WATERSHED NEEDS ASSESSMENT

TAUGHANNOCK CREEK
TOMPKINS COUNTY, NEW YORK

April 13, 2011

MMI #4395-01

Prepared for:

Tompkins County Planning Department
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1.0 INTRODUCTION

1.1 Background and Purpose

The Tompkins County Planning Department has retained Milone & MacBroom, Inc. (MMI) to conduct a Watershed Needs Assessment for the Taughannock Creek Watershed as an addition to the Watershed Needs Assessment completed by MMI for the Six Mile Creek, Salmon Creek, Fall Creek and Cayuga Inlet watersheds in September 2005. The subject report is intended to serve as a supplemental chapter to the original Watershed Needs Assessment. Background information provided in Sections 1 through 3 includes information that is also included in the 2005 report; however, it is provided herein for context.

Tompkins County encompasses the city of Ithaca as well as the towns of Ithaca, Lansing, Groton, Dryden, Caroline, Danby, Newfield, Enfield, and Ulysses. Figure 1-1 is a location plan of the county.

The Tompkins County Planning Department (the Department) provides planning and related services to county government and local municipalities. The Department is charged with preparing a comprehensive development plan; collecting and distributing data and information on population, land use, housing, environment and community facilities; preparing planning studies and analyses; and acting as a resource for other county agencies as well as the member communities seeking outside funding.

The following objectives have been identified for the subject planning initiative:

- to evaluate effective flood mitigation in the Taughannock Creek watershed
- to reemphasize watershed approaches through the development of a strategy to address watershed needs
- to consider cumulative flood mitigation measures
- to identify watershed management and flood mitigation priorities

In all, 10 watersheds drain into Cayuga Lake within Tompkins County. These watersheds are depicted in Figure 1-2. They are:

- Salmon Creek
- East Cayuga Lakeshore North Watershed
- East Cayuga Lakeshore South Watershed
- Fall Creek Watershed
- Cascadilla Creek Watershed
- Sixmile Creek Watershed
- Taughannock Creek Watershed
- Cayuga Inlet Watershed
- West Cayuga Lakeshore South Watershed
- West Cayuga Lakeshore North (part of Trumansburg Creek watershed

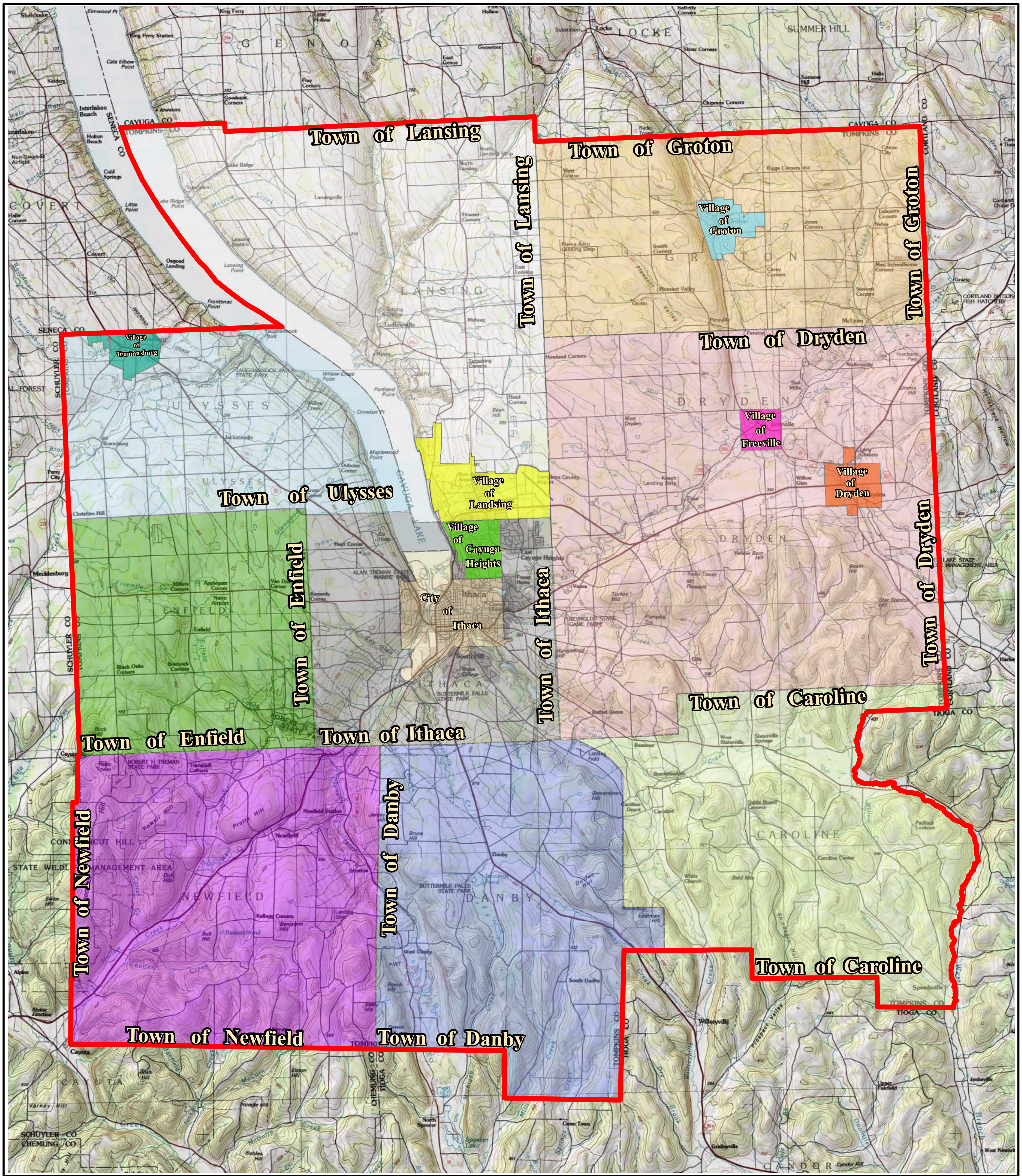
In 2003, a pilot watershed assessment was conducted for Six Mile Creek, the results of which are presented in the document entitled *Watershed Needs Assessment; Six Mile Creek; Tompkins County, New York*, dated October 2003. In 2005, watershed assessments were completed in the Salmon Creek, Fall Creek, and Cayuga Inlet watersheds. The composite analysis was presented in the document dated September 2005 and included the earlier work from 2003. Most recently, funding was made available for this assessment of the Taughannock Creek watershed as an addition to the assessments completed in 2005.

1.2 Project Stakeholders

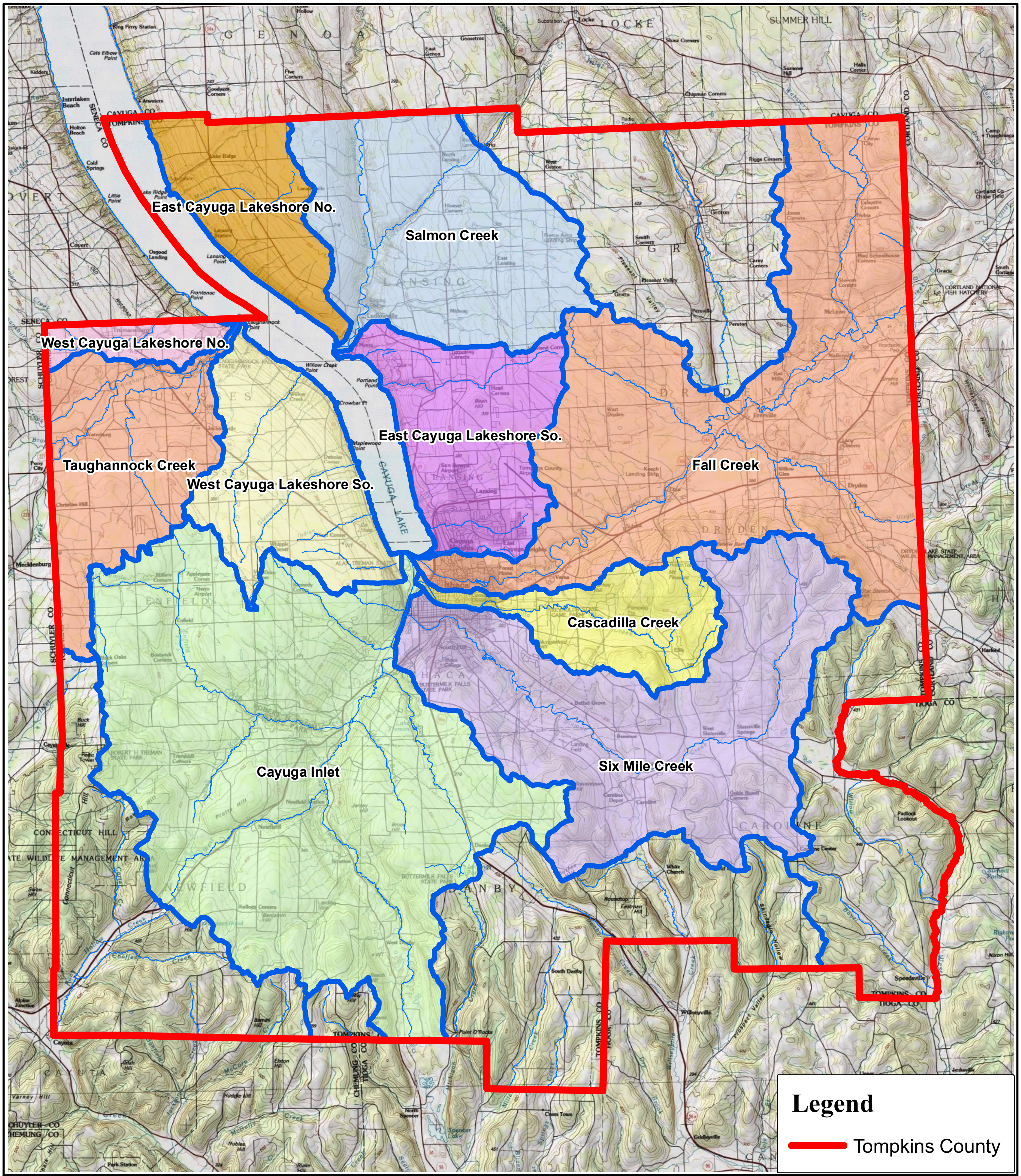
Numerous stakeholders have been identified for the Watershed Needs Assessment, including the individuals and organizations summarized in Table 1-1.

TABLE 1-1
Partial List of Project Stakeholders

Organization
Tompkins County Planning Department
Tompkins County Soil & Water Conservation District
Town of Ulysses Highway Department
Taughannock Falls State Park
Town of Ulysses Town Board
Cayuga Lake Watershed Intermunicipal Organization
Cayuga Lake Watershed Network
Tompkins County Environmental Management Council
Tompkins County Water Resources Council



Engineering, Landscape Architecture and Environmental Science **MILONE & MACBROOM®** **99 Realty Drive** **Cheshire, Connecticut 06410** **(203) 271-1773 Fax: (203) 272-9733** **www.miloneandmacbroom.com**	**Location Plan** **Tompkins County**		**LOCATION:** **Tompkins County, NY**
	MMI#: 4395-01-3 **MXD:** H:\Figure 1-1.mxd **SOURCE:** Cornell University CUGIR	N **Taughannock Creek Flood Mitigation Needs Assessment**	**Map By: DRM** **Date: March 2011** **Scale: 1" = 17,000'** **SHEET: Figure 1-1**



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Cayuga Lake
Watershed Location Map

LOCATION: Tompkins County, NY

MMI#: 4395-01-3
MXD: H:\Figure 1-2.mxd
SOURCE: Cornell University CUGIR

N

Taughannock Creek
Flood Mitigation
Needs Assessment

Map By: DRM
Date: March 2011
Scale: 1" = 17,000'

SHEET: **Figure 1-2**

2.0 EXISTING GEOMORPHIC CONDITIONS IN TOMPKINS COUNTY

2.1 Geologic and Geomorphic Background

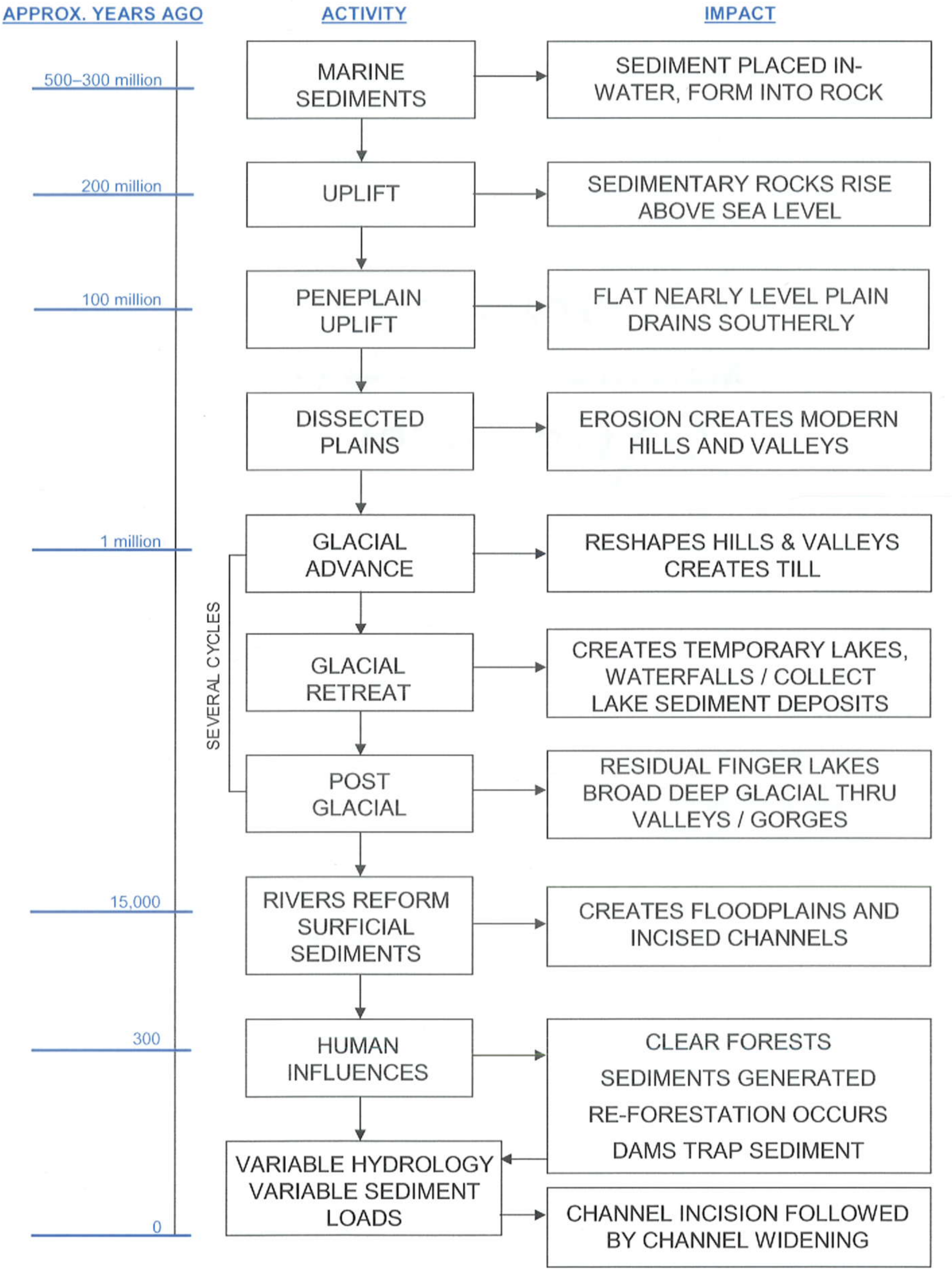
The Finger Lakes region of New York is often cited for its classic examples of "U-shaped" valleys carved by the advancing glaciers of the most recent ice ages. Indeed, these valleys are the prominent characteristic of the area, but many geologic forces have shaped the landscape of Tompkins County, and these must be addressed to understand the natural processes in the Taughannock Creek basin. Figure 2-1 presents a summary of regional channel evolution.

Most of the consolidated sedimentary rocks in the Ithaca area were formed 375 million years ago during the Devonian period. At least 1.2 miles (vertical) of sedimentary rock have been removed from the Ithaca region by erosion over several million years, including erosion that occurred over several glacial periods.

The cycle between glacial periods is estimated at 100,000 years to 150,000 years (Bloom, 1990). The most recent glaciers (known as the Wisconsin advance) were completely retreated from New York about 11,000 years ago. Between 13,500 years ago and 11,000 years ago, while the glaciers were melting, several ancient lakes existed in the Ithaca region, each with different elevations and outlets. Each ancient lake is associated with ancient beaches, ancient deltas, outlet stream deposits, and lake-bottom deposits that currently exist as landforms and subsurface deposits.

SUMMARY OF REGIONAL CHANNEL EVOLUTION

FIGURE 2-1



As ancient lake levels formed and were replaced by lower lake levels, ancient deltas formed at different elevations in stream valleys. The net result is a series of ancient deltas that lie along the valley main stems, found along several of the major streams draining toward Cayuga Lake. Existing streams have eroded and cut into some of the ancient deltas that were deposited by their ancestral streams, with the result being the downstream transport of sediment.

Some of the boundaries of the ancient lakes can be approximately located based on the locations on landforms. For example, an ancient beach deposit marks the uppermost elevation of Lake Ithaca (1,020 feet) far to the east of the Cornell University campus. An ancient delta located beyond the eastern edge of the Cornell University campus (elevation 970 to 975 feet) marks another position of ancient Lake Ithaca. Southwest of Ithaca, three small ancient deltas lie along Coy Glen, at elevations of 980 feet, 1,040 feet, and 1,060 feet.

As exhibited by the constant adjustment of hydrologic systems in response to geologic forces, constant stability is rarely observed in natural rivers. Instead, rivers constantly change their alignment and capacity to transport both water and sediment in reaction to hydrologic and geologic conditions. However, according to Knighton, "…they can become relatively stable in the sense that, if disturbed, they will tend to return approximately to their previous state…" (Knighton, 1998) To expand further: one widely accepted tenant of fluvial geomorphology is that if the main variables affecting channel form; discharge , sediment load, and slope, show little variation, minor disturbances to channel form will trigger natural feedback loops that will eventually return the channel to its original shape and functionality. (Brierley, 2005) A river exhibiting a self-maintained stable form is often classified as in "equilibrium."

Equilibrium rivers often display a classic profile extending from ridge to valley floor, beginning in high-gradient areas with many cascades, flowing through intermediate areas with pools and riffles, and eventually flowing through large, low-gradient floodplain areas that may be characterized by meanders and wide channels. Although these types of streams are found in the northeastern United States, most rivers in the Ithaca area are not in equilibrium with their landscape due to the glacial cycles and resulting lake levels detailed above.

Fall Creek, flowing through the largest contributing watershed in Tompkins County, is a good example of a stream that is not in equilibrium due to recent glacial forces. The midstream reaches of Fall Creek have a base level control due to the presence of bedrock at "flat rock." Upstream of flat rock, Fall Creek has inherited large meanders that were formed under previous flow conditions. The downstream reaches of Fall Creek (in the vicinity of the Cornell University campus) are characterized by deep gorges with near-vertical walls. Similarly, Taughannock Creek features large meanders with wide floodplains in the mid-valley reaches formed by historic flow conditions before the stream bed grade is controlled by exposed bedrock around the Waterburg Road Bridge. The reaches downstream of the base level control provided by this bedrock feature deep gorges with vertical walls and waterfalls, the most prominent of which is Taughannock Falls in Taughannock Falls State Park at the bottom of the watershed.

Furthermore, Fall Creek and Taughannock Creek are examples of rivers that cannot easily adjust to their down-valley slope. Because the regional base level control (Cayuga Lake) is so much lower in elevation than the upper portions of the watershed, and because their valleys are U-shaped, both creeks must fall through a very large change in elevation in a relatively short distance. Taughannock Creek has naturally worked toward cutting a more gradual profile, resulting in gorges in the downstream reaches, while constrained by other bedrock base level control at the Waterburg Road Bridge.

Because rivers in the Ithaca region are not in equilibrium with the current landscape due to glacial processes, they are actively eroding many of the sediments that were deposited directly by glaciers and their melt water, or that formed beneath the ancient lakes, at the edges of the ancient lakes (the ancient deltas), or during outflow from the ancient lakes.

Although this is a natural process that has occurred in many other watersheds that have already reached equilibrium conditions, in the watersheds under study, this process is ongoing. In geomorphic terms, the term for erosion over an expansive area is "denudation." Rates of denudation typically indicate a vertical loss of material averaged over a wide area.

Denudation rates for glaciated areas have been estimated at 3.0 centimeters (cm) per thousand years, and there is evidence that the Ithaca region has lost an average of 4.5 meters (vertical) since the beginning of the last glacial cycle (Bloom, 1990). Denudation rates are higher for intense agricultural areas, such as the Mississippi valley (estimate of 5.0 cm per thousand years), and for mountainous areas (as much as 13.0 cm per thousand years in the Sierra Nevada). Nonetheless, the estimate for glaciated areas indicates that the Ithaca region may continue to experience erosion and downstream sedimentation at an overall vertical rate of 3.0 cm per thousand years, at a minimum.

If left alone, these streams will continue in their dynamic nature towards eventual equilibrium in the environment. The challenge, however, is the integration of this natural process with existing development and the management of natural resources. Examples of this management challenge are the ongoing sediment deposition in the city's and Cornell University's sources of drinking water supply, and in Cayuga Lake below Taughannock Falls, as well as the bank failures on Taughannock Creek banks between bedrock control points.

2.2 Channel Incision

The dominant fluvial process along much of the Finger Lakes Region is the incision of channels into the landscape. The overall process of regional landscape degradation has been described by Von Engeln (1961) and is summarized in Section 2.1 of this report. Schumm, et. al. (1984) described several different types of channel incision, all of which have been observed in the watersheds under study.

- *Rills* – are small intermittent channels as a result of erosion by overland flow. They are often seasonal and are "plowed" out during planting.

- *Valley Side Gullies* – are small to intermediate size channels, generally with relatively high steep unvegetated banks, extending down the side of steep valley walls without a defined valley or watershed.

- *Valley Bottom Gullies* – are found where intermittent or perennial flows have eroded a new steep-sided channel across a valley base or floodplain to the valleys main stream. As a result of their position in the valley bottom, they often erode deeper to match the grade of an entrenched river or extend longer to reach a meandering river into which they discharge.

- *Entrenched Streams* – occur where a natural stream has become incised in its own valley and below the elevation of its floodplain. Entrenched channels may occur in bedrock or in surficial soils, or in earlier sediment deposits.

Channel degradation can have mild to significant adverse impacts to both natural and cultural systems. Much depends upon the rate and magnitude of degradation and whether systems can adjust to the degradation. For example, rapid degradation can undermine bridge foundations or pipe crossings in less than the physical life span of the structure and require remedial action. Sediments transported downstream from incised channels can settle in and fill reservoirs prior to the life span of the dam.

Incised channels have significant ecological impacts. The deep channels have increased flow capacity and thus have less frequent floodplain inundation. This reduces over-bank floodwater storage, leading to higher peak flows and less sediment deposition on the floodplains. Alluvial ground water levels, dependent on river stages, will decline. This tends to "dry up" or eliminate riparian wetlands. Table 2-1 lists some of the adverse impacts of channel incision.

TABLE 2-1
Adverse Impacts Due to Channel Incision

Natural	***Anthropogenic***
creates excess sediment	undermines bridges
banks erode, trees collapse	exposes utility pipes
lowers alluvial ground water levels	reservoir sedimentation
creates unstable bed habitat	loss of riverbank land
reduces biological diversity	downstream flood damages
higher velocities occur	poor channel access
reduces floodwater storage	degrades water quality
increased peak flood flows	
knick points inhibit fish passage	
sediments fill downstream lakes	

3.0 CONCEPTS IN WATERSHED ASSESSMENT AND MANAGEMENT

3.1 Principles of Watershed Management

Many factors require that river management efforts extend far beyond the banks that contain flowing water. Some management issues result from upstream land use, runoff, and sources of pollution. Others arise because of floodplain encroachments, inadequate riparian buffers, or loss of wetlands. The evolving methods of river management emphasize a holistic approach, addressing the watershed and stream corridor in addition to the actual channel. Traditional approaches to river management are often limited in scope, prohibitively expensive, and environmentally unsound. The concept of managing the watershed and corridor as well as the river channel itself provides an alternate approach that allows each river function to be managed at the appropriate level.

Watershed management has evolved in response to the need for a broad approach that considers rivers to be important natural resources with many, often competing uses. It is essential to recognize that, besides conveying storm runoff, streams serve many other ecological, economic, and social functions; and the planning and design of management systems must consider water supply needs, recreational uses, wildlife, aesthetics, and the cost and maintenance of the management measures that are implemented.

The concept of watershed management has been in existence for many years. The practical application of the watershed management approach is constantly evolving as new technologies are developed. An effective watershed management program should be based on scientific and engineering guidance but also needs to be communicated to and implemented by the stakeholders of the watershed in a complementary and coordinated effort.

Effective watershed protection involves a multifaceted approach that encompasses land use (past, present, and future); stream and wetland buffers; responsible development through adequate site selection, design, and maintenance; stormwater best management practices; control of nonstormwater discharges; control of destructive and unnatural erosion and sedimentation; and watershed stewardship programs that have the ability to span corporate boundaries and governmental divides.

The process of watershed management begins with a watershed needs assessment, wherein the following basic tasks are conducted:

- identification of the study area
- identification and notification of interested individuals, organizations, and public agencies
- establishment of an advisory or coordinating board
- collection of existing data and evaluation of natural and cultural features
- collection of new data as needed
- identification of watershed and stream issues and problems
- identification of highest priority issues
- evaluation of alternative solutions to problems
- researching of funding sources and needed regulatory programs
- development of a proposed strategy
- adoption of a management plan
- implementation of the plan
- follow-up and assessment of the success of the strategy and management plan
- adjustment of the strategy and redevelopment of a management plan

This watershed needs assessment is designed to follow the above approach. The subject document is organized accordingly.

3.2 Stream Dynamics

The movement of sediments through a river system is a complex process, often made up of many cycles of scour, movement, transport, and deposition. Sediment movement occurs when water flow exerts sufficient force to overcome the resistance produced by the weight of individual particles, their cohesion to similar particles, and their friction with the streambed. Most sediment is transported during periods of high water flows and high velocities. High flow velocities are able to erode and transport larger particles and so accelerate erosion. Similarly, long-duration floods can cause more erosion and sediment transport as compared to short-duration floods. The sediment concentrations in river water and long-term sediment loads depend on the availability of erodible soil and the ability of a river to transport it.

Aggradation is the general increase in elevation of a long reach of a riverbed over a long period. This process occurs when sediment is continually added to the riverbed, or even the floodplain; and the river does not have the necessary slope, velocity, or flow rate to wash away the sediment. Therefore, the riverbed will rise, increasing the slope in relation to the segment farther downstream. This increased slope accelerates erosion, until sediment transport is equal to the sediment supply rate and equilibrium is achieved.

In contrast, degradation is the general lowering of the streambed. This occurs where the slope, discharge, and flow velocity combine to transport more sediment than is supplied to a river section. As a result, the riverbed will erode until the slope and velocity are reduced to a point of equilibrium. Natural degradation can result from an uplift of the land, climatic changes, or even an increase in vegetation. Humans can cause or accelerate degradation through watershed development that increases surface runoff and flow rates. Dams on alluvial rivers (i.e., those that are dynamic, whose beds and banks can erode and change course over time) encourage degradation by trapping sediment that would normally be carried downstream.

An entrenched channel is one that has degraded so much that its flood flow is unable to spread across its floodplain. Such channels are confined by well defined banks that are higher than the mean annual flood level, thereby preventing inundation. Entrenched meanders occur when the channel's original pattern was preserved as the channel degraded, such as in the Grand Canyon. In other words, entrenched meanders are those that have eroded vertically but not laterally. They have steep valley walls on both sides of the meander bends.

Incised meanders occur where the channel has eroded both vertically and laterally. They move downstream by eroding the outside of the bends. They are characterized by steep banks on the outside of bends, with mild sloping banks on the inside. Active meandering channels often occur where a low-gradient river flows through highly erodible sediments, or where the stream is down-cutting through glacial deposits in its preglacial channel, exposing historic meander bends.

3.3 Sediment Budget and Transport Mechanisms

Open channels with flowing water have a discrete ability to transport sediment based upon their flow velocities, shear strength, flow rates, and flow duration. The first two parameters are related to channel slope, friction, width, and water depth. Steep and smooth channels can carry more sediment as compared to low gradient or rough high friction channels.

Under equilibrium conditions, the sediment load produced by a watershed is equal to the channel's sediment transport capacity. Rivers that can transport more sediment than that which is supplied to them will tend to scour any erodible bed or bank material, while rivers with a transport capacity that is lower than the watershed yield will tend to aggrade or deposit sediment on the bed or floodplain. The basic relationship is:

$$\Delta S = \Sigma Y - Q_s$$

where:
ΔS = change in channel sediment storage (volume)
Q_s = channels sediment transport capacity
Y = watershed sediment yield

Channel erosion in steep gradient rivers has a vicious, self-perpetuating cycle. As shown by Schemm's (1984) model, first they erode the bed where the greatest shear stress exists, concentrating even more flood water in the channel. Then they incise vertically until either the bed slope (and velocity) is reduced or until the even higher banks collapse (supplying fresh sediment). Eventually, (after decades or centuries) they reach a new equilibrium. In mountainous and shallow bedrock regions, including Taughannock Creek, incision may cease when bedrock is reached or the riverbed becomes armored with natural rock fragments of cobbles or gravel.

3.4 Types of Erosion

Two types of erosion and sediment load can occur in a stream system. The first is called surface erosion and occurs in the contributing watershed to a stream. For example, surface erosion can occur at construction sites, where bare earth is exposed to the forces of stormwater or in road ditches during high precipitation events. It can also notably occur as a result of agricultural practices and poor soil management leading to the formation of gullies and high sediment runoff from fields. Sediment load can also be introduced to a river or stream through the application of road sand or through urbanization. The second type of erosion is bed or bank erosion, where the source of sediment is the stream bed or bank walls.

In recent years, local planning and zoning ordinances, as well as state legislation, have focused on erosion control practices for land development, often accomplished through the use of hay bales, silt fences, and sediment basins. Nonpoint pollution controls have also been the focus of much attention in recent years, with stormwater management treatment and best management practices becoming commonplace.

Hills and uplands form as the result of forces form by tectonic plate interaction warp the earth's crust. Plutonic igneous rock masses can also push up through the crust, forming mountain ranges such as the Sierra Nevada. These mountainous areas and uplands in turn are subject to degradation and wear by the twin processes of surficial erosion and mass movement. Man-made slopes are subject to the same degradation processes. In order to control or prevent this wearing or wasting away of the earth's surface, it is first necessary to understand these two processes of degradation and the factors that affect them (Gray & Sotir, 1996).

Surficial erosion is the detachment and transport of the surface layers of soil by wind, water, and ice. Common forms of surficial erosion include rainfall and wind erosion. This type of erosion is most notable at poorly managed construction sites on exposed steep slopes. However, erosion can also occur along stream banks, where high velocities erode vulnerable, particularly unvegetated, banks.

Mass movement involves the sliding, toppling, falling, or spreading of fairly large and sometimes relatively intact masses. A slide is a relatively slow slope movement in which a shear failure occurs along a specific surface or combination of surfaces in the failure mass (Gray & Sotir, 1996).

Eroding banks can contribute large volumes of sediment to downstream receiving waters. When the receiving waters are of critical value, it is important to minimize the transport of sediment to them in order to maintain water quality. This often entails using bioengineering techniques to regrade and replant the channel banks.

Stream banks may erode and/or collapse due to many different causes and may undergo various types of failures. The potential factors involved in bank failure include watershed hydrology, river flow hydraulics, sediment transport, geology, soils, ground water hydrology, and vegetation cover. The specific factors in any particular case depend on the type of failure that is occurring.

Surface erosion along stream banks can result in soil loss and bank undercutting. That situation can result in an eventual mass failure, in which the soil slumps or slides as a unit. While bank protection can address the underlying cause of the problem (i.e. surface erosion), the potential for mass failure also needs to be addressed on a location-specific basis. In general, bank failure can be attributed to mass failure or surface erosion.

Numerous types of mass soil failures can occur on steep slopes as summarized in Table 3-1.

TABLE 3-1
Types of Mass Soil Failures

Shallow Soil Slides	Occurs on steep low cohesion soils, often-coarse grain material. Has thin slide layers parallel to the surface.
Circular Plane Failures	Deep-seated circular failure planes, common on strongly cohesive soils.
Slab or Wedge Failures	Occur on steep moderately cohesive soils. The slabs crack along the top and tip outward with near vertical upper slopes.
Cantilever Failures	Due to the collapse of an undercut block of soil, often due to erosion at the base of the slope.
Granular Flow	An avalanche-type failure of dry cohesionless soils on steep slopes, creating a loose layer of debris in a fan pattern.
Saturated Flow	Saturated soils lose their strength and become plastic, often following heavy rain or high water levels.
Seepage Failure	Caused by saturation of the lower slope, creating a "semi-moon"-shaped popout cavity in the lower bank.

The analysis of mass bank failures is a geotechnical evaluation that compares the weight of the soil mass (usually saturated) versus the shear strength of the potential failure plane. Quantitative assessment shows that the higher and steeper banks are more failure prone and that failures decrease as the slope is reduced by past failures building up a berm of debris at the base of the bank. A stable bank may have gradual erosion of individual particles over a long period of time, while an unstable bank is one with frequent mass block failures every few years.

3.5 Bank Stabilization

Many methods of stabilizing riverbanks can be employed, each with its own advantages and disadvantages. Milone & MacBroom, Inc. has classified available methods into categories based upon two primary functions, mass failure protection, and surface soil erosion protection. A single project site may often use multiple stabilization methods depending on site, soil, and slope conditions. In addition, the type of treatment may vary based on its position on the slope and frequency or duration of inundation.

Two types of strategies can be applied to protect a bank undergoing surface erosion from a river. One is instream modification of the river's flow patterns to decrease the attack on the bank, and the other is modification of the bank itself to strengthen its ability to resist the erosive forces. In cases where the velocities of the water, rather than the alignment of the river, are causing erosion, modification of the bank is appropriate.

The approach to bank stabilization can be "soft" or "hard." The softest approach relies primarily on vegetation for bank strengthening. This type of approach typically provides instream and riparian habitat value that is superior to the harder methods; however, it may not provide the level of stability required to decrease the erosion to acceptable levels. The harder approach relies primarily on structural methods, such as large riprap or concrete, to armor the riverbank. A balance of both soft and hard methods is often required, where some hard structural components are used and combined with softer habitat features to create a stable and attractive bank that provides both instream and riparian habitat.

3.6 Management Practices

Milone & MacBroom, Inc. team members inspected and reviewed various watershed management practices that have been applied, or could be applied, to minimize flooding, erosion, and sediment problems in the subject watersheds. The specific interest was to identify the performance of individual practices with regard to short- and long-term objectives.

Watershed management measures can be classified by primary functional groups as listed in Table 3-2. Typical measures are tabulated below by primary function.

TABLE 3-2
Primary Watershed Management Functional Groups

Hydrology	***Hydraulics***	***Surface Erosion Control***
detention basins	channel clearing	vegetation ground cover
infiltration systems	channel enlargement	rill/gully controls
created wetlands	bridge improvements	mulch
flood control dams	channel alignment	biofabrics
low impact development	floodways	silt fence barriers
Channel Stabilization	***Sediment Control***	***Water Quality***
vegetation	upland sediment basins	catch basins sumps
biotechnical	instream silt basins	hooded outlets
stone riprap	vegetative buffers	vegetated buffers
log revetments	diversions	oil traps
geomorphic design	biofilters	grit chambers
retaining walls		

Hydrologic measures are intended to reduce the volume or peak rate of runoff and ideally attempt to mimic natural conditions. Hydraulic measures are traditionally used to lower flood water levels, reduce flood damages to natural or community assets, or modify flow velocities. Surface erosion controls are used to limit upland erosion on the ground surface to reduce production of sediment such as at construction sites and agricultural fields. Many types of channel stabilization are in use throughout the country, ranging from simple use of vegetation and stone to geomorphic design process to reshape channels.

In some cases, a reactive strategy is implemented to control sediments that have already been eroded from the earth. In these instances, suspended sediment is captured downstream of its source and is subsequently settled by gravity or is treated through other physical or mechanical mechanisms.

Channels located in alluvial soils that were placed as fluvial sediments have the ability to modify and form their channel widths, depths, and slope in proportion to their dominant discharge. Channels that are initially undersized will be subject to scour that increases their widths and depths in proportion to a channel forming flow rate, while channels that are excessively large will tend to be subject to sediment deposition that decreases width and depth. Over long time periods, alluvial channels thus approach an equilibrium condition.

There has been some discussion in Tompkins County related to use of the hydraulic geometry method of channel analysis (Leopold, 1994) for application in developing restoration plans for distressed stream sections. This concept is the basis of the "natural" design approach to evaluating self-stable alluvial channels. It originated over 100 years ago in India and Pakistan and evolved in the United States beginning in the 1950s, becoming a popular alternative to earlier rigid boundary hydraulic engineering procedures and being much simpler than modern sediment transport techniques. It is only valid for channels at near equilibrium conditions in alluvial material.

Hydraulic geometry relations may be applied by either copying the dimensions of a stable cross section of a similar channel classification or by using statistical analysis of regional channels to find their bankfull width and depth as a function of the watershed area or preferably their dominant discharge.

There are many alternative techniques available to address channel incision and minimize its adverse impacts. The specific management techniques and design details for individual sites is beyond the scope of this study. However, the broad alternatives that are available are described below.

<u>*Do Nothing*</u> – This no-action alternative allows the renewed channel degradation to continue towards a natural self-imposed equilibrium. The long process (on the order of 10 to 100 years) has several consequences, including downstream sediment loading, bank

collapses, channel widening and land loss, and ground water recession. In rural areas, this is often acceptable and unavoidable.

Channel Linings – A traditional technique for minimizing channel incision is the use of continuous linings on the bed and/or banks to stop erosion. Common linings include use of concrete, stone riprap, stone filled gabions, precast concrete blocks, and revetments as well as biomechanical plantings such as root wads, fascines, brush layers, and use of dormant cuttings or stakes. Channel linings usually have significant ecologic and hydrologic impacts due to vegetation removal to regrade the bank, loss of habitat diversity, and aesthetics.

Watershed Scale Measures – These are applied in selective situations where broad cultural land use activities are contributing to channel incision. Activities that stimulate incision could include deforestation; overgrazing by cattle, goats or sheep; gravel mining or mineral extraction; channelization; wetland destruction or urbanization. MMI did not observe significant watershed-scale activities that would accelerate natural channel incision. Previous activity, such as deforestation, may have contributed to present incisement.

Flow Control – In watersheds subject to deforestation or urbanization, control of peak flood flows is essential to minimize downstream impacts. Higher or more frequent peak flows increase flow velocities and sediment transport that lead to channel bed or bank scour. Specific control techniques include dry storage dams, detention basins, and created wetlands.

Channel Slope Control – Incision can be minimized or contained by use of grade controls or drop structures. Various types of grade controls can be used, including low weirs, flush sills, boulder clusters, anchored logs, gabions, check dams, and rock ramps. It is important to recognize that some grade control structures on perennial streams obstruct fish passage, and restoration design must incorporate detailed sediment, hydrologic and hydraulic modeling, and analysis. Site inspections along numerous streams in the subject watersheds revealed that clusters of glacier erratics (boulders of non-native rock) were very effective in stopping knick points.

Velocity Control – Providing increased channel roughness with boulders and anchored logs or bank vegetation reduces flow velocity and subsequent bed erosion. However, extensive roughness may increase flood water levels and the frequency of overbank flows. This is in conflict with many regulatory programs.

Floodplain Connectivity – A fundamental problem with incised channels is that their increasing depth and flow capacity reduces the frequency and magnitude of overbank flow on their floodplains. As they erode and deepen, more and more of the flood flow is trapped in the channel, increasing velocity and shear stress that creates even more erosion. A very effective approach is to mimic a natural system by recreating a new floodplain at a lower grade to increase its usage and reduce velocities via a larger cross sectional area. These compound channels (low flow channel plus floodway) are complex to design but are very effective if sufficient land is available.

Channel Fill – Occasional suggestions in the literature refer to refilling incised channels to raise the bed elevation and allow floodplain flow again. However, in developed areas, this increases flood levels as well as hazards and is a regulated activity with significant ecological impact. MMI discourages this alternative.

Sediment Load – Channels become incised when sediment transport capacity exceeds their supply of sediment. The Colorado River is a classic example where construction of large dams that trap sediment reduce downstream loads, leading to severe channel incision. Some European rivers are managed by increasing sediment loads to create an equilibrium condition. This is not desirable in many areas due to water supply intakes, water quality, and ecological concerns. Examples of measures to increase sediment loads include removing abandoned dams that remove trees and woody debris and ceasing gravel mining in rivers.

<u>*Bank Protection*</u> – Armoring the banks with retaining walls helps to protect private property by reducing channel widening. However, it does not address the source of the problem and can accelerate further incision that would undermine the walls as knick points migrate upstream. Similarly, the use of conventional plantings or biotechnical methods to reduce bank erosion is most effective if the channel width is already adequate for flood flows and the banks are regraded below the angle of repose.

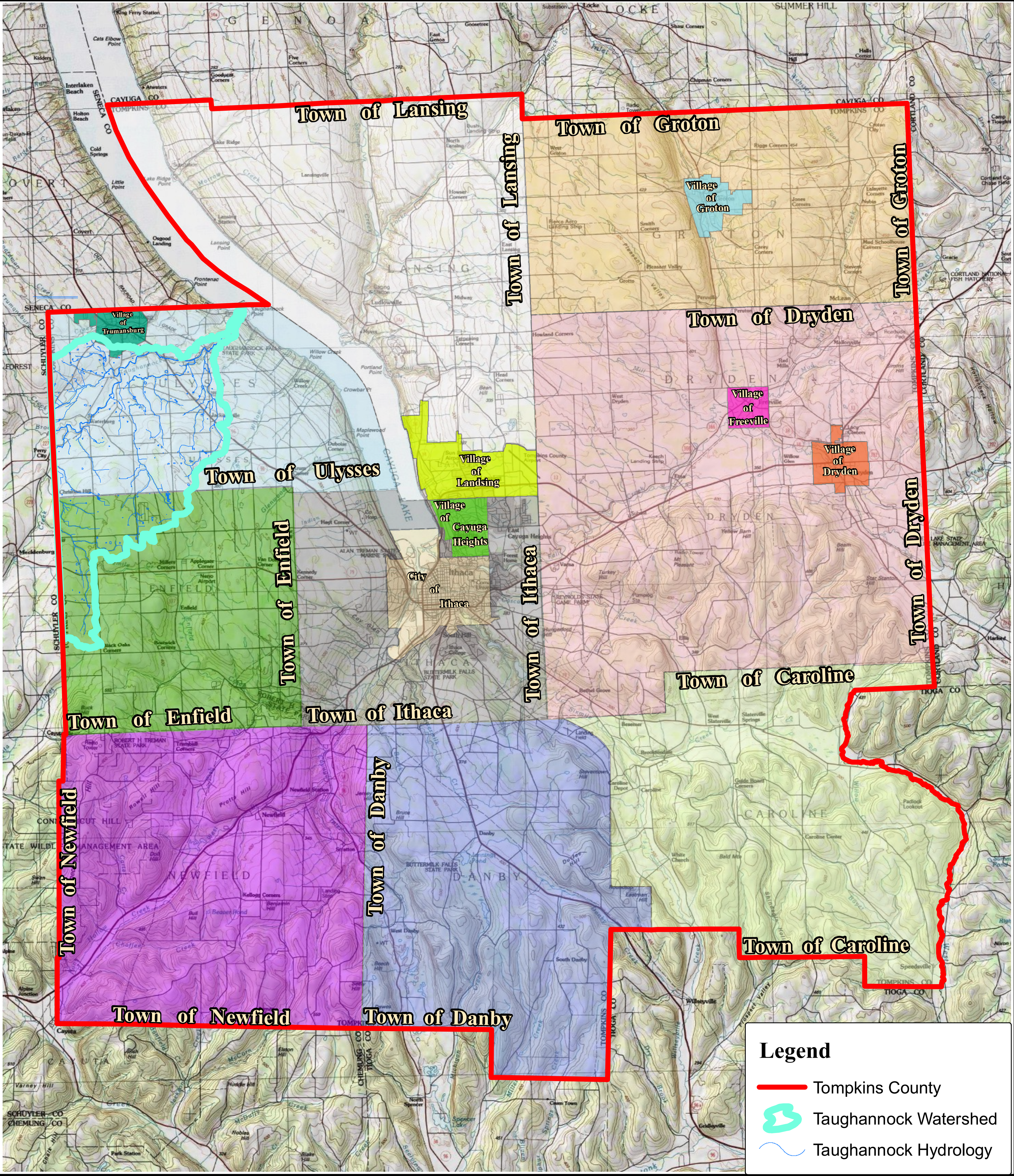
It is noted that channel clearing operations that remove trees and debris for local flood protection tend to increase flow velocities and increase erosion by reducing channel roughness. Similarly, channel straightening will shorten the river's length and increase velocity and scour, contributing to more channel erosion.

4.0 EXISTING CONDITIONS – TAUGHANNOCK CREEK

4.1 Background

While the headwaters of Taughannock Creek are located partially in the town of Enfield within Tompkins County and in the town of Hector within Schuyler County to the west, the majority of the main channel of Taughannock Creek is within the borders of the town of Ulysses. Ulysses, founded in 1790, is located in the Central New York Military Tract, a two million acre tract of land that was used to pay soldiers from New York State who fought in the Revolutionary War. Thus, the dominant land use in Ulysses has been agriculture, including dairy farms and fruit orchards. Fruit orchards no longer exist in Ulysses, and there is but one remaining dairy. There is, however, a number of active farm operations though they predominately consist of agronomic field crop production. The town of Ulysses is composed of several hamlets including Halseyville, Jacksonville, Krums Corners, Podunk, Waterburg, Willow Creek, and the village of Trumansburg.

The village of Trumansburg, incorporated in 1872, is the commercial center of Ulysses. The village was settled near a cascade falls on Taughannock Creek (located upstream of the New York State Route 96 Bridge) to take advantage of the stream power for operation of a mill. Most of the hamlets in Ulysses, Podunk, Waterburg, and Halseyville, in particular, were centered around mills located on Taughannock Creek. Most of these mills were still in existence until they were largely destroyed during a flood on July 8, 1935, which also flooded Main Street in Trumansburg. Figure 4-1 is a location map of the Taughannock Creek watershed. The creek flows through the hamlets of Waterburg, Podunk, and Halseyville before entering Taughannock Falls State Park just downstream of the Route 96 Bridge. The contributing watershed to Taughannock Creek is approximately 67 square miles, portions of which lie within the town of Hector in Schuyler County and the towns of Enfield and Ulysses within Tompkins County.



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Location Plan
Taughannock Creek

LOCATION: Tompkins County, NY

MMI#: 4395-01-3
MXD: H:\Figure 4-1.mxd
SOURCE: Cornell University CUGIR

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Taughannock Creek Flood Mitigation Needs Assessment

Map By: DRM
Date: March 2011
Scale: 1" = 17,000'

SHEET: Figure 4-1

Taughannock Creek is 19.2 miles long from its headwaters to the outlet in Taughannock Falls State Park at Cayuga Lake. The headwaters are located near the hamlet of Smith Valley within the town of Hector near the intersection of Route 228 and Culver Road. The headwaters of the creek are in the foothills of the Finger Lakes National Forest, just north of Cayuta Lake. The creek flows in a northerly direction through Mecklenburg and Perry City before it flows beneath Mecklenburg Road to enter Tompkins County.

Once in Tompkins County, Taughannock Creek flows under Perry City Road. It then turns east to parallel Brook Road for 700 feet before turning north and passing beneath the road where Spring Brook joins the main channel. Spring Brook flows from the northwest, originating in the hamlet of Reynoldsville in Schuyler County. The main channel then meanders toward the hamlet of Waterburg with several wide meander bends before encountering the first exposed bedrock at the Waterburg Road Bridge (former location of the Waterburg Mill).

Taughannock Creek parallels Waterburg Road for 1.5 miles before flowing under Podunk Road in the hamlet of Podunk where Bolter Creek, a tributary that flows from the northwestern corner of Ulysses, joins the main channel. Downstream of the confluence with Bolter Creek, Taughannock Creek parallels the South Street Extension and Rabbit Run Road for approximately two miles, entering Taughannock Falls State Park slightly upstream of the Route 96 Bridge and the hamlet of Halseyville. Approximately three-quarter of a mile downstream of the Route 96 Bridge, Jenny Creek, which flows northward from Enfield, joins the main channel. A small tributary known as Cold Spring Branch converges with Taughannock Creek at Jacksonville Road. A half-mile downstream from the Jacksonville Road Bridge the creek flows over Taughannock Falls, a 215-foot drop into a gorge with 400-foot high walls. It then flows over bedrock for approximately a mile before it flows under Taughannock Boulevard (New York State Route 89) and ends at a delta in Cayuga Lake.

Table 4-1 presents a listing of subwatersheds within Taughannock Creek. These are shown graphically in Figure 4-2.

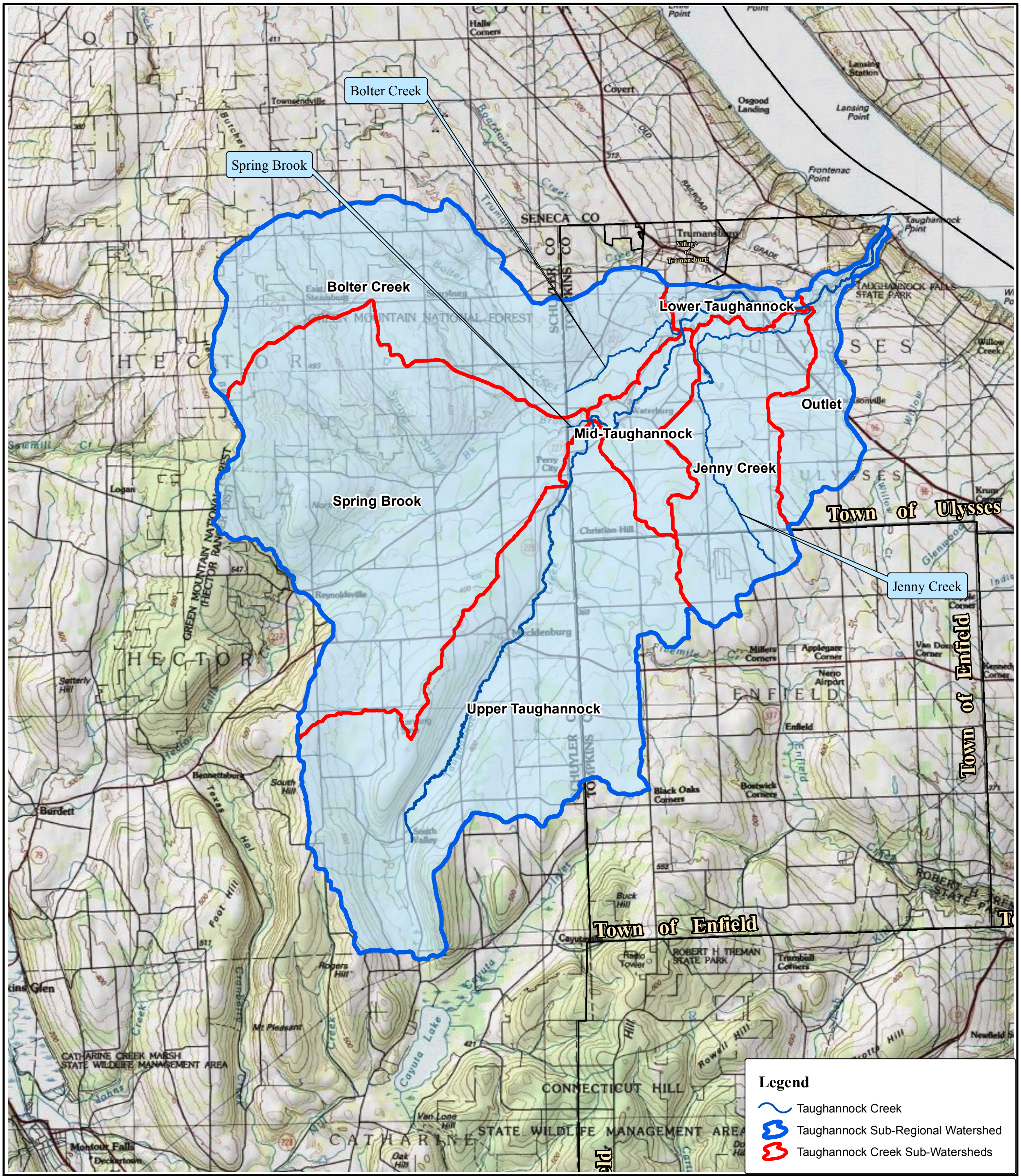
TABLE 4-1
Summary of Subwatershed Areas – Taughannock Creek

Watershed Designation	***Watershed Area***	***Watershed Area***
Upper Taughannock	13,312 acres	20.8 sq. mi.
Spring Brook	12,672 acres	19.8 sq. mi.
Middle Taughannock	1,664 acres	2.61 sq. mi.
Bolter Creek	8,192 acres	12.8 sq. mi.
Jenny Creek	4,288 acres	6.7 sq. mi.
Lower Taughannock	640 acres	1.0 sq. mi.
Outlet	2,112 acres	3.3 sq. mi.

For analysis purposes, in addition to subwatershed delineations, reach segments were defined along the length of Taughannock Creek. These are summarized in Tables 4-2 and 4-3. Figure 4-3 presents a schematic diagram of the subwatershed structure.

TABLE 4-2
Summary of Stream Segment Designations – Taughannock Creek

Segment	***Description of Geographic Limits***	***Length***	***Description of Conditions***
1	Tompkins County Border to Brook Road Crossing	0.52 mi.	Slightly entrenched, meandering, well-developed floodplain.
2	Brook Road Crossing to Waterburg Road Bridge	1.65 mi.	Slightly entrenched, meandering until exposed bedrock; transitions to deeply incised bedrock channel.
3	Waterburg Road Bridge to Podunk Road Bridge	1.55 mi.	Slightly entrenched, meandering, some sections of deeply incised bedrock channel.
4	Podunk Road Bridge to Route 96 Bridge	2.00 mi.	Meandering alluvial channel contained within a deeply incised bedrock channel.
5	Route 96 Bridge to Taughannock Falls	1.73 mi.	Moderately entrenched steep channel, some areas of exposed bedrock with some headcutting.
6	Taughannock Falls to Route 89 Bridge	1.00 mi.	Stable bedrock channel with gorge and falls.
7	Route 89 Bridge to outlet at Cayuga Lake	0.43 mi.	Entrenched, deeply incised channel with low slope; no floodplain connectivity.



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Taughannock Creek Sub-Watersheds

LOCATION: Tompkins County, NY

MMI#: 4395-01-3
MXD: H:\Figure 4-2.mxd
SOURCE: Cornell University CUGIR

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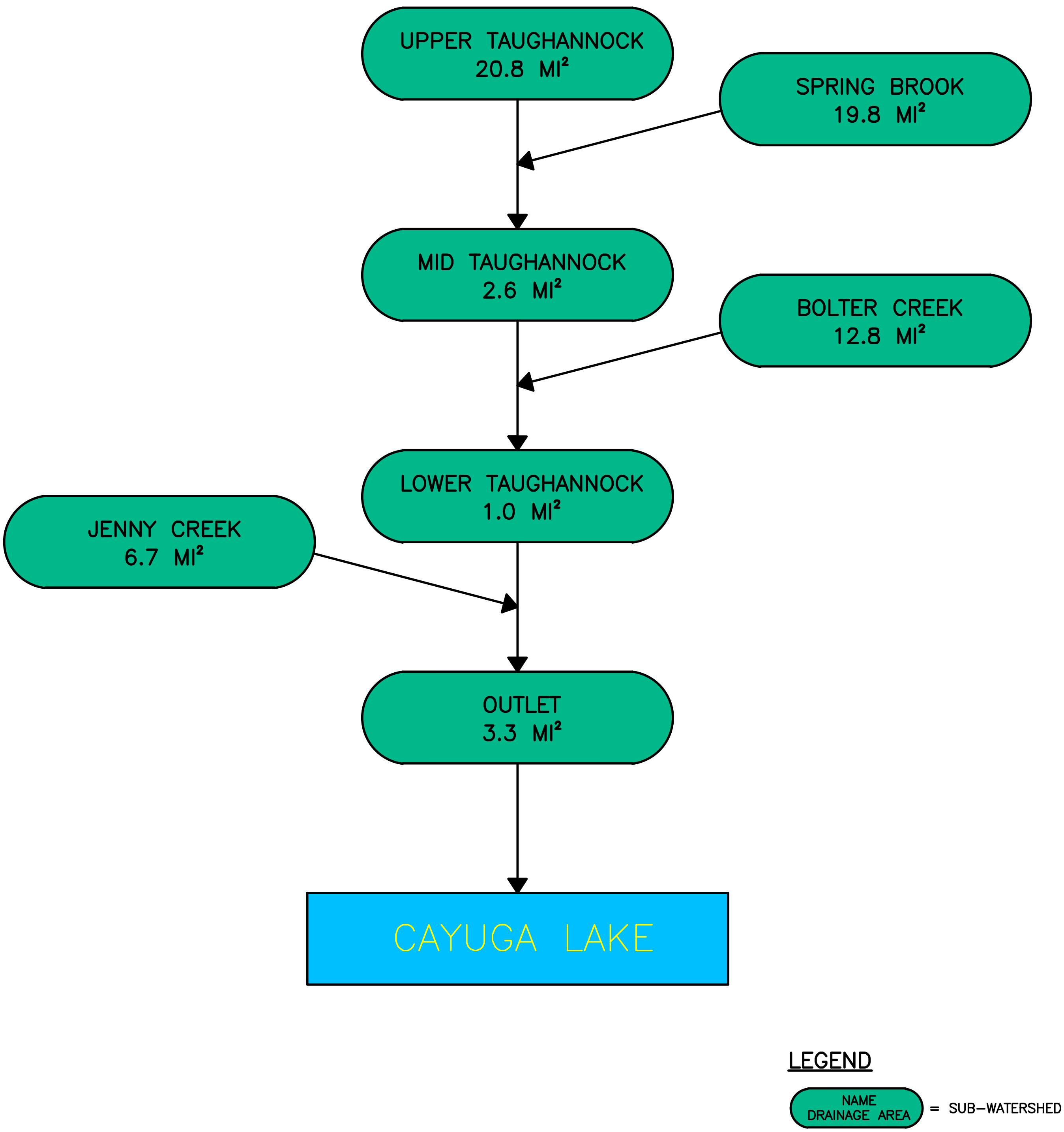
Taughannock Creek Flood Mitigation Needs Assessment

Map By: DRM
Date: March 2011
Scale: 1" = 10,000'

SHEET: Figure 4-2



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TAUGHANNOK CREEK FLOOD MITIGATION NEEDS ASSESSMENT

LOCATION: TOMPKINS COUNTY, NY

MMI #: 4395–01–3
DWG: H:\FIGURE 4–3.dwg
BY: DRM

SUB-WATERSHEDS STRUCTURE SCHEMATIC

DATE: MARCH 2011
SCALE: N.T.S.
SHEET: FIG 4-3

TABLE 4-3
Correlations of Subwatersheds to Stream Segments – Taughannock Creek

Segment Number	*Description of Geographic Limits*	*Incremental Contributing Subwatersheds*
1	Tompkins County border to Brook Road crossing	Upper Taughannock*
2	Brook Road crossing to Waterburg Road Bridge	Upper Taughannock*, Spring Brook, Middle Taughannock*
3	Waterburg Road Bridge to Podunk Road Bridge	Middle Taughannock*
4	Podunk Road Bridge to Route 96 Bridge	Middle Taughannock*, Bolter Creek, Lower Taughannock*
5	Route 96 Bridge to Taughannock Falls	Lower Taughannock*, Jenny Creek
6	Taughannock Falls to Route 89 Bridge	Outlet*
7	Route 89 Bridge to outlet at Cayuga Lake	Outlet*

*Indicates that only a portion of the watershed drains into the stream reach.

4.2 Terrain

The terrain in the Taughannock Creek watershed is quite diverse, ranging from broad flat expanses in the Schuyler County and the western portion of Tompkins County to markedly steep side slopes with a nonexistent floodplain around the Waterburg Bridge and downstream of the Podunk Road crossing. In some reaches, the creek has downcut through the former clay and silt lake deposits down to the underlying till and bedrock. The highest elevations in the watershed occur at around elevation 1,000 to 1,100 feet above mean sea level along the western and southern perimeters. Cayuga Lake is the low point in the watershed, with normal water surface at elevation 382 feet.

4.3 Existing Land Uses Within the Taughannock Creek Watershed

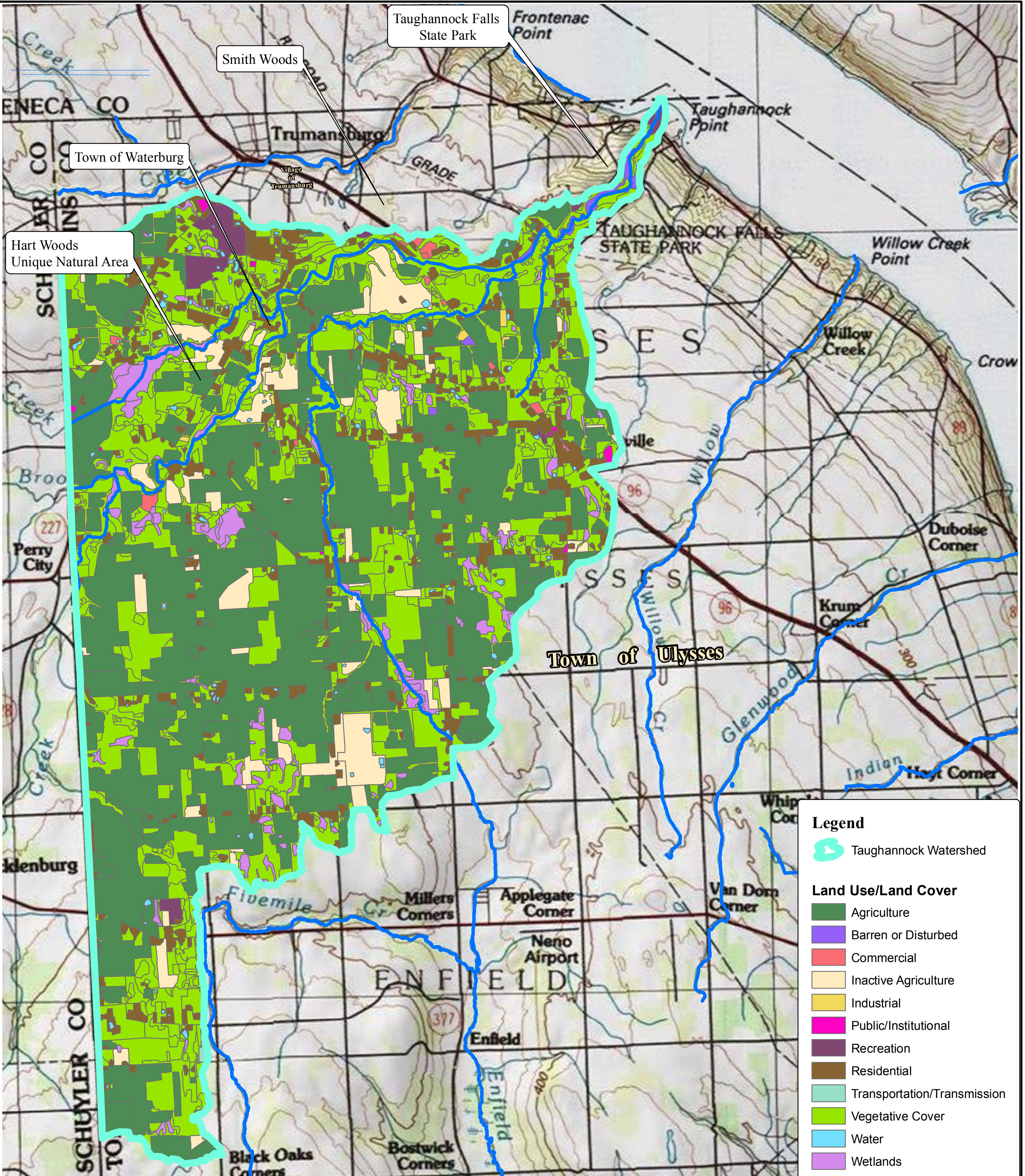
A great deal of information and insight can be gained from evaluating existing land uses in a watershed, comparing them with historic land uses and projecting possible future land use changes. The latter can become a complex issue when dealing with multiple forms of zoning (or lack thereof) within different governmental and jurisdictional territories. Ideally, future land use should be governed and guided by effective land use planning along with the adoption and adherence to complementary regulations.

In many instances, land use has evolved based upon topography, terrain, and proximity to water resources. For instance, existing and historic agricultural uses tend to occur in areas with fertile soil types, relatively flat land, and proximity to irrigation supplies. In steeply sloped areas, one would expect a different type of development, perhaps sporadic single homes set amidst large forested areas.

The history of land use in the Taughannock Creek area is typical of many other areas in the northeast United States. The first land use activities of European settlers consisted of clearing the forests for fields and pastures on small farms. This has several implications. First, agricultural land use increases runoff by removing the natural vegetation and its resulting forest litter and porous humus soils that help retain water. Further, surface water storage is reduced by repeated plowing and smoothing of the land. Farmers also built ditches to drain wetlands and dry out their fields. Tilling of agricultural fields also contributes to surface erosion.

Current land use in the Taughannock Creek watershed is largely agricultural (29% watershed land) and forest cover (22% of watershed land) including three areas of protected forestland and moderate amounts of residential uses. Overall, the density of development is quite low, and severe impacts caused by urbanization have not occurred in the watershed.

Figure 4-4 presents land use within the Taughannock Creek watershed based upon 2007 GIS mapping. Figure 4-5 is the Town of Ulysses Zoning Map showing land use intent for the Taughannock Creek watershed and surrounding areas as adopted on August 31, 2005.



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Taughannock Watershed 2007 Land Use/Land Cover

LOCATION: Tompkins County, NY

MMI#: 4395-01-3

MXD: H:\Figure 4-4.mxd

SOURCE: Cornell University CUGIR

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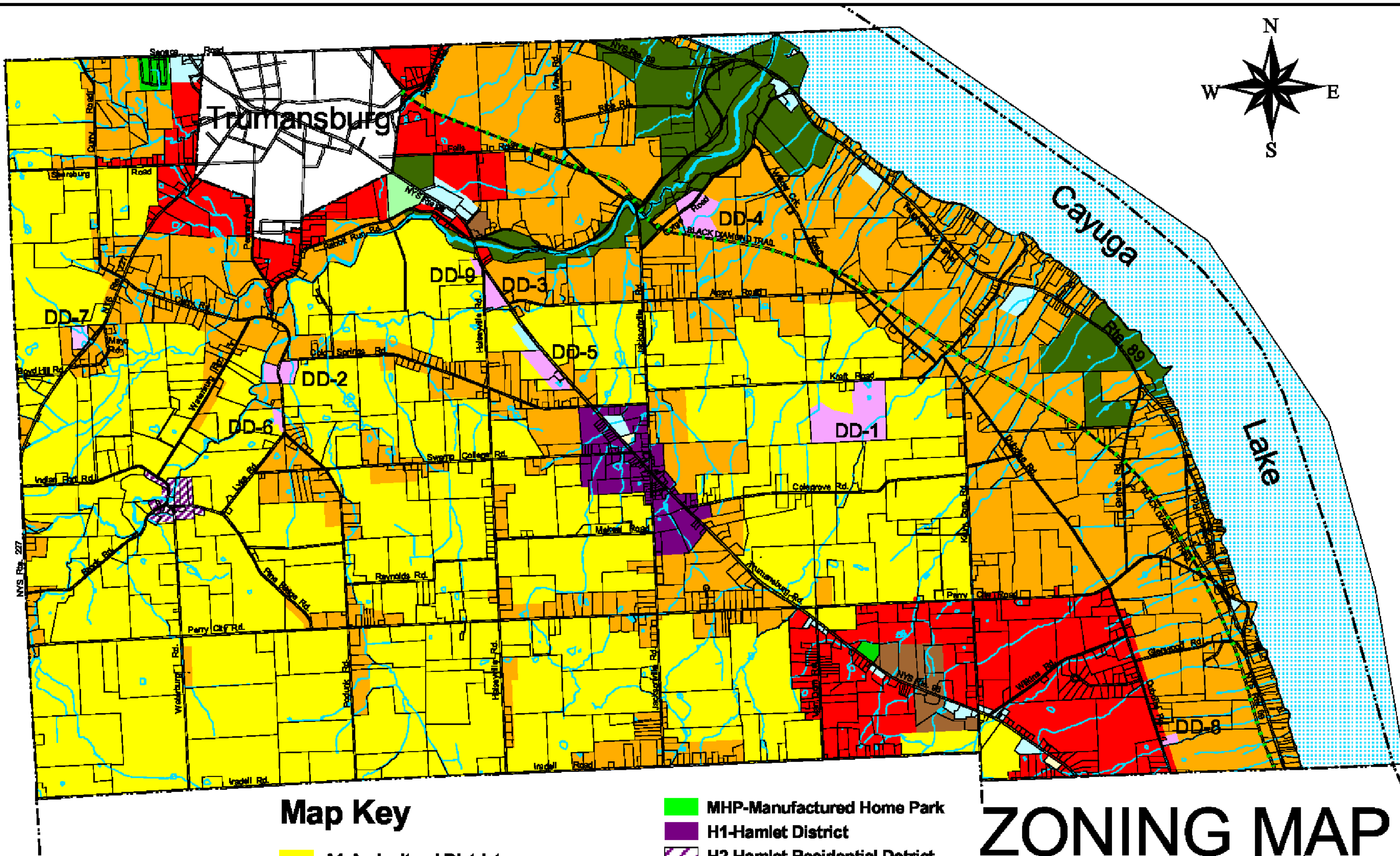
Taughannock Creek Flood Mitigation Needs Assessment

Map By: DRM

Date: March 2011

Scale: 1" = 5,500'

SHEET: Figure 4-4



Map Key

- A1-Agricultural District
- A2-Special Agricultural District
- R1-Rural Residence District
- R2-Moderate Density Residence District
- RM-Multiple Residence District
- MHP-Manufactured Home Park
- H1-Hamlet District
- H2-Hamlet Residential Dstrict
- B1-Business District
- IL-Light Industrial District
- PR-Park/Recreation District
- DD-Development District

0.5 0 0.5 1 1.5 2 Miles

SOURCE: Tax parcel, stream, road and municipal boundary data provided by Tompkins County ITS/GIS Division & Tompkins County Assessment Dept. The data produced by Tompkins County ITS/GIS Division and Tompkins County Assessment Department may not be reproduced without the express written consent of the originators. Tompkins County does not warrant the accuracy or the completeness of the data portrayed.

ZONING MAP

Town of Ulysses
Tompkins County
New York

Adopted August 31, 2005

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Zoning Map
Tompkins County 2005

Location: Tompkins County, NY

MMI#: 4395-01-3
MXD: H:\Figure 4-5.mxd
Source: Tompkins County ITS/GIS
Town of Ulysses

N

Taughannock Creek
Flood Mitigation
Needs Assessment

Map By: DRM
Date: March 2011
Scale: As Noted

Sheet: Figure 4-5

Urban Areas – The only significant urban area in the watershed is the southern portion of Trumansburg, located in the Bolter Creek subwatershed. This basin supports residential, commercial, and light industrial development. Urban areas have a high impervious cover, catch basins with storm drains, and high surface runoff rates.

Moderate Development – Portions of the Jenny Creek and Bolter Creek subwatersheds can be described as moderately developed with low density residential areas (referred to as Rural Residence or Hamlet Districts on the Zoning Map).

Rural – Large areas of the remainder of the watershed are dominated by open cornfield, pasture, and cropland (Agricultural Districts on the Zoning Map). During the October 2010 inspection by Milone & MacBroom, Inc., many tilled fields were observed, although few areas of surface erosion, rills, or gullies were evident. Extensive forest (mostly second growth hardwoods in the Finger Lakes National Forest) exists around the headwaters of Taughannock Creek. The overall pattern is stable forestland on the steeper slopes around the upper perimeter of the Taughannock Creek watershed, with agricultural land in the valley bottoms and flatter uplands such as in around the hamlet of Podunk.

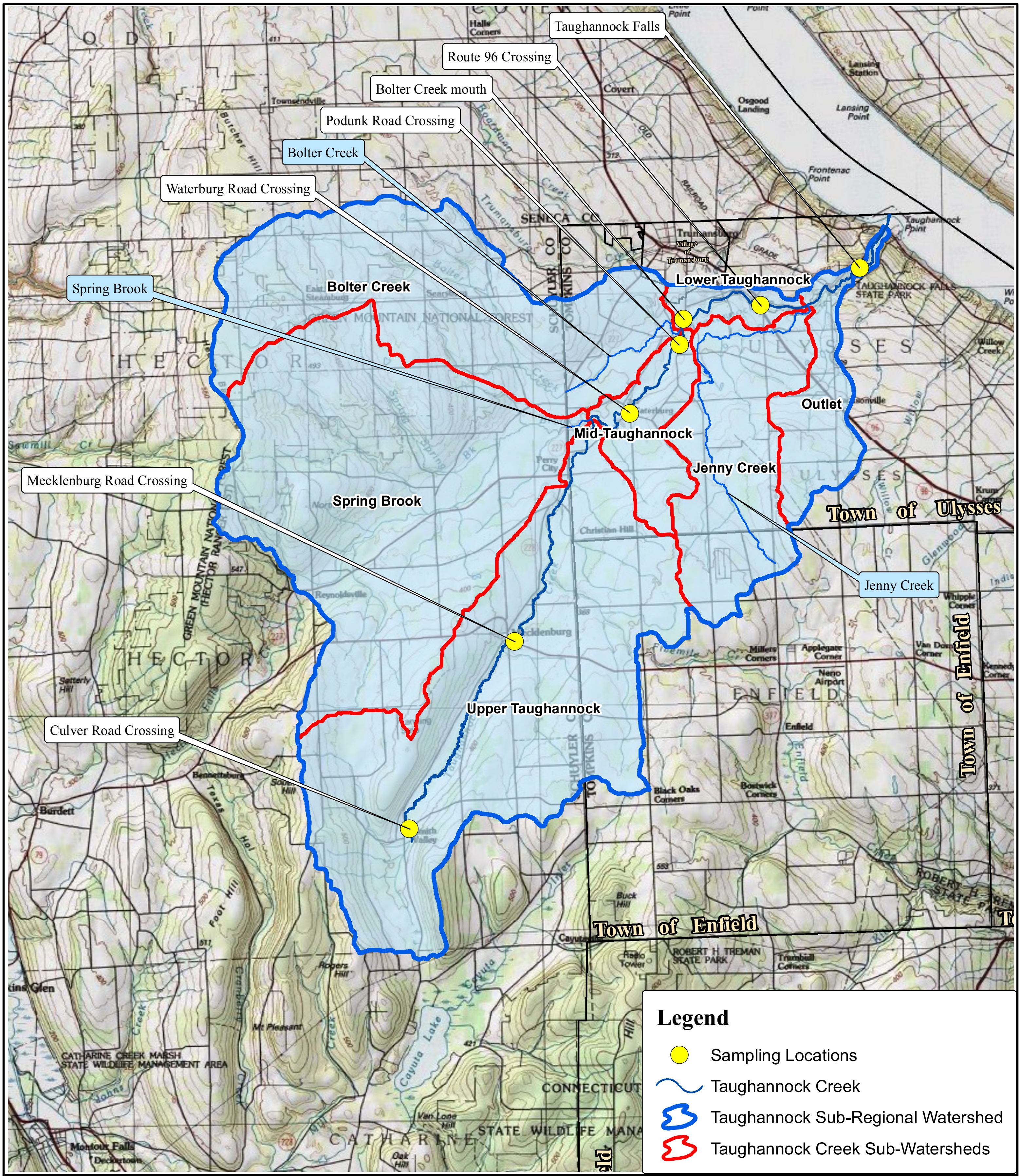
In summary, the Taughannock Creek watershed's hydrologic regime is reflective of rural land uses with limited impervious cover and constructed drainage systems. The landscape has been previously cleared and is currently returning to hardwood forest as farm land is abandoned. The watershed has many active fields that are tilled regularly.

4.4 Water Quality

The New York State Department of Environmental Conservation completed the Oswego River/Finger Lakes Basin Waterbody Inventory/Priority Waterbodies List (WI/WPL Report) Report in February of 2008. The middle portion of Cayuga Lake was evaluated as threatened due to activities in the associated watersheds, and the southern basin of Cayuga Lake was evaluated as impaired due to algal growth, high phosphorous concentrations, pathogens and high silt and sediment concentrations. The threats to water quality identified in the middle segment of the lake and high concentrations of the pollutants in the southern portion of the lake could be linked to nonpoint source pollution due to land use in the Taughannock Creek watershed, highlighting the necessity of a watershed approach to restoration. The lower portion of Taughannock Creek and its tributaries are listed as threatened in the WI/WPL Report due to impacts of high concentrations of phosphorous on aquatic life in the river. As there are no permitted wastewater discharges to Taughannock Creek, it is suspected that the phosphorous is from nonpoint source pollution due to agricultural land use in the watershed.

The nonprofit Community Science Institute (CSI) organizes and enables volunteers to collect water samples for analysis at a state-certified testing laboratory in an effort to collect baseline data for six rivers contributing to Cayuga Lake, including Taughannock Creek. The CSI monitoring locations, shown on Figure 4-6, are at Culver Road, in Mecklenburg, the Waterburg Road Bridge, mouth of Bolter Creek, at the Podunk Road crossing, at the Route 96 crossing, and at Route 89 downstream of Taughannock Falls.

The CSI monitoring locations have been sampled regularly since 2006. Figure 4-7 shows the average base flow and stormwater turbidity values for the seven sampling locations for the period of record. The turbidity in the base flow of Taughannock Creek increases between the Mecklenburg location and the Waterburg Road Bridge, indicating the land management practices or natural geologic conditions in the Spring Brook subwatershed likely contributes significant amounts of fine sediments and silt to Taughannock Creek. This is consistent with the visibly higher turbidity in Spring Brook and in Taughannock Creek downstream of the confluence with Spring Brook observed during the October 2010 watershed inspection. The peaks in the stormwater turbidity values could be associated with additional sediment load provided by top of bank conditions during high flow events or increased entrainment of fine sediments at bank erosion sites due to high water levels. A detailed inspection of the reached upstream of the sample locations during a high flow event would be necessary to account for the stormwater sampling results.



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Taughannock Creek Sub-Watersheds

LOCATION: **Tompkins County, NY**

MMI#: 4395-01-3
MXD: H:\Figure 4-6.mxd
SOURCE: Cornell University CUGIR, CSI 2009

N

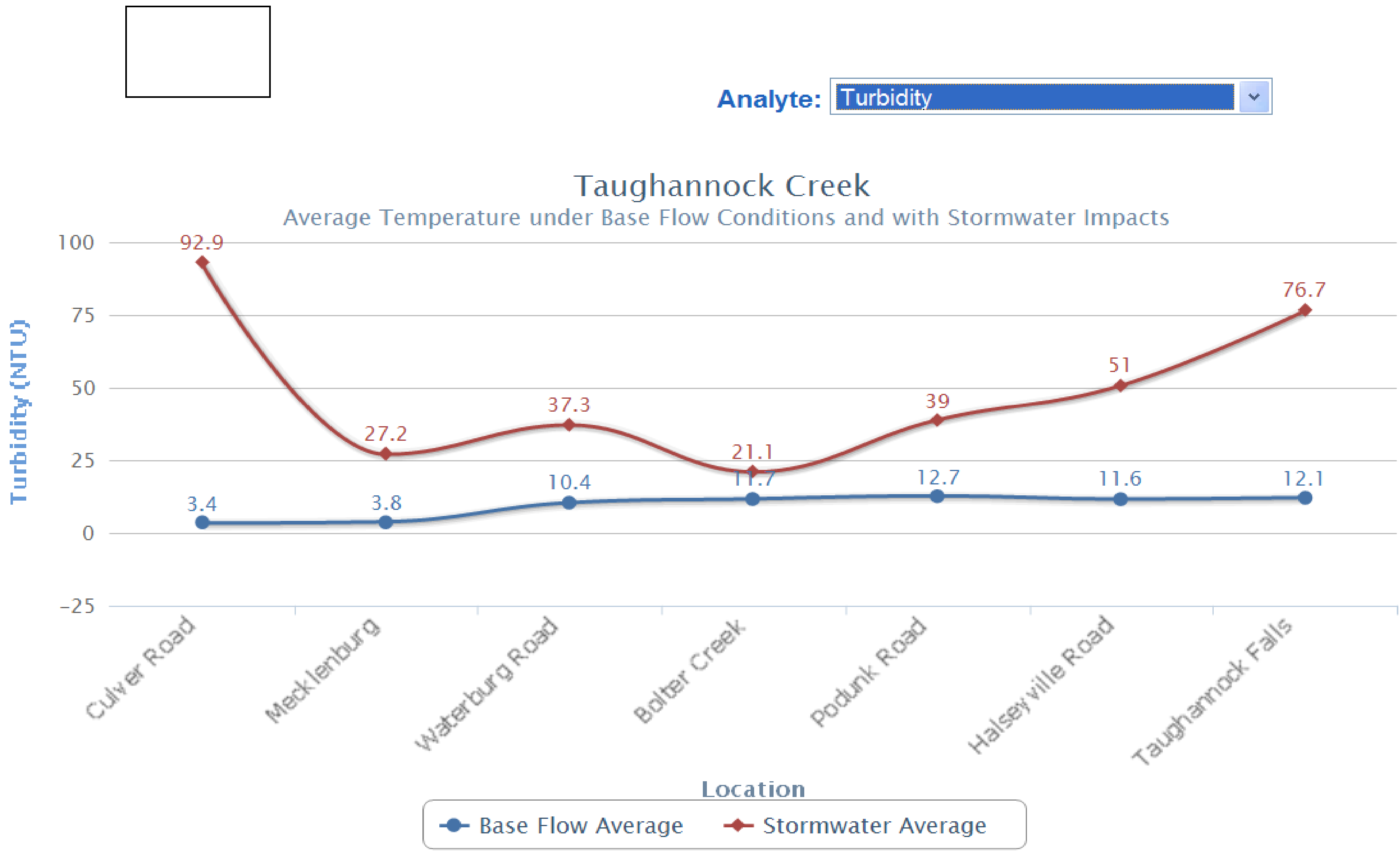
Taughannock Creek Flood Mitigation Needs Assessment

Map By: DRM
Date: March 2011
Scale: 1" = 10,000'

SHEET: **Figure 4-6**

TAUGHANNOCK CREEK

FIGURE 4-7



Developed by: Abner X. Figueroa

4.5 A Review of Past Studies on Taughannock Creek

Although the watersheds contributing to Cayuga Lake have been the subject of numerous study efforts, including academic studies affiliated with Cornell University, no studies focusing specifically on the Taughannock Creek watershed are readily available.

One study of the Finger Lakes region (Nagle and Fahey) analyzed the proportional contributions of stream bank and surface sources to define sediment loads in streams of the southern Cayuga Lake Basin and other nearby watersheds. The study notes that many stretches of the stream below Brooktondale in the Six Mile Creek watershed are characterized by slumping hillslopes and large eroding banks above the channel, similar to those observed on Taughannock Creek downstream from its confluence with Bolter Creek. According to Nagle and Fahey, even forested slopes with minimal human impact exhibit this instability. In fact, extensive radionuclide testing indicates that the sediment load from bank erosion along Six Mile Creek is 82% of the total load, whereas surface erosion load accounts for only 18%.

Nagle and Fahey report that sediment loads in streams of the southern Cayuga watershed are not unusually high compared to the rest of the Northeast. However, high levels of bank erosion are occurring in response to channel incision, valley filling, and changes in stream channel morphology.

The Taughannock Creek channel is laterally unstable in some areas, particularly downstream of Bolter Creek near Podunk where large steep areas of bank failure were observed along the South Street Extension and near the Durling Farm at the end of Durling Road. This instability is coupled with channel degradation or down-cutting by several feet in some areas, which is resulting in an incised channel.

The Cayuga Lake Watershed Intermunicipal Organization completed the Cayuga Lake Watershed Restoration and Protection Plan (WRPP) in July, 2001. The WRPP project included analyses of the status and restoration needs of the Taughannock Creek watershed as a drainage area contributing to Cayuga Lake. These analyses mostly related to understanding, mitigating, and preventing high sediment concentrations in Cayuga Lake. They include (1) streambank erosion and encroachment of riparian corridors; (2) analysis of the subwatershed area with the highest potential for nonpoint source pollution based on land use and hydrologic characteristics; (3) estimated annual total solids loss from land in the watershed via runoff; (4) estimated annual sediment loss from roadways and road drainage systems and restoration priority areas (5) aquatic habitat health; and (6) return frequency of flood events as in indicator of the effect of impervious cover. While details of these analyses can be found in the WRPP, Table 4-4 summarizes the findings for the Taughannock Creek watershed.

TABLE 4-4
Summary of Findings Related to the Taughannock Creek Watershed
Cayuga Lake Watershed Restoration and Protection Plan

Description of Analysis	Finding for the Taughannock Creek Watershed*
Percent of 150-foot Riparian Zone with Developed Land Use	54% of buffer is developed. Of that, 50% is agricultural, 4% is residential, ranked at "Medium" on encroachment scale of high, medium, or low
Potential for Nonpoint Source Pollution (Based on Annual Loading per Unit Area)	Moderate; 8% of total suspended solids enter creek via runoff per year
Estimated Annual Sediment Loss from Roadways and Restoration Priority Areas	Moderate local impact, moderate lake impact: 100-250 tons sediment contributed from roadways per year (>2 tons sediment/mile/year)
Biological Characteristics	Important spawning area for smelt in early spring, recommended macroinvertebrate sampling due to indications that population is stressed
Severe Roadbank Erosion Segments	Schuyler County: Bergen Road at Newtown Road: exposed collapsing roots and banks, washed out gravel

*Refer to the Cayuga Lake Watershed Restoration and Protection Plan for additional information.

The WRPP assessment concluded that relative to other watersheds contributing to Cayuga Lake Taughannock Creek has a moderate contribution of suspended sediments due to land use practices and eroding bank segments. However, several eroding bank segments that appeared to be contributing fine sediments were observed in the watershed during MMI's field investigations. A detailed baseline inventory and monitoring strategy for these sites is recommended to support a watershed-scale restoration strategy. Recommendations for restoration alternatives for many of these sites are provided in Sections 5.0 and 6.0 of this report.

Several planning documents and regulations of the Tompkins County Planning Department and the Town of Ulysses have sections that are relevant to management of the Taughannock Creek watershed. The Tompkins County Conservation Plan identifies Taughannock Creek as a focus area for conservation in the county due to outdoor recreational value provided by the Taughannock Falls State Park, scenic views associated with Taughannock Falls, and critical habitat and biodiversity value particularly in the state park, Smith Woods (a privately owned preserve near Trumansburg), and Hart Woods Unique Natural Area (along the Bolter Creek tributary).

The Town of Ulysses' Comprehensive Plan of September 2009 includes a discussion of the watersheds and waterbodies within the town including Taughannock Creek and its associated wetlands and floodplains and recognizes these as important environmental resources. The Ulysses Zoning Law includes standards for vegetated buffer areas (Section 17.6), with a minimum 50-foot buffer on each side of a stream. Finally, the Town of Ulysses Local Law No. 03-2007 establishes minimum stormwater management strategies and guidelines to mitigate the effects of erosion and sedimentation from development on the Taughannock Creek watershed.

4.6 Hydrology of Taughannock Creek

Surface water hydrology is the quantitative study of the presence, form, and movement of water in and through a drainage basin. The primary independent variables affecting runoff are precipitation, watershed area, surficial geology (soil characteristics), and slope. Dependent variables that change over short and intermediate time spans include vegetative cover, land use, wetland and floodplain water storage, reservoir size and volume, water diversion for irrigation or municipal use, and beaver dams.

For the purpose of studying bank erosion, sediment transport, and flooding, the primary interest is in peak stream flows due to intense precipitation, sometimes in combination with snow melt. It is the peak flood flows that shape and form the river channels, scour the banks, and carry the majority of sediment. Subsequent storm runoff events, perhaps up to the mean annual flood, also convey sediment and tend to dominate the formation of the inner channel dimensions, bars, pools, and riffles. Monthly mean stream flow rates are a good indicator of seasonal flow patterns that affect water supply, habitat, and recreation.

A watershed's stream flow rate can be obtained or estimated using several different techniques including direct measurement, use of surrogate gauge data in nearby watersheds, physical deterministic computer models, statistical or stochastic analysis, or empirical techniques.

Within Taughannock Creek, use of surrogate gauge data is possible via the U.S. Geological Survey (USGS) stream flow gauging station located on Salmon Creek at Ludlowville, New York (USGS Gauge # 04234018). The Salmon Creek watershed, although slightly larger than the Taughannock Creek watershed (81.7 square miles versus 67 square miles), has very similar land use patterns indicating comparable percentages of impervious cover versus vegetated cover, as well as topography and surficial geologic conditions, factors that would impact hydrologic data in the river.

Gauge 04234018 was only operated full time from October 1964 to September 1968, most of which was a drought period. The mean monthly flows are reported in Table 4-5.

TABLE 4-5
Historic Mean Monthly Flows – Salmon Creek
(1964 – 1968)

Month	Mean Monthly Flow
January	65.8 cfs
February	129.0 cfs
March	217.0 cfs
April	136.0 cfs
May	95.1 cfs
June	50.3 cfs
July	23.9 cfs
August	13.8 cfs
September	16.0 cfs
October	23.2 cfs
November	72.0 cfs
December	78.8 cfs

The USGS also measured the annual peak flood flow rates for the same period as well as recording the flood flow from the 1935 event. The peak flows are summarized in Table 4-6.

TABLE 4-6
Peak Flows – Salmon Creek

Year	Peak Flow
1935	1,320 cfs
1965	536 cfs
1966	1,940 cfs
1967	1,170 cfs
1968	1,870 cfs
1969	2,000 cfs
1971	1,100 cfs
1972	4,160 cfs

The Fall Creek watershed, which drains from the south into the southern end of Cayuga Lake through the city of Ithaca, has a long-term USGS gauge, USGS #04234000 (126-square mile drainage area) with data from 1927 to the present that helps to define trends and patterns in the region. The most notable pattern is that there is no distinct change in peak runoff rates over the period of record. Unusual peak flows occurred in 1935 (15,500 cfs), 1982 (11,900 cfs), and 1996 (9,450 cfs). All other peaks were uniformly distributed and below 6,000 cfs. The plot of the peak annual flow is quite consistent.

The Cayuga Lake Watershed Restoration and Protection Plan (detailed in Section 4.5 above) reported the return frequency of floods in Cayuga Lake tributaries calculated using the Log Pearson Type 3 distribution from historical annual maximum flows recorded in Cayuga Inlet and Fall Creek. The calculated flows for Taughannock Creek are reported in Table 4-7.

TABLE 4-7
Flows Reported in the Cayuga Lake Watershed Restoration and Protection Plan for Taughannock Creek

Frequency Flood	Flow
1- year	306 cfs
2- year	1,062 cfs
5-year	1,166 cfs
10-year	2,108 cfs
25-year	2,709 cfs
100-year	3,684 cfs

Low stream flow is primarily a function of precipitation patterns, land use and runoff characteristics, soil types, and geology. Nearby Salmon Creek has a mean August flow of 0.17 cubic feet per second per square mile, which is typical for the Northeast. However, the minimum of the daily flow rates range from 2.0 to 8.0 cfs, which are inadequate for larger fish in the broad river typical in the region.

Beyond instream flow rates, aquatic habitat and fish are very sensitive to the corresponding stream channel depth and cross sectional area. Deep pools are necessary for fish survival during low flows. The channel structure in Taughannock Creek features some reaches with distinct concentration of flow. These river segments with defined thalwegs (i.e., the deepest portion of the channel) are conducive to aquatic habitat during low flows.

5.0 WATERSHED NEEDS ASSESSMENT – TAUGHANNOCK CREEK

5.1 Overview of Field Investigations

On October 25, 26, and 27, 2010, MMI project team members conducted a two-day field investigation of Taughannock Creek and its contributing watershed. All seven subwatersheds were inspected to visually assess the properties that could influence downstream surface runoff and sediment loads. In addition, topographic maps, aerial photographs, and geographic information system (GIS) land use/cover data were reviewed prior to the initiation of field investigations. The investigations targeted areas of previously identified problems as well as representative stream sections, natural and man-made control points (natural falls, reaches flowing over bedrock, bridges), and areas of extensive lateral migration.

5.2 Stream Profile and Control Points

Appended Figure I is a profile and plan view of the Taughannock Creek from its inlet at Cayuga Lake to the headwaters in Hector. The center line of the channel is highlighted on the map as a black solid line, and the distances along the channel are stationed to aid descriptions – Station 10+00 (1,000 feet) is placed at the edge of the lake. The main channel starting at the Tompkins County border is moderately entrenched, but not incised (meaning the surrounding river valley has steep banks and a narrow floor with relatively little floodplain but the river has the ability to overtop banks and flood the floodplain during high flow events), with some active lateral migration indicated by formation of point bars in the inside of bends and scour in the low banks at the outside of bends as it meanders across the plateau with well-connected floodplains. This channel pattern changes with the first bedrock control point extending 1,000 feet upstream and 500 feet downstream of the Waterburg Road Bridge from station 365+00 to station 350+00.

Downstream of the exposed shale bedrock, the channel is frequently semiconfined with a high bluff on one bank and a low bank on the opposite bank interrupted by fully incised bedrock channels as the river begins to erode into the plateau. Near station 230+00, approximately 3,000 feet downstream from the confluence with Bolter Creek, a bedrock gorge and cascade composed of layered shale bedrock was observed. Downstream of this location, the main channel is confined laterally and longitudinally by bedrock. Slightly upstream of the Route 96 Bridge near station 170+00, there is a distinct falls reach composed of exposed limestone. Jenny Creek converges with the main channel at another bedrock cascade near station 127+00. The elevation of the main channel drops 70 feet at "Little Falls" within Taughannock Falls State Park near station100+00 and almost 215 feet at Taughannock Falls near station 76+00. Downstream of Taughannock Falls, the main channel is confined by a gorge and limestone bed. Cayuga Lake controls the most downstream elevation, at a normal water surface elevation of 382 feet.

5.3 Slope and Sinuosity

The bed slope and sinuosity of Taughannock Creek were estimated for various segments based upon GIS and USGS mapping as well as aerial photography. For each reach, the valley length, stream length, and change in elevation were used to calculate slope and sinuosity. These data are presented in Table 5-1.

TABLE 5-1
Segment Data – Taughannock Creek

Segment	*Sinuosity*	*Slope*	*Comment*
1	1.27	0.50%	Alluvial, meandering channel
2	1.89	0.37%	Alluvial, meandering channel
3	1.18	0.49%	Actively incising
4	1.50	0.73%	Actively incising
5	1.24	1.99%	Few bedrock cascades
6	1.13	5.18%	Bedrock gorge, Taughannock Falls
7	1.02	0.16%	Incised, stable

A river segment slope (i.e., change in vertical grade divided by horizontal length) is a good indicator of its velocity and sediment transport capacity, while the sinuosity is an indicator of the degree of channel meandering and maturity. Briefly, the normal trend is for river segments that are "geologically" young or actively incising to be fairly steep and straight (low sinuosity), while "mature" channels that have worn down the landscape toward an equilibrium condition have low gradients and a higher sinuosity with a curvilinear meandering pattern and fine grain sediments. The implication of these metrics on the river segment form and process will be further discussed in the individual segment description in Section 5.4.

Most rivers have steep upstream headwaters, with declining slope as they proceed downstream. Taughannock Creek has the opposite pattern, with low gradient headwaters and steeper downstream reaches that are headcutting.

5.4 Needs Assessment by Stream Segment

5.4.1 Segment #1 – Tompkins County Border to Brook Road Crossing

This river segment includes a half-mile of Taughannock Creek, extending from the border of Tompkins County at Route 227 and the Perry City Road Crossing (station 475+50) to the Brook Road Crossing (station 442+50). The slope of the channel in this segment is 0.50%, and the sinuosity is 1.27. The Upper Taughannock subwatershed is the only watershed contributing flow to the main channel in this segment.

This segment begins with a 200-foot bank section with no riparian buffer as the bordering agricultural field is mowed all the way to the right bank. A corrugated metal culvert conveying flow from the Perry City Road and the field were observed on the right bank in this location. It appears the river is largely alluvial in the segment, with a vegetated cobble and gravel point bar forming on the left bank and scour on the right bank, indicating lateral migration of the channel. This pattern repeats on alternating banks for the remainder of the river segment with occasional woody debris jams leading to gravel depositional bars (Photo 1).

The bankfull width of this segment is approximately 48 feet and the bankfull depth is approximately four feet. Approximately 1,000 feet downstream of the Perry City Bridge, the landowner is managing the main channel and floodplain on both banks for wildlife habitat as bird boxes and minimal clearing were observed accompanying appropriate signage. The channel features a pool-riffle sequence with at least a 100-foot buffer comprised of woody vegetation until a sparse woody buffer was observed on both banks leading up to the Brooks Road Crossing. The Brook Road Bridge has a 45-foot wide normal span with eight-foot high abutments.

Photo 1: Apex of a meander bend near station 455+00. Note scour on the left bank and point bar formation on the right bank.

This stream segment is an alluvial channel exhibiting some signs of lateral migration, consistent with the relatively low slope and high sinuosity in their river segment. Eroding segments of the low banks are typical during this migration process. In addition, there are well-connected floodplains on both banks throughout this segment that would most likely be inundated during high flow events. Maintenance of a healthy riparian buffer can mitigate damage to the banks and decrease the load of fine sediments to the water by increasing bank stability with a healthy root mass and slowing the flow of water during flood events. This segment should be further evaluated for active restoration of the riparian buffer, particularly the right bank directly downstream of the Perry City Road crossing (before the posted wildlife management area).

5.4.2 Segment #2 – Brook Road Crossing to Waterburg Road Bridge

Segment #2 includes 1.65 miles of Taughannock Creek, extending from the Brook Road Crossing (station 442+50) to the Waterburg Road Bridge (station 355+00). The slope of the channel in this segment is 0.37%, and the sinuosity is 1.89. A portion of the Upper Taughannock and Middle Taughannock subwatersheds and the entire Spring Brook subwatershed contribute to flow in the main channel in this segment.

Downstream of the Brook Road Crossing, the main channel flows northeast for over a mile to the confluence of Spring Brook. This section of the river is very similar to Segment #1, with a relatively low slope and high sinuosity indicating a meandering channel featuring a pool-riffle bed form. A minimum of a 100-foot riparian buffer on both banks comprised of woody vegetation was observed for the majority of this segment.

Spring Brook joins the main channel near station 410+00. During the river inspection in October 2010, a visual increase in turbidity was observed at this location. Inspection of the upstream reaches of Spring Brook revealed significantly higher turbidity in this tributary due to bank scour segments exposing clay (particularly the reach of Spring Brook near the county line). The fine sediments in the banks are entrained via hydraulic erosion and conveyed via Spring Brook to the main channel. Increased turbidity in the main channel downstream of the confluence with Spring Brook is also evidenced in the water quality samples collected and analyzed by the Community Science Institute (reported in Section 4.4) and shown in Figure 4-6. It is likely that the additional turbidity in Spring Brook is caused both by natural conditions (geologic composition of the banks and stream bed) as well as anthropogenic conditions (land use in the Spring Brook subwatershed). Photo 2 shows the turbid conditions at an eroding bank segment in Spring Brook.

Downstream of the Spring Brook confluence, the main channel reaches the apex of a large meander bend and flows southeast for a half-mile to Brook Road, with a narrow riparian buffer for 750 feet. Near station 385+00, an automobile junk yard is located on the right bank followed by the former Brook Road relocation. The Brook Road relocation project was completed to avoid river erosion of the road at the bend in the river. The river bank in this area is now protected with riprap at the toe and planted banks. The bankfull width in this segment is 62 feet, wider than Segment #1 due to the addition of flow conveyed by Spring Brook. The main channel continues to alternate bank cutting and point bar formation, with larger sediment sizes (including some boulders). Beginning at station 372+50, there is minimal riparian buffer at both banks. The main channel becomes increasingly incised with high banks and no floodplain connectivity until the first exposed bedrock, observed near station 350+00. The bedrock is largely composed of shale as evidenced by the foliations and rectilinear fracturing pattern (Photo 3). This bedrock constrains the channel on both the bed and banks from this location, underneath the Waterburg Bridge, to station 350+00.

Photo 2: Exposed clay in eroding bank segment and high turbidity conditions in Spring Brook near the Tompkins County line.

Photo 3: Exposed foliated shale bedrock in left bank and channel bed upstream of Waterburg Road Bridge.

Similar to conditions in Segment #1, the lateral migration observed in the upper reaches of Segment #2 can lead to increased turbidity and entrained fines in creek water, which can adversely affect the aquatic ecosystem in the creek as well as in Cayuga Lake downstream. Maintenance of a healthy riparian buffer can mitigate damage to the banks and the associated addition of fine sediments to the water by increasing bank stability with a healthy root mass and slowing the flow of water during flood events.

Segment #2 should be further evaluated for active restoration of the riparian buffer, particularly downstream of station 372+50. Additionally, the agricultural land use practices in the Spring Brook watershed should be further investigated to establish best management practices that can reduce sediment runoff into Spring Brook. Finally, the automobile staging area in the right floodplain on Brook Road could be a point source of pollution not only due to runoff during precipitation events but also conveyed to the main channel by flood waters that overtop the banks during high flow events in this location and should be investigated for responsible runoff management.

5.4.3 Segment #3 – Waterburg Road Bridge to Podunk Road Bridge

Segment #3 includes 1.55 miles of Taughannock Creek, extending from the Waterburg Road Bridge (station 355+00) to the Podunk Road Bridge (station 273+00). The slope of the channel in this segment is 0.49%, and the sinuosity is 1.18. A portion of the Middle Taughannock subwatershed contributes to flow in the main channel of this segment.

Segment #3 features two channel types. The reaches that are constrained laterally and longitudinally by exposed bedrock are entrenched and deeply incised, with some meander but no well-developed floodplains available for water storage. The banks in these reaches were generally observed to be near vertical. The typical bankfull width for these reaches is approximately 60 feet. The second channel type in this river segment is a slightly entrenched meandering channel with a well-developed and well-connected floodplain, at least on one bank (in some areas these reaches were semiconfined with a high bluff blocking floodplain connectivity on one bank). The streambed is composed of cobble and gravel with a riffle-pool sequence. The typical bankfull width for these reaches is approximately 80 feet.

In some locations, the channel has evolved to contain a meandering alluvial channel similar to the second type described above within an entrenched and constrained bedrock channel, as was observed between station 330+00 and station 320+00. For example, along approximately 1,000 feet upstream of the Podunk Road Bridge, a side channel was observed that supports two years of emergent growth on the stream bank. The channel was most likely formed as a flood chute through a floodplain that had formed within a bedrock-constrained channel. An eroding bank segment was also observed on the right bank in this location, exposing lacustrine clay deposits (Photo 4). As the fine clay particles are entrained via hydraulic erosion, they increase turbidity in the main channel.

The village of Trumansburg has operated a small landfill within this segment in the Bolter Creek subwatershed. It is located near the intersection of Pennsylvania Avenue and South Street Extension on the north bank of Bolter Creek between Curry Road and South Street Extension. Currently, the village only uses the site for dumping leaves and tree cuttings, though historically it has been the target of community concern because Bolter Creek had been eroding the toe of the landfill slope. This area should be further investigated for monitoring and remediation as appropriate.

Photo 4: Eroding bank segment in a high bluff.

It is recommended that this river segment be further inspected for eroding banks that could be contributing fine sediments in the main channel, like the one pictured in Photo 4 above. These types of eroding banks can often be restored through natural bank stabilization techniques (a healthy riparian buffer, for example), or with instream techniques such as channel relocation or strategic placement of deflecting structures along the eroding bank.

5.4.4 Segment #4 – Podunk Road Bridge to Route 96 Bridge

Segment #4 includes two miles of Taughannock Creek, extending from the Podunk Road Bridge (station 273+00) to the Route 96 Bridge (station 167+50). The slope of the channel in this segment is 0.73%, and the sinuosity is 1.49. Portions of the Middle

Taughannock and Lower Taughannock subwatersheds as well as the entire Bolter Creek subwatershed contribute to flow in the main channel in this river segment.

This two-mile long river segment is of special interest because it begins to exhibit the continued incision of the channel into the uplands along with a new factor, valley widening. This contrasts with upstream reaches that featured channel incision only.

The Podunk Road Bridge is located at a sharp curve in the road over Taughannock Creek. The bridge has a single clear span of 56 feet with 10 feet of underclearance. It has vertical steel sheeting abutments and wingwalls in good condition, supporting five steel cor-ten beams and an open grate steel deck. The waterway under the bridge is slightly incised with rock riprap on the banks and a sandy grain deposits covering a large cobble creek bed. Channel banks in this area are composed of brown firm silt over gray clay near the waterline. The silt and clay both contribute to high turbidity, and further incision will release clay and create additional turbidity.

Passing downstream of Podunk Road, the channel bends to the left at station 271+00, with a low stable left bank along an active cattle pasture and a high wooded bank on the right. The latter is actually the beginning of a valley wall. Proceeding downstream at the rear of the pasture, the channel has classic alternate bars indicating that it now has bedload transport. The field inspection found a gravel bed with a few cobbles and rare boulders along this stable straight reach to the confluence of Bolter Creek. The channel is a Rosgen type F3/4 with a wetted width of 45 feet. Bolter Creek is a mid-size tributary with a large gravel bedload. A bar formed by deposition of this bedload spans Taughannock Creek and creates a deep pool in the creek that could not be crossed on foot.

River station 255+00 is roughly located behind the intersection of South Street Extension and Pennsylvania Avenue. The left and right riverbanks both have flat terraces perched above the river as the valley begins to widen, while South Street Extension remains at a higher plain on the slightly rolling piedmont-like landscape.

A sharp river bend to the right begins at station ±253 as the channel has a large low point bar on the right and is in contact with the left valley wall forming an escarpment (bluff). South Street Extension was previously relocated from the top of the escarpment due to slope failures that threatened the roadway. This feature is a classic case of valley widening and increasing channel sinuosity. The increased channel incision reduces the bed grade, and bedload sediment input from Bolter Creek supplies coarse material that enables more bar formation and sinuosity.

The South Street Extension escarpment (Photo 5) includes several geomorphic processes, including lateral channel migration into the toe of slope, toe erosion, and evidence of mass slope failure. The nearly barren face of the slope failure was measured at 58 feet high by 320 feet long, at a mean gradient of 122% (50 degrees). The upper 15 feet of the escarpment is near vertical, undercutting the root depth of mature hardwood, which periodically fail and fall. Ground water discharges were observed 10 to 15 feet below the top of ground. The soil consists of a clay-rich glacial till with moderate numbers of small stones but few cobbles. Neighborhood residents report that local water supply wells penetrated 120 feet of nearly impermeable clay soils. As a result, when slides occur, they do not provide enough coarse material to form a stable talus slope or to stop fluvial toe erosion. Only three- to 12-inch rocks were found at the toe.

Photo 5: Facing upstream at the downstream end of the South Street Extension bank failure site.

The escarpment angle exceeds the assumed gradient of glacial till soils (35 to 45 degrees) and is weakened by ground water; seeps were observed only three feet below the crown. An active storm drain also discharges onto the face at its upstream end. Further toe erosion and mass failures can be expected. See Section 6.0 for specific recommendations.

In between our October 2010 and March 2011 inspections, the top of bank near South Street Extension had another slope failure and receded about eight feet, and a fresh riverbank cut near the edge of water was also evident.

The channel at the toe of the bank failure area is semiconfined Rosgen type C4 and has a wooded floodplain on the right side, followed by a higher terrace used for agriculture and accessible from Durling Road. The channel had a measured bankfull width of 69 feet, bankfull depth of four feet, and active wetted width of just 39 feet. It is migrating left into the slope failure. A meander chute subchannel on the inside of the bend opposite the big slope failure suggests where the channel used to be and where it should be returned.

Downstream of South Street Extension, the lower left bank was reinforced by a private landowner in the late 1990s with rock-filled wire basket gabions.

No longer flowing adjacent to South Street Extension, the creek crosses the valley floor and proceeds downstream with low floodplains and higher terraces on both banks that become the higher valley walls to the upper plateau. By station ±243+00, the river has crossed the valley bottom, narrowing the right terrace and contacts the right valley wall at a bend at the end of Durling Road.

Two separate high valley wall failures are present on the right side, one at Durling Road (Photo 6), the other of few hundred feet downstream near station 238+00. Each is about 200 feet long, 60 feet high, with average grades of 83%, and becoming steeper at the top. There is no rock cover on these barren clay-rich till slopes. The opposite left bank has a point bar on the inside of a bend. This large, lightly vegetated point bar and the following, previously absent, mid-channel bar may be due to excess sediment from the valley wall failures.

Durling Road used to cross Taughannock Creek until a bridge was damaged in the 1930s.

Photo 6: Bank failure site on the right bank at the end of Durling Road (facing downstream).

Continuing downstream, the channel is increasingly incised and, by station 228+00, begins a long reach with bedrock controls. A remote falls is present near station 224+00, parallel to Rabbit Run Road, and the rectangular faults in the shale bedrock channel are clearly visible, forming a type F1 channel flume. The bankfull width was 64 feet, with near vertical 25-foot banks near station 210+00.

A second falls is present near station 170+00, just upstream of Route 96. Some bank erosion has occurred at the bends, above the level of the bedrock. The channel between the bedrock falls and Route 96 is overly wide due to degradation in weak bedrock.

5.4.5 Segment #5 – Route 96 Bridge to Taughannock Falls

Segment #5 includes 1.73 miles of Taughannock Creek, extending from the Route 96 Bridge (station 167+50) to Taughannock Falls (station 76+00). The slope of the channel in this segment is 1.99%, and the sinuosity is 1.23. A portion of the Lower Taughannock subwatershed as well as the entire Jenny Creek subwatershed contribute to flow in the main channel in this river segment.

Segment #5 begins at the Route 96 Bridge over Taughannock Creek. The bridge is a single-span simply supported structure, supported by short concrete stub abutments on bedrock. It sits high above the incised channel, and no part contacts the water.

This entire river segment runs parallel to Taughannock Park Road within the state park. The channel is slightly incised into bedrock, is fairly straight, and is a fast run with occasional rapids (Photo7). The stratified rock provides a flat flume bed in some reaches. The channel is semiconfined on the right, while the left bank provides informal public access. The Rosgen classifications are type F1 and type B1.

Photo 7: Slightly incised, straight bedrock Channel typical in Segment #5 (facing downstream).

The river was viewed and measured near the gas main crossing near station 160+00. The bankfull width was 101 feet with a wetted width of 56 feet. A second downstream measurement near the confluence of Jenny Creek found a bedrock flume with a wetted width of 71 feet, a Rosgen type B1 channel.

The river enters a deep bedrock gorge on the downstream side of Jacksonville Road (County Route 148) that leads through incised bedrock meanders to the top of Taughannock Falls.

5.4.6 Segment #6 – Taughannock Falls to the Route 89 Bridge

Segment #6 includes one mile of Taughannock Creek, extending from the bottom of Taughannock Falls (station 76+00) to the Route 89 Bridge (station 22+50). The slope of the channel in this segment is 5.18%, and the sinuosity is 1.12. A portion of the Outlet subwatershed contributes all the flow in the main channel in this river segment.

Segment #6 includes the large falls and the subsequent gorge to Route 89, all within the state park. The falls have a single drop, reportedly 215 feet, higher than Niagara Falls. It is the result of a hanging valley created when glaciers scoured the receiving valley that is now Cayuga Lake. The gorge has vertical walls up to 400 feet high and lacks till soil, indicating that it is postglacial and up to 10,000 years old (Photo 8).

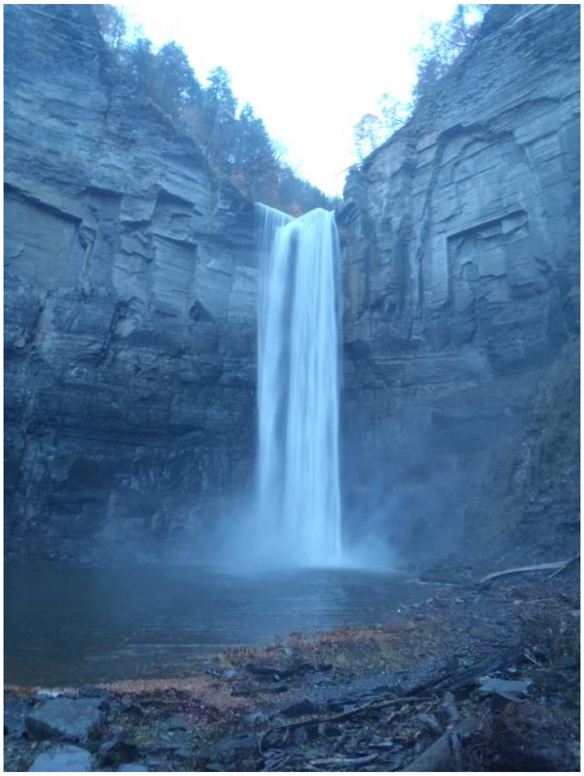


Photo 8: Taughannock Falls.

Von Engeln (1961) reports the floor of the wide gorge is limestone, evident by its many solution pocketed surfaces. The sides of the lower gorge are composed of a dark shale and are subject to failures and rock falls, one of which was observed. The cap rock at the falls is sandstone.

5.4.7 Segment #7 – Route 89 Bridge to the Outlet at Cayuga Lake

Segment #7 includes 0.43 miles of Taughannock Creek, extending from the Route 89 Bridge (station 22+50) to the creek outlet at Cayuga Lake (station 00+00). The slope of the channel in this segment is 0.16%, and the sinuosity is 1.02. A portion of the Outlet subwatershed contributes all the flow in the main channel in this segment.

This final segment of Taughannock Creek has a flat delta extending into the lake from Route 89. The presence of this classic delta into the deep lake is a testimony to huge quantities of material eroded from the watershed and especially the gorge below the falls in just 10,000 years.

The Route 89 Bridge is a twin span arch structure in good visual condition. It is a concrete structure with a stone façade (Photo 9). One span is over the river, the other over a park lawn floodplain. The channel lined with stone walls is 100-feet wide. The water entering the lake was very turbid with poor visibility.

Photo 9: Route 89 Bridge showing turbidity in main channel (facing upstream).

6.0 PRIORITY ISSUES AND RECOMMENDATIONS – TAUGHANNOCK CREEK

The most notable issue raised by the stakeholders of the Taughannock Creek watershed is ongoing erosion that is occurring in the watershed, along with the resulting risk to nearby property and roadways and increased turbidity of the water. Based on discussions and interviews with watershed stakeholders, as well as a visual inspection of the watershed, the highest priority concerns in Taughannock Creek center around the following issues:

Protection of property and infrastructure (i.e., roadways, bridges, pipelines, etc.) via stabilization of eroding banks. Widespread concern has been voiced from private property owners along the creek with regard to the loss of land and, in some cases, vulnerability of roadways due to bank failure. There is a general level of discomfort associated with the stark eroding banks along the Taughannock Creek.

Protection of water quality. Ongoing erosion in the creek and in the watershed due to streambank erosion and land management practices in the watershed regularly result in elevated sediment and turbidity in Taughannock Creek and at the outlet in Cayuga Lake. Water quality impairment has been documented in Cayuga Lake, resulting in its placement on the 303(d) list of water quality-impaired waterbodies. The impairment is associated with the sediment loading from watersheds contributing to Cayuga Lake, including the Taughannock Creek watershed. Water quality impairment via additional turbidity can decrease aesthetic, recreational, and aquatic habitat value of the Taughannock Creek.

In addition to addressing the aforementioned concerns, a common goal of establishing riparian buffers along the creek has been identified by numerous watershed stakeholders. Healthy riparian buffers can contribute to both protection of private property and infrastructure and protection of water quality by increasing bank stabilization and decreasing bank scour and erosion. Furthermore, a watershed-scale approach should be utilized to improve land management practices to decrease sediment loading and restore riparian buffer. This can be best accomplished with an integrated and coordinated planning effort involving all stakeholders with vested interests in Taughannock Creek watershed health.

6.1 Priority Issue # 1 – Streambank Erosion

With regard to streambank erosion, critical questions are:

- Should degradation be controlled?
- Would placement of bed controls in the creek to prevent down-cutting result in exacerbated lateral migration?
- Should the channel be relocated at the heavily eroding meanders?

Controlling degradation for the entire Taughannock Creek watershed through conventional means would be a daunting and cost-prohibitive venture. Traditional approaches to river management are often limited in scope, prohibitively expensive, and environmentally unsound.

The high bank failure at South Main Street Extension and the end of Durling Road both occur where the valley had become incised below the peneplain and then widened creating a narrow floodplain. Although within an incised valley, the creek itself is not incised but is eroding laterally at the valley wall. Consequently, there is no need for degradation (bed erosion) control structures; in fact, their use could even encourage further lateral migration if the river were to widen around the grade control structures.

The concept of managing the watershed and corridor as well as the river channel itself provides an alternate approach that allows each river function to be managed at the appropriate level. As such, bank stabilization techniques or flow deflection techniques should be judiciously applied in priority areas to protect existing structures, private property, and infrastructure (i.e., bridges and roads).

There were two main types of streambank erosion observed in the Taughannock Creek watershed: (1) low bank scour on the outside of meander bends eroding into well-developed floodplains; and (2) mass bank failures in high bluffs and valley walls. The recommended approaches to management and restoration of these sites are detailed separately below.

Eroding Bank Segments Due to Channel Migration

Field conditions indicate that significant lateral migration has occurred along portions of Taughannock Creek. In many locations, the creek has hit bedrock or till vertical control, and the creek bed is now relatively stable. In some locations, however, particularly in Segment #3, scour on the outside of migrating meander bends has exposed clay or sand that is being entrained during hydraulic erosion. Active restoration of these sites via planting and flow deflection could help prevent further loss of bank material and the associated increases in turbidity levels in the channel and Cayuga Lake.

Both past and future mitigation efforts in the form of structural walls and other vertical barriers are likely to require continued maintenance and experience repeated failures. Rigid riverbank retaining walls should be designed by a qualified licensed professional engineer and should include a hydraulic analysis of velocity and scour impacts as well as a stability analysis considering active earth pressures, hydrostatic pressure, surcharge loads, and foundation conditions.

In some instances, channel relocation away from the valley wall provides a more permanent, stable, and lower maintenance restoration alternative that provides environmental habitat benefits beyond erosion control. This approach is generally preferable over "spot repairs" such as riprap armoring or the erection of structural controls.

Minor channel relocation toward the inside of bends in combination with creating an "artificial floodplain" to reduce peak velocities can provide a highly effective fix. However, caution is warranted in designing restoration projects for sites that are not stable. For instance, the application of a geomorphic-based design such as Rosgen is a powerful tool. However, the methodology is not appropriate in many areas of instability, especially areas with clay banks or where high flood flow rates occur.

Valley Wall Failures (South Street Extension and Durling Farm Sites)

The riverbank erosion and subsequent high valley wall failures at South Street Extension and the end of Durling Road are so severe that they generate significant quantities of sediment, cause the loss of land, and threaten infrastructure. Mitigation efforts are warranted even though they will require main stem channel modifications. Potential measures include both protecting the toe of slope from further fluvial erosion plus slope protection against rill erosion and mass failure. Specific recommendations are listed below.

1. Both mass failure sites are located along the wall of an incised valley at the outside of a sharp bend. Lateral channel migration erodes the toe of the slope, steepens the bank angle, and leads to failures. As such, the channel must be moved away from the slope. In both cases, there is room on the low floodplain on the inside of the bend. MMI recommends that standard NRCS barbs or deflector vanes be installed along the outer bank. Deflector vanes, also known as rock vanes or spurs, are relatively short linear rock structures that extend from the bank angled upstream. The crest at the landward end is equal to the channel's bankfull level and then slopes downward toward mid-channel. In contrast, bendway weirs are long low rock structures used as a submerged weir in larger rivers.

2. The deflector vanes could be supplemented by minor excavation on the point bars on the inside of the bends to help accelerate returning the channel to its previous alignment.

3. A preliminary geomorphic analysis of this channel cross section was conducted as a guide for potential bank protection efforts. Based on New York State regional geometry relations, the bankfull width should be approximately 70 feet, and the bankfull depth is 3.3 feet. The U.S. Army Corps of Engineers Sediment Analysis Model (SAM) predicts a bankfull width of 69 feet at four feet deep.

4. The toe of slope should be reinforced with a combination of a low stone or log revetment.

5. The lower slopes, which have a limited amount of relocated slide material, can be reinforced using bioengineering techniques to replant with woody materials and live plants.

6. The upper slopes are too steep for effective revegetation unless they are graded by pulling the crown back and reducing their slope, which would result in loss of land at the top of the bank. This option should be discusses with landowners.

7. Large trees are located on the crest of the South Street Extension slope. Although the root mass reinforces the soil, the trees add weight and torque. We recommend that trees over four inches in diameter at breast height within 15 feet of the top of slope be cut with the stumps left in place. The tops can be dropped and left in place on the sloped bank.

8. The storm drain outfall that discharges onto the South Street Extension slope should be relocated to avoid direct discharges onto steep slopes. Potential water infiltration areas (depressions, swales) should be graded to drain or be eliminated by filling.

Summary

The following priorities for streambank stabilization are recommended along the Taughannock Creek. The highest priority segment is Segment #4 (from the Podunk Road Bridge to the Route 96 Bridge). Moderate priority reaches include Segments #1, #2 and #3 (from the Tompkins County border to the Podunk Road Bridge). Downstream of the Route 96 Bridge, Taughannock Creek is constrained by relatively steep bedrock banks, indicating few eroding bank sections.

TABLE 6-1
Segment Restoration Priorities – Taughannock Creek

Segment	*Description of Geographic Limits*	*Description of Conditions*	*Restoration Priority*
1	Tompkins County border to Brook Road crossing	Slightly entrenched, meandering, well-developed floodplain.	Moderate
2	Brook Road crossing to Waterburg Road Bridge	Slightly entrenched, meandering until exposed bedrock; transitions to deeply incised bedrock channel.	Moderate
3	Waterburg Road Bridge to Podunk Road Bridge	Slightly entrenched, meandering, some sections of deeply incised bedrock channel.	Moderate
4	Podunk Road Bridge to Route 96 Bridge	Meandering alluvial channel contained within a deeply incised bedrock channel.	High
5	Route 96 Bridge to Taughannock Falls	Moderately entrenched steep channel, some areas of exposed bedrock with some headcutting.	Low
6	Taughannock Falls to Route 89 Bridge	Stable bedrock channel with gorge and falls.	Low
7	Route 89 Bridge to outlet at Cayuga Lake	Entrenched, deeply incised channel with low slope; no floodplain connectivity.	Low

6.2 Priority Issue #2 – Water Quality

The water quality impairment associated with sediment loading due to streambank erosion and land management practices in the watershed is a priority issue for watershed restoration and protection efforts. The discussion of stream bank erosion in Section 6.1

details recommendations for addressing impaired water quality due to sediment released from bank erosions sites. However, land use practices, particularly agricultural practices, roadway drainage practices, and minimization of impervious cover can also have an impact on sediment runoff in the watershed.

Impervious Cover

Of the three land management practice discussed here, impervious cover had the least direct linkage to sediment loading: increased impervious cover can lead to increased runoff, which leads to increased erosion and conveyance of sediment to waterways. These processes and related hydrologic effects are detailed in this section.

The increased industrialization and urban growth after the Civil War was followed in this century by the rapid growth of suburbs dependent on automobile transportation. Urban and suburban areas both increase the area of impervious surfaces and use artificial drainage systems to collect runoff. The prevailing philosophy for 100 years, which began to change only recently, was to convey the runoff to rivers as rapidly as possible. This reduces infiltration and evapotranspiration, increases the volume of runoff (and therefore sediment delivery) and raises peak flow rates in the rivers.

Generally speaking, in developed areas water quality impacts (sediment as well as other water quality metrics) begin to occur above 10% impervious area coverage in a watershed, wherein the most sensitive stream elements are lost from the system. Above 25%, water quality is often impaired, where most indicators of stream quality consistently shift to a poor condition, including diminished aquatic diversity, water quality, and habitat scores.

Detailed studies of numerous watersheds have shown that the physical, biological, and chemical (water conditions) usually deteriorate as the watershed becomes developed. The percentage of the watershed covered with impervious material such as rooftops, parking lots, roadways, and driveways is often used as an indication of urbanization. Research has demonstrated the following relationships between watersheds impervious cover and the streams condition (Center for Watershed Protection, 1998). This information provides an initial method to rapidly assess watersheds susceptible to change.

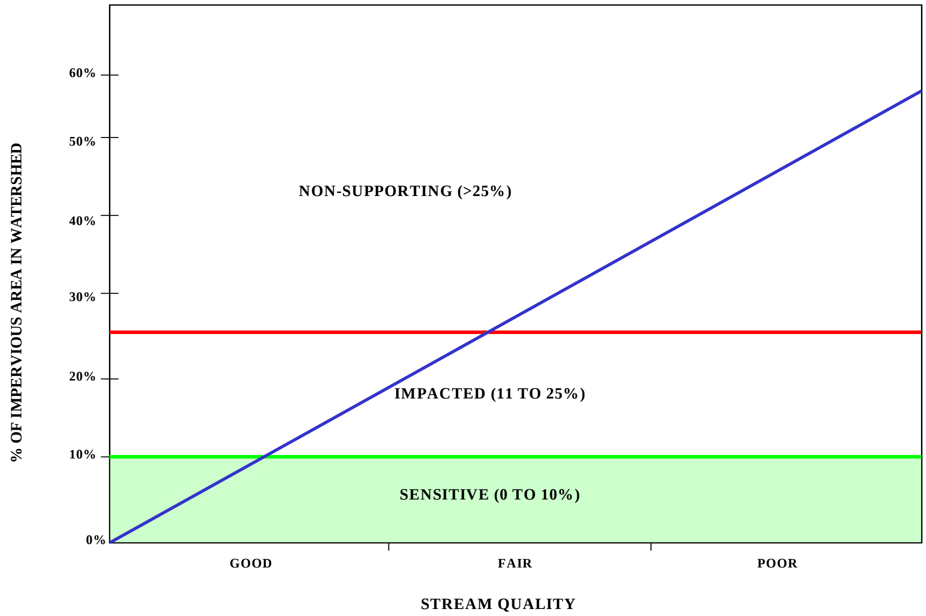
TABLE 6-2
Relationship of Imperviousness to Water Quality

Watershed Impervious Cover	***Stream Quality***
0-10%	Good
11-25%	Fair, probable impacts
>25%	Low, significant impacts

Streams with 10 to 25% impervious cover usually are impacted with channel deterioration due to erosion, unstable banks, reduced habitat, reduced biodiversity, and declining water quality. Streams within watersheds of over 25% impervious cover tend to be flood prone and highly unstable, with poor water quality and limited aquatic life. Figure 6-1 illustrates the relationship between impervious cover and stream quality, information that can be used to categorize streams as sensitive, impacted, or nonsupporting.

The visual water quality of the subwatersheds within Taughannock Creek as observed in the field and assessed directly by turbidity data from the Community Science Institute and indirectly by the impervious cover metric is generally quite good. The only subareas with high impervious cover and extensive storm drainage are the Bolter Creek and Lower Taughannock subwatersheds surrounding the village of Trumansburg within the Taughannock Creek watershed. Consequently, watershed urbanization is not a significant factor in the health of Taughannock Creek. However, future land uses and development practices and trends have the potential to have a marked negative impact on Taughannock Creek and its contributing tributaries. If unchecked, land use development could have profound and unwanted impacts. Future growth around hamlets such as Podunk and along Route 96 in the Jenny Creek subwatershed should be considered for development practices that minimize impervious cover.

FIGURE 6-1
Relationship of Imperviousness to Water Quality



Source: Schueler & Claytor, 1996 ASCE

The Town of Ulysses Local Law No. 03 2007 (addressing stormwater management and erosion and sediment control) and the Tompkins County Riparian Protection Agreement and Model Stream Buffer Ordinance are progress toward responsible development for watershed protection and a strategic approach to buffer-zone management. Development of a consortium or task force among the local Taughannock Creek watershed member towns as well as the county and state government is strongly encouraged, wherein the framework can be developed for a consolidated watershed-scale approach to future development.

Agricultural Land Use Practices

Turbid flows from field runoff, field ditches, and road ditches have been observed during rain events in the Taughannock Creek watershed. Specifically, it is likely that the high turbidity observed in Spring Brook is partially caused by field runoff from the Spring

Brook subwatershed, and it is likely that this occurs in other areas throughout the watershed where active agricultural fields abut Taughannock Creek.

Altered hydrology in the form of field and road ditches is the primary impact of direct drainages like those observed in the watershed since runoff moves directly to the main channel with less opportunity for sediment deposition and nutrient uptake on floodplains. Planting ditches with vegetation and conversion of select pieces of land back to natural vegetation is desired to naturalize hydrology, decrease sediment conveyance, and improve water quality. The use of vegetated buffer zones between active agricultural field and roadside ditches and natural channels would help reduce sediment loads.

Photo 10 shows direct conveyance of runoff from Perry City Road and an adjacent agricultural field into Taughannock Creek near station 470+00. Photo 11 shows a well-vegetated ditch, which is an improved method of water conveyance from farm fields. In the latter case, the vegetation slows flow and traps sediment before it reaches the streams. It is likely that this ditch had been cleaned recently. Since removal of vegetation from a ditch like this one greatly decreases sediment capture functionality, it is recommended that small check dams remain in the ditch to maintain sediment trapping capabilities and that the trapped sediment be periodically removed.

Further investigation is recommended to identify likely flow paths where sediment and nutrients are delivered to Taughannock Creek and its tributaries. For example, an NRCS field hydrology study can reveal likely flow paths where sediment and nutrients are delivered to waterways. These potential runoff sites can be field verified with local farmers and then efforts should be made to employ best management practices to separate runoff from farms during floods from the creek and lake.

Photo 10: Direct conveyance of runoff into Taughannock Creek from nearby roads and farm fields.

Photo 11: Vegetated agricultural ditch conveying runoff to a nearby stream.

Continued effort is needed to work with local farmers in the direct drainages to implement agriculture best management practices (BMPs) to naturalize land cover and field hydrology. Land use conversion on regularly inundated areas as well as direct drainage of turbid runoff from agricultural fields is a threat to water quality in the Taughannock Creek and Cayuga Lake. Additionally, adjusting cropping plans based on field inundation (i.e., changing the wettest areas from corn to hay), cover cropping, conservation tillage, injection spreading, row cropping, and other practices should be discussed with farmers to reduce nutrient-rich runoff.

6.3 Priority Issue #3 – Need for Coordinated Watershed Management

Development of a consortium or task force among the local Taughannock Creek member towns, Tompkins County Planning Department and associated agencies, and state and federal agencies with resources that can support watershed management (i.e., the NRCS, EPA, and New York DEC) is strongly encouraged. Such a consortium can develop a strategy for conducting a detailed watershed assessment of stream bank erosion and formulate reasonable controls for future land uses in the watershed. Of particular concern would be mechanisms to protect the hydrology and water quality and to develop a consistently healthy riparian corridor within which development would not occur.

There are many federal programs, like the Conservation Programs administered by the USDA Farm Service Agency, that provide assistance to farmers converting active field to riparian buffer in a stream corridor or excluding livestock from the stream. In some states there are state-funded watershed associations that act as the local arena for education, information, and assistance on programs like these.

Because the Taughannock Creek watershed crosses several municipal boundaries and the mechanisms for assistance in stream restoration projects can be complicated, formation of a watershed association is recommended for the Taughannock Creek watershed. The organization could be a focal point for activity and efforts in the watershed, both facilitating landowner involvement in watershed-scale management of Taughannock Creek and the tributaries as well as ensuring that collective efforts are not overlapping and well prioritized to maximize benefits to the citizens of the watershed and ecosystem health in general.

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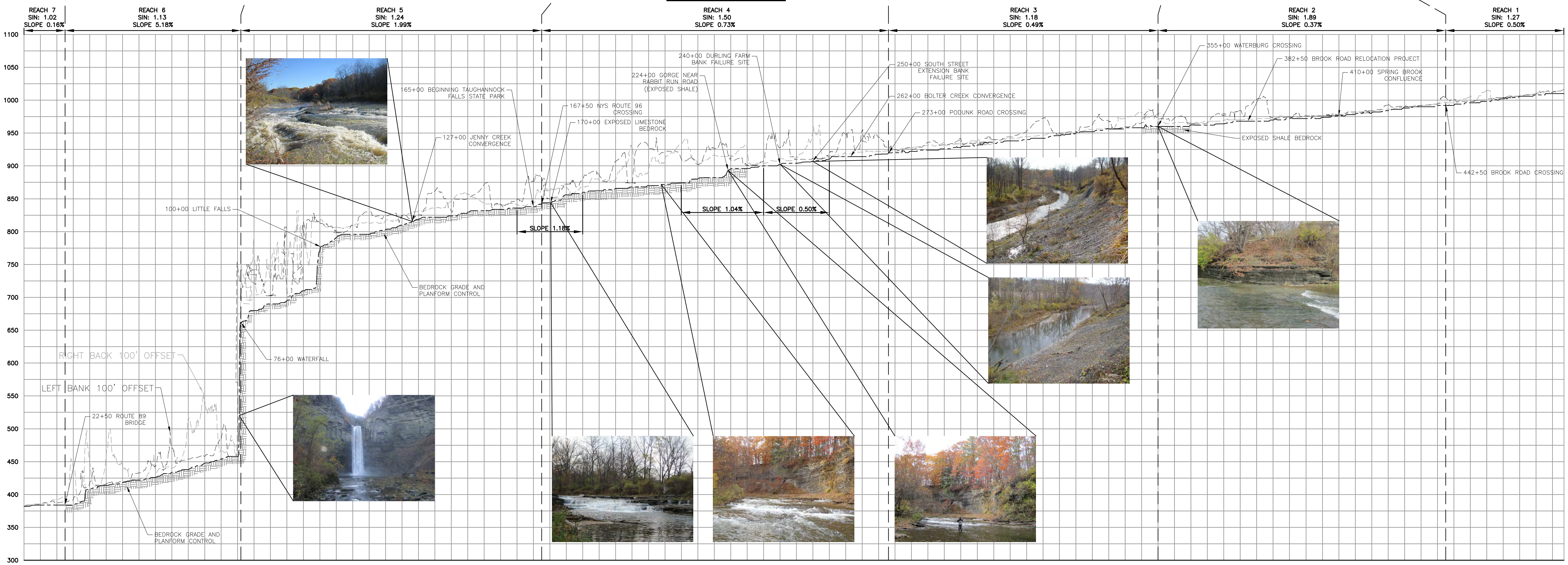
PLAN VIEW



TAUGHANNOCK CREEK – PROFILE VIEW

(SCALE: 1"=1,500'H, 1"=75'V)

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REVISIONS

TAUGHANNOCK CREEK PROFILE
FLOOD MITIGATION NEEDS ASSESSMENT
TOMPKINS COUNTY, NEW YORK

DESIGNED	DRAWN	CHECKED
JBH	DRM	JBH

SCALE: AS NOTED
DATE: MARCH 2011
PROJECT NO. 4395-01

SHEET NO. APP. 1