Wappasening Creek Background Report

SUBMITTED TO

Tioga County Soil and Water Conservation District

AUGUST 2019

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SUBMITTED TO
Tioga County Soil and Water Conservation District
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Table of Contents

List of Figures

List of Tables

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 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 seven priority watersheds within Tioga and Broome counties.

This report focuses on the Wappasening 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 existing 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 recent 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, 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 Irene and Sandy 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 WAPPASENING CREEK

Wappasening Creek is a tributary of the Susquehanna River (Figure 1). The junction with the Susquehanna is in the Village of Nichols, New York, but a large portion of the watershed sits in Pennsylvania. This background report will focus on the portion of the watershed within the State of New York, though the resilience and mitigation strategies we present are applicable to the entire watershed. In its entirety, the watershed encompasses 73 square miles of high-relief terrain, with a maximum elevation of 1889 feet and an outlet into the Susquehanna at 775 feet (Figure 2). The portion of the watershed within New York is 14.5 square miles, which includes the junction with the Susquehanna and a maximum elevation of 1785 feet. The mainstem of Wappasening Creek is fed by over thirty tributaries, almost all in Pennsylvania. The unnamed tributary at Briggs Hollow is the only significant tributary watershed in New York. The Wappasening mainstem is approximately 21.2 miles long. The Briggs Hollow tributary is 3.3 miles long and has a drainage area of 4.2 square miles. Additional flow inputs to the Wappasening in New York include numerous small rivulets 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, and culvert failure in upland areas and substantial sediment deposition and inundation in low-lying areas. The flood and damage history of the watershed is discussed in more detail in the Tioga County Multi-Jurisdictional Hazard Mitigation Plan (Tetra Tech 2012, 2018). Notable impacts in the Wappasening Creek watershed of the 2011 event include “total destruction of Kirby Park” and damages to numerous residences. Lower Briggs Hollow Road has been repeatedly damaged by high flows, including a July 2017 storm that required emergency repair work.

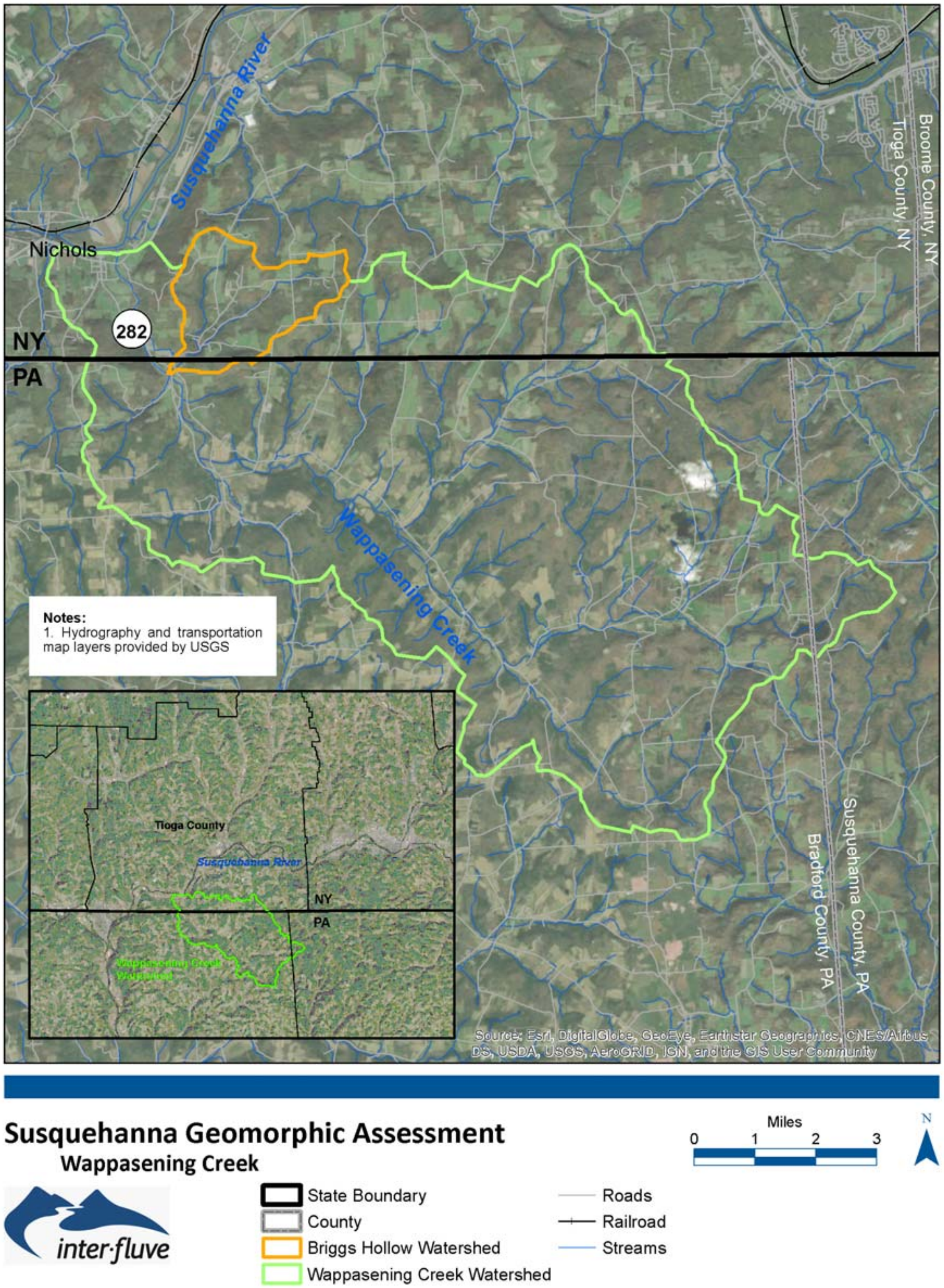

Figure 1. Wappasening Creek watershed location map, Briggs Hollow sub-watershed outlined in orange. 2017 aerial imagery from ESRI.

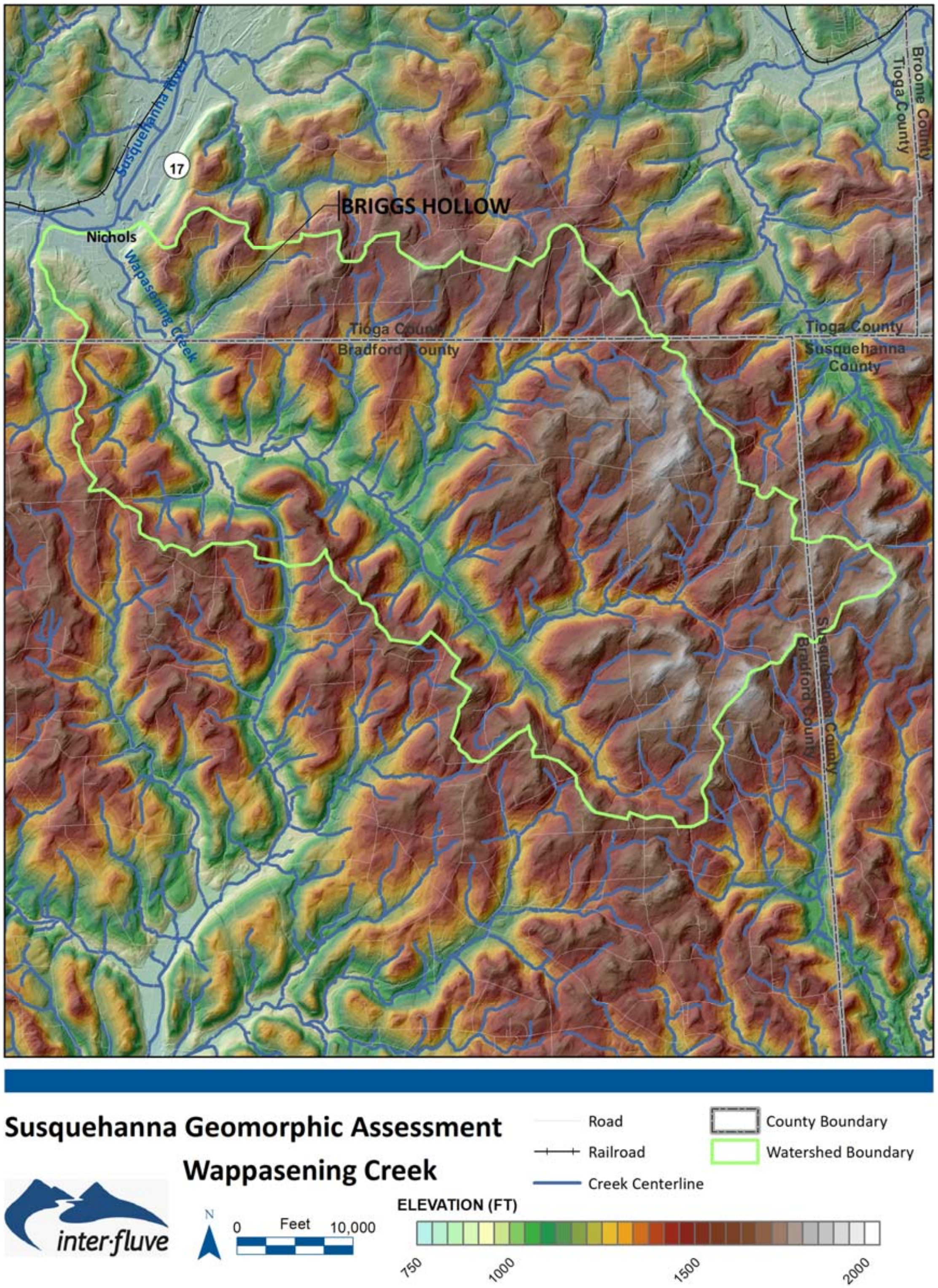

Figure 2. Digital elevation model (DEM) of the Wappasening Creek watershed

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 Wappasening 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.

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 on shaping future conditions. This context provides a framework for identifying proactive flood mitigation measures tailored to the Wappasening 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). 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 land mass 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 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 beginning its retreat from New York around 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 valley floors. Both till and alluvial deposits are composed of thin, platy clasts derived from the region's siltstones and sandstones which break apart along shallow parallel bedding planes.

The Wappasening Creek watershed can be broken into two broad regions: the steep uplands and tributaries and the low-relief valley floor that the mainstem meanders across (Figure 3 and Table 1). The steep uplands, which include the Briggs Hollow tributary, are characterized by steep and confined channels with small or nonexistent overbank areas. The average slope along the Briggs Hollow drainage is approximately 0.03 ft/ft (Table 1), with higher slopes occurring locally and along smaller tributaries. The combination of high slope and confinement is capable of generating flood flows with sufficient velocity and depth to erode and transport the abundant sediment present in surficial deposits, as well as dislodge/abrade and transport the highly erodible bedrock.

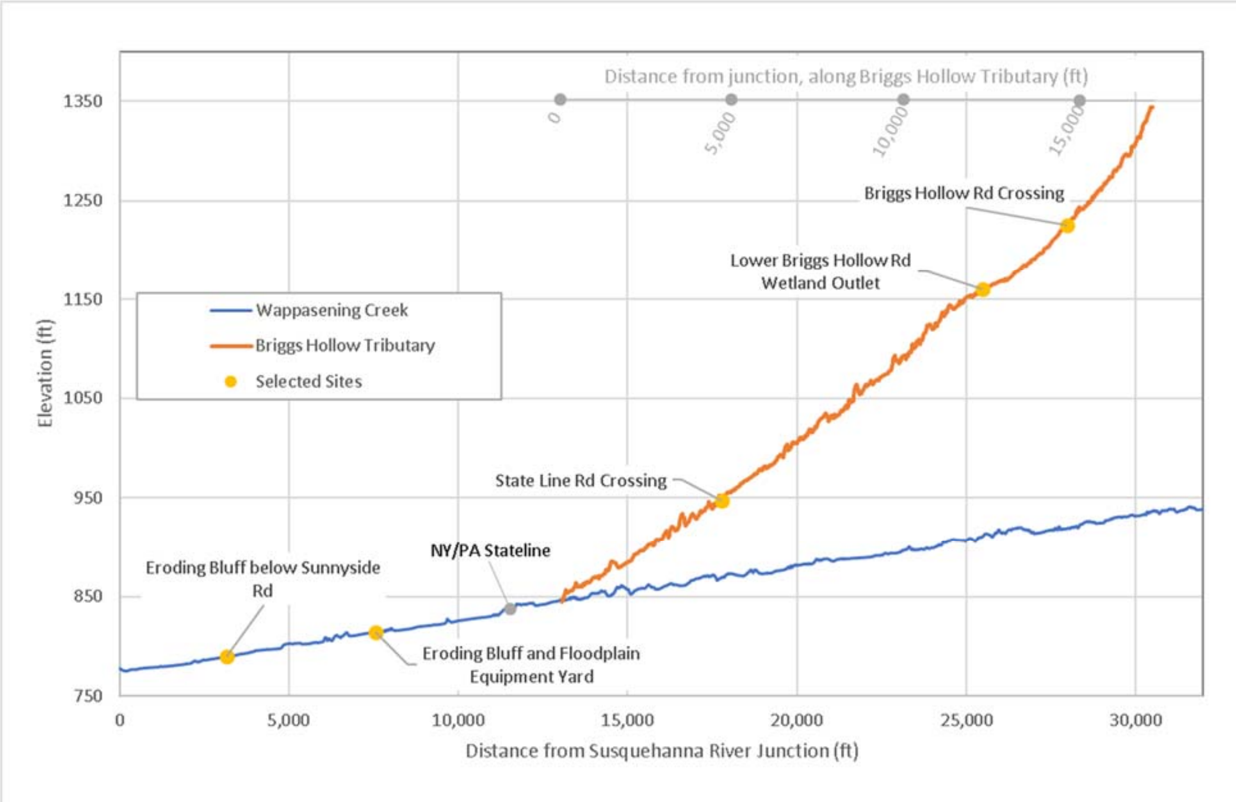

Figure 3. Longitudinal profile of Wappasening Creek and the unnamed tributary in Briggs Hollow based on 2007 LiDAR data provided by Tioga County. Several locations discussed in this report are shown along the profiles for reference. A secondary x-axis is included for the unnamed tributary at Briggs Hollow.

Along the New York portion of the Wappasening Creek mainstem, the average slope is approximately 0.005 ft/ft. The abrupt transition to a lower slope on the broader valley floor results in a substantial reduction in sediment transport capacity and subsequent deposition.

Table 1. Average slopes along primary channels in the Wappasening Creek watershed in New York

Stream channel	Average slope (ft/ft)
Briggs Hollow tributary	0.03
Wappasening Creek within limits shown in Figure 3	0.005

2.3 LAND COVER AND LAND USE

Analysis of data from the National Landcover Database shows that the major landcover in the watershed (including the Pennsylvania portion) is forest (approximately 60%), with agricultural cover types over approximately 30% of the watershed (Figure 4 and Figure 5).

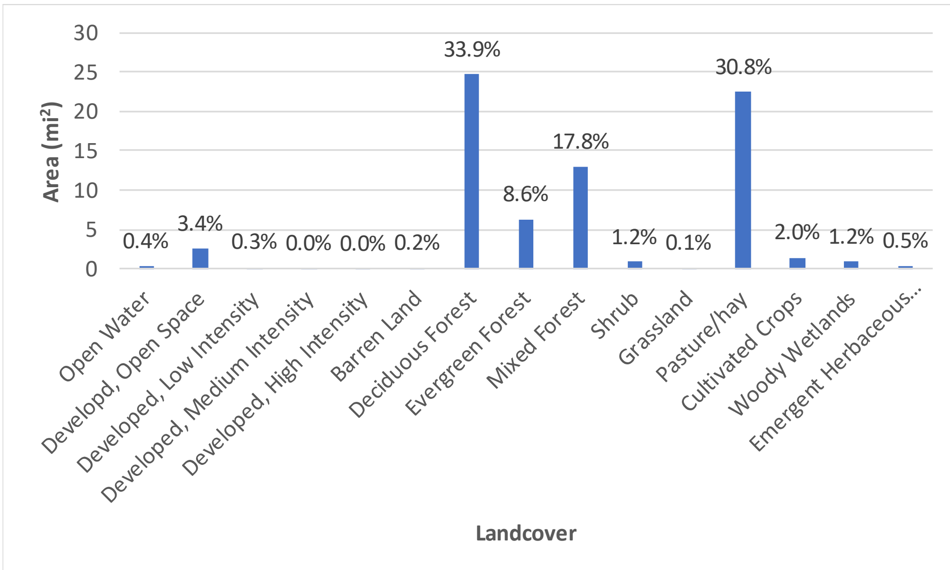

Figure 4. Histogram of Wappasening Creek watershed landcover by area

Our review of historical aerial imagery suggests that this reflects current conditions; however, watershed's history is more varied. Historical aerial photos show in the early 20th century land use in the watershed consisted of more farmland than the modern land use (Figure 6). 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 New York State portion of the Wappasening Creek watershed (NCED 2018[1], NYNHP 2016). There are two parcels in Nichols owned by the state for flood control purposes, and one vacant parcel near the mouth of the creek owned by the Village of Nichols. The 11.9-acre Nichols Kirby Park is located near the confluence of the Susquehanna River as well. No other records were found for protected land in the New York portion of the watershed.

The 2018 County Hazard Mitigation Plan update (Tetra Tech 2018) notes that some homes along the flood-prone portion of South Main Street (State Route 282) have been purchased and structures demolished with the aim of converting the properties to green space for the Town of Nichols.

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

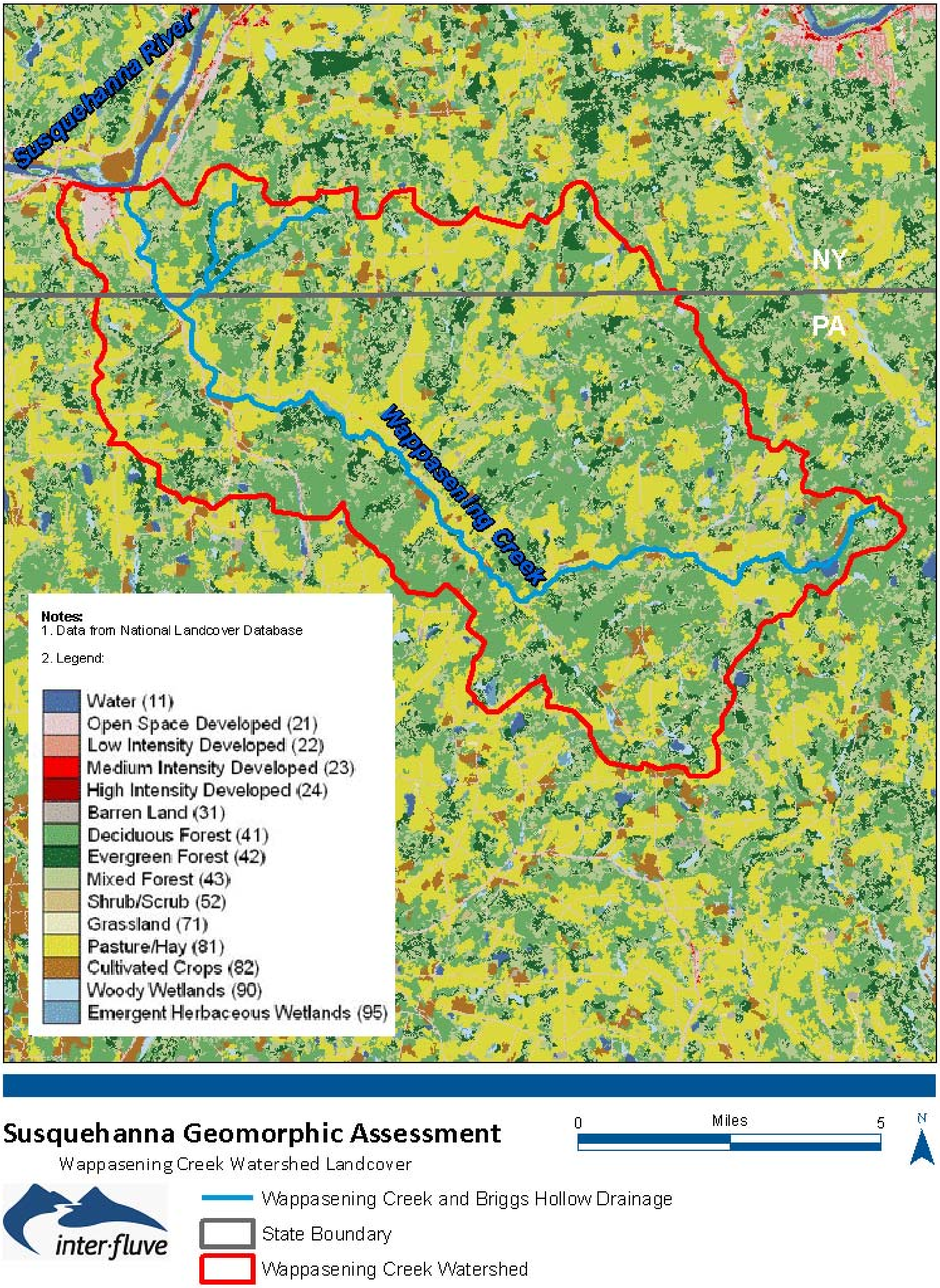

Figure 5. Land cover in the Wappasening Creek watershed

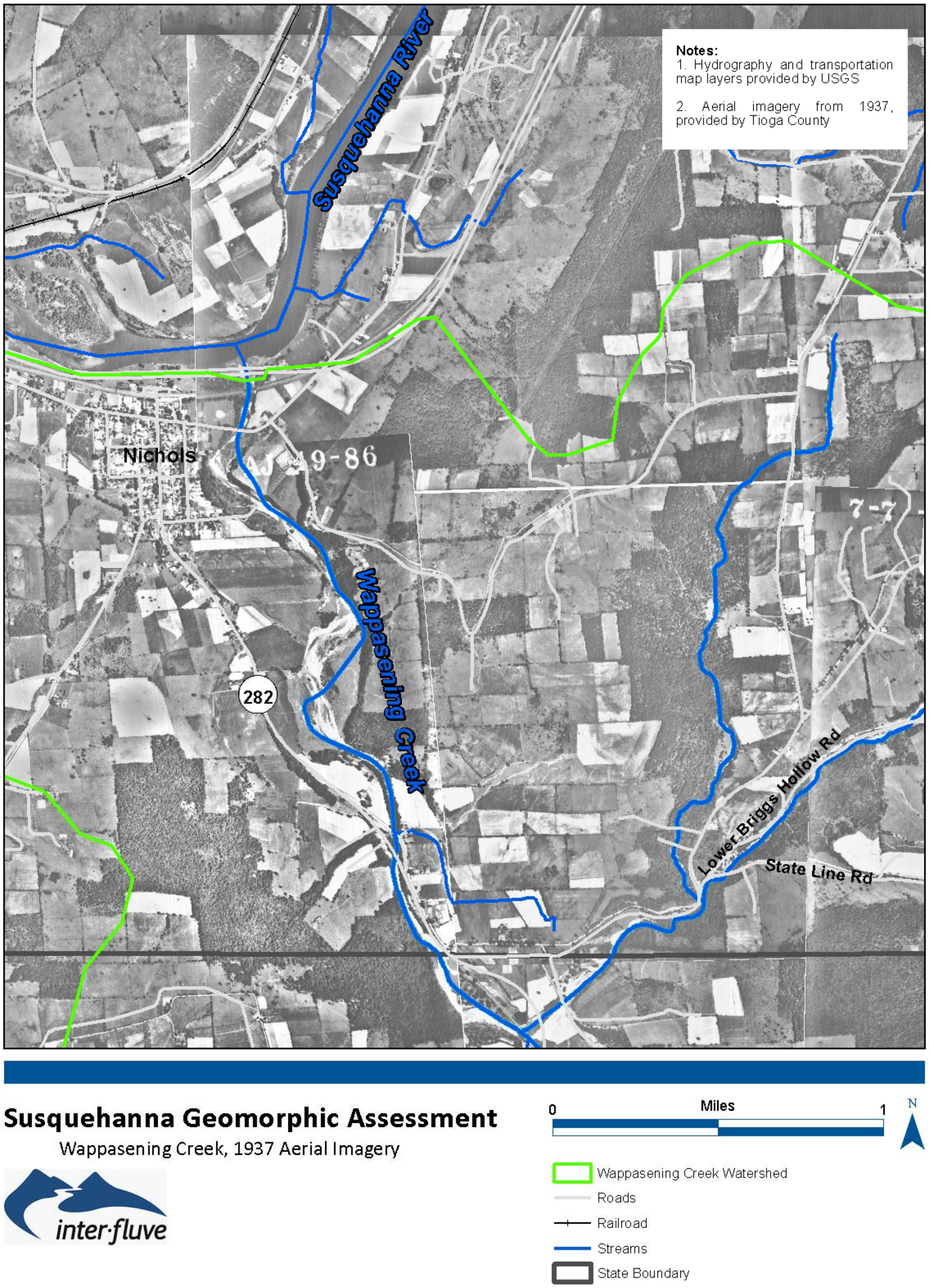

Figure 6. 1937 aerial imagery of the New York portion of the Wappasening Creek watershed

2.4 HYDROLOGY

To provide an estimate of peak flows on Wappasening 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 2. Because the results are derived from a regional regression rather than a long historical record of gage data specific to Wappasening Creek, they should be viewed as an estimate of potential peak flood discharges.

Table 2. Estimated peak flood discharges for Wappasening Creek

Recurrence interval	USGS StreamStats discharge (cfs)
2 years (50% annual chance)	2,920
10 years (10% annual chance)	6,020
50 years (2% annual chance)	9,530
100 years (1% annual chance)	11,200

Floods in Wappasening Creek 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. Throughout the watershed, roads have been constructed alongside creeks, often in narrow valley bottoms where they restrict channel movement and floodwater access to naturally limited overbank areas. Roads in the uplands 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.

The runoff characteristics of the Wappasening 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 available for Wappasening Creek and the Susquehanna River, but not for the Briggs Hollow tributary. FEMA maps show much of the land adjacent to Wappasening Creek within the 1% annual chance flood extent, including portions of State Route 282 and homes built along it near the state line (Figure 7) (FEMA 2012). A U.S. Army Corps of Engineers (USACE) flood control project exists along the downstream reaches of Wappasening Creek to protect the Village of Nichols, protecting it from inundation up through the 1% annual chance flood event. The federal flood protection project is discussed in more detail in Section 0.

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 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/Wappasening Creek watershed was updated in 2009 and indicates no known use impacts for Wappasening Creek and its tributaries. Suspected impairments include nutrients from both point and nonpoint sources (NYS DEC 2009).

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, New York 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 Wappasening Creek watershed, including improvements in storm water management practices, green infrastructure, implementation of 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).

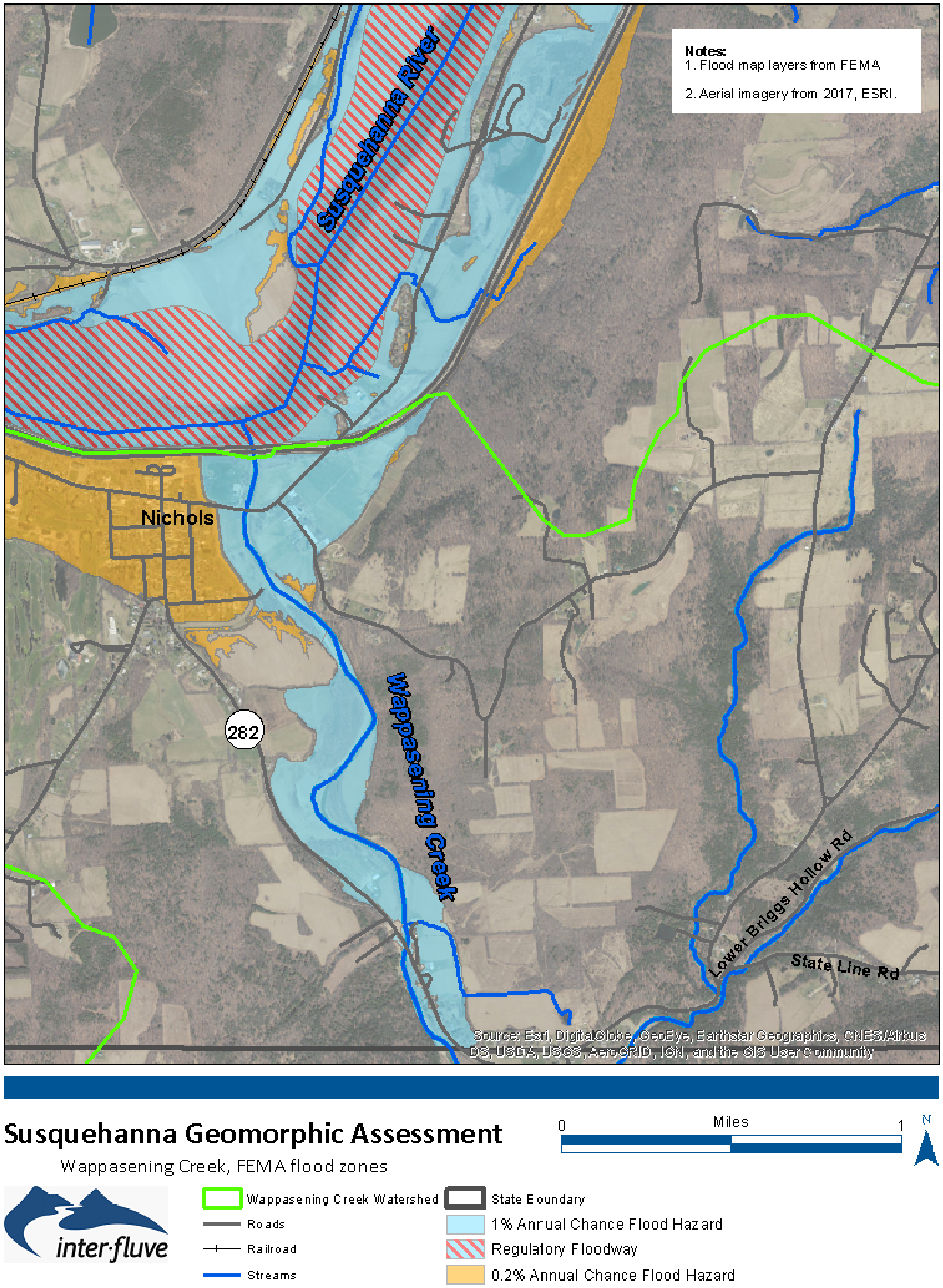

Figure 7. FEMA flood mapping for the Tioga County portion of Wappasening Creek and the Susquehanna River

2.7 ECOLOGY

Wappasening 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 Wappasening Creek was conducted in 2003 as part of the state's rotating integrated basin studies (RIBS) biological screening at River Road/Route 502 with results indicating slightly impacted conditions (NYS DEC 2009). For projects conducted in Wappasening Creek and its tributaries, permitting and work schedules will not be as stringent as in other watersheds because these watercourses are not considered trout streams.

Based on the New York State Department of Environmental Conservation (NYS DEC) Environmental Resource Mapper (NYS DEC 2019a), there are no state mapped freshwater wetlands identified within the watershed. The National Wetlands Inventory (USFWS) shows riverine habitat and numerous forested/shrub wetlands along the mainstem Wappasening Creek and at the mouth of the tributary as well as a ponded area and forested/shrub wetland in the headwaters of the unnamed tributary in Briggs Hollow. 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 threatened and endangered plants and animals by county and rare plants and animals by town. We searched the NHP database via NYS DEC's Nature Explorer (NYS DEC 2019b) for the Town of Nichols and identified the presence of one rare animal: the freshwater mussel, yellow lampmussel (*Lampsilis cariosa*). A search of Tioga County includes the presence of 10 threatened or endangered animals, 34 threatened or endangered plants, and 14 animals of special concern. These species may be present throughout the watershed, and potential impacts of projects should be considered and mitigated against in design and construction phases.

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 (EAB), an invasive wood boring insect that attacks ash trees, eventually killing them. There have been reports of EAB in Tioga County. All of New York's ash trees are vulnerable, and the loss of this species would eliminate 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; therefore, the state of New York has a regulation in place to restrict the movement of firewood.

Japanese knotweed is an invasive plant species introduced into the United States in the late 1800s. It is currently not found in expansive patches in Tioga County, although there are expansive 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 is expected to be available for public review in early 2019.

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 Nichols has several existing regulatory tools to locally enforce hazard mitigation including building codes, zoning ordinances, and a stormwater management (SWMP) plan [refer to Section 9.8 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). The plan 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) and focuses on reduction of contaminants in stormwater from County offices and grounds and is not specific to the Town of Nichols.

2.9 EXISTING MAINTENANCE AND EMERGENCY WORK

We contacted NYS DEC (D. Fuller, personal communication, October 31, 2018) and reviewed the operation and maintenance manual and record drawings (USACE 1988) and record drawings of a repair (McFarland-Johnson-Gibbons Engineers, Inc. 1973) for the USACE flood control project located along the downstream reaches of Wappasening Creek at the Village of Nichols. The existing levee on the left bank floodplain of the creek is approximately 3,900 feet long and runs from the New York State Route 17 Southern Tier Expressway near the confluence with the Susquehanna River upstream around the Town to Main Street. Along the Susquehanna River, the expressway at Nichols forms part of the project and was constructed with an impervious core over a length of about 3,900 feet and is tied into the levee along Wappasening Creek and into a second levee on the western side of Nichols. The entire project, constructed in 1970, is approximately 9,700 feet long and forms a horseshoe shape around the village, protecting it from flooding from both the Susquehanna River (145,000 cfs design flood) and Wappasening Creek (32,000 cfs design flood).

The levee along the creek was damaged during tropical storm Agnes in June 1972. When repairs were carried out, the reach of Wappasening Creek immediately upstream of River Street was re-channelized and shifted approximately 200 feet to the east of its former alignment and away from the levee. The creek within the project limits appears overwide with a uniform cross section and lined with rip rap.

Ongoing maintenance activities involve levee repairs and removal of accumulated sediments on an as-needed basis by the USACE and NYS DEC under a permanent easement. Recently, the USACE reports that they have removed approximately 32,000 cubic yards of gravel from the channelized portion of the creek and have an estimated 8,000 cubic yards more to remove before the creek is restored to as-built dimensions (D. Fuller, personal communication, October 31, 2018). Much of this material was deposited during high-flow events in 2017 and 2018. In 2011, approximately 11,000 cubic yards were removed by NYS DEC following Tropical Storm Irene, and in 2007, approximately 1,700 cubic yards were removed after flooding in June/July 2006. NYS DEC is supportive of projects that would reduce sediment delivery to the flood control project site.

Tioga County SWCD assists landowners with permits for emergency channel work on an ongoing basis under a regional permit issued by the USACE. Permits are generally sought and issued following large flow events and for work such as streambank stabilization, culvert replacement, and dredging.

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

On October 17 and 18, 2018, Inter-Fluve geomorphologists conducted a field investigation of the New York portion of the Wappasening Creek watershed. The assessment involved walking the entire length of Wappasening Creek (within Tioga County) and several tributaries, most notably the Briggs Hollow drainage. Observations and measurements were collected throughout the investigation. Along the way, we collected photos, observations, and measurements in Survey123 by ESRI, a customizable data collection application 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 findings documented in the field. River stations are provided as distances in feet from the confluence with the Susquehanna River as shown in Figure 3.

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

3.1 BRIGGS HOLLOW

As described in Section 0, the watershed is defined by the contrast between steep, narrow upland channels, like the Briggs Hollow tributary, and the more gently sloped Wappasening mainstem channel. Briggs Hollow sits above Wappasening Creek to the east. The hollow is locally known by its upper and lower parts, separated by a saddle that provides a rare spot of low relief in the otherwise steep and dissected landscape (Figure 3 and Figure 8). In general, the channel is narrow and steep, with bankfull widths ranging from less than 20 feet in the upper reaches to approximately 40 feet in the lower reaches and an average slope of approximately 0.03 ft/ft. One notable Briggs Hollow tributary enters the main channel downstream of State Line Road. The steep, narrow channels of Briggs Hollow are capable of transporting large volumes and calibers of sediment. Upland areas of watersheds are naturally source areas of sediment, but some aspects of the Briggs Hollow watershed appear to exacerbate sediment generation.

Observations from throughout the Briggs Hollow drainage consistently suggest that its stream channels have relatively recently experienced widespread lowering of bed levels. The evidence includes perched culverts, head cuts, formerly flood-prone areas stranded above current bankfull levels, and gullying along small side drainage channels. The result is that flood flows are generally focused in relatively deep confined channels and do not have access to floodplain areas or exposure to the roughness that would be afforded by adjacent forest floor. Furthermore, in-channel roughness is primarily provided by coarse gravel and cobbles. Bedforms with features such as large wood and dense, woody root networks that provide substantial habitat opportunity are less common. Vegetative cover on the steep bank slopes is generally poor and the bank material is vulnerable to fluvial erosion as well as mass failure. Forest cover in the uplands is typically hemlock-beech type with sparse shrubs along the forest floor.

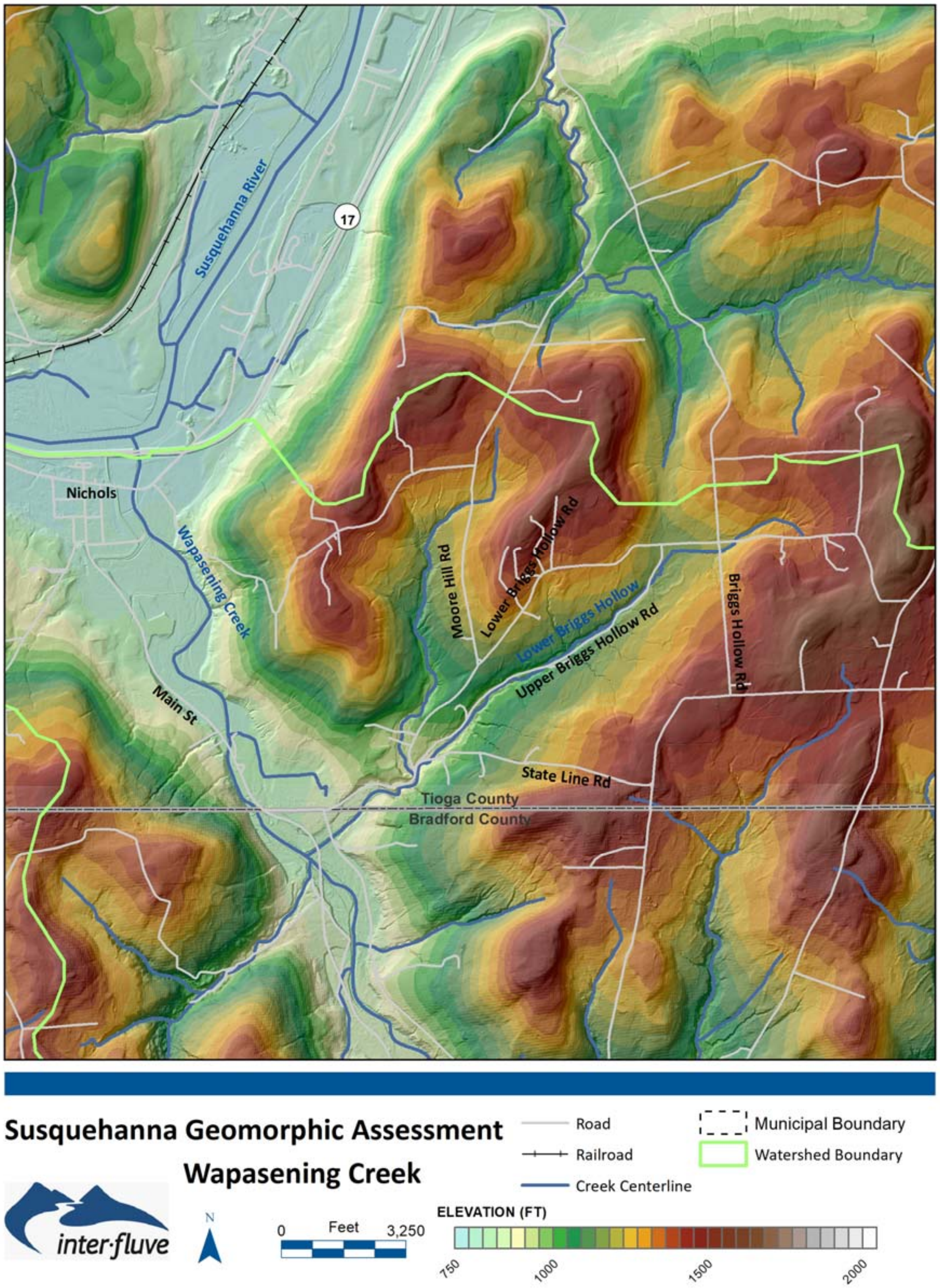

Figure 8. Shaded relief map including the Briggs Hollow area

3.1.1 Upper Briggs Hollow

In Upper Briggs Hollow, large wood is present in the stream channel in the form of channel-spanning large woody debris jams where forest cover is good. Generally, jams appear to have been initiated by fallen trees large enough to span the channel and be anchored in place by root wads or wedged into the channel (Figure 9). Once wedged across the channel, trees trap sediment and smaller woody debris. This recruitment of additional material bolsters jams into relatively stable features that are self-sustaining; if the original wood pieces degrade, often the material that had subsequently been added to the jams will maintain the structures. The jams provide local grade control, creating lower gradient reaches immediately upstream that allow floodwaters to flow onto overbank areas slowing and dispersing erosional forces. Where the channel is less incised and closer in elevation to adjacent forest floor areas, trees growing at the tops of the banks are more effective at forming jams and at stabilizing the full height of the bank slope. The latter occurs through added cohesion (i.e., resistance to failure) and shielding soil from fluvial forces.

The channel locations with these log jams have greater in-channel habitat opportunities than elsewhere. The log jams initiate localized scour, producing deep pools that provide shaded cover and low-velocity resting areas for aquatic species. Elsewhere, the primary habitat opportunities only vary with bed substrate, with gravel and cobble reaches providing modest habitat complexity.

The Briggs Hollow Road culvert is acting as a local grade control and causing accumulation of coarse sediment immediately upstream that is periodically dredged by a neighboring landowner. Downstream of the culvert, which is perched by 8 to 10 feet above the channel bed, forest cover is poor and in-stream large wood is sparse. No bedrock outcrops were observed in this or other reaches of Upper Briggs Hollow. The steep and narrow nature of the valley means that without adequate grade control elements in the bed, channels are subject to a positive feedback loop: They convey deep flows, which generate high shear stresses on the beds and promote further erosion and lowering of bed levels (Figure 10). In addition to the high hydraulic transport capacity, the local bed material is particularly mobile due to its platy shape and high surface area to mass ratio. Observations from the field suggest that the above combination of factors results in frequent mobilization of the bed material present in upland reaches.

Figure 9. Example of large wood in Upper Briggs Hollow impounding a substantial volume of coarse sediment and improving upstream connectivity between floodwaters and the forest floor. Photo taken October 17, 2018.

Figure 10. Incised reach of the Briggs Hollow tributary immediately downstream of Briggs Hollow Road. Poorly developed bedforms and freshly eroded banks suggest that the channel bed may be continuing to cut down. Photo taken October 17, 2018.

3.1.2 Lower Briggs Hollow

A natural topographical saddle separates Upper Briggs Hollow from the downstream reaches of the Briggs Hollow tributary. The area (1 acre) is mapped as freshwater forested/shrub wetland (USFWS). It has no distinct channel and instead, flow disperses across the wetland, rejoining the creek near Lower Briggs Hollow Road. Downstream for approximately 1.5 miles, the channel shares the valley with Lower Briggs Hollow Road, which occupies overbank areas that might have otherwise been present. The channel is laterally constrained and deep relative to estimated bankfull conditions (Figure 11), and large wood is rare. Numerous small, steep drainages enter the channel or are culverted under the road. The road embankment is known to be susceptible to damage and is protected by extensive rip rap and large rock revetment. The most recent road repairs and stabilization work was completed after flood events in 2017 when the road embankment sustained substantial damage (Tetra Tech 2018). The one road crossing present along this stretch of the creek had been replaced prior to 2017 also following flood damage.

Figure 11. Typical condition of the channel between Briggs Hollow Road and State Line Road. Photo taken October 17, 2018.

A major tributary enters the main Briggs Hollow channel just downstream of State Line Road. This tributary benefits from an intact forested riparian corridor along much of its length up to Moore Hill Road. We observed frequent large woody debris jams in its lower reaches (Figure 12). We also observed evidence of active removal of large wood (Figure 13), which we understand is a widespread practice throughout watersheds in Tioga County in response to the perception that downed wood causes channel instability, reduces channel capacity, and blocks road crossings.

Figure 12. Large woody debris jam in tributary to main Briggs Hollow channel. Photo taken October 17, 2018.

Figure 13. Example of a location where large wood had been removed from the channel. Photo taken October 17, 2018.

The downstream boundary of the steep, upland channels is approximately defined by the bedrock exposed in the bed downstream of the State Line Road crossings (Figure 14). The State Line Road crossing over the main creek was replaced after debris blockage during the July 2017 flood caused substantial damage (Tetra Tech 2018). Between here and the confluence with Wappasening Creek, the channel diverges from the road and is less incised.

Figure 14. Exposed bedrock in the channel downstream of State Line Road. Photo taken October 17, 2018.

3.2 WAPPASENING MAINSTEM

With our survey limited to the New York portion of Wappasening Creek, this assessment covers only the lower 2.2 miles of the stream. Compared to its tributaries, like the stream at Briggs Hollow, the mainstem is much wider and lower gradient. Bankfull width through this section is on the order of 150 feet, and the channel has an average slope of 0.005 ft/ft. The channel's sediment transport competency diminishes as a result of the lower gradient; which is evidenced by the large deposit of sediment at the mouth of the Briggs Hollow tributary.

From the state line to the junction with the Susquehanna, Wappasening Creek meanders across the valley floor, generally with a floodplain on either side of the channel. In several locations, however, the channel has migrated to the edge of the valley and is eroding the tall banks forming the valley side (Figure 15).

Figure 15. Eroding outer bank along the edge of the Wappasening Creek valley. Photo taken October 17, 2018.

Private property accounts for most of the river corridor between the state line and the Susquehanna River. Through this section, there is a range of land management strategies being practiced. Some landowners have allowed for a riparian buffer of sycamores and maples to grow, while others have cleared land up to the edge of the river bank. In addition, major flood events within the watershed also have had a negative impact on the riparian buffer along the mainstem and combined with landowner clearing result in reaches of stream with inadequate riparian buffers. The reaches without adequate riparian buffers appear to exhibit higher rates of bank erosion.

Coarse sediment derived from bank erosion and tributaries is deposited on large, unvegetated bars along Wappasening Creek. 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. The coarse sediment load of Wappasening Creek is eventually deposited within the USACE flood control project at Nichols where it is periodically removed from the channel (Figure 16).

Figure 16. Large pile of material removed from Wappasening Creek near Nichols. Photo taken October 17, 2018.

The entire valley floor, including a number of remaining residential properties along South Main Street (State Route 282), is mapped within the 1% annual chance flood event extent. The July 2017 flood event resulted in closure of the Route 282 bridge and caused structural damage to residential properties along the road (Tetra Tech 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 Wappasening 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/slow 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 increased rates of bed level lowering than would be anticipated under natural conditions.

The Briggs Hollow and other Wappasening tributaries are characterized by steep channels that occupy narrow valleys incised into readily erodible glacial (till) 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 Wappasening Creek watershed consists of sedimentary rocks that break apart along shallow parallel 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. Observed differences in bed levels upstream and downstream of jams are 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 incised relative to adjacent overbank areas often with 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 17). 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 suggest that the Wappasening 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.

Estimated dredge volumes from the flood control project at the Village of Nichols provides some context for considering the potential sediment contribution from tributaries and the potential efficacy of large wood in moderating the outflux. Recent dredge volumes discussed in Section 2.4 are 40,000 cubic yards (2017-18), 11,000 cubic yards (2011), and 1,700 cubic yards (2006). One foot of bed-level lowering along the 3.3-mile-long Briggs Hollow tributary assuming the minimum channel width of 20 feet could produce approximately 13,000 cubic yards of material. In a number of locations, bed levels appear to have dropped more than one foot in recent decades as indicated by perched culverts. The scale of this potential contribution from a single tributary is similar to what was dredged from the channel after the 2011 event. Based on our observations from Briggs Hollow, it is reasonable to conclude that some tributaries within the Wappasening Creek watershed are experiencing a reduction in bed levels and that this presents a major contribution of coarse sediment into the system.

Our observations of a limited number of large woody debris jams in Briggs Hollow suggest that a single jam is capable of storing on the order of 200 cubic yards of sediment. In watersheds where jams are allowed to form naturally, this may be multiplied by dozens. Thus, the storage potential of allowing and facilitating large wood recruitment is significant when compared with the scale of sediment yields from the basin.

The mainstem Wappasening Creek is naturally a lower gradient channel occupying the bottom of the main valley. Under natural conditions, the channel would meander laterally, reworking and building its broad, flat floodplain through bank erosion on the outside of meander bends and deposition of coarse bed material on bars on the insides of bends. Lateral movement of the channel under existing conditions has been restricted in some reaches by bridges and associated bank erosion countermeasures, agricultural and residential development, and/or channelization. Such activities or measures may be associated with increased scour at the toe of the bank or upstream or downstream limits at the transition to natural bank material. Where the channel is free to migrate, bar building and bank erosion may be exacerbated by accelerated delivery of sediment from tributaries and other sources such as eroding valley walls.

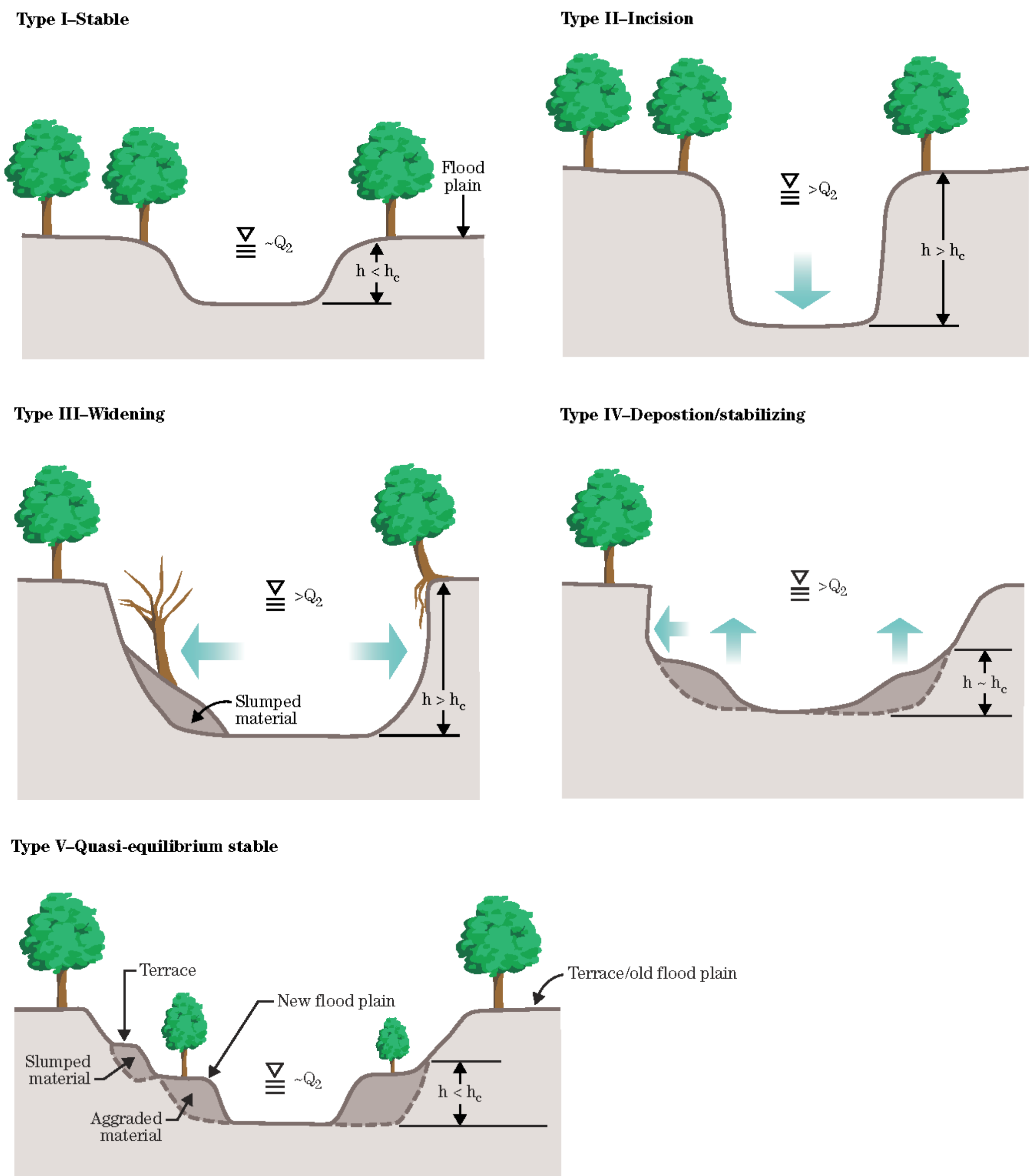

Figure 17. Conceptual model of incision channel evolution by Schumm et al. (1984). Reprinted from USDA NRCS (2008).

Bank erosion along the mainstem Wappasening represents a secondary source of sediment to the system. A large bank failure approximately 200 feet long causing 25 feet of bank retreat could contribute as much as 1,000 cubic yards[2] of sediment to the creek's sediment yield. This figure is an order of magnitude less than the potential scale of material contribution from tributaries, suggesting that a focus on moderating sediment supply from tributaries would provide the greatest benefit from a sedimentation perspective. While lateral migration often appears to be contributing substantial volumes of sediment to channels, typically the eroded material does not travel far and is deposited within the channel downstream where it will eventually be incorporated into newly formed floodplain. The net effect is a reorganization of sediment within the system with much smaller yields than one might assume.

Bed material transported by Wappasening Creek is eventually deposited within the USACE flood control reach at Nichols, which has been widened and deepened to improve flow conveyance, creating flow conditions that precipitate deposition of coarse load. The practice of dredging the channel to maintain a channel form that cannot transport coarse sediment load perpetuates the need for active management in this reach.

In conclusion, stream and floodplain management practices, land-use patterns and upland management practices, and infrastructure along the mainstem and tributaries currently contribute to flood risk in the watershed. Rates of bank erosion along Wappasening 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 is greater than the scale of sediment production through bank erosion along the mainstem itself, in part because bank erosion is partially balanced by deposition on bars at the inside of meander bends. Within the tributaries, downcutting of the channel bed and related bank instability are likely the greatest contributor to sediment yields. High rates of runoff within Briggs Hollow in particular are associated with Lower Briggs Hollow Road which reduces valley width and accelerates hydrologic response.

[2] Figure is a net volume equal to 50% of the gross bank erosion volume assuming that bank erosion creates accommodation space in the channel that is filled by bar deposition along the opposite bank. Studies suggest that this estimate may be as low as 10 to 20%, with 80 to 90% of eroded bank material redeposited within the channel nearby the erosion site (e.g., Lauer and Parker 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 works 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 withstand extreme flood events and the passage of sediment and debris; and allowing for active meander migration along the downstream, low-gradient reaches of Wappasening Creek tributaries and the mainstem itself.

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 Wappasening Creek community, but implemented together, these projects represent a comprehensive approach that is expected to have mitigating effects. Recommendations from Fuss & O'Neill (see Appendix B) have been incorporated into these lists.

A map of site-specific construction projects is provided in Figure 18. At each site, a project number has been assigned based on the distance of the site from the mouth of the stream (e.g., WaBH-3400 is located 3,400 feet upstream of the Briggs Hollow tributary confluence with Wappasening 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 with reference to 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 elements 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 functional channel-floodplain relationship, increase floodplain 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 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 have been provided as a starting point for prioritization given available funding. Many of the projects described could be implemented more widely as future opportunities arise. The lists will be prioritized and amended in a subsequent report following receipt of feedback from stakeholders.

In subsequent phases of design and construction, potential impacts to 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.

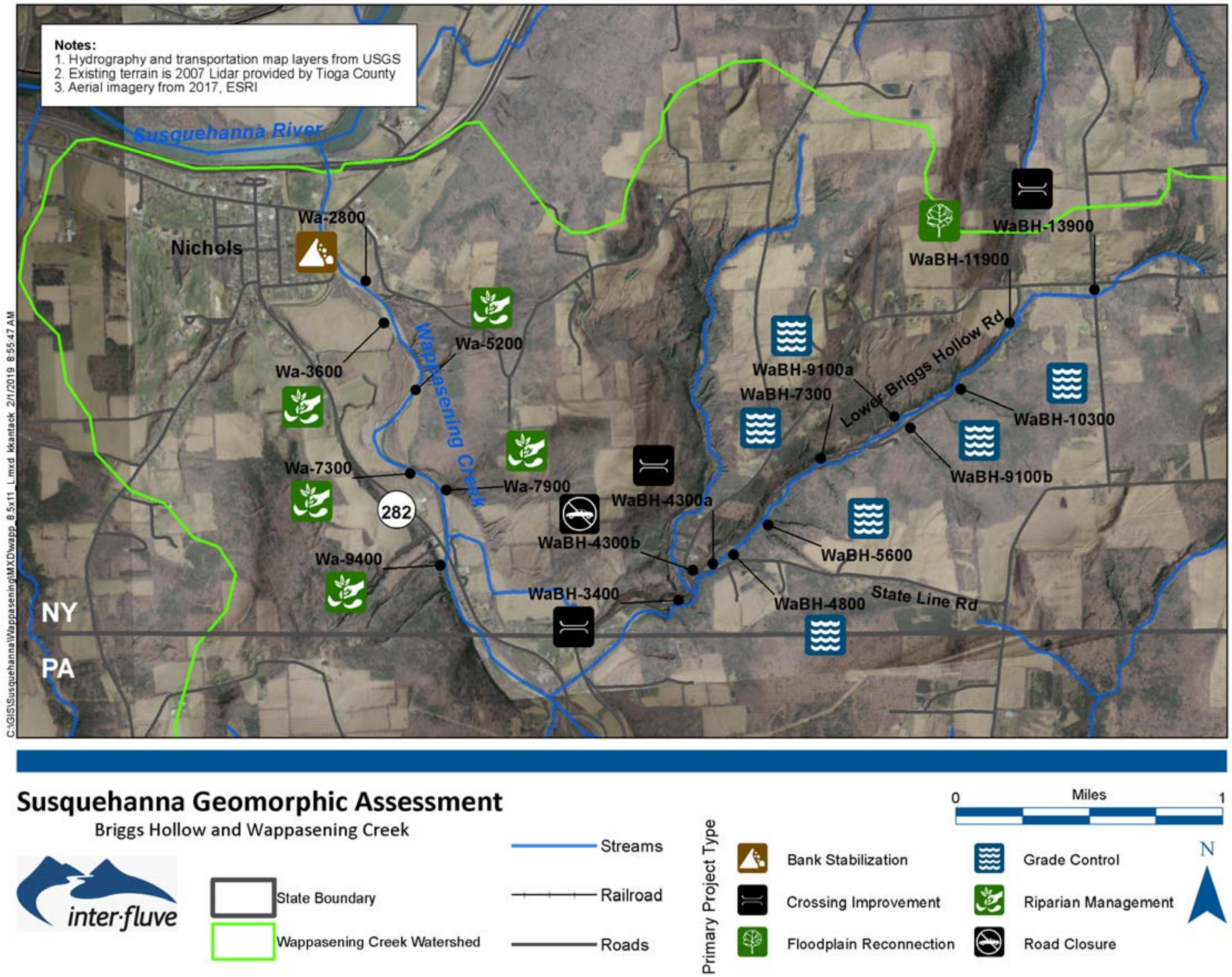

Figure 18. Map of site-specific potential flood mitigation and resilience construction projects. Refer to Table 3 for descriptions.

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

Project number	Type	Description	Photo or image reference
Wa-9400	Riparian Management	From the state line downstream to the NY 282 bridge, Wappasening Creek is constrained to the western edge of the valley. A handful of residences have been built within the 1% annual chance flood event extent, including on a narrow strip of the right bank floodplain between the channel and NY 282. Buy out properties that have not already been purchased as a part of the initiative described in the Hazard Mitigation Plan (Tetra Tech 2018) and remove or relocate the affected structures. Remove rip rap that might currently be protecting homes and allow the creek to evolve naturally to the extent possible given the alignment of NY 282.	Figure 19
Wa-7900	Riparian Management	Landowner mows and farms up to the top of the bank along the right bank. An informal berm constructed of material dredged from the channel has been built at the top of the right bank extending from NY 282 to approximately 400 feet downstream. The berm protects residences and some farm outbuildings from flooding. Remove the berm to allow floodwater to access the right bank floodplain. Buy out property owners and remove affected structures or, where the parcel is large enough, establish conservation easements and relocate affected structures to higher ground. The latter would require an alternative to Old State Road 82 for access. Re-establish forest cover on the right bank floodplain.	Figure 20
Wa-7300	Riparian Management	An approximately 17-acre portion of a larger parcel classed as a cattle farm is located on the left bank floodplain between the channel and NY 282. A residence, outbuildings, and a substantial collection of old equipment and vehicles are vulnerable to flooding. During a large magnitude flood, equipment stored on the floodplain could be washed downstream. Across the creek, the channel is eroding into a tall bank that forms the northeastern boundary of the valley. Examination of historical photographs shows relatively low rates of bank retreat; however, a scarp approximately 700 feet in length runs along the top of the steep bank face providing evidence of previous slope movement. The scarp has been present since at least 1995. There is a risk of catastrophic failure of the slope and blockage of the main channel which could cause flooding of upstream areas and channel avulsion. Mitigate the risks to the farm by buying out the affected portion of the parcel or establishing a conservation easement. Remove the equipment and vehicles and relocate the structures to higher ground to the west of NY 282.	Figure 21, Figure 22

Project number	Type	Description	Photo or image reference
Wa-5200	Riparian Management	This particular bend in the river has been an area of very active channel migration and, historically, multi-threaded channels. The left bank has repeatedly undergone substantial retreat following large flood events. The landowner has responded by actively realigning the channel to force the river into a single channel along the eastern side of the valley and reclaim the floodplain for agricultural production. Purchase the parcel and allow the channel to migrate naturally. The creek is likely to migrate before a mature riparian buffer can be established. Use the site as a demonstration project instead and solicit volunteers to plant native riparian trees on the distal floodplain. Adopt an adaptive management approach at the site which should include monitoring the evolution of the channel, in particular bank erosion of the left bank that might threaten NY 282. Consider bioengineering methods for stabilizing the bank if necessary.	Figure 23
Wa-3600	Riparian Management	The left bank is currently cleared for agriculture with a narrow or absent riparian buffer. Purchase land or establish a conservation easement, establish a riparian buffer, and allow the river to actively migrate.	Figure 24
Wa-2800	Bank Stabilization	Wappasening Creek is eroding into an approximately 30-foot-high bluff forming the right bank. Sunnyside Road runs along the top of the bank. The eroding bank material is till and has a substantial fines component. An existing side channel that appears to be activated during large magnitude events is present along the left side of the valley. Stabilize the toe of the bank using large wood and/or rock over a length of approximately 400 feet to tie into stable bank both upstream and downstream of the active erosion site. Install an engineered large wood structure in the main channel to encourage flow through the side channel along river left. Excavate the side channel to increase capacity.	Figure 25
WaBH-13900	Crossing Improvement	The existing Briggs Hollow Road culvert appears to be undersized and in poor condition. The downstream reach is incised with the culvert acting as grade control for the upstream channel. Field evidence suggests that sediment deposited in the upstream channel is regularly dredged by the adjacent landowner and the material used to form a berm at the top of the right bank. Install a series of engineered large wood and/or rock structures to establish grade control in the downstream channel and replace the culvert with an appropriately sized open-bottom structure to reduce flood risk, minimize the risk of blockage by woody debris, allow for continuity of sediment transport, improve road user safety, and enable aquatic organism passage. Refer to Section 4.1 of Appendix B for more information.	Figure 26

Project number	Type	Description	Photo or image reference
WaBH-11900	Floodplain Reconnection	The outlet to a natural wetland has been dredged and the dredged sediment left in piles between the right bank of the creek and Lower Briggs Hollow Road. Remove the sediment piles. Install a series of engineered large wood structures to slow outflow from the wetland. Buy out low-lying property immediately upstream at 177 Lower Briggs Hollow Road. Investigate whether work would increase flood risk on Lower Briggs Hollow Road; if so, implement after WaBH-4300b.	Figure 27
WaBH-10300	Grade Control	A small drainage channel on the left side of the valley appears to be cutting down and is a source of coarse bed material. Install grade control.	Figure 28
WaBH-9100b	Grade Control	A small drainage channel on the left side of the valley appears to be cutting down and is a source of coarse bed material. Install grade control.	Figure 29
WaBH-9100a	Grade Control	A small drainage channel on the right side of the valley appears to be cutting down and is a source of coarse bed material. Install grade control.	Figure 30
WaBH-7300	Grade Control	A small drainage channel carrying runoff from agricultural land on the left side of the valley appears to be cutting down and is a source of coarse bed material. Install grade control. Educate the landowner on agricultural BMPs such as cover crops and no till practices to slow surface runoff.	Figure 31
WaBH-5600	Grade Control	A small drainage channel carrying runoff from agricultural land on the left side of the valley appears to be cutting down and is a source of coarse bed material. Install grade control. Educate the landowner on agricultural BMPs such as cover crops and no till practices to slow surface runoff.	Figure 32
WaBH-4800	Grade Control	The mainstem channel at Briggs Hollow is confined to a narrow valley and shows signs of continued erosion along the channel bed. Install a series of engineered large wood and/or rock structures to establish grade control, slow flows, and moderate coarse sediment supply.	Figure 33

Project number	Type	Description	Photo or image reference
WaBH-4300b	Road Closure	Lower Briggs Hollow Road has been constructed within the narrow valley occupied by the tributary. The road embankment is narrow, steep sided, and protected in numerous places with rip rap, blockstone, and less formal measures in various states of repair and disrepair. Perched culverts discharge drainage from numerous side drainage channels, and these also require erosion protection. The primary crossing over the creek was damaged in July 2017. Repairs included new concrete block wingwalls and erosion protection measures. The culvert remains undersized and vulnerable to blockage by debris, and has a concrete apron that is perched at the downstream end. Close Lower Briggs Hollow Road upstream of the intersection with State Line Road. Relocate residents of three affected residential parcels or establish alternative access via another route. Remove road infrastructure, including crossings and erosion protection measures. Or, convert part of the former road to a public hiking trail, which would involve replacing existing culverts with appropriately sized footbridges, improving trail drainage, and maintaining the trail. Implement bank stabilization and grade control projects using bioengineering methods where needed to manage sediment yields following construction. Refer to Section 4.2 of Appendix B for remedial measures that can be carried out at the primary creek crossing to reduce risks at the crossing while road removal is being planned.	Figure 34, Figure 35, Figure 36
WaBH-4300a	Crossing Improvement	The State Line Road culvert washed out in 2017 and was replaced shortly thereafter with a corrugated metal pipe arch culvert similar in size to the one that was washed out. The present culvert appears to be undersized and vulnerable to blockage. Replace the culvert with an appropriately sized open-bottom structure minimize the risk of blockage by woody debris and subsequent failure, and to facilitate aquatic organism passage and improve ecological conditions. Replace the existing rock revetment on the upstream banks with a more ecologically sensitive bioengineered design. See Section 4.1 of Appendix B for more information.	Figure 37
WaBH-3400	Crossing Improvement	The existing State Line Road culvert carrying a tributary to the Briggs Hollow drainage is a corrugated metal pipe arch. The present culvert appears to be undersized and vulnerable to blockage. Replace the culvert with an appropriately sized open-bottom structure to minimize the risk of blockage by woody debris and subsequent failure, and to facilitate aquatic organism passage and improve ecological conditions.	Figure 38

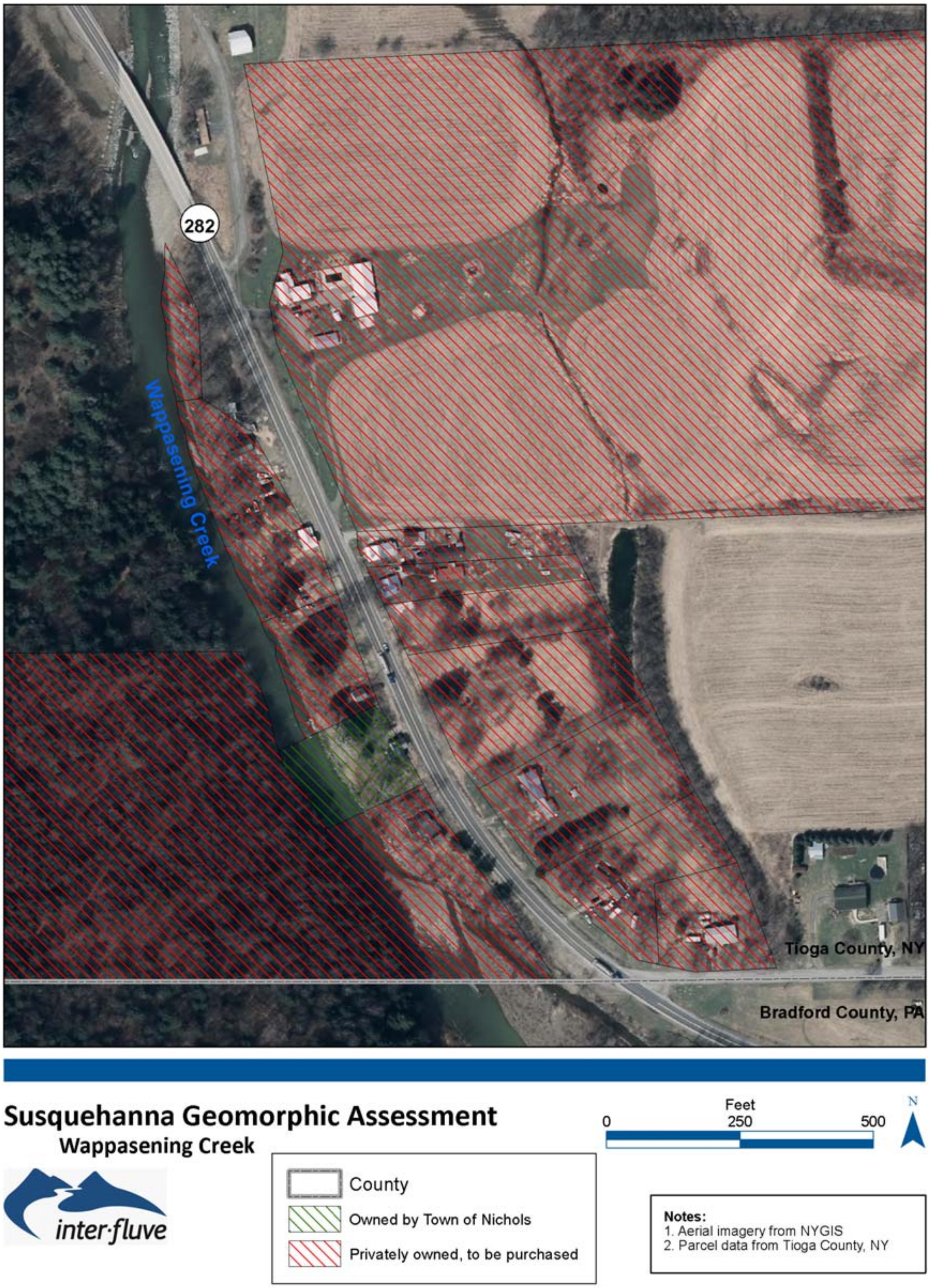

Figure 19. Aerial image of Wappasening Creek at Wa-9400. Hatched parcels not already in Town ownership could be purchased and structures removed to reduce flood risk and allow the river to inundate the area.

Figure 20. Looking upstream at Wa-7900. The bridge over NY-282 is in the distance, with both river banks devoid of riparian buffer. Photo taken October 17, 2018.

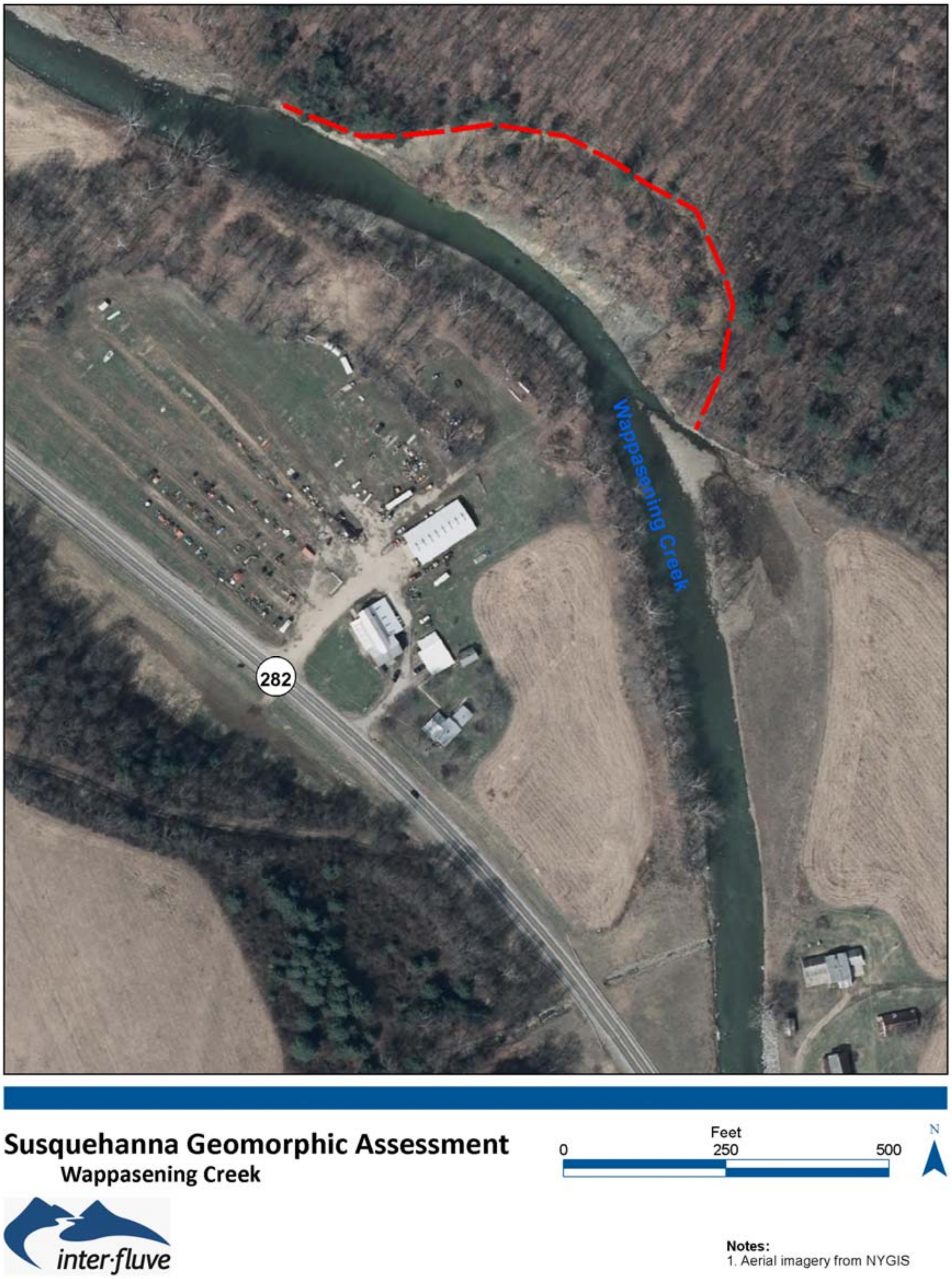

Figure 21. Aerial image from of Wa-7300. A large collection of equipment is visible on the floodplain on river left. The eroding bank is evident on the opposite side of Wappasening Creek. The head scarp of the bank failure is visible and highlighted by the red line.

Figure 22. Eroding bank at Wa-7300. The eroding face is large at approximately 40 feet high and 700 feet long. Catastrophic failure of the bank along the scarp visible in Figure 21 could block flow along Wappasening Creek and cause flooding upstream. Photo taken October 17, 2018.

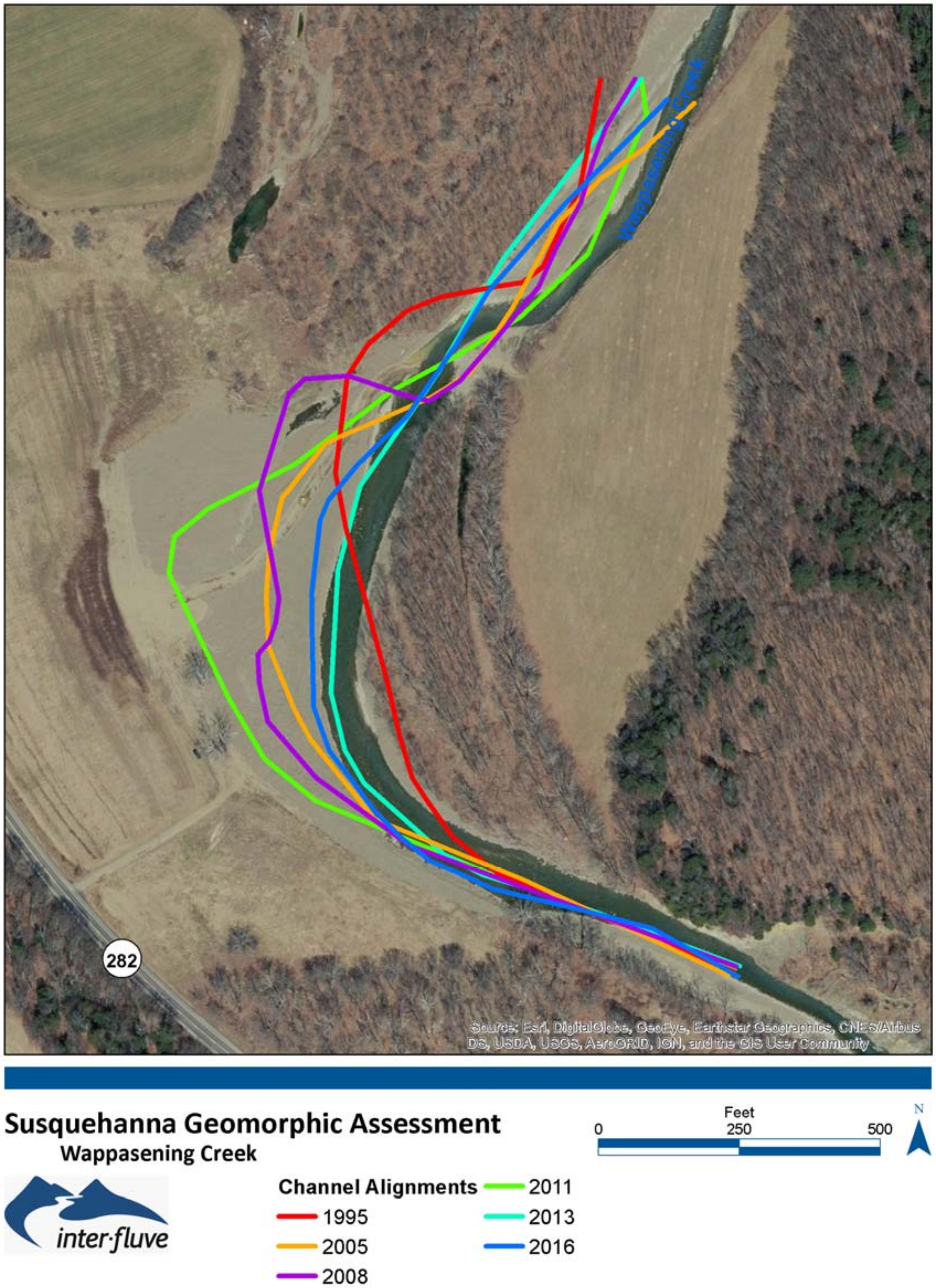

Figure 23. Aerial photograph of Wa-5200 with historic channel alignments shown. The natural migration of Wappasening Creek toward the outside of the bend has been repeatedly counteracted by the landowner and the channel mechanically realigned. Additionally, the right bank of the river downstream of the bend has been stripped of trees and mowed to the edge, which has made the bank susceptible to erosion.

Figure 24. Left bank of Wappasening Creek at Wa-3600. Absence of riparian buffer has resulted in accelerated bank erosion. Photo taken October 17, 2018.

Figure 25. Looking downstream towards eroding bluff at Wa-2800. Residence on Sunnyside Road is visible at the top of the bluff. Photo taken October 17, 2018.

Figure 26. Perched culvert and incised channel at Briggs Hollow Road (WaBH-13900). Photo taken October 17, 2018.

Figure 27. Looking downstream at the dredged wetland outlet at WaBH-11900. The dredged material is piled on the top of the right bank. Photo taken October 17, 2018.

Figure 28. Drainage channel flowing into the Briggs Hollow tributary at WaBH-10300. Coarse material apparent on the bed of the channel is delivered to mainstem during high flows. Photo taken October 17, 2018.

Figure 29. Large deposit of coarse material delivered by an intermittent tributary at WaBH-9100b. Photo taken October 17, 2018.

Figure 30. Large deposit of coarse material delivered by an intermittent tributary at WaBH-9100a. Photo taken October 17, 2018.

Figure 31. Incised intermittent tributary at WaBH-7300 that appears to deliver a large volume of coarse sediment to the channel. Flow originates in a hilltop field. Photo taken October 17, 2018.

Figure 32. Intermittent tributary at WaBH-5600 that appears to deliver a large volume of coarse sediment to the channel. Flow originates in a hilltop field. Photo taken October 17, 2018.

Figure 33. Reach along the mainstem of the Briggs Hollow tributary at WaBH-4800. Photo taken October 17, 2018.

Figure 34. Undersized and perched culvert beneath Lower Briggs Hollow Road. Photo taken October 17, 2018.

Figure 35. Bank erosion and rock revetment along Lower Briggs Hollow Road. Note television dumped at the top of the bank. Photo taken October 17, 2018.

Figure 36. Channel along Lower Briggs Hollow Road showing deep, narrow nature of channel and erosion protection measures along road embankment. Photo taken October 17, 2018.

Figure 37. Undersized culvert beneath State Line Road at WaBH-4300a. The right bank is eroding at the upstream limit of the large rock revetment installed as part of the culver replacement. Photo taken October 17, 2018.

Figure 38. Undersized culvert carrying tributary to the Briggs Hollow drainage beneath State Line Road at WaBH-3400. Photo taken October 17, 2018.

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

Project number	Type	Description
Wa-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.
Wa-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.
Wa-C	Public Education	A relatively small proportion of the Wappasening Creek watershed is located within New York. Many of the issues experienced in the New York portion of the mainstem are likely affected by activities and management practices upstream in Pennsylvania. Expand the current project to include the Pennsylvania portion of the watershed for a holistic approach to addressing flood hazards and improving resilience. Work across state lines on prioritization and implementation.
Wa-D	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.
Wa-E	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.
Wa-F	Public Education	Conduct flood and erosional hazard mapping along Wappasening Creek. 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.
Wa-G	Policy	Consider strengthening floodplain protection, erosion control, and stormwater treatment requirements in local ordinances. 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

Project number	Type	Description
Wa-H	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.
Wa-I	Riparian Management	Establish and advertise a stream buffer program to assist private landowners in developing and implementing planting plans
Wa-J	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.
Wa-K	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 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.
Wa-L	Road Relocation	Work with New York State and Pennsylvania to consider an alternative route for NY 282/PA 187 between Osborne Hill Road in Pennsylvania and the NY 282 bridge in New York. A route along the western side of the valley would eliminate two damage-prone crossings.
Wa-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.
Wa-N	Riparian Management	Numerous informal stream crossings exist within the watershed. Educate private landowners about sustainable trail construction and usage, including maintaining a riparian buffer and minimizing crossings.
Wa-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
Wa-P	Public Education	Hold workshops on agricultural BMPs focused on riparian area protection and water quality improvement
Wa-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
Wa-R	Public Education	Run a campaign to promote local electronic waste recycling programs and inform the public of consumer obligations under New York law

Project number	Type	Description
Wa-S	Public Education	Use the opportunities created by implementation of floodplain restoration projects such as Wa-5200 to educate and involve area students and the public. Example projects and teaching aids include: • Inclusion of students/public 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/public in monitoring efforts to document post-construction geomorphic conditions and changes, water quality, and biodiversity; and • Installation of interpretive signage at the replaced bridge and restored floodplain area with engaging graphics that explain the process and benefits of stream and floodplain restoration.

6. Project 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 final score out of 100 possible points. 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 and cost of land or easement acquisition unless otherwise noted. 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.

The prioritization results suggest that the greatest flood mitigation benefits in the Wappasening Creek watershed in New York could be achieved through projects to move development out of the mainstem's meander belt and the Briggs Hollow valley. The general approach of giving the streams space to flood and move would reduce flood damages, improve flood attenuation, improve the system's ability to store and process sediment, and improve the ecological health of the watershed. Many projects of this type would be highly visible to the public and would have the potential to serve as demonstration projects. However, many would require willingness on the part of private landowners or occupiers who would be affected. Phasing of project implementation across the watershed should consider potential downstream and upstream impacts of particular projects.

A public meeting was held on March 5, 2019, to present the findings of the study and draft report, including draft project recommendations (Wa-5200 and WaBH-10300 through WaBH-5600). Feedback obtained at the meeting suggests that projects along the mainstem requiring landowner or occupier willingness may be less feasible for this particular round of funding than other projects.

Based on the results of the prioritization, phasing considerations, feedback from the public meeting, and the funds currently available for implementation, we recommend proceeding to conceptual design with one of the following projects or packages of projects. By packaging a number of projects together, it is likely that cost savings may be achieved in both the design and construction phases. Note that current funding may be insufficient to cover the total cost of project implementation, and a local match may be required.

The recommended options are:

- Wa-4300a – This project would improve the resilience of the Stateline Road crossing over the Briggs Hollow tributary by providing greater conveyance capacity. The banks would be redesigned to reduce erosion and improve sediment transport conditions through the structure, further reducing the risk of blockage. The structure is owned by the Town of Nichols, which is a willing participant;
- WaBH-10300 through WaBH-5600 – These projects would slow runoff and reduce sediment input from five intermittent drainage channels that empty into the Briggs Hollow tributary; or
- Wa-2800 – This project would reduce sediment input into the mainstem Wappasening Creek from localized bluff erosion and would reduce risk to Sunnyside Road.

The above options would deliver benefits in the short term while funding is sought for other highly ranked but also expensive projects. 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

1 of 12

My Survey

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

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 – Wappasening 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 Wappasening 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 Wappasening 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 Wappasening 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.

Six (6) road-stream crossings in the Wappasening 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.

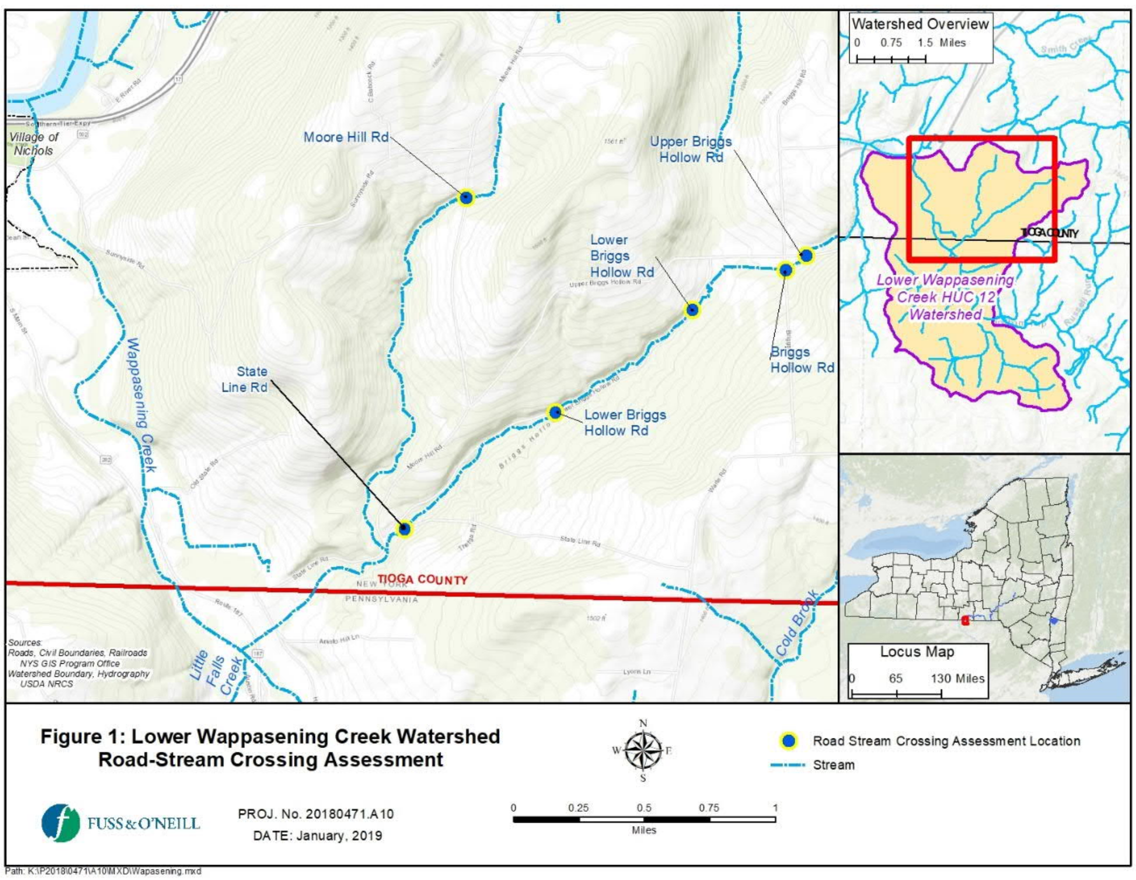


Figure 1. Road-stream crossings selected for assessment in the Wappasening Creek watershed

All of the selected crossings are in the Town of Nichols in Tioga County. The six (6) locations are all located on unnamed tributaries to Wappasening Creek.

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

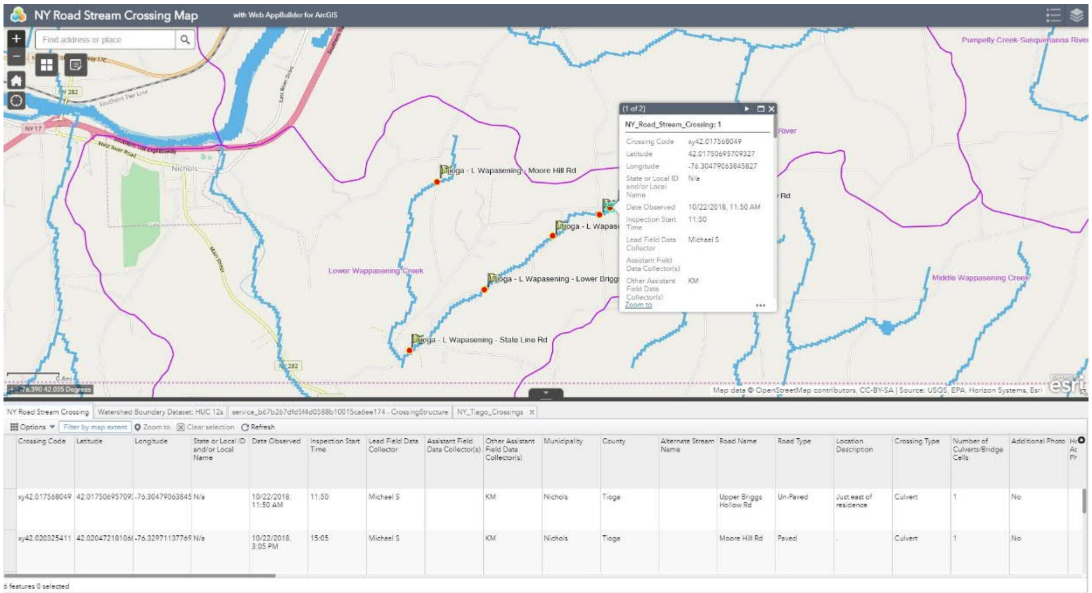
Stream	Road Name	Description	Ownership	Road Type	Crossing Type	Structure Material
Unnamed Tributary to Unnamed Tributary at Briggs Hollow	Moore Hill Road	Culvert under public road	Town	Paved	Round Culvert	Corrugated Metal
Unnamed Tributary at Briggs Hollow	State Line Road	Culvert under public road	Town	Paved	Arched Culvert	Corrugated Metal
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road (downstream crossing)	Culvert under public road	Town	Unpaved	Elliptical Culvert	Corrugated Metal
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road (upstream crossing)	Culvert under public road	Town	Unpaved	Elliptical Culvert	Corrugated Metal
Unnamed Tributary at Briggs Hollow	Briggs Hollow Road	Culvert under public road	Town	Unpaved	Round Culvert	Smooth Metal
Unnamed Tributary at Briggs Hollow	Upper Briggs Hollow Road	Culvert under public road	Town	Unpaved	Elliptical Culvert	Corrugated Metal

2.2 Field Data Collection

Field surveys of the selected crossings were conducted on October 22, 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 Wappasening 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 Wappasening Creek watershed.

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

Stream	Road Name	Structural Condition	Flow Constriction	Physical Barrier	Channel Erosion	Sediment Deposition	Recommendation Section Number
Unnamed Tributary to Unnamed Tributary at Briggs Hollow	Moore Hill Road	Adequate	Severe	Yes	Downstream banks	Upstream	
Unnamed Tributary at Briggs Hollow	State Line Road	Adequate	Severe	Yes		Upstream, downstream, within structure	
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road (downstream crossing)	Poor	Severe	Yes	Upstream and downstream banks	Upstream, downstream, within structure	Section 3.2
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road (upstream crossing)	Adequate	Moderate	Yes	Upstream and downstream banks	Downstream	
Unnamed Tributary at Briggs Hollow	Briggs Hollow Road	Poor	Severe	Yes	Upstream and downstream banks	Upstream and downstream	Section 3.1
Unnamed Tributary at Briggs Hollow	Upper Briggs Hollow Road	Adequate	Severe	No	Upstream and downstream banks	Upstream, downstream, and within structure	

The following issues were observed at the surveyed stream crossings:

- Poor Structural Condition: Two of the assessed crossings (Lower Briggs Hollow Road, downstream crossing, and Briggs HIl Road) were observed to be in poor condition and in need of significant repairs or replacement. Significant erosion of the crossing embankment and deteriorating headwalls and wingwalls are common at many of these crossings.
- 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.
- Physical Barriers: Most of the upstream private and public crossings serve as full or partial barriers to aquatic organism passage. The stream crossings on Moore Hill Road and Lower Briggs Hollow Road (upstream crossing), have perched outlets, while the crossings on State Line Road and Briggs Hollow 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.
- Sediment Deposition: Substantial sediment deposition was generally observed upstream of crossings that constrict flow.

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 <u>Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act</u>.
- 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 Unnamed Tributary at Briggs Hollow	Moore Hill Road	Round Culvert	10	8	4	5	0.23
Unnamed Tributary at Briggs Hollow	State Line Road	Arched Culvert	15	12	3	5	0.33
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road (downstream crossing)	Elliptical Culvert	6	6	10	2	0.17
Unnamed Tributary at Briggs Hollow	Lower Briggs Hollow Road (upstream crossing)	Elliptical Culvert	4	16	8	3	0.31
Unnamed Tributary at Briggs Hollow	Briggs Hollow Road	Round Culvert	16	16	8	5	0.35
Unnamed Tributary at Briggs Hollow	Upper Briggs Hollow Road	Elliptical Culvert	8	16	4	2	0.29

Hydraulic Risk

Several of the assessed crossings in the Huntington Creek watershed are undersized, having insufficient hydraulic capacity to convey the 25-year peak flow (Moore Hill Road, State Line Road, and Briggs Hollow Road). The hydraulic capacity of the State Line Road crossing is less than the 10-year peak flow. Only the upstream Lower Briggs Hollow Road crossing has sufficient capacity to convey the 100-year return interval peak flow.

Geomorphic Risk

Most of the assessed crossings were rated as having moderate to severe observed geomorphic impacts, combined with possible to likely potential geomorphic impacts, resulting in uniformly high geomorphic vulnerability scores.

Structural Risk

Several of the assessed crossings were replaced following flooding in 2011 and are in relatively good structural condition. Although also replaced relatively recently, the downstream crossing at Lower Briggs Hollow Road has gaps between the wingwalls/headwall and pipe that may allow seepage and misaligned wingwall blocks, which resulted in a higher structural condition score and greater structural risk of failure during extreme flood events.

Aquatic Organism Passage

Most of the assessed crossings are moderate to severe barriers to aquatic organism passage due to outlet drops or other physical barriers.

Prioritization

The crossing priority scores for the assessed crossings were relatively uniform, with the Briggs Hollow Road crossing receiving the highest score.

4 Recommendations

Recommendations were developed for the stream crossings in the Wappasening 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 the Briggs Hollow Road crossing, we also recommend channel or floodplain restoration in upstream or downstream areas along with the proposed crossing upgrade 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 Wappasening Creek watershed where upgrades or replacement are recommended.

4.1 Briggs Hollow Road over Unnamed Tributary at Briggs Hollow

Existing Issues

- The crossing is hydraulically undersized and severely limits aquatic organism passage. The elevation of the outlet above the streambed is a further barrier to fish passage.
- The downstream channel is deeply incised (as much as 15 feet) and portions of the downstream banks are overhanging. This may be because the culvert is undersized and due to its steep slope of 5.3%. The upstream banks are severely eroded.
- Soil loss is occurring on the road embankment.
- The upstream headwall, which may be acting mainly as a substitute for a guardrail, is tilted upward and sitting at an angle.
- Gaps between the pipe and the wingwalls may be allowing seepage through the embankment.

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.
- Restore floodplain access in the downstream channel, either by replacing scoured material in the streambed or by lowering the streambanks to provide floodplain terraces.

Screening-Level Cost Estimate

- Crossing Structure Replacement: $250K-$500K
- Stream Restoration: to be determined by Inter-Fluve

Briggs Hollow Road over Unnamed Tributary at Briggs Hollow - crossing inlet. Note gaps between wingwalls/headwall and pipe that may allow seepage, and misaligned headwall/guardrail block.

Briggs Hollow Road over Unnamed Tributary at Briggs Hollow - crossing outlet. Note steep drop from culvert, eroded channel downstream, and sloughing of soil from road embankment.

Briggs Hollow Road over Unnamed Tributary at Briggs Hollow – downstream channel. Note incised streambed and overhanging streambanks.

4.2 Lower Briggs Hollow Road over Unnamed Tributary at Briggs Hollow (downstream crossing)

Existing Issues

- Although the crossing is capable of conveying the 25-year return interval peak flow, the crossing is significantly narrower that bankfull width, severely constricting the stream. The drop in elevation from the end of the large apron on the downstream side of the culvert limits fish passage.
- Severe erosion of streambanks and mass wasting of hillslopes above the stream has negatively impacted habitat and introduced large amounts of sediment to the stream.
- The end of the apron is eroding due to scour.
- The shallow depth of flow over the apron during normal flow conditions likely causes increases in stream temperature at the apron and immediately downstream, which would reduce water quality and habitat quality for in-stream organisms.
- The crossing structure appears to have been reconstructed relatively recently.

Recommendations

- The recommended long-term action is to remove Lower Briggs Hollow Road. The alternate long term recommendation is to consider replacement of the culvert with an appropriately sized crossing near the end of the culvert's lifespan, as the culvert appears to have been replaced relatively recently.
- The following short-term measures are recommended until one of the long-term recommendations can be accomplished:
  - Fill gaps between outside of pipe and wingwalls, headwall, and endwall with hydraulic cement to reduce seepage along outside of pipe and extend crossing lifespan.
  - Stabilize and restore streambanks in areas of mass wasting and erosion, using large wood, rootwads, or other nature-based solutions as appropriate to reduce further erosion, protect residential properties, slow sediment inputs to stream, and improve in-stream habitat.

Screening-Level Cost Estimate

- Sealing of gaps with hydraulic cement: $15,000
- Streambank restoration: to be determined by Inter-Fluve

Lower Briggs Hollow Road over Unnamed Tributary at Briggs Hollow - crossing inlet. Note gaps between wingwalls/headwall and pipe that may allow seepage, and misaligned wingwall blocks.

Lower Briggs Hollow Road over Unnamed Tributary at Briggs Hollow - crossing outlet. Note drop at end of apron and scour of apron and streambed below.

Lower Briggs Hollow Road over Unnamed Tributary at Briggs Hollow – downstream channel. Note erosion of streambanks.

4.3 State Line Road over Unnamed Tributary at Briggs Hollow

Existing Issues

- The crossing was replaced by a similarly-sized arch culvert following washout in 2011. The existing crossing is undersized (less than 10-year peak flow capacity) and significantly narrower that bankfull width, severely constricting the stream and making the crossing susceptible to blockage. Aquatic passage is limited by a drop in elevation at the crossing outlet.
- Stone armoring were placed on the streambanks upstream of the crossing as part of the previous crossing replacement. The right bank is eroding at the upstream limit of the stone armoring.

Recommendations

- Replace the culvert with an appropriately sized, open-bottom structure to minimize the risk of blockage by woody debris and subsequent failure and to facilitate aquatic organism passage and improve ecological conditions.
- Replace the existing rock revetment on the upstream banks with a more ecologically sensitive bioengineered design.

Screening-Level Cost Estimate

- Crossing Structure Replacement: $500K-$1M
- Streambank restoration: to be determined by Inter-Fluve

State Line Road over Unnamed Tributary at Briggs Hollow - crossing inlet. Note stone revetment placed upstream of the inlet when the crossing structure was replaced following washout in 2011.

State Line Road over Unnamed Tributary at Briggs Hollow – upstream of crossing. Right stream bank is eroding at upstream end of stone revetment.

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Attachment A

Stream Crossing Survey Field Data Form (blank)

Road-Stream Crossing Assessment Field Data Form

FUSS & O'NEILL

QA/QC INITIALS:______ DATE:______

Status ____FINAL ____FOLLOW-UP

CROSSING DATA

pp. 4-5

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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FORM ADAPTED BY FUSS & O'NEILL, INC. (WITH PERMISSION) FROM THE NAACC AQUATIC CONNECTIVITY STREAM CROSSING SURVEY DATA FORM

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

pp. 44

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FORM PUBLISHED: OCTOBER 18, 2018

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

pp. 44

FORM PUBLISHED: OCTOBER 18, 2018

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

pp. 44

FORM PUBLISHED: OCTOBER 18, 2018

STRUCTURE 4

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

FORM PUBLISHED: OCTOBER 18, 2018

STRUCTURE 5

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

FORM PUBLISHED: OCTOBER 18, 2018

STRUCTURE 6

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

FORM PUBLISHED: OCTOBER 18, 2018

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

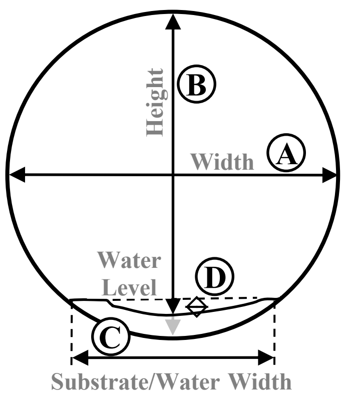
FORM PUBLISHED: OCTOBER 18, 2018

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.

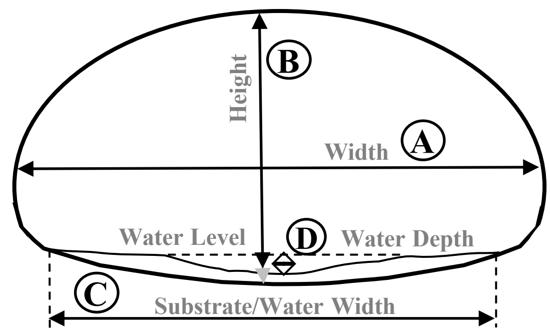
NOTE: Culverts 1, 2 & 4 may or may not have substrate in them, so height measurements (B) are taken from the level of the "stream bed", whether that bed is composed of substrate or just the inside bottom surface of a culvert (grey arrows below show measuring to bottom, black arrows show measuring to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

1



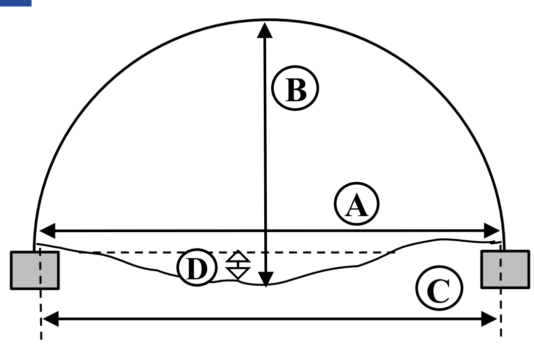
Round Culvert

2



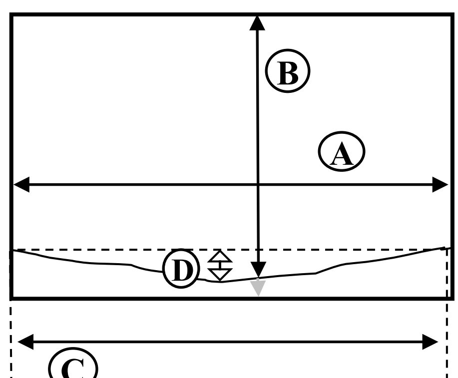
Pipe Arch/Elliptical Culvert

3



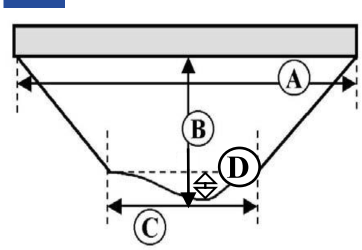
Open Bottom Arch Bridge/Culvert

4



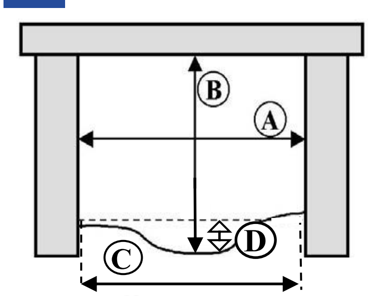
Box Culvert

5



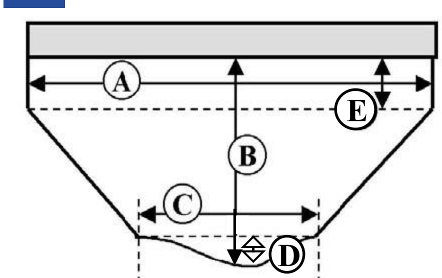
Bridge with Side Slopes

6



Box/Bridge with Abutments

7



Bridge with Abutments and Side Slopes

FUSS & O'NEILL

Attachment B

Road-Stream Crossing Scoring and Prioritization Results

Hydraulic Capacity Worksheet
Road-Stream Crossing Assessment
Tioga County Watersheds

June 2019

		Crossing Hydraulic Capacity @ Failure				Existing Streamflow Conditions								Future Streamflow Conditions (20% Increase in Flows - Projected Climate Change)								Scoring	
Stream Name	Road Name	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 Hollow 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

		Potential for Geomorphic Impacts				Observed Geomorphic Impacts			Scoring			
Stream Name	Road Name	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 Hollow 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 I	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 I	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 I	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 I	Briggs Hollow 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 I	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 I	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 I	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 I	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 I	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

June 2019

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

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

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

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 Hollow 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

Transporta Disruptic Score
1
2
3
4
5

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 Hollow 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

June 2019

		Aquatic Organism Passage Component Scores														Final Score		
Stream Name	Road Name	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 Hollow 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
Road-Stream Crossing Assessment
Tioga County Watersheds

June 2019

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 Hollow 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
p	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

June 2019

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

$$\begin{aligned} Impact\ Score\ &= Transportation\ Disruption\ Score \\ &+ Flood\ Impact\ Potential\ Score \end{aligned}$$

Equation 3: Hydraulic Risk Score

$$\begin{aligned} &Hydraulic\ Risk\ Score \\ &= Hydraulic\ Capacity\ Score \\ &\times Impact\ Score \end{aligned}$$

Equation 4: Geomorphic Risk Score

$$\begin{aligned} &Geomorphic\ Risk\ Score \\ &= Geomorphic\ Vulnerability\ Score \\ &\times Impact\ Score \end{aligned}$$

Equation 5: Structural Risk Score

$$\begin{aligned} &Structural\ Risk\ Score \\ &= Structural\ Condition\ Score \\ &\times Impact\ Score \end{aligned}$$

Equation 6: Crossing Risk Score

$$\begin{aligned} &Crossing\ Risk\ Score \\ &= Maximum(Hydraulic\ Risk\ Score, \\ &Geomorphic\ Risk\ Score, \\ &Structural\ Risk\ Score) \end{aligned}$$

Equation 7: Crossing Priority Score

$$\begin{aligned} &Crossing\ Priority\ Score \\ &= Crossing\ Risk\ Score \\ &+ Aquatic\ Passability\ Score \end{aligned}$$

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				
Wappasening Creek	Wappasening Creek mainstem	Wa-9400	Riparian Management	5	9	1	5	5	9	9	$500k - $1M	Would allow channel to evolve naturally, reduce flood damages, and create public open space. High visibility from NY-282.	**64**	**4**
Wappasening Creek	Wappasening Creek mainstem	Wa-7900	Riparian Management	9	9	5	5	5	9	5	$500k - $1M	Would reduce flood damages and attenuate flood flows. High visibility from NY-282.	**76**	**2**
Wappasening Creek	Wappasening Creek mainstem	Wa-7300	Riparian Management	9	9	1	1	5	9	9	$250-500k	Would reduce flood damages, attenuate flood flows, and remove potentially hazardous objects from the floodplain. Possible conversion to public open space.	**64**	**4**
Wappasening Creek	Wappasening Creek mainstem	Wa-5200	Riparian Management	9	5	1	9	9	9	9	$150-250k	Would allow channel to evolve naturally. High visibility from NY 282. Would eliminate future channel modifications. Potential as demonstration project.	**76**	**2**
Wappasening Creek	Wappasening Creek mainstem	Wa-3600	Riparian Management	5	5	1	5	5	5	1	$25-75k	Project would provide moderate benefits. Private land.	**44**	**14**
Wappasening Creek	Wappasening Creek mainstem	Wa-2800	Bank Stabilization	9	1	5	9	5	5	1	$150-250k	Would reduce bank erosion and risk to Sunnyside Road and residences	**60**	**6**
Wappasening Creek	Briggs Hollow tributary	WaBH-13900	Crossing Improvement	1	5	9	9	5	1	5	$250-500k	Town road, educational opportunity with municipal staff	**60**	**6**
Wappasening Creek	Briggs Hollow tributary	WaBH-11900	Floodplain Reconnection	9	1	5	5	5	9	5	$150-250k	Potential for attenuation by enhancing storage in natural wetland. Relatively remote with low visibility but possible conversion of land to public space. May increase flood risk to Lower Briggs Hollow Road therefore consider implementing after WaBH-4300b.	**60**	**6**
Wappasening Creek	Briggs Hollow tributary	WaBH-10300	Grade Control	5	1	5	9	5	1	5	$25-75k	Would slow runoff and trap coarse sediment with benefits for Lower Briggs Hollow Road	**52**	**9**
Wappasening Creek	Briggs Hollow tributary	WaBH-9100b	Grade Control	5	1	5	9	5	1	5	$25-75k	Would slow runoff and trap coarse sediment with benefits for Lower Briggs Hollow Road	**52**	**9**
Wappasening Creek	Briggs Hollow tributary	WaBH-9100a	Grade Control	5	1	1	9	5	1	5	$25-75k	Would slow runoff and trap coarse sediment. On opposite side of valley from Lower Briggs Hollow Road.	**44**	**14**

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
Wappasening Creek	Briggs Hollow tributary	WaBH-7300	Grade Control	5	1	5	9	5	1	5	$25-75k	Would slow runoff and trap coarse sediment with benefits for Lower Briggs Hollow Road. Opportunity to education landowner.	**52**	**9**
		WaBH-5600	Grade Control	5	1	5	9	5	1	5	$25-75k	Would slow runoff and trap coarse sediment with benefits for Lower Briggs Hollow Road. Opportunity to education landowner.	**52**	**9**
		WaBH-4800	Grade Control	5	1	1	9	5	1	1	$250-500k	Would help stabilize channel, slow runoff, and trap coarse sediment. Private land.	**40**	**16**
		WaBH-4300b	Road Closure	9	1	9	9	9	9	9	> $1M	Would eliminate current and future hazards and damages associated with Lower Briggs Hollow Road	**84**	**1**
		WaBH-4300a	Crossing Improvement	1	5	9	5	5	1	5	$250-500k	Town road, educational opportunity with municipal staff. Would restore sediment and flow dynamics.	**52**	**9**
		WaBH-3400	Crossing Improvement	1	1	5	1	5	1	5	$250-500k	Town road, educational opportunity with municipal staff. Would restore sediment and flow dynamics.	**28**	**17**