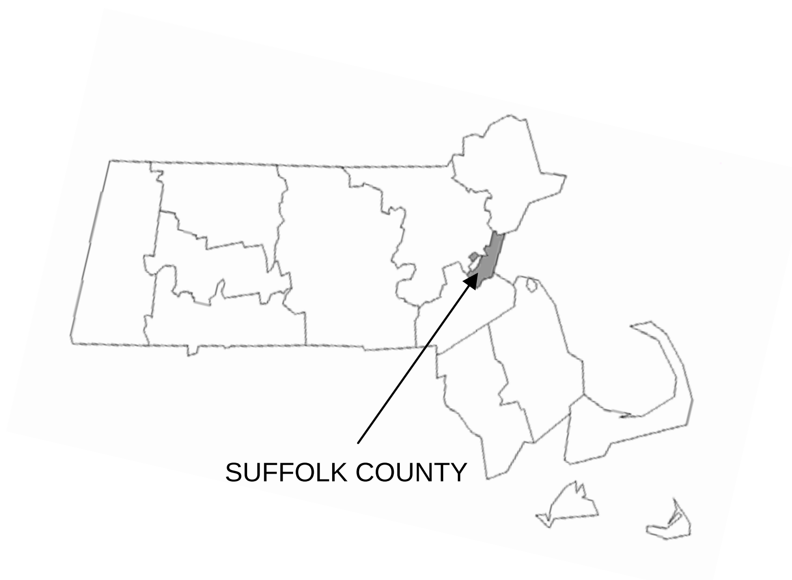
FLOOD INSURANCE STUDY

SUFFOLK COUNTY, MASSACHUSETTS
(ALL JURISDICTIONS)



COMMUNITY NAME	COMMUNITY NUMBER
BOSTON, CITY OF	250286
CHELSEA, CITY OF	250287
REVERE, CITY OF	250288
WINTHROP, TOWN OF	250289

REVISED
MARCH 16, 2016

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
25025CV000B

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.

The Federal Emergency Management Agency (FEMA) may revise and republish part or all of this Preliminary FIS report at any time. In addition, FEMA may revise part of this FIS report by the Letter of Map Revision (LOMR) process, which does not involve republication or redistribution of the FIS report. Therefore, users should consult community officials and check the Community Map Repository to obtain the most current FIS components.

Initial Countywide FIS Effective Date: September 25, 2009

Revised Countywide FIS Date: March 16. 2016

TABLE OF CONTENTS

TABLE OF CONTENTS - continued

Page

FIGURES

TABLES

TABLE OF CONTENTS - continued

EXHIBITS

FLOOD INSURANCE STUDY
SUFFOLK COUNTY (ALL JURISDICTIONS)

1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study (FIS) revises and updates information on the existence and severity of flood hazards in the geographic area of Suffolk County, including the Cities of Boston, Chelsea, Revere and the Town of Winthrop; (referred to collectively herein as Suffolk 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 the community 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.

In some states or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. These criteria take precedence over the minimum federal criteria for purposes of regulating development in the floodplain, as set forth in the Code of Federal Regulations at 44 CFR, 60.3. In such cases, the more restrictive criteria take precedence and the state (or other jurisdictional agency) will be able to explain them.

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.

The September 25, 2009 FIS (Reference 1) was prepared to include the incorporated communities within Suffolk County in a countywide format. Information on the authority and acknowledgments for each jurisdiction included in the 2009 countywide FIS, as compiled from their previously printed FIS reports, is shown below.

Boston, City of:	The hydrologic and hydraulic analyses for the November 2, 1990 study represent a revision of the original October 1, 1983 analyses prepared by Harris-Toups Associates for the Federal Emergency Management Agency (FEMA) under Contract No. H-4024. The work for the original 1983 study was completed in November 1979. The hydrologic and hydraulic analyses for this updated 1990 study were prepared by Dewberry & Davis for FEMA under Contract No. EMW-85-C-2044. This work was completed in December 1987.
Chelsea, City of:	The hydrologic and hydraulic analyses for the original February 2, 1982 study were prepared by Anderson Nichols & Co., Inc. for FEMA under Contract No. H-4524. This work was completed in May 1980.

Revere, City of:	The hydrologic and hydraulic analyses for the original April 16, 1984, FIS report and the October 16, 1984, Revere FIRM (hereinafter referred to as the 1984 Revere FIS), were prepared by Stone & Webster Engineering Corporation for FEMA under Contract No. H-4772 Modification No. 5. That work was completed in April 1983. The hydrologic and hydraulic analyses for the August 20, 2002 revision were prepared by Roald Haestad, Inc. for FEMA under Contract No. EMB-1999-CO-0564. This work was completed in November 2000.
Winthrop, Town of:	The hydrologic and hydraulic analyses for the original and revised February 15, 1984 FIS were prepared by Stone & Webster Engineering Corporation for FEMA under Contract No. H-4772. This work was completed in January 1983.

For the 2009 countywide study, the 1- and 0.2-percent-annual-chance floodplain boundaries for the Atlantic coastline in Suffolk County were redelineated using more up to date topographic information, including MassGIS and LiDAR data, which meets the accuracy standards for flood hazard mapping (https://www.mass.gov/mgis/ and https://maps.csc.noaa.gov.TMC/). That work was performed by CDM for FEMA, under Contract No. EME-2003-CO-0340, and by Ocean and Coastal Consultants, Inc. for CDM, under Contract No. 2809-999-003-CS. No new detailed or approximate studies were performed.

The coastal wave height analysis for this coastal study was prepared by the Strategic Alliance for Risk Reduction (STARR) for FEMA under Contract No. HSFEHQ-09-D-0370 and completed September 13, 2013. This new analysis resulted in revisions to the coastal Special Flood Hazards Areas (SFHA) for all communities in Suffolk County. The far outer islands in Boston Harbor (City of Boston) were not included in this analysis.

STARR mapped the results of the September 13, 2013 analysis under Contract No. HSFEHQ-09-D-0370 up to the November 13, 2013 Preliminary release of the Suffolk County FIS.

FEMA funded the Post Preliminary Processing of coastal analyses based on appeal under Contract No. HSFEHQ-09-D-0370 and Task Order No.s HSFEHQ-10-J-0004 and HSFE01-14-J-0015. Under this contract, the hydrologic and hydraulic analyses in the November 13, 2013 Preliminary FIS report were updated by STARR for FEMA for the Belle Island Inlet, Boston Harbor, Dorchester Bay and the Pines, Chelsea, Charles, and Neponset River flooding sources affecting the communities of Boston, Chelsea, Revere, and Winthrop. That work was completed May 30, 2015.

For the 2009 countywide study FIRM panels, base map information shown 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 scale of 1:5,000. Aerial photography is dated April 2005. The projection used in the preparation of this map was Massachusetts State Plane mainland zone (FIPSZONE2001). The horizontal datum was NAD 83, GRS80 spheroid (Reference 2).

Base map information shown on the FIRM panels produced for this 2013 revision and post preliminary appeal were derived from USGS High Resolution orthophotography dated April 10 and April 18, 2008 produced at six inch and one foot resolution cells. The horizontal datum used was North American Datum of 1983 (NAD 83) (Reference 3).

Differences in datum, spheroid, projection or State Plane zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

1.3 Coordination

Consultation Coordination Officer's (CCO) meetings may be held for each jurisdiction in this countywide FIS. An initial CCO meeting is held typically with representatives of FEMA, the community, and the study contractor to explain the nature and purpose of a FIS and to identify the streams to be studied by detailed methods. An intermediate CCO meeting is held typically with representatives of FEMA, the community, and the study contractor to discuss interim concerns of the study. A final CCO meeting is held typically with representatives of FEMA, the community, and the study contractor to review the results of the study.

Prior to the initial 2009 countywide FIS, the dates of the initial, intermediate, and final CCO meetings held for the incorporated communities within Suffolk County are shown in Table 1, "Initial, Intermediate, and Final CCO Meetings."

TABLE 1 – INITIAL, INTERMEDIATE, AND FINAL CCO MEETINGS

Community Name	Initial CCO Date	Intermediate CCO Date	Final CCO Date
City of Boston	April 13, 1987	*	April 11, 1989
City of Chelsea	May 13, 1977	July 27, 1980	July 22, 1981
City of Revere	January 4, 2000	*	August 28, 2001
Town of Winthrop	April 13, 1978	December 13, 1979	September 26, 1983

* Data not Available

For the 2009 countywide FIS, no initial CCO meeting was held. The results of the study were reviewed at the final CCO meetings held on December 17th, 2008 and January 14th, 2009, and were attended by representatives of FEMA, Massachusetts Department of Conservation and Recreation (DCR), CDM, Ocean & Coastal Consultants Inc. (OCC), and Suffolk County communities. All problems raised at that meeting have been addressed in this study.

For the 2013 coastal study revision, outreach meetings were held on March 28 and 29, 2011. Letters were sent to inform the communities of the scope of the FIS, and to solicit pertinent local information. Work map discussion meetings were held with the communities on August 1 and 12, 2013, to discuss the initial results of the new coastal flood hazard analysis.

For this revised preliminary based on appeal, CCO meetings were held on January 21, 2014 and January 29, 2014 and were attended by representatives of FEMA Region I, STARR, and the Massachusetts NFIP Coordinator.

2.0 AREA STUDIED

2.1 Scope of Study

This FIS report covers the geographic area of Suffolk County, MA 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.

2009 Countywide Study:

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 FIRM.

TABLE 2 – FLOODING SOURCES STUDIED BY DETAILED METHODS

Flooding Source	Description
Atlantic Ocean	For the entire coastline within the Town of Winthrop
Charles River	From upstream of the Route 28 bridge in the City of Boston to the City of Boston-Town of Dedham corporate limits
Mill Creek	From its confluence with the Chelsea River to approximately 5,400 feet upstream.
Mother Brook	From its confluence with Neponset River to the City of Boston-Town of Dedham corporate limits.
Muddy River	From its confluence with Charles River to Willow Pond
Neponset River	From upstream of the dam at Lower Mills to the Boston-Dedham corporate limits
Stony Brook	From upstream of the entrance to the Stony Brook culvert to Turtle Pond in the City of Boston.

Portions of the Muddy River within the detailed study limits are referred to locally as the Back Bay Fens. Wherever referenced in this report, the name Muddy River shall be assumed to include the area known as the Back Bay Fens.

All or portions of numerous flooding sources in the county were studied by approximate methods. 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 Suffolk 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 pre-countywide FISs.

TABLE 3 – FLOODING SOURCES STUDIED BY APPROXIMATE METHODS

Flooding Source	Community
Chandler's Pond	Boston
Jamaica Pond	Boston
Chestnut Hill Reservoir	Boston
Muddy River including Back Bay Fens	Boston
Neponset River	Boston
Sawmill Brook	Boston
Stony Brook	Boston
Unnamed Ponding Area near Genoa Street	Revere

This FIS also incorporates 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	Flooding Source(s)/Project Identifier	Effective Date	Type	Case Number
Boston, City of	Massachusetts Bay/Boston Harbor	07/09/2004	LOMR	04-01-013P
Boston, City of	Dorchester Bay	12/05/2008	LOMR	08-01-1020P
Revere, City of	Broad Sound	09/20/2007	LOMR	07-01-0489P

Detail studied streams that were not restudied as part of this revision 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.

2013 Coastal Study

The coastal wave height analysis for this countywide coastal study and Post Preliminary Processing of coastal analyses based on appeal, was prepared by STARR. This new analysis resulted in revisions to the FIRM for the Cities of Boston, Chelsea, and Revere and the Town of Winthrop. Based on the new updated analysis, the results of LOMR cases 05-01-0110A, 10-01-0596P, 10-01-0786A, 10-01-1204A, and 10-01-1783A were superseded.

2.2 Community Description

Suffolk County is located on the seacoast of the Atlantic Ocean in eastern Massachusetts. In Suffolk County there are four (4) incorporated communities. The Cities of Boston, Chelsea, and Revere and the Town Winthrop.

Suffolk County is bordered by the Atlantic Ocean on the east; by Essex County, including the towns of Lynn and Saugus, to the north; by Middlesex County, including the towns of Melrose, Malden, Everett, Somerville, Cambridge, Watertown and Newton, to the west; and by Norfolk County, including the towns of Needham, Dedham, Canton, Milton and Quincy, to the South. It is 44 miles from Providence, Rhode Island, 106 miles from Portland, Maine, and 93 miles from Hartford, Connecticut.

According to the U.S. Census, the population of Suffolk County was 722,023 in 2010, 689,807 in 2000 and 663,906 in 1990. The land area of Suffolk County consists of 120.19 square miles (Reference 4).

Suffolk County is the hub of a larger metropolitan area, serving some 3.25 million people; the sixth largest population center in the United States.

The climate of Suffolk County is moderate and can be described as a continental climate. Summers are warm and humid, while winters are cold, windy and snowy. The hottest month is July, with an average high of 82 degrees Fahrenheit (ºF) and an average low of 66ºF. The coldest month is January, with an average high of 36F and an average low of 22ºF. The mean annual temperature is 50 degrees Fahrenheit (ºF). The temperature ranges from an average of 29°F in January to an average of 72°F in July (Reference 5). The average annual rainfall is 42 inches. The average annual snowfall is approximately 40.9 inches (Reference 6). There is no dry season and, on the average, no dry spell lasts more than two weeks. From June to September, rainfall usually occurs in the form of showers or thunderstorms, which produce heavy, sometimes excessive, amounts of rain. Throughout the year, the heaviest gales are usually from the northeast or east and are more common and severe during the winter. Though the coastal location on the North Atlantic moderates temperatures in Suffolk County, it also makes the County very prone to Northeaster weather systems, which can result in an abundance of snow and rain (Reference 7).

Boston was originally a peninsula with great areas of salt marsh to the north, along the banks of the Charles and Mystic Rivers, and at the mouth of the Neponset River to the south. Large areas of filled land occur in the Back Bay, the West End, South Boston, Dorchester, Charlestown and East Boston. In 1910, a dam on the Charles River at Leverett Street was constructed to prevent tidal flooding of the lowlands, to cover unsightly tidal flats at the mouth of the river, and to create an aesthetically pleasing recreational pool – now known as the Charles River Basin.

However, the creation of the basin accelerated growth along its banks, which in turn resulted in the conversion of many former open spaces to developed and paved areas. This change increased the speed and amount of runoff above the existing dam, making it inadequate to carry the discharges predicted. The U.S. Army Corps of Engineers (USACE) constructed a new dam at Warren Avenue to replace the 1910 dam at Leverett Street in order to accommodate the increased run-off. The Warren Avenue bridge was removed preconstruction of the Charles River Dam Local Protection Project that was initiated back in November, 1972. The project was completed in May 1978 and it situated the new dam approximately 2,250 feet downstream of the old Charles River Dam.

The land throughout the City of Boston is densely settled, except for limited areas in the west.

The City of Revere is also densely developed and attracts both permanent and transient populations. Coastal development in Revere is a mixture of residential, commercial, industrial, and recreational. Located along the eastern shore, from Point of Pines to Elliott Circle, is Revere Beach, a popular Metropolitan District Commission recreational facility. The beach experiences severe erosion problems. A breakwater is located at the southern end of Revere Beach at Cherry Island Bar.

Of the Town of Winthrop's total land area, the majority of the land is classified as urban land, Within urban land space, high density residential areas comprises more than half of that land classification (Reference 8). The recreational lands consist primarily of the beaches along the eastern shore of the town. Exposure of the beaches to the open coast has caused severe erosion. To retard erosion, a 0.4-mile long breakwater was constructed 0.2 mile off of and parallel to Winthrop Beach. Coastal development is primarily residential and recreational. Because Winthrop is long and narrow in shape, the entire town is within the Massachusetts Coastal Zone.

The coastline of the City of Chelsea is heavily developed with commercial and industrial properties, predominately related to petroleum products and storage. The Mill Creek watershed is heavily developed with commercial and residential properties.

The topography of the County is generally level, with elevations ranging from sea level to 180 feet. Occasional hills composed of glacial till, rise as high as 300 feet. The tidal shoreline along the Atlantic Ocean is 87.7 miles in length. Most of the county was formed by glacial till; its coastline includes scattered coves, beaches, and rocky shoals. Located at the northwest boundary of Winthrop is Belle Isle Marsh, a 250-acre salt marsh that is one of the last remaining salt marshes in the Boston Harbor region.

The Charles River has its headwaters in Echo Lake in Hopkinton. It flows generally northeast, finally becoming the northern boundary of the City of Boston, before discharging into Boston Harbor. It has a drainage area of approximately 300 square miles. Mother Brook, beginning as a partial diversion of the Charles River in the Town of Dedham, flows east through the Hyde Park section of Boston, discharging into the Neponset River. Flows in Mother Brook are limited to approximately one-third that of the Charles River. Muddy River rises out of Jamaica Pond and flows north, passing through highly-developed areas of Boston and Brookline before discharging into the Back Bay Fens. The Fens then empty into the Charles River Basin. The Neponset River originates in the Neponset Reservoir in Foxborough. It flows generally northeast, becoming the southern boundary for the City of Boston before discharging into Dorchester Bay. Stony Brook originates in Turtle Pond and flows south through Stony Brook Reservation before entering the Stony Brook culvert.

Boston Harbor is bordered by the Atlantic Ocean to the east and is protected on the north by Winthrop Peninsula and to the south by Hull Peninsula. From north to south, Boston Harbor is bounded by the Logan International Airport, East Boston, Charlestown, the Mystic and Charles Rivers, the downtown area, South Boston, Dorchester, and the

Neponset River. The harbor has a number of islands including Deer, Spectacle, Thompson, Long and Gallops Islands. The entire coastline is densely developed, and much of the waterfront is under redevelopment pressure. Much of the recent construction has involved the downtown waterfront area, including condominiums, offices, parks and commercial establishments.

2.3 Principal Flood Problems

Suffolk County is most vulnerable to riverine and coastal flooding from severe storms that produce heavy rain, such as hurricanes, tropical storms and northeasters; and winter events that can produce significant snowfall and heavy rain. Snowmelt and ice jams can also create flood hazards. The Suffolk County coastline is heavily populated and susceptible to coastal storms with high winds, causing coastal erosion and storm surge.

Investigations into flooding within the corporate limits of Boston have revealed that there has been severe flooding resulting in extensive damage, especially to the Charles River Basin and the surrounding lowlands. The problem is caused primarily by the difference between the established normal water level in the basin and the high tide in the harbor. In the flood of August 1955, 12.5 inches of rain coupled with a peak high tide of 8.2 feet resulted in raising the basin elevation to a record high of 6.90 feet. Over 1,750 acres, mostly highly-developed Cambridge and Boston, lying along the 8.6-mile long basin were subject to serious flooding. The 1955 hurricane, equivalent to a 1-percent-annual-chance storm, resulted in flood damage along the lower Charles River amounting to 5.5 million dollars. The same flood level in 1980 would have resulted in an estimated damage of 20 million dollars. In March 1968, 7.7 inches of rain combined with the spring thaw produced the second highest basin levels of 4.5 feet, inundating many areas along Storrow Drive. Although the peak discharge upstream was the same as the 1955 flood, the river peak did not coincide with the tidal peaks as in the 1955 flood, and resulting damage was less extensive. Flooding problems from the 1955 and 1968 storms also occurred along the Neponset River in the Hyde Park area. Numerous private properties, automobiles and roadways were damaged as a result of the storm.

Flooding also occurs along the coastline of Boston and Chelsea and in the low-lying coastal areas of Revere and Winthrop, greatly influenced by storm surge elevations of Boston Harbor that result from severe storms. The most recent example of severe flooding was during the northeaster of February 1978, which was comparable to a 1-percent-annual-chance flood event. Elevations of flooding ranged from 8.6 to 10.1 feet, which caused one to three feet of flooding in areas such as Rowes, India, Long, Commercial and Battery Wharves. Low-level flooding occurred at a number of East Boston locations such as East Boston Pier, the airport access road, and several parking lots on commercial piers. More serious damage occurred as a result of wave action. The recorded flood elevation was 9.8 feet at the New Charles River Dam, 9.5 feet at the U.S.S. Constitution, and 9.5 feet at the Commonwealth Pier gage. The 1978 northeaster caused significant damage in excess of $15 million in the City of Revere. Other significant storms to cause flooding in Revere include the storms of December 1909 and 1959 (a flood event that had approximately 0.6- and 6.7-percent-annual-chance of occurring or being exceeded, respectively) and February 1972 (approximate recurrence of 4-percent-annual-chance).

In Chelsea, severe flooding due to poor drainage frequently occurs near Mill Creek upstream of U.S. Route 1. This area was not studied in detail because of its small drainage area. Minor flooding has been reported from residents near Mill Creek adjacent to Forbes Park (formerly Forbes Industrial Park), though no structural damage or injuries have been reported.

The heavily developed areas of Point of Pines and Oak Island, in Revere, have suffered severe damage from storms annually. The Point of Pines area is subject to coastal and riverine flooding. The encroachment of development into the Saugus River - Pines River Marsh has reduced storage capacity of the marsh and increased the flooding potential in the area. The Beachmont area, which faces the ocean and backs up to Belle Isle Marsh, experiences flooding as a result of storms and high tides.

In Winthrop, the majority of storms cause damage only to low coastal roads, boats, beaches, and seawalls. Occasionally, a major storm accompanied by strong onshore winds results in high tides and wave activity that cause extensive property damage and erosion. Some of the more significant storms in the Winthrop area include those of December 1909, December 1959, February 1972, and February 1978. The storms had approximate recurrence of 0.6-, 6.7-, 4-, and 1.1-percent annual chance, respectively. Harbors, marinas, and residential and commercial developments were damaged by the storms.

More than ten major flooding events have occurred in Massachusetts over the last 50 years. Many of these have caused minimal-to-moderate damage to Suffolk County. Hurricane Gloria in September 1985 arrived at low tide and resulted in storm surges less than 5 feet above normal, minimizing damage to the coastline. Hurricane Bob in August 1991 passed south of Suffolk County primarily affecting southeastern Massachusetts, Cape Cod and the Islands. An unnamed coastal storm in October 1991 joined up with the remains of Hurricane Grace and produced the third highest tide recording at the Boston gage. This storm was labeled as the Perfect Storm by the National Weather Service. Winds measured over 80 MPH and waves were over 30 feet in some parts of the Massachusetts coastline, causing flooding and wind damage to several counties, including Suffolk (References 9 and 10).

A coastal storm in December 1992 caused more than $12.6 million in damages to the Massachusetts public infrastructure such as; roads, bridges, public facilities, and public utilities. Suffolk County also saw flooding from severe storms in October 1996, June 1998, March 2001, April 2004 and May 2006. The June 1998 storm was slow moving and produced rainfall of 6 to 12 inches over much of eastern Massachusetts (Reference 10).

In August 2011, Hurricane Irene, weakened to a tropical storm, flooded numerous roads in the Greater Boston area, including Storrow Drive and Memorial Drive. More than 150 fallen trees blocked MBTA tracks, shutting down service temporarily. Boston’s strongest wind gusts were 63 mph at 11:10 am (Reference 11).

In March 2010, heavy rainfall of 6 to 10 inches fell over much of Southern New England resulting in major flooding across eastern Massachusetts and Rhode Island, including the Boston area (Reference 12).

From December 2010 through February 2011, Southern New England, including Suffolk County, saw a series of winter storms that led to record snowfall for the season. Boston snowfall total was over 70 inches, more than 45 inches above average for the time of year.

Heavy snow, combined with rain led to numerous flooding problems across the county, roof collapses, and downed trees and utility lines (Reference 13).

On October 29 and October 30, 2012, Hurricane Sandy, a hybrid storm with both tropical and extra-tropical characteristics, brought high winds and coastal flooding to southern New England, including Suffolk County. Sandy reached hurricane status over the southwest Caribbean and headed north through the Bahamas where it interacted with a vigorous weather system loving west to east across the United States, making landfall near Atlantic City, NJ on October 29, 2012 as a category 1 hurricane based on the Saffir-Simpson Hurricane Wind Scale. Sustained wind speeds of 41 mph and gusts to 62 mph were reported by the Automated Surface Observing System at Logan International Airport in East Boston. Seas built to between 20 and 25 feet just off the east coast with a storm surge generally about 2.5 feet to 4.5 feet, peaking in between high tide cycles. Moderate coastal flooding occurred within Suffolk County. In Revere, eighteen inches of water flooded Bell Circle. In Boston, the intersection of Columbia Road and Quincy Street flooded and the ramp for Morissey Boulevard was closed due to flooding. In Winthrop, rocks from the seawall were pushed with the morning high tide onto Winthrop Shore Drive. Several other coastal locations were flooded due to water coming over seawalls and numerous roads were closed countywide due to flooding and down trees (Reference 12).

The Blizzard of 2013 occurred on February 8th and 9th of that year, and produced moderate to major coastal flooding, most notably during the time of the high tide Saturday morning along the Massachusetts east coast. At the storm's height near the early morning low tide, the storm surge reached 3 to 4 feet along much of the Massachusetts east coast from Boston south. At the time of the mid-morning high tide, the winds had shifted from northeast to north and the surge had dropped to 1.5 to 2.5 feet for most Massachusetts east coast locations. However, this was an astronomically high tide given the nearness to the time of the new moon, and waves to 30 feet had built just 15 miles off the coast. In Revere, Pines Road was inundated by ocean water. Winthrop Parkway experienced splashover with ocean debris in the road. In Winthrop, Shirley Street, Tafts Avenue, and Winthrop Shore Drive were flooded with up to two feet of water. Yirrell Beach at Mugford Street was flooded with water flowing around and under buildings (Reference 12).

On March 7th and 8th of 2013, a storm brought heavy snow and significant coastal flooding to the area. The Massachusetts east coast was hit by widespread moderate and pockets of major coastal flooding for two high tide cycles and beach erosion for at least 5 high tide cycles. In Boston, Morrissey Boulevard was closed in both directions from the University of Massachusetts Boston campus to Freeport Street. Exit 14 from Interstate 93 northbound was closed due to the flooding on Morrissey Boulevard. In Winthrop, six roads were flooded up to the curbs with splashover reaching the front steps of houses. Winthrop Shore Drive was flooded with water and overwash material. In Revere, Winthrop Parkway was flooded with water and debris (Reference 12).

Hurricanes Irene and Sandy, and the snowstorms of early 2013 that impacted the Suffolk County shoreline, occurred while the coastal flood hazard study completed in 2013 was in progress. Consequently, those events were not included in this study.

2.4 Flood Protection Measures

The primary flood problem within the City of Boston is in the area along the Charles River Basin. In 1910, a dam on the Charles River at Leverett Street was constructed, but with newly developed and paved areas, the dam became inadequate to carry the discharge predicted. The USACE replaced the Leverett Street dam with the new and improved Warren Avenue Dam to accommodate the growth of metropolitan Boston.

In the early 1970’s the Charles River Dam Local Protection Project was initiated, thus removing the Warren Avenue Dam and replacing it with the current Charles River Dam, which provides flood protection to 2,440 acres of urban property along the banks of the Charles River. The project consisted of the construction of an earthfill and concrete dam with stone slope protection stretching between Boston and Charlestown. The dam is 400 feet long with an elevation of 12.5 feet above mean sea level. The connecting pumping station is 190 feet long and 122 feet high and contains six pumps. There are three navigation locks for commercial and recreational vessels. Two of the locks, for small recreational craft, each measure 200 feet long, 22 feet wide, and eight feet deep. The third lock, 40 feet wide, 300 feet long, and 17 feet deep, accommodates commercial vessels, large recreational boats, and the overflow of small craft during peak days.

The Baker Dam is located within the boundaries of the Dorchester/Milton Lower Mills Industrial Complex along the Neponset River and was originally built in the mid-1960’s for the purpose of privately owned industrial mills. In the wake of hurricane Diane, the MDC took over the Lower Neponset, including its dams. In 1962, the MDC flood control project began, covering a stretch of the Neponset River from the freshwater limit to upstream of the Neponset Valley Parkway and CONRAIL crossing. The Baker dam was rebuilt in the same general style as the original, except the top of the dam was lowered by three or more feet to improve its discharge capacity during storm events. The average water level at Baker was also reduced by about three feet, thus providing better flood protection. This project also included channel straightening and channel and bridge modifications. These measures, in conjunction with proper operation of the floodgates on the dams, will effectively contain the 1- and 0.2-percent-annual-chance floods within the channel banks. Much of the land bordering riverine areas has been designated as parkland, thereby limiting development in floodplain areas. Flood control measures along the harbor are scattered, but include such measures as seawalls and rip-rapping.

At the time of this study, the USACE was conducting a feasibility study regarding the removal of the Baker Dam for Neponset River restoration purposes (http://www.neponset.org/projects.htm). It was recommended by the Massachusetts Riverways Program’s Technical Advisory Committee to remove this dam, as it is no longer serving the purpose for which it was built.

In Chelsea, a tide gate exists on Mill Creek at the culvert under the east ramp of the U.S. Route 1 interchange with State Route 16. In 1979, the state locked the gate in an open position to help alleviate the occasional flooding problems upstream. There are no other flood protection structures or measures in Chelsea.

In Revere and Winthrop, the MDC provides concrete seawalls and stone revetments to protect coastal highways. Other protective structures are generally built and maintained by the local municipality and private property owners to satisfy individual requirements within their financial capabilities. These structures include such backshore protection as timber and steel sheet piles, bulkheads, stone revetments, concrete seawalls, and pre-cast concrete units (Reference 14). Limited financial resources sometimes result in less than adequate protection.

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-, 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-, 50-, 100-, and 500-year floods, have a 10-, 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 Riverine Hydrologic Analyses

Hydrologic analyses were carried out to establish peak discharge-frequency relationships for floods of the selected recurrence intervals for each flooding source studied by detailed methods affecting the county

For the 2009 countywide FIS, no new Hydrologic Analyses were conducted. For each community within Suffolk County, the hydrologic analyses described in their previous FIS reports have been compiled and summarized below.

Peak discharge estimates for the upper reach of the Charles River for the 10-, 2-, 1-, and 0.2-percent-annual-chance floods were based on a log-Pearson Type III analysis of the USGS gage data from the gages (no. 01104500 and no. 01103500) located at Waltham and Charles River Village, respectively (Reference 15).

As a result of the 8,400 cfs pumping capacity of the New Charles River Dam, peak discharge estimates for the Charles River Basin for floods of the selected recurrence intervals were not determined. Peak inflow hydrographs developed by the USACE were used to determine pumping curves so as to maintain basin levels near the normal elevation of 2.5 feet during the 10-, 2-, and 1-percent-annual-chance floods (Reference 16). Damage resulting from floodwaters along the Charles River Basin begins at an elevation of 3.8 feet. During a 1-percent-annual-chance event, the pumping station will control basin levels to an elevation of 3.5 feet, which is below the level at which damage will occur. For the 0.2-percent-annual-chance event, basin levels will be held to an elevation of 5.2 feet and minimal damage will result. This assumes, however, that the basin will not be drawn down and that sluicing will not be possible.

Mother Brook acts as a diversion channel from the Charles River to the Neponset River. The discharges for Mother Brook are limited by law to approximately one-third of the peak discharge for the Charles River (Reference 17).

Peak discharge estimates for the Muddy River and Back Bay Fens for floods of the selected recurrence intervals were not calculated, as the Muddy River and Back Bay Fens act as a reservoir during periods of great runoff. For this reason, hydrologic analyses were conducted to establish peak volume rather than peak discharge-frequency data. Flood volume data was developed by the USACE using unit hydrographs and rainfall-frequency analyses (References 16 and 18). This data was checked for reasonableness and incorporated into this study.

Peak discharge-frequency estimates of the Neponset River for the 10-, 2-, 1-, and 0.2-percent-annual-chance floods were determined for the FIS for the Town of Milton in Norfolk County and were incorporated into this study (Reference 19).

Peak discharge-frequency estimates for Stony Brook for the 10-, 2-, and 1-percent-annual-chance floods were computed using the SCS peak discharge determination methods for small watersheds (Reference 17). The 0.2-percent-annual-chance peak discharge estimate was determined by linear extrapolation of a log-Pearson Type III probability curve on the other floods.

Two high-water marks in Chelsea were obtained from the USGS. The elevation on Mill Creek upstream of Broadway Avenue in Chelsea is 8.8, and the elevation on the Chelsea River at the MDC Sewerage Division Maintenance Yard is 9.5 (Reference 20).

The Mill Creek discharges in Chelsea and Revere were obtained from a drainage study of Mill Creek prepared for the Massachusetts Department of Public Works in 1975 (Reference 21). The analysis incorporated rainfall simulation modeling, simulation of runoff, and the drainage system response to rainfall through the use of a computerized catchments model. The 0.2-percent-annual-chance discharge was extrapolated from the three calculated flow values.

Peak discharge-drainage area relationships for the flooding sources studied by detailed methods are shown in Table 5, “Summary of Discharges.”

TABLE 5 – 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
CHARLES RIVER					
At upstream Boston-Dedham corporate limits	227	2,125	3,102	3,578	4,850
MILL CREEK					
At confluence with Chelsea River	1.3	600	1,690	2,300	4,790
MOTHER BROOK					
At City of Boston corporate limits	2.4	740	1,210	1,470	2,250
NEPONSET RIVER					
At dam at Lower Mills in the City of Boston	98	2,450	3,410	3,730	4,750
STONY BROOK					
At Stony Brook culvert in the City of Boston	13	90	150	200	286

3.2 Riverine 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 [Flood Insurance Rate Map (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 sections were field surveyed and located at close intervals above and below bridges and culverts in order to compute the significant backwater effects of these structures. All bridges, dams, and culverts in the county were field surveyed to obtain elevation data and structural geometry. In long reaches between structures, appropriate valley sections were also surveyed.

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.

For the 2009 countywide FIS, no new hydraulic analyses were conducted. For each community within Suffolk County that has a previously printed FIS report, the hydraulic analyses described in those reports have been compiled and are summarized below.

In Boston, overbank extensions of field-surveyed channel cross sections, and additional sections needed for hydraulic continuity were taken from topographic maps at a scale of 1:1,200 with a 5 foot contour interval (Reference 22). Present culvert conditions were used and recent modifications were taken into consideration in the use of flood marks.

The overbank portions of the cross-section data for Mill Creek were obtained from topographic maps prepared by photogrammetric methods (Reference 23). The below-water sections were obtained by field measurement. All bridges and culverts were field surveyed to obtain elevation data and structural geometry.

Water-surface elevations for Stony Brook, Mill Creek, Mother Brook, Neponset River, and the upper reach of the Charles River were developed using the HEC-2 computer program developed by the USACE (Reference 24). Starting water-surface elevations for Mill Creek were based on mean high-water elevations. The storm surge elevations from the coastline were superimposed on the profile to the location on Mill Creek where backwater flooding from the coast no longer exists. Starting water-surface elevations for Stony Brook were taken from a rating curve developed at the entrance to the Stony Brook culvert.

At one location on Mill Creek, the analysis indicates that the flow would be supercritical. Because of the inherent instability of supercritical flow, critical depth was assumed at this location when establishing the profile elevations for this study.

Water-surface elevations for floods of the selected recurrence intervals along the Neponset River were obtained from a previously published report by Anderson-Nichols Co. and the FIS for the Town of Milton in Norfolk County (References 19 and 25). They were checked for reasonableness and incorporated into this study.

For the Charles River Basin, elevations were developed using inflow hydrographs in respect to the pumping capacity of the New Charles River Dam (References 16 and 26). Elevations along the Muddy River were developed using the "modified puls" method of reservoir routing in conjunction with the discharge capacity of the Charles River Basin (References 16, 18, 26 and 27). Elevations for the floods for the Back Bay Fens, the Muddy River and the Charles River Basin were developed by the USACE in their detailed analysis of the Charles River Basin (References 16 and 18).

In some locations, such as the Boston Harbor shoreline within Winthrop, water levels were computed by correlating synthetically-produced water levels with elevations obtained during historic floods (Reference 28). Historic flood damage information was also used to ensure reasonable delineation of flood-prone areas along the Revere and Winthrop shoreline (Reference 29).

The City of Revere has no qualifying bench marks within its corporate limits.

Roughness factors (Manning's "n") used in the hydraulic computations were estimated based on field inspection of flood plain areas. The channel "n" and overbank "n" values for the streams studied by detailed methods are shown in Table 6, "Manning's "n" Values":

TABLE 6 – MANNING'S "n" VALUES

FLOODING SOURCE	CHANNEL "n"	OVERBANK "n"
Charles River	0.025-0.035	0.065
Mill Creek	0.040	0.060-0.085
Mother River	0.015-0.100	0.100
Neponset River	0.035	0.060
Stony Brook	0.020-0.050	0.100

3.3 Coastal Hydrologic Analyses

In Suffolk County, for the coastal areas within the limits of tidal inundation, water level fluctuations above astronomical tide levels are caused primarily by the passage of hurricanes and winter storms known as northeasters. Of these, the northeasters produce the more frequent and severe storm tides.

Extreme water levels along the shoreline are caused by the combination of storm surges and high astronomical tides. Astronomical tide levels are extremely important in the determination of total water levels as they have a mean range of 8.7 feet and a spring range of more than 11.2 feet (Reference 1). These ranges are considerably larger than the expected storm surges, thus making the phasing of the astronomical tide critical to the determination of total water levels.

Storm surges in the Boston area are caused mainly by onshore winds, wave setup and low barometric pressures that cause a rise in the water-surface elevation. As discussed above, these water level fluctuations are due primarily to the passage of hurricanes and northeasters through the area. The dominant surge-producing storm in the Boston area, as in most of the New England regions, is the northeaster. These storms are typically less intense than hurricanes, but they occur more frequently and are larger and slower-moving. Thus, they have a significantly greater probability of combining with a high astronomical tide causing an extreme high-water level. Hurricanes in the New England region are considerably weaker than the very destructive storms found in the Gulf of Mexico and off the southeastern coast of the United States. These factors, along with the relatively narrow continental shelf off Boston, combine to reduce the effect of the hurricanes on the tide levels at the coast.

Revised coastal analyses were performed for the open water flooding sources for Belle Island Inlet, Boston Harbor, Dorchester Bay and the Pines, Chelsea, Charles, and Neponset River flooding sources affecting the communities of Boston, Chelsea, Revere, and Winthrop. A description of these revised analyses is presented in the countywide coastal analyses sections below.

Coastal Stillwater elevations presented in the pre-countywide FISs that have not been superseded by this coastal study update have been compiled and are summarized below.

Pre-countywide Analyses

Stillwater elevations for the Charles River Basin upstream of the New Charles River Dam were obtained from a 1979 USACE report (Reference 30). The 2013 coastal study extends only as far as the Route 28 bridge over the Charles River between Boston and Cambridge, therefore the pre-countywide analysis of the Charles River remains in effect upstream of that point.

The pre-countywide stillwater elevations have been determined for the 10-, 2-, 1-, and 0.2-percent-annual-chance floods for the flooding sources studied by detailed methods and are summarized in Table 7, "Summary of Pre-countywide Stillwater Elevations."

TABLE 7 – SUMMARY OF PRE-COUNTYWIDE STILLWATER ELEVATIONS

	ELEVATION (NAVD 88)[1]			
FLOODING SOURCE AND LOCATION	10-PERCENT-ANNUAL-CHANCE	2-PERCENT-ANNUAL-CHANCE	1-PERCENT-ANNUAL-CHANCE	0.2-PERCENT-ANNUAL-CHANCE
CHARLES RIVER BASIN				
Immediately upstream of Route 28 Bridge	3.0	3.2	3.5	5.2

[1]North American Vertical Datum of 1988 (NAVD 88)

2013 Coastal Study

The stillwater elevation is the elevation of the water due to the effects of the astronomic tides and storm surge on the water surface. Hydrologic analyses carried out to establish the peak discharge-frequency relationships for the Belle Island Inlet, Boston Harbor, Dorchester Bay and the Pines, Chelsea, Charles, and Neponset River flooding sources affecting the communities of Boston, Chelsea, Revere, and Winthrop serve as a basis of coastal hydraulic analyses using detailed methods in accordance with Appendix D of the "Guidance for Coastal Flooding Analyses and Mapping," of the April 2003 FEMA "Guidelines and Specifications for Flood Hazard Mapping Partners" (Reference 31).

For this study, the 10-, 2-, 1-, and 0.2-percent-annual-chance floods for the nearest gages to Suffolk County on the Belle Island Inlet, Boston Harbor, Dorchester Bay and the Pines, Chelsea, Charles, and Neponset River were obtained from the "Regional Frequency Analyses using L-Moments" memorandum developed by STARR (Reference 32) for areas subject to coastal flooding. There is one gage located within Suffolk County. Stillwater elevations at the nearest two gages (USACE-NED gage at New Bedford; and NOAA gage 8419870 at Seavey Island) were linearly interpolated to all coastal transects throughout the county for use in the coastal hydraulic analyses. Table 8, "Summary of Countywide Stillwater Elevations" contains the stillwater elevations determined at the Boston tide gage station within Suffolk County.

TABLE 8 – SUMMARY OF COASTAL STILLWATER ELEVATIONS

FLOODING SOURCE AND LOCATION	ELEVATION (NAVD 88)[1] 10-PERCENT-ANNUAL-CHANCE	2-PERCENT-ANNUAL-CHANCE	1-PERCENT-ANNUAL-CHANCE	0.2-PERCENT-ANNUAL-CHANCE
Boston, MA tide gage station 8443970 (42˚21.2' N, 71˚3.2' W)	8.45	9.51	10.04	11.46

[1]North American Vertical Datum of 1988 (NAVD 88)

During the Appeal period for Suffolk County, the stillwater elevations were revised using an independent frequency analysis performed on the Boston Harbor tide gage data recorded from 1921 to 2007. Annual maxima were identified, corrected to current MSL using the most recent sea level trend, and fit to a Pearson Type III distribution. A summary of the stillwater elevations developed for the appeal are provided in Table 9, "Summary of Revised Coastal Stillwater Elevations."

TABLE 9 – SUMMARY OF REVISED COASTAL STILLWATER ELEVATIONS

FLOODING SOURCE AND LOCATION	ELEVATION (NAVD 88)[1] 10-PERCENT-ANNUAL-CHANCE	2-PERCENT-ANNUAL-CHANCE	1-PERCENT-ANNUAL-CHANCE	0.2-PERCENT-ANNUAL-CHANCE
Atlantic Ocean				
Entire Shoreline within the City of Revere	*	*	9.2	10.0
At Broad Sound in the Town of Winthrop	*	*	9.1	9.9
Belle Isle Inlet				
Entire Shoreline	*	*	8.8	9.6
Boston Harbor				
East of Logan Airport	*	*	8.8	9.6
East of Governor's Island	*	*	9.1	9.6
Northeast of Spectacle Island	*	*	9.2	10.1
Southeast of Castle Island	*	*	9.3	10.1
At Long Island	*	*	9.3	10.2
East of Thompson Island	*	*	9.4	10.3

[1]North American Vertical Datum of 1988 (NAVD 88)
*Data not available

TABLE 9 – SUMMARY OF REVISED COASTAL STILLWATER ELEVATIONS - continued

FLOODING SOURCE AND LOCATION	ELEVATION (NAVD 88)[1] 10-PERCENT-ANNUAL-CHANCE	2-PERCENT-ANNUAL-CHANCE	1-PERCENT-ANNUAL-CHANCE	0.2-PERCENT-ANNUAL-CHANCE
Boston Inner Harbor				
Entire shoreline in the City of Boston	*	*	9.4	10.2
Dorchester Bay				
At Old Harbor	*	*	9.7	10.5
West of Thompson Island	*	*	9.9	10.7
At Neponset River	*	*	10.6	11.4
Massachusetts Bay				
At Deer and Lovell Islands	*	*	9.2	10.1
Mystic River				
Immediately upstream of Mystic River Bridge	*	*	9.5	*

[1]North American Vertical Datum of 1988 (NAVD 88)
*Data not available

3.4 Coastal Hydraulic Analyses

The hydraulic methods described in this section are those used for the 2013 coastal study.

As a result of incorporating appeals received during the study, there are different coastal hydraulic methods used based upon the source of the studied transect. Table 10, "Summary of Transect Methodology" contains the wave climatology and wave setup information used on each transect along with the study source.

TABLE 10 – SUMMARY OF TRANSECT METHODOLOGY

TRANSECT	1-PERCENT-ANNUAL-CHANCE STILLWATER[1]	SIGNIFICANT WAVE HEIGHT[1]	PEAK PERIOD	HOW DETERMINED	WAVE SETUP	HOW DETERMINED
1	9.2	2.3	12.5	SWAN 2D	0.46	SWAN 1D
2	9.2	5.8	12.5	SWAN 2D	0.94	SWAN 1D
3	9.2	21.22	12.5	SWAN 2D	1.76	SWAN 1D
4	9.2	21.22	12.5	SWAN 2D	1.76	SWAN 1D
5	9.2	21.22	12.5	SWAN 2D	1.86	SWAN 1D
6	9.2	21.22	12.5	SWAN 2D	1.9	SWAN 1D
7	9.8	21.22	12.5	STWAVE	3.12	DIM

[1]North American Vertical Datum of 1988 (NAVD 88)

TABLE 10 – SUMMARY OF TRANSECT METHODOLOGY - continued

TRANSECT	1-PERCENT-ANNUAL-CHANCE STILLWATER[1]	SIGNIFICANT WAVE HEIGHT[1]	PEAK PERIOD	HOW DETERMINED	WAVE SETUP	HOW DETERMINED
8	9.2	21.22	12.5	SWAN 2D	2	SWAN 1D
9	9.1	23.09	12.5	SWAN 2D	2.67	SWAN 1D
10	9.7	23.09	12.5	STWAVE	4.44	DIM
11	9.7	23.09	12.5	STWAVE	4.5	DIM
12	9.1	23.09	12.5	SWAN 2D	2.3	SWAN 1D
13	9.1	23.09	12.5	SWAN 2D	2.45	SWAN 1D
14	9.7	23.09	12.5	STWAVE	3.96	DIM
15	9.1	23.09	12.5	SWAN 2D	2.4	SWAN 1D
16	9.8	23.09	12.5	STWAVE	3.62	DIM
17	8.8	2.3	5.6	SWAN 2D	0.03	SWAN 1D
18	9.7	2.83	12.5	STWAVE	1.17	DIM
19	9.4	2.58	5.17	SWAN 2D	0.04	SWAN 1D
20	9.4	1.3	2.1	ACES	0.04	SWAN 1D
21	8.8	0.93	1.77	ACES	0.32	SWAN 1D
22	9.5	1.53	2.22	ACES	0.07	SWAN 1D
23	9.4	0.85	5.17	SWAN 2D	0.18	SWAN 1D
24	9.4	2.58	5.17	SWAN 2D	0.04	SWAN 1D
25	9.4	2.58	5.17	SWAN 2D	0.08	SWAN 1D
26	9.4	5.47	5.17	SWAN 2D	0.72	SWAN 1D
27	9.9	15.62	12.5	STWAVE	3.48	DIM
28	9.7	3.85	4.15	SWAN 2D	0.41	SWAN 1D
29	9.7	3.85	4.15	SWAN 2D	0.37	SWAN 1D
30	9.9	3.85	4.15	SWAN 2D	0.59	SWAN 1D
31	9.9	3.7	3.72	SWAN 2D	0.36	SWAN 1D
32	10.6	3.7	3.72	SWAN 2D	0.19	SWAN 1D
33	10	15.62	12.5	STWAVE	1.93	DIM
34	9.8	15.62	12.5	STWAVE	3.8	DIM
35	9.9	15.62	12.5	STWAVE	3.83	DIM
36	9.8	21.73	12.5	STWAVE	2.93	DIM
37	9.8	21.73	12.5	STWAVE	4.62	DIM

[1]North American Vertical Datum of 1988 (NAVD 88)

Wave Climatology

STWAVE

The energy-based significant wave height (Hmo) and peak wave period (Tp) are used as inputs to wave setup and wave runup calculations and were calculated using the Steady-State Spectral Wave Model (STWAVE). STWAVE is a phased-averaged spectral wave model that simulates depth-induced wave refraction and shoaling, depth-and steepness-induced wave breaking, diffraction, wind-wave growth, and wave-wave interaction and white capping that redistribute and dissipate energy in a growing wave field. The model accepts a spectral form of the wave as an input condition and provides Hmo and Tp results over the gridded model domain.

STARR team developed STWAVE models for the entire coastline of Suffolk County, and the results were obtained from the model for the coastal flooding analysis in the Cities of Boston, Chelsea, Revere, and the Town of Winthrop.

Offshore (deepwater) wave heights, wave setup, and wave runup for each transect were calculated using Mathcad sheets developed by STARR to apply methodologies from the USACE's Coastal Engineering Manual (Reference 33) and FEMA Guidelines and Specifications (Reference 34). Methodologies for each type of calculation are discussed in more detail below. Results from the Mathcad calculations performed for each transect were compiled in a summary spreadsheet.

<u>SWAN</u>

SWAN is a third-generation wave model, approved by FEMA, for obtaining realistic estimates of wave parameters in coastal areas from given wind, bottom, and current conditions. SWAN includes wave generation, dissipation, non-linear interactions, and transformations. It also includes bottom friction, currents, shoaling, refraction, diffraction, depth induced breaking, and wave setup. SWAN represents a model based approach that accounts for the physics of the waves, including the process of wave setup.

The SWAN 2D simulations were run using the same model domains, bathymetric grids, wind, and input deepwater wave conditions that were utilized during the STWAVE modeling for Suffolk County. Data available from the US Army Corps of Engineers (USACE) Wave Information Studies (WIS) were used to confirm the deepwater wave conditions used to drive the STWAVE model. The WIS database contains 20 years of wave hindcast data from 1979 to 1999 at locations along the Atlantic, Gulf of Mexico, and Pacific US coastlines. The closest WIS station to Boston Harbor is Sta. 63053, located near the southeast corner of the coarse grid model domain. Extremal analyses published by the USACE on data from Sta. 63053 indicate a 100-year wave height of 9.35 meters (30.66 ft).

Results from the SWAN 2D simulation of 100-year wave conditions were used to generate significant wave conditions required for input at each transect in FEMA's CHAMP program. FEMA followed the same steps in using results from their STWAVE model to generate significant wave conditions needed for CHAMP. However, FEMA's criteria used to select representative wave conditions from the model output (as described above) varied from those used for transects evaluated in the appeals. The SWAN model also provides a more robust approach for producing wind-generated waves, in addition to the wave transformations. This is particularly important for complex shorelines and sheltered regions like Boston Harbor where the ocean swell waves may eventually have less energy than the local wind generated waves. As such, SWAN generally produces higher wave heights in areas where the wind-generated components of the wave field become more dominant.

ACES

For the more sheltered transects added during the appeal period at SF-20, SF-21, and SF-22; the Automated Coastal Engineering System (ACES) software available through the Coastal Engineering and Design Analysis System (CEDAS, Version 4.0) was utilized to generate the wave conditions needed for CHAMP and the SWAN 1-D modeling of wave setup. At these locations, it is expected that the wave conditions will be solely wind generated waves from storm winds. The geometry of the shoreline and landforms that surround the transects were defined by establishing a series of radial fetches at 10 degree intervals. The fetch bands were used in the Wave Prediction – Wind Adjustment and Wave Growth (restricted fetch) module of ACES to define the distance and depth over water that storm winds can generate local waves. A wind speed of 25.7 meters/sec (50 knots) taken from the FEMA FIS for Suffolk County was used to simulate the 100-year storm condition.

Overland Wave Propagation

Overland wave heights were calculated for restricted and unrestricted fetch settings using the Wave Height Analysis for Flood Insurance Studies (WHAFIS), Version 4.0 (Reference 35), within the Coastal Hazard Analysis for Mapping Program (CHAMP) (Reference 36), following the methodology described in the FEMA Guidelines and Specifications for each coastal transect.

The fundamental analysis of overland wave effects for an FIS is provided by FEMA's Wave Height Analysis For Flood Insurance Studies computer program, WHAFIS 4.0, a computer program that uses representative transects to compute wave crest elevations in a given study area. Topographic, vegetative, and cultural features are identified along each specified transect landward of the shoreline. WHAFIS uses this and other input information to calculate wave heights, wave crest elevations, flood insurance risk zone designations, and flood zone boundaries along the transects.

The original basis for the WHAFIS model was the 1977 National Academy of Sciences (NAS) report "Methodology for Calculating Wave Action Effects Associated with Storm Surges" (Reference 39). The NAS methodology accounted for varying fetch lengths, barriers to wave transmission, and the regeneration of waves over flooded land areas. Since the incorporation of the NAS methodology into the initial version of WHAFIS, periodic upgrades have been made to WHAFIS to incorporate improved or additional wave considerations.

WHAFIS 4.0 was applied using CHAMP to calculate overland wave height propagation and establish base flood elevations. For profiles with vertical structures or revetments, a failed structure analysis was performed and a new profile of the failed structure was generated and analyzed.

The general working procedure for the transects included eight steps: 1) laying out transects; 2) determining off-shore significant wave heights and corresponding wave periods from STWAVE outputs; 3) performing the off-shore engineering analysis; 4) preparing WHAFIS input data and populating the CHAMP database; 5) performing erosion analysis for erodible transects without a coastal structure; 6) performing WHAFIS modeling runs on eroded transects and transects with both intact and failed structures, as applicable; 7) performing wave runup analysis on intact and failed structures; and 8) identifying primary frontal dunes.

Coastal engineering analysis was performed for each coastal transect using wave condition extracted from the wave climatology model output and stillwater elevation (SWEL) data to generate wave setup and wave runup values for open coast transects and transects with vertical structures or revetments, and to generate input used in developing CHAMP and WHAFIS input data. Mathcad sheets were developed and applied by STARR for the calculations to help ensure consistency and accuracy. The input data and results of the analysis were compiled for each transect in a summary spreadsheet. The Mathcad sheets and summary spreadsheet are included in the digital data files compiled for the coastal submittal. This STWAVE model was developed for the entire coastline of Suffolk County, and the results were obtained from the model for the coastal flooding analysis in the Cities of Boston, Chelsea, and Revere; and the Town of Winthrop.

CHAMP is a Microsoft (MS) Windows-interfaced Visual Basic language program that allows the user to enter data, perform coastal engineering analyses, view and tabulate results, and chart summary information for each representative transect along a coastline within a user-friendly graphical interface. With CHAMP, the user can import digital elevation data, perform storm-induced erosion treatments, wave height and wave runup analyses, plot summary graphics of the results, and create summary tables and reports in a single environment. CHAMP version 2.0 (Reference 36) was used to perform erosion analysis, run WHAFIS, and apply RUNUP 2.0 to transects without coastal structures. Application of CHAMP followed the instructions in the FEMA Guidelines and Specifications (Reference 34) and the Coastal Hazard Analysis Modeling Program user's guide found in the software documentation (Reference 37).

<u>Wave Setup</u>

<u>Direct Integration Method</u>
Wave setup can be a significant contributor to the total water level at the shoreline and was included in the determination of coastal base flood elevations. Wave setup is defined as the increase in total stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup values were calculated for each coastal transect using the Direct Integration Method (DIM),developed by Goda (2000) (Reference 38), as described in the FEMA Guidelines and Specifications, Equation D.2.6-1. For those coastal transects where a structure was located, documentation was gathered on the structure, and the wave setup against the coastal structure was also calculated.

<u>SWAN</u>
For the appeal submitted engineering, the wave setup values were revised using the SWAN 1D model. Results from the SWAN 2D simulation of 100-year wave conditions were used as input to drive SWAN 1D simulations at each of the transects evaluated as part of the appeal. The purpose of the SWAN 1D simulations was to develop wave setup at each site specific transect location.

Bathymetric and topographic conditions were taken directly from the 2013 Preliminary FIS FEMA CHAMP database. Transects where FEMA modeled structure failure and erosion were utilized in place of the intact conditions. The FEMA CHAMP transect data were interpolated to an evenly-spaced 1 meter resolution for input to SWAN 1D. Water levels were set to reflect the revised 100-year SWELs shown in Table 10. Incident wave conditions were obtained from the SWAN 2D model simulation and summarized in Table 10. For the transects SF-20, SF-21, and SF-22, the incident wave conditions were obtained from the ACES modeling. Waves were assumed to conservatively approach normal to the shoreline (along the axis of the transects) and spectral spreading was turned off in the model (to ensure that the peak energy was not muted). This represents a conservative assumption where the model computed wave setup using peak wave conditions, rather than a spectral spread of the waves. Results from the SWAN 1D simulations were reviewed and the maximum wave setup along each transect was identified.

Wave Runup

Wave runup is the uprush of water caused by the interaction of waves with the area of shoreline where the stillwater hits the land or other barrier intercepting the stillwater level. The wave runup elevation is the vertical height above the stillwater level ultimately attained by the extremity of the uprushing water. Wave runup at a shore barrier can provide flood hazards above and beyond those from stillwater inundation. Guidance in the FEMA Guidelines and Specifications (Reference 34) suggests using the 2-percent wave runup value, the value exceeded by 2 percent of the runup events. The 2-percent wave runup value is particularly important for steep slopes and vertical structures.

Wave runup was calculated for each coastal transect using methods described in the FEMA Guidelines and Specifications (Reference 34). Runup estimates were developed for vertical walls using the guidance in Figure D.2.8-3 of the FEMA Guidelines and Specifications (Reference 34), taken from the Shore Protection Manual (Reference 40). Technical Advisory Committee for Water Retaining Structures (TAW) method was applied for sloped structures with a slope steeper than 1:8. For slopes milder than 1:8, the FEMA Wave Runup Model RUNUP 2.0 was used. Both the SPM and RUNUP 2.0 provide mean wave runup. The mean wave runup was multiplied by 2.2 to obtain the 2percent runup height. Wave runup elevation was added to the stillwater elevation and does not include wave setup.

Limit of Moderate Wave Action

Areas of coastline subject to significant wave attack are referred to as coastal high hazard zones. The USACE (Reference 41) has established the 3-foot breaking wave as the criterion for identifying the limit of coastal high hazard zones. The 3-foot wave has been established as the minimum size wave capable of causing major damage to conventional wood frame and brick veneer structures. WHAFIS results show where the waves are greater than 3 feet (VE zone) and less than 3 feet (AE zone).

The LiMWA is determined and defined as the location of the 1.5-foot wave. Typical constructions in areas of wave heights less than 3-feet high have experienced damage, suggesting that construction requirements within some areas of the AE zone should be more like those requirements for the VE zone. Testing and investigations have confirmed that a wave height greater than 1.5 feet can cause structure failure. The LiMWA was determined for all areas subject to significant wave attack in accordance with "Procedure Memorandum No. 50 – Policy and Procedures for Identifying and Mapping Areas Subject to Wave Heights Greater than 1.5 feet as an Informational Layer on Flood Insurance Rate Maps (FIRMs)" (Reference 42). The effects of wave hazards in the Zone AE areas (or shoreline in areas where VE Zones are not identified) and the limit of the LiMWA boundary are similar to, but less severe than, those in Zone VE where 3-foot breaking waves are projected during a 1-percent-annual-chance flooding event.

The effects of wave hazards in the Zone AE areas (or shoreline in areas where VE Zones are not identified) and the limit of the LiMWA boundary are similar to, but less severe than, those in Zone VE where 3-foot breaking waves are projected during a 1-percent-annual-chance flooding event.

Primary Frontal Dune

Primary frontal dune (PFD) evaluations were performed for all communities in Suffolk County and mapped where sufficient data was available to support the delineation. PDFs were identified in the City of Revere. Provided below is a summary of the analyses performed. All revised coastal analyses were performed in accordance with the FEMA Guidelines and Specifications (Reference 34).

In accordance with 44 CFR Section 59.1 of the National Flood Insurance Program (NFIP), the effect of the PFD on coastal high hazard area (V Zone) mapping was evaluated for the communities in Suffolk County. Identification of the PFD was based upon a FEMA-approved numerical approach for analyzing the dune's dimensional characteristics. Using this methodology, the landward toe of the PFD is delineated based on knowledge of local geological processes and remote sensing/GIS technologies utilizing LiDAR data. The PFD defined the landward limit of the V Zone along the northeastern shoreline of the Point of Pines in Revere.

Figure 1 is a profile for a typical transect illustrating the effects of energy dissipation and regeneration on a wave as it moves inland. This figure shows the wave crest elevations being decreased by obstructions, such as buildings, vegetation, and rising ground elevations, and being increased by open, unobstructed wind fetches. Actual wave conditions in the community may not include all the situations illustrated in Figure 1.

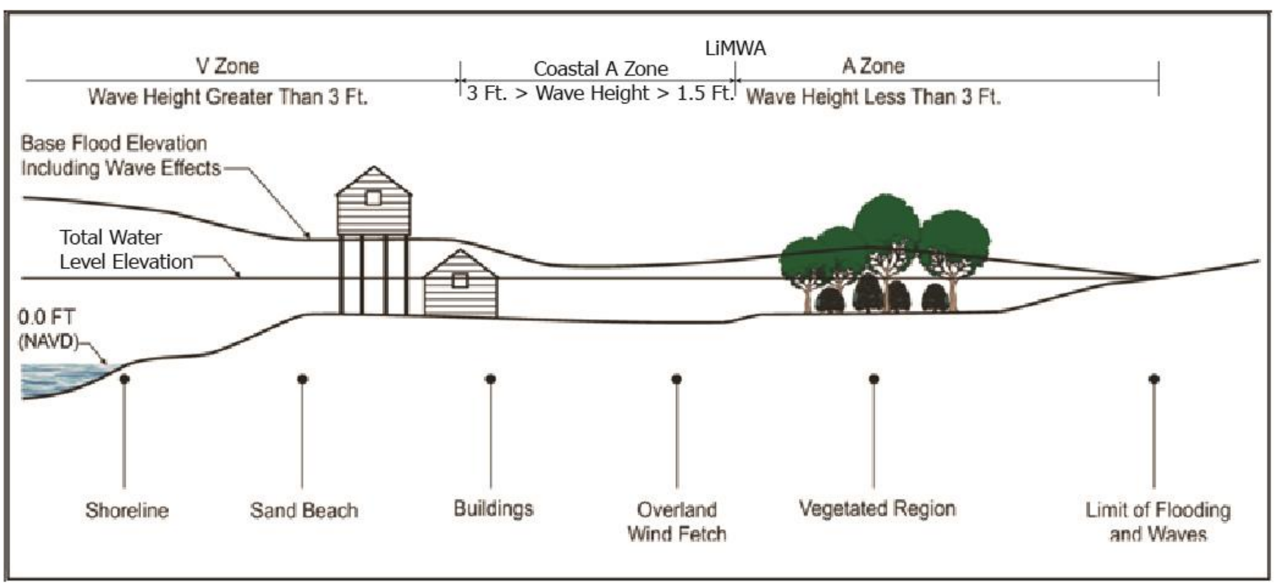


FIGURE 1 – TRANSECT SCHEMATIC

Transects (profiles) were located for coastal hydrologic and hydraulic analyses perpendicular to the average shoreline along areas subject to coastal flooding; transects extend off-shore to areas representative of deep water conditions and extend inland to a point where wave action ceases, in accordance with the “User’s Manual for Wave Height Analysis” (Reference 43). Transects were placed with consideration of topographic and structural changes of the land surface, as well as the cultural characteristics of the land, so that they would closely represent local conditions. Transects were spaced close together in areas of complex topography and dense development. In areas having more uniform characteristics, transects were spaced at larger intervals. It was also necessary to locate transects in areas where unique flooding existed and in areas where computed wave heights varied significantly between adjacent transects.

Coastal transect topography data was obtained from Light Detection and Ranging (LiDAR) data collected in 2011 by STARR, accurate to 2-foot contours (Reference 44). Additionally, portions of fifteen (15) coastal transects were surveyed by Green International Affiliates in May 2011 to supplement the contour data for the study area. Coastal field inspection were also conducted in February 2011. Georeferenced global positioning system (GPS) points and tracks, as well as photographs, were collected and attributed with various descriptive information, such as upland type, coastal formations, including dunes and bluffs, coastal vegetation, coastal structures, and shore type. As appropriate, coastal protection structure details and 0.0 ft NAVD88 elevation were included and noted in the transect field surveys. Bathymetric data was obtained from the NOAA National Ocean Service (NOS) Hydrographic Data Base (NOSHDB) and Hydrographic Survey Meta Data Base (HSMDB) (NOAA, May 27, 2010) (Reference 45). The sounding datum of mean low low water (MLLW) was converted to vertical datum NAVD 88.

Transects were spaced close together in areas of complex topography and dense development. In areas having more uniform characteristics, transects were spaced at larger intervals. It was also necessary to locate transects in areas where unique flooding existed and in areas where computed wave heights varied significantly between adjacent transects.

Table 11 provides a description of the transect locations, the 1-percent-annual-chance stillwater elevations, and the maximum 1-percent-annual-chance wave crest elevations. Figure 2, "Transect Location Map," illustrates the location of the transects for the county.

TABLE 11 – TRANSECT DESCRIPTIONS

TRANSECT	LOCATION	ELEVATION (feet NAVD 88[2]) 1-PERCENT-ANNUAL-CHANCE STILLWATER	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST[1]
1	The transect extends over Point of Pines barrier spit in Revere. It intersects grassy vegetated dunes, a retaining wall at Rice Ave, and down Bateman Ave. The shoreline is sandy, upland development is dense single-family residential homes.	9.2	12.3
2	The transect crosses a sandy beach, five-foot concrete seawall, then intersects Rice Ave. Upland vegetation is limited to turf and ornamental trees and shrubs on residential properties. Development is dense single-family residential homes.	9.2	15.6
3	The transect extends over sandy beach, a 2.5 ft concrete seawall, and Revere Beach Blvd. Upland vegetation is generally open with few ornamental shrubs and trees. Development is limited to one row of single family residential houses.	9.2	16.8
4	The transect crosses sandy beach and a small 2.5 foot concrete seawall at Revere Beach Blvd. Upland vegetation is very sparse. The transect then extends over low lying residential area and across the tidal flats of Pine River.	9.2	16.8
5	The transect crosses sandy beach and a 2.5 ft concrete seawall-boardwalk at Revere Beach Blvd. Upland development is mostly open parking lots. The transect crosses a low marshy area before terminating in a dense residential area.	9.2	17.0

[1]Because of map scale limitations, the maximum wave elevation may not be shown on the FIRM.
[2]North American Vertical Datum of 1988

TABLE 11 – TRANSECT DESCRIPTIONS - continued

TRANSECT	LOCATION	ELEVATION (feet NAVD 88[2]) 1-PERCENT-ANNUAL-CHANCE STILLWATER	ELEVATION (feet NAVD 88[2]) MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST[1]
6	The transect crosses sandy beach separated from the upland area by a small 2.5 foot concrete seawall at Revere Beach Blvd. Upland development consists of mostly parking lots and some high rise residential structures.	9.2	17.0
7	This transect extends over a gabion revetment and 15 foot concrete seawall into the residential area of Roughan's Point Revere. The shoreline is heavily engineered with a gabion revetment approximately 20 feet wide and 6 feet high.	9.8	19.8
8	The transect crosses a mixed sand and gravel beach and 7 foot concrete seawall with some large gabions at the base of Winthrop Parkway (State Highway 145) near Beachmont in Revere. Upland development consists of single and multi-family residential units.	9.2	17.2
9	The transect crosses a cobble shoreline with both stable and eroding sections of 12 ft gabion revetment. Upland development is medium density single-family residential. Elevations increase sharply moving inland.	9.1	18.1
10	The transect crosses a cobble beach with a double concrete revetment built into the steep hillside at Seal Point in Winthrop. Upland development consists of large high-rise apartment buildings.	9.7	22.3

[1]Because of map scale limitations, the maximum wave elevation may not be shown on the FIRM.
[2]North American Vertical Datum of 1988

TABLE 11 – TRANSECT DESCRIPTIONS - continued

TRANSECT	LOCATION	ELEVATION (feet NAVD 88[2]) 1-PERCENT-ANNUAL-CHANCE STILLWATER	ELEVATION (feet NAVD 88[2]) MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST[1]
11	The transect crosses a mixed sand, gravel, and cobble beach with a small revetment below a 10 foot concrete seawall. Upland development is medium density single-family residential. Topography is steep and elevations rise quickly moving inland.	9.7	21.8
12	The transect crosses a sandy beach at Winthrop Beach and is separated from the upland area by a 10-foot concrete seawall with two groins to the North and South. Upland development is medium density single-family residential.	9.1	17.5
13	The transect crosses a mostly sand beach with some mixed cobble/gravel substrate extending towards the offshore breakwaters. A four foot concrete seawall separates the beach from Winthrop Shore Dr. Upland development is medium density residential.	9.7	22.1
14	The transect crosses a mixed sand, gravel, and cobble beach and a small 3 foot concrete seawall at the base of a large gabion reinforced bluff. Upland development is single family residential. Topography rises quickly to the top of Cottage Hill.	9.7	21.0
15	The transect crosses sandy beach at Point Shirley extends over a small 2-foot concrete seawall running parallel to Brewster Ave. Upland development is medium to high density residential homes.	9.1	17.6

[1]Because of map scale limitations, the maximum wave elevation may not be shown on the FIRM.
[2]North American Vertical Datum of 1988

TABLE 11 – TRANSECT DESCRIPTIONS - continued

TRANSECT	LOCATION	ELEVATION (feet NAVD 88[2]) 1-PERCENT-ANNUAL-CHANCE STILLWATER	ELEVATION (feet NAVD 88[2]) MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST[1]
16	The transect crosses over the Deer Island wastewater treatment plant. The shoreline is heavily reinforced with a large concrete seawall approximately 15ft high. Upland development is almost solely impervious surface and treatment plant buildings.	9.8	20.6
17	The transect crosses a gravel shore and seawall built into a steep bluff at Bartlett Pkwy at Cottage Park in Winthrop. Development is medium density residential homes.	8.8	11.4
18	The transect crosses over a section of Logan Airport at Governors Island. The shoreline is reinforced with a gabion revetment approximately 15 feet high. Upland development and vegetation is open grass, with some impervious surfaces.	9.7	14.0
19	The transect crosses a 3 foot concrete seawall with a 5 foot gabion revetment in front, then extends into parkland and a residential area of East Boston.	9.4	12.3
20	The transect extends from Boston Inner Harbor over an undeveloped piece of property and then into a residential area of East Boston.	9.4	10.9
21	The transect extends from Belle Island Inlet over the parkland of Constitution Beach and then in a residential area of East Boston.	8.8	9.9

[1]Because of map scale limitations, the maximum wave elevation may not be shown on the FIRM.
[2]North American Vertical Datum of 1988

TABLE 11 – TRANSECT DESCRIPTIONS - continued

TRANSECT	LOCATION	ELEVATION (feet NAVD 88[2]) 1-PERCENT-ANNUAL-CHANCE STILLWATER	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST[1]
22	The transect extends from the Mystic River over a rock revetment backed by a 3 foot seawall. This transect is in Charlestown and extends back to the county boundary.	9.5	11.2
23	The transect extends over one of the main steel seawall piers at Charlestown Navy Yard, then terminates in vegetated parkland.	9.4	10.5
24	This transect crosses a seawall approximately 10 feet high at Lewis Wharf in downtown Boston. Upland development is high density mixed use commercial and residential with parking lots.	9.4	12.3
25	The transect crosses a seawall at the South Boston Waterfront, extending over parking lot areas and over Seaport Blvd.	9.4	12.3
26	The transect crosses a 15 foot timber seawall at the South Boston waterfront around the Black Falcon area. Upland development is mostly large industrial buildings and impervious surface.	9.4	15.0
27	The transect crosses a gabion breakwater at Pleasure Bay in South Boston, extends into Pleasure Bay, then runs up a sandy beach and small seawall before ending in parkland.	9.9	20.5

[1]Because of map scale limitations, the maximum wave elevation may not be shown on the FIRM.
[2]North American Vertical Datum of 1988

TABLE 11 – TRANSECT DESCRIPTIONS - continued

TRANSECT	LOCATION	ELEVATION (feet NAVD 88[2]) 1-PERCENT-ANNUAL-CHANCE STILLWATER	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST[1]
28	The transect crosses a sandy beach immediately adjacent to Day Blvd in South Boston, and rises in elevation to parkland and dense multi-family residential.	9.7	14.4
29	The transect crosses a sandy beach approximately 150 ft wide at Carson Beach in South Boston, intersects both Day Blvd and Columbia Rd, enters parkland, then terminates at a large housing development complex.	9.7	14.3
30	The transect crosses a gabion revetment and through open space at UMASS Boston Campus. Topography rises gradually and is mostly open parkland with some rigid vegetation. Upland development is institutional buildings and parking lots.	9.9	14.8
31	The transect crosses a mixed sand and cobble beach at Morrissey Blvd, crosses over parkland, then extends through Dorchester Bay, and over Interstate 93 to Dorchester Ave.	9.9	14.3
32	The transect crosses a mixed timber seawall at a marina on the mouth of the Neponset River, extends south down Lawley Street, then terminates at Redfield St.	10.6	14.9
33	The transect crosses a sand-gravel beach at Thompson Island within Boston Harbor. Upland vegetation is composed of manicured turf. No development exists along the transect.	10.0	18.4

[1]Because of map scale limitations, the maximum wave elevation may not be shown on the FIRM.
[2]North American Vertical Datum of 1988

TABLE 11 – TRANSECT DESCRIPTIONS - continued

TRANSECT	LOCATION	ELEVATION (feet NAVD 88[2]) 1-PERCENT-ANNUAL-CHANCE STILLWATER	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST[1]
34	The transect crosses a 15 foot gabion revetment at the shoreline of Spectacle Island. Upland vegetation is open turf parkland with some small stature trees. There is no private development on the island and no structures along the transect.	9.8	23.5
35	This transect represents Long Island within Boston Harbor. The transect crosses an 8 foot masonry seawall, with a small gabion revetment at the base. Upland of the shoreline, elevations rise sharply and with dense medium stature trees and shrubs.	9.9	21.1
36	This transect runs across Lovells Island in Boston Harbor. The shoreline is a mixed substrate beach with remnants of old gabion revetment. Vegetation upland of the shoreline is composed of dense small stature trees and shrubs.	9.8	19.6
37	This transect crosses George's Island and Fort Warren. The shoreline is 6 foot masonry seawall with a small gabion revetment below. Elevations increase sharply moving inland. Upland vegetation is limited to turf and small shrubs.	9.8	22.4

[1]Because of map scale limitations, the maximum wave elevation may not be shown on the FIRM.
[2]North American Vertical Datum of 1988

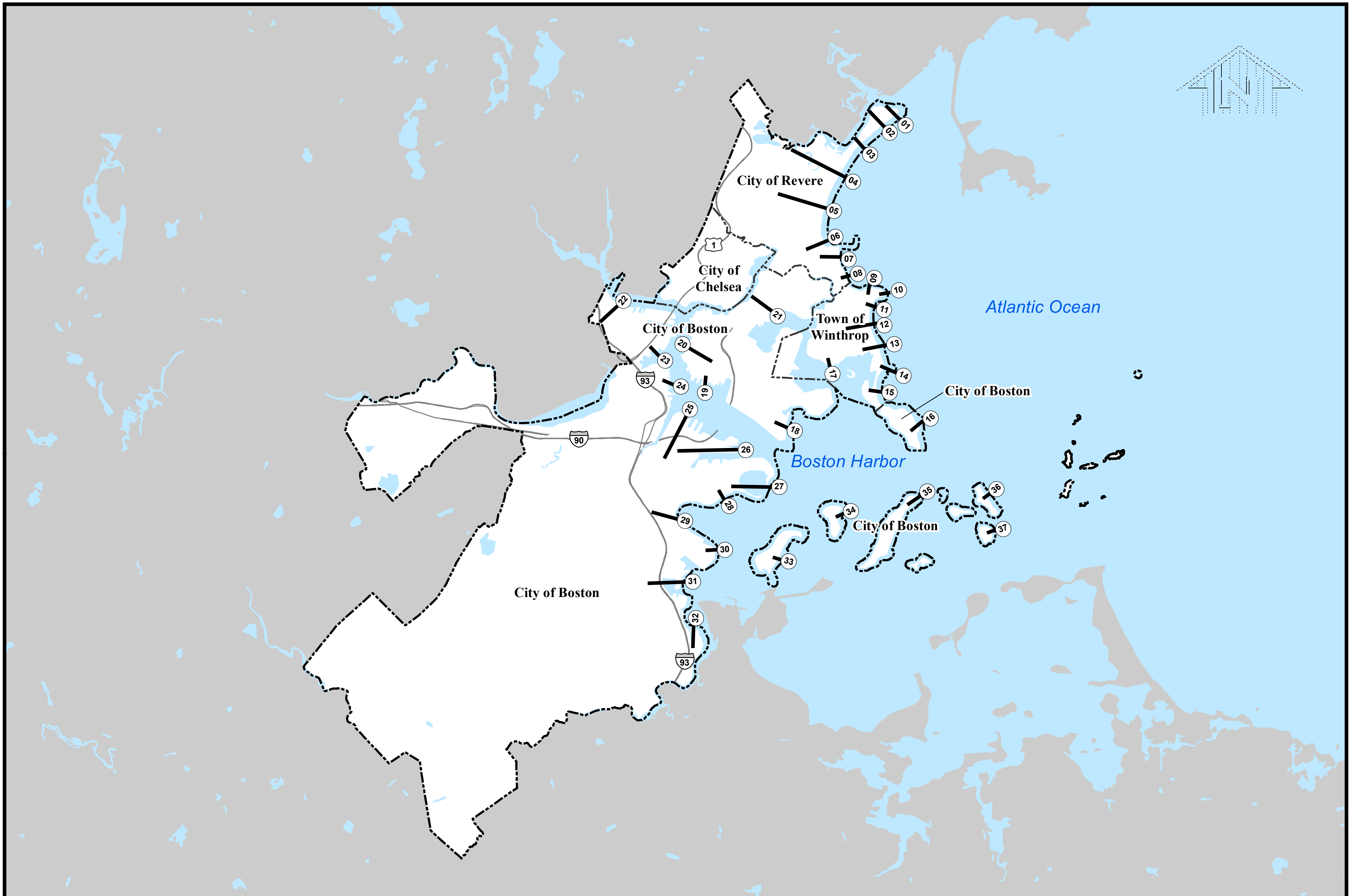


FIGURE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

APPROXIMATE SCALE

0 2 4 6 8 10 Miles

TRANSECT LOCATION MAP

The results of the coastal analysis using detailed methods are summarized in Table 12, "Transect Data," which provides the flood hazard zone and base flood elevations for each coastal transect, along with the 10-, 2-, 1- and 0.2-percent-annual-chance flood stillwater elevations from the Belle Island Inlet, Boston Harbor, Dorchester Bay and the Pines, Chelsea, Charles, and Neponset River flooding sources, including effects of wave setup where applicable.

TABLE 12 – TRANSECT DATA

	STILLWATER ELEVATIONS (FEET NAVD88[3])						
TRANSECT	10-PERCENT-ANNUAL CHANCE	2-PERCENT-ANNUAL-CHANCE	1-PERCENT-ANNUAL-CHANCE	0.2-PERCENT-ANNUAL-CHANCE	TOTAL WATER LEVEL[1] 1-PERCENT-ANNUAL-CHANCE	ZONE	BASE FLOOD ELEVATION[2] (FEET NAVD 88[3])
1	*	*	9.2	10.0	9.7	VE	12, 13
						AE	10,11
2	*	*	9.2	10.0	10.1	VE	13, 15
						AE	10,11
3	*	*	9.2	10.0	11.0	VE	15
						AE	10, 11, 12, 14
4	*	*	9.2	10.0	11.0	VE	10, 15, 16
						AE	8, 9, 10, 11, 12
5	*	*	9.2	10.0	11.1	VE	14, 16
						AE	11, 12
6	*	*	9.2	10.0	11.1	VE	14, 16, 17
						AE	11, 12
7	*	*	9.8	11.2	12.9	VE	22
						AH	6
8	*	*	9.2	10.0	11.2	VE	15
						AE	11, 12

*Data not available.
[1]Including stillwater elevation and effects of wave setup.
[2]Due to map scale limitations, base flood elevations shown on the FIRM represent average elevations for the zones depicted.
[3]North American Vertical Datum of 1988

TABLE 12 – TRANSECT DATA - continued

TRANSECT	STILLWATER ELEVATIONS (FEET NAVD88[3]) 10-PERCENT-ANNUAL CHANCE	2-PERCENT-ANNUAL-CHANCE	1-PERCENT-ANNUAL-CHANCE	0.2-PERCENT-ANNUAL-CHANCE	TOTAL WATER LEVEL[1] 1-PERCENT-ANNUAL-CHANCE	ZONE	BASE FLOOD ELEVATION[2] (FEET NAVD 88[3])
9	*	*	9.1	9.9	11.8	VE	16
						AE	12
10	*	*	9.7	11.1	14.6	VE	17
11	*	*	9.7	11.1	14.2	VE	17
12	*	*	9.1	9.9	11.4	VE	16
						AE	11
						AO	1
13	*	*	9.1	9.9	11.6	VE	17
						AE	11, 15, 16
14	*	*	9.7	11.1	13.7	VE	19
						AE	15
15	*	*	9.1	9.9	11.5	VE	12, 13, 15
						AE	11, 12
16	*	*	9.8	11.4	13.4	VE	29
17	*	*	8.8	9.6	8.8	VE	15
18	*	*	9.7	11.1	10.9	VE	13
19	*	*	9.4	10.2	9.4	VE	13
20	*	*	9.4	10.2	9.4	AE	11, 10

*Data not available.
[1]Including stillwater elevation and effects of wave setup.
[2]Due to map scale limitations, base flood elevations shown on the FIRM represent average elevations for the zones depicted.
[3]North American Vertical Datum of 1988

TABLE 12 – TRANSECT DATA - continued

TRANSECT	STILLWATER ELEVATIONS (FEET NAVD88[3]) 10-PERCENT-ANNUAL CHANCE	2-PERCENT-ANNUAL-CHANCE	1-PERCENT-ANNUAL-CHANCE	0.2-PERCENT-ANNUAL-CHANCE	TOTAL WATER LEVEL[1] 1-PERCENT-ANNUAL-CHANCE	ZONE	BASE FLOOD ELEVATION[2] (FEET NAVD 88[3])
21	*	*	8.8	10.2	8.8	AE	10
22	*	*	9.5	10.2	9.5	AE	10, 11
						AO	2
23	*	*	9.4	10.2	9.5	VE	11
						AE	10
24	*	*	9.4	10.2	9.4	VE	13
						AE	10
25	*	*	9.4	10.2	9.4	VE	13
						AE	10, 11
26	*	*	9.4	10.2	10.1	VE	15
						AE	12, 10
27	*	*	9.9	11.4	13.4	VE	16
						AE	15, 16
28	*	*	9.7	10.5	10.0	VE	13
						AE	11
29	*	*	9.7	10.5	10.0	VE	13
						AE	10, 11, 12
30	*	*	9.9	10.7	10.4	VE	13, 14
31	*	*	9.9	10.7	10.2	VE	12, 13, 14
						AE	11, 12

*Data not available.
[1]Including stillwater elevation and effects of wave setup.
[2]Due to map scale limitations, base flood elevations shown on the FIRM represent average elevations for the zones depicted.
[3]North American Vertical Datum of 1988

TABLE 12 – TRANSECT DATA - continued

TRANSECT	STILLWATER ELEVATIONS (FEET NAVD88[3]) 10-PERCENT-ANNUAL CHANCE	2-PERCENT-ANNUAL-CHANCE	1-PERCENT-ANNUAL-CHANCE	0.2-PERCENT-ANNUAL-CHANCE	TOTAL WATER LEVEL[1] 1-PERCENT-ANNUAL-CHANCE	ZONE	BASE FLOOD ELEVATION[2] (FEET NAVD 88[3])
32	*	*	10.6	11.4	10.7	VE	14
						AE	11, 13
33	*	*	10.0	11.6	12.0	VE	14
						AE	12
34	*	*	9.8	11.4	14.0	VE	19
35	*	*	9.9	11.5	13.8	VE	33
						AE	15
36	*	*	9.8	11.4	12.8	VE	15
37	*	*	9.8	11.4	14.7	VE	17

*Data not available.
[1]Including stillwater elevation and effects of wave setup.
[2]Due to map scale limitations, base flood elevations shown on the FIRM represent average elevations for the zones depicted.
[3]North American Vertical Datum of 1988

3.5 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.

All 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 -0.8, and from NAVD 88 to NGVD 29 is +0.8.**

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 county. 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.

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The National Flood Insurance Program encourages State and local governments to adopt sound floodplain management programs. To assist in this endeavor, each FIS report provides 1-percent-annual-chance floodplain data, which may include a combination of the following: 10-, 2-, 1-, and 0.2-percent-annual-chance flood elevations; delineations of the 1- and 0.2-percent-annual-chance floodplains; and a 1-percent-annual-chance floodway. This information is presented on the FIRM and in many components of the FIS report, including Flood Profiles, Floodway Data tables, and Summary of Stillwater Elevation tables. Users should reference the data presented in the FIS report as well as additional information that may be available at the local community map repository before making flood elevation and/or floodplain boundary determinations.

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1-percent-annual-chance flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2-percent-annual-chance flood is employed to indicate additional areas of flood risk in the community. For each stream studied by detailed methods, the 1- and 0.2-percent-annual-chance floodplain boundaries have been delineated using topographic maps (Reference 15, 21, 46, 47, 49, 50).

In the pre-countywide, City of Boston FIS, floodplain boundaries were interpolated between cross-sections using topographic maps at a scale of 1"=400' with a contour interval of 5 feet (Reference 15).

In the 1984 Winthrop FIS, the boundaries were interpolated between cross-sections, using topographic maps at a scale of 1:4,800 with a contour interval of 5 feet (Reference 47).

Flood boundaries for areas in Boston studied by approximate methods were obtained from the previous October 1, 1983 FIS for the City of Boston (Reference 48). For areas in Chelsea studied by approximate methods, the boundary of the 1-percent-annual-chance flood was delineated using USGS topographic maps and a drainage study prepared for the Massachusetts Department of Public Works (References 21 and 49). In the 1984 Revere FIS, for areas of flooding studied by approximate methods, the 1-percent-annual-chance flood boundary was delineated using the topographic maps referenced above. In the Revere August 2, 2002 revision, an area of approximate flooding in the northeast comer of Revere was delineated in order to match the approximate flooding in the contiguous community of the City of Malden in Middlesex County. The delineation involved the use of topographic maps at a scale of 1:25,000 and a contour interval of 10 feet (Reference 50)

For the 2009 countywide study, the 1- and 0.2-percent-annual-chance floodplain boundaries for detailed study flooding sources in Suffolk County were redelineated using more up to date topographic information, including MassGIS and LiDAR data, which meets the accuracy standards for flood hazard mapping (https://www.mass.gov/mgis/ and https://maps.csc.noaa.gov.TMC/).

For the 2013 coastal study and post preliminary processing of coastal analyses based on appeal, the 1-, and 0.2-percent-annual-chance coastal floodplains have been delineated using the flood elevations determined at each transect and LiDAR data with a 2-foot contour interval accuracy equivalency (Reference 44).

The 1- and 0.2-percent-annual-chance floodplain boundaries are shown on the FIRM. On this map, the 1-percent-annual-chance floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A, AE, AH, AO and VE), and the 0.2-percent-annual-chance floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 1- and 0.2-percent-annual-chance floodplain boundaries are close together, only the 1-percent-annual-chance floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations, but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

For the streams studied by approximate methods, only the 1-percent-annual-chance floodplain boundary is shown on the FIRM.

4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 1-percent-annual-chance floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the base flood can be carried without substantial increases in flood heights. Minimum Federal standards limit such increases to 1 foot, provided that hazardous velocities are not produced. The floodways in this study are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodway presented in this study was computed on the basis of equal conveyance reduction from each side of the floodplain. Floodway widths were computed at cross sections. Between cross sections, the boundaries were interpolated. In cases where the floodway and 1-percent-annual-chance floodplain boundaries are either close together or collinear, only the floodway boundary has been shown. Portions of the floodway widths of Chelsea and Revere's Mill Creek extend beyond the corporate limits. The results of the floodway computations are tabulated at selected cross sections for each stream segment for which a floodway is computed (See Table 11).

Encroachment into areas subject to inundation by floodwaters having hazardous velocities aggravates the risk of flood damage, and heightens potential flood hazards by further increasing velocities. A listing of stream velocities at selected cross sections is provided in Table 11, "Floodway Data". To reduce the risk of property damage in areas where the stream velocities are high, the community may wish to restrict development in areas outside the floodway.

Floodway encroachments were not determined for the Neponset River. This river is located entirely within the Neponset River Reservations. In analyzing this portion of the river using the HEC-2 program, the selected effective flow areas of the river were well inside the boundaries of the reservation. The computer was programmed not to recognize the areas of slack water beyond the effective flow limits. Therefore any encroachment up to the reservation boundary will have no appreciable effect on the river velocity or water-surface elevation. However, almost the entire land area from the banks of the Neponset River up to the 1-percent-annual-chance flood boundary has been subjected to an Order of Restriction in accordance with Chapter 131, Section 40A, of the General Laws of the Commonwealth of Massachusetts. Under this law, any permanent wetland so designated by the state cannot be built upon in any way.

The identical situation exists along the Charles River. The restricted wetlands almost completely occupy the areas inundated by the 1-percent-annual-chance flood. The areas not covered are so small that the delineation of a floodway would be useless as a functional tool to be used by the community for its floodplain management program. Therefore, no floodway has been defined for both the Neponset and Charles Rivers. Additionally, floodways were not computed for Muddy River and Stony Brook.

The area between the floodway and 1-percent-annual-chance floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation of the 1-percent-annual-chance flood by more than 1.0 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 3, "Floodway Schematic".

In Chelsea and Revere, near the mouths of streams studied in detail, floodway computations were made without regard to flood elevations on the receiving water body. Therefore, "Without Floodway" elevations presented in Table 11 for certain downstream cross sections of Mill Creek are lower than the regulatory flood elevations in that area, which must take into account the 1-percent-annual-chance flooding due to backwater from other sources.

Additionally, no floodways were computed for the Town of Winthrop.

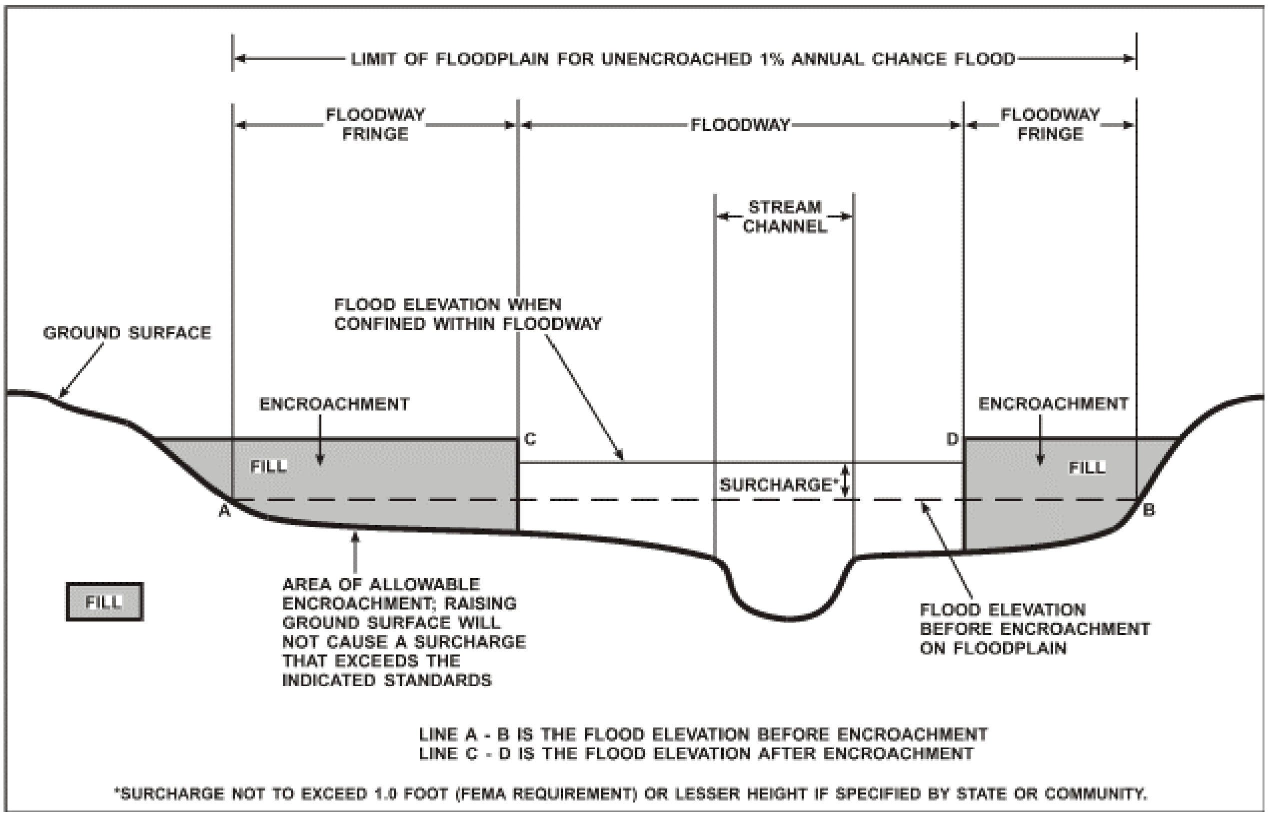


FIGURE 3 – FLOODWAY SCHEMATIC

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	502	310 / 210 [2]	2561	0.9	9.8	4.1 [3]	5.1	1.0
B	1447	140 / 40 [2]	753	3.1	9.8	4.1 [3]	5.1	1.0
C	2777	120 / 100 [2]	951	2.4	12.5	12.5	12.5	0.0
D	3305	80 / 60 [2]	897	2.6	12.6	12.6	12.6	0.0
E	4572	90 / 20 [2]	786	2.9	13.0	13.0	13.5	0.5

[1] FEET ABOVE CONFLUENCE WITH CHELSEA RIVER

[2] WIDTH/WIDTH WITHIN SUFFOLK COUNTY

[3] ELEVATION COMPUTED WITHOUT CONSIDERATION OF TIDAL FLOODING FROM CHELSEA RIVER

TABLE 13

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

ALL JURISDICTIONS

FLOODWAY DATA

MILL CREEK

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	300	45	187	7.8	43.1	43.1	43.1	0.0
B	750	52	324	4.5	43.4	43.4	43.4	0.0
C	950	50	322	4.6	43.6	43.6	43.6	0.0
D	1,100	64	414	3.6	43.8	43.8	43.8	0.0
E	1,233	64	415	3.5	43.8	43.8	43.8	0.0
F	1,600	60	321	4.6	43.9	43.9	43.9	0.0
G	2,050	60	379	3.9	44.6	44.6	44.8	0.2
H	2,725	153	646	2.3	45.6	45.6	45.8	0.2
I	4,095	84	186	7.9	48.5	48.5	48.5	0.0
J	5,000	200	1445	1.0	49.9	49.9	49.9	0.0
K	6,000	147	1036	1.4	49.9	49.9	49.9	0.0
L	7,130	102	728	2.0	50.1	50.1	50.2	0.1

[1] FEET ABOVE CONFLUENCE WITH NEPONSET RIVER

TABLE 13

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

ALL JURISDICTIONS

FLOODWAY DATA

MOTHER BROOK

5.0 INSURANCE APPLICATIONS

For flood insurance rating purposes, flood insurance zone designations are assigned to a community based on the results of the engineering analyses. The zones are as follows:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 1-percent annual chance floodplains that are determined in the FIS by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no base (1-percent-annual-chance) flood elevations (BFEs) or depths are shown within this zone.

Zone AE

Zone AE is the flood insurance rate zone that corresponds to the 1-percent annual chance floodplains that are determined in the FIS by detailed methods. In most instances, whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AH

Zone AH is the flood insurance rate zone that corresponds to areas of 1-percent-annual-chance shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AO

Special Flood Hazard Areas inundated by types of 1-percent-annual-chance flood shallow flooding, where depths are between 1 and 3 feet. Depths are shown within this zone

Zone D

Zone D is the flood insurance rate zone that corresponds to unstudied areas where flood hazards are undetermined, but possible.

Zone VE

Zone VE is the flood insurance rate zone that corresponds to the 1-percent annual chance coastal floodplains that have additional hazards associated with storm waves. Whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 500-year floodplain, areas within the 0.2-percent annual chance floodplain, and areas of 1-percent annual chance flooding where average depths are less than 1 foot, areas of 1-percent annual chance flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 1-percent annual chance flood by levees. No BFEs or depths are shown within this zone.

6.0 FLOOD INSURANCE RATE MAP

The FIRM is designed for flood insurance and floodplain management applications.

For flood insurance applications, the map designates flood insurance rate zones as described in Section 5.0 and, in the 1-percent-annual-chance floodplains that were studied by detailed methods, shows selected whole-foot BFEs or average depths. Insurance agents use zones and BFEs in conjunction with information on structures and their contents to assign premium rates for flood insurance policies.

For floodplain management applications, the map shows by tints, screens, and symbols, the 1- and 0.2-percent-annual-chance floodplains, floodways, and the locations of selected cross sections used in the hydraulic analyses and floodway computations.

The countywide FIRM presents flooding information for the entire geographic area of Suffolk County. Previously, FIRMs were prepared for each incorporated community and the unincorporated areas of the County identified as flood-prone. This countywide FIRM also includes flood-hazard information that was presented separately on Flood Boundary and Floodway Maps (FBFMs), where applicable. Historical data relating to the maps prepared for each community are presented in Table 14, "Community Map History."

COMMUNITY NAME	INITIAL IDENTIFICATION	FLOOD HAZARD BOUNDARY MAP REVISION DATE(S)	FLOOD INSURANCE RATE MAP EFFECTIVE DATE	FLOOD INSURANCE RATE MAP REVISION DATE(S)
Boston, City of	November 22, 1974	February 11, 1977 June 7, 1977	April 1, 1982	October 1, 1983 November 2, 1990 July 2, 1992
Chelsea, City of	June 7, 1974	December 27, 1974	August 2, 1982	N/A
Revere, City of	June 28, 1974	February 18, 1977	October 16, 1984	August 20, 2002
Winthrop, Town of	June 28, 1974	None	October 8, 1976	August 15, 1984 July 2, 1992

TABLE 14

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA (ALL JURISDICTIONS)

COMMUNITY MAP HISTORY

7.0 OTHER STUDIES

Information pertaining to revised and unrevised flood hazards for each jurisdiction within Suffolk County has been compiled in this FIS. Therefore, this FIS supersedes all previously printed FIS reports, FIRMs, and/or FHBMs for all of the incorporated jurisdictions within Suffolk County.

Suffolk County is bordered by Essex County, MA to the north, Norfolk County, MA to the south, and Middlesex County, MA to the west. The results of the 2013 coastal analysis of the Suffolk County coast indicate that coastal flooding will affect communities in Middlesex County. However, at the time of this revision, no revision to the Middlesex County FIS has been initiated and therefore the results of the Suffolk County coastal analysis have not been incorporated into the Middlesex County FIS.

Due to its highly developed state, the City of Boston has been subject to numerous flood-related studies as a result of construction proposals, waterway improvements, water quality assessments and flood plain management studies.

The Charles River and the lower Charles River Basin have been extensively studied by the USACE, SCS, and C. E. Maguire, Inc., as a result of its serious flood problems (References 16, 18 and 26). Elevations for the floods of the selected recurrence intervals, discharge data, inflow hydrographs and other pertinent hydrologic and hydraulic data were adopted into this countywide FIS, as were flood elevations for the Muddy River.

Flood elevations for the Neponset River and Mother Brook were coordinated with detailed studies done in 1971 and 1973 (References 25 and 51). Elevations were coordinated with the FISs of the surrounding Cities of Quincy and Newton, and Towns of Milton, Dedham, Needham, Brookline, and Winthrop (References 17, 19, and 52-56).

Flood elevations for Mother Brook at the Boston-Dedham corporate limits are slightly higher in this study than those shown calculated in the Dedham FIS (Middlesex County) because of more up-to-date hydraulic analyses.

In Chelsea, a drainage study of Mill Creek was performed for the Massachusetts Department of Public Works in 1975 (Reference 21). The purpose of the study was to analyze the causes of frequent flooding at the housing project near Mill Creek upstream of U. S. Route 1. Discharges related to the drainage study were compared to discharges developed by a Massachusetts regional equation (Reference 57). The differences between the values determined by the two methods were so great that a third method was applied. A SCS method derived for small watersheds was incorporated to develop additional flow values (Reference 58). The 1-percent-annual-chance discharge determined by the SCS method was very similar to that developed for the drainage study. As the SCS method may not be appropriate for such extensively urbanized watersheds, the values from the drainage study were adopted for the hydraulic analysis in this countywide study.

8.0 LOCATION OF DATA

Information concerning the pertinent data used in the preparation of this study can be obtained by contacting FEMA Region I, 99 High Street, 6th Floor, Boston, MA 02110.

9.0 BIBLIOGRAPHY AND REFERENCES

1. Federal Emergency Management Agency, Flood Insurance Study, Suffolk County, Suffolk County, Massachusetts, Washington, D.C., September 25, 2009.

2. MassGIS, 2005 1:5,000 Color Orthoimagery, http://www.massgis.gov/mgis, April 2005.

3. MassGIS, 2008 USGS High Resolution Color Orthoimagery, http://www.massgis.gov/mgis, April 2008

4. U.S. Census Bureau (2010): Retrieved June 13, 2012. http://quickfacts.census.gov/qfd/states/09/09007.html

5. National Weather Service, Taunton. Boston Daily Normals. 2006.

6. Weatherbase. Historical Weather for Boston, Massachusetts, United States of America. 2008.

7. City of Boston Film Bureau. Weather. 2007.

8. Massachusetts Agricultural Experiment Station, Remote Sensing 20 Years of Change in Suffolk and Norfolk Counties, Massachusetts, 1951-1971 by William P. McConnell, August 1974.

9. NOAA Satellite and Information Service, National Climatic Data Center, US Department of Commerce, retrieved July 2012 from http://www.ncdc.noaa.gov/oa/satellite/satelliteseye/cyclones/pfctstorm91/pfctstorm.html

10. Massachusetts Emergency Management Agency, Department of Conservation and Recreation, Commonwealth of Massachusetts, State Hazard Mitigation Plan, October 2010.

11. Boston Globe, Tired Irene slaps N.E., retrieved July 2012 from http://articles.boston.com/2011-08-29/news/29941847_1_flood-waters-hurricane-irene-vermont-town/

12. NOAA Satellite and Information Service, National Climatic Data Center, US Department of Commerce, retrieved November 2013 from http://www.ncdc.noaa.gov/stormevents

13. Boston Globe, Strain on roofs, roads, spirits, retreived July 2012 from, http://www.boston.com/news/local/massachusetts/articles/2011/02/03/slush_collapses_roofs_floods_roads

14. U.S. Army Corps of Engineers, North Atlantic Division. National Shoreline Study. Regional Inventory Report, North Atlantic Region, Volume I. New York, 1971.

15. Water Resources Council, A Uniform Technique for Determining Flood Flow Frequency, Bulletin 15, Washington, D. C., December 1967.

16. U.S. Army Corps of Engineers, New England District, Interim Report on the Charles River for Flood Control and Navigation; Lower Charles River, Waltham, Massachusetts, May 1968.

17. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, Town of Dedham, Norfolk County, Massachusetts, Washington, D.C., May 1977.

18. U.S. Army Corps of Engineers, New England District, Charles River Study, Appendices D and H, Waltham, Massachusetts, May 1972.

19. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, Town of Milton, Norfolk County, Massachusetts, Washington, D.C., March 1977.

20. U.S. Department of the Interior, Geological Survey, Coastal Flood of February 7, 1978, in Maine, Massachusetts, and New Hampshire, No. 79-61, Boston, Massachusetts, 1979.

21. Congdon, Gurney and Towle, Inc., prepared for the Massachusetts Department of Public Works, Mill Creek Drainage Study, Boston, Massachusetts, 1975.

22. Stone & Webster Engineering Corporation, Development and Verification of a Synthetic Northeaster Model for Coastal Flood Analysis, Boston, Massachusetts, October 1979

23. Moore Survey and Mapping Corporation of Shrewsbury, Massachusetts, Topographic Maps compiled by photogrammetric methods, Scale 1"=400’, Contour Interval 5 Feet: Chelsea, Massachusetts, 1977.

24. U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-2 Water Surface Profiles, Generalized Computer Program, Davis, California, October 1973.

25. Anderson-Nichols Co., Neponset River Basin Flood Plain and Wetland Encroachment Study, Boston, Massachusetts, April 1971.

26. C.E. Maguire, Inc., The Proposed Charles River Project, Waltham, Massachusetts, October 1974.

27. U.S. Army Corps of Engineers, New England District, Charles River Locks and Dam (Design Memorandum No. 1) Hydrology and Tidal Hydraulics, Waltham, Massachusetts, May 1971.

28. U.S. Department of the Interior, Geological Survey, Water Resources Investigations 79-61, Coastal Flood of February 7, 1978, Maine, Massachusetts, and New Hampshire, Boston, Massachusetts, 1979.

29. Federal Disaster Assistance Administration, Damage Survey Reports & the Town of Winthrop, Massachusetts, Washington, D.C., February 1978.

30. U.S. Army Corps of Engineers, New England District, Frequency of Tidal Flooding at Boston Harbor, Waltham, Massachusetts, April 1979.

31. Federal Emergency Management Agency, Guidelines and Specifications for Flood Hazard Mapping Partners. Appendix D, Guidance for Coastal Flooding Analyses and Mapping, April 2003.

32. STARR, prepared for the Federal Emergency Management Agency, Regional Frequency Analyses using L Moments, November 3, 2010.

33. U.S. Army Corps of Engineers. 2002, updated through 2011. Coastal Engineering Manual. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).

34. Federal Emergency Management Agency, Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, Final Draft, Washington, D.C., February 2007.

35. Divoky, D., Supplementary WHAFIS Documentation, WHAFIS 4.0, A Revision of FEMA's WHAFIS 3.0 Program, August 10, 2007.

36. Federal Emergency Management Agency, Coastal Hazard Analysis Modeling Program (CHAMP), Version 2.0, Washington, D.C., August 2007.

37. Federal Emergency Management Agency, Coastal Hazard Analysis Modeling Program (CHAMP), Users Guide, Version 2.0, Washington, D.C., August 2007.

38. Yoshimi Goda, Random Seas and Design of Maritime Structures, 2nd Edition, World Scientific, 2000.

39. National Academy of Sciences, Methodology for Calculating Wave Action Effects Associated with Storm Surges, Washington, D.C., 1977.

40. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Shore Protection Manual, (Volumes I and II, 4th Edition), Washington, D.C., 1984.

41. U.S. Army Corps of Engineers, Galveston District, Guidelines for Identifying Coastal High Hazard Zones, Galveston, Texas, June 1975.

42. Federal Emergency Management Agency, Procedure Memorandum No. 50 – Policy and Procedure for Identifying and Mapping Areas Subject to Wave Heights Greater than 1.5 feet as an Information Layer on Flood Insurance Rate Maps (FIRMs), Washington, D.C., December 3, 2008.

43. Federal Emergency Management Agency, Users Manual for Wave Height Analysis, Washington, D.C., Revised February 1981.

44. STARR, Light Detecting and Ranging (LiDAR) data. 5-foot floating point digital elevation model (DEM), North American Vertical Datum of 1988 (NAVD 88). 2-foot contours were created from the terrain deliverable.

45. National Oceanographic and Atmospheric Administration (NOAA) National Ocean Service (NOS) Hydrographic Data Base (NOSHDB) and Hydrographic Survey Meta Data Base (HSMDB) (NOAA), Bathymetry, May 27, 2010.

46. Boston Redevelopment Authority, Topographic Mapping, City of Boston, Scale 1:1,200, Contour Interval 5 Feet, Boston, Massachusetts, 1967.

47. James W. Sewall Co., of Old Town, Maine, Topographic Maps, Scale 1: 2,400, Contour Interval 5 Feet: Winthrop, Massachusetts, December 1978.

48. Federal Emergency Management Agency, Flood Insurance Study, City of Boston, Suffolk County, Massachusetts, Washington, D. C., October 1, 1983.

49. U.S. Department of the Interior, Geological Survey, 7.5-Minute Series Topographic Maps, Scale 1:24,000, Contour Interval 10 Feet: Boston North, Massachusetts, 1971.

50. U.S. Department of Interior, USGS. Topographic Maps. Scale 1:25,000, Contour Interval 10 feet. Lynn, 1970; Boston North, 1979.

51. Anderson-Nichols Co., Mother Brook, Flood Control Feasibility Study, Boston, Massachusetts, February 1973.

52. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, City of Quincy, Norfolk County, Massachusetts, Washington, D.C., March 1973.

53. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, City of Newton, Middlesex County, Massachusetts, Washington, D.C., December 1977.

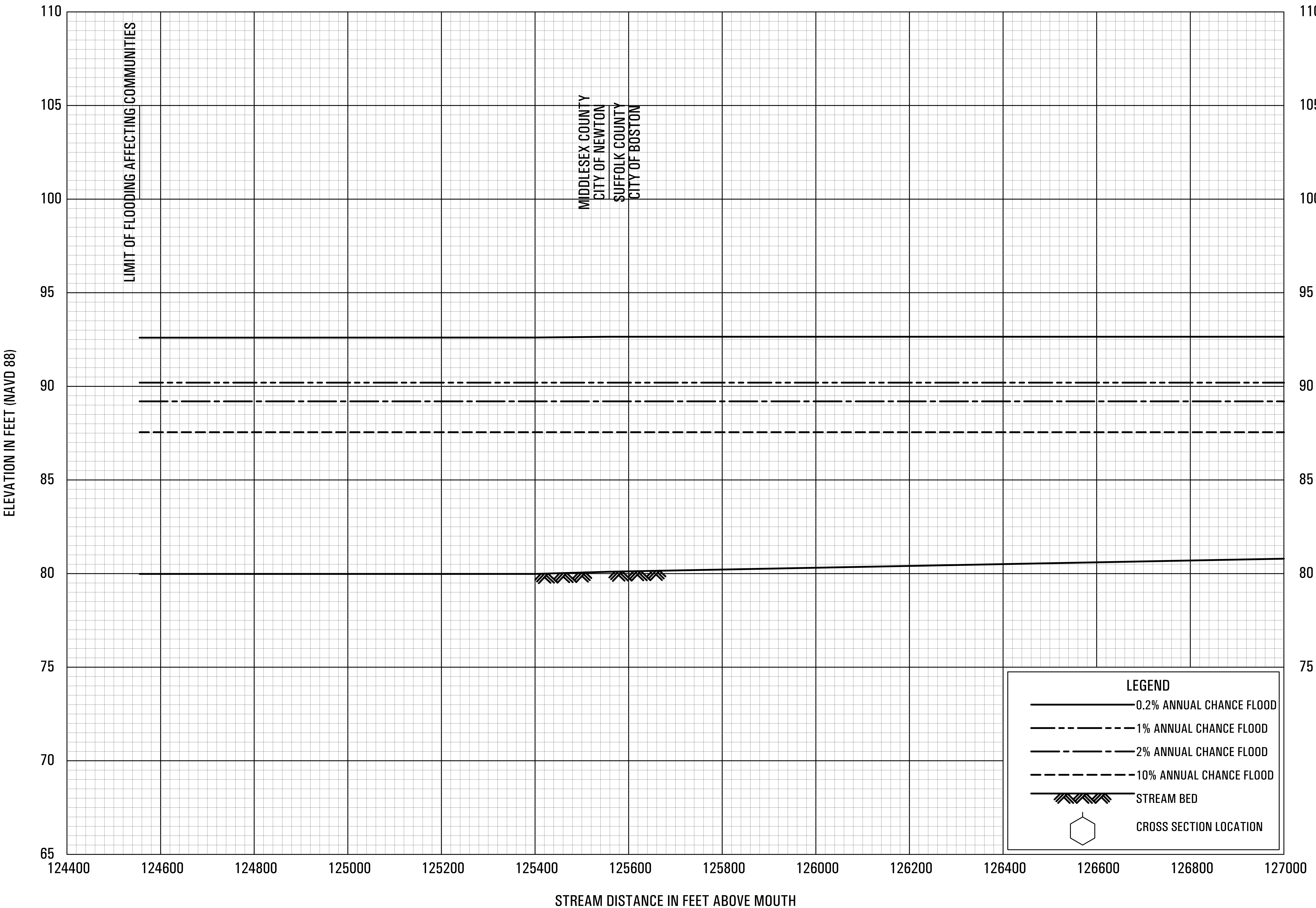
54. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, Town of Needham, Norfolk County, Massachusetts, Washington, D.C., November 1972.

55. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, Town of Brookline, Norfolk County, Massachusetts, Washington, D.C., November 1976.

56. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, Town of Winthrop, Suffolk County, Massachusetts, Washington, D.C., September 1975.

57. U.S. Department of the Interior, Geological Survey, Water Resources Investigations 77-39, Estimating the Magnitude and Frequency of Floods Natural-Flow Streams in Massachusetts by S.W. Wandle, Jr., Washington, D.C. 1977.

58. U.S. Department of Agriculture, Soil Conservation Service, Technical Paper 149, A Method for Estimating Volume and Rate of Runoff in Small Watersheds, Washington, D.C., April 1973.



FLOOD PROFILES

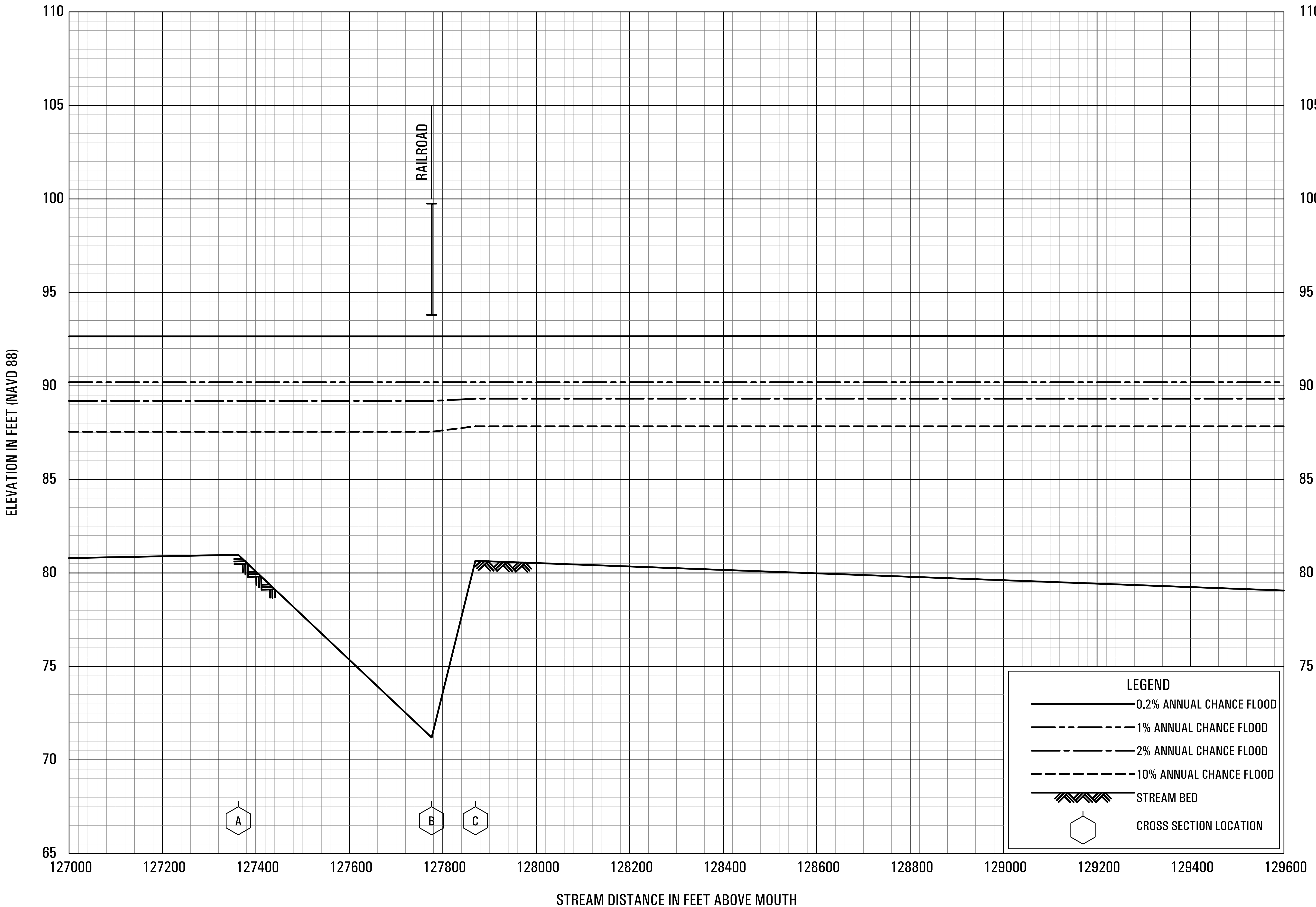
CHARLES RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

01P



FLOOD PROFILES

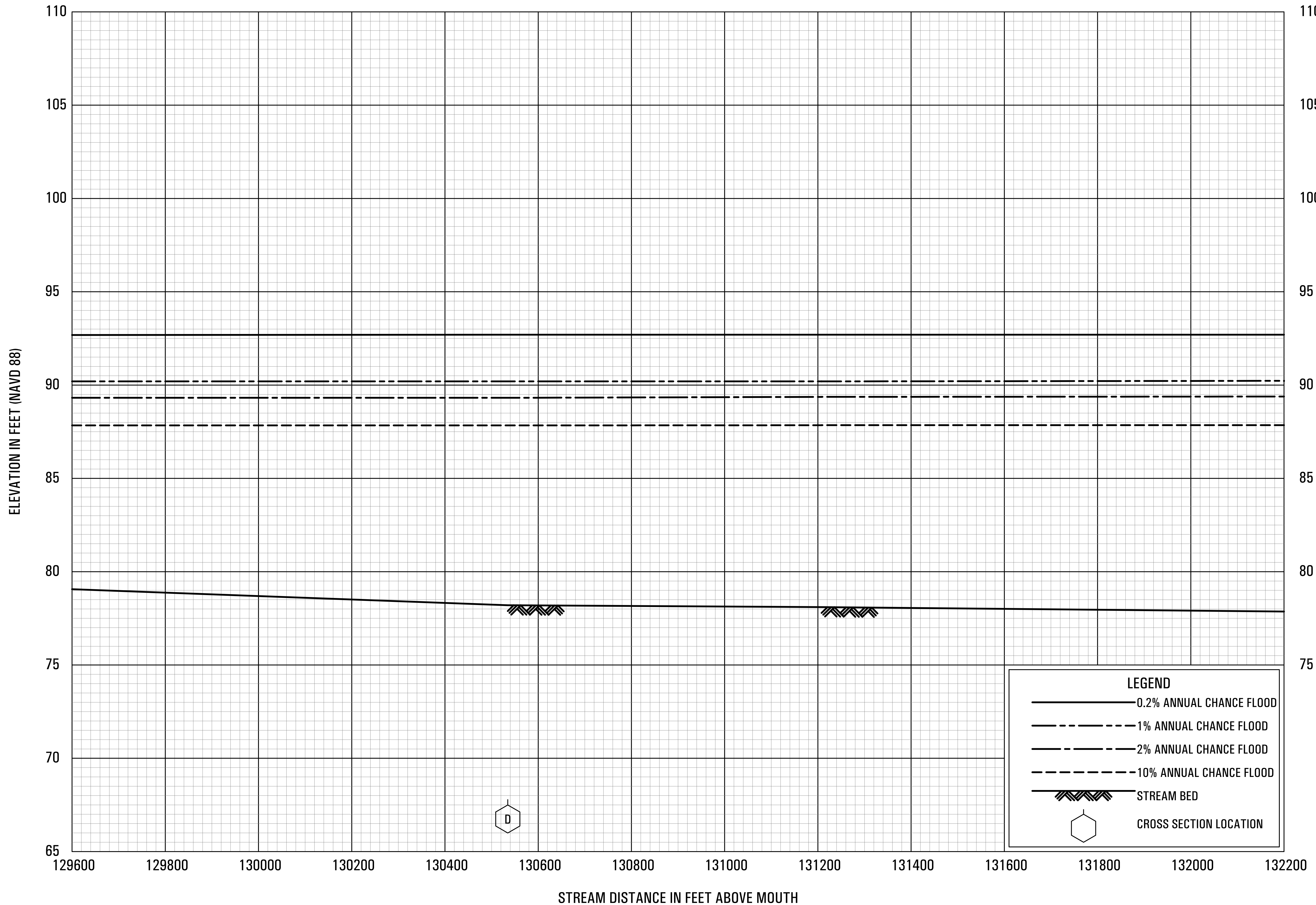
CHARLES RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

02P



FLOOD PROFILES

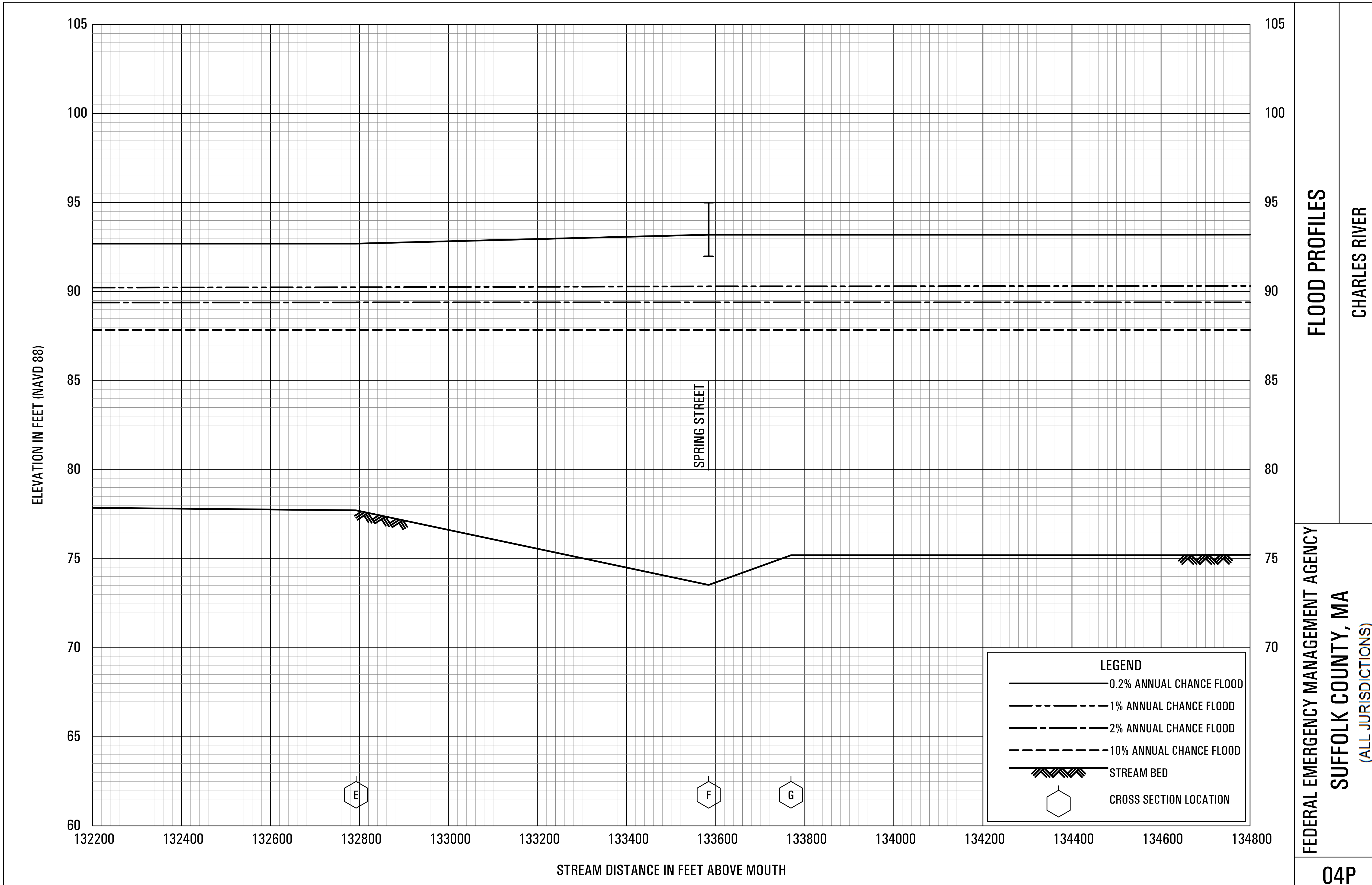
CHARLES RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

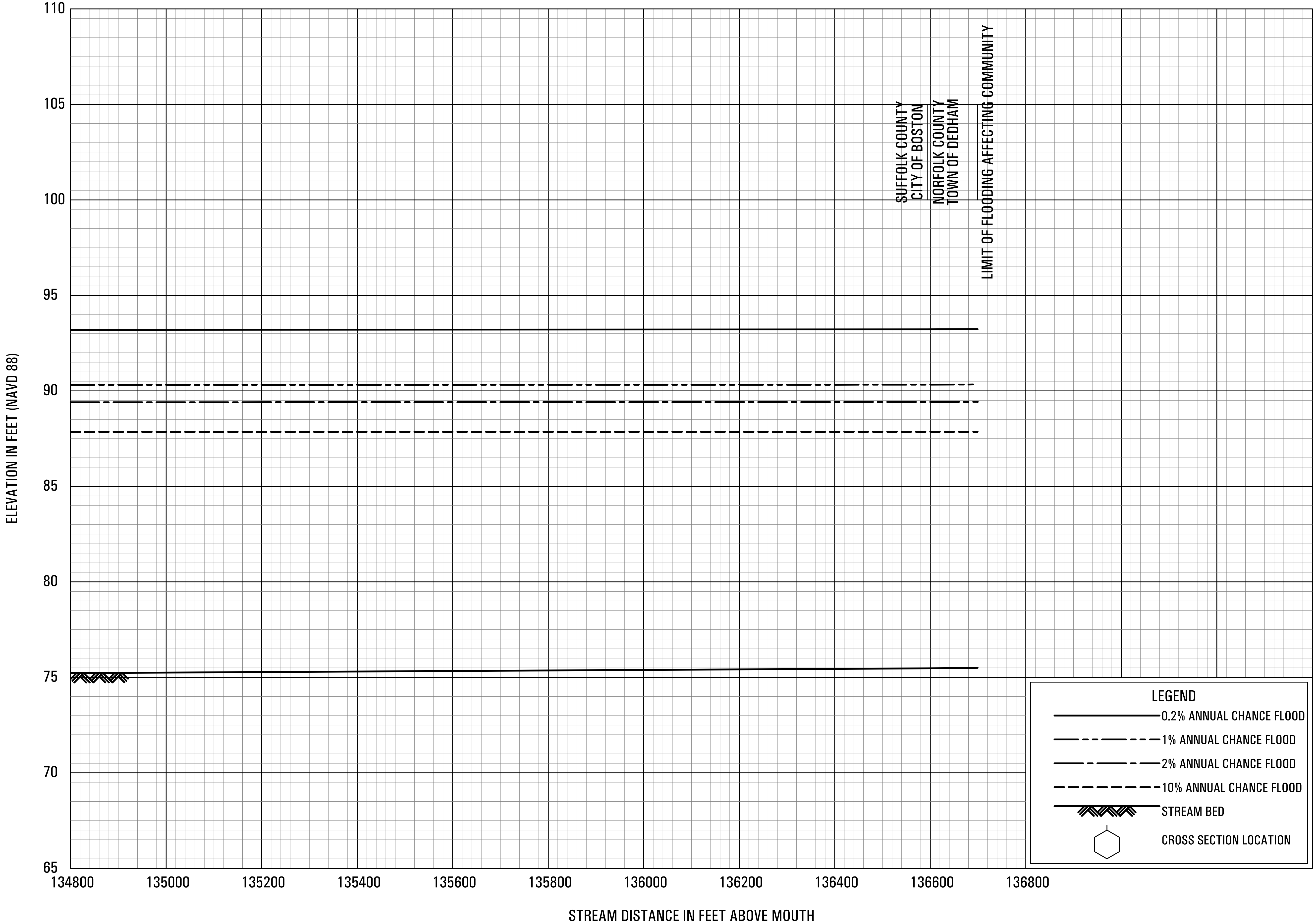
SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

03P



FLOOD PROFILES
CHARLES RIVER
FEDERAL EMERGENCY MANAGEMENT AGENCY
SUFFOLK COUNTY, MA
(ALL JURISDICTIONS)
04P
ELEVATION IN FEET (NAVD 88)
STREAM DISTANCE IN FEET ABOVE MOUTH
SPRING STREET
LEGEND
0.2% ANNUAL CHANCE FLOOD
1% ANNUAL CHANCE FLOOD
2% ANNUAL CHANCE FLOOD
10% ANNUAL CHANCE FLOOD
STREAM BED
CROSS SECTION LOCATION
E
F
G
105
100
95
90
85
80
75
70
65
60
132200
132400
132600
132800
133000
133200
133400
133600
133800
134000
134200
134400
134600
134800



FLOOD PROFILES

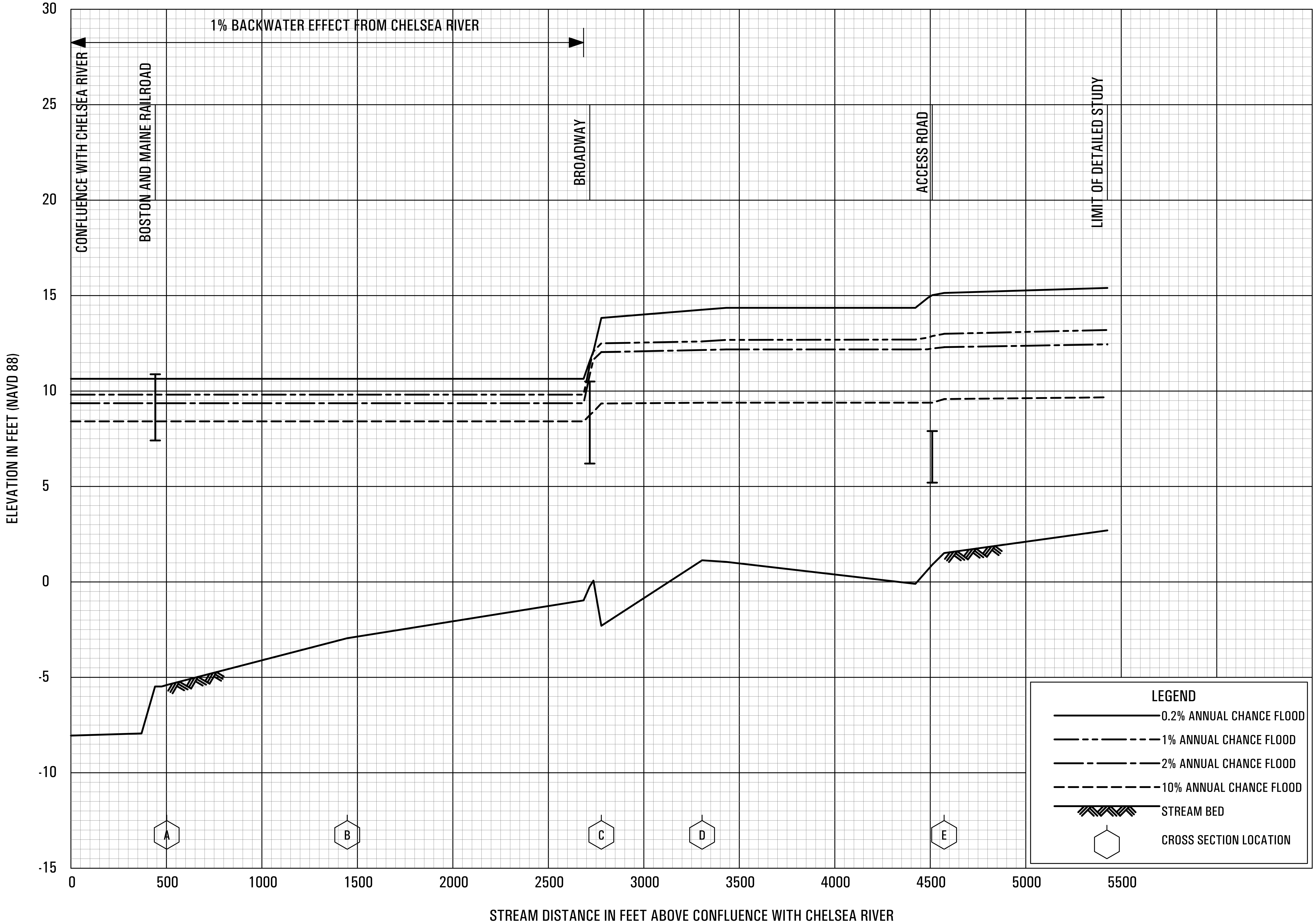
CHARLES RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

05P



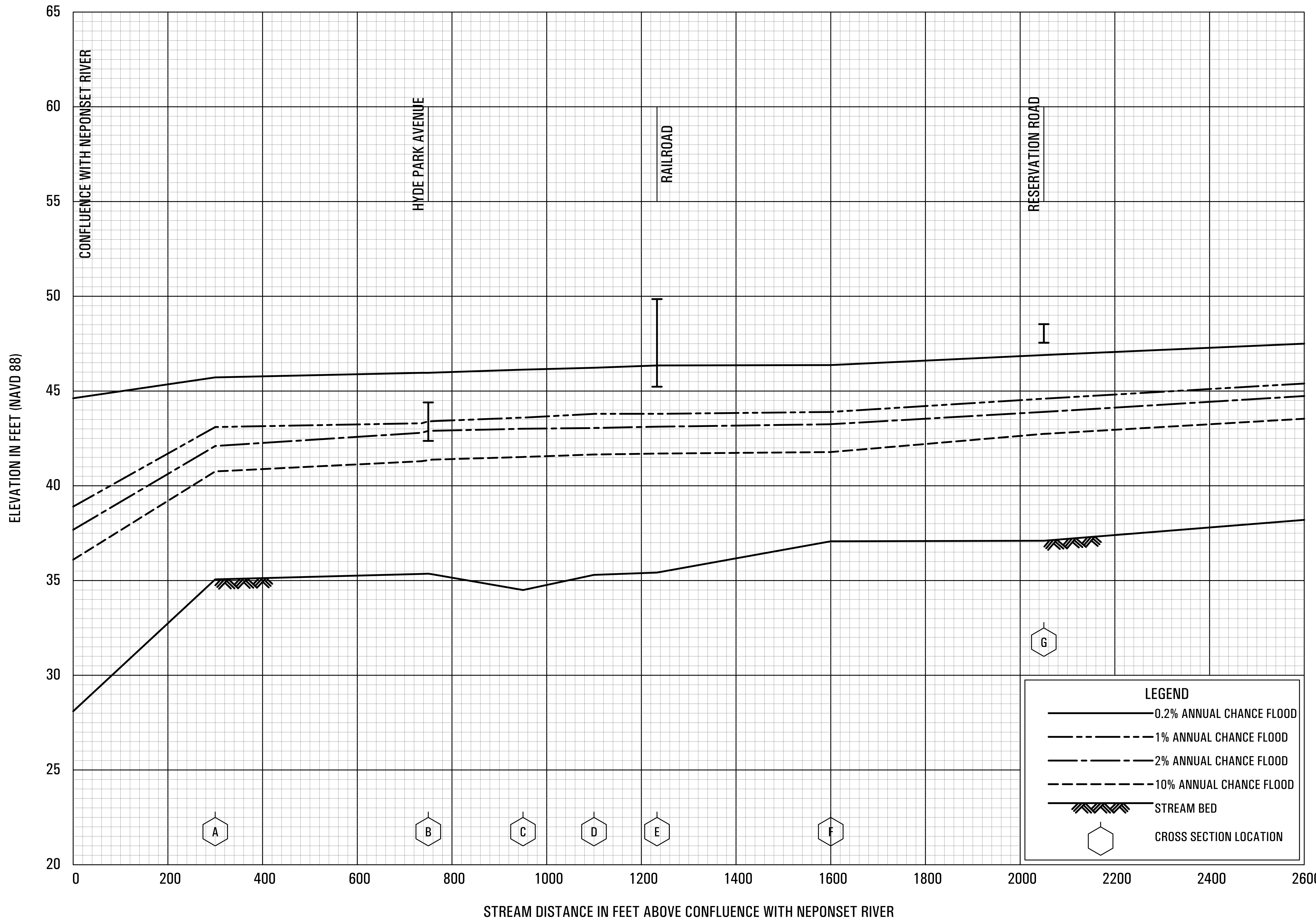
FLOOD PROFILES

MILL CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)



FLOOD PROFILES

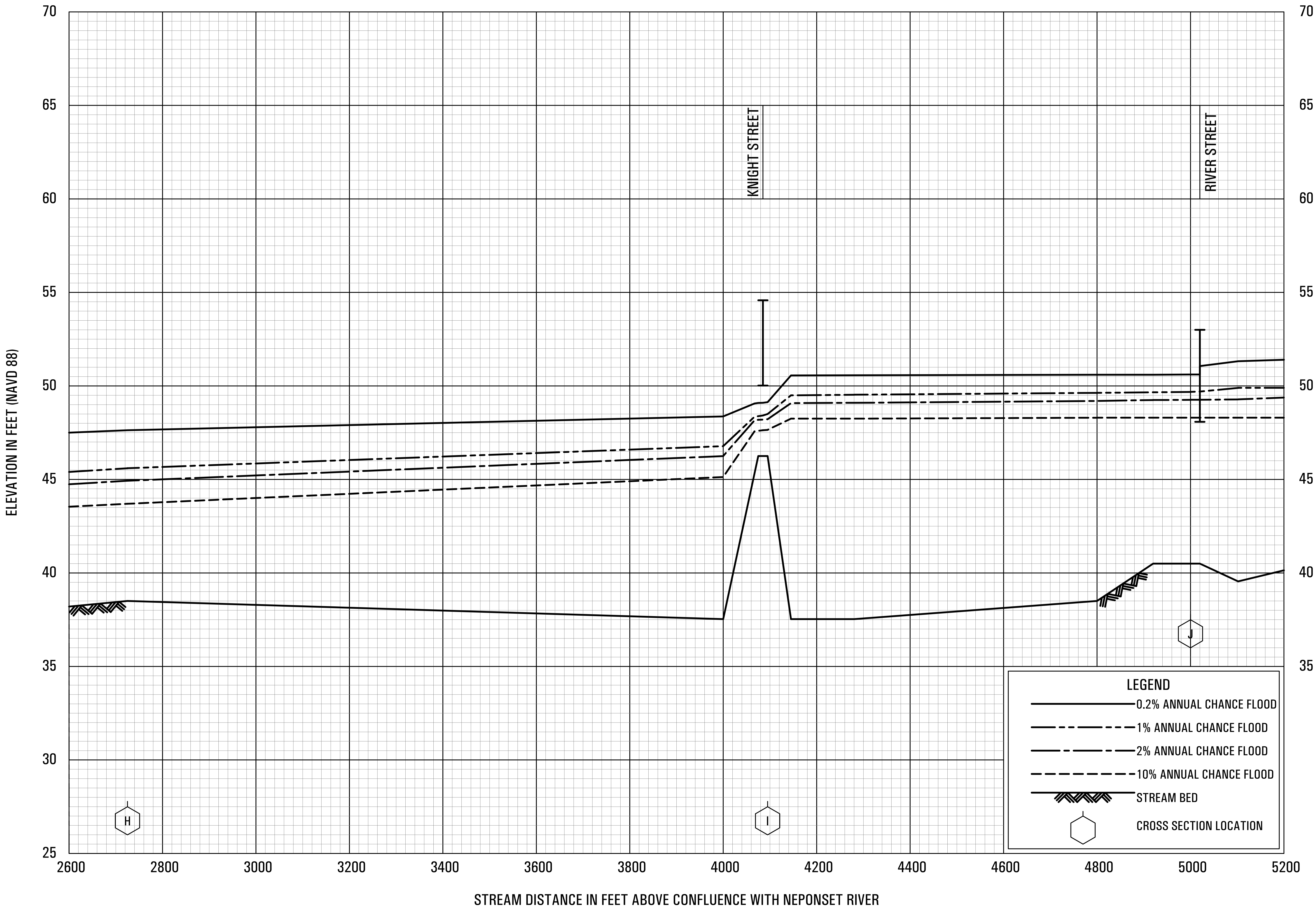
MOTHER BROOK

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

07P



FLOOD PROFILES

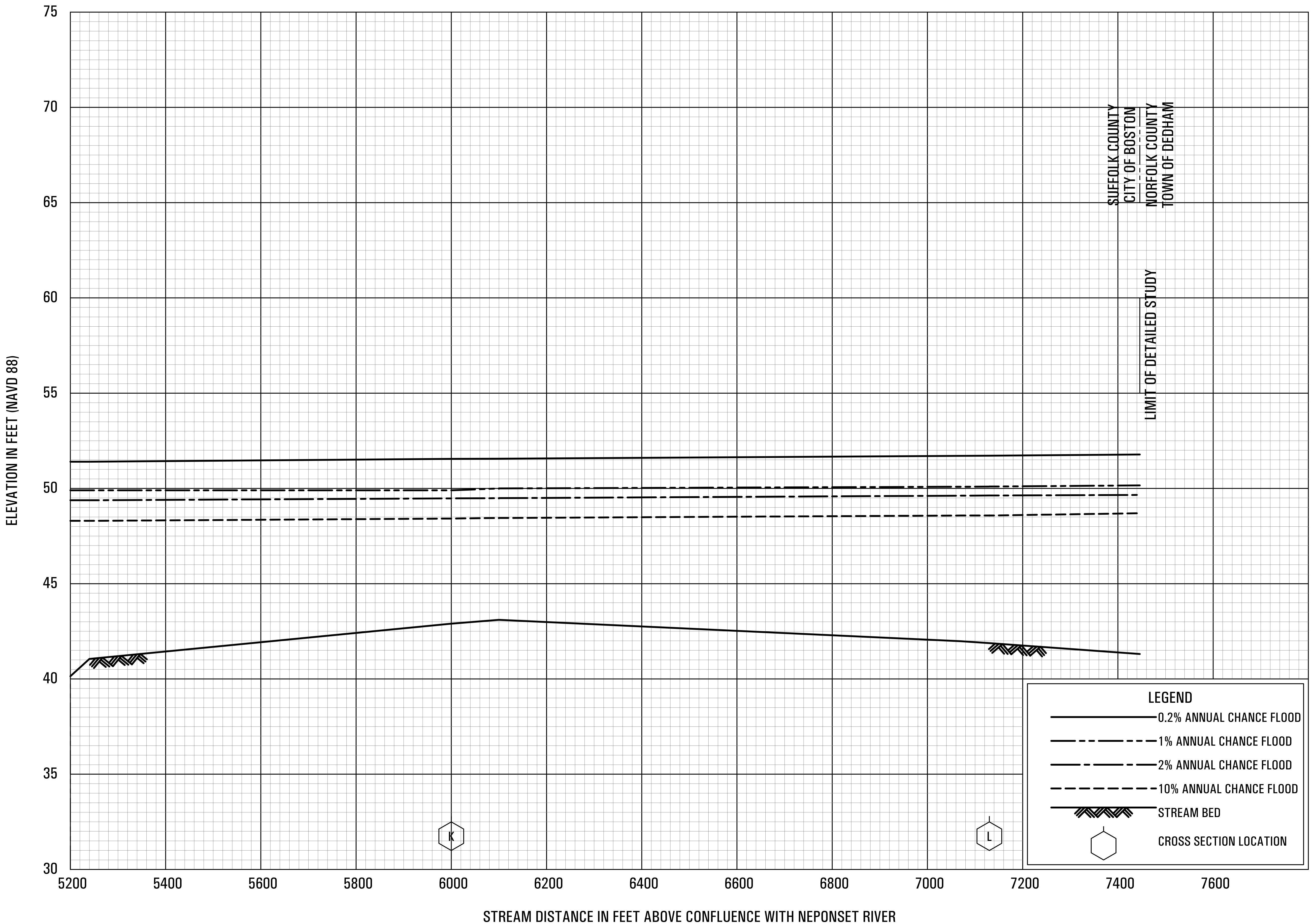
MOTHER BROOK

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

08P



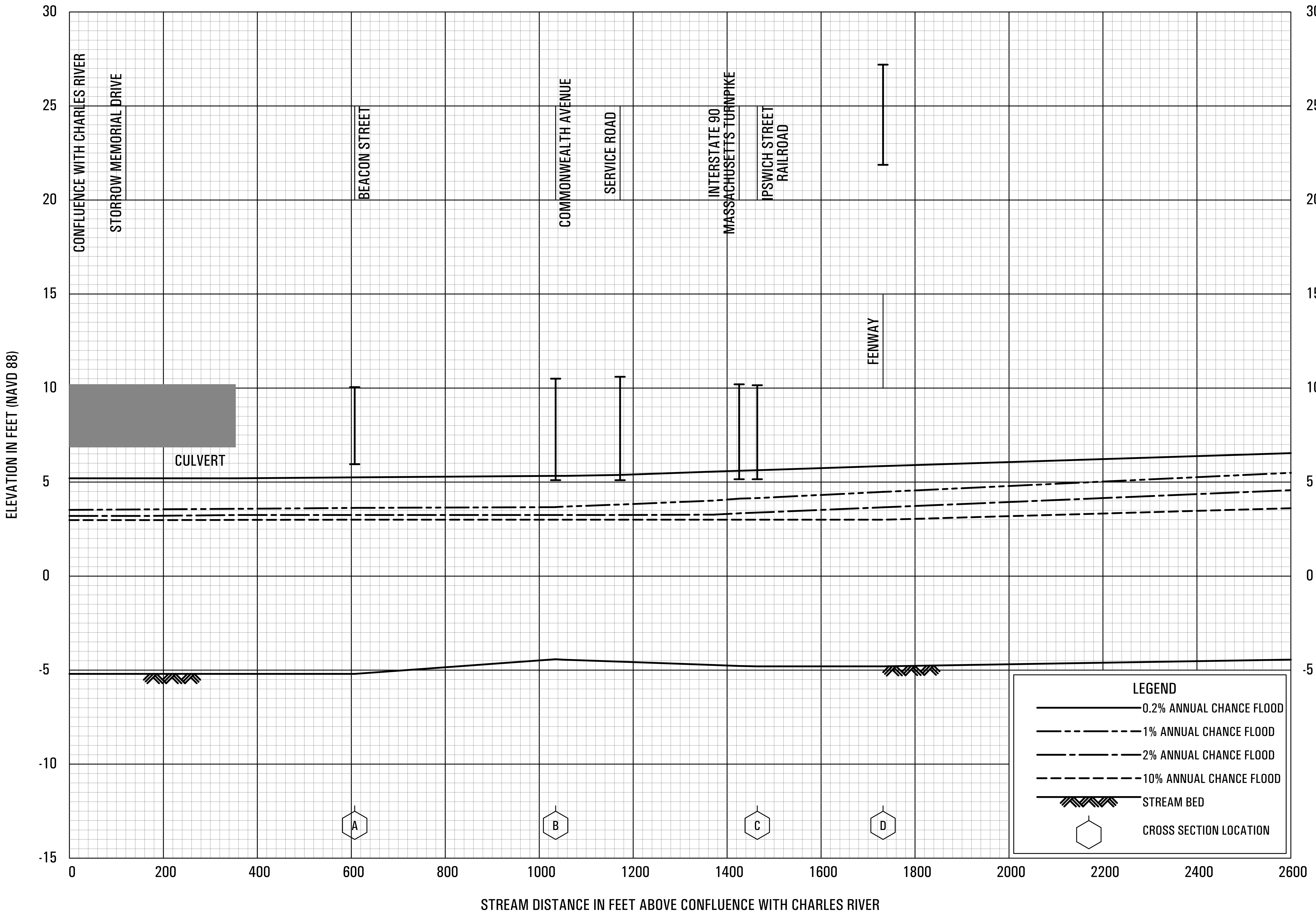
FLOOD PROFILES

MOTHER BROOK

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)



FLOOD PROFILES

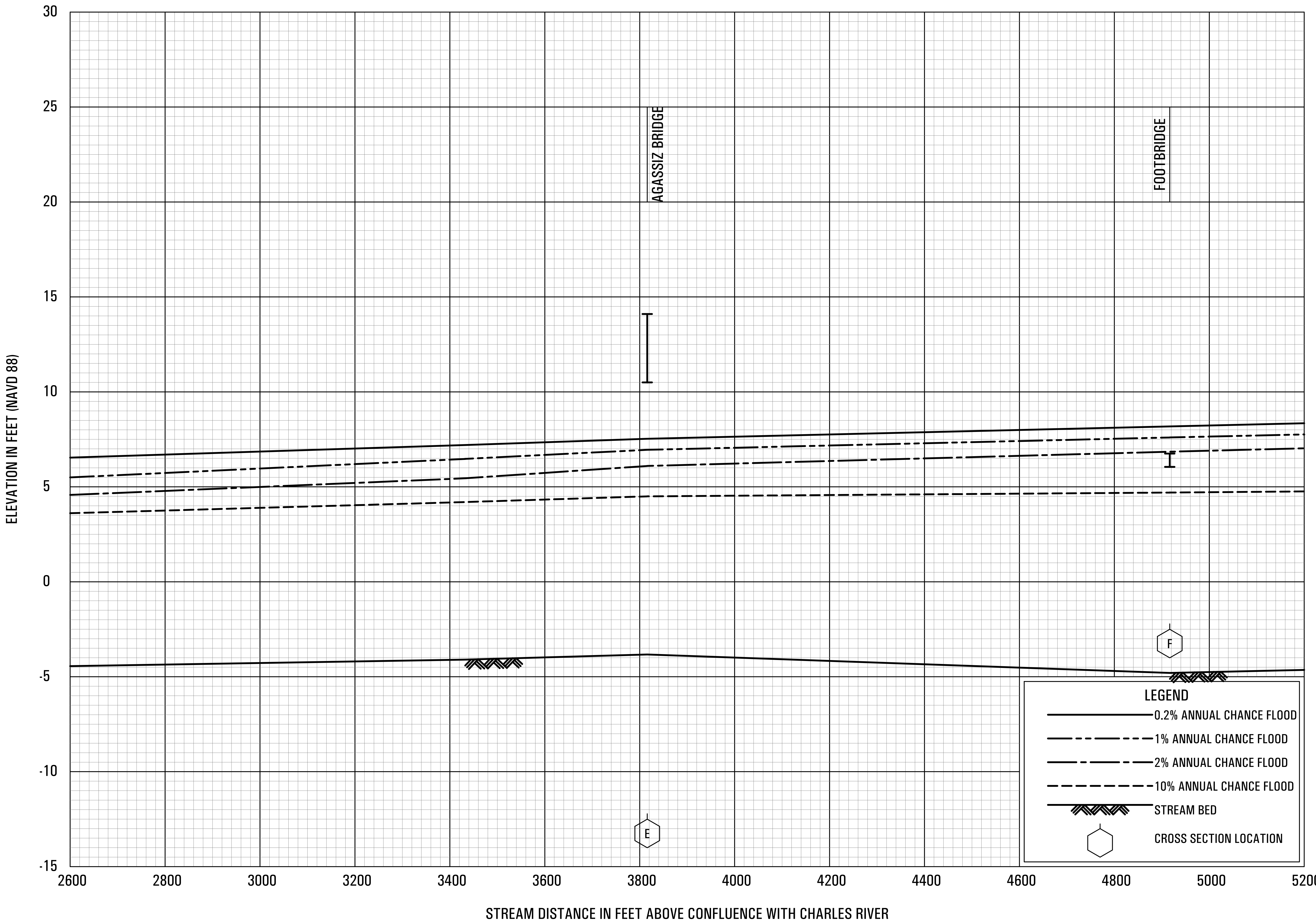
MUDDY RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

10P



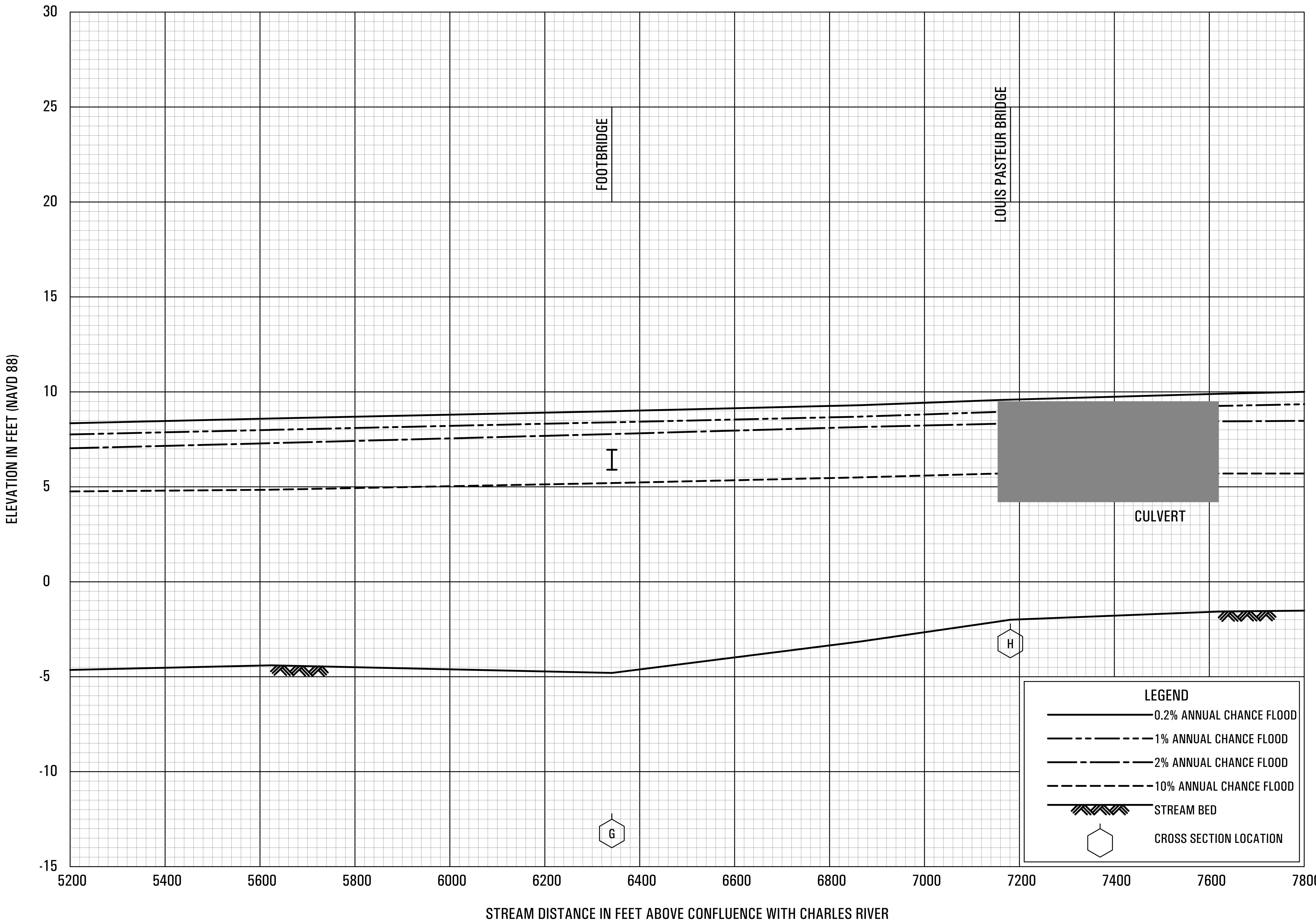
FLOOD PROFILES

MUDDY RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)



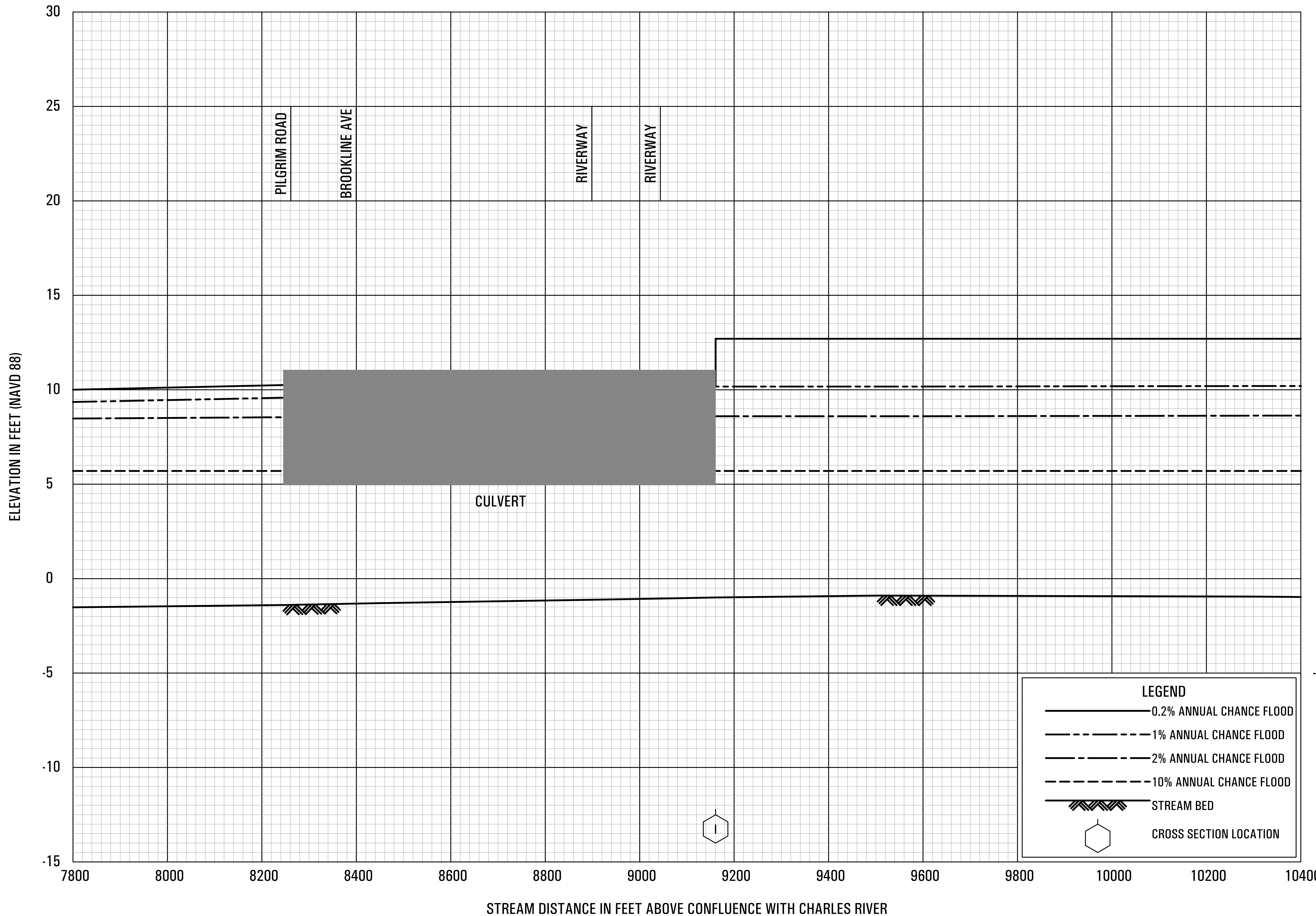
FLOOD PROFILES

MUDDY RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)



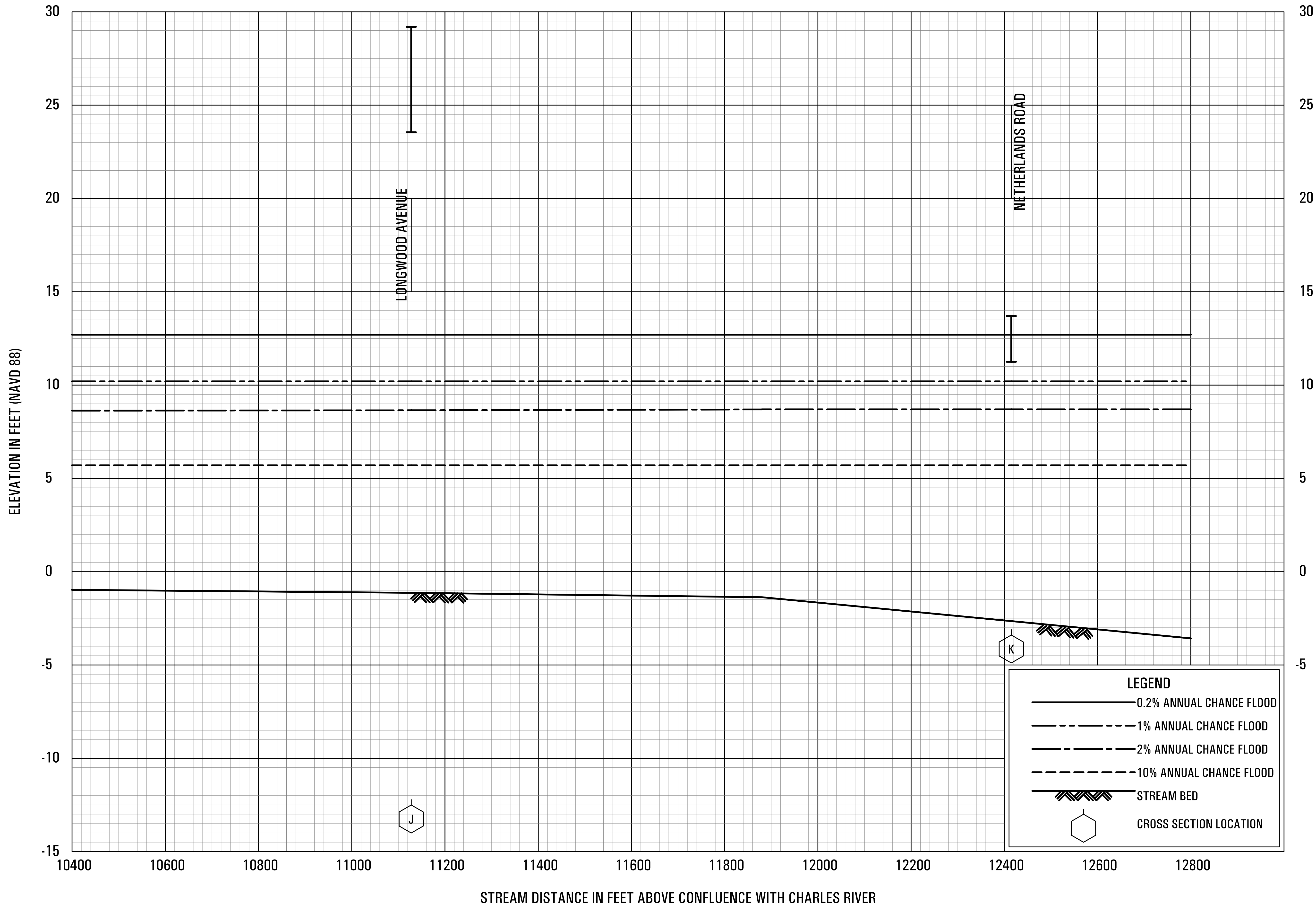
FLOOD PROFILES

MUDDY RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)



FLOOD PROFILES

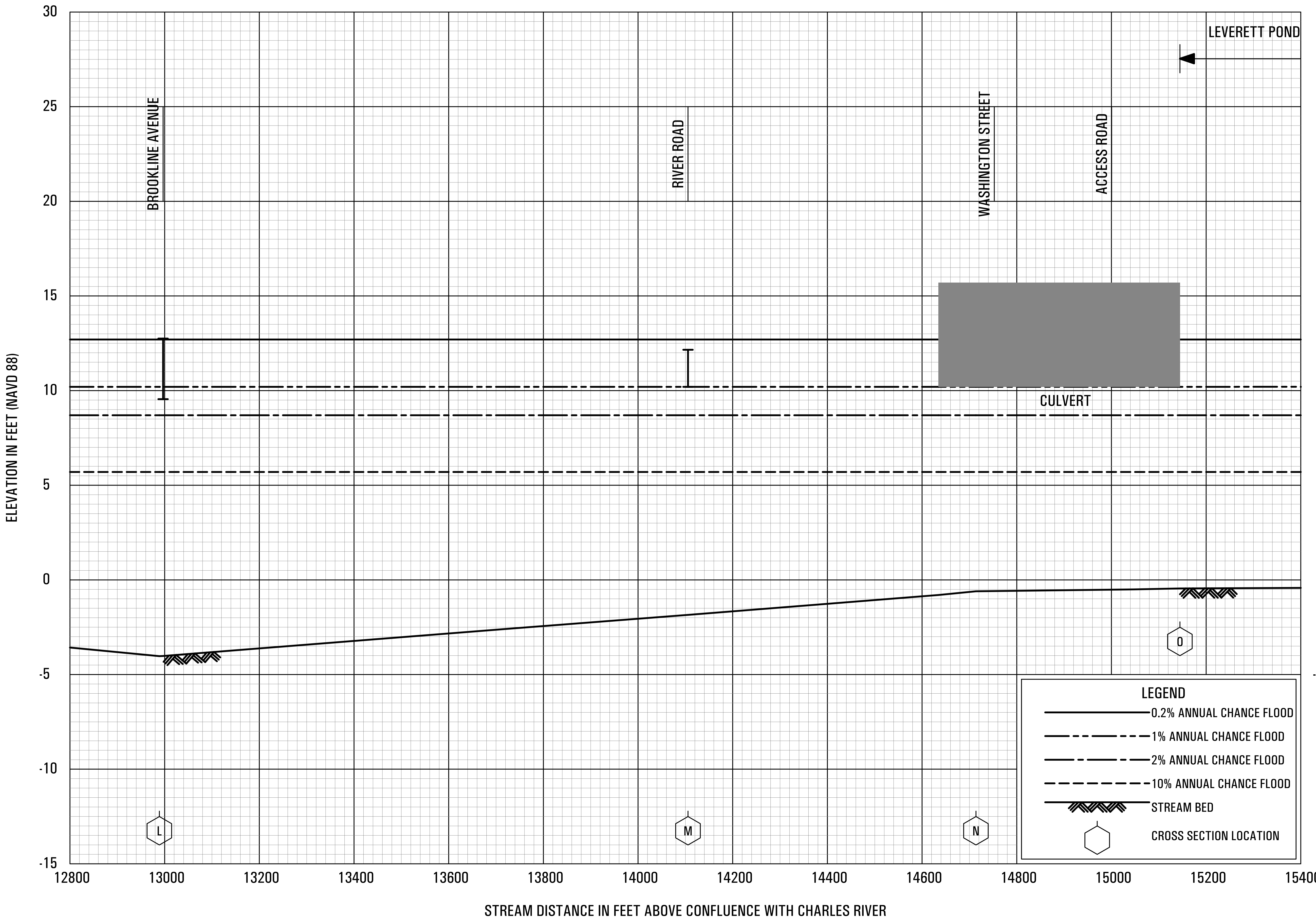
MUDDY RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

14P



FLOOD PROFILES

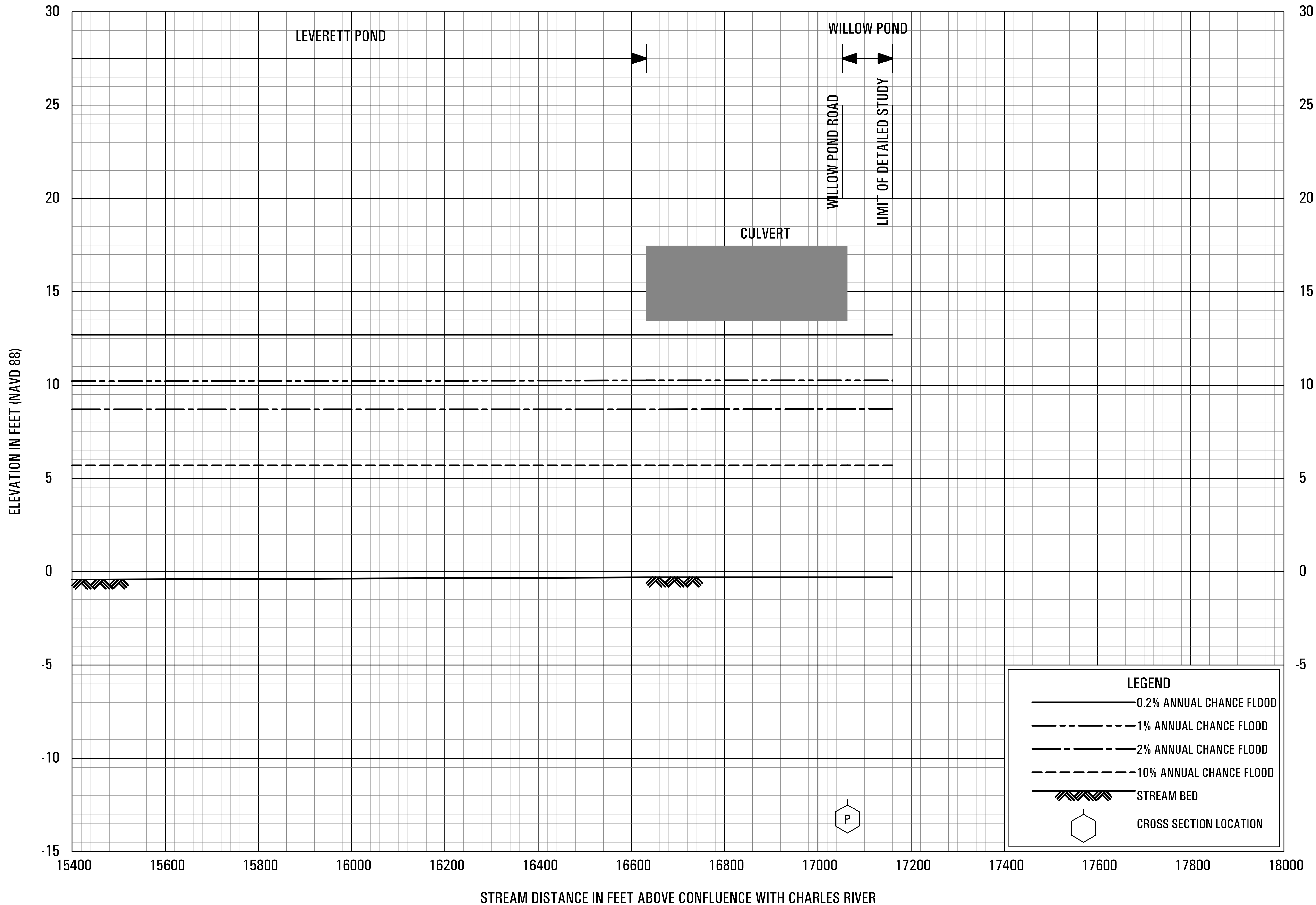
MUDDY RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

15P



FLOOD PROFILES

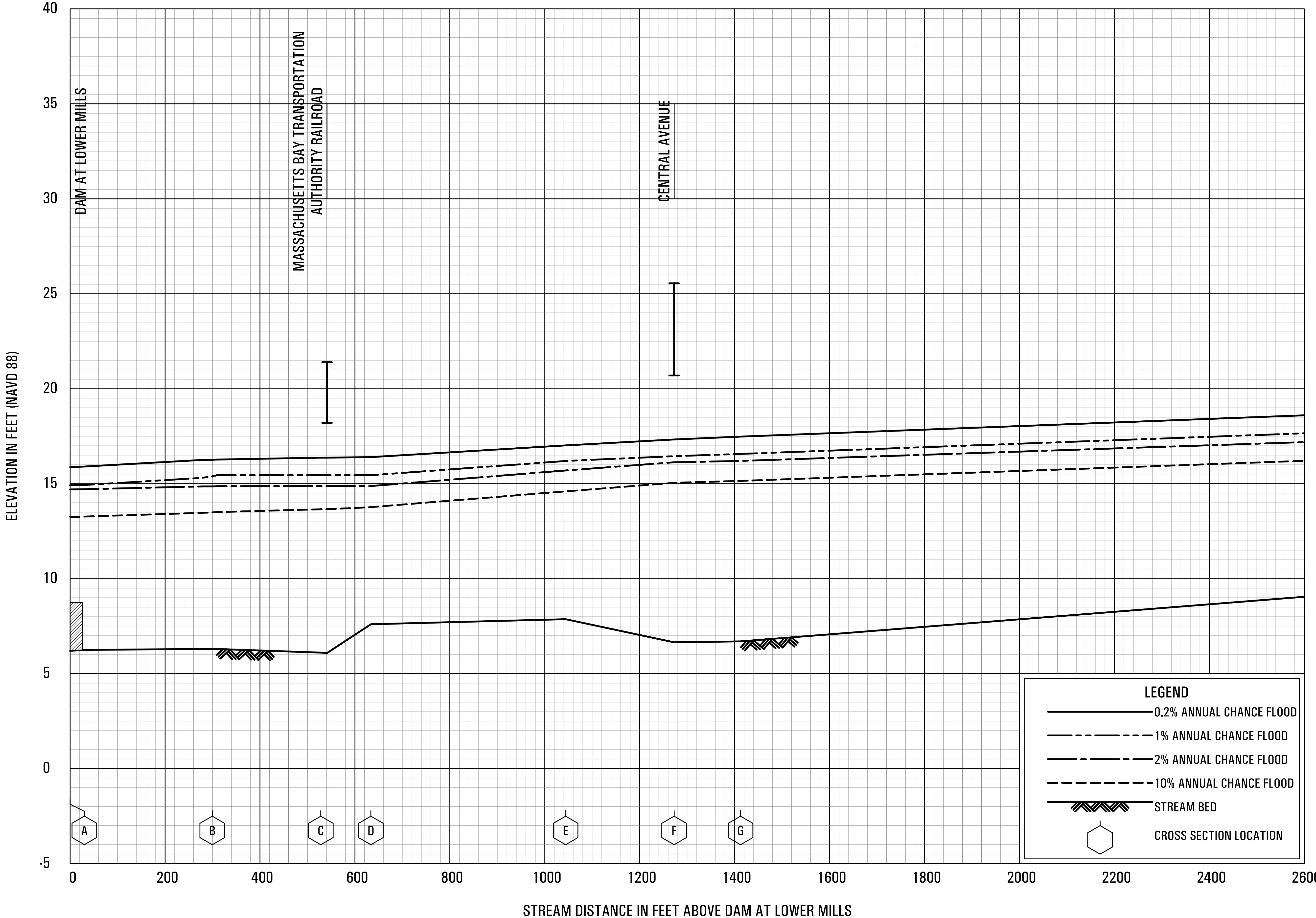
MUDDY RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

16P



FLOOD PROFILES

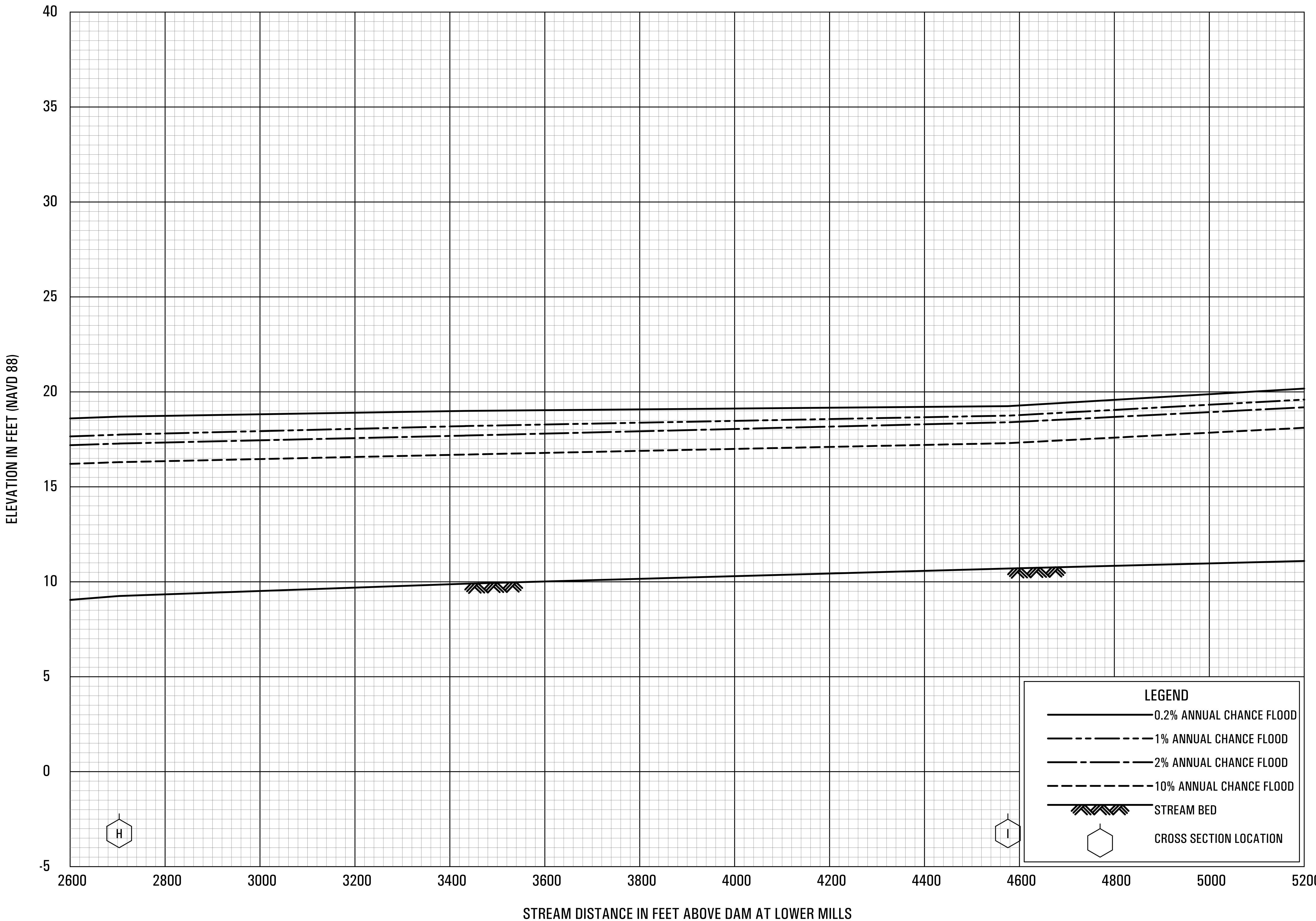
NEPONSET RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

17P



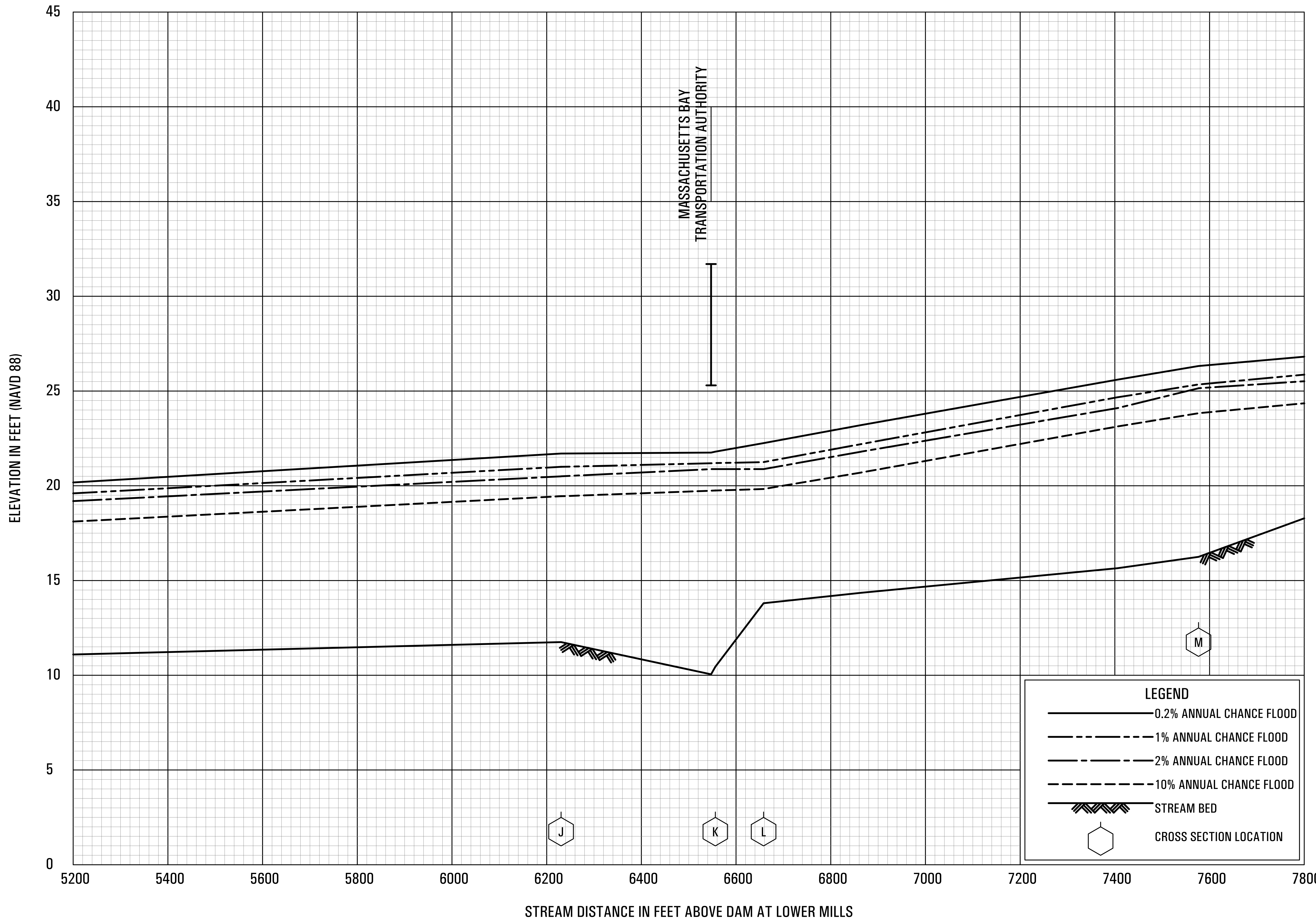
FLOOD PROFILES

NEPONSET RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)



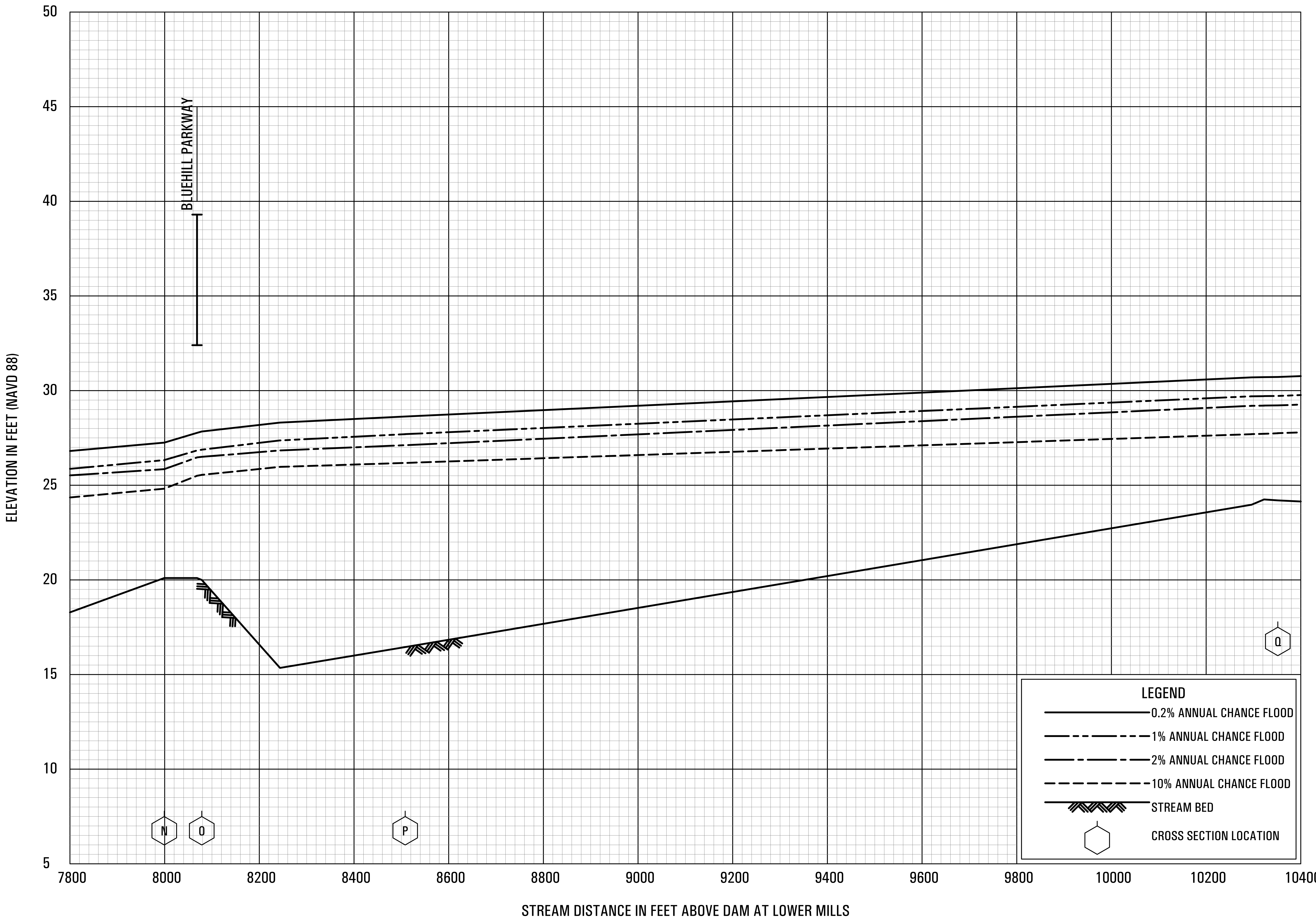
FLOOD PROFILES

NEPONSET RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)



FLOOD PROFILES

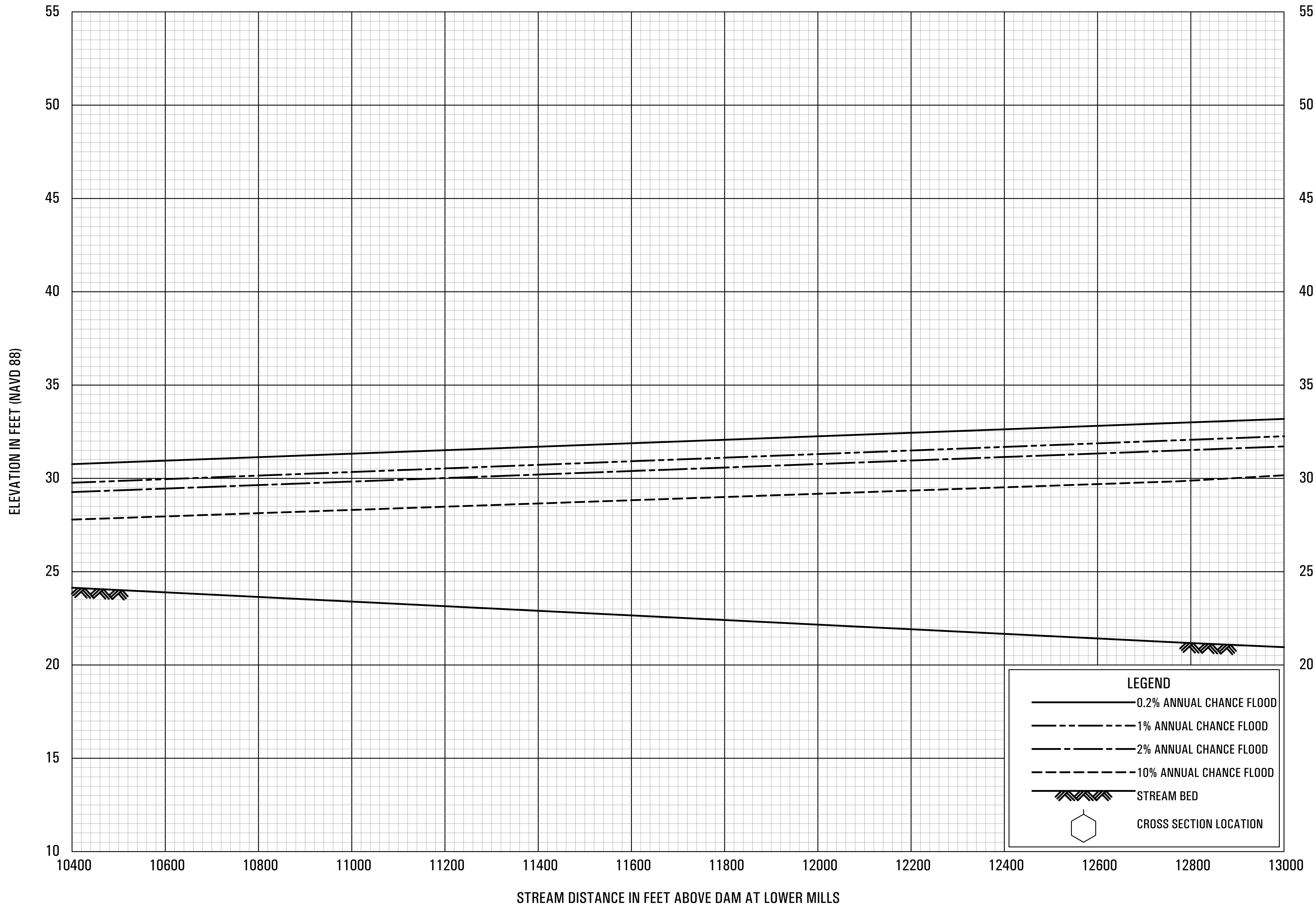
NEPONSET RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

20P



FLOOD PROFILES

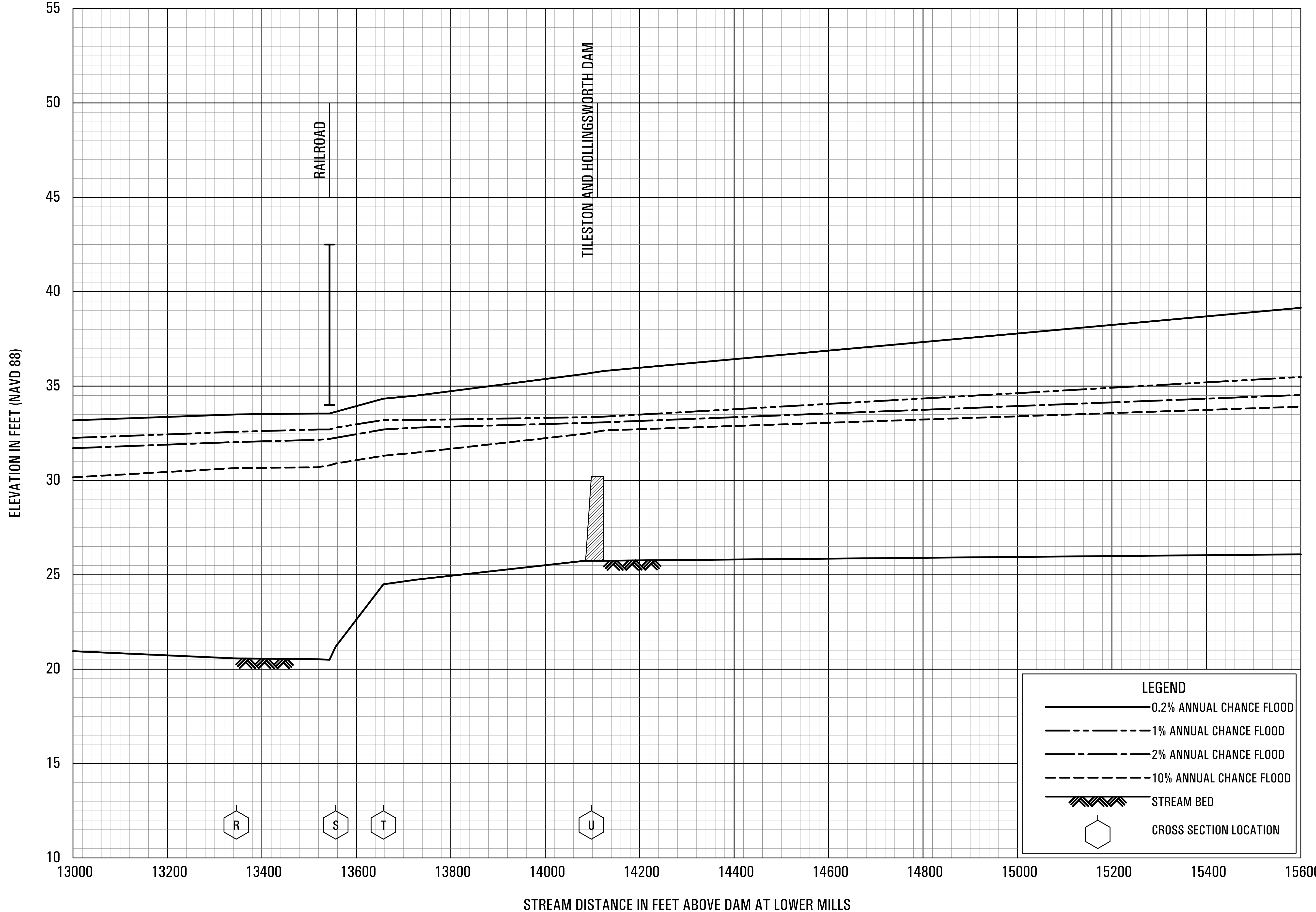
NEPONSET RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

21P



FLOOD PROFILES

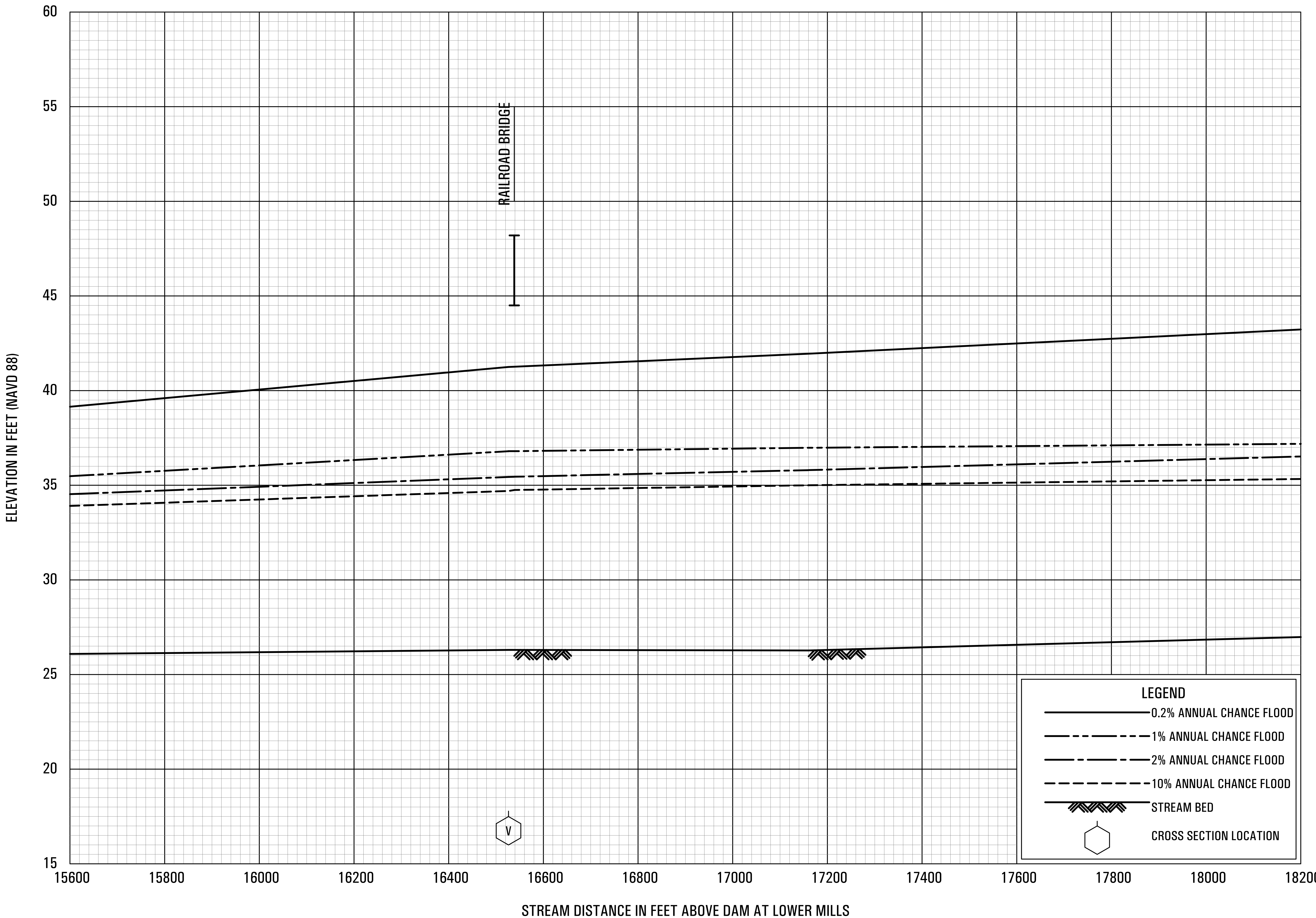
NEPONSET RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

22P



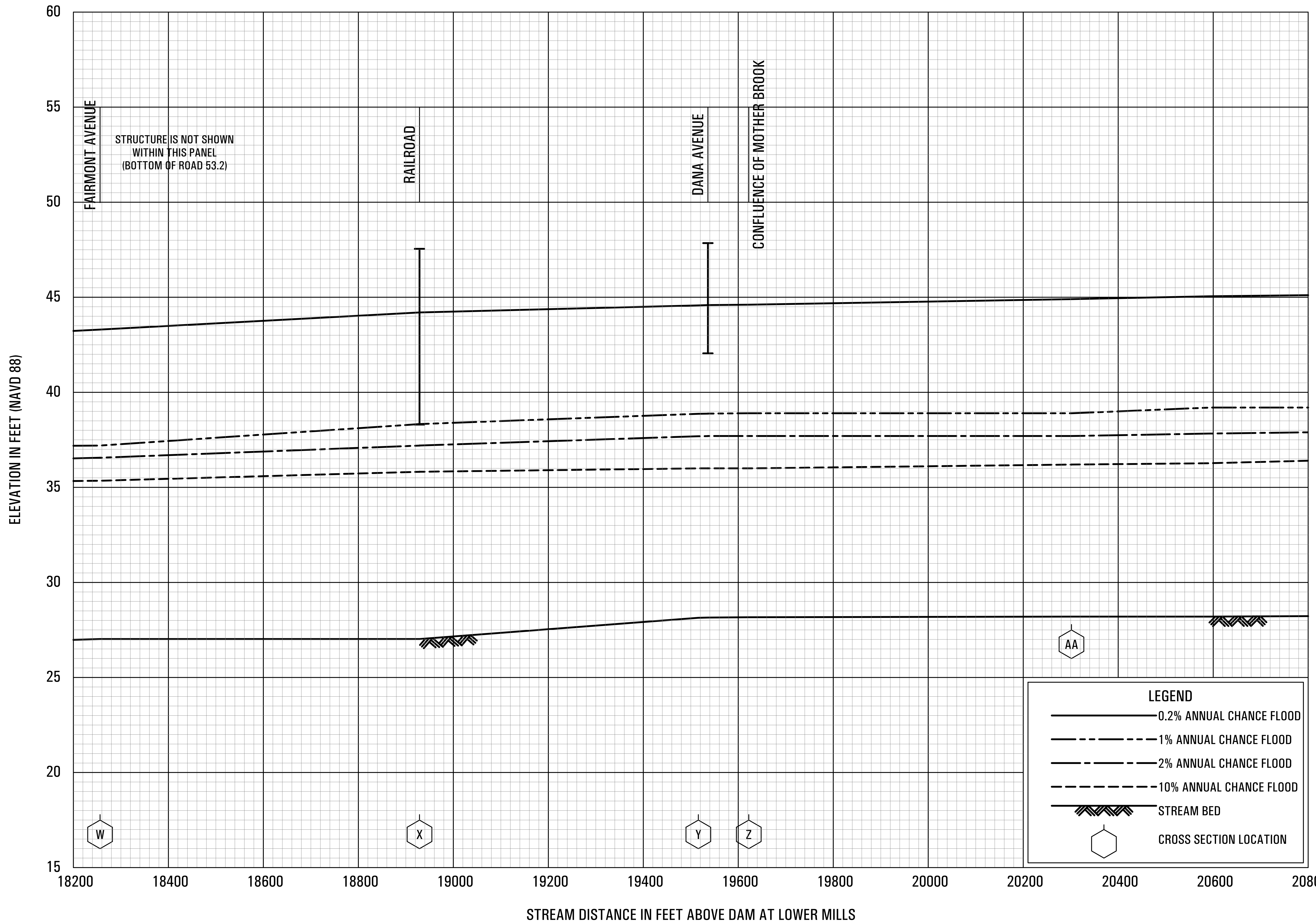
FLOOD PROFILES

NEPONSET RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)



FLOOD PROFILES

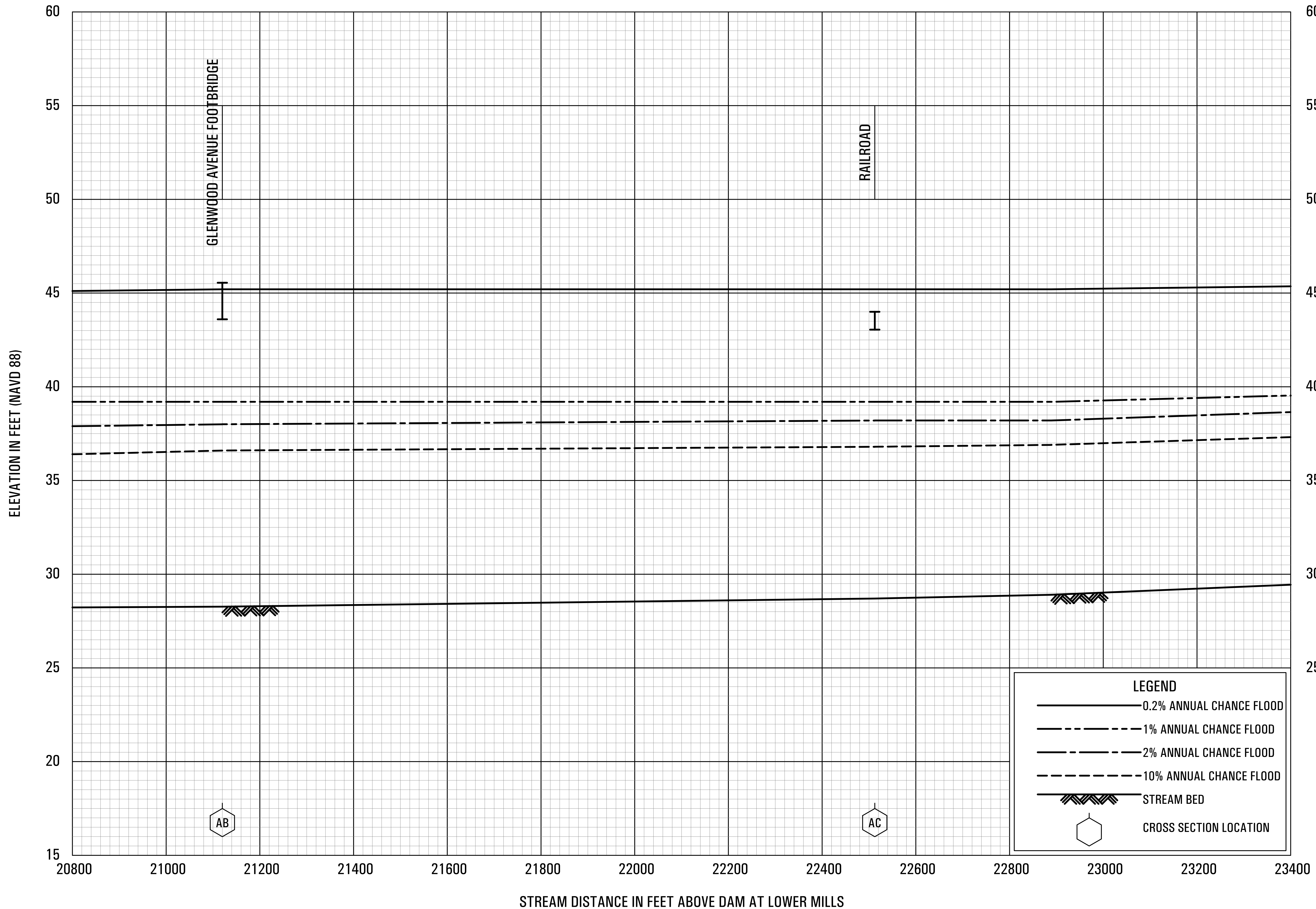
NEPONSET RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)

24P



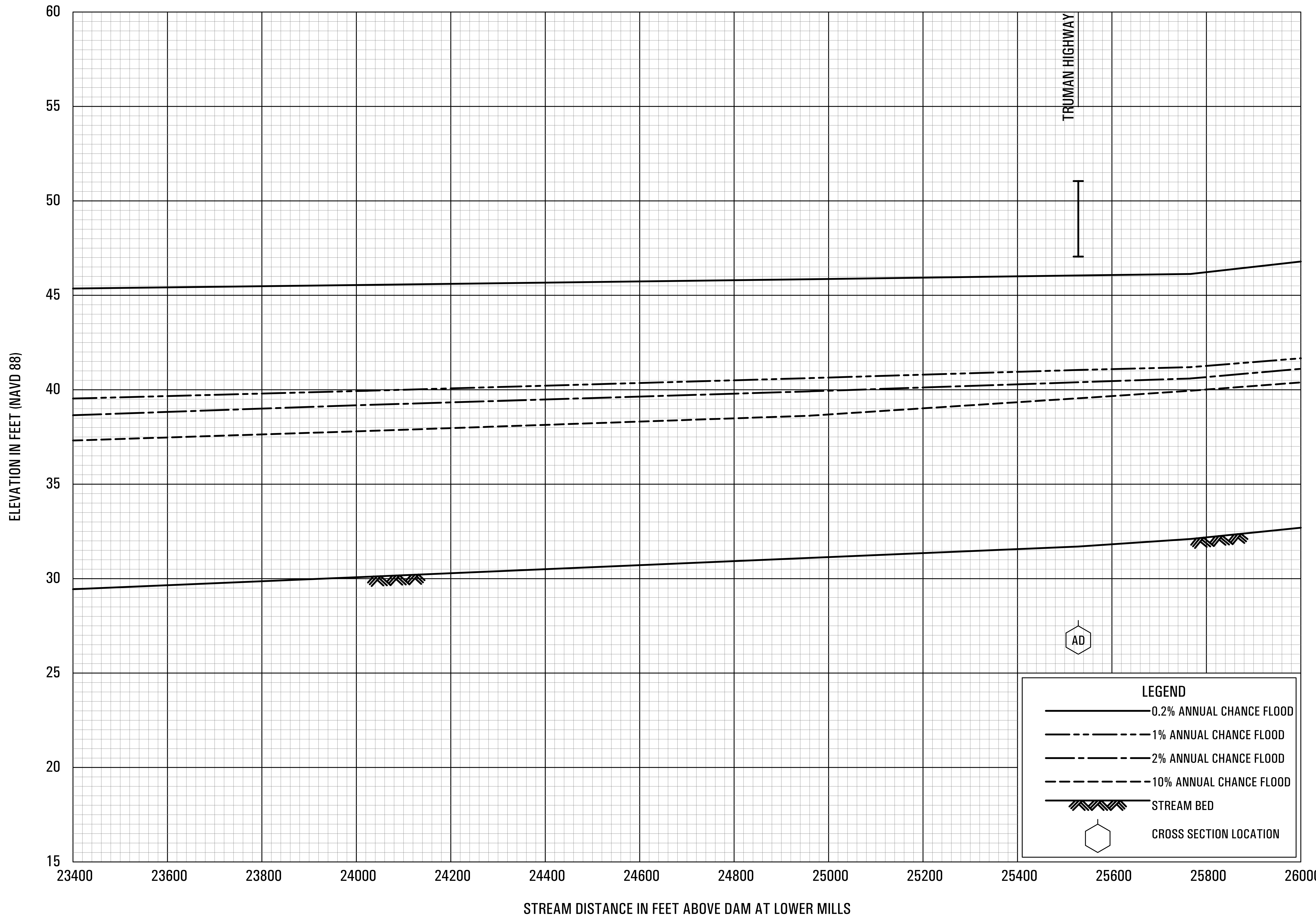
FLOOD PROFILES

NEPONSET RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)



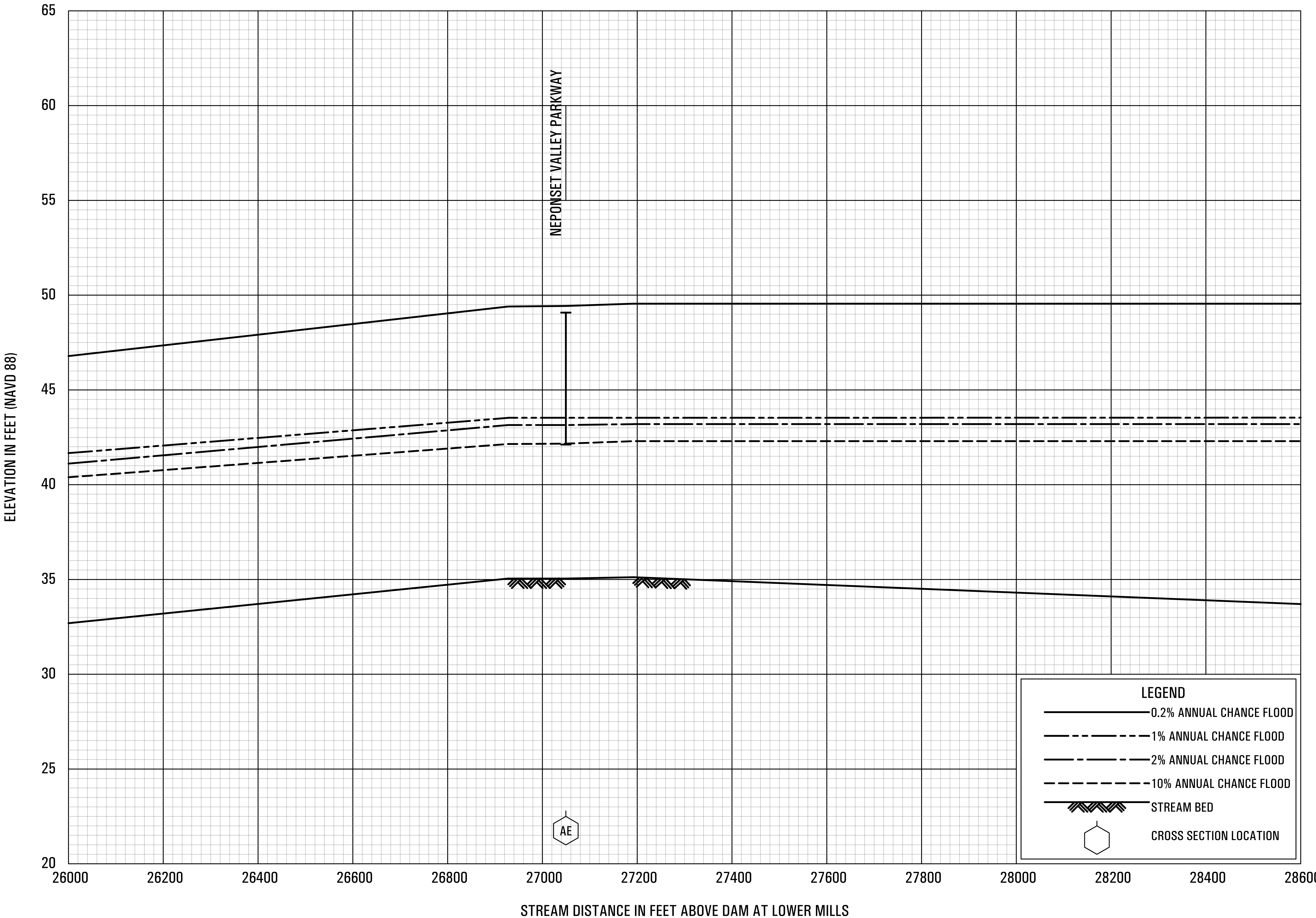
FLOOD PROFILES

NEPONSET RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)



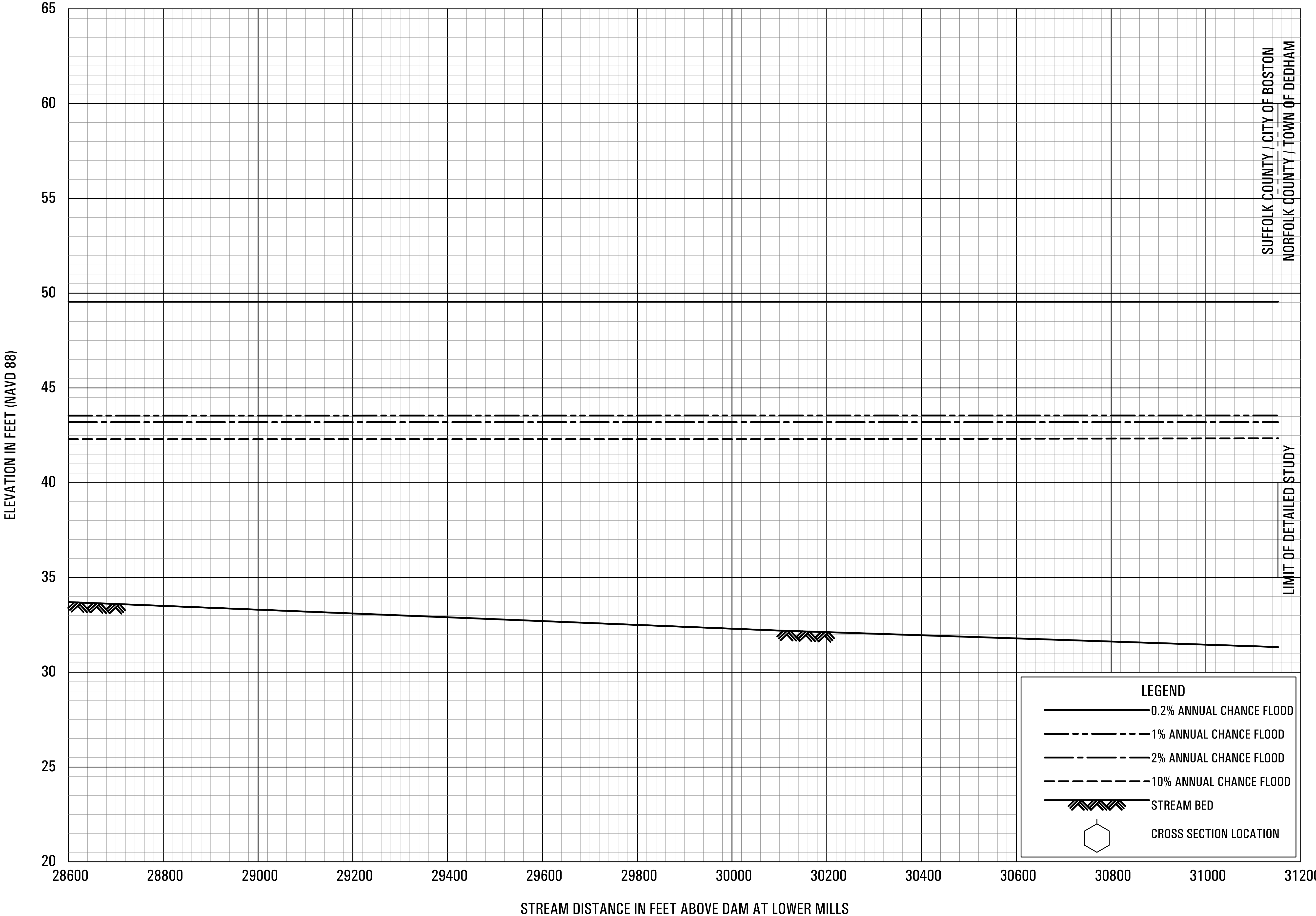
FLOOD PROFILES

NEPONSET RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)



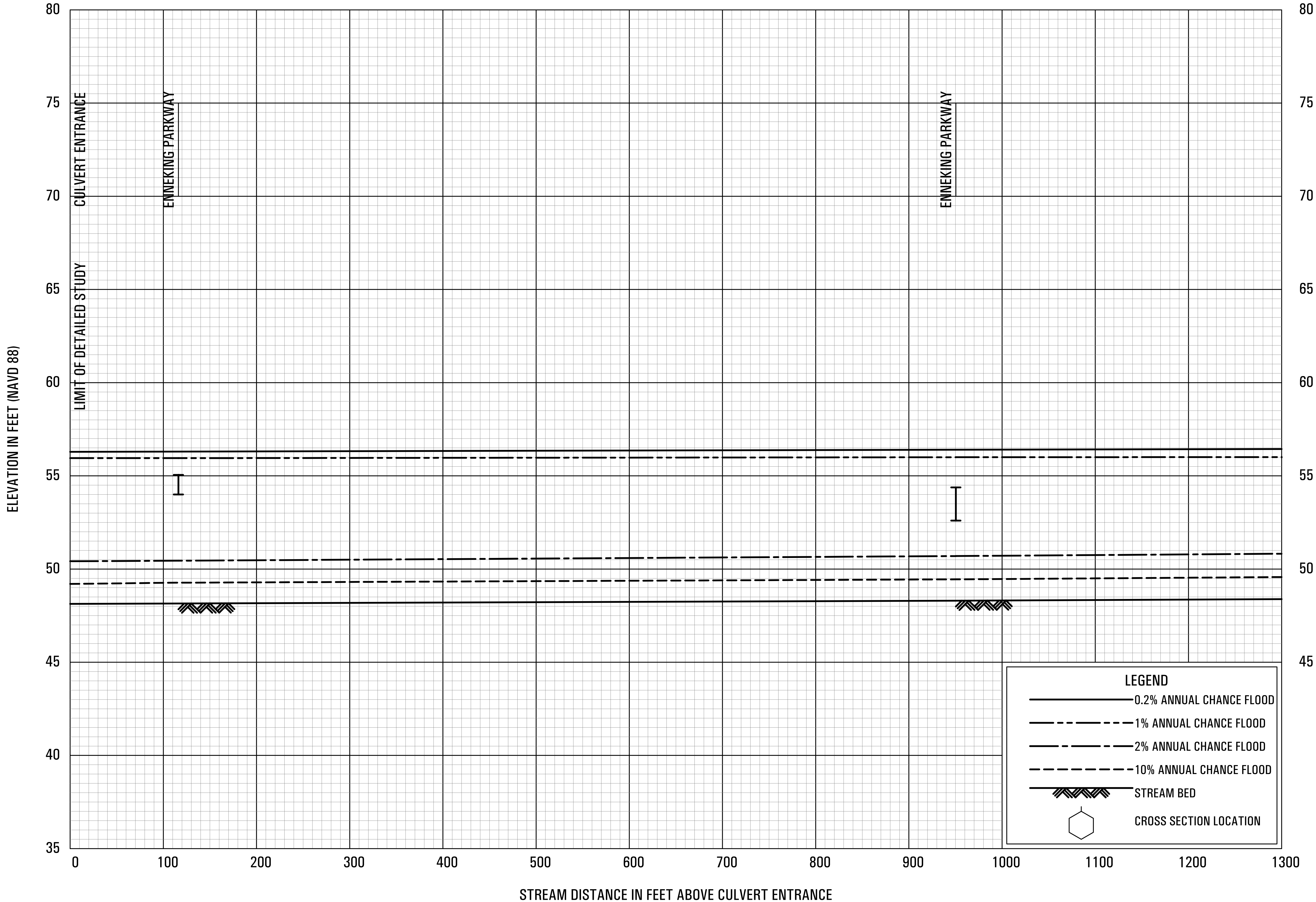
FLOOD PROFILES

NEPONSET RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNTY, MA

(ALL JURISDICTIONS)



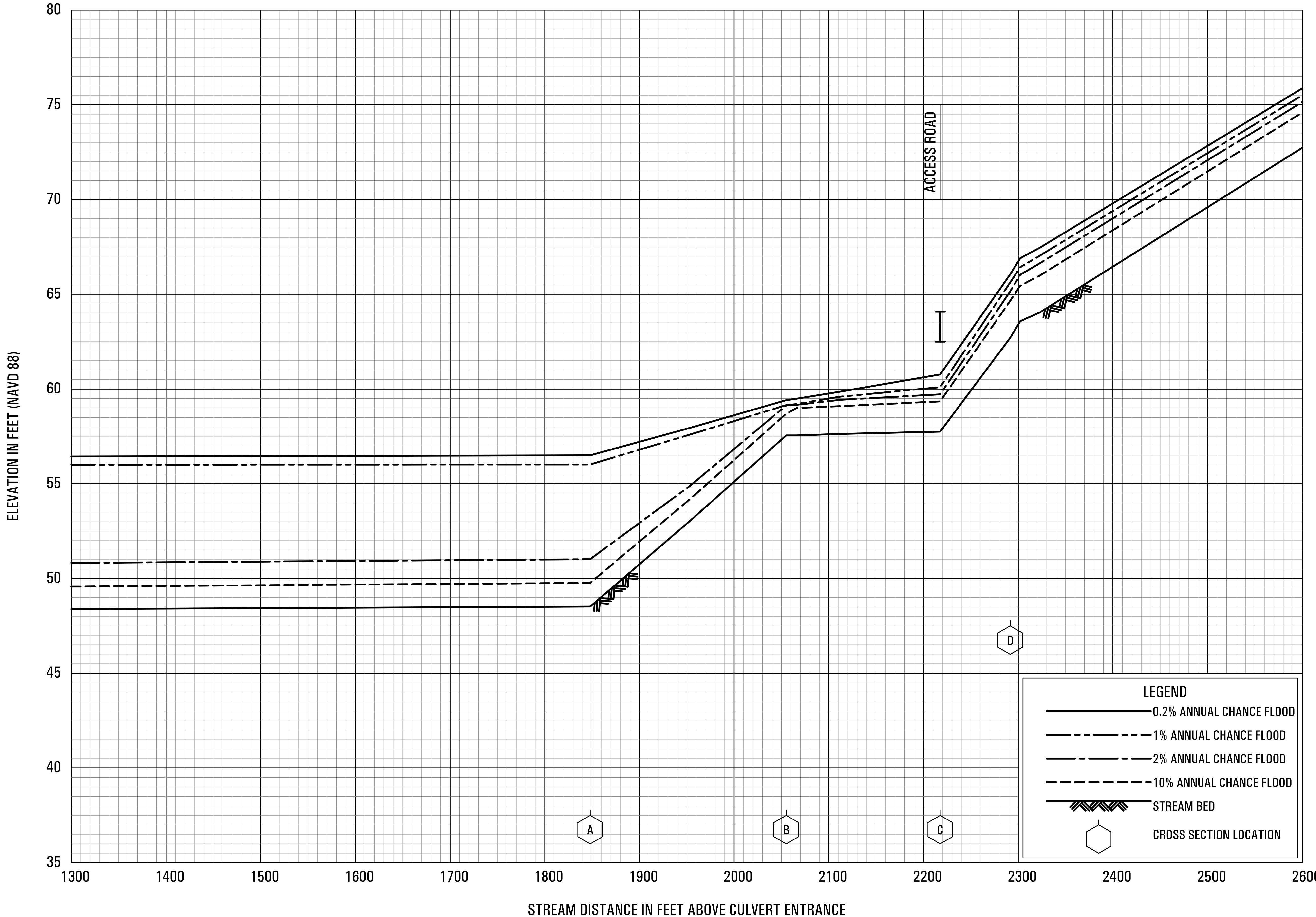
FLOOD PROFILES

STONY BROOK

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNT, MA

(ALL JURISDICTIONS)



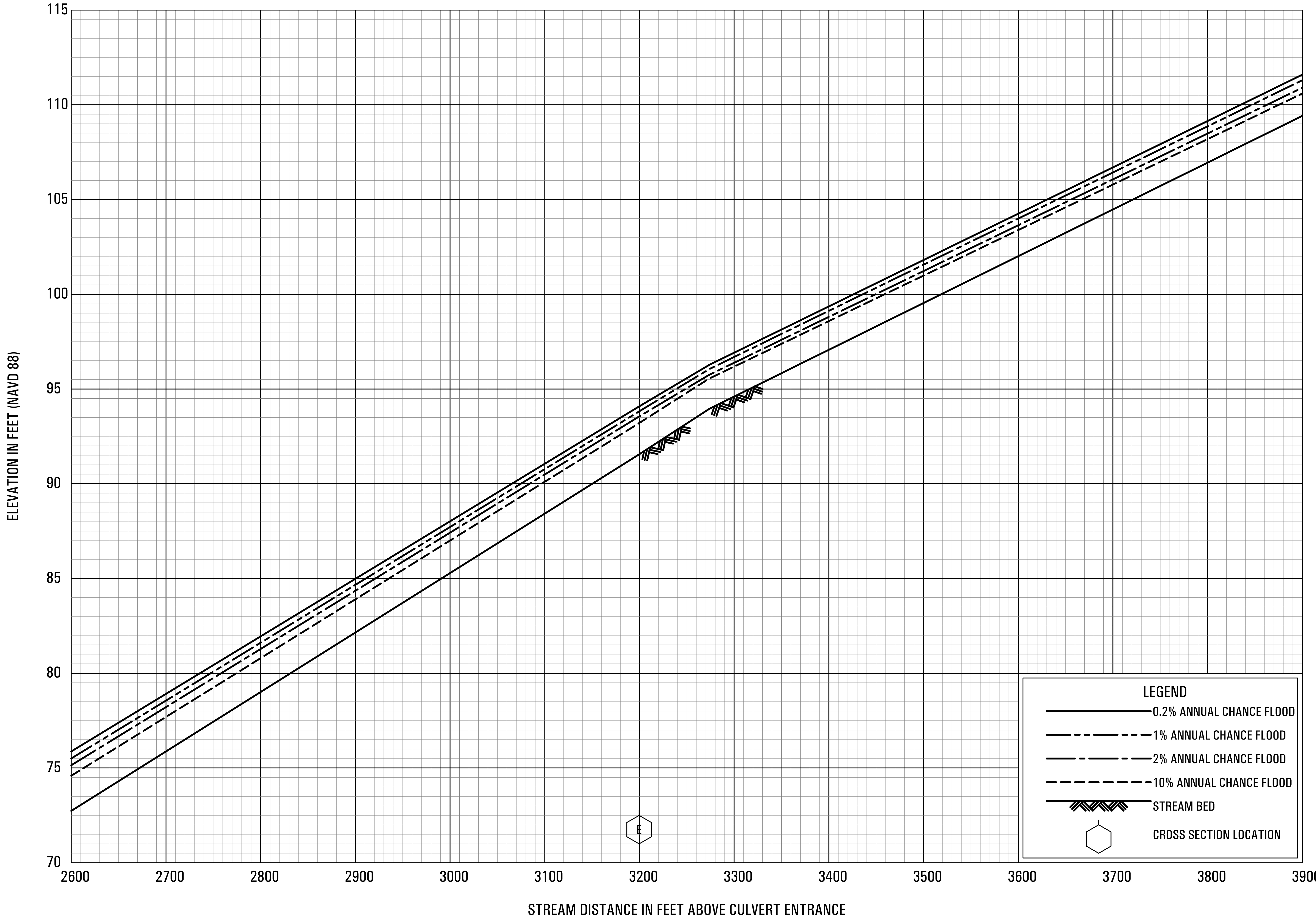
FLOOD PROFILES

STONY BROOK

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNT, MA

(ALL JURISDICTIONS)



FLOOD PROFILES

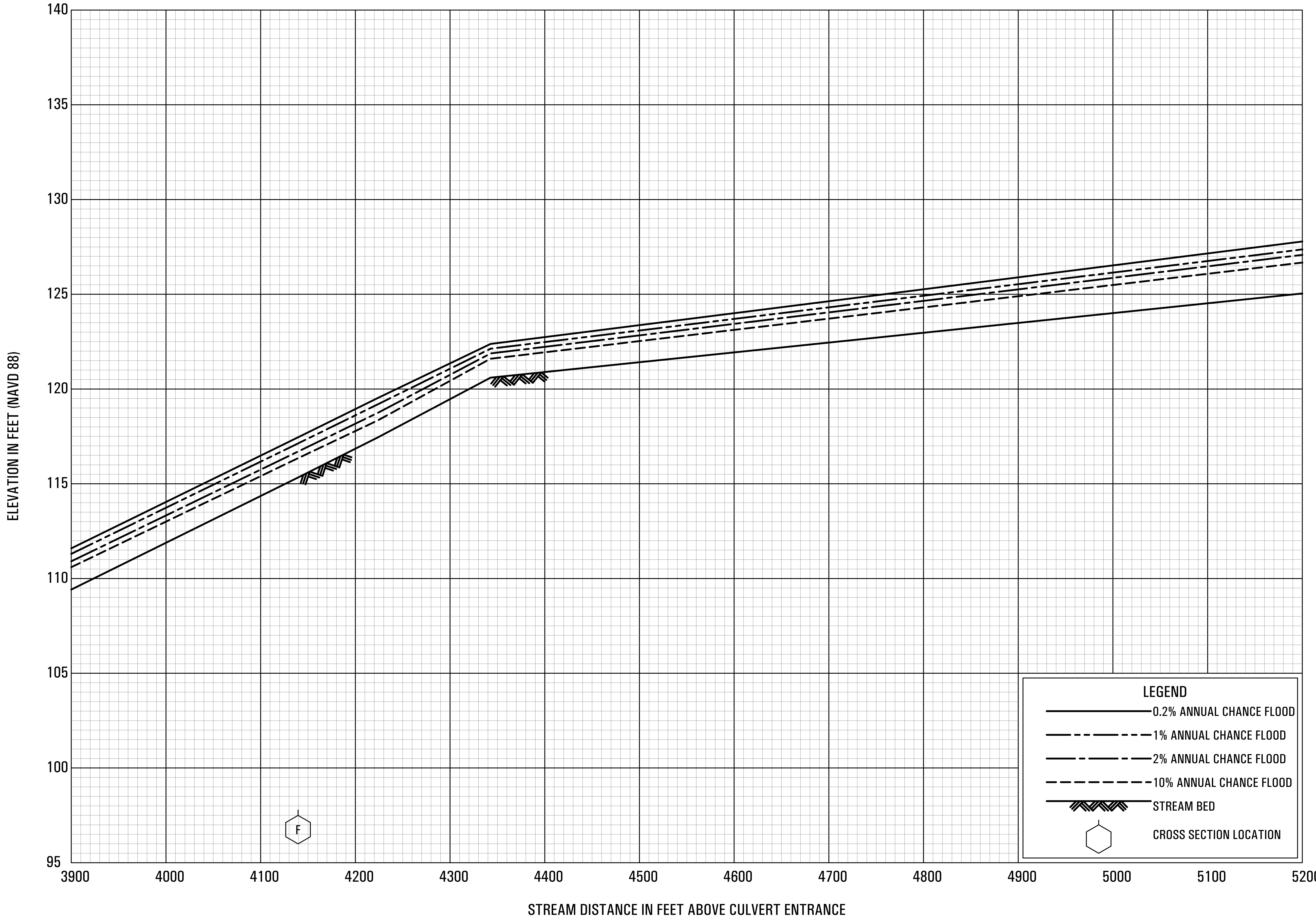
STONY BROOK

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNT, MA

(ALL JURISDICTIONS)

31P



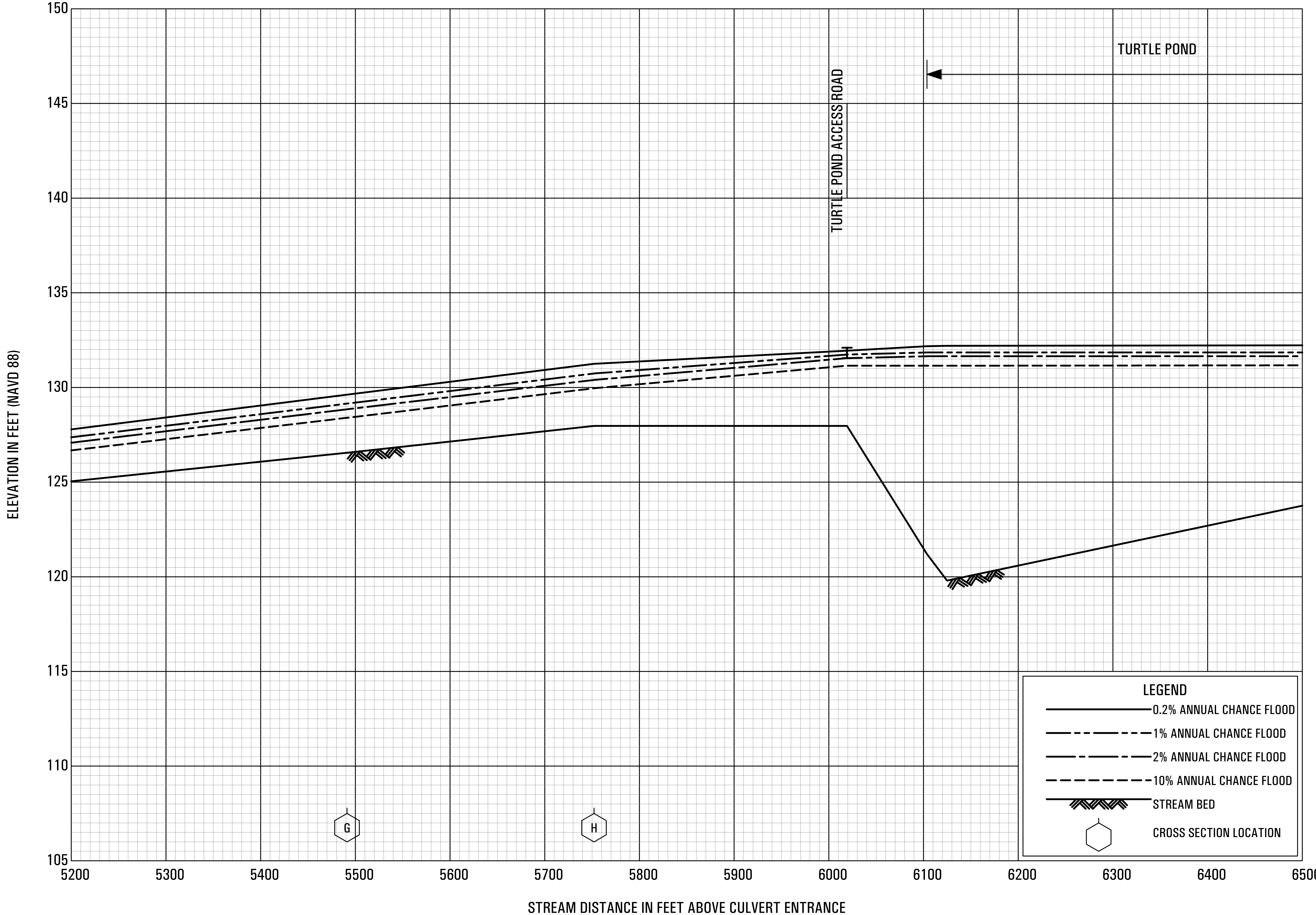
FLOOD PROFILES

STONY BROOK

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNT, MA

(ALL JURISDICTIONS)



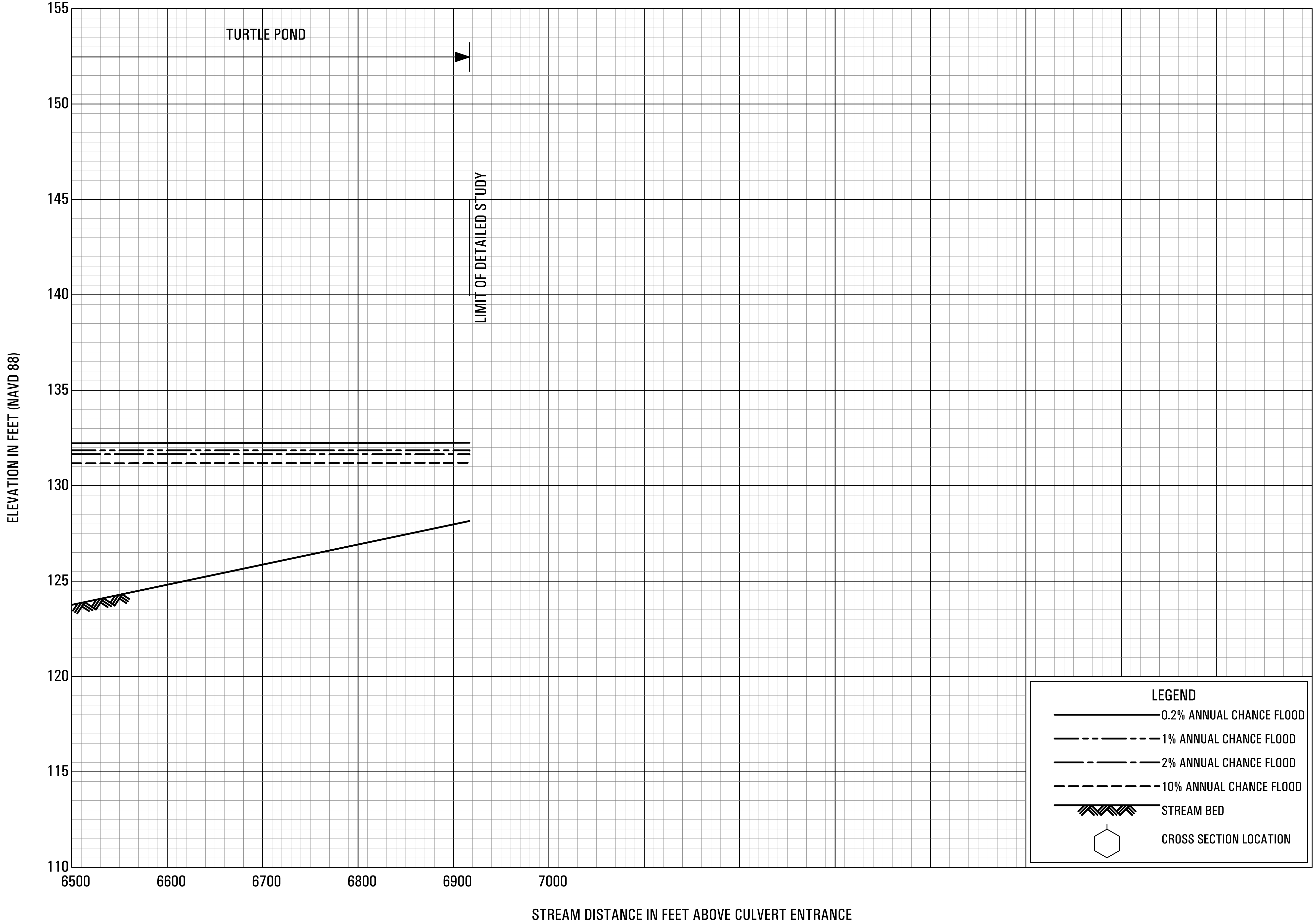
FLOOD PROFILES

STONY BROOK

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNT, MA

(ALL JURISDICTIONS)



FLOOD PROFILES

STONY BROOK

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUFFOLK COUNT, MA

(ALL JURISDICTIONS)