Bridge Replacement
Lockwood Lane over Fish Brook

Boxford
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COMMONWEALTH OF MASSACHUSETTS
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1.0 Executive Summary

This report has been developed to present the results of the hydraulic study conducted for the replacement of the Lockwood Lane over Fish Brook Bridge in Boxford, Massachusetts. The study includes evaluation of hydraulic performance and scour safety for the existing structure and preferred replacement bridge types. This evaluation has been performed in conformance with the relevant standards and guidelines promulgated by the American Association of State Highway Officials (AASHTO), Federal Highway Administration (FHWA), and the Massachusetts Department of Transportation (MassDOT).

2.0 Project Description

2.1 Existing Bridge

The existing bridge B-19-013 (81B) is oriented east-west, has an unknown date of construction and consists of a prestressed concrete slab superstructure. The bridge carries Lockwood Lane over Fish Brook. Lockwood Lane is functionally classified as a local road with a 2017 average daily traffic of 300 vpd. The substructure consists of field stone abutments. The structure has a 13' span. The total superstructure width is approximately 28'.

Waterway

The Fish Brook is a perennial river with headwaters originating at Stiles Pond in Boxford, Massachusetts. The brook drains to the Ipswich River in Topsfield, Massachusetts. The tributary watershed upstream of Lockwood Lane is 14.1 square miles. The watershed is 67% forested and is less than 23% developed. The land use adjacent to the bridge is primarily forests with low-density residential.

The existing channel under the bridge includes natural stones and primarily granular material. There is strong evidence of scour from the collapsed areas of the east and west abutments.

The Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for Boxford, MA dated July 19, 2018, has established a floodplain and a floodway for Fish Brook.

2.2 Proposed Bridge

2.2.1 Description of Project Parameters and Constraints

2.2.2 Description of Proposed Roadway Cross Section

Road Width:	28 Feet, Out to Out
Lane width:	2 - 11'-0" lanes
Shoulder Width:	2 - 3' shoulders
Sidewalks:	No sidewalks
Roadway System:	Local Road
Design Speed:	30 mph
Present ADT:	300 (2017)
Truck Traffic Percentage:	5%
Vertical Alignment:	0.2% downgrade from west to east
Horizontal Alignment:	Normal crown across bridge
NHS:	No

2.2.3 Proposed Traffic Management

The bridge is currently closed and will remain closed during construction. Detour signs are in place to direct motorists.

2.2.4 Proposed Clearances

The proposed clear width is 19.7' and the proposed clear height 4.22' at the center of the channel

2.2.5 Hydraulic Data

Drainage Area	14.1 square miles
Design Flood Discharge	400 cubic feet/sec
Design Flood Frequency	10 year
Design Flood Velocity	3.9 feet/sec max @ channel center
Design Flood Elevation (Proposed)	54.63 NAVD
Base (100 year) Flood Discharge	970 cubic feet/sec
Base (100 year) Flood Elevation	56.32 NAVD
Design Scour Flood	50 year
Check Scour Flood	100 year
Flood of Record	(unknown)
Proposed Lower Chord Elevation	54.68 NAVD

2.2.6 Preliminary Geotechnical Data

Borings were performed in the approximate location of the proposed abutments. The borings had refusal at 28.5 and 30.5 feet.

2.2.7 Constraints Imposed by Approach Roadway Features

The properties adjacent to the bridge are owned by the Town of Boxford. The southerly property is an Article 97 protected property. The use of this land is not proposed.

2.2.8 Constraints Imposed by Feature Crossed

Additional hydraulic capacity under the structure by means of increased span length will be necessary to prevent changes to the established flood elevations. Channel grade under the structure will be raised to be consistent with the channel slope beyond the influence of the crossing.

2.2.9 Constraints Imposed by Utilities

There is a gas line attached to the downstream face of the existing bridge; relocation will be part of the bridge project.

2.2.10 Constraints Imposed by Environmentally Sensitive Areas

The existing channel width will not be reduced by the proposed bridge and a temporary water

control system may be required to control flow during construction. The bridge and surrounding area is designated as NHESP Priority Habitat of Rare Species and NHESP Estimated Habitat of Rare Wildlife. Appropriate measures will be employed to ensure habitat protection.

2.2.11 Constraints Imposed by Cultural Resource Areas

A search of the Massachusetts Cultural Resources Information System (MaCRIS) shows no resources within the project area. Remnants of a water-powered mill are located upstream. Construction is not anticipated to adversely affect these areas.

2.2.12 Hazardous Material Disposition

Based on a review of available information, there are no known hazardous materials at the bridge site.

3.0 Data Collection/Sources

Reference No.	Title
1	MassDOT NBIS Bridge Inspection File, Br. No. B-19-013
2	Federal Emergency Management Agency (FEMA), Flood Insurance Study (FIS), Town of Boxford, Massachusetts; Essex County, June 1, 1989
3	Federal Emergency Management Agency (FEMA), Flood Insurance Rate Map (FIRM), Town of Boxford, Massachusetts; Essex County, Community Panel 25009C0263F; July 3, 2012
4	Georgetown, MA, USGS Topographical Map, Scale 1:24,000
5	MassDOT Bridge Load and Resistance Factor Design (LRFD) Manual, June 2013
6	MassGIS Datalayers Web Application, http://www.mass.gov
7	Federal Highway Administration (FHWA), Hydraulic Engineering Circular, HEC-18 Evaluating Scour at Bridges, May 2012
8	U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) Web Soil Survey web Application, http://websoilsurvey.nrcs.usda.gov/
9	US Army Corps of Engineers (USACOE), Hydrologic Engineering Center, HEC-RAS River Analysis System , Version 5.0.7

Hydrologic and hydraulic data from References 2 and 3, and were used in conjunction with field observations, measurement, soil data and project survey data to build and calibrate a hydraulic model of the bridge crossing site. Inspection reports were used to verify field observations. Pertinent data entries are included in the appendices.

4.0 Engineering Methods

4.1 Hydrologic Analysis

Peak Discharge for Fish Brook were obtained from the FIS (reference 2). The discharges (obtained from the FIS) are presented in Table 1.

Table 1 – Summary of Discharges

Fish Brook	Drainage Area (mi^2)	10 – Year (ft^3/s)	50 – Year (ft^3/s)	100 – Year (ft^3/s)	500 – Year (ft^3/s)
@ Lockwood Lane 5950	14.1	400	630	750	970

4.2 Hydraulic Analysis

Water surface profiles for the brook's local 10, 50, 100, and 500-year return frequency flood events were developed and calibrated using ACOE HEC-RAS v.5.0.7 with the record FIS model (Reference 2) data obtained from FEMA. Since the original model was developed using the HEC-2 program, some minor adjustments to the data were necessary to develop a duplicate effective model. After developing the duplicate effective model, updates were made to the stream cross sections to reflect the current conditions in the vicinity of the bridge.

Flood simulations were performed as subcritical flow. The channel and left and right overbanks (LOB/ROB) were assigned roughness coefficients (Manning's "n") that are identical to the FIS model of 0.06 and 0.15, and 0.15 respectively. The comparison of model flood elevations is presented in Table 2.

Table 2
Summary of FEMA Analysis
Base (100 year) Flood – 750 cfs

Cross Section Station (FEMA Letter Section)	HEC-2 (ft, NAVD)	Duplicate Effective Model (ft, NAVD)	Duplicate Effective vs. FIS (ft, NAVD)	Existing Conditions Model (ft, NAVD)	Proposed Conditions Model (ft, NAVD)	Proposed vs. existing (ft, NAVD)
12650	55.84	57.28	1.44	57.49	56.32	-1.17
12515	53.40	53.40	0.00	53.79	53.79	0

Duplicate Model

Because of differences in calculation methods of the 2 programs (HEC-2 vs. HEC-RAS), the duplicate effective model required the following adjustments:

1. Because of the dual crossing on Lockwood Lane, the entire area between the mill race and the Fish Brook double culvert 320 feet to the west was modeled as a pier. Because HEC-RAS has multiple obstructed area capability, the bridge pier was removed from the HEC-2 "BT" bridge culvert data and the area between the two culverts was modeled as an obstruction.

2. Changed Mannings “n” calculation option to use the old (HEC-2) method.

HEC-2 uses the SB record BAREA input variable for pressure (orifice) flow under bridges. This is the area under the structure available for flow in square feet. In HEC-RAS, the net flow area under the bridge is calculated by the program using the bridge data and cross section data. The two values are slightly different:

HEC-2 BAREA variable	= 130 ft^2
HEC-RAS calculated flow area	= 115 ft^2

Since the flow area calculated in HEC-RAS is a more accurate representation of the flow area, the model has not been adjusted to duplicate the elevations in this location.

Current Conditions Model

The current condition model results reflect minor changes in the cross sections in the immediate vicinity of the bridge, including:

1. Revising the Mannings “n” of the upstream and downstream cross-sections to be consistent with the adjacent channel and used the FIS Mannings “n” from those sections in the adjacent internal bridge sections.
2. Updating the existing cross sections using the existing conditions survey terrain model.
3. Changing the channel bank stations to include only the mill race portion of the Fish Brook for easier calculation of scour.
4. Assigning individual Mannings “n” to the internal bridge cross-sections at the mill race and double culvert.
5. Added Section Station 12795 to accurately model the stone rubble mill race “weir” in the upstream bank of the Fish Brook (where the flow splits).

The current conditions model results are similar to the FIS model.

Proposed Model

The LRFD Bridge Manual 1.3.2 (8 and 9) and current state wetland protection regulations require compliance with the Massachusetts Stream Crossing Standards to the maximum extent practicable (310 CMR 10.24 Section 10(a)). The standards specify that replacement stream crossings should ideally be designed to span the banks of the waterway (approximately the 1-year flood elevation) to provide a more “open” cross-section. This reduces the conditions that contribute to the bridge being a barrier to wildlife passage during normal river stage. These factors support the need for a longer span and increased waterway opening.

The open area under the proposed structure has been increased by increasing the span. The channel grade under the structure will be raised to provide a consistent channel slope that is similar to the downstream channel grade. Because of this, the flood elevation was evaluated downstream to ensure that the base flood elevation (Station 12515) remains unchanged. This is a result of downstream backwater effects. As such, the proposed changes result in no increase in base flood elevations (no-rise) either upstream or downstream. The results are shown in Table 2.

Table 3 – Summary of Hydraulic Performance (Station 12645/12650)

Structure	Return Frequency (Years)	Discharge (ft^3/s)	U/S Stage (ft, NAVD)	Channel Vel. (ft/s)*
Existing	10	400	55.2	4.0
	50	630	56.8	5.1
	100	750	57.3	5.5
	500	970	57.8	4.2
Proposed	10	400	54.6	3.9
	50	630	55.8	4.9
	100	750	56.3	5.6
	500	970	57.8	4.8

* velocity inside the structure

4.3 Scour/Stability Analysis

Scour potential at the crossing site under existing conditions was analyzed using the guidelines set forth in Reference 3, and AASHTO LRFD Bridge Design Specifications, Subsections 2.6.4.4.2 and 3.7.5. In accordance with Subsection 1.3.4 of Reference 3, the brook's 25-year and 50-year floods are the scour design and scour check events, respectively. Due to the availability of data, the 50-year and 100-year floods will be used as the scour and check events, respectively. There is currently no existing scour protection. The east abutment has collapsed due to scour at the abutment toe.

Our general analytical approach was to estimate long term streambed elevation changes, compute flood related contraction (conveyance reduction) and local (vortex induced) abutment scour depths, then sum the three scour components to yield estimates of total 50- and 100-year flood related abutment scour.

In both the scour design and scour check event analyses, we assumed that the brook's channel bed elevation profile at the project location would not measurably degrade over the replacement bridge's service life. A summary of computed 50- and 100-year flood scour depths under existing conditions is presented in Table 4.

Table 4. Summary of Calculated Scour

Alternative	Return Period (Yrs)	Flow (Ft^3/S)	Long Term Degradation (Feet)	Contraction Scour (Feet)	Local Abut. Scour (Feet)	Total Abut. Scour (Feet)
Proposed Bridge	50	630	0.0	0.0	3.4	3.4
	100	750	0.0	0.4	4.1	4.6**

** Total is different due to rounding

5.0 Conclusions and Recommendations

5.1 Conclusions

1. The hydraulic model shows the existing waterway opening is not hydraulically adequate to pass the design storm with 2 feet of freeboard (existing low chord = 55.72; FIS 10-year flood = 54.34).

2. Because of adjacent grading issues, the proposed bridge will have a lower chord that the existing bridge and it is not possible to provide 2 feet of freeboard, as required in LRFD Bridge Manual Section 1.3.2 (7). Proposed conditions 10 year flood = 54.63 and the proposed lower chord elevation = 54.68.

3. The analysis indicates that project activities will have no adverse impact on the Fish Brook's existing 100-year regulatory flood regime (no-rise). The "No-Rise" review has been performed in accordance with the guidelines in the LRFD Bridge Manual 1.3.5.

4. The proposed structure was selected for conformance with LRFD Bridge Manual 1.3.2 (8 and 9) – 2011 Massachusetts Stream Crossing Standards; MassDOT Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams; and FHWA Hydraulic Engineering Circular Number 26, "Culvert Design for Aquatic Organism Passage".

5.2 Recommendations

1. The proposed bridge will include the removal of the existing concrete deck beams and stone masonry abutments and installation of new cast-in-place abutments, precast deck beams and a cast-in-place deck. The resulting velocity under the bridge will be comparable to existing conditions.

2. The total scour depths computed for the scour design and scour check events under proposed conditions will be employed when designing the bridge substructure as required for the foundation bearing capacity and structural stability verification computations specified within Section 3.2.9.2, 3.2.9.3 and 3.2.9.4 of the 2013 MassDOT Bridge LFRD Manual.

4. The following information in will be included in the General Notes of the Bridge Plans:

Hydraulic Design Data

Drainage Area	14.1 Square Miles
Design Flood Discharge	400 Cubic Feet Per Second
Design Flood Frequency	10 Years
Design Flood Velocity	3.9 Feet Per Second
Design Flood Elevation	54.63 Feet, NAVD

Base (100-Year) Flood Data

Base Flood Discharge	970 Cubic Feet Per Second
Base Flood Elevation	56.32 Feet, NAVD

Design and Check Scour Data

Design Scour Flood Event Return Frequency	50 Years
Check Scour Flood Event Return Frequency	100 Years

Flood Of Record

Discharge	Unknown
Frequency	Unknown
Maximum Elevation	Unknown
Date	Unknown

Evidence of scour and erosion: Existing easterly abutment has collapsed due to scour at the abutment toe.

APPENDICIES

FIGURES & SUPPORTING MODEL CALCULATIONS

HEC-RAS Plan: NAVD Locations: User Defined

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Crit W.S.	Frctn Loss	C & E Loss	Top Width	Q Left	Q Channel	Q Right	Vel Chnl
				(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft/s)
Fish Brook	Boxford	12705	10 Year	55.41	55.19	53.84	0.12	0.06	150.17	9.73	234.37	155.90	4.86
Fish Brook	Boxford	12705	50 Year	56.92	56.80	54.46	0.05	0.04	299.96	42.88	297.61	289.51	4.11
Fish Brook	Boxford	12705	100 Year	57.37	57.25	54.75	0.05	0.03	343.68	57.49	329.01	363.50	4.16
Fish Brook	Boxford	12645	10 Year	55.22	55.21	52.37	0.00	0.10	372.88		400.00		0.76
Fish Brook	Boxford	12645	50 Year	56.84	56.83	52.76	0.00	0.16	385.60	8.12	621.88		0.56
Fish Brook	Boxford	12645	100 Year	57.29	57.28	52.93	0.00	0.19	392.50	8.66	741.34	0.00	0.58
Fish Brook	Boxford	12644 BR U	10 Year	55.12	54.87	52.80	0.49	0.31	22.85		400.00		4.01
Fish Brook	Boxford	12644 BR U	50 Year	56.68	56.27	53.49	0.86	0.40	8.31		630.00		5.11
Fish Brook	Boxford	12644 BR U	100 Year	57.10	56.63	53.81	0.97	0.42	7.91		696.28		5.51
Fish Brook	Boxford	12644 BR D	10 Year	54.32	53.30	53.30	0.08	0.51	24.09		400.00		8.11
Fish Brook	Boxford	12644 BR D	50 Year	55.42	54.01	54.01	0.08	0.75	23.40		630.00		9.53
Fish Brook	Boxford	12644 BR D	100 Year	55.71	54.19	54.34	0.08	0.82	23.22		696.28		9.88
Fish Brook	Boxford	12615	10 Year	53.15	52.98	52.62	0.57	0.05	159.92		400.00		3.37
Fish Brook	Boxford	12615	50 Year	53.63	53.47	52.98	0.40	0.06	218.00		630.00		3.17
Fish Brook	Boxford	12615	100 Year	53.85	53.70	53.12	0.34	0.05	245.51		750.00		3.07
Fish Brook	Boxford	12515	10 Year	52.53	52.45	51.55	1.56	0.01	303.68	15.28	168.99	215.73	3.49
Fish Brook	Boxford	12515	50 Year	53.18	53.11	52.00	1.23	0.00	363.57	20.60	193.35	416.05	3.39
Fish Brook	Boxford	12515	100 Year	53.46	53.40	52.15	1.14	0.00	366.35	22.97	202.33	524.70	3.33

HEC-RAS Plan: Current Locations: User Defined

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Crit W.S.	Frctn Loss	C & E Loss	Top Width	Q Left	Q Channel	Q Right	Vel Chnl
				(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft/s)
Fish Brook	Boxford	12705	10 Year	55.16	55.08	54.49	0.09	0.00	121.10	1.84	355.34	42.81	2.52
Fish Brook	Boxford	12705	50 Year	56.16	56.05	54.63	0.10	0.01	194.39	8.16	533.30	88.54	2.91
Fish Brook	Boxford	12705	100 Year	57.56	57.49	54.63	0.03	0.01	306.55	15.18	561.06	173.76	2.28
Fish Brook	Boxford	12645	10 Year	55.07	54.93	53.74	0.00	0.03	150.96	2.68	261.86	135.46	3.47
Fish Brook	Boxford	12645	50 Year	56.05	55.84	54.63	0.00	0.07	220.84	8.07	388.66	233.27	4.42
Fish Brook	Boxford	12645	100 Year	57.52	57.49	54.63			365.08	13.02	222.38	514.59	2.01
Fish Brook	Boxford	12644 BR U	10 Year	55.04	54.83	54.53	0.13	0.02	22.94	0.00	239.29	160.71	3.39
Fish Brook	Boxford	12644 BR U	50 Year	55.98	55.59	54.63	0.22	0.05	22.07	0.00	372.09	257.91	4.62
Fish Brook	Boxford	12644 BR U	100 Year	57.52	57.49	54.63			113.86	22.39	321.86	405.70	3.57
Fish Brook	Boxford	12644 BR D	10 Year	54.89	54.63	54.63	0.02	0.07	23.16		242.17	157.83	3.72
Fish Brook	Boxford	12644 BR D	50 Year	55.71	55.21	54.63	0.04	0.26	22.51		374.58	255.42	5.16
Fish Brook	Boxford	12644 BR D	100 Year	57.52	57.36	57.01			145.03	22.39	321.56	406.00	3.75
Fish Brook	Boxford	12615	10 Year	54.77	54.34	53.64	1.44	0.20	56.04		0.48	399.52	5.95
Fish Brook	Boxford	12615	50 Year	55.42	54.27	54.27			55.57		0.77	629.23	9.71
Fish Brook	Boxford	12615	100 Year	55.28	54.63	54.63	0.33	0.35	59.39		540.33	209.67	7.45
Fish Brook	Boxford	12515	10 Year	53.13	53.03	52.56	2.20	0.01	362.05	42.23	146.38	211.39	3.96
Fish Brook	Boxford	12515	50 Year	53.61	53.54	52.95	1.68	0.00	383.71	62.65	161.92	405.43	3.77
Fish Brook	Boxford	12515	100 Year	53.85	53.79	53.04	1.55	0.00	393.50	74.01	171.98	504.02	3.74

HEC-RAS Plan: Prop-NAVD Locations: User Defined

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Crit W.S.	Frctn Loss	C & E Loss	Top Width	Q Left	Q Channel	Q Right	Vel Chnl
				(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft/s)
Fish Brook	Boxford	12705	10 Year	55.00	54.90	54.49	0.14	0.01	106.94	1.52	354.65	43.83	2.66
Fish Brook	Boxford	12705	50 Year	56.24	56.13	54.63	0.11	0.02	200.25	8.55	529.94	91.51	2.84
Fish Brook	Boxford	12705	100 Year	56.81	56.71	54.63	0.10	0.03	243.99	12.85	602.08	135.07	2.84
Fish Brook	Boxford	12650	10 Year	54.85	54.63	53.74			151.35		324.75	75.25	4.16
Fish Brook	Boxford	12650	50 Year	56.10	55.79	54.63	0.03	0.02	218.21		501.58	128.42	5.01
Fish Brook	Boxford	12650	100 Year	56.68	56.32	54.63	0.03	0.04	246.51		593.26	156.74	5.38
Fish Brook	Boxford	12644 BR U	10 Year	54.83	54.63	54.53			29.16		301.59	98.41	3.86
Fish Brook	Boxford	12644 BR U	50 Year	56.06	55.68	54.63	0.29	0.02	8.99		386.55	243.45	4.85
Fish Brook	Boxford	12644 BR U	100 Year	56.61	56.10	54.63	0.38	0.03	8.51		444.61	305.39	5.58
Fish Brook	Boxford	12644 BR D	10 Year	54.82	54.63	54.63			29.16		289.49	110.51	3.61
Fish Brook	Boxford	12644 BR D	50 Year	55.75	55.31	54.63	0.12	0.21	9.40		372.34	257.67	4.56
Fish Brook	Boxford	12644 BR D	100 Year	56.20	55.60	54.63	0.15	0.21	9.07		429.15	320.85	5.25
Fish Brook	Boxford	12610	10 Year	54.77	54.32	53.65	1.47	0.17	65.70			400.00	
Fish Brook	Boxford	12610	50 Year	55.42	54.27	54.27			65.29			630.00	
Fish Brook	Boxford	12610	100 Year	55.84	54.55	54.55			68.69			750.00	
Fish Brook	Boxford	12515	10 Year	53.13	53.03	52.56	2.20	0.01	362.05	42.23	146.38	211.39	3.96
Fish Brook	Boxford	12515	50 Year	53.61	53.54	52.95	1.68	0.00	383.71	62.65	161.92	405.43	3.77
Fish Brook	Boxford	12515	100 Year	53.85	53.79	53.04	1.55	0.00	393.50	74.01	171.98	504.02	3.74

Contraction Scour

		Left	Channel	Right
Input Data				
	Average Depth (ft):	1.59	4.31	1.39
	Approach Velocity (ft/s):	0.47	2.84	0.45
	Br Average Depth (ft):		4.22	5.36
	BR Opening Flow (cfs):		386.55	243.45
	BR Top WD (ft):		19.7	8.99
	Grain Size D50 (mm):	0.54	8.70	0.88
	Approach Flow (cfs):	8.55	529.94	91.51
	Approach Top WD (ft):	11.55	43.34	145.36
	K1 Coefficient:	0.690	0.640	0.690
Results				
	Scour Depth Ys (ft):		0.00	5.14
	Critical Velocity (ft/s):		4.36	1.68
	Equation:		Clear	Clear

Abutment Scour

		Left	Right
Input Data			
	Station at Toe (ft):	668.00	687.00
	Toe Sta at appr (ft):	680.17	1045.91
	Abutment Length (ft):	11.65	0.00
	Depth at Toe (ft):	5.09	4.80
	K1 Shape Coef:	1.00 - Vertical abutment	
	Degree of Skew (degrees):	90.00	90.00
	K2 Skew Coef:	1.00	1.00
	Projected Length L' (ft):	11.65	0.00
	Avg Depth Obstructed Ya (ft):	1.61	
	Flow Obstructed Qe (cfs):	9.92	
	Area Obstructed Ae (sq ft):	18.78	
Results			
	Scour Depth Ys (ft):	3.35	
	Qe/Ae = Ve:	0.53	
	Froude #:	0.07	
	Equation:	Froehlich	Default

Combined Scour Depths

Left abutment scour + contraction scour (ft):	3.35

Contraction Scour

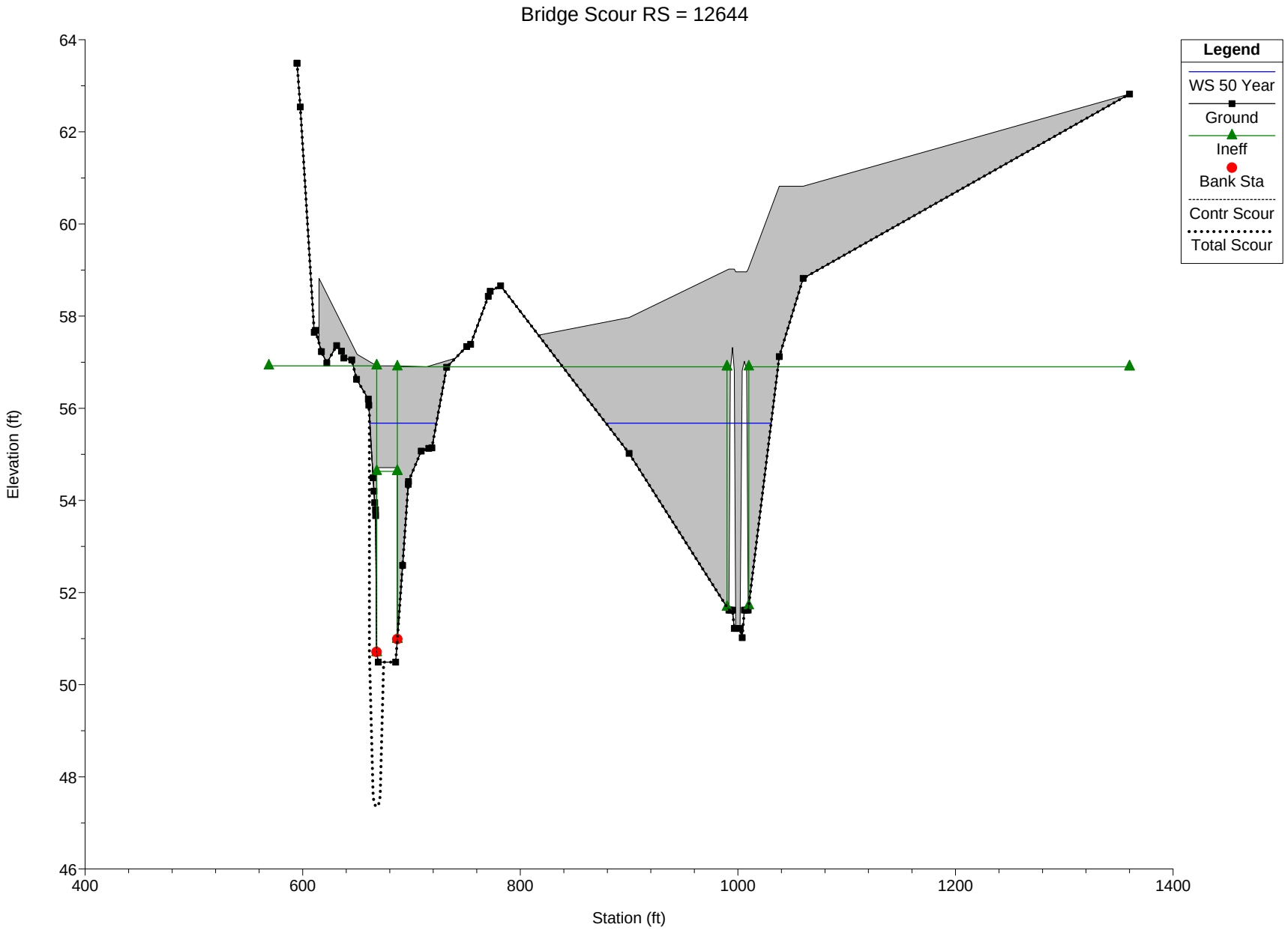
		Left	Channel	Right
Input Data				
	Average Depth (ft):	2.14	4.88	1.58
	Approach Velocity (ft/s):	0.51	2.84	0.45
	Br Average Depth (ft):		4.22	6.10
	BR Opening Flow (cfs):		444.61	305.39
	BR Top WD (ft):		19.70	8.51
	Grain Size D50 (mm):	0.54	8.70	0.88
	Approach Flow (cfs):	12.85	602.08	135.07
	Approach Top WD (ft):	11.71	43.34	188.94
	K1 Coefficient:	0.640	0.590	0.640
Results				
	Scour Depth Ys (ft):		0.44	7.27
	Critical Velocity (ft/s):		4.45	1.72
	Equation:		Clear	Clear

Abutment Scour

		Left	Right
Input Data			
	Station at Toe (ft):	668.00	687
	Toe Sta at appr (ft):	680.17	1045.91
	Abutment Length (ft):	11.81	0.01
	Depth at Toe (ft):	5.62	5.33
	K1 Shape Coef:	1.00 - Vertical abutment	
	Degree of Skew (degrees):	90.00	90.00
	K2 Skew Coef:	1.00	1.00
	Projected Length L' (ft):	11.81	0.01
	Avg Depth Obstructed Ya (ft):	2.16	0.16
	Flow Obstructed Qe (cfs):	14.39	0.00
	Area Obstructed Ae (sq ft):	25.56	0.00
Results			
	Scour Depth Ys (ft):	4.13	
	Qe/Ae = Ve:	0.56	
	Froude #:	0.07	
	Equation:	Froehlich	Default

Combined Scour Depths

	Left abutment scour + contraction scour (ft):	4.57


Bridge Scour RS = 12644
Legend
WS 50 Year
Ground
Ineff
Bank Sta
Contr Scour
Total Scour
Elevation (ft)
Station (ft)
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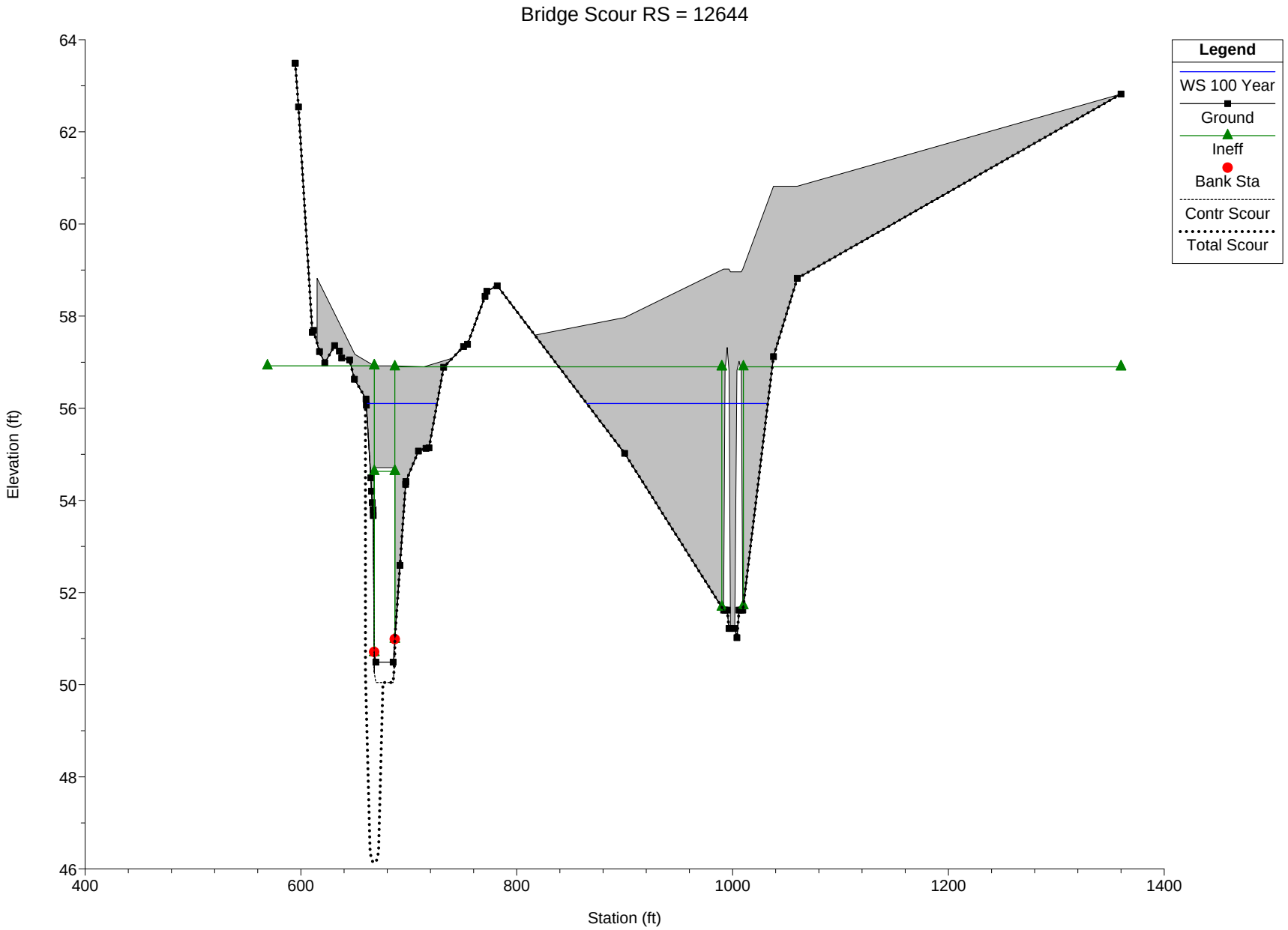
52
50
48
46
400
600
800
1000
1200
1400


Bridge Scour RS = 12644
Legend
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Ground
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Bank Sta
Contr Scour
Total Scour
Elevation (ft)
Station (ft)
64
62
60
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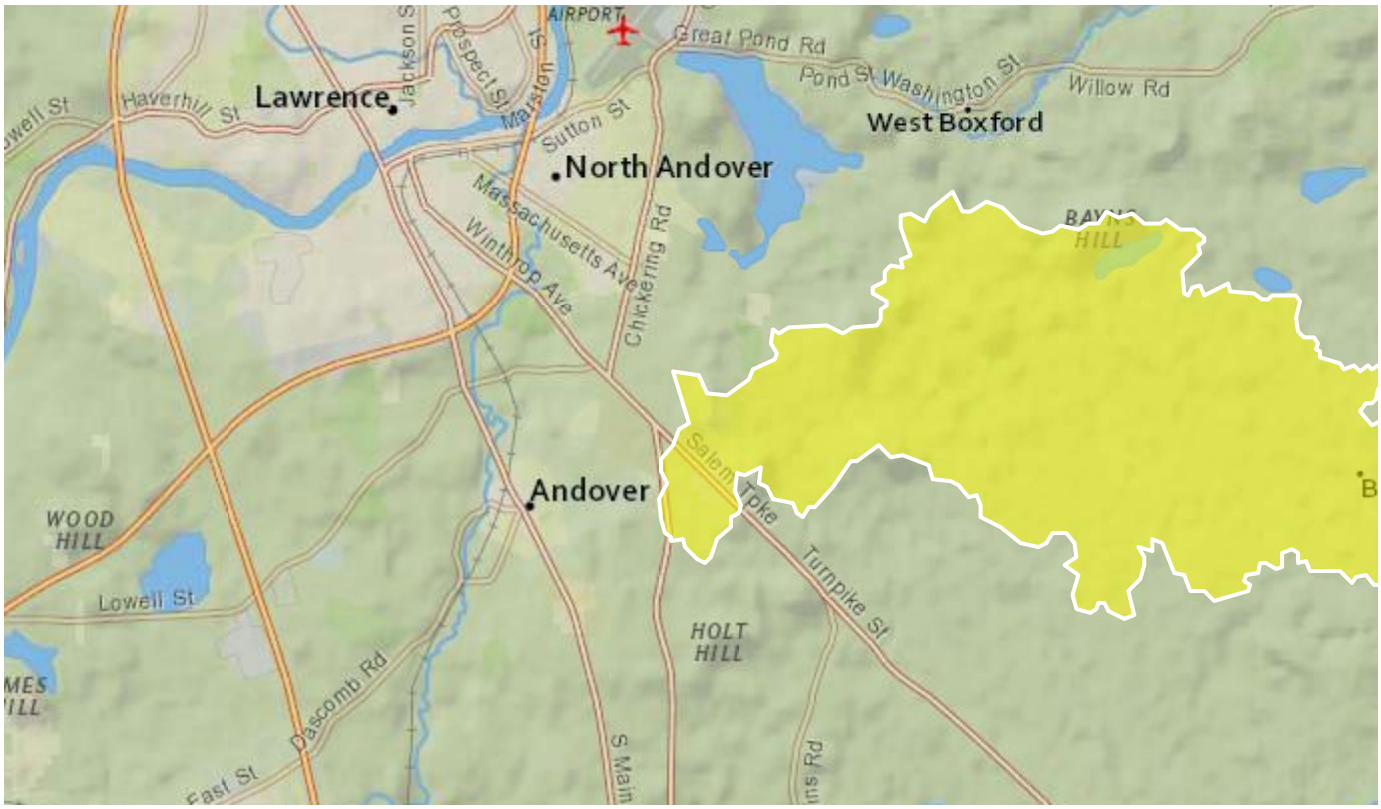
400
600
800
1000
1200
1400

StreamStats Report

Region ID: MA
Workspace ID: MA20181226143734581000
Clicked Point (Latitude, Longitude): 42.64498, -70.98897
Time: 2018-12-26 09:37:50 -0500



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	14.1	square miles
ELEV	Mean Basin Elevation	150	feet
LC06STOR	Percentage of water bodies and wetlands determined from the NLCD 2006	21.74	percent
DRFTPERSTR	Area of stratified drift per unit of stream length	0.0933	square mile per mile
MAREGION	Region of Massachusetts 0 for Eastern 1 for Western	0	dimensionless

Parameter Code	Parameter Description	Value	Unit
BSLDEM250	Mean basin slope computed from 1:250K DEM	1.691	percent
BSLDEM10M	Mean basin slope computed from 10 m DEM	5.475	percent
PCTSNDGRV	Percentage of land surface underlain by sand and gravel deposits	21.69	percent
FOREST	Percentage of area covered by forest	66.63	percent
ACRSDFT	Area underlain by stratified drift	3.07	square miles
CENTROIDX	Basin centroid horizontal (x) location in state plane coordinates	237263.7	feet
CENTROIDY	Basin centroid vertical (y) location in state plane units	935472.2	feet
CRSDFT	Percentage of area of coarse-grained stratified drift	21.69	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	22.4	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	6.9	percent
WETLAND	Percentage of Wetlands	20.49	percent

Peak-Flow Statistics Parameters [Peak Statewide 2016 5156]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	14.1	square miles	0.16	512
ELEV	Mean Basin Elevation	150	feet	80.6	1948
LC06STOR	Percent Storage from NLCD2006	21.74	percent	0	32.3

Peak-Flow Statistics Flow Report [Peak Statewide 2016 5156]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	SEp
2 Year Peak Flood	214	ft^3/s	110	417	42.3

Statistic	Value	Unit	PIl	Plu	SEp
5 Year Peak Flood	347	ft^3/s	176	685	43.4
10 Year Peak Flood	451	ft^3/s	223	910	44.7
25 Year Peak Flood	598	ft^3/s	286	1250	47.1
50 Year Peak Flood	718	ft^3/s	333	1550	49.4
100 Year Peak Flood	844	ft^3/s	380	1870	51.8
200 Year Peak Flood	979	ft^3/s	428	2240	54.1
500 Year Peak Flood	1170	ft^3/s	491	2790	57.6

Peak-Flow Statistics Citations

Zarriello, P.J.,2017, Magnitude of flood flows at selected annual exceedance probabilities for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2016–5156, 99 p. (https://dx.doi.org/10.3133/sir20165156)

Flow-Duration Statistics Parameters [Statewide Low Flow WRIR00 4135]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	14.1	square miles	1.61	149
DRFTPERSTR	Stratified Drift per Stream Length	0.0933	square mile per mile	0	1.29
MAREGION	Massachusetts Region	0	dimensionless	0	1
BSLDEM250	Mean Basin Slope from 250K DEM	1.691	percent	0.32	24.6

Flow-Duration Statistics Flow Report [Statewide Low Flow WRIR00 4135]

PIl: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	Plu	SE	SEp
50 Percent Duration	14.2	ft^3/s	8.43	23.8	17.6	17.6
60 Percent Duration	10	ft^3/s	6.04	16.6	19.8	19.8
70 Percent Duration	5.73	ft^3/s	2.7	12.1	23.5	23.5
75 Percent Duration	4.36	ft^3/s	2.04	9.2	25.8	25.8
80 Percent Duration	2.97	ft^3/s	1.23	7.07	28.4	28.4

Statistic	Value	Unit	PIl	Plu	SE	SEp
85 Percent Duration	2.13	ft^3/s	0.831	5.38	31.9	31.9
90 Percent Duration	1.4	ft^3/s	0.521	3.67	36.6	36.6
95 Percent Duration	0.815	ft^3/s	0.273	2.35	45.6	45.6
98 Percent Duration	0.527	ft^3/s	0.154	1.71	60.3	60.3
99 Percent Duration	0.393	ft^3/s	0.107	1.36	65.1	65.1

Flow-Duration Statistics Citations

Ries, K.G., III,2000, Methods for estimating low-flow statistics for Massachusetts streams: U.S. Geological Survey Water Resources Investigations Report 00-4135, 81 p. (http://pubs.usgs.gov/wri/wri004135/)

Low-Flow Statistics Parameters [Statewide Low Flow WRIR00 4135]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	14.1	square miles	1.61	149
BSLDEM250	Mean Basin Slope from 250K DEM	1.691	percent	0.32	24.6
DRFTPERSTR	Stratified Drift per Stream Length	0.0933	square mile per mile	0	1.29
MAREGION	Massachusetts Region	0	dimensionless	0	1

Low-Flow Statistics Flow Report [Statewide Low Flow WRIR00 4135]

PIl: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	Plu	SE	SEp
7 Day 2 Year Low Flow	0.969	ft^3/s	0.314	2.88	49.5	49.5
7 Day 10 Year Low Flow	0.333	ft^3/s	0.0842	1.23	70.8	70.8

Low-Flow Statistics Citations

Ries, K.G., III,2000, Methods for estimating low-flow statistics for Massachusetts streams: U.S. Geological Survey Water Resources Investigations Report 00-4135, 81 p. (http://pubs.usgs.gov/wri/wri004135/)

August Flow-Duration Statistics Parameters [Statewide Low Flow WRIR00 4135]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	14.1	square miles	1.61	149
BSLDEM250	Mean Basin Slope from 250K DEM	1.691	percent	0.32	24.6
DRFTPERSTR	Stratified Drift per Stream Length	0.0933	square mile per mile	0	1.29
MAREGION	Massachusetts Region	0	dimensionless	0	1

August Flow-Duration Statistics Flow Report [Statewide Low Flow WRIR00 4135]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	SE	SEp
August 50 Percent Duration	2.35	ft^3/s	0.912	5.93	33.2	33.2

August Flow-Duration Statistics Citations

Ries, K.G., III,2000, Methods for estimating low-flow statistics for Massachusetts streams: U.S. Geological Survey Water Resources Investigations Report 00-4135, 81 p. (http://pubs.usgs.gov/wri/wri004135/)

Bankfull Statistics Parameters [Bankfull Statewide SIR2013 5155]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	14.1	square miles	0.6	329
BSLDEM10M	Mean Basin Slope from 10m DEM	5.475	percent	2.2	23.9

Bankfull Statistics Flow Report [Bankfull Statewide SIR2013 5155]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
Bankfull Width	40.7	ft	21.3
Bankfull Depth	1.97	ft	19.8

Statistic	Value	Unit	SEp
Bankfull Area	79.5	ft^2	29
Bankfull Streamflow	223	ft^3/s	55

Bankfull Statistics Citations

Bent, G.C., and Waite, A.M.,2013, Equations for estimating bankfull channel geometry and discharge for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2013–5155, 62 p., (http://pubs.usgs.gov/sir/2013/5155/)

Probability Statistics Parameters [Perennial Flow Probability]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	14.1	square miles	0.01	1.99
PCTSNDGRV	Percent Underlain By Sand And Gravel	21.69	percent	0	100
FOREST	Percent Forest	66.63	percent	0	100
MAREGION	Massachusetts Region	0	dimensionless	0	1

Probability Statistics Disclaimers [Perennial Flow Probability]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Probability Statistics Flow Report [Perennial Flow Probability]

Statistic	Value	Unit
Probability Stream Flowing Perennially	0.984	dim

Probability Statistics Citations

Bent, G.C., and Steeves, P.A.,2006, A revised logistic regression equation and an automated procedure for mapping the probability of a stream flowing perennially in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2006–5031, 107 p. (http://pubs.usgs.gov/sir/2006/5031/pdfs/SIR_2006-5031rev.pdf)

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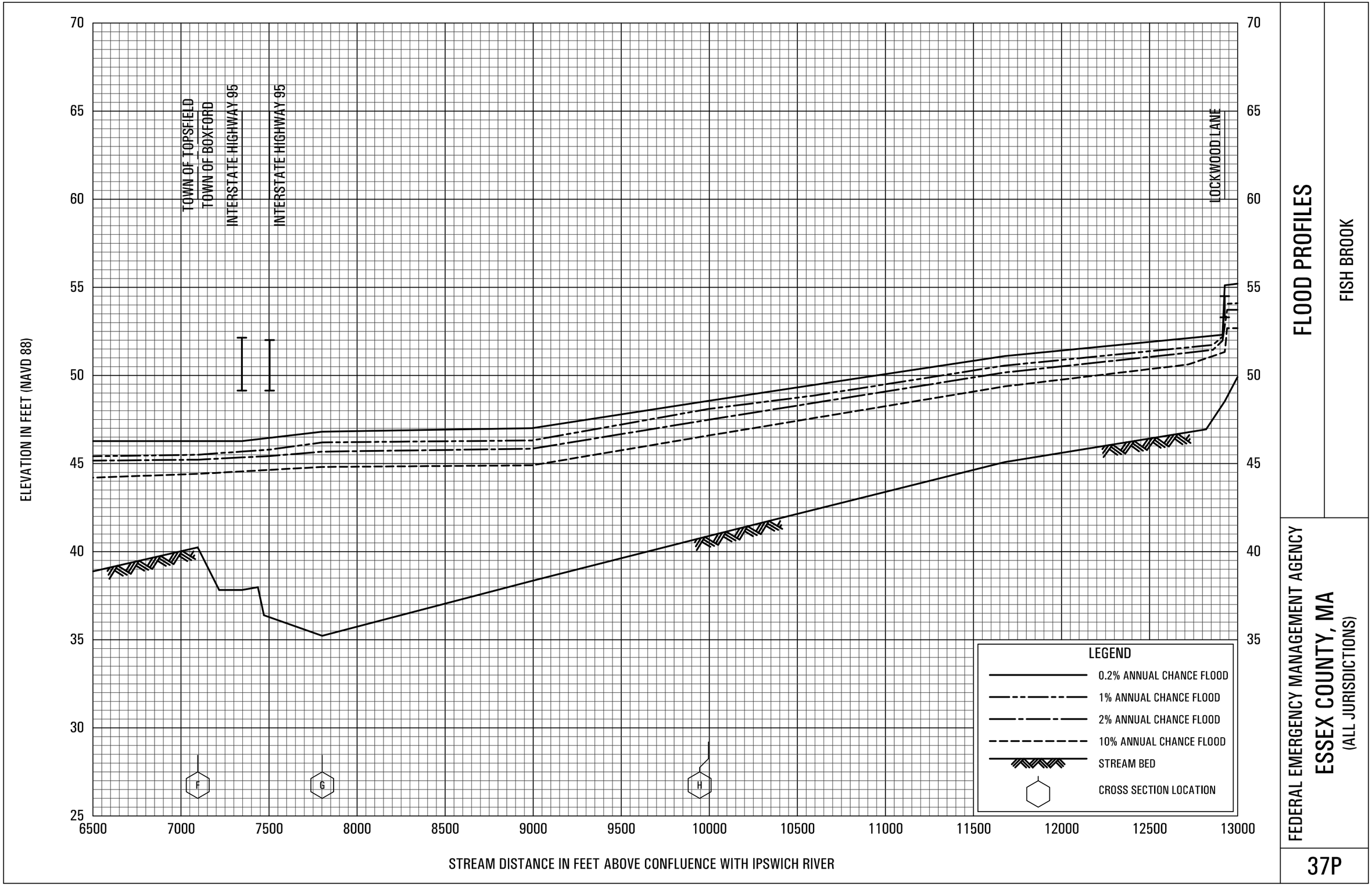
Application Version: 4.3.0



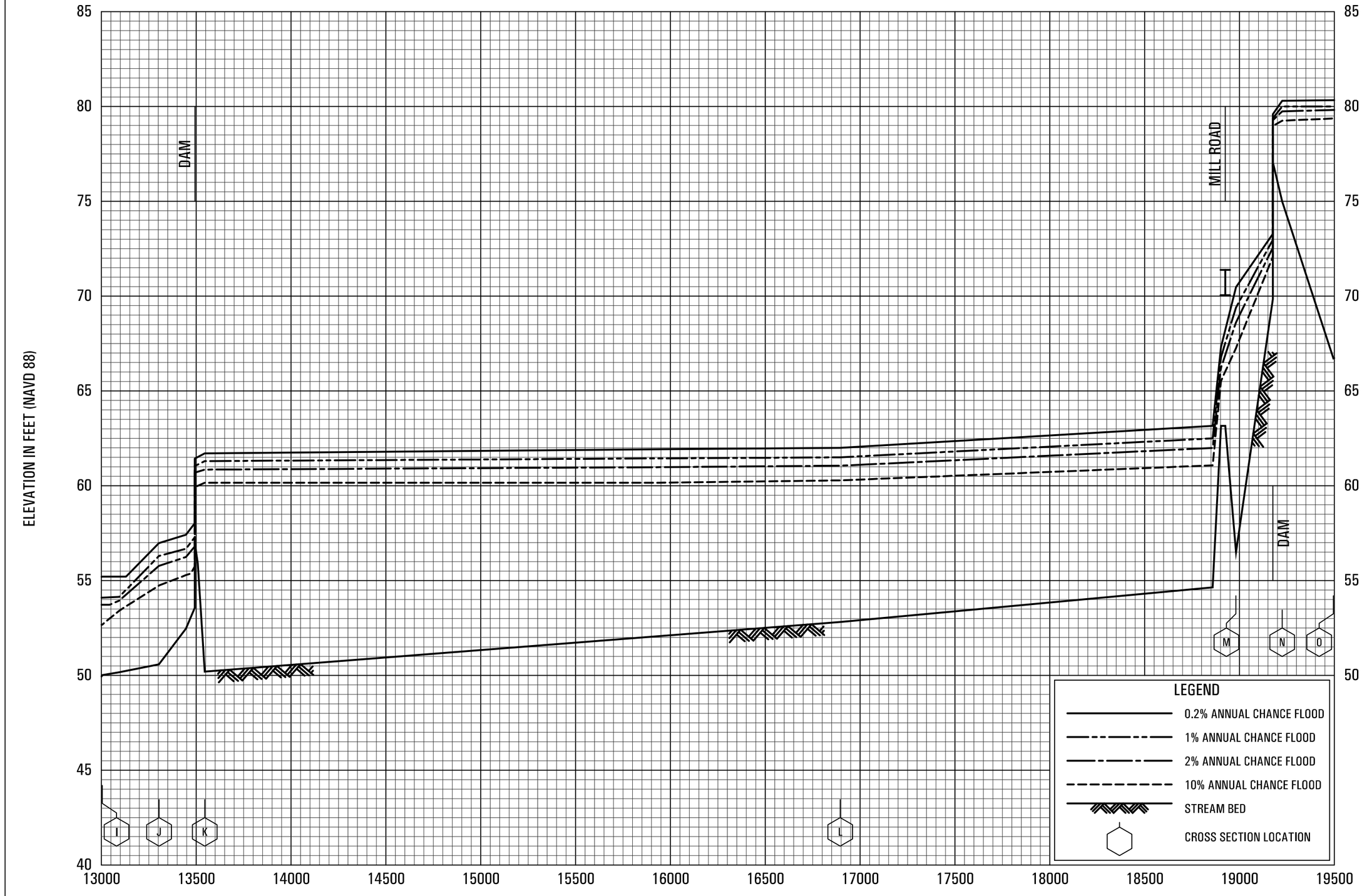
FLOOD PROFILES

FISH BROOK

FEDERAL EMERGENCY MANAGEMENT AGENCY

ESSEX COUNTY, MA

(ALL JURISDICTIONS)



FLOOD PROFILES

FISH BROOK

FEDERAL EMERGENCY MANAGEMENT AGENCY

ESSEX COUNTY, MA

(ALL JURISDICTIONS)

38P

Fish Brook

THIS RUN EXECUTED 1-JUN-89 15:56:30

```
**********************************************
  HEC2 RELEASE DATED NOV 76 UPDATED MARCH 1982
  ERROR CORR =  01,02,03,04,05
  MODIFICATION =  50,51,52,53,54,55
**********************************************

C
T1 FEMA FIS
T2  FISH BROOK AT BOXFORD MASS
T3 MULTIPLE PROFILE RUN - 10 YR FLOOD

J1  ICHECK    INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         USEL      FQ
      0.        2.        0.        0.  0.000000      0.00      0.0       0.      45.040    0.000
J2  NPROF     IPLOT     PRFVS     XSECV     XSECH     FN        ALLOC     IBW       CHNIM     ITRACE
     1.000     0.000    -1.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
J3  VARIABLE CODES FOR SUMMARY PRINTOUT
    38.000    39.000    40.000    41.000    42.000    43.000     1.000     2.000     3.000    34.000

    21.000    22.000    26.000     0.000    38.000     1.000    50.000    61.000    51.000    53.000

    27.000     4.000    28.000    54.000    13.000    14.000    15.000     0.000     0.000     0.000

QT      4.000   450.000   700.000   830.000  1065.000     0.000     0.000     0.000     0.000     0.000
NC      0.060     0.060     0.035     0.100     0.300     0.000     0.000     0.000     0.000     0.000
X1   -311.000    18.000  1594.000  1606.000     0.000     0.000     0.000     0.000     0.000     0.000
GR     61.800   400.000    57.800   450.000    53.800   550.000    51.800   750.000    49.800   850.000
GR     45.800   960.000    45.100  1200.000    44.300  1544.000    43.900  1594.000    41.700  1595.000
GR     41.300  1600.000    41.700  1605.000    43.900  1606.000    44.300  1656.000    45.800  1680.000
GR     49.800  2000.000    53.800  2020.000    57.800  2070.000     0.000     0.000     0.000     0.000

          CROSS SECTION A
X1      0.000    11.000   990.000  1005.000   311.000   311.000   311.000     0.000     0.000     0.000
GR     50.000   530.000    46.000   570.000    42.000   980.000    40.000   990.000    38.500   995.000
GR     38.000  1000.000    38.500  1005.000    42.000  1020.000    46.000  1100.000    54.000  1150.000
GR     57.000  1200.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000

NC      0.028     0.028     0.028     0.300     0.500     0.000     0.000     0.000     0.000     0.000
X1    227.000     5.000   990.000  1019.000   227.000   227.000   227.000     0.000     0.000     0.000
X3     10.000     0.000     0.000     0.000     0.000     0.000     0.000    50.000    50.000     0.000
GR     51.230   990.000    40.000   990.100    38.700  1000.000    40.000  1019.000    50.980  1019.010
```

NC	0.060	0.060	0.040	0.300	0.500	0.000	0.000	0.000	0.000	0.000
X1	298.000	0.000	0.000	0.000	71.000	71.000	71.000	0.000	0.000	0.000
BT	-11.000	834.000	54.840	54.600	900.000	54.490	53.000	956.000	54.190	51.450
BT	0.000	989.990	53.900	41.830	990.000	53.900	50.600	1000.000	53.900	49.940
BT	0.000	1019.000	53.900	50.100	1019.010	53.900	41.750	1040.000	53.540	45.700
BT	0.000	1089.000	53.140	46.420	1150.000	52.890	52.890	0.000	0.000	0.000
	INTERSTATE HIGHWAY 95									
X1	369.000	0.000	0.000	0.000	71.000	71.000	71.000	0.000	0.000	0.000
X2	0.000	0.000	1.000	49.940	52.890	0.000	0.000	0.000	0.000	0.000
NC	0.080	0.080	0.000	0.100	0.300	0.000	0.000	0.000	0.000	0.000
X1	440.000	14.000	990.000	1019.000	71.000	71.000	71.000	0.000	0.000	0.000
X3	10.000	0.000	0.000	0.000	0.000	0.000	0.000	52.890	52.890	0.000
GR	54.600	834.000	53.800	878.000	53.000	900.000	51.450	956.000	47.450	978.000
GR	41.830	989.990	41.830	990.000	38.850	1000.000	41.750	1019.000	41.750	1019.010
GR	43.350	1027.000	45.700	1040.000	46.400	1089.000	52.890	1150.000	0.000	0.000
X1	480.000	16.000	987.000	1009.000	40.000	40.000	40.000	0.000	0.000	0.000
GR	54.700	834.000	53.900	878.000	53.250	916.000	51.550	956.000	47.550	978.000
GR	43.550	986.000	40.200	987.000	38.150	997.000	37.250	1000.000	41.850	1009.000
GR	42.850	1018.000	43.450	1027.000	45.800	1040.000	46.750	1055.000	46.500	1089.000
GR	53.500	1150.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NC	0.000	0.000	0.000	0.100	0.300	0.000	0.000	0.000	0.000	0.000
	CROSS SECTION B									
X1	807.000	16.000	987.000	1012.000	525.000	327.000	327.000	0.000	0.000	0.000
GR	50.000	700.000	48.150	830.000	46.220	878.000	44.170	911.000	43.270	957.000
GR	38.730	987.000	36.600	993.000	36.100	1000.000	36.600	1006.000	38.900	1012.000
GR	42.170	1022.000	44.150	1032.000	45.220	1044.000	46.770	1057.000	47.130	1092.000
GR	50.000	1350.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X1	2000.000	11.000	992.000	1007.000	800.000	1300.000	1193.000	0.000	0.000	0.000
GR	54.000	700.000	50.000	760.000	48.000	850.000	46.000	980.000	40.300	992.000
GR	39.200	1000.000	40.300	1007.000	46.000	1020.000	48.000	1300.000	50.000	1400.000
GR	54.000	1430.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
QT	4.000	430.000	680.000	810.000	1050.000	0.000	0.000	0.000	0.000	0.000
	CROSS SECTION C									
X1	3000.000	15.000	992.000	1007.000	800.000	1000.000	1000.000	0.000	0.000	0.000
GR	61.000	882.000	59.200	937.000	47.910	970.000	46.110	989.000	43.310	992.000
GR	42.600	996.000	42.060	1000.000	42.960	1004.000	43.300	1007.000	46.210	1010.000
GR	48.170	1039.000	48.700	1100.000	50.000	1300.000	54.000	1350.000	58.000	1380.000
X1	4600.000	10.000	993.000	1007.000	1600.000	1200.000	1600.000	0.000	0.000	0.000
GR	58.000	830.000	54.000	840.000	52.000	875.000	50.000	990.000	47.000	993.000
GR	45.760	1000.000	47.000	1007.000	48.000	1100.000	50.000	1140.000	54.000	1180.000

QT	4.000	400.000	630.000	750.000	970.000	0.000	0.000	0.000	0.000	0.000
X1	5820.000	14.000	669.000	682.000	1220.000	1220.000	1220.000	0.000	0.000	0.000
GR	66.000	576.000	62.000	616.000	54.000	656.000	47.900	669.000	47.770	676.000
GR	48.210	682.000	50.000	709.000	52.000	986.000	50.600	988.000	49.300	1000.000
GR	51.300	1013.000	52.000	1021.000	54.000	1036.000	58.000	1076.000	0.000	0.000
NC	0.000	0.000	0.000	0.400	0.600	0.000	0.000	0.000	0.000	0.000
X1	5920.000	14.000	677.000	1036.000	100.000	100.000	100.000	0.000	0.000	0.000
X3	10.000	0.000	0.000	0.000	0.000	0.000	0.000	53.900	53.900	0.000
GR	58.500	484.000	57.170	534.000	56.350	609.000	49.750	677.000	49.270	684.000
GR	49.750	690.000	51.420	717.000	54.200	987.000	52.100	988.000	50.800	1000.000
GR	52.800	1013.000	53.500	1021.000	55.500	1036.000	59.130	1099.000	0.000	0.000
SB	1.050	1.560	3.500	0.000	342.000	312.000	130.000	0.000	50.400	50.000
NC	0.150	0.150	0.060	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	LOCKWOOD LANE									
X1	5950.000	22.000	668.000	1038.000	30.000	30.000	30.000	0.000	0.000	0.000
X2	0.000	0.000	1.000	54.900	56.100	0.000	0.000	0.000	0.000	0.000
X3	10.000	0.000	0.000	0.000	0.000	0.000	0.000	56.100	56.100	0.000
BT	-22.000	615.000	58.000	58.000	650.000	56.350	56.350	668.000	56.100	49.600
BT	0.000	668.010	56.100	54.900	681.000	56.100	54.900	681.010	56.100	49.600
BT	0.000	714.000	56.080	53.050	800.000	56.690	54.200	900.000	57.150	54.200
BT	0.000	991.700	58.200	50.800	993.000	58.200	56.000	995.000	58.200	56.500
BT	0.000	996.700	58.200	56.000	998.000	58.140	50.400	1002.000	58.140	50.400
BT	0.000	1004.000	58.140	56.000	1006.000	58.140	56.200	1008.000	58.140	56.000
BT	0.000	1009.500	58.200	50.800	1038.000	60.000	56.300	1060.000	60.000	58.000
BT	0.000	1360.000	62.000	62.000	0.000	0.000	0.000	0.000	0.000	0.000
GR	58.000	615.000	56.350	650.000	49.600	668.000	49.600	668.010	49.600	681.000
GR	49.600	681.010	53.050	714.000	54.200	800.000	54.200	900.000	50.800	991.700
GR	50.800	993.000	50.800	995.000	50.400	996.700	50.400	998.000	50.400	1002.000
GR	50.200	1004.000	50.800	1006.000	50.800	1008.000	50.800	1009.500	56.300	1038.000
GR	58.000	1060.000	62.000	1360.000	0.000	0.000	0.000	0.000	0.000	0.000
NC	0.000	0.000	0.040	0.100	0.300	0.000	0.000	0.000	0.000	0.000
	CROSS SECTION D									
X1	6010.000	19.000	677.000	692.000	60.000	60.000	60.000	0.000	0.000	0.000
GR	66.000	546.000	58.000	606.000	54.000	656.000	52.990	677.000	51.000	679.000
GR	50.890	686.000	51.330	692.000	51.330	711.000	53.050	719.000	57.250	781.000
GR	54.000	976.000	52.000	986.000	52.140	991.000	51.140	995.000	51.000	1000.000
GR	51.140	1005.000	52.200	1009.000	55.400	1021.000	58.000	1046.000	0.000	0.000
X1	6100.000	11.000	989.000	1009.000	40.000	125.000	90.000	0.000	0.000	0.000
GR	58.000	920.000	56.500	960.000	54.760	977.000	52.440	989.000	51.500	991.000
GR	51.000	1000.000	51.500	1007.000	52.140	1009.000	53.550	1015.000	55.580	1018.000
GR	58.000	1090.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	CROSS SECTION E									
X1	6309.000	14.000	985.000	1014.000	210.000	210.000	209.000	0.000	0.000	0.000
GR	68.900	894.000	67.700	929.000	66.210	959.000	59.500	975.000	54.600	985.000
GR	51.950	992.000	51.450	1000.000	51.950	1007.000	54.600	1014.000	56.900	1037.000
GR	58.310	1056.000	58.800	1085.000	60.300	1111.000	68.300	1150.000	0.000	0.000

X1	6447.000	10.000	985.000	1014.000	138.000	138.000	138.000	0.000	0.000	0.000
GR	70.000	900.000	68.000	941.000	61.000	951.000	57.300	963.000	53.300	985.000
GR	53.300	1000.000	55.200	1014.000	58.200	1037.000	60.800	1100.000	68.500	1150.000
NC	0.100	0.100	0.040	0.300	0.500	0.000	0.000	0.000	0.000	0.000
X1	6497.000	7.000	969.000	1032.000	50.000	50.000	50.000	0.000	0.000	0.000
X3	10.000	0.000	0.000	0.000	0.000	0.000	0.000	56.000	56.000	0.000
GR	69.910	949.000	63.010	959.000	54.500	969.000	54.400	1000.000	54.500	1032.000
GR	61.310	1042.000	69.110	1052.000	0.000	0.000	0.000	0.000	0.000	0.000
SB	0.000	1.560	2.600	0.000	63.000	0.000	0.100	0.000	58.710	54.400
NC	0.000	0.000	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	WEIR									
X1	6500.000	9.000	969.000	1032.000	3.000	3.000	3.000	0.000	0.000	0.000
X2	0.000	0.000	1.000	58.700	58.920	0.000	0.000	0.000	0.000	0.000
X3	10.000	0.000	0.000	0.000	0.000	0.000	0.000	58.700	58.700	0.000
BT	-6.000	949.000	69.910	69.910	959.000	63.000	63.000	969.000	58.400	58.400
BT	0.000	1000.000	58.710	58.700	1042.000	63.710	63.710	1100.000	69.200	69.200
GR	70.500	900.000	69.910	949.000	68.000	959.000	58.400	969.000	58.700	1000.000
GR	58.910	1032.000	63.710	1042.000	69.110	1052.000	69.200	1100.000	0.000	0.000
NC	0.000	0.000	0.020	0.100	0.300	0.000	0.000	0.000	0.000	0.000
	CROSS	SECTION F								
X1	6550.000	11.000	963.000	1037.000	50.000	50.000	50.000	0.000	0.000	0.000
GR	71.000	900.000	69.910	941.000	63.000	951.000	58.410	963.000	55.110	981.000
GR	51.000	1000.000	54.710	1018.000	59.310	1037.000	61.110	1046.000	69.110	1056.000
GR	69.500	1100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NC	0.070	0.070	0.035	0.100	0.300	0.000	0.000	0.000	0.000	0.000
	CROSS	SECTION G								
X1	9900.000	10.000	987.000	1013.000	3350.000	3350.000	3350.000	0.000	0.000	0.000
GR	74.000	530.000	70.000	700.000	66.000	950.000	57.100	987.000	53.740	1000.000
GR	57.730	1013.000	59.250	1041.000	66.000	1220.000	70.000	1310.000	74.000	1520.000
X1	11861.000	11.000	987.000	1013.000	1960.000	1960.000	1961.000	0.000	0.000	0.000
GR	79.000	850.000	71.870	923.000	71.470	936.000	68.830	950.000	63.670	964.000
GR	58.850	987.000	55.500	1000.000	59.280	1013.000	61.000	1041.000	62.000	1080.000
GR	79.000	1175.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NC	0.070	0.070	0.000	0.300	0.500	0.000	0.000	0.000	0.000	0.000
X1	11910.000	10.000	990.000	1010.000	49.000	49.000	49.000	0.000	0.000	0.000
X3	10.000	0.000	0.000	0.000	0.000	0.000	0.000	70.000	70.000	0.000
GR	78.000	920.000	74.000	940.000	70.000	960.000	66.000	965.000	64.000	990.000
GR	64.000	1000.000	64.400	1010.000	70.000	1020.000	74.000	1060.000	78.000	1100.000
SB	0.000	1.560	3.000	0.000	20.500	0.000	182.450	0.000	64.040	64.000
	MILL	STREET								
X1	11936.000	12.000	991.000	1009.500	26.000	26.000	26.000	0.000	0.000	0.000
X2	0.000	0.000	1.000	72.920	74.220	0.000	0.000	0.000	0.000	0.000
X3	10.000	0.000	0.000	0.000	0.000	0.000	0.000	74.220	74.220	0.000
BT	-11.000	850.000	79.620	79.600	900.000	75.880	75.800	950.000	74.620	74.600
BT	0.000	975.000	74.350	74.300	990.990	74.220	66.000	991.000	74.220	72.920
BT	0.000	1009.500	74.220	72.920	1009.510	74.300	66.000	1025.000	74.220	74.200

THIS RUN EXECUTED 1-JUN-89 15:57:20

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**************************************************
  HEC2 RELEASE DATED NOV 76 UPDATED MARCH 1982
  ERROR CORR =  01,02,03,04,05
  MODIFICATION =  50,51,52,53,54,55
**************************************************

T1  FEMA FIS
T2  BOXFORD MASS - FISH BROOK
T3  MULTIPLE PROFILE RUN - 100 YR FLOOD

J1  ICHECK    INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ
       0.        4.        0.        0.  0.000000      0.00      0.0         0.    46.280    0.000

J2  NPROF     IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE
     3.000     0.000    -1.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
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THIS RUN EXECUTED 1-JUN-89 15:57:34

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*****************************************************
  HEC2 RELEASE DATED NOV 76 UPDATED MARCH 1982
  ERROR CORR =  01,02,03,04,05
  MODIFICATION =  50,51,52,53,54,55
*****************************************************

T1  FENA FIS
T2  BOXFORD MASS - FISH BROOK
T3  MULTIPLE PROFILE RUN - 500 YR FLOOD

J1  ICHECK    INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ
       0.        5.        0.        0.  0.000000      0.00      0.0        0.    46.790     0.000
J2  NPROF     IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE
    15.000     0.000    -1.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

THIS RUN EXECUTED 4-JUN-89 14:23:11

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**************************************************
  HEC2 RELEASE DATED NOV 76 UPDATED MARCH 1982
  ERROR CORR -  01,02,03,04,05
  MODIFICATION -  50,51,52,53,54,55
**************************************************

T1 FEMA FIS
T2 BOXFORD MASS - FISH BROOK
T3 FLOODWAY RUN:  METHOD 1   RUN #3

J1  ICHECK    INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ
       0.       3.        0.        0.  0.000000      0.00      0.0       0.    47.280    0.000
J2  NPROF     IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE
    15.000    0.000    -1.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

THIS RUN EXECUTED 4-JUN-89 14:23:15

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**************************************************
  HEC2 RELEASE DATED NOV 76 UPDATED MARCH 1982
  ERROR CORR =  01,02,03,04,05
  MODIFICATION -  50,51,52,53,54,55
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NOTE= ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

DWAY RUN: 100 YR. NATUR

SUMMARY PRINTOUT

SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRIWS	EG	.01K	STCHL	STCHR	VCH
*311.000	0.00	0.00	0.00	41.30	830.00	46.38	0.00	46.33	262.94	1595.00	1606.00	3.44
*311.000	0.00	0.00	0.00	41.30	830.00	47.28	0.00	47.31	409.88	1595.00	1606.00	2.52
0.000	311.00	0.00	0.00	38.00	830.00	46.39	0.00	46.40	828.35	990.00	1005.00	1.65
0.000	311.00	0.00	0.00	38.00	830.00	47.34	0.00	47.36	379.24	990.00	1005.00	1.68
227.000	227.00	0.00	0.00	38.70	830.00	46.32	0.00	46.58	305.87	990.00	1019.00	4.12
227.000	227.00	0.00	0.00	38.70	830.00	47.29	0.00	47.49	369.24	990.00	1019.00	3.61
298.000	71.00	52.89	54.60	38.70	830.00	46.39	0.00	46.65	221.54	990.00	1019.00	4.07
298.000	71.00	52.89	54.60	38.70	830.00	47.34	0.00	47.54	272.74	990.00	1019.00	3.59
369.000	71.00	52.89	49.94	38.70	830.00	46.50	0.00	46.75	222.47	990.00	1019.00	4.01
369.000	71.00	52.89	49.94	38.70	830.00	47.41	0.00	47.61	264.21	990.00	1019.00	3.56
440.000	71.00	0.00	0.00	38.85	830.00	46.55	0.00	46.87	224.13	990.00	1019.00	4.59
440.000	71.00	0.00	0.00	38.85	830.00	47.44	0.00	47.69	280.41	990.00	1019.00	4.01
480.000	40.00	0.00	0.00	37.25	830.00	46.70	0.00	46.93	274.24	987.00	1009.00	4.16
480.000	40.00	0.00	0.00	37.25	830.00	47.57	0.00	47.73	343.83	987.00	1009.00	3.56
807.000	327.00	0.00	0.00	36.10	830.00	47.00	0.00	47.05	679.88	987.00	1012.00	2.06
807.000	327.00	0.00	0.00	36.10	830.00	47.77	0.00	47.83	672.31	987.00	1012.00	2.19
2000.000	1193.00	0.00	0.00	39.20	830.00	47.20	0.00	47.51	222.01	992.00	1007.00	5.26
2000.000	1193.00	0.00	0.00	39.20	830.00	48.00	0.00	48.24	267.12	992.00	1007.00	4.68
3000.000	1000.00	0.00	0.00	42.06	810.00	48.92	0.00	49.44	153.22	992.00	1007.00	6.58
3000.000	1000.00	0.00	0.00	42.06	810.00	49.23	0.00	49.67	170.21	992.00	1007.00	6.12
4600.000	1600.00	0.00	0.00	45.76	810.00	51.39	0.00	51.44	284.89	993.00	1007.00	3.06
4600.000	1600.00	0.00	0.00	45.76	810.00	51.83	0.00	51.93	243.98	993.00	1007.00	3.78

	SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRIWS	EG	.01K	STCHL	STCHR	VCH
	5820.000	1220.00	0.00	0.00	47.77	750.00	52.51	0.00	52.56	230.06	669.00	682.00	3.35
	5820.000	1220.00	0.00	0.00	47.77	750.00	53.00	0.00	53.05	273.06	669.00	682.00	3.02
	5920.000	100.00	0.00	0.00	49.27	750.00	52.68	0.00	52.89	78.17	677.00	1036.00	3.73
	5920.000	100.00	0.00	0.00	49.27	750.00	53.12	0.00	53.22	126.87	677.00	1036.00	2.55
*	5950.000	30.00	56.10	54.90	49.60	750.00	55.05	0.00	55.06	308.24	668.00	1038.00	0.99
*	5950.000	30.00	56.10	54.90	49.60	750.00	55.05	0.00	55.06	308.20	668.00	1038.00	0.99
	6010.000	60.00	0.00	0.00	50.89	750.00	54.90	0.00	55.25	98.73	677.00	692.00	6.58
*	6010.000	60.00	0.00	0.00	50.89	750.00	54.43	54.43	55.59	57.39	677.00	692.00	10.34
	6100.000	90.00	0.00	0.00	51.00	750.00	54.97	54.88	56.36	66.12	989.00	1009.00	9.78
	6100.000	90.00	0.00	0.00	51.00	750.00	55.66	0.00	56.57	90.65	989.00	1009.00	8.01
	6309.000	209.00	0.00	0.00	51.45	750.00	57.12	0.00	57.55	141.23	985.00	1014.00	5.38
	6309.000	209.00	0.00	0.00	51.45	750.00	57.16	0.00	57.63	124.67	985.00	1014.00	5.51
	6447.000	138.00	0.00	0.00	53.30	750.00	57.54	0.00	58.08	109.17	985.00	1014.00	6.18
	6447.000	138.00	0.00	0.00	53.30	750.00	57.69	0.00	58.36	91.18	985.00	1014.00	6.59
	6497.000	50.00	0.00	0.00	54.40	750.00	58.15	0.00	58.30	210.75	969.00	1032.00	3.16
	6497.000	50.00	0.00	0.00	54.40	750.00	58.50	0.00	58.63	222.65	969.00	1032.00	2.94
	6500.000	3.00	58.92	58.70	58.40	750.00	61.89	0.00	62.09	167.94	969.00	1032.00	3.61
	6500.000	3.00	58.92	58.70	58.40	750.00	61.87	0.00	62.09	151.90	969.00	1032.00	3.73
	6550.000	50.00	0.00	0.00	51.00	750.00	62.08	0.00	62.11	1446.62	963.00	1037.00	1.41
	6550.000	50.00	0.00	0.00	51.00	750.00	62.08	0.00	62.11	1363.48	963.00	1037.00	1.42
	9900.000	3350.00	0.00	0.00	53.74	750.00	62.26	0.00	62.36	364.13	987.00	1013.00	3.02
	9900.000	3350.00	0.00	0.00	53.74	750.00	62.23	0.00	62.45	278.06	987.00	1013.00	3.95
	11861.000	1961.00	0.00	0.00	55.50	750.00	63.26	0.00	63.41	289.16	987.00	1013.00	3.54
	11861.000	1961.00	0.00	0.00	55.50	750.00	64.03	0.00	64.32	210.30	987.00	1013.00	4.28
*	11910.000	49.00	0.00	0.00	64.00	750.00	67.61	67.61	69.38	68.76	990.00	1010.00	10.69
*	11910.000	49.00	0.00	0.00	64.00	750.00	67.62	67.62	69.38	62.56	990.00	1010.00	10.66
	11936.000	26.00	74.22	72.92	64.04	750.00	67.91	67.85	69.71	67.51	991.00	1009.50	10.74
	11936.000	26.00	74.22	72.92	64.04	750.00	68.15	0.00	69.75	74.57	991.00	1009.50	10.12
	11986.000	50.00	0.00	0.00	57.10	750.00	70.23	0.00	70.25	1301.63	964.00	1041.00	1.05
	11986.000	50.00	0.00	0.00	57.10	750.00	70.21	0.00	70.22	1176.97	964.00	1041.00	1.07
*	12173.000	187.00	0.00	0.00	70.76	750.00	73.66	73.66	74.68	56.70	961.00	1038.00	8.13
*	12173.000	187.00	0.00	0.00	70.76	750.00	73.66	73.66	74.70	54.90	961.00	1038.00	8.20
*	12178.000	5.00	0.00	0.00	70.76	750.00	73.74	73.74	74.89	63.38	973.00	1035.00	8.67
*	12178.000	5.00	0.00	0.00	70.76	750.00	73.79	73.79	74.97	60.40	973.00	1035.00	8.72