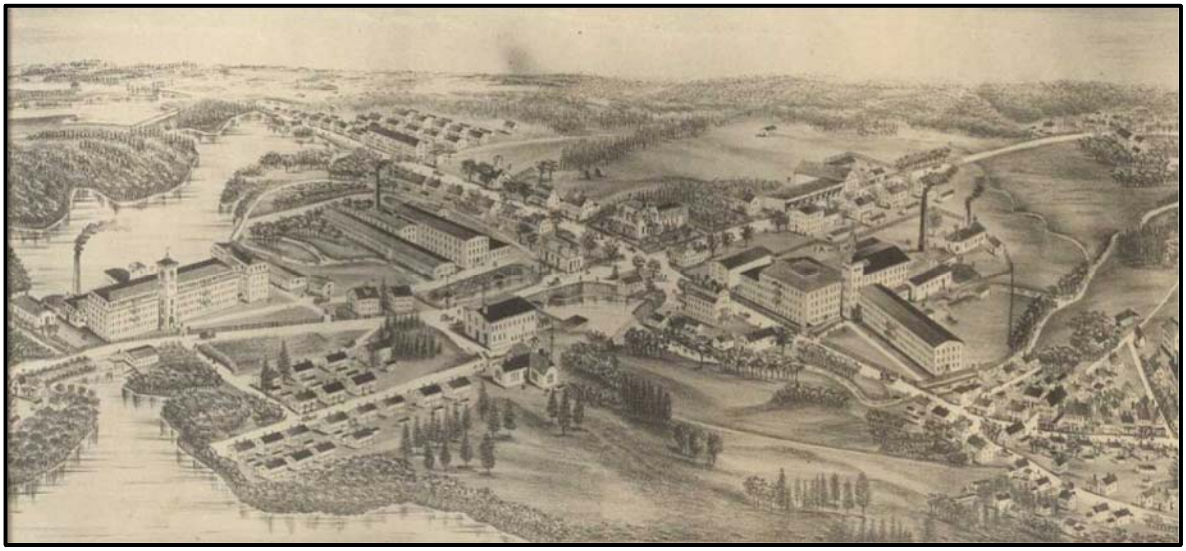
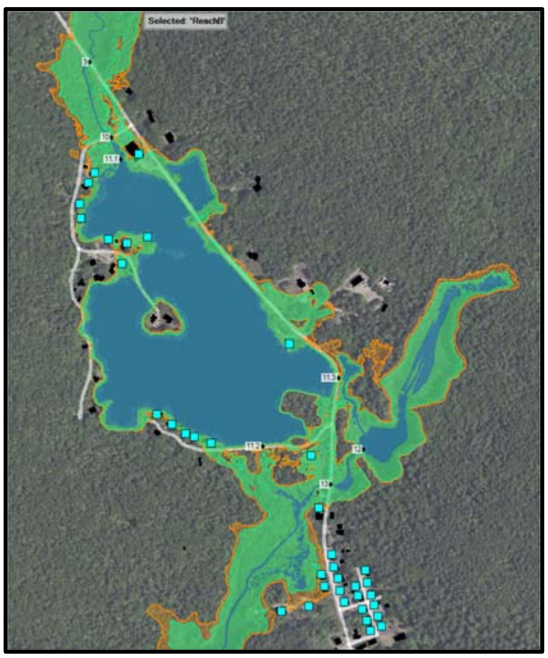
PREPARED FOR: TOWN OF SUTTON

MANCHAUG WATER RESOURCES RESILIENCY ACTION PLAN (MWRRAP)

Sutton, Massachusetts





PREPARED BY:

PARE CORPORATION
10 LINCOLN ROAD, SUITE 210
FOXBORO, MASSACHUSETTS 02035

PARE PROJECT NUMBER 22153.00

FINAL Report – June 2023

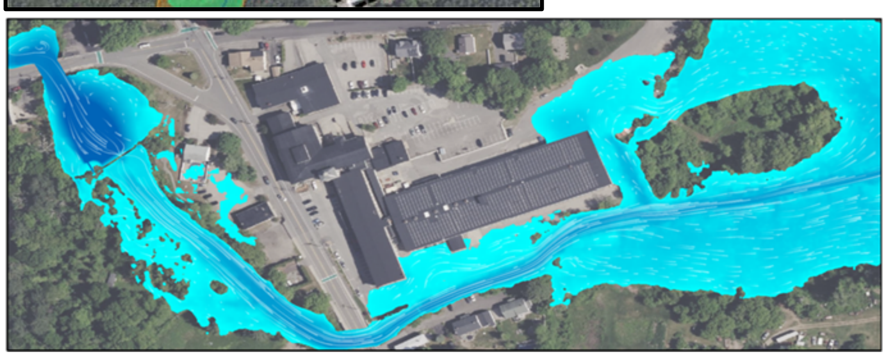


TABLE OF CONTENTS

SECTION PAGE

0.0 MWRRAP OVERVIEW IV
0.1 Plan Process & Scope....iv
0.2 Public Engagement iv
0.3 Project Team v
0.4 Plan Report....vi
1.0 MUMFORD RIVER AND DARK BROOK CORRIDOR – AN OVERVIEW 1-1
1.1 Reach A – Upper Mumford River....1-2
1.2 Reach B – Dark Brook 1-3
1.3 Reach C – Mumford River (Manchaug Village)....1-4
1.4 Reach D – Mumford River (Douglas)....1-5
2.0 EXISTING CONDITIONS H&H MODELING & RESULTS 2-1
2.1 Model Development....2-1
2.2 Model Results Along Reach A (Upper Mumford)....2-2
2.2.1 Dams....2-2
2.2.2 Roadways 2-3
2.2.3 Buildings 2-3
2.3 Model Results Along Reach B (Dark Brook) 2-5
2.3.1 Dams....2-5
2.3.2 Roadways 2-5
2.3.3 Buildings 2-6
2.4 Model Results Along Reach C (Mumford River – Manchaug Village)....2-8
2.4.1 Dams....2-8
2.4.2 Roadways 2-9
2.4.3 Buildings 2-9
2.5 Model Results Along Reach D (Mumford River – Douglas)....2-11
2.5.1 Dams....2-11
2.5.2 Roadways 2-11
2.5.3 Buildings 2-11
3.0 BUILDING DAMAGE ASSESSMENT 3-1
4.0 SUMMARY OF EXISTING CONDITIONS EVALUATIONS 4-1
4.1 Reach A: Upper Mumford River....4-1
4.2 Reach B: Dark Brook....4-1
4.3 Reach C: Mumford River (Manchaug Village)....4-2
4.4 Reach D: Mumford River (Douglas)....4-2
5.0 GENERAL IMPROVEMENT STRATEGIES 5-1
5.1 Watershed-Wide Strategies....5-1
5.2 Building-Level Strategies....5-2
5.3 In-Stream Strategies....5-2
6.0 POTENTIAL WATERSHED-WIDE STRATEGIES 6-1

6.1 Emergency Action Plan (EAP) 6-1
6.2 Land Cover Interventions....................6-1
6.2.1 Land Cover Preservation....................6-2
6.2.2 Land Cover Improvements....................6-2
6.2.3 Green Stormwater Infrastructure (GSI)....................6-3
6.3 River Obstruction Interventions....................6-4
6.3.1 Complexity of the Problem and Solutions of River Obstructions 6-4
6.3.2 Potential General Solution Strategies for River Obstructions 6-4
6.3.3 Specific River Obstruction Locations within the Watershed....................6-5
7.0 POTENTIAL BUILDING-LEVEL STRATEGIES 7-1
7.1 Sump Pump Improvements....................7-1
7.2 Wet Floodproofing....................7-1
7.3 Dry Floodproofing 7-1
7.4 Elevation 7-1
7.5 Retreat....................7-1
7.6 Specific Buildings Identified within this Watershed....................7-2
8.0 POTENETIAL IN-STREAM STRATEGIES 8-1
8.1 Reach A (Upper Mumford) In-Stream Strategies 8-1
8.1.1 Dam Modifications....................8-1
8.1.1.1 Stevens Pond Dam Modifications....................8-1
8.1.1.2 Manchaug Pond Dam Modifications 8-3
8.1.1.3 Sutton Falls Pond Dam Modifications....................8-4
8.1.1.4 Other Dams along Reach A 8-4
8.1.2 Roadway Crossing Replacements 8-5
8.2 Reach B (Dark Brook) In-Stream Strategies....................8-5
8.2.1 Dam Modifications....................8-5
8.2.1.1 Upper Tucker Pond Dam Systems (East and South Dams) 8-6
8.2.1.2 Other Dams along Reach B....................8-8
8.2.2 Roadway Crossing Replacements 8-8
8.3 Reach C (Mumford River – Manchaug Village) In-Stream Strategies 8-9
8.3.1 Dam Modifications....................8-9
8.3.1.1 Mill Pond Dam #1....................8-9
8.3.1.2 Potter Road Dam & Bridge....................8-10
8.3.1.3 Stone Weir Downstream of Main Street....................8-11
8.3.2 Roadway Crossing Replacements 8-11
8.4 Reach D (Mumford River – Douglas) In-Stream Strategies....................8-12
9.0 SUMMARY OF SOLUTION STRATEGIES 9-1

APPENDICES

Appendix A: Supporting Graphics
Appendix B: Corridor Photographs
Appendix C: Public Meeting Materials
Appendix D: Report Limitations

0.0 MWRRAP OVERVIEW

0.1 Plan Process & Scope

The Town secured a $75,000 action grant through the Municipality Vulnerability Preparedness (MVP) program within the Executive Office of Energy and Environmental Affairs (EOEEA) to complete a resiliency action plan for the Mumford River and Dark Brook watersheds and river corridors with a specific focus on the issue of riverine flooding within Manchaug Village. The intent of the plan is to serve as a master planning document for the Town and project stakeholders to prioritize, explore funding opportunities, and implement individual projects that increase the resiliency of the Manchaug Village community relative to the hazard of riverine flooding.

The plan, entitled Mancahaug Water Resources Resiliency Action Plan (MWRRAP) was carried out in a five-phased approach:

1. ***Phase I: Data Collection & Inventory*** – Inventoried the Mumford River and Dark Brook river corridors within the study limits, through file review, field data collection, and data compilation.
2. ***Phase II: Existing Conditions Evaluations*** – Completed hydrologic and hydraulic (H&H) evaluations for both current and future rainfall conditions to determine the extent of flooding within the river corridors; identified the strengths and vulnerabilities of the assets located along the corridors (dams, roadways, buildings).
3. ***Phase III: Solution Strategy Development*** – Developed potential improvement ("solution") strategies (watershed-wide, building level, in-stream) aimed at addressing the identified vulnerabilities from Phase II.
4. ***Phase IV: Plan/Report Development*** – Compiled the work completed as part of this plan into a single summation report; issued the report draft for review and comment from the general public and project stakeholders.
5. ***Phase V: Plan/Report Finalization*** – Incorporated comments and feedback received from the draft report into a final report.

0.2 Public Engagement

The plan involved open engagement and involvement with the community and its residents. This engagement was completed primarily through a series of in-person public meetings, each of which took the form of presenting material to the meeting attendees and encouraging and receiving feedback from the attendees during and after each meeting; feedback that was used to refine the development of the plan. All meeting materials as well as a recording of each meeting was made available on the Town's website Manchaug Vulnerability Preparedness (MVP) Grant - Manchaug Water Study Project Information | Sutton MA. The three meetings included:

1. ***The Listening Session (November 17, 2022):*** The first public meeting, named The Listening Session, was held at the completion of Phase I. At that meeting, the Project Team presented an overview of the scope of the study/plan as well as the watershed and river corridors. The Project Team utilized the valuable feedback received to refine the reporting of Phase I and the scope of Phase II. The meeting was followed by a site walk on December 6th where the MVP team and other project stakeholders provided insight into site specific concerns within the Village.

2. ***The "Problem" Meeting (March 16, 2023):*** The second public meeting, named The "Problem" Meeting, was held at the completion of Phase II. At that meeting, the Project Team presented an overview of the modeling and evaluations that had been completed as well as the strengths/vulnerabilities of the existing assets located along the river corridors that were identified, relative to the hazard of riverine flooding. The Project Team utilized the valuable feedback received to refine the reporting of Phase II and the scope of Phase III.

3. ***The "Solutions" Meeting (April 27, 2023):*** The third and final public meeting, named The "Solutions Meeting", was held at the completion of Phase III. At that meeting, the Project Team presented the solutions strategies that were conceptually developed to address the vulnerabilities of the assets identified at the previous meeting. The Project Team utilized the valuable feedback received to refine the reporting of Phase III and the scope of Phase IV.

In addition to these three public meetings, a final meeting, named The Select Board Meeting, was held at the completion of Phase IV at the Board of Selectman's meeting on June 6th. At that meeting, The Project Team, presented a broad overview of the plan development and the draft report. The Project Team utilized the valuable feedback received to refine the plan report.

0.3 Project Team

The project team tasked with the completion of the plan included:

A. ***EOEEA:*** Hillary King — *MVP Central Regional Coordinator*

B. ***Town of Sutton***
   - i. Lead: Jennifer Hager — *Planning and Economic Development Director*
   - ii. MVP Team:
     - Pamela Nichols — *Communications Director*
     - Lee Dillard Adams — *Resident*
     - Robin Dresser — *Deputy Fire Chief*
     - Paul Maynard — *Former Fire Chief & Emergency Management Director*
     - Bill Wence — *Conservation Chairperson*
     - Matthew Stencel — *Highway Superintendent*
     - Cheryl Rawinski — *Board of Health Department Head*
     - Sara Plutnicki — *CMRPC*

C. ***Project Stakeholders***
   - i. Residents of Manchaug Village and the Town of Sutton
   - ii. Manchaug Pond Foundation – Phyllis Charpentier
   - iii. Blackstone Watershed Collaborative (BWC) – Stephani Covino
   - iv. Blackstone River Watershed Association (BRWA) – Ted Beauvais
   - v. Central Massachusetts Regional Planning Commission (CMRPC) – Sara Plutnicki
   - vi. State Agencies – EOEEA, MassDOT, MADCR, MADER

D. ***Project Consultants***
   - Pare Corporation
   - Traverse Landscape Architects

0.4 Plan Report

The work completed as part of this plan was summarized within this plan report. The report includes the following nine sections:

1. ***Mumford River and Dark Brook Corridor – An Overview:*** Provides an overview of each of the 4 defined reaches (A-D) located within the study limits as well as a description of each of the infrastructure crossings (roadways and dams) located along each reach.

2. ***Existing Conditions H&H Modeling & Results:*** Provides an overview of the hydrologic and hydraulic modeling that was completed for this study including a discussion of the model results under existing conditions.

3. ***Building Damage Assessment:*** Provides an overview of the flooding damage assessment completed for all individual buildings located within the limits of maximum inundation from the H&H modeling.

4. ***Summary of Existing Conditions Evaluations:*** Provides a broad summation of the general conclusions developed from the existing conditions evaluations.

5. ***General Improvement Strategies:*** Provides a broad overview of the different categories of general improvement strategies available within the watershed and river corridors.

6. ***Potential Watershed-Wide Strategies:*** Provides a discussion of the potential watershed-wide strategies that were developed as part of this study including the watershed specific Emergency Action Plan (EAP), land cover interventions, as well as river obstruction interventions.

7. ***Potential Building - Level Strategies:*** Provides a discussion of the potential building-level strategies that were developed as part of this study including sump pump modifications, wet and/or dry floodproofing, elevation, and retreat.

8. ***Potential In-Stream Strategies:*** Provides a discussion of the potential in-stream strategies identified within each of the four reaches (A-D) including dam modifications, dam removals, roadway crossing replacements, as well as other site-specific improvement strategies.

9. ***Summary of "Solution" Strategies:*** Combines the different potential "solution" strategies into a single list along with information on ownership, costs, and available funding sources for each strategy as well as a discussion on the initial prioritization ranking for the strategies.

The report was submitted draft on May 22nd, 2023 for review and comment from the general public and project stakeholders. Comments received were incorporated into this final version of the report, issues final on June 30th, 2023.

1.0 MUMFORD RIVER AND DARK BROOK CORRIDOR – AN OVERVIEW

The river corridor of the Mumford River and the Dark Brook was subdivided into four reaches (Reaches A-D), as shown on Graphic #1 and as described below:

A. ***Reach A***: ***Upper Mumford River***

- Mumford River and its tributaries (all unnamed) from its upstream limits north of Central Turnpike through three dam structure (Sutton Falls Dam, Manchaug Pond Dam, and Stevens Pond Dam (the former water supply of Mill Site #3)), where it then joins the confluence with the Dark Brook upstream of the former/breached Lower Tucker Pond Dam (the former water supply of Mill Site #2).

B. ***Reach B: Dark Brook***

- Dark Brook and its tributaries (all unnamed) from its upstream reaches at Central Turnpike, through the Blackstone National Golf Course, through two dam structures (Upper Tucker Pond Dam, and the former/breached original Upper Tucker Pond Dam), where it then joins the confluence with the Mumford River upstream of the former/breached Lower Tucker Pond Dam.

C. ***Reach C: Mumford River – Manchaug Village***

- The Mumford River and its tributaries (all unnamed) after its confluence with the Dark Brook that extends through the former/breached Lower Tucker Pond Dam, Mill Pond Dam #1 (the former water supply of Mill Site #1), and then continues as an open channel for 1.5 miles where it then goes through the Potter Road Dam. Along this reach (0.6 miles upstream of the Potter Road Dam), a large unnamed tributary from the Whitins Reservoir Dam joins the Mumford River.

D. ***Reach D***: ***Mumford River – Douglas***

- The Mumford River and its tributaries (Caswell Brook, Riddle Brook, Centerville Brook, several other unnamed) from the Potter Road Dam to the Old Mill Pond Dam at Cook Street; which served as the downstream limits of the H&H modeling of this study.

Each of the four reaches are described in more detail below.

1.1 Reach A – Upper Mumford River

Reach A, shown on Graphic #2, is Mumford River and its tributaries (all unnamed) from its upstream limits north of Central Turnpike through three dam structures (Sutton Falls Dam, Manchaug Pond Dam, and Stevens Pond Dam (the former water supply of Mill Site #3)), where it then joins the confluence with the Dark Brook upstream of the former/breached Lower Tucker Pond Dam (the former water supply of Mill Site #2).

The following provides some general information relative to this specific reach:

- The length of the reach along the main stem, the Mumford River, is close to 5.4 river miles.
- The total drainage area is 7.8 mi^2
- This reach includes fourteen crossings, including six dams, one former dam, and seven roadway crossings.
- A total of fifteen locations were identified along this reach; the table below provides general information for each of the identified locations:

Crossings along Reach A (Upper Mumford River)						
ID	***Location***	***+Tribs***	***Drng. Area***	***Crossing Information***		
#	*River Mi.*	*No.*	*s.m.*	*Name*	*Description*	*Owner*
1*	0.2	-	0.3	***MA00671 Stump Pond Dam***	8' high dam embankment	Private
2*	0.6	-	0.6	***MA03383 Number Two Pond Dam***	5' high dam embankment	Private
3*	0.8	-	0.7	***MA03382 Number One Pond Dam (Town Farm Road)***	11' high dam/roadway embankment with three 3' CMP spillway conduits	Private
4*	1.0	-	0.8	***West Sutton Road***	11' high roadway embankment with uninventoried low head dam upstream	Town
5	1.2	-	1.0	***Central Turnpike***	7' high roadway embankment with 4'wx6'h box culvert	Town
6*	1.4	+1	1.7	***Mendon Road***	4' high roadway embankment	Town
7	1.6	+1	2.3	***Manchaug Road***	9' high roadway embankment with 6' CMP conduit	Town
8*	1.9	-	2.4	***MA02899 Homes Pond Dam***	7' high partially breached dam embankment	Private
9.1	2.0	-	2.8	***Sutton Falls Pond***	Impoundment	Private
9.2	2.3	-	2.8	***MA00956 Sutton Falls Pond Dam (Aldrich Lane)***	12' high dam embankment with 19' long spillway	Private
10.1	2.4	+2	6.7	***Manchaug Pond***	Impoundment	Town & Private
10.2	4.4	-	6.7	***MA00955 Mancahug Pond Dam (Torrey Road)***	29' high dam/roadway embankment with 10' wide stop log controlled spillway culvert and 2' square gated LLO conduit	Town
11.1	4.6	+1	7.7	***Stevens Pond***	Impoundment	Town
11.2	5.3	-	7.7	***MA00957 Stevens Pond Dam (Manchaug Road)***	30' high dam/roadway embankment with 16' wide spillway and 3' square LLO routed to 16'wx5'h arch culvert under road	Town
12	5.4	-	7.8	***Confluence with Dark Brook***	Open Channel	Private
*Not included in data collection task; information provided from available documentation, LiDAR terrain data, and aerial imagery						

1.2 Reach B – Dark Brook

Reach B, shown on graphic #3, is the Dark Brook and its tributaries (all unnamed) from its upstream reaches at Central Turnpike, through the Blackstone National Golf Course, through two dam structures (Upper Tucker Pond Dam, and the former/breached original Upper Tucker Pond Dam), where it then joins the confluence with the Mumford River upstream of the former/breached Lower Tucker Pond Dam (the former water supply of Mill Site #2).

The following provides some general information relative to this specific reach:

- The length of the reach along the main stem, the Dark Brook, is close to 3.7 river miles.
- The total drainage area is 3.5 mi^2
- This reach includes ten crossings, including three dams, one former dam, three cart path crossings through the golf course, and three roadway crossings.
- A total of sixteen locations were identified along this reach; the table below provides general information for each of the identified locations:

Crossings along Reach B (Dark Brook)						
ID	Location	+Tribs	Drainage Area	Crossing Information		
#	River Miles	No.	Square Miles	Name	Description	Owner
1*	0.5	-	0.2	MA02894 Summit Pond Dam	10' high dam embankment	Private
2*	0.6	-	0.2	Mendon Road	5' high roadway embankment	Town
3*	1.2	-	0.6	Golf Course Road/Path #1	2' high roadway embankment	Private
4*	1.4	-	0.7	Golf Course Road/Path #2	6' high roadway embankment	Private
5*	1.5	-	0.8	Golf Course Road/Path #3	7' high roadway embankment	Private
6*	1.8	+1	1.5	Golf Course Limits	Open Channel	Private
7*	2.3	+1	2.0	Wetland/Impoundment (Possible Beaver Dam)	Possible Beaver Dam	State
8*	2.6	+1	2.5	Wetland/Impoundment (Possible Beaver Dam)	Possible Beaver Dam	State & Private
9	2.7	-	2.6	Putnam Hill Road	7' high roadway embankment with 8.5'wx4.4'h concrete bridge	State
10	2.9	-	2.7	Tucker Lane	9' high roadway embankment with two 20'wx7'h bridge spans (Steel I Beam on Concrete Abutments	Private
11.1	2.9	-	2.9	Upper Tucker Pond	Impoundment	Private
11.2	3.3	-	2.9	MA00660 Upper Tucker Pond South Dam (Cote Lane)	22' high dam/roadway embankment with gated 2' LLO conduit and overflow section at right abutment	Private
11.3	3.3	-	2.9	MA02882 Upper Tucker Pond East Dam (Putnam Hill Road)	10' high dam/roadway embankment with stop log controlled 5.5' square stone box culvert spillway	Private (Roadway: State)
12	3.4	+1	3.4	Former Upper Tucker Pond Dam (Current Beaver Dam)	21' high partially breached former dam with 9' high beaver dam present within breach	Town
13	3.4	-	3.4	Putnam Hill Road	7' high roadway embankment with 4' square concrete box culvert	Town
14	3.7	-	3.5	Mumford River Confluence	Open Channel	Private
*Not included in data collection task; information provided from available documentation, LiDAR terrain data, and aerial imagery						

1.3 Reach C – Mumford River (Manchaug Village)

Reach C, shown on Graphic #4, is the Mumford River and its tributaries after its confluence with the Dark Brook that extends through the former/breached Lower Tucker Pond Dam, Mill Pond Dam (the former water supply of Mill Site #1), and then continues as an open channel for 1.5 miles where it then goes through the Potter Road Dam.

The following provides some general information relative to this specific reach:

- The length of the reach along the main stem, the Mumford River, is close to 1.9 river miles.
- The total drainage area is 18.3 mi^2; subdivided as follows:
  - *7.8 mi^2 drainage area of Reach A*
  - *3.5 mi^2 drainage area of Reach B*
  - *11.4 mi^2 drainage area from tributaries along and direct runoff to Reach C; including 10.4 mi^2 from the unnamed tributary of the Whitin Reservoir Dam*
- This reach includes six crossings, including two dams, one former dam, three roadway crossings.
- A total of nine locations were identified along this reach; the table below provides general information for each of the identified locations:

Crossings along Reach C (Mumford River- Manchaug Village)						
ID	**Location**	**+Tribs**	**Drainage Area**	**Crossing Information**		
No.	River Miles	No.	Square Miles	Name	Description	Owner
1	0.1	-	11.2	***Former Lower Tucker Pond Dam (Current Beaver Dam)***	13' high partially breached former dam with 3' high beaver dam present within breach	Town & Private
2	0.2	-	11.3	***Manchaug Road***	15' high roadway embankment with 40'wx 12'h bridge (Steel I beam with concrete abutments)	Town
3	0.3	-	11.3	***MA02881 Mill Pond #1 Dam***	17' high dam embankment with 80' auxiliary spillway and drop inlet primary spillway	Private
4	0.4	-	11.4	***Main Street***	12' high roadway embankment with 40'wx3'-8'h bridge (Steel I beam with concrete abutments)	State
5	0.4	-	11.4	***Stone Weir***	3'hx13'w stone weir located	Private
6	1.2	+2	22.3	***Confluence from Whitin Reservoir (Main Street Crossings)***	Main Street - 9' high roadway embankment with 10'wx6'h stone arch culvert	State
-	**1.3**	**-**	**22.3**	***Sutton - Douglas Town Line***		
7	1.6	-	22.7	***Potter Road Impoundment***	Impoundment	Private
8	1.9	-	22.7	***MA01172 Potter Road Dam***	10' high dam embankment with 50' wide spillway	Private
9	1.9	-	22.7	***Potter Road***	10' high roadway embankment with 20'wx9'h bridge (wooden bridge on stone wall abutments)	Town

1.4 Reach D – Mumford River (Douglas)

Reach D, shown on Graphic #5, is the Mumford River and its tributaries (Caswell Brook, Riddle Brook, Centerville Brook, several other unnamed) from the Potter Road Dam to the Old Mill Pond Dam at Cook Street; which serves as the downstream limits of the H&H modeling of this study.

The following provides some general information relative to this specific reach:

- The length of the reach along the main stem, the Mumford River, is close to 1.6 river miles.
- The total drainage area is 29.4 mi^2; subdivided as follows:
  - *7.8 mi^2 drainage area of Reach A*
  - *3.5 mi^2 drainage area of Reach B*
  - *11.4 mi^2 drainage area of Reach C*
  - *6.7 mi^2 drainage area from tributaries along and direct runoff to Reach D*
- This reach includes four crossings, including one dam and three roadway crossings.
- A total of four locations were identified along this reach; the table below provides general information for each of the identified locations:

Crossings along Reach D (Mumford River - Douglas)						
ID	***Location***	***+Tribs***	***Drainage Area***	***Crossing Information***		
No.	*River Miles*	*No.*	*Square Miles*	*Name*	*Description*	*Owner*
1	0.0	-	23.6	***Confluence with Coswell Brook***	Open Channel	Private
2	0.6	-	24	***Manchaug Road***	16' high roadway embankment with 40'wx11'h bridge (Steel I Beam on concrete abutments)	State
3	1.3	+2	29	***Mechanic Street***	21' high roadway embankment with 38'wx17'h stone arch bridge	Town
4	1.6	-	29.4	***Cook Street***	15' high roadway embankment with 56'wx12'h concrete bridge (bottom 9' is only 26'w)	Town
5	1.6	-	29.4	***MA01173 Old Mill Pond Dam***	20' high dam embankment with 52' w spillway	Private

2.0 EXISTING CONDITIONS H&H MODELING & RESULTS

Hydrologic and hydraulic (H&H) modeling of the existing conditions within the corridor was completed as part of this project; the following provides a general overview of the model development followed by a discussion of the model results within each of the four reaches (A-D). *Note that the modeling did not include failure or debris clogging of any of the crossings (dams, roadways, beaver dams, etc.). Inclusion of failure and/or debris clogging of these crossings would significantly impact the findings reported herein.*

2.1 Model Development

The total drainage area within the model limits (29.4 mi^2) was subdivided into 31 subbasins, as shown on Graphic #6 and described below:

- The 7.8 mi^2 drainage area of Reach A (Upper Mumford River) was subdivided into seven subbasins (A, B1, B2, and C through F).
- The 3.5 mi^2 drainage area of Reach B (Dark Brook) was subdivided into 10 subbasins (G through P).
- The 11.5 mi^2 drainage area that contributes directly to Reach C (Mumford River – Manchaug Village) was subdivided into ten subbasins.
    - Six of those subbasins (Q through U and V1), totaling 1.2 mi^2, contribute directly to the Reach.
    - Four of the subbasins (1 through 3 and V), totaling 10.3 mi^2, contribute to an unnamed tributary from the Whitin Reservoir.
- The 6.7 mi^2 drainage area that contributes directly to Reach D (Mumford River – Douglas) was subdivided into four subbasins (W through Z).

Graphic #7 provides a tabulated summary of all 31 subbasins. In addition to the subbasins, approximately 35 hydraulic structures were included within the model. These hydraulic structures include many of those included within the Reach summary tables presented within Section 1 of this report. The 31 subbasins, along with the 35 hydraulic structures were combined into a single HydroCAD model of the corridor (See Graphic #10 for the Routing Diagram of the Model). In addition to the HydroCAD model, a supplemental HEC-RAS 2D model was developed to better represent/model the river along the corridor, specifically, along Reaches 2, 3, and 4; Graphic #11 shows the limits of the HEC-RAS model. Reach 1 was not included within the HEC-RAS model as most of the reach could be well represented and modeled within the HydroCAD model alone, due in large part to the number of dams/impoundments located along that Reach.

The modeling was completed utilizing both current rainfall data (NOAA Atlas 14) as well as climate change informed predicted future (CCIPF) rainfall data (NOAA Atlas 14++); shown on Graphic #8. Based upon a cursory review of the 15-year (2008-2023) record of rainfall data available through CoCoRaHS[1], it appears this watershed has not experienced a storm event that exceeds the equivalent of the 5-year recurrence interval over this 15-year span. Graphic #9 provides a tabulated summary of 17 identified high rain events that have occurred in this area

[1] CoCoRaHS - Community Collaborative Rain, Hail & Snow Network

since 2008 with total rainfall depths ranging from 1.9 to 5.6 inches and durations between 1 and 3 days. Of those 17 events, three were close to the 5-year recurrence interval equivalent, six were close to the 2-year, two were close to the 1-year, and the remaining six were less than the 1-year recurrence interval equivalent.

The following four subsections (2.2 through 2.5) provide a summary of the model results in each of the four reaches (A-D).

2.2 Model Results Along Reach A (Upper Mumford)

The table on page 2-4 provides a tabulated summary of the model results at each of the identified locations within Reach A – Upper Mumford; the model results are demonstrated graphically on Graphic #12. Note that the model results and discussion provided for this reach is based solely upon the results of the HydroCAD Model as this reach was not included within the HEC-RAS Model.

The following provides a broad overview of the model results at specific locations organized by three general asset categories: dams, roadways, and buildings.

2.2.1 Dams

Of the six dams and one former dam located along this reach, the model results at the following locations were highlighted:

- ***9.1 & 9.2: Sutton Falls Pond Dam***, a Significant Hazard Dam in Fair Condition, provides very little to no flood attenuation and has limited hydraulic capacity; expected to overtop during storm events in excess of the 10-year event, far less than its required spillway design flood (SDF), the 100-year event. Failure of the dam would most likely have generally low to moderate impacts aside from making Aldrich Lane (the camp site access way that runs along the dam) impassible and potential flooding of the Sutton Falls Camping Area Intake Building.
- ***10.1 & 10.2: Manchaug Pond Dam***, a High Hazard Dam in Fair Condition that also supports Torrey Road, and its impoundment provides extensive flood attenuation during all storm events, reducing peak outflows to $1/7^{th}$ (15%) of the peak inflows into the impoundment. The dam has the capacity to accommodate all recurrent storm events with sufficient freeboard; however, its SDF (the ½ PMF[2] event) is expected to overtop the dam. Failure of the dam would most likely have extensive and catastrophic impacts to the downstream area.
- ***11.1 & 11.2: Stevens Pond Dam***, a High Hazard Dam in Fair Condition, and its impoundment provides moderate flood attenuation during all storm events, reducing peak outflows to 60-80% of the peak inflows into the impoundment. Similar to the Manchaug Pond Dam, the dam has the capacity to accommodate all recurrent storm events with sufficient freeboard; however, its SDF (½ PMF) is expected to overtop the dam. Failure of the dam would most likely have extensive and catastrophic impacts to the downstream area.

[2] The ½ PMF is ½ of the Probable Maximum Flood (PMF) Event which is generated by the Probable Maximum Precipitation rainfall. The ½ PMF does not have a rainfall depth or recurrence interval associated with it, but some methods estimate the 24-hour ½ PMF to be approximately a 20-inch event that roughly correlates to the 6,000-year recurrence interval.

2.2.2 Roadways

Of the seven roadway crossings along this reach, the model results at the following locations were highlighted:

- ***Most of the roadway crossings located upstream of Sutton Falls Dam*** have limited hydraulic capacity (ranging between the 5- and 25-year), poor stream connectivity[3], and appear to be highly prone to debris clogging. These crossings include 1: Stump Pond Dam, 2: Number Two Pond Dam, 3: Town Farm Road (Number One Pond Dam), 4: West Sutton Road, Old County Road, 5: Central Turnpike (three locations), 6: Mendon Road, and 7: Manchaug Road (two locations).
- ***Roadways Along Perimeter of Manchaug Pond:*** Eleven roadways (thirteen different locations) along the perimeter of Manchaug Pond become inundated and impassible during due to elevated pool levels within Manchaug Pond; starting at the 25-year event. Specific locations are identified on Graphic #12 and include two locations of Manchaug Road, two locations of Waters Road, Ledgestone Road, Lakeshore Drive, Summer Court, Bigelow Road, Hough Road, Parker Court, Holt Road, Torrey Road, as well as Irma Jones Road.
- ***The bridge under Manchaug Road located downstream of Stevens Pond Dam*** is a relatively small span and height based upon the size of its contributing drainage area; additionally, it offers no stream connectivity in its current state and may be prone to debris clogging given its relatively shallow height. However, its hydraulic performance is more than sufficient due in large part to the attenuating effect of the Manchaug Pond Dam and Stevens Pond Dam; without this attenuating effect, the bridge would likely have limited hydraulic capacity.

2.2.3 Buildings

To determine the impact of flooding at the building level, a preliminary planning level flood damage assessment was completed; explained in more detail within Section 3 of this report. As shown on the table provided as Graphic #13, this assessment identified 59 buildings along this Reach as having the potential for sustaining flood damage. Included within the table for each building is the event at which flood damage is expected to begin as well as Expected Annual Damages (EAD) estimated from the assessment.

Of these 59 buildings:

- 4 (#1-#4) are located upstream of the Manchaug Pond area
- 1 (#59) is located along the perimeter of Stevens Pond
- and the remaining 54 (#5-#58) are located along the perimeter of Manchaug Pond

[3] A crossing's stream connectivity is defined as how well the stream upstream and downstream of the crossing is connected and to what degree the crossing (culvert/bridge/dam) impacts that stream connectivity. Examples of crossings that have poor stream connectivity include ones that have spans less than the stream's bank full width, inverts that are higher than that of the stream channel, heights that are less than what they could be, material types that do not support fish/wildlife passage, as well as other factors that create conditions such that the river/stream is notably impacted by the presence of the roadway embankment and its crossing.

Crossings along Reach A (Upper Mumford River)									
ID	***Location***	***+Tribs***	***Drng. Area***	***Crossing Information***			***General Discussion***	***Capacity***	
#	*River Mi.*	*No.*	*s.m.*	*Name*	*Description*	*Owner*		*Current*	*CCIPF*
1*	0.2	-	0.3	***MA00671 Stump Pond Dam***	8' high dam embankment	Private	Significant Hazard Dam; Likely no attenuation, not modeled	-	-
2*	0.6	-	0.6	***MA03383 Number Two Pond Dam***	5' high dam embankment	Private	Non-Jurisdictional Dam; Likely no attenuation, not modeled	-	-
3*	0.8	-	0.7	***MA03382 Number One Pond Dam (Town Farm Road)***	11' high dam/roadway embankment with three 3' CMP spillway conduits	Private	Significant Hazard Dam in Poor Condition; Some attenuation provided by impoundment and dam	25-yr	10-yr
4*	1.0	-	0.8	***West Sutton Road***	11' high roadway embankment with uninventoried low head dam upstream	Town	Crossing provides no attenuation; not modeled	-	-
5	1.2	-	1.0	***Central Turnpike***	7' high roadway embankment with 4'wx6'h box culvert	Town	Split flow upstream sends a portion of the flow to a second crossing along a trib located 600' east - 7' high embankment with 3' pipe; Neither culvert offers attenuation; Capacity of main culvert is fine (1,000-yr), but capacity of east culvert is limited (10-yr)	10-yr	2-yr
6*	1.4	+1	1.7	***Mendon Road***	4' high roadway embankment	Town	Crossing provides no attenuation; not modeled	-	-
7	1.6	+1	2.3	***Manchaug Road***	9' high roadway embankment with 6' CMP conduit	Town	Crossing provides some attenuation; Split flow condition upstream sends a portion of the flow to a second crossing located 1,400' southeast - 4' high embankment with 1.5' pipe; Capacity of main culvert is fine (100-yr), but capacity of east culvert is limited (5-yr)	5-yr	2-yr
8*	1.9	-	2.4	***MA02899 Homes Pond Dam***	7' high partially breached dam embankment	Private	Non-Jurisdictional Dam that appears to be partially breached; Likely no attenuation, not modeled	-	-
9.1	2.0	-	2.8	***Sutton Falls Pond***	Impoundment	Private	9' deep impoundment with 3' of freeboard	10-yr	5-yr
9.2	2.3	-	2.8	***MA00956 Sutton Falls Pond Dam (Aldrich Lane)***	12' high dam embankment with 19' long spillway	Private	Significant Hazard Dam in Fair Condition; Little attenuation provided by impoundment and dam; >10-year storm will overtop the dam; SDF for dam is 100-year - not SDF compliant	10-yr	5-yr
10.1	2.4	+2	6.7	***Manchaug Pond***	Impoundment	Town & Private	37' deep impoundment with 8' of freeboard; Grade control within impoundment limits the drawdown potential to 8' below normal pool	-	-
10.2	4.4	-	6.7	***MA00955 Mancahug Pond Dam (Torrey Road)***	29' high dam/roadway embankment with 10' wide stop log controlled spillway culvert and 2' square gated LLO conduit	Town	High Hazard Dam in Fair Condition; Dam provides extensive attenuation; Dam can accommodate all recurrent storm events; Cannot accommodate its SDF, the 1/2 PMF; therefore, dam is not SDF compliant	>1,000-yr	200-yr
11.1	4.6	+1	7.7	***Stevens Pond***	Impoundment	Town	18' deep impoundment with 5' of freeboard	-	-
11.2	5.3	-	7.7	***MA00957 Stevens Pond Dam (Manchaug Road)***	30' high dam/roadway embankment with 16' wide spillway and 3' square LLO routed to 16'wx5'h arch culvert under road	Town	High Hazard Dam in Fair Condition; Dam provides some attenuation; Dam can accommodate all recurrent storm events; Cannot accommodate its SDF, the 1/2 PMF; therefore, dam is not SDF compliant	>1,000-yr	200-yr
12	5.4	-	7.8	***Confluence with Dark Brook***	Open Channel	Private		-	-

*Not included in data collection task; information provided from available documentation, LiDAR terrain data, and aerial imagery

2.3 Model Results Along Reach B (Dark Brook)

The table on page 2-8 provides a tabulated summary of the model results at each of the identified locations within Reach B – Dark Brook; the model results are demonstrated graphically on Graphic #14. The following provides a broad overview of the model results at specific locations organized by three general asset categories: dams, roadways, and buildings.

2.3.1 Dams

Of the two dams and one former dam located along this reach, the model results at the following locations were highlighted:

- ***11, 11.1, & 11.2: Upper Tucker Pond Dams***, two Significant Hazard Dams in Poor Condition, are both expected to experience overtopping during events greater than the 2-year storm event; therefore, the dams do not meet their current SDF (100-year storm). The hazard posed by a failure of either dam appears to warrant a High Hazard Classification; such a change would increase the SDF to the ½ PMF event. The roadway overtopping conditions that occur along this system (at Cote Lane, Tucker Lane, and Putnam Hill Road) for events greater than the 2-year event, creates a condition where normal and emergency access/egress is cutoff to 30+ homes.
- ***13: Former Upper Tucker Pond Dam / Current Beaver Dam,*** the beaver dam that has formed in the breached section of the former Upper Tucker Pond Dam, provides some attenuation during lower storms (< 10-year); however, with that attenuation, a notable head differential forms across the dam that increases the likelihood of failure during those lower storms. Failure of the beaver dam would have a notable impact at the Putnam Hill Road crossing located just downstream[4].
- ***Other Potential Beaver Activity***: Beaver damming is quite prevalent along Dark Brook both upstream and downstream of Upper Tucker Pond. Although only one notable beaver dam was encountered as part of the data collection tasks (#13 described above), there are areas of beaver debris and evidence of other potential beaver dams along Dark Brook. There are several locations where aerial imagery and LiDAR terrain data suggest that beaver dams are present. Graphic #21 provides a map of the suspected and observed beaver activity along Dark Brook as well as the Mumford River. These beaver dams carry with them a risk of failure that would further exacerbate the flooding issues determined from this study; both in the flood wave that a failure would release as well as the potential for the beaver debris clogging downstream crossings.

2.3.2 Roadways

All of the roadway crossings along this reach (with the exception of Tucker Lane) are significantly hydraulically undersized with capacities ranging from the 2-year to the 10-year storm, have poor stream connectivity, and are highly prone to debris clogging. Specific crossings include Putnam Hill Road at all three locations (9: Upstream of Tucker Lane, 11.3: At the Upper Tucker Pond East Dam, and 13: Downstream of the Former Upper Tucker Pond Dam (Current

[4] Reportedly, this beaver dam did fail during a high rain event in 2010 and its failure resulted in the full washout of Putnam Hill Road in the area of the culvert crossing.

Beaver Dam)).

Although the Tucker Lane crossing is sufficient, the upstream channel leading to the crossing has limited hydraulic capacity that leads to out of bank flooding and overtopping of Tucker Lane further West (Right) of the crossing. This condition occurs during events greater than the 5-year storm.

2.3.3 Buildings

To determine the impact of flooding at the building level, a preliminary planning level flood damage assessment was completed; explained in more detail within Section 3 of this report. As seen in the table provided as Graphic #15, this assessment identified 37 buildings along this Reach as having the potential for sustaining flood damage. Included within the table for each building is the event at which flood damage is expected to begin as well as EAD estimated from the assessment.

Of these 37 buildings:

- 15 (#2-#13, #15, #24, #26) are located along the perimeter of Upper Tucker Pond
- and the remaining 11 (#1, #14, #16-#23, #25, #27-#37) are located along Dark Brook downstream of Upper Tucker Pond along Putnam Hill Road and Ledge Street.

Crossings along Reach B (Dark Brook)									
ID	***Location***	***+Tribs***	***Drainage Area***	***Crossing Information***			***General Discussion***	**Capacity**	
#	*River Miles*	*No.*	*Square Miles*	*Name*	*Description*	*Owner*		*Current Rainfall*	*CCIPF Rainfall*
1*	0.5	-	0.2	***MA02894 Summit Pond Dam***	10' high dam embankment	Private	Significant Hazard Dam; Likely some attenuation but small drainage area, not modeled	-	-
2*	0.6	-	0.2	***Mendon Road***	5' high roadway embankment	Town	Crossing provides no attenuation; not modeled	-	-
3*	1.2	-	0.6	***Golf Course Road/Path #1***	2' high roadway embankment	Private	Area included within limits of model	-	-
4*	1.4	-	0.7	***Golf Course Road/Path #2***	6' high roadway embankment	Private	Area included within limits of model	-	-
5*	1.5	-	0.8	***Golf Course Road/Path #3***	7' high roadway embankment	Private	Area included within limits of model	-	-
6*	1.8	+1	1.5	***Golf Course Limits***	Open Channel	Private	Area included within model limits	-	-
7*	2.3	+1	2.0	***Wetland/Impoundment (Possible Beaver Dam)***	Possible Beaver Dam	State	Area included within model limits	-	-
8*	2.6	+1	2.5	***Wetland/Impoundment (Possible Beaver Dam)***	Possible Beaver Dam	State & Private	Area included within model limits	-	-
9	2.7	-	2.6	***Putnam Hill Road***	7' high roadway embankment with 8.5'wx4.4'h concrete bridge	State	Roadway overtopping occurs during events > 10-year; Combination of undersized culvert and poor DS channel capacity within 300 feet of culvert	10-yr	5-yr
10	2.9	-	2.7	***Tucker Lane***	9' high roadway embankment with two 20'wx7'h bridge spans (Steel I Beam on Concrete Abutments	Private	Out of bank flooding occurs that overtops the road west (right) of the bridge during events > 5-year - cuts off access to Tucker Lane; Result of limited US channel capacity; bridge itself does not impact water levels until 500-yr event	5-yr	2-yr
11.1	2.9	-	2.9	***Upper Tucker Pond***	Impoundment	Private	18' deep impoundment with 2.5' of FB from dam crest and 0.5' of FB from overflow area at South Dam	-	-
11.2	3.3	-	2.9	***MA00660 Upper Tucker Pond South Dam (Cote Lane)***	22' high dam/roadway embankment with gated 2' LLO conduit and overflow section at right abutment	Private	Significant Hazard Dam in Poor Condition; Right abutment overflow section flows during events > 1-year cutting off access/egress to Cote Lane; Left abutment overtops during events > 2-year further cutting off access/egress; Dam appears to warrant reclassification to High Hazard; Would bump up required SDF from 100-year to 1/2 PMF; Not SDF compliant with current or future SDF	2-yr	1-yr
11.3	3.3	-	2.9	***MA02882 Upper Tucker Pond East Dam (Putnam Hill Road)***	10' high dam/roadway embankment with stop log controlled 5.5' square stone box culvert spillway	Private (Roadway: State)	Significant Hazard Dam in Poor Condition; Right abutment overtops and floods road during events >2-year cutting off access/egress to Cote Lane; Dam appears to warrant reclassification to High Hazard; Would bump up required SDF from 100-year to 1/2 PMF; Not SDF compliant with current or future SDF	2-yr	1-yr
12	3.4	+1	3.4	***Former Upper Tucker Pond Dam (Current Beaver Dam)***	21' high partially breached former dam with 9' high beaver dam present within breach	Town	Beaver Dam creates 5' head differential up until it overtops during the 10-year storm, then goes down to a 2' head differential; Provides some attenuation for events <10-year but at a risk of failure that would impact downstream area (Putnam Hill Road) during those events	-	-
13	3.4	-	3.4	***Putnam Hill Road***	7' high roadway embankment with 4' square concrete box culvert	Town	Roadway overtopping occurs during events > 10-year; Undersized culvert highly prone to debris clogging; no substantial tailwater impacts	10-yr	2-yr
14	3.7	-	3.5	***Mumford River Confluence***	Open Channel	Private		-	-

*Not included in data collection task; information provided from available documentation, LiDAR terrain data, and aerial imagery

2.4 Model Results Along Reach C (Mumford River – Manchaug Village)

The table on page 2-12 provides a tabulated summary of the model results at each of the identified locations within Reach C – Mumford River (Manchaug Village); the model results are demonstrated graphically on Graphic #16. The following provides a broad overview of the model results at specific locations organized by three general asset categories: dams, roadways, and buildings.

2.4.1 Dams

Of the two dams and one former dam located along this reach, the model results at the following locations were highlighted:

- ***1: Former Lower Tucker Pond Dam / Current Beaver Dam***, the beaver dam that has formed in the breached section of the former Lower Tucker Pond Dam, likely provides little to no attenuation and results in a notable head differential during all storms that increases the likelihood of failure. Failure of the beaver dam would have an impact on the area downstream of the dam; in both elevated flow conditions from the flood wave as well as the potential for debris clogging downstream crossings.
- ***3: Mill Pond #1 Dam,*** a Non-Jurisdictional dam structure, has limited hydraulic capacity; expected to experience overtopping during events greater than the 10-year storm. Overtopping of the dam increases the risk of dam failure. A failure of the dam would have notable to significant impacts at both the upstream and downstream crossings. At the upstream crossing (Manchaug Road) the flow conditions that would occur through the bridge during and after failure of the dam could lead to erosion/scour of the stream channel, which in turn could lead to bridge abutment failure. At the downstream crossing (Main Street) the flood wave alone may overtop the roadway and impact adjacent buildings; the impact would be further exacerbated if debris leads to the partial or full clogging of the Main Street bridge, which is likely given the crossing geometry. With these potential impacts, the dam likely warrants a reclassification to a Significant Hazard structure, which would establish an SDF of the 100-year storm event.
- ***9: Potter Road Dam,*** Non-Jurisdictional dam structure, has limited hydraulic capacity expected to experience overtopping during events greater than the 10-year storm. Overtopping of the dam increases the risk of failure and also leads to overtopping of Potter Road, a dead end road located downstream of the dam. Additionally, based upon the dam’s height (10 feet) and storage volume (85 acre-ft) the dam does not meet the criteria to be considered a Non-Jurisdictional structure; the dam should be considered a Low or Significant Hazard structure, a rating that would establish an SDF at the 50-year or 100-year storm event.
- ***Other Beaver Activity***: Similar to Reach B – Dark Brook, beaver activity (including damming) is quite prevalent along Reach C. In addition to the 3-foot high beaver dam of #1 (described above), from Main Street to the Potter Road impoundment there are several beaver dams (with beavers observed recently) as well as numerous areas of fallen trees and debris dams. These beaver and debris dams along this very mildly sloped section of the reach are currently resulting in elevated river levels even during normal baseflow conditions that will likely catch additional debris during rain events and further elevate river levels.

2.4.2 Roadways

Most of the roadway crossings along this reach (with the exception of Potter Road) have sufficient hydraulic capacity and have effective stream connectivity. The geometry of the ***Main Street*** crossing does appear to be prone to debris clogging, which would drastically reduce its capacity and lead to flooding issues that would affect not only the roadway but several adjacent buildings. The ***Potter Road*** bridge is significantly undersized with a hydraulic capacity only capable of accommodating up to the 10-year storm event.

In addition to the crossings along the Mumford River; several of the crossings along the tributaries were also included within the model limits including Mumford Road and Main Street (3 locations) along the unnamed tributary from the Whitin Reservoir Dam, as well as two culvert crossings along much smaller tributaries along Whitins Road.

- ***Mumford Road***, twin 4'hx6'w CMP semi-arch culverts through a 7'h roadway embankment, has limited hydraulic capacity (expected to overtop during events > 10-year storm), has fair-poor stream connectivity, and has moderate proneness to debris clogging.
- ***Main Street – Main Crossing***, a 6'hx10'w stone arch culvert through a 9'h roadway embankment, has limited hydraulic capacity (high head differentials during most storms), fair stream connectivity, and moderate to high proneness to debris clogging. The limited hydraulic capacity forces flows to the west over a private driveway and to the East Crossing; overtopping occurs at the East crossing during events >50-year storm.
- ***Main Street – West Crossing***, a 2' square concrete box culvert through a 5'h roadway embankment, has limited hydraulic capacity (high head differentials during most storms and overtopping expected during storm events > 200-year), poor stream connectivity, and high preened to debris clogging.
- ***Main Street – East Crossing,*** a 2' cast iron conduit through a 10'h roadway embankment, has limited hydraulic capacity (high head differentials during most storms and overtopping expected during events >50-year), poor stream connectivity, and high proneness to debris clogging.
- ***Whitins Road – East Crossing***, a 3' CMP conduit through a 7'h roadway embankment, has limited hydraulic capacity (notable head differentials during most storms and overtopping expected during events >50-year), poor stream connectivity, and high proneness to debris clogging.
- ***Whitins Road – West Crossing***, a presumably fully collapsed culvert through a 7'h roadway embankment, has limited to no hydraulic capacity (notable head differentials during most storms and overtopping expected during events >1-year), poor stream connectivity, and high proneness to debris clogging.

2.4.3 Buildings

To determine the impact of flooding at the building level, a preliminary planning level flood damage assessment was completed; explained in more detail within Section 3 of this report. As seen in the table provided as Graphic #17, this assessment identified 25 buildings along this Reach as having the potential for sustaining flood damage from riverine flooding. Public feedback was received after the second public meeting that identified a wetland area that results in frequent structure flooding; the list and graphics were amended to include 5 additional structures for a total of 30 within this Reach. Included within the table for each building is the event at which flood damage is expected to begin as well as EAD estimated from the assessment.

Crossings along Reach C (Mumford River- Manchaug Village)									
ID	***Location***	***+Tribs***	***Drainage Area***	***Crossing Information***			***General Discussion***	***Capacity***	
No.	*River Miles*	*No.*	*Square Miles*	*Name*	*Description*	*Owner*		*Current Rainfall*	*CCIPF Rainfall*
1	0.1	-	11.2	***Former Lower Tucker Pond Dam (Current Beaver Dam)***	13' high partially breached former dam with 3' high beaver dam present within breach	Town & Private	Beaver Dam / Breach geometry creates 3' head differential during all storms; poses risk of failure that could impact downstream area; impacts water elevations upstream to some degree	-	-
2	0.2	-	11.3	***Manchaug Road***	15' high roadway embankment with 40'wx 12'h bridge (Steel I beam with concrete abutments)	Town	Bridge span can accommodate greater than the 1,000-year storm without resulting in roadway overtopping; Head differential across bridge is minimal; Low potential for debris clogging	> 1,000-yr	500-yr
3	0.3	-	11.3	***MA02881 Mill Pond #1 Dam***	17' high dam embankment with 80' auxiliary spillway and drop inlet primary spillway	Private	Non-Jurisdictional Dam; Dam overtops during events >10-year; Failure of the dam would likely have significant impacts at Manchaug Road US and Main Street DS - Impacts may warrant reclassification to a jurisdictional dam, likely Significant Hazard - would not be SDF compliant	10-yr	5-yr
4	0.4	-	11.4	***Main Street***	12' high roadway embankment with 40'wx3'-8'h bridge (Steel I beam with concrete abutments)	State	Bridge span can accommodate up to the 500-year storm without resulting in roadway overtopping; Head differential across bridge is minimal until the 1,000-year; Moderate potential for debris clogging - rise in WSEL's from debris clogging would have a significant impact	500-yr	100-yr
5	0.4	-	11.4	***Stone Weir***	3'hx13'w stone weir located	Private	Impacts WSEL and stream connectivity for storm events up to the 1-year; little to no effect by storm events > 1-year	-	-
6	1.2	+2	22.3	***Confluence from Whitin Reservoir (Main Street Crossings)***	Main Street - 9' high roadway embankment with 10'wx6'h stone arch culvert	State	OT of US driveway sends flow to the second culvert (2' square box) located 400' north starting at the 50-year; overtopping of the roadway itself starts at the 500-year; Out of bank flooding further upstream sends flow to a third culvert (2' Pipe) located 900' south - overtopping occurs at this location starting at the 100-year; All three culverts have high potential for debris clogging	200-yr	50-yr
-	1.3	-	22.3	***Sutton - Douglas Town Line***					
7	1.6	-	22.7	***Potter Road Impoundment***	Impoundment	Private	7' deep impoundment with 3' of freeboard	-	-
8	1.9	-	22.7	***MA01172 Potter Road Dam***	10' high dam embankment with 50' wide spillway	Private	Non-Jurisdictional Dam; Dam north of the spillway overtops during events >10-year; Dam height of 10' may warrant reclassification to a jurisdictional dam, likely Significant Hazard - would not be SDF compliant	10-yr	5-yr
9	1.9	-	22.7	***Potter Road***	10' high roadway embankment with 20'wx9'h bridge (wooden bridge on stone wall abutments)	Town	Roadway overtops during events > 10-year	10-yr	5-yr

2.5 Model Results Along Reach D (Mumford River – Douglas)

The table on page 2-14 provides a tabulated summary of the model results at each of the identified locations within Reach D – Mumford River (Douglas); the model results are demonstrated graphically on Graphic #18. The following provides a broad overview of the model results at specific locations organized by three general asset categories: dams, roadways, and buildings.

2.5.1 Dams

The one dam along this reach, ***Old Mill Pond Dam***, has sufficient hydraulic capacity; however, its presence and the pool levels it creates through the Cook Street bridge impacts the hydraulic capacity of that bridge.

2.5.2 Roadways

The Manchaug Road and Mechanic Street bridge crossings both appear to have sufficient hydraulic capacity. The arch geometry of the Mechanic Street bridge has a minimal to moderate debris clogging potential.

The Cook Steet bridge crossing has fair hydraulic capacity (overtopping not expected until storm events >200-year); however notable head differentials do develop across the bridge during events > 25-year event. The geometry of the bridge and low velocities through the bridge also combine to create moderate debris clogging potential.

2.5.3 Buildings

To determine the impact of flooding at the building level, a preliminary planning level flood damage assessment was completed; as explained in more detail within Section 3 of this report. As seen in the table provided as Graphic #19, this assessment identified 22 buildings along this Reach as having the potential for sustaining flood damage. Included within the table for each building is the event at which flood damage is expected to begin as well as EAD estimated from the assessment.

Crossings along Reach D (Mumford River - Douglas)									
ID	***Location***	***+Tribs***	***Drainage Area***	***Crossing Information***			***General Discussion***	***Capacity***	
No.	*River Miles*	*No.*	*Square Miles*	*Name*	*Description*	*Owner*		*Current Rainfall*	*CCIPF Rainfall*
1	0.0	-	23.6	***Confluence with Coswell Brook***	Open Channel	Private		-	-
2	0.6	-	24.0	***Manchaug Road***	16' high roadway embankment with 40'wx11'h bridge (Steel I Beam on concrete abutments)	State	Bridge span can accommodate greater than the 1,000-yr storm without resulting in roadway overtopping; Head differential across bridge is minimal; Low potential for debris clogging	> 1,000-yr	200-yr
3	1.3	+2	29.0	***Mechanic Street***	21' high roadway embankment with 38'wx17'h stone arch bridge	Town	Bridge span can accommodate greater than the 1,000-yr storm without resulting in roadway overtopping; Head differential across bridge is minimal until the 500-yr event; Moderate potential for debris clogging	> 1,000-yr	200-yr
4	1.6	-	29.4	***Cook Street***	15' high roadway embankment with 56'wx12'h concrete bridge (bottom 9' is only 26'w)	Town	Bridge span can accommodate up to and including the 200-yr storm without resulting in roadway overtopping; Head differential across bridge is minimal until the 25-yr event; Moderate potential for debris clogging	200-yr	50-yr
5	1.6	-	29.4	***MA01173 Old Mill Pond Dam***	20' high dam embankment with 52' w spillway	Private	Significant Hazard Dam in Poor Condition; Dam can accommodate up to the 500-yr event without overtopping.	500-yr	100-yr

3.0 BUILDING DAMAGE ASSESSMENT

A preliminary planning level assessment of the building related flood damage expected for each recurrent storm event was completed utilizing the H&H model results, a building inventory that was compiled from available assessor's and GIS data, and a FEMA sourced generic flood depth – percent damage curve[5].

The table below presents the results of this preliminary planning level assessment of flood damage at the building level under existing conditions utilizing current rainfall data (table to the left) and CCIPF rainfall data (table to the right).

Structural Damage Assessment - Existing Conditions (Preliminary Planning Level)												
Current Rainfall							*CCIPF Rainfall*					
Storm	*Town*	*# with Damage*	*Total Damages*	*EAD*	*EAD %*		*Storm*	*Town*	*# with Damage*	*Total Damages*	*EAD*	*EAD %*
1-year	*Sutton*	*2*	*$ 5,473*	*$ 3,608*	*3.5%*		**1-year**	*Sutton*	*6*	*$ 8,988*	*$ 8,267*	*2.8%*
	Douglas	*0*	*$ -*	*$ -*	*0.0%*			*Douglas*	*0*	*$ -*	*$ 1,438*	*0.5%*
	Total	***2***	***$ 5,473***	*$ 3,608*	***3.5%***			***Total***	***6***	***$ 8,988***	*$ 9,705*	***3.3%***
2-year	*Sutton*	*4*	*$ 8,988*	*$ 9,196*	*8.9%*		**2-year**	*Sutton*	*6*	*$ 24,147*	*$ 28,503*	*9.7%*
	Douglas	*0*	*$ -*	*$ -*	*0.0%*			*Douglas*	*1*	*$ 5,763*	*$ 17,889*	*6.1%*
	Total	***4***	***$ 8,988***	***$ 9,196***	***8.9%***			***Total***	***7***	***$ 29,910***	*$ 46,392*	***15.8%***
5-year	*Sutton*	*7*	*$ 52,320*	*$ 4,070*	*3.9%*		**5-year**	*Sutton*	*12*	*$ 165,873*	*$ 22,540*	*7.7%*
	Douglas	*0*	*$ -*	*$ 5,505*	*5.3%*			*Douglas*	*12*	*$ 113,499*	*$ 15,371*	*5.2%*
	Total	***7***	***$ 52,320***	*$ 9,576*	***9.2%***			***Total***	***24***	***$ 279,372***	*$ 37,910*	***12.9%***
10-year	*Sutton*	*12*	*$ 165,873*	*$ 31,011*	*29.9%*		**10-year**	*Sutton*	*21*	*$ 284,919*	*$ 48,830*	*16.6%*
	Douglas	*12*	*$ 110,109*	*$ 20,965*	*20.2%*			*Douglas*	*15*	*$ 193,914*	*$ 44,053*	*15.0%*
	Total	***24***	***$ 275,982***	*$ 51,976*	***50.1%***			***Total***	***36***	***$ 478,833***	*$ 92,883*	***31.6%***
25-year	*Sutton*	*21*	*$ 277,145*	*$ 6,026*	*5.8%*		**25-year**	*Sutton*	*23*	*$ 412,658*	*$ 53,845*	*18.3%*
	Douglas	*15*	*$ 189,394*	*$ 5,167*	*5.0%*			*Douglas*	*23*	*$ 435,411*	*$ 10,834*	*3.7%*
	Total	***36***	***$ 466,539***	*$ 11,193*	***10.8%***			***Total***	***46***	***$ 848,068***	*$ 64,679*	***22.0%***
50-year	*Sutton*	*21*	*$ 325,479*	*$ 3,691*	*3.6%*		**50-year**	*Sutton*	*29*	*$ 494,235*	*$ 5,781*	*2.0%*
	Douglas	*20*	*$ 327,259*	*$ 3,802*	*3.7%*			*Douglas*	*29*	*$ 648,012*	*$ 8,301*	*2.8%*
	Total	***41***	***$ 652,738***	*$ 7,493*	***7.2%***			***Total***	***58***	***$ 1,142,247***	*$ 14,083*	***4.8%***
100-year	*Sutton*	*23*	*$ 366,846*	*$ 2,109*	*2.0%*		**100-year**	*Sutton*	*39*	*$ 661,992*	*$ 3,834*	*1.3%*
	Douglas	*23*	*$ 433,151*	*$ 2,596*	*2.5%*			*Douglas*	*38*	*$ 1,012,273*	*$ 6,146*	*2.1%*
	Total	***46***	***$ 799,997***	*$ 4,705*	***4.5%***			***Total***	***77***	***$ 1,674,265***	*$ 9,980*	***3.4%***
200-year	*Sutton*	*24*	*$ 430,974*	*$ 1,604*	*1.5%*		**200-year**	*Sutton*	*43*	*$ 871,634*	*$ 2,990*	*1.0%*
	Douglas	*29*	*$ 605,261*	*$ 2,354*	*2.3%*			*Douglas*	*47*	*$ 1,446,221*	*$ 6,343*	*2.2%*
	Total	***53***	***$ 1,036,235***	*$ 3,958*	***3.8%***			***Total***	***90***	***$ 2,317,855***	*$ 9,333*	***3.2%***
500-year	*Sutton*	*37*	*$ 638,664*	*$ 682*	*0.7%*		**500-year**	*Sutton*	*57*	*$ 1,121,832*	*$ 1,254*	*0.4%*
	Douglas	*37*	*$ 963,841*	*$ 1,095*	*1.1%*			*Douglas*	*63*	*$ 2,782,186*	*$ 3,090*	*1.1%*
	Total	***74***	***$ 1,602,504***	*$ 1,776*	***1.7%***			***Total***	***120***	***$ 3,904,018***	*$ 4,344*	***1.5%***
1,000-year	*Sutton*	*41*	*$ 724,782*	*$ 72*	*0.1%*		**1,000-year**	*Sutton*	*72*	*$ 1,386,764*	*$ 1,387*	*0.5%*
	Douglas	*43*	*$ 1,225,688*	*$ 123*	*0.1%*			*Douglas*	*66*	*$ 3,397,322*	*$ 3,397*	*1.2%*
	Total	***84***	***$ 1,950,470***	*$ 195*	***0.2%***			***Total***	***138***	***$ 4,784,086***	*$ 4,784*	***1.6%***
Totals				***$ 103,676***	***/year***		**Totals**				***$ 294,094***	***/year***

The table shows the following:

1. The expected annual damage (EAD) is just over $103K with current rainfall and $294K with CCIPF rainfall.

2. The bulk of this EAD (72% with current rainfall and 64% with CCIPF rainfall) is during

5 A single depth-damage curve was used for each building for this planning level assessment. The curve selected is that for a two-story, with basement, residential building; with the % damage truncated to begin at -2.5 feet of flooding/freeboard. The refined damage assessment that would be completed during subsequent planning/design will build a building specific depth-damage curve for each individual building. Additionally, the refined assessment would verify first floor elevations for all buildings; the current assessment used LiDAR terrain data around the perimeter of each building, which may differ from the actual first floor elevations

storm events less than the 25-year event; the more frequent (more likely to occur) recurrent storm events.

3. Damages are only reported at the building level and do not take into account other types of damages that are likely to occur during these various recurrent storm events. Once evaluated and accounted for, these other types of damages could be economically, societally, and environmentally significant. Examples of these other types of damages include, but are not limited to, the following:

   a. Economical:
      i. Infrastructure related damages to dams, roadways, and utilities
      ii. Monetary costs associated with Societal and Environmental damages.

   b. Societal:
      i. Individual: Potential direct or indirect loss of life, impacts to quality of life and mental health
      ii. Emergency Response: Restricted access to individual homes and entire blocks
      iii. Community: Negative community-based impacts such as viewing the community poorly, potential desire for individuals to relocate out of the community

   c. Environmental:
      i. Release and spread of hazardous materials such as wastewater, petrochemicals, and other hazardous material within the inundation zones

Additionally, as noted previously within this report, the modeling of this study/plan did not include failure or debris clogging of any of the crossings (dams, roadways, beaver dams, etc.). Inclusion of infrastructure failure and/or debris clogging would likely significantly impact the results reported herein.

4.0 SUMMARY OF EXISTING CONDITIONS EVALUATIONS

The following provides a summary of the asset areas highlighted (dams, roadways, buildings) at each of the four reaches (A-D) based upon the completed evaluations of existing conditions.

4.1 Reach A: Upper Mumford River

- ***Dams***
  - i. Sutton Falls Pond Dam – *limited capacity and SDF compliance*
  - ii. Manchaug Pond Dam – *attenuation, hazard, and SDF compliance*
  - iii. Stevens Pond Dam – *attenuation, hazard, and SDF compliance*
- ***Roadways***
  - i. All roadways upstream of Sutton Falls Pond Dam – *limited capacity, poor stream connectivity, proneness to debris clogging*
  - ii. Roadways along perimeter of Manchaug Pond – *flooding from elevated pool levels within Manchaug Pond during storm events*
  - iii. Manchaug Road DS of Stevens Pond – *poor stream connectivity, proneness to debris clogging, capacity dependent on dam attenuation provided upstream*
- ***Buildings***:
  - i. 59 buildings identified as having potential to sustain flood damage from riverine flooding.

4.2 Reach B: Dark Brook

- ***Dams***
  - i. Upper Tucker Pond Dam – *condition, hazard, limited capacity, and SDF compliance*
  - ii. Former/Breached Upper Tucker Pond Dam / Current Beaver Dam – *attenuation, hazard, debris source*
  - iii. Beaver Activity – *hazard and debris source*
- ***Roadways***
  - i. All roadways except for Tucker Lane – *limited capacity, poor stream connectivity, proneness to debris clogging*
  - ii. Tucker Lane US Channel – *out of bank flooding that overtops the road*
- ***Buildings***:
  - i. 37 buildings identified as having potential to sustain flood damage from riverine flooding.

4.3 Reach C: Mumford River (Manchaug Village)

- ***Dams***
  - i. Former/Breached Upper Tucker Pond Dam / Current Beaver Dam – *hazard and debris source*
  - ii. Mill Pond #1 Dam – *jurisdictional status, limited capacity*
  - iii. Potter Road Dam – *jurisdictional status, limited capacity*
  - iv. Beaver Activity – *hazard and debris source*
- ***Roadways***
  - i. Main Street – *proneness to debris clogging*
  - ii. Potter Road – *limited capacity and proneness to debris clogging*
  - iii. Roadways along tributaries (Mumford Road, Main Street (3 locations), Whitins Road (2 locations) **-** *limited capacity and proneness to debris clogging*
- ***Buildings***:
  - i. 25 buildings identified as having potential to sustain flood damage from riverine flooding.
  - ii. 5 buildings identified as having potential to sustain flood damage from adjacent poorly draining wetland. *(Added from public input)*

4.4 Reach D: Mumford River (Douglas)

- ***Dams***
  - i. Old Mill Pond Dam – *condition and impact at Cook Street*
- ***Roadways***
  - i. Cook Street – *head differentials*
- ***Buildings***:
  - i. 22 buildings identified as having potential to sustain flood damage from riverine flooding.

5.0 GENERAL IMPROVEMENT STRATEGIES

There are a multitude of improvement strategies that could be implemented in efforts to alleviate the flooding issues that exist along the Mumford River and Dark Brook Corridor. Potential strategies can be subdivided into three general categories, watershed-wide, building-level, and in-stream strategies. Each is described below:

5.1 Watershed-Wide Strategies

Strategies that can be applied to the watershed as a whole as opposed to a specific asset or location. Section 6.0 of this report provides additional detail on these watershed-wide strategies and how they could be applied for this specific watershed. Specific strategies under this category include:

- ***Emergency Action Plan:*** Development of a watershed specific emergency action/response plan utilizing and building off of the results of this study/plan. The plan would improve both public knowledge of the hazard of riverine flooding within the community as well as emergency preparedness and response to that hazard.

- ***Land Cover Interventions:*** Development and implementation of policy and improvements aimed at maintaining and improving land cover conditions throughout the watershed; measures that would offer a multitude of benefits including maximized rainfall absorption potential. Three general subcategories of this strategy type include:

    - *Land Cover Preservation:* Watershed management policies and action to conserve land cover / land use in order to preserve the current rainfall absorption capacity of the watershed; a watershed that is currently comprised of over 90% undeveloped vegetated areas.

    - *Land Cover Improvements:* Measures installed at the impervious surfaces of the watershed to improve absorption/infiltration capacity of those areas. Impervious surfaces currently account for less than 1% of the total watershed area; however, they do exist. In addition to the impervious surface improvements, measures could also be targeted at other non-impervious areas to improve or establish the vegetation in those areas.

    - *Green Stormwater Infrastructure (GSI):* Installation of GSI adjacent to impervious areas to collect, treat, and absorb the runoff from that impervious area.

- ***River Obstruction Interventions:*** Improvements along the river corridor to remove/address areas of beaver activity (dams and debris) as well as other debris (fallen trees, misc. debris) with high risk/impact. Following initial action, recurrent monitoring and maintenance of the corridor to identify and address recurrence of obstructions in these high risk/impact areas. Benefits of this strategy include lowered flood elevations upstream, failure risk reduction/elimination, as well as improved ecosystem services.[6]

[6] Ecosystem services is defined as the general ecological health/value of the river and its floodplain; particularly the connectivity of the river and its floodplain across stream crossing, as well as the current and potential future value that it provides to living organisms (aquatic and terrestrial) as well as vegetation.

5.2 Building-Level Strategies

Strategies to make individual buildings less prone to flood damage and more resilient to the hazard of riverine flooding. Section 7.0 of this report provides additional detail on these building level strategies and how they could be applied to this specific watershed. Specific strategies under this category include:

- ***Sump Pump Improvements***: Installation and/or improvements of existing sump pump systems and their power supplies.
- ***Wet Floodproofing:*** Relocating or otherwise protecting high value content currently stored in the basement/lower levels of a building to avoid damage to that content when the lower levels of that building experience flooding.
- ***Dry Floodproofing:*** Installation of improvements to the building to limit the potential for flooding to occur inside of the building.
- ***Elevation:*** Raising of the building on its foundation such that its first floor elevation is above a specific desired flood elevation.
- ***Retreat:*** Relocation of the building to a less flood prone area of the property. If relocation is not feasible, selling of the property, demolition of the building and restoration of property to a natural floodplain, and relocating to a less flood prone location of the community

5.3 In-Stream Strategies

Strategies that are applied at a specific asset or location to address the identified vulnerabilities of that asset and in-so-doing converting it from an at-risk vulnerability into a resilient strength for the community. Section 8.0 of this report provides additional detail on site specific in-stream strategies organized by the four different reaches (A-D). Specific strategies under this category include:

- ***Dam Modifications***: Modifications to and/or formally establishing effective and dependent operational procedures at dams.
  - General benefits of this strategy include regulatory compliance (SDF, condition rating, other dam safety requirements), increased flood attenuation, lowered flood elevations (upstream and downstream), failure risk reduction, and potential to provide improved ecosystems services (stream connectivity, fish/wildlife passage).
- ***Dam Removals:*** Full and/or partial removal of dams no longer serving a desired purpose. Additionally, removal of former/partially beached dams that are prone to beaver/debris dams.
  - General benefits of this strategy include elimination of the failure risk of the dam, lower flood elevations upstream, and providing vastly improved ecosystem services.
- ***Roadway Crossing Replacements:*** Replacements of crossings that are hydraulically undersized, are prone to debris clogging, and/or have poor stream connectivity.
  - General benefits of this strategy include lowered flood elevations upstream, reduced frequency of overtopping and in turn reduced damage and accessibility issues that come with roadway overtopping, failure risk reduction from differential loading, as well as vastly improved ecosystem services.

6.0 POTENTIAL WATERSHED-WIDE STRATEGIES

This section includes certain watershed-wide strategies that were developed for this specific watershed. The strategies developed include the development of a watershed-specific emergency action plan, land cover intervention strategies, as well as river obstruction interventions.

6.1 Emergency Action Plan (EAP)

The current study/plan has identified the:

- Extent of riverine flooding under a wide range of rain events (2-inch to 18-inch)
- Vulnerabilities of the existing assets as it pertains to the hazard of riverine flooding
- Triggering rainfall event for each asset
- Failure potential for each asset
- Potential impacts from failure of each asset

It provides a basis for the development of a watershed specific emergency action/response plan for riverine flooding. This plan could improve:

- Knowledge of both the hazard itself and the impacts that the hazard poses to the community
- Preparedness for both preventative and reactive response to the hazard
- Preventative action and warning that could be completed prior to a specific storm
- Reactive response to impacted areas during and after the storm
- Duration of recovery actions needed after the storm.

The plan could help first identify the impacted area and second develop a list of actionable items (prior to, during, and after the storm) for each storm event.

The impacted area will largely depend on whether or not specific assets (dams and roadways) are expected to fail during the specific storm event; therefore, the plan should be adaptable to provide information on both situations (storm event without and with failure of specific assets), likely requiring the intertwining of any asset specific EAP's into this watershed-wide EAP. For example, all High and Significant Hazard dams should have updated EAP's specific to that dam and contain information on both impacted area and actionable items specific to a failure of that dam. Similar asset specific EAP's could be developed for certain roadways that warrant such as part of this watershed-wide EAP.

This EAP is presented as Solution Strategy #1 within Section 9.0 of this report.

6.2 Land Cover Interventions

Land cover intervention strategies in general are the development and implementation of policy and improvements aimed at maintaining and improving land cover conditions throughout the watershed; measures that would offer a multitude of benefits including maximized rainfall absorption potential. Three general subcategories of this strategy type include land cover preservation, land cover improvements, and green stormwater infrastructure; each described in more detail in the subsections below.

6.2.1 Land Cover Preservation

Land cover preservation strategies in general are watershed management policies and action to conserve land cover / land use to preserve the current rainfall absorption capacity of the watershed; a watershed that is currently comprised of over 90% undeveloped vegetated areas. Potential land cover preservation strategies include:

- ***Education/Outreach:*** Complete outreach and educational programs to inform the community as to the multitude of benefits that are provided by well established vegetated areas.
- ***Incentive Programs:*** Establishment of new or education of existing programs that incentivize the preservation of vegetated areas.
- ***Restriction Policies:*** Establishment of new or refinement of existing land use restriction policies that restrict the disturbance of vegetated land cover areas, while also not inhibiting private property rights and new development.

Land cover preservation strategies are grouped together and presented as Solution Strategy #2 within Section 9.0 of this report. It was beyond the scope of this study to identify specific land cover preservation programs and policies.

6.2.2 Land Cover Improvements

Land cover improvement strategies in general are measures installed at the impervious surfaces of the watershed to improve absorption/infiltration capacity of those areas. Impervious surfaces currently account for less than 1% of the total watershed area; however, they do exist. In addition to the impervious surface improvements, measures could also be targeted at other non-impervious areas to improve or establish the vegetation in those areas. Potential land cover improvement strategies include:

- ***Education/Outreach:*** Complete outreach and educational programs to inform the community as to the multitude of benefits that are provided by well established vegetated areas as well as the impacts of impervious surfaces.
- ***Incentive Programs:*** Establishment of new or education of existing programs that incentivize the conversion of impervious surfaces to vegetated surfaces as well as the enhancement of existing vegetated areas.
- ***Conversion of Impervious Surfaces:*** Measures installed at areas of existing impervious surfaces to allow them to become pervious. Two specific measures include conversion of unused pavement areas to vegetated areas as well as conversion of needed paved areas to permeable pavement where appropriate.
- ***Enhancement of Pervious Surfaces:*** Measures installed at areas of existing pervious surfaces that currently do not offer the most beneficial land coverage. Two specific measures include establishing vegetation at areas of bare/barren land as well as improvement/enhancement of existing vegetated surfaces.

Land cover improvement strategies are grouped together and presented as Solution Strategy #3 within Section 9.0 of this report. It was beyond the scope of this study/plan to identify specific land cover improvement programs and/or conversion/enhancement locations.

6.2.3 Green Stormwater Infrastructure (GSI)

There are a number of GSI strategies that could be installed within the watershed, particularly adjacent to existing or proposed impervious areas, that could collect, treat, and absorb the runoff from that impervious area. Potential GSI strategies include the following:

1. ***Downspout Disconnection:*** Measures to allow rainfall on building roofs that makes its way into gutters and downspouts to be stored or infiltrated into the ground as opposed to routing directing to impervious surfaces and/or storm drainage systems. Storage and infiltration options are discussed within the Rainwater Harvesting strategy (#3 below).

2. ***Rooftop Measures:*** Measures installed on rooftops to provide rainfall storage capability (Blue Roofs) or vegetated absorption potential (Green Roofs). These measures are most suitable for roofs with little to no pitch and are often most effective when paired with downspout disconnection and rainwater harvesting.

3. ***Rainwater Harvesting:*** Measures to allow for the collection of rainfall on impervious surfaces of an individual property/building and storage of that water for later outdoor watering needs. Storage options include above or below grade containers (rain barrels) that often have overflow options that allow excess water to infiltrate into the ground via a rain garden (#3 below) or soak away barrel (below grade perforated or open bottom rain barrel).

4. ***Rain Garden:*** Measures to allow for the collection of rainfall on impervious surfaces of an individual property/building and infiltration of that rainfall/runoff into the ground. A typical rain garden is a subsurface trench excavated 18-24 inches below the ground surface that is filled with a bioretention soil/sand that has high absorption potential and supports a surface coverage of choice (grass, mulch, plantings, stone, etc.)

5. ***Planter Boxes:*** This measure is essentially a rain garden with a single tree or planting as its surface coverage.

6. ***Bio Swales:*** This measure is essentially a larger scale rain garden that can be used adjacent to larger impervious areas such as parking lots and roadways. The swales can collect runoff directly from the impervious areas or by routing the storm drainage system of that impervious area to the swale.

7. ***Bio Retention/Detention Ponds:*** In situations where the amount of impervious surface area being sent to the GSI is expected to exceed the absorption potential of the GSI, a bioretention pond can be used to store the amount of runoff that exceeds the absorption potential of the area. These ponds are equipped with overflow structures that provide hydraulic relief prior to the ponds reaching their “fully filled” capacity; these overflow structures are either routed to downstream/downgradient GSI, storm drainage systems, or directly into rivers/streams.

8. ***Underground Retention/Detention Systems:*** Where sites have surficial surface constraints that make it such that open surface GSI strategies are not feasible or need to be supplemented, systems can be installed underground that are capable of both infiltration and retention/detention of runoff collected from stormwater drainage systems.

9. ***Permeable Pavement:*** Measures to convert typical impervious pavement to permeable pavement in locations where pavement use in such that it can accommodate such a conversion (i.e. low traffic areas, etc.)

GSI strategies are grouped together and presented as Solution Strategy #4 within Section 9.0 of this report. It was beyond the scope of this study/plan to identify specific locations where GSI strategies could be implemented.

6.3 River Obstruction Interventions

This section includes certain intervention strategies that could be completed along the river corridor to remove/address areas of beaver activity (dams and debris) as well as other debris (fallen trees, misc. debris) with high risk/impact. Following initial action, recurrent monitoring and maintenance of the corridor to identify and address reoccurrence of these high risk/impact obstructions. Benefits of this strategy include lowered flood elevations upstream, failure risk reduction/elimination, as well as improved ecosystem services.

6.3.1 Complexity of the Problem and Solutions of River Obstructions

Addressing these areas of river obstructions could prove to be a complex and convoluted solution with certain benefits and tradeoffs to be considered.

In terms of benefits, in some instances, these obstructions may currently be providing:

- Certain value to the river's ecosystem
- Flood attenuation, which could be offering a flood reduction benefit to the area downstream of the obstruction.

However, in most instances, these obstructions in their natural/current state also have negative impacts and potential risks including:

- Certain degradation of the river's ecosystem
- Increased river levels and flooding upstream (both under normal conditions and storm events)
- Potential for accumulating additional debris that would further increase river levels and flooding upstream
- High potential for failure of the beaver/debris dams that do our could exist; a failure that could lead to increased river levels and flooding downstream

6.3.2 Potential General Solution Strategies for River Obstructions

Due to this complexity, the solution to these areas of river obstructions will likely vary depending on the location and factors influencing that specific location. The following three generic solution scopes have been developed.

Generic Solution Scope #1 (Type 1): Obstruction ***cannot*** be removed and is of ***low risk/impact*** that does not necessarily warrant preventive action.

a) Complete routine monitoring and maintenance to ensure the obstruction does not substantially expand such that it is no longer of low risk/impact.

Generic Solution Scope #2 (Type 2): Obstruction ***cannot*** be removed and is of ***high risk/impact*** that warrants preventive action.

a) Install measures to stabilize the obstruction to limit the potential for failure of the obstruction.

b) Complete routine monitoring and maintenance to ensure the obstruction does not substantially expand such that additional action is warranted.

Generic Solution Scope #3 (Type 3): Obstruction ***can*** be removed and is of ***high risk/impact*** that warrants preventive action.

a) If a beaver dam, relocate the beavers if permissible.

b) Remove the full lateral and vertical limits of the obstruction; provide bank and/or channel stabilization measures if required.

c) Complete routine monitoring and maintenance to ensure the obstruction does not reestablish.

6.3.3 Specific River Obstruction Locations within the Watershed

As shown on Graphic #21, there are several specific locations of beaver activity and areas of river debris that were identified during the completion of this study/plan. Each location is described below along with some discussion on the site specifics of that particular location. Note that this list of locations should be considered a partial list; other locations of river obstructions are likely.

The majority of the locations are grouped together and presented as Solution Strategy #5 within Section 9.0 of this report, unless otherwise noted below.

1. A suspected beaver dam based upon topography and aerial imagery in the upper reach of an unnamed tributary to Dark Brook upstream of the Blackstone National Golf Course. (Reach B)
    - This area is an undeveloped wooded wetland that would be largely unimpacted by elevated pool levels upstream.
    - There is a relatively large amount of storage (130 acre-feet) within the area upstream of the presumed beaver dam location. This storage may provide flood attenuation and also creates a condition where a large volume of water would be released if the dam were to fail.
    - The height of the beaver dam based upon topography is up to 8 feet. Beaver dams of this height are subject to high head differentials that increase the potential of dam failure.
    - The area downstream of the beaver dam is undeveloped woodlands along the Dark Brook and its floodplain, including two other suspected beaver dam locations (#2 and #3), before reaching the Putnam Hill Road (PHR) crossing a little over 1 mile downstream of the beaver dam. Failure of this beaver dam may result in sequential failures of suspected beaver dams #2 and #3 and could lead to flooding issues at the Putnam Hill Road (PHR) crossing, Tucker Lane, and within Upper Tucker Pond. Dam failure analyses could be completed to determine the actual potential impacts from a failure of the beaver dam.

This combination of factors warrant recommendation for preventative action at this obstruction location. The recommended solution strategy is Type 3[7]; however it could certainly be a Type 2 as there is limited to no impact of the upstream flooding created by the beaver dam.

2. Suspected beaver activity based upon topography and aerial imagery located along the Dark Brook downstream of the Blackstone National Golf Course and 0.4 miles upstream of the PHR crossing. (Reach B)

    - This area is an undeveloped wooded wetland that would be largely unimpacted by elevated pool levels upstream.
    - There is a relatively small amount of storage (20 acre-feet) within the area upstream of the presumed beaver activity location. This storage may provide a marginal amount of flood attenuation during low rain events.
    - The height of the beaver activity based upon topography appears to be less than 2 feet.
    - The area downstream of the beaver activity is undeveloped woodlands along the Dark Brook and its floodplain, including one other suspected beaver dam locations (#3), before reaching the PHR crossing a just under 0.4 miles downstream of the beaver dam. Failure of a beaver dam at this location could result in sequential failure of suspected beaver #3 and could lead to flooding issues at the PHR crossing. Dam failure analyses could be completed to determine the actual potential impacts from a failure of the beaver dam.

    This combination of factors make it such that preventive action does not appear warranted at this time for this obstruction location and that a Type 1 solution is sufficient for this obstruction location. Note that actual observations of the location and/or dam break analyses may impact that recommendation.

3. Suspected beaver activity based upon topography and aerial imagery located along the Dark Brook 0.2 miles downstream of Location #2 and 0.2 miles upstream of the PHR crossing. (Reach B). The upstream flooding impacts, storage, height, failure impact discussion, are similar to Location #2; therefore, the recommended solution strategy is the same as it is for Location #2.

4. Observed beaver debris 20 feet upstream of the PHR crossing. (Reach B)

    - The primary impact of the debris is its impact on the PHR crossing itself. The debris is limiting the hydraulic capacity of the crossing which could lead to increased pool levels upstream of the crossing and in turn, the frequency and extents of overtopping of the roadway. Additionally, the debris could mobilize to the crossing itself, collect additional debris, and lead to the partial/full obstruction of the crossing, which would further exacerbate the roadway overtopping concerns.

    A Type 3 solution is recommended for this specific location given the proximity to the PHR crossing. The solution could be incorporated within the recommended crossing replacement project for this PHR crossing.

[7] See Section 6.2.3 for the three different categories of generic solutions scopes (Categories 1-3).

5. Suspected river obstruction (beaver or other debris) of the Dark Brook channel located at some location(s) between the PHR and Tucker Lane crossing. (Reach B)

    - The primary impact of the suspected obstructions is its impact on the hydraulic capacity of the channel, which both creates a tailwater condition at the PHR crossing that limits the hydraulic capacity of that crossing and also results in out of bank flooding that occurs in the Tucker Lane area that begins to overtop this dead end roadway during the 5-year storm event.

    A Type 3 solution is recommended for this specific location given its relatively high impact on flooding conditions that occurs at Tucker Lane mostly, but also the PHR crossing. The solution may need to be more involved than typical Type 3 solutions and may require some notable channel and floodplain regrading. The solution could be incorporated within the recommended culvert replacement project for the PHR crossing. This solution is presented as Solution #14 within Section 9.0.

6. An observed beaver dam along the Dark Brook that has formed within the breached section of the former Upper Tucker Pond (UTP) Dam embankment, located 500 feet downstream of the UTP East Dam and 300 feet upstream of the PHR crossing. (Reach B)

    - This area is an undeveloped wooded wetland that would be largely unimpacted by elevated pool levels upstream.
    - There is a relatively moderate amount of storage (50 acre-feet) within the area upstream of the presumed beaver dam location. This storage may provide flood attenuation and also creates a condition where a moderate volume of water would be released if the dam were to fail.
    - The height of the beaver dam was measured at 9 feet. Beaver dams of this height are subject to high head differentials that increase the potential of dam failure.
    - This beaver dam failed during a high rain event in 2010; the failure caused the full washout of the PHR crossing located 300 feet downstream of the dam as well as other damage further downstream. Dam failure analyses could be completed to determine the actual potential impacts from a failure of the beaver dam.

    This combination of factors warrant preventative action at this obstruction location; the solution strategy would likely be Type 2 as there is limited to no impact of the upstream flooding created by the beaver dam.

7. A beaver fence with some accumulated debris located upstream of the PHR crossing. (Reach B). The nature of the impact and recommended solution strategy is same as Location #4.

8. An observed beaver dam along the Mumford River that has formed within the breached section of the former Lower Tucker Pond Dam embankment, located 400 feet downstream of the merge of the Dark Brook with the Upper Mumford River and 800 feet upstream of the Mill Pond / Manchaug Road bridge crossing. (Reach C)

    - This area is an undeveloped wooded wetland that would be largely unimpacted by elevated pool levels upstream.
    - There is a relatively small amount of storage (25 acre-feet) within the area upstream of the presumed beaver dam location. This storage is likely not providing a notable amount of flood attenuation. condition where a moderate volume of water would be released if the dam were to fail.

- The height of the beaver dam was measured at 4 feet. Beaver dams of this height are subject to high head differentials that increase the potential of dam failure.
- Failure of the beaver dam would likely impact pool levels within Mill Pond, that could impact the performance/stability of the Mill Pond Dam. Dam failure analyses could be completed to determine the actual impacts from a failure of the beaver dam.

This combination of factors warrant recommendation for preventative action at this obstruction location. The recommended solution strategy is Type 3; however it could certainly be a Type 2 as there is limited to no impact of the upstream flooding created by the beaver dam.

In addition to the preventive action at the beaver dam, this location and area was also identified as an ideal location for the development of pedestrian trails with recreational and educational opportunities through the historic Mill Site #2 with the potential to also incorporate GSI features at specific locations, providing further educational opportunity. This project concept is presented as Solution Strategy #16 within Section 9.0 of this report and presented graphically on Graphic #28.

9. Observed vegetation and accumulated soil material and debris located within the Main Street bridge crossing. (Reach C)
    - The primary impact of the debris / soil accumulation is its impact on the hydraulic capacity and debris proneness of the bridge, both of which could impact river levels upstream of the bridge and lead to flooding issues to residential buildings right (South) of the crossing as well overtopping of the roadway. The source of the soil accumulation appears to be erosion of the left (East) bank of the Mumford River upstream of the bridge.

    A Type 3 solution is recommended for this specific location given its impact and potential impact on the Main Street bridge crossing. In addition to removal of the vegetation and accumulated material/debris, it is recommended to install stabilization measures of the left bank of the river upstream to avoid continued erosion of that bank and reoccurrence of the accumulation of that material at the Main Street bridge.

10. Observed debris dam along the the Mumford River channel located 1,300 feet (0.2 miles) downstream of the Main Street bridge crossing. (Reach C)
    - The primary impact of the debris dam is elevated river levels upstream of the debris dam that could lead to flooding issues along the river between the Main Street Bridge and this location (including the Mill Site #1 Building). Impacts of failure of the debris dam are likely minimal.

    A Type 3 solution is recommended for this specific location given the debris material type and apparent limited to no benefits provided by the debris dam.

11. Observed fallen tree along the the Mumford River channel located 1,000 feet downstream of Location #10, 0.4 miles downstream of the Main Street Bridge crossing. (Reach C)
    - The fallen tree is highly prone to accumulation and formation of a debris dam; that could result in higher river levels upstream of this location. If a debris dam was to form, the impacts of failure of that dam are likely minimal.

    A Type 3 solution is recommended for this specific location. Should regulatory agencies (local ConCom) not permit the removal of the fallen tree, a Category 1 solution would be recommended.

12. Observed beaver dam along the the Mumford River channel located 400 feet downstream of Location #11, 0.5 miles downstream of the Main Street Bridge crossing. (Reach C)

    - The beaver dam was measured at approximately 4 feet in height and was creating a 2-foot head differential in river levels upstream to downstream of the dam
    - The primary impact of the beaver dam is elevated river levels upstream of the dam that could lead to flooding issues along the river between the Main Street Bridge and this location (including the Mill Site #1 Building). Impacts of failure of the beaver dam are likely minimal.

    A Type 3 solution is recommended for this specific location. Should regulatory agencies (local ConCom) not permit the removal of the beaver dam (and beavers) from this location, a Type 1 solution would be recommended.

13. Observed beaver dam along the the Mumford River channel located 50 feet downstream of Location #12, 0.5 miles downstream of the Main Street Bridge crossing. (Reach C)

    - The beaver dam was measured at approximately 2 feet in height and was creating a 6-inch head differential in river levels upstream to downstream of the dam
    - The primary impact of the beaver dam is elevated river levels upstream of the dam that could lead to flooding issues along the river between the Main Street Bridge and this location (including the Mill Site #1 Building). Impacts of failure of the beaver dam are likely minimal.

    A Type 3 solution is recommended for this specific location. Should regulatory agencies (local ConCom) not permit the removal of the beaver dam (and beavers) from this location, a Type 1 solution would be recommended.

14. Observed fallen tree along the the Mumford River channel located 1,700 feet downstream of Location #13, 100 feet downstream of the confluence of the Whitins Reservoir tributary, and 1,800 feet upstream of the Potter Road impoundment. (Reach C)

    - Similar to location #11, the fallen tree is prone to accumulation and formation of a debris dam; that could result in higher river levels upstream of this location. If a debris dam was to form, the impacts of failure of that dam are likely minimal.

    A Type 3 solution is recommended for this specific location. Should regulatory agencies (local ConCom) not permit the removal of the fallen tree, a Type 1 solution would be recommended.

15. Observed fallen tree along the the Mumford River channel located 400 feet downstream of Location #14. (Reach C)

    - Similar to location #11, the fallen tree is prone to accumulation and formation of a debris dam; that could result in higher river levels upstream of this location. If a debris dam was to form, the impacts of failure of that dam are likely minimal.

    A Type 3 solution is recommended for this specific location. Should regulatory agencies (local ConCom) not permit the removal of the fallen tree, a Type 1 solution would be recommended.

7.0 POTENTIAL BUILDING-LEVEL STRATEGIES

This section includes certain building-level strategies that were developed to make individual buildings less prone to flood damage and more resilient to the hazard of riverine flooding. Specific strategies under this category include sump pump improvements, wet floodproofing, dry floodproofing, elevation, and retreat; each described in more detail within this section.

7.1 Sump Pump Improvements

Many buildings within this watershed, particularly in Manchaug Village, are reported to often experience flooded basements as the result of their sump pumps not working due to power outages and/or sump pump malfunctions. Ensuring that buildings with sump pump systems have operable and working sump pumps as well as adequate and reliable backup power supply will reduce the risk of flood damage at these buildings. Additionally, some buildings that do not currently have sump pump systems could benefit from the installation of one.

7.2 Wet Floodproofing

There are likely buildings within the watershed where sump pump systems alone are insufficient and that could benefit from a wet floodproofing program that relocates or otherwise protects high value content currently stored in the basement/lower levels of a building to avoid damage to that content when the lower levels of that building experience flooding.

7.3 Dry Floodproofing

There are likely buildings within the watershed where sump pump systems alone are insufficient and allowing the lower levels to experience flooding under a wet flooding proofing program is not desirable or feasible. For these structures, a dry floodproofing program would allow for the basement / lower levels of the building to be sealed to prevent the entrance of floodwaters. Specific dry floodproofing measures include exterior sealing of the foundation walls and construction joints, sealing of all openings (windows/doors) below a certain predicted flood elevation, backflow preventers on septic systems, among other measures.

7.4 Elevation

There are likely buildings within the watershed where expected flood elevations at the building are high enough to justify the physical raising of the building to a certain height such that the first floor elevation is above a certain flood elevation.

7.5 Retreat

There are no apparent buildings within this specific watershed that require this measure; however, in some watersheds, relocation of the building to a less flood prone area of the property is warranted. If relocation of the structure on the property is not feasible, selling of the property, demolishing of the building, restoring of property to a natural floodplain, and relocating to a less flood prone location of the community may be necessary.

7.6 Specific Buildings Identified within this Watershed

A total of 147 buildings were identified by this study as having the potential to sustain flood damage during the range of storm events modeled. The buildings were organized by reach as identified within Subsections 2.2.3 for Reach A (59 each), 2.3.3 for Reach B (37 each), 2.4.3 for Reach C (30 each), and 2.4.4 for Reach D (22 each).

It was beyond the scope of this study/plan to determine the most suitable building level strategy for each of these buildings. However, the results of this study and building damage assessment provide a basis for determining the most appropriate building level strategy to be implemented at individual buildings.

It should be noted that many of the buildings would benefit from the in-stream strategies identified within Section 8.0; in some instances, the benefit could be so large as to eliminate the need to implement a building level strategy. As such, it is recommended that in-stream strategies, and the likelihood/schedule of their progressions towards eventual installation, be considered when developing building specific building-level strategies.

Note that there is likely buildings that were not identified by this study/plan that have the potential to sustain flood damage; such buildings can and should be added to this report accordingly. The focus of this study/plan was on the hazard of riverine flooding and the buildings identified by the study are those that are impacted by elevated river levels. Additional buildings that are prone to flooding unrelated to riverine flooding such as areas of high groundwater, areas of poor drainage, or areas adjacent to storm drainage systems that are undersized or prone to clogging may be present in the study area.

Additionally, flood damage predicted by this study/plan may not fully represent the flooding that would occur at each buildings identified by this study/plan. The parameters used for the building damage assessment of this study were broad and completed at the watershed-wide scale; it is likely that the parameters for some buildings were not representative of the conditions at those buildings.

Building levels strategies for Reach A, B, and C are presented as Solution Strategies #6, #7, and #8 respectively within Section 9.0 of this report. Building level strategies for Reach D is presented as Solution Strategy #26.

8.0 POTENETIAL IN-STREAM STRATEGIES

This section includes certain in-stream strategies that were developed[8] at a specific asset or location to address the identified vulnerabilities of that asset and to converting it from an at-risk vulnerability into a resilient strength for the community. The general categories of the in-stream strategies considered include modifications/removal of existing dams, replacement of roadway stream crossings, as well as other site-specific improvements described below. The grouping of these strategies was completed at the reach level (A-D) as described below.

8.1 Reach A (Upper Mumford) In-Stream Strategies

As shown on supporting Graphic #22, a number of in-stream strategies were developed for Reach A including three dam modification programs and eleven roadway crossing replacements; each described in more detail below.

8.1.1 Dam Modifications

Dam modification programs were conceptually developed at three dams, Sutton Falls Pond Dam (#9.2), Manchaug Pond Dam (#10.2), and Stevens Pond Dam (#11.2). The priority ranking of the three was determined to be relatively higher for both Stevens Pond Dam and Manchaug Pond Dam while Sutton Falls Pond Dam has lower priority.

A dam removal alternative for these three dams was not explored given the high valued recreational benefit provided by all three impoundments. Ignoring the recreational benefit, dam removal appears to be a viable alternative at Sutton Falls Pond Dam. However, due to the significant flood attenuation provided by Manchaug Pond Dam and Stevens Pond Dam, removal of these dams would have significant impacts on downstream flooding that would necessitate extensive downstream channel and stream crossing improvements, as well as other mitigation associated with the increase in downstream flooding elevations. Given the extent of potential downstream mitigation, dam removal does not appear to be cost effective.

The scope of the modification programs for each dam is provided in the subsections below.

8.1.1.1 Stevens Pond Dam Modifications

As previously discussed within this report, specifically within Sections 2.2.1 and 4.0:

Stevens Pond Dam has relatively good hydraulic performance, being able to accommodate up to the 1,000-year storm event without experiencing overtopping of the dam crest. However, given its High Hazard potential rating, the Spillway Design Flood (SDF) for the dam is the ½ PMF event and it cannot safely accommodate that event without experiencing dam overtopping. Additionally, the dam has other deficiencies including an inoperable low level outlet (LLO), embankment stability and vegetation concerns, as well as other dam safety concerns that warrant a modification program; particularly when considering the High Hazard classification of the dam and the consequences of dam failure.

[8] Note that all strategies developed as part of this study/plan are preliminary concept level scopes of work and should not be considered designed construction-ready projects. The strategies outlined throughout this report will likely change to some degree during the actual engineering and design phases of these individual projects.

In addition to the concerns at the dam, there are safety concerns of the roadway located 20 feet downstream of the dam, Manchaug Road; concerns with both the bridge crossing itself as well as the alignment and width of the roadway in the area of the crossing. Given the close proximity of the roadway to the dam and the interconnectivity of the two, the inclusion of improvements to Manchaug Road into the Stevens Pond Dam modification scope is likely a worthwhile approach.

The concept level scope of the modification program at this dam is shown graphically on Graphic #24, and includes the following:

1. EAP Update: Update the Emergency Action Plan (EAP) for the dam including updated inundation mapping; incorporate the EAP and an identified operational plan of current control systems into the Watershed-Specific EAP described in Section 6.0.
2. Replace the Spillway Control System: Remove the existing flashboards; cut and remove the top 2 feet of the concrete control section; install a 16-foot wide by 3-foot high bascule gate.
3. Replace the LLO Control System: Remove existing gate; square downstream end of LLO conduit, install 3-foot square orifice gate.
4. Control System Automation: Automate both control systems to facilitate the ability to operate both systems from a remote location.
5. Crest Elevation: Establish a consistent embankment crest elevation of EL. 475.0 (current min El. 474.2)
6. Embankment Improvements: Provide upstream slope protection (riprap), regrade crest and downstream slope, install underdrain system, establish grass vegetation.
7. Other Dam Repairs and Modifications: As/if needed. Could incorporate fish passage and/or ecological connectivity improvements.
8. Manchaug Road Improvements: Replace the existing 16-foot wide by 5-foot high arch culvert with a 20-foot wide by 16-foot high bridge; Realign and widen roadway to improve safety of roadway.
9. Operation Plan: Develop the idealized operational plan for the dam to determine and establish the ideal operations of the new control systems that offer the ideal pond elevations and outflow released from the dam and downstream area during specific storm events up to and including the dam's SDF (½ PMF)

This modification program will provide multiple benefits including:

- Compliance with regulatory requirements
- Increased flood attenuation potential provided by the dam
- Reduction in flooding and flood levels both upstream and downstream of the dam
- Reduction in potential for failure of the dam
- Potential for improved ecosystem services
- Improved safety along Manchaug Road.

This dam modification program is presented as Solution Strategy #10 within Section 9.0 of this report.

8.1.1.2 Manchaug Pond Dam Modifications

As previously discussed within this report, specifically within Sections 2.2.1 and 4.0:

Similar to Stevens Pond Dam, Manchaug Pond Dam has relatively good hydraulic performance, being able to accommodate up to the 1,000-year storm event without experiencing overtopping of the dam crest. However, with it being a High Hazard dam, the Spillway Design Flood (SDF) for the dam is the ½ PMF event and it cannot safely accommodate that event without experiencing dam overtopping. An additional concern is the eleven sections of roadway that become inundated and impassible due to elevated pool levels within Manchaug Pond; a condition that occurs during the 25-year storm event. Additionally, the condition/stability/performance is largely unknown; both the dam embankment itself as well as certain components of its outlet works including the spillway control system, LLO control system, as well as the LLO conduit. These unknowns combined with its inability to safely accommodate the SDF warrants a modification program; particularly when considering the High Hazard classification of the dam as well as the consequences of dam failure.

The concept level scope of the modification program at this dam is shown graphically on Graphic #23, and includes the following:

1. EAP Update: Update the Emergency Action Plan (EAP) for the dam including updated inundation mapping; incorporate the EAP and an identified operational plan of current control systems into the Watershed-Specific EAP described in Section 6.0.
2. Replace the Spillway Control System: Remove the existing timber stop logs; complete repairs/modifications to the stone masonry in the area of the control section, install a 16-foot wide by 4-foot high bascule gate.
3. LLO Conduit: Inspect the existing LLO conduit. If replacement of the conduit is needed, install a larger conduit to allow for increased drawdown capabilities, which would eliminate the need for the siphon system (#6).
4. Replace the LLO Control System: Remove existing gate; install new orifice gate sized for existing 2-foot square conduit (or larger if new conduit is needed).
5. Control System Automation: Automate both control systems to facilitate the ability to operate both systems remotely.
6. Siphon System: If replacement of the LLO conduit is unnecessary, install a new siphon system to provide increased drawdown capabilities. This system has been conceptually sized as three 18-inch diameter siphon conduits.
7. Other Dam Repairs and Modifications: As/if needed. Could incorporate fish passage and/or ecological connectivity improvements.
8. Operation Plan: Develop the idealized operational plan for the dam to determine and establish the ideal operations of the new control systems that offer the ideal pond elevations and outflow released from the dam and downstream area during specific storm events up to and including the dam's SDF (½ PMF)

This modification program will provide multiple benefits including:

- Compliance with regulatory requirements
- Increased flood attenuation potential provided by the dam
- Reduction in flooding and flood levels both upstream and downstream of the dam

- Reduction in potential for failure of the dam
- Potential for improved ecosystem services

This dam modification program is presented as Solution Strategy #10 within Section 9.0 of this report.

8.1.1.3 Sutton Falls Pond Dam Modifications

As previously discussed within this report, specifically within Sections 2.2.1 and 4.0:

Sutton Falls Pond Dam has insufficient hydraulic performance, being able to accommodate up to the 10-year storm event without experiencing overtopping of the dam crest; less than its SDF, the 100-year storm. Additionally, the dam has other deficiencies including a presumably inoperable low level outlet (LLO), embankment stability and vegetation concerns, as well as other dam safety concerns that warrant a modification program.

The concept level scope of the modification program at this dam includes the following:

1. EAP Update: Update the Emergency Action Plan (EAP) for the dam including updated inundation mapping; incorporate the EAP and an identified operational plan of current control systems into the Watershed-Specific EAP described in Section 6.0.
2. Install Auxiliary Spillways: Install two (one left and one right) 10-foot wide auxiliary spillways to either side of the existing primary spillway. Install bridges over the new auxiliar spillways.
3. Replace the LLO: Remove the existing conduit and controls and install a new conduit and controls
4. Crest Elevation: Establish a consistent embankment crest elevation of EL. 476.0 (current min El. 475)
5. Other Dam Repairs and Modifications: As/if needed, could incorporate fish passage and/or ecological connectivity improvements.

This modification program will offer a multitude of benefits including:

- Compliance with regulatory requirements
- Reduction in flooding and flood levels upstream of the dam
- Reduction in potential for failure of the dam
- Potential for improved ecosystem services

This dam modification program is presented as Solution Strategy #10 within Section 9.0 of this report.

8.1.1.4 Other Dams along Reach A

The three other dams located within this reach, Stump Pond Dam, Number Two Pond Dam, and Number One Pond Dam (Town Farm Road) were outside the limits of the detailed analyses part of this study. These three dams are located in series at the upstream extent of the reach and do not have a large contributing drainage area. However, there may exist hydraulic or other dam safety concerns that warrant the development and implementation of either a dam modification or dam removal program at these dams.

8.1.2 Roadway Crossing Replacements

Roadway crossing replacements were conceptually developed at all eight crossings upstream of the Sutton Falls Pond Dam including the following from downstream to upstream:

1. Manchaug Road (Two Locations – Main Crossing (#7) and East Crossing (#7.1))
2. Mendon Road (Two Locations – Main Crossing (#6) and East Crossing (#6.1))
3. Central Turnpike (Three Locations – Main Crossing (#5), and two East Crossings (#7.1&7.2))
4. West Sutton Road

The general scope of all of these culvert replacements would be similar; replace the undersized, debris-prone culvert with larger stream crossing compliant culverts. All four main crossings would benefit from 10-foot wide spans for both improved ecosystem services as well as hydraulic performance while the secondary crossings could likely have smaller spans (4-6 feet). All crossings would benefit by maximizing the height of the crossing to the extent possible by limiting the coverage between the top of the road and the top of the culvert; in most instances paving right on top of the culvert. This approach would likely require a precast concrete material type; either as an infilled 4-sided box or as an open bottom 3-sided supported on fittings.

Each roadway crossing replacement project will offer a multitude of benefits including:

- Lowered flood elevation upstream
- Reduced frequency of overtopping; and in turn reduced damage and accessibility issues that come with roadway overtopping
- Reduced potential for failure of the roadway due to differential loading an/or overtopping
- Improved ecosystem services

These eight crossing replacement projects are grouped together and presented as Solution Strategy #15 within Section 9.0 of this report.

8.2 Reach B (Dark Brook) In-Stream Strategies

As shown on supporting Graphic #25, a number of in-stream strategies were developed for Reach B including one dam modification program and two roadway crossing replacements; each described in more detail below.

8.2.1 Dam Modifications

A dam modification program was conceptually developed at one dam system (two dam structures), the Upper Tucker Pond Dam system that is comprised of the South Dam (#11.2) and East Dam (#11.3).

A dam removal alternative at this dam system was not explored due in large part to the high valued recreational benefit provided by the Upper Tucker impoundment. Ignoring the recreational benefit, a dam removal alternative would have to first identify and evaluate the impacts of the loss of the low to moderate flood attenuation provided by the Upper Tucker Pond impoundment and dam system to the downstream area; results of this evaluation may suggest that increased/induced flooding resulting from dam removal may make dam removal prohibitively expensive due to required downstream mitigation associated with increased flooding.

The scope of the modification programs for the dam system is provided in the subsection below.

8.2.1.1 Upper Tucker Pond Dam Systems (East and South Dams)

As previously discussed within this report, specifically within Sections 2.3.1 and 4.0:

The Upper Tucker Pond Dam system has relatively poor hydraulic performance, expected to begin experiencing overtopping of the dam crest during the 5-year storm, which is less than its current SDF of the 100-year storm. The implications of dam failure also appear to warrant a reclassification of the dam from its current hazard classification of Significant to High, a change that would increases the dam's SDF to the ½ PMF event. An additional concern is the 5 sections of roadway that become inundated and impassible due to elevated pool levels within the impoundment; a condition that occurs starting at the 5-year event and one that creates a situation where the sole access/egress routes to 30+ houses becomes cut off, possibly for an extended period of time if the roadway sections were to sustain notable flood damage. Additionally, both dam embankments have been found to be in Poor Condition citing a number of concerns including stability and seepage issues of both the embankments and outlet structures as well as other dam safety concerns that warrant a modification program; particularly when considering the apparent High Hazard potential of the dam as well as the consequences of dam failure.

The concept level scope of the modification program at this dam is shown graphically on Graphic #26, and includes the following:

1. <u>EAP Update</u>: Update the Emergency Action Plan (EAP) for the dam system including updated inundation mapping; incorporate the EAP and an identified operational plan of current control systems into the Watershed-Specific EAP described in Section 6.0.

<u>Complete a Modification Program at the East Dam that includes:</u>

2. <u>Install a New Spillway</u>[9]: Remove the existing spillway; Install a new spillway structure, conceptually designed as a 40-foot wide (Left to Right width) by 15-foot deep (US to DS width) by 10-foot high trapezoidal concrete weir structure.
3. <u>Spillway Operations</u>: Install two mid level outlet (MLO) gates within the new spillway structure to facilitate impoundment drawdown capabilities, conceptually designed as two 4-foot wide by 5-foot high gates.
4. <u>Control System Automation:</u> Automate both MLO gates to facilitate remote operations.

[9] There was public comment received following the Solutions Meeting that suggested eliminating the spillway at the East Dam altogether and have all flow leave the dam system via the new spillway at the South Dam. That is certainly a viable alternative if desired and would offer certain economic and hazard reduction benefits; however, it would significantly increase the extent of the new spillway system needed at the South Dam.

5. Putnam Hill Road Crossing Replacement: Replace the existing 5-foot square box with a 20-foot wide by 12-foot high bridge.

6. Crest Elevation: Establish a minimum embankment crest elevation of El. 459.0 (One low area of the right abutment currently at El. 458.0)

7. Embankment Improvements: Install upstream slope protection (riprap), regrade crest and downstream slope, install underdrain system and rock toe system, establish grass vegetation.

8. Other Dam Repairs and Modifications: As/if needed. Could incorporate fish passage and/or ecological connectivity improvements.

Complete a Modification Program at the South Dam that includes:

9. Install a New Spillway: Remove the LLO system; Install a new spillway structure, conceptually designed as a 35-foot wide (Left to Right width) by 35-foot deep (US to DS width) by 170-foot high octagon concrete inlet structure.

10. Spillway Operations: Install one LLO gate and one MLO gates within the new spillway structure to facilitate impoundment drawdown capabilities, conceptually designed as as 2-foot square LLO gate and an 8-foot wide by 6-foot high MLO gate.

11. Control System Automation: Automate both gates to facilitate remote operations.

12. Cote Lane Crossing Replacement: Replace the existing 2-foot diameter LLO conduit with a 14-foot square concrete box culvert.

13. Crest Elevation: Establish a minimum embankment crest elevation of El. 459.0 (Three low areas including the current overflow spillway area at the right abutment with a min grade of El. 456.5[10] and two low areas of the left abutment with a min. grade of El. 458.2)

14. Embankment Improvements: Install sheetpile cutoff wall, upstream slope riprap, downstream slope buttress, and underdrain system; establish grass vegetation.

15. Other Dam Repairs and Modifications: As/if needed. Could incorporate fish passage and/or ecological connectivity improvements.

16. Operation Plan for Both Dams: Develop the idealized operational plan for the dam to determine and establish the ideal operations of the new control systems that offer the ideal pond elevations and outflow released from the dam and downstream area during specific storm events up to and including the dam's SDF (½ PMF)

This modification program will provide multiple benefits including:

- Compliance with regulatory requirements

[10] There was public comment received during the Solutions Meeting that suggested maintaining overflow capabilities at this location through the use of culverts or a bridge. This is certainly a viable alternative if desired and could help reduce the required capacities of the new spillway systems at the East and South Dams. However, it would come at a cost and would result in the installation of a new component of infrastructure in the culvert/bridge.

- Increased flood attenuation potential provided by the dam
- Reduction in flooding and flood levels both upstream and downstream of the dam
- Reduction in potential for failure of the dam
- Potential for improved ecosystem services

This dam modification program is presented as Solution Strategy #9 within Section 9.0 of this report.

8.2.1.2 Other Dams along Reach B

The other dam located within this reach, Summit Pond Dam, was outside the limits of the detailed analyses part of this study. This dam is located at the upstream extent of the reach and does not have a large contributing drainage area. However, there may exist hydraulic or other dam safety concerns that warrant the development and implementation of either a dam modification or dam removal program at this dam.

8.2.2 Roadway Crossing Replacements

Roadway crossing replacements were conceptually developed at both Putnam Hill Road crossings (#9 and #13).

The general scope of both culvert replacements would be similar; replace the undersized, debris-prone culvert with larger stream crossing compliant culverts/bridges. The span of both crossings was conceptually sized at 19 feet for both ecosystem services and hydraulic performance purposes. Both crossings would benefit by maximizing the height of the crossing to the extent possible by limiting the coverage between the top of the road and the top of the culvert; in most instances paving right on top of the culvert. This approach would likely require a precast concrete material type; either as an infilled 4-sided box or as an open bottom 3-sided supported on fittings. As conceptually developed, both crossing should have a height of 6 feet,

Both roadway crossing replacement projects will offer a multitude of benefits including:

- Lowered flood elevation upstream
- Reduced frequency of overtopping; and in turn reduced damage and accessibility issues that come with roadway overtopping
- Reduced potential for failure of the roadway due to differential loading an/or overtopping
- Improved ecosystem services

The culvert replacement for the PHR crossing #13 is presented as Solution Strategy #12 and the culvert replacement for the PHR crossing #9 is presented as Solution Strategy #13 within Section 9.0 of this report.

The other two roadway crossings located within this reach that were not explicitly targeted as a solution strategy was Mendon Road (#2) and Tucker Lane (#10). Tucker Lane is a 40-foot bridge span and does not require replacement from a hydraulic performance or ecosystem services standpoint. Mendon Road was outside the limits of this study but may warrant a culvert replacement solution strategy.

8.3 Reach C (Mumford River – Manchaug Village) In-Stream Strategies

As shown on supporting Graphic #27, a number of in-stream strategies were developed for Reach B including one dam modification program, one dam removal program, one river weir removal project, and seven roadway crossing replacements; each described in more detail below.

8.3.1 Dam Modifications

Dam related solutions that were conceptually developed along this reach included a dam modification program at Mill Pond Dam #1 (#3), a combined dam removal and bridge replacement program at Potter Road Dam (#8) and Bridge (#9), and the removal of the stone weir (#5) located just downstream of the Main Street Bridge. Each of these three are described in greater detail in the following sections.

8.3.1.1 Mill Pond Dam #1

As previously discussed within this report, specifically within Sections 2.4.1 and 4.0:

The Mill Pond Dam #1 has relatively fair hydraulic performance, expected to begin experiencing overtopping of the dam crest during the 25-year storm. The dam is currently classified as a Non-Jurisdictional Structure due to its low storage volume and therefore the dam does not have a state mandated SDF. However, it appears that the potential impacts from dam failure warrants this dam becoming a jurisdictional Significant Hazard dam, which would result in the dam's SDF becoming the 100-year storm. In addition to the limited hydraulic performance, there are other dam safety concerns at this structure including a presumably inoperable LLO as well as other potential dam safety concerns that are often associated with a dam structure of this age that warrant a dam modification program.

A dam removal alternative was initially explored for this dam; however, was not further explored due to public input on the high valued aesthetic and historical benefit provided by the waterfall at the dam. Ignoring these benefits, a dam removal alternative appears to be a feasible approach from an induced flooding standpoint; the dam and its impoundment offer no flood attenuation and therefore no increases in flood elevations downstream of the dam are expected if the dam were to be removed. A traditional dam removal approach (removing the full vertical extent of the dam) would impact flow conditions through and scour potential for the streambed at the Manchaug Road Bridge located directly upstream of the dam. The condition could likely be mitigated through the installation of scour counter measures at the bridge as part of a dam removal program.

There are also other partial dam removal alternatives that could provide a balance of all the factors to consider for this dam (i.e., aesthetics, historical, reduced dam failure potential, Main Street Bridge scour). One such alternative is a partial removal of the dam and installation of a nature-like fishway that is designed to maintain the pool level within the impoundment, maintain some version of the waterfall effect of the current dam, while also limiting the failure potential of the dam. However, for the purposes of this study/plan, a dam modification program was carried forward, the scope of which is described below.

The concept level scope of the modification program at this dam is shown graphically on Graphic #28, and includes the following:

1. EAP: Develop an Emergency Action Plan (EAP) for the dam system including inundation mapping and expected impacts upstream and downstream of the dam; incorporate the EAP and an identified operational plan of current control systems into the Watershed-Specific EAP described in Section 6.0.
2. Extend the Spillway: Remove the existing drop inlet spillway; Extend the overflow (waterfall) spillway 60 feet to the right abutment.
3. LLO Replacement: Install a new low level outlet system near the existing drop inlet spillway with a control gate installed at either end (upstream or downstream).
4. Control System Automation: Automate the LLO gate to facilitate remote operations.
5. Impoundment Dredging: Remove accumulated material (sediment, leaves, vegetation) from the impoundment. Environmental testing of the sediment would need to be performed to determine appropriate re-use and/or disposal requirements.
6. Abandoned Sluiceway: Investigate the abandonment of the former sluiceway at the dam's left abutment; Install a formal plug on the upstream end of the sluiceway if warranted.
7. Other Dam Repairs and Modifications: As/if needed. Could incorporate fish passage and/or ecological connectivity improvements.
8. Operation Plan for Dam: Develop an operation plan for the dam to determine required pre-, during, and post-storm operations to meet flood control and discharge requirements for storm events up to and above the dam's SDF 100-year storm).

This modification program will provide multiple benefits including:

- Compliance with regulatory requirements
- Reduction in flooding and flood levels upstream of the dam
- Reduction in potential for failure of the dam
- Potential for improved ecosystem services

This dam modification program is presented as Solution Strategy #9 within Section 9.0 of this report.

8.3.1.2 Potter Road Dam & Bridge

As previously discussed within this report, specifically within Sections 2.4.1 and 4.0:

The Potter Road Dam has relatively poor hydraulic performance, expected to begin experiencing overtopping of the dam crest and overtop Potter Road during the 10-year storm. The dam is currently classified as a Non-Jurisdictional Structure due to its short height and therefore the dam does not have a state mandated SDF. However, it appears that the the actual height of the Potter Road Dam is large enough that it should be considered a jurisdictional structure. The hazard potential of the dam could be considered Low, but may warrant Significant; depending on this rating, the SDF would either be the 50-year storm or the 100-year storm. In addition to the limited hydraulic performance, there are other dam safety concerns at this structure including a no apparent LLO as well as other potential dam safety concerns that are often associated with a dam structure of this age that warrant a dam modification or removal program.

A dam removal alternative appears to be feasible at this location as the dam and its impoundment does not offer significant flood attenuation nor significant/obvious recreational or aesthetic benefits that would be significantly impacted if the dam were to be removed. If that proves to be incorrect and dam removal is not the preferred alternative, a dam modification program could be implemented instead of the dam removal program. The dam removal alternative has been carried forward for the purposes of this study/plan as described below:

As part of the dam removal program, the Potter Road bridge would be replaced with a larger span bridge for improved hydraulic performance and ecosystem services

The concept level scope of the dam removal program at this dammay include the following:

1. Remove the Spillway: Remove the full lateral and vertical extent of the spillway.
2. Impoundment Sediment: Evaluate, determine, and implement the appropriate method for handling sediment within the impoundment that will become exposed and/or is expected to be mobilized as a result of removal of the dam. Environmental testing of the sediment would need to be performed to inform this approach.
3. Bridge Replacement: Replace the existing 20-foot span bridge with a 40-foot span bridge.

This dam removal and bridge replacement program will provide multiple benefits including:

- Increased flood attenuation potential provided by the dam
- Reduction in flooding and flood levels upstream of the dam
- Elimination of the failure risk posed by the dam
- Vastly improved ecosystem services

This dam removal program is combined with the Potter Road bridge replacement and presented as Solution Strategy #23 within Section 9.0 of this report. One of the reasons for its lower prioritization ranking is that the dam and bridge area located beyond the Town of Sutton’s boundaries (located in Douglas); included work would not directly influence flooding resilience within Sutton.

8.3.1.3 Stone Weir Downstream of Main Street

The 3-foot high stone weir that spans the width of the channel located 50 feet downstream of Main Street currently serves no apparent purpose and the river appears to benefit from removal of the weir in its entirety; provided its removal does not significantly impact flow conditions and scour potential at the Main Street Bridge. The removal of this weir is presented as Solution Strategy #18 within Section 9.0.

8.3.2 Roadway Crossing Replacements

Roadway crossing replacements were conceptually developed at the following six locations:

1. Whitins Road West Crossing (#5.2): Blocked/collapsed stone conduit of unknown size
2. Whitins Road East Crossing (#5.1): 3-foot CMP pipe

3. Main Street Main Crossing (#6.1): 8-foot wide stone arch
4. Main Street West Crossing (#6.2): 2-foot square concrete box culvert
5. Main Street East Crossing (#6.3): 2-foot cast iron pipe
6. Mumford Street (#6.4): Twin 4-foot wide CMP pipe arches.

The general scope of the culvert replacements would be similar; replace the undersized, debris-prone culvert with a larger culvert. The span of the crossing replacements was conceptually sized for both ecosystem services and hydraulic purposes. All crossings would benefit by maximizing the height of the crossing to the extent possible by limiting the coverage between the top of the road and the top of the culvert; in most instances paving right on top of the culvert. This approach would likely require a precast concrete material type; either as an infilled 4-sided box or as an open bottom 3-sided supported on fittings. The following provides the proposed culvert replacement geometry at all six locations as conceptually developed:

1. Whitins Road West Crossing (#5.2): 10-foot wide by 4-foot high culvert
2. Whitins Road East Crossing (#5.1): 10-foot wide by 4-foot high culvert
   Main Street Main Crossing (#6.1): 20-foot wide by 6-foot high culvert
3. Main Street West Crossing (#6.2): 6-foot square culvert
4. Main Street East Crossing (#6.3): 6-foot square culvert
5. Mumford Street (#6.4): 20-foot wide by 6-foot high culvert

Each roadway crossing replacement program will offer a multitude of benefits including:

- Lowered flood elevation upstream
- Reduced frequency of overtopping; and in turn reduced damage and accessibility issues that come with roadway overtopping
- Reduced potential for failure of the roadway due to differential loading an/or overtopping
- Improved ecosystem services

The culvert replacement for the the Whitins Road West and East crossings are presented presented as Solution Strategy #20 and #21 respectively, all three Main Street crossing are grouped together and presented as Solutions Strategy #22, and the Mumford Road crossing is presented as Solutions Strategy #24 within Section 9.0 of this report.

The other two roadway crossings located within this reach that was not explicitly targeted as a solution strategy was Manchaug Road (#2) and Main Street (#4) as both bridges are of sufficient size from a hydraulic performance and ecosystem services standpoint. However, the limited height of the Main Street bridge (3-8 feet) results in a crossing that is moderately prone to debris clogging; full replacement of the bridge does not appear warranted at this time; however, monitoring is justified, which should be incorporated within the watershed-wide river debris monitoring and maintenance program described in Section 6.3.3 (#9 specifically).

8.4 Reach D (Mumford River – Douglas) In-Stream Strategies

With the entirety of Reach D being located beyond the Town of Sutton's boundaries (entirely within Douglas) no specific solution strategies were developed along this reach.

9.0 SUMMARY OF SOLUTION STRATEGIES

This section provides a culmination of the 26 individual solution strategies that were developed as part of this study/plan and described within previous sections of this report; namely Sections 6.0, 7.0, and 8.0. Supporting Graphics #29 and #30 provide tabulated summaries of the 26 individual solution strategies; with Graphic #29 being an abbreviated summary and Graphic #30 providing additional detail as to the scope and benefits of each solution strategy. Graphic #29 is also provided on the following page of this report.

Included within the abbreviated table (Graphic #29) for each solution strategy is an ID/prioritization number, location information (Reach, #, Name, Owner), a title, report section references, hydraulic performance information under both current and future (CCIPF) rainfall conditions, an estimated range of probable costs, and potential funding sources (at the agency level). The more detailed table (Graphic #30) provides all the same information along with a brief description of the conceptualized scope of work of the solution strategy as well as brief discussion of the benefits and/or hazard reduction provided by the strategy.

Within these tables, the solutions strategies are sorted and numbered by an initial prioritization ranking. Several factors were considered in developing the ranking including the degree of hazard reduction, the existing condition of the asset/location, the extent and variation of the benefits provided, as well as the expected duration and level of effort to reach implementation. This prioritization ranking should be considered preliminary intended to present the author's opinion of prioritization based upon experience gained through the completion of this study.

This prioritization ranking should be refined based upon input from the Town, project stakeholders, and the general public. To help facilitate the refined ranking, a prioritization matrix could be established that quantifies and/or qualifies both the benefits offered and the feasibility of an individual improvement strategy. The graphic to the right provides an example matrix that takes the product of the project benefits value (0-10) and the project feasibility value (0-5) to determine the overall project value (0-50), which serves as the basis of the prioritization ranking.

Prioritization Matrix Example

Project Benefits	Project Value						Priority Level
10	0	10	20	30	40	50	Highest
9	0	9	18	27	36	45	(41-50)
8	0	8	16	24	32	40	High
7	0	7	14	21	28	35	(31-40)
6	0	6	12	18	24	30	Medium
5	0	5	10	15	20	25	(21-30)
4	0	4	8	12	16	20	Low
3	0	3	6	9	12	15	(11-20)
2	0	2	4	6	8	10	Lowest
1	0	1	2	3	4	5	(1-10)
0	0	0	0	0	0	0	Impractical
	0	1	2	3	4	5	
	Project Feasibility						

In determining the project benefit value (0-10), several factors would be considered including, but not limited to: *severity of the hazard(s) addressed, degree to which the hazard(s) is addressed, number of beneficiaries, type of beneficiaries (private versus public), environmental benefits, ecological benefits, social benefits, and economic benefits.*

Similar, in determining the project feasibility value (0-5), several factors would be considered including, but not limited to: *implementation cost, long term costs (operation, maintenance, etc.), available funding (in-hand and potential), jurisdictional requirements, schedule duration, and technical feasibility.*

Additionally, the completion of benefit cost analyses (BCA) and the determination of a benefit cost ratio (BCR) for each project would further guide the refinement of the prioritization ranking. A completed BCA and known BCR would also guide and bolster efforts in exploring available grant opportunities for individual projects to assist in the implementation cost of that project.

Potential "Solutions" - Abbreviated Tabulated Summary

#	Location				Report Section	Action Item	Capacity - Current		Capacity - CCIPF		Estimate Range ($K's)		Potential Funding
	Reach	#	Name	Owner			EC	PC	EC	PC	Lower	Higher	
1	All	-	Watershed Wide	Private, Town, State	6.1	Emergency Action Plan	-	-	-	-	$ 50	$ 100	EOEEA, FEMA
2	All	-	Watershed Wide	Private, Town, State	6.2.1	Land Cover Preservation	-	-	-	-	$ 50	$ 300	EOEEA, FEMA
3	All	-	Watershed Wide	Private, Town, State	6.2.2	Land Cover Conversion	-	-	-	-	$ 200	$ 2,000	EOEEA, FEMA
4	All	-	Watershed Wide	Private, Town, State	6.2.3	Green Stormwater Infrastructure	-	-	-	-	$ 100	$ 5,000	EOEEA, FEMA
5	All	-	River Wide	Private, Town, State	6.3.3	Beaver Dam and River Debris Removal, Monitoring & Maintenance (M&M)	-	-	-	-	$ 750	$ 3,000	MADER, NOAA
6	A	-	Reach A Buildings	Private	7.6	Building Modifications (59EA)	1	-	1	-	$ 1,000	$ 3,000	FEMA
7	B	-	Reach B Buildings	Private	7.6	Building Modifications (37EA)	1	-	1	-	$ 500	$ 1,000	FEMA
8	C	-	Reach C Buildings	Private	7.6	Building Modifications (30EA)	10	-	5	-	$ 500	$ 1,000	FEMA
9	B	11.2&11.3	Upper Tucker Pond (UTP) East and South Dams	Private, State	8.2.1.1	Hazard Reclassification, Spillway Design Flood (SDF) Modifications & Operational Plan	5	>1/2 PMF	2	>1,000	$ 6,000	$ 9,000	EOEEA, FEMA
10	A	11.2	Stevens Pond Dam (SPD)	Town	8.1.1.1	SDF Modifications & Operational Plan	>1,000	>1/2 PMF	200	>1,000	$ 2,000	$ 3,000	EOEEA, FEMA
10	A	11.2	Manchaug Road	Town	8.1.1.1	Crossing Replacement	-	-	-	-	$ 2,500	$ 5,000	MassDOT, MADER
11	A	10.2	Manchaug Pond Dam (MPD)	Town	8.1.1.2	SDF Modifications & Operational Plan	>1,000	>1/2 PMF	500	>1,000	$ 1,500	$ 4,000	EOEEA, FEMA
12	B	13	Putnam Hill Road	State	8.2.2	Crossing Replacement	10	200	5	50	$ 2,000	$ 3,000	MADER
13	B	9	Putnam Hill Road	State	8.2.2	Crossing Replacement	25	100	10	25	$ 2,000	$ 3,000	MADER
14	B	10	Tucker Lane Channel	Private	6.3.3 #5	Channel and Floodplain Regrading Upstream of Crossing	5	100	2	50	$ 500	$ 1,000	MADER, NOAA
15	A	1-7.1	Crossings US of SFPD	Town, Private	8.1.2	Crossing Replacements (11EA)	5-25	100	2-10	25-50	$ 8,000	$ 12,000	MADER
16	C	1	Mill #2 Site	Town, Private	6.3.3 #8	Floodplain Restoration at Mill #2 Site	-	-	-	-	$ 500	$ 1,000	EOEEA, MADER
17	C	3	Mill Pond Dam #1	Private	8.3.1.1	Modifications at Mill Pond Dam #1	10	500	5	100	$ 1,000	$ 1,500	EOEEA
18	C	5	Channel Weir	Private	8.3.1.3	Remove Weir and Restore Channel	-	-	-	-	$ 50	$ 100	MADER, NOAA
19	A	9	Sutton Falls Pond Dam (SFPD)	Private	8.1.1.3	SDF Modifications & Operational Plan	10	500	5	100	$ 1,500	$ 3,000	EOEEA, FEMA
20	C	5.2	Whitins Road	Town	8.3.2	Crossing Replacement	1	>1,000	<1	1,000	$ 1,000	$ 1,500	MADER
21	C	5.1	Whitins Road	Town	8.3.2	Crossing Replacement	50	>1,000	25	1,000	$ 1,000	$ 1,500	MADER
22	C	6.1-6.3	Main Street	State	8.3.2	Crossing Replacements (3EA)	50-200	1,000	25-50	500	$ 3,000	$ 5,000	MADER
23	C	8-9	Potter Road Dam & Bridge	Town, Private	8.3.1.2	Dam Removal/Modification and Crossing Replacement	10	200	5	50	$ 2,000	$ 4,000	EOEEA, MADER, MassDOT
24	C	6.4	Mumford Street	Town	8.3.2	Crossing Replacement	10	500	5	100	$ 2,000	$ 3,000	MassDOT,MADER
25	D	-	Reach D Buildings	Private	7.6	Building Modifications (22EA)	200	-	50	-	$ 300	$ 500	FEMA
											$ 40	**$ 77**	***$M's***
											$ 40,000,000	$ 76,500,000	*$*

Legend:
- Channel / Ecosystem Restoration
- Infrastructure Upgrade with Ecosystem Benefit
- Dam Modifications
- Structure Floodproofing

APPENDIX A:
Supporting Graphics

APPENDIX B:
Corridor Photographs

APPENDIX C:
Public Meeting Materials

APPENDIX D:
Report Limitations

LIMITATIONS

Use of Report

1. This report has been prepared for the exclusive use of the Town of Sutton for specific application to the Manchaug Water Resources Resiliency Action Plan in accordance with generally accepted engineering practices. No other warranty, expressed or implied, is made.

2. The material in this report reflects Pare's judgment in light of the information available to it at the time of preparation. Any use, reliance on, or decisions made based on this report, its findings or conclusions by any third party are the sole responsibility of such third parties.

3. Pare Corporation accepts no responsibility for damages, if any, suffered by any third party as a result of their use of, decisions made or actions taken based on this report.

Hydrologic & Hydraulic Model Limitations

1. The H&H results discussed herein as well as the conclusions that have been drawn from those results are based on the assumed model conditions and H&H processes and procedures that were used. Some of the processes involved with H&H analyses are theoretical and subject to engineering judgment and estimation.

2. Variations between the assumed model conditions and actual event conditions (rainfall, ground surface conditions, debris clogging, etc.) are likely; as such, deviations between model results and actual conditions are likely.