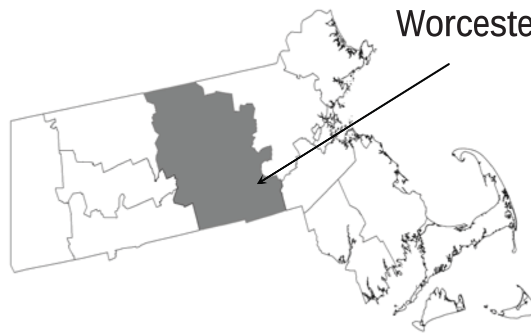
FLOOD INSURANCE STUDY

WORCESTER COUNTY, MASSACHUSETTS
(ALL JURISDICTIONS)



Volume 1 of 5

COMMUNITY NAME	COMMUNITY NUMBER
ASHBURNHAM, TOWN OF*	250290
ATHOL, TOWN OF*	250291
AUBURN, TOWN OF	250292
BARRE, TOWN OF*	250293
BERLIN, TOWN OF	250294
BLACKSTONE, TOWN OF	250295
BOLTON, TOWN OF	250296
BOYLSTON, TOWN OF	250297
BROOKFIELD, TOWN OF*	250298
CHARLTON, TOWN OF	250299
CLINTON, TOWN OF	250300
DOUGLAS, TOWN OF	250301
DUDLEY, TOWN OF	250302
EAST BROOKFIELD, TOWN OF*	250303
FITCHBURG, CITY OF*	250304
GARDNER, CITY OF*	250305
GRAFTON, TOWN OF	250306
HARDWICK, TOWN OF*	250307
HARVARD, TOWN OF	250308
HOLDEN, TOWN OF*	250309
HOPEDALE, TOWN OF	250310
HUBBARDSTON, TOWN OF*	250311
LANCASTER, TOWN OF	250312
LEICESTER, TOWN OF	530313
LEOMINSTER, CITY OF*	250314
LUNENBURG, TOWN OF*	250315
MENDON, TOWN OF	250316
MILFORD, TOWN OF	250317
MILLBURY, TOWN OF	250318
MILLVILLE, TOWN OF	250319
NEW BRAINTREE, TOWN OF*	250320

COMMUNITY NAME	COMMUNITY NUMBER
NORTH BROOKFIELD, TOWN OF*	250323
NORTHBOROUGH, TOWN OF	250321
NORTHBRIDGE, TOWN OF	250322
OAKHAM, TOWN OF*	250324
OXFORD, TOWN OF	250325
PAXTON, TOWN OF	250326
PETERSHAM, TOWN OF*	250327
PHILLIPSTON, TOWN OF*	250328
PRINCETON, TOWN OF*	250329
ROYALSTON, TOWN OF*	250330
RUTLAND, TOWN OF*	250331
SHREWSBURY, TOWN OF	250332
SOUTHBOROUGH, TOWN OF	250333
SOUTHBRIDGE, TOWN OF	250334
SPENCER, TOWN OF	250335
STERLING, TOWN OF*	250336
STURBRIDGE, TOWN OF	250337
SUTTON, TOWN OF	250338
TEMPLETON, TOWN OF*	250339
UPTON, TOWN OF	250340
UXBRIDGE, TOWN OF	250341
WARREN, TOWN OF*	250342
WEBSTER, TOWN OF	250343
WEST BOYLSTON, TOWN OF	250345
WEST BROOKFIELD, TOWN OF*	250346
WESTBOROUGH, TOWN OF	250344
WESTMINSTER, TOWN OF*	250347
WINCHENDON, TOWN OF*	250348
WORCESTER, CITY OF	250349

*Community is not included in this partial countywide Flood Insurance Study and will retain its existing, separately published FIS and/or FIRM

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
25027CV001B

REVISED
JULY 16, 2014

NOTICE TO
FLOOD INSURANCE STUDY USERS

Communities participating in the National Flood Insurance Program have established repositories of flood hazard data for floodplain management and flood insurance purposes. This Flood Insurance Study (FIS) may not contain all data available within the repository. It is advisable to contact the community repository for any additional data.

Selected Flood Insurance Rate Map panels for the community contain information that was previously shown separately on the corresponding Flood Boundary and Floodway Map panels (e.g., floodways, cross sections). In addition, former flood hazard zone designations have been changed as follows:

Old Zone	New Zone
A1 through A30	AE
B	X
C	X (Shaded)

Part or all of this Flood Insurance Study may be revised and republished at any time. In addition, part of this Flood Insurance Study may be revised by the Letter of Map Revision process, which does not involve republication or redistribution of the Flood Insurance Study. It is, therefore, the responsibility of the user to consult with community officials and to check the community repository to obtain the most current Flood Insurance Study components.

Initial Countywide FIS Effective Date: July 4, 2011

Revised Countywide FIS Effective Date: July 16, 2014

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EXHIBITS - continued

Exhibit 1 - Flood Profiles - continued

FLOOD INSURANCE STUDY
WORCESTER COUNTY, MASSACHUSETTS (ALL JURISDICTIONS)

1.0 INTRODUCTION

1.1 Purpose of Study

This partial countywide Flood Insurance Study (FIS) revises and updates information on the existence and severity of flood hazards in the geographic area of Worcester County, Massachusetts including the City of Worcester; and the Towns of Auburn, Berlin, Blackstone, Bolton, Boylston, Charlton, Clinton, Douglas, Dudley, Grafton, Harvard, Hopedale, Lancaster, Leicester, Mendon, Milford, Millbury, Millville, Northborough, Northbridge, Oxford, Paxton, Shrewsbury, Southborough, Southbridge, Spencer, Sturbridge, Sutton, Upton, Uxbridge, Webster, West Boylston, and Westborough (referred to collectively herein as Worcester County), and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study has developed flood risk data for various areas of Worcester County that will be used to establish actuarial flood insurance rates and to assist the community in its efforts to promote sound floodplain management. Minimum floodplain management requirements for participation in the National Flood Insurance Program (NFIP) are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

The communities of Ashburnham, Athol, Barre, Brookfield, East Brookfield, Fitchburg, Gardner, Hardwick, Holden, Hubbardston, Leominster, Lunenburg, New Braintree, North Brookfield, Oakham, Phillipston, Princeton, Royalston, Rutland, Sterling, Templeton, Warren, West Brookfield, Westminster, and Winchendon are not included in this partial countywide FIS and each will retain its existing, separately published FIS and/or FIRM. Users should refer to the separately published FIS report and FIRM for effective data. Note that there was no previously printed FIS for the Town of Petersham, however a FIRM does exist for this community. Petersham was not updated as part of this partial countywide FIS.

In some States or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence, and the State (or other jurisdictional agency) will be able to explain them.

The Digital Flood Insurance Rate Map (DFIRM) and FIS report for the countywide study have been produced in digital format. Flood hazard information was converted to meet the Federal Emergency Management Agency (FEMA) DFIRM database specifications and Geographic Information Systems (GIS) format requirements. The flood hazard information was created in and is provided in a digital format for GIS use.

1.2 Authority and Acknowledgments

The sources of authority for this FIS report are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

This partial countywide FIS was prepared to incorporate the communities within Worcester County listed above in a countywide format (with the exception of those communities noted). Information on the authority and acknowledgements for each jurisdiction included in this partial countywide FIS, as compiled from their previously printed FIS reports, is shown below:

Auburn, Town of	The hydrologic and hydraulic analyses in the June 3, 1991 study represent a revision of the original analyses prepared by Camp Dresser & McKee, Inc. (CDM), for the Federal Emergency Management Agency (FEMA), under Contract No. H-3861. The work for the original study was completed in January 1977. In the 1991 revised study, hydrologic and hydraulic analyses for Dark Brook #1 (Auburn Pond to Central Street) were prepared by Rivers Engineering Corporation for FEMA under Contract No. EMW-89-C-2821. The work for the 1991 updated study was completed in June 1989.
Berlin, Town of	The hydrologic and hydraulic analyses for the original 1979 study were performed by Harris-Toups Associates, for the Federal Insurance Administration (FIA), under Contract No. H-4024. This work was completed in November 1977.
Blackstone, Town of	The hydrologic and hydraulic analyses for the original September 1977 study were performed by CDM, Environmental Engineers, for the FIA, under Contract No. H-3861. This work was completed in July 1976.
Bolton, Town of	The hydrologic and hydraulic analyses for the original December 1979 study were performed by Harris-Toups Associates, for the FIA under Contract No. H-4024. This work was completed in April 1978.
Boylston, Town of	The original hydrologic and hydraulic analyses for the 1979 study were prepared by Schoenfeld Associates, Inc., for FEMA, under Contract No. H-4794. The original work was completed in June 1979. The revised hydraulic analysis for Sewall Brook was prepared by Dewberry & Davis, under agreement with FEMA. The revised work was completed in May 1984.
Charlton, Town of	The hydrologic and hydraulic analyses for the original January 19, 1982 study were prepared by Schoenfeld Associates, Inc., for FEMA, under Contract No. H-4794. This work was completed in July 1980.

Clinton, Town of	The hydrologic and hydraulic analyses for the original December 15, 1981 study were prepared by the U.S. Army Corps of Engineers (USACE) for FEMA under Inter-Agency Agreement No. IAA-H-10-77, Project Order No. 16. This work was completed in May 1979.
Douglas, Town of	The hydrologic and hydraulic analyses for the original December 1, 1981 study were prepared by Vollmer Associates, Inc., for FEMA, under Contract No. H-4792. This work was completed in November 1980.
Dudley, Town of	The hydrologic and hydraulic analyses for the original December 15, 1981 study were prepared by Schoenfeld Associates, Inc., for FEMA, under Contract No. H-4794. This work was completed in February 1980.
Grafton, Town of	The hydrologic and hydraulic analyses for the original November 2, 1982 study were prepared by Vollmer Associates, Inc., for FEMA, under Contract No. H-4792. That work was completed in November 1980. In the September 30, 1992 revision, the hydrologic and hydraulic analyses were prepared by Rivers Engineering Corporation for FEMA under Contract No. EMW-89-C-2821. The work for the 1992 revised study was completed in November 1989.
Harvard, Town of	The hydrologic and hydraulic analyses for the original December 15, 1982 study were prepared by Howard, Needles, Tammen and Bergendoff, for FEMA, under Contract No. H-4004. This work was completed in January 1978.
Hopedale, Town of	The hydrologic and hydraulic analyses for the original January 19, 1982 study were prepared by Vollmer Associates, Inc., for FEMA, under Contract No. H-4792. This work was completed in July 1980.
Lancaster, Town of	The hydrologic and hydraulic analyses for the original January 5, 1982 study were prepared by Howard, Needles, Tammen and Bergendoff, for FEMA, under Contract No. H-4004. This work was completed in January 1978.
Leicester, Town of	The hydrologic and hydraulic analyses for the original January 5, 1982 study were performed

Leicester, Town of - continued	by Schoenfeld Associates, Inc., for FEMA, under Contract No. H-4794. This work was completed in March 1980.
Mendon, Town of	The hydrologic and hydraulic analyses for the original January 19, 1982 study were prepared by Vollmer Associates, Inc., for FEMA, under Contract No. H-4792. This work was completed in July 1980.
Milford, Town of	The hydrologic and hydraulic analyses for the original January 5, 1984 study were prepared by Vollmer Associates, Inc., for FEMA, under Contract No. H-4792. This work was completed in July 1980.
Millbury, Town of	For the January 1979 FIS and the July 2, 1979 FIRM, the hydrologic and hydraulic analyses were prepared by CDM, for the FIA, under Contract No. H-3861. That work was completed in January 1978. For the January 7, 2000 revision, the hydrologic and hydraulic analyses for Dorothy Pond and Ramshorn Brook (including Ramshorn Pond) were prepared by Green International Affiliates, Inc., for FEMA, under Contract No. EMW-93-C-4144, Task No. 16. This work was completed in June 1996.
Millville, Town of	The hydrologic and hydraulic analyses for the original January 19, 1982 study were prepared by Vollmer Associates, Inc., for FEMA, under Contract No. H-4792. This work was completed in August 1980.
Northborough, Town of	The hydrologic and hydraulic analyses for the original May 1979 study were performed by Harris-Toups Associates, for the FIA, under Contract No. H-4024. This work was completed in November 1977.
Northbridge, Town of	For the original FIRM dated June 15, 1983, and FIS dated December 15, 1982, the hydrologic and hydraulic analyses were prepared by Vollmer Associates, Inc., for FEMA, under Contract No. H-4792. That work was completed in November 1980. For the February 2, 2002 revision, the hydrologic and hydraulic analyses for a portion of the Blackstone River and the Riverdale Mills Sluice Gates and Tail Race were prepared by Green International Affiliates, Inc., for FEMA, under Contract No. EMB-96-CO-

Northbridge, Town of - continued	0403 (Task #8). This work was completed in September 1999.
Oxford, Town of	The hydrologic and hydraulic analyses for the original July 20, 1981 study were prepared by Schoenfeld Associates, Inc., for FEMA, under Contract No. H-4794. This work was completed in March 1980.
Paxton, Town of	The analyses for the August 18, 1980 FIS report were performed by Green International Affiliates, Inc., for the FIA, under Contract No. H-4793. This work was completed in February 1980.
Shrewsbury, Town of	The hydrologic and hydraulic analyses for the December 1979 study were performed by Harris-Toups Associates, for the FIA, under Contract No. H-4024. This work was completed in March 1978.
Southborough, Town of	The hydrologic and hydraulic analyses for the April 15, 1981 study were prepared by Howard, Needles, Tammen & Bergendoff, for the FIA, under Contract No. H-4004. This work was completed in November 1979.
Southbridge, Town of	The hydrologic and hydraulic analyses for the original September 15, 1981 study were prepared by Schoenfeld Associates, Inc., for FEMA, under Contract No. H-4794. This work was completed in August 1980.
Spencer, Town of	The hydrologic and hydraulic analyses in the September 14, 1990 study represent a revision of the original analyses prepared by Green International Affiliates, Inc., for FEMA, under Contract No. H-4793. The work for the original study was completed in September 1979. The hydrologic and hydraulic analyses in the revised study were completed by the Natural Resources Conservation Service (NRCS; formerly SCS) for FEMA. The work for this revision was completed in October 1988.
Sturbridge, Town of	The hydrologic and hydraulic analyses for the original January 19, 1982 study were prepared by Schoenfeld Associates, Inc., for FEMA, under Contract No. H-4794. This work was completed in November 1980.

Sutton, Town of	The hydrologic and hydraulic analyses for the original December 1, 1981 study were prepared by Vollmer Associates, Inc., for FEMA, under Contract No. H-4792. This work was completed in November 1980.
Upton, Town of	The hydrologic and hydraulic analyses for the original February 2, 1982 study were prepared by Vollmer Associates Inc., for FEMA, under Contract No. H-4792. This work was completed in August 1980.
Uxbridge, Town of	The hydrologic and hydraulic analyses for the original December 1, 1982 study were prepared by Vollmer Associates Inc., for FEMA, under Contract No. H-4792. This work was completed in August 1980.
Webster, Town of	The hydrologic and hydraulic analyses for the original study were prepared by Schoenfeld Associates, Inc., for FEMA, under Contract No. H-4794. That work was completed in February 1980. In the June 16, 1993 revision, a hydrologic analysis of Lake Chargoggagoggmanchauggagoggchaubuna-gungamaugg, herein referred to as Lake Webster, was carried out by Rivers Engineering Corporation, for FEMA, under Contract No. EMW-89-C-282l. This work was completed in November 1989.
West Boylston, Town of	The hydrologic and hydraulic analyses in the August 2, 1990 study represent a revision of the original analyses prepared by Schoenfeld Associates. Inc., for FEMA, under Contract No. H-4794. The hydrologic and hydraulic analyses in the August 2, 1990 revision were prepared by the New England District of the USACE, under Inter-Agency Agreement No. EMW-84-E1506, Project No.1, Amendment No. 26. This study was completed in May 1988.
Westborough, Town of	The hydrologic and hydraulic analyses for the original November 1979 study were performed by Harris-Toups Associates, for the FIA, under Contract No. H-4024. This work was completed in March 1978.

Worcester, City of	For the original February 1980 FIS report and August 15, 1980 FIRM, the hydrologic and hydraulic analyses were performed by CDM, for the FIA, under Contract No. H-3861. That work was completed in January 1978. For the January 16, 2003 revision, the hydrologic and hydraulic analyses for Beaver Brook, Broad Meadow Brook, and Mill Brook Conduit, were performed by Hydraulic & Water Resources Engineers, Inc., for FEMA, under Contract No. EMB-96-CO-0406. This work was completed in February 2000. An additional hydraulic analysis for the entire portion of Beaver Brook located downstream of Maywood Street was performed by Dewberry & Davis, LLC. This work was completed on September 6, 2001.

The July 4, 2011 partial countywide FIS was prepared by CDM, for FEMA, under Contract No. EME-2003-CO-0340. The Blackstone River was restudied by detailed methods as part of the partial countywide FIS preparation; no new approximate analyses were completed. The Blackstone River study was completed March 30, 2007.

For this revised partial countywide FIS, the FIRM database and mapping were prepared for FEMA by STARR, under Contract No. EMP-2003-CO-2606, Task Order No. HSFE01-10-J-0006. This revision includes detailed hydraulic analyses, redelineation, digitizing of effective flood hazard information, and new approximate analyses for the Concord River Watershed, which includes parts of both Worcester and Middlesex Counties. This FIS only covers work completed in Worcester County. This work was completed in October 2012.

Base map information shown on this FIRM was derived from digital orthophotography. Base map files were provided in digital form by Massachusetts Geographic Information System (MassGIS). Ortho imagery was produced at a maximum scale of 1:5,000. Aerial photography is dated April 2008. The projection used in the preparation of this map was Massachusetts State Plane mainland zone (FIPSZONE2001). The horizontal datum was NAD83, GRS1980 spheroid.

A 10-foot by 10-foot horizontal grid digital elevation model (DEM) was derived from Light Detection and Ranging (LiDAR) data, provided by Photo Science Geospatial Solutions (Reference 1), a STARR subconsultant. This DEM was constructed to cover all drainage areas for streams within the Concord River Watershed; it was the only DEM used during hydraulic modeling, including floodplain delineation. The vertical precision of the DEM is 0.03 feet. Stream centerlines developed during the scoping process were compared to orthophotos and United States Geological Survey (USGS) National Hydrography Dataset (NHD) (Reference 2) flow lines and revised as required to ensure that the stream channels were in the correct locations. Two-foot contour intervals were created from the DEM to use as a reference when adjusting overbank, centerline, and cross section geometry. A total of 111 flightlines of highest density (Nominal Pulse Spacing of 1.0 meter) using an Optech Gemini LiDAR system were collected over the Concord River Watershed, totaling 405 square miles. A total of 12 missions were flown between December 2 and December 12, 2010.

1.3 Coordination

The purpose of an initial Consultation Coordination Officer's (CCO) meeting is to discuss the scope of the FIS. A final CCO meeting is held to review the results of the study.

The dates of the initial and final CCO meetings held for the applicable incorporated communities within Worcester County are shown in Table 1, "CCO Meeting Dates for Precountywide FISs."

TABLE 1 – CCO MEETING DATES FOR PRECOUNTYWIDE FISs

Community Name	Initial CCO Date	Intermediate CCO Date	Final CCO Date
Town of Auburn	June 21, 1988	July 13, 1989	April 6, 1990
Town of Berlin	September 13, 1976	*	November 1, 1978
Town of Blackstone	August 25, 1975	*	September 15, 1976
Town of Bolton	April 29, 1976	*	November 30, 1978
Town of Boylston	May 1978	*	February 28, 1980
Town of Charlton	May 8, 1978	*	April 6, 1981
Town of Clinton	*	*	May 28, 1981
Town of Douglas	May 19, 1978	*	June 23, 1981
Town of Dudley	May 1978	*	February 2, 1981
Town of Grafton	June 21, 1988	January 22, 1990	April 16, 1991
Town of Harvard	November 1, 1976	March 1980	July 20, 1981
Town of Hopedale	May 24, 1978	*	August 10, 1981
Town of Lancaster	May 5, 1976	January 25, 1978	October 1, 1980
Town of Leicester	May 1978	*	February 24, 1981
Town of Mendon	May 24, 1978	*	June 8, 1981
Town of Milford	May 24, 1978	*	July 28, 1981
Town of Millbury	September 11, 1975	*	July 25, 1978
Town of Millville	May 19, 1978	*	August 3, 1981
Town of Northborough	November 16, 1976	*	July 26, 1978
Town of Northbridge	May 10, 1979	*	December 7, 1981
Town of Oxford	May 9, 1978	*	February 10, 1981
Town of Paxton	May 22, 1978	*	*
Town of Shrewsbury	April 30, 1976	*	November 2, 1978
Town of Southborough	April 15, 1976	October 17, 1979 November 1979	October 28, 1980
Town of Southbridge	May 8, 1978	*	April 6, 1981
Town of Spencer	May 1978	August 2, 1979	March 3, 1980
Town of Sturbridge	May 1978	*	August 24, 1981
Town of Sutton	May 18, 1978	*	July 21, 1981

*Data Not Available

TABLE 1 – CCO MEETING DATES FOR PRECOUNTYWIDE FISs - continued

Community Name	Initial CCO Date	Intermediate CCO Date	Final CCO Date
Town of Upton	May 26, 1978	*	July 27, 1981
Town of Uxbridge	May 19, 1978	*	March 8, 1982
Town of Webster	June 21, 1988	*	August 26, 1991
Town of West Boylston	November 16, 1984	*	September 26, 1989
Town of Westborough	April 30, 1976	*	October 25, 1978
City of Worcester	October 4, 1995	*	May 3, 2001

*Data Not Available

For the July 2011 partial countywide analysis, the initial CCO meeting was held on October 17, 2006, and was attended by representatives of FEMA, Massachusetts Department of Conservation and Recreation (MADCR), and relevant communities in Worcester County.

The results of the study were reviewed at the final CCO meetings held on May 11 and 12 of 2009, and attended by representatives of FEMA, the communities, MADCR, Regional Management Center for Region I (RMC I), and CDM. All problems raised at that meeting have been addressed in the partial countywide study.

For this revised partial countywide FIS, which includes a restudy of the Concord River Watershed, three initial CCO meetings were held. The first meeting was held on January 13, 2011 in the Town of Southborough, Worcester County. The second meeting was held on January 18, 2011 in the Town of Chelmsford, Middlesex County. The third meeting was held on February 7, 2011 in the Town of Concord, Middlesex County. All meetings were attended by representatives of FEMA Region I, STARR, and state and community officials.

2.0 AREA STUDIED

2.1 Scope of Study

July 2011 Partial Countywide Analysis

The July 2011 FIS covers a portion of the geographic area of Worcester County, Massachusetts, including the incorporated communities listed in Section 1.1.

The areas studied by detailed methods were selected with priority given to all known flood hazards and areas of projected development or proposed construction.

All or portions of the flooding sources listed in Table 2, "Flooding Sources Studied by Detailed Methods," were studied by detailed methods in the pre-countywide FISs. Limits of detailed study are indicated on the Flood Profiles (Exhibit 1) and on the DFIRM. Flood Profiles for the following flooding sources were not created in the original FIS reports and by extension, are not available in this partial countywide FIS report: Still River in Bolton; Broad Meadow Brook and Weasel Brook in Worcester.

TABLE 2 –FLOODING SOURCES STUDIED BY DETAILED METHODS

Flooding Source Name	Description of Study Reaches
Assabet River	From the Berlin / Marlborough corporate limits to just upstream of Main Street in Northborough. Past the confluence with Cold Harbor Brook (Lower Reach)
Assabet River (Lower Reach)	From approximately 29.6 miles above confluence with Concord River to the Assabet River Dam (George Nichols Dam) in Westborough
Assabet River (Upper Reach)	From the mouth of the Assabet Reservoir to approximately 1,800 feet upstream of Nourse Street in Westborough
Assabet River Branch No. 2	From the Berlin / Hudson corporate limits to approximately 765 feet upstream of Gates Pond Road
Auburn Pond	For its entire shoreline within the Town of Auburn
Axtell Brook	From the confluence with Lake Ripple in Grafton to the downstream side of the Massachusetts Turnpike in Grafton
Beaver Brook	From the confluence with Middle River in Worcester to a point approximately 1,855 feet upstream of May Street in Worcester
Bennetts Brook	From the Ayer, MA (Middlesex County) / Harvard corporate limits to Shaker Road in Harvard

TABLE 2 –FLOODING SOURCES STUDIED BY DETAILED METHODS – continued

Flooding Source Name	Description of Study Reaches
Big Bummet Brook	From its confluence with Quinsigamond River to the corporate to approximately 2,140 feet after Gold Street in Shrewsbury
Blackstone River*	From Providence County/Worcester County boundary to its confluence with Middle River
Bowers Brook	From the Ayer, MA (Middlesex County) / Harvard corporate limits to Woodside Road in Harvard
Brierly Pond	Within the Town of Millbury
Broad Meadow Brook	From the downstream Worcester corporate limits to a point approximately 8,630 feet upstream of U.S. Highway 20 in Worcester
Cady Brook	From its confluence with the Quinebaug River in Southbridge to the dam located approximately 1,200 feet upstream of the U.S. Route 20 bridge in Charlton
Cedar Meadow Brook	From Cooper Road (confluence with Quinebaug River in Sturbridge) to elevation 571 in Sturbridge
Cedar Pond	From Cedar Pond Dam to approximately 1.6 miles upstream
Center Brook	From the Station Street bridge in Upton upstream to Pratt Pond Dam in Upton
Charles River	From Norfolk County/Worcester County Boundary, 4,450 feet upstream of Box Pond Dam, to the Town of Milford (Worcester County)/ Town of Hopkinton (Norfolk County) Boundary
Cohasse Brook	From its confluence with the Quinebaug River in Southbridge to approximately 1.25 miles upstream of State Route 198 (Eastford Road).

TABLE 2 –FLOODING SOURCES STUDIED BY DETAILED METHODS – continued

Flooding Source Name	Description of Study Reaches
Cold Harbor Brook (Lower Reach)	From its confluence with Assabet River in Northborough to approximately 1,800 feet upstream of Lincoln Street in Northborough
Cold Harbor Brook (Town of Boylston)	From the downstream Town of Northborough/Town of Boylston corporate limits to approximately 1700 feet upstream of Reservoir Road in Town of Boylston
Cold Harbor Brook (Upper Reach)	From Cherry Street in Northborough to approximately 700 feet upstream of Fisher Street in Northborough
Cold Spring Brook (Town of Harvard)	From its confluence with Bowers Brook in Harvard to 1,900 feet upstream of Boston and Maine Railroad
Cold Spring Brook (Town of Sutton)	From its confluence with Blackstone River in Sutton to a point approximately 5,400 feet upstream
Counterpane Brook	Entire length within the Town of Clinton
Cronin Brook	From its confluence with Blackstone River in Grafton to the upstream side of Millbury Street in Grafton
Curtis Pond	Within the City of Worcester
Dark Brook	From its confluence with Mumford River to approximately 1,950 feet upstream of Tucker's Pond Dam
Dark Brook #1 (Auburn Pond to Central Street)	From its confluence with Auburn Pond to Central Street
Dark Brook #2 (Stoneville Pond to Leicester Street)	From its confluence with Stoneville Pond to Leicester Street Bridge
Deans Brook	From confluence with Quinebaug River to approximately 0.35 miles upstream of McIntyre Road

TABLE 2 –FLOODING SOURCES STUDIED BY DETAILED METHODS – continued

Flooding Source Name	Description of Study Reaches
Denny Brook	From above South Street in Westborough to approximately 700 feet upstream of High School Road
Dorothy Brook	From its confluence with Blackstone River in Millbury to approximately 1,030 feet above mouth of Blackstone River in Millbury
Dorothy Pond	From Riverlin Street to approximately 700 feet upstream of Wheelock Avenue
Dunn's Brook (Kettle Brook to Auburn Pond)	In Auburn, from its confluence with Kettle Brook to Auburn Pond
Elizabeth Brook	In Harvard, from approximately 4,500 feet upstream of Harvard Road to the Harvard / Boxborough (Middlesex County) corporate limits, continuing in Harvard from the Boxborough (Middlesex County) / Harvard corporate limits to approximately 1,000 feet upstream of Sherry Road in Harvard
Flagg Street Pond	Within the City of Worcester
French River	From Norwich & Worcester Branch Railroad to confluence with Town Meadow Brook
Gates Brook	In West Boylston, from a point approximately 120 feet downstream of the Boston and Maine Railroad to a point approximately 80 feet upstream of Pierce Street
Godfrey Brook	From its confluence with Charles River in Milford to a point 1,000 feet upstream of Congress Terrace in Milford
Goodridge Brook	From downstream of the Clinton/ Lancaster corporate limits to approximately 1,000 feet upstream of Parker Road in the Town of Lancaster
Great Brook	Within the corporate limits of Town of Bolton

TABLE 2 –FLOODING SOURCES STUDIED BY DETAILED METHODS – continued

Flooding Source Name	Description of Study Reaches
Hamant Brook	From Access Road to approximately 0.6 miles upstream of Interstate Route 86 North
Harris Pond	For its entire shoreline in the Town of Blackstone
Howard Brook	In Northborough, from its confluence with Cold Harbor Brook (Lower Reach) to just upstream of Brewer Street
Huckleberry Brook	From its confluence with Cedar Swamp Pond to Erin Street
Indian Lake	For its entire shoreline in the City of Worcester
Ivy Brook	In Milford, from its confluence with Huckleberry Brook to a point approximately 1,300 feet upstream of Silver Hill Road
Jackstraw Brook	In Westborough, between Hopkinton Road and Warren Street
Kettle Brook (East)	In Worcester, from its confluence with Curtis Pond to Leesville Pond
Kettle Brook (Town of Auburn)	In Auburn, from Leesville Pond to Stoneville Pond
Kettle Brook (West)	From James Street to approximately 7,200 feet upstream
Lake Webster	For its entire shoreline within the Town of Webster
Lancaster Mill Pond	A portion of Lancaster Mill Pond in Clinton
Leadmine Brook	From Mashapaug Road in Sturbridge to approximately 3,000 feet upstream of Leadmine Road

TABLE 2 –FLOODING SOURCES STUDIED BY DETAILED METHODS – continued

Flooding Source Name	Description of Study Reaches
Lebanon Brook	From its confluence with the Quinebaug River to a point approximately 6,500 feet upstream of State Route 169 (North Woodstock Road)
Leesville Pond	For its entire shoreline within the Town of Auburn and the City of Worcester.
Little Nugget Brook	In Charlton, from Pikes Pond to Little Nugget Lake
Little River	From just downstream of Turner Road to a point approximately 0.5 miles feet upstream Oxbow Road
Lowes Brook	From its confluence with French River to approximately 0.3 miles upstream of Sutton Avenue
Lynde Brook	In Leicester, from State Route 9 (Main Street) to Lynde Brook Reservoir
McKinstry Brook	From its confluence with the Quinebaug River to approximately 0.7 miles upstream.
Meadow Brook	In Shrewsbury, from approximately 120 feet downstream of Oak Street to approximately 4,480 feet upstream of Oak Street
Middle River	From its confluence with Blackstone River to just upstream of St. Johns Cemetery Road.
Mill Brook	From the Town of Bolton/Town of Hudson corporate limits to Spectacle Hill Road
Mill Brook #1	From its confluence with French River to 0.185 miles upstream of Arkwright Road
Mill Brook Conduit	In Worcester, from Salisbury Pond to the Indian Lake Outlet

TABLE 2 –FLOODING SOURCES STUDIED BY DETAILED METHODS – continued

Flooding Source Name	Description of Study Reaches
Mill River	From its confluence with Harris Pond in the Town of Blackstone to its confluence with North Pond in the Town of Milford
Miscoe Brook	In Grafton, from Silver Lake upstream of Old Upton Road to the upstream side of Adams road
Muddy Brook	In Mendon, from its confluence with Mill River to a point 1,000 feet upstream of the Milford Road Bridge
Mumford River	For its entire lengths within the Towns of Uxbridge, Northbridge, Douglas and continuing from the Douglas / Sutton corporate limits to downstream of Stevens Pond in Sutton
Nashua River	Entire lengths within the Towns of Clinton, Lancaster, Bolton and Harvard
North Brook	From its confluence with Assabet River in Berlin to the Berlin / Bolton corporate limits
North Nashua River	In Lancaster, from its confluence with Nashua River to Town of Lancaster upstream corporate limits
O'Brien Brook	From its confluence with Godfrey Brook to Vincenzo Road
Piccadilly Brook	From approximately 1,100 feet downstream of the Town of Hopkinton (Middlesex County)/ Town of Westborough (Worcester County) corporate limits to just upstream of Upton Road
Pikes Pond Tributary	In Charlton, from Pikes Pond to approximately 900 feet upstream of the Conrail tracks
Pondville Pond	In Town of Millbury and for its entire shoreline within the Town of Auburn

TABLE 2 –FLOODING SOURCES STUDIED BY DETAILED METHODS – continued

Flooding Source Name	Description of Study Reaches
Quacumquasit Pond	For its entire area within the Town of Sturbridge
Quick Stream	In Blackstone, from its confluence with Harris Pond to approximately 3200 feet upstream from Harris Pond
Quinebaug River	From approximately 2,000 feet upstream of Old Turnpike Road (Route 197) to approximately 0.5 miles upstream of Holland Road
Quinsigamond River	From confluence with Blackstone River to Hovey Pond Dam
Ramshorn Brook (Town of Auburn)	From its confluence with Auburn Pond to Pondville Pond
Ramshorn Brook (Town of Millbury)	From Pondville Pond to Millbury/Sutton corporate limits
Rawson Hill Brook	In Shrewsbury, from the upper reach (approximately 0.025 miles) before Prospect Street to the Shrewsbury / Boylston corporate limits
Riverdale Mills Sluice Gates & Tail Race	In Northbridge, from its divergence from Blackstone River downstream of the Mill Complex to its confluence with the Blackstone River upstream of the Mill Complex
Rutters Brook	From the Railroad approximately 1,900 feet upstream of confluence with Jackstraw Brook to approximately 1,200 feet upstream of Robin Road
Saranac Canal	Within the Town of Blackstone
Sevenmile River	From the downstream corporate limits of East Brookfield / Spencer to approximately 1,200 feet upstream of State Route 31

TABLE 2 –FLOODING SOURCES STUDIED BY DETAILED METHODS – continued

Flooding Source Name	Description of Study Reaches
Sewall Brook	In Boylston, from 1,400 feet downstream of Sewall Pond Outlet to the New England Telephone Company culvert beneath Mill Road
Singletary Brook	In Millbury, from its confluence with Blackstone River to confluence of Unnamed Tributary to Mayo Pond
Singletary Pond	Within the Town of Millbury
Southwick Brook	From its confluence with Mumford River in upstream Douglas to Weeks Pond in Douglas
Stall Brook	In Milford, from Interstate Highway 495 to a point approximately 100 feet upstream of Beaver Street
Still River	Within the corporate limits of Town of Bolton
Stone Brook	In Auburn, from its confluence with Pondville Pond to South Street
Stoneville Pond	For its entire shoreline within the Town of Auburn
Stony Brook / Sudbury Reservoir	In Southborough, from the corporate limits to Deerfoot Road
Sudbury River	Within the corporate limits of Town of Southborough
Tatnuck Brook	In Worcester, from its confluence with Beaver Brook to upstream corporate limits
Town Meadow Brook	In Leicester, from French River to Sargent Pond
Tributary 1	In Dudley, from New Pond outlet to a point 1,000 feet upstream of Mason Road

TABLE 2 –FLOODING SOURCES STUDIED BY DETAILED METHODS – continued

Flooding Source Name	Description of Study Reaches
Tributary to Elizabeth Brook	From its confluence with Elizabeth Brook in Harvard to the culvert at Stow Road in Harvard
Tributary to Sudbury Reservoir	From confluence with Sudbury Reservoir in Southborough to 4,400 feet above confluence with Sudbury Reservoir in Southborough
Tributary to Sudbury River	From confluence with Sudbury River in Southborough to approximately 60 feet after Cordaville Road in Southborough
Tributary to Waushacum Brook	In West Boylston, from its confluence with Waushacum Brook to a point approximately 50 feet downstream of Fairbanks Road
Tupperware Mill Canal	Within the Town of Blackstone
Unnamed Tributary	In Auburn, from its confluence with Leesville Pond to Rockland Road
Unnamed Tributary to Mayo Pond	From its confluence with Mayo Pond to the Millbury / Sutton corporate limits
Walker Pond	From Walker Pond Dam to approximately 1.38 miles upstream
Waushacum Brook	In West Boylston, from a point approximately 150 feet upstream of its confluence with Wachusett Reservoir to Boylston/Sterling corporate limits
Weasel Brook	Within the City of Worcester
West Brook	In Shrewsbury, from culvert entrance before Oregon Avenue to approximately 1,000 feet upstream of Main Street
West River	From Hartford Avenue in Upton to approximately 2,700 feet upstream of Silver Lake Dam in Grafton
West River (Town of Uxbridge)	From its confluence with Blackstone River in Uxbridge upstream to the West Hill Dam

TABLE 2 –FLOODING SOURCES STUDIED BY DETAILED METHODS – continued

Flooding Source Name	Description of Study Reaches
Whitins Pond	For its entire area within the Town of Sutton
Wrack Meadow Brook	From its confluence with North Brook in Berlin to the Berlin / Boylston corporate limit

For the July 2011 partial countywide FIS, the Blackstone River was restudied from the upstream corporate limit in the City of Woonsocket, Rhode Island to the formation of the Blackstone River at the confluence of Middle River and Mill Brook in the City of Worcester, Massachusetts.

The Blackstone River flows in a general southeasterly direction from Massachusetts into Rhode Island. It enters Rhode Island in the Town of North Smithfield through which it flows for approximately 1 mile before re-entering the Town of Blackstone, Massachusetts further downstream. The Blackstone River was modeled as a single continuous hydraulic model.

Approximate analyses were used to study those areas having a low development potential or minimal flood hazards. The scope and methods of study were proposed to, and agreed upon, by FEMA and the individual communities within Worcester County.

All or portions of the flooding sources listed in Table 3, "Flooding Sources Studied by Approximate Methods," were studied by approximate methods in the precountywide FISs. No new approximate studies were performed for the July 2011 partial countywide FIS.

TABLE 3 - FLOODING SOURCES STUDIED BY APPROXIMATE METHODS

Flooding Source Name	Community (ies)
Aldrich Brook	Uxbridge
Alum Pond	Sturbridge
Angelica Brook	Southborough
Asnebumskit Pond	Paxton
Assabet Reservoir	Westborough
Assabet River	Berlin, Northborough, Westborough
Axtell Brook	Grafton
Bacon Brook	Uxbridge
Barefoot Brook	Northborough
Bartlett Pond	Northborough
Bartons Brook	Leicester

TABLE 3 - FLOODING SOURCES STUDIED BY APPROXIMATE METHODS – continued

Flooding Source Name	Community (ies)
Bating Brook	Douglas
Bennetts Brook	Harvard
Big Bummet Brook	Shrewsbury
Breakneck Brook	Sturbridge
Brimfield Reservoir	Sturbridge
Bugs Swamp	Oxford
Bumbo Brook	Paxton
Burncoat Brook	Leicester
Burncoat Pond	Spencer
Carbuncle Pond	Oxford
Card Machine Brook	Uxbridge
Carpenter Reservoir	Northbridge
Caruth Brook	Paxton
Cascade Brook	Worcester
Caswell Brook	Douglas
Cedar Swamp	Uxbridge
Cedar Swamp Brook	Douglas, Oxford, Uxbridge
Center Brook	Upton
Centerville Brook	Douglas
Chauncy Lake	Westborough
Chimney Pond	Oxford
Chockalog River	Douglas
Cider Mill Pond	Spencer
Clamshell Pond	Clinton
Clark Reservoir	Sutton
Coachlace Pond	Clinton
Cold Brook	Sutton
Cold Harbor Brook (Lower Reach)	Northborough
Cold Harbor Brook (Town of Boylston)	Boylston
Cold Harbor Brook (Upper Reach)	Northborough
Cold Spring Brook	Harvard, Uxbridge
Cook Allen Brook	Sutton
Cooledge Brook	Northborough
Craddock Crewes Pond	Milford
Cranberry River	Spencer
Crane Swamp	Northborough, Westborough
Cronin Brook	Grafton, Millbury

TABLE 3 - FLOODING SOURCES STUDIED BY APPROXIMATE METHODS – continued

Flooding Source Name	Community (ies)
Crystal Lake	Douglas
Dark Brook	Auburn, Sutton
Dark Brook Reservoir	Auburn
Denny Brook	Westborough
Denny Brook Branch	Westborough
Dorothy Brook	Millbury
Dunleavy Brook	Uxbridge
Eames Pond	Oxford
Echo Lake	Milford
Eddy Pond	Auburn
Elizabeth Brook	Harvard
Emerson Brook	Uxbridge
Farrel Brook	Uxbridge
Fish Pond	Northbridge
Flint Pond	Grafton, Worcester, Shrewsbury
Flint Pond Branches	Shrewsbury
Fox Brook	Blackstone, Millville
Freemans Brook	Webster
French Brook	Boylston
French River	Oxford
Fuller Pond	Clinton
Gates Brook	West Boylston
Gilboa Brook	Douglas
Globe Brook	Sturbridge
Godfrey Brook	Milford
Goodridge Brook	Lancaster
Grassy Pond	Oxford
Great Brook Branch 1	Bolton
Great Brook Branch 2	Bolton
Great Brook Branch 3	Bolton
Great Brook Branch 4	Bolton
Great Cedar Swamp	Leicester
Greene Brook	Douglas
Grindstone Brook	Leicester
Happy Hollow Brook	Uxbridge
Hatchet Brook	Southbridge
Hemlock Brook	Douglas

TABLE 3 - FLOODING SOURCES STUDIED BY APPROXIMATE METHODS – continued

Flooding Source Name	Community (ies)
Hobbs Brook	Sturbridge
Hog Swamp	Berlin
Honey Pond	Grafton
Hop Brook	Blackstone, Northborough, Shrewsbury
Hop Brook Branches	Northborough, Shrewsbury
Howard Brook	Northborough
Howard Brook (Branch 1)	Northborough
Howard Brook (Branch 2)	Northborough
Howe Pond	Millbury
Howe Reservoirs	Millbury
Huckleberry Brook	Milford
Hudson Pond	Oxford
Ironstone Reservoir	Uxbridge
Ivy Brook	Milford
Jackstraw Brook	Westborough
Joels Pond	Uxbridge
Jordan Pond	Shrewsbury
Jordan Pond Branches	Shrewsbury
Kettle Brook	Leicester, Paxton
Kettle Brook Reservoir No. 3	Paxton
Kettle Brook Reservoir No. 4	Paxton
Lake Quinsigamond	Shrewsbury, Worcester
Lake Quinsigamond Branches	Shrewsbury
Lamson Brook	West Boylston
Lancaster Mill Pond	Clinton
Laurel Brook	Douglas, Uxbridge
Leadmine Pond	Sturbridge
Lee Pond	Uxbridge
Lily Pond	West Boylston
Little Brook	Northborough
Little Brook Branches (Smith Pond)	Northborough
Little Bummet Brook	Shrewsbury
Little Chauncy Pond	Northborough
Little Crane Swamp	Northborough
Little River	Oxford
Little Bummet Brook	Shrewsbury
Little Chauncy Pond	Northborough

TABLE 3 - FLOODING SOURCES STUDIED BY APPROXIMATE METHODS – continued

Flooding Source Name	Community (ies)
Little Crane Swamp	Northborough
Little River	Oxford
Long Pond	Sturbridge
Lowes Brook	Oxford
Lynde Brook	Leicester
Maiden Brook	West Boylston
Malagasco Brook	Boylston
Manchaug Pond	Sutton
Marble Pond	Sutton
McGovern Brook	Lancaster
McKinstry Brook	Sturbridge
McKinstry Pond	Oxford
Meadow Brook	Mendon, Uxbridge, Shrewsbury
Meadow Brook Branch	Shrewsbury
Mill Brook Branch	Bolton
Mill Brook Swamp	Bolton
Mill River	Blackstone
Miscoe Brook	Grafton
Morse Pond	Southbridge
Mossy Pond	Clinton
Muddy Brook	Mendon
Muzzy Pond	Spencer
Nashua River Branch	Bolton
Newton Pond	Boylston, Shrewsbury
Newton Pond Branches	Shrewsbury
Nipmuck Pond	Mendon, Webster
No. 2 Pond	Oxford
North Brook	Bolton, Berlin
O'Brien Brook	Milford
Ohio Brook	Mendon
Peabody Pond	Uxbridge
Piccadilly Brook	Westborough
Pine Hill Reservoir	Paxton
Pine Swamp	Boylston
Poor Farm Brook	Worcester
Pout Pond	Boylston, Uxbridge
Purgatory Brook	Sutton

TABLE 3 - FLOODING SOURCES STUDIED BY APPROXIMATE METHODS – continued

Flooding Source Name	Community (ies)
Quinapoxet River	West Boylston
Quinebaug River	Sturbridge
Rawson Hill Brook	Boylston, Shrewsbury
Riddle Brook	Douglas
Rigby Brook	Clinton
Rivulet Pond	Uxbridge
Robinson Pond	Oxford
Rock Meadow Brook	Mendon
Rocky Brook	Douglas
Rocky Pond	Boylston
Round Meadow Brook	Mendon
Round Top Brook	Douglas
Rutters Brook	Westborough
Salisbury Pond	Worcester
Sawmill Pond	Uxbridge
Scadden Brook	Uxbridge
Scarletts Brook	West Boylston
Scotland Swamp	Boylston
Sevenmile River	Spencer
Sevenmile River (Tributaries To)	Spencer
Sewall Brook	Boylston
Sibley Reservoir	Sutton
Slaters Pond	Oxford
Solomon Pond	Northborough
South Meadow Pond	Clinton
Southwick Brook	Douglas
Southwick Pond	Paxton
Spring Brook	Mendon
Stall Brook	Milford
Steamburg Brook	Sutton
Stevens Pond	Sutton
Stiles Reservoir	Leicester, Spencer
Still Corner Brook	Millville
Still River Branch 1	Bolton
Still River Branch 2	Bolton
Stillwater Basin	West Boylston
Stirrup Brook	Northborough

TABLE 3 - FLOODING SOURCES STUDIED BY APPROXIMATE METHODS – continued

Flooding Source Name	Community (ies)
Stream flowing from Clamshell Pond	Clinton
Stream flowing from Muzzy Pond	Spencer
Stream flowing from Lake Whittemore	Spencer
Stump Pond	Oxford
Stumpy Pond	Oxford
Sucker Brook	Webster
Sudbury River	Westborough
Sunk Meadow	Berlin
Swans Pond	Northbridge, Sutton
Taft Pond	Upton
Thomas Basin	West Boylston
Tinkerville Brook	Douglas
Tributary to Miscoe Brook	Grafton
Trout Brook	Sturbridge
Tuckers Pond	Sutton
Turkey Hill Brook	Paxton, Spencer
Turkey Hill Pond	Paxton
Unnamed Areas	Clinton, Harvard, Spencer, Southbridge, Webster
Unnamed Brooks	Lancaster
Unnamed Lakes	Leicester
Unnamed Ponds	Charlton, Clinton, Douglas, Northbridge, Sutton
Unnamed Streams	Blackstone, Charlton, Douglas, Dudley, Northbridge, Sutton, Upton, West Boylston Boylston, Douglas, Leicester, Mendon, Milford, Oxford, Sturbridge, Upton
Unnamed Swamps	Auburn, Paxton, Southborough
Unnamed Tributaries	Paxton
Unnamed Tributaries to and from Kettle Brook Reservoir No. 3 and 4	Paxton
Wachusett Aqueduct	Southborough
Wachusett Reservoir	Boylston, Clinton, West Boylston
Wallale Pond	Sturbridge
Wallum Lake	Douglas
Warren Brook	Upton
Wekepeke Brook	Lancaster
Wellington Brook	Oxford
West Brook	Shrewsbury

TABLE 3 - FLOODING SOURCES STUDIED BY APPROXIMATE METHODS – continued

Flooding Source Name	Community (ies)
West River	Northbridge, Upton, Uxbridge
Westborough Reservoir	Westborough
Whitin Reservoir	Douglas
Wigwam Brook	Mendon

The July 2011 FIS also incorporated the determinations of letters issued by FEMA resulting in map changes (Letter of Map Revision [LOMR], Letter of Map Revision – based on Fill [LOMR-F], and Letter of Map Amendment [LOMA]), as shown in Table 4, "Letters of Map Change."

TABLE 4 – LETTERS OF MAP CHANGE

Community	Case Number	Flooding Source	Letter Date
Milford, Town of	97-01-001P	Huckleberry Brook	04/20/1998
Milford, Town of	05-01-0129P	Stall Brook	12/21/2005
Southborough, Town of*	07-01-0993P	Main Street between Parkerville Road and Middle Road	1/31/2008
Southbridge, Town of	99-01-047P	Quinebaug River	6/2/2000
Westborough, Town of	08-01-0865P	Piccadilly Brook	9/26/2008

*This LOMC has been superseded with a new study completed for the Concord River Watershed partial countywide analysis

For the July 2011 partial countywide study, redelineation of Special Flood Hazard Areas (SFHAs) for selected areas was performed by CDM. This redelineation was based on improved topographic information that became available.

Detailed studied streams that were not restudied as part of this partial countywide analysis may include a profile baseline on the FIRM. The profile baselines for these streams were based on the best available data at the time of their study and are depicted as they were on the previous FIRMs. In some cases the transferred profile baseline may deviate significantly from the channel or may be outside of the floodplain.

Concord River Watershed Partial Countywide Analysis

As part of the Concord River Watershed partial countywide FIS, updated analyses have been completed. There were instances where the name of the studied flooding source has changed between the July 2011 partial countywide analysis and the Concord River Watershed partial countywide analysis. These name changes are detailed in Table 5.

TABLE 5 – FLOODING SOURCE NAME CHANGE

Stream Name in July 2011 Partial Countywide Analysis	Stream Name in Concord River Watershed Partial Countywide Analysis
Stony Brook / Sudbury Reservoir	Stony Brook
Tributary to Sudbury Reservoir	Stony Brook Tributary 2
Tributary to Sudbury River	Sudbury River Tributary 12

Flooding sources that have been studied using detailed methods are shown in Table 6, "Flooding Sources Studied by Detailed Methods in Concord River Watershed Partial Countywide Analysis".

TABLE 6 – FLOODING SOURCES STUDIED BY DETAILED METHODS IN CONCORD RIVER WATERSHED PARTIAL COUNTYWIDE ANALYSIS

Flooding Source Name	Description of Study Reaches
Assabet River	From approximately 2,300 feet downstream of Allen Street in Northborough to its confluence with the Concord River in Middlesex County
Denny Brook	From approximately 2,050 feet upstream of Harvey Lane to its confluence with Jackstraw Brook
Denny Brook Tributary 1	From approximately 550 feet upstream of Chestnut Street to its confluence with Denny Brook
Elizabeth Brook	From approximately 1,000 feet upstream of Sherry Road to approximately 100 feet downstream of Interstate 495
Hop Brook	From approximately 650 feet upstream of Spring Street to approximately 50 feet downstream of Main Street
Hop Brook Tributary 4	From approximately 1,000 feet upstream of Flanagan Drive to its confluence with Hop Brook
Hop Brook Tributary 4.1	From approximately 200 feet downstream of Main Street to its confluence with Hop Brook Tributary 4
Jackstraw Brook	From approximately 650 feet upstream of Garfield Drive to its confluence with Sullivan Brook

TABLE 6 –FLOODING SOURCES STUDIED BY DETAILED METHODS IN CONCORD RIVER WATERSHED PARTIAL COUNTYWIDE ANALYSIS – continued

Flooding Source Name	Description of Study Reaches
Rutters Brook	From approximately 300 feet upstream of Wessonville Village Way to its confluence with Sullivan Brook
Rutters Brook Tributary 1	From approximately 250 feet upstream of Walkup Street to its confluence with Rutters Brook
Rutters Brook Tributary 1.1	From approximately 200 feet upstream of Research Drive to its confluence with Rutters Brook Tributary 1
Stony Brook	From approximately 100 feet upstream of Deerfoot Road in Southborough to its confluence with Sudbury River in Middlesex County
Sudbury River	From approximately 200 feet upstream of Interstate 495 in Westborough to its confluence with the Concord River in Middlesex County
Sudbury River Split 1	From its divergence with the Sudbury River in Southborough to its convergence with the Sudbury River in Southborough
Sullivan Brook	From the confluence of Rutters Brook and Jackstraw Brook to its confluence with the Sudbury River

As part of the Concord River Watershed study, the following flooding sources were redelineated using the topographic data developed for the watershed, as described in Section 1.2: Assabet River, Assabet River (Lower Reach), Assabet River (Upper Reach), Assabet River Branch No. 2, Cold Harbor Brook (Lower Reach), Cold Harbor Brook (Town of Boylston), Cold Harbor Brook (Upper Reach), Denny Brook, Elizabeth Brook, Great Brook, Howard Brook, Mill Brook, North Brook, Piccadilly Brook, Rawson Hill Brook, Stony Brook Tributary 2, Sudbury River Tributary 12, Tributary to Elizabeth Brook, and Wrack Meadow Brook. This effort also included the determination of floodplains for the most downstream portions of North Brook, Stony Brook Tributary 2, Sudbury River Tributary 12, and Tributary to Elizabeth Brook, which was controlled by the backwater effects from the Assabet River, Stony Brook, Sudbury River, and Elizabeth Brook, respectively. The redelineation effort also included tie-ins with new detailed or approximate studies on the Assabet River, the Assabet River (Lower Reach), the Assabet River (Upper Reach), Denny Brook, and Elizabeth Brook.

Approximate analyses were used to study those areas having a low development potential or minimal flood hazards. The scope and methods of the study were proposed to, and agreed upon by FEMA and Worcester County. The areas studied by approximate analyses in the revised countywide analysis are listed in Table 7.

TABLE 7 – FLOODING SOURCES STUDIED BY APPROXIMATE METHODS IN CONCORD RIVER WATERSHED PARTIAL COUNTYWIDE ANALYSIS

Angelica Brook	Assabet River Upper Reach 1	Assabet River Upper Reach 2
Assabet River Tributary 7	Assabet River Tributary 10	Assabet River Tributary 11
Assabet River Tributary 12	Assabet River Tributary 13	Assabet River Tributary 14
Assabet River Tributary 15	Assabet River Tributary 16	Assabet River Tributary 17
Barefoot Brook	Chauncey Lake	Chauncey Lake Tributary 1
Chauncey Lake Tributary 1.1	Cold Harbor Brook Reach 1	Cold Harbor Brook Reach 2
Cold Harbor Brook Tributary 1	Cooledge Brook	Cooledge Brook Tributary
Elizabeth Brook 1	Elizabeth Brook Tributary 3	Great Brook Tributary 1
Great Brook Tributary 2	Great Brook Tributary 2.2	Great Brook Tributary 2.3
Great Brook Tributary 4	Hop Brook	Hop Brook Tributary 1
Howard Brook	Howard Brook Tributary	Jackstraw Brook Tributary 1
Mill Brook West	Mill Brook West Tributary 1	Mill Brook West Tributary 2
Mill Brook West Tributary 3	Mill Brook West Tributary 3.1	Mill Brook West Tributary 4
Mill Brook West Tributary 5	Mill Brook West Tributary 6	North Brook
North Brook Tributary 2	North Brook Tributary 8	Piccadilly Brook
Rawson Hill Brook Reach 1	Rawson Hill Brook Reach 2	Road Brook
Road Brook Tributary 2	Road Brook Tributary 2.1	Road Brook Tributary 2.2
Stirrup Brook	Stirrup Brook Tributary 1	Stirrup Brook Tributary 2
Stirrup Brook Tributary 3	Stony Brook Tributary 1	Stony Brook Tributary 2
Sudbury River Tributary 12A	Sudbury River Tributary 13	Sudbury River Tributary 13.2
Sudbury River Tributary 14	Wrack Meadow Brook	Wrack Meadow Brook Tributary 1

One LOMR was incorporated into the Concord River Watershed study: Case Number 13-01-0608P, located in the Town of Northborough for Howard Brook. The effective date for this LOMR is October 4, 2013.

2.2 Community Description

Worcester County is located in central Massachusetts. In this partial FIS for Worcester County, there are thirty-three (33) towns and one (1) city. The participating communities are all located within the eastern, central and southern portions of Worcester County. The towns of Berlin, Bolton, Boylston, Clinton, Grafton, Harvard, Lancaster, Northborough, Shrewsbury, Southborough, Upton and Westborough are located in eastern Worcester County. The towns of Auburn, Leicester, Millbury, Paxton, Spencer, West Boylston and the City of Worcester are located in central Worcester County. The towns of Blackstone, Charlton, Douglas, Dudley, Hopedale, Mendon, Milford, Millville, Northbridge, Oxford, Southbridge, Sturbridge, Sutton, Uxbridge and Webster are located in southern Worcester County.

Worcester County is bordered on the north by the Cheshire and Hillsborough counties in New Hampshire. It is bordered on the east by the Middlesex and Norfolk counties in Massachusetts. It is bordered on the west by Franklin, Hampden and Hampshire counties in Massachusetts; and the Quabbin Reservoir in Massachusetts. It is bordered on the south by Providence County, Rhode Island and Tolland and Windham counties in Connecticut.

According to census records, the population of Worcester County was 750,963 in 2000 and 798,552 in 2010 (Reference 3). The total area in Worcester County consists of 1,579 mi^2, including 68 mi^2 of water area. All communities included in this partial FIS in Worcester County, along with their population and total area, are listed in Table 8, "Population and Total Area by Community."

According to the National Climatic Data Center, the average yearly rainfall for Worcester County is 45 inches and the average snowfall is 58 inches. The Worcester County July high is around 81 degrees and the January low is 17 degrees.

TABLE 8 –2010 POPULATION AND TOTAL AREA BY COMMUNITY

Community	Total Area (sq. mi)[1]	Population[1]
Auburn, Town of	16.4	16,188
Berlin, Town of	13.2	2,866
Blackstone, Town of	11.4	9,026
Bolton, Town of	20.1	4,897
Boylston, Town of	19.8	4,355
Charlton, Town of	43.8	12,981
Clinton, Town of	7.3	13,606
Douglas, Town of	37.9	8,471
Dudley, Town of	21.9	11,390
Grafton, Town of	23.3	17,765
Harvard, Town of	27.2	6,520
Hopedale, Town of	6.9	5,911
Lancaster, Town of	28.0	8,055
Leicester, Town of	24.6	10,970
Mendon, Town of	18.0	5,839
Milford, Town of	15.0	27,999
Millbury, Town of	16.4	13,261
Millville, Town of	5.0	3,190
Northborough, Town of	18.7	14,155
Northbridge, Town of	18.1	15,707
Oxford, Town of	27.4	13,709
Paxton, Town of	15.5	4,806
Shrewsbury, Town of	21.7	35,608
Southborough, Town of	15.5	9,767
Southbridge, Town of	20.9	16,719
Spencer, Town of	34.0	11,688
Sturbridge, Town of	39.0	9,268
Sutton, Town of	34.0	8,963
Upton, Town of	21.8	7,542
Uxbridge, Town of	30.3	13,457
Webster, Town of	14.6	16,767
West Boylston, Town of	13.9	7,669
Westborough, Town of	21.4	18,272
Worcester, City of	38.5	181,045

[1]Data obtained from U.S Census Bureau (Reference 3).

2.3 Principal Flood Problems

Past flooding on the streams within Worcester County indicates that flooding can occur during any season of the year. Most major floods have occurred during the spring, fall and winter seasons. Floods occurring in early spring are usually a result of snowmelt and heavy rains. Floods occurring during midsummer and fall are often associated with tropical storms moving up the Atlantic coastline. "Northeaster" storms generate very strong winds and heavy rain or snow and are one of the frequent causes of flooding.

Severe flooding in Worcester County generally occurs as a result of hurricanes or melting snows and spring rains, with more localized flooding caused by summer thunderstorms. Heavy thunderstorms can result in rapid runoff and flooding in the downstream portions of the small streams. Flood elevations in this region can also be raised by ice jams or by the accumulation of uprooted trees and other debris at bridges. Some of the most severe flooding occurred during the hurricane of August 1955.

The flood problems for the communities within Worcester County participating in this partial FIS have been compiled and are described below:

In the Towns of Boylston, Charlton, Dudley, Leicester, Oxford, Southbridge, Sturbridge and Webster major storms have occurred in nearly every month of the year. Northeasters are one of the most serious types of storms, generating very strong winds and heavy rain or snow. In winter, northeasters produce the heaviest snowfalls, and are one of the most frequent causes of flooding during the fall and spring.

Some of the most severe floods have been those associated with hurricanes or tropical storms, which usually occur in late summer and early fall. The most significant floods in this century were caused by the hurricanes of September 1938, August 1955, and September 1960, and the storms of November 1927, March 1936, November 1953, March 1963, and March 1968 (References 4, 5 and 6).

In the Town of Auburn, the flooding sources studied by detailed methods have caused severe flooding problems in the past, even though their watersheds are small. Filling has contributed to these problems in some areas.

During the August 1955 flood, the flood of record was measured at USGS Survey Station No. 01109500, on Kettle Brook (East) in the City of Worcester. This flood had an approximately 1-percent-annual-chance of recurrence. Severe effects from this flood were felt in many areas in the community, especially in Drury Square, at the confluence of Dark Brook # 1 and Stone Brook in the Town of Auburn.

In the Town of Berlin, investigations have revealed numerous instances of major flooding during the storms of August 1955 and March 1968. The most serious flooding occurred during the August 1955 hurricane in which a total of 18 inches of rain fell in a four-day period. Flooded areas included the lower side of Carter Street, State Route 62, and several other roadways in Berlin. The 1955 flood caused considerable damage to town roads and to the Berlin Memorial School. Numerous personal losses included fields and crops. Both North Brook and the Assabet River were reported to have overrun their banks. The 1968 flood was less severe but still resulted in some basement flooding and lowland inundation. Jones Road was closed due to flooding.

Based on the USGS gaging station record on the Assabet River in the Town of Maynard, No. 01097000, the 1955 storm was approximately a 1-percent-annual-chance storm. The 1968 flood was close to a 1.33-percent chance storm (References 7 and 8). Floods such as the 1955 flood would be expected to recur in the late summer hurricane season. The March 1968 storm was a "northeaster" aggravated by snowmelt.

In the Town of Blackstone, during large flooding events, the Blackstone River flood stages are increased by backwater caused by bridge crossings and by two dams, the Saranac Dam, located near Canal Street, and the Tupperware Mill Dam, commonly called Rolling Dam. Tributary flood flows within the study area are short-lived and flow in narrow channels.

Large magnitude floods have occurred on the Blackstone River during the past 50 years, causing extensive destruction to buildings and to transportation lines in the Town of Blackstone. These floods occurred in 1927, 1936, 1938, 1955, and 1968. Reliable records of flood stages have been kept at the U.S. Geological Survey, gaging station No. 0111250, at Woonsocket since 1929. During the flood of August 1955, the Blackstone River attained a discharge of approximately 29,500 cfs, which was the greatest ever observed. This flood had an estimated 1-percent-annual-chance of recurrence.

The Mill River watershed has experienced large magnitude floods also, particularly the record flood of August 1955. The flood was responsible for several dam failures along the watercourse, including the breaching of Harris Pond Dam in the Town of Woonsocket, Rhode Island.

The Town of Bolton experienced minor instances of flooding during the floods of August 1955 and March 1968. These storms produced cellar flooding and field inundation. On the Nashua River, the flood of record occurred in March 1936, a storm aggravated by a rare occurrence of quick thaw, snowmelt, ice jams, and two heavy rainstorms. The area around the East Bolton Dam, a flood storage pool, is also subject to inundation.

In the Town of Charlton, more than 20 inches of rain fell from August 11 to August 15, 1955, over the headwaters of Cady Brook. Heavy damage to residential and commercial property occurred along the entire length of the stream. The failure of Glen Echo Dam produced a tremendous surge along Cady Brook that destroyed several other smaller dams in Charlton and continued unabated to the Quinebaug River (Reference 9).

The Board of Selectmen reported that, "During the fall of 1954, the Town of Charlton was struck by two hurricanes that the Weather Bureau had named Carol and Edna. At the time, the damage created by those two hurricanes seemed quite large in that it cost the town several thousand dollars to repair damage wrought by these two storms" (Reference 10).

In the Town of Clinton, during the March 1936 record flood, the USGS reported a peak flow of 4,680 cubic feet per second (cfs) at Wachusett Dam, located at the headwaters of the Nashua River in Clinton. On Counterpane Brook, the two most significant floods occurred on March 26, 1876, and March 18, 1968. On Coachlace Pond the water level reached an elevation of 331.98 feet during the 1876 flood.

Repeated damage to structures in the floodplains in the Town of Douglas has occurred in 1936, 1938, 1955, 1968 and 1979. The flood of 1955 is the flood of record for the Mumford River (Reference 11).

In the Town of Dudley, the maximum recorded discharge on the French and Quinebaug Rivers near Dudley occurred on August 19, 1955 when a flow of 14,400 cfs produced a flood elevation of 432.09 feet on the French River and a flow of 49,300 cfs produced a flood elevation of 359.78 feet on the Quinebaug River. The maximum recorded discharge on the French River since the operation of two USACE dams occurred on April 2, 1960 when a flow of 1,020 cfs produced a flood elevation of 413.60 feet (Reference 12).

Repeated damage to structures in the floodplains in the Town of Grafton has occurred in 1936, 1938, 1955, 1968 and 1979. The 1955 flood is the largest on record for the Blackstone and Quinsigamond Rivers, which was slightly less than 1-percent-annual-chance storm (Reference 11).

Town of Grafton community officials noted that more frequent damage (mostly scouring action around bridge abutments) has occurred along the Blackstone River in recent years. Observations by community officials indicate that increased runoff may be occurring due to upstream development in the Blackstone River Basin. There was no indication from community officials that the March/April 1987 rainfall event, which caused severe flooding along certain watercourses in Massachusetts, caused any major damage along streams in Grafton (Reference 13). No data was obtained for the precountywide revised FIS for Grafton concerning peak flows in either the Blackstone River or the Quinsigamond River.

Low-lying areas of the Towns of Harvard and Lancaster are subject to periodic flooding caused by the overflow of the Nashua River. Also in Lancaster, the North Nashua River causes periodic flooding. While in Harvard, overflows also occur along Spring Brook, Bowers Brook, Elizabeth Brook, and Bennetts Brook. The most severe flooding in recent years, especially on the Nashua River, occurred in March 1936. Above average snowfall with accompanying cold weather and frozen ground, followed by mild temperatures and repeated rainfall in the early spring, saturated the ground and caused intensive runoff and massive flooding. Roads were awash, bridges collapsed, and factories and homes were inundated.

In the Town of Harvard, the peak flow during the March 1936 flood as recorded by the USGS East Pepperell gaging station on the Nashua River was 20,900 cubic feet per second. Damage also occurred to structures in the Nashua River floodplain as a result of the floods of May 1850, December 1878, July 1897, February 1900, March 1900, March 1936, and March 1968.

In the Town of Lancaster, the peak flow during the March 1936 flood, as recorded by the USGS Leominster gaging station on the North Nashua River, was 16,300 cfs. During that same flood, Metropolitan District Commission records indicate a flow of 4,070 cfs from the Wachusett Reservoir to the Nashua River. Repeated structure damage has occurred in the Nashua River floodplain as a result of the floods of May 1850, December 1878, July 1879, February 1900, March 1900, March 1936, and March 1968.

Damage to structures in the floodplains of the Town of Hopedale occurred in 1936, 1938, 1955, 1968, and 1979. The 1955 flood was slightly less than a 1-percent-annual-chance storm, the largest on record for the Charles River (Reference 14). In the 1955 storm, major flooding occurred at the Draper factory building on the Mill River near the outlet of Hopedale Pond. Flooding in this area was especially severe due to the pond level being held high for water storage and wood, logs and other debris blocking the opening under Freedom Street.

In the past, major floods occurred in the Towns of Mendon and Milford. Damage to structures in the floodplains occurred in 1936, 1938, 1955, 1968, and 1979. In Mendon, in 1936, 1954, and in the spring of 1979, flooding occurred at the Bellingham Road Bridge over the Mill River. In Milford, major flooding in the Louisa Lake area necessitated the construction of flood control structures.

During large flooding events on Ramshorn and Singletary Brooks and the Unnamed Tributary to Singletary Brook, flood stages are increased due to the backwater caused by inadequate culverts and several small dams.

Large magnitude floods have occurred on the Blackstone River during the past 50 years, causing damage to buildings and transportation lines in the Town of Millbury. These floods occurred in March 1936, August 1955, and March 1968. Reliable records of flood stages have been kept at the USGS Gaging Station No. 01110500 at Northbridge (drainage area 139 square miles), Massachusetts since 1936. During the flood of August 1955, the flood of record, the Blackstone River attained the greatest discharge ever observed, which had an estimated frequency of a 1-percent-annual-chance flood event.

During large flooding events, the Blackstone River flood stages in the Town of Millbury are increased by backwater caused by bridge crossings and one dam, the New England Power Dam. Tributary flood flows to the Blackstone River are ephemeral and flow in narrow channels.

Ramshorn and Singletary Brooks and the Unnamed Tributary to Mayo Pond have also experienced large-magnitude floods, particularly the flood of August 1955, which was caused by Hurricane Diane.

In the Town of Millville, damage to structures in the floodplains occurred in 1936, 1938, 1955, 1968, and 1979. The August 1955 flood was the largest on record for the Blackstone River. Peak discharges recorded at USGS gaging stations at Woonsocket, Rhode Island, and Northbridge, Massachusetts, (Nos. 0111250 and 0111050, drainage areas of 416 square miles and 139 square miles) for the August 1955 flood were 32,900 cfs and 16,900 cfs, respectively (Reference 15). The Blackstone River has a drainage area of approximately 260 square miles at Millville.

Investigations into instances of flooding in the Town of Northborough revealed that the town has been subject to serious flooding. During the storm of August 1955, the Assabet River rose over its banks, causing an estimated $120,000 worth of damage to roadways and properties. Damaged areas included the Machinery Electrification Factory, Gothic Craft Factory, and Jersey Mills. Hudson Street, Woodside Mills, School Street, Church Street, and West Street were all closed to traffic due to flooding from the Assabet River.

The 1955 flood was the flood of record on the Assabet River. At the time of occurrence, this flood was approximately a 2-percent-annual-chance flood. However, the installment of 10 flood control dams on the Assabet River (Upper Reach) Watershed has modified the frequency curve at the Maynard gaging station such that a recurrence of the 1955 flood discharge would constitute a 0.5-percent-annual-chance flood.

Numerous incidents of cellar inundation resulting from flooding from both the August 1955 and March 1968 storms were reported. Due to flood protection measures taken by the Town of Northborough, the March 1968 storm was considerably less destructive than the August 1955 storm.

Repeated damage to structures in floodplains in the Town of Northbridge has occurred in 1936, 1938, 1955, 1968, and 1979, with the 1955 flood being the largest flood on record for the Mumford and Blackstone Rivers (Reference 11). There is one USGS gaging station located along the Blackstone River within the Town of Northbridge, approximately 800 feet downstream from the Paul Whitin Company Dam.

At the time of the Town of Paxton report, no information was available or verifiable in regard to past significant flood problems on the streams being investigated.

Investigations into instances of flooding in the Town of Shrewsbury have revealed that major flooding occurred during the August 1955 flood. During this storm, eight streets were closed completely, the Boston Turnpike (State Highway 9) was closed from State Highway 20 to Framingham, and washout closed other principal streets, creating a state of emergency. There were numerous reports of cellar flooding and damage to private and commercial properties. Damage was estimated at $100,000. The 1955 flood, the maximum flood of record, was a 1-percent-annual-chance flood. During the March 1968 storm, a flash thaw, combining with 4.4 inches of rain, resulted in only minor flooding. This was due to improvements in structures as a result of the 1955 flood.

Low-lying areas of the Town of Southborough are subject to periodic flooding caused by the overflow of the Sudbury River and the Sudbury Reservoir. The most severe flooding in recent years, especially on the Sudbury River, took place in August 1955. The flooding resulted from Hurricane Diane deluging the area with 12 inches of rain during a 37-hour period extending over three days. Roads were overtopped and industrial and commercial businesses, as well as private residences, were flooded. Deerfoot Road and Middle Road were flooded along with Willow Street and Pine Hill Road near Framingham; Central Street, Parkerville Road, Northborough Road, and Brook Lane in the Fayville section; and Woodbury Street in the Cordaville section.

Damage to industries and residences has occurred within the Sudbury River floodplain as a result of the floods of November 1927, March 1936, July and September 1938, August 1955 and March 1968 (References 16 , 17, 18, 19, and 20).

In the Town of Southbridge, the flood of September 1938 resulted from three days of heavy rains preceding a disastrous hurricane which dumped a total of 13.5 inches of rainfall on the community. New England was experiencing heavy rainfall on September 18, 19, and 20, and streams were running full when the rain associated with the hurricane brought the total rainfall during a 4-day period to about 17 inches in certain limited areas and to 10 to 14 inches in the Quinebaug River basin.

Damage was particularly severe in the Town of Southbridge where the Ames Worsted Company Dam and five small dams on tributary streams failed. The large plant of the American Optical Company had six to seven feet of water over its main working floors. About five other industries also sustained large losses. Over 300 dwellings had flooded basements from overflow of brooks and backwater of the Quinebaug River. Losses sustained were close to $950,000 (Reference 9).

Between August 11 and 15, 1955, Hurricane Connie brought substantial amounts of rainfall to southwestern New England, but very little runoff occurred as a result of dry antecedent moisture conditions. Approximately five inches of rain fell in Southbridge during this period. Between August 18 and 20, Hurricane Diane dropped approximately 12 inches of rain on the Southbridge area. In the neighboring Town of Charlton, more than 20 inches of rain fell between August 11 and 19 over the headwaters of Cady Brook (Reference 9).

Flooding on the Quinebaug River and Cady Brook in the Town of Southbridge caused nearly 30 percent of the total damage in the Thames River basin. Southbridge industries were particularly hard hit, with their losses accounting for over 70 percent of the town total. The flooding along Cady Brook caused heavy residential and commercial damage along its entire length (Reference 9).

The failure of Glen Echo Dam in the Town of Charlton produced a tremendous surge of water that destroyed several other smaller dams in Charlton and continued unabated down Cady Brook to the Quinebaug River. Where the drainage area of Cady Brook is 12 square miles, the peak discharge of this surge was approximately 26,300 cfs. Based on the data available, the peak discharge on the Quinebaug River below Cady Brook was estimated to have been between 35,000 cfs and 40,000 cfs.

The Town of Southbridge experienced losses of over $18,000,000, with 350 dwellings flooded and 70 commercial establishments damaged, ranging from flooded and silted basements to the complete loss of stock, equipment, and buildings. Eight highway bridges in the town were destroyed and sections of several roads were undercut and washed out.

Losses sustained by Southbridge industries amounted to over $13,000,000. The American Optical Company, located below the confluence of Cady Brook and the Quinebaug River, was particularly hard hit when the flood overtopped and breached dikes constructed by the company following the September 1938 flood.

In the past, the most serious flooding in the Town of Spencer has resulted from rainfall over a period of several days that produced large volumes of runoff and exceeded the natural storage of the watershed. An example of this was hurricane Diane, which in August 1955 deposited 15 inches of rainfall over a two-day period.

Also in the Town of Spencer, the possibility for shallow flooding exists on Muzzy Pond, since the Muzzy Pond Dam was nearly breached and the roadway above the dam, Maple Street, was overtopped in 1955. Again in 1979, the flow from Muzzy Pond overtopped the dam and nearly overtopped Maple Street. The culvert system downstream of Muzzy Pond is a large factor in the recurrent flood problems in the area. Many of the culverts have collapsed causing restrictions in flow and thus severe backwater conditions which promote shallow flood problems. Hydraulic computations are hindered by the fact that the exact sizes of several underground culverts are not known.

In September 1959, the study contractor, under contract to the Massachusetts Department of Public Works, submitted a report on the recurrent flooding of Muzzy Pond and Muzzy Meadow Brook (Reference 21). The report recommended that a correction of the dam outlet and culvert system be initiated as soon as possible through review, acceptance and construction of the 1959 report-recommended facilities or initiation of an updated study.

In the Town of Sturbridge, the major flooding on the Quinebaug River occurs in the spring and can be the result of spring rains combined with snowmelt. However, records show that the two most severe floods were the result of tropical storms. The greatest floods known to have occurred on the Quinebaug River occurred in August 1955 when tropical storm Diane deposited record amounts of rain on ground that was previously saturated by tropical storm Connie.

Damage to structures in the floodplains in the Towns of Sutton, Upton and Uxbridge has occurred in 1936, 1938, 1955, 1968 and 1979. The flood of 1955 was the flood of record for the Blackstone, Mill and Mumford Rivers (Reference 11). Flood frequencies and peak discharges were not recorded for these streams in Upton.

In the Town of Uxbridge, the flood of record for the Blackstone River at Woonsocket, Rhode Island (Gage No. 0111250; drainage area of 416 square miles) and Northbridge, Massachusetts (Gage No. 0111050; drainage area of 139 square miles) occurred in 1955. For the August 1955 flood, the discharges at these two gaging stations were 32,900 cfs and 16,900 cfs, respectively (Reference 15).

In the Town of Webster, the following tabulation shows the highest water levels recorded on Lake Webster since the town began keeping records in 1953 (References 22 and 23). The levels are referenced to a benchmark elevation of 478.90 feet North American Vertical Datum (NAVD).

Date	Height Above Benchmark (Inches)	Elevation (feet NAVD)
March 22, 1968	7	479.48
January 29, 1979	15	480.15
April 6, 1987	6	479.40

Investigation into instances of flooding in the Town of Westborough revealed that major damage to roadways, and municipal and private properties occurred. During the hurricane of August 1955, more than 16 inches of rain fell, resulting in damage well over $100,000 to municipal properties alone. Floodwaters washed out Adams Street, Ruggles Street, Bowman Street, Upton Road, and Hopkinton Road. Many other roadways were impassable due to the floodwaters. Numerous incidents of private and commercial basement flooding were reported. The extent of damage to private dwellings, automobiles, and businesses was estimated in the hundreds of thousands of dollars. The Westborough Reservoir was weakened nearly to the point of collapse due to erosion by the floodwater (Reference 24).

In March 1968, a flash thaw, combined with 4.98 inches of rainfall, resulted in numerous cases of cellar flooding and road closings. Damage was, however, nowhere near as severe as that caused by the 1955 flood (References 25 and 26).

Detailed study areas in the City of Worcester, though representing small watersheds, have in the past caused severe flooding problems. Much of the floodplain in Worcester is extensively urbanized, which has contributed to the flooding problems.

Hurricane Diane, and the accompanying flood of August 19 and 20, 1955, was the most severe flood in the history of the City of Worcester. In Webster Square, near the confluence of Beaver and Kettle Brooks, flooding was approximately 12 feet deep. Flooding would have been more severe in the Square had the two Holden Reservoirs not been approximately 3 feet below their normal water surface elevations. The additional 3 feet of storage delayed runoff, which may otherwise have reached Webster Square at the peak of the flood. On Middle River, the Freemont Street Bridge was overtopped by 1 foot, and the Southbridge Street Bridge was overtopped by approximately 1 foot (Reference 27).

Also, there was severe flooding associated with the Mill Brook Conduit in the August 1955 flood. Lamartine, Gold, and Washington Streets were under 2 to 3 feet of water, and Brosnihan Square was under 5 feet of water. At the intersection of Madison and Washington streets, there was 3 feet of water, and at the intersection of Madison and Gold Streets there was 4 feet. The Shrewsbury Street Brook Conduit, which is a large lateral storm drain connected to the Mill Brook Conduit, surcharged and flooded Shrewsbury Street to a depth of approximately 2 feet. Between Washington Square and Lincoln Square on Central Street, the surcharged Mill Brook Conduit flooded Central Street to a depth of approximately 3 feet (Reference 28).

2.4 Flood Protection Measures

Flood protection measures for the communities included in this partial countywide FIS have been compiled and are summarized below:

Several communities have adopted community zoning, conservation or other non-structural measures of flood protection to aid in the prevention of future flood damage. The communities of Auburn, Berlin, Bolton, Harvard, Lancaster, Northborough, Shrewsbury, Southborough and Westborough have adopted floodplain zoning ordinances and by-laws that restrict building in wetlands and other flood-prone areas.

Additional restrictions include: The Town of Auburn has placed restrictions on construction in wetlands by using Chapter 131, Section 40 of the General Laws of the Commonwealth of Massachusetts. This law is commonly referred to as the Wetlands Protection Act and is administered by the Massachusetts Department of Environmental Quality Engineering (DEQE). The result is that development in the floodplain has been limited. The Town of Berlin has both the Assabet River and the North Brook floodplain zoned. The Town of Bolton has areas designated as water resources protection districts along major streams and bodies of water. Lastly, the Town of Southborough, through a 1975 amendment to its zoning by-laws, has adopted measures to protect its floodplains and wetlands from use as residential or other purpose where the public's welfare could be endangered, to protect the water table recharge areas, and to maintain existing waterways and flood storage areas.

Other non-structural measures of flood protection are being utilized to prevent future flood damage in several towns. The Towns of Boylston, Charlton, Dudley, Leicester, Oxford, Webster and West Boylston use the Wetlands Protection Act to manage and aid in flood protection. The Wetlands Protection Act requires a permit to remove, fill, dredge, or alter wetlands and gives the responsibility for issuing these permits to the town conservation commission. A permit is required whenever the town determines that an area "is significant to public or private water supply, to the groundwater supply, to flood control, to storm damage prevention, to prevention of pollution, to protection of land containing shellfish, or to the protection of fisheries" (Reference 29). The town can impose conditions to protect these interests. The commissioner of the DEQE can also impose conditions, and these conditions supersede the town's conditions.

In addition, the Towns of Boylston, Charlton, Leicester, Southbridge, Webster and West Boylston utilize the protections afforded under the Wetlands Protection Act. The language in this act gives the commissioner of the DEQE the authority to protect inland wetlands and floodplains by establishing encroachment lines "for the purpose of preserving and promoting public safety, private property, wildlife, fisheries, water resources, floodplain areas and agriculture" (Reference 29). The commissioner may adopt orders regulating, restricting or prohibiting the altering or polluting of inland wetlands by designating lines with which no obstruction or encroachment would be permitted without prior approval. These restrictions require notifications to each landowner affected, public hearings, and approval by the town.

The civil defense office is responsible for alerting residents of impending disasters and coordinating emergency operations with town and state public service agencies in the Towns of Douglas, Hopedale, Grafton, Milford, Millville, Northbridge, Upton and Uxbridge.

There are no flood protection measures existing or planned in the Towns of Clinton, Douglas, Grafton and Upton; and no formal flood fighting or emergency evacuation plans for the Towns of Douglas, Hopedale, Milford, Millville, Southborough, Sutton and Uxbridge.

The Town of Grafton has adopted into its building codes certain regulations required by FEMA. The building codes specify building permit procedures and flood proofing measures for structures located in flood hazard areas. In addition, restrictions on construction in wetlands imposed by Massachusetts Law (as imposed by the DEQE) have limited floodplain development. The Town of West Boylston has incorporated into its zoning laws a set of floodplain management regulations to help minimize future flood damages and related hazards.

In 1960, the USACE completed the Worcester Diversion Flood Control Project (Reference 30). The primary function of the project is to protect Webster Square in the City of Worcester by diverting flood flows through the Leesville Diversion tunnel on Kettle Brook (East), just upstream of Leesville Pond, in Auburn and into the Blackstone River in Millbury (Reference 30). The Blackstone River was dredged for a distance of approximately 1,000 feet downstream of where the diverted flood flows discharge into the river. As a result, major flood stages have been reduced along Dunn's Brook to the Auburn Pond Dam upstream (Reference 30).

Several dams were constructed to control flooding associated with the Sudbury, Assabet, and Concord Rivers, known as the NRCS SuAsCo Watershed Flood-Control project.

Within the Town of Bolton, the East Bolton Dam, part of the Delaney Dam complex on Elizabeth Brook, was constructed as a flood control measure for the Assabet River on Elizabeth Brook Tributary. When flooding occurs, the dam serves as a floodwater storage pool on Great Brook. There also exists a diversion channel between Harvard and Bolton, which serves as a connector of floodwater storage needed in event of severe flooding within the Delaney complex (Reference 31). Otherwise, no structural measures exist within the Town of Bolton.

In the Town of Shrewsbury, the Rawson Hill Dam, located on Rawson Hill Brook upstream of Prospect Street provided flood control of the Assabet River for the SuAsCo watershed project.

Within the corporate limits of the Town of Westborough, one flood-control structure, the Assabet River Dam (also known as the George H. Nichols Dam) has been built. This flood-storage reservoir, controlling flooding on the Assabet River, is also part of the SuAsCo watershed project (Reference 32).

There are two structures offering flood protection primarily within the French River basin. The Towns of Charlton, Dudley, Oxford and Webster are protected by these structures. These structures also protect other small towns downstream along the French River to Putnam, Connecticut from a repeat of the 1955 flood disaster (Reference 33). Optimum flood control protection is realized by close coordination of flood control between the Hodges Village and Buffumville Dams. The Hodges Village Dam and the Buffumville Dam were constructed by the USACE in October 1959 and April 1958, respectively. Both are upstream of the Town of Dudley.

The Hodges Village Dam is located on the French River at Hodges Village in the Town of Oxford and is an earth-fill core dam with rip-rap on both faces. The structure is 2,140 feet long and has a reservoir surface area of 740 acres when filled to the spillway crest. The drainage area upstream of the dam is 19,904 acres. Regulation is accomplished by two 5 feet by 6 feet electrically-operated metal slide gates and a 125-foot long concrete ogee spillway. The Buffumville Dam is located on the Little River in Charlton 100 feet upstream from Old Webster Road in Oxford and is a rolled earth-fill embankment. The structure is 3,255 feet long and 66 feet high, has a spillway crest elevation of 523.3 feet, and has a reservoir surface area of 530 acres when filled to the spillway crest. The drainage area upstream of the dam is 16,960 acres. Regulation is accomplished by three 3feet by 4.5 feet electrically-controlled metal slide gates and a 220-foot long concrete ogee spillway. Pierpoint Meadow Pond, located in the north portion of Dudley, forms the south portion of the Buffumville Reservoir system. A rolled fill dike exists that is 610 feet long topped by 16 feet of pavement with 4-foot wide shoulders, and has an elevation of 533.3 feet. A flowage easement at 523.3 feet, identical to that of Buffumville Reservoir, is carried around the pond. Hayden Pond Road connects Pierpoint Road with the Dudley-Oxford Road and provides access to the land leased by Dudley from the USACE for recreational purposes.

For the Town of Webster, a third structure, the Lake Webster outlet system consisting of two gated 6.08 feet by 4.58 feet pipe arches, acts as a flood retarding unit at times. Care must be exercised by the Cranston Print Works to control the water surface elevation.

In 1982, the DEQE conducted an engineering feasibility study to identify recommendations on the establishment of optimal water surface elevations for Lake Webster (Reference 34). As a means of providing a measure of flood protection, DEQE recommended a two-level program for regulating water surface elevations. This program called for keeping the lake's water surface elevation at one foot below the benchmark level of 478.90 feet NAVD during the spring, summer and early fall, and at 1.5 feet below the benchmark level during the late fall and early winter.

In the Town of Charlton, there are no other structures above the downstream limits of the streams studied in detail which were designed specifically for flood protection. The NRCS has identified 15 locations above the downstream limits of the streams studied in detail as potential reservoir sites (Reference 35).

In the Town of Dudley, the Boise-Cascade Company dam, upstream of Dudley Road, is not specifically designed for flood control. The dam is used for power generation by the paper mill.

In the Town of Oxford, other non-structural measures of flood control are being utilized to aid in the prevention of future flood damage. In addition, a study by the NRCS has identified several existing and potential reservoir sites within the Town of Oxford (Reference 35).

The East Brimfield Dam, located in the Town of Sturbridge approximately one (1) mile southwest of the Village of Fiskdale, and the Westville Dam, located at the Southbridge-Sturbridge corporate limits, both located upstream of the Town of Dudley, provide flood protection on the Quinebaug River. Together, the dams control 80 percent of the drainage area for the Quinebaug River and were designed to prevent serious flooding in Southbridge. The construction of the East Brimfield Dam was initiated in 1958 and was completed in June 1960 at a cost of $7,020,000. The reservoir can store 30,000 acre-feet, which is equivalent to 8.3 inches of runoff from the drainage area of 67.5 square miles. Construction of the Westville Dam started in 1960 and was completed in 1962 at a cost of $5,590,000. The reservoir is capable of storing 11,100 acre-feet which is the equivalent to 6.5 inches of runoff from the net drainage area of 32 square miles below the East Brimfield Dam (Reference 9).

There are no other structures designed specifically for flood protection in the Town of Sturbridge above the downstream limits on the streams studied by detailed methods. Elevation 571 feet is the limit of the flowage easement as established by the USACE for the Westville Reservoir. No residential of commercial development is permitted below this elevation.

For the Town of Auburn, several dams are located along the streams studied by detailed methods, and have been determined to be in poor condition under the dam inspection program administered by the Department of Environmental Management (DEM) (Reference 36). Because of their inadequate conditions, these dams pose hazards to downstream areas.

Within the Town of Berlin there are two flood control structures: the Ross Dam on North Brook, and the Brewer Brook Dam on Brewer Brook. Although these two structures were constructed by the NRCS primarily for flood control on the Assabet River, flood control is also afforded on each stream below the dams due to the impoundment effect of the dams.

In 1959, as a result of the 1955 flood, the USACE constructed two local protection projects, benefiting the Town of Blackstone, involving channel improvements and the construction of dikes in Woonsocket, Rhode Island. Again, after the 1968 flood and under Public Law 99, a protection project, which included an earth dike and channel improvements, was constructed by the USACE in the Town of Blackstone downstream of the St. Paul Street Bridge. According to a C.E. Maguire, Inc. report (Reference 37), the recurring 1955 flood stage has been lowered by 1 foot upstream of the Tupperware Mill Dam and by approximately 10 feet downstream of the dam within the Town of Blackstone due to these improvements. In 1968, the Harris Pond Dam was reconstructed with a new crest at 166.80 feet NAVD, 1.5 feet lower than the old breached dam crest.

In 1970, the USACE completed the Blackstone River Local Protection Project in the Town of Blackstone. This project provides flood protection along the right bank of the Blackstone River in Blackstone, Massachusetts, and consists of:

- An earthfill dike with stone slope protection that ties into an existing floodwall.

- Two concrete culverts that extend through the dike.

(Reference 38)

There are no flood protection structures in the Town of Boylston. However, there are three existing reservoirs on Cold Harbor Brook (Town of Boylston) whose dams retard same flow. These reservoirs have been identified by the NRCS (References 39 and 40).

For the Town of Clinton, the three dams that currently exist within the community were found to have no effect on flood control.

For the Town of Harvard, the Delaney Dam, an NRCS flood control project located on Elizabeth Brook in Stow, provides flood protection to the communities downstream of that project. The flood pool of the Delaney project extends into the southeastern corner of Harvard. There are no significant man-made flood protection works on the waterways in Harvard. A short dike was constructed to protect one home from the flood pool of the Delaney project. The natural storage available in swamps and lakes, including Bare Hill Pond, provides some reduction in peak flood flows and serve as a form of natural flood protection.

Since 1955 in the Town of Hopedale, floodwater storage has been increased along the Mill River. Various improvements were made to the dams at North Pond, Fiske Mill Pond and another unnamed pond upstream of Hopedale Pond. There are no flood protection measures planned for the near future in Hopedale.

There are no flood protection works on the rivers and streams in the Towns of Lancaster and Mendon.

For the Town of Milford, the Louisa Lake Flood Control project was constructed to help alleviate past flooding problems in the Louisa Lake area on Huckleberry Brook. The project consisted of the construction of two dams and diversion structures at the upstream and downstream ends of the lake, and channelization and culvert improvements downstream of the lake at Dilla Street.

In the Town of Millbury, the Dolan Road Roadway Reconstruction Project included the repair and reconstruction of the Ramshorn Pond Dam and Spillway in 1985. The new outlet subsequently lowered the elevation of the pond approximately three feet. The January 2000 FIS revision showed that during the 1-percent-annual-chance flood, the base flood elevation should not exceed the water surface elevation of the pond prior to 1985.

Flooding in the Towns of Millville and Uxbridge are controlled by the West Hill Dam and Reservoir. Completed in 1960, the West Hill Dam and Reservoir is located on the West River (Town of Uxbridge) approximately 3.5 miles upstream of its junction with the Blackstone River and approximately 5.8 miles upstream of the Millville-Uxbridge corporate limits. Constructed and operated by the USACE, its primary purpose is flood control. West Hill Dam modifies flood discharges on the West River (Town of Uxbridge) and the Blackstone River, thereby greatly reducing the downstream flooding in Millville.

Within the Town of Northborough, there are three flood control structures: Cold Harbor Brook Dam, Hop Brook Dam, and Barefoot Dam. These structures were constructed under supervision of the NRCS to control floodwater on the Assabet River. The dams also control flooding on the three streams below the dam outlets. Stirrup Brook, while having no actual control structures along its course, has three large water bodies which provide large amounts of natural flood storage. The large swamp areas along reaches between the ponds also add to the large amounts of natural flood storage within the Assabet River basin. Howard Brook remains uncontrolled.

The Riverdale Mills Corporation owns and operates the Riverdale Street Dam. The company has developed an Emergency Action Plan for the operation of the dam during a flood event. The Emergency Action Plan has been submitted to the Town of Northbridge and FEMA and was incorporated into the hydraulic analysis for the February 2, 2002 revised study. Under the Emergency Action Plan, Riverdale Mills Corporation is responsible for opening a flood modulator gate and removing the stoplogs at the Riverdale Street Dam during a major flood event. In addition, the sluice gates in the two westerly gate structures of the dam must be fully opened, allowing flow to pass beneath the mill through a sluiceway to a tail race on the south side of the building. "Opening" the dam as outlined in the Emergency Action Plan will prevent a flood with a magnitude of 9,700 cfs (i.e., the 1-percent-annual-chance flood) from overtopping Riverdale Street and causing damage to the Riverdale Mills Complex and will also help reduce flood damage upstream of the dam.

Aside from the Riverdale Mills Corporation's Emergency Action Plan, there are no other flood protection measures in the Town of Northbridge.

There are several reservoirs and dams located within the Town of Paxton. The dam at Kettle Brook Reservoir No. 4 on Kettle Brook controls 2.0 square miles of the total 13.2-square mile drainage basin of Kettle Brook at Leesville Pond in Leicester, Massachusetts. Downstream of the Paxton corporate limits on Kettle Brook there are three additional reservoirs in the Town of Leicester. Kettle Brook Reservoir Nos. 1, 2, and 3 have a combined capacity of controlling 10.9 square miles or 82 percent of the brook's drainage basin. On Turkey Hill Brook, Thompson Pond and Turkey Hill Pond reduce flooding along the brook by acting as temporary storage areas in the event of a significant flood. A dam located in the Town of Holden controls Pine Hill Reservoir in Paxton and Holden and has a drainage area of nearly 7 square miles, but does not reduce flooding for the Town of Paxton. It does, however, reduce flooding downstream in Holden.

In the Town of Shrewsbury, the reach of West Brook downstream of Mill Pond to the culvert entrance, as well as the conduit running into Lake Quinsigamond, was subjected to modification after the 1955 flood. The channel and culvert were modified to carry a design flow equal to or slightly greater than the calculated 1-percent-annual-chance discharge of 400 cfs. For this reason, the area downstream of the culvert entrance is not a flood hazard area as the 1-percent-annual-chance flow is carried within the modified channel banks and culvert. Many of the culverts throughout Shrewsbury have been replaced and enlarged after the 1955 flood, greatly reducing the flood hazard during the 1968 storm.

In the Town of Southborough, the natural upstream storage area available in Cedar Swamp in the Towns of Westborough and Hopkinton substantially reduces peak flows and, hence, the extent of flooding along the Sudbury River through Southborough. The Sudbury Reservoir, although a water-supply reservoir, provides a significant retention area which reduces peak flood flows in the Sudbury River as it flows through the communities downstream of Southborough. Modifications to the outlet works of Crystal Pond and the construction of a flood retention pond have provided some degree of flood protection to industrial development along a portion of State Route 9. These man-made improvements also reduce peak flows for Tributary to Sudbury Reservoir.

In the Town of Southbridge, in order to improve the hydraulics of Cady Brook, the Commonwealth of Massachusetts widened and deepened the channel and constructed 1,100 feet of concrete retaining walls in the vicinity of Charlton Street. However, portions of Cady Brook still remain susceptible to flooding. The NRCS has identified five locations above the downstream study limits of the streams studied in detail as potential or existing reservoirs sites (Reference 35).

In the Town of Spencer, there are no flood control structures on the Sevenmile River within the Town of Spencer. However, the Moose Hill Dam and Reservoir, located on Turkey Hill Creek in the Town of Leicester is used for flood control of the Sevenmile River. The release facilities for this purpose are uncontrolled. When a 1-percent-annual-chance storm is routed starting from the permanent pool, the maximum water level stays well below the emergency spillway crest. The 24-hour rainfall for the 1-percent-annual-chance storm is 6.5 inches. The project design storm for flow through the emergency spillway is based on a 12.9-inch rainfall with a duration of six hours and adjusted for the longer time of concentration.

There are a number of dams within the towns of Sutton and Upton, none of which provide substantial flood protection to either town.

In the City of Worcester, after the 1955 flood, several projects were undertaken by the Massachusetts Department of Public Works, Diversion of Waterways. Beaver Brook was placed in the rectangular concrete channel in the area of Webster Square. West Tatnuck Brook was placed in a conduit from its outfall downstream of Pleasant Street to Joppa Road. The old Shrewsbury Street conduit was enlarged to a 96-inch diameter at its lower end and an 84-inch diameter east of Fantasia Drive. To provide better access, a boat passageway was built between Lake Quinsigamond and Flint Pond in Shrewsbury. In addition, levees were constructed on Leesville Pond and along Blackstone River in Worcester.

As of April 1977, the City of Worcester has had the right to deny a permit to build any structure near a water body or watercourse until it is satisfied that the sill height of the proposed structure is above expected flood heights (Reference 41).

3.0 ENGINEERING METHODS

For the flooding sources studied by detailed methods in the community, standard hydrologic and hydraulic study methods were used to determine the flood-hazard data required for this study. Flood events of a magnitude that is expected to be equaled or exceeded once on the average during any 10-, 25-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 25-, 50-, 100-, and 500-year floods, have a 10-, 4-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term, average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood that equals or exceeds the 1-percent-annual-chance flood in any 50-year period is approximately 40 percent (4 in 10); for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish peak discharge-frequency relationships for each flooding source studied by detailed methods affecting the community.

For each community within Worcester County that has a previously printed FIS report and is participating in this partial FIS report, the hydrologic analyses described in those reports have been compiled and are summarized below.

Precountywide Analyses

In the Town of Paxton, there were no detailed studies and no hydrologic analyses performed in the original FIS.

Discharges for areas of approximate study were determined in the Towns of Lancaster, Southborough and Spencer. In Lancaster and Southborough, 1-percent-annual-chance discharges for streams studied by approximate methods were calculated using regional discharge-frequency equations (Reference 42). These areas included Wekepeke Brook, McGovern Brook, several brooks in undeveloped parts of the town, and a portion of Goodridge Brook in Lancaster and portions of the Wachusett Aqueduct, Angelica Brook, and numerous unnamed tributaries in Southborough. In Spencer, in the original study, flood discharges for the areas of approximate study were derived from a regional methods based on regression analysis. This method relates drainage area, channel slope, percent area of storage, and an index of average annual excess precipitation to the peak discharge by empirical equations (Reference 43). These areas included the remainder of the Sevenmile River not studied in detail within the corporate limits, the Cranberry River and Turkey Hill Brook (tributaries to the Sevenmile River), tributaries to the Sevenmile River from Brooks Pond, the Stiles Reservoir (through Alder Pond), Burncoat Pond and areas of shallow ponding located in the central portion of the Town of Spencer. These areas included Muzzy Pond, Cider Mill Pond, the streams flowing from Muzzy Pond and from Lake Whittemore, and the area from the confluence of these two streams to the culvert below Water Street.

Discharge-frequency relationships for the smaller drainage basins in the Towns of Auburn and Millbury, including, Dunn's Brook (Kettle Brook to Auburn Pond), Dark Brook #2, Ramshorn Brook, Unnamed Tributary, Stone Brook, Dorothy Brook, Ramshorn Brook, Singletary Brook, Unnamed Tributary to Mayo Pond, Brierly Pond, Pondville Pond, and Singletary Pond were determined using the U.S. Department of Agriculture National Resource Conservation Service (NRCS), formerly Soil Conservation Service or (SCS) runoff curve number. In Auburn, it was determined that this would be the most accurate technique when applied to the Kettle Brook (Town of Auburn) drainage basin (Reference 44). The exception to this was the portion of Kettle Brook (Town of Auburn) upstream of Interstate Route 290. In order to determine peak discharge-frequency relationships for this portion of the stream, the NRCS "discharge versus drainage area" method was used to calculate natural flows at the gage downstream of Interstate Route 290; these flows were then adjusted to represent a reduced drainage area (Reference 45). In Millbury, runoff curve numbers for Ramshorn Brook, Dorothy Brook, Dorothy Pond, Singletary Brook and Unnamed Tributary to Mayo Pond were developed from area soils mapping (Reference 45).

For the French River in the Towns of Dudley, Leicester, Oxford, and Webster, regional discharge-frequency equations for ungaged streams were used to determine peak discharges. Flows were transposed using the following formula:

$$Q_1 = Q_2 (A_1/A_2)^n$$

where Q_1 and Q_2 are the flows at the site and gage, respectively, A_1 and A_2 are the drainage areas at the site and gage, respectively, and n is the regional drainage area ratio exponent.

Discharges for the French River in the Town of Leicester were determined using peak flows from the Webster gage, No. 01125000, having a discharge of 25 years of record, and transposing these flows to points just above the Oxford-Leicester corporate limits and just above Pleasant Street using the formula above with an n value of 0.75.

Discharges for the French River below the Hodges Village Dam were obtained using both actual and statistical data in Oxford and Webster. For the Towns of Dudley, Oxford and Webster, outflows from the Hodges Village Dam in Oxford and the Buffumville Dam in Charlton were obtained by utilizing the discharge records presented in the annual reports of the USACE Reservoir Control Center, the operating procedures outlined in Thames River Basin, Massachusetts, Connecticut and Rhode Island, Master Manual of Reservoir Regulation, and discussions with representatives of the USACE Reservoir Control Center (References 46 and 47).

Data used for the French River in the Town of Dudley was a combination of outflow data from the Hodges Village and Buffumville Dams and data from two USGS gaging stations near the Dudley corporate limits. One of these gaging stations (No. 01125000) is on the French River and is located in the Town of Webster near the Pleasant Street bridge (drainage area is 85.3 square miles). The other gaging station (No. 01124000) is on the Quinebaug River and is located in Quinebaug, Connecticut, 0.2 miles south of the state border (drainage area is 156 square miles). Peak discharges on the French River in Dudley were determined using the log-Pearson Type III method of analysis.

Due to the relatively small releases from the Hodges Village and Buffumville Reservoirs for the 10-, 2- and 1-percent-annual-chance floods, the peak discharges downstream of these reservoirs are generally the result of runoff from the uncontrolled drainage area below the reservoirs. Values calculated for peak discharges below the reservoirs are based upon the Webster USGS gaging station (No. 01125000). Between 1950 and 1978, the average discharge was 158 cubic feet per second (cfs). The maximum recorded discharge occurred on August 19, 1955, when a flow of 14,400 cfs produced a flood elevation of 432.09 feet. Since operation of the two USACE dams, the maximum recorded discharge occurred on April 2, 1960, when a flow of 1,020 cfs produced a flood elevation of 413.60 feet (Reference 12). Flow records at the Webster gaging station prior to the completion of Hodges Village and Buffumville Dams are available for 1949-1958 only.

The period of record at the Webster gage was extended by applying the two-station comparison method described in Water Resources Bulletin 17A (Reference 48) and was used to extend the period of record at the Webster gage for the Towns of Dudley, Oxford and Webster. The Webster gage was compared with the USGS gaging station (No. 1124000) on the Quinebaug River in Quinebaug, Connecticut. Flow records for the Quinebaug River prior to the completion of the East Brimfield reservoir are available for the years 1931-1961. The log-Pearson Type III method was applied to the flows to determine peak discharges at the Webster gage. These flows were then transposed to points below the Hodges Village and Buffumville Dams using an n value of 0.75.

The 0.2-percent-annual-chance discharges below Hodges Village Dam were obtained by analyzing the discharges for the 1955 flood and for the Standard Project Flood, as modified by the Hodges Village and Buffumville Dams, which were obtained from the Master Manual of Reservoir Regulation, and from discussions with representatives of the USACE Reservoir Control Center (References 12 and 47).

The 0.2-percent-annual-chance flood will overtop both the Buffumville and the Hodges Village Reservoirs. This will occur long after the flooding to the uncontrolled drainage area below the reservoirs has peaked. Therefore, as the overtopping flood moves downstream there is very little inflow and there is a lot of storage available in the floodplain which will retain some of the flood waters as they move downstream, causing the 0.2-percent-annual-chance flood discharge at the gaging station to be less than that upstream.

The drainage area for Lake Webster was not included in the transposition of the Webster gage data for the peak discharges on the French River, but the outflows from Lake Webster were added to the peak discharges obtained after the transposition.

In the Town of Webster, Lake Webster, which discharges into Mill Brook #1, has a drainage area of about 10.2 square miles. The large surface area of the lake impounds a large amount of runoff and greatly reduces the peak discharges of Mill Brook #1 into the French River. High-water elevations from 1975 to 1979 were 478.6, 478.8, 478.9, 478.8, and 480.1 feet, respectively. Inflow hydrographs into Lake Webster were developed using the method described in the National Engineering Handbook and were routed through the lake using the Modified Puls routing technique (Reference 49). The peak discharges for the Lake Webster outlet to Mill Brook #1 were 116 cfs, 129 cfs, 134 cfs, and 160 cfs, respectively. The peak elevations for the Lake Webster outlet to Mill Brook #1 were 479.8, 480.3, 480.4, and 481.1 feet (NAVD), respectively.

During the 1982 DEQE feasibility study for establishing optimal water surface elevations on Lake Webster, peak inflows were evaluated using the following hydrologic techniques: the Triangular Hydrograph Method, developed by NRCS; the New England Hill and Lowland Method, developed by the U. S. Bureau of Public Roads; the Eastern Massachusetts Equation, developed by the Massachusetts Department of Public Works; and the Rational Method, developed for the U. S. Department of Transportation. The results of the four equations were then evaluated to select the most appropriate inflow rates. These inflow rates were compared to discharges used in the original FIS for the Town of Webster and in all cases, the differences were less than 10 percent. These inflow rates were then hydraulically routed through Lake Webster, allowing for flood storage volume. Peak elevations for the Lake Webster outlet to Mill Brook #1 were compared to those values in the original study, and proved to be in close agreement. As a result, the peak elevations calculated during the preparation of the original FIS for the Town of Webster were used in the updated study (Reference 50).

In addition, in the Town of Oxford discharges for the French River above the Hodges Village Dam were determined using flows developed for the USGS gaging stations on the French River at Webster (No. 01125000), and the Little River near Oxford (No. 01124500). The period of record for the French River gage, before the construction of the Hodges Village Reservoir, was extended by applying the two-station comparison method, with the USGS gaging station on the Quinebaug River at Quinebaug, Connecticut, and the log-Pearson Type III method was then applied to determine the peak discharges at the gage (Reference 48). The peak discharges at the Little River gage were determined by applying the log-Pearson Type III method to the gage records before the construction of the Buffumville Reservoir. The peak discharges from these gages were then transposed to points on the French River above the Hodges Village Dam, using the transposition formula previously mentioned, and then averaged.

For the Mumford River in the Town of Northbridge, regional discharge-frequency equations for ungaged streams were used to determine peak discharges. Flows were transposed using the following formula:

$$Q_1 = Q_2 (A_1/A_2)^n$$

where Q_1 and Q_2 are the flows at the site and gage, respectively, A_1 and A_2 are the drainage areas at the site and gage, respectively, and n is the regional drainage area ratio exponent.

For the Mumford River in the Town of Northbridge, annual peak discharges were measured at the East Douglas USGS gage (Reference 51). Results of the analysis were then transposed to the mouth of the river using the equation above with an n value of 0.70 based on Chow's Handbook of Applied Hydrology (Reference 52). Peak flows applicable to the mouth of the Mumford River were then transposed to upstream reaches using the above equation with a transfer coefficient (n) of 0.70 (Reference 51). Peak discharges on the Mumford River in Northbridge were determined using the log-Pearson Type III method of analysis.

For the Mumford River in the Towns of Douglas, Sutton and Uxbridge, a log-Pearson Type III analysis was used on peak discharges measured at the East Douglas gage (No. 01111000, with 13 years of record and a drainage area of 27.8 square miles) (Reference 51). The results of the analysis were then transposed to the mouth of the Mumford River by applying a transfer equation raising the ratio of drainage areas to the 0.7 power (References 52 and 53). Since the period of record at the East Douglas gage was short, the peak flows finally adopted for the mouth of the Mumford River were the average of the transposed gage predictions and peak discharges attributed to the Mumford River in the hydrologic analysis of the Blackstone River (Reference 54). Peak flows applicable to the mouth of the Mumford River were transposed to upstream reaches of the river. In Sutton and Uxbridge, flows were multiplied by the ratio of the drainage areas raised to the 0.7 power. In Uxbridge, flows were confirmed by checking them with flows computed by regional equations.

The Riverdale Mills Sluice Gates and Tail Race discharge values in the Town of Northbridge were obtained from the Blackstone River values in the 1983 Northbridge FIS.

Flooding on the upper and lower sections of the Assabet River in the Towns of Berlin, Northborough and Westborough is presently controlled by flood storage reservoirs constructed by the NRCS in the Assabet River (Upper Reach) basin. Hydrographs of the peak flows for the 10- and 1-percent-annual-chance floods, both without the flood control structures and modified by the structures, were prepared by NRCS at Maynard and at Hudson (Reference 55). The USGS has maintained a gage at Maynard for approximately 40 years. From the USGS Gage No. 010907000 at Maynard, a log-Pearson Type III statistical analysis (Reference 56) for the 21 years of record before construction of the control structures yielded results comparable to the 10- and 1-percent-annual-chance peak flow hydrographs developed, without structural modification, by NRCS at Maynard (Reference 56). Therefore, the hydrograph analysis can be assumed to be valid.

As a result of the construction of the control structures, the unmodified flow record of the USGS gage can no longer be used. Therefore, the modified hydrographs at Maynard and Hudson, Massachusetts were used to develop peak discharge-frequency curves for the 10- and 1-percent-annual-chance floods for the Assabet River. The curves account for drainage area and reservoir storage and were used to develop peak discharge estimates on the Assabet River in Berlin and Northborough, and the Assabet River (Lower & Upper Reach) in Westborough. Frequency curves on the 10- and 1-percent-annual-chance floods were then extended according-to a log-Pearson Type III distribution to establish the 2- and 0.2-percent-annual-chance flows.

The USGS regional formula was used to estimate the peak discharge-frequency for the 10-, 2-, and 1-percent-annual-chance floods for the Assabet River Branch No. 2 in Berlin (Reference 42); Mill Brook in the Town of Bolton (Reference 43); Bowers Brook, Bennetts Brook, Elizabeth Brook, and Tributary to Elizabeth Brook in the Town of

Harvard (Reference 42); Goodridge Brook in the Town of Lancaster (Reference 42); West Brook, Meadow Brook, Big Bummet Brook and Rawson Hill Brook above Rawson Hill Dam in the Town of Shrewsbury; Tributary to Sudbury River and Tributary to Sudbury Reservoir in the Town of Southborough (Reference 42); Assabet River, upstream of the Assabet Reservoir, and Denny Brook in the Town of Westborough (Reference 57).

For the upper portion of Bowers Brook, Bennetts Brook, Elizabeth Brook, and Tributary to Elizabeth Brook, Goodridge Brook, Tributary to Sudbury River and Tributary to Sudbury Reservoir, the equations used relate basin characteristics to stream flow, providing the method for which the 10-, 2-, and 1-percent-annual-chance peak discharges were obtained.

For the upper portion of Bowers Brook, Bennetts Brook, Elizabeth Brook, and Tributary to Elizabeth Brook, Goodridge Brook, Tributary to Sudbury River and Tributary to Sudbury Reservoir, the 0.2-percent-annual-chance peak discharge was obtained graphically using the data obtained from the regional equations. For Goodridge Brook, discharge-frequency data obtained as described above were compared with previously compiled data where such data were available. In Harvard, discharges for Bowers Brook and Elizabeth Brook increase with decreasing drainage areas due to the effects of storage on the streams.

Discharge estimates for the 0.2-percent-annual-chance flood for the Assabet River Branch No. 2 in the Town of Berlin (Reference 56); Mill Brook in the Town of Bolton; and the Assabet River, upstream of the Assabet Reservoir, and Denny Brook in the Town of Westborough, were determined by straight-line extrapolation of a log-Pearson Type III probability distribution of the 10-, 2-, and 1-percent-annual-chance floods. In Bolton, discharges on Mill Brook were coordinated with the downstream FIS in Hudson, Massachusetts (Middlesex County) on Danforth Brook (Reference 58).

For the Sudbury River in the Town of Southborough, the results of a mathematical model developed by NRCS was the source of the 10-, 1-, and 0.2-percent-annual-chance peak discharges (Reference 59). The peak discharge for the 2-percent-annual-chance flood on the Sudbury River in Southborough was obtained graphically using NRCS data. Also in Southborough, regional discharge-frequency equations were utilized to determine discharge-frequency data for Tributary to Sudbury River and Tributary to Sudbury Reservoir (Reference 42).

In the Town of Shrewsbury, 0.2-percent-annual-chance peak discharge estimates for West Brook, Meadow Brook, Rawson Hill Brook above Rawson Hill Dam, and Big Bummet Brook were determined by linear extrapolation of a log-Pearson type III probability curve. Discharge at other points along the streams studied in detail were modified in order to reflect changes in drainage area. (Reference 60). Discharges at Rawson Hill Dam were computed by NRCS for their study on the Assabet River (Upper Reach) tributaries (Reference 32). The decrease in discharges downstream is caused by storage in the floodwater retarding pool at the Rawson Hill Dam.

Discharge-frequency estimates for the 10-, 2-, and 1-percent-annual-chance floods on the Still River in the Town of Bolton were computed by the USGS regional formula (Reference 43). This equation uses area, slope, and precipitation relations. Discharges for the 0.2-percent-annual-chance flood were based on an extension of the frequency curve on the other floods according to a log-Pearson Type III distribution. Coordination with the FIS in the Towns of Lancaster and Harvard showed that flooding from the Nashua River would control the entire floodplain of the lower Still River (References 61 and 62). Therefore, discharges for the Nashua River were used in developing profiles for the Nashua River and the Still River's floodplain. The Nashua River discharges were developed by Howard, Needles, Tammen and Bergendoff for their studies in the adjoining towns, using NRCS computer program TR-20, Project Formulation-Hydrology (Reference 16). This program computes surface runoff, taking into account conditions having an effect on runoff, and routes the flow through stream channels and reservoirs. It combines the routed hydrograph with those from other tributaries and computes the peak discharges, time of peak, and the water surface elevations at selected cross sections and reservoirs. It takes into account the retarding effect of storage areas, such as the Nashua River floodplain, in decreasing discharges. The TR-20 computations were calibrated to the USGS gage records on the Nashua River basin at the Clinton, (No. 01095500, period of record from 1896 to present), the Leominster (No. 01094500, period of record from 1935 to present), and the Pepperill (No. 01096500, period of record from 1935 to present) gages (References 63 and 64).

In the Town of Bolton, on Great Brook, downstream of the East Bolton Dam, discharges were developed by NRCS in their study on Elizabeth Brook in Stow (Reference 65). These discharges were also developed by the TR-20 program and account for the retarding effect of the East Bolton Dam, and for the diversion channel to the Delaney Dam complex in Stow. Above the dam, discharges for the 10-, 2-, and 1-percent-annual-chance floods were computed according to the USGS regional formula (Reference 43). The 0.2-percent-annual-chance peak discharges were determined by extension of the frequency curve according to a log-Pearson Type III distribution.

Peak discharge-frequency estimates for the 10-, 2-, 1-, and 0.2-percent-annual-chance floods on North Brook and Wrack Meadow Brook in Berlin, Cold Harbor Brook (Town of Boylston), Howard Brook and Cold Harbor Brook (Lower and Upper Reach) in the Town of Northborough were based on a study performed by NRCS of the Assabet River (Upper Reach) tributaries. In the Town of Westborough, peak-discharge frequency estimates for Piccadilly, Jackstraw, and Rutters Brooks were developed by NRCS in their study of the Upper Sudbury River (Reference 59). Both studies used the NRCS computer program for Project Formulation-Hydrology, TR-20 (References 16 and 32). The TR-20 methodology takes into consideration variables such as time of concentration, soil characteristics, and storage described in NRCS Technical Release No. 55 (Reference 66). In Berlin, the decreasing discharge on North Brook is caused by the storage capacity at Ross Dam.

The hydrologic analysis of the West River (Town of Uxbridge) resulted in the conclusion that the area contributing runoff between the West Hill Dam and the confluence with the Blackstone River has a short time-to-peak compared to the area above the dam. Therefore, peak discharge-frequency relationships adopted for the study of the West River (Town of Uxbridge), downstream of the West Hill Dam, were determined by adding 100 cfs as outflow from the dam (determined by an analysis of the USGS gage No. 01111200 just below West Hill Dam, with a drainage area of 27.9 square miles) to peak discharges determined by application of regional equations to areas below the West Hill Dam (References 43 and 67).

Predictions of flows in the Tupperware Mill Canal in the Town of Blackstone were based on two floods of record, the 1936 and 1955 floods, which were field surveyed by the USGS (Reference 68). For frequencies less than 1-percent-annual-chance, the Blackstone River overtops the Saranac Canal inlet wall. When this occurs, the canal carries a substantially higher flow and the Blackstone River below the Saranac Dam reflects the reduced flow.

In the Town of Blackstone, by using the HEC-1 flood hydrograph computer program developed by the USACE (Reference 69), a discharge-frequency relationship was developed for the Mill River watershed (which includes Harris Pond, Mill River, and Quick Stream). On the Mill River, flows were adjusted to conditions above the confluence of Hop Brook by deducting the runoff from the drainage areas below Hop Brook. From survey sections taken on the banks of Harris Pond, stage-discharge-frequency relationships were developed for the pond.

Peak discharges for the Mill River in the Towns of Hopedale, Mendon, Milford and Upton were developed from results of the September 1977 FIS for the Town of Blackstone, which utilized the USACE HEC-l program (References 70, 71 and 72). Discharges were available at four points on the Mill River. Peak discharges at intermediate points were calculated by applying the drainage area ratios raised to the 0.7 power (In Upton, this was the reach drainage area/drainage area at the corporate limits) to the four available data points.

Discharge frequencies were developed for the Nashua River at the Town of Clinton based on a volume frequency analysis of Nashua River flows at Wachusett Reservoir. Utilizing data from a nearby long-term gaging station inflow hydrographs of the 10-, 2-, 1- and 0.2-percent-annual-chance floods were routed through the reservoir. The gaging station (No. 01162500) is located on Priest Brook near Winchendon, Massachusetts and has a period of record from 1916 to the present. The resulting peak outflows for the various frequency floods were used for the Nashua River in Clinton.

A gaging station on the Nashua River located in East Pepperell and a gaging station on the North Nashua River in Leominster were the principal sources of the data used for defining discharge-frequency relationships for the Nashua and North Nashua Rivers (References 73 and 74) in Harvard and Lancaster. These gages have been in operation since 1936. Values for the 10-, 2-, 1-, and 0.2-percent-annual-chance peak discharges at each gage were obtained from a log-Pearson Type III statistical analysis of annual peak flow data. In order to define discharge-frequency relationships for the Nashua River at locations within the Towns of Harvard and Lancaster and the North Nashua River in Lancaster, a method of analysis as defined by the NRCS National Engineering Handbook was utilized (Reference 49). The method provides for the hydrologic routing of flows to account for the large floodplain storage available along the Nashua River. In Harvard, on the Nashua River, discharges increase with decreasing drainage areas due to the effects of storage on the streams. In Lancaster, the discharge can decrease as the drainage area increases. Due to natural storage, discharges on the Nashua River and the North Nashua River decrease as the drainage areas increase.

For the Quinsigamond River in the Town of Grafton, a log-Pearson Type III analysis was performed on annual peak discharges recorded at the USGS North Grafton gage No. 1100, with 38 years of record (Reference 51). Peak discharges determined by the statistical analysis were transposed to downstream areas by multiplication of the ratio of drainage areas raised to the 0.7 power (Reference 52). Peak discharges calculated by this method for the outlet of Lake Ripple were routed through the lake to account for the attenuation effect of lake storm water storage on peak discharges downstream (Reference 75). These peak discharges for the outlet of Lake Ripple were then transposed to the mouth of the river by multiplying by the ratio of the drainage area relationship. Peak flows adopted for the mouth of the Quinsigamond River were the average of these transposed discharges and the peak discharge that resulted from the original hydrologic analysis of the Blackstone River. These average peak discharges were then transposed to the upstream reaches (downstream of Lake Ripple) by again utilizing the ratio of the drainage area raised to the 0.7 power.

Using a log-Pearson Type III regression analysis of annual maximum discharges, discharge-frequency relationships for the Charles River in the Towns of Hopedale, Mendon and Milford were established by the New England Division of the USACE using the USGS Charles River Village gage, which has 41 years of record (Reference 14). The peak discharges computed were then transposed to other locations on the Charles River in Hopedale, Mendon and Milford by multiplying by the ratio of drainage areas raised to the 0.7 power.

Using a method developed specifically by the USGS for Massachusetts (Reference 43). that takes into consideration the slope of the main channel and the drainage area in its evaluation, discharges were determined for the following flooding sources; Sewall Brook in the Town of Boylston; Little River, Cady Brook, Deans Brook, Little Nugget Brook, Pikes Pond Tributary in the Town of Charlton; Lynde Brook and Town Meadow Brook in the Town of Leicester; McKinstry Brook, Lebanon Brook and Cohasse Brook in the Town of Southbridge; Cedar Meadow Brook, Hamant Brook, Leadmine Brook, Cedar Pond, Walker Pond, Quacumquasit Pond in the Town of Sturbridge; Mill Brook #1 downstream of Lake Webster in the Town of Webster; and Gates Brook in the Town of West Boylston.

In the Town of Charlton, peak discharges for Deans Brook are lower at Blood Road than those downstream of Wabash Brook because of storage losses within the drainage basin.

In the Town of Southbridge, for Cady Brook, the 2- and 1-percent-annual-chance flows were obtained from the Southbridge Flood Plain Information report (Reference 9). The 10- and 0.2-percent-annual-chance values were extrapolated exponentially.

In the Town of West Boylston, however, because the USGS method does not adequately provide for increased flow rates resulting from urbanization, the flows determined were modified using a second reference, a method also developed by the USGS, for urbanization in Oklahoma (Reference 76). The latter provides for increased flows by taking into consideration the degree of imperviousness of the drainage area and the percentage of area served by storm sewers.

Peak discharges for Southwick Brook in the Town of Douglas, Big Bummet Brook and the West River in the Town of Grafton, Muddy Brook in the Town of Mendon, O'Brien Brook, Stall Brook, Godfrey Brook, Huckleberry Brook, and Ivy Brook in the Town of Milford and West River and Center Brook in the Town of Upton were determined by application of USGS regional equations for eastern Massachusetts (Reference 43). This method uses drainage areas and streambed slope of streams with the same regional characteristics, along with annual precipitation in the area, as parameters in the equations.

There are no discharge records for Counterpane Brook in the Town of Clinton. Peak discharge frequencies for this stream were derived by using procedures presented in the report Estimating the Magnitude and Frequency of Floods on Natural-Flow Streams in Massachusetts (Reference 43). Resulting flow values were then compared with discharge frequencies for Counterpane Brook published in a report by the Commonwealth of Massachusetts and were found to be in general agreement (Reference 77).

Discharges for Tributary 1 in the Town of Dudley and Lowes Brook in the Town of Oxford were determined using the Wandle Method, developed by the USGS specifically for Massachusetts (Reference 43). This methodology takes slope of the main channel and drainage area into consideration in its evaluation of discharges. The USGS derived the equation used in the Wandle method by applying multiple regression techniques to flow data and physical characteristics of 113 stream gaging stations in or near Massachusetts (Reference 43).

In the Town of Sutton, peak discharge-frequency relationships for Dark Brook and Cold Spring Brook (Town of Sutton) were determined by applications of USGS regional equations (Reference 43).

Flood flows for Miscoe, Axtell and Cronin Brooks in the Town of Grafton were determined by using regional equations for peak discharges applicable to the area (Reference 78). This method combines basin and climatic characteristics through specific regression equations to yield discharges of 10-, 2-, and 1-percent-annual-chance. Peak discharges for the 0.2-percent-annual-chance return storm were based on the USGS regional equations used to compute peak discharges presented in the previous study (Reference 43).

In the Town of West Boylston, regional equations developed by the USGS were used to compute discharge-frequency data for the net contributing watersheds of Waushacum and Tributary to Waushacum Brooks in West Boylston (Reference 79). Peak discharges from the upper 5.1 square miles of Waushacum Brook are generally controlled by surcharge storage in East Waushacum and West Waushacum Ponds, according to the FIS for the Town of Sterling (Reference 80). Therefore, peak flows are based on the regional equations applied to the net drainage areas downstream of the two ponds. These equations relate discharge frequencies to basin characteristics and were used to estimate 10-, 2-, and 1-percent-annual-chancepeak discharges. The 0.2-percent-annual-chance peak discharges were estimated by frequency curve extrapolation.

Discharges from the Quinebaug River below the East Brimfield Dam in the Towns of Southbridge and Sturbridge and the Westville Dam in the Towns of Southbridge, Sturbridge and Dudley were determined using several sources. They include the Flood Plain Information Report for the Quinebaug River in Southbridge, discussions and correspondence with the USACE and utilization of stream data at the USGS stream gage (No. 01124000) in Quinebaug, Connecticut (Reference 9). With 47 years of record at the Quinebaug gage, the average discharge is 296 cfs (adjusted for storage in flood-control reservoirs). In addition, Southbridge and Sturbridge also used the Flood Plain Information Report for the Cady Brook, the USACE manual on the regulations of reservoirs in the Thames River basin and USGS gage No. 01123000 downstream of the Westville Dam in Southbridge (References 9, 47 and 73).

Discharges for the 2- and 1-percent-annual-chance floods on the Quinebaug River below the Westville Dam to the state line were obtained from correspondence with the USACE (Reference 81) in the Town of Dudley and from back-up data included in the Town of Southbridge Flood Plain Information report (Reference 9) in Southbridge and Sturbridge. The 10- and 0.2-percent-annual-chance discharges were developed by both extrapolation of the 2- and 1-percent-annual-chance discharges assuming a logarithmic-probability distribution and transposition of discharges using the USGS stream gage data at Quinebaug, Connecticut to the location being studied upstream (Reference 48). In Southbridge and Sturbridge, discharges below the East Brimfield Dam were obtained utilizing the USACE manual on regulations of reservoirs in the Thames River basin and discussions and correspondence with the USACE (Reference 47).

For Cold Spring Brook (Town of Harvard), the lower portion of Bowers Brook in Harvard and for the Stony Brook / Sudbury Reservoir in the Town of Southborough, discharge-frequency data were developed using computer modeling techniques developed by NRCS (Reference 49). In this method, a precipitation event was simulated over a basin, the runoff calculated, and the resulting quantity of flow routed through stream reaches and control structures. The 10-, 2-, 1- and 0.2-percent-annual-chance peak discharges were determined by applying the appropriate total rainfall depth associated with a particular frequency.

The discharge-frequency relationship for the Sevenmile River in the Town of Spencer was determined through analysis of anticipated rainfall and runoff. A NRCS report, <u>Flood Hazard Analysis, Upper Quaboag River (Including East Brookfield River, Sevenmile River, Mill River, Turkey Hill Brook, Cranberry River and Great Brook), Worcester County</u>, provided information for the analysis (Reference 82). A hydrologic watershed model was developed, which extended downstream to include the USGS gaging station at the Town of West Brimfield, Massachusetts, gage No. 01176000. This gage has been in operation since 1912. A log-Pearson Type III analysis of the gage record provided a discharge-frequency relationship for the Quaboag River at that location. This relationship was then used to adjust the watershed model to agree with historical flood flows. The March 1968 flood was used to verify the watershed model. The 10-, 2-, 1- and 0.2-percent-annual-chance synthetic storm runoff was then flood-routed through the upstream areas of the watershed using the NRCS <u>Computer Program, Project Formulation, Hydrology</u>, which computes surface runoff resulting from synthetic or natural rainstorms (Reference 16). Rainfall data used in the analyses were obtained from Weather Bureau publications (References 83 and 84). A rainfall distribution of 48 hours was developed using frequency rainfall depth-duration relationships from a Massachusetts Department of Commerce and Development publication and the methods described in NRCS Technical Paper No. 149 (References 85 and 86).

The hydrology for Quacumquasit Pond in the Town of Sturbridge was developed as part of the Quaboag River Flood Hazard Analyses (Reference 82). In the analysis, the watershed was divided into areas of relatively uniform characteristics. An analysis of slope, soils, vegetation, land use and stream channels was made to compute composite runoff curve numbers, times of concentration and travel times. Storage capacity and stage-discharge curves were then computed. The SWAMP computer program was used to model the Quaboag marsh area in Brookfield (Reference 87). The Quaboag River, Quaboag Pond, East Brookfield River and adjacent wetland area were treated as a series of interconnected storage areas rather than as stream reaches. In this way, the available flood storage for different storm frequencies was more adequately utilized. This method made it possible to show a flow reversal situation into Quacumquasit Pond from Quaboag Pond. Rainfall data for the various storms were obtained from National Weather Service publications (References 84 and 88). A 48-hour storm distribution, which included the standard SCS 24-hour Type II rainfall distribution, was used for all frequency storms. The March 1968 flood was used to verify the watershed model by comparing the discharges computed to those at the USGS stream gaging stations on the Quaboag River in West Brimfield and on the Sevenmile River in Spencer.

In the Town of Millbury, peak flows and peak flood stages at the dams for Dorothy and Ramshorn Ponds were calculated using the USACE HEC-I Flood Hydrograph Package using the NRCS, runoff curve number method (Reference 89). Flood hydrographs for both ponds were routed through natural valley flood storage in the ponds to determine peak discharge and flood stage.

For the Tatnuck Brook watershed in the City of Worcester, the discharge-frequency relationship was developed with the aid of the flood hydrograph model, HEC-l, developed by the USACE (Reference 69).

For the City of Worcester 1980 FIS, a discharge-frequency relationship for Kettle Brook (East) at the USGS gaging station No. 01109500 (3.13 square miles) in Worcester was established by using log-Pearson Type III statistical analyses (Reference 56) of the annual peak discharge recorded since 1960. Since then, the City of Worcester has diverted flood flows upstream of the Kettle Brook (East) gage at the Leesville Diversion weir.

Another discharge-frequency relationship was established for Kettle Brook (West), which lies between Leicester and Auburn in southwest the City of Worcester. This relationship was established by using log-Pearson Type III statistical analyses (Reference 56) of the annual peak discharge data recorded before construction of the Worcester Diversion Project (36 years of record). Natural stream flows recorded at the gage were adjusted to reflect actual flows in Kettle Brook (West) by using the NRCS method of discharge versus drainage area relationships (Reference 44). In the Town of Auburn, a discharge-frequency relationship for Kettle Brook (Town of Auburn) at Leesville Pond in Auburn was established using a log-Pearson Type III statistical analysis of the annual peak discharge data recorded for Kettle Brook at Worcester (Reference 90) before 1959. Record flows after 1959 were not included in this analysis because, since 1959, peak flows for Kettle Brook have been estimated by adding gaged flows to approximations of flows diverted to the Leesville tunnel; these estimates were not accurate enough for this study.

For Middle River in the City of Worcester, flows were determined by adding the flow contributions from Kettle Brook (East), Tatnuck Brook, and Beaver Brook. To verify the flows determined for the Middle River, flows obtained from the USGS gaging station No. 01110500 (36 years of record) for the Blackstone River at Northbridge (139 square miles) were examined. A log-Pearson Type III statistical analysis (Reference 56) of gaged flows was performed and adjusted to reflect the actual flows in Worcester by deduction the runoff from the drainage area between the Northbridge gage and Worcester. The two techniques of developing flows compared to within 5 percent of each other.

For the City of Worcester 2003 FIS revision, the hydrologic analyses for Beaver Brook, from the confluence with Middle River to a point approximately 1,855 feet upstream of May Street; Mill Brook Conduit, from Salisbury Pond to the Indian Lake Outlet; and Broad Meadow Brook were performed using the USACE's rainfall-runoff model HEC-l (Reference 69). Flood frequencies were related to rainfall records using the U.S. Weather Bureau Technical Paper No. 40. These rainfalls were applied to the City of Worcester uniformly for each watershed. Hydrologic analyses were carried out to establish the peak discharge-frequency relationships for 10-, 2-, 1- and 0.2-percent-annual-chance flood events. The Clark method was used to estimate parameters for synthetic unit hydrograph. Clark unit hydrograph parameters such as time of concentration for the basin, t_c and watershed storage coefficient, R, were estimated for each subwatershed from the watershed hydraulic characteristics. The NRCS curve number method was selected to estimate infiltration losses. The NRCS curve number is directly related to land use and soil properties of a watershed. The Muskingum method was selected for flood routing.

Discharge-frequency relationship was developed for Curtis Pond, Flagg Street Pond, and the Indian Lake drainage areas in the City of Worcester using the NRCS runoff curve number method (Reference 44), Runoff curve numbers were developed from area soils mapping (Reference 45).

Flows for of Dark Brook #1 (Auburn Pond and Central Street), the NRCS runoff curve number method was used to compute flows into Eddy Pond, and to verify the flows from the effective study (Reference 44). The flows were then routed through the pond to account for the reduction in peak flows offered by the available storage in the pond. Downstream of the small tributary entering Dark Brook #1 northeast of Water Street, peak flows were increased because of runoff to the tributary. Recent development in the Dark Brook #1 drainage area in Auburn was found not to have a significant impact on flows. The area around Eddy Pond has not been heavily developed, partly because of its use as a conservation area. The additional development in the already-heavily developed drainage area for the tributary did not have a significant impact on flows, either.

<u>July 2011 Partial Countywide Analysis</u>

For the July 2011 partial countywide FIS, hydrologic analyses were conducted to establish the peak discharge frequency relationships for floods of the selected recurrence intervals for the Blackstone River within Worcester County.

For gaged locations, peak flood discharges were calculated using standard hydrologic methods described in Bulletin 17B (Reference 90). The Pearson Type III distribution with log transformation of the flood data (log-Pearson Type III) was applied to annual peak discharge data from USGS gages located in or within 10 miles of the Blackstone watershed that were found to have gaging records of sufficient length (at least 10 years) and not appreciably altered by reservoir regulation in order to define annual flood series. Statistical parameters of the flow distributions were determined from the station data for Blackstone River, including a generalized skew coefficient. The annual flood frequency analysis PeakFQ computer program (Reference 91) was used to compute the flood discharges based on these statistical parameters and annual flood series.

For ungaged locations, discharges were developed using the following drainage-area transfer equation:

$$(Q_1/Q_2) = (DA_1/DA_2)^{0.75}$$

where Q_1 and Q_2 are discharges at specific locations and DA_1 and DA_2 are the drainage areas at these locations with the exponent (0.75) reflecting a relevant value for the area (Reference 92).

The peak discharge-frequency relationships used for the Blackstone River flows in Worcester County were based on stream gaging records of the following USGS gages:

- 01109500 located on Kettle Brook at Worcester, Massachusetts. The gage has a recording period from 1924 to 1980. However, because the Leesville Diversion weir causes a significant diversion of peak discharges in Kettle Brook, only flow records measured prior to construction of this diversion structure were used (i.e., from 1924 to 1959) and were termed "Kettle Brook West, or 01109500W".

- 01110500 located on Blackstone River at Northbridge, Massachusetts. The gage has a recording period from 1936 to present.

- 01112500 located on Blackstone River at Woonsocket, Rhode Island. The gage has a recording period from 1929 to present.

Geographic data for the analysis was obtained from the Massachusetts Geographic Information System (www.mass.gov/mgis) and digital USGS 1:24,000-scale topographic maps. Drainage basins for selected discharge locations were delineated using Geographic Information System (GIS) software and based on the digital Watershed and Subwatershed hydrologic unit boundaries for Massachusetts (www.mass.gov/mgis).

Information on the methods used to determine peak-discharge frequency relationships for all the streams studied by detailed methods is shown in Table 9, "Summary of Discharges."

Concord River Watershed Partial Countywide Analysis

Flood discharges were estimated using the most current regression equations for rural and urban watersheds developed by the USGS for various regions of Massachusetts. Peak flows were computed for the 10-, 4-, 2-, 1-, and 0.2-percent-annual-chance-flood events. The following USGS reports were used in this study: for rural areas, Water Supply Paper 2214, "Estimating Peak Discharges of Small, Rural Streams in Massachusetts, 1983" (Reference 78); for urban areas, USGS Water Supply Paper 2207, "Flood Characteristics of Urban Watersheds in the United States, 1983" (Reference 93).

Adjustments to the USGS regression equations were made to better represent conditions in the watershed. The adjustments were made to account for:

- Reduced discharge downstream of flood storage reservoirs;
- Comparisons of stream gage records through 2010 and the gage records used to produce the equations; and
- Comparisons of regression discharges to a schematic HEC-HMS model (Reference 94).

The hydrologic analysis included a review and update of flood-flow frequency estimates for stream gages within the Concord River Watershed using the most current stream flow records available. The flood-flow frequency data was updated using the methods described in USGS "Bulletin 17B Guidelines for Determining Flood Flow Frequency" (Reference 90). Adjustments to discharges on streams with gages were applied based on the procedures in USGS Water Supply Paper 2214 (Reference 78). Discharges at ungaged locations were determined using the equation below, following the procedures in Bulletin 17B (Reference 90).

$Q_t(u) = (Au/Ag)^x \, Qt(g)$

where:

Q_t (u) is the peak discharge at ungaged site for exceedance probability
Q_t (g) is the gage discharge from log-Pearson type III frequency analysis
Au is the drainage area of ungaged site
Ag is the drainage area of gaged site
x is the exponent for each flood region

Revised hydrologic discharges calculated for the Assabet River, Elizabeth Brook, Jackstraw Brook, Rutters Brook, Stony Brook, and the Sudbury River were used in the revised hydraulic analysis. These revised discharges supersede the discharges calculated prior to the Concord River Watershed partial countywide analysis.

Estimates for flood discharges in rural drainage basins were determined using regression equations as described in USGS Water Supply Paper 2214, "Estimating Peak Discharges of Small, Rural Streams in Massachusetts, 1983" (Reference 78). The regression equation used is defined below.

$Q = C\,(DA)^{b}$

where:

Q is the discharge (cfs)
C is the regional coefficient
DA is the drainage area (square miles)
b is the regional exponent

	Q10	**Q25**	**Q50**	**Q100**	**Q500**
Eastern MA Region 'C'	72.12	96.71	118.1	143.1	198.75
Eastern MA Region 'b'	0.66	0.651	0.645	0.638	0.622

The rural regression equations do not provide an equation for the 0.2-percent-annual-chance flood event. Therefore, these discharge estimates are based on a regression equation developed from gages in the eastern Massachusetts region as defined in the USGS Water Supply Paper 2214 (Reference 78).

Discharges were estimated for selected urban basins based on the USGS Water Supply Paper 2207, "Flood Characteristics of Urban Watersheds in the United States, 1983" (Reference 93). The urban equations were used when the impervious area exceeded 10% of the basin area. The regression equation used is defined below.

$$Q = C(DA)^{b}\ (13\text{-}BDF)^{m}\ RQ^{f}$$

where:

Q is the discharge (cfs)
C is the constant for drainage area
DA is the drainage area (square miles)
b is the exponent for drainage area
BDF is the basin development factor
m is the exponent for the development factor
RQ is the rural discharge
f is the exponent for the rural discharge

	Q10	Q25	Q50	Q100	Q500
'C'	9.51	8.68	8.04	7.7	7.47
'b'	0.16	0.15	0.15	0.15	0.16
'm'	-0.36	-0.34	-0.32	-0.32	-0.3
'f'	0.79	0.8	0.81	0.82	0.82

Data was reviewed from the USGS stream gages within the Concord River Watershed. The gage locations used in the analysis were to have a minimum of 10 years of records. The Concord River Watershed includes four active gages and four discontinued gages with a period of record of 10 years or more. These gages range in drainage area from 1.6 square miles to 400 square miles and include records ranging from 12 to 73 years in length.

The annual peak flow record for the active gages was obtained from USGS and was used to update the flood-flow frequency data using the methods described in the USGS "Bulletin 17B Guidelines for Determining Flood Flow Frequency". The USGS PEAKFQ (Reference 95) computer program was used to perform the flood-flow frequency computations. The updated analysis includes peak flow data through 2010. The analysis utilized the weighted skew coefficient, except for those gages that are affected by urbanization and by flow regulation; these gages utilized the station skew.

The regression discharges for the 1% frequency vary from 71% to 125% of the gage discharges. The regression equations from the USGS Water Supply Paper 2214 were developed from gage records through 1983; therefore, a comparison was made between the 1983 gage discharges and the active gage discharges through 2010 to determine if the regression equations would over-predict or under-predict discharges due to the additional period of record. The comparison indicated that the 1% frequency discharges through 2010 increased an average of 123% above the 1983 discharges. As a result, an adjustment factor was applied to the regression equation discharges.

The regression equation discharges were reduced downstream of flood storage reservoirs identified in the Middlesex and Worcester Counties Flood Insurance Studies. The discharges were reduced based on the average reduction of outflow compared to inflow as determined by flood routing computations. Subsequent discharges downstream were added to the reservoir outflow based on the additional downstream drainage area and the regression equations. The flood routing computations were obtained from the NRCS for reservoirs located in the Assabet River watershed. Flood routing computations were prepared for this study for reservoirs located in the Sudbury River watershed. Discharges were reduced at the following reservoirs:

Sudbury River Watershed

- Framingham #1 Reservoir
- Framingham #2 Reservoir
- Framingham #3 Reservoir
- Lake Cochituate Dam
- Whitehall Reservoir
- Ashland Reservoir
- Hopkinton Reservoir

Assabet River Watershed

- Nichols Dam
- Tyler Dam
- Cold Harbor Brook Dam

A schematic HEC-HMS (Reference 94) rainfall-runoff model for the Sudbury, Assabet, and Concord Rivers was prepared to validate and compare the discharges computed using the USGS Water Supply Paper 2214 gage transfer equations. A schematic model was used to limit the model to include only the critical basins within the Sudbury, Assabet, and Concord sub-watersheds. The schematic model is suitable for comparison and validation of the large sub-watersheds; a larger HEC-HMS model incorporating all sub-watersheds was not practical for this purpose. Discharges from the HEC-HMS model were not intended to be used directly in the hydrologic computations.

Due to the schematic nature of the model, some parameters included less detailed information than a traditional HEC-HMS model application. The sub-basins were located on major rivers at the USGS gages and at the confluence of major streams. Drainage areas for sub-basins in the model vary from 0.7 to 45 mi^2. Due to the large drainage areas, there are fewer reaches for routing and the reach lengths are longer. Only major flood control reservoirs were included for flood routing, and smaller reservoirs and storage areas upstream of roadway embankments were excluded in the model.

Within HEC-HMS, the SCS Curve Number method was used to calculate runoff and the SCS Unit Hydrograph was selected to transform runoff. The SCS Type III storm was used and the model was run using 5-minute time steps.

The model was calibrated using a storm event from 2007 with discharges from the following stream gages:

- 01097000 Assabet River at Maynard
- 01098530 Sudbury River at Saxonville
- 01099500 Concord River below Meadow Brook

The calibration procedure consisted of comparing the HEC-HMS model discharges using actual precipitation from the 2007 storm event with recorded stream gage discharges from the same storm event. Systematic adjustment of the HEC-HMS parameters were made until the HEC-HMS model agreed favorably with the actual storm event discharges at the stream gages. Significant adjustments were required to lag time and curve number values during model calibration.

The regression equation discharges were adjusted at several locations based on a comparison to the results of the HEC-HMS model.

The effective discharges were obtained from the "Summary of Discharges" table located in the effective FIS report from Worcester County dated July 2011 (Reference 96). Differences between the effective discharges and the revised discharges are due to the different computation methods used, the date of records used in the effective computations (approximately 1975-1985), and the additional 30-year period stream gage records in the watershed used for the revised computations.

The Assabet River average ratio of the revised discharges to the effective discharges was 1.22. The effective discharge-frequency data was obtained from USGS gage analysis with records through 1984 and by using modified flow hydrographs. The revised discharges were determined from USGS gage analysis with records through 2010 and USGS Urban Regression Equations.

The Sudbury River average ratio of the revised discharges to the effective discharges was 0.77. The effective discharge-frequency data was obtained using computer modeling techniques developed by the SCS in 1972. The revised discharges were determined from USGS gage data through 2010 and USGS Urban Regression Equations.

TABLE 9 – SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
ASSABET RIVER					
Approximately 400 feet downstream of Interstate 495	59.0	1370	2020	2380	3130
Approximately 250 feet downstream of Bridge Road	57.4	1350	1990	2350	3080
Above the confluence with North Brook	40.2	380	560	660	870
Approximately 100 feet downstream of Interstate 290	40.1	350	520	620	810
Approximately 375 feet upstream of Robin Hill Street	39.5	1650	2420	2860	3760
Approximately 900 feet downstream of Boundary Street	35.3	1500	2210	2610	3440
Approximately 400 feet upstream of Boundary Street	35.2	1500	2210	2610	3430
Approximately 2,550 feet upstream of Boundary Street	29.9	1260	1870	2210	2920
Below Cold Harbor Brook (Lower Reach)	29.66	860	1490	1850	2970
Below Hop Brook	16.83	631	1070	1321	2090

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
ASSABET RIVER – continued					
At Northborough / Westborough Corporate Limits	8.8	532	882	1077	1667
ASSABET RIVER (LOWER REACH)					
Below Dam in Westborough	6.86	368	605	736	1130
ASSABET RIVER (UPPER REACH)					
At Assabet Reservoir in Westborough	1.3	54	86	114	178
ASSABET RIVER BRANCH NO. 2					
Northeast corporate limit in Berlin	2.02	92	138	159	220
AXTELL BROOK					
At confluence with Lake Ripple	2.0	99	150	176	397
At downstream side of Massachusetts Turnpike in Grafton	1.3	72	108	126	247

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
BEAVER BROOK					
At the confluence with Curtis Pond Outflow and Middle River in Worcester	61.5	2390	3560	4140	5360
At Main Street in Worcester	10.8	1430	2330	2700	3450
BEAVER BROOK					
At Maywood Street in Worcester	3.86	448	597	676	916
At May Street in Worcester	3.58	409	546	619	840
At Chandler Street in Worcester	3.11	337	453	513	700
BENNETTS BROOK					
At the downstream Harvard corporate limits	2.6	120	180	210	280
2,800 feet upstream of the Harvard / Ayer corporate limits	1.86	80	130	150	200
BIG BUMMET BROOK					
Upstream of confluence with Quinsigamond River	4.3	260	440	540	840

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
BIG BUMMET BROOK - continued					
Upstream of Westborough Road in Grafton	2.6	180	310	380	590
At State Highway 140 in Shrewsbury	1.22	110	191	236	372
At Shrewsbury Corporate Limits	2.51	169	289	355	556
BLACKSTONE RIVER					
At downstream end of Tupperware Mill Canal in Town of North Smithfield	358.0	9520	14900	17600	24900
Just above Saranac Dam in Town of Blackstone	358.0	9920	15500	18300	25900
Just upstream of confluence with Branch River	269.2	7600	11900	14100	19900
Just above Tupperware Mill Dam in Town of Blackstone	269.0	8000	12500	14800	20900
Just downstream of Millville - Blackstone corporate limits	260.2	7810	12200	14400	20400
Just upstream of Uxbridge - Millville corporate limits	256.0	7710	12100	14200	20100

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
BLACKSTONE RIVER – continued					
Just upstream of confluence with Bacon Brook	253.6	7660	12000	14100	20000
Just upstream of confluence with Emerson Brook	244.0	7440	11700	13700	19400
Just upstream of confluence with West River (Town of Uxbridge)	205.3	6540	10200	12100	17100
Just upstream of confluence with Mumford River	148.3	4220	6540	7730	11000
Approximately 3,800 feet upstream of Northbridge-Uxbridge corporate limit	146.0	4170	6470	7640	10900
At confluence of Riverdale Mills sluice gates and tail race in the Town of Northbridge	*	4080	6330	7480	10700
At divergence of Riverdale Mills sluice gates and tail race in the Town of Northbridge	*	3535	5215	6213	9212

* No Data Available

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
BLACKSTONE RIVER – continued					
Just upstream of Riverdale Mills sluice gates and tail race in the Town of Northbridge	142.0	4080	6330	7480	10700
Just upstream of Main Street Bridge (State Route 122)	139.0	4020	6230	7360	10500
Approximately 600 feet downstream of Grafton-Northbridge corporate limits	137.0	3970	6170	7280	10400
Just upstream confluence of Quinsigamond River	96.0	3050	5660	7220	12300
Just upstream of Pleasant Street bridge and Cronin Brook confluence in Grafton	94.0	3010	5580	7110	12100
Just upstream of confluence with Cold Spring Brook in Town of Sutton	86.0	2810	5220	6650	11300
At Millbury-Sutton corporate limits	85.0	2790	5170	6590	11200
Just upstream of confluence with Dorothy Brook in Town of Millbury	77.8	2610	4840	6170	10500

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
BLACKSTONE RIVER – continued					
Just upstream of confluence with Singletary Brook	71.4	2450	4540	5780	9830
At Worcester - Millbury corporate limits	63.4	2240	4150	5290	9010
BOWERS BROOK					
At the Harvard downstream corporate limits	10.7	370	980	1120	2230
At the confluence of Cold Spring Brook	9.07	290	720	810	1530
Upstream of Old Mill Road in Harvard	8.55	430	1120	1250	2240
At Cruft Lane in Harvard	7.45	330	870	980	1750
Downstream of Ayer Road in Harvard	5.15	130	380	440	810
At the confluence with Bare Hill Pond in Harvard	1.2	70	100	110	150
BROAD MEADOW BROOK					
At Worcester / Millbury corporate limits	2.11	246	333	378	523

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
BROAD MEADOW BROOK - continued					
At U.S. Route 20 in Worcester	2.08	246	332	377	520
At upstream end of culvert near Woodcliff Avenue in Worcester	1.48	225	302	341	464
At intersection of Indiana Street and Everton Avenue in Worcester	0.78	174	231	260	349
At Worcester-Millbury corporate limits	2.11	246	333	378	523
CADY BROOK					
At the confluence with Quinebaug River in Southbridge	12.9	1130	3000	4200	8400
At the downstream corporate limits in Charlton	11.1	1015	2690	3765	7530
Upstream of confluence of stream from Prindle Lake in Charlton	9.8	925	2450	3435	6865
Upstream of confluence of stream from Sibley Ponds in Charlton	4.9	550	1455	2035	4075

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
CEDAR MEADOW BROOK					
Upstream of Westville Reservoir easement in Sturbridge	1.7	135	233	287	452
CEDAR POND					
Upstream of Westville Reservoir easement in Sturbridge	3.4	181	307	376	583
CENTER BROOK					
At Grove Street bridge in Upton	4.7	180	300	360	560
CHARLES RIVER					
At Box Pond in Mendon	12.9	430	820	1130	1720
At the Hopedale / Mendon corporate limits	11.9	430	800	1130	1670
At the Hopedale / Milford corporate limits in Milford	11.9	430	800	1130	1670
At the confluence of Godfrey Brook in Milford	9.0	340	640	870	1330
At Depot Street Bridge in Milford	8.6	330	620	850	1290
At the head of Cedar Swamp Pond in Milford	3.0	180	360	500	770

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
COHASSE BROOK					
At the confluence with Quinebaug River in Southbridge	4.2	250	430	525	815
At Laurel Hill Road in Southbridge	3.6	220	370	455	710
Downstream of Wells Road in Southbridge	2.8	185	310	385	600
Downstream of Cohasse Reservoir in Southbridge	2.0	145	245	305	475
COLD HARBOR BROOK (LOWER REACH)					
At Hudson Street in Northborough	9.69	387	719	919	1474
At Church Street in Northborough	6.79	216	347	410	569
At Lincoln Street in Northborough	6.31	144	202	231	303
COLD HARBOR BROOK (TOWN OF BOYLSTON)					
At the downstream corporate limits in Boylston	3.9	535	710	820	1120

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
COLD HARBOR BROOK (TOWN OF BOYLSTON) - continued					
Above Reservoir Road in Boylston	1.3	385	615	725	1000
COLD HARBOR BROOK (UPPER REACH)					
At Cherry Street in Northborough	5.25	550	687	821	1155
At West Street in Northborough	5.15	540	674	805	1133
At Crawford in Northborough	4.48	493	624	740	1034
COLD HARBOR BROOK (UPPER REACH) - continued					
At Reservoir in Northborough	4.37	504	645	759	1055
COLD SPRING BROOK (TOWN OF HARVARD)					
At the confluence with Bowers Brook in Harvard	1.23	160	440	490	920

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
COLD SPRING BROOK (TOWN OF SUTTON)					
Upstream of confluence with Blackstone River	7.5	360	620	760	1170
COUNTERPANE BROOK					
At confluence with Nashua River in Clinton	5.7	280	480	585	900
CRONIN BROOK					
At confluence with Blackstone River in Grafton	2.9	127	191	224	508
At southern most crossing of Fitzpatrick Road in Grafton	2.5	111	166	194	446
At northern most crossing of Fitzpatrick Road in Grafton	2.1	96	142	165	400
At Millbury Street in Grafton	1.7	80	117	136	363
DARK BROOK					
Upstream of confluence with Mumford River	3.6	230	440	570	1030

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
DARK BROOK #1 (AUBURN POND TO CENTRAL STREET)					
At Swanson Road	2.1	450	670	840	1450
At Water Street	1.0	240	360	450	780
DARK BROOK #2 (STONEVILLE POND TO LEICESTER STREET)					
At Stoneville Pond	2.8	230	320	400	740
DEANS BROOK					
At the downstream corporate limits in Charlton	7.3	357	603	737	1137
At Blood Road in Charlton	5.9	333	565	692	1073
Downstream of Wabash Brook in Charlton	5.6	346	591	724	1126
Upstream of Wabash Brook in Charlton	3.0	207	356	437	684
At McIntyre Pond outlet in Charlton	2.6	190	326	401	628
DENNY BROOK					
At the confluence with Jackstraw Brook	1.1	140	210	250	330

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
DENNY BROOK - continued					
Approximately 1,250 feet downstream of South Street	0.6	100	160	180	240
At South Street in Westborough	0.6	54	95	117	187
DENNY BROOK TRIBUTARY 1					
At confluence with Denny Brook	0.4	70	100	120	160
DOROTHY BROOK					
At confluence with Blackstone River in Millbury	4.1	255	460	520	640
DOROTHY POND					
At outflow structure in Millbury	3.4	155	405	565	1334
DUNN'S BROOK (KETTLE BROOK TO AUBURN POND)					
At confluence with Kettle Brook (Town of Auburn)	11.4	1025	1500	1900	3300

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
ELIZABETH BROOK					
At the downstream corporate limits in Harvard	6.52	110	210	220	590
At Eldridge Road in Harvard	4.6	210	340	400	560
At Interstate 495 in Harvard	4.42	230	380	450	620
At the upstream corporate limits in Harvard	1.11	90	160	190	260
FRENCH RIVER					
At Connecticut / Massachusetts boundary in Dudley and Webster	93.7	1280	2560	3370	6140
At USGS gaging station No. 01125000	85.3	1000	1950	2550	5500
Upstream of confluence with Mill Brook #1 in Dudley and Webster	73.4	900	1670	2230	5600
Above Lowes Brook in Oxford	61.0	900	950	1000	5800
Below Hodges Village Dam in Oxford	31.0	550	575	600	3500
Above Hodges Village Dam (at 500 feet) in Oxford	24.9	1025	2150	2860	5335

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
FRENCH RIVER - continued					
Below Texas Pond in Oxford	22.2	940	1975	2630	4900
Above Leicester corporate limits	19.4	885	1820	2406	4415
Above Pleasant Street in Leicester	14.4	708	1455	1924	3503
GATES BROOK					
At Boston and Maine Railroad in West Boylston	1.9	211	325	384	556
At State Route 140 in West Boylston	1.6	191	294	347	503
Above intersection of Worcester Road and Howard Avenue in West Boylston	1.2	159	241	282	404
GODFREY BROOK					
At the confluence with the Charles River in Milford	1.7	240	350	420	650
At the confluence of O'Brien Brook in Milford	1.1	175	265	310	485
At Water Street in Milford	0.56	110	165	195	300

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
GOODRIDGE BROOK					
At Main Street (State Route 110) in Lancaster	2.76	148	229	266	360
GREAT BROOK					
Downstream of East Bolton Dam in Bolton	8.1	138	152	156	166
Upstream of East Bolton Dam in Bolton	8.0	292	478	573	861
East End Road in Bolton	5.2	206	330	391	575
State Route 117 in Bolton	4.1	167	264	310	450
Interstate Route 495 Exit Ramp in Bolton	1.8	86	130	151	212
Main Street, 3rd Crossing in Bolton	1.0	56	83	95	131
HAMANT BROOK					
Approximately 1,000 feet downstream of Hamant Pond in Sturbridge	1.6	81	137	168	261
Upstream of Westville Reservoir easement in Sturbridge	3.8	191	322	394	610

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
HARRIS POND					
Spillway Discharge (cfs) in Blackstone	*	1,470	2,590	3,100	4,600
HOP BROOK					
Approximately 80 feet downstream of Main Street	1.2	150	230	280	370
Approximately 350 feet downstream of Brookway Drive	0.3	60	100	110	150
HOP BROOK TRIBUTARY 4					
At the confluence with Hop Brook	1.8	240	360	430	560
Approximately 380 feet upstream of Walnut Street	1.3	190	290	340	450
Approximately 500 feet downstream of Old Brook Road	0.3	70	110	130	170
HOP BROOK TRIBUTARY 4.1					
At the confluence with Hop Brook Tributary 4	0.3	60	100	120	150

* No Data Available

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
HOWARD BROOK					
At Whitney Road in Northborough	2.68	249	436	527	846
At Howard Street in Northborough	2.48	295	490	585	882
At Church Street in Northborough	1.92	261	425	505	738
HUCKLEBERRY BROOK					
At the confluence with the Charles River at Cedar Swamp Pond in Milford	3.5	214	369	485	664
At the confluence of Ivy Brook in Milford	1.4	115	210	270	380
IVY BROOK					
At the confluence with Huckleberry Brook in Milford	1.5	110	190	230	360
2,000 feet upstream of the confluence with Huckleberry Brook in Milford	1.2	100	160	200	310
JACKSTRAW BROOK					
At the confluence with Sullivan Brook	2.9	280	420	490	660

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
JACKSTRAW BROOK - continued					
Approximately 270 feet downstream of Hopkington Road	1.7	190	290	340	460
Approximately 1,900 feet upstream of Warren Street	0.7	100	160	190	250
KETTLE BROOK (EAST)					
At Curtis Pond Outlet in Worcester	32.8	400	570	780	1250
At USGS Gage Station No. 01109500 in Worcester	31.3	260	310	330	1670
KETTLE BROOK (TOWN OF AUBURN)					
Interstate Route 290 in Auburn	30.1	950	2100	2850	5500
KETTLE BROOK (WEST)					
Between Auburn and Paxton in Worcester	18.1	930	2050	2770	5380
LEADMINE BROOK					
Upstream of Leadmine Road in Sturbridge	1.4	110	189	232	366

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
LEADMINE BROOK - continued					
Upstream of state boundary in Sturbridge	2.9	173	295	361	562
LEBANON BROOK					
At the confluence with Quinebaug River in Southbridge	10.0	440	740	905	1390
At Old North Woodstock Road in Southbridge	9.4	410	685	835	1285
800 feet downstream of Lebanon Hill Road in Southbridge	8.4	365	615	750	1150
LITTLE NUGGET BROOK					
At Pikes Pond outlet in Charlton	7.0	382	817	1097	2079
At Pikes Pond inlet in Charlton	5.2	305	653	877	1663
At Massachusetts Turnpike in Charlton	4.1	254	543	729	1383
At Northside Turnpike in Charlton	3.2	213	457	613	1163

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
LITTLE RIVER					
About 400 feet downstream of Turner Road in Charlton	10.5	514	1101	1478	2803
At U. S. Route 20 in Charlton	8.6	445	952	1278	2423
LOWES BROOK					
At the French River in Oxford	8.8	446	754	922	1423
At Huguenot Road in Oxford	8.0	430	730	892	1380
At Sutton Brook in Oxford	2.4	173	298	366	574
LYNDE BROOK					
Above State Route 9 (Main Street) in Leicester	3.0	200	343	422	660
McKINSTRY BROOK					
At the confluence with Quinebaug River in Southbridge	8.0	405	680	835	1285
MEADOW BROOK					
At Oak Street in Shrewsbury	1.43	121	210	258	408

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
MIDDLE RIVER					
At Worcester corporate limits	61.5	2390	3560	4140	5360
MILL BROOK					
At Hudson / Bolton town line	4.9	190	305	362	536
Mill Road	3.5	145	226	262	360
MILL BROOK #1					
At the confluence with French River	10.7	163	210	233	317
MILL BROOK CONDUIT					
At Salisbury Pond in Worcester	6.39	903	1144	1303	1587
At Grove Street in Worcester	6.01	792	986	1113	1344
At Mill Brook Street in Worcester	5.62	688	836	946	1131
At West Boylston Terrace in Worcester	5.08	545	664	737	872
At Neponset Street in Worcester	4.5	453	542	602	705

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
MILL BROOK CONDUIT – continued					
At the confluence with Weasel Brook in Worcester	4.31	414	498	554	656
At the outflow from Indian Lake in Worcester	2.81	78	106	143	195
At the inflow into Indian Lake in Worcester	2.81	603	783	860	1152
MILL RIVER					
Harris Pond in Blackstone	*	1470	2590	3100	4600
Above Hop Brook in Blackstone	*	1300	2250	2750	3850
At the Blackstone / Mendon corporate limits	24.8	1340	2310	2800	4400
At the confluence of Round Meadow Brook in Mendon	22.3	1100	1870	2270	3540
At the confluence of Muddy Brook in Mendon	13.7	510	830	1000	1520
1,200 feet upstream of Neck Hill Road in Hopedale	13.1	470	760	910	1390

* No Data Available

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
MILL RIVER – continued					
1,000 feet downstream of Mill Street in Hopedale	12.3	430	690	820	1240
400 feet upstream of Mendon Street in Hopedale	11.2	360	570	680	1010
At Hopedale Pond Dam	10.8	340	530	630	940
At the head of Hopedale Pond	5.8	780	1320	1590	2480
Downstream of Milford Street Bridge in Milford	4.4	780	1320	1590	2480
Upstream of Fisk Pond in Milford in Milford	2.2	540	880	1050	1620
800 feet upstream of Camp Road Bridge in Milford	1.0	300	450	520	760
400 feet below Milford Street bridge in Upton	4.4	670	1110	1330	2070
2,000 feet above Milford Street bridge in Upton	3.0	540	880	1050	1620
At Fiske Pond in Upton	2.2	460	730	860	1320
800 feet above Camp Road bridge in Upton	0.9	300	450	520	760

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
MISCOE BROOK					
At confluence with Silver Lake (West River) in Grafton	5.6	203	310	365	652
Downstream of Cider Mill Pond Dam in Grafton	5.4	195	296	348	616
Downstream of Merriam Road in Grafton	2.9	122	183	214	475
Downstream of Adams Road in Grafton	1.4	71	105	121	228
MUDDY BROOK					
At the confluence with the Mill River in Mendon	6.3	350	600	740	1140
At the confluence with Spring Brook in Mendon	3.8	250	420	520	800
At the George Street bridge in Mendon	2.0	160	270	330	510
MUMFORD RIVER					
At confluence with Blackstone River in Uxbridge	54.9	1510	2880	3740	6750

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
MUMFORD RIVER – continued					
At confluence of Cold Spring Brook in Uxbridge	51.0	1430	2730	3550	6410
At State Route 122 bridge in Uxbridge	50.4	1430	2730	3540	6390
At Uxbridge / Sutton corporate limits	33.3	1060	2030	2640	4750
At State Route 146 bridge in Uxbridge	31.6	1030	1970	2560	4620
At Linwood Pond Dam in Northbridge	49.8	1420	2700	3510	6340
At head of Linwood Pond in Northbridge	48.5	1390	2650	3440	6200
At Meadow Pond Dam in Northbridge	47.4	1370	2620	3400	6130
Below confluence with Whitins Pond in Northbridge	34.3	1090	2090	2710	4890
Upstream of Gilboa Pond Dam in Douglas	29.8	990	1880	2440	4410
Upstream of Charles Street bridge in Douglas	28.4	950	1820	2370	4270

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
MUMFORD RIVER – continued					
Upstream of confluence of Centerville Brook in Douglas	23.0	830	1590	2060	3720
Upstream of confluence of Caswell Brook in Douglas	21.9	800	1530	1990	3580
Upstream of Douglas / Sutton corporate limits	12.0	520	1000	1300	2340
NASHUA RIVER					
At the downstream corporate limits in Clinton	113.4	1100	2900	4900	7000
At State Route 2 Bridge in Lancaster	154.69**	4300	8600	11800	17000
At Harvard Road Bridge in Lancaster	149.45**	5200	10000	14000	28000
0.5 mile downstream of confluence with the North Nashua River in Lancaster	138.89**	6400	13200	17900	35100
At the confluence with the North Nashua River in Lancaster	7.98**	1100	2900	4900	7000

** Does not include 107 square miles regulated by Wachusett Reservoir

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
NASHUA RIVER – continued					
At Hudson/Harvard Town Line	153.0	5200	10000	14000	28000
At the downstream corporate limits of Harvard / Bolton	183.9	5400	9100	11600	18000
Above the confluence with Catacoonamug Brook in Harvard	161.0	5100	8600	11800	17000
At State Route 2 in Harvard	154.69	4300	8600	11800	24000
At still River Depot Road in Harvard	149.96	5200	10000	14000	28000
NORTH BROOK					
Stream Mouth in Berlin	16.94	1217	2036	2510	3712
Whitney Street in Berlin	15.29	1192	1999	2460	3636
Crosby Street in Berlin	14.38	1031	1681	2020	2904
Jones Road in Berlin	11.29	666	1042	1239	1750
10.0 feet upstream of Linden Street in Berlin	10.31	636	970	1131	1546
West Street in Berlin	7.35	1409	2300	2736	3825
200 feet downstream of Randall Road in Berlin	7.33	1403	2291	2725	3810

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
NORTH BROOK – continued					
Randall Road in Berlin	3.45	672	115	1336	1889
Conrail bridge in Berlin	2.01	494	809	963	1253
1,000 feet downstream of Asphalt Road in Berlin	1.47	385	622	735	944
NORTH NASHUA RIVER					
At the confluence with the Nashua River in Lancaster	130.49	6060	12350	16700	31200
At the Lancaster / Leominster town boundary	107.73	6000	13000	18000	34500
O'BRIEN BROOK					
At the confluence with Godfrey Brook in Milford	0.38	90	130	160	240
PICCADILLY BROOK					
At Westborough Reservoir in Westborough	1.3	280	655	930	1420
At Hopkinton Road in Westborough	1.8	335	708	965	1460

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
PIKES POND TRIBUTARY					
At Pikes Pond inlet in Charlton	1.6	125	267	358	679
About 1,200 feet downstream of Conrail right-of-way in Charlton	1.2	98	210	282	535
QUICK STREAM					
In Town of Blackstone	*	130	360	440	630
QUINEBAUG RIVER					
At Connecticut / Massachusetts boundary	155.6	2800	7200	10500	19900
At Dudley / Southbridge corporate limits	148.7	2480	6300	9100	17600
At the American Optical Company Dam in Southbridge	126.8	1800	4500	6300	10400
Upstream of Cohasse Brook in Southbridge	122.3	1700	3920	5500	8900
Upstream of Cady Brook in Southbridge	108.7	1650	2000	2800	4000
At the Westville Reservoir in Southbridge	99.1	1600	1800	2500	3000

* No Data Available

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
QUINEBAUG RIVER – continued					
At East Brimfield Dam outlet in Sturbridge	67.5	1000	1100	1200	2000
At Westville Dam outlet in Sturbridge	99.1	1600	1800	2500	3000
QUINSIGAMOND RIVER					
Upstream of confluence with Blackstone River in Grafton	37.3	650	1105	1330	2290
5,900 feet upstream of confluence with Blackstone River in Grafton	36.3	630	1065	1290	2200
Upstream of Pleasant Creek in Grafton	35.1	610	1025	1230	2100
Upstream of Lake Ripple Dam in Grafton	34.5	650	1090	1340	2150
Upstream of head of Lake Ripple in Grafton	31.2	570	950	1160	1840
Upstream of confluence Big Bummet Brook in Grafton	28.1	390	580	680	980
RAMSHORN BROOK (TOWN OF AUBURN)					
At Swanson Road in Auburn	8.3	700	1070	1360	2500

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
RAMSHORN BROOK (TOWN OF AUBURN) - continued					
At Pondville Pond in Auburn	1.9	210	340	550	1100
RAMSHORN BROOK (TOWN OF MILLBURY)					
At confluence with Pondville Pond in Millbury	4.8	760	1210	1560	2040
At Carleton Street in Millbury	4.2	465	720	950	1280
At West Main Street in Millbury	3.3	230	325	465	675
At outflow structure from Ramshorn Pond in Millbury	2.5	103	200	261	453
RAWSON HILL BROOK					
At Rawson Hill Dam in Shrewsbury	1.5	45	67	85	280
RIVERDALE MILLS SLUICE GATES AND TAIL RACE					
At Riverdale Street in Northbridge	*	445	1075	1284	2060

* No Data Available

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
RUTTERS BROOK					
At the confluence with Sullivan Brook	3.9	360	540	640	840
At the confluence with Rutters Brook Tributary 1.1	1.2	160	240	290	380
Approximately 560 feet downstream of East Main Street	0.7	120	180	210	280
RUTTERS BROOK TRIBUTARY 1					
At the confluence with Rutters Brook Tributary 1.1	1.3	170	260	300	400
Approximately 0.8 miles downstream of Walkup Street	1.0	140	220	250	340
Approximately 1,150 feet downstream of Walkup Street	0.3	60	100	110	150
RUTTERS BROOK TRIBUTARY 1.1					
At the confluence with Rutters Brook Tributary 1	0.9	120	190	220	300

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
SEVENMILE RIVER					
At Spencer / East Brookfield corporate limits	39.1	1550	2900	3800	6150
Upstream of the confluence of Cranberry River in Spencer	31.6	1250	2220	2880	4520
SEWALL BROOK					
Below Sewall Pond in Boylston	2.7	189	325	399	624
Above Sewall Pond in Boylston	1.7	131	226	278	426
At the dam 2,000 feet below State Route 140 in Boylston	1.2	101	175	216	340
SINGLETARY BROOK					
At confluence with Blackstone River in Millbury	6.3	520	895	1040	1380
At State Route 146 in Millbury	6.0	430	725	820	990
SOUTHWICK BROOK					
Upstream of confluence with Mumford River in Douglas	0.9	80	140	170	280

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
STALL BROOK					
At the Milford / Medway town boundary	1.5	100	160	200	360
STILL RIVER					
At Hudson/Harvard Town Line	4.12	170	250	310	450
STONE BROOK					
At Brook Street in Auburn	1.9	210	340	550	1100
Approximately 3,200 feet downstream of South Street in Auburn	0.6	120	190	310	610
STONY BROOK					
Approximately 1,400 feet downstream of Stony Brook Reservoir Dam	22.5	1240	1820	2150	2830
Approximately 1.0 mile upstream of Stony Brook Reservoir Dam	12.7	760	1130	1340	1770
Approximately 1,900 feet downstream of Boston Road	12.0	750	1120	1320	1750
Approximately 1,600 feet upstream of Boston Road	11.2	720	1070	1260	1670

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
STONY BROOK - continued					
Approximately 1,200 feet downstream of White Bagley Road	10.5	680	1020	1210	1600
Approximately 470 feet downstream of Cordaville Road	9.7	670	1000	1180	1550
Approximately 830 feet downstream of Parkerville Road	7.9	580	870	1030	1360
STONY BROOK TRIBUTARY 2					
At the Sudbury Reservoir in Southborough	1.27	70	100	120	150
SUDBURY RIVER					
Approximately 1,050 feet downstream of Howe Street	23.8	1290	1890	2240	2940
Approximately 190 feet downstream of Cordaville Street	21.4	1150	1700	2010	2650
Approximately 750 feet upstream of Fay Court	19.7	1130	1670	1970	2590
Approximately 140 feet upstream of Fruit Street	18.4	1080	1590	1880	2470

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
SUDBURY RIVER TRIBUTARY 12					
At the confluence with Sudbury River in Southborough	1.41	90	130	150	200
SULLIVAN BROOK					
At Interstate 90 / Massachusetts Turnpike	17.6	1090	1610	1900	2490
Approximately 0.8 miles upstream of Interstate 495	9.4	680	1010	1190	1570
Approximately 1.2 miles upstream of Interstate 495	7.0	530	800	940	1250
TATNUCK BROOK					
At Coes Reservoir Outlet in Worcester	10.8	1430	2330	2770	3450
At Patch Reservoir Outlet in Worcester	9.0	1670	2610	3120	4250
At Cook Pond Outlet in Worcester	7.0	1100	1830	2250	3300
TOWN MEADOW BROOK					
Above Greenville Road in Leicester	8.7	452	765	935	1444

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
TOWN MEADOW BROOK - continued					
Above Pine Street in Leicester	3.6	228	389	477	743
Above State Route 9 (Main Street) in Leicester	2.9	184	314	385	600
TRIBUTARY 1					
At outlet from New Pond in Dudley	2.0	128	219	269	420
At private road upstream of New Pond in Dudley	1.3	89	153	188	294
TRIBUTARY TO ELIZABETH BROOK					
At the confluence with Elizabeth Brook in Harvard	2.41	130	200	240	330
TRIBUTARY TO WAUSHACUM BROOK					
At confluence with Waushacum Brook in West Boylston	1.7	140	250	310	470
Upstream of confluence of unnamed brook in West Boylston	0.2	17	30	40	60

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
UNNAMED TRIBUTARY					
At Pondville Road in Auburn	0.3	250	270	310	340
UNNAMED TRIBUTARY TO MAYO POND					
At confluence with Mayo Pond in Millbury	0.6	310	540	615	745
WALKER POND					
Upstream of Massachusetts Turnpike in Sturbridge	3.8	213	362	443	688
WAUSHACUM BROOK					
At confluence with Wachusett Reservoir in West Boylston	8.3	235	410	520	840
Upstream of confluence of Tributary to Waushacum Brook in West Boylston	6.4	95	170	210	340
WEST BROOK					
At Entrance to Culvert in Shrewsbury	3.4	202	353	403	675
At Main Street in Shrewsbury	2.46	174	298	366	574

TABLE 9 – SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGES (CUBIC FEET PER SECOND) 10-PERCENT ANNUAL CHANCE	2-PERCENT ANNUAL CHANCE	1-PERCENT ANNUAL CHANCE	0.2-PERCENT ANNUAL CHANCE
WEST RIVER					
At Hartford Avenue bridge in Upton	13.1	560	950	1160	1770
At confluence with Baker Pond in Upton	7.3	370	630	770	1170
At Upton / Grafton corporate limits	6.2	330	560	680	1040
WEST RIVER (TOWN OF UXBRIDGE)					
At confluence with Blackstone River in Uxbridge	37.9	510	790	940	1400
At confluence of Rock Meadow Brook in Uxbridge	34.1	375	400	600	800
WRACK MEADOW BROOK					
Stream Mouth in Berlin	7.33	1403	2291	2725	3810
West Street in Berlin	3.87	740	1199	1422	1980
Boylston Road in Berlin	3.78	723	1171	1389	1934

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals. Users should be aware that flood elevations shown on the FIRM represent rounded whole-foot elevations and may not exactly reflect the elevations shown on the Flood Profiles or in the Floodway Data tables in the FIS report. Flood elevations shown on the FIRM are primarily intended for flood insurance rating purposes. For construction and/or floodplain management purposes, users are cautioned to use the flood elevation data presented in this FIS in conjunction with the data shown on the FIRM.

Cross section data for the below-water sections were obtained from field surveys. Cross sections were located at close intervals above and below bridges, culverts, and dams in order to compute the significant backwater effects of these structures. In addition, cross sections were taken between hydraulic controls whenever warranted by topographic changes.

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross section locations are also shown on the FIRM.

The hydraulic analyses for this study were based on unobstructed flow. The flood elevations shown on the Flood Profiles (Exhibit 1) are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

Flood profiles were drawn showing the computed water surface elevations for floods of the selected recurrence intervals.

For each community participating in this partial FIS within Worcester County that has a previously printed FIS report, the hydraulic analyses described in those reports have been compiled and are summarized below.

Precountywide Analyses

In the Town of Paxton, there were no detailed studies and no hydraulic analyses performed in the effective FIS.

In the Towns of Bolton, Northborough, and Shrewsbury, for the areas studied by approximate methods, information on flooding was utilized, including backwater elevations for detailed reaches, wetlands information, aerial photos, historic observation, and field survey. In Bolton, the emergency phase Flood Hazard Boundary Map was also utilized (Reference 97). In Northborough, the emergency phase Flood Hazard Boundary Map and previous flood related studies were utilized (References 16, 31, 32, 42, 61 and 98 through 110), and in Shrewsbury the emergency phase Flood Hazard Boundary Map and previous flood related studies were utilized in the study (References 57, 106, 111 and 112 through 118).

In the Town of Milford, for the areas studied by approximate methods, the extent of the 1-percent-annual-chance flood was determined using a regional relationship developed between the drainage area and depth of flooding based on a regression analysis of gaged, small drainage area streams in Massachusetts.

In the Town of Northbridge, the areas studied by approximate methods were delineated considering USGS Flood Prone Area Maps, USGS topographic maps, a regional relationship developed between the drainage area and depth of flooding based on a regional analysis of gaged small drainage area streams in Massachusetts and the Flood Hazard Boundary Map for the Town of Northbridge (Reference 119 and 120). In Worcester, approximate study methods were used to study Cascade Brook, Poor Farm Brook from the Worcester-Shrewsbury corporate limits to approximately 1,200 feet upstream, Green Hill, Flint, Salisbury, Bell, and Burncoat Park Ponds, Lake Quinsigamond, and the Rooney and Shrewsbury Street areas. Field investigation in conjunction with hydrologic and hydraulic calculations was used to delineate areas prone to a 1-percent-annual-chance of flooding. In Westborough, this included USGS studies on the Assabet River (Upper Reach) tributaries (Reference 32) and on the Upper Sudbury River (Reference 59), and the study by the USACE of the Assabet River (Reference 121). Also utilized was historic flood information (References 24, 25, 26, and 110), backwater data from streams studied by detailed methods, wetlands information, aerial photos, and emergency phase Flood Hazard Boundary Maps (Reference 122).

Structures and channel cross section for the backwater analysis for the Nashua River, Still River, Great Brook and Mill Brook in Bolton; Big Bummet Brook, West Brook, Meadow Brook, and Rawson Hill Brook in Shrewsbury were field surveyed. Cross sections were located at close intervals above and below bridges and culverts in order to compute the significant backwater effects in urbanized areas. In Bolton, overbank extensions of field surveyed cross sections and additional sections needed for hydraulic continuity were taken from the 4 foot contour interval topographic maps prepared by Teledyne Geotronics (Reference 123), and from maps prepared by Raytheon at a scale of 1:2400 and a contour interval of 2 feet (Reference 124). In Shrewsbury, overbank extensions of field-surveyed channel cross sections and additional sections needed for hydraulic continuity were taken from topographic maps at a scale of 1:2400, with a contour interval of 4 feet (Reference 111).

For the entire Mumford River and for the Southwick Brook in the Town of Douglas; the Quinsigamond River, Big Bummet Brook and West River in the Town of Grafton, the Charles River and Mill River in the Towns of Hopedale, Mendon and Milford; the Muddy Brook in the Town of Mendon, O’Brien Brook, Stall Brook, Godfrey Brook, Huckleberry Brook, and Ivy Brook in the Town of Milford; Dark Brook, Cold Spring Brook, and Whitins Pond in the Town of Sutton; Mill River, West River, and Center Brook in the Town of Upton; and the West River in the Town of Uxbridge, cross sections of the backwater analyses of the detailed study streams were located at close intervals above and below bridges in order to compute the significant backwater effects of these structures. In long reaches between structures, appropriate valley cross sections were also used. The below-water valley portions of cross sections were obtained by field measurement. Bridge plans were utilized to obtain elevation data and structural geometry. All bridges for which plans were unavailable or out-of-date were surveyed. Except for the Mumford River in Northbridge, the valley portions of the cross section data for the detail study streams were obtained from topographic maps in Douglas (Reference 125), Hopedale, (Reference 6), Mendon (Reference 126), Milford (Reference 127), Millville (Reference 128), Sutton (Reference 129), Upton (Reference 130) and Uxbridge (Reference 131).

In the Town of Grafton, the valley portions of the cross section data for the Quinsigamond River, from the upstream side of Lake Ripple to a point approximately 30 feet downstream of the Factory Dam; Axtell Brook, from the confluence with lake Ripple to the downstream side of the Massachusetts Turnpike; Miscoe Brook, from Silver Lake upstream of Old Upton Road to the upstream side of Adams Road; and Cronin Brook, from its confluence with the Blackstone River to the upstream side of Millbury Street were obtained by field measurement and/or from topographic maps. The below-water portions of the cross section data were obtained by field surveyor interpolated based on field survey data and topographic mapping.

For the Quinsigamond River, Big Bummet Brook, West River, Axtell Brook, Miscoe Brook and Cronin Brook in the Town of Grafton, water surface elevations of floods of the selected recurrence intervals were computed using the USACE HEC-2 step-backwater computer program (Reference 132). For the Quinsigamond River, from the upstream side of Lake Ripple to a point approximately 30 feet downstream of the Factory Dam; Axtell Brook, from the confluence with lake Ripple to the downstream side of the Massachusetts Turnpike; Miscoe Brook, from Silver Lake upstream of Old Upton Road to the upstream side of Adams Road; and Cronin Brook, from its confluence with the Blackstone River to the upstream side of Millbury Street, additional 1-percent-annual-chance water surface elevations was developed for small, isolated locations in connection with subdivision plans submitted for review by community officials. For locations where such data has been developed, the information should be considered the "best available information" and used for setting building first floor elevations where appropriate.

Structures and channel cross sections for the backwater analysis were field surveyed for the Assabet River, in the Towns of Berlin and Northborough; the upper reach of North Brook, and Assabet River Branch No.2 in Berlin; the Assabet River (Lower and Upper Reach), Piccadilly Brook and Denny Brook in Westborough. Cross sections were located at close intervals above and below bridges and culverts in order to compute the significant backwater effects in urbanized areas. Overbank extensions of field surveyed channel cross sections and additional sections needed for hydraulic continuity were taken from topographic maps, at a scale of 1:2400, with a 4-foot contour interval (Reference 133) in Berlin; topographic maps at a scale of 1:9600, with a contour interval of 10 feet (Reference 99) in Northborough.

Structure and channel cross section survey data for hydraulic analyses for Howard Brook and Cold Harbor Brook (Lower and Upper Reach) in the Town of Northborough were provided by NRCS (Reference 32). For all hydraulic analyses, present culvert conditions were used and recent modifications were taken into consideration in the use of flood marks in Northborough.

In the Town of Berlin, from the Assabet River to the Ross Dam, from West Street to downstream of Randall Road of North Brook, and from the confluence with North Brook to approximately 100 feet downstream of Boylston Road of Wrack Meadow Brook, field survey data were provided by NRCS (Reference 134). For North Brook, additional cross sections needed for hydraulic continuity were taken from 1:1,200 scale, two-foot contour interval maps provided by the Town of Berlin (Reference 135). The starting water surface elevations for the computer model for the Assabet River were taken from the original FIS of the Town of Hudson, performed by Harris-Toups Associates (Reference 136). The elevations were projected through Marlborough and coordinated with the FIS being performed by Howard, Needles, Tammen and Bergendoff (Reference 137). The starting water surface elevation for the upper reach of North Brook was taken from the NRCS profiles of the lower reach (Reference 32). For Assabet River Branch No.2, starting water surface elevations were determined by the slope-area method. For the Assabet River in the Towns of Berlin and Northborough, the upper reach of North Brook, and Assabet River Branch No.2, water surface elevations of floods of the selected recurrence intervals were computed through use of the USACE HEC-2 step-backwater computer program (References 138, 139, and 140). The computed program for these streams was calibrated to the August 1955 flood through flood marks obtained through newspaper articles, the USACE report on the Assabet River (References 98, 121, and 141), and interviews with local residents. For the lower reach of North Brook and for Wrack Meadow Brook, flood elevations were taken from profiles developed by the NRCS in their Assabet River (Upper Reach) study (Reference 32). For North Brook, elevations at the point of confluence with the Assabet River were coordinated with the Assabet River profiles and for Wrack Meadow Brook elevations at the point of confluence with North Brook were coordinated with the North Brook profiles.

Starting water surface elevations for the Assabet River in the Town of Northborough were taken from the USACE report on the Assabet River (Reference 98). The elevations used were projected back from backwater resulting from the Tyler Dam project. For both Howard Brook and Cold Harbor Brook (Lower and Upper Reach), flood elevations were taken from profiles developed by the NRCS in their study of the Assabet River (Upper Reach) tributaries (Reference 32). Also, elevations for Cold Harbor Brook (Lower Reach) at the point of confluence with the Assabet River were coordinated with the Assabet River profile; for Howard Brook, elevations at the point of confluence with Cold Harbor Brook (Lower Reach) were coordinated with the Cold Harbor Brook (Lower Reach) profiles. Thus, the most downstream elevations on these streams may not agree exactly with profiles prepared by the NRCS.

In the Town of Westborough, the Assabet River (Upper Reach), Piccadilly Brook, and Denny Brook water surface elevations for floods of the selected recurrence intervals were computed through use of the USACE HEC-2 step-backwater computer program (Reference 140). The computer models for the Assabet River (Upper Reach), Piccadilly Brook, and Denny Brook were calibrated to floodmarks of the March 1968 flood. Floodmarks were obtained from newspaper articles (References 25 and 26), a USGS publication on the flood of March 1968 on the Sudbury, Assabet, and Concord Rivers (Reference 110), and interviews with local residents. Starting water surface elevations for the HEC-2 model on the Assabet River (Lower Reach) were based on backwater from the Tyler Dam Project (Reference 141). Starting water surface elevations for the Assabet River (Upper Reach) were based on backwater from the Nichols Dam (Reference 32). Starting water surface elevations for Piccadilly Brook were obtained from profiles prepared by the NRCS (Reference 59) on Piccadilly Brook below Hopkinton Road. For Denny Brook, the starting water surface elevations were computed by the slope-area method. Flood profiles were drawn showing computed water surface elevations to an accuracy of 0.5 foot for floods of the selected recurrence intervals.

Also in the Town of Westborough, water surface elevations for floods of the selected recurrence intervals for Jackstraw Brook and Rutters Brook were obtained from profiles developed by the NRCS in their study on the Upper Sudbury River tributaries (Reference 59). On Jackstraw and Rutters Brooks, the field survey prepared by the NRCS for their Upper Sudbury River Study (Reference 59) was used and was supplemented by additional field-surveyed cross sections. Overbank extensions of field-surveyed channel cross sections and additional sections needed for hydraulic continuity were taken from topographic maps at a scale of 1:2,400 with a contour interval of 4 feet (Reference 142).

Starting water- surface elevations for the Mill River in the Town of Mendon were calculated using the slope/area method. Starting water- surface elevations for the Mill River in the Town of Hopedale were obtained from the FIS for the Town of Mendon (Reference 143). And in the Towns of Milford and Upton, starting water- surface elevations for the Mill River were obtained from the FIS for the Town of Hopedale (Reference 144). Water surface elevations for the Mill River in Upton were computed through the use of the USACE HEC-2 step- backwater computer program (Reference 140). In Upton, those areas where the analysis indicated supercritical flow conditions, critical depth was assumed for the flood flow elevation because of the inherent instability of supercritical flow.

For the Charles River and Mill River in the Towns of Hopedale and Mendon and for Muddy Brook in Mendon, water surface elevations of floods of the selected recurrence intervals were computed through the use of the USACE HEC-2 step-backwater computer program (References 145 and 146). Starting water surface elevations for the Muddy Brook in Mendon were calculated using the slope/area method.

Starting water surface elevations for the Charles River in the Town of Hopedale were obtained from the original FIS for the Town of Mendon (Reference 143). Starting water surface elevations for the Charles River in Mendon and Milford were obtained from the Town of Bellingham, Massachusetts (Norfolk County) FIS (Reference 147).

For the Charles River, Mill River, and Muddy Brook in the Town of Mendon, it was determined that certain bridges on the streams studied by detailed methods would not be included in the analyses due to the minimal effects they would have on flood elevations. In these instances, the location of the road where it crosses the stream is indicated on the profile but no structure with low chord and top of the road elevations is shown.

In the Town of Milford, for Godfrey Brook and Stall Brook, starting water surface elevations were determined using the slope/area method. Starting water surface elevations for O'Brien Brook, Huckleberry Brook, and Ivy Brook were taken from the Godfrey Brook, Charles River, and Huckleberry Brook flood profiles, respectively. Water surface elevations for floods of the selected recurrence intervals were computed through the use of the USACE HEC-2 step-backwater program (Reference 146).

Starting water surface elevations for the West River and Center Brook in the Town of Upton; and for the Mumford River and West River (Town of Uxbridge) in the Town of Uxbridge were determined by the slope/area option of the HEC-2 computer program (Reference 140, and 148 respectively). Water surface elevations of floods of selected recurrence intervals were computed for the streams studied by detailed methods through the use of the USACE HEC-2 step- backwater computer program (Reference 140, and 148 respectively). In Upton, those areas where the analysis indicated supercritical flow conditions, critical depth was assumed for the flood flow elevation because of the inherent instability of supercritical flow.

In the Town of Auburn, cross sections for the backwater analyses for Kettle Brook, Dunn’s Brook, Ramshorn Brook, Stone Brook, and Unnamed Tributary were field surveyed. The cross sections were placed at specific intervals along the streams so that hydraulic properties would be accurately modeled. Additional cross sections were interpolated between certain surveyed cross sections as required by the step-backwater computer program. These cross sections were prepared from the field survey data and from USGS topographic maps (Reference 149).

Cross sections for Dark Brook #1 (Auburn Pond to Central Street) in the Town of Auburn were obtained from a combination of field surveys and measurements from design drawings (References 150, 151 and 132). Water surface elevations were computed using the USACE HEC-2 step-backwater computer program (Reference 132). Starting water surface elevations for Kettle Brook (Town of Auburn) were developed from a known stage-frequency relationship for Leesville Pond. For Dunn's Brook, from its confluence with Kettle Brook to Auburn Pond, starting elevations were developed from a known stage-frequency relationship for Kettle Brook (Town of Auburn). For Dark Brook #1 (Auburn Pond to Central Street) and Ramshorn Brook (Town of Auburn), from Auburn Pond to Pondville Pond, starting elevations were developed from a known stage-frequency relationship for Auburn Pond. In the 1991 updated study, the starting elevations for the restudied portion of Dark Brook #1 (Auburn Pond to Central Street) were taken from the hydraulic analysis of Dark Brook prepared for the previously printed FIS for the Town of Auburn (Reference 152). For Dark Brook #2 (Stoneville Pond to Leicester Street), starting elevations were taken from a known stage-frequency relationship for Stoneville Pond. For Stone Brook, from Pondville Pond to South Street, starting elevations were taken from a known stage-frequency relationship for Pondville Pond.

In the Town of Blackstone, water surface elevations for the Mill River, Tupperware Mill Canal, Harris Pond, Saranac Canal, and Quick Stream were computed using the USACE, HEC-2 step-backwater computer program (References 139, 153, and 154). Cross sections for the backwater analysis of the Mill River were field surveyed. The cross sections were placed at specific intervals along the river channels such that hydraulic properties would be accurately modeled by the computer. Sections were interpolated between certain surveyed sections as required by the step-backwater program. These interpolated sections were prepared from the survey data along with the aid of enlarged USGS mapping (Reference 155).

In the Town of Blackstone, on Quick Stream, bridge data for Elm Street were derived from field measurement. The stream profile and cross sections were derived from the available mapping. On the Saranac Canal, bridge data for St. Paul Street were also derived from field measurements. Manual standard step calculations were made by predicting flood stages in the canal. For the Tupperware Mill Canal, field surveyed cross sections were used to define the geometry and profile of the canal for hand calculations (Reference 155). The starting water surface elevations for the Mill River and Quick Stream study areas were developed from a known stage-discharge relationship for Harris Pond.

In the Town of Bolton, starting water surface elevations for the computer models for the lower reach of Great Brook were taken from the NRCS report on Elizabeth Brook in Stow (Reference 31). The starting elevations for the upper reach were based on computations by the NRCS of flood storage elevations at the East Bolton Dam (Reference 31). Mill Brook elevations were obtained from the FIS in Hudson prepared by Harris-Toups Associates (Reference 58). Water surface elevations for the Nashua River were taken from Profiles developed by Howard, Needles, Tammen and Bergendoff, for their FIS reports for the Towns of Harvard and Lancaster (References 61 and 62). The HEC-2 model for the Nashua River was calibrated to the March 1936 flood. Flood marks for this flood were published by the USGS in their report on the flood of March 1936 on New England Rivers (Reference 156). For Mill Brook and Great Brook, the HEC-2 model for each stream was checked with flood marks from the August 1955 storm (Reference 157). As stated previously, the Nashua River controls the floodplain of the lower Still River. For this reason, no profiles for the Still River has been included in this report. Flood profiles for the remaining detailed study streams were drawn showing computed water surface elevations to an accuracy of 0.5 foot for floods of the selected recurrence intervals.

In the Town of Boylston, cross sections for the backwater analysis of Sewall Brook were obtained from expanding the scale of the existing Shrewsbury quadrangle map prepared by the USGS from a scale of 1:24,000 to 1:4,800 and also from field measurement (Reference 158). The below-water sections were obtained by field measurement. All bridges and culverts were field checked to obtain elevation data and structural geometry. Cross sections for the backwater analysis of Cold Harbor Brook (Town of Boylston) for both overbank and below-water sections as well as elevation data and structural geometry for all bridges and culverts were obtained from the NRCS report of the Assabet River (Upper Reach) (Reference 32).

Water surface elevations for Sewall Brook and Cold Harbor Brook (Town of Boylston) were computed using the USACE HEC-2 step-backwater computer program (Reference 140). Water surface elevations for Cold Harbor Brook (Town of Boylston), as presented in the NRCS report of the Assabet River (Upper Reach), were also computed using the NRCS WSP-2 computer program (References 32 and 159).

Starting water surface elevations for Sewall Brook in the Town of Boylston were obtained by calculating headwater elevations upstream of the Mill Road culvert. Starting water surface elevations Cold Harbor Brook (Town of Boylston) were those established on the upstream side of Church Street in Northborough, as shown in the NRCS report of the Assabet River (Upper Reach) (Reference 32)

In the Town of Charlton, cross sections for the Little River, Cady Brook, Deans Brook, Little Nugget Brook, and Pikes Pond Tributary were obtained from aerial photographs flown in December 1978 (Reference 160). The below-water sections were obtained by field measurement. All bridges, dams, and culverts were field checked to obtain elevation data and structural geometry. Water surface elevations of floods of the selected recurrence intervals were computed through the use of the USACE HEC-2 step-backwater computer program (Reference 140). Starting water surface elevations were calculated using the slope/area method.

In the Town of Clinton, flood profiles for the Nashua River and Counterpane Brook were computed using the USACE HEC-2 Computer Program (Reference 161). Starting water surface elevations for the Nashua River were taken from the FIS for the Town of Lancaster (Reference 162). For Counterpane Brook, starting water surface elevations were computed by the slope/area method. Flood profiles for the open channel portion of the stream were determined using the USACE computer program previously mentioned. For the 2,500 foot portion of Counterpane Brook enclosed in a concrete culvert, separate hand calculations were made. In order to determine the upstream starting water surface elevations, it was necessary to compute headwater and tailwater elevation-discharge relationships. Cross section data was obtained by field surveys conducted at bridges and road crossings on the Nashua River and Counterpane Brook.

In the Town of Douglas, starting water surface elevations for the Mumford River were taken from the FIS for the Town of Uxbridge (Reference 54). Starting water surface elevations for Southwick Brook were determined using the slope/area option of the USACE HEC-2 step-backwater computer program (Reference 148). Water surface elevations for the floods of selected recurrence intervals were computed through the use of the USACE HEC-2 step-backwater computer program (Reference 148).

In the Town of Dudley, cross sections for the backwater analyses of the French and Quinebaug Rivers and Tributary 1 were obtained from aerial photographs flown in December 1978 at a scale of 1:14,400 (Reference 163). The below water cross sections were obtained by field measurement. All bridges, dams and culverts were field surveyed to obtain elevation data and structural geometry. Water surface elevations for floods of selected recurrence intervals were computed through the use of the USACE HEC-2 step-backwater computer program (Reference 164). Starting water surface elevations for the French River were calculated using the slope/area method. Starting water surface elevations for the Quinebaug River were obtained from the Flood Plain Study for Thompson, Connecticut at the corporate limits (Reference 165). A rating curve was used to obtain starting water surface elevations for Tributary 1.

In the Town of Grafton, starting water surface elevations for the Quinsigamond River analyses were revised upstream of Lake Ripple Dam. A second spillway was added to the dam since the previous study was performed. In addition, assumptions concerning the availability of manually operated sluice gates to pass flow were revised. Starting water surface elevations for the Quinsigamond River were determined using the slope/area option of the USACE HEC-2 step-backwater computer program (Reference 132). For Big Bummet Brook, starting water surface elevations were taken from the Quinsigamond River profiles. Starting water surface elevations for the West River were taken from the FIS for the Town of Upton (Reference 166).

Starting water surface elevations for the Quinsigamond River at Lake Ripple Dam in the Town of Grafton were based on a rating curve developed for the dam. Manually operated sluice gates in the center of the dam between the two spillway sections and in a "flume" section on the west bank adjacent to the dam were not considered to be available to pass flow. Information received from community officials prior to the performance of the hydraulic analyses for the Quinsigamond River at Lake Ripple Dam did not provide justification acceptable to FEMA that the gates would be operated in an emergency. Subsequent to the intermediate CCO meeting, revised information concerning operation of the gates was transmitted to the study contractor (Reference 167). An amendment to the Town's Emergency Action Plan specifically addresses operation and maintenance of the gates so that they will be available to pass flow during a rainfall event (References 168 and 169).

The starting water surface elevation for the peak 10-percent-annual-chance return period flow in Axtell Brook in the Town of Grafton was based on a “normal" water surface elevation in Lake Ripple. For all other return period storms in Axtell Brook, starting water surface elevation was assumed to be the peak 10-percent-annual-chance return period storm elevation in Lake Ripple. Starting water surface elevations for Miscoe Brook were taken as the water surface elevations at the upstream end of Silver Lake shown on profile panel number 15P in the previous study. Starting water surface elevations for Cronin Brook were determined using the slope/area option of the HEC-2 program (Reference 132).

In the Town of Harvard, water surface elevations for Nashua River, Bowers Brook, Bennetts Brook, Cold Spring Brook, Elizabeth Brook and Tributary to Elizabeth Brook were computed through the use of the USACE HEC-2 step-backwater program (References 139 and 140). Starting water surface elevations for the Nashua River, Bowers Brook, and Bennetts Brook were obtained from the FIS for the Town of Ayer, Massachusetts (Middlesex County) (Reference 170). Starting water surface elevations for Cold Spring Brook and Tributary to Elizabeth Brook were determined using normal depth analyses. Starting water surface elevations for Elizabeth Brook were determined from information provided by the NRCS for the Delaney Dam project (Reference 31). Cross sections for the backwater analyses of the streams studied by detailed methods were obtained from topographic maps compiled by photogrammetric methods (References 171, 172, and 173). The below-water sections were obtained by field measurements and from previously compiled survey information. All bridges, dams, and culverts were surveyed to obtain elevation data and structural geometry in order to compute the significant backwater effects of these structures.

In the Town of Lancaster water surface profiles for the Nashua River, North Nashua River, and Goodridge Brook were computed through the use of the USACE HEC-2 step-backwater computer program (References 139 and 140). Starting water surface elevations for the Nashua River were determined by a series of backwater computations done for the FIS for the Town of Harvard (Reference 174). For Goodridge Brook and the North Nashua River, starting water surface elevations were taken from 1-percent-annual-chance elevations of the Nashua River at their respective confluences, assuming coincident flood flows. Cross section data were obtained from photogrammetric mapping (Reference 175). The below-water sections were obtained by field measurements and from previously compiled survey information. All bridges, culverts, and dams were surveyed to obtain elevation data and structural geometry in order to compute the significant backwater effects of these structures.

Cross sections for the backwater analyses of the French River, Lynde Brook and Town Meadow Brook in the Town of Leicester were obtained from aerial photographs flown in December 1978, at a negative scale of 1: 14,400 (Reference 176). The below water sections were obtained from field measurement. All bridges, dams and culverts were field checked to obtain elevation data and structural geometry. Water surface elevations of floods of selected recurrence intervals were computed through the use of the USACE HEC-2 step-backwater computer program (Reference 164). Starting water surface elevations were calculated using the slope/area method for Lynde Brook and from flood elevations on the French River at the Oxford-Leicester corporate limits as determined in the Town of Oxford precountywide FIS (Reference 177). The Town Meadow Brook starting water surface elevations were taken from the French River.

For the 1979 Town of Millbury FIS, Cross sections for Singletary Brook, Unnamed Tributary to Mayo Pond, Ramshorn Brook (Town of Millbury) and Dorothy Brook in Millbury were obtained from field surveys. The cross sections were placed at specific intervals along the watercourses so that hydraulic properties would be accurately modeled by the computer. Additional sections were interpolated between certain surveyed sections, as required by the step-backwater program. These sections were prepared from the survey data along with the aid of USGS topographic maps (Reference 178). All bridges, dams, and culverts were field surveyed to obtain elevation data and structural geometry.

The starting water surface elevation for Ramshorn Brook (Town of Millbury) was developed from water surface elevations on Pondville Pond. The starting water surface elevations for Dorothy and Singletary Brooks were developed from calculations of normal depth at their confluence with the Blackstone River. Starting water surface elevations for Unnamed Tributary to Mayo Pond were developed from known water surface elevations on Mayo Pond. Flood profiles were drawn showing computed water surface elevations for floods of the selected recurrence intervals. Between Brierly Pond and Mayo Pond, there is an area of shallow flooding less than 1-foot in depth, which occurs during the 1-percent-annual-chance flooding event. The elevations for Mayo Pond were determined in conjunction with the backwater analysis of Singletary Brook, and are shown on the Flood Profiles. Approximate elevations were determined on the basis of field investigation in conjunction with hydrologic and hydraulic calculations. Floodwaters from watershed areas upstream of Singletary Brook are attenuated at Singletary Pond. Adequate culvert capacity is provided at the Harris Road and westerly crossing of West Main Street over Singletary Brook with the 0.2-percent-annual-chance flood contained in the channel. There should not be any serious flooding in this area provided that the gate at the factory intake (downstream of the westerly crossing of Main Street) is fully opened in time of flood.

Water surface elevations at Dorothy Pond (from its outlet at the dam on the west side of Riverlin Road to a point just south of the Massachusetts Turnpike) and for Ramshorn Pond, part of Ramshorn Brook (Town of Millbury) (from a point approximately 1,300 feet downstream of Dolan Road to the upstream corporate limits) in the Town of Millbury, were computed using the HEC-2 step-backwater computer (Reference 179). Cross sections for the backwater analyses were field surveyed at dams and hydraulic structures. Additional cross sections were interpolated between surveyed cross sections using available topographic mapping to develop an accurate computer backwater model. For both Dorothy Pond and Ramshom Pond, the HEC-2 computer model was used to develop state-discharge rating curves for the HEC-l analysis. Peak discharges from the HEC-l analysis for the 10-, 2-, 1-, and 0.2-percent-annual-chance flood events were then reentered into the HEC-2 computer model to develop flood profiles for each pond. In all cases, the HEC-2 models were started downstream of the control dams using the slope/area method.

In the Town of Northbridge, cross sections for the Mumford River and Riverdale Mills Sluice Gates and Tail Race were obtained from field surveys. All bridges, dams, and culverts were field surveyed to obtain elevation data and structural geometry. Along certain portions of Riverdale Mills Sluice Gates and Tail Race, a profile base line is shown on the maps to represent channel distances as indicated on the flood profiles and floodway data tables.

Starting water surface elevations for the Mumford River in the Town of Northbridge were taken from the FIS for the Town of Uxbridge (Reference 180). The starting water surface elevations for Whitins Pond were taken from the Mumford River profile.

Water surface elevations for the Mumford River in Northbridge were computed using the USACE HEC-2 step-backwater computer program (References 148 and 181).

Water surface elevations for the Riverdale Mills Sluice Gates and Tail Race were computed using the USACE HEC-RAS Computer Program. The HEC-RAS model was started with a full valley cross section downstream of the mill taken from the HEC-2 model for the Blackstone River. The HEC-RAS model was then compared against the HEC-2 model for the Blackstone River by dividing the total 1-percent-annual-chance flow between the two models. Using trial and error, the models were run until the same water surface elevations were computed upstream of the dam for both models. Based on the divided flow analysis, approximately 87% of the 1-percent-annual-chance flood (or 8,420 cfs) flows under the Riverdale Street Bridge and through the main spillway of the dam while the remaining 13% (1,280 cfs) flows through the sluice gates.

In the Town of Oxford, cross sections for the backwater analyses of the French River and Lowes Brook were obtained from aerial photographs flown in December 1978 at a scale of 1.0 inch equals 1,200 feet (Reference 182). The below water sections were obtained by field measurement. All bridges, dams and culverts were field checked to obtain structural geometry. Water surface elevations of the floods of selected recurrence intervals were computed through the use of the USACE HEC-2 step-backwater computer program (Reference 183). The starting water surface elevation for the French River downstream of the Hodges Village Dam was taken from the Town of Webster FIS; upstream of the dam the starting water surface elevation was computed by normal slope/area method (Reference 184). The starting water surface elevation for Lowes Brook was also computed by normal slope/area method.

In the Town of Shrewsbury, starting water surface elevations for the HEC-2 computer model for Big Bummet Brook, West Brook, and Meadow Brook were determined by the slope-area method. Starting elevations for Rawson Hill Brook were taken from elevations determined by the SCS in their study of Rawson Hill Brook as part of the Assabet River (Upper Reach) tributaries (Reference 32). For the reach of Rawson Hill Brook below the Rawson Hill Dam, structure surveys and channel cross sections were obtained from the NRCS backup data for their study on the Assabet River (Upper Reach) tributaries (Reference 32). Water surface elevations for floods of the selected recurrence intervals were obtained by using the USACE HEC-2 computer program (Reference 185). The computer program, in general, was calibrated from the August 1955 flood through flood marks obtained from interviews with local residents and newspaper articles (Reference 186). Present culvert conditions were used and recent modifications were taken into consideration in the use of flood marks.

In the Town of Southborough, water surface profiles for the Sudbury River were computed through the use of the NRCS water surface profiles WSP-2 computer program (Reference 187). Water surface profiles for the Sudbury Reservoir, Stony Brook, Tributary to Sudbury River, and Tributary to Sudbury Reservoir were computed through the use of the USACE HEC-2 step-backwater computer program (References 139 and 140). Starting water surface elevations for the Sudbury River were determined from backwater computations determined in the FIS for the downstream Town of Ashland (Reference 188). Starting water surface elevations for the Sudbury Reservoir were determined from flood routing computations through the reservoir using the NRCS TR-20 computer program (Reference 16). Starting water surface elevations for Stony Brook were determined from backwater computations determined in the precountywide Town of Framingham FIS (Reference 17). Starting water surface elevations for Tributary to Sudbury River and Tributary to Sudbury Reservoir were determined at the confluences with the waterways which they feed. Cross sections, below-water sections, and bridge, culvert, and dam sections for the Sudbury River were supplied by the NRCS. Cross sections for the backwater analyses of the Stony Brook / Sudbury Reservoir, Tributary to Sudbury River, and Tributary to Sudbury Reservoir were obtained from topographic maps compiled by photogrammetric methods (Reference 18). The below-water sections were obtained by field measurements. All bridges, culverts, and dams were surveyed to obtain elevation data and structural geometry in order to compute the significant backwater effects of these structures. In those areas where hydraulic analysis indicated supercritical flow conditions, critical depth was assumed for the flood elevation because of the inherent instability of supercritical flow.

In the Town of Southbridge, water surface elevations for the Quinebaug River, McKinstry Brook, Lebanon Brook, Cady Brook, and Cohasse Brook were computed through the use of the USACE HEC-2 step-backwater computer program (Reference 140). Starting water surface elevations were calculated using the slope/area method. For the Quinebaug River and Cady Brook, cross sections, below-water sections, and structural geometry were obtained from the backup data of the Southbridge Flood Plain Information report and were field checked where discrepancies with topographic maps produced for this study were found (Reference 9). Cross sections for the backwater analyses of McKinstry Brook, Lebanon Brook, and Cohasse Brook were obtained from aerial photographs flown in November and December 1978 (References 189 and 190). The below-water sections were obtained by field measurement. All bridges, dams, and culverts were field checked to obtain elevation data and structural geometry.

In the Town of Spencer, cross sections for the Sevenmile River were obtained by field survey and were located at typical valley sections and restrictions such as roads, bridges and dams. In the original study and in the 1990 revision, water surface elevations for floods of the selected recurrence intervals were computed through use of the NRCS WSP-2 computer program (Reference 187). The hydraulic computations used in this study did not take into account a bridge which was constructed in 1972. This bridge is a seven span bridge, labeled "Bridge No. S-23-25" by the Massachusetts Department of Public Works. Modifications have been made to include the backwater from this structure at cross section B. Construction plans for this bridge were obtained from the Massachusetts Department of Public Works. Backwater computations were determined by the hydraulic methods found in the U. S. Department of Transportation report entitled Hydraulics for Bridge Waterways (Reference 191). In the original study the limits of the 1- and 0.2-percent-annual-chance flood boundaries were delineated by the NRCS on aerial photomosaics (Reference 192). A stereoscopic study of the aerial photography by the study contractor assisted in the delineation of flood boundaries between surveyed cross sections. An attempt was made to field verify all boundaries, however the limits of flooding differ slightly on the ground and on the map, especially in swampy or wooded areas.

In the Town of Sturbridge, cross sections for the backwater analyses for the Quinebaug River, Cedar Meadow Brook, Hamant Brook, Leadmine Brook, Cedar Pond, Walker Pond, and Quacumquasit Pond were obtained from aerial photographs flown in December 1978 (Reference 193). The below-water sections were obtained by field measurement. All bridges, dams and culverts were field checked to obtain elevation data and structural geometry. The acceptability of all assumed hydraulic factors, cross sections and hydraulic structure data for the Quinebaug River was checked by computations that duplicated historic flood profiles. Water surface elevations of floods of selected recurrence intervals were computed through the use of the USACE HEC-2 step-backwater computer program (Reference 164). Starting water surface elevations for Cedar Meadow Brook, Hamant Brook, Leadmine Brook and the Quinebaug River downstream of the East Brimfield Dam were calculated using the slope/area method. Starting water surface elevations for Cedar Pond and Walker Pond were developed from elevation-discharge curves. Starting water surface elevations for the Quinebaug River downstream of the Westville Dam were taken from the Town of Southbridge, Massachusetts FIS (Reference 194).

In the Town of Sutton, starting water surface elevations for the Mumford River were taken from the Flood Insurance Studies for the Towns of Grafton and Douglas, respectively (References 195 and 196). Starting water surface elevations for Dark Brook were taken from the Mumford River profile. Elevations within the community of each of these water courses were determined through application of the USACE HEC-2 computer program (Reference 148). Starting water surface elevations for Cold Spring Brook were calculated by the slope/area method. The elevations of the 10-, 2-, 1- and 0.2-percent-annual-chance floods on Whitins Pond were taken from the FIS for the Town of Northbridge (Reference 197).

In the Town of Webster, cross sections for the backwater analyses of the French River and Mill Creek were obtained from aerial photographs at a scale of 1:2,400 with a contour interval of 5 feet (Reference 198). The below water sections were obtained from field measurement. All bridges, dams, and culverts were field checked to obtain elevation data and structural geometry. Water surface elevations of floods of the selected recurrence intervals were computed through the use of the USACE HEC-2 step-backwater computer program (Reference 199). Flood profiles were drawn showing computed water surface elevations for floods of the selected recurrence intervals. Starting water surface elevations for the French River were calculated using the slope/area method. Starting water surface elevations for Mill Brook #1 were taken from the water surface profile of the French River at their point of confluence.

In the Town of West Boylston, cross sections for the backwater analysis of Gates Brook were obtained from aerial photographs flown in November 1978 at a scale of 1:1,200 (Reference 200). The below-water sections were obtained by field measurement. All bridges, dams, and culverts were field-checked to obtain elevation data and structural geometry. The valley portions of the cross section data for Waushacum Brook and Tributary to Waushacum Brook were obtained photogrammetrically by James W. Sewall Co.; the below-water portions were estimated based on surveyed data at structures (Reference 201). Elevation data and structural geometry for all bridges were obtained by field survey. Water surface elevations of floods of the selected recurrence intervals were computed using the USACE HEC-2 step-backwater computer program (Reference 132). Starting water surface elevations for Gates Brook and Waushacum Brook were calculated using the slope/area method. For Tributary to Waushacum Brook, the 10-percent-annual-chance return water surface elevation at the confluence of Waushacum Brook was used as the starting water surface elevation. Flood profiles were drawn showing computed water surface elevations for floods of the selected recurrence intervals. In those areas where the analysis indicated supercritical flow conditions, critical depth was assumed for the flood elevation because of the inherent instability of supercritical flow.

Water surface elevations for the Middle River, Beaver Brook (portion of), Kettle Brook (East), Kettle Brook (West), Tatnuck Brook, Indian Lake, Curtis Pond, Flagg Street

Pond, Lessville Pond, Mill Brook Conduit (portion of), and Weasel Brook were computed using the USACE HEC-2 step-backwater computer program (Reference 139, 154 and 202). Cross sections for backwater analyses of all the watercourses studied in detail were field surveyed. The cross sections were placed at specific intervals along the watercourses to ensure that hydraulic properties would be accurately modeled by the computer. Additional cross sections were interpolated between certain surveyed cross sections, as required by the step-backwater computer program. These cross sections were prepared from the survey data, as well as from topographic maps at a scale of 1:1,200, with contour interval of 2 feet (Reference 203). Flood profiles were drawn showing computed water surface elevations to an accuracy of 0.5 foot. The starting water surface elevations for the initial downstream cross section on the Blackstone River-Middle River system were developed from known water surface elevations in the Town of Millbury. The starting water surface elevations for Kettle Brook (East) were developed from a known stage-discharge relationship for Curtis Pond. The starting water surface elevations for Kettle Brook (West) were developed from a known stage-discharge relationship for Stoneville Pond in Auburn. The starting water surface elevations for Tatnuck Brook were developed from known water surface elevations on Beaver Brook. For Weasel Brook in the City of Worcester, overbank flooding is caused by inadequate capacity of culverts. North of Brooks Street, floodwaters again pond upstream of an inadequately sized culvert. This culvert conveys the brook underneath a factory which extends into the overbank areas on both sides of the brook. Once the pond elevation is higher than the railroad embankment to the east of the factory, flood waters flow down West Boylston Street to join the downstream pond at Brooks Street. Hydraulic calculations were made to determine the depth of flooding in the two-flood pond area and along West Boylston Street. The depth of flooding will be less than 3 feet, and the product of depth (in feet) and velocity (in feet per second) will be less than 15.

For Beaver Brook (from its confluence with the Middle River to a point approximately 1,855 feet upstream of May Street), Broad Meadow Brook, and Mill Brook Conduit (from Salisbury Pond to the Indian Lake Outlet) in the City of Worcester, the USACE HEC-2 step-backwater program (Reference 204) was used to compute water surface elevations of floods of the selected recurrence intervals. Cross sections for backwater analyses of all three watercourses were field surveyed, as well as prepared from topographic maps at a scale of 1:6,000, with a contour interval of 2 feet (Reference 205) produced and provided by the City Manager's Office of Planning and Community Development (OPCD), Worcester, Massachusetts. Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles. The slope/area method was used to provide a computed water surface elevation corresponding to specified energy grade line slope at the first downstream cross section for Broad Meadow Brook. HEC-2/HEC-RAS performs a normal depth computation to determine the water surface elevation. The slope/area method provides a very reasonable estimate of the starting water surface elevations if a good estimate is available for the slope of the energy grade line. The average channel slope in the vicinity of the first cross section has been used as an estimate of the energy grade line slope. The starting water surface elevations for Mill Brook Conduit were assumed to be equal to the crest elevation of the embankment of Salisbury Pond in Worcester. The starting water surface elevations for Beaver Brook were developed from known water surface elevations on Middle River. The starting water surface elevations for Tatnuck Brook were revised to reflect the revised starting water surface elevations for Beaver Brook.

July 2011 Partial Countywide Analysis

For the July 2011 analysis, the USACE computer program HEC-RAS 3.1.3 was used to compute water surface elevations of floods of the selected recurrence intervals and floodways for each of the detailed study streams. Middle River and the Blackstone River were modeled using the HEC-RAS program for the various communities located along the study reach. The total length of studied stream located within Worcester County, Massachusetts was 31.3 miles. This study reach includes an approximate 1-mile length of river where a branch of the Blackstone River flows through the Town of North Smithfield, Rhode Island between Tupperware Mill Dam and Saranac Dam.

Information on hydraulic structures such as bridges, culverts, and dams were obtained from previous flood insurance studies, field survey, 2005 LiDAR survey or "as-built" record drawings obtained from the Massachusetts Department of Transportation (MADOT) or communities in the study area. Cross sections were generated from the LiDAR topography and field survey using computer program HEC-GeoRAS 4.1.

The downstream starting water surface elevations for the Blackstone River were obtained from the Flood Insurance Study for the City of Pawtucket, Rhode Island dated January 3, 1986. As detailed in the 1986 FIS report, hydraulic analyses were performed to consider tidal flooding impacts and estimate flood elevations along the shoreline.

The Saranac Canal in the Town of Blackstone, Massachusetts, was visually inspected and found to be blocked. The canal was therefore assumed to be ineffective for flow conveyance, with only backwater effects.

For the short reach segment where the Blackstone River flows into and back out of Rhode Island, through the Town of Blackstone, Massachusetts, a portion of the flow is diverted out of the main stem and flows through the Tupperware Mill Canal. Estimated flows through this canal were obtained from the FIS for the Town of Blackstone, Massachusetts, dated September 1977. These flows were subtracted from the flood discharges of Blackstone River between Saranac Dam and Tupperware Mill Dam to reflect this canal diversion:

Flood recurrence interval	10-Percent	2-Percent	1-Percent	0.2-Percent
Flow through Tupperware Mill Canal (cfs)	400	600	700	1,000

The Riverdale Street Dam provides flood control in the Town of Northbridge and is owned and operated by the Riverdale Mills Corporation. Under the Emergency Action Plan developed for this dam, Riverdale Mills Corporation is responsible for opening a flood modulator gate and removing the stoplogs at the dam during a major flood event. In addition, two sluice gates which allow flow to pass through a tail race under the mill must also be opened. "Opening" the dam as outlined in the Emergency Action Plan will prevent a flood with a magnitude of 9700 cfs (i.e. the 1-percent-annual-chance flood) from overtopping Riverdale Street and causing damage to the Riverdale Mills Complex and will also help reduce flood damage upstream of the dam. The HEC-RAS model developed for this study accounted for the sluice gates being open at the Riverdale Street Dam. With the sluice gates open, flow in the Blackstone River becomes divided, with the majority of flow passing under the Riverdale Street Bridge and through the main spillway of the dam, while a smaller portion passes through the sluice gates and through a tail race under the mill complex. These flows rejoin in the river downstream of the mill. To determine the correct proportions of flow and corresponding water surfaces, a separate computer step backwater model was developed for the flow through the sluice gates and tail race. Starting water surface elevations were based on a full valley cross section downstream of the mill. The two HEC-RAS models were then compared against the former model water surface elevations for the Blackstone River by dividing the total 1-percent-annual-chance flow between the two models. Using trial and error, the models were run until the same water surface elevations were computed upstream of the dam for both models. Based on the divided flow analysis, approximately 83% of the 1-percent-annual-chance flood (or 6,213 cfs) flows under the Riverdale Street Bridge and through the main spillway of the dam while the remaining 17% (1,267 cfs) flows through the sluice gates.

The hydraulic analyses for this study were based on unobstructed flow. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

Concord River Watershed Partial Countywide Analysis

Detailed analyses were conducted for the Assabet River, Denny Brook, Denny Brook Tributary 1, Elizabeth Brook, Hop Brook, Hop Brook Tributary 4, Hop Brook Tributary 4.1, Jackstraw Brook, Rutters Brook, Rutters Brook Tributary 1, Rutters Brook Tributary 1.1, Stony Brook, Sudbury River and Sullivan Brook in Worcester County. The analyses conducted on the Assabet River, Elizabeth Brook, Jackstraw Brook, Rutters Brook, Stony Brook, and Sudbury River supersede the studies conducted previous to the Concord River Watershed partial countywide analysis.

For these detailed analyses, floodplain cross sections were placed at representative locations, approximately 500 feet apart along the stream centerline. Cross sections may also have been spaced at closer intervals, such as at locations of sudden changes in the stream geometry or direction. Surveyed channel sections were obtained at all significant structures, as well as a survey of the geometric attributes of the structures. Additional in-channel surveys were collected on an "as-needed" basis at bridge approach sections and at long stretches of streams between structures.

HEC-GeoRAS v.10 (Reference 206) was used to convert the stream centerline and additional cross section data created in ArcGIS v.10 (Reference 207) for use in HEC-RAS v.4.1 (Reference 208). HEC-GeoRAS utilized the 5-foot Digital Elevation Model for the Concord River Watershed to develop the overbank portions of the model cross sections; the DEM was built from LiDAR data collected in 2010 (Reference 1).

After the initial hydraulic calculations were completed, warnings presented by the HEC-RAS model were reviewed. Additionally, the model was run through cHECk-RAS (Reference 209), which completes a series of reasonableness checks to ensure that all input data to the model is appropriate. The results of both reviews were assessed for validity, accuracy, and appropriate engineering practices. Some of the areas of concern included: critical WSEL calculations, WSEL differences between adjacent cross-sections, and correct usage of ineffective flow areas. After the initial areas of concern were addressed, the HEC-RAS models were recalculated. All remaining warnings generated by HEC-RAS were reviewed and judged acceptable for the final models.

A similar methodology was used in the hydraulic computations for the approximate study reaches. The 5-foot DEM was used to develop model cross sections. Structures crossings were not built into the model; however, cross sections were placed at the faces of the structures to simulate the constriction.

The downstream boundary condition for all profiles on the Assabet River, Elizabeth Brook, Hop Brook, Hop Brook Tributary 4, Rutters Brook, Rutters Brook Tributary 1, Rutters Brook Tributary 1.1, and Sullivan Brook used the known water surface elevations from the effective FIS, FIRM, or the upstream boundaries of the new studies completed in HEC-RAS. Additionally, some streams were broken into multiple reaches. In these cases, the known water surface elevation of the downstream reach was used so that there would be a seamless tie-in between study reaches.

The downstream boundary condition for Denny Brook, Denny Brook Tributary 1, Hop Brook Tributary 4.1, Jackstraw Brook, Sudbury River, and Stony Brook were calculated using the normal depth method.

A summary of the stillwater elevations calculated as part of the precountywide analyses is presented in Table 10. No additional stillwater elevations were determined during the countywide analyses.

TABLE 10 – PRECOUNTYWIDE SUMMARY OF STILLWATER ELEVATIONS

	ELEVATION (feet NAVD[1])			
FLOODING SOURCE AND LOCATION	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
AUBURN POND				
At Auburn	498.7	499.7	500.5	502.1
BRIERLY POND				
At Millbury	518.2	518.8	519.0	519.5
CURTIS POND				
At Worcester	471.4	474.5	475.4	477.4
FLAGG STREET POND				
At Worcester	566.0	566.3	566.4	566.6
HARRIS POND				
Lake Stage Upstream of Railroad Embankment in Blackstone	168.9[2]	172.7[2]	175.1[2]	180.5[2]

[1]North American Vertical Datum of 1988
[2]Elevation NAVD feet of Stage-Discharge-Frequency Relationship

TABLE 10 – PRECOUNTYWIDE SUMMARY OF STILLWATER ELEVATIONS - continued

FLOODING SOURCE AND LOCATION	ELEVATION (feet NAVD[1]) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
HARRIS POND - continued				
Lake Stage at Dam in Blackstone	168.9[2]	169.7[2]	170.2[2]	171.1[2]
INDIAN LAKE				
At Worcester	540.6	541.4	542.4	542.9
LANCASTER MILL POND				
Within the Town of Clinton	*	*	*	*
LAKE WEBSTER				
Entire shoreline within Webster	479.8	480.3	480.4	481.1
LEESEVILLE POND				
Downstream of Interstate Route 290 in Auburn	485.7	485.8	485.9	488.5
Upstream of Interstate Route 290 in Auburn	486.6	486.8	487.1	492.7
At Worcester	485.7	485.8	485.9	488.5
MILL BROOK CONDUIT				
At Crompton Park Area	440.3	440.8	449.3	449.8
PONDVILLE POND				
Upstream of Washington Street in Auburn	514.4	515.7	516.7	525.1
At Millbury	514.4	515.7	516.7	525.1

* No Data Available
[1]North American Vertical Datum of 1988
[2]Elevation NAVD feet of Stage-Discharge-Frequency Relationship

TABLE 10 – PRECOUNTYWIDE SUMMARY OF STILLWATER ELEVATIONS – continued

FLOODING SOURCE AND LOCATION	ELEVATION (feet NAVD[1]) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
QUACUMQUASIT POND				
Within the entire shoreline in Webster	602.5	604.1	605.6	608.2
SARANAC CANAL				
Saranac Inlet Wall in Blackstone	163.0	163.3	171.7	176.3
St. Paul Street in Blackstone	161.3	161.5	168.5	171.0
Blackstone Corporate Blackstone	158.7	159.6	167.5	168.1
SINGLETARY POND				
At Millbury	558.3	558.9	559.1	559.4
STONEVILLE POND				
At Auburn	516.3	518.4	520.0	522.7
TUPPERWARE MILL CANAL				
Blackstone Corporate Boundary	196.5	198.50	197.8	198.1
Main Street (east crossing) in Blackstone	196.5	197.8	197.9	198.1
Main Street (west crossing) in Blackstone	196.5	199.0	200.3	203.8
WHITINS POND				
In Northbridge and Sutton	309.6	311.3	311.9	314.0

[1]North American Vertical Datum of 1988

Roughness factors (Manning's "n") used in the hydraulic computations were estimated based on field inspection of floodplain areas. The channel "n" and overbank "n” values for all the streams studied by detailed methods are shown in Table 11, “Manning’s “n” Values”.

TABLE 11 – MANNING'S "n" VALUES

Flooding Source	Channel "n"	Overbanks
Assabet River (Berlin) [3, 8]	0.040-0.055	0.040-0.120
Assabet River (Northborough)[8]	0.015-0.050	0.040-0.120
Assabet River (Lower Reach)	0.010-0.050	0.025-0.100
Assabet River (Upper Reach)	0.010-0.050	0.025-0.100
Assabet River Branch No. 2[3]	0.018-0.05	0.05-0.12
Axtell Brook	0.030-0.060	0.040-0.016
Beaver Brook	0.013-0.045	0.035-0.110
Bennetts Brook[5]	0.015-0.035	0.045-0.075
Big Bummet Brook (Grafton)	0.013-0.050	0.060-0.080
Big Bummet Brook (Shrewsbury)	0.015-0.050	0.07-0.11
Blackstone River[1, 6]	0.025-0.050	0.025-0.120
Bowers Brook[5]	0.015-0.035	0.045-0.075
Brierly Pond[6]	0.030-0.040	0.040-0.12
Broad Meadow Brook	0.013-0.045	0.035-0.110
Cady Brook (Charlton)	0.035	0.070-0.080
Cady Brook (Southbridge)	0.020-0.035	0.060-0.090
Cedar Meadow Brook	0.022-0.045	0.060-0.095
Cedar Pond	0.035	0.060-0.090
Center Brook	0.024-0.050	0.070
Charles River (Hopedale)	0.030-0.060	0.050-0.100
Charles River (Mendon)	0.030-0.055	0.050-0.100
Charles River (Milford)	0.015-0.040	0.040-0.100
Cohasse Brook	0.015-0.035	0.080-0.100
Cold Harbor Brook (Lower Reach)	0.015-0.050	0.040-0.120
Cold Harbor Brook (Town of Boylston)	0.035-0.040	0.045-0.100
Cold Harbor Brook (Upper Reach)	0.015-0.050	0.040-0.120
Cold Spring Brook (Town of Harvard) [5]	0.015-0.035	0.045-0.075
Cold Spring Brook (Town of Sutton)	0.020-0.050	0.070-0.080
Concrete Culvert (Town of Clinton)**	0.012	*
Counterpane Brook	0.030-0.035	0.070
Cronin Brook	0.020-0.045	0.020-0.110
Dark Brook	0.030-0.040	0.080
Dark Brook #1 (Auburn Pond to Central Street)	0.019-0.040	0.040-0.100
Dark Brook #2 (Stoneville Pond to Leicester Street)[2]	0.030-0.040	0.040-0.090
Deans Brook	0.035-0.060	0.080-0.120

TABLE 11 – MANNING'S "n" VALUES – continued

Flooding Source	Channel "n"	Overbanks
Denny Brook[8]	0.040-0.060	0.040-0.100
Dorothy Brook[6]	0.030-0.040	0.040-0.12
Elizabeth Brook[5, 8]	0.015-0.055	0.040-0.120
French River (Dudley)	0.027-0.055	0.070-0.095
French River (Leicester)	0.017-0.055	0.065-0.080
French River (Webster)	0.027-0.055	0.070-0.095
French River downstream of the Hodges Village Dam (Oxford)	0.035-0.040	0.080-0.100
French River upstream of the Hodges Village Dam (at elevation 500 feet) (Oxford)	0.030-0.075	0.050-0.100
Gates Brook	0.030-0.045	0.060-0.100
Godfrey Brook	0.024-0.045	0.040-0.100
Goodridge Brook	0.035	0.050
Great Brook[4]	0.02-0.07	0.05-0.10
Hamant Brook	0.015-0.040	0.060-0.100
Harris Pond	0.034-0.035	*
Hop Brook[8]	0.030-0.060	0.030-0.150
Hop Brook Tributary 4[8]	0.045-0.060	0.045-0.150
Hop Brook Tributary 4.1[8]	0.060	0.060-0.150
Howard Brook	0.015-0.050	0.040-0.120
Huckleberry Brook	0.012-0.070	0.050-0.080
Ivy Brook	0.013-0.060	0.050-0.060
Jackstraw Brook[8]	0.035-0.060	0.035-0.150
Kettle Brook (East)	0.020-0.040	0.040-0.090
Kettle Brook (Town of Auburn)[2]	0.030-0.040	0.040-0.090
Kettle Brook (West)	0.020-0.040	0.040-0.090
Leadmine Brook	0.015-0.040	0.065-0.100
Lebanon Brook	0.025-0.045	0.060-0.120
Little Nugget Brook	0.020-0.045	0.050-0.075
Little River	0.035-0.060	0.065-0.080
Lowes Brook	0.036-0.042	0.070-0.110
Lynde Brook	0.030-0.035	0.060-0.100
McKinstry Brook	0.036-0.044	0.080-0.100
Meadow Brook	0.015-0.050	0.07-0.110
Middle River	0.020-0.040	0.040-0.090
Mill Brook[4]	0.02-0.07	0.05-0.10
Mill Brook #1	0.035	0.080
Mill Brook Conduit	0.013-0.045	0.035-0.110
Mill River (Blackstone)	0.034-0.035	*
Mill River (Hopedale)	0.030-0.060	0.050-0.100
Mill River (Mendon)	0.030-0.055	0.050-0.100
Mill River (Milford)	0.028-0.050	0.040-0.080
Mill River (Upton)	0.020-0.040	0.040-0.080
Miscoe Brook	0.250-0.040	0.030-0.090

TABLE 11 – MANNING'S "n" VALUES – continued

Flooding Source	Channel "n"	Overbanks
Muddy Brook	0.030-0.055	0.050-0.100
Mumford River (Douglas)	0.060-0.090	0.030-0.050
Mumford River (Northbridge)	0.025-0.055	0.050-0.100
Mumford River (Sutton)	0.028-0.060	0.050-0.090
Mumford River (Uxbridge)	0.028-0.048	0.040-0.090
Nashua River (Bolton) [4]	0.02-0.07	0.05-0.10
Nashua River (Clinton)	0.030-0.035	0.070
Nashua River (Harvard) [5]	0.030	0.060-0.070
Nashua River (Lancaster)	0.0285-0.030	0.060-0.070
North Brook[3]	0.018-0.05	0.05-0.120
North Nashua River	0.035	0.060-0.100
O'Brien Brook	0.025-0.060	0.040-0.070
Piccadilly Brook	0.010-0.050	0.025-0.100
Pikes Pond Tributary	0.020-0.040	0.060-0.090
Pondville Pond[6]	0.030-0.040	0.040-0.120
Quick Stream	0.034-0.035	*
Quinebaug River (Dudley)	0.035-0.040	0.070-0.100
Quinebaug River (Southbridge)	0.035-0.043	0.060-0.100
Quinebaug River Below Westville Dam (Sturbridge)	0.022-0.045	0.060-0.095
Quinebaug River From East Brimfield Dam to Westville Reservoir (Sturbridge)	0.035-0.045	0.065-0.095
Quinsigamond River	0.011-0.055	0.070-0.080
Ramshorn Brook (Town of Auburn)[2]	0.030-0.040	0.040-0.090
Ramshorn Brook (Town of Millbury)[6]	0.030-0.040	0.040-0.120
Rawson Hill Brook	0.015-0.050	0.07-0.11
Riverdale Mills Sluice Gates & Tail Race	0.025-0.055	0.050-0.100
Rutters Brook[8]	0.035-0.060	0.035-0.120
Rutters Brook Tributary 1[8]	0.040-0.060	0.040-0.100
Rutters Brook Tributary 1.1[8]	0.040-0.060	0.040-0.100
Saranac Canal	0.034-0.035	*
Sevenmile River	0.025-0.045	0.050-0.085
Sewall Brook	0.035-0.045	0.05-0.090
Singletary Brook[6]	0.030-0.040	0.040-0.12
Singletary Pond[6]	0.030-0.040	0.040-0.12
Southwick Brook	0.040	0.080
Stall Brook	0.024-0.050	0.024-0.090
Still River[4]	0.020-0.070	0.050-0.100
Stony Brook[8]	0.033-0.050	0.032-0.090
Stony Brook Tributary 2[8]	0.025-0.035	0.040-0.060
Sudbury River[8]	0.032-0.090	0.032-0.100
Sudbury River Split 1[8]	0.050	0.040-0.090
Sudbury River Tributary 12[8]	0.025-0.035	0.040-0.060

TABLE 11 – MANNING'S "n" VALUES – continued

Flooding Source	Channel "n"	Overbanks
Sullivan Brook[8]	0.030-0.060	0.030-0.090
Tatnuck Brook	0.020-0.040	0.040-0.090
Town Meadow Brook	0.030-0.040	0.065-0.090
Tributary 1	0.035-0.040	0.080-0.100
Tributary to Elizabeth Brook[5]	0.015-0.035	0.045-0.075
Tributary to Waushacum Brook	0.030	0.020-0.100
Tupperware Mill Canal	0.034-0.035	*
Unnamed Tributary[2]	0.030-0.040	0.040-0.090
Unnamed Tributary to Mayo Pond[6]	0.030-0.040	0.040-0.12
Walker Pond	0.018-0.035	0.018-0.080
Waushacum Brook	0.030	0.020-0.100
West Brook	0.015-0.050	0.07-0.11
West River (Grafton)	0.015-0.060	0.030-0.090
West River (Upton)	0.015-0.060	0.030-0.090
West River (Town of Uxbridge)	0.013-0.060	0.060-0.085
Wrack Meadow Brook	0.018-0.05	0.05-0.12

[1] Updated values for the July 2011 partial countywide revision
[2] (Reference 210)
[3] (Reference 133)
[4] (Reference 123)
[5] (References 156, 211, 212, 213 & 214)
[6] (Reference 215)
[7] (Reference 19)
[8] Updated values for the revised partial countywide study for the Concord River Watershed

* Data not available
**Energy loss due to gradual changes in cross sectional flow areas were computed using coefficients of 0.1 and 0.3 for contraction and expansion, respectively, and 0.3 and 0.5 were used for abrupt changes.

3.3 Vertical Datum

All FIS reports and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. Until recently, the standard vertical datum used for newly created or revised FIS reports and FIRMs was the National Geodetic Vertical Datum of 1929 (NGVD). With the completion of the North American Vertical Datum of 1988 (NAVD), many FIS reports and FIRMs are now prepared using NAVD as the referenced vertical datum.

Flood elevations shown in this FIS report and on the FIRM are referenced to the NAVD 88. These flood elevations must be compared to structure and ground elevations referenced to the same vertical datum. Ground, structure, and flood elevations may be compared and/or referenced to NGVD 29 by applying a standard conversion factor. **The**

conversion factor from NGVD 29 to NAVD 88 is -0.7, and from NAVD 88 to NGVD 29 is +0.7.

For information regarding conversion between the NGVD and NAVD, visit the National Geodetic Survey website at www.ngs.noaa.gov, or contact the National Geodetic Survey at the following address:

Vertical Network Branch, N/CG13
National Geodetic Survey, NOAA
Silver Spring Metro Center 3
1315 East-West Highway
Silver Spring, Maryland 20910
(301) 713-3191

Temporary vertical monuments are often established during the preparation of a flood hazard analysis for the purpose of establishing local vertical control. Although these monuments are not shown on the FIRM, they may be found in the Technical Support Data Notebook associated with the FIS report and FIRM for this community. Interested individuals may contact FEMA to access these data.

The BFEs shown on the FIRM represent whole-foot rounded values. For example, a BFE of 102.4 will appear as 102 on the FIRM and 102.6 will appear as 103. Therefore, users that wish to convert the elevations in this FIS to NGVD 29 should apply the stated conversion factor to elevations shown on the Flood Profiles and supporting data tables in the FIS report, which are shown at a minimum to the nearest 0.1 foot.

To obtain current elevation, description, and/or location information for benchmarks shown on this map, please contact the Information Services Branch of the NGS at (301) 713-3242, or visit their website at www.ngs.noaa.gov.