BROOME COUNTY WATERSHED FLOOD HAZARD MITIGATION PLAN

Prepared for:

Broome County Planning Department & Economic Development
Edwin L. Crawford County Office Building
60 Hawley Street
Binghamton, NY 13902

Flash Flood Hazards in Broome County

Riverine Flood Hazards in Broome County

Prepared by:

Woidt Engineering

Woidt Engineering & Consulting, PC
41 Chenango Street, Suite 200
Binghamton, NY 13901

May 2016

BROOME COUNTY
WATERSHED FLOOD HAZARD
MITIGATION ANALYSIS

Prepared for:

Broome County Planning & Economic Development Department
Edwin L. Crawford County Office Building
60 Hawley Street
Binghamton, NY 13902

May 2016

TABLE OF CONTENTS

Appendix A

Appendix B

Appendix B (continued)

1.0 Executive Summary

Occurrences of flooding events and their associated damage have taken a financial toll on local municipalities in Broome County, including capital costs for infrastructure repairs, upgrades and indirect impacts to local economic and community development. Considering local financial constraints, the prioritization of projects that improve stormwater and flood management, while minimizing impacts to the local economy is essential for maximizing the benefits received from infrastructure investments.

Investments in stormwater and flood control infrastructure are often handled in a reactive manner, on a project by project basis to deal with specific complaints or problems, or to simply repair damage. As a result, projects may occur in a vacuum, without considering opportunities to improve the watershed as a whole. This strategy is understandable considering the financial constraints that municipalities are experiencing. However, by taking a more comprehensive view of the watershed and including all the municipalities working together, it is easier to prioritize and identify strategies that may have broader impacts for managing flood water flow, and also to incorporate more proactive, innovative strategies.

The intent of this project is to provide a broad comprehensive view of the flood hazards in Broome County and their impacts. The expected outcome of this project is a resource tool that local municipal officials can use to make informed decisions on where to locate flood mitigation activities to achieve maximum benefit of their flood mitigation dollars. This tool, the Watershed Flood Hazard Mitigation Plan (WFHMP) is a living document that is updated to capture the dynamic nature of flooding and its impacts. The County will use the Plan to direct multi-municipal flood mitigation projects. Optimally, all flood mitigation activities should be prioritized on the cumulative benefit of the mitigation activity and its ability to mitigate deleterious flooding impacts across municipal boundaries.

The project goals are to achieve the following specific objectives:

1. Locate frequent flood hazard locations in Broome County and assist local municipalities and agencies in gaining a better understanding of the nature of the repeated flooding concerns.
2. Create an updatable database that contains pertinent flood hazard characteristics, designed to be updated as mitigation activities are completed and new flood hazard locations identified.
3. Use the database to prioritize the County's watersheds based on the level of deleterious impacts caused by the flooding hazards. The prioritization process should reflect the goal that local mitigation activities with broader benefits in the regional watershed have the highest priority.
4. Develop a standardized approach for the identification and design of flood mitigation activities in the County's watersheds.
5. Implement a standardized approach for three of the County's high priority watersheds as identified during the prioritization process (in 2016).

Two meetings with Broome County's Flood Task Force (Task Force) and one public meeting were held to gather information on the location and damage associated with flood hazards in the county. Federal, state and county GIS data and other electronic resources were reviewed to assess the nature of the flooding hazards. Representatives from several municipalities were consulted including local officials, public works employees and town engineers, to obtain supplemental information on the flood hazards in the communities. Two hundred and three flood hazards were identified in the County's forty two (42) watersheds.

The Task Force was engaged to develop methods to quantify the damage caused by each flood hazard. Six damage categories were developed and each hazard was assigned a low, moderate or high rating for each category. Ratings were converted to numerical values to quantify the damage caused by each flood hazard and summarized for each hazard. All the hazard scores were summarized by watershed and the County's watersheds were ranked from highest score to lowest. The three highest ranked watersheds were Lower Choconut, Thomas Creek/Chenango River and Patterson Creek/Susquehanna River.

Broome County's WFHMP provides a standardized protocol for identifying, documenting and prioritizing flood hazards in the county which is outlined in this document. The protocol does provide flexibility to the professional who is furthering watershed wide flood mitigation investigations. The protocol was designed so additional flood mitigation investigations not listed in section 3.0 can be utilized as long as they produce results that allow for a comparison and prioritization of flood mitigation strategies within the county.

As part of WFHMP's initial efforts, the standardized approach to identify and justify flood hazard mitigation strategies were used in the three highest priority watershed as identified during this process. The standardized approach involved an assessment of varying flood mitigation strategies. The following strategies were considered, with a priority to integrate non-structural flood mitigation solutions. Flood hazard mitigation strategies were as follows: Watershed wide interventions (land use changes, wetland creation, etc.), sub-regional flood mitigation facilities (dams, retention ponds), site flood mitigation activities (floodplain benches, levees), building flood mitigation activities (flood proofing, elevation) and finally relocation/buyouts.

Several cost effective projects using FEMA's Benefit to Cost Ratio (BCR) were identified as the result of the WFHMP's initial efforts. These included the following:

- Replacing the Juneberry Road Bridge over the Choconut Creek in the Town of Vestal.

- Construction of an earthen berm in the Town of Chenango that protects several commercial properties and the Town's drinking water well.

- Non-structural recommendations were identified including requesting a letter of map revision (LOMR) and letters of map amendments (LOMA) for two neighborhoods in the Town of Vestal which will help reduce annual flood insurance premiums for home owners.

- Flood mitigation solutions for several critical transportation corridors with high traffic volumes that are frequently flooded were also assessed.

After initial WFHMP efforts it was found that often the BCR results were low for many flood mitigation strategies since the BCR module used to calculate annual benefits and costs does not account for impacts unrelated to physical property damage, including interruption to emergency response, economic development, social impacts, and others. This underrepresents the benefits gained by the community if the flood hazard is mitigated. For example, two of the proposed mitigation projects that were identified as part of the initial efforts have since been funded by the community and are currently in the design phase despite receiving a low BCR score.

Despite the low BCR scores, this Plan identifies the need for these projects and identifies funding opportunities for projects with low BCRs. For future iterations of this Plan, it is recommended that additional considerations should be integrated into the method for prioritizing mitigation projects for advancement to the design phase. The WFHMP also includes recommendations of how to emphasize the need for mitigating a particular hazard despite low FEMA BCR scores. For example, the projects listed below are a couple of the several investigation projects that have would have a notable community benefit despite their BCR score.

- Proposed Mitigation Site #1 in Thomas Creek/Chenango River featured a flood protection facility that would protect 44 homes.

- Proposed Mitigation site #5 in Lower Chocnunut Creek featured a flood protection facility that would protect 17 homes.

2.0 Flood Hazard Identification and Watershed Prioritization

Section 2.0 outlines the methods to collect, organize and prioritize individual flood hazards in Broome County as a tool for local officials and agencies to make strategic, informed decisions about flood mitigation actions in their communities. This is an ongoing effort that can be updated once individual flood hazards are mitigated or new hazards are developed when new flooding occurs.

The goals of this phase of the project are:

- Locate frequent flood hazard locations in Broome County and assist local municipalities and agencies in gaining a better understanding of the nature of the repeated flooding concerns.
- Create an updatable database that contains pertinent flood hazard characteristics, designed to be updated as mitigation activities are completed and new flood hazard locations identified.
- Use the database to prioritize the County's watersheds based on the level of deleterious impacts caused by the flooding hazards. The prioritization process should reflect the goal that local mitigation activities should be combined to achieve broader benefits in the regional watershed.

The intent is that once the work is completed, specific flood mitigation strategies can be explored in the highest priority watersheds following the methodology in Section 2.

2.1 Background

Flooding is the primary natural hazard in New York State because the state exhibits a unique blend of climatological and meteorological features that influence the potential for flooding. These factors include topography, elevations, latitude, water bodies and waterways. Flooding occurs in every part of the State. Some areas are more flood prone than others, but no area is exempt, including Broome County (Broome County Hazard Mitigation Plan, 2013).

The NYSDEC conducted a vulnerability assessment that depicted how vulnerable a county is to flood hazards. Broome County's rating is 28 out of a possible 35 making it the 6th most vulnerable county (out of 62 counties) to flood hazards in New York State (NYS Hazard Mitigation Plan 2011).

Flooding has historically been a significant threat to properties in Broome County. There are over 636 miles of streams, creeks and rivers in Broome County of which 222 miles are within a Federal Emergency Management Agency (FEMA) Special Flood Hazard Area (SFHA). The land area covered by the floodwaters of the base flood (100-year or 1% annual flood) is the Special Flood Hazard Area (SFHA). The SFHA is the area where the National Flood Insurance Program's (NFIP's) floodplain management regulations must be enforced and the area where flood insurance must be purchased if a home owner is seeking a federally backed mortgage.

Approximately 26 square miles of the county is located within a SFHA, including several urbanized areas, which makes flooding a primary concern (Broome County Comprehensive Plan 2013). The SFHA is the only published flood prone boundary in the county but the SFHA alone does not fully describe all the flooding problems. The WFHMP looked outside these boundaries for additional flooding hazards. For example, outside of SFHAs, there is 15.5 mi^2 of the county located within 100' of a stream which could be damaged by overbank flooding or erosion hazards. In addition, the currently adopted floodmaps are outdated, dating back to the 1970's, so may not reflect the current hydrological conditions in some areas. So the amount of the county that could be exposed to a flooding hazard is much greater that what is captured in a SFHA alone.

Additionally, flash-flooding and stormwater related flood hazards aren't always captured by the SFHA. There are approximately 800 culvert or bridge crossings in the county. When flood waters exceed a crossing's capacity to transport floodwater, they can be overtopped and damaged which poses a threat to public safety, economic development and quality of life due to the closure of the road. These crossings can also be plugged by debris leading to damaging erosion and overtopping of the road.

Stream bank erosion is a major hazard associated with flood events though also not documented by the SFHA. This process occurs when the soil lining a water body is physically removed by moving water. This phenomenon can occur episodically during a flood event or the erosion can be a continual problem. Stream bank erosion is a water quality concern in Broome County (Broome County Comprehensive Plan 2013). Sediments released from an eroding bank increases water turbidity reducing the water's value as a recreational resource and a drinking water source. Excessive sediments also bury aquatic habitat for animals that live along water corridor bottoms.

When erosion removes the sands and gravels along the stream banks, the buffer between the river and proximal infrastructure decreases. Unrepaired, the erosion process will continue until the infrastructure collapses within the water corridor. Many pieces of critical infrastructure in the County are at risk to stream bank erosion (New York Rising 2014). There is not a county wide database that documents these locations. Typically, erosional problems are addressed on a case by case basis and not using a watershed wide approach which could address multiple erosion problems at one.

For all these reasons, the identification and mapping of stream bank erosion, stormwater impacts, and other undocumented flood hazards was a major priority to the County. In this study, these hazards were mapped, their causes defined and the impacts they create measured.

2.2 Methodology

Existing Data Collection and Data Gap Analysis

1. Review existing county and local flood hazard/mitigation plans.
2. Obtain available GIS data. A GIS inventory can be seen in Appendix A (A-1).
3. Interview municipal representatives as necessary.
4. Establish a Stakeholder Group to provide information, data and feedback. The Broome County Flood Task Force, an existing group of local officials and agencies that cooperate regarding flooding issues, was utilized as the Stakeholder Group for this study. A list of the Flood Task Force group is in Appendix A (A-51)

Flood Hazard Characterization

5. Define common floods hazard types and establish consensus among members of the Stakeholder Group and incorporate their comments.
6. Define common flood hazard impacts and develop a weighting system based on their deleterious impacts to adjoining community, infrastructure, etc. Establish consensus from the Stakeholder Group and incorporate their comments.

Flood Hazard Data Collection

7. Develop forms and tables to capture standardized flood hazard information (location, cause of flooding, frequency) and proposed mitigation information (location, which hazard it mitigates, level of completion, etc.)
8. Send .forms and tables to a subset of the Stakeholder Group for review. Incorporate feedback.
9. Distribute the forms and tables to the entire the Stakeholder Group (municipal officials, staff and flood management agencies) and to other relevant agencies (NY Department of Transportation, Broome County Department of Public Works, and National Weather Service).
10. Conduct one-on-one meetings with entities when necessary to ensure completeness and accuracy of data.
11. Conduct a public meeting to collect additional flood hazard information.

Database Creation

12. Create GIS shapefiles from the collected flood hazard and flood hazard impact data and include attributes to record all collected data.
13. Integrate the data from these shapefiles into an excel database.

Prioritization of County's Watersheds

14. Define watershed scale to be utilized in the study.
15. Prioritize watersheds based on cumulative flood hazard impacts using a prioritization model established by the consultant and approved by the Stakeholder Group.
16. Determine the three highest priority watersheds as determined by the prioritization model, for further analysis in the Phase II detailed study. Present to the Stakeholder Group and incorporate any comments
17. Finalize the three highest priority sites.

Database Maintenance

18. Develop methodology for the County to continually update the flood hazard database and GIS shapefiles, and to rerun the prioritization analysis as needed. This methodology can be seen in Appendix A (A-49 through A-50).

2.3 Flood Hazard Data Collection and Prioritization

2.3.1 Defining Flood Hazards

Analysis of existing plans (County All-Hazard Mitigation Plan, NY Rising, etc.) showed a lack of a specific and consistent definition of flood hazards to be able to understand the cause, frequency, expected damage, etc. of the flood hazard. Therefore definitions were developed for several types of hazards created by flooding. Another reason to create specific definitions of flood hazards is to assist in identifying an appropriate mitigation strategy since similar flood hazards often have similar mitigation activities. The specific flood hazard definitions were developed by the County and approved by the Stakeholder group as identified below:

- *Riverine Flood Hazard:* A location where overflow from a river, stream or creek channel (a published DEC water corridor) damages assets and often results in a federal disaster declaration. This type of flooding generally occurs more than six hours after peak rainfall.
- *Flash Flood Hazard:* A location where a rapid and extreme flow of high water overflows from a river, stream or creek channel (a published DEC water corridor) into normally dry area beginning within six hours of an intense rainfall event. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters i.e. a minor flooding event rapidly becomes a larger flooding event after another burst of intense rain.
- *Stormwater Flood Hazard:* At locations where damage to an asset occurs resulting from insufficient capacity of private or municipal stormwater drainage infrastructure. This includes ditches, catch basins and piping systems.
- *Debris Jam Flood Hazard:* A location where damage to assets occurs resulting from flooding or erosion that is caused by debris reducing the capacity of water corridors, bridges, culverts or stormwater drainage infrastructure. Debris can be wood, bedload (stones moved by water in streams) or manmade (sofas, car parts, propane tanks, etc.).
- *Erosion Hazard:* Eroding Banks that threaten public or private infrastructure. Threatened infrastructure is near an actively eroding bank (notable movement of bank over the last five years) and the rate of erosion could threaten infrastructure within the next five years.

- *Ice-Jam Flood Hazard:* A location where damage to assets occur resulting from flooding or erosion caused by ice jams. An ice jam is an accumulation of ice that acts as a natural dam and restricts flow of a body of water. Ice jams may build up to a thickness great enough to raise the water level and cause flooding.
- *High Groundwater Level Flood Hazard:* An area where damage occurs in areas not connected to recognizable drainage channels. Through a combination of infiltration and surface runoff (sheet flow) water may accumulate and cause flooding problems generally in concave basins.
- *Unknown Flooding Hazard:* The cause of flooding is not known.

In addition to collecting information about flood hazards, the WFHMP also asked participants to identify flood mitigation activities (completed, being completed or being planned for). Flood mitigation activies that have been completed were flood hazards before the intervention. Knowing where and the type of historic flood hazards are helps corroborate the causes of existing hazards. Knowing where future flood hazard mitigation activities are going to occur informs that existing flood hazards may be fixed. Participants were asked to identify where the hazard mitigation activity was/or had occurred and which type. Several common types of flood hazard mitigation activies are listed below.

Proposed flood mitigation activities:

- *Property Protection (PP)* Actions that reduce potential damage to buildings by acquisition, elevation, relocation and structural retrofits.
- *Flood Damage Prevention (FD)* Actions that lower flood water elevations or prevent future losses (such as channel and floodplain modifications, floodplain reclamation)
- *Natural Resource Protection (NR)* Actions that minimize Hazard Loss and preserve or restore the function of natural systems using soil stabilization measures such as bank protection and stabilization, wetland restoration, attenuation of peak flows through detention facilities and debris management.
- *Structural Projects (SP) A*ctions that use or modify structures to mitigate a hazard such as replacement or retrofit of bridges, culverts, protection of critical utilities, levees, floodwalls and dams.
- *Emergency Services (ES)* Actions that protect people and property, during and immediately following a disaster or hazard event including protection of essential facilities or critical transportation routes.
- *Public Education (PE)* Can the project serve as an educational tool to the community to protect themselves and the community from flood disasters and associated losses.

2.3.2 Calculating Hazard Impact Scores

In order to quickly understand the extent of damage a hazard creates and to compare one hazard damages to another, it was essential to develop a scoring system. The scoring system begins by assigning a severity score to each of the six categories of potential hazard impacts. Each category was rated by participants for each hazard as having a “low impact”, “medium impact,” or “high impact” are defined in Table 1 below. This methodology was reviewed, commented on and approved by the Stakeholder Group.

Table 1: Hazard Impact Categories

Category	*Low Impact*	*Medium Impact*	*High Impact*
Neighborhood Community Impact	Hazard impacts one or less land owner, commuter, business, etc.	Hazard impacts one to five land owners, commuters, business, etc.	Hazard impacts more than five land owners, commuters, business, etc.
Critical Transportation Corridors Impact	Minor road, multiple detour routes possible	Moderately used road, single short (<0.5mi) detour possible	Major road, frequently used for emergency services, long detour (>0.5 mi) required
Critical Infrastructure Impact	No Critical infrastructure impacted	1 or more Critical infrastructure damaged but functionality can be maintained	1 or more Critical infrastructure damaged and must be shut down
Community Economic Impact	Little to no economic impact to community	Moderate economic impact to the community	Major economic impact to the community
Duration Impact	Hazard will render the Asset unusable for less than 12 hours	Hazard will render the Asset unusable for between 12 hours to 24 hours	Hazard will render the Asset unusable for more than 24 hours
Increase of Hazard Occurring In Last 5 years Impact	No noticeable increase	Marginal increase	Noticeable increase
Notes	Stakeholder can add notes describing impact		

The severity score for each category was then assigned a numerical value of 5,3,1 (the severity score) for "high", "moderate" and "low" respectively.

The County recognized there is variability in magnitude each impact category. For example, a road closure, preventing emergency response during and after the flood was deemed as having a broader impact than flooding of private residences due to public health and safety concerns. To capture this, a weighting scale was developed to skew the impact scoring of each category by mathematically separating each category from one another depending on that category's importance. Each category was assigned a constant value. This is the category's "weighted scale". For example, a constant value of 1.1 and 1.0 were assigned to hazard impact categories with greater and lesser negative impacts respectively. The weighted scales of all the categories can be seen in Table 2 below.

Next, the 5, 3 and 1 severity scores were multiplied by that category's weighted scale. This was completed for each category (6 categories in all). The products were then summed forming the hazard impact score for each hazard. This was completed for all hazards and was approved by the Stakeholder Group.

Table 2: Weighting of Hazard Impact Categories

Hazard Impact Category	Neighborhood Community	Critical Transportation Corridor	Critical Infrastructure	Community Economic	Duration Impact	Increase of Hazard Occurring in Last 5 Year
Weighting Scale	1.0	1.2	1.1	1.1	1.0	1.05

2.3.3 Collecting Flood Hazard Data.

To collect information on hazard locations and hazard impacts, electronic tables were developed. These tables were then sent to three Flood Task Force members to pilot test them to ensure the tables were easy to understand and complete. Their feedback was incorporated into the tables. The final tables and their instructions can be seen in Appendix A (A-5 through A-25).

Representatives from each municipality were asked to complete the tables and one on one interviews were conducted as deemed necessary for data completion and accuracy. Three other organizations that were not part of the Flood Task Force but deemed important to the study were also sent tables. They were: NYS Department of Transportation, Broome County Department of Public Works, and National Weather Service. The Flood Task Force and these three organizations formed the Stakeholder Group. Eighteen municipalities and institutions returned completed tables as shown in Table 3. Note that all Broome County municipalities were contacted for participation in the project. However, some were not heavily impacted by flooding and therefore, did not have data to contribute.

Table 3: Participating Municipalities and Organizations

Participating Municipality or Organization	
Town of Barker	Town of Kirkwood
BC DOT	Town of Lisle
BC SWCD	Town of Maine
Town of Chenango	Port Dickinson
City of Binghamton	Town of Union
Town of Conklin	Town of Vestal
Town of Dickinson	Village of Whitney Point
Village of Endicott	Village of Windsor
Town of Fenton	
Village of Johnson City	
*information collected from public meeting as well	

The information from the .tables was integrated into GIS shapefiles using Adobe Acrobat, Microsoft Excel and ArcGIS 10.1 and used to create flood hazard maps for the entire county. A public meeting was then advertised in local newspapers and held in Binghamton to collect additional flood hazard data from the public. Several additional hazards were collected during this meeting and the data was updated.

2.4 Results and Conclusions: 2015

2.4.1 Review of Existing Flood Hazard Plans

The County's Multi-Jurisdictional All Hazard Mitigation Plan was used to understand flood hazards in each municipality. Also, data from the New York Rising Broome Reconstruction Plan (NY Rising) which identified the locations of community assets was obtained. These can be seen in Appendix A (A-2) The plan identified 629 community assets, 145 of them located within a Special Flood Hazard Area (SFHA). Examples of community assets were major employment centers, residences, public infrastructure and key human service and cultural assets. Unfortunately, the scope of the NY Rising plan was limited to only six of the 24 communities in the county. Due to this underrepresentation, this data is not enough to complete a county wide flood mitigation plan. The Town of Union Community Plan for Recovery and Resilience was completed during the time of this study and the locations of flood hazards in these municipalities were obtained from that study.

Geographic data for proposed and completed FEMA buyouts were obtained to assist in locating flood hazards and siting potential flood mitigation techniques such as Flood Damage Prevention (FD) and Structural Projects (SP). Flood prone areas without structures that were bought out and removed can be manipulated to increase flood attenuation which would reduce downstream flooding impacts. There were 440 flood buyout locations across 7 municipalities, with 353 of them located within a SFHA. Twenty percent of the buyouts were located outside of a SFHA further stressing that its important to look for flooding issues outside of the SFHA.

Locations of repetitive flood damage areas (301) were also mapped which could assist in siting other potential flood mitigation techniques such as Property Protection (PP). An example of a Property Protection activity is structural flood proofing. 290 of these locations are located within SFHA which again points to the need of additional data collection. Maps for each data type can be seen in Appendix A (A-3 and A-4).

2.4.2 Flood Hazard Data Collection Results

Using the definitions described in section 2.3.1 and the methodology outlined in section 2.3.3, 203 hazard locations and 43 mitigation locations were identified through this initial effort and can be seen in Appendix A (A-26) and in Figure 1 below. Sixty-eight (68) of the identified hazards were located within a FEMA SFHA so the majority were located outside of the SFHA. This effort therefore shows that many areas in Broome County with flood problems that are not captured by published sources (ie. flood insurance maps). This shows that flood mitigation studies that only focus on SFHAs, are likely to be less comprehensive and miss a large proportion of the flooding problems in the community.

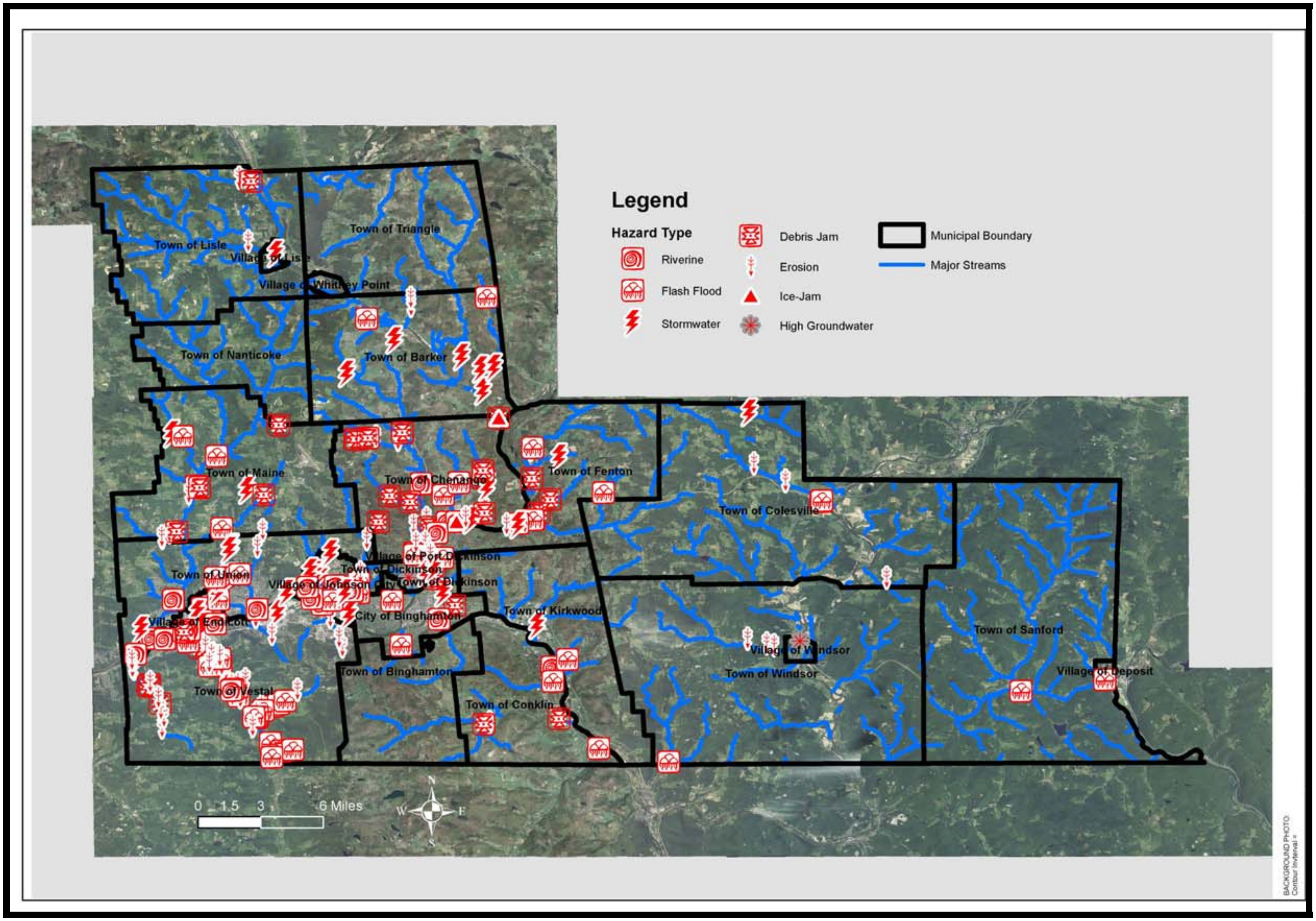

Figure 1: Location Map of Flooding Hazards in Broome County

2.4.3 Watershed Prioritization Results

The United States Geologic Survey (USGS) divides the United States in successively smaller hydrologic units (watersheds) with each unit arranged or nested within each other from larger to smaller area. Each hydrologic unit is identified by a hydrologic unit code (HUC) consisting of two to eight digits based on the level of classification in the hydrologic unit system. Broome County has eight (8) HUC10 hydrologic units in the county. Initially we explored conducting the analysis at this scale, however HUC10's have such a large area, that it would not allow smaller perennial streams in the county to be analyzed separately allowing for effective mitigation strategies to be developed. As such, smaller HUC12 hydrologic units were used in this study as the 42 HUC12s in the County provided better definition for the prioritization analysis. For the remainder of this report, "watershed" will be used in lieu of HUC12.

The County selected three governing scoring metrics to prioritize each watershed. They are as follows:

-Raw Score (Raw).

All the hazard impact scores (the severity score multiplied by the weighted scale) were summed for each hazard in a watershed. The sum is called the Raw Score (Raw). There are 42 Raw Scores in Broome County (one for each watershed). Again, the Raw Score represents the total of negative flooding impacts in each watershed. The higher the Raw Score, the higher the priority. The Raw Score is heavily influenced by the number of hazards within a watershed. A watershed with only a few but very bad flooding problems gets a lower overall Raw Score (and consequently lower prioritization) simply due to the low number of identified hazards.

-Normalized Score (Norm)

This score was developed to ensure watersheds with only a few but severe flooding problems are represented in the study. The Normalized Score is the watershed's Raw Score divided by the number of hazards in the watershed. The higher the Normalized Score, the higher the priority.

-Paired Aggregate Score" (Paired)

This score uses the adjacent downstream watershed's Raw Score as an additional prioritization tool. The WFHMP is a comprehensive watershed-based analysis of flood mitigation, highlighting the need for intermunicipal coordination. One of the goals is to identify flood mitigation solutions that can benefit multiple municipalities. Municipalities are limited in fixing their flooding problems within their municipal boundaries yet solutions to their flooding problems could exist in neighboring municipalities. Using the adjacent downstream watershed's Raw Score as a prioritization metric increases the likelihood that these broader intermunicipal mitigation opportunities could be recognized. By pairing an upstream and downstream watershed together, their aggregate watershed area is more likely to cross a municipal boundary, increasing the likelihood of finding multi-municipal opportunities. The higher the Paired Aggregate Score, the higher the priority.

Each HUC12's three scoring metrics were then divided into five classes identifying their priority level. The five classes were "High", "Moderate/High", "Moderate", "Low" and "No Score" with an assigned numerical value of 4,3,2,1 and 0 respectively. The sum of these three values were tabulated for each watershed and all 42 watersheds were ranked from highest to lowest depending on the sum for each of the three scoring metric (Raw, Norm, Paired).

Based on this ranking, the three highest scoring, and therefore highest priority, watersheds were presented to the Stakeholder Group. The Stakeholder Group provided feedback that the hazards caused by auxiliary spillway discharge during the 2011 flood (Tropical Storm Irene and Lee) should be removed from the prioritization approach because this flood was such a large event it is unlikely for these spillways to be activated again. Four hazard locations were removed (Maine -4, SWCD-19, SWCD-20 and SWCD-22). Refer to the table in Appendix A (A-27 through A-29) for reference about these four hazards.

The prioritization analysis was modified and can be seen graphically in Appendix A (A-30 through A-40) as well as numerically in Appendix A (A-41 through A-48). The top three watersheds for each metric can be seen in Table 4 and graphically in Figure 2. The three watersheds with the highest prioritization scores from the numerical tables in Appendix A (A-41), that will be investigated for flood mitigation solutions are shown in Table 5.

Efforts were taken to ensure that data was collected for all flood hazards throughout the County. However, since the data upon which this analysis was based was dependent on participation from the flood-impacted communities, there may be additional hazards that were not captured for a variety of reasons. For that reason, the database was designed to integrate any hazards identified into the future during updated analysis.

Table 4: Top Three HUC12s for Each Prioritization Metric

Rank	Prioritization Score From Raw Score	Prioritization Score From Normalized Score	Prioritization Score From Paired Aggregate Score
1	Lower Choconut Creek	Belden Brook-Susquehanna River	Little Choconut Creek-Susquehanna River
2	Patterson Creek-Susquehanna River	Jennings Creek	Lower Choconut Creek
3	Thomas Creek-Chenango River	Little Snake Creek	Middle Choconut Creek

Note: The USGS lists Lower Choconut creek as Lower Chocohut creek and is listed as Lower Chocohut creek in the maps

Table 5: Selected Three Highest Priority Watershed

Rank	HUC12 Name	Prioritization Score From Raw Score	Prioritization Score From Normalized Score	Prioritization Score From Paired Aggregate Score	Total
1	Patterson Creek-Susquehanna River	4	3	4	11
2	Lower Choconut Creek	4	2	4	10
3	Thomas Creek-Chenango River	4	2	4	10

Note: The USGS lists Lower Choconut creek as Lower Chocohut creek and is listed as Lower Chocohut creek in the maps

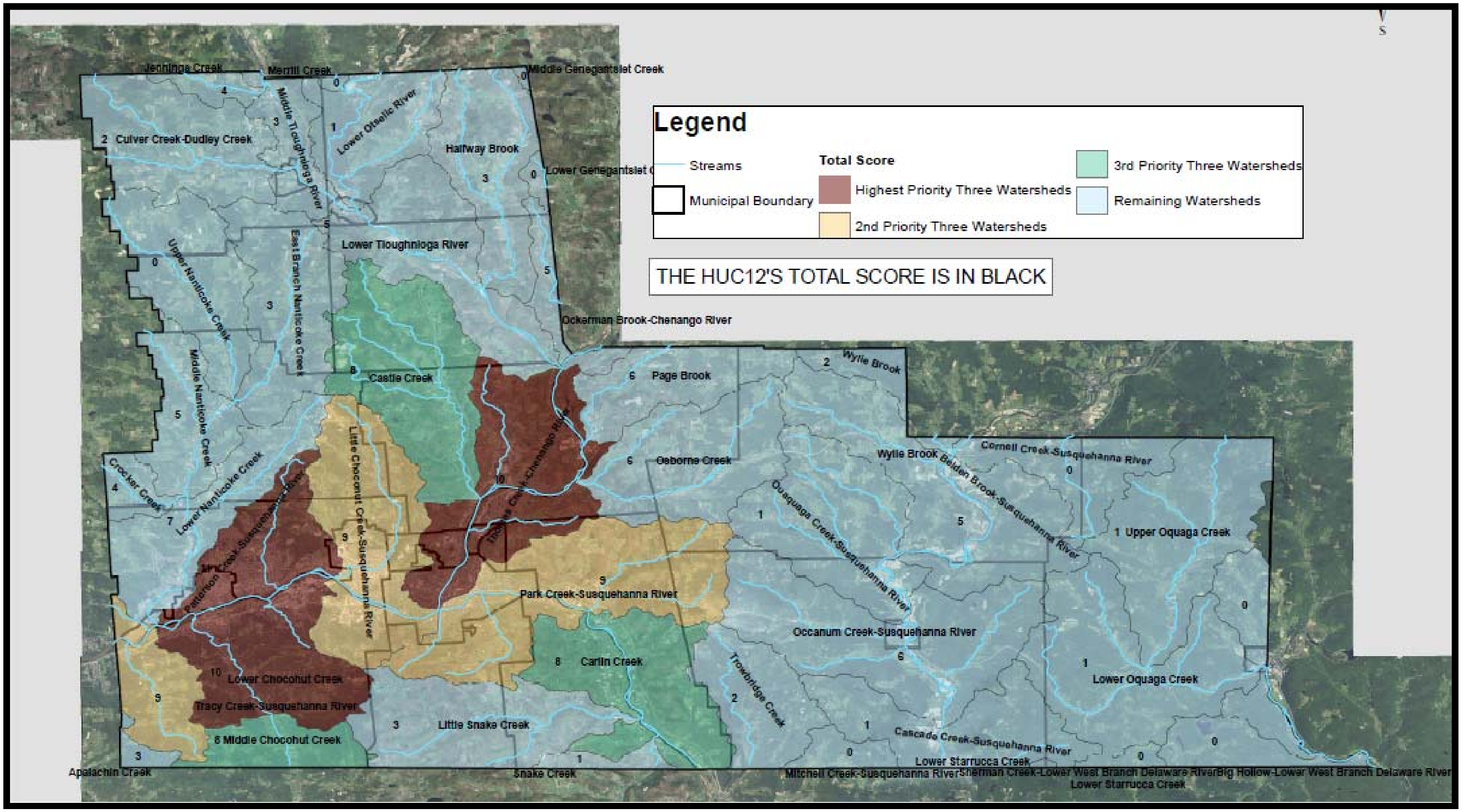

Figure 2: Map of Total Score For All Watersheds

2.4.5 Three Highest Priority Watersheds General Hazard Description

The number of each hazard types (7 total) of the three selected watersheds can be seen in Figure 3 and have the following characteristics:

-Lower Choconut

Erosion and flash flooding are by far the most common flood hazards in the Lower Choconut watershed.

-Patterson Creek,

Stormwater, riverine and flash floods have roughly the same number of hazards, 10, 6 and 5 respectively.

-Thomas Creek

There are more flash flood hazards (8) than any other hazard while stormwater and erosion hazards have the same number (7).

Patterson Creek watershed and Thomas Creek watershed contain four and six municipalities within their drainage areas respectively. There may be flood mitigation opportunities that will have benefits that cross municipal lines in these two watersheds. Lower Choconut Creek only contains the Town of Vestal and its downstream neighbor is not in Broome County so flood mitigation opportunities in this watershed may transcend county boundaries. A more detailed description of each watershed's flood hazard mitigation investigation is included in Section 4.

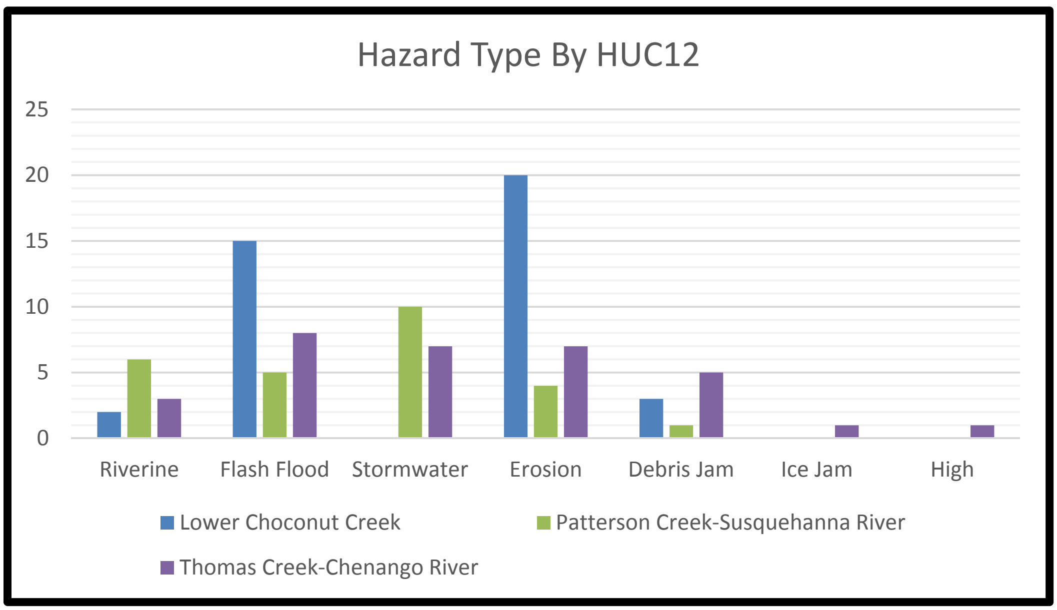

Figure 3: Bar Plot of Hazard Types in the Three Selected Watersheds

2.5 Updating Flood Hazard Identification and Watershed Prioritization

The WFHMP has been designed to be a "living document", to be updated regularly. Optimally, data will be collected annually from municipalities and stakeholder groups. Minimally, the document will be updated once every five years as part of the County's All Hazard Mitigation Plan or after a notable flooding event which has impacted most of the communities in the County. A notable flooding event will be determined by the Broome County Planning Department.

New hazard information and hazard mitigation information will be collected following the methodology in Section 2.2 (step #7 through step #18). The watersheds will be ranked following the protocol in Appendix A (A-49 and A50) and the Total Score, Raw Score, Paired Score and Aggregate Score tables and maps will be produced. It is envisioned Broome County Planning Department will be the keeper of all data and be responsible for updating this plan.

For the next WFHMP update, a new Section will be created, Section 7 with the title "Results and Conclusions: XXXX". The "XXXX" is the year the Plan update occurred. Section 7 will follow the format as described in Section 2.4 including all the tables and figures found in Section 2.4.

3.0 Watershed Flood Mitigation Strategies

3.1 Summary

Broome County's Phase II Watershed Flood Mitigation Plan (WFMP) establishes a protocol to identify potential flood hazard mitigation locations in a watershed and the method to understand if proposed flood mitigation solutions are cost effective. As part of the initial WFMP efforts, the standardized approach was applied to the three highest priority watersheds identified in Phase I: Patterson Creek-Susquehanna River, Lower Choconut Creek, and Thomas Creek-Chenango River.

The approach includes a set of scientific, engineering and geomorphic guidelines (hydraulics, hydrology, etc.) that future flood mitigation investigations in other watersheds shall follow in order to maintain consistency in the Broome County Watershed Flood Mitigation Analysis. The guidelines allow the person completing the scientific, engineering, etc. investigations flexibility to utilize whatever methodology they feel is most applicable as long as the analysis produces results that can be used to develop a benefit to cost ratio.

The goals of this phase of the project are:

- Develop a standardized approach for the identification and design of flood mitigation activities in the County's watersheds.
- Implement the standardized approach for three of the County's high priority watersheds as identified during the prioritization process (in 2015).

Phase II consists of two sections. The first section is the general technical approach to identify locations for flood mitigation solutions in a watershed and how to generate the data needed to complete a benefit to cost ratio. The second consists of multiple sections, one for each studied watershed. In each watershed section, a description of the specific technical methods used to understand the flooding source and the steps to identify flood mitigation solutions can be found, as well as a conceptual mitigation cost and benefit to cost ratio. The second section will expand over time as the rest of the watersheds in Broome County are investigated for flood hazard mitigation solutions. Also, as more flood hazards are investigated in a previously studied watersheds, those Sections will be updated to include the findings.

3.2 Methodology for Identifying Flood Mitigation Locations

To identify an area for proposed flood hazard mitigation activities in a watershed, areas were selected where one or more of the following features were clustered together: Publicly submitted flood hazards, Task Force submitted flood hazards, National Flood Insurance Program (NFIP) repetitive loss locations (RLL) and Special Flood Hazard Areas (SFHA) that contained a large amount of buildings. Dense clusters of these features represent a high concentration of flood hazards and where the highest benefit of flood mitigation could be achieved. These areas, called Flood Mitigation Locations (FML) were assigned unique identification numbers and placed on a map. As the Watershed Flood Hazard Mitigation Plan is updated over time using Section 1's methodology, the number of features will increase or decrease and the location of dense clusters and FML's may change.

Watershed wide interventions such as land use changes or regional detention facilities were investigated first to understand if these strategies could be used to address the flooding problems at FMLs. The goal of land use changes is to reduce peak runoff discharges which result in lower amount of flood waters at the potential FML. Examples of land use changes include: reducing impervious surfaces in the watershed, changing farmland to forested land or converting farmland adjacent to the water course to frequently flooded floodplains (wetlands). Examples of large or small peak discharge detention facilities are a flood protection dam upstream of the FML or smaller detention facilities in the tributaries draining to the FML.

If large physical or geographic solutions were financially or logistically impractical, then localized solutions at the FML were investigated. The goal of the first tier of localized flood mitigation solutions was to increase the volume of flood storage and/or hydraulic capacity for floodwater. One example of providing more flood volume storage is by excavating and removing material in the floodplain effectively lowering the floodplain elevation by creating a floodplain bench. This increases the available area for floodwaters to flow through. Creating a floodplain bench often will reduce floodwater elevations. An example of increasing the volume and hydraulic capacity of conveyed floodwater is to increase the size of bridges or culverts. If a bridge or culvert is obstructing floodwaters by a creating a waterway constriction, this often results in higher upstream water surface elevations (backwater) and unwanted flooding problems. By increasing the opening, more floodwaters will flow through the opening often reducing flood water elevations.

If the first tier of mitigation solutions are not logistically feasible or do not produce the desired reduction in floodwater elevations, the next tier of flood mitigation solutions are structural solutions. These solutions include flood protection facilities such as earthen levees or floodwalls. Also included in this tier of solutions are “protect in place” measures such as flood proofing or elevating buildings. The third and last tier of flood mitigation solution is relocating buildings out of the flooding hazard area using Federal or State buyout or relocation programs. Flood buyouts were deemed the last tier of solutions often because they result in families leaving their communities and a loss of municipal tax base.

3.3 General Flood Mitigation Strategies Approach

3.3.1 Hydrology Analysis

Flood discharge values used in the flood mitigation solution analysis were obtained from the most recent FEMA Flood Insurance Studies (FIS), calculated using the USGS Scientific Investigation Report (2006-5112) methodology or were developed from SCS unit hydrograph methodology. The flood return interval discharges used in this initial effort were the 2-year, 10-year, 50-year and 100-year return intervals.

3.3.2 Hydraulic Analysis

To understand the flooding extents and depths in the flood mitigation locations (FMLs), a hydraulic model was used to develop a relationship between each flood return interval discharge and water depths/extents. There are several watersheds in Broome County that have been studied by FEMA using a detailed flood method. This method requires the use of a hydraulic model software package. If available, this model was obtained for use in the WFMP. If a hydraulic model was not available, then one was created. The information to develop the model’s for non-studied FEMA streams were obtained from topographic survey data and observations collected in the field. The hydraulic software used in the analysis was the US Army Corps of Engineers’ HEC-RAS hydraulic model software.

Hydrologic (flow rate) data was added to the HEC-RAS model and run for the four discharge values creating the existing conditions model. Water depth grid maps were developed using HEC-GeoRAS, and ESRI ArcGIS software extension. Water depth is the resultant of the water surface elevation subtracted by the underlying ground topography. A water depth grid map is a color coded map depicting a range of water depths. A water depth grid map was created for each flood discharge. Color stratification intervals were determined at one foot intervals. One foot intervals match the same interval depth used in FEMA’s Benefit to Cost Analysis (BCA) flood depth-damage curves. Therefore the water depth maps are also used as a tool to determine where the flood damage is the highest. The water depth grid maps are also a useful tool to understand the location of where overbank flooding begins and how deep floodwaters are. This method locates areas of shallow versus deep water which informs where mitigation strategies are most appropriate. This is not possible from Flood Insurance Rate Maps (FIRM) which only shows the 100-year water surface elevation.

Once the existing flooding conditions were understood, flood mitigation strategies were identified. Proposed conditions were then modeled by inserting the proposed mitigation activity into the HEC-RAS model. Examples of modeled mitigation activities include: floodplain manipulation (the creation of a floodplain bench to increase the volume of flood water conveyance), flood protection structures (such as levees or walls) and modified bridge crossings (wider clear spans, higher low chord elevation, etc.). Water depth grid maps under proposed conditions were then developed for each mitigation site to assess the efficacy of the proposed works. The proposed works were then modified iteratively until the desired hydraulic goals such as a certain reduction in water depth were reached. It should be noted that the proposed mitigation solutions are conceptual and should be used for planning purposes only. It is noted that additional detailed design work and environmental investigations will be required to move these strategies towards final design.

For example, the design of the earthen levees are conceptual and will need further investigation (geotechnical, topographic survey, interior stormwater provisions etc.) and detailed design to finalize the final dimensions and alignment. All modeled levees were based on FEMA design criteria for freeboard which requires the top of the levee be 3.0’ above the base flood elevation (BFE which is equivalent to the 100-year return interval flood water surface elevation) and 3.5’ above the BFE at the upstream end of the levee.

3.3.3 Selecting Flood Mitigation Strategies

The following flood mitigation solution flow chart (Figure 4) shall be followed to identify mitigation strategies. Start with basin wide solutions and work through the flow chart until an appropriate mitigation effort is reached. At some flood mitigation sties there may be applicable strategies at varying tiers of flood mitigation solutions. The investigator shall provide documentation that each tier of flood mitigation solution was vetted.

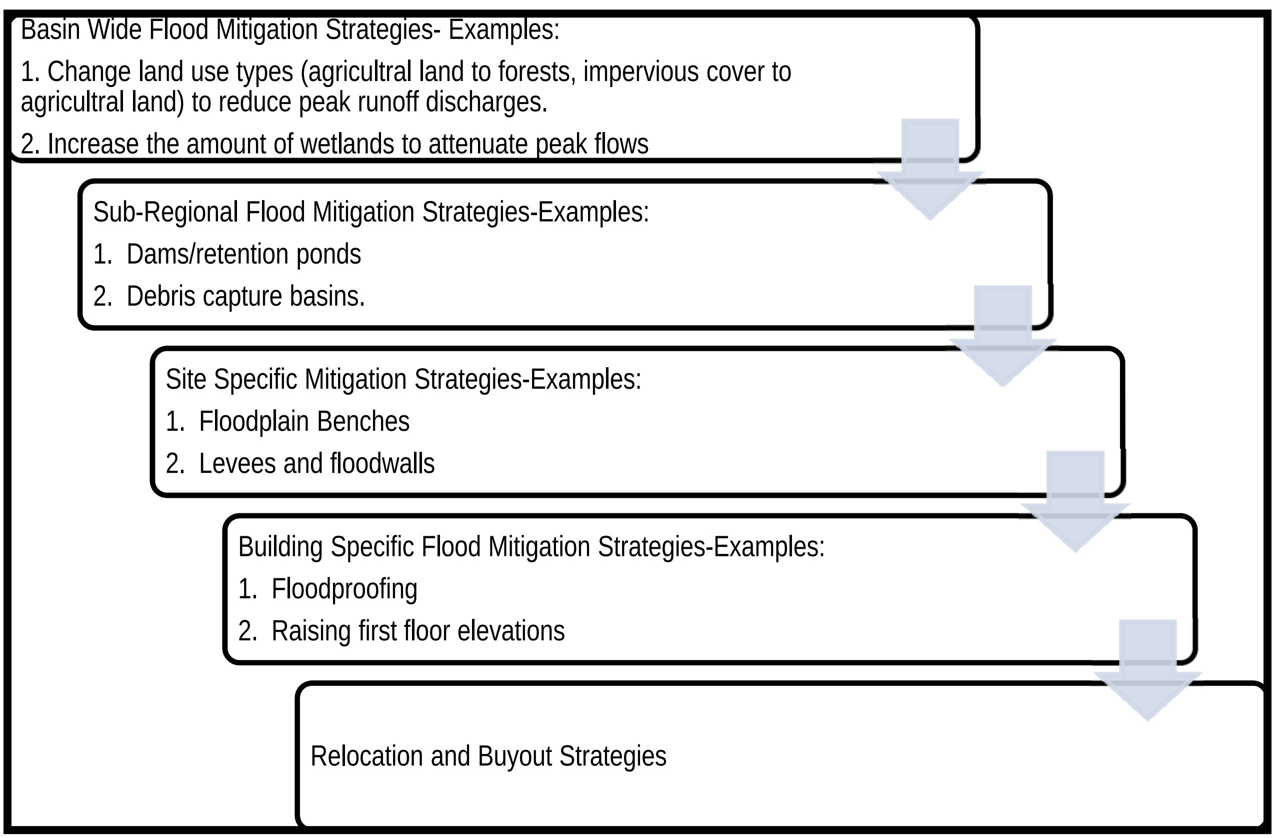

Figure 4: Flow Chart to Identifying Flood Hazard Mitigation Strategies

3.3.4 Calculating the Benefit to Cost Ratio

Flood damage information (the benefit created by the flood protection works) was developed using two methods. For damages incurred by municipalities such as repair to public infrastructure the NYS Division of Homeland Security and Emergency Services' Benefit Cost Analysis (BCA) for Hazard Mitigation Projects template was used. This template identifies which damage costs can be used in the Benefit to Cost Ratio (BCR) and how they need to be documented. The second method used Broome County GIS parcel data and building data.

To calculate the BCR, a building value per square foot was needed. To complete this, building size was measured from Broome County's (County) GIS building shapefile and the building value was calculated from the County's GIS parcel shapefile (2014). First floor elevations were calculated by determining the average adjacent land elevation next to the building using the 2007 LiDAR mapping and adding the height to first floor obtained from field measurements. Water surface elevations were obtained from the existing condition's hydraulic model for the 10-year, 50-year, 100-year and 500-year return interval flood events. This data was then input into FEMA's Benefit to Cost Analysis (BCA) software package (Version 5.1). Using the US Army Corp of Engineers generic depth damage function (DDF) curve embedded in the BCA software, an annual flood damage cost was calculated.

Planning level construction costs for the proposed flood mitigation works were determined for each flood mitigation site. If earthen levees or concrete floodwalls are needed, their costs were developed using FEMA's Technical Manual 551 "Selecting Appropriate Mitigation Measures for Floodplain Structures". For earthen levees, this reference recommends $106 per linear foot and $170 per linear foot as a general unit cost estimate for levees that are 4 feet above the ground and 6 feet above the ground respectively. Since this manual was issued in 2008 a 20% adjustment was added to all unit costs to adjust to 2015 dollars. For concrete walls, a $900 per linear foot cost was used. This was developed from previous flood mitigation work WEC has completed in Broome County for a 4' exposed vertical stem T-wall with an underground foundation.

The cost of the proposed pumping stations were based on WEC's flood mitigation experience by determining the size of the interior drainage area, available storage areas and the amount of grading or underground water conveyance systems that would be needed to direct flow towards the pumping stations. For all mitigation activities that required a barrier system, a cost to acquire a permanent right of way was assumed based on the size of the barrier's footprint.

The proposed benefits and planning level construction costs were then input into FEMA's BCA software and the short form of the software's Flood Module was used to develop the Benefit to Cost Ratio. Using FEMA's "BCA Reference Guide" (June 2009), a value of 67 years was selected as the project's useful life span. A benefit to cost ratio was then calculated for each home or infrastructure feature that was being protected by the proposed mitigation works using the BCA software. The individual BCR values were then summed to compute the proposed mitigation project's final BCR value.

3.4 Updating Watershed Flood Mitigation Strategies

In the next iteration of the WFHMP, additional watersheds may have been investigated for flood mitigation strategies. Broome County will continue to pursue funding opportunities for further analysis of additional priority watersheds, as well as assist local municipalities in conducting their own analyses. As these analyses are completed, they will be integrated into the plan in the following manner. A new Section will be created for each watershed starting with Section 8.0 with the title "YYYY Watershed Proposed Flood Mitigation Activities". The "YYYY" stands for the name of the watershed. The methodology for investigating flood mitigation strategies will follow the protocol outlined in Section 3.0 which was used to investigate the three highest priority watersheds as part of this initial effort. It is envisioned this information will be developed by the County Planning Department using a professional service provider.

It is recommended that in updates of the WFHMP, the BCR method should not be the only criteria to prioritize flood hazards along flooded roadways and homes. After the initial efforts, it was discovered using the BCR alone will make it difficult to economically justify projects. In applying the BCR method to protecting flooded homes, property values were not high enough to justify protecting them because the cost of construction of the proposed mitigation strategies were often much higher than the benefit gained from them. In applying the BCR method to protect flooded roadways, the benefits gained from flood mitigation activities such as detours and interruption of first responder services were not large so the cost of the flood mitigation activities were often much higher.

It is recommended additional metrics be used along with the BCR to justify implementing flood mitigation activities. Another recommendation may be for the Flood Task Force to take an active role to encourage state and federal funding that takes these into account (such as additional funding under the NY Rising program).

Each watershed will have its own Section. In this example the Section's number is "X". Each Section will be broken into sections and sub-sections. There will be one section for each proposed mitigation site. In Table 6 below describes how the Section should be formatted.

Table 6: Outline of New Sections for Previously Not Investigated Watersheds.

Section	Sub-section	Section Title	Note
X@.0		<u>"Watershed Name" Proposed Flood Mitigation Activities</u>	
	.0.1	Watershed Background	Insert information about that watershed. Municipality, land use, type of hazards, etc.
	.0.2	Flood Mitigation Site	Description and location of sites, include a map, add to this section as more flood mitigation sites are identified
	.0.3	Watershed Hydrology	General description of hydrologic analysis approach. Where existing information was obtained, how data was collected, etc.
	.0.4	Watershed Hydraulics	General description of hydraulic analysis approach. Where existing information was obtained, how data was collected, etc.
	.0.5	Flood Mitigation Summary	Summary of what mitigation strategies were found, which had favorable results.
X@.1		Proposed Mitigation Site's Number	
		Background	Location, number of buildings at site, other site characteristics
		Existing Hydraulic Conditions	Summary of existing hydraulic conditions
		Proposed Hydraulic Conditions	Summary of hydraulic conditions after intervention, image of proposed interventions
		Benefit Cost Ratio	Benefit to Cost Ratio Findings
		Funding Opportunities	Possible Funding Opportunities
@Represents the New Section Number			

For new flood mitigation strategy investigations in watersheds that have already been studied, all of the sub-sections in section ".0" as described in Table 7 below.

Table 7: Outline of Existing Sections For Previously Investigated Watersheds.

Section	Sub-section	Section Title	Note
Y[#].0			
	.0.W[$]	Flood Mitigation Summary: Updated ZZZZ[%]	Summary of what mitigation strategies were found, which had favorable results.
Y[#].1		Proposed Mitigation Site's Number	
		Background	Location, number of buildings at site, other site characteristics
		Existing Hydraulic Conditions	Summary of existing hydraulic conditions
		Proposed Hydraulic Conditions	Summary of hydraulic conditions after intervention, image of proposed interventions
		Benefit Cost Ratio	Benefit to Cost Ratio Findings
		Funding Opportunities	Possible Funding Opportunities
[#]Represents the Existing Section's Number			
[$]Represents the next subsection number in numerical order			
[%]Represents the year the new flood mitigation strategy was completed.			

4.0 Lower Choconut Watershed Proposed Flood Mitigation Activities

4.0.1 Watershed Background

Choconut Creek is a tributary to the Susquehanna River in the Town of Vestal that flows north from the Town's border with Pennsylvania towards the River. Lower Choconut, the northernmost HUC12 watershed before its the confluence with the Susquehanna, is 6.32 mi^2 in size either drains into the creek or directly into the Susquehanna River. In general, land use in this watershed consists of mostly residential land. However, there is a highly developed commercial area, with some adjacent residential development, located in the northern portion of the watershed, along Route 434, closer to the Susquehanna River. In general residential development is rural in nature, throughout most of the watershed, with higher density residential along Choconut Creek and adjacent to the commercial areas. Land cover outside of the developed areas is mostly forested, with some pastureland and limited cropland interspersed throughout the landscape.

4.0.2 Mitigation Sites: 2015

Six proposed mitigation sites were identified in the Lower Choconut watershed (HUC12# 020501030205) as be seen in Figure B-1 (Appendix B) and below in Figure 5. The entire HUC12 is located within the Town of Vestal municipal limits.

Mitigation Site 1: Located in the Town of Vestal, adjacent Coleman Road (42.033114°, -76.019573°) and is bordered to the north by West Hill Road (42.031482°, -76.017153°).

Mitigation Site 2: Located in the Town of Vestal adjacent to Gary Drive (42.046374° -76.029121°)

Mitigation Site 3: Located in the Town of Vestal and is bordered to the north by the Juneberry Road crossing over Choconut Creek (42.052542°, -76.035232°).

Mitigation Site 4: Located in the Town of Vestal and is bordered to the north by the Meeker Road crossing over Choconut Creek (42.063112°, -76.039760°).

Mitigation Site 5: Located in the Town of Vestal and is bordered to the north by the Main Street crossing over Choconut Creek (42.069773°, -76.041754°).

Mitigation Site 6: Located in the Town of Vestal and is bordered to the north by the Main Street crossing in Mitigation Site 5 over Choconut Creek (42.069773°, -76.041754°) and to the south by another Main Street crossing of Choconut Creek (42.071261°, -76.046800°)

Three sites from the original six flood hazard mitigation sites were selected using a preliminary benefit to cost analysis (BCA). The benefit to cost ratio is a calculation dividing the prevented flood damage in dollars by the cost of the proposed flood mitigation project costs. The preliminary BCA was completed by counting the number of homes or critical infrastructure that would be protected (the benefit) versus the potential costs (capital and operating and maintenance costs) of the flood protection project (the cost). These three sites were believed to have a reasonable benefit to cost ratio for this preliminary BCA around or greater than 1.0 meaning the benefits would meet or exceed the costs of the project. These three sites were Mitigation Sites 6, 5 and 3. It is recommended that the remaining sites be considered for future investigations and subsequent iterations of the WFHMP.

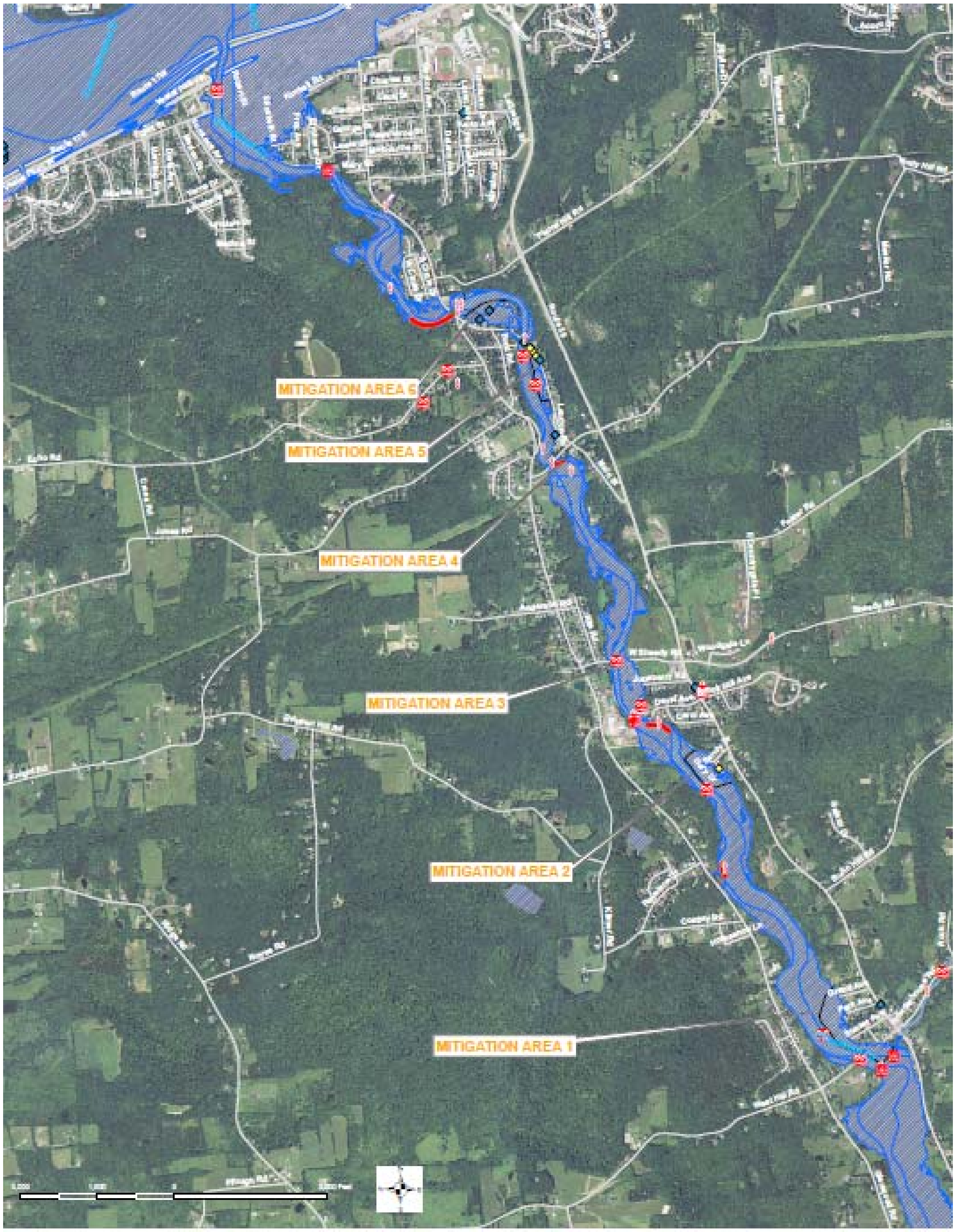

Figure 5: Location Map of Lower Choconut Proposed Flood Mitigation Sites

4.0.3 Watershed Hydrology

The Flood Insurance Study (FIS) for the Town of Vestal, NY (community #360057) completed in 1998 was obtained and reviewed. The 10-year, 50-year and 100-year return interval flood discharge values from the FIS were then plotted. A line of best fit was plotted for the three FIS discharge values and the 2-year and 5-year return interval flood discharges were calculated using extrapolation of the line of best fit. The discharges used in the analysis are listed in Table 8.

Table 8: Flood Discharges for Mitigation Sites In Choconut Creek

Return Interval Flood	FIS Discharge (cfs)
2-year	3,900
5-year	5,900
10-year	7,800
50-year	9,850
100-year	11,750

4.0.4 Watershed Hydraulics

Flood Mitigation sites #6, #5 and #3 had been studied by detailed method as part of the 1998 FIS. The detailed study was completed using the US Army Corps of Engineers (USACE) HEC-2 program and an electronic copy of the model was not available. Also, since the 1998 FIS was completed, the two Main Street Bridges in mitigation sites #6 and #5 have been replaced. For these reasons, a new hydraulic model was developed using the USACE HEC-RAS program. To create the HEC-RAS model, a field investigation was completed to obtain topographic information using a RTK GPS survey of the stream channel geometry. Light Detection and Ranging (LiDAR) data (surveyed in 2007) was obtained and used for floodplain topography. In-channel and floodplain relative roughness values were determined from field observation and published values.

This geometric information was used to develop the HEC-RAS hydraulic model. Interpolated cross sections were then created using HEC-RAS's cross section interpolation function. Cross sections for the three sites can be seen in Figure B-2 and Figure B-3 (Appendix B).

4.0.5 Flood Mitigation Solutions Summary from the WFHMP's Initial Efforts

For the Lower Choconut Watershed, six (6) potential mitigation sites were identified and ultimately three sites underwent detailed analysis for flood mitigation solutions. The analyses for each mitigation site can be found in the in the following sections. The major findings of these analyses are as follows. There are potentially a dozen homes in mitigation site six (6) that may not be in a Special Flood Hazard Area and consequently may not need to pay high flood insurance annual premiums and a Letter of Map Change (LMOC) should be pursued. The flood mitigation solutions for sites #6 and site #5 produced BCRs of 0.64 and 0.62 respectively which reduces the likelihood of securing funding from federal sources but may make them more competitive for state funding. Mitigation Site #3's BCR was 1.66 which makes it very competitive for federal funding and NYSDOT state funded programs.

4.1 Proposed Flood Mitigation Site #6

Background

Proposed Treatment Area #6 is located between the two Main Street Bridges approximately 2.0 miles upstream of the Lower Choconut Creek and the Susquehanna River confluence in the Town of Vestal. Four (4) submitted erosion hazards are within this treatment area. The Town of Vestal also identified a 700' long section of sewer line that needs chronic protection due stream bank instability. Sixteen (16) homes are located within the SFHA along with two (2) NFIP repetitive loss locations. The hydraulic goals of this mitigation project area is to remove the homes from the SFHA and reduce velocities during the 10-year return interval flood at the sewer line location.

Existing Hydraulic Conditions

Inundation of the homes in the SFHA begins between the 25-year flood event and the 50-year flood event proximal to stream cross section 1747. Each home in the SFHA was given an arbitrary identification number. Floodwater spills over the top of bank at a low point and inundates homes LC54, LC52 and LC59 (Figure B-4, Appendix B). The maximum water depth is 1.3'. No other homes are inundated during the 50-year flood event. During the 100-year return interval flood, the water continues to overtop the stream banks near section 1747 and the maximum depth of water increases to 3.0' and inundates home LC56 (Figure B-5, Appendix B).

Additional floodwater overtops the stream banks between sections 323 and 710 and inundates house LC60. It is noteworthy that the WEC analysis shows only five homes are inundated during the 100-year return interval flood, not the 16 homes that are listed in the SFHA. The water surface elevations used to delineate the SFHA were calculated in the 1998 FIS. A review of the FIS 100-year flood water surface profile (Figure B-6, Appendix B) showed the downstream Main Street Bridge caused a backwater condition, i.e. it was an obstruction to flood flow causing the water surface to rise. The downstream Main Street Bridge was replaced after the 1998 study was completed. Since the WFMP analysis used the newer Main Street bridge geometry in the modeling efforts, it is likely the newer bridge has more hydraulic capacity resulting in lower 100-year water surface elevations than in the governing Flood Insurance Rate Maps. This means some homes that are listed in the SFHA may be paying a higher flood insurance premium than need be.

Proposed Hydraulic Conditions

The drainage area for Mitigation Site #6 is 55.5 mi^2 with a large portion of the watershed located to the south in Pennsylvania. With a drainage are this large and a large portion of the watershed in a different state, land use changes or increasing the amount of wetlands within the drainage area will be logistically challenging to coordinate and will have a negligible impacts at reducing peak discharges and flood water elevations at Mitigation Site #6. Large detention basins (dams, etc.) are also not practicable with a drainage area this large.

Three mitigation approaches were evaluated and modeled to understand the optimal mitigation approach to prevent the homes from being inundated. The three methods were: floodplain manipulation (excavating a floodplain bench to increase flood water conveyance), flood protection barrier (to cut off the floodwaters from entering the areas around the homes) and a combination of the floodplain manipulation and flood protection barriers.

After modeling the three approaches, the optimal mitigation approach to prevent inundation of the five homes was using a flood protection barrier (an earthen levee). Two proposed levee locations are needed to prevent inundation and can be seen in B-7 and Figure 6. The total length of levee is 1,100'. The average height of the levee is 3.5' with a top width of 10' with 3 horizontal to 1 vertical side slopes along the berm. A typical section view of a proposed levee can be seen in B-8. The levees prevent the homes from being inundated and result in a negligible rise of the BFE (100-year flood) as seen in Table B1 in Appendix B (p. B-42) and summarized in Table 9. In addition to modeling water surface elevations, the speed of water (velocity) was also assessed to evaluate if the proposed works reduce the speed of water and the erosion at the Town's sewer line. The 10-year return interval flood was used for this analysis because it is a moderately sized frequent flood event that likely produces erosion. The proposed flood mitigation works do not reduce the speed of water at the downstream end of the project (HEC RAS cross section number 243) and therefore does not benefit the eroding streambank at the Town's sewer line.

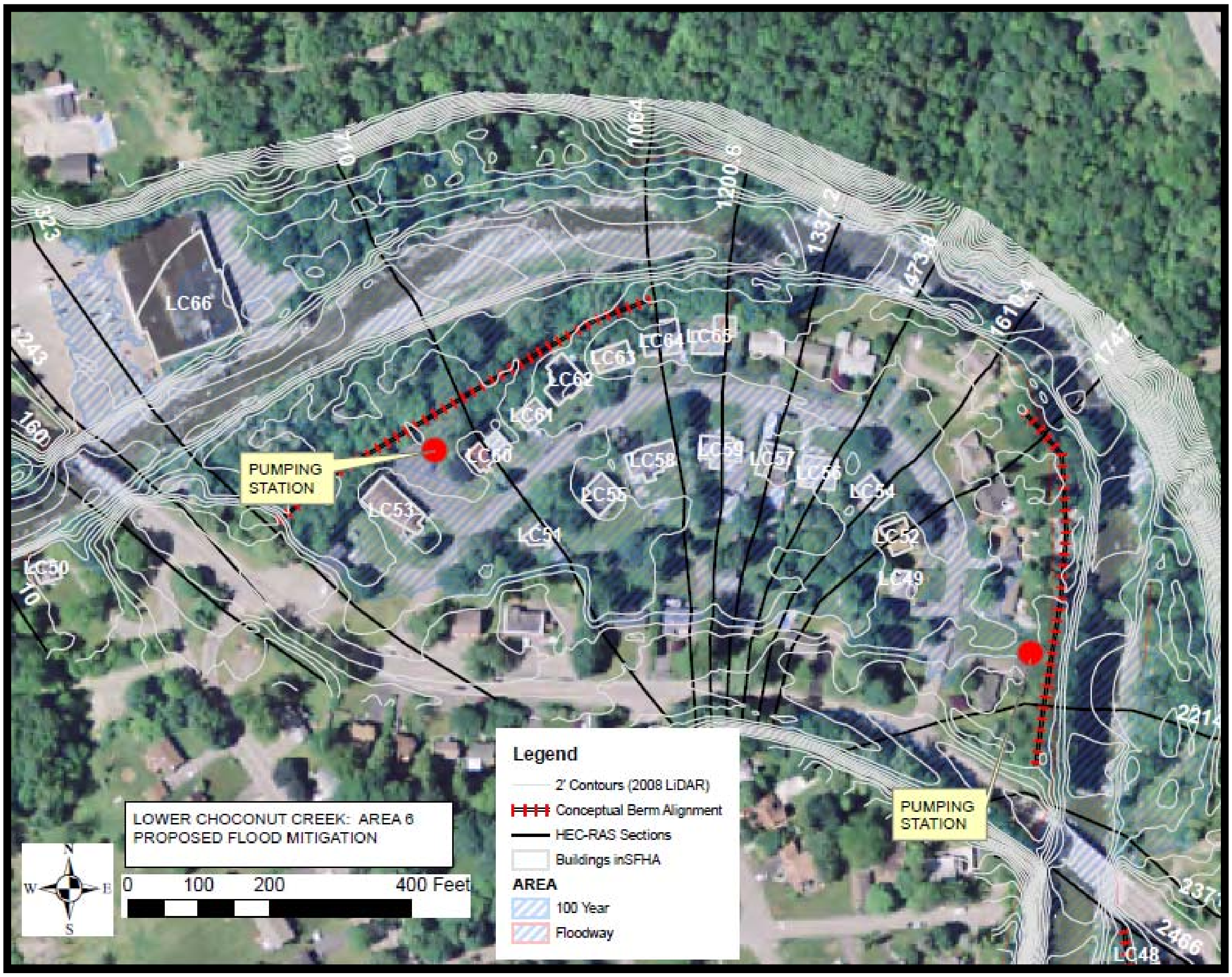

Figure 6: Location Map of Proposed Mitigation Activities at Site #6

Table 9: Existing and Proposed Hydraulic Conditions for Flood Mitigation Site #6

I HEC-RAS Section	100-year Water Surface Elevation			10-year Velocity		
	Existing Condition	Proposed Conditions:	Difference (ft)	Existing Conditions ft/sec	Proposed Conditions ft/sec	Difference ft/sec
2214	886.22	886.21	-0.01	11.27	11.27	0
1337	876.64	876.66	0.02	11.76	11.76	0
243	872.38	872.38	0	7.69	7.69	0

Benefit Cost Ratio

The total length of proposed berm was 1,100 feet and its maximum height was 3.5'. The 4.0' high earthen berm unit cost was increased from $130 per linear foot to $175 per linear foot because rip rap has been proposed to armor the river side of the levee. A conceptual berm alternative can be seen in a typical section view in B-8. Two pumping stations will be needed to pump the interior stormwater on the landward side of the levee that will be trapped during stream flooding conditions. The pumping stations would pump stormwater from less than a 0.5 acre of land and thus needs only minor grading to direct flow towards the pumping stations (see B-7, Appendix B). A cost to acquire a permanent right of way was also calculated using the berm's footprint and a unit area cost. The proposed mitigation cost can is shown in Table 10.

Table 10: Conceptual Construction Costs for Flood Mitigation Site #6

Cost Item	Item Description	Unit	Quantity	Unit Cost	Subtotal
1	3.5' High Earthen Levee	LF	1,100	$175	$192,500
2	Pumping Station	EA	2	$125,000	$250,000
3	Right of Way Acquisition	Acre	0.75	$100,000	$75,000
Grand Total					$517,500

The first floor elevations of all five homes being inundated during the 100-year flood were entered into the BCA software and a BCR was calculated for each home and summarized to calculate the project's overall BCR which is 0.64 (see B-9 in Appendix B). This investigation showed that several homes may not be in the Special Flood Hazard Area and consequently may not need to be paying high flood insurance rate premiums. It is recommended that a letter of map revision be completed to remap the SHFA in this neighborhood which is the first step in reducing these homeowner's flood insurance premiums.

Funding Opportunities

Since the BCR for this project came out to less than 1.0, there are several funding opportunities this project could apply for. They are as follows.

- U.S. Army Corps of Engineers: Small Flood Damage Reduction Projects (Section 205 of Flood Control Act)
- Emergency Streambank and Shoreline Protection (Section 14)
- New York Rising Funds
- New York State HMGP

4.2 Proposed Flood Mitigation Site #5

Background

Proposed Flood Mitigation Site #5 is located directly upstream of Site #6 beginning at the upstream Main Street bridge in the Town of Vestal and extending approximately 1,500 feet upstream. This site can be seen in Figure B-2, Appendix B. Using the preliminary effective digital Federal Insurance Rate Map (DFIRM) boundaries, seventeen (17) homes are located within the SFHA along with four (4) NFIP repetitive loss locations. Two flash flood hazards and one erosion hazard location were submitted by the Flood Task force and the public. The hydraulic goals of this mitigation project were to remove the homes from the SFHA and reduce velocities at the Main Street Bridge.

Existing Hydraulic Conditions

The 17 homes in the SFHA are inundated by floodwater beginning at the 50-year return interval storm with overbank flooding beginning at the Main Street Bridge and extending all the way through the study area. Water depth increases around all homes during the 100-year flood and eight homes have floodwater above their first floor elevations. Water depth maps can be seen in B-10 and B-11, Appendix B and houses LC40, LC41, LC35-LC38 and LC32 all have water over their first floor elevations. The Main Street Bridge is not overtopped during the 100-year return interval flood and does not appear to cause any deleterious flooding conditions as can be seen on the water surface profiles in B-12, Appendix B. All the homes that are flooded are on the west side of Main Street and the DFIRM boundaries are approximately the same as the 100-year flood water extents created from WEC's hydraulic analysis.

The WFHMP's hydraulic investigation showed that only eight of the 17 homes in the SHFA have water over the first floor elevations. This means the remaining nine landowners, if they carry flood insurance, maybe paying higher annual insurance premiums than need be. First floor elevations are one of several factors (lowest adjacent grade, building type, etc.) that effect insurance premiums. WFHMP recommends that these property owners consider exploring how these building owners can lower their flood insurance premiums or eliminate the need for insurance all together.

Proposed Hydraulic Conditions

The same constraints for watershed wide land use changes or detention facilities at Mitigation Site #6 also exist for Mitigation Site #5. Three mitigation approaches were evaluated and modeled to understand the optimal mitigation approach to prevent the homes from being inundated. The three methods were: floodplain manipulation (excavating a floodplain bench to increase flood water conveyance), flood protection barrier (to cut off the floodwaters from entering the areas around the homes) and a combination of the floodplain manipulation and flood protection barriers. After modeling the three approaches, the optimal mitigation approach to prevent inundation of the seventeen homes was using a combination of a flood protection barrier (an earthen levee) with floodplain manipulation (floodplain bench).

One levee was needed to prevent inundation as shown in B-13, Appendix B and in Figure 7. The total length of the proposed levee is 1,450'. The average height of the levee is 5.5' with a top width of 10' and 3 horizontal to 1 vertical side slopes along the berm. A typical section view of a proposed levee can be seen in B-14, Appendix B. A typical section view of how a proposed levee was modeled can be seen in B-15, Appendix B. Starting at the upstream Main Street Bridge and extending up to cross section 3326, a floodplain bench was needed to offset the rise in the 100-year water surface elevation the flood barriers created. The flood plain bench is on average 1.5' deep, 60' wide and is 850' long. It is envisioned that the floodplain bench would be a grassy mowed field instead of the existing forested floodplain. The combination of these two measures prevent the 17 homes from being inundated and generally result in a lower 100-year water surface elevation except at cross section 2759 which has a negligible rise of the BFE. See Table B2 (p. B-43) and Table 11 below for representative hydraulic results near the upstream extent, middle and downstream extent of the modeling area. The proposed works do not reduce water speed (velocity) at the bridge and result in a slight velocity increase which should not be detrimental to the Main Street Bridge (this should be confirmed in final design phase).

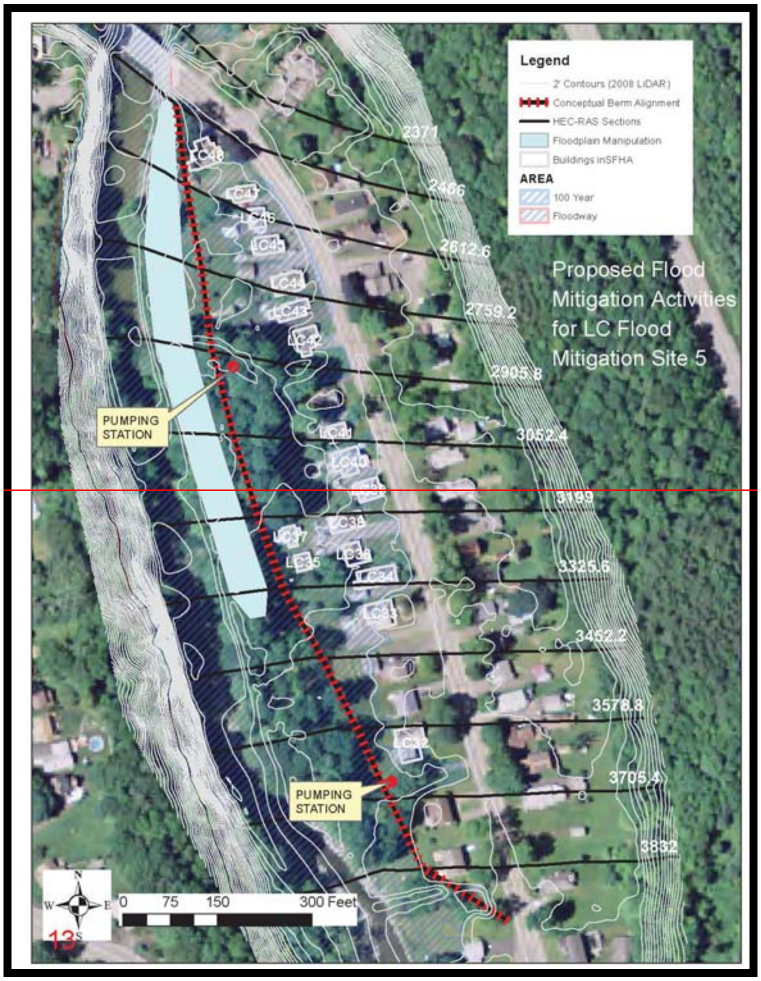

Figure 7: Location Map of Proposed Mitigation Activities at Site #5

Table 11: Existing and Proposed Hydraulic Conditions for Flood Mitigation Site #5

HEC-RAS Section	100-year Water Surface Elevation			10-year Water Velocity (ft/sec)		
	Existing Conditions:	Proposed Conditions:	Difference	Existing Conditions:	Proposed Conditions	Difference
3705.4	895.06	894.78	-0.28	7.05	6.61	-0.44
3119	893.17	892.77	-0.4	7.96	7.35	-0.61
2616.2	888.95	888.35	-0.6	10.19	10.47	0.28

Benefit Cost Ratio

The total length of proposed berm was 1,450 feet with an average height of 5.5'. The 6.0' high earthen berm unit cost was increased from $196 per linear foot to $265 per linear foot because rip rap has been proposed to armor the river side of the levee. Two pumping stations are needed to pump the interior stormwater that during pre-mitigation conditions would drain into the creek but now are trapped on the landward side of the levee. Pumping station "A" and pumping station "B" as seen in Figure 7 and B-13 will drain approximately 2.7 acres and 1.3 acres respectively and both will only need minor grading to direct flow towards the pumping stations. A cost to acquire a permanent right of way was calculated using the berm's footprint and a unit area cost. The proposed mitigation cost can be seen in Table 12 below the subtotal values have been rounded for planning purposes).

Table 12: Conceptual Flood Mitigation Costs for Flood Mitigation Site #5

Cost Item	Item Description	Unit	Quantity	Unit Cost	Subtotal
1	3.5' High Earthen Levee	LF	1,450	$265	$384,000
2	Pumping Station "A"	EA	1	$250,000	$250,000
3	Pumping Station "A"	EA	1	$160,000	$160,000
4	Right of Way Acquisition	Acre	1.3	$100,000	$130,000
Grand Total					$924,000

The first floor elevations of all eight homes being inundated during the 100-year flood were entered into the BCA software and a BCR was calculated for each home and summarized to calculate the projects overall BCR which is 0.62 as seen in Figure B-16 in Appendix B.

Funding Opportunities

Since the BCR for this project came out to less than 1.0, there are several funding opportunities this project could apply for. They are as follows.

- U.S. Army Corps of Engineers: Small Flood Damage Reduction Projects (Section 205 of Flood Control Act)
- Emergency Streambank and Shoreline Protection (Section 14)
- New York Rising
- New York State HMGP

4.3 Proposed Flood Mitigation Site #3

Background

Flood Mitigation Site #3 begins at the Juneberry Road bridge crossing and extends 2,100' upstream as shown in Figure 3, Appendix B. Using the preliminary effective digital Federal Insurance Rate Map (DFIRM) boundaries, fifteen (15) homes, two (2) flash flood hazards, one (1) erosion hazard and one (1) riverine hazard were submitted by the Flood Task force and the public. Flooding inundation occurs primarily along the east bank of Choconut Creek as the west bank is generally higher than the 100-year flood elevation. The hydraulic goals of this mitigation project were to remove the homes from the SFHA.

Existing Hydraulic Conditions

Inundation of the homes in the SFHA begins at the 10-year return interval flood beginning just upstream of the Juneberry Road Bridge crossing of Choconut Creek and continuing through Flood Mitigation Site #3. Most of the homes closest to the creek are inundated with 1' to 2' of water as seen in B-17, Appendix B. Water depths increase during the 100-year flood as seen in Figure B-18. The Juneberry Road Bridge obstructs floodwaters beginning at the 10-year flood. This can be observed by the flattening of the water surface profile slope at and immediately upstream of the Juneberry Road Bridge as seen in B-19. The obstruction caused by the bridge results in higher upstream water surface elevations causing inundation of the upstream homes.

Proposed Hydraulic Conditions

The drainage area for Mitigation Site #6 is 51.8 square miles with a large portion of the watershed located to the south in Pennsylvania. With a drainage area this large and a large portions of the watershed in a different state land use changes or increasing the amount of wetlands within the drainage area will be logistically challenging to coordinate and will have a negligible impacts at reducing peak discharges and flood water elevations at Mitigation Site #3. Detention basins (dams, etc.) are also not practicable with a drainage area this large.

The proposed mitigation solution for the Juneberry Bridge crossing consists of raising the low chord of the bridge 2.5' while maintaining the existing clear span width. This results in a reduction in water surface elevations during the 10-year flood event such that flooding is reduced on average to less than 0.5' surrounding the homes (below the first floor elevation) (see B-20, Appendix B). The homes are still inundated during the 100-year flood (although with a slight reduction in water depths) as seen in Figure B-21, Appendix B. Therefore, increasing the low chord elevation of the bridge improves flooding conditions at this area beginning at a more frequent (10-year) flood event however does not completely solve flooding problems during larger floods. Completely removing the bridge reduces water elevation directly at the bridge but this benefit mostly disappears at the homes and only a slight reduction (0.5') occurs as seen in B-22, Appendix B.

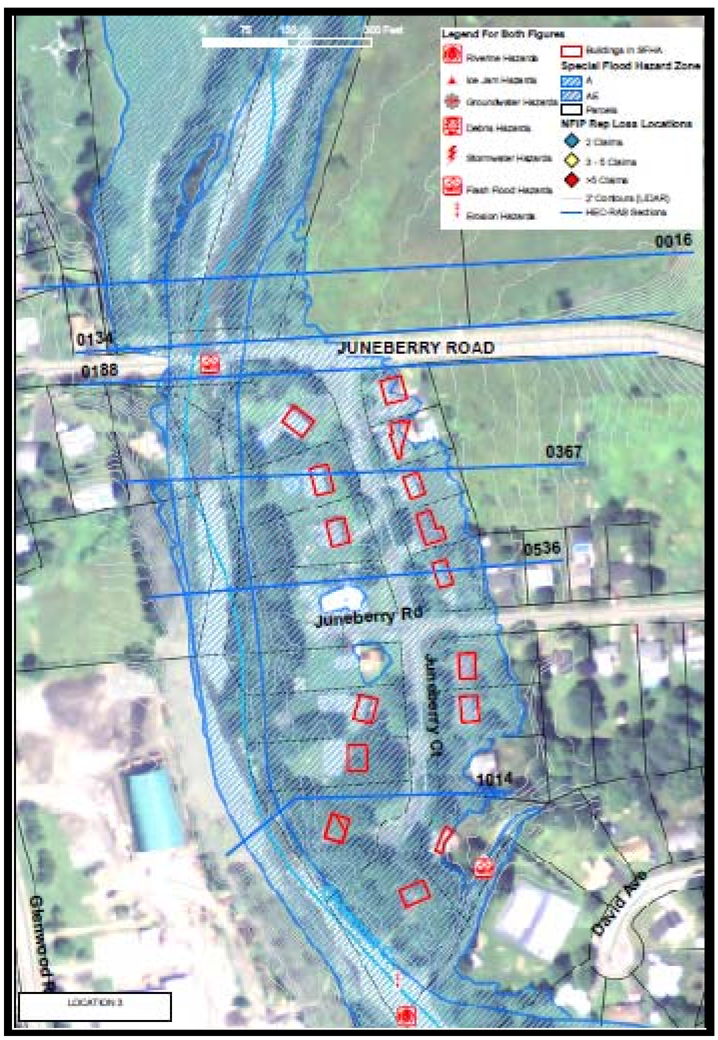

Figure 8: Location Map of Proposed Mitigation Activities at Site #3

Benefit Cost Ratio

The Juneberry Road Bridge enhancement will raise the low chord elevation 2.5'. The eastern approach road and western approach road will have to be raised and graded to meet the new bridge deck elevation. The proposed bridge replacement cost is $1,325,000 and can be seen in Table 13 below.

Table 13: Conceptual Flood Mitigation Costs for Flood Mitigation Site #3

Cost Item	Item Description	Unit	Quantity	Unit Cost	Subtotal
1	Procure and Install 85' Clear Span Super Structure	EA	1	$850,000	$850,000
2	Procure and Install Sheet Pile Abutment	EA	2	$95,000	$190,000
3	Grade and repave Juneberry and Sheedy Road Intersection	LS	1	$75,000	$75,000
4	Grade and repave Western Bridge Approach	LS	1	$45,000	$45,000
5	Traffic Control to Maintain Existing Bridge Alignment	LS	1	$25,000	$25,000
6	Remove and Dispose of Existing Bridge	LS	1	$140,000	$140,000
Grand Total					$1,325,000

The following buildings first floor elevations were above the 100-year water surface elevation and were omitted from the BCR analysis: LC30, LC69, LC70, LC72 and LC75. The remaining buildings in the SFHA were included in the BCR and the resultant BCR was 1.66 as seen in B-23. The water surface elevation at buildings LC 68, LC 71, LC 73 and LC74 did not change from existing and proposed conditions hence there was no benefits in the BCR. The main benefit of this project was eliminating the flood threat to some homes and reducing the threat to others.

Funding Opportunities

Since the BCR was more than 1.0, there are several funding opportunities this project could apply for. They are as follows.

- FEMA's Pre-Disaster Mitigation (PDM),
- Federal and State Hazard Mitigation Grant Program (HMGP),
- Flood Mitigation Assistance (FMA)
- New York State HMGP

5.0 Thomas Creek/Chenango River Watershed Proposed Flood Mitigation Activities

5.0.1 Watershed Background

The Thomas Creek-Chenango River HUC12 watershed (referred to as Thomas Creek watershed for the remainder of this section) is contained mostly within the Towns of Chenango and Fenton, but also includes small parts of the Towns of Dickinson and Kirkwood, the Village of Port Dickinson, and the City of Binghamton. This watershed is 31.64 mi^2 and contains the portion of the Chenango River downstream from its entry into Broome County from Chenango County. The watershed also contains Thomas Creek, a tributary that flows south to the Chenango River from Kettelville to the north, and Phelps Creek, a tributary to the Chenango River that flows from Kirkwood to the east, and their drainage areas. This watershed is highly variable in terms of land use with residential, mostly rural land uses dominating in the northern upstream reaches of the watershed, and more commercial and industrial development, along with more dense residential development dominating from the Chenango Bridge area to the watershed boundary downstream. The more densely developed areas are dominated by impervious surface, while the more rural areas are a mix of forest and agricultural land.

5.0.2 Mitigation Sites: 2015

Five (5) mitigation sites were identified in the Thomas Creek/Chenango River watershed (HUC12# 020501020810) and can be seen in Figure B-24 and in Figure 9 below.

Mitigation Site 1: Located in the Town of Chenango southeast of Upper Front Street and northwest of the Chenango River. This location is bordered to the east by Matthews Road (42.167757°, -75.883675°) and to south by Quinn Road (42.161789°, -75.890658°) within FEMA's detailed study area.

Mitigation Site 2: Located in the Town of Chenango, just south of the Castle Creek, Chenango River confluence 42.158967°, -75.892416°) between Upper Front Street and the Chenango River. The Weis Supermarket and the Town's drinking water intake are located in this area.

Mitigation Site 3: Located in the Town of Dickinson, west of Upper Front Road (42.136593°, -75.905099°) near the intersection of Upper Front Road with Boland and Jameson Roads.

Mitigation Site 4: Located in the Town of Fenton at the intersection of Canal Street and Albany Street (42.164680°, -75.834783°) where an unnamed tributary passes under the road.

Mitigation Site 5: Located in the Village of Port Dickinson along Rochelle Road (42.141137°, -75.889806°).

Two sites from the original five flood hazard mitigation sites were selected using a preliminary benefit to cost analysis (BCA). The preliminary BCA was completed by counting the number of homes or critical infrastructure that would be protected (the benefit) versus the costs (capital and operating and maintenance costs) of the flood protection project (the cost). Mitigation Site 1 and Mitigation Site 2 were believed to have a reasonable benefit to cost ratio for this preliminary BCA around 1.0 meaning the benefits would meet or exceed the costs of the project.

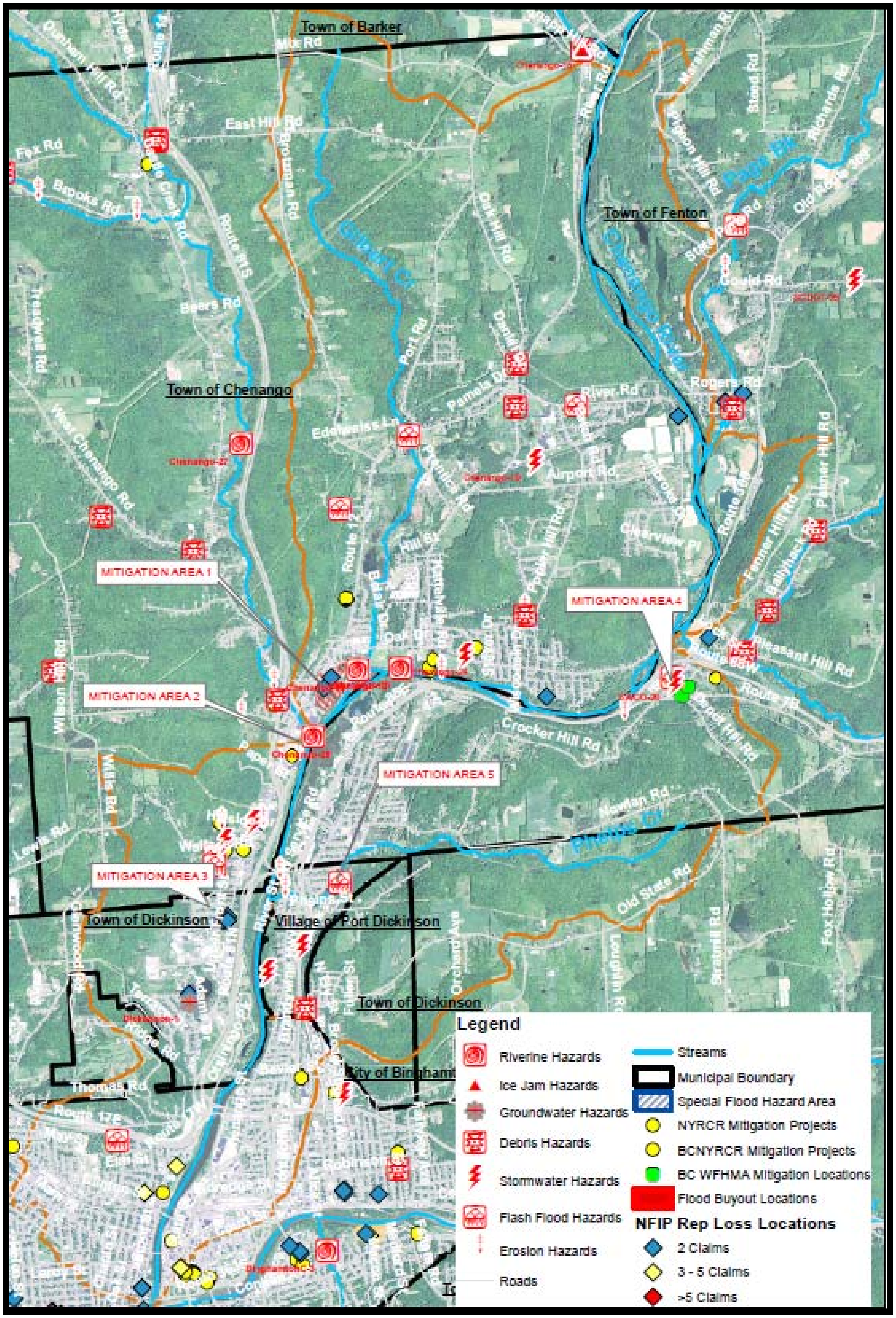

Figure 9: Location Map of Thomas Creek Proposed Flood Mitigation Sites

5.0.3 Watershed Hydrology Approach

The County wide Flood Insurance Study for Broome County (2010) was obtained which includes the Town of Chenango (Community #360040). The most appropriate discharges for the mitigation locations were calculated at the Town of Fenton and Chenango corporate limits (drainage area 1,585.3 square miles. The 10-year, 50-year, 100-year and 500-year return interval flood discharges were obtained were plotted. A line of best fit was developed for the four discharge values and the 2-year and 25-year discharges were calculated by extrapolating the line of best fit (see Table 14).

Table 14: Flood Discharges Used For Flood Mitigation Sites #1 and #2

Return Interval Flood	FIS Discharge (cfs)
2-year	29,658
10-year	38,769
25-year	46,610
50-year	53,866
100-year	60,803
500-year	78,094

5.0.4 Watershed Hydraulics Approach

The two flood mitigation sites have been studied by detailed method as part of the 2010 preliminary FIS. The detailed study was completed using the US Army Corps of Engineers (USACE) HEC-RAS program and an electronic copy of the model was obtained. The geometric information to create the HEC-RAS program was obtained from the 2007 LiDAR topographic survey. Field visits were completed to both sites to ground truth the data noting any pertinent changes in the topography. No notable topographic changes were observed.

5.0.5 Flood Mitigation Solutions Summary from the WFHMP's Initial Efforts

Five (5) mitigation sites were identified and two were furthered for detailed analysis. Sixty six (66) homes are located in the SFHA in Mitigation Site 1 and the proposed mitigation activity would remove forty four (44) of them from the SFHA reducing their flood insurance premiums. Nineteen of these homes (19) have a foot or more of flooding depth over their first floor elevation during the 100-year flood. The benefit to cost ratio for Mitigation Site 1 was 0.25. Mitigation Site 2's BCR was 1.1 and featured an earthen berm that protected several commercial buildings from flood damage and the Town of Chenango's drinking water well.

5.1 Proposed Flood Mitigation Site #1

Background

Flood Mitigation Site #1 is located between Upper Front Street and the Chenango River. It is bordered to the north by Thomas Creek and to the south by Lowes and can be seen in B-25, Appendix B. There are up to 66 homes in the SFHA and two (2) NFIP repetitive loss locations. No flood buyouts were located in this area.

Existing Hydraulic Conditions

Inundation of the homes located in the SFHA begins at the 50-year flood event proximal to cross section 29566. Floodwater spills over the top of bank at two low points as seen in B-25, Appendix B near the northern low point just east of Matthews Road and the southern low point along Jacobs Highway, parallel to the Chenango River. The 50-

year flood limits extend to Upper Front Street. The maximum water depth during the 50-year event is over six feet while the average water depth around homes is 1'-2' as seen in B-26, Appendix B. Water depths and inundation extents increase during the 100-year flood with the average water depth around homes between 2'-3'. There is a notable high location in the middle of the mitigation site starting between Carmichael Road and Bishop Road that is not inundated during the 50-year or 100-year flood.

Proposed Hydraulic Conditions

Since the drainage area for Mitigation Site #1 is over 1,500 square miles, the area of impervious surfaces in the watershed is very low compared to the size of the contributing drainage area so land use changes such as reducing imperviousness will have little to no impacts in reducing peak flood discharges. Detention basins (dams, etc.) are also not practicable with a drainage area this large because the facility would have to be extremely large, require a very large storage area that would flood at least several square miles of land. Therefore this mitigation practice is not realistic and beyond the scope of this project.

Since the 100-year floodplain width is over 1,200' wide, the size of a floodplain bench that would be required to reduce water surface elevations would have to be several hundred feet wide requiring large amounts of material to be excavated and removed. Also, the size of a floodplain bench is limited since a gravel pit is located directly east of the Mitigation Site which is filled with water providing no opportunity to increase floodwater volume conveyance. With the previously mentioned strategies being eliminated, the hydraulic goals of this project are to remove the homes from the SFHA using a flood protection facility.

Two flood protection facilities are needed to protect Mitigation Site #1 (B-27, Appendix B). The first facility would be located in the low spot between Chenango Bridge Road and Bishop Road. The second facility would be located to the southwest in the low spot between Quinn Road and the notable high location in the middle of the mitigation site starting between Carmichael Road and Bishop Road.

Two alignments were selected for analysis and can be seen in Figure 10 below. The proposed facility height would exceed the 100-year flood elevation (the base flood elevation or BFE) by 3.0' to comply with existing FEMA regulations. The average water depth along the proposed alignments was 4' so the facility would be approximately 7' in height. The facility would consist of an earthen berm that would have a 12' top width and 6 horizontal to 1 vertical side slopes to allow for ease of mowing. The proposed berm concept is shown in B-28. The earthen berm concept was selected as the desired flood protection facility since it is much less expensive than a concrete floodwall and there is ample space to construct it. The proposed berm will prevent flood waters from surrounding 44 homes. The proposed berm will result in a slight rise of the 100-year water surface elevations but it still meets the local floodplain development ordinance that any work in a SFHA cannot result in a foot or more of rise. Proposed and existing hydraulic results are shown in Table 15.

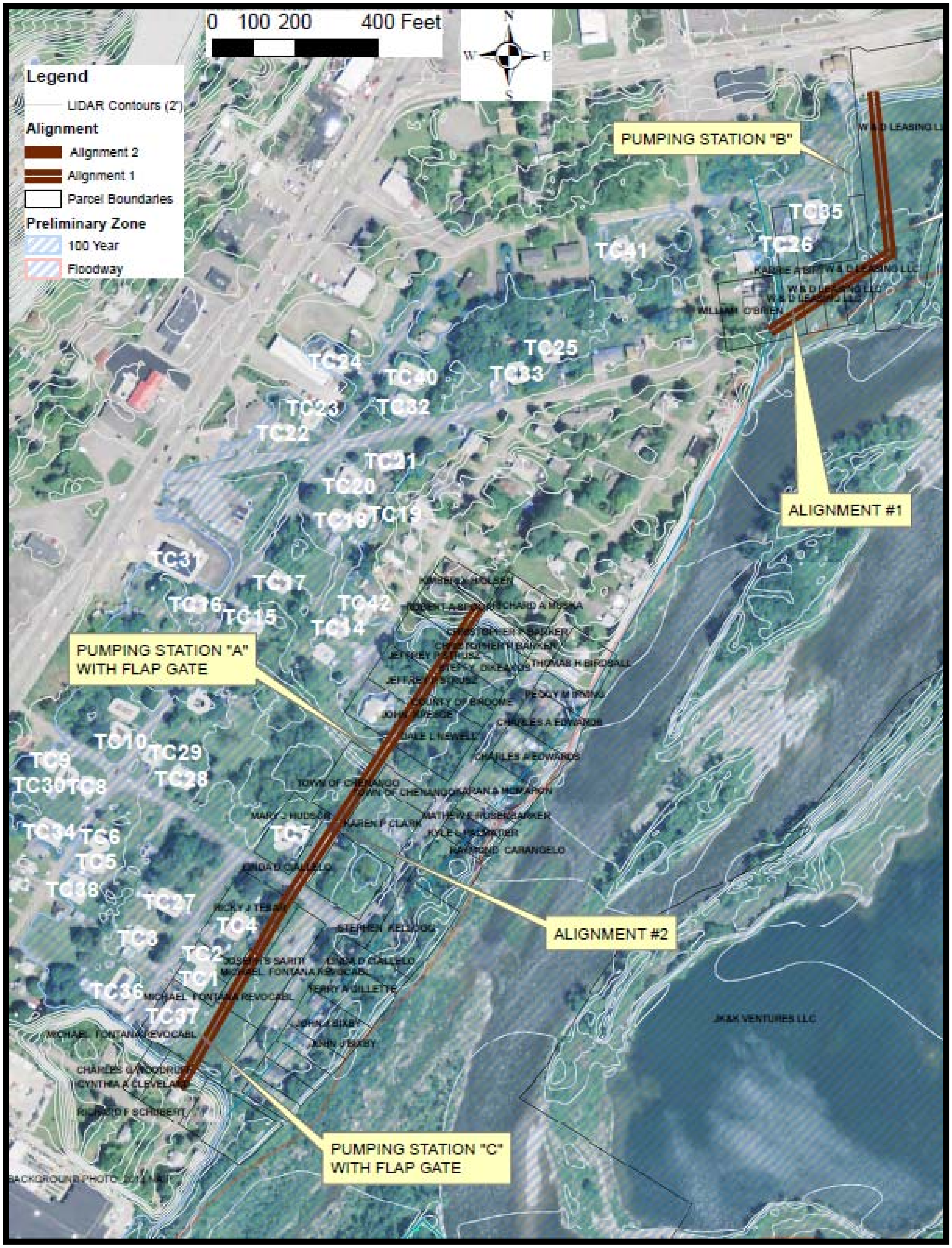

Figure 10: Location Map of Proposed Mitigation Activities at Site #1

Table 15: Existing and Proposed Hydraulic Conditions for Flood Mitigation Site #1

HEC-RAS Section	Existing Water Surface Elevation 100-year Flood Elevation	Proposed Water Surface Elevation (100-year Flood Elevation)	Difference (feet)
29566	855.31	855.33	+0.02
29151.2	854.62	854.64	+0.02
28050	854.19	854.18	-0.01

Benefit Cost Ratio

The total length of the proposed berms is 2,100 feet and crosses 15 parcels and Merrill Road (per field observations, Aldrich Road as seen in B-27 does not exist in the alignment area). The 6' high earthen berm unit cost was increased from $205 per linear foot to $215 per linear foot because a 7' high berm will be required. Since there is room between the berm and adjacent homes and driveways, it is proposed that the Merrill Road profile be adjusted upwards to meet the crest elevation of the berm. The additional cost for this adjustment was included in the unit cost of the berm. Three pumping stations will be required to pump stormwater that during pre-mitigation conditions would drain into the Chenango River but now is trapped on the landward side of the levee. Pump Station "A" is located along an existing stormwater channel (see photo below) and drains approximately 20 acres, therefore the pump would be larger than the other two stations and more grading work is anticipated. Pump Station "B" is located landward of Alignment #1 and would drain less than 0.5 acres and will require only minor grading. Pump Station "C" would be draining less than a 0.5 acre of land and need only minor grading to direct flow towards the pumping stations. A cost to acquire a permanent right of way was calculated using the berm's footprint and a unit cost. The proposed mitigation costs are shown in Table 16.

Looking West at the Stormwater Channel Outfall

Table 16: Conceptual Construction Costs for Flood Mitigation Site #1

Cost Item	Item Description	Unit	Unit Cost	Quantity	Subtotal
1	Construct 7' High Earthen Berm	LF	$215	2,100	$451,500
2	Pumping Station "A"	LS	$175,000	1	$200,000
3	Pumping Station "B"	LS	$75,000	1	$75,000
4	Pumping Station "C"	LF	$75,000	1	$75,000
5	Right of Way Acquisition	Parcel	$10,000	15	$150,000
Grand Total					$926,500

Of the sixty-six homes that are located in the floodplain, nineteen homes were found to have more than a foot of water over the first floor elevation during the 100-year flood. The water surface elevations for the 10-year, 50-year, 100-year and 500-year flood were obtained from the hydraulic modeling results and entered into the into the BCA software. A BCR was calculated for each home and the project's overall BCR is 0.24 as seen in B-29 in Appendix B.

Since the flood protection facility's score was so low, the next tier of flood mitigation strategies was investigated. The average damage cost to the buildings in this area was is $11,500. The estimated average cost of elevating a building was determined to be $75,000 (Table 17). Since this is not a cost effective mitigation strategy it was also dropped from further consideration. The final tier of mitigation strategies involved the relocation of homes through a buyout program. The total house value of all the homes impacted by flooding in the SFHA was estimated to be $1,270,000 which would be the minimal amount of money needed to relocate homes. The total damage costs to the homes in the SFHA was estimated to be $220,000 thus relocating homes is not a financial feasibly strategy.

Table 17: Conceptual Costs To Elevate Homes for Flood Mitigation Site #1

Item	Unit	Unit Cost	Quantity@	Subtotal
Lifting House	SF	$15	1,500 SF	$22,500
Building New Foundation	SF	$30	1,500 SF	$45,000
Permitting/Engineering Costs	SF	$5	1,500 SF	$7,500
Total				$75,000

@ Average Size home in SFHA

Funding Opportunities

Since the BCR for this project came out to be much less than 1.0, there are limited funding opportunities this project could apply for and are listed below.

- U.S. Army Corps of Engineers: Small Flood Damage Reduction Projects (Section 205 of Flood Control Act)
- Emergency Streambank and Shoreline Protection (Section 14)
- New York Rising
- New York State HMGP

5.2 Proposed Flood Mitigation Site #2:

Background

Mitigation Site #2 is located in the Town of Chenango east of US Route 11 (Front Street) in the commercial complex with Weis Supermarket, UHS Primary Care-Front street and a CVS. The site is bordered to the north by Castle Creek, to the east by the Chenango River and the west by Front Street. There are ten (10) buildings located within the SFHA and all are zoned commercial. Five (5) of these buildings have a foot or more water depth during the 100-year flood. There are no records of NFIP repetitive loss locations and no flood buyouts in this area. The Town's drinking water supply well is located north of building TC101 as shown in Figure B-30 and Figure 10.

The drainage area to Mitigation Site #2 is over 1,500 square miles so land use changes or increasing the amount of wetlands within the drainage area will not reduce peak flood discharges. Since the 100-year floodplain width is over 1,200' wide, the size of a floodplain bench that would reduce water surface elevations would have to be several hundred feet wide requiring large amounts of material to be excavated and removed and could not be financially justified. With the previously mentioned strategies being eliminated, the hydraulic goals of this project are to remove the buildings from the SFHA using a flood protection facility.

Existing Hydraulic Conditions

Inundation of the businesses in the SFHA begins at 50-year flood event proximal to cross section 25954 as seen in B-31, Appendix B. Floodwater extends into the commercial plaza in a low point between the Weis Supermarket and the Town of Chenango's transfer station. All five buildings are inundated on average by 0.3' of water during the 50-year flood with the maximum inundation depth occurring at building TC101 (1.9'). The Town's drinking water intake is surrounded by floodwater and the plaza parking is also inundated. Water depths increase during the 100-year return interval flood (B-32) with average depths at 1.5' and the maximum depth at 3.0'.

Proposed Hydraulic Conditions

To project Mitigation Site #2, one flood protection facility is needed as seen in Figure 11. The proposed facility would consist of an earthen berm located between the Weis Supermarket and the transfer station. Both of these buildings are located above the 100-year flood elevation which provides high ground to tie the berm into. This berm eliminates flooding for all five businesses and the Town's drinking water supply (B-33). The berm crest height would exceed the 100-year flood elevation (the baseflood elevation or BFE) by 3' to comply with existing FEMA regulations. The average water depth along the proposed alignments was 9' so the facility's height would be approximately 12'. The berm does not result in a rise in the BFE (Table 18) so this proposed mitigation measure would adhere to federal and local floodplain development regulations.

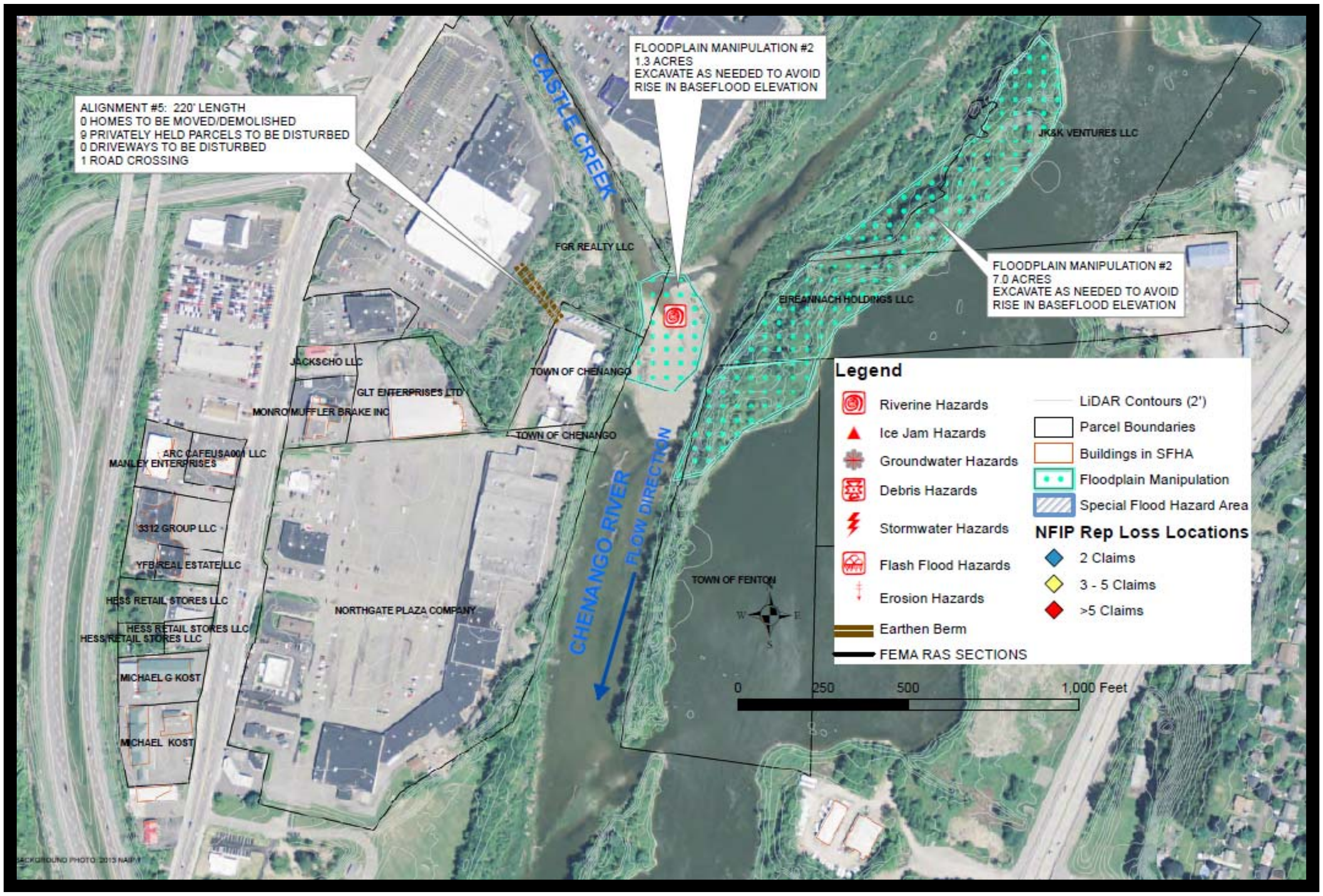

Figure 11: Location Map of Proposed Mitigation Activities at Site #2

Table 18: Proposed and Existing Hydraulic Conditions for the 100-year Flood at Mitigation Site #2

HEC-RAS Section	Existing Water Surface Elevation 100-year Flood	Proposed Water Surface Elevation 100-year Flood	Difference (feet)
26760	853.80	853.80	0.00
25954	853.84	853.84	0.00
24976	853.64	853.64	0.00

Benefit Cost Ratio

The total length of the proposed berm is 200 feet and it crosses two parcels. One parcel is owned by the Town of Chenango and the other is privately held. Field observations showed that the area between the two buildings is a low-lying area (as seen in photo below) that appears to be undevelopable which will reduce the cost of acquiring a construction right of way. The 6' high earthen berm unit cost was increased from $205 per linear foot to $300 per linear foot because a 12' high berm is needed. A pumping station will be needed because interior stormwater that during pre-mitigation conditions would drain to the Chenango River through the low-lying area would be trapped on the landward side of the levee. The pump station location will be near the proposed berm and a moderate amount of grading will be needed to increase the amount of storage area on the landward side of the berm. The grading and removal of material in this area will increase the amount of available interior storage volume of water. By increasing the amount of interior stormwater storage, the size and cost of the pumps can be decreased. The proposed mitigation costs are shown in Table 19.

Looking East at the Town's Transfer Station the Proposed Flood Mitigation Work Site.

Table 19: Conceptual Flood Mitigation Costs Flood Mitigation Site #2

Item Cost	Item Description	Unit	Unit Cost	Quantity	Subtotal
1	Construct 12' High Earthen Berm	LF	$300	200	$60,000
2	Pumping Station With Moderate Grading	LS	$165,000	1	$165,000
5	Right of Way Acquisition	Parcel	$5,000	1	$5,000
Grand Total					$230,000

Of the ten commercial properties located in the floodplain, five buildings were found to have more than a foot of water over the first floor elevation during the 100-year flood. The water surface elevations for the 10-year, 50-year, 100-year and 500-year flood were obtained from the hydraulic modeling results and entered into the into the BCA software and a BCR was calculated for each commercial property and summarized to calculate the projects overall BCR which is 1.06 as seen in Figure B-34 in Appendix B. The BCR does not include benefits of preventing the Town's drinking water supply well from being flooded. The Town of Chenango may have records of the damage incurred at the well which will increase the BCR favorably. In addition, to justify the benefit and cost ratio, the well is considered a piece of critical infrastructure which will increase the competitiveness of a hazard mitigation grant application.

Funding Opportunities

Since the BCR was greater than 1.0, there are several funding opportunities this project could apply for. They are as follows.

- FEMA's Pre-Disaster Mitigation (PDM),
- Federal and State Hazard Mitigation Grant Program (HMGP),
- Flood Mitigation Assistance (FMA)

6.0 Patterson Creek/Susquehanna River Watershed Proposed Flood Mitigation Activities

6.0.1 Watershed Background

The Patterson Creek-Susquehanna River watershed is 23.5 mi^2 and its drainage area lies primarily in the Town of Union, and also includes portions of the Village of Endicott, Town of Maine and Town of Vestal. The major tributary within this watershed is Patterson Creek, which flows from the Town of Maine south to the Susquehanna River. The northern upstream portion of this watershed is dominated by less dense residential development and agricultural uses, and land cover consists of a significant amount of pastureland and cropland, as well as forests. The southern, downstream portion is dominated by significant industrial and commercial development, along with denser urban and suburban development. Between these two portions is a flood control dam. It is notable that suburban residential development is quite significant in this watershed compared to others throughout the County.

6.0.2 Mitigation Sites: 2015

Five proposed mitigation sites were initially identified in the Paterson Creek/Susquehanna River watershed (HUC12# 020501030205) and can be seen in Figure B-35 and in Figure 12. As discussed above, no further discussion of Mitigation Sites 2 and 3 will be provided in this report since they have successfully been advanced to detailed design and eventual construction phases. They are listed below for reference purposes only.

Mitigation Site 1: Located along Patterson Creek in the Town of Union near the intersection of Smith Drive and Hooper Road (42.118394, -76.020265). The hazard is located upstream of the Smith Drive Bridge along the left bank.

Mitigation Site 2: Located along Brixius Creek in the Town of Union near the intersection of Pine St and North McKinley Ave (42.115076, -76.045398). A second location is downstream on Brixius Creek near the intersection of N. Arthur Ave and Watson Boulevard (42.109532, -76.041222).

Mitigation Site 3: Located in the Village of Endicott, near the intersection of Skye Island Drive and E. Franklin Street adjacent to the Central Endicott/Huron (42.102670, -76.057284).

Mitigation Site 4: Located in the Town of Vestal in the Castle Gardens neighborhood between the Susquehanna River and State Route 17. The center of this Mitigation Site is (42.076674, -76.085749).

Mitigation Site 5: Located in the Town of Union, bordered to the south by State Route 17, to the North by E. Main Street, to the west by Brixius Creek and to the east by Fairmont Ave. The center of this Mitigation Site is (42.104859, -76.022850).

Mitigation Site 1 was the one site from the original five flood hazard mitigation sites that was selected for additional analysis based on using a preliminary benefit to cost analysis (BCA). Mitigation Site 1 was believed to have a reasonable benefit to cost ratio because it was assumed they had the highest one-way traffic volume.

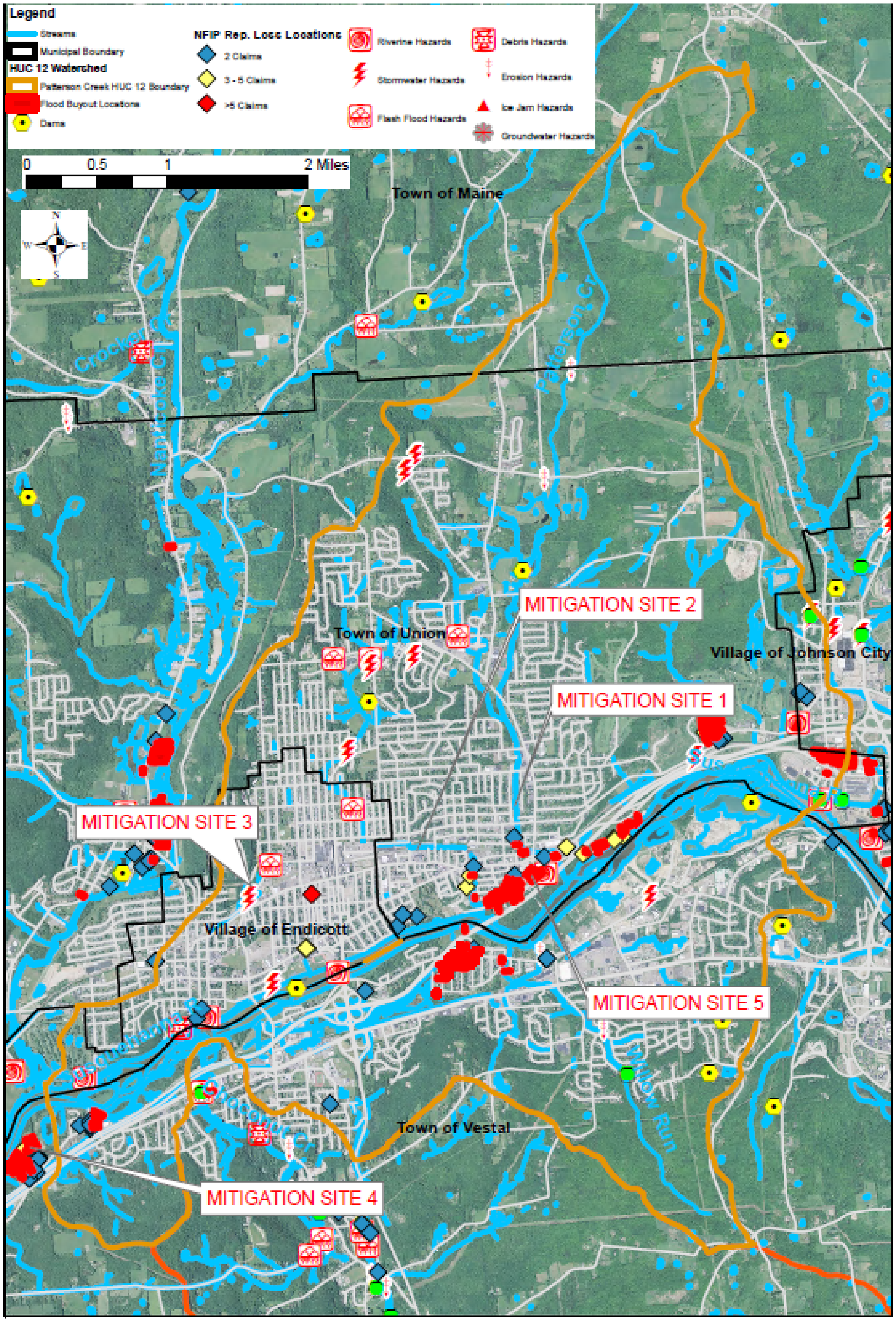

Figure 12: Location Map of Patterson Creek Proposed Flood Mitigation Sites

6.0.3 Watershed Hydrology Approach

The hydrology for Mitigation Site 1 was developed using the Soil Conservation Service discharge runoff and routing methods embedded in the HydroCAD software modeling package. The hydrologic computations included consideration of an upstream flood control dam that significantly attenuates (reduces) peak flows below the dam location.

6.0.4 Watershed Hydraulics Approach

Hydraulics for Mitigation Site 1 were calculated by obtaining new geometric information along Patterson Creek to create a new HEC-RAS hydraulic model. The geometric information was obtained using Broome County's 2007 LiDAR topographic survey and traditional total station survey methods.

6.0.5 Flood Mitigation Solutions Summary from the WFHMP's Initial Efforts

Five (5) mitigation sites were originally identified within the Patterson Creek/Susquehanna River Watershed. It is noted that Mitigation Site's 2 and 3 have since obtained New York Rising Funding and are currently being progressed through the design and construction phase. As such, additional analysis and detailed computation of Benefit-Cost Ratios' were not conducted for these two sites. Only a background of the site and brief summary of the flooding conditions at Mitigation Sites #2 and #3 have been included. Of the remaining three sites, only one mitigation site was progressed for further analysis (Mitigation Site 1).

It is further noted that Mitigation Sites 2 and 3, have successfully obtained funding despite low BCR results through our initial investigations. These particular mitigation sites are associated with correcting stormwater flooding along key roadways that are chronically flooded even by low frequency storms. Closure of high volume roadways result in costly detours, public inconvenience and can effect important emergency response corridors. The highest BCR from Mitigation Sites 2 and 3 was 0.14 which shows the limitations of the BCR methodology in capturing non-financial damages such as closure of important emergency or economic corridors. It is recommended that the BCR method should not the only criteria to prioritize flood hazards along flooded roadways because using the BCR alone will make it difficult to economically justify projects.

6.1 Proposed Flood Mitigation Site #1

Background

Mitigation Site 1 is located 100 feet upstream of the Smith Drive Bridge over Patterson Creek as seen in Figure 13 and there is one erosion hazard located at Mitigation Site 1 (B-36, Appendix B). The drainage area to Site #1 is 6.5 square miles whose largest land use type is forested area (53%). The drainage area contains 4.8% impervious cover (per 2011 National Land Coverage Dataset (NLCD)). Patterson Brixius Grey Watershed 1 Flood Control Dam (State ID: 086-3457) is located upstream of Mitigation Site #1 which reduces flood discharges by storing flood waters for 4.5 square miles (70%) of the watershed. The dam is a high hazard class "C" dam and was studied by detailed hydrology and hydraulic modeling methods. The erosion hazard consists of a 600' long eroding left bank (east bank of the creek) that is composed of a silty sand soil material with bank angles that approach near vertical and average 8 'in height. There is very little to no riparian corridor along the top of the stream bank and therefore there is very low root density along the stream bank toe to provide bank cohesion and resistance to erosion. A typical bank section can be seen in the photo below.

Looking East at Erosion Hazard at a Private Home.

A stable bank angle for this material type is a 3 horizontal to 1 vertical. A silty sandy soil and low root density (such as planted with sod) will begin to erode when velocities exceed 1.0 ft/second (referred to in this report as incipient velocity).

The eroding bank threatens one house, two outbuildings and seven property parcels. Through discussions with the Town of Union Planning Department, the bank is eroding on average 0.5' per year.

Existing Hydrologic and Hydraulic Conditions

The existing Dam Engineering Assessment Report detailing the dam's hydrology and hydraulic information was obtained from Broome County Engineering Department. The dam's depth storage relationship and the upstream drainage area characteristics were input into the HydroCAD software program to calculate inflow discharges. Outflows from the dam was computed by the dynamic storage indication routing method embedded in the software program. The drainage area characteristics for the contributing drainage area between the dam and Mitigation Site #1 were determined and combined with the outflow discharges from the dam.

The composite discharges and stream channel velocities at Mitigation Site #1 were calculated and are shown in Table 20. The average stream velocity far exceeds the stream bank material's incipient velocity (1 ft/sec) beginning at the 1-year flood event. This means that the stream banks will erode at its toe because of hydraulic entrainment (fast moving water removing the stream bank material). The stream banks will also fail because their angle is much steeper (near vertical) than the material's stable angle (3 horizontal to 1 vertical).

Table 20: Discharge and Velocities at Flood Mitigation Site 1

Flood Return Interval	Discharge (cfs)	Velocity (ft/sec)
1-year	147	4.6
2-year	235	5.4
5-year	412	6.4
10-year	600	7.2
50-year	1,270	9.1
100-year	1,700	9.8

Proposed Hydraulic Conditions

The existing hydraulic conditions far exceed the stability threshold for the stream bank material during the lowest studied return interval flood (1-year). Therefore it is unlikely any watershed wide modification (land use changes, increased area of wetlands) will lower peak discharges and the resulting velocities below incipient velocity (1ft/sec) preventing hydraulic entrainment. Also, the flood control dam already reduces peak discharges from 70% of the watershed area dropping peak discharges at the 1 year flood event (157cfs into the dam, 36 cfs out of the dam). Therefore the dam is functioning properly as a flood control dam and therefore further modifications to reduce discharges at the dam are unlikely to occur. Adding another flood control dam between the site and the Dam to reduce discharge from the drainage area between the Dam and Mitigation Site 1 is not feasible due to siting, environmental and cost considerations.

The next tier of solutions is to try to mitigate the problem at the site. One solution is to create floodplain benches on the opposite side (west bank) of Patterson Creek. This would increase the amount of area floodwaters could flow into and reduce erosive velocities. However, this solution does not address the geotechnical instability of the banks. Therefore armoring the channel banks using rip rap protection was selected as the most viable option to investigate.

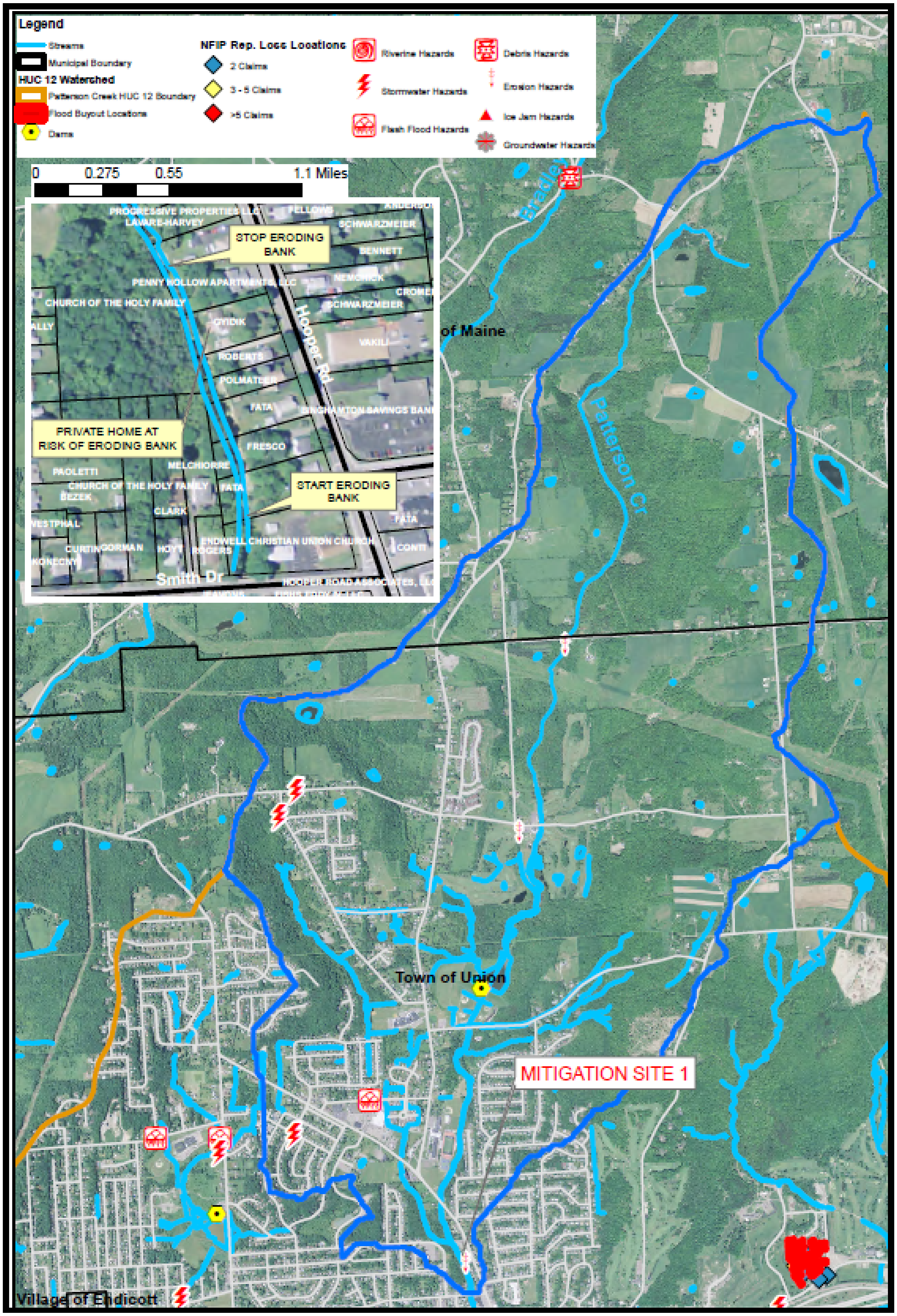

Figure 13: Location Map of Proposed Mitigation Activities at Site #1

Benefit Cost Ratio

The entire length of the eroding bank would be protected using large stone. More detailed design is needed to calculate the precise stone size, gradation and scour depths. For estimating purposes, the large stone rip rap bank will use large stone fill per the NYS Department of Transportation's standard provision. The large stone will be placed below scour depth which is estimated to be 2.0'. Habitat logs will be placed 1 every 10' on center to provide aquatic habitat. A typical section view can be seen in B-37.

Table 21: Conceptual Construction Costs for Flood Mitigation Site #1

Cost Item	Item Description	Unit	Quantity	Unit Cost	Subtotal
1	Procure and Install Heavy Stone Fill	Tons	1,600	$75	$120,000
2	Water Quality Protection Measures	Day	10	$1,500	$15,000
3	Excavate, Backfill and Compact New Stream Bank	CY	1,500	$20	$30,000
4	Procure and Install Geotextile	SY	1,500	$7.50	$11,000
5	Procure and Install Habitat Logs	EA	60	$450	$27,000
6	Sediment and Erosion Control	LS	1	$4,000	$4,000
Grand Total					$207,000

The hazard at Mitigation Site #1 is caused by erosion, not by flood inundation, therefore the damage frequency module in FEMA's BCR software package was used instead of the Flood Module. The damage frequency module requires an entry of the utility, building or other item of value that has been or will be damaged by at least three flooding/erosion events (with a recurrence interval for each event) that have caused or will cause the damage.

The house (parcel ID 142.09-1-12), the two outbuildings and the land of seven parcels were identified as being the items of value being threatened by the erosion hazards. There is approximately 10' of land between the edge of the house and the stream bank. Given the 0.5' annual erosion rate of the bank, the house would become damaged in 20 years. As such, 20 years was used as the event's frequency (the recurrence interval) for the damage-frequency assessment and the value of the house was used as the damage. Since the damage frequency module requires a minimum of three flooding/erosion events, three events, each with a 20 year recurrence interval, were entered and a 1/3rd of the house's value was added for each event. Since the price of this particular house was not known from Broome County parcel data, the entered value was $29,000 which is a third of $87,000, the average sale price of surrounding homes.

To assess the damage to the outbuildings, there is on average 15' between the two outbuildings and the top of the stream bank. Thirty (30) years was used as the frequency and it was assumed the outbuildings value is $15,000. Three events, each with a recurrence interval of 30 years were entered and each event had a damage value of $5,000 ($15,000 divided by 3).

To assess the damage to landowner's land, the average parcel size (19,100 ft^2) for the seven lots that would be damaged was measured using the County's GIS parcel data and the average parcel value (excluding buildings) was computed to be $4,320. The dollar value of a square foot of land was $4.43. Given the 0.5' annual erosion rate over the 600' eroding bank length, 300 square feet of land that is being lost annually computed to $1,329 in damages. Three events with a 1 year recurrence interval were entered, each with a damage value of $443 ($1,329 divided by three).

The project's useful life considered to be 67 year and resulting in a 0.13 BCR as shown in B-38.

Funding Opportunities

Since the BCR for this project came out to be much less than 1.0, there are limited funding opportunities this project could apply for. They are as follows.

- U.S. Army Corps of Engineers: Small Flood Damage Reduction Projects (Section 205 of Flood Control Act)
- Emergency Streambank and Shoreline Protection (Section 14)
- New York Rising
- New York State HMGP

6.2 Proposed Flood Mitigation Site #2

Background

There are two areas of flood hazards within Mitigation Site #2 along Brixius Creek and can be seen in B-39. Site 2A is located at the intersection near Pine St and North McKinley Ave in the Town of Union and Site 2B is located near the intersection of N. Arthur Ave and Watson Boulevard also in the Town of Union.

A stormwater hazard was identified at Site 2A at the crossing underneath Pine Avenue. The intersection has high traffic volumes estimated to be 800 one way vehicle trips per day, and when it is inundated, can be closed for three to four hours. This happens even after moderate flooding events. The Town of Union also has had to remove sediments from the culvert crossing several times over the last ten years due to the culvert plugging.

A flash flood hazard was identified at Site 2B at the crossing underneath Watson Boulevard. This crossing is an important transportation corridor for commerce and first responders. Per discussions with the Town of Union Planning Department and the Village of Endicott Engineering Department, the culvert underneath Watson Boulevard is undersized resulting in flooding of the business to the west of Brixius Creek (funeral home), inundation of the intersection and flooding of the Huron Campus. The intersection has high traffic volumes, estimated to be 2,000 one way vehicle trips per day and when it is inundated, can be closed for three to four hours.

Existing Hydraulic Conditions

As can be observed from Table 22, the N. Rogers crossing and Pine Street crossing are inundated at the 10 year storm. It is also noted that the waterway constriction at the North Rogers Street/Pine Street are towards the outlet of the structure where bedload deposits have accumulated and reduced the effective waterway opening.

Table 22: Existing Hydraulic Conditions Proposed Mitigation Site #1

Culvert Location	Approximate Size	Culvert Type	Waterway Opening (SF)	Overtopping Storm Event
N. Rogers/Pine Street	17.5' W X 4.8' H[1]	Metal Arch	45	10-year
Watson Boulevard	15' W X 5' H[2]	Metal Arch	32	10-year

Field investigations showed that there is an ample supply of sediment sources in the headwaters upstream of the crossing that will continue to plug the culvert if not managed.

Proposed Hydraulic Conditions

This flood hazard mitigation solution is currently in the design phase and the Town of Union is the lead project organization.

6.3 Proposed Flood Mitigation Site #3

Background

There is one stormwater flood hazard (Endicott_H2) and one flash flood hazard (Endicott_H1) at Mitigation Site #3. There are no NFIP repetitive loss locations nor flood buyout parcels in the project area. Mitigation Site location map can be seen in B-40.

Frequent flooding occurs along sections of East Franklin Street, Clark Street, Oak Hill Avenue and areas within the Huron Campus during periods of heavy rainfall. The area along East Franklin Street and Clark Street is the area that is most chronically affected with street flooding occurring even after moderate rainfall events. The photos below were taken on May 9th, 2014 after a rainfall event of approximately 1.3 inches of total rainfall. Residents and Huron Campus staff have reported that the existing stormwater sewer system in these areas frequently back up through the inlets and manholes, resulting in street flooding and sheet flow flooding of adjacent homes and properties. Ponding of stormwater within the travel lanes of public roadways also creates a public safety issue and potential liability to the Village of Endicott. The affected areas along Clark Street and East Franklin Street require the placement of barricades and flares by Village Police to prevent vehicular/pedestrian traffic from entering flooded areas. It is estimated there are 4,000 one-way vehicle trips on Clark Street and East Franklin Street.

Robble Ave/Clark Street, view east

Robble Ave/East Franklin Street, view west

Existing Hydrologic and Hydraulic Conditions

During the 1-year storm event, the hydraulic investigation showed surcharging out of numerous manholes and inlets primarily located along East Franklin and Clark Streets leading to flooding. The approximate limits of flooding are depicted on B-41. During the larger 2-year storm event, the surcharging limits, depths and durations are more extensive and are also shown graphically on B-41.

Proposed Hydraulic Conditions

This flood hazard mitigation solution is currently in the design phase and the Town of Union is the lead project organization.

7.0 References

Booth, Derek. 1991. Urbanization and the Natural Drainage System-Impacts, Solutions and Prognoses. The Northwest Environmental Journal.

Broome County. 2013. Broome County Multi-Jurisdictional All-Hazard Mitigation Plan.

FEMA. 1998. Flood Insurance Study: Town of Vestal, NY

FEMA. 2009. BCA Reference Guide.

FEMA. 2010. Preliminary Flood Insurance Study: Broome County.

FEMA. 2013. Hazard Mitigation Assistance Unified Guidance.

New York Rising. 2014. New York Rising Community Reconstruction Program, Broome.

New York State. 2014. New York State Hazard Mitigation Plan.