure 1). The creek itself empties into the Susquehanna River near Apalachin, New York located within the Town of Owego. One small dam is located on Apalachin Creek in Pennsylvania and creates the Minkler Lake reservoir; other small dams may be present upstream of the reservoir. Because of the source of funding for this project, our study has been limited to the downstream portion of the watershed located within New York State (approximately 23 square miles). The maximum elevation in upland areas of the New York portion of the watershed is between 1,500 and 2,000 feet, while the outlet of the creek is near 800 feet in elevation (Figure 2).

Seven tributaries in addition to the mainstem Apalachin Creek within New York were selected by TCSWCD for inclusion in the study or visited during our site assessment as time allowed: Deerlick Creek (drainage area of 4.0 square miles), Long Creek (2.9 square miles), an unnamed tributary along Gaylord Road (2.2 square miles), an unnamed tributary along South Apalachin Road (2.8 square miles), an unnamed tributary along Card Road (0.7 square miles), an unnamed tributary along Harnick Road (0.7 square miles), and an unnamed tributary along Fox Road (1.4 square miles). Flow inputs to tributaries include numerous small rivulets (i.e., very small stream) that are typically dry but convey significant water and sediment during high-intensity precipitation events.

In recent years, the watershed has experienced several instances of extreme flooding, most notably during Tropical Storm Lee in September 2011. Flood impacts in the watershed were severe and included intense erosion, debris blockage of channels and culverts including culvert failure in upland areas and substantial sediment deposition, bank erosion and channel migration, and inundation in low-lying areas. The flood and damage history of the watershed is discussed in more detail in the Apalachin Creek Background Report (USC 2018a) and the Tioga County Multi-Jurisdictional Hazard Mitigation Plan (Tetra Tech 2012, 2018).

1.3 GOALS AND OBJECTIVES OF THE STUDY

The primary goal of the project is to increase resilience to flooding and flood-related impacts within the Apalachin Creek watershed. Objectives include:

1. Utilizing and restoring natural watershed processes that help mitigate flooding and flood-related impacts by reducing flood peaks and moderating sediment loads;
2. Adapting infrastructure, watershed management approaches, and land-use practices and policies to work with natural processes to improve resilience;
3. Improving public awareness and acceptance of the need to adapt and the critical role of natural watershed processes;
4. Supporting implementation of the Chesapeake Bay TMDL through water quality improvements, specifically reductions in nutrient and sediment loads; and
5. Improving ecological health of the watershed.

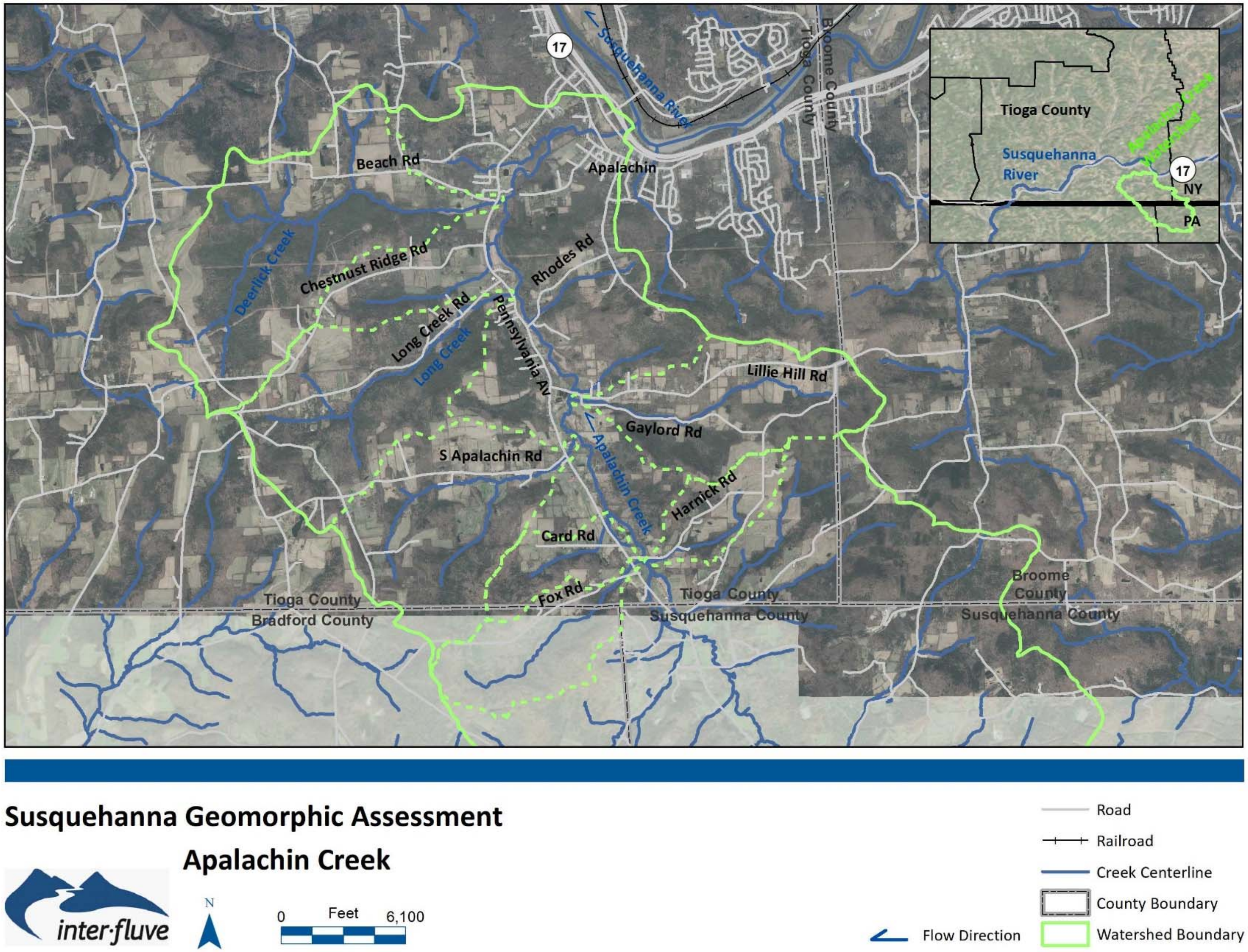

Figure 1. Apalachin Creek watershed location map

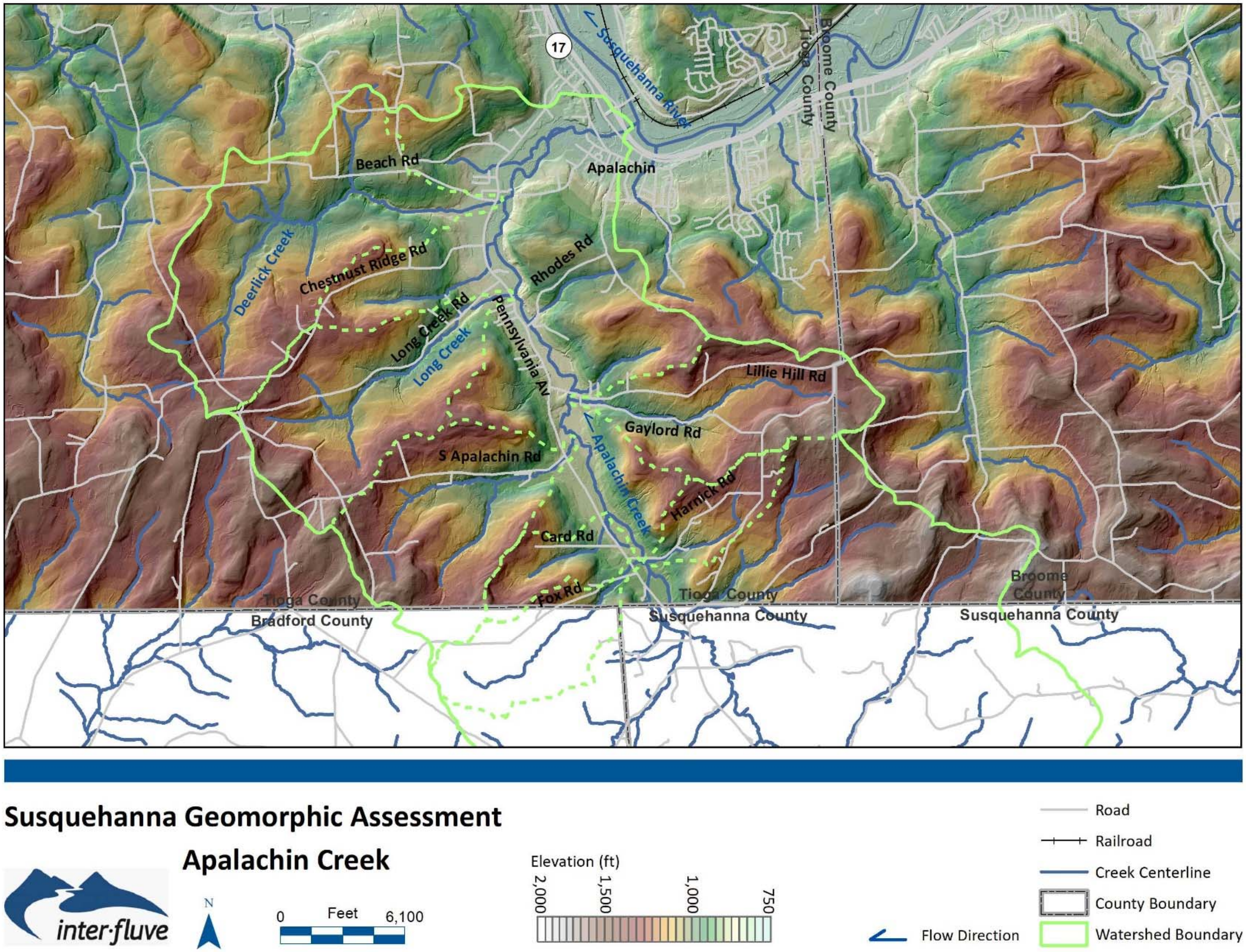

Figure 2. Digital elevation model (DEM) of the Apalachin Creek watershed in New York. 2007 LiDAR for Tioga County and portions of Broome County was provided by TCSWCD.

2. Existing Data Review

Our technical approach began with developing an understanding of landscape context, including watershed history and the role flood and geomorphic processes have played in shaping conditions to date. Additional consideration was given to understanding what trajectories these processes may have in shaping future conditions. This context provides a framework for identifying proactive flood mitigation measures tailored to the Apalachin Creek watershed. The following sections summarize our findings based on a review of existing information. In Section 3, we provide additional insight gained during field assessments.

2.1 CLIMATE

A general description of the region's current climate has been provided in existing background reports for the Huntington Creek and Apalachin Creek watersheds (USC 2018a,b) and is summarized briefly here. The County has a humid continental climate characterized by warm summers and cold winters. Average low temperatures dip to 15°F in the winter and 60°F in the summer, and average highs reach 29°F in the winter and 78°F in the summer. Average annual precipitation as rainfall is 39 inches, and average annual snowfall is 83 inches.

Precipitation totals in Tioga County, part of ClimAID Region 3, Southern Tier, is are projected to increase between 4 and 10% by the 2050s and 6 to 14% by the 2080s (baseline of 35 inches, middle range projection) (Horton et al. 2014). It is anticipated that the additional precipitation will be delivered via more intense storms rather than distributed evenly over time.

2.2 GEOLOGY AND GEOMORPHOLOGY

Many of the processes and unique issues discussed in this report can be partly attributed to the geologic history of the region. During the Devonian Period (415 million years ago), the North American landmass was situated close to the equator and much of North America was inundated by warm, tropical seas. These depositional environments trapped large volumes of fine-grained sediment along with the skeletons of marine organisms, which are evident in the abundant fossils that can be found in the area's rocks today (Craft and Bridge 1987). Over time, and with subsequent mountain building events heat and pressure transformed these deposits into broad, flat-lying beds of sandstone and siltstone that make up the region's present-day bedrock geology. The modern Allegheny Plateau was uplifted during the end of the Paleozoic era (320-250 million years ago).

Erosion of the plateau since that time has generated the general landscape that exists today. While the plateau was initially flat lying, surface irregularities, regional slopes, and climate combined to initiate the formation of the drainage (stream channel) network that is still evolving today. The plateau has not eroded evenly but rather it has been dissected by the drainage network, which focuses runoff and erosional processes along stream beds and banks, sculpting the present-day topography out of the former plateau. The consistent elevation of the hilltops in the region (all around 1600 feet) is an attribute common to dissected plateaus and represents the elevation of the pre-dissection plateau surface.

This evolution of the landscape has also been influenced by periodic ice ages during which continental ice sheets surged over the region, flowing north to south. The most recent glaciation ended approximately 12,000 years ago, with ice retreating from New York beginning approximately 18,000 years ago. The flowing ice preferentially followed river valleys like the Susquehanna and its larger tributaries, eroding the large river valleys while blocking off the smaller tributaries with ice dams. This resulted in broad and gently sloped mainstem river valleys with steep side tributary valleys filled with glacial till.

The surficial geology of the watershed reflects its glacial history with till dominating upland areas and glacial outwash and more recent alluvial deposits occupying the Apalachin Creek valley floor. Both till and alluvial deposits are composed of thin, platy clasts derived from the region's siltstones and sandstones which break apart along shallow bedding planes. Refer to the previous background report (USC 2018a) for a discussion of the soils found in the watershed and maps of bedrock and soils.

Examination of topographic maps for the area show that alluvial fans have developed at the mouths of the Apalachin Creek tributaries over time and continue to influence the alignment of the mainstem creek by forcing it toward the opposite side of the valley (Figure 3).

2.3 LAND COVER AND LAND USE

A discussion along with maps of land cover types in the Apalachin Creek watershed is provided in a previous background report (USC 2018a). The report describes the major land cover as forest (approximately 68%) with agricultural cover types over approximately 25% of the watershed. The remainder of the watershed is covered by a mix of shrub/grassland, water/wetlands, and developed space. Historical aerial photos show that in the early 20th century land use in the watershed consisted of more farmland than the modern land use (Figure 4). Potential impacts of historical deforestation are discussed in Section 2.4.

Publicly available data show no existing conservation easements and limited protected land within the Apalachin Creek watershed in New York State (NCED 2018[1], NYNHP 2016). There are four parcels in Apalachin owned by the Town of Owego that are shown as set aside for uses other than development: Muth Park and three parcels designated Local Resources Management Areas. The largest protected area present is the 512-acre Tracey Creek State Forest, a small portion of which is within the watershed of the Gaylord Road tributary.

[1] Estimated completeness of records in New York State is 80%.

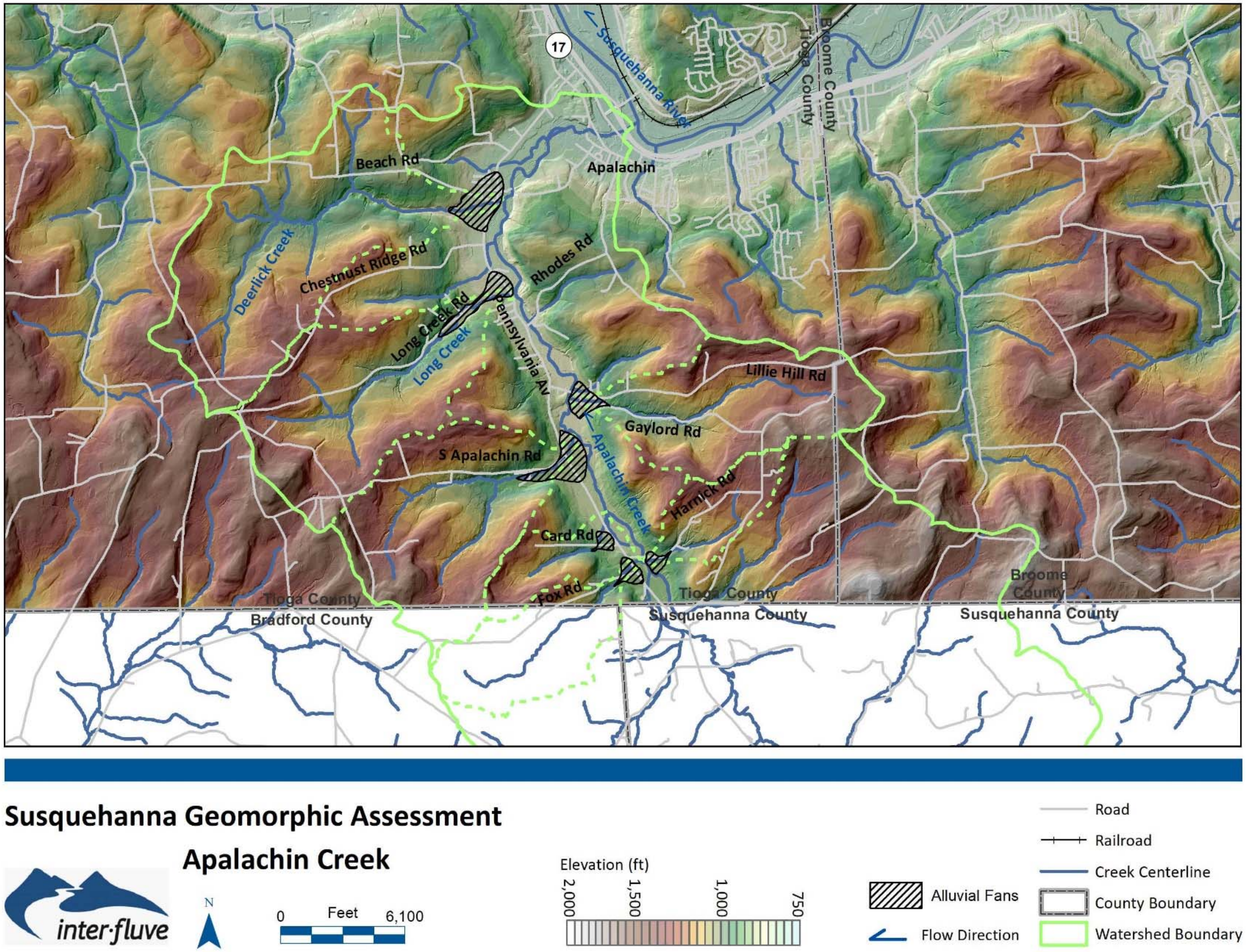

Figure 3. Delineated alluvial fans in the Apalachin Creek watershed. Delineations based on 2007 LiDAR.

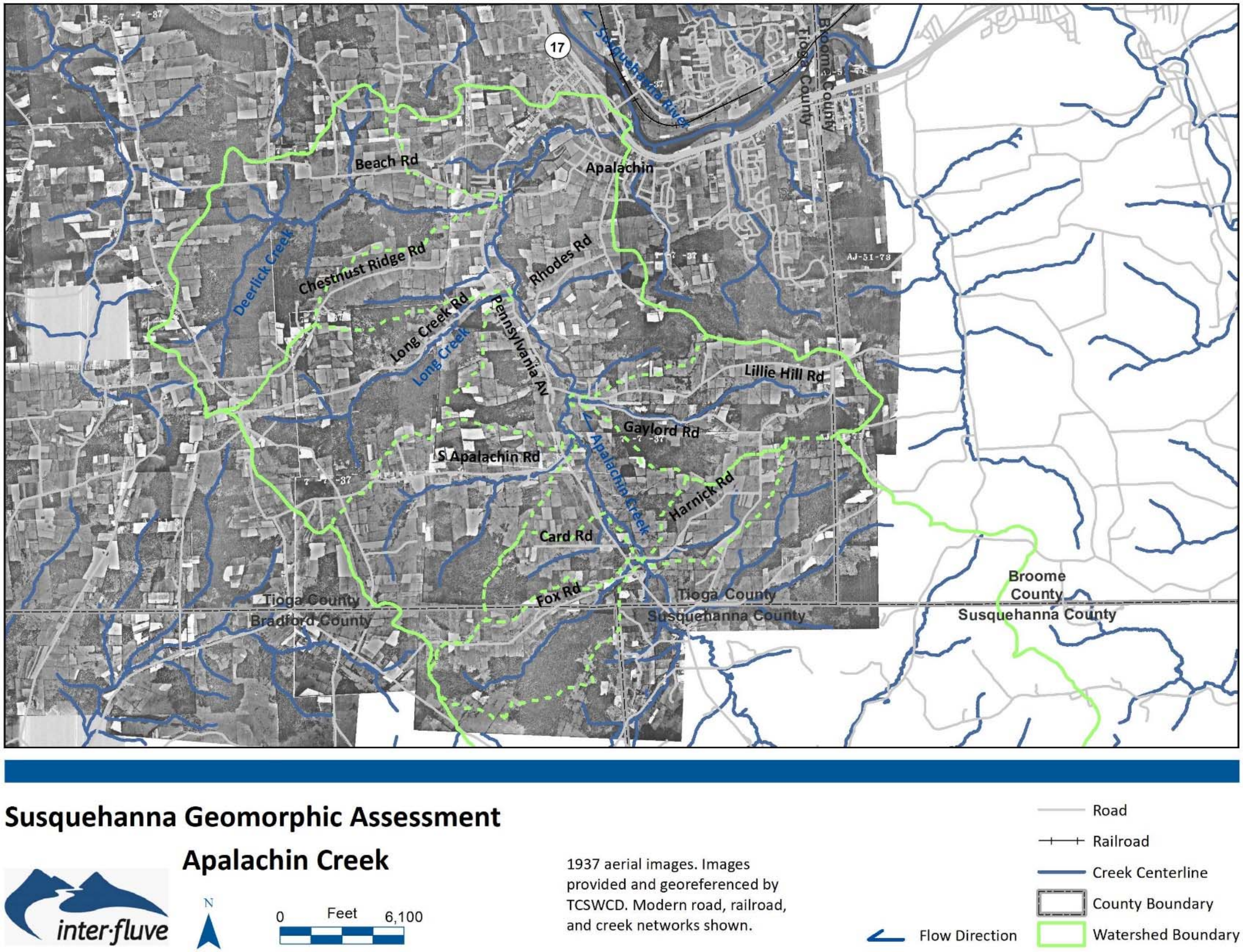

Figure 4. 1937 aerial imagery of the New York portion of the Apalachin Creek watershed provided by TCSWCD. Compare with Figure 1.

2.4 HYDROLOGY

To provide an estimate of peak flows for Apalachin Creek, we used USGS StreamStats, which estimates peak flows for a range of recurrence intervals using regional regression equations derived from stream gage data. The results are presented in Table 1. Because the results are derived from a regional regression rather than a long historical record of gage data specific to Apalachin Creek, they should be viewed as estimates of potential peak flood discharges.

Table 1. Estimated peak flood discharges for Apalachin Creek

Recurrence interval	USGS StreamStats discharge (cfs)
2 years (50% annual chance)	1,710
10 years (10% annual chance)	3,360
50 years (2% annual chance)	5,150
100 years (1% annual chance)	5,960

Floods in Apalachin Creek, and especially the Apalachin Creek tributaries, can be intense and sudden, or "flashy". The flashiness of the system is a function of the intense rainstorms that occur in the region in combination with watershed characteristics. Thin soils saturate quickly, and the steep slopes allow water to flow rapidly via shallow subsurface pathways and over the land surface to the channel. This rapid runoff response is capable of producing large and damaging floods. Forest and other dense vegetation cover can help to moderate this response by intercepting rainfall, protecting soil from erosion and thinning, and providing roughness that slows surface runoff. Historical deforestation (as evident in the 1937 photo above) would have contributed to rapid runoff and associated impacts. Another factor contributing to the flashiness of the system is the road and road drainage network within the watershed. A previous report states that there are 88 miles of road within the watershed (USC 2018a). Roads within the tributary watersheds of Apalachin Creek are generally steep and generate runoff that is either delivered directly to channels or is routed into equally steep drainage ditches that quickly discharge into channels.

These runoff characteristics of the Apalachin Creek watershed are particularly vulnerable to the increasing rainfall in the region as a result of climate change. As such, there is a high likelihood of more frequent and more intense flood events occurring in the future.

2.5 EXISTING FLOOD MAPPING AND MODELING

Federal Emergency Management Agency (FEMA) flood mapping is limited to mapping for the mainstem Apalachin Creek and has not been carried out for all of the streams in the Apalachin Creek watershed (Figure 5). The mapping does not include potential flooding on tributaries caused by the backwatering effects of an elevated water surface along Apalachin Creek, nor does it provide insight into potential geomorphic changes as a result of flooding such as avulsions (i.e., rapid changes in channel alignment through abandonment of former channels and erosion of new ones) or meander cutoffs, which have occurred in the past (USC 2018a), aggradation on the bed or at the mouths of tributaries, or bank erosion.

The FEMA mapping generally delineates the valley bottom. Of note is the fact that some stretches of Pennsylvania Avenue, the primary route into and out of the watershed, and residences located along the road lie within the 1% annual chance flood extent of Apalachin Creek. The current Flood Insurance Study for the county focuses largely on the Susquehanna River but does include modeled water-surface profiles along Apalchin Creek (FEMA 2012). The profiles show that backwater from the Susquehanna may extend up to approximately 4,000 feet upstream of the confluence. They also indicate that all of the bridges along the mainstem (Rhodes Road, Lillie Hill Road, Harnick Road, and Pennsylvania Avenue) restrict flood flows during events as low as the 50% annual chance event. Past infrastructure damage from flooding is summarized in the Tioga County Hazard Mitigation Plan (Tetra Tech 2012, 2018) and is not repeated here.

2.6 WATER QUALITY

Water quality within a watershed is important for maintaining aquatic biota as well as providing a potential drinking water source. Diminished water quality can be caused from point sources, such as a direct discharge from a pipe, or nonpoint sources, such as overland flow coming off of agricultural lands. Waterbody Inventory/Priority Waterbodies List (WI/PWL) is a statewide inventory of the water quality for all waterbodies in New York. The most recent one for the Susquehanna/Pipe Creek watershed, which includes Apalachin Creek and tributaries, was updated in 2009 and indicates minor impacts for Apalachin Creek and tributaries. Suspected impairments include nutrients from both point and nonpoint sources (NYS DEC 2009).

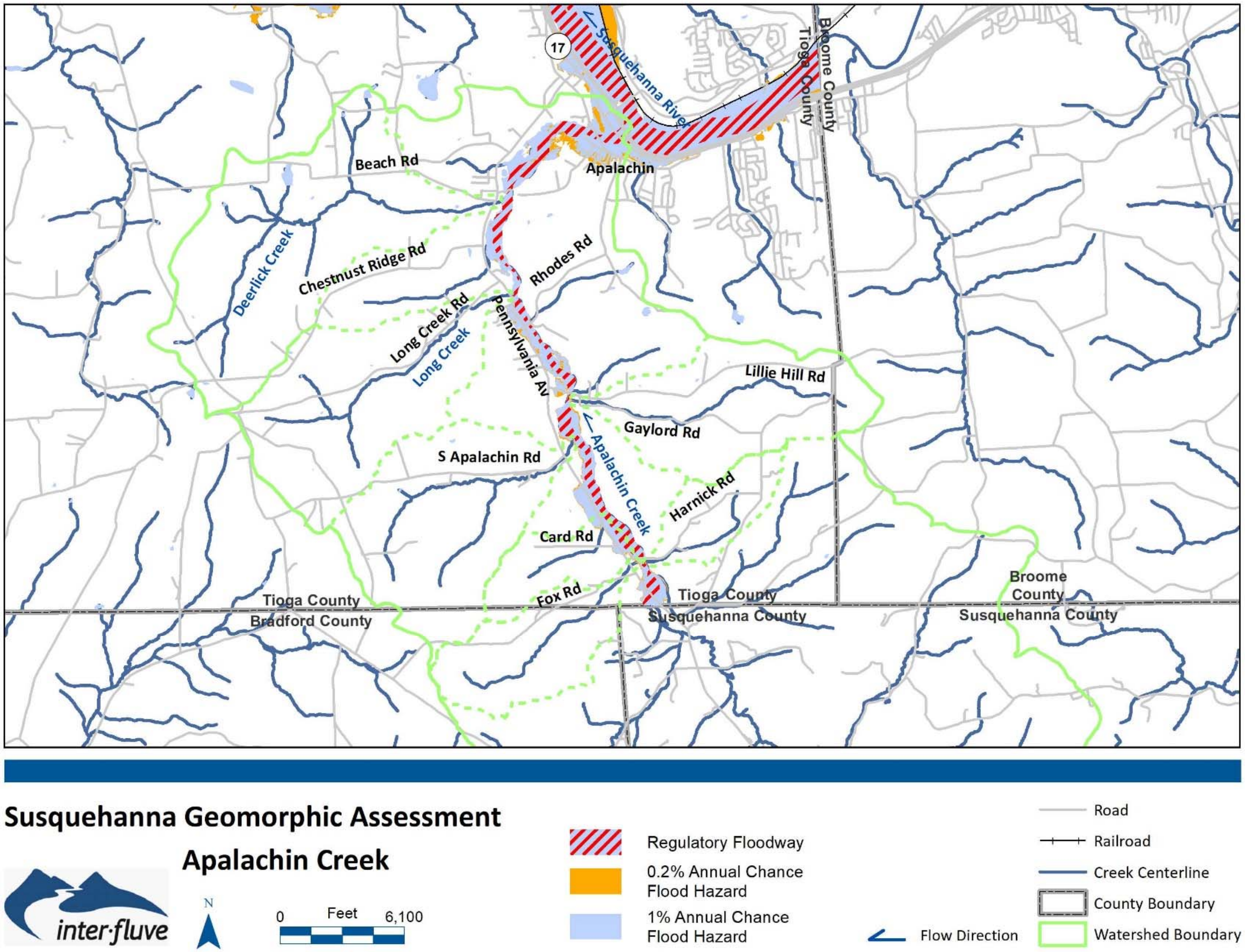

Figure 5. Available FEMA flood mapping for Apalachin Creek and the Susquehanna River at Apalachin

A Total Maximum Daily Load (TMDL) was established for the Chesapeake Bay in December 2010 by the US EPA; the New York portion includes 6,250 square miles of the upper Susquehanna River watershed (NYS DEC 2013). Load reductions for phosphorus, nitrogen, and sediment were determined for the upper Susquehanna River watershed in New York as part of the TMDL and includes targets of 9.28 million pounds per year (mpy), down from 10.72 mpy for nitrogen; 0.67 mpy, down from 0.96 mpy for phosphorus, and 293 to 322 mpy, down from 332 mpy for sediment by 2025 (NYS DEC 2013). As part of the final TMDL determination, New York State developed a Phase I Watershed Implementation Plan (WIP) detailing how and when the state would meet its pollution allocations. A Phase II WIP was completed in 2013 and provides milestones for achieving load reductions by 2025, with controls in place by 2017 that will achieve 60% of the load reductions from 2009 loads. A Phase III WIP will be finalized in 2019. To reduce loading of the three parameters, New York is assessing load reductions among wastewater, stormwater, and agriculture with the greatest effort on agriculture reductions because they represent the greatest controllable load that is generally most cost effective to mitigate (NYS DEC 2013). While loading estimates are for the entire New York portion of the Susquehanna River, several options are highlighted within the Phase II WIP to achieve additional required pollution reductions that align with recommendations to improve flood resiliency in the Apalachin Creek watershed, including improvements in storm water management practices, green infrastructure, road-side ditch maintenance practices that reduce erosion and allow stormwater to infiltrate into the ground in rural areas, and continued stream restoration and stabilization projects to reduce erosion (NYS DEC 2013).

2.7 ECOLOGY

Apalachin Creek and its tributaries in New York State are classified as C, which indicates waters supporting fisheries and non-contact activities. None of the classifications contain the “T” standard which would indicate they support trout. A biological assessment of Apalachin Creek was conducted in 2003 as part of the state’s rotating integrated basin studies (RIBS) biological screening at Route 434 with results indicating slightly impacted conditions (NYS DEC 2009). For projects conducted in Apalachin Creek and its tributaries, permitting and work schedules will not be as stringent because these watercourses are not considered trout streams.

Based on the New York State Department of Environmental Conservation (NYS DEC) Environmental Resource Mapper, there are no state mapped freshwater wetlands identified within the watershed. The National Wetlands Inventory (USFWS) shows several freshwater ponds and numerous forested and emergent wetlands along the mainstem Apalachin Creek and at the mouth of the tributary along Card Road. Potential projects identified will need to consider what, if any, wetland impacts may occur and how to mitigate for those impacts.

Records available from the New York Natural Heritage Program (NHP) indicate occurrences of rare plants and animals. We searched the NHP database via NYS DEC’s Nature Explorer for the Town of Owego and identified the presence of five rare animals and eight rare plants (Table 2). These species may be present throughout the watershed, and potential impacts of projects should be considered and mitigated against in design and construction phases.

Table 2. Recorded rare, threatened, and endangered species in the Town of Owego, New York

Common Name	Scientific Name	Type	Group	Distribution	Year last documented	State Protection Status
Blackchin Shiner	*Notropis hertodon*	Animal	Fish	Recently Confirmed	1992	
Cobra Clubtail	*Gomphus vastus*	Animal	Dragonflies and Damselflies	Recently Confirmed	2009	
Comet Darter	*Anax longipes*	Animal	Dragonflies and Damselflies	Recently Confirmed	2016	
Spatterdock Darner	*Rhionaeschna mutata*	Animal	Dragonflies and Damselflies	Recently Confirmed	1988	
Yellow Lampmussel	*Lampsilis cariosa*	Animal	Mussels and Clams	Recently Confirmed	1997	
Ambiguous Sedge	*Carex amphibola*	Plant	Flowering Plants	Possible but not Confirmed	1920	Endangered
Bent Sedge	*Carex styloflexa*	Plant	Flowering Plants	Historically Confirmed	1898	Endangered
Cat-tail Sedge	*Carex typhina*	Plant	Flowering Plants	Historically Confirmed	1905	Endangered
Jacob's Ladder	*Polemonium vanbruntiae*	Plant	Flowering Plants	Possible but not Confirmed		Rare
Porter's Reed Grass	*Calamagrostis porteri ssp. porteri*	Plant	Flowering Plants	Historically Confirmed	1920	Endangered
Southern Wood Violet	*Viola hirsutula*	Plant	Flowering Plants	Historically Confirmed	1900	Endangered
Sweet-scented Indian Plantain	*Senecio suaveolens*	Plant	Flowering Plants	Historically Confirmed	1898	Endangered
Violet Wood Sorrel	*Oxalis violacea*	Plant	Flowering Plants	Historically Confirmed	1920	Threatened

Note: Comprehensive field studies have not been conducted in most areas and this list and would need to be confirmed with on-site surveys.

In addition to understanding unique habitats and rare or protected species, our review of existing data included the presence of invasive species. One in particular, the hemlock wooly adelgid (HWA), has the potential to change the forested landscape in the headwaters of the several Apalachin Creek tributaries. The HWA attacks hemlock trees, feeding on the stored starches in the tree, which severely damages the canopy of the tree by interrupting the flow of nutrients to the twigs and needles. Tree health declines over time and mortality usually occurs within 4 to 10 years (NYS DEC 2016). HWA has been identified in Tioga County, and there are efforts underway to slow the spread to additional locations. Hemlock trees are a critical component of local forests, and loss of this species would temporarily expose riparian areas to the potential for stream warming and increased erosion resulting from a lack of root structure to stabilize hillslopes and stream banks and would completely alter the forest species composition over the long term.

Another invasive is the emerald ash borer, an invasive wood boring insect, that attacks ash trees, eventually killing them. There has been one report of emerald ash borer within the Apalachin watershed according to mapping available through NHP's iMapInvasives website. All of New York's ash trees are vulnerable, which could remove an important forest tree, as well as street trees in many communities. The major mode of transport is by movement of the plant itself because the organism is not a strong flier. New York therefore has a regulation in place to restrict the movement of firewood.

Japanese knotweed is an invasive plant introduced into the United States in the late 1800s. It is currently not found in dense patches in Tioga County, although there are dense patches in counties to the east. Japanese knotweed will form dense monocultures in disturbed areas, often along streambanks, spreading rapidly and threatening native communities and wildlife. Establishment can be controlled by planting native vegetation in disturbed areas prior to invasion.

2.8 EXISTING PLANS AND POLICIES

In recognition of the need for building resilience to the impacts of climate change including flooding, Governor Cuomo signed into law the Community Risk and Resiliency Act (CRRA) in 2014. The Act will result in guidance for considering and managing future risk, developing natural resilience, and adapting local laws. Guidance on natural resiliency measures was expected to be available for public review in 2019 but was not yet available at the time of finalizing this report.

In response to the Disaster Mitigation Act of 2000, the Tioga County government and local municipalities maintain a Hazard Mitigation Plan (HMP) that is "designed to improve planning for, response to, and recovery from, disasters" and facilitates disaster relief funding (Tetra Tech 2012). This plan covers potential hazards likely to arise within Tioga County, and a major focus of the plan is flooding because it is one of the most costly disaster types that have historically and cumulatively affected the county. The HMP lists 43 significant flood events in the period from 1950 to 2011, including 28 flash floods and 15 major floods. Each municipality and some school districts have their own chapter within the plan outlining specific hazard mitigation actions. A five-year regulatory update of the plan was completed in 2018 and is currently available in draft form (Tetra Tech 2018).

The Town of Owego chapter of the HMP identifies flooding in August 2018 that led to closing the lower Long Creek Road bridge due to flash flooding and the town has identified six structures along Pennsylvania Avenue that are susceptible to flooding (Tetra Tech 2018).

The Town of Owego has several existing regulatory tools to locally enforce hazard mitigation including building codes, zoning ordinances, and a stormwater management program (SWMP) plan and ordinance [refer to Section 9.10 of Tetra Tech (2018)]. The County's stormwater management plan was updated for 2015-2020 and includes the six minimum control measures required based on the Federal Stormwater Phase II Rule (1999) and was developed to comply with the NYS DEC general permit for stormwater discharges from Municipal Separate Storm Sewer Systems (MS4s) (Broome-Tioga Stormwater Coalition 2015). The plan is focused on reduction of contaminants in stormwater and lacks a component focused on reductions in stormwater to increase resiliency. With regard to zoning, the Town of Owego Zoning Ordinance includes an article (XVI) to address flood damage protection by requiring a permit to develop in areas of special flood hazard defined as the 100-year floodplain as shown on the existing Flood Insurance Rate Map.

2.9 EXISTING MAINTENANCE AND EMERGENCY WORK

Tioga County SWCD assists landowners with permits for emergency channel work on an ongoing basis under a regional permit issued by the US Army Corps of Engineers. Permits are generally sought and issued following large flow events and for work such as streambank stabilization, culvert replacement, and dredging. Records from Tioga County SWCD show that 35 emergency permits have been issued within the Apalachin Creek watershed since 2007 with some sites subject to multiple permits in that timeframe.

Highway personnel and other local contractors in Tioga County have attended training on Emergency Stream Intervention protocols developed by Delaware County Soil and Water Conservation District and Delaware County Planning Department and expanded for statewide application by NYS DEC. This three-day training provides participants information on streams and watersheds and details on developing a protocol to prioritize damaged reaches and suggested repairs to maintain the natural structure and function of the stream.

3. Field Assessment

A team of three Inter-Fluve geomorphologists and one Integrated Aquatic Sciences aquatic ecologist assessed the watershed on October 17 through 20, 2018. For parts of both days, Mike Jura of the TCSWCD joined the team in the field. During the assessment, the team visited targeted reaches of the mainstem Apalachin Creek (6.7 miles total) and walked the following lengths of the tributaries included in the study:

- Fox Road tributary – 0.7 miles;
- Harnick Road tributary – 1.4 miles;
- Card Road tributary – 0.7 miles;
- Spot checks along the South Apalachin Road tributary;
- Gaylord Road tributary – 2.6 miles;
- Long Creek – 2.7 miles; and
- Deerlick Creek – 4.5 miles.

We collected photos, observations, and measurements in Survey123 by ESRI, a customizable data collection app that stores field data in a geotagged and tabulated form. A blank copy of our field data collection form is provided in Appendix A.

The complete dataset has been provided to the county in GIS format. The following sections provide a summary of the observations documented in the field. River stations are provided as distances in feet from the confluence with the Susquehanna River for Apalachin Creek, and distance from the confluence with Apalachin Creek for tributaries.

Fuss and O'Neill assessed 16 culverts in the watershed. The results of the culvert assessment are provided in Appendix B.

3.1 APALACHIN CREEK

The 6.7-mile-long reach of Apalachin Creek surveyed in this assessment, the portion of the creek flowing through New York, occupies a low-gradient (approximately 0.005 ft/ft) valley bottom with a meander belt ranging in width from approximately 600 feet to 2,500 feet near its confluence with the Susquehanna River. The creek naturally carries a substantial coarse sediment load, and large, unvegetated point bars are common. Large deposits at the mouths of many of the creek's tributaries suggest that tributaries are a primary source of coarse sediment (i.e., gravel and cobbles). Deposition of the abundant load within the channel and on bars forces changes in flow direction and dynamics, resulting in a tendency toward lateral migration, formation of multiple channels, and avulsion. The historic footprint of these dynamic geomorphic processes is what defines the creek's meander belt. Hazards arise where infrastructure has been built within the meander belt and is threatened by both flooding and the naturally active channel movement characteristic of this environment.

Numerous projects have been completed to protect infrastructure and property by installing bank erosion countermeasures or realigning the creek (USC 2018a). Some of the primary affected assets are roads, particularly Pennsylvania Avenue, residences and agricultural lands, and sewer lines.

Figure 6 shows a longitudinal profile along Apalachin Creek within New York and the locations of the confluences of the tributaries assessed as a part of this study.

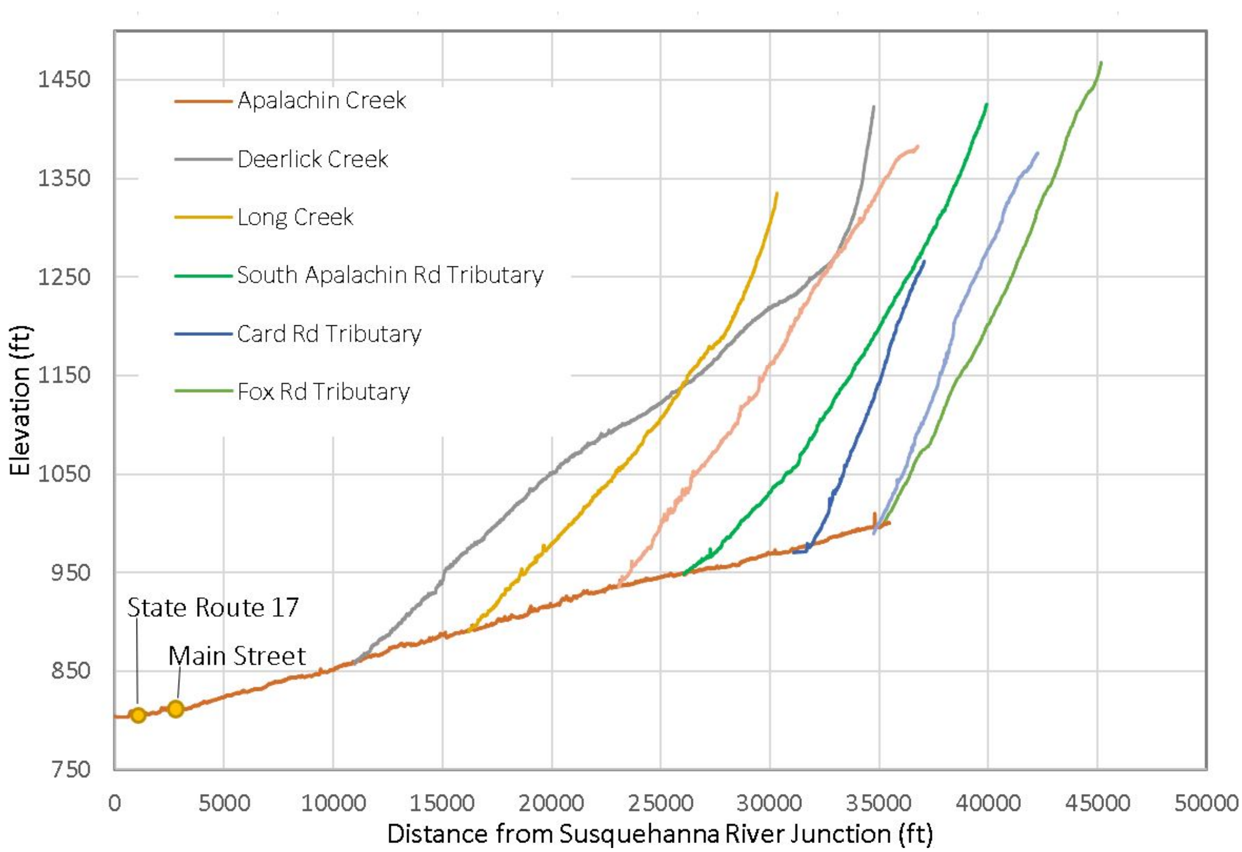

Figure 6. Longitudinal profile along Apalachin Creek and its tributaries in New York based on 2007 LiDAR data provided by Tioga County

3.2 TRIBUTARY WATERSHEDS

In general, tributary watersheds can be divided into five main reaches defined geomorphology (i.e., channel slope, stability, large wood presence, channel planform): An upper reach, mid-upper reach, middle reach, mid-lower reach, and lower reach. Due to local variations in land cover, topology, geology, and hydrology, not all reaches are present in each tributary nor do all similarly classed reaches in all tributaries exhibit the exact same characteristics. The terms upper, mid-upper, middle, mid-lower, and lower reaches simply provide a conceptual framework for discussing the unique aspects of each tributary. The five main reach types identified are described below; detailed descriptions of each tributary are included after.

The upper reach is a steep headwater reach typically characterized by a steep, narrow bedrock or colluvium lined channel. Where unconsolidated deposits are present, or a road crossing is improperly sized/aligned, the upper reach can be an area of excessive erosion as evidenced by perched culverts. This reach is typically a cascade or step-pool channel, closely connected to forested hillsides.

The mid-upper reach is typically characterized by a channel morphology that consists of irregularly spaced bedforms ranging from steps and pools to riffles and runs depending on the size of the bed material present and the presence or absence of large wood. Bank exposures are typically unconsolidated deposits. Large wood and channel-spanning log jams are present in locations where land cover is primarily forest and streams are not actively managed to reduce wood inputs. In these cases, the large woody debris jams are effective in reducing local gradients in the channels immediately upstream and forcing flows out of bank onto the forest floor thereby helping to attenuate flood flows. Generally, jams appear to have been initiated by a fallen tree that is large enough to span the channel and be anchored in place by its root wad or otherwise wedged into the channel. Once wedged across the channel, the tree traps sediment and smaller woody debris. This recruitment of additional material bolsters jams into relatively stable features that are self-sustaining; if the original wood piece degrades, often the material that had subsequently been added to the jam will maintain the structure. Mature trees are most effective at forming jams and, prior to falling, their extensive root structures help to stabilize the bank slope. The latter occurs through added cohesion (i.e., resistance to failure) and shielding soil from fluvial forces.

The middle reach is characterized by deep channels that are below the adjacent forest floor. Perched culverts, head cuts, formerly flood-prone areas stranded above current bankfull levels, and gullying along small drainage channels and the main channel indicate that these reaches are often areas of active downcutting. The result is that flood flows are generally focused in relatively deep channels without access to potential overbank areas or exposure to the roughness that would be afforded by the forest floor. Furthermore, in-channel roughness is limited to coarse gravel and cobbles and some intermittent bars, with features such as large wood and dense, woody root networks that provide substantial habitat opportunity largely absent from the tributaries assessed for this study. Vegetative cover on the steep bank slopes is generally poor and the bank material is vulnerable to fluvial erosion as well as mass failure. Active downcutting and lateral erosion of the steep banks produces substantial volumes of sediment that are transported downstream.

The mid-lower reach is typically characterized by organization of cobbles and gravels into more consistent and regularly occurring bedforms with a sinuous thalweg. Sediment deposition is evident on wide, unvegetated lateral bars that are visible on aerial imagery. Bar deposition forces flow towards the banks, causing erosion and bank retreat that threatens infrastructure built on or near the bank tops. Bank erosion also contributes coarse sediment load to the tributaries. The mid-lower reach generally widens to the point where individual pieces of large wood may no longer form channel-spanning log jams and instead require the build-up of more complex structures composed of numerous logs. Where present, however, some large individual pieces are capable of retaining coarse sediment and producing flow and habitat complexity. The actual occurrence of large wood in this reach is rare within the Apalachin Creek tributaries as a result of the land-use and management histories and current practices. Instead, local grade control is provided by intermittent bedrock outcrops on the bed, which are likely to have been exposed by incision of the bed and generally become more frequent near the downstream end of the reach.

The lower reach includes the lower part of the tributary valley and the channel across the alluvial fan formed at the mouth. This reach generally has the lowest gradient and thus a diminished sediment transport capacity, making it a natural zone of deposition. Bed material grain size diminishes through this reach, and deposition reduces the capacities of the channel and road crossings. Under natural conditions, the channel would likely shift position periodically in response to deposition events, but the current channel location has been fixed by channelization, road crossings, and other stabilization measures. Although an attempt is made to maintain channel capacity through localized periodic dredging, it is common that the bed level in the channel at crossings sits above the groundwater level of the surrounding floodplain, causing the channel to run dry during periods of low flow.

Brief summaries of unique observations from each tributary are provided in the following sections.

3.2.1 Unnamed tributary along Fox Road

The portion of the unnamed tributary along Fox Road that is within New York was investigated. This stretch of the creek is 0.7 mile long with an average slope of 0.04 ft/ft (Figure 7). The mid-lower reach extends from the New York-Pennsylvania border downstream to station 2,000 feet (as measured upstream from the confluence). The valley is predominantly forested with the valley bottom occupied by the channel and surrounding floodplain or low-lying forested area; no roads have been constructed along the valley bottom. The channel is characterized by abundant large wood that traps substantial volumes of coarse sediment and other woody debris, provides local grade control, and results in flow and habitat complexity including large, shaded plunge pools. We saw evidence that the jams may be associated with avulsions where floodwaters have cut alternative channels that bypass the large woody debris obstructions (Figure 8).

The undeveloped nature of the valley bottom and the presence of large wood in the channel correspond with healthier stream functioning than observed on other tributaries. The presence of wood correlates with improved connection between flows overtopping the channel and adjacent forest floors with high flows often able to access forested overbank areas. The absence of infrastructure allows for natural sediment deposition and erosion processes, sediment storage, and lateral instability. This condition is unlike conditions observed in other mid-lower reaches in the Apalachin Creek watershed and most closely resembles what a mid-lower reach might look like under natural conditions.

The lower reach of the Fox Road tributary has been straightened and channelized with agriculture, residences, and infrastructure encroaching on both banks (Figure 9). Rip rap has been locally placed to prevent lateral movement of the stream and protect infrastructure. In addition, field observations during the culvert inspection (see Appendix C) suggest culvert placement and elevation affects the overall longitudinal slope of the creek.

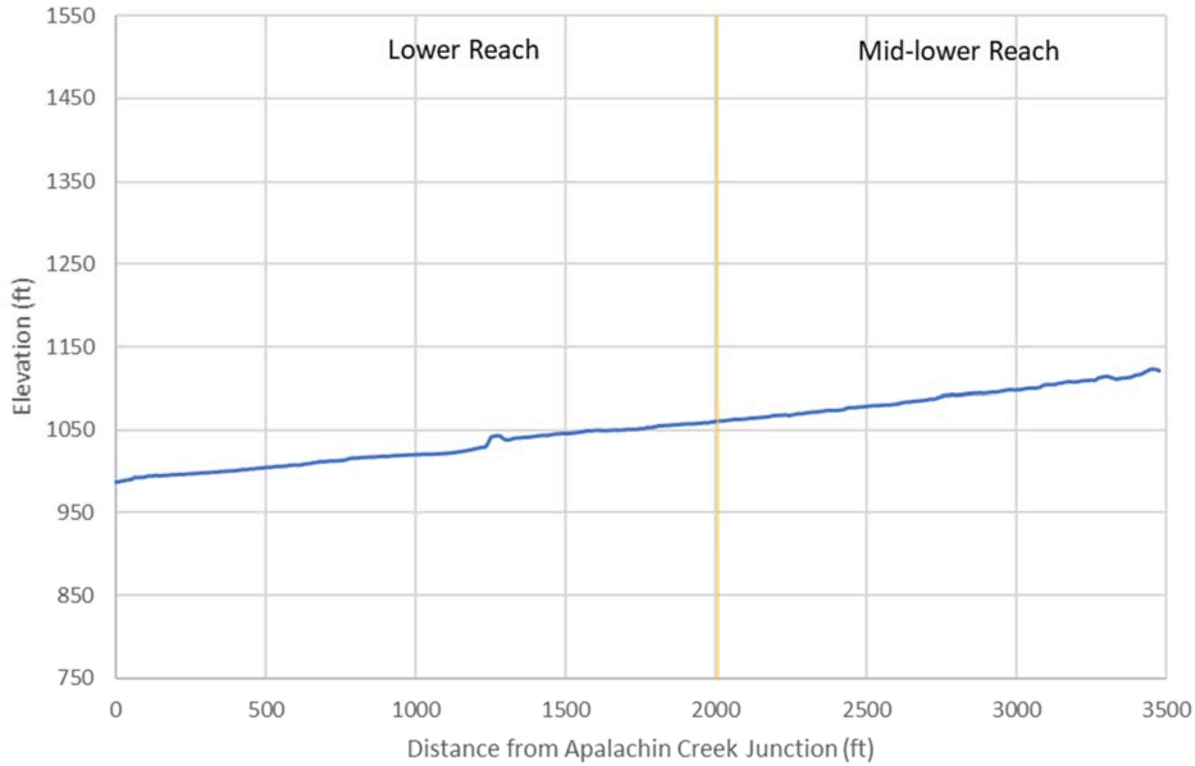

Figure 7. Longitudinal profile of the unnamed tributary along Fox Road in New York based on 2007 LiDAR data provided by Tioga County

Figure 8. Example of large wood in the unnamed tributary along Fox Road. Note how flow has bypassed the large woody debris jam by cutting a new channel on the right side of the picture. The flat bench along the forest floor visible in the background is the former top of bank corresponding to when the debris jam functioned as local grade control and defined the channel thalweg elevation. Note that although bypassed, the wood has remained in place, continuing to retain a substantial volume of coarse sediment. Photo taken October 19, 2018.

Figure 9. Lower reach of the unnamed tributary along Fox Road showing rip rap placed on the channel banks to protect infrastructure and private property. Photo taken October 19, 2018.

3.2.2 Unnamed tributary along Harnick Road

The unnamed tributary along Harnick Road is 1.4 miles long with an average slope of 0.05 ft/ft (Figure 10). The profile shows no steep, upper reach in this particular watershed, and that is corroborated by field observations. The headwaters upstream of Harnick Road instead consist of various field and road drainage channels that converge near the beginning of a recognizable channel at Harnick Road. The mid-upper reach extends to station 6,000 feet and flows through a narrow, forested corridor adjacent to pastured or mowed fields. The middle reach of the tributary runs through a steep forested valley with minimal floodplain. The lower reach downstream of station 1,200 feet is entrenched below the former floodplain with poor connectivity. Houses built near the channel are being threatened by bank erosion (Figure 11).

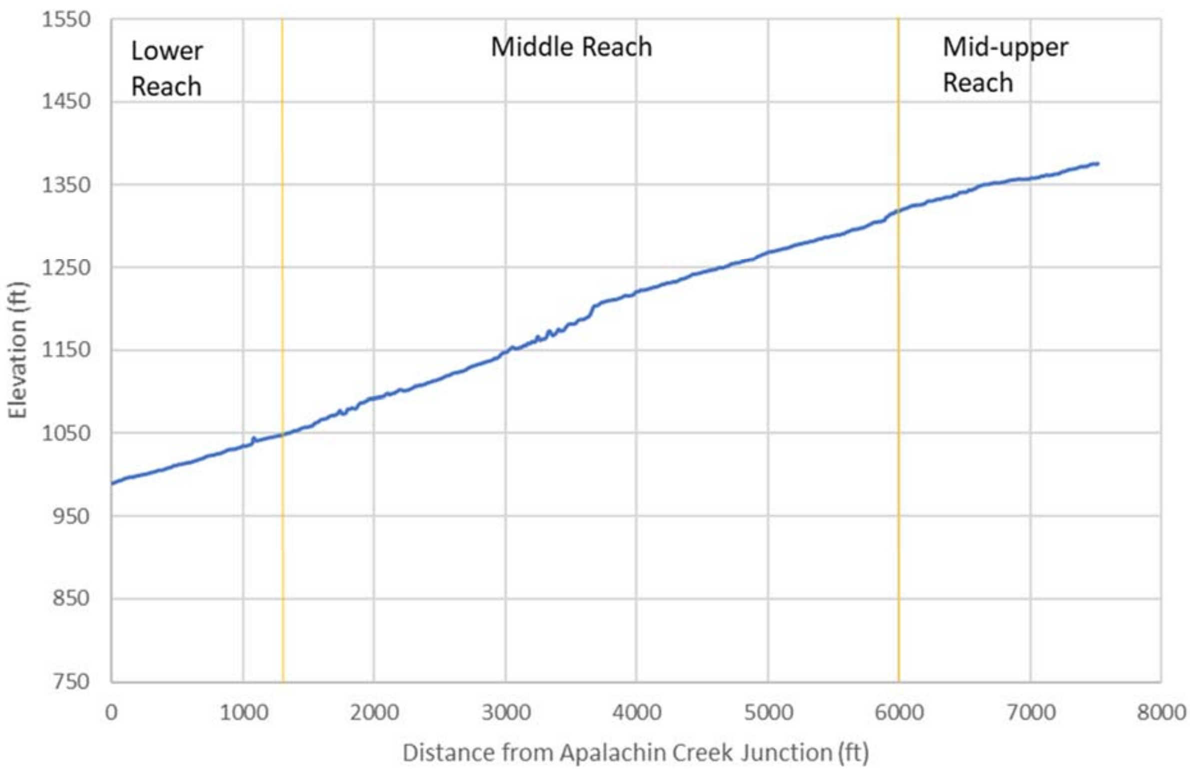

Figure 10. Longitudinal profile of the unnamed tributary along Harnick Road based on 2007 LiDAR data provided by Tioga County

Figure 11. House built near the bank of the unnamed tributary along Harnick Road. Photo taken October 19, 2018.

3.2.3 Unnamed tributary along Card Road

The unnamed tributary along Card Road is 1.1 miles long with an average slope of 0.05 ft/ft (Figure 12). Based on elevation data and aerial imagery, the creek upstream of station 6,000 feet divides into numerous tributaries which drain forested hillslopes. No single channel representing a steep upper reach is present. The mid-lower reach extends from the start of the definable creek to station 2,500 feet. The mid-lower reach riparian zone is beech-hemlock forest that is narrow to absent on river left as a result of encroachment by agricultural and residential land uses. In October 2018, a fence was present across the creek at approximately station 3,500 feet, limiting our assessment to downstream of that point. The creek in this reach is generally confined to a narrow valley with some local overbank areas where the valley widens (Figure 13). The channel is scoured down to bedrock in numerous locations. A number of issues were observed in the mid-lower reach including heavy river corridor use by livestock, forest harvesting with no erosion control or stream channel BMPs in place, and evidence of sewage contamination.

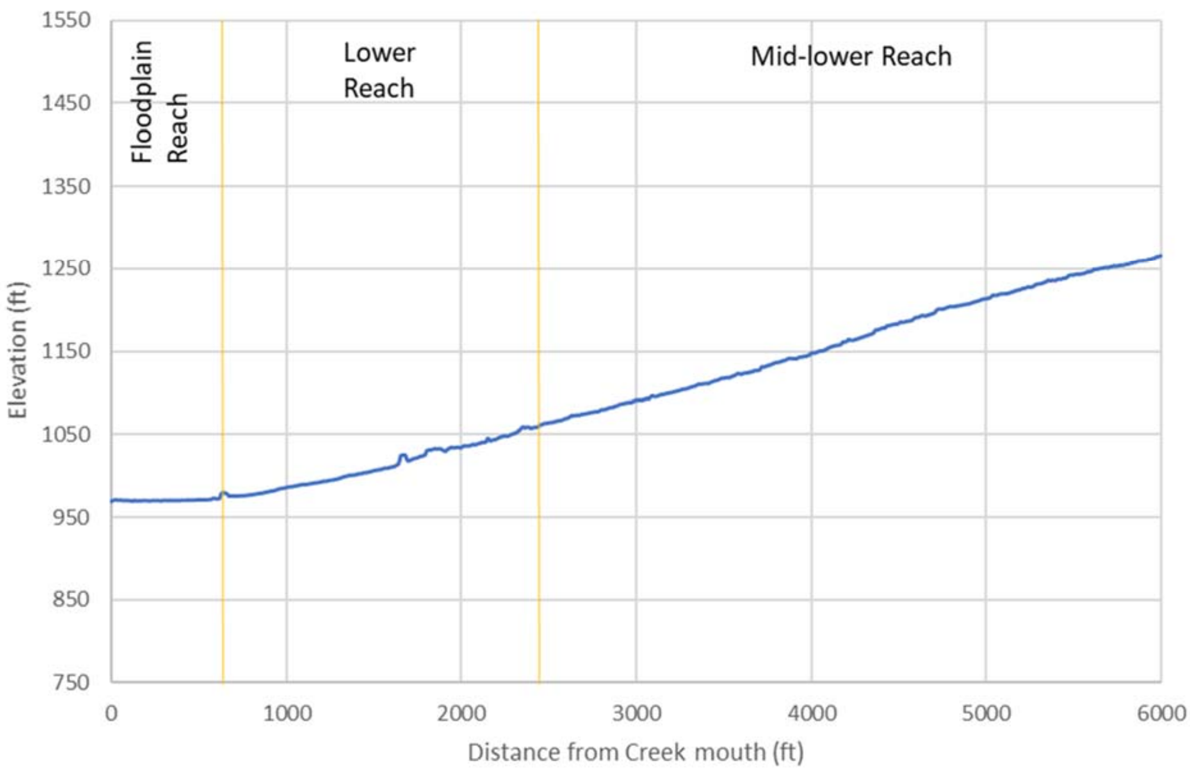

Figure 12. Longitudinal profile of the unnamed tributary along Card Road based on 2007 LiDAR data provided by Tioga County

Figure 13. Example of mid-lower reach of unnamed tributary along Card Road. Photo taken October 19, 2018.

The lower reach of the Card Road tributary extends to Pennsylvania Avenue and includes the Card Road crossing and a private crossing immediately upstream. An additional floodplain reach was identified downstream of Pennsylvania Avenue where the channel has a relatively flat slope as it flows across the Apalachin Creek floodplain.

3.2.4 Unnamed tributary along Gaylord Rd

The unnamed tributary along Gaylord Road is 2.6 miles long with an average slope 0.03 ft/ft (Figure 14). The upper reach type channel was not observed along this stream, but based on elevation data and aerial photographs likely exists in numerous small drainages which feed into the better defined mid-upper reach of the main tributary. The mid-upper reach can be divided into two subreaches based on land use. From the headwaters to station 11,500 feet, the creek meanders through wetlands at the base of pastured or mowed hillslopes (Figure 15) interspaced with numerous ford crossings. From station 11,500 feet to station 8,500 feet, the creek runs through hillsides of beech-hemlock forests. Abundant channel-spanning large wood provides local grade control and sediment retention.

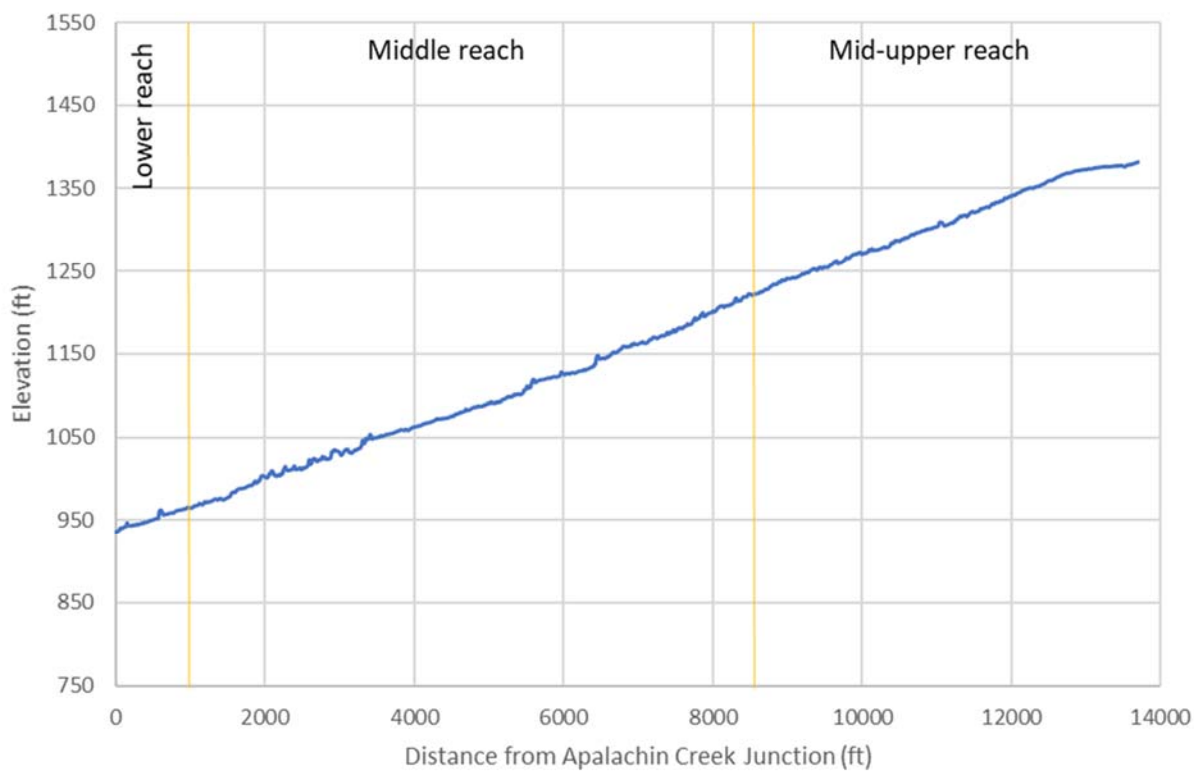

Figure 14. Longitudinal profile along unnamed tributary along Gaylord Road based on 2007 LiDAR data provided by Tioga County

Figure 15. Wetland at base of mowed hillslope. Creek is near back of photo. Photo taken October 19, 2018.

The middle reach of the Gaylord Road tributary is characterized by a confined channel with limited overbank areas; Gaylord Road runs along the top of the bank. Bank erosion threatens the road in numerous places, many of which have been stabilized using large rock revetment (Figure 16). The lower reach of the tributary extends from station 1,000 feet to the creek mouth. The channel has been straightened and dredged, and the culvert beneath Gaylord Road at station 600 feet is perched with bank erosion occurring along the downstream banks. The structural condition of the crossing is considered critical (see Appendix C).

All three Gaylord Road culverts, including the culvert at station 600 feet, were noted in the County's Hazard Mitigation Plan (Tetra Tech 2012) as being undersized with replacement considered high priority. The 2018 update (Tetra Tech 2018) states that culverts were made 50% larger at a cost of $22,000.

Figure 16. Stacked stone revetment used to protect Gaylord Road from being eroded by the creek. Photo taken October 19, 2018.

3.2.5 Long Creek

Long Creek is 2.7 miles long with an average slope of 0.03 ft/ft (Figure 17). The upper reach descends from the top of the creek to station 13,000 feet. The reach is characterized by a step-pool channel with numerous bedrock outcrops interspaced with colluvial deposits. The mid-upper reach continues to station 10,500 feet. In the mid-upper reach, the creek runs through a beech-hemlock forested valley and flood flows appear to readily access overbank areas. The middle reach descends to station 9,000 feet. The middle reach is deeply incised into till deposits with the channel bed up to 20 feet below the former valley floor on river left (Figure 18). Large wood preserved near the top of the bank differentiates alluvial deposits from glacially derived till and clay till below. A constructed pond sits on the abandoned valley surface, and the clay till below appears to provide a natural liner that allows the pond to continue to hold water. We discovered a seep through an alluvial lens in the till and associated slumping of bank material, suggesting that the pond may not be indefinitely stable in its current state (Figure 19). The right bank is an approximately 75-foot-high till bluff. The substantial volume of sediment that has been eroded from this reach appears to be deposited on large unvegetated bars that exist throughout the mid-lower reach (Figure 20). In a number of locations, the bars are forcing flow toward the outer bank, causing bank erosion that poses a risk to Long Creek Road and local residences.

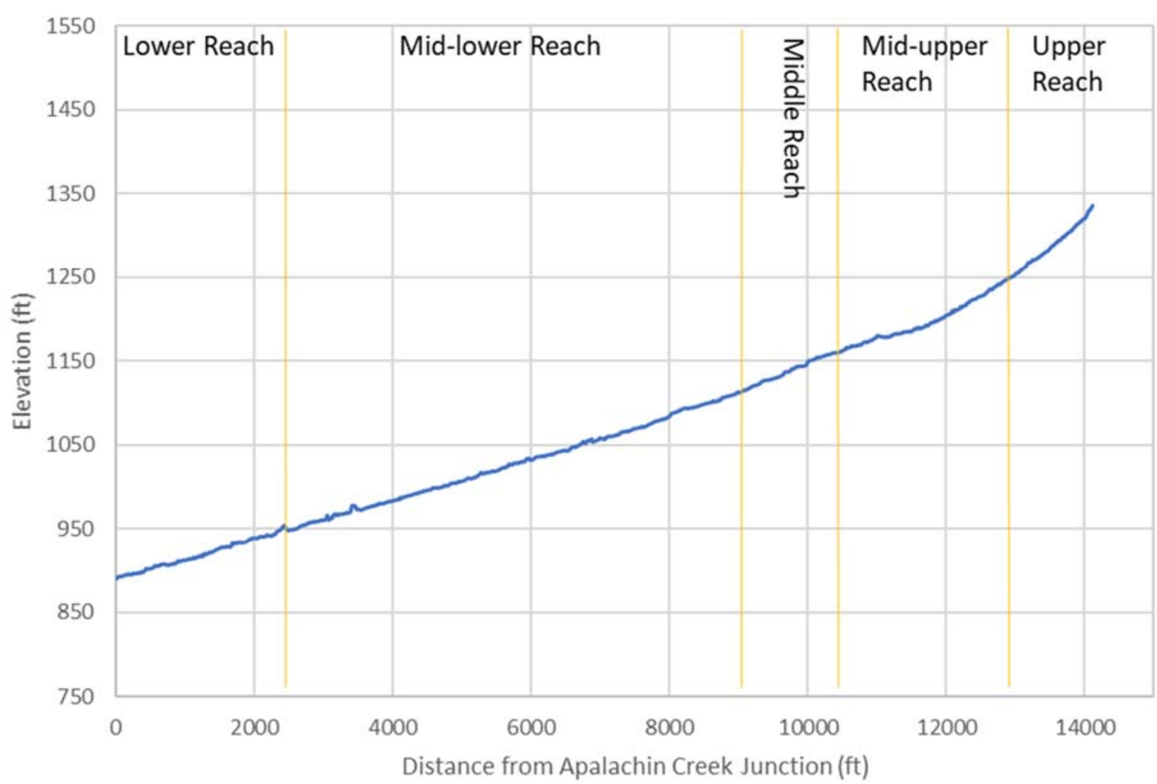

Figure 17. Longitudinal profile along Long Creek based on 2007 LiDAR data provided by Tioga County

Figure 18. Incised Long Creek channel. Note large wood preserved in alluvium forming the top of the left bank. Bank material below that is till. Photo taken October 19, 2018.

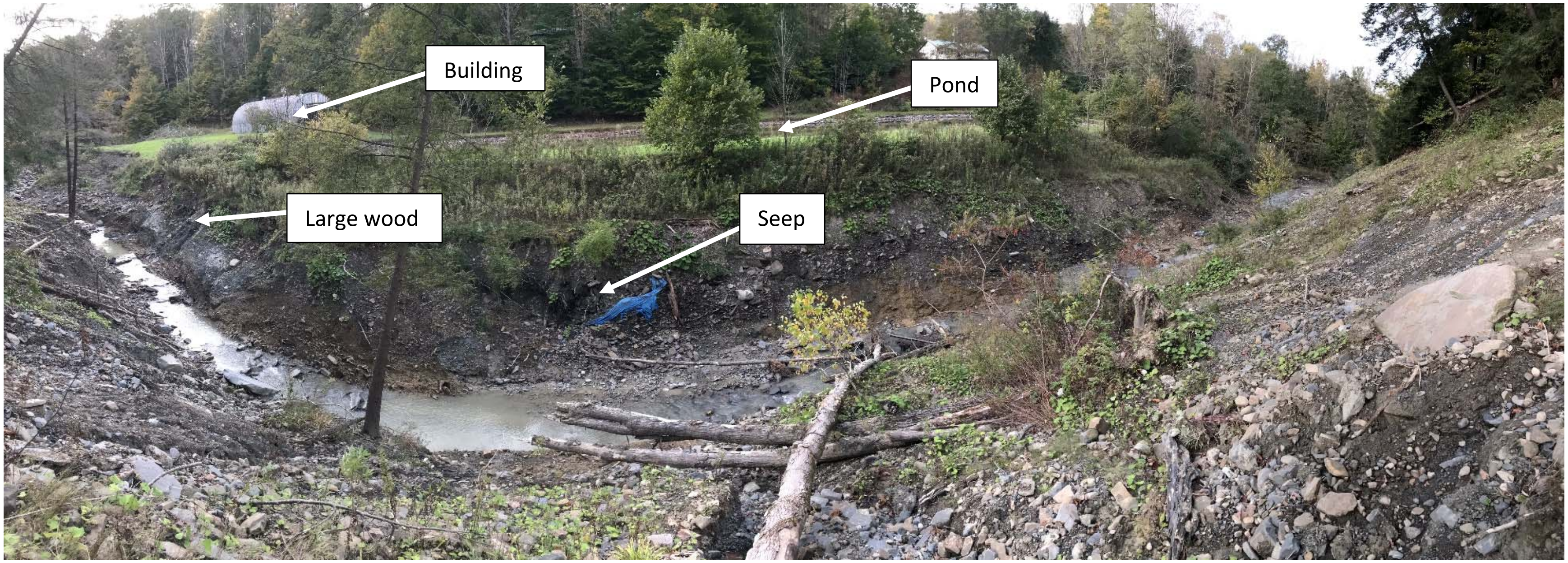

Figure 19. Panoramic view of incised channel and left bank with pond. Location of seep is noted. Blue article in photograph is a geotextile trapped within slumped bank material below the seep. Photo taken October 19, 2018.

Figure 20. Bar deposited a short distance downstream of incised channel at pond. Exposed roots and undercut tops of the opposite bank suggest that bank erosion occurred during recent high flows. Photo taken October 18, 2018.

The lower reach of Long Creek is relatively well forested compared with that of other tributaries but similarly shows signs of straightening and dredging activity. The downstream Long Creek Road bridge was damaged during high flows in 2018 (Tetra Tech 2018); the bridge was closed and a detour was in place at the time of our field survey.

3.2.6 Deerlick Creek

Deerlick Creek is 4.5 miles long with an average slope 0.02 ft/ft (Figure 21). The upper reach flows from the start of the creek to station 22,000 feet. The reach is eroding through colluvial deposits downstream of a perched culvert at Chestnut Ridge Road. The mid-upper reach continues to station 11,000 feet. In the mid-upper reach, channel-spanning log jams provide local grade control and sediment retention (Figure 22), and flood flows within the creek readily access overbank areas. The middle reach continues to station 9,000 feet. In this reach the creek becomes more confined and active incision is evident. The creek is straight, and flood flows appear to have negligible access to former overbank areas, which are currently 10 to 15 feet above the current channel bed. Large wood is absent from the channel. Sediment eroded from the middle reach has been deposited throughout the mid-lower reach on bars, and bar growth has exacerbated bank erosion in some locations. Bedrock outcrops provide grade control and are most frequently exposed near the downstream limit of this reach (Figure 23). In the lower reach the channel has been straightened, dredged, and has minimal access to its former floodplain. Infrastructure is present on either side of the channel near Pennsylvania Avenue.

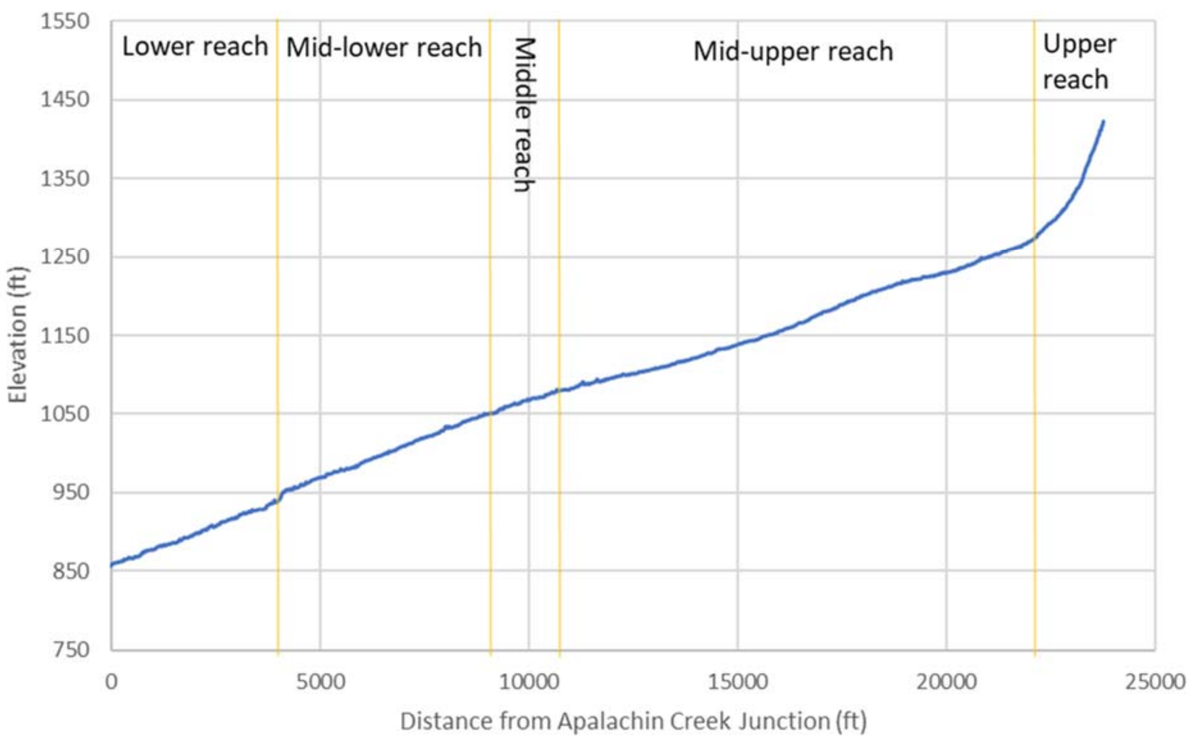

Figure 21. Longitudinal profile along Deerlick Creek based on 2007 LiDAR data provided by Tioga County

Figure 22. Example of a small channel-spanning log jam providing grade control and retaining sediment in Deerlick Creek. Photo taken October 18, 2018.

Figure 23. Bedrock outcrop looking downstream from the downstream boundary of the mid-lower reach of Deerlick Creek. Photo taken October 18, 2018.

4. Discussion

Our review of existing information combined with our field observations strongly suggest that under purely natural conditions the steep, forested tributaries of the Apalachin Creek watershed would be sites of long-term incision but that naturally occurring large woody debris jams would help to control grade, moderate the sediment producing effects of large flood events, and regulate rates of bed level lowering. Watershed changes including deforestation, road construction, field and road drainage, and active management of channels by dredging and removing large wood have combined with increasing hydrology to result in more rapid runoff and rates of bed level lowering than would be anticipated under natural conditions.

The Apalachin Creek tributaries are characterized by steep channels that occupy narrow valleys incised into readily erodible glacial deposits and bedrock. Bed material ranges from sand to boulders, and all sizes up to the largest clasts appear to be mobilized during large flow events. This is unusual in that in other systems, large boulders (particularly glacial lag) might be more stable and only sporadically mobilized, helping to maintain bed levels. However, the geology of the Apalachin Creek watershed consists of sedimentary rocks that break apart along shallow bedding planes resulting in flat clasts that are subject to relatively high lift forces and thus frequent mobilization. In rare instances where the banks are forested and the channel has been left to evolve naturally, large wood that falls into the channel creates jams, or natural dams, that trap sediment and control upstream bed levels. The best examples of this in the Apalachin Creek watershed assessment area are along the Fox Road tributary and the upper reaches of Deerlick Creek. Observed differences in bed levels upstream and downstream of jams were between one and three feet. The larger the wood (i.e., the more mature the forest), the more effective it is at forming a jam. Where large wood is absent, channels appear more disconnected; i.e., flood flows do not routinely access or flow across potential overbank areas. This disconnected characteristic leads to head cuts progressing upstream to artificial grade controls such as culverts, resulting in substantial perching, undermining, and grade differences upstream and downstream of the structures. Continued erosion has resulted in conversion of some reaches from alluvial to bedrock channels.

The recently published National Large Wood Manual (USBR and ERDC 2016) provides a wealth of information on the role of large wood in stream geomorphology and ecology. Section 4.2.5 in particular focuses on the role of large wood in dissipating flow energy, capturing sediment, and limiting down-cutting or incision of small headwater streams. As referenced in the manual, a conceptual model by Schumm et al. (1984) is useful for understanding the various stages of channel evolution associated with incision (Figure 24). Type I channels are in a state of dynamic equilibrium where sediment transport is balanced by sediment supply and the channel bankfull capacity approximates a 50% annual chance flood with high magnitude flows spreading out across overbank areas. Stream bed incision or lowering leads to an increase in channel capacity and shear stresses on the bed surface (Type II), which exacerbate incision rates until banks become unstable and the channel widens (Type III) or natural or artificial downstream grade controls prevent further down-cutting. Type III channels may exhibit lateral movement or multi-threaded conditions as the channel adjusts to the increased supply of sediment from the banks. The transition to Type IV is marked by sediment deposition within the widened channel; return to a single-threaded channel with more stable bars, riffles, and pools; and formation of new overbank areas at a lower elevation. Type V is similar to Type 1 but with the bankfull channel established at a lower elevation.

Field observations suggests that the Apalachin Creek tributaries are currently in stages exemplified by channel types II and III. For sites in these early stages of the evolution process, it may be possible to reverse or arrest the effects of incision and re-establish a Type I channel (USBR and ERDC 2016). Where channel widening has already begun, restoration design should take the risk of widening into account.

The lowermost reaches of Apalachin Creek tributaries are lower gradient and flow over alluvial fans formed by the delivery of sediment eroded from the upper reaches of the watershed and deposited on the valley floor occupied by Apalachin Creek. Under natural conditions, an alluvial fan channel would meander laterally or bifurcate across the fan, continually distributing and depositing its sediment load in a natural fan shape. Fan channels in the Apalachin Creek watershed have been artificially straightened and lateral movement restricted by bridges and other development, bank erosion countermeasures, and ongoing dredging practices. Dredging, although temporarily increasing local channel capacity, can initiate headcutting that migrates upstream and causes further erosion of material that is then washed downstream. The creeks' sediment-laden flood flow access to overbank areas for flood conveyance and sediment deposition has been reduced by berms constructed of dredge spoils. Without access to the alluvial fan surface, the substantial load of coarse sediment carried by the creek is deposited within the channel bed rather than on the fan surface itself. This process raises the bed level and reduces channel capacity, exacerbating flood impacts and leading to more dredging. Thus, both stream management approaches and tributary conditions including rapid runoff and high rates of sediment production contribute to flooding and flood-related impacts along the lower reaches of the tributaries and the Apalachin Creek mainstem.

A primary source of impacts along Apalachin Creek itself is development within the creek's meander belt, or zone of active lateral migration. This low-lying area of the valley is subject to inundation during floods and relatively high rates of bank erosion and bar deposition, both of which conflict with the presence of infrastructure and residential and agricultural land uses. Rates of bank erosion along Apalachin Creek are likely exacerbated by the substantial contribution of coarse sediment from tributaries which gets deposited as bars that act to push flow out toward the opposite bank. Field observations suggest that the scale of sediment delivery from tributaries dwarfs sediment production through bank erosion along the mainstem itself, in part because as described above, bank erosion is partly balanced by deposition on bars at the insides of meander bends. Sediment production via bank erosion along the mainstem may be further reduced by human intervention in the form of bank protection and hardened infrastructure. Both disrupt natural sediment transport processes, however, and are usually associated with detrimental effects such as accelerated bed scour or bank scour at the edges. Within the tributaries, downcutting of the channel bed and related bank instability are likely the greatest contributors to sediment yields.

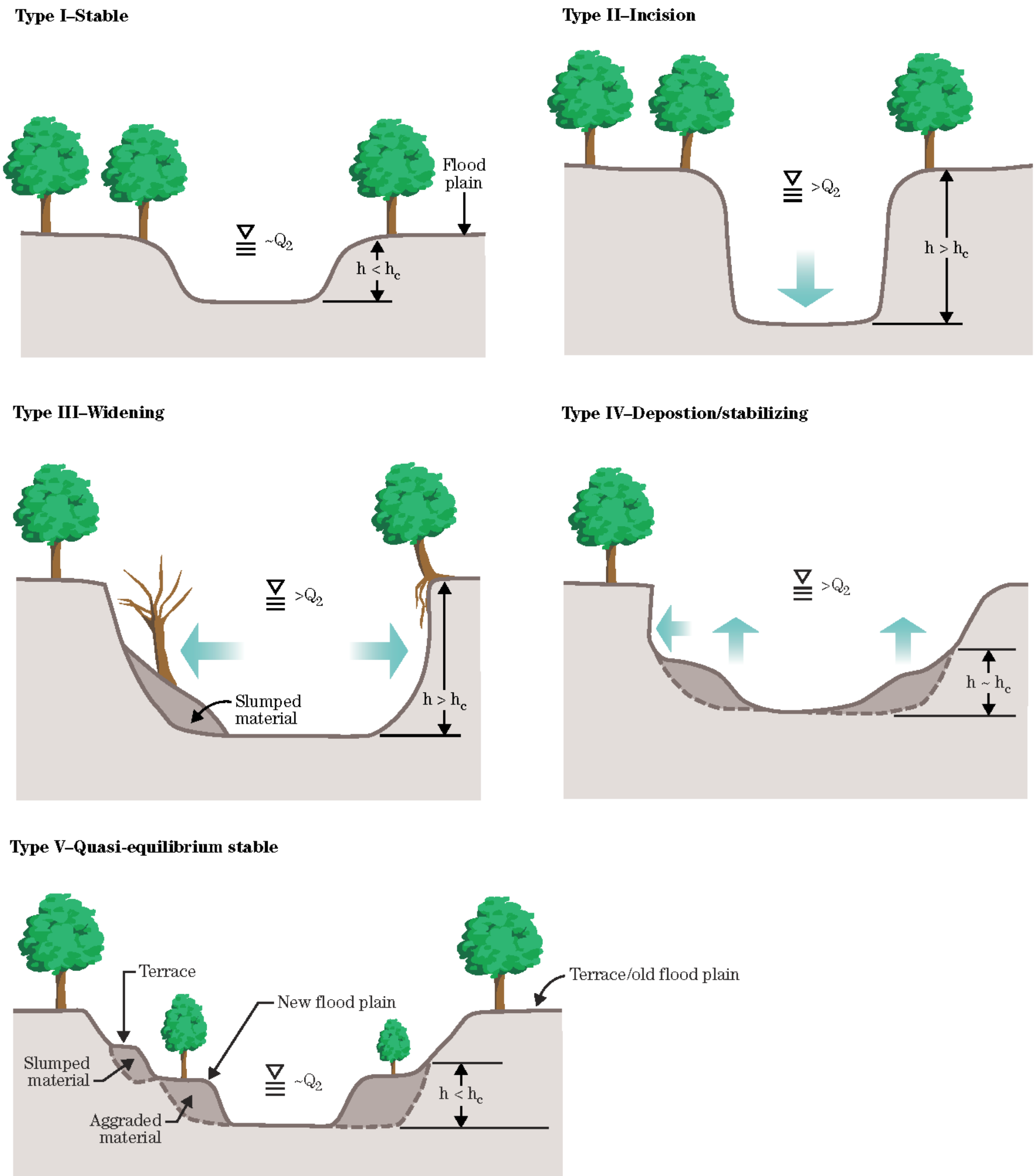

Figure 24. Conceptual model of incision channel evolution by Schumm et al. (1984). Reprinted from USDA NRCS (2008).

5. Flood Mitigation Approach and Alternatives

Sustainable flood resiliency can only be achieved by understanding the processes governing the watershed and applying solutions that work within that framework. We recommend an approach to increasing resilience to flooding and flood-related impacts that focuses on restoring natural watershed function to the greatest extent possible. Generally, that means reforesting tributaries and allowing natural recruitment and functioning of large wood elements; reducing the impacts of roads on valley width and watershed hydrology; where they cannot be eliminated, upgrading road crossings to make them more resilient by sizing them for extreme flood events, with consideration for sediment transport dynamics and the stream's local transport competence and capacity, and to pass debris; and allowing for active meander migration along Apalachin Creek and for actives meander migration and alluvial fan deposition along the downstream, low-gradient reaches of its tributaries. Within the Apalachin Creek floodplain, buy-outs are an important component of this strategy.

We have developed two lists of potential projects based on the above recommendations: One focused on site-specific, on-the-ground construction projects (Table 3) and one capturing other types of projects (Table 4). No single project will resolve the issues facing the Apalachin Creek watershed communities, but implemented together, these projects represent a comprehensive approach that is expected to have a measurable effect.

At each site, a project number has been assigned based on the distance of the site from the mouth of the stream (e.g., ApLo-3600 is located 3,600 feet upstream of the Long Creek confluence with Apalachin Creek). For each project that involves treatment over an extended length of the channel, the project number and and location marker is set at the downstream limit of treatment; the corresponding project description in Table 3 provides the distance that the treatment extends upstream of that point.

Construction projects have been developed in accordance with the environmental review guidance published by GOSR for CDBG-DR funded projects in the NY Rising Community Reconstruction Program. Each project has been assigned a project type that describes the approach to mitigating flood impacts and increasing community resilience. Many projects could fall into more than one category; the chosen category reflects the primary element(s) of the project. The project types are:

- **Riparian Management** – Channel and floodplain restoration and/or enhancement, including creation or enhancement of wetlands, riparian buffers, and other features to slow flow, increase flood conveyance capacity, and capture sediment;
- **Bank Stabilization** – Bioengineering bank stabilization to slow bank retreat, protect existing infrastructure, and reduce input of coarse sediment at identified point sources;
- **Floodplain Reconnection** – Measures to reconnect the channel with its floodplain such as berm removal, floodplain regrading, or installation of bioengineering measures to raise the channel bed and restore a more functional channel-floodplain flood flow dispersion relationship, increase floodplain flood conveyance capacity, and slow flood flows;

- **Grade Control** – Sustainable and ecologically sensitive bed stabilization to arrest channel bed erosion and/or protect structures or infrastructure;
- **Barrier Removal** – Removal of barriers that cause backwater effects and prevent aquatic organism passage;
- **Crossing Improvement** – Road crossing improvements to increase hydraulic capacity, improve road user safety, increase resilience and reduce risk of failure, and improve aquatic organism passage;
- **Road Relocation/Closure** – Relocation or closure of roads or sections of roads as a more sustainable alternative to repeated culvert and road repairs;
- **Structure Removal** – Removal, relocation, flood-proofing, or raising flood-impacted and at-risk structures;
- **Upland Land Management** – Implementation of best management practices in upland areas to slow overland flow and increase infiltration;
- **Green Infrastructure** – Green stormwater infrastructure to reduce surface water flooding;
- **Policy –** Regulatory or policy creation or changes to preserve undeveloped areas, move development out of the floodplain, and encourage sustainable and resilient design; and
- **Public Education** – Opportunities to education the public and municipal bodies on watershed processes and sustainable watershed management to reduce flood risk and improve resilience.

We recognize that the initial project lists are by nature incomplete in that they do not cover all possible actions that could be taken at every site within the watershed. These project examples are provided as a starting point for prioritization given available funding. Many of the projects described could be implemented more widely as future opportunities arise.

In subsequent phases of design and construction, potential impacts to wetlands and the rare plant and animal species present in the watershed should be considered in more detail and mitigation measures developed where necessary. Future updates to the project lists and project designs should also incorporate the guidance for considering and managing future risk, developing natural resilience, and adapting local laws that is currently being developed by NYS DEC under the CRRA.

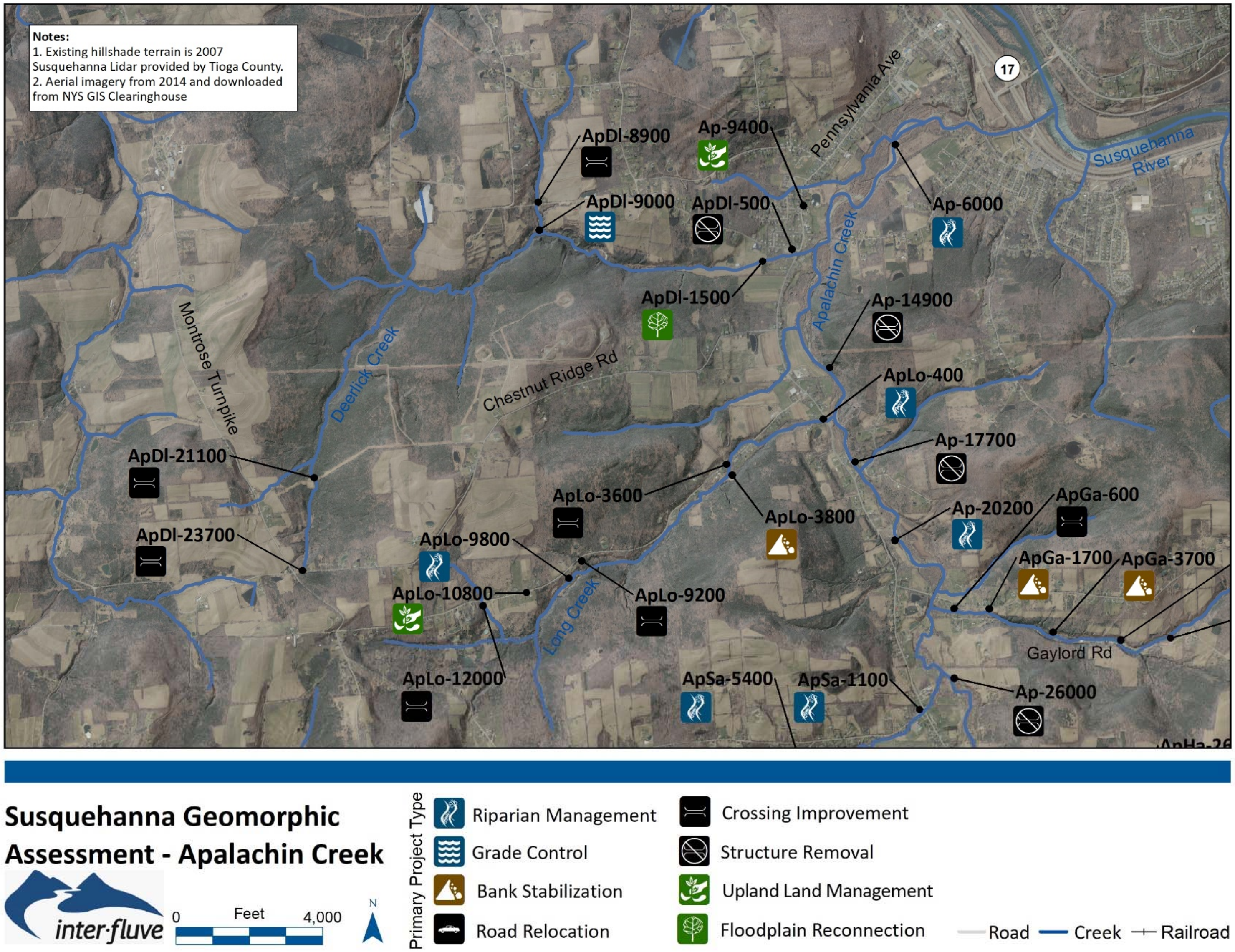

Figure 25. Map of site-specific potential flood mitigation and resilience construction projects. Refer to Table 3 for descriptions.

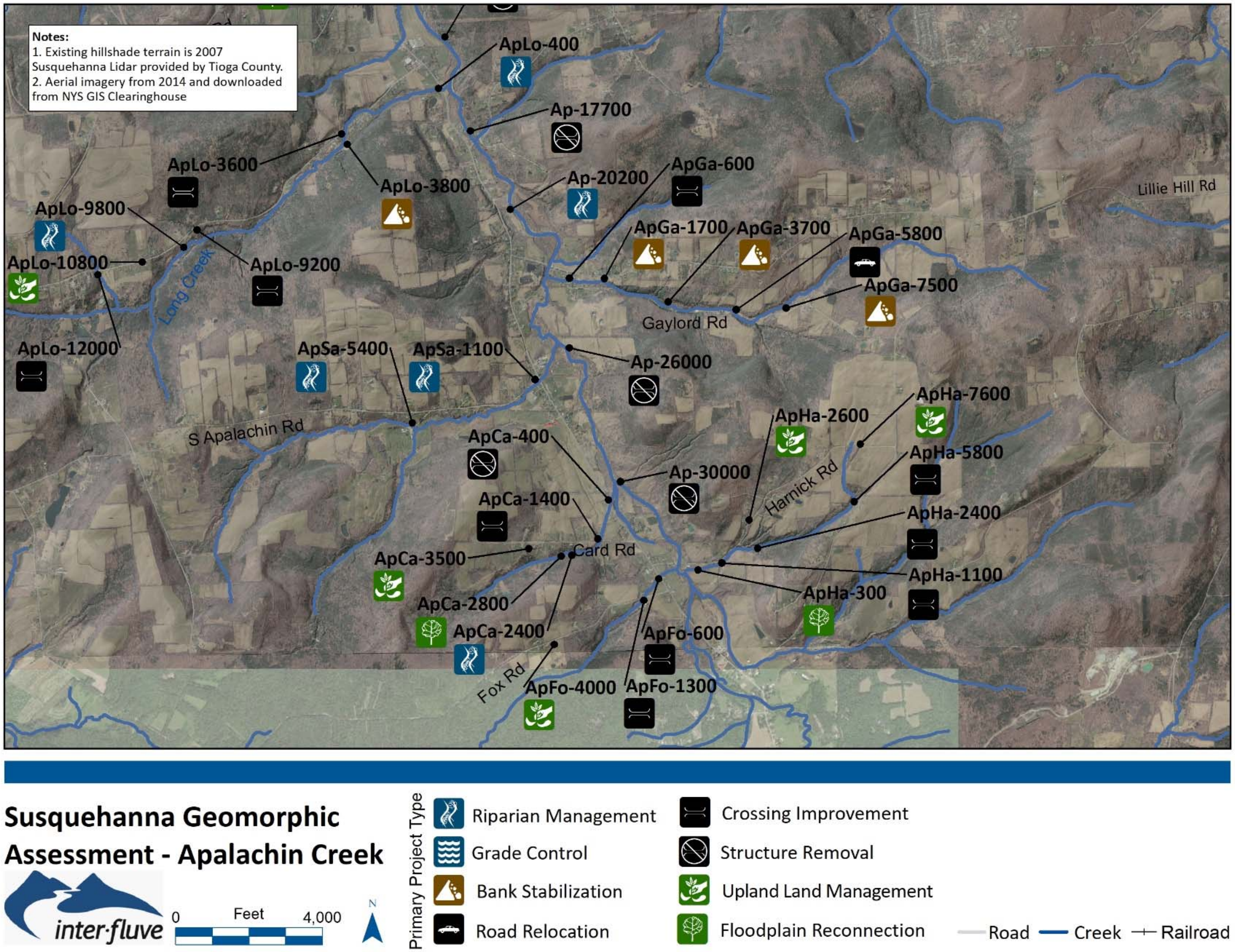

Figure 26. Map of site-specific potential flood mitigation and resilience construction projects. Refer to Table 3 for descriptions.

Table 3. List of potential flood mitigation and resilience alternatives – Site-specific projects

Project number	Type	Description	Photo or Image Reference
Ap-30000	Structure Removal	An approximately 2,500-foot-long reach of Apalachin Creek immediately downstream of Harnick Road was realigned and channelized in the 1960s to facilitate development of residences on parcels located on the floodplain. Most of the properties are located within the regulatory floodway and are subject to frequent flooding. The channel is frequently dredged to maintain its current alignment, and dredged material is used to form berms at the top of the left bank. Buy out properties and remove structures on the floodplain. Remove berms and allow the river to meander naturally. Area could be converted to public open space and used for public education.	Figure 27,Figure 28
Ap-26000	Structure Removal	An approximately 4,500-foot, low-lying length of Pennsylvania Avenue adjacent to project site Ap-30000 and including the Card Road intersection is within the Apalachin Creek 1% annual chance flood extent. Buy out properties east of Pennsylvania Avenue not already purchased as part of Ap-30000 and raise Pennsylvania Avenue between approximately 300 feet downstream of the Harnick Road intersection and approximately 1,000 feet upstream of South Apalachin Road. Replace the Pennsylvania Avenue crossing over the Card Road tributary with an appropriately sized open-bottom structure. Remove all abandoned structures on the floodplain and revegetate with native riparian species. Would expand open space created by Ap-30000.	Figure 29
Ap-20200	Riparian Management	Industrial forestry activity and agricultural operations occur adjacent to the stream channel with no riparian buffer. The site includes numerous informal ford crossings and evidence of on-going mechanical modification of the channel and gravel deposits. Around 2017, a boulder weir was constructed at the upstream limit of the reach and rip rap was installed along a 400-foot stretch of the left bank. Total reach length is approximately 2,000 feet. Establish riparian buffer, improve stream crossings, stabilize segment of bank directly downstream of rip rap and segment adjacent to log yard with engineered large wood and/or rock and riparian plantings. Educate landowners on sustainable forestry and river management practices using the New York State Forestry Voluntary Best Management Practices for Water Quality BMP Field Guide, and on agricultural BMPs such as cover crops and no till practices.	Figure 30

Project number	Type	Description	Photo or Image Reference
Ap-17700	Structure Removal	The bridge across the creek at Rhodes Road was deemed unsafe and closed in 2003 because of lack of funds to carry out repairs. There are no plans to re-open the bridge. The reach immediately downstream is laterally confined by hard bank protection along the left bank. Two residences sit at the top of the left bank, and one is located on the right bank; all are within the Apalachin Creek 1% annual chance flood extent. Remove the bridge, buy out affected property owners and remove structures and hard bank protection. Of the five affected properties, publicly available parcel information shows that one has a damaged foundation and another is the site of repetitive flood and erosion losses. Reconnect the channel and floodplain by lowering floodplain elevations adjacent to the creek. Reconstruct the banks where necessary using bioengineering methods, and establish a riparian buffer between the creek and Pennsylvania Avenue.	Figure 31
Ap-14900	Structure Removal	An approximately 2,400-foot, low-lying length of Pennsylvania Avenue adjacent to project site Ap-17700 and including the Rhodes Road intersection is within the Apalachin Creek 1% annual chance flood extent. Buy out properties east of Pennsylvania Avenue not already purchased as part of Ap-17700 and raise an approximately 0.5-mile length of Pennsylvania Avenue from approximately 820 feet upstream of Rhodes Road to approximately 160 feet upstream of the Long Creek bridge. Provide adequate drainage from upstream of the road embankment into Apalachin Creek. Remove all abandoned structures on the floodplain and revegetate with native riparian species.	Figure 32
Ap-9400	Upland Land Management	Road runoff and runoff from private properties flows rapidly down slope in a ditch along the side of the road. The runoff is fed into a stormwater system appears to be frequently overwhelmed leading to regular surface water flooding and a history of flood damage at the Giggle Box Playhouse daycare. Work with homeowners on Barton Road to implement stormwater BMPs and reduce runoff and runoff rates. Evaluate the current capacity of the stormwater drainage system and make improvements to reduce surface water flooding. The cost of the project may vary widely depending on the scope of the stormwater system improvements.	Figure 33

Project number	Type	Description	Photo or Image Reference
Ap-6000	Riparian Management	Location of a sewer siphon crossing beneath the creek bed. Siphon crossing has been subject to damage during numerous flood events since 2007. The sewer line itself is encased in concrete with a steel sheet pile wall. After 2011, the channel over a distance of 1,000 feet upstream of the crossing was shifted to the west and narrowed with rip rap installed on the right bank to constrain lateral movement. Stacked rock, rock vanes, and a weir for downstream grade control were also installed. The work was carried out through the NRCS Emergency Watershed Protection Program. One of the rock vanes was damaged during flash flooding in 2017. Monitor the site for changes or further damage and risk to the crossing. When repairs or further work is required, consider widening the channel to its pre-2011 extent to improve functionality in terms of flood conveyance and sediment transport. Also consider construction of a riffle grade control structure over the siphon to provide the desired grade control and protection while re-establishing a natural streambed and providing aquatic organism passage. Revegetate the right bank floodplain.	Figure 34
ApFo-4000	Upland Land Management	The watershed is largely forested, and much of the watershed is in Pennsylvania. Implement drainage improvements along Fox Road within New York to slow runoff and reduce erosion. Repair road ditches and install ditch relief culverts where opportunities exist to divert flow onto fields and into the forest and thus promote infiltration. Provide adequate erosion control at culvert outlets. Explore opportunities for runoff detention on the few agricultural parcels along Fox Road within New York.	Figure 35
ApFo-1300	Crossing Improvement	The upstream and downstream headwalls at the Fox Road culvert are in poor condition, and the downstream wingwall is in danger of collapse. The structure appears to be undersized and is deformed and misaligned. Bank erosion along the left bank immediately downstream of the culvert threatens a home. Replace the crossing with an appropriately sized open-bottom structure better aligned with the stream to reduce risk of flood damage, minimize the risk of blockage by woody debris, and improve road user safety. Install a riffle grade control structure immediately downstream to raise grade level at the crossing as needed. Stabilize banks over 100 feet upstream and 100 feet downstream of the culvert using engineered large wood and/or rock and riparian plantings. Refer to Section 4.11 of Appendix B for more information about this crossing's relatively high risk score and prioritization.	Figure 36,Figure 37

Project number	Type	Description	Photo or Image Reference
ApFo-600	Crossing Improvement	The Pennsylvania Avenue crossing is located in a natural zone of periodic deposition and subsequent erosion as deposited bed material is dispersed downstream. The existing concrete box appears to have been installed in 2016. Although the culvert appears to be structurally sound and in better general condition that others throughout the watershed, it is undersized and its width is less than that of the upstream and downstream channel, and the concrete invert is perched on the downstream side. The design of the structure puts upstream and downstream banks at risk of scour and cannot accommodate the natural fluctuations in bed level anticipated at this location. The upstream wingwalls are already in poor condition. Monitor the culvert for signs of erosion or damage that may affect Pennsylvania Avenue. When replacement is warranted, replace the culvert with an appropriately sized open-bottom structure to increase resilience and enable aquatic organism passage. Refer to Section 4.10 of Appendix B for more information about this crossing’s relatively high risk score and prioritization.	Figure 38
ApHa-7600	Upland Land Management	Cultivated fields form the headwaters of the tributary at Harnick Road. The Harnick Road crossing at ApHa-7600 is the divide between a well-defined channel downstream and fields and field rivulets and ditches upstream and is located at a low spot on the road. The ditches are currently vegetated, but evidence of recent excavation near the culvert suggests that the culvert bocks with debris and sediment, resulting in overtopping of the road. Raise the road elevation over a distance of approximately 500 feet, leaving the diameter of the culvert the same as existing to slow outflow from the fields. Install simple wood check structures along the drainage ditches to slow flow and encourage sedimentation. Establish a conservation easement and reforest an approximately six-acre area upstream of the culvert where runoff from adjacent hillslopes converges and enters the ditch and culvert. Work with landowners to implement agricultural BMPs such as cover crops and no till practices if not already in place.	Figure 39
ApHa-5800	Crossing Improvement	Existing culvert beneath private residential access appears to be undersized. The downstream reach is incised with the culvert acting as grade control for the upstream channel. Install a series of engineered large wood and/or rock structures to establish grade control and reconnect the channel with the floodplain. Replace the culvert with an appropriately sized open-bottom structure to reduce risk of flood damage, minimize the risk of blockage by woody debris, improve road user safety, and enable aquatic organism passage.	Figure 40,Figure 41

Project number	Type	Description	Photo or Image Reference
ApHa-2600	Upland Land Management	Implement drainage improvements along Harnick Road to slow runoff and reduce erosion. Repair road ditches and install ditch relief culverts where opportunities exist to divert flow onto fields and into the forest and thus promote infiltration. Provide adequate erosion control at culvert outlets. Explore opportunities for runoff detention on private land north of the road. ApHa-7600 is one example.	Figure 42
ApHa-2400	Crossing Improvement	Site includes twin 36-inch culverts under a private field access off of Harnick Road. The culverts carry drainage from Harnick Road and adjacent hillsides. The drainage channel empties into the main tributary channel approximately 50 feet downstream of the crossing. The bed of the main channel is bedrock at this location. One of the culverts is completely blocked with sediment, the other is partially blocked. Replace culverts with a single, appropriately sized structure and install engineered large wood and/or rock structures along drainage channel to establish grade control, trap coarse sediment, and slow runoff. Implementation of ApHa-2600 will be required in conjunction with this project to reduce the effects of rapid road runoff. Working with the landowner, explore the option of removing this crossing and utilizing the crossing at ApHa-1100.	Figure 43
ApHa-1100	Crossing Improvement	The existing culvert beneath private field and residential access appears undersized. The downstream reach is incised with the culvert acting as grade control for the upstream channel. Install a series of engineered large wood and/or rock structures to establish grade control and reduce the risk of headcutting. Replace the culvert with an appropriately sized open-bottom structure to reduce risk of flood damage, minimize the risk of blockage by woody debris, improve user safety, and enable aquatic organism passage.	Figure 44
ApHa-300	Floodplain Reconnection	Flood flows in the channel appear to be disconnected from the surrounding floodplain. Local base level control is currently provided by a tenuous large wood jam at the mouth of the tributary such that the bed of the tributary sits approximately 4 feet above the bed of Apalachin Creek. The jam relies on a single piece of small diameter wood; failure of the jam would initiate a headcut along the lower reaches of the tributary. Install a series of engineered large wood and/or rock structures, tied into the Apalachin Creek bed as the local grade control, to reconnect the channel with the floodplain, prevent migration of a headcut, and trap coarse sediment. The treatment length is approximately 400 feet. Project should be implemented prior to ApHa-1100.	Figure 45

Project number	Type	Description	Photo or Image Reference
ApCa-3500	Upland Land Management	A fence has been constructed across the stream at this site. A riparian buffer is absent along some stretches, and there is evidence of livestock having direct access to the stream channel. Runoff from heavy use livestock areas appears to drain directly to the stream, and an animal carcass was left in a field adjacent to the watercourse. Establish continuous riparian buffer, remove fence across channel, and exclude livestock from creek. Work with landowners to implement other agricultural BMPs such as heavy use area protection, contained animal waste storage, and critical area planting.	Figure 46,Figure 47
ApCa-2800	Floodplain Reconnection	Low-gradient reach with opportunity to utilize storage potential along the valley floor. Install a series of engineered large wood structures spanning the channel and valley to slow flows, trap sediment, and enhance flood storage in overbank areas. Length of treatment is approximately 300 feet.	Figure 48
ApCa-2400	Riparian Management	At the time of the field assessment, a temporary culvert crossing had been constructed across the channel and a forest access road cleared up the steep right bank to facilitate harvest operations. No erosion control or stream crossing BMPs were observed. Slash was left in the channel. Educate landowners on sustainable forestry and river management practices using the New York State Forestry Voluntary Best Management Practices for Water Quality BMP Field Guide. Restore stream channel to pre-harvest or better conditions.	Figure 49
ApCa-1400	Crossing Improvement	The existing Card Road culvert appears undersized and is misaligned and perched. The banks upstream and downstream of the culvert are overhanging and eroding. Replace culvert with an appropriately sized open-bottom structure to reduce risk of flood damage, minimize the risk of blockage by woody debris, improve road user safety, and enable aquatic organism passage. Stabilize banks over 100 feet upstream and 50 feet downstream of the culvert using engineered large wood and/or rock and riparian plantings. Refer to Section 4.9 of Appendix B for more information.	Figure 50

Project number	Type	Description	Photo or Image Reference
ApCa-400	Structure Removal	The reach of the tributary between Card Road and Pennsylvania Avenue is lower gradient than upstream and thus a natural zone of deposition. Historical aerial photographs show substantial deposition in the channel upstream of the Pennsylvania Avenue crossing and possible damage to the properties on either side of the creek in 2011. Coarse sediment deposited in the channel appears to be periodically dredged and piled up along the tops of banks to form berms. Riparian buffer is absent, including along the left bank which is operated as a cattle farm. Buy out properties or purchase easements along the creek and remove structures within flooded areas. Remove berms, establish a riparian buffer, and work with remaining landowners living or with operation adjacent to the creek to implement BMPs including agricultural BMPs such as livestock exclusion, heavy use area protection, contained animal waste storage, and critical area planting. Dovetails with projects Ap-30000 and Ap-26000.	Figure 51
ApSa-5400	Riparian Management	The Apalachin Golf Course is located at the confluence of the unnamed tributary at South Apalachin Road and a smaller tributary. Golf course owners have constructed numerous creek crossings including two crossings over the main tributary and a ford crossing and second crossing over the smaller tributary. The downstream crossing on the main tributary had recently been damaged and was being replaced at the time of the field assessment. Riparian buffer is very narrow or absent and course is mowed up to the top of the banks. Main tributary channel is disconnected from the floodplain, and banks are eroding at the site and in downstream reaches. Work with golf course owners to develop actions to improve the health and resilience of the creek at this location in ways that are compatible with the current use. Some options are: Eliminate downstream crossing on the main tributary and the ford crossing on the smaller tributary; install a series of engineered large wood structures along an approximately 1,500-foot length of the main tributary downstream of the remaining crossing, and tied into bedrock at the downstream end, to establish grade control, stabilize banks, reconnect the floodplain, and trap course sediment; establish a riparian buffer or turf-reinforced channel boundaries where vertical obstructions are unsuitable; implement turf management BMPs if not already in place.	Figure 52,Figure 53

Project number	Type	Description	Photo or Image Reference
ApSa-1100	Riparian Management	The lower reach of the unnamed tributary along South Apalachin Road is lower gradient than upstream portions of the tributary and thus a natural depositional zone that forms a fan on the Apalachin Creek floodplain. Ongoing and substantial deposition is apparent in historical aerial photographs. Riparian buffer is narrow to absent. Coarse sediment deposited in the channel upstream of Pennsylvania Avenue appears to be periodically dredged and piled up along the tops of banks to form berms. Sedimentation also occurs within the farmland downstream of Pennsylvania Avenue. Establish dredging thresholds and limits (horizontal as well as vertical) to reduce the frequency and volume of local dredging operations, avoid over dredging, and avoid initiating headcuts that exacerbate the problem. Remove berms that have been constructed from dredged material. Establish conservation easements on the parcels downstream of Pennsylvania Avenue, re-establish riparian buffer, and allow the tributary to migrate laterally across the natural fan at the confluence. Reforest the Apalachin Creek floodplain within the 1% annual chance flood extent. Remove structures within the easements.	Figure 54
ApGa-7500	Bank Stabilization	Active erosion of an approximately 12-foot-high bank on river right. Stabilize the toe of the bank using engineered large wood and/or rock and riparian plantings over an approximately 50-foot length. Regrade the bank to a more stable angle and install native seed and plants.	Figure 55
ApGa-5800	Road Relocation	The existing culvert beneath Gaylord Road appears to be undersized and headwalls are in poor condition. A joint inside the culvert is displaced, and the culvert outlet is perched. A second undersized culvert with headwalls in similarly poor condition is present a short distance (approximately 800 feet) upstream where the channel turns north again. In between the crossings, the creek runs parallel to Gaylord Road through a single parcel, separated from the road by a narrow, forested floodplain. Remove both crossings and realign the road through the field south of the creek. Remove the former road segment and revegetate. If an agreement cannot be reached with the landowner, replace the culverts with appropriately sized open-bottom structures to reduce flood risk, minimize the risk of blockage by woody debris, restore aquatic organism passage, and reduce risk to road users.	Figure 56,Figure 57
ApGa-3700	Bank Stabilization	Active erosion of an approximately 25-foot-high bank on river left. Stabilize toe of bank using engineered large wood and/or rock and riparian plantings over an approximately 50-foot length of the bank.	Figure 58
ApGa-1700	Bank Stabilization	Bedrock cascade immediately upstream focuses flow directly toward right bank at a bend in the creek. Stabilize the toe of the 20-foot-high bank using engineered large wood and/or rock and riparian plantings over an approximately 50-foot length.	Figure 59

Project number	Type	Description	Photo or Image Reference
ApGa-600	Crossing Improvement	The existing culvert under Gaylord Road near the intersection with Lillie Hill Road appears undersized and its wing walls are in critical condition. A sinkhole has developed between the road and one of the headwalls. The outlet of the structure is undermined and perched, with the culvert serving as a grade control for upstream reaches. Bank erosion in the reach downstream of the culvert is threatening a resident's boiler structure and an outbuilding. Other residences and buildings sit close to the top of the bank both upstream and downstream of the culvert; upstream banks are lined with stacked stone and rip rap. Replace the crossing with an adequately sized, open-bottom structure to reduce risk of flood damage, minimize the risk of blockage by woody debris, improve road user safety, and enable aquatic organism passage. Stabilize a 150-foot length of the left bank upstream and downstream of the crossing. Coordinate with downstream property owner on the left bank who is independently pursuing funding to stabilize the bank. Refer to Section 4.6 of Appendix B for more information.	Figure 60
ApLo-12000	Crossing Improvement	The existing Long Creek Road crossing over a tributary to Long Creek appears undersized and is deformed with collapsed and misaligned wingwalls. Soil is eroding from beneath the road. At the time of assessment by Fuss & O'Neill, the road appeared to have been recently overtopped. Replace crossing with an appropriately sized open-bottom structure aligned with stream channel to improve road resilience and road user safety. Refer to Section 4.4 of Appendix B for more information.	Figure 61
ApLo-10800	Upland Land Management	Implement drainage improvements along Long Creek Road to slow runoff and reduce erosion. Repair road ditches and install ditch relief culverts where opportunities exist to divert flow into the forest and thus promote infiltration. Provide adequate erosion control at culvert outlets. Explore opportunities for runoff detention on private land throughout the watershed. Large parcels of agricultural land between Chestnut Hill Road and Long Creek Road appear to be good candidates.	Figure 62

Project number	Type	Description	Photo or Image Reference
ApLo-9800	Riparian Management	A private swimming pond is located on the left bank on what used to be the floodplain of Long Creek. In recent years, the channel bed has incised approximately 15 feet into till and clay till. Pieces of large wood are preserved in the alluvial deposits at the top of the left bank, marking the level of the former channel. The pond remains on the stranded floodplain with the clay till acting as a natural clay liner. At the downstream end of the pond, alluvial lenses eroded into the clay till act as conduits, and seepage was noted during our field assessment. The right bank at the site is an approximately 75-foot-high bluff also composed of till and clay till. Both banks are steep and largely bare. A second smaller pond is located on a lower elevation floodplain area downstream of the main pond. The channel bed here is also much lower than the floodplain, but incision is less severe with the bank height reaching 7 feet. At the upstream end of the reach, concrete rubble and reinforcement from a collapsed crossing are present in the channel. Install a series of engineered large wood structures, beginning approximately 400 feet downstream of the larger pond, to establish grade control, raise the bed level, and trap coarse sediment. Drain the pond and excavate a new channel alignment through the pond site, incorporating engineered large wood structures and bank stabilization. Remove concrete debris from the site, fill the existing incised channel at the toe of the eroding bluff and establish a riparian buffer between the bluff and the new channel.	Figure 63,Figure 64, Figure 65
ApLo-9200	Crossing Improvement	The culvert under Long Creek Road carrying a small tributary to Long Creek appears to be undersized. Sediment has filled the channel upstream of the culvert, but the downstream channel is severely eroded such that a substantial grade difference exists across the structure. The downstream headwall is in poor condition and undermined. Concrete rubble has been thrown into the channel in what appears to be an attempt to arrest the scour that is undermining the culvert and road. Replace the culvert with an appropriately sized structure capable of passing sediment. Install a series of engineered large wood and/or rock structures in the downstream ravine to establish grade control, slow flows, and trap coarse sediment. Tie into project ApLo-9800.	Figure 66

Project number	Type	Description	Photo or Image Reference
ApLo-3800	Bank Stabilization	The 0.5-mile reach upstream of the corrugated metal arch Long Creek Road crossing (see ApLo-3600) marks the transition from the upper and lower portions of the watershed. The valley width increases and the valley and channel slopes decline in this reach, making it an area of coarse sediment and large wood deposition. As a result, the reach is geomorphically dynamic and experiences rapid changes including bank erosion. Rock bank protection was previously installed intermittently along the left bank where bank erosion threatens Long Creek Road or residential properties; however, some of the rock has been displaced or is flanked by upstream or downstream bank erosion. Along river right, the creek is eroding into high, unvegetated banks of till that are contributing to the coarse sediment load. Small, steep drainage channels entering from both banks also contribute sediment. Riparian buffer is absent from most of the left bank and some of the right bank. Stabilize the banks at key locations using engineered large wood and/or rock to reduce sediment input and protect private property and infrastructure, regrade banks to more stable angles, and install native seed and plants to encourage vegetative cover. Install engineered wood and/or rock structures to stabilize the beds of the small drainage channels entering the creek and capture sediment. Establish riparian buffer.	Figure 67,Figure 68
ApLo-3600	Crossing Improvement	The existing Long Creek Road crossing is misaligned and deformed with footings exposed. Erosion of the road embankment is undermining the guard rail and possibly the road and bank erosion is evident upstream and downstream of culvert. Gabions are present on the right bank downstream of the culvert. Replace the culvert with an appropriately sized open-bottom structure correctly aligned with the stream channel. Remove the existing gabions and stabilize both banks over a 150-foot length upstream and downstream of the culvert using engineered large wood and/or rock. Regrade the banks to more stable angles and install native seed and plants. Refer to Section 4.3 of Appendix B for more information.	Figure 69

Project number	Type	Description	Photo or Image Reference
ApLo-400	Riparian Management	Long Creek at Pennsylvania Avenue is within a natural zone of deposition near the confluence with Apalachin Creek. Although outside the 1% annual chance flood extent of Apalachin Creek, the bridge at Pennsylvania Avenue sustained damage in 2011 and was replaced. The reach upstream of Pennsylvania Avenue has been straightened and dredged, and the channel bed is currently approximately 5 feet below the floodplain. Restore the riparian zone by removing existing bank protection measures and improving riparian cover on the banks by treating invasives and installing native seed and plants. The length of treatment would be approximately 500 feet. Establish dredging thresholds and limits (horizontal as well as vertical) to reduce the frequency and volume of local dredging operations, avoid over dredging, and avoid initiating headcuts that exacerbate the problem. Remove berms that have been constructed from dredged material. Refer to Section 4.2 of Appendix B for more information on the Pennsylvania crossing over Long Creek.	Figure 70,Figure 71
ApDl-23700	Crossing Improvement	The existing Chestnut Ridge Road culvert appears to be undersized and is in poor condition with road material eroding over the banks at the upstream and downstream openings. There is a substantial grade change across the culvert, and the downstream end is perched. Replace the culvert with an appropriately sized embedded structure aligned with the stream channel and install guardrails to reduce risk of flood damage, reduce the risk of blockage, and improve road user safety. Install a series of engineered large wood and/or rock structures in the downstream ravine to establish grade control, slow flows, and trap coarse sediment. Refer to Section 4.5 of Appendix B for more information.	Figure 72
ApDl-21100	Crossing Improvement	Twin HDPE pipes carry Deerlick Creek past a natural gas pipeline crossing. The culverts appear undersized, the inlets were clogged with debris on the day of the field assessment, and the outlets are perched. The level of the pipeline crossing in relation to the culvert is unknown and requires further investigation. Coordinate with the gas company to replace the culverts with an appropriately sized structure to improve resilience of the pipeline crossing and provide aquatic organism passage.	Figure 73
ApDl-9000	Grade Control	The bed level along an approximately 1,000-foot reach currently sits 10 to 15 feet below the top of the bank. Bank failure has contributed some large wood to the channel, but natural jam structures that could help trap sediment and slow erosion are generally absent. Install a series of engineered large wood and/or rock structures to establish grade control, slow flows, and trap coarse sediment.	Figure 74

Project number	Type	Description	Photo or Image Reference
ApDl-8900	Crossing Improvement	The culvert under Beach Road carrying a small tributary to Deerlick Creek appears to be undersized. The upstream gabion headwall is deformed and collapsing, and upstream and downstream banks are eroding and overhanging. The inlet is partially blocked by debris, and a substantial volume of coarse sediment is deposited in the channel upstream. The downstream outlet is perched by approximately 5 feet above the streambed which is scoured down to bedrock. Replace the culvert with an appropriately sized open-bottom structure to reduce the risk of flood damage, reduce the risk of blockage, and improve road user safety. Remove the gabions and stabilize the banks over approximately 100 feet upstream and downstream using engineered large wood and/or rock and riparian plantings. Install a series of engineered large wood and/or rock structures to establish grade control in the downstream channel. Refer to Section 4.1 of Appendix B for more information.	Figure 75
ApDl-1500	Floodplain Reconnection	The channel bed over an approximately 1,500-foot reach is 5 to 10 feet below the surrounding floodplain. Riparian buffer is absent, and the channel appeared to have been recently dredged at the time of the survey and material piled up at the tops of the banks to form berms. A private field crossing to access the right bank floodplain is present. Purchase the portion of the parcel that includes the right bank or establish a conservation easement, and remove the private crossing and small outbuildings on the right bank. Install a series of engineered large wood and/or structures to improve channel connection to the floodplain and trap coarse sediment. Remove berms, revegetate the banks, and establish riparian buffers.	Figure 76
ApDl-500	Structure Removal	The channel upstream and downstream of Pennsylvania Avenue has been straightened and dredged with dredged material piled up along the tops of the banks to form berms. The Faith Christian Fellowship Church at the corner of Pennsylvania Avenue and Beach Road has sustained repeated flood damage in recent decades. Buy out or raise the church and buy out the property on the right bank to give the stream space and opportunity to migrate laterally, access overbank areas, and deposit and process sediment. Remove the berms and affected structures that are not being raised, and improve riparian cover on the banks by installing native seed and plants. Install bank erosion countermeasures immediately upstream of the Pennsylvania Avenue bridge to manage the return of flood flows into the channel. At the Pennsylvania Avenue crossing itself, establish dredging thresholds and limits (horizontal as well as vertical) to reduce the frequency and volume of local dredging operations, avoid over dredging, and avoid initiating headcuts that exacerbate the sedimentation problem.	Figure 77

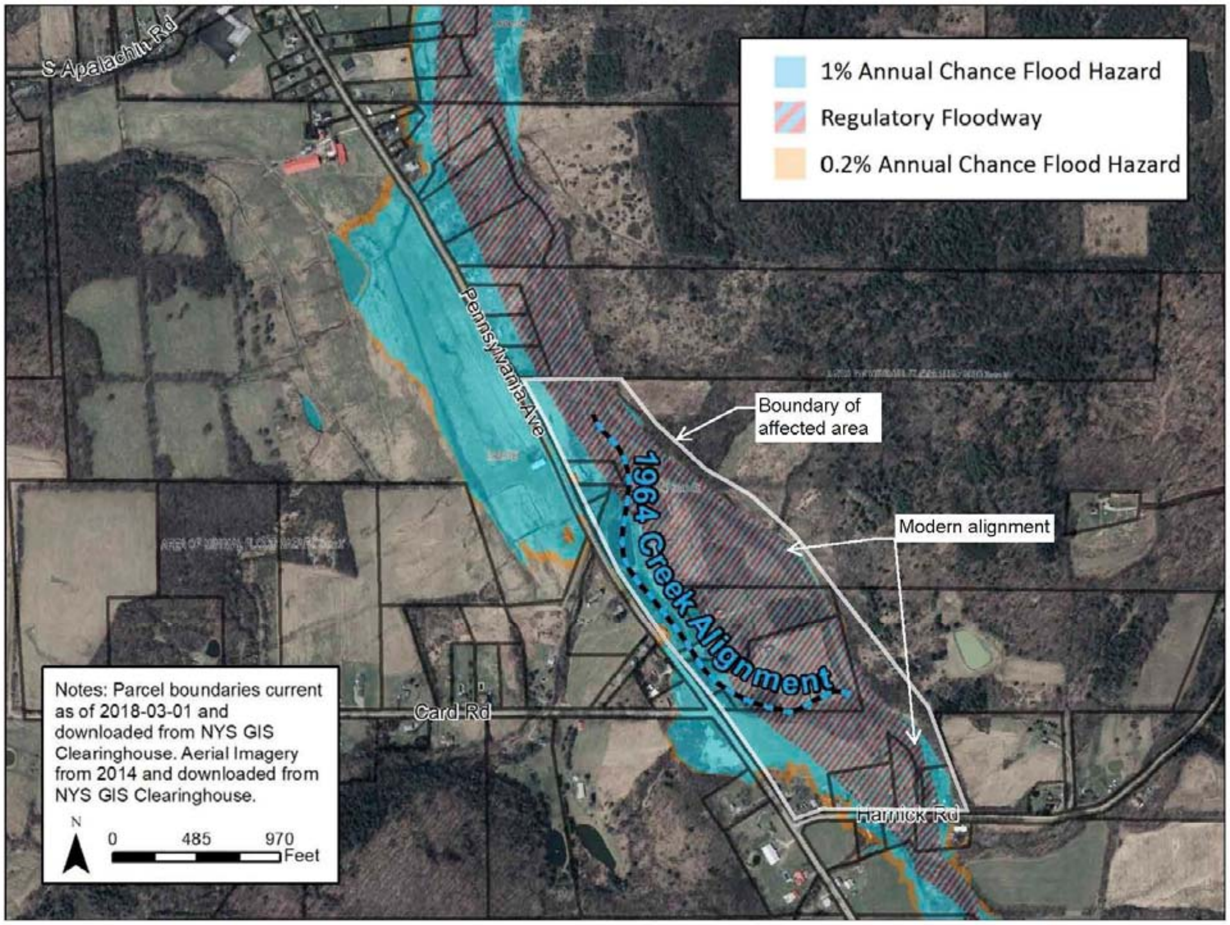

Figure 27. Aerial photograph showing current (2014) and pre-1960s alignment of Apalachin Creek at Ap-30000. Parcels and portions of parcels proposed for purchase or easement shown outlined in white. Flow is south to north.

Figure 28. Looking downstream along Apalachin Creek near Ap-30000. Dredging and berming of the channel has resulted in an over-wide cross section, which reduces the channel's ability to transport sediment, resulting in deposition and more dredging. Furthermore, dredging is an activity that can have detrimental effects on upstream bed levels (i.e., causing headcutting), downstream hydraulics and sediment transport, aquatic habitat, and riparian species and therefore requires a permit. Berming can reduce instances of overbank flow and floodplain storage, thereby increasing downstream flood peaks. Photo taken October 19, 2019.

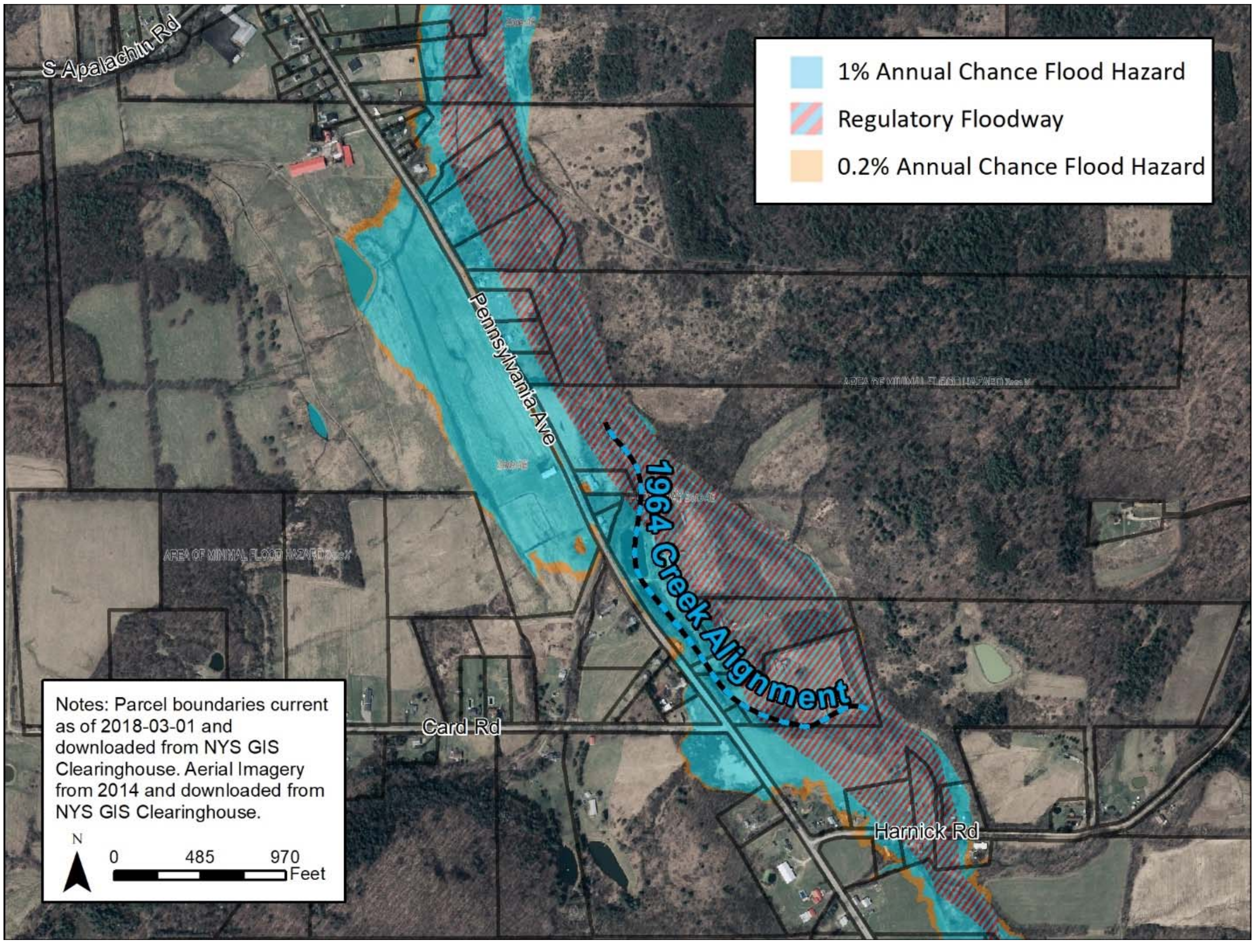

Figure 29. Mapped flood extents at Ap-26000. Flow is south to north.

Figure 30. Site at Ap-20200. Parcel boundaries (in black) obtained from NYS GIS Clearinghouse.

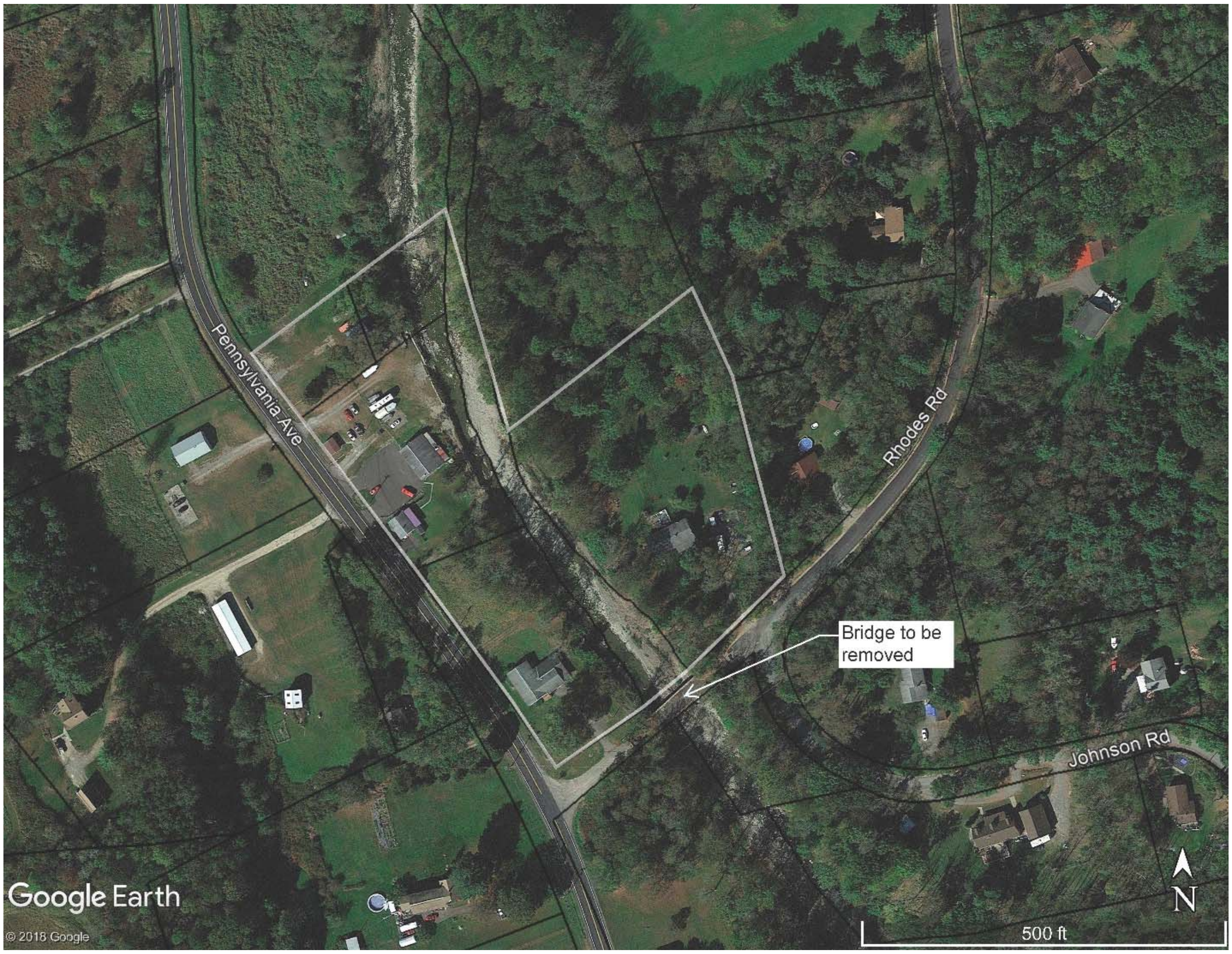

Figure 31. Ap-17700. Parcels proposed for purchase shown outlined in white. Parcel boundaries obtained from NYS GIS Clearinghouse. Flow is south to north.

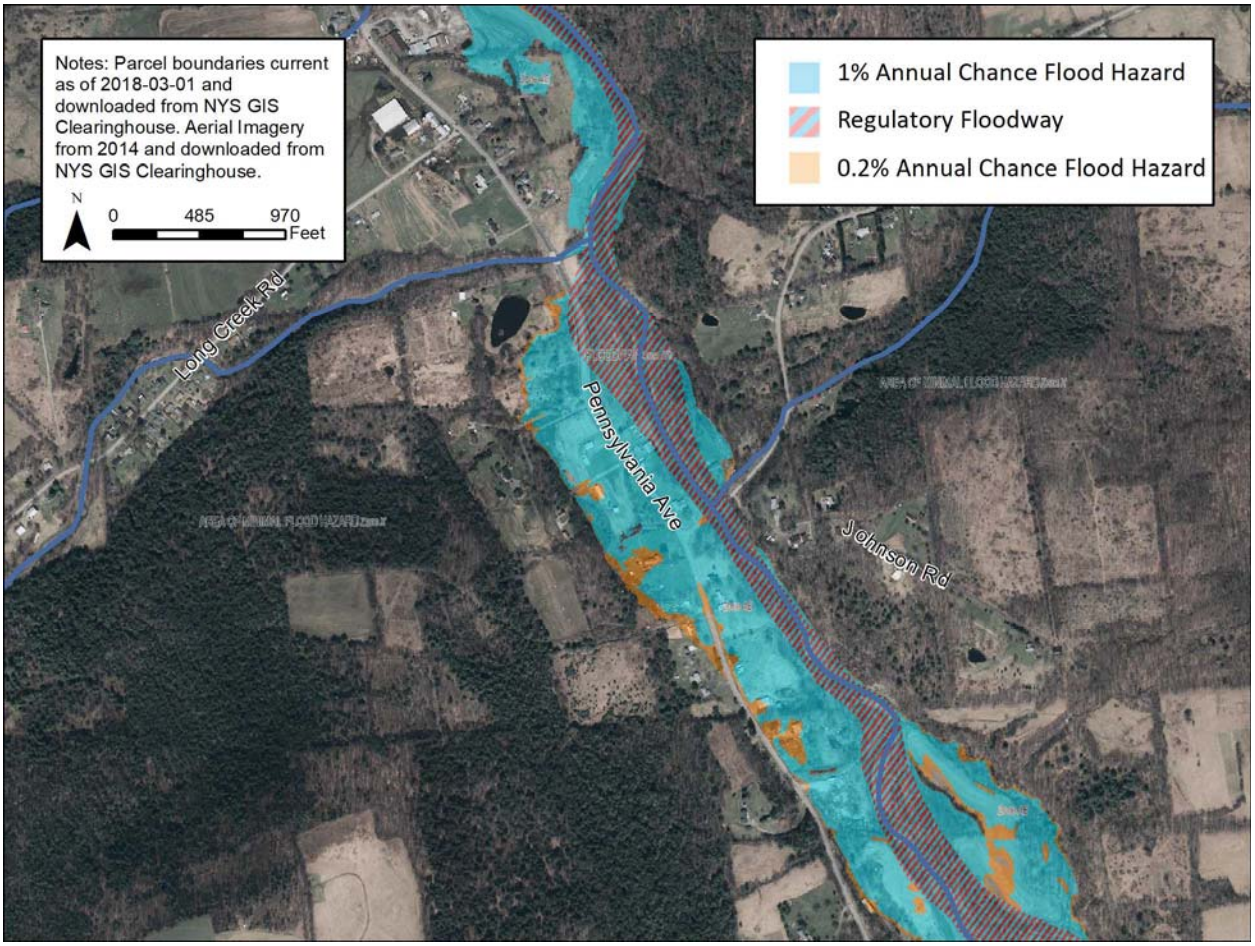

Figure 32. Mapped flood extents at Ap-14900

Figure 33. Looking up slope along Barton Road. Photo taken March 7, 2019.

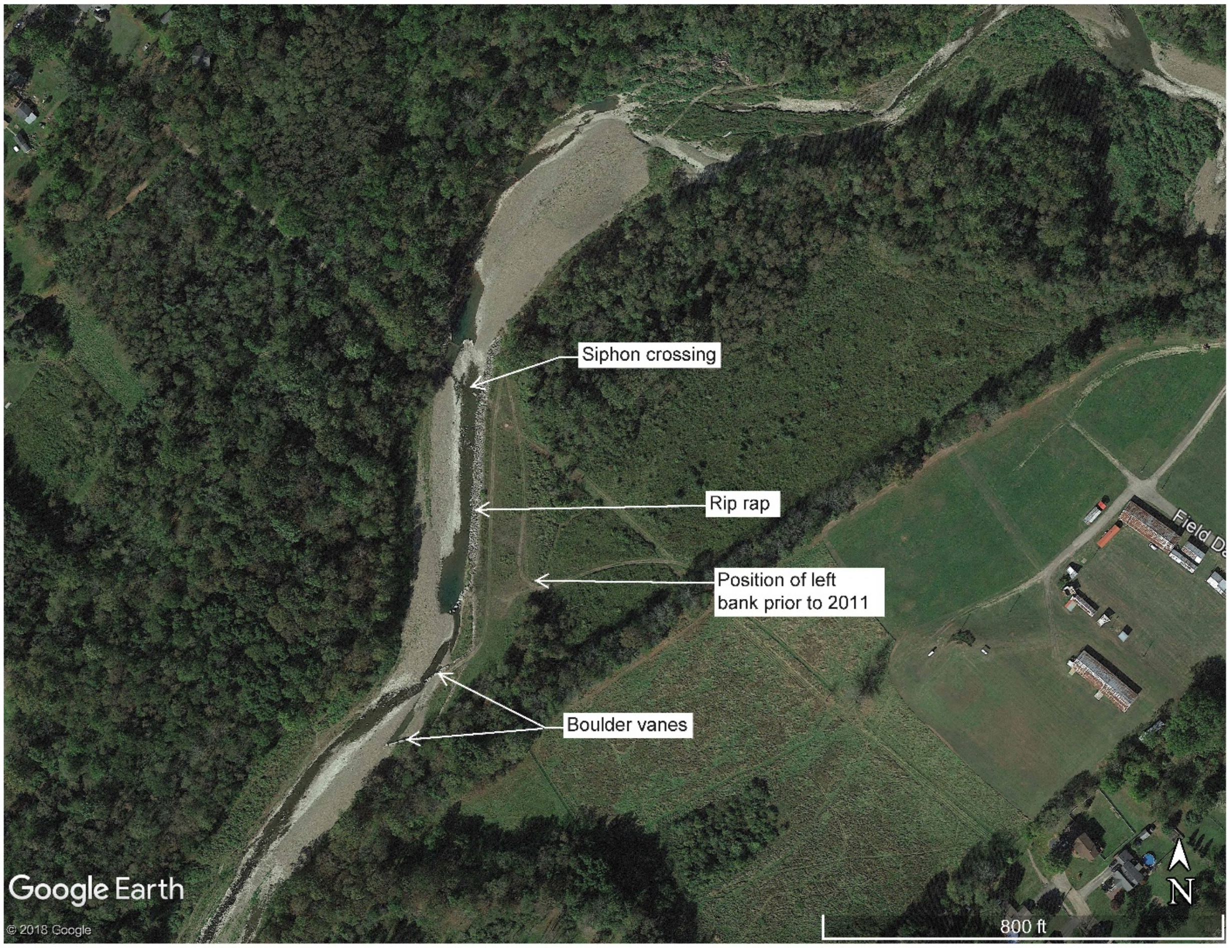

Figure 34. Sewer siphon crossing at Ap-6000

Figure 35. Incised road ditch along Fox Road (ApFo-4000). Photo taken October 19, 2018.

Figure 36. Downstream headwall at ApFo-1300. Photo taken October 19, 2018.

Figure 37. Eroding bank immediately downstream of culvert at ApFo-1300. Note proximity of residence. Photo taken October 19, 2018.

Figure 38. Looking upstream at Pennsylvania Avenue crossing ApFo-600. Concrete bed is slightly perched. Photo taken October 19, 2018.

Figure 39. Headwaters of Harnick Road tributary at ApHa-7600. Photo taken October 19, 2018.

Figure 40. Undersized box culvert at ApHa-5800. Photo taken October 19, 2018.

Figure 41. Looking downstream from crossing at ApHa-5800. Photo taken October 19, 2018.

Figure 42. Eroding road ditch along Harnick Road delivering sediment to the Harnick Road tributary (project ApHa-2600). Photo taken October 19, 2018.

Figure 43. Private field access off of Harnick Road at ApHa-2400. Photo taken October 19, 2018.

Figure 44. Private access at ApHa-1100. Photo taken October 19, 2018.

Figure 45. Looking upstream at ApHa-300. Photo taken October 19, 2018.

Figure 46. Fence across channel at ApCa-3500. Photo taken October 19, 2018.

Figure 47. Gap in riparian buffer at ApCa-3500. Photo taken October 19, 2018.

Figure 48. Low-lying forest floor at ApCa-2800. Photo taken October 19, 2018.

Figure 49. Looking downstream at temporary crossing and new access constructed up steep right bank at ApCa-2400. Photo taken October 19, 2018.

Figure 50. The channel upstream of the Card Road crossing at ApCa-1400. Photo taken October 19, 2018.

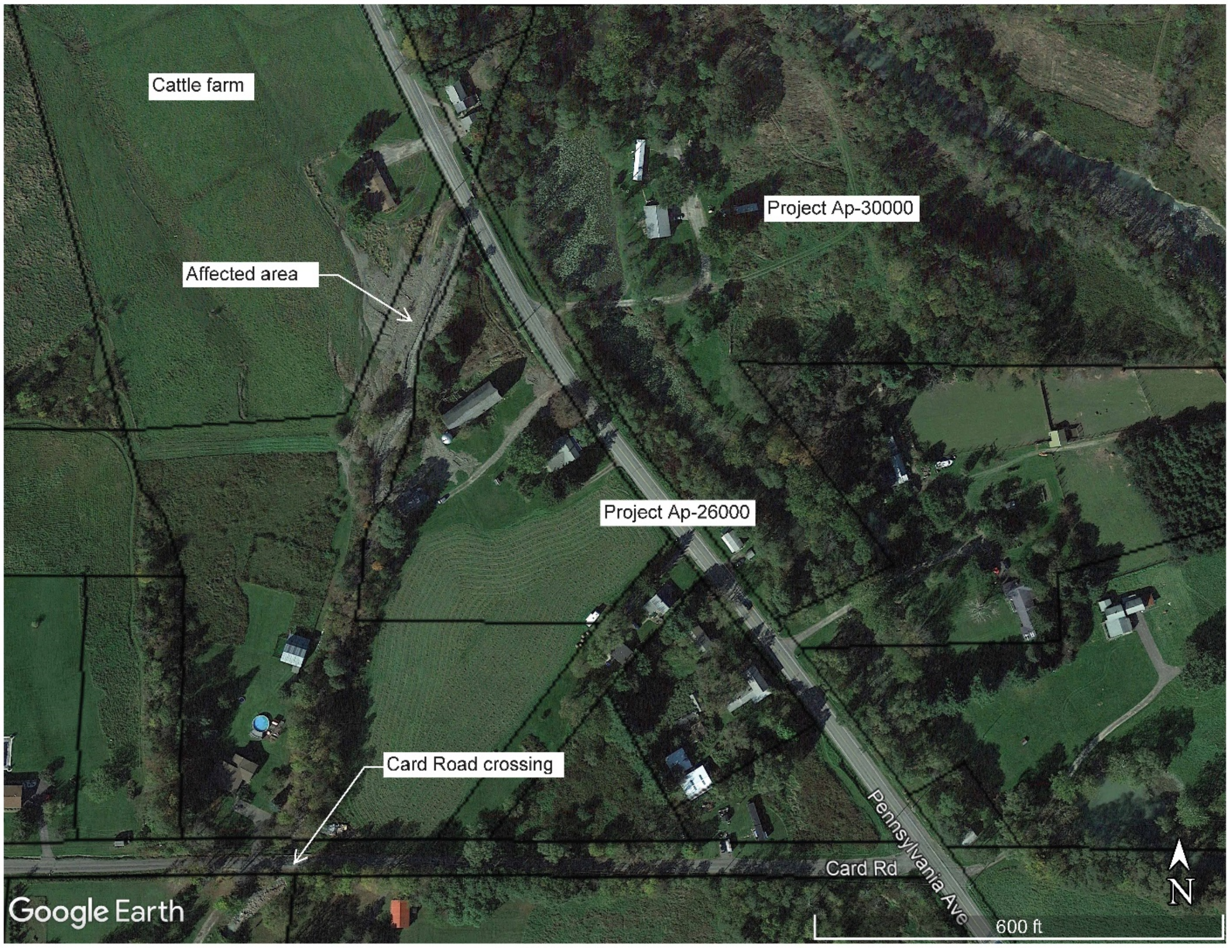

Figure 51. 2011 aerial image of ApCa-400. Locations of project recommendations Ap-30000 and Ap-26000 are shown. Parcel boundaries obtained through NYS GIS Clearinghouse.

Figure 52. Apalachin Golf Course at ApSa-5400 showing crossings on main South Apalachin tributary and a smaller tributary

Figure 53. Looking downstream along the South Apalachin tributary between the two crossings at the golf course. Photo taken October 18, 2018.

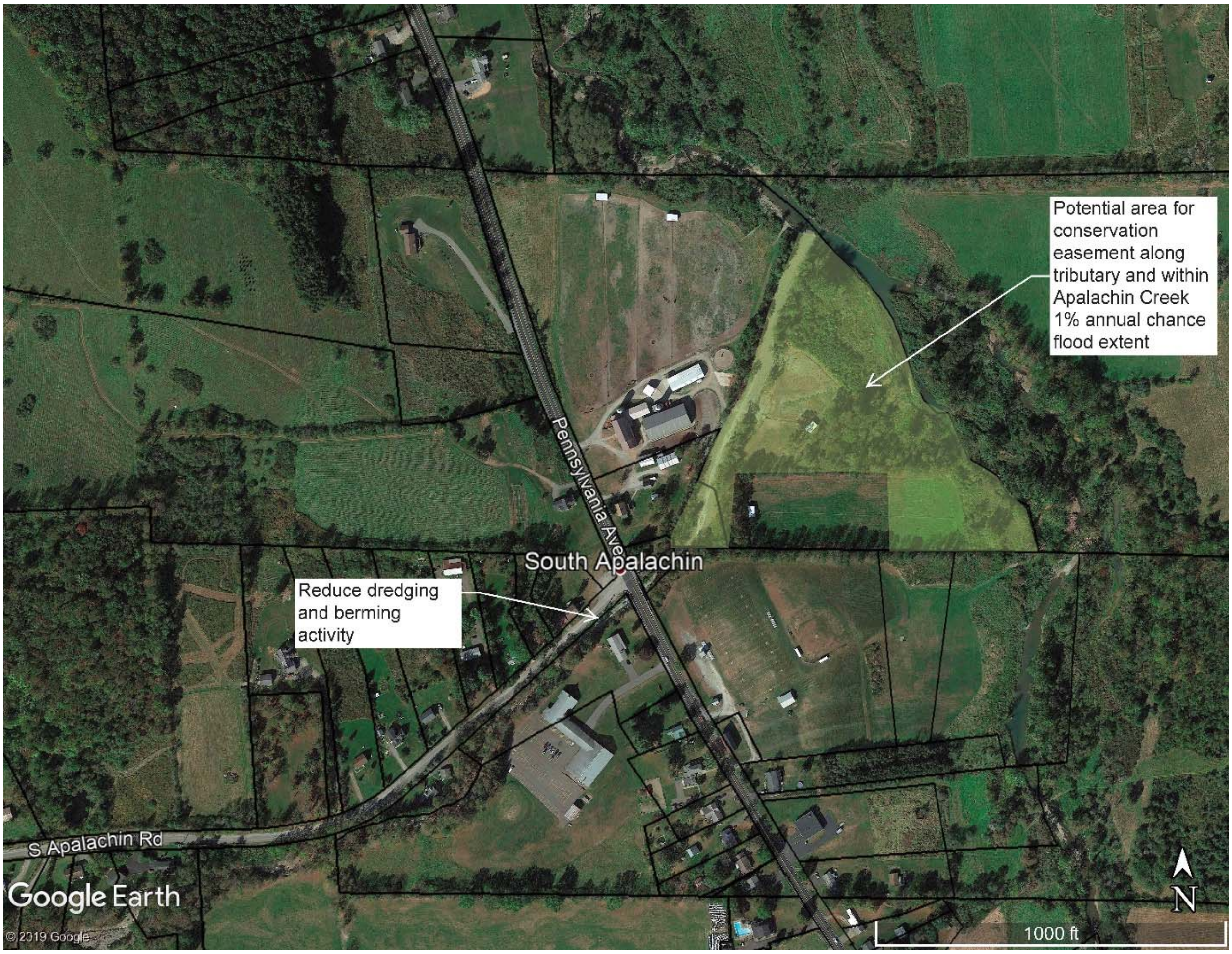

Figure 54. Proposed easement area at ApSa-1100 shown in light green shading. Parcel data obtained from NYS GIS Clearinghouse.

Figure 55. Eroding bank at ApGa-7500. Photo taken October 19, 2018.

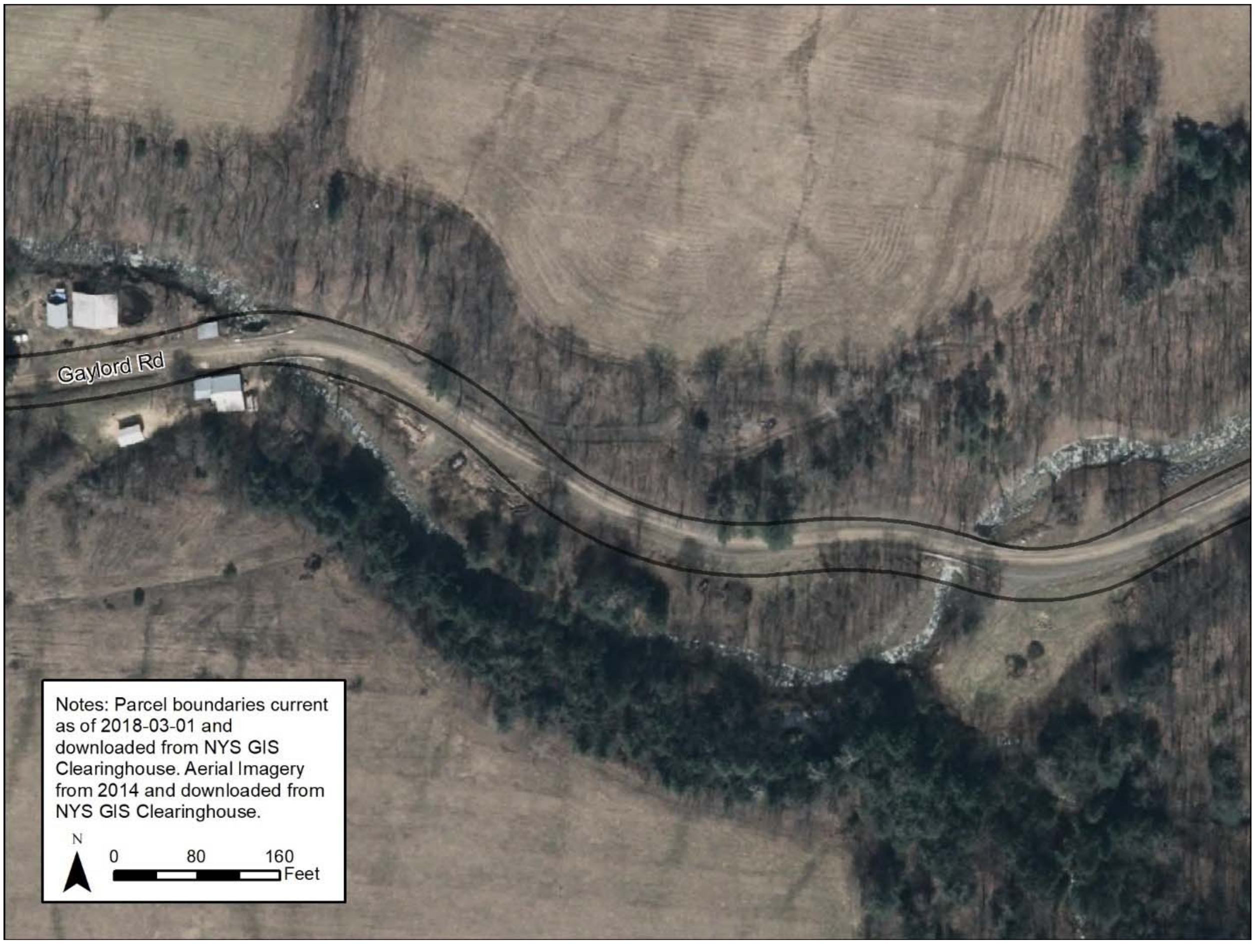

Figure 56. Aerial image of ApGa-5800. Current alignment crosses creek twice. Project proposes investigating alternative alignments to eliminate creek crossings.

Figure 57. Looking upstream at culvert outfall at ApGa-5800. Photo taken October 19, 2018.

Figure 58. Bank erosion at ApGa-3700. Photo taken October 19, 2018.

Figure 59. Eroding bank at ApGa-1700. Photo taken October 19, 2018.

Figure 60. Outlet of perched and undersized culvert at ApGa-600. Photo taken October 19, 2018.

Figure 61. Outlet of perched and undersized Long Creek Road culvert carrying tributary to Long Creek at ApLo-12000. Photo credit Fuss & O'Neill.

Figure 62. Incised road drainage ditch along Long Creek Road (ApLo-10800). Photo taken October 19, 2018.

Figure 63. Long Pond map ApLo-9800. Project proposes remeandering creek through currently existing pond to re-establish natural alignment.

Figure 64. Looking downstream from top of former floodplain and pond area at ApLo-9800. Photo taken October 19, 2018.

Figure 65. Collapsed bridge at near upstream end of pond area at ApLo-9800. Photo taken October 19, 2018.

Figure 66. Perched culvert outfall at ApLo-9200. Photo taken October 19, 2018.

Figure 67. Eroding bank at ApLo-3800. Photo taken October 18, 2018.

Figure 68. Failing rock bank protection at ApLo-3800. Photo taken March 7, 2019.

Figure 69. Culvert inlet at ApLo-3600. Photo credit Fuss & O'Neill.

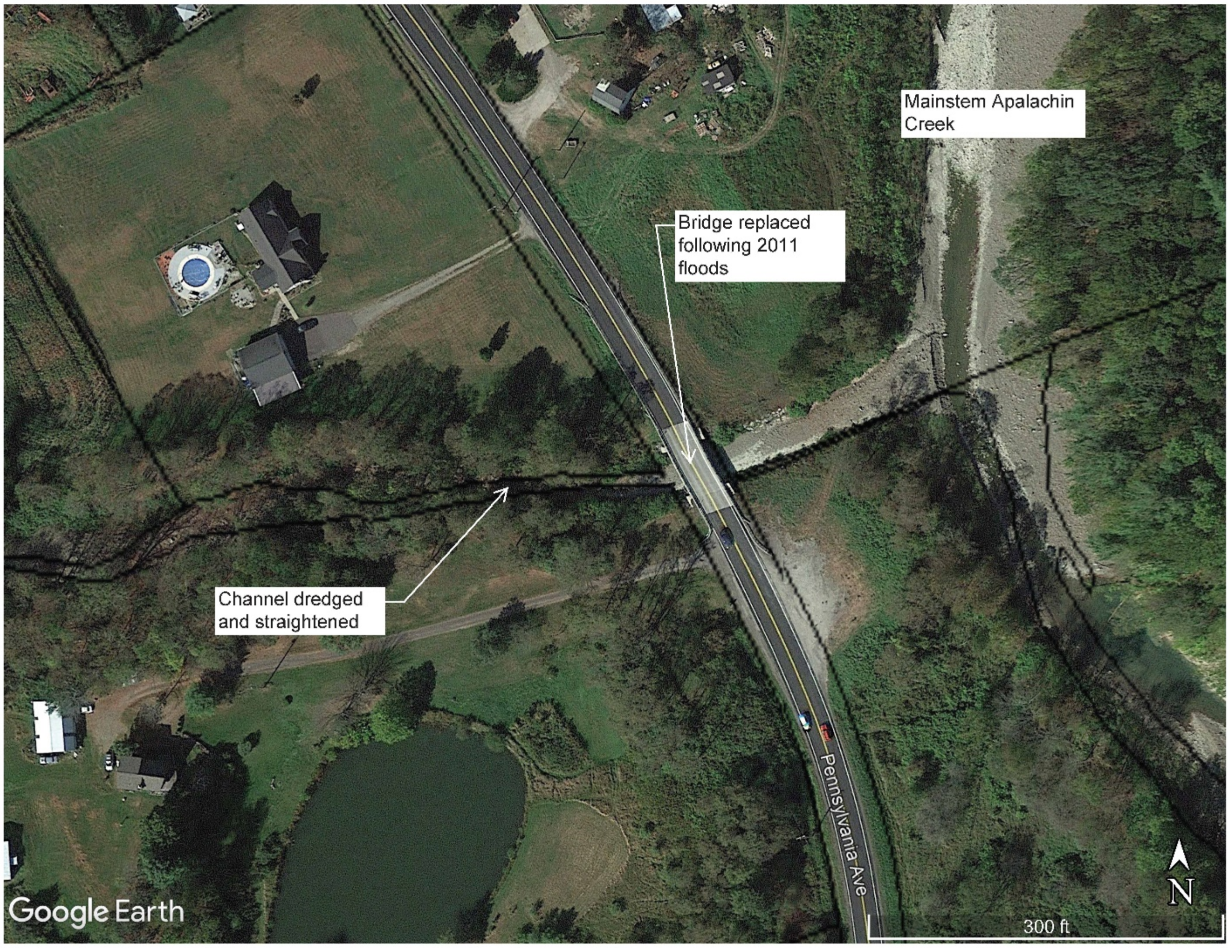

Figure 70. Long Creek at ApLo-400. Parcel boundaries from Tioga County.

Figure 71. Long Creek channel at ApLo-400. Channel has been straightened and dredged, minimizing potential access to former floodplain. Note rock bank protection and the presence of the invasive Japanese knotweed on the banks. Photo taken October 18, 2018.

Figure 72. Chestnut Ridge Road crossing at ApDl-23700. Left image shows perched outlet. Right image is looking downstream along Deerlick Creek. Photo credit Fuss & O'Neill.

Figure 73. Twin undersized and perched culverts at ApDl-21100. Photo taken October 18, 2018.

Figure 74. Eroding bank at ApDl-9000. Photo taken October 18, 2018.

Figure 75. Undersized and blocked Beach Road tributary culvert inlet at ApDl-8900. Photo taken October 18, 2018.

Figure 76. Deerlick Creek at ApDl-1500. Channel has been straightened and dredged, minimizing potential access to former floodplain. Photo taken October 18, 2018.

Figure 77. Deerlick Creek at ApDl-500. Channel has been straightened and dredged, minimizing potential access to former floodplain. Photo taken October 18, 2018.

Table 4. List of potential flood mitigation and resilience alternatives – Other projects

Project number	Type	Description
Ap-A	Public Education	Expand and formalize training and resources for the public and county and municipal staff that focus on flood resilience and natural systems solutions and management practices that support watershed resilience. Examples of specific areas of focus are the benefits of natural watershed processes such as large wood recruitment and the benefits of minimizing dredging activity. Among other sources of information and ideas are Vermont's Rivers and Roads and Flood Ready Vermont programs, Maine Audubon's Stream Smart program, the UMass Amherst River Smart Communities Program, and the National Large Wood Manual.
Ap-B	Public Education	Establish a watershed group to help guide implementation efforts, assist with fundraising, raise awareness about critical issues, educate the public, and lead stream improvement and clean-up projects.
Ap-C	Public Education	Complete a comprehensive assessment of the South Apalachin Road tributary, which was not selected as a priority tributary for the current study. Identify sources of bed material and expand the list of recommendations to address vulnerabilities throughout the tributary watershed.
Ap-D	Public Education	Expand the current project to include the Pennsylvania portion of the watershed for a truly holistic approach to addressing flood hazards and improving resilience. Work across state lines on prioritization and implementation.
Ap-E	Green Infrastructure	Encourage county departments and municipalities to exceed minimum requirements for incorporating green infrastructure and other stormwater BMPs into stormwater infrastructure planning and capital projects, as well as into comprehensive planning and other town/village/county planning documents.
Ap-F	Crossing Improvement	Amend county and municipal culvert and bridge design standards to improve crossing resilience by designing for larger floods, to maintain natural sediment transport properties (competence and capacity), and to accommodate fluctuating bed levels where appropriate.
Ap-G	Public Education	Conduct flood and erosional hazard mapping along Apalachin Creek and its tributaries. Develop interactive mapping to display results for current and future conditions. Identify evacuation routes and procedures. Host the map on a county website and advertise its availability.

Project number	Type	Description
Ap-H	Policy	Review zoning ordinances and strengthen floodplain protection, erosion control, and stormwater treatment requirements. Example potential ordinances include but are not limited to: • A No Adverse Impact (NAI) ordinance; • Fluvial erosion hazard zoning to prevent development on highly erodible streambanks; • Riparian buffer ordinance or zoning provision to restrict development within 100 feet of streams (see resources at https://www.dec.ny.gov/chemical/106345.html); and • An ordinance to allow transfer of development rights from properties located in the floodplain to properties located in upland areas. New York State Department of State (NYS DOS) in cooperation with the Department of Environmental Conservation (NYS DEC), through the Community Risk and Resiliency Act, is expected to publish Model Local Laws Concerning Climate Risk. Review the model laws when available and consider adopting relevant ordinances. See https://www.dec.ny.gov/energy/102559.html
Ap-I	Riparian Management	Establish conservation easements to protect and restore priority riparian corridors, wetlands, and forested areas. Support the program with a study that prioritizes parcels for easement acquisition.
Ap-J	Riparian Management	Establish and advertise a stream buffer program to assist private landowners in developing and implementing planting plans
Ap-K	Structure Removal	Establish a fund to support continued participation in the FEMA buyout program and facilitate additional buyouts of properties vulnerable to flooding and erosional hazards. Allow these spaces to revert to natural floodplain.
Ap-L	Upland Land Management/ Green Infrastructure	Systematically inventory roadway drainage issues and opportunities for green infrastructure and other stormwater BMPs in the watershed. Opportunities likely include stormwater detention on agricultural land; green infrastructure retrofits associated with buildings, parking lots, and driveways; and drainage improvements and low-cost linear BMPs within roadway rights of way. Review existing guidance documents (e.g. Vermont Stormwater Management Manual) and adopt/adapt as fitting.
Ap-M	Public Education	Current stormwater management education efforts focus on reducing pollutant loads. Expand the scope of the Broome-Tioga Stormwater Coalition public education and outreach efforts and www.waterfromrain.org website to also highlight the flood resilience benefits of reducing stormwater discharges. Emphasize and better incorporate information on green practices to reduce runoff such as water efficient landscaping, rain gardens, and rain barrels. Review existing stormwater BMP guides for homeowners and small businesses such as those available from the Vermont Department of Environmental Conservation (see resources at https://dec.vermont.gov/watershed/cwi/green-infrastructure). Adopt/adapt guides for use in public education efforts.
Ap-N	Riparian Management	Numerous informal stream crossings exist within the watershed. Educate private landowners about sustainable stream crossing construction and usage, including maintaining a riparian buffer and minimizing crossings.
Ap-O	Public Education	Hold workshops and circulate the New York State Forestry Voluntary Best Management Practices for Water Quality BMP Field Guide to landowners harvesting timber
Ap-P	Public Education	Hold workshops on agricultural BMPs focused on riparian area protection and water quality improvement

Project number	Type	Description
Ap-Q	Public Education	Via the New York State Hemlock Initiative, partner with NYS DEC and Cornell University Cooperative Extension to hold a Hemlock Woolly Adelgid (HWA) workshop to educate public and private landowners and managers on the importance of hemlock trees in local forests, the threat presented by HWA, and how landowners can identify and manage HWA infestations
Ap-R	Public Education	Investigate the source of sewage discharge into the Card Road tributary. Educate landowners and work with them to resolve the issue. Hold public workshops or do targeted outreach on proper disposal of sewage and maintenance of septic systems.
Ap-S	Public Education	Run a campaign to promote local electronic waste recycling programs and consumer obligations under New York law
Ap-T	Public Education	Use the opportunities created by implementation of project Ap-30000 and others to educate and involve area students. Example projects and teaching aids include: • Inclusion of students in tree and shrub planting as part of the restoration efforts; • Use of the site as an outdoor classroom with pre- and post-construction lessons and comparative studies; • Involvement of students in monitoring efforts to document post-construction geomorphic conditions and changes, water quality, and biodiversity; and • Installation of interpretive signage with engaging graphics that explain the process and benefits of stream and floodplain restoration.

6. Prioritization and Recommendation

We have ranked the site-specific projects in Table 3 according to seven metrics closely tied to the study goals and objectives:

- Flood risk – Attenuation (potential for project to attenuate floods);
- Flood risk – Damage reduction (potential for project to reduce property damage associated with inundation or erosion);
- Stream corridor infrastructure risk (potential for project to reduce risk to infrastructure located in the stream corridor and reduce risk to infrastructure users);
- Erosion/ channel stability (potential for project to improve stream stability and reduce sediment input);
- In-stream ecological benefit (potential for project to improve in-stream habitat and reduce barriers to aquatic organism passage);
- Riparian ecological benefit (potential for project to improve the quality of habitat within the wider riparian corridor); and
- Public education value.

Possible scores of 1, 5, and 9 were assigned for each metric with the first four metrics above assigned twice the weight of others for a total possible score of 99. One additional point was added to each total to provide a score out of 100. The top scoring projects are highlighted in the summary table (Appendix C).

Implementation considerations such as cost, complexity, and land ownership will also likely play into project selection; therefore, estimated cost ranges and notes on implementation have been included with the prioritization results. Estimated costs have been provided for the purpose of comparison at the screening level and not as estimates of actual project costs. The screening level cost banding shown includes estimates of the anticipated design and construction efforts but excludes other elements such as permitting. Where land purchase costs are a large proportion of project costs, fair market property values have been included; no other purchase related costs have been accounted for. Construction costs are based on review of costs for similar items in past projects and applicable reference cost data, have been adjusted for prevailing wage, and include a 30% contingency to account for uncertainty around scope, changing market factors, actual date of implementation, and other unknowns at this early stage. Costs have been developed assuming projects will be carried out individually. Cost savings may be achieved by packaging work as well as through scope reduction and value engineering in future project phases.

Overall, we recommend that downstream grade control and projects along the mainstem Apalachin Creek are implemented prior to replacing restrictive culverts in tributaries which may currently be holding back flow and sediment. However, culverts in critical condition should be closely monitored and replacement expedited to avoid substantial damages or losses. Downstream grade control should be established prior to implementing bank stabilization projects. In general, project phasing should be planned to mitigate potential downstream and upstream impacts of particular projects.

Based on the results of the prioritization, the above phasing considerations, and the funds currently available for implementation, we recommend proceeding to conceptual design with one of the following options:

- ApCa-3500 and ApCa-2400 – These projects would reduce risk to downstream property and infrastructure and improve water quality;
- ApLo-9800 – This project would eliminate a flood hazard. The current level of funding is likely insufficient to complete construction of a comprehensive restoration project; however, the first steps of draining the pond and designing the project could be completed;
- ApLo-3800– This project would help protect Long Creek Road and residential properties and would reduce coarse sediment input;
- ApDl-23700 – This project would resolve an immediate risk to infrastructure and public safety. This culvert is located in the upstream reaches of the watershed; the risk of exacerbating sedimentation or flow issues by replacing the culvert is considered low as long as the recommended grade control measures are installed; or
- One of the other crossing improvements where the current structural condition is critical and replacement would resolve an immediate risk to public safety. Potential projects include ApCa-1400, ApGa-600, and ApLo-3600. These are located in the downstream reaches of tributaries and therefore, the risk of exacerbating downstream flooding is low.

The above options would deliver immediate benefits while funding is sought for other public-facing, highly ranked but also expensive projects such as those along the mainstem Apalachin Creek. Final selection of a preferred option will depend on feedback from project partners, landowners, and the public.

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Appendix A - Inter-Fluve Field Data Collection Form

AT&T LTE 10:12 AM 15%

My Survey

Site Basics

Date and Time of survey

January 2, 2019 | 10:11 AM

Location

42.120°N 76.269°W

Watershed Name

- ○ Huntington
- ○ Apalachin
- ○ Wapasening
- ○ Other (see notes)

Stream Name

Site Name

Is this a potential project site?

- [ ] Yes
- [ ] No
- [x] Unsure

Site Photos

Site Photos

Setting

Site or Reach?
- ◯ Site
- ◯ Reach

Adjacent landuse/cover
- ◯ Forest
- ◯ Shrub
- ◯ Urban
- ◯ Field
- ◯ Industrial
- ◯ Developed Open Space

Potential for flood water storage?
- ◯ Yes
- ◯ No

Stream crossing?
- ◯ Yes
- ◯ No

Existing infrastructure?
- ◯ Yes
- ◯ No

% of bank artificially stabilized

0-25% — 25-50% — 50-75% — 75-100%

Flow inputs?
- ☐ Seep
- ☐ Tributary
- ☐ Culvert outfall

Flow outputs?
- ◯ None
- ◯ Diversion

Geomorphology

Reach Planform

Reach Type (see Montgomery-Buffington table, if applicable)

Valley Confinement

Unconfined | Partially Confined | Confined | Variable (see notes)

Bankfull Width (ft)

Bankfull Depth (ft)

Bank Height (ft) (see BEHI example)

Floodplain Connectivity?

BEHI Assessment- only do if erosion risk is obviously high

Bankfull to Bank Height Ratio

Use BEHI table to enter Index Value:

Depth of Roots (ft)

Root Depth to Bank height Ratio

Use BEHI table to enter Root Depth-Bank Height Index Value:

Root Density (%)

Use BEHI Table to enter Root Density Index Value:

Bank Angle (°)

Use BEHI table to enter Bank Angle Index Value:

Surface Protected (%)

Use BEHI table to enter Surface Protection Index Value:

Bank Angle (°)

Use BEHI table to enter Bank Angle Index Value:

Surface Protected (%)

Use BEHI table to enter Surface Protection Index Value:

BEHI Total:

Estimated Near Bank Shear Stress:

- [ ] 1-Very Low
- [ ] 2-Low
- [ ] 3-Moderate
- [ ] 4-High
- [ ] 5-Very High
- [ ] 6-Extreme

Riparian Vegetation

% Bank Covered By Woody Veg:

0-25% | 25-50% | 50-75% | 75-100%

Invasives Present?

- Yes
- No

Species Present

- Hemlock
- Maple
- Poplar
- Beech
- Birch
- Ash
- Spruce
- Sumac
- Knotweed
- Ironwood
- Other (see notes)

Riparian Zone Width (# of Bankfull Channels Wide):

0 to 0.5 | 0.5 to 1 | 1 to 2 | > 2

Bed Substrate

Bed Substrate (select 1-3)

- [ ] Clay (Stick Mud)
- [ ] Silt (Mud)
- [ ] Sand (< 2 mm)
- [ ] Fine Gravel (< 8 mm; ladybug)
- [ ] Coarse Gravel (< 64 mm, golf ball)
- [ ] Cobble (< 256 mm; volleyball)
- [ ] Boulders (> 256 mm; basketball)
- [ ] Bedrock (> 4096 mm; 13.5 ft)

Embeddedness (burial of gravel, cobbles by fine sediment)

0-25% 25-50% 50-75% 75-100%

Is the bed armored (depleted of fines)?

- ○ Yes
- ○ No

Sediment Dynamics

Mass wasting occurring along the reach?

- ◯ Yes
- ◯ No

Dominant sediment sources:

- ☐ Fluvial
- ☐ Hillslope
- ☐ Bank Failure
- ☐ Debris Flow

Dominant sediment transport mode:

- ◯ Suspended
- ◯ Bedload
- ◯ Mix

In-stream largewood presence:

- ◯ None
- ◯ Minimal
- ◯ Moderate
- ◯ Abundant

Bars (select multiple, if applicable):

- ☐ Point
- ☐ Mid Channel
- ☐ Lateral
- ☐ Terrace
- ☐ Sand Sheets
- ☐ None

Evidence of flood impacts (select multiple, if applicable):

- ☐ Debris Jams
- ☐ Floodplain Sedimentation
- ☐ Severe Erosion
- ☐ Other (see notes)
- ☐ None

Channel Stability

Evidence of Degradation:

- [ ] Banks undercut
- [ ] Exposed "air" roots
- [ ] Leaning Trees
- [ ] Suspended Culvert
- [ ] Headcuts
- [ ] Terraces
- [ ] Armored Bed
- [ ] Perched Channel/Tribs
- [ ] Exposed pipe crossing
- [ ] Undercut bridge piers
- [ ] Incised channel
- [ ] Failed stabilization

Evidence of Aggradation:

- [ ] Buried Culverts
- [ ] Sedimetation of FP
- [ ] Sedimentation of Bars
- [ ] Reduced bridge clearance
- [ ] Fine grains covering bed
- [ ] Mid Channel Bars
- [ ] Buried Veg
- [ ] Backwatering of Trib(s)
- [ ] Channel at or above FP elev.

Evidence of Stability

- [ ] Vegetated bars or banks
- [ ] Bridges or culverts with bottom near grade
- [ ] Limited bank erosion
- [ ] Tribs entering at or near grade
- [ ] Tree roots flush with bank

Stage of Channel Evolution (see Simon, Channel Evol. Model)

- ○ Class I - Stable / Pre-modified
- ○ Class II - Channelized
- ○ Class III - Bed Incision
- ○ Class IV - Incision and Widening
- ○ Class V - Aggradation and Widening
- ○ Class VI - Quasi-equilibrium
- ○ N/A - Constructed Concrete or Rip Rap Channel

Habitat

Water Quality

- ◯ Poor
- ◯ Fair
- ◯ Good
- ◯ Excellent

Water Quality Issues

- ☐ Stormwater Runoff
- ☐ Algae
- ☐ High Water Temp
- ☐ Stagnation
- ☐ Other (see notes)

Canopy cover

- ◯ None
- ◯ Minimal
- ◯ Moderate
- ◯ Full

Instream Habitat Notes:

Recommended Actions

Potential Restoration/Resiliency Enhancements

- ☐ Enhance Floodplain Connectivity
- ☐ Reduce Floodplain Development
- ☐ Enhance Floodplain Roughness
- ☐ Enhance Channel Roughness
- ☐ Bed grade controls
- ☐ Large wood installation
- ☐ Instream habitat
- ☐ Off-channel habitat
- ☐ Dam removal
- ☐ Bridge/Culvert Replacement
- ☐ Levee removal
- ☐ Bank Stabilization
- ☐ Re-meander

Other Restoration, Describe:

Site Access/Constraints

Is the site on private or public property?

- Private
- Public
- Private/Public
- Unsure

Assess site accessibilty:

Is there a reasonable place for staging?

Note any obvious constraints:

General Notes

Notes:

Appendix B - Crossings Assessment by Fuss & O’Neill

FUSS & O'NEILL

MEMORANDUM

TO: Candice Constantine, Inter-Fluve Engineering

FROM: Erik Mas, PE, Rachael Weiter, EIT, Fuss & O'Neill, Inc.

DATE: June 28, 2019

RE: Regional Susquehanna River Initiative Floodplain Management and Stream Restoration Assessment and Design
Road-Stream Crossing Assessment – Apalachin Creek Watershed

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1 Introduction

Inadequate or undersized road-stream crossings can be flooding and washout hazards and can serve as barriers to the passage of fish and other aquatic organisms. In the Upper Susquehanna River watershed, inadequate or undersized road-stream crossings contributed to the widespread damage to homes and businesses, transportation infrastructure, utilities, and stream channel erosion that occurred during both Tropical Storm Irene and Tropical Storm Lee in 2011.

Fuss & O'Neill assessed selected road-stream crossings in the Apalachin Creek watershed in support of Tioga County Soil and Water Conservation District's (TCSWCD's) Regional Susquehanna River Initiative Floodplain Management and Stream Restoration Assessment and Design project. The primary goal of the overall project is to increase resilience to flooding and flood-related impacts within the priority watersheds in Tioga County, Broome County, and the community of Sidney, including the Apalachin Creek watershed. Project objectives include utilizing and restoring natural watershed processes that help mitigate flooding and flood-related impacts, combined with infrastructure-based approaches, land use practices and policy, and improving public awareness.

The assessments consisted of field surveys of individual stream crossings using established road-stream crossing assessment protocols, followed by analysis of the field data to assign vulnerability ratings to each crossing based on multiple factors including hydraulic capacity, structural condition, geomorphic risk, aquatic organism passage, transportation and emergency services, other flooding impacts, and climate change considerations. The vulnerability ratings are used to prioritize structures for upgrade or replacement. The road-stream crossing assessments were conducted in conjunction with stream channel and floodplain geomorphic assessments completed by Inter-Fluve. The results of the stream crossing and geomorphic assessments will inform the selection of infrastructure and natural system solutions to increase flood resilience in the watershed.

This memorandum summarizes the methods and results of the road-stream crossing field surveys and vulnerability assessment. Recommendations are presented based on field observations and the vulnerability assessment and prioritization process.

2 Stream Crossing Field Surveys

2.1 Selection of Crossings

Road-stream crossings to be included in the assessment were initially identified based on review of aerial imagery, flood mapping, and other local, county, or state-wide data layers. TCSWCD and the project partners also identified stream crossings where flooding has occurred or that are known or suspected flow constrictions based on recent and historical flood events. The number of crossings selected for assessment in the Apalachin Creek watershed was also dictated by the available project budget and the need to assess crossings in the other priority watersheds that are included in the study.

Sixteen road-stream crossings in the Apalachin Creek watershed were ultimately selected for field surveys and vulnerability assessment. The locations of the selected crossings are shown on the watershed map in Figure 1. Summary information on each crossing is provided in Table 1.

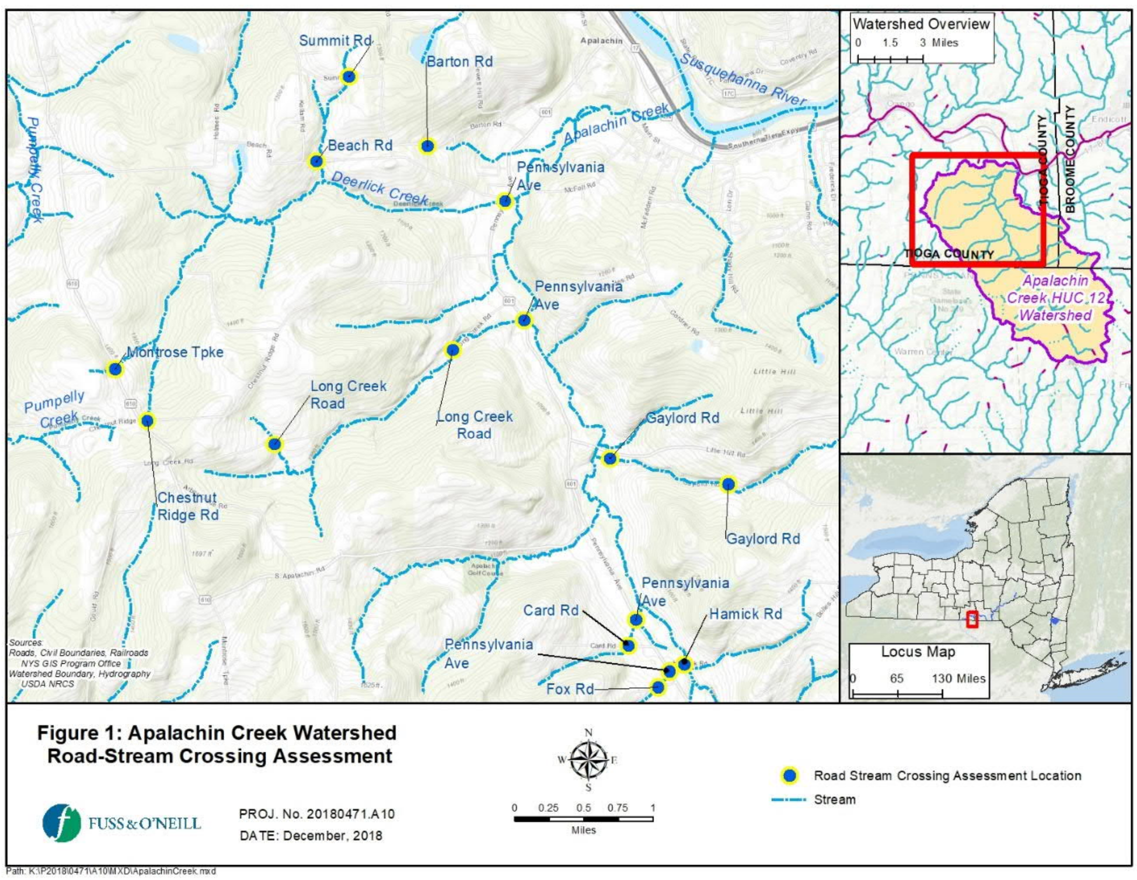


Figure 1. Road-stream crossings selected for assessment in the Apalachin Creek watershed

All of the selected crossings are in the Town of Owego in Tioga County. The locations include one (1) crossing of the Apalachin Creek mainstem and 15 crossings of named and unnamed tributaries to Apalachin Creek. Four (4) of these crossings are located on Pennsylvania Avenue, the only major road and the main corridor through the watershed.

Table 1. Road-stream crossings selected for assessment in the Apalachin Creek watershed

Stream	Road Name	Description	Ownership	Road Type	Crossing Type	Structure Material
Unnamed	Summit Road	Culvert under public road	County	Paved	Round Culvert	Corrugated Plastic
Unnamed Tributary to Deerlick Creek	Beach Road	Culvert under public road	County	Paved	Round Culvert	Smooth Metal
Unnamed Tributary to Apalachin Creek	Barton Road	Culvert under public road – Drainage Ditch	County	Paved	Round Culvert	Corrugated Plastic
Deerlick Creek	Pennsylvania Avenue	Public Bridge	County	Paved	Bridge	Metal, Concrete
Long Creek	Pennsylvania Avenue	Public Bridge	County	Paved	Bridge ID 8370930	Metal, Concrete
Long Creek	Long Creek Road	Culvert under public road	County	Paved	Arched Culvert (State ID 2218740)	Corrugated Metal
Unnamed Tributary to Long Creek	Long Creek Road	Culvert under public road	County	Paved	Round Culvert	Corrugated Plastic
Deerlick Creek	Chestnut Ridge Road	Culvert under public road	County	Paved	Round Culvert	Smooth Plastic
Unnamed Tributary to Deerlick Creek	Montrose Turnpike	Culvert under public road	County	Paved	Round Culvert	Smooth Plastic
Unnamed Tributary to Apalachin Creek	Gaylord Road (downstream crossing)	Culvert under public road	County	Paved	Arched Culvert	Corrugated Metal
Unnamed Tributary to Apalachin Creek	Gaylord Road (upstream crossing)	Culvert under public road	County	Paved	Round Culvert	Corrugated Metal
Unnamed Tributary to Apalachin Creek (Card Road Tributary	Pennsylvania Avenue	Culvert under public road	County	Paved	Arched Culvert	Corrugated Metal
Unnamed Tributary to Apalachin Creek (Card Road Tributary)	Card Road	Culvert under public road	County	Paved	Round Culvert	Corrugated Metal
Apalachin Creek	Harnick Road	Public Bridge	County	Paved	Bridge	Wood, Metal
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	Culvert under public road	County	Paved	Box Culvert	Concrete
Unnamed Tributary to Apalachin Creek	Fox Road	Culvert under public road	County	Paved	Round Culvert	Corrugated Metal

2.2 Field Data Collection

Field surveys of the selected crossings were conducted on October 22 and 23, 2018 using road-stream crossing assessment procedures and field data collection forms adapted from the North Atlantic Aquatic Connectivity Collaborative (NAACC) and similar standardized assessment protocols used in the northeastern U.S. In addition to the 2016 NAACC stream crossing survey protocol for assessing aquatic connectivity, the road-stream crossing survey methods used for this project also incorporated structural condition assessment protocols from the 2017 NAACC Culvert Condition Assessment Manual and collection of other field data for evaluating geomorphic vulnerability, hydraulic capacity, and potential flooding impacts to infrastructure and public services. Digital photographs were also taken at each crossing. A blank copy of the field data collection form is provided in Attachment A.

The crossing surveys were performed by a two-person field crew consisting of a water resources engineer and wetland scientist. The field crew was led by a NAACC-Certified Lead Observer; additional training was also provided for all field personnel prior to the field work. Digital field data collection methods were used to complete the crossing surveys, using a GPS-enabled tablet with a pre-loaded digital version of the field form and aerial imagery for the project locations. Field data for the project are saved and managed using an ArcGIS database and web application (Figure 2). Following the stream crossing surveys, field data were checked for quality control purposes.

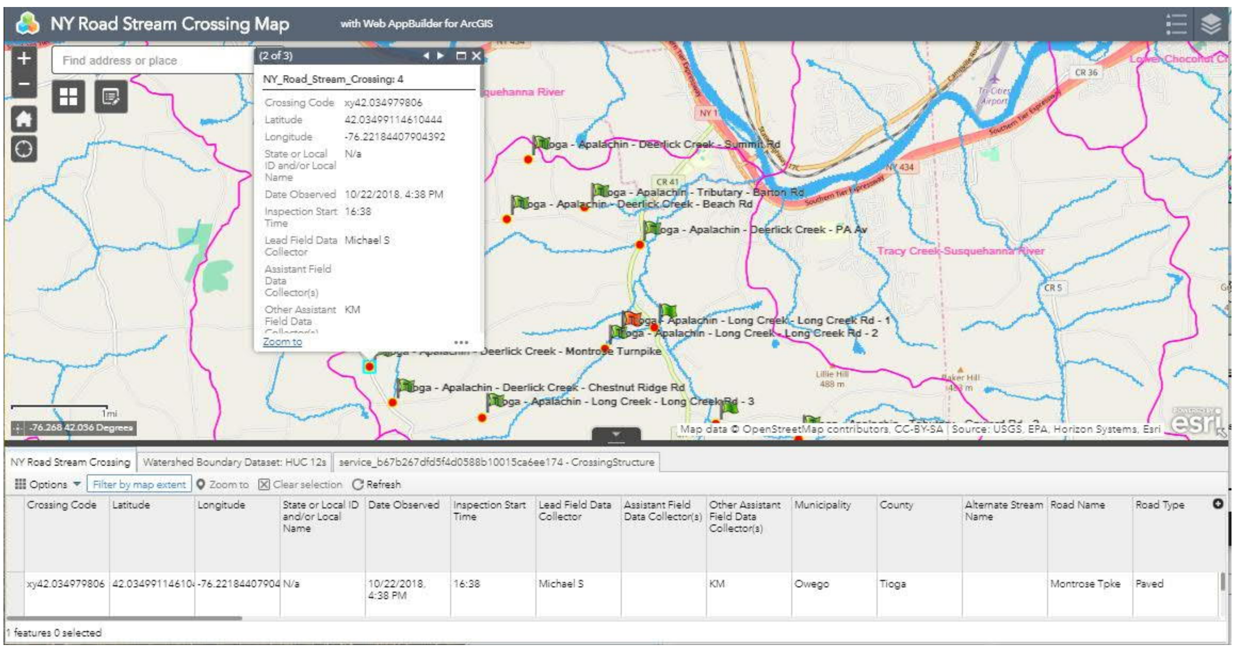


Figure 2. ArcGIS web application for Apalachin Creek watershed stream crossing survey data

2.3 Crossing Survey Findings Summary

Table 2 summarizes key field data and findings of the road-stream crossing surveys for the Apalachin Creek watershed.

The following issues were observed at the surveyed stream crossings:

- Poor Structural Condition: Many of the crossings (Summit Road, Beach Road, Barton Road, Long Creek Road, Chestnut Ridge Road, Gaylord Road, Pennsylvania Avenue, Card Road, and Fox Road) were observed to be in poor condition and in need of significant repairs or replacement. Significant erosion of the crossing embankment and unstable or deteriorating wingwalls are common at many of these crossings.

Table 2. Summary data for road-stream crossing field surveys in the Apalachin Creek watershed

Stream	Road Name	Structural Condition	Flow Constriction	Physical Barrier	Channel Erosion	Sediment Deposition
Unnamed Tributary to Deerlick Creek	Summit Road	Poor	Severe	Yes	Low	Upstream
Unnamed Tributary to Deerlick Creek	Beach Road	Critical	Severe	Yes	Upstream and downstream banks; Downstream channel scoured to bedrock	Upstream, downstream
Unnamed Tributary to Apalachin Creek	Barton Road	Poor	Severe	No	Upstream and downstream banks	Downstream
Deerlick Creek	Pennsylvania Avenue	Adequate	Moderate	No	Not significant	Not Significant
Long Creek	Pennsylvania Avenue	Adequate	Moderate	No	Upstream and downstream banks	Upstream, downstream, and within structure
Long Creek	Long Creek Road	Critical	Moderate	No	Upstream and downstream banks	Upstream, downstream, and within structure
Unnamed Tributary to Long Creek	Long Creek Road	Poor	Severe	No	Upstream and downstream banks	Upstream, Downstream
Deerlick Creek	Chestnut Ridge Road	Critical	Severe	Yes	Moderate upstream bank erosion and severe downstream bank erosion	Upstream, downstream, and within structure
Unnamed Tributary to Deerlick Creek	Montrose Turnpike	Poor	Moderate	Yes	Not significant	Not significant
Unnamed Tributary to Apalachin Creek	Gaylord Road (downstream crossing)	Critical	Severe	Yes	Severe upstream and downstream bank erosion	Upstream, downstream, and within structure
Unnamed Tributary to Apalachin Creek	Gaylord Road (upstream crossing)	Poor	Severe	Yes	Upstream and downstream banks	Upstream, downstream.
Unnamed Tributary to Apalachin Creek (Card Road Tributary)	Pennsylvania Avenue	Critical	Moderate	Yes	Upstream and downstream banks	Upstream, downstream, and within structure
Unnamed Tributary to Apalachin Creek (Card	Card Road	Critical	Severe	Yes	Upstream and downstream banks	Upstream, downstream, and within structure

Stream	Road Name	Structural Condition	Flow Constriction	Physical Barrier	Channel Erosion	Sediment Deposition
Road Tributary)						
Apalachin Creek	Harnick Road	Adequate	Moderate	No	Upstream and downstream banks	Upstream, downstream, and within structure
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	Adequate	Moderate	No	Upstream and downstream banks	Upstream, downstream, and within structure
Unnamed Tributary to Apalachin Creek	Fox Road	Poor	Severe	Yes	Upstream and downstream banks	Upstream, downstream, and within structure

- Flow Constriction: Virtually all of the assessed crossings, including the assessed culverts and bridges, are significantly narrower than the bankfull width of the stream channel and therefore appear to constrict flood flows. The hydraulic capacities of many of the crossings in the watershed are limited due to undersized crossing structures and/or significant accumulation of sediment at some locations.
- Physical Barriers: Most of the upstream private and public crossings serve as full or partial barriers to aquatic organism passage. The stream crossings on Beach Road, Barton Road, Montrose Turnpike, Chestnut Ridge Road, Gaylord Road (downstream crossing), and Card Road have perched outlets, while the downstream crossing on Long Creek Road and the upstream crossing on Gaylord Road have cascading outlets.
- Channel Erosion: Varying degrees of stream channel erosion were observed in the reaches immediately upstream and/or downstream of the assessed crossings. Efforts to repair recent channel erosion through channel grading and bank stabilization were evident at several of the surveyed locations.
- Sediment Deposition: Substantial sediment deposition was observed at the crossings in the low-gradient, lower reaches of Apalachin Creek (i.e., Pennsylvania Avenue, Harnick Road, Long Creek Road) and generally upstream of crossings that constrict flow. The sediment deposition has reduced flow conveyance capacity, increased potential for blockage or clogging during higher flows, and potentially restricts aquatic passage during low-flow conditions.

3 Vulnerability Assessment and Prioritization

Using data from the stream crossing surveys and available GIS data, each of the assessed crossings was assessed for vulnerability to flooding and associated impacts relative to hydraulic capacity, structural condition, geomorphic conditions, aquatic organism passage, transportation services, land use, and climate change considerations. The vulnerability and impact ratings were then combined to generate an overall rating, which was used to assign a priority to each crossing for potential upgrade or replacement.

3.1 Assessment Method

The following individual assessments were performed for each stream crossing:

- Existing and Projected Future Streamflow: Estimated existing and future (climate change scenario) peak discharge for common recurrence intervals using regional regression equations developed by USGS for estimating peak flows at ungaged locations (i.e., StreamStats). Flood flows under future climate change were estimated using a design flow multiplier of 1.2 (20% increase) recommended by the New York State Department of Environmental Conservation for Tioga County in the draft Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act.
- Hydraulic Capacity: Estimated the hydraulic capacity of each road-stream crossing using standard Federal Highway Administration culvert/bridge hydraulic calculation methods following FHWA Hydraulic Design Series Number 5 (HDS-5). Bentley CulvertMaster, which employs HDS-5 methods, was used for the analysis. Hydraulic capacity was determined for a selected headwater depth, which represents that depth at which the crossing is at risk of structural failure or the roadway is at risk of overtopping, depending on crossing type and material. Manning's Equation for uniform open channel flow was used to estimate the crossing hydraulic capacity for lager structures (bridges) or where the cross-sectional area could not be approximated with CulvertMaster. A capacity ratio (defined as the ratio of estimated hydraulic capacity to the estimated peak discharge for a specified return interval) was calculated for each crossing for existing and projected future peak streamflow.
- Structural Condition: Assigned condition ratings and scores based on visual observation of the structural condition of the crossing inlet, outlet, and barrel adapted from the latest version of the NAACC Culvert Condition Assessment Manual, which was developed with input from state transportation departments throughout the Northeast and other stakeholders. The NAACC condition assessment methodology is designed as a rapid assessment tool for use by trained observers for purposes of flagging crossings that should be examined more closely for potential structural deficiencies.
- Geomorphic Impacts: Assessed the potential for crossing structures to impact geomorphic processes that might, in turn, threaten the structure itself and other adjacent infrastructure. The assessment procedure distinguishes between crossings that are: 1) not prone to and have not experienced geomorphic adjustments; 2) prone to but have not experienced geomorphic adjustments; and 3) prone to and have experienced geomorphic adjustments. The approach rates the relative likelihood that impacts could occur and the type and severity of impacts that have already occurred. Factors that were considered include stream alignment, bankfull width, degree of constriction, significant breaks in valley slope, bank erosion, sediment deposition, structure and channel slope, stream bed material, and other geomorphic parameters.

- Aquatic Organism Passage: Assessed aquatic organism passage (AOP) using the latest NAACC protocols and rating system for assessing stream continuity. The method was adapted from the NAACC Numeric Scoring System for AOP, which was developed with input from multiple experts in aquatic passability. The NAACC Numeric Scoring System methodology is designed as a quantitative but rapid assessment tool for use by trained observers. The assessment is not species-specific, but rather seeks to evaluate passability for the full range of aquatic organisms likely to be found in rivers and streams.
- Impacts to Transportation Services: Evaluated the potential disruption of transportation services resulting from single crossing failures by considering the functional classification of the roadway (i.e., level of travel mobility and access to property that it provides). Disruption of transportation services is assumed to occur if the crossing is either overtopped or washed away by flooding, as either failure mode would prohibit the use of the road-stream crossing by traffic.
- Other Potential Flooding Impacts: Assessed the potential impact to existing development, infrastructure, and land use upstream and downstream of each stream crossing in the event of failure of the crossing. A potential impact area was approximated for each crossing, having a width defined by buffering the stream centerline by a distance equal to two times the bankfull width, and a length defined as 0.5 miles upstream and downstream of the crossing. Flooding vulnerability was quantified based on the percentage of developed land cover, using 1-meter resolution land cover data for the Chesapeake Bay watershed, and the presence of upstream or downstream crossings within the impact area, as well as any infrastructure (gas, sewer, water, etc.) observed to be attached to or located within the crossing structure.

3.2 Prioritization Method

The crossing structures were assigned a relative priority for upgrade or replacement based on the results of the individual assessments and consideration of failure risk. Failure risk is defined as the product of the probability of failure of a crossing (i.e., vulnerability) and the potential consequences of failure (i.e., impacts). A crossing may be at risk if the probability of failure is high, if the consequences of failure are high, or both. An overall priority score was calculated based on the combined hydraulic risk (existing and future climate change), geomorphic risk, structural risk, and aquatic organism passability of each crossing. The combined hydraulic risk, geomorphic risk, and structural risk was weighted more heavily (approximately 90%) than aquatic organism passability (approximately 10%) given the limited high-quality fisheries habitat in the watershed. It is important to note that the crossing priority scores should only be used for relative comparisons between crossings.

3.3 Assessment and Prioritization Results

Table 3 summarizes the hydraulic risk, geomorphic risk, structural risk, and aquatic organism passability scores, as well as the relative priority score (normalized on a scale of 0 to 1) for each crossing. The detailed road-stream crossing assessment and prioritization worksheets and scores are provided in Attachment B.

Table 3. Road-Stream crossing vulnerability assessment and prioritization results summary

Stream	Road Name	Crossing Type	Hydraulic Risk Score (2-50)	Geomorphic Risk Score (2-50)	Structural Risk Score (2-50)	Aquatic Passability Score (1-5)	Crossing Priority Score (0-1)
Unnamed Tributary to Deerlick Creek	Summit Road	Round Culvert	4	8	4	5	0.19
Unnamed Tributary to Deerlick Creek	Beach Road	Round Culvert	2	10	10	5	0.23
Unnamed Tributary to Apalachin Creek	Barton Road	Round Culvert	10	10	10	4	0.21
Deerlick Creek	Pennsylvania Avenue	Bridge	5	10	5	1	0.15
Long Creek	Pennsylvania Avenue	Bridge (State ID 8370930)	6	18	30	1	0.54
Long Creek	Long Creek Road	Arched Culvert ID 2218740	4	12	20	3	0.38
Unnamed Tributary to Long Creek	Long Creek Road	Round Culvert	10	8	10	3	0.19
Deerlick Creek	Chestnut Ridge Road	Round Culvert	2	10	10	2	0.17
Unnamed Tributary to Deerlick Creek	Montrose Turnpike	Round Culvert	15	12	3	5	0.33
Unnamed Tributary to Apalachin Creek	Gaylord Road (downstream crossing)	Arched Culvert	12	12	15	5	0.33
Unnamed Tributary to Apalachin Creek	Gaylord Road (upstream crossing)	Round Culvert	12	12	15	5	0.33
Unnamed Tributary to Apalachin Creek (Card Road Tributary)	Pennsylvania Avenue	Arched Culvert	25	15	25	1	0.44
Unnamed Tributary to Apalachin Creek (Card Road Tributary)	Card Road	Round Culvert	3	12	15	4	0.31
Apalachin Creek	Harnick Road	Bridge	12	12	4	1	0.19
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	Box Culvert	12	24	12	2	0.44
Unnamed Tributary to Apalachin Creek	Fox Road	Round Culvert	20	16	20	2	0.37

Hydraulic Risk

Several of the assessed crossings in the Apalachin Creek watershed are hydraulically undersized, having insufficient capacity to convey the 10-year peak flow (Barton Road, Long Creek Road over the unnamed tributary to Long Creek, Montrose Turnpike, Pennsylvania Avenue over an unnamed tributary to Apalachin Creek, and Fox Road). Several other crossings are hydraulically undersized relative to the 25-year return interval flow, including the two Gaylord Road crossings. The Pennsylvania Avenue crossing noted above and the Fox Road crossing received the highest hydraulic risk scores.

Geomorphic Risk

Many of the assessed crossings were rated as having moderate to severe observed geomorphic impacts, combined with possible to likely potential geomorphic impacts. Crossings with the highest geomorphic risk include Pennsylvania Avenue over Long Creek, the two Pennsylvania Avenue crossings over unnamed tributaries to Apalachin Creek, and the Fox Road crossing.

Structural Risk

Many of the assessed crossings were rated as poor or critical relative to structural condition. Pennsylvania Avenue over Long Creek, Pennsylvania Avenue over the unnamed tributary to Apalachin Creek, Long Creek Road over Long Creek, and the Fox Road crossing received the highest structural risk scores based on structural condition and potential for flooding impacts in these areas.

Aquatic Organism Passage

Over half of the assessed crossings are moderate to severe barriers to aquatic organism passage. Other crossings, such as the downstream Pennsylvania Avenue crossings and the Harnick Road crossing, provide full aquatic passage or are only minor or insignificant barriers.

Prioritization

The Pennsylvania Avenue crossings at Long Creek and at the unnamed tributaries to Apalachin Creek received the highest overall crossing priority scores, followed by crossings at Long Creek Road at Long Creek, Fox Road, Montrose Turnpike, the Gaylord Road crossings.

4 Recommendations

Recommendations were developed for the stream crossings in the Apalachin Creek watershed that were evaluated as part of this assessment. These planning-level recommendations are intended to enhance the resilience of the stream crossings and river system by withstanding extreme flood events, providing for the passage of debris during floods, and providing for passage of aquatic organisms under normal flow conditions. At several of the crossings, we also recommend channel or floodplain restoration in upstream or downstream areas along with the proposed crossing upgrades to enhance flood resilience, water quality, and aquatic habitat using a combination of natural and infrastructure-based approaches.

Planning-level cost estimates are provided for each of the recommendations. Estimated costs are presented as screening-level cost ranges for the purpose of comparing and prioritizing various alternatives and to help select a preferred alternative based on relative project benefits and costs. The planning-level cost ranges include estimates of the anticipated design and construction costs, adjusted for prevailing wage rates, and contingency. Design and construction costs are based on costs of recent similar stream crossing replacement projects in the northeastern U.S.

The following sections provide a summary of the existing issues, recommendations, and screening-level cost ranges for the stream crossings in the Apalachin Creek watershed where upgrades or replacement are recommended.

4.1 Beach Road over Unnamed Tributary to Deerlick Creek

Existing Issues

- The structure inlet is partially blocked by debris. Gabions at the inlet are collapsing and the structure is deformed at the inlet.
- The structure, as designed, has sufficient hydraulic capacity to convey the 100-year peak flow, although the flow capacity is reduced by the debris blockage at the inlet. The structure width is significantly smaller than bankfull width, which constricts streamflow.
- The structure outlet is perched approximately 4.6 feet above the downstream streambed.
- The streambanks upstream and downstream of the structure are eroded and overhanging.
- The streambed downstream of the structure has been scoured to bedrock, while a substantial amount of sediment has been deposited upstream of the culvert.

Beach Road over Unnamed Tributary to Deerlick Creek - structure inlet. Note debris blocking inlet. Gabions behind debris near culvert base are partially or fully collapsed.

Beach Road over Unnamed Tributary to Deerlick Creek - structure outlet. Note that culvert is perched 4.6 feet above streambed. Downstream channel has been scoured to bedrock due to high-velocity flows exiting culvert and limited sediment supply (likely due to constriction).

Recommendations

- Replace the structure with an appropriately-sized structure aligned with the stream channel to reduce flood risk, improve public safety, and provide aquatic passage.
- Remove the gabions and debris, and use the material and additional large wood to restore the streambed and banks.

Screening-Level Cost Estimate

- Replace Crossing: $500K-$1M (estimated $500-800K)

4.2 Pennsylvania Avenue over Long Creek

Existing Issues

- The streambanks on the upstream side of the crossing and the armoring below the structure are severely eroded.
- The structure has sufficient hydraulic capacity to convey the 100-year peak flow.

Pennsylvania Avenue over Long Creek - structure inlet. Note the bank erosion on the upstream side of the crossing and scour of the embankment at the crossing structure.

Pennsylvania Avenue over Long Creek - structure outlet. Note the erosion of the embankment and armoring below and immediately downstream of the crossing structure.

Recommendations

- Restore the eroded streambanks and replace armoring at the bridge abutments.

Screening-Level Cost Estimate

- Streambank Restoration and Armoring: Costs to be provided by Inter-Fluve

4.3 Long Creek Road over Long Creek (downstream of Section 4.4 crossing)

Existing Issues

- The structure has sufficient hydraulic capacity to convey the 100-year peak flow, although this capacity has likely been reduced due to sediment deposits at the inlet and within the structure. The crossing also constricts streamflow since the structure is significantly narrower than bankfull width.
- Erosion of material from the road embankment threatens the integrity of the guardrail and possibly the road.
- The structure is deformed and undermined, and footings are exposed.
- At the outlet, gabions are used to armor the downstream right bank for over 150 feet. The other streambanks both upstream and downstream of the structure are severely eroded.
- Sediment deposits are located in the channel and in the structure.

Long Creek Road over Long Creek (downstream of Section 4.4 crossing) - structure inlet. Note different wingwall materials on either side of outlet; exposed footings; and deformation of structure.

Long Creek Road over Long Creek (downstream of Section 4.4 crossing). Photograph of downstream channel. Note gabions retaining bank on right, eroded bank on left, and sediment deposition on left side of channel. Gabions farther downstream are undermined and leaning into stream.

Recommendations

- Replace the structure with an appropriately-sized structure to reduce flood risk, improve public safety, and enhance aquatic passage.
- Remove the gabions and restore the streambanks with large wood and plantings; lay back the banks to reconnect the floodplain if space is available.
- Identify upstream sediment sources and restore those locations to reduce sediment inputs to location.

Screening-Level Cost Estimate

- Replace Crossing: $250-500K
- Pair with replacement of the crossing described in Section 4.4 (Long Creek Road over Unnamed Tributary to Long Creek) to achieve cost efficiencies for each.

4.4 Long Creek Road over Unnamed Tributary to Long Creek

Existing Issues

- The crossing is severely undersized (capable of passing significantly less than the 10-year peak flow) and severely limits fish passage.
- The structure is deformed at the outlet, and the wingwalls are misaligned or collapsed.
- Fill above the structure is eroding from under the road, and appears to be supported in part by exposed geotechnical fabric.
- The road appears to have overtopped during past flooding, based on the amount of material that appears to have washed over the road.

Long Creek Road over Unnamed Tributary to Long Creek - structure outlet. Note deformed outlet of pipe; misaligned wingwalls; vertical hydraulic drop downstream of outlet, and eroding soil and exposed geotechnical fabric supporting the road above the culvert.

Recommendations

- Replace the crossing with an appropriately-sized structure to reduce flood risk, improve public safety, and provide aquatic passage.

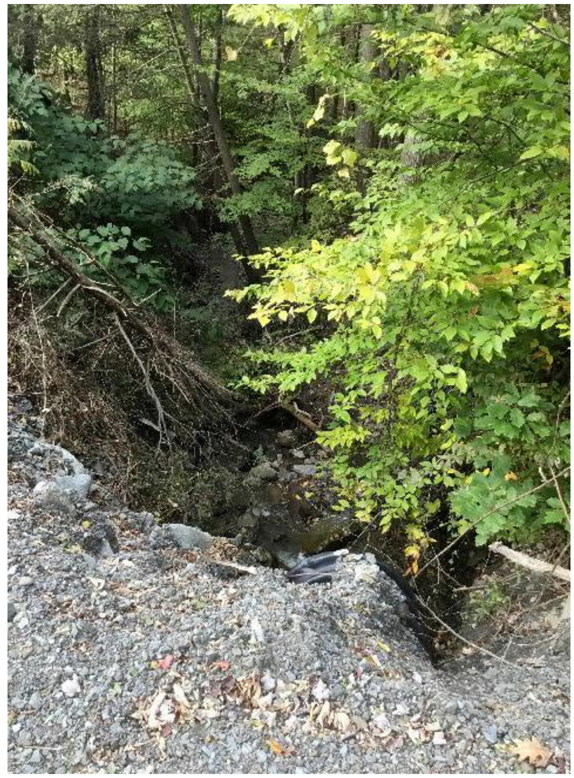
Screening-Level Cost Estimate

- Replace Crossing: $250-500K (estimated $250-300K)
- Pair with replacement of the crossing described in Section 4.3 (Long Creek Road over Long Creek) to achieve cost efficiencies for each.

4.5 Chestnut Ridge Road over Deerlick Creek

Existing Issues

- The structure appears to have completely collapsed in the center.
- The structure outlet is perched at least 10 feet above the streambed and prohibits aquatic passage.
- Road embankment material is eroding, threatening the road and public safety.
- A local landowner who owns land downstream of the crossing seemed interested in improving the crossing and may be cooperative with any efforts to replace or upgrade the crossing; he recalled that the crossing was blocked in part when an upstream pond "blew out."

Chestnut Ridge Road over Deerlick Creek. Photograph of crossing outlet (left) and looking down at outlet from above (right). Note the large grade change, the perched outlet, and the erosion of the road evident in both photos.

Recommendations

- Replace the crossing with an appropriately-sized structure to reduce flood risk and improve public safety. Due to the existing grade, the structure is not anticipated to accommodate full aquatic passage. An appropriately-sized box culvert (as opposed to an arch culvert spanning the entire bankfull width) is recommended. Install headwalls on the structure to support the road.
- Restore the streambanks downstream of the crossing with large wood, rootwads, or other nature-based solutions as appropriate to reduce further erosion.
- Consider appropriate stream gradient and grade controls for the location to accommodate the existing grade change.
- Install guardrails on either side of the road, but particularly on the north side of the road.

Screening-Level Cost Estimate

- Replace Crossing: $75K - $150K (does not address aquatic passage)

4.6 Gaylord Road over Unnamed Tributary to Apalachin Creek (at Little Hill Road)

Existing Issues

- The structure appears to be severely constricting flow. The estimated hydraulic capacity is slightly less than the 25-year peak flow.
- A sinkhole is developing between the road and the headwall of the outlet, approximately 2 feet wide and 6 feet long, which penetrates completely through the headwall.

- Residents at #54 Gaylord Road have observed approximately 5 feet of the vegetated bank downstream of the crossing erode in the past year, and are concerned that it will undermine their boiler structure and additional outbuilding. The residents plan to contact the Conservation District about the problem.
- The structure's wingwalls are in critical condition and may be in danger of collapse.
- The outlet of the structure is undermined and perched, limiting or prohibiting aquatic passage.

Gaylord Road over Unnamed Tributary to Apalachin Creek (at Little Hill Road) - crossing outlet. Note unstable headwalls and perched, undermined outlet of culvert.

Gaylord Road over Unnamed Tributary to Apalachin Creek (at Little Hill Road). Eroded channel banks downstream of structure threaten residential property on river left.

Recommendations

- Replace the crossing with an appropriately-sized structure to reduce flood risk, improve public safety, and provide aquatic passage.
- Restore streambanks upstream and downstream of the crossing with large wood, rootwads, or other nature-based solutions as appropriate to reduce further erosion and protect residential properties.

Screening-Level Cost Estimate

- Replace Crossing: $500K-$1M

- Pair with replacement of the crossing described in Section 4.7 (Gaylord Road over Unnamed Tributary to Apalachin Creek) to achieve cost efficiencies for each.

4.7 Gaylord Road over Unnamed Tributary to Apalachin Creek (upstream of Section 4.6 crossing)

Existing Issues

- The structure is slightly undersized (capable of conveying slightly less than the 25-year return interval peak flow) and constricts streamflow.
- The structure's upstream and downstream headwalls are in poor condition.
- The displacement of a joint inside the structure appears to create a small drop in the culvert.

Gaylord Road over Unnamed Tributary to Apalachin Creek (upstream of Section 4.6 crossing) - structure inlet. Note misaligned headwall and constriction of stream.

Gaylord Road over Unnamed Tributary to Apalachin Creek (upstream of Section 4.6 crossing) - structure outlet. Note that outlet is perched. Also note headwall in poor condition and displacement of joint inside of culvert pipe.

Recommendations

- Replace the structure with an appropriately-sized structure to reduce flood risk, improve public safety, and provide aquatic passage.
- Restore the streambank with large wood, rootwads, or other nature-based solutions as appropriate to stabilize the streambed and banks and reduce further erosion.

Screening-Level Cost Estimate

- Replace Crossing: $500K-$1M
- Pair with replacement of the crossing described in Section 4.6 (Gaylord Road over Unnamed Tributary [Card Road Tributary] to Apalachin Creek at Little Hill Road) to achieve cost efficiencies for each.

4.8 Pennsylvania Avenue over Unnamed Tributary (Card Road Tributary) to Apalachin Creek

Existing Issues

- The culvert appears to be recently reconstructed, presumably following washout during flooding in 2011. However, the culvert is undersized, capable of passing less than the 10-year recurrence interval peak flow. Sediment blocks the culvert inlet almost completely, further limiting hydraulic capacity and aquatic passage.
- The channel appears to have been regraded using heavy machinery without restoration, which exposed and loosened sediment in the streambed and banks and may have contributed to the sediment blockage at the culvert.
- The crossing is located at a substantial reduction in valley slope from steeper headwaters to low-gradient open valley.

Pennsylvania Avenue over Unnamed Tributary (Card Road Tributary) to Apalachin Creek - structure inlet. Note sagging abutment and displaced concrete waste block on left bank.

Recommendations

- Remove sediment deposits from the crossing and restore streambanks and streambed (upstream, downstream, and within crossing).
- Identify the upstream sediment sources and determine if nature-based methods can be used to reduce the sediment supply and restore a more natural sediment flow regime.
- Educate local public works staff regarding the use of heavy machinery in streambeds.

Screening-Level Cost Estimate

- Restore streambanks and streambed: Costs to be provided by Inter-Fluve
- Pair with replacement of the crossing described in Section 4.9 (Card Road over Unnamed Tributary to Apalachin Creek) to achieve cost efficiencies for each.

4.9 Card Road over Unnamed Tributary (Card Road Tributary) to Apalachin Creek

Existing Issues

- The structure is capable of passing the 100-year peak flow, but constricts streamflow given its narrow width relative to bankfull flow.
- The structure's upstream and downstream headwalls are misaligned.
- The streambanks upstream and downstream of the structure are eroded and overhanging.

Card Road over Unnamed Tributary (Card Road Tributary) to Apalachin Creek - structure inlet. Note misaligned headwall, constriction in stream, and sharp bend in stream as it approaches the culvert.

Card Road over Unnamed Tributary (Card Road Tributary) to Apalachin Creek - structure outlet. Note that outlet is perched.

Recommendations

- Replace the structure with an appropriately-sized structure to reduce flood risk, improve public safety, and provide aquatic passage.
- Restore the streambank with large wood, rootwads, or other nature-based solutions as appropriate to stabilize the streambed and banks and reduce further erosion.

Screening-Level Cost Estimate

- Replace Crossing: $250-500K
- Pair with replacement of the crossing described in Section 4.8 (Pennsylvania Avenue over Unnamed Tributary [Card Road Tributary] to Apalachin Creek) to achieve cost efficiencies for each.

4.10 Pennsylvania Avenue over Unnamed Tributary to Apalachin Creek

Existing Issues

- The existing concrete box structure appears to have been installed relatively recently. The concrete box is structurally sound, although the wingwalls and armoring at the structure inlet are in poor condition.
- The structure serves as a moderate constriction since its width is less than the bankfull width of the channel. The crossing has sufficient hydraulic capacity to convey approximately the 100-year return interval peak flow.
- The concrete invert of the box culvert is slightly perched on the downstream side.
- The upstream and downstream banks are vulnerable to erosion and scour, as evidenced by the significant bank erosion upstream of the crossing.

Pennsylvania Avenue over Unnamed Tributary to Apalachin creek – structure inlet. Note the relatively poor condition of the wingwalls and armoring.

Pennsylvania Avenue over Unnamed Tributary to Apalachin creek – structure outlet. Note the slightly perched invert at the structure outlet.

Recommendations

- Replace the structure with an appropriately-sized, open-bottom structure to reduce flood risk, improve public safety, and provide aquatic passage.

Screening-Level Cost Estimate

- Replace Crossing: $500K-$1M

4.11 Fox Road over Unnamed Tributary to Apalachin Creek

Existing Issues

- The structure is undersized hydraulically (capable of conveying slightly less than the 10-year return interval peak flow) and constricts streamflow.
- The structure is deformed and misaligned at the upstream end.
- The upstream and downstream headwalls are in poor condition, and a downstream wingwall is in danger of collapse.
- The streambed downstream of the crossing has been scoured to bedrock, while a large amount of sediment has been deposited upstream of the culvert.
- The road appears to have been overtopped during a previous flood event.

- The streambanks upstream and downstream of the structure are eroded and overhanging.

Fox Road over Unnamed Tributary to Apalachin Creek - structure inlet. Note misaligned headwall, constriction in stream, and sharp bend in stream as it approaches the culvert.

Fox Road over Unnamed Tributary to Apalachin Creek - structure outlet. Note unstable wingwall with large void at base, at left side of photo.

Recommendations

- Replace the structure with an appropriately-sized structure that is aligned with the stream to reduce flood risk, improve public safety, and provide aquatic passage.
- Use stone comprising existing wingwalls in stream restoration.

Screening-Level Cost Estimate

- Replace Crossing: $500K-$1M

FUSS & O'NEILL

Attachment A

Stream Crossing Survey Field Data Form (blank)

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Road-Stream Crossing Assessment Field Data Form

QA/QC INITIALS: ________ DATE: ________
Status ____ FINAL ____ FOLLOW-UP

CROSSING DATA

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Crossing Code ____________ State or Local ID/Name ____________ Date ________ Start Time ________ AM / PM

Lead Field Data Collector ____________ Asst. Field Data Collectors ____________ End Time ________ AM / PM

Municipality ____________ County ____________ Stream ____________

Road ____________ Type ☐ MULTI-LANE ☐ PAVED ☐ UNPAVED ☐ DRIVEWAY ☐ TRAIL ☐ RAILROAD

GPS Coordinates (Decimal degrees) ☐☐.☐☐☐☐☐ °N Latitude — ☐☐.☐☐☐☐☐ °W Longitude

Location Description ____________

pp. 5-7

Crossing Type ☐ BRIDGE ☐ CULVERT ☐ MULTIPLE CULVERT ☐ FORD ☐ NO CROSSING ☐ REMOVED CROSSING ☐ BURIED STREAM ☐ INACCESSIBLE ☐ PARTIALLY INACCESSIBLE ☐ NO UPSTREAM CHANNEL ☐ BRIDGE ADEQUATE

Number of Culverts / Cells ________

Photo #______ INLET Photo #______ OUTLET Photo #______ ____________ Photo #______ ____________

Photo #______ UPSTREAM Photo #______ DOWNSTREAM Photo #______ ____________ Photo #______ ____________

Photo #______ ROADWAY Photo #______ ____________ Photo #______ ____________ Photo #______ ____________

Flow Condition ☐ NO FLOW ☐ TYPICAL-LOW ☐ MODERATE ☐ HIGH

Road-Killed Wildlife ____________ or None

Visible Utilities ☐ OVERHEAD WIRES ☐ WATER/SEWER PIPES ☐ GAS LINE ☐ NONE ☐ OTHER ____________

pp. 9-12

Alignment ☐ SHARP BEND ☐ MILD BEND ☐ NATURALLY STRAIGHT ☐ CHANNELIZED STRAIGHT

Road Fill Height ________ Road Crest Height ________

Bankfull Width ______ Confidence ☐ HIGH ☐ LOW/ESTIMATED

Constriction ☐ SEVERE ☐ MODERATE ☐ SPANS ONLY BANKFULL/ACTIVE CHANNEL ☐ SPANS FULL CHANNEL & BANKS

Tailwater Scour Pool ☐ NONE ☐ SMALL ☐ LARGE

HY-8

pp. 8, 13-15

Using HY-8? ☐ YES ☐ NO

Estimated Overtopping Length ________ Crest Width ________

Road Surface Type ☐ PAVED ☐ GRAVEL ☐ GRASS

Channel Slope ________

Side Slope ☐ 5:1 ☐ 4:1 ☐ 3:1 ☐ 2:1 ☐ 1:1 ☐ 0.5:1 ☐ steeper than 0.5:1

Stream Substrate ☐ MUCK/SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

GEO.

pp. 13

Bank Erosion ☐ HIGH ☐ LOW ☐ ESTIMATED ☐ NONE

Significant Break in Valley Slope ☐ YES ☐ NO ☐ UNKNOWN

Sediment Deposition ☐ UPSTREAM ☐ DOWNSTREAM ☐ WITHIN STRUCTURE ☐ NONE

Elevation of Sediment Deposits >= 1/2 Bankfull Height ☐ YES ☐ NO

TIDAL

pp. 16-18

Tidal? ☐ YES ☐ NO ☐ UNKNOWN

Tide Chart Location ____________

Tide Prediction ____:____ AM / PM

Tide Stage ☐ LOW SLACK TIDE ☐ LOW EBB TIDE ☐ LOW FLOOD TIDE ☐ UNKNOWN ☐ OTHER ____________

Vegetation Above/Below ☐ COMPARABLE ☐ SLIGHTLY DIFFERENT ☐ MODERATELY DIFFERENT ☐ VERY DIFFERENT ☐ UNKNOWN

Tide Gate Type ☐ NONE ☐ STOP LOGS ☐ FLAP GATE ☐ SLUICE GATE ☐ SELF-REGULATING ☐ OTHER ____________

Tide Gate Severity ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE ☐ NO AQUATIC PASSAGE

CROSSING COMMENTS

pp. 5

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STRUCTURE 1

OUTLET

pp. 19-35

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width________.___ B. Height________.___ C. Substrate/Water Width________.___ D. Water Depth________.___

Outlet Drop to Water Surface________.___ Outlet Drop to Stream Bottom________.___ E. Abutment Height (Type 7 bridges only)________.___

L. Structure Length (Overall length from inlet to outlet)________.___

INLET

pp. 35-43

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width________.___ B. Height________.___ C. Substrate/Water Width________.___ D. Water Depth________.___

ADDITIONAL CONDITIONS

pp. 43-56

Slope % ________ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN

Height above Dry Passage________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

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STRUCTURE 2

OUTLET

pp. 19-35

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width________.____ B. Height________.____ C. Substrate/Water Width________.____ D. Water Depth________.____

Outlet Drop to Water Surface__________.____ Outlet Drop to Stream Bottom__________.____ E. Abutment Height (Type 7 bridges only)______________.____

L. Structure Length (Overall length from inlet to outlet)______________.____

INLET

pp. 35-43

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width________.____ B. Height________.____ C. Substrate/Water Width________.____ D. Water Depth________.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % ____________ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN

Height above Dry Passage____________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

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STRUCTURE 3

OUTLET

pp. 19-35

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width_______.____ B. Height_______.____ C. Substrate/Water Width_______.____ D. Water Depth_______.____

Outlet Drop to Water Surface_______.____ Outlet Drop to Stream Bottom_______.____ E. Abutment Height (Type 7 bridges only)_______.____

L. Structure Length (Overall length from inlet to outlet)_______.____

INLET

pp. 35-43

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width_______.____ B. Height_______.____ C. Substrate/Water Width_______.____ D. Water Depth_______.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % ___________ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER___________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN

Height above Dry Passage___________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

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STRUCTURE 4

pp. 19-35

OUTLET

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED   Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width_________.____ B. Height_________.____ C. Substrate/Water Width_________.____ D. Water Depth_________.____

Outlet Drop to Water Surface___________.____ Outlet Drop to Stream Bottom___________.____ E. Abutment Height (Type 7 bridges only)_______________.____

L. Structure Length (Overall length from inlet to outlet)______________.____

INLET

pp. 35-43

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width_________.____ B. Height_________.____ C. Substrate/Water Width_________.____ D. Water Depth_________.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % ______________ Slope Confidence ☐ HIGH ☐ LOW   Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER__________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN   Height above Dry Passage______________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

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STRUCTURE 5

pp. 19-35

OUTLET

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width________.____ B. Height________.____ C. Substrate/Water Width________.____ D. Water Depth________.____

Outlet Drop to Water Surface________.____ Outlet Drop to Stream Bottom________.____ E. Abutment Height (Type 7 bridges only)________.____

L. Structure Length (Overall length from inlet to outlet)________.____

INLET

pp. 35-43

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width________.____ B. Height________.____ C. Substrate/Water Width________.____ D. Water Depth________.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % ________ Slope Confidence ☐ HIGH ☐ LOW Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN Height above Dry Passage________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

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STRUCTURE 6

OUTLET

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

pp. 19-35

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width__________.____ B. Height__________.____ C. Substrate/Water Width__________.____ D. Water Depth__________.____

Outlet Drop to Water Surface__________.____ Outlet Drop to Stream Bottom__________.____ E. Abutment Height (Type 7 bridges only)__________.____

L. Structure Length (Overall length from inlet to outlet)__________.____

INLET

pp. 35-43

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width__________.____ B. Height__________.____ C. Substrate/Water Width__________.____ D. Water Depth__________.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % __________ Slope Confidence ☐ HIGH ☐ LOW Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER__________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN Height above Dry Passage__________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

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STRUCTURE 7

OUTLET

pp. 19-35

Structure Material ☐ SMOOTH PLASTIC ☐ CORRUGATED PLASTIC ☐ SMOOTH METAL ☐ CORRUGATED METAL ☐ CONCRETE ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ UNKNOWN

Outlet Dimensions A. Width__________.____ B. Height__________.____ C. Substrate/Water Width__________.____ D. Water Depth__________.____

Outlet Drop to Water Surface____________.____ Outlet Drop to Stream Bottom____________.____ E. Abutment Height (Type 7 bridges only)_________________.____

L. Structure Length (Overall length from inlet to outlet)_______________.____

INLET

pp. 35-43

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL WITH SQUARE EDGE ☐ HEADWALL WITH GROOVED EDGE ☐ HEADWALL WITH SQUARE EDGE AND WINGWALLS ☐ HEADWALL WITH GROOVED/BEVELED EDGE AND WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET DROP ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions A. Width__________.____ B. Height__________.____ C. Substrate/Water Width__________.____ D. Water Depth__________.____

ADDITIONAL CONDITIONS

pp. 43-56

Slope % _______________ Slope Confidence ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER__________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN

Height above Dry Passage_______________

STRUCTURAL CONDITION ASSESSMENT

pp. 57-70

	INLET					OUTLET				
	Adequate	Poor	Critical	Unknown	N/A	Adequate	Poor	Critical	Unknown	N/A
Longitudinal Alignment										
Level of Blockage										
Flared End Section										
Invert Deterioration										
Buoyancy or Crushing										
Cross-Section Deformation										
Structural Integrity of Barrel										
Joints and Seams										
Footings										
Headwall/Wingwalls										
Armoring										
Apron/Scour Protection										
Embankment Piping										

STRUCTURE COMMENTS

pp. 44

____

____

____

____

____

____

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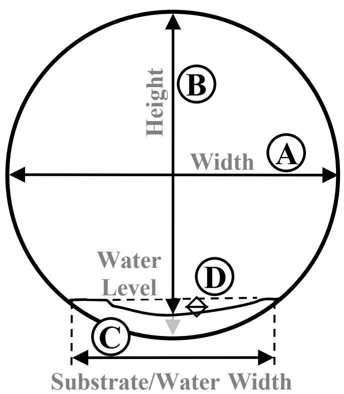
FORM PUBLISHED: OCTOBER 18, 2018

Structure Shape & Dimensions

1) Select the Structure Shape number from the diagrams below and record it on the form for Inlet and Outlet Shape.
2) Record on the form in the appropriate blanks dimensions **A, B, C** and **D** as shown in the diagrams;
   C captures the width of water or substrate, whichever is wider; for dry culverts without substrate, C = 0.
   D is the depth of water -- be sure to measure inside the structure; for dry culverts, D = 0.
3) Record Structure Length (**L**) . (Record abutment height (**E**) only for Type 7 Structures.)
4) For multiple culverts, also record the Inlet and Outlet shape and dimensions for each additional culvert.

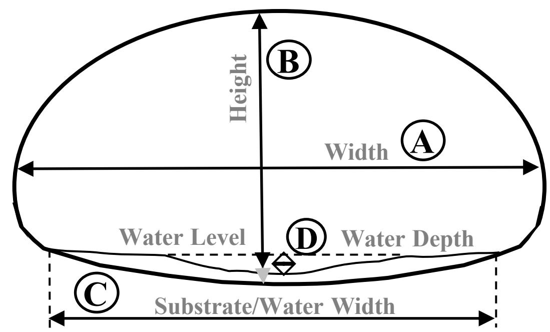
NOTE: Culverts 1, 2 & 4 may or may not have substrate in them, so height measurements (B) are taken from the level of the "stream bed", whether that bed is composed of substrate or just the inside bottom surface of a culvert (grey arrows below show measuring to bottom, black arrows show measuring to substrate).

1



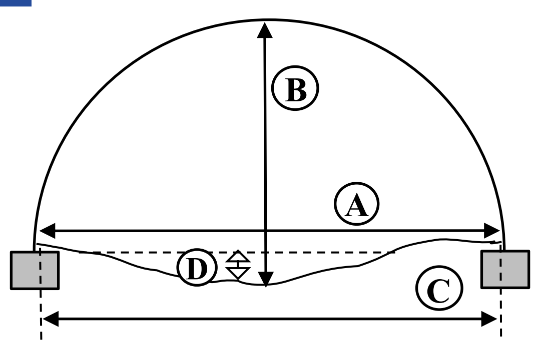
Round Culvert

2



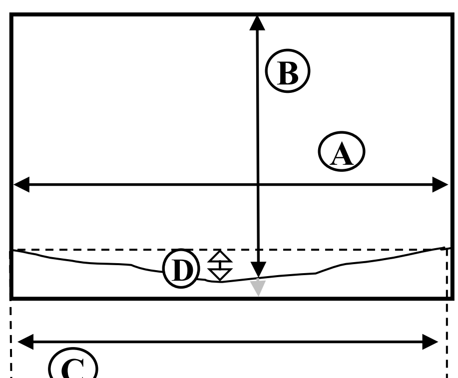
Pipe Arch/Elliptical Culvert

3



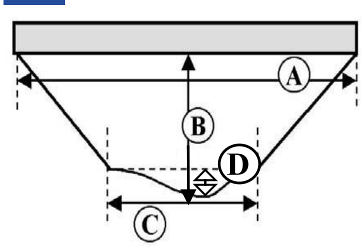
Open Bottom Arch Bridge/Culvert

4



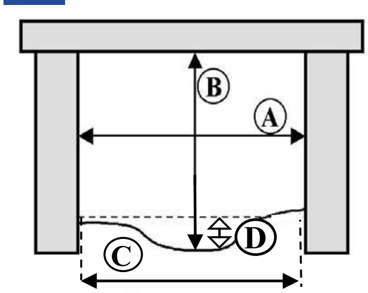
Box Culvert

5



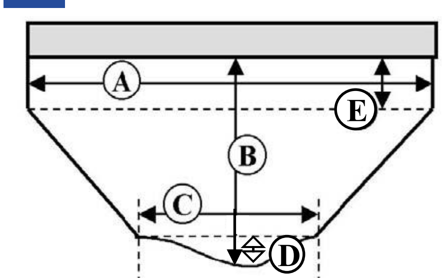
Bridge with Side Slopes

6



Box/Bridge with Abutments

7



Bridge with Abutments and Side Slopes

Attachment B

Road-Stream Crossing Scoring and Prioritization Results

Hydraulic Capacity Worksheet
Road-Stream Crossing Assessment
Tioga County Watersheds

June 2019

Stream Name	Road Name	Crossing Hydraulic Capacity @ Failure				Existing Streamflow Conditions								Future Streamflow Conditions (20% Increase in Flows - Projected Climate Change)								Scoring	
		Capacity Structure 1 (cfs)	Capacity Structure 2 (cfs)	Total Culvert Capacity (cfs)	Drainage Area (mi2)	10-Year Peak Flow (cfs)	25-Year Peak Flow (cfs)	50-Year Peak Flow (cfs)	100-Year Peak Flow (cfs)	10-Year Capacity Ratio	25-Year Capacity Ratio	50-Year Capacity Ratio	100-Year Capacity Ratio	10-Year Peak Flow (cfs)	25-Year Peak Flow (cfs)	50-Year Peak Flow (cfs)	100-Year Peak Flow (cfs)	10-Year Capacity Ratio	25-Year Capacity Ratio	50-Year Capacity Ratio	100-Year Capacity Ratio	Existing Hydraulic Capacity Score (1-5)	Future Hydraulic Capacity Score (1-5)
Wappasening Creek Watershed																							
Unnamed Trib to Unnamed Trib at Briggs Hollow	Moore Hill Road	99		99	0.37	99	137	171	206	1.00	0.72	0.58	0.48	118	164	205	247	0.83	0.60	0.48	0.40	5	5
Unnamed Tributary at Briggs Hollow	State Line Road	382		382	2.47	501	691	858	1030	0.76	0.55	0.45	0.37	601	829	1030	1236	0.64	0.46	0.37	0.31	5	5
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road	637		637	1.82	415	576	719	867	1.54	1.11	0.89	0.73	498	691	863	1040	1.28	0.92	0.74	0.61	3	4
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road	664		664	1.13	304	426	535	648	2.18	1.56	1.24	1.02	365	511	642	778	1.82	1.30	1.03	0.85	1	2
Unnamed Tributary at Briggs Hollow	Briggs Hill Road	235		235	0.55	169	237	298	363	1.39	0.99	0.79	0.65	203	284	358	436	1.16	0.83	0.66	0.54	4	4
Unnamed Tributary at Briggs Hollow	Upper Briggs Hollow Road	328		328	0.52	166	234	295	360	1.98	1.40	1.11	0.91	199	281	354	432	1.65	1.17	0.93	0.76	2	3
Huntington Creek Watershed																							
Huntington Creek	Sheldon Guile Boulevard	244	271	515	1.92	473	663	832	1010	1.09	0.78	0.62	0.51	568	796	998	1212	0.91	0.65	0.52	0.43	4	5
Huntington Creek	Owego & Hartford Railroad	59		59	1.92	473	663	832	1010	0.12	0.09	0.07	0.06	568	796	998	1212	0.10	0.07	0.06	0.05	5	5
Huntington Creek	North Avenue (NY 96)	6179		6179	1.91	477	669	840	1020	12.95	9.24	7.36	6.06	572	803	1008	1224	10.80	7.70	6.13	5.05	1	1
Huntington Creek	Driveway off Dean Street	2601		2601	1.51	383	536	673	816	6.79	4.85	3.86	3.19	460	643	808	979	5.66	4.04	3.22	2.66	1	1
Huntington Creek	Driveway off Dean Street	236		236	1.49	379	531	667	810	0.62	0.44	0.35	0.29	455	637	800	972	0.52	0.37	0.29	0.24	5	5
Huntington Creek	Winery Driveway off Allen Glen Rd	224		224	1.37	353	495	622	755	0.63	0.45	0.36	0.30	424	594	746	906	0.53	0.38	0.30	0.25	5	5
Huntington Creek	Allen Glen Road	492		492	0.79	206	288	361	437	2.39	1.71	1.36	1.12	247	346	433	524	1.99	1.42	1.13	0.94	1	2
Tributary to Huntington Creek	Winery Trail off Allen Glen Rd	3810		3810	0.58	199	284	360	441	19.14	13.41	10.58	8.64	239	341	432	529	15.95	11.18	8.82	7.20	1	1
Tributary to Huntington Creek	Carmichael Road	75		75	0.14	54	76	97	118	1.40	0.98	0.78	0.64	64	92	116	142	1.17	0.82	0.65	0.53	4	4
Tributary to Huntington Creek	Driveway off Carmichael Rd	220		220	0.09	35	49	62	76	6.37	4.49	3.55	2.90	41	59	74	91	5.31	3.74	2.96	2.42	1	1
Apalachin Creek Watershed																							
Unnamed Tributary to Deerlick Creek	Summit Road	18		18	0.03	10	14	17	20	1.76	1.28	1.04	0.87	12	16	20	24	1.47	1.07	0.87	0.73	2	3
Unnamed Tributary to Deerlick Creek	Beach Road	241		241	0.30	82	113	141	169	2.95	2.13	1.71	1.43	98	136	169	203	2.45	1.78	1.42	1.19	1	1
Unnamed Tributary to Apalachin Creek	Barton Road	18		18	0.05	19	26	33	39	0.95	0.68	0.54	0.45	22	31	39	47	0.79	0.56	0.45	0.37	5	5
Deerlick Creek	Pennsylvania Avenue	3696		3696	4.01	636	858	1050	1250	5.81	4.31	3.52	2.96	763	1030	1260	1500	4.84	3.59	2.93	2.46	1	1
Long Creek	Pennsylvania Avenue	4625		4625	2.85	586	804	996	1190	7.89	5.75	4.64	3.89	703	965	1195	1428	6.58	4.79	3.87	3.24	1	1
Long Creek	Long Creek Road	3075		3075	2.70	570	784	972	1170	5.40	3.92	3.16	2.63	684	941	1166	1404	4.50	3.27	2.64	2.19	1	1
Unnamed Tributary to Long Creek	Long Creek Road	25		25	0.26	65	89	110	131	0.39	0.28	0.23	0.19	78	107	132	157	0.32	0.24	0.19	0.16	5	5
Deerlick Creek	Chestnut Ridge Road	39		39	0.05	12	16	20	23	3.27	2.41	1.98	1.67	14	19	23	28	2.72	2.01	1.65	1.39	1	1
Unnamed Tributary to Deerlick Creek	Montrose Turnpike	18		18	0.07	22	30	38	45	0.81	0.58	0.47	0.39	26	36	45	54	0.67	0.49	0.39	0.32	5	5
Unnamed Tributary to Apalachin Creek	Gaylord Road	607		607	2.22	480	657	812	972	1.26	0.92	0.75	0.62	576	788	974	1166	1.05	0.77	0.62	0.52	4	4
Unnamed Tributary to Apalachin Creek	Gaylord Road	536		536	1.73	396	543	672	806	1.35	0.99	0.80	0.67	475	652	806	967	1.13	0.82	0.67	0.55	4	4
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	58		58	0.50	156	217	272	329	0.37	0.27	0.21	0.18	187	260	326	395	0.31	0.22	0.18	0.15	5	5
Unnamed Tributary to Apalachin Creek	Card Road	327		327	0.48	152	211	265	320	2.15	1.55	1.23	1.02	182	253	318	384	1.79	1.29	1.03	0.85	1	2
Apalachin Creek	Harnick Road	3792	356	4148	23.80	3000	3990	4850	5720	1.38	1.04	0.86	0.73	3600	4788	5820	6864	1.15	0.87	0.71	0.60	3	4
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	661		661	1.35	326	449	557	669	2.03	1.47	1.19	0.99	391	539	668	803	1.69	1.23	0.99	0.82	2	3
Unnamed Tributary to Apalachin Creek	Fox Road	295		295	1.34	327	451	560	673	0.90	0.65	0.53	0.44	392	541	672	808	0.75	0.55	0.44	0.37	5	5

Hydraulic Capacity Worksheet
Road-Stream Crossing Assessment
Tioga County Watersheds

June 2019

Headwater Depth at $Q_{failure}$

Road-Stream Crossing Structure Type and Material	Allowable Headwater Depth[1]
Stone Masonry or Wood Culvert	HW = 1.0 x D
Smooth or Corrugated Metal or Plastic Culvert[2]	HW = 1.2 x D
Concrete Culvert	HW = 1 foot below lowest point in roadway surface
Bridge	HW = 1 foot below lowest point of bottom of bridge deck

[1] In some cases a lower elevation in the approach to a road-stream crossing may be utilized instead to estimate the allowable headwater depth. It is the responsibility of the Assessment Coordinator to determine when this is appropriate.
[2] Includes fiberglass culverts.

Hydraulic Capacity Score

Hydraulic Capacity Rating (Capacity Ratio > 1.0 for listed Return Interval)	Hydraulic Capacity Score
100-Year	1
50 Year	2
25-Year	3
10 Year	4
< 10-Year	5

Tailwater Depth used in Calculating Hydraulic Capacity ($Q_{failure}$)

Crossing Type	Crossing Structure Slope	Tailwater Depth
Non-Tidal Crossings	> 2%	TW = 0.75 x D
	< 2%	TW = 0.75 x D when HW/D < 1.3 TW = 1.0 x D when HW/D ≥ 1.3
Tidal Crossings	Not Applicable	TW = 1.0 x D
Crossings discharging directly into a lake, pond, or wetland[1]	Not Applicable	Based on elevation of receiving water body or wetland
Crossings with cascade or free fall at the outlet with a significant drop to the normal elevation of the downstream channel	Not Applicable	Based on elevation drop at outlet

[1] Situations where the tailwater depth is dictated by the water elevation in the downstream receiving water body or wetland and does not vary with flow, where available.

Geomorphic Vulnerability Worksheet
Road-Stream Crossing Assessment
Tioga County Watersheds

June 2019

Stream Name	Road Name	Potential for Geomorphic Impacts				Observed Geomorphic Impacts			Scoring			
		Alignment Impact Potential Rating	Bankfull Width Impact Potential Rating	Slope Impact Potential Rating	Substrate Size Impact Potential Rating	Sediment Continuity Impact Rating	Bank Erosion and Outlet Amoring Impact Rating	Inlet/ Outlet Grade Impact Rating	Combined Potential Impact Rating	Combined Observed Impact Rating	Geomorphic Vulnerability Score (sum)	Geomorphic Vulnerability Score (1-5)
Wappasening Creek Watershed												
Unnamed Trib to Unnamed Trib at Briggs Hollow	Moore Hill Road	1	5	3	4	5	5	4	13	14	27	4
Unnamed Tributary at Briggs Hollow	State Line Road	2	5	1	3	4	5	2	11	11	22	4
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road	2	5	1	3	4	5	1	11	10	21	3
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road	2	4	1	3	3	5	5	10	13	23	4
Unnamed Tributary at Briggs Hollow	Briggs Hill Road	1	5	4	4	4	5	3	14	12	26	4
Unnamed Tributary at Briggs Hollow	Upper Briggs Hollow Road	4	5	1	3	3	5	1	13	9	22	4
Huntington Creek Watershed												
Huntington Creek	Sheldon Guile Boulevard	4	3	3	3	3	5	1	13	9	22	4
Huntington Creek	Owego & Hartford Railroad	4	3	3	3	2	5	1	13	8	21	3
Huntington Creek	North Avenue (NY 96)	4	1	3	2	2	5	1	10	8	18	3
Huntington Creek	Driveway off Dean Street	1	5	1	3	3	5	1	10	9	19	3
Huntington Creek	Driveway off Dean Street	2	5	5	3	5	5	2	15	12	27	4
Huntington Creek	Winery Driveway off Allen Glen Rd	2	5	3	3	3	5	5	13	13	26	4
Huntington Creek	Allen Glen Road	2	5	3	4	3	5	1	14	9	23	4
Tributary to Huntington Creek	Winery Trail off Allen Glen Rd	2	1	3	3	3	5	1	9	9	18	3
Tributary to Huntington Creek	Carmichael Road	2	5	4	4	2	5	5	15	12	27	4
Tributary to Huntington Creek	Driveway off Carmichael Rd	5	5	4	3	4	5	4	17	13	30	5
Apalachin Creek Watershed												
Unnamed Tributary to Deerlick Creek	Summit Road	5	5	1	4	4	3	4	15	11	26	4
Unnamed Tributary to Deerlick Creek	Beach Road	5	5	3	3	3	5	5	16	13	29	5
Unnamed Tributary to Apalachin Creek	Barton Road	5	5	4	5	1	5	4	19	10	29	5
Deerlick Creek	Pennsylvania Avenue	1	1	1	3	2	5	1	6	8	14	2
Long Creek	Pennsylvania Avenue	2	2	1	4	1	5	1	9	7	16	3
Long Creek	Long Creek Road	2	2	1	4	3	5	1	9	9	18	3
Unnamed Tributary to Long Creek	Long Creek Road	4	5	3	3	4	5	2	15	11	26	4
Deerlick Creek	Chestnut Ridge Road	5	5	4	5	2	5	4	19	11	30	5
Unnamed Tributary to Deerlick Creek	Montrose Turnpike	5	4	5	5	2	3	4	19	9	28	4
Unnamed Tributary to Apalachin Creek	Gaylord Road	2	5	3	3	4	5	5	13	14	27	4
Unnamed Tributary to Apalachin Creek	Gaylord Road	2	5	3	2	3	5	3	12	11	23	4
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	2	3	1	3	3	5	1	9	9	18	3
Unnamed Tributary to Apalachin Creek	Card Road	2	5	5	3	5	5	3	15	13	28	4
Apalachin Creek	Harnick Road	2	2	1	3	3	5	1	8	9	17	3
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	2	4	1	3	4	5	4	10	13	23	4
Unnamed Tributary to Apalachin Creek	Fox Road	2	5	5	3	5	5	1	15	11	26	4

Geomorphic Vulnerability Worksheet
Road-Stream Crossing Assessment
Tioga County Watersheds

June 2019

Crossing alignment impact potential ratings

Impact Rating	Alignment
1	Naturally straight
2	Mild bend
3	--
4	Channelized straight
5	Sharp bend

Bankfull width impact potential ratings when confident width measurements are available

Impact Rating	Inlet Width/Bankfull Width Ratio (ft/ft)
1	≥1.0
2	1.0-0.85
3	0.85-0.7
4	0.7-0.5
5	≤0.5

Bankfull width impact potential ratings when no confident width measurements are available

Impact Rating	Constriction
1	None – Spans full channel and banks
2	Slight – Spans only bankfull/active channel
3	-
4	Moderate
5	Severe

Substrate size impact potential ratings

Impact Rating	Stream Substrate
1	Bedrock
2	Boulder
3	Cobble
4	Gravel
5	Sand or muck/silt

Channel and crossing structure slope impact potential ratings

Impact Rating	Slope Conditions at Crossing
1	No natural break in slope AND crossing structure slope and channel slope the same
2	No natural break in slope but crossing structure slope greater than channel slope
3	Natural break in slope present but crossing structure and channel slope the same
4	No natural break in slope but crossing structure slope less than channel slope
5	Natural slope break present AND crossing structure slope different from channel slope (less than or greater than)

Sediment continuity impact ratings

Impact Rating	Sediment Deposition, Elevation of Sediment Deposits, and Tailwater Scour Pool
1	No deposition upstream AND no tailwater scour pool downstream
2	Deposition upstream <½ bankfull height OR small tailwater pool downstream
3	No deposition upstream AND large tailwater scour pool downstream
3	Deposition upstream <½ bankfull height AND small tailwater pool downstream
3	Deposition upstream ≥½ bankfull height AND no tailwater scour pool downstream
4	Both deposition & pool present w/ either large pool or deposition ≥½ bankfull height
5	Deposition upstream ≥½ bankfull height AND large tailwater pool downstream

Bank erosion and outlet armoring impact ratings

Impact Rating	Bank Erosion and Outlet Armoring
1	No bank erosion or outlet armoring
2	--
3	Low levels of bank erosion and/or not extensive outlet armoring
4	--
5	High levels of bank erosion and/or extensive outlet armoring

Inlet and outlet grade impact ratings

Impact Rating	Character of Inlet and Outlet Grade
1	Both inlet and outlet at stream grade
2	Inlet drop OR cascade at outlet
3	Inlet drop AND cascade at outlet
4	Perched inlet OR free fall or free fall onto cascade at outlet
5	Inlet drop AND free fall or free fall onto cascade at outlet

Combined geomorphic potential impact ratings

Combined Potential Impact Rating	Likelihood for Geomorphic Impacts
4	Very unlikely
5-8	Unlikely
9-12	Possible
13-16	Likely
17-20	Very likely

Combined observed geomorphic impact ratings

Combined Impact Rating	Degree of Observed Geomorphic Impacts
3	None
4-6	Minor
7-9	Moderate
10-12	Significant
13-15	Severe

Structural Condition Worksheet
Road-Stream Crossing Assessment
Tioga County Watersheds

June 2019

Stream Name	Road Name	Inlet, Outlet or Barrel Condition	Inlet, Outlet or Barrel Condition A = Adequate P = Poor C = Critical U-NA = Unknown or Not Applicable												Scoring					
		Longitudinal Alignment	Level of Blockage	Flared End Section	Invert Deterioration	Buoyancy or Crushing	Cross-Section Deformation	Structural Integrity of Barrel	Joints & Seams	Footings	Headwalls & Wingwalls	Armoring	Apron/ Scour Protection	Embankment Piping	Level 1 Variables V1 (0.0-1.0)	Level 2 Variables V2 Part I (0.0-1.0)	Level 2 Variables V2 Part II (0.0-1.0)	Level 3 Variables V3 (0.0-1.0)	Structural Condition Score (0.0-1.0)	Structural Condition Score (1-5)
Wappasening Creek Watershed																				
Unnamed Trib to Unna	Moore Hill Road	U-NA	A	U-NA	P	A	A	A	A	U-NA	P	U-NA	U-NA	P	1.0	1.0	1.0	0.7	0.7	2
Unnamed Tributary at	State Line Road	U-NA	A	A	A	A	A	A	A	A	A	A	P	A	1.0	1.0	1.0	0.9	0.9	1
Unnamed Tributary at	Lower Briggs Hollow Road	U-NA	A	U-NA	A	A	A	A	A	U-NA	C	P	P	C	1.0	0.1	1.0	0.8	0.1	5
Unnamed Tributary at	Lower Briggs Hollow Road	U-NA	A	U-NA	A	A	A	A	A	U-NA	A	P	U-NA	P	1.0	1.0	1.0	0.8	0.8	2
Unnamed Tributary at	Briggs Hill Road	U-NA	A	U-NA	A	A	A	A	A	U-NA	P	U-NA	P	P	1.0	1.0	1.0	0.7	0.7	2
Unnamed Tributary at	Upper Briggs Hollow Road	U-NA	A	U-NA	A	A	A	A	A	U-NA	P	U-NA	U-NA	A	1.0	1.0	1.0	0.9	0.9	1
Huntington Creek Watershed																				
Huntington Creek	Sheldon Guile Boulevard	U-NA	P	U-NA	A	A	U-NA	A	A	U-NA	A	P	U-NA	A	1.0	1.0	0.2	0.9	0.2	5
Huntington Creek	Owego & Hartford Railroad	U-NA	A	U-NA	A	A	A	A	U-NA	A	U-NA	A	U-NA	A	1.0	1.0	1.0	1.0	1.0	1
Huntington Creek	North Avenue (NY 96)	U-NA	A	U-NA	A	A	U-NA	A	A	A	A	P	P	A	1.0	1.0	1.0	0.8	0.8	2
Huntington Creek	Driveway off Dean Street	U-NA	A	U-NA	A	A	A	C	U-NA	U-NA	P	U-NA	U-NA	P	0.0	1.0	1.0	0.8	0.0	5
Huntington Creek	Driveway off Dean Street	U-NA	A	U-NA	A	A	A	A	A	U-NA	U-NA	C	U-NA	C	1.0	0.1	1.0	1.0	0.1	5
Huntington Creek	Winery Driveway off Allen Glen Rd	U-NA	A	U-NA	A	A	A	A	A	U-NA	C	C	U-NA	C	1.0	0.0	1.0	1.0	0.0	5
Huntington Creek	Allen Glen Road	U-NA	A	U-NA	A	A	A	A	A	A	C	C	P	C	1.0	0.0	1.0	0.9	0.0	5
Tributary to Huntingtor	Winery Trail off Allen Glen Rd	U-NA	A	U-NA	A	A	A	U-NA	U-NA	A	U-NA	U-NA	U-NA	A	1.0	1.0	1.0	1.0	1.0	1
Tributary to Huntingtor	Carmichael Road	U-NA	P	U-NA	C	C	C	C	C	U-NA	U-NA	C	U-NA	C	0.0	0.0	0.2	1.0	0.0	5
Tributary to Huntingtor	Driveway off Carmichael Rd	U-NA	A	U-NA	P	A	A	C	A	U-NA	U-NA	U-NA	U-NA	C	0.0	0.2	1.0	0.9	0.0	5
Apalachin Creek Watershed																				
Unnamed Tributary to	Summit Road	U-NA	A	U-NA	A	A	A	A	A	A	U-NA	P	U-NA	P	1.0	1.0	1.0	0.8	0.8	2
Unnamed Tributary to	Beach Road	U-NA	P	U-NA	A	A	A	A	A	U-NA	C	U-NA	A	C	1.0	0.1	0.2	1.0	0.1	5
Unnamed Tributary to	Barton Road	U-NA	A	A	A	A	A	A	A	U-NA	U-NA	C	U-NA	P	1.0	0.2	1.0	0.9	0.2	5
Deerlick Creek	Pennsylvania Avenue	U-NA	A	U-NA	A	A	A	A	A	A	A	A	U-NA	A	1.0	1.0	1.0	1.0	1.0	1
Long Creek	Pennsylvania Avenue	U-NA	A	U-NA	A	U-NA	A	A	A	A	A	C	U-NA	A	1.0	0.2	1.0	1.0	0.2	5
Long Creek	Long Creek Road	U-NA	A	U-NA	P	A	A	P	A	C	P	C	U-NA	C	0.0	0.1	0.2	0.8	0.0	5
Unnamed Tributary to	Long Creek Road	U-NA	A	U-NA	P	A	A	A	A	U-NA	U-NA	C	U-NA	P	1.0	0.2	1.0	0.8	0.2	5
Deerlick Creek	Chestnut Ridge Road	U-NA	C	U-NA	A	C	C	C	P	U-NA	U-NA	C	P	C	0.0	0.0	1.0	0.8	0.0	5
Unnamed Tributary to	Montrose Turnpike	U-NA	A	U-NA	P	A	A	A	A	U-NA	U-NA	U-NA	U-NA	A	1.0	1.0	1.0	0.9	0.9	1
Unnamed Tributary to	Gaylord Road	U-NA	A	U-NA	P	A	A	A	P	U-NA	C	P	P	P	1.0	0.2	1.0	0.5	0.2	5
Unnamed Tributary to	Gaylord Road	U-NA	A	U-NA	P	A	A	A	P	P	P	P	P	P	1.0	1.0	0.2	0.4	0.2	5
Unnamed Tributary to	Pennsylvania Avenue	U-NA	C	U-NA	A	A	A	A	A	A	P	U-NA	U-NA	A	0.0	1.0	1.0	0.9	0.0	5
Unnamed Tributary to	Card Road	U-NA	A	U-NA	P	A	A	P	A	U-NA	C	P	U-NA	P	1.0	0.2	0.2	0.7	0.2	5
Apalachin Creek	Harnick Road	U-NA	A	U-NA	A	A	U-NA	A	A	A	U-NA	A	U-NA	A	1.0	1.0	1.0	1.0	1.0	1
Unnamed Tributary to	Pennsylvania Avenue	U-NA	A	U-NA	A	A	A	A	A	U-NA	P	P	U-NA	A	1.0	1.0	1.0	0.8	0.8	2
Unnamed Tributary to	Fox Road	U-NA	A	U-NA	A	A	A	A	A	U-NA	C	P	U-NA	P	1.0	0.2	1.0	0.8	0.2	5

Structural Condition Worksheet
Road-Stream Crossing Assessment
Tioga County Watersheds

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Table 1: Level 1 Variables

Number of Variables Marked "Critical" (Inlet, Outlet, or Both)	Score
Any one of the following variables: • Cross Section Deformation • Barrel Condition/Structural Integrity • Footing Condition • Level of Blockage	0.0
None of the above variables are marked "Critical"	1.0

Table 2A: Level 2 Variables – Part I

Number of Variables Marked Critical	Score
Any three of the following variables (inlet, outlet, or both): • Buoyancy or Crushing • Invert Deterioration • Joints and Seams Condition • Headwall/Wingwall Condition • Flared End Section Condition • Apron/Scour Protection Condition (outlet only) • Armoring Condition • Embankment Piping	0.0
Any two of the following variables (inlet, outlet, or both): • Buoyancy or Crushing • Invert Deterioration • Joints and Seams Condition • Headwall/Wingwall Condition • Flared End Section Condition • Apron/Scour Protection Condition (outlet only) • Armoring Condition • Embankment Piping	0.1
Any one of the following variables (inlet/outlet/both): • Buoyancy or Crushing • Invert Deterioration • Joints and Seams Condition • Headwall/Wingwall Condition • Flared End Section Condition • Apron/Scour Protection Condition (outlet only) • Armoring Condition • Embankment Piping	0.2
None of the above variables are marked "Critical"	1.0

Table 2B: Level 2 Variables – Part II

Number of Variables Marked "Poor"	Score
Any three of the following variables (inlet, outlet, or both): • Cross Section Deformation • Barrel Condition/Structural Integrity • Footing Condition • Level of Blockage	0.0
Any two of the following variables (inlet, outlet, or both): • Cross Section Deformation • Barrel Condition/Structural Integrity • Footing Condition • Level of Blockage	0.1
Any one of the following variables (inlet, outlet, or both): • Cross Section Deformation • Barrel Condition/Structural Integrity • Footing Condition • Level of Blockage	0.2
None of the above variables are marked "Poor"	1.0

Table 3: Level 3 Variables

Variables marked as "Poor" (inlet, outlet, or both)
Buoyancy or Crushing
Invert Deterioration
Joints and Seams Condition
Headwall/Wingwall Condition
Flared End Section Condition
Apron/Scour Protection Condition (outlet only)
Armoring Condition
Embankment Piping

Equation 1: Level 3 Score

$$Score = 1.0 - (0.1 \times N)$$

$N = \text{number of variables from Table 3 marked "Poor"}$

Table 4: Structural Condition Binned Score

Lowest Score Resulting from Level 1, Level 2, and Level 3 Variable Assessment	Condition Binned Score
0.81 - 1.00	1
0.61 - 0.80	2
0.41 - 0.60	3
0.21 - 0.40	4
0.0 - 0.20	5

Transportation Services Disruption Worksheet
Road-Stream Crossing Assessment
Tioga County Watersheds

June 2019

Stream Name	Road Name	NYS Road Functional Classification	Transportation Disruption Score (1-5)
Wappasening Creek Watershed			
Unnamed Trib to Unnamed Trib at Briggs Hollow	Moore Hill Road	9	1
Unnamed Tributary at Briggs Hollow	State Line Road	9	1
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road	9	1
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road	9	1
Unnamed Tributary at Briggs Hollow	Briggs Hill Road	9	1
Unnamed Tributary at Briggs Hollow	Upper Briggs Hollow Road	9	1
Huntington Creek Watershed			
Huntington Creek	Sheldon Guile Boulevard	7	2
Huntington Creek	Owego & Hartford Railroad	14	4
Huntington Creek	North Avenue (NY 96)	14	4
Huntington Creek	Driveway off Dean Street	9	1
Huntington Creek	Driveway off Dean Street	9	1
Huntington Creek	Winery Driveway off Allen Glen Rd	9	1
Huntington Creek	Allen Glen Road	9	1
Tributary to Huntington Creek	Winery Trail off Allen Glen Rd	9	1
Tributary to Huntington Creek	Carmichael Road	9	1
Tributary to Huntington Creek	Driveway off Carmichael Rd	9	1
Apalachin Creek Watershed			
Unnamed Tributary to Deerlick Creek	Summit Road	9	1
Unnamed Tributary to Deerlick Creek	Beach Road	9	1
Unnamed Tributary to Apalachin Creek	Barton Road	9	1
Deerlick Creek	Pennsylvania Avenue	16	3
Long Creek	Pennsylvania Avenue	16	3
Long Creek	Long Creek Road	9	1
Unnamed Tributary to Long Creek	Long Creek Road	9	1
Deerlick Creek	Chestnut Ridge Road	9	1
Unnamed Tributary to Deerlick Creek	Montrose Turnpike	8	2
Unnamed Tributary to Apalachin Creek	Gaylord Road	9	1
Unnamed Tributary to Apalachin Creek	Gaylord Road	9	1
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	16	3
Unnamed Tributary to Apalachin Creek	Card Road	9	1
Apalachin Creek	Harnick Road	9	1
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	16	3
Unnamed Tributary to Apalachin Creek	Fox Road	9	1

FUNCTIONAL CLASSIFICATION CODES	NYS Codes Urban	NYS Codes Rural	FHWA Codes
Principal Arterial - Interstate	11	01	1
Principal Arterial - Other Freeway/Expressway	12	02	2
Principal Arterial - Other	14	04	3
Minor Arterial	16	06	4
Major Collector	17	07	5
Minor Collector	18	08	6
Local	19	09	7

https://www.dot.ny.gov/gisapps/functional-class-maps

Transportation Disruption Score	Road Classification (Highway Functional Classification)
1	Local Roads, Trails, Driveways
2	Major and Minor Collectors
3	Minor Arterials
4	Other Principal Arterials
5	Interstates, Freeways, and Expressways

Potential Flooding Impacts Worksheet
Road-Stream Crossing Assessment
Tioga County Watersheds

June 2019

Stream Name	Road Name	Potential Flood Impacts			Scoring				
		Percent Developed Area within Flood Impact Area	Number of Stream Crossings within Flood Impact Area	Number of Utilities (Gas, Water, Sewer) conveyed by Crossing	Developed Area Score	Crossings Score	Utilities Score	Flood Impact Potential Score (sum)	Flood Impact Potential Score (1-5)
Wappasening Creek Watershed									
Unnamed Trib to Unnamed Trib at Briggs Hollow	Moore Hill Road	1.2%	0	0	1	1	1	3	1
Unnamed Tributary at Briggs Hollow	State Line Road	2.4%	1	0	1	3	1	5	2
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road	0.9%	0	0	1	1	1	3	1
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road	6.0%	2	0	2	5	1	8	3
Unnamed Tributary at Briggs Hollow	Briggs Hill Road	3.7%	2	0	1	5	1	7	3
Unnamed Tributary at Briggs Hollow	Upper Briggs Hollow Road	4.3%	2	0	1	5	1	7	3
Huntington Creek Watershed									
Huntington Creek	Sheldon Guile Boulevard	5.7%	2	0	2	5	1	8	3
Huntington Creek	Owego & Hartford Railroad	6.1%	3	0	2	5	1	8	3
Huntington Creek	North Avenue (NY 96)	5.1%	3	1	2	5	3	10	4
Huntington Creek	Driveway off Dean Street	6.6%	6	0	2	5	1	8	3
Huntington Creek	Driveway off Dean Street	5.0%	5	0	2	5	1	8	3
Huntington Creek	Winery Driveway off Allen Glen Rd	0.8%	3	0	1	5	1	7	3
Huntington Creek	Allen Glen Road	1.0%	3	0	1	5	1	7	3
Tributary to Huntington Creek	Winery Trail off Allen Glen Rd	0.2%	2	0	1	5	1	7	3
Tributary to Huntington Creek	Carmichael Road	5.3%	1	0	2	3	1	6	2
Tributary to Huntington Creek	Driveway off Carmichael Rd	1.2%	1	0	1	3	1	5	2
Apalachin Creek Watershed									
Unnamed Tributary to Deerlick Creek	Summit Road	0.9%	0	0	1	1	1	3	1
Unnamed Tributary to Deerlick Creek	Beach Road	0.6%	0	0	1	1	1	3	1
Unnamed Tributary to Apalachin Creek	Barton Road	1.1%	0	0	1	1	1	3	1
Deerlick Creek	Pennsylvania Avenue	22.4%	0	0	3	1	1	5	2
Long Creek	Pennsylvania Avenue	12.5%	2	0	3	5	1	9	3
Long Creek	Long Creek Road	15.8%	2	0	3	5	1	9	3
Unnamed Tributary to Long Creek	Long Creek Road	3.6%	0	0	1	1	1	3	1
Deerlick Creek	Chestnut Ridge Road	0.0%	0	0	1	1	1	3	1
Unnamed Tributary to Deerlick Creek	Montrose Turnpike	1.0%	0	0	1	1	1	3	1
Unnamed Tributary to Apalachin Creek	Gaylord Road	8.6%	1	0	2	3	1	6	2
Unnamed Tributary to Apalachin Creek	Gaylord Road	4.3%	1	0	1	3	1	5	2
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	4.0%	1	0	1	3	1	5	2
Unnamed Tributary to Apalachin Creek	Card Road	4.9%	1	0	1	3	1	5	2
Apalachin Creek	Harnick Road	5.0%	2	0	1	5	1	7	3
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	3.3%	2	0	1	5	1	7	3
Unnamed Tributary to Apalachin Creek	Fox Road	3.3%	2	0	1	5	1	7	3

Flooding impact potential ratings

Impact Rating	Percent Developed Area within Flood Impact Area	Number of Stream Crossings within Flood Impact Area
1	<5% developed area	0
2	<10% developed area	--
3	<25% developed area	1
4	<50% developed area	--
5	>50% developed area	>1

Utility impact potential ratings

Impact Rating	Utilities Present at the Crossing
1	None
2	--
3	Single Utility (Gas, Water, or Sewer) attached to or buried within crossing
4	--
5	Two or more utilities attached to or buried within crossing

Binned Flood Impact Potential Scores

Impact Rating	Sum of Component Scores
1	1 - 3
2	4 - 6
3	7 - 9
4	10 - 12
5	13 - 15

Aquatic Organism Passage Worksheet
Road-Stream Crossing Assessment
Tioga County Watersheds

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Stream Name	Road Name	Aquatic Organism Passage Component Scores														Final Score		
		Constriction	Inlet Grade	Internal Structures	Outlet Armoring	Physical Barriers	Scour Pool	Substrate Coverage	Substrate Matches Stream	Water Depth	Water Velocity	Openness Measurement	Openness Score (So)	Height Score (Sh)	Outlet Drop Score (Sod)	Weighted Composite Passability Score	Aquatic Passability Score	Aquatic Passability Score (1-5)
Wappasening Creek Watershed																		
Unnamed Trib to Unnamed Trib at Briggs Hollow	Moore Hill Road	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0	0.34	0.66	0.97	0.07	0.461	0.067	5
Unnamed Tributary at Briggs Hollow	State Line Road	0.0	1.0	1.0	0.0	1.0	0.8	0.5	1.0	0.0	0.0	1.27	1.00	0.96	0.08	0.518	0.079	5
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road	0.0	1.0	1.0	0.0	0.0	0.8	0.5	1.0	0.0	1.0	1.65	1.00	1.00	1.00	0.613	0.613	2
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road	0.5	0.0	1.0	1.0	1.0	0.0	0.5	1.0	0.0	0.0	1.32	1.00	1.00	0.96	0.599	0.599	3
Unnamed Tributary at Briggs Hollow	Briggs Hill Road	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.0	0.0	0.56	0.89	0.97	-0.02	0.272	-0.022	5
Unnamed Tributary at Briggs Hollow	Upper Briggs Hollow Road	0.0	1.0	1.0	1.0	1.0	0.8	0.5	1.0	0.0	1.0	0.70	0.95	0.95	1.00	0.780	0.780	2
Huntington Creek Watershed																		
Huntington Creek	Sheldon Guile Boulevard	1.0	1.0	1.0	1.0	0.5	1.0	1.0	1.0	1.0	1.0	1.29	1.00	0.93	1.00	0.929	0.929	1
Huntington Creek	Owego & Hartford Railroad	0.9	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	2.91	1.00	0.35	1.00	0.925	0.925	1
Huntington Creek	North Avenue (NY 96)	0.9	1.0	1.0	0.5	0.5	1.0	1.0	1.0	1.0	1.0	6.27	1.00	1.00	1.00	0.905	0.905	1
Huntington Creek	Driveway off Dean Street	0.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	1.0	14.33	1.00	1.00	1.00	0.883	0.883	1
Huntington Creek	Driveway off Dean Street	0.0	0.0	1.0	1.0	0.8	0.0	0.7	1.0	1.0	1.0	1.36	1.00	0.99	1.00	0.706	0.706	2
Huntington Creek	Winery Driveway off Allen Glen Rd	0.0	0.0	1.0	1.0	0.8	0.8	0.0	0.0	0.0	0.0	0.88	0.98	1.00	0.74	0.449	0.449	3
Huntington Creek	Allen Glen Road	0.0	1.0	1.0	0.0	0.5	0.8	0.0	0.0	0.0	0.5	1.36	1.00	0.99	1.00	0.542	0.542	3
Tributary to Huntington Creek	Winery Trail off Allen Glen Rd	0.5	1.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	11.66	1.00	0.97	1.00	0.940	0.940	1
Tributary to Huntington Creek	Carmichael Road	0.0	0.0	1.0	1.0	0.0	1.0	0.5	1.0	0.0	0.5	0.16	0.27	0.84	1.00	0.491	0.491	3
Tributary to Huntington Creek	Driveway off Carmichael Rd	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.5	1.25	1.00	0.90	-0.01	0.422	-0.013	5
Apalachin Creek Watershed																		
Unnamed Tributary to Deerlick Creek	Summit Road	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.5	0.07	0.06	0.50	0.04	0.364	0.041	5
Unnamed Tributary to Deerlick Creek	Beach Road	0.0	0.0	1.0	1.0	0.5	1.0	0.0	0.0	0.0	0.0	0.62	0.93	0.97	-0.02	0.297	-0.017	5
Unnamed Tributary to Apalachin Creek	Barton Road	0.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.04	0.02	0.50	0.50	0.244	0.244	4
Deerlick Creek	Pennsylvania Avenue	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4.63	1.00	1.00	1.00	0.955	0.955	1
Long Creek	Pennsylvania Avenue	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	7.30	1.00	1.00	1.00	0.955	0.955	1
Long Creek	Long Creek Road	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.98	1.00	0.72	0.50	0.862	0.500	3
Unnamed Tributary to Long Creek	Long Creek Road	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	1.0	0.07	0.06	0.72	0.50	0.545	0.500	3
Deerlick Creek	Chestnut Ridge Road	0.0	1.0	1.0	0.5	0.0	1.0	1.0	1.0	0.5	0.5	0.13	0.18	0.72	1.00	0.620	0.620	2
Unnamed Tributary to Deerlick Creek	Montrose Turnpike	0.5	1.0	1.0	1.0	1.0	0.8	0.0	0.0	1.0	0.0	0.08	0.06	0.50	0.02	0.504	0.016	5
Unnamed Tributary to Apalachin Creek	Gaylord Road	0.0	0.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.0	1.88	1.00	1.00	0.08	0.371	0.079	5
Unnamed Tributary to Apalachin Creek	Gaylord Road	0.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	1.13	1.00	1.00	0.01	0.416	0.007	5
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.26	1.00	0.68	1.00	0.941	0.941	1
Unnamed Tributary to Apalachin Creek	Card Road	0.0	0.0	1.0	0.0	1.0	0.0	0.5	1.0	1.0	0.5	0.88	0.98	0.60	0.33	0.519	0.332	4
Apalachin Creek	Harnick Road	0.9	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	1.0	8.39	1.00	1.00	1.00	0.964	0.964	1
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	0.5	1.0	1.0	1.0	1.0	0.8	0.0	0.0	0.0	0.5	3.89	1.00	1.00	0.61	0.629	0.612	2
Unnamed Tributary to Apalachin Creek	Fox Road	0.0	1.0	1.0	1.0	0.8	0.0	0.5	1.0	0.0	0.0	1.10	1.00	1.00	1.00	0.621	0.621	2

Aquatic Organism Passage Worksheet
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Equation 1: Openness Measurement (feet)

$$\text{Openness Measurement} = \frac{\text{Structure Cross Sectional Area}}{\text{Structure Length}}$$

Equation 2: Openness Score (S_o), for openness measurement (x) in feet

$$S_o = (1 - e^{-5.7x})^{2.6316}$$

Equation 3: Height Score (S_h) for height measurement (x) in feet

$$S_h = min\left(\left(\frac{1.1x^2}{4.84 + x^2}\right), 1\right)$$

Equation 4: Outlet Drop Score (S_{od}) for outlet drop measurement (x) in feet

$$S_{od} = 1 - \frac{1.029412x^2}{0.26470588 + x^2}$$

Equation 5: Aquatic Passability Score

Aquatic Passability Score =
Min [Composite Score, Outlet Drop score]

Component Scores for AOP field variables

Field Variable	Level	Component Score
Constriction	Severe	0
	Moderate	0.5
	Spans Only Bankfull/Active Channel	0.9
	Spans Full Channel and Banks	1
Inlet Grade	Inlet Drop	0
	Perched	0
	Clogged/Collapsed/Submerged	1
	Unknown	1
	At Stream Grade	1
Internal Structures	Baffles/Weirs	0
	Supports	0.8
	Other	1
	None	1
Outlet Apron	Extensive	0
	Not Extensive	0.5
	None	1
Physical Barriers	Severe	0
	Moderate	0.5
	Minor	0.8
	None	1
Scour Pool	Large	0
	Small	0.8
	None	1
Substrate Coverage	None	0
	25%	0.5
	50%	0.5
	75%	0.7
	100%	1
Substrate Matches Stream	None	0
	Not Appropriate	0.25
	Contrasting	0.75
	Comparable	1
Water Depth	No (Significantly Deeper)	0.5
	No (Significantly Shallower)	0
	Yes (Comparable)	1
	Dry (Stream Also Dry)	1
Water Velocity	No (Significantly Faster)	0
	No (Significantly Slower)	0.5
	Yes (Comparable)	1
	Dry (Stream Also Dry)	1

Weights associated with each variable in the component scoring algorithm

Parameter	Weight
Outlet Drop	0.161
Physical Barriers	0.135
Constriction	0.090
Inlet Grade	0.088
Water Depth	0.082
Water Velocity	0.080
Scour Pool	0.071
Substrate Matches Stream	0.070
Substrate Coverage	0.057
Openness	0.052
Height	0.045
Outlet Armoring	0.037
Internal structures	0.032

Aquatic Passability Binned Score

Aquatic Passability Score	Descriptor	Aquatic Passability Binned Score
1.00	No Barrier	1
0.80 - 0.99	Insignificant Barrier	1
0.60 - 0.79	Minor Barrier	2
0.40 - 0.59	Moderate Barrier	3
0.20 - 0.39	Significant Barrier	4
0.0 - 0.19	Severe Barrier	5

Prioritization Worksheet
Road-Stream Crossing Assessment
Tioga County Watersheds

June 2019

Stream Name	Road Name	XY Code	Lat.	Long.	Probability of Failure			Magnitude of Failure Impact		Aquatic Passability Score (1-5)	Risk Score				Priority		
					Hydraulic Capacity Score (1-5)	Geomorphic Vulnerability Score (1-5)	Structural Condition Score (1-5)	Transportation Disruption Score (1-5)	Flood Impact Potential Score (1-5)		Hydraulic Risk Score (2-50)	Geomorphic Risk Score (2-50)	Structural Risk Score (2-50)	Crossing Risk Score (2-50)	Crossing Priority Score (3-55)	Normalized Crossing Priority Score (0.00 - 1.00)	Relative Priority Rating
Wappasening Creek Watershed																	
Unnamed Trib to Unnamed Trib at Briggs Hollow	Moore Hill Road	xy42020297632978	42.0203	-76.3298	5	4	2	1	1	5	10	8	4	10	15	0.23	Medium
Unnamed Tributary at Briggs Hollow	State Line Road	xy42001917633382	42.0019	-76.3338	5	4	1	1	2	5	15	12	3	15	20	0.33	Medium
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road	xy42008547632281	42.0085	-76.3228	3	3	5	1	1	2	6	6	10	10	12	0.17	Low
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road	xy42014377631276	42.0144	-76.3128	1	4	2	1	3	3	4	16	8	16	19	0.31	Medium
Unnamed Tributary at Briggs Hollow	Briggs Hill Road	xy42016697630592	42.0167	-76.3059	4	4	2	1	3	5	16	16	8	16	21	0.35	Medium
Unnamed Tributary at Briggs Hollow	Upper Briggs Hollow Road	xy42017497630441	42.0175	-76.3044	2	4	1	1	3	2	8	16	4	16	18	0.29	Medium
Huntington Creek Watershed																	
Huntington Creek	Sheldon Guile Boulevard	xy42119547627212	42.1195	-76.2721	4	4	5	2	3	1	20	20	25	25	26	0.44	High
Huntington Creek	Owego & Hartford Railroad	xy42119437627142	42.1194	-76.2714	5	3	1	4	3	1	35	21	7	35	36	0.63	High
Huntington Creek	North Avenue (NY 96)	xy42119767626976	42.1198	-76.2698	1	3	2	4	4	1	8	24	16	24	25	0.42	High
Huntington Creek	Driveway off Dean Street	xy42120687626354	42.1207	-76.2635	1	3	5	1	3	1	4	12	20	20	21	0.35	Medium
Huntington Creek	Driveway off Dean Street	xy42120867626199	42.1209	-76.262	5	4	5	1	3	2	20	16	20	20	22	0.37	Medium
Huntington Creek	Winery Driveway off Allen Glen Rd	xy42120077625744	42.1201	-76.2574	5	4	5	1	3	3	20	16	20	20	23	0.38	Medium
Huntington Creek	Allen Glen Road	xy42119867625699	42.1199	-76.257	1	4	5	1	3	3	4	16	20	20	23	0.38	Medium
Tributary to Huntington Creek	Winery Trail off Allen Glen Rd	xy42120347625712	42.1203	-76.2571	1	3	1	1	3	1	4	12	4	12	13	0.19	Low
Tributary to Huntington Creek	Carmichael Road	xy42124927626243	42.1249	-76.2624	4	4	5	1	2	3	12	12	15	15	18	0.29	Medium
Tributary to Huntington Creek	Driveway off Carmichael Rd	xy42127037626128	42.127	-76.2613	1	5	5	1	2	5	3	15	15	15	20	0.33	Medium
Apalachin Creek Watershed																	
Unnamed Tributary to Deerlick Creek	Summit Road	xy42065897618994	42.0659	-76.1899	2	4	2	1	1	5	4	8	4	8	13	0.19	Low
Unnamed Tributary to Deerlick Creek	Beach Road	xy42057077619369	42.0571	-76.1937	1	5	5	1	1	5	2	10	10	10	15	0.23	Medium
Unnamed Tributary to Apalachin Creek	Barton Road	xy42058847617863	42.0588	-76.1786	5	5	5	1	1	4	10	10	10	10	14	0.21	Medium
Deerlick Creek	Pennsylvania Avenue	xy42053247616751	42.0532	-76.1675	1	2	1	3	2	1	5	10	5	10	11	0.15	Low
Long Creek	Pennsylvania Avenue	xy42040787616462	42.0408	-76.1646	1	3	5	3	3	1	6	18	30	30	31	0.54	High
Long Creek	Long Creek Road	xy42037637617443	42.0376	-76.1744	1	3	5	1	3	3	4	12	20	20	23	0.38	Medium
Unnamed Tributary to Long Creek	Long Creek Road	xy42027377619932	42.0274	-76.1993	5	4	5	1	1	3	10	8	10	10	13	0.19	Low
Deerlick Creek	Chestnut Ridge Road	xy42029607621714	42.0296	-76.2171	1	5	5	1	1	2	2	10	10	10	12	0.17	Low
Unnamed Tributary to Deerlick Creek	Montrose Turnpike	xy42034967622191	42.035	-76.2219	5	4	1	2	1	5	15	12	3	15	20	0.33	Medium
Unnamed Tributary to Apalachin Creek	Gaylord Road	xy42026487615216	42.0265	-76.1522	4	4	5	1	2	5	12	12	15	15	20	0.33	Medium
Unnamed Tributary to Apalachin Creek	Gaylord Road	xy42024117613557	42.0241	-76.1356	4	4	5	1	2	5	12	12	15	15	20	0.33	Medium
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	xy42009657614802	42.0097	-76.148	5	3	5	3	2	1	25	15	25	25	26	0.44	High
Unnamed Tributary to Apalachin Creek	Card Road	xy42006937614894	42.0069	-76.1489	1	4	5	1	2	4	3	12	15	15	19	0.31	Medium
Apalachin Creek	Harnick Road	xy42005297614114	42.0053	-76.1411	3	3	1	1	3	1	12	12	4	12	13	0.19	Low
Unnamed Tributary to Apalachin Creek	Pennsylvania Avenue	xy42004357614315	42.0044	-76.1432	2	4	2	3	3	2	12	24	12	24	26	0.44	High
Unnamed Tributary to Apalachin Creek	Fox Road	xy42002707614470	42.0027	-76.1447	5	4	5	1	3	2	20	16	20	20	22	0.37	Medium

Prioritization Worksheet
Road-Stream Crossing Assessment
Tioga County Watersheds

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Equation 1: Risk Equation

$$\begin{aligned}&Risk\ of\ Failure\\&= Probability\ of\ Failure\\&\times Magnitude\ of\ the\ Impact\ of\ Failure\end{aligned}$$

Equation 2: Impact Score

$$Impact\ Score = Transportation\ Disruption\ Score + Flood\ Impact\ Potential\ Score$$

Equation 3: Hydraulic Risk Score

$$Hydraulic\ Risk\ Score = Hydraulic\ Capacity\ Score \times Impact\ Score$$

Equation 4: Geomorphic Risk Score

$$Geomorphic\ Risk\ Score = Geomorphic\ Vulnerability\ Score \times Impact\ Score$$

Equation 5: Structural Risk Score

$$Structural\ Risk\ Score = Structural\ Condition\ Score \times Impact\ Score$$

Equation 6: Crossing Risk Score

$$Crossing\ Risk\ Score = Maximum(Hydraulic\ Risk\ Score, Geomorphic\ Risk\ Score, Structural\ Risk\ Score)$$

Equation 7: Crossing Priority Score

$$Crossing\ Priority\ Score = Crossing\ Risk\ Score + Aquatic\ Passability\ Score$$

Normalized Crossing Priority Score	Relative Priority Rating
0.40 – 1.00	High
0.20 - 0.40	Medium
0.00 - 0.20	Low

Appendix C - Summary Prioritization Matrix

Summary Prioritization Matrix

Watershed	Watercourse	Project number	Project type	Flood risk - Attenuation	Flood risk - Damage reduction	Stream corridor infrastructure risk	Erosion/ channel stability	In-stream ecological benefit	Riparian ecological benefit	Public education value	Estimated implementation cost	Notes	Total Score (Out of 100)	Rank
Location				Criteria weight									Summary	
				2	2	2	2	1	1	1				
Apalachin Creek	Apalachin Creek mainstem	Ap-30000	Structure Removal - Ponds area	9	9	1	9	9	9	9	> $1M	Would allow channel to evolve naturally and create open space for recreation. High visibility from Pennsylvania Ave.	**84**	**1**
Apalachin Creek	Apalachin Creek mainstem	Ap-26000	Structure Removal - Pennsylvania Ave	1	9	9	1	1	9	9	> $1M	Implement in conjunction with or after Ap-30000. High visibility and impact.	**60**	**7**
Apalachin Creek	Apalachin Creek mainstem	Ap-20200	Riparian Management - Forestry	5	1	1	9	9	9	5	> $1M	Requires working closely with a private landowner	**56**	**12**
Apalachin Creek	Apalachin Creek mainstem	Ap-17700	Structure Removal - Rhodes Road	5	9	1	5	9	9	9	> $1M	Implement in conjuction with Ap-14900. High visibility from Pennsylvania Ave.	**68**	**3**
Apalachin Creek	Apalachin Creek mainstem	Ap-14900	Structure Removal - Pennsylvania Ave	1	9	9	1	1	9	9	> $1M	Implement in conjunction with Ap-17700. High visibility and impact.	**60**	**7**
Apalachin Creek	Apalachin Creek mainstem	Ap-9400	Upland Land Management - Barton Road stormwater	5	5	5	1	5	1	9	<$25k (BMPs) to $500k+ (large stormwater improvement project)	Would involve a large number of homeowners.	**48**	**16**
Apalachin Creek	Apalachin Creek mainstem	Ap-6000	Riparian Management - Sewer siphon	1	1	9	9	1	5	1	<$25k (monitoring and planting) to > $1M (reconstruction)	Sewer line and siphon owned and maintained by Town of Owego	**48**	**16**
Apalachin Creek	Fox Road tributary	ApFo-4000	Upland Land Management - Fox Road drainage	5	1	5	5	5	1	9	$250-500k	Town road, educational opportunity with municipal staff and agricultural landowners	**48**	**16**
Apalachin Creek	Fox Road tributary	ApFo-1300	Crossing Improvement - Fox Road	1	9	9	5	5	1	5	$500k - $1M	Town road, educational opportunity with municipal staff	**60**	**7**
Apalachin Creek	Fox Road tributary	ApFo-600	Crossing Improvement - Pennsylvania Ave	1	1	5	1	5	1	5	<$25k (monitoring) to $500k - $1M (replacement)	County road, educational opportunity with County staff	**28**	**40**
Apalachin Creek	Harnick Road tributary	ApHa-7600	Upland Land Management - Harnick headwaters	5	1	5	1	5	9	9	$500k - $1M	Private land but on Town road. Opportunity for landowner education and public demonstration site if easement established.	**48**	**16**
Apalachin Creek	Harnick Road tributary	ApHa-5800	Crossing Improvement - Private crossing	1	1	5	9	5	1	1	$150-250k	Private land with access off of Bolles Hill Road. Requires downstream grade control.	**40**	**30**

Summary Prioritization Matrix

Location				*Criteria weight*									Summary	
				2	2	2	2	1	1	1				
Watershed	**Watercourse**	**Project number**	**Project type**	**Flood risk - Attenuation**	**Flood risk - Damage reduction**	**Stream corridor infrastructure risk**	**Erosion/ channel stability**	**In-stream ecological benefit**	**Riparian ecological benefit**	**Public education value**	**Estimated implementation cost**	**Notes**	**Total Score** *(Out of 100)*	**Rank**
Apalachin Creek	Harnick Road tributary	ApHa-2600	Upland Land Management - Harnick Road drainage	5	1	5	5	5	1	5	$250-500k	Town road, educational opportunity with municipal staff	**44**	**20**
		ApHa-2400	Crossing Improvement - Private crossing	5	1	5	5	1	1	1	$75-150k	Private crossing. Requires implementation of ApHa-2600 to improve conditions at site. Good access off of Harnick Road	**36**	**33**
		ApHa-1100	Crossing Improvement - Private crossing	1	1	5	9	5	1	1	$150-250k	Requires coordination with two landowners	**40**	**30**
		ApHa-300	Floodplain Reconnection	5	1	1	9	5	5	1	$250-500k	Private land, channel-spanning large wood structures	**44**	**20**
	Card Road tributary	ApCa-3500	Upland Land Management	1	5	1	1	5	5	5	$75-150k	Opportunity to educate landowners	**32**	**36**
		ApCa-2800	Floodplain Reconnection	5	1	1	9	5	5	1	$250-500k	Private land, valley-spanning large wood structures to maximize flood retention	**44**	**20**
		ApCa-2400	Riparian Management - Forestry	1	1	5	9	5	1	5	$75-150k	Opportunity to educate landowner	**44**	**20**
		ApCa-1400	Crossing Improvement - Card Road	1	1	9	5	5	1	5	$250-500k	Condition of existing culvert poses risk to public safety. Town road, educational opportunity with municipal staff.	**44**	**20**
		ApCa-400	Riparian Management	9	9	1	9	5	9	9	$500k - $1M	Implement in conjunction with Ap-30000, Ap-26000, and ApSa-1100. High visibility from Pennsylvania Ave.	**80**	**2**
	South Apalachin Road tributary	ApSa-5400	Riparian Management - Apalachin Golf Course	5	1	5	9	9	9	9	$500k - $1M	Golf course presents opportunity for demonstration site in area regularly visited by members of the public	**68**	**3**
		ApSa-1100	Riparian Management	5	5	1	5	9	9	5	$75-150k	Opportunity to educate landowners and municipal staff	**56**	**12**
	Gaylord Road tributary	ApGa-7500	Bank Stabilization	1	1	1	9	5	1	1	$75-150k	Private land but good access off of Gaylord Road	**32**	**36**
		ApGa-5800	Road Relocation - Gaylord Road	1	5	9	1	9	5	5	> $1M	Town road, educational opportunity with municipal staff	**52**	**15**

Summary Prioritization Matrix

Location				Criteria weight									Summary	
				2	2	2	2	1	1	1				
Watershed	**Watercourse**	**Project number**	**Project type**	**Flood risk - Attenuation**	**Flood risk - Damage reduction**	**Stream corridor infrastructure risk**	**Erosion/ channel stability**	**In-stream ecological benefit**	**Riparian ecological benefit**	**Public education value**	**Estimated implementation cost**	**Notes**	**Total Score** *(Out of 100)*	**Rank**
Apalachin Creek	Gaylord Road tributary	ApGa-3700	Bank Stabilization	1	1	1	9	5	1	1	$25-75k	Private land but good access off of Gaylord Road	**32**	**36**
		ApGa-1700	Bank Stabilization	1	1	1	9	5	1	1	$25-75k	Private land but good access off of Gaylord Road	**32**	**36**
		ApGa-600	Crossing Improvement - Gaylord Road	1	5	9	9	5	1	5	$500 - $1M	Condition of existing culvert poses risk to public safety. Town road, educational opportunity with municipal staff.	**60**	**7**
	Long Creek	ApLo-12000	Crossing Improvement - Trib to Long Creek	1	1	9	1	5	1	5	$250-500k	Town road, educational opportunity with municipal staff	**36**	**33**
		ApLo-10800	Upland Land Management - Long Creek Rd drainage	5	1	5	5	5	1	5	$250-500k	Town road, educational opportunity with municipal staff	**44**	**20**
		ApLo-9800	Riparian Management - Pond	5	9	1	9	9	5	1	> $1M	Pond poses flood hazard to downstream areas. Private land.	**64**	**6**
		ApLo-9200	Crossing Improvement - Trib to Long Creek	1	1	9	5	5	1	5	$250-500k	Town road, educational opportunity with municipal staff	**44**	**20**
		ApLo-3800	Bank Stabilization	1	9	1	9	5	5	9	> $1M	Would affect a number of private landowners. Visible location along local road so opportunity for demonstration project	**60**	**7**
		ApLo-3600	Crossing Improvement - Long Creek Road	1	1	9	5	5	1	5	$250-500k	Condition of existing culvert poses risk to public safety. Town road, educational opportunity with municipal staff.	**44**	**20**
		ApLo-400	Riparian Management	5	5	1	5	9	9	5	$250-500k	Implement in conjuction with Ap-17700 and Ap-14900	**56**	**12**
	Deerlick Creek	ApDl-23700	Crossing Improvement - Chestnut Ridge Road	1	1	9	5	5	1	5	$150-250k	Condition of existing culvert poses risk to public safety. Town road, educational opportunity with municipal staff.	**44**	**20**
		ApDl-21100	Crossing Improvement - Pipeline	1	1	5	1	5	1	1	$75-150k	Private land. Requires coordination with gas company.	**24**	**41**

Summary Prioritization Matrix

Location				Criteria weight									Summary	
				2	2	2	2	1	1	1				
Watershed	**Watercourse**	**Project number**	**Project type**	**Flood risk - Attenuation**	**Flood risk - Damage reduction**	**Stream corridor infrastructure risk**	**Erosion/ channel stability**	**In-stream ecological benefit**	**Riparian ecological benefit**	**Public education value**	**Estimated implementation cost**	**Notes**	**Total Score** *(Out of 100)*	**Rank**
Apalachin Creek	Deerlick Creek	ApDl-9000	Grade Control	5	1	1	9	5	1	1	$250-500k	Private land. Relatively remote.	**40**	**30**
		ApDl-8900	Crossing Improvement - Beach Rd trib	1	1	9	5	5	1	5	$500k - $1M	Condition of existing culvert poses risk to public safety. Town road, educational opportunity with municipal staff.	**44**	**20**
		ApDl-1500	Floodplain Reconnection	5	1	1	5	5	5	1	> $1M	Private land	**36**	**33**
		ApDl-500	Riparian Management - Faith Christian Fellowship Church	5	9	1	9	5	5	9	> $1M	Would allow channel to evolve naturally and create open space for recreation. High visibility from Pennsylvania Ave.	**68**	**3**