

Hydrologic and Hydraulic Report



Queensville Dam Removal Feasibility Study and Buttery Brook Watershed Enhancement South Hadley, MA

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1 Executive Summary

The Town of South Hadley (Town) has been awarded a FY22 EEA Municipal Vulnerability Preparedness Program Action Grant to fund a feasibility study for the removal of Queensville Dam, located at Titus Pond on Newton Street, restoration and ecological enhancement of the Titus Pond impoundment to increase flood storage capacity and habitat function, and downstream watershed improvements along Buttery Brook. The impoundment, Titus Pond, is part of an underutilized conservation area that is impaired by significant algal blooms during much of the summer season—conditions which are expected to worsen as temperatures and precipitation-driven nutrient inputs increase with climate change. A 2018 Phase 1 Dam Inspection showed the Queensville Dam to be in poor condition and in need of roughly \$175K in repairs to bring it to safe condition. The Town wants to explore ways to remove the dam and restore the surrounding ecosystem for improved stormwater retention capacity to prevent flooding of densely populated downstream neighborhoods and improve water quality and alleviate potential public health concerns associated with nutrient and bacteria impairments. The purpose of this report is to summarize the hydrologic and hydraulic analyses completed to size and design dam removal concepts and replace stream crossings based on Massachusetts Stream Crossing Standards while also addressing future climate conditions using the guidelines created by the Resilient Massachusetts Action Team (RMAT).

Three alternatives for removing the Queensville Dam at Newton Street and restoring the natural wetland ecosystem of Titus Pond are presented in this report. Proposed improvements of the stream crossing at Mountain Avenue will replace the existing 24" corrugated metal pipe with a 14' span x 5' rise box culvert and realign the stream channel to decrease erosion. Additionally, the inlet of the Joffre Avenue culvert is in poor condition and a suitable replacement inlet structure will be designed once the culvert's condition has been filmed and assessed.

2 Project Description

2.1 Existing Conditions

The upstream portion of the project area consists of Titus Pond and Queensville Dam on Newton Street. Titus Pond is a small impoundment that is frequently impaired by significant algal blooms during the summer months. The outlet control structure of the dam is a rectangular concrete box, approximately 5' wide x 5' length x 13' height. There is a 3' x 3' grated square inlet located at the normal pool of the pond that allows water to enter the outlet structure. At the bottom of the structure, approximately 8' down from the inlet there is a 24" reinforced concrete pipe (RCP) that runs from Titus Pond under Newton Street for approximately 210 feet. The culvert runs under commercial property and daylight into Buttery Brook southwest of Newton Street.

Further downstream, Buttery Brook crosses Mountain Avenue through a 24" corrugated metal pipe (CMP), measuring approximately 104 feet in length. The crossing was assessed as unable to safely pass the current 10-year storm due to its insufficient hydraulic capacity. The crossing also suffers from poor alignment causing erosion problems along the bank and allowing material to pile up at the inlet, causing blockages. Upon exiting Mountain Avenue, Buttery Brook continues approximately 315 feet through

residential backyards. North of Joffre Avenue, the creek enters a storm sewer of unknown size for roughly 650 feet under several residential properties before daylighting south of Joffre Avenue. While the conditions of the buried pipe are unknown, residents report frequent flooding in the area and the headwall of the Joffre Avenue inlet may have collapsed. A standpipe at the inlet has been set as an emergency measure. The Town will film this storm sewer which conveys Butter Brook in the Spring of 2022 to determine maintenance that may be needed.

2.2 Proposed Conditions

Three design alternatives were developed to determine the feasibility of removing the dam. In addition to the three design alternatives at the dam location, the road crossing at Mountain Avenue was assessed as well as the feasibility of daylighting the conveyance pipe under Joffre Avenue. Based on the level of criticality and an expected useful life of more than 50 years, it was determined that the proposed road crossings should be sized based on the Tier 2 RMA2 rainfall recommendations. The 50-year storm was used for the design storm plus a 20% magnification for additional capacity to accommodate predicted climatic condition peak flows.

The first alternative considered for removing the dam is to construct a new culvert under Newton Street that meets Massachusetts Stream Crossing Standards, remove the outlet control structure, and allow a natural channel to reestablish through Titus Pond. A new open channel would be constructed from Newton Street to the existing 24" CMP outlet at Buttery Brook. The proposed crossing is a 14-foot span x 5-foot rise box culvert. This would provide sufficient conveyance capacity for a 50-year storm event in future climatic conditions, as well as meet stream crossing standards. The culvert would be moved south of its current location so the outlet of the proposed box culvert would daylight immediately west of Newton Street, rather than running under several commercial properties. This alternative would require the construction of a 10-foot retaining wall on the downstream side of the box culvert where the channel would abut a 7-Eleven parking lot as well as purchasing property or easements from two separate landowners. Alternative 1 is depicted on Figure 1 below.

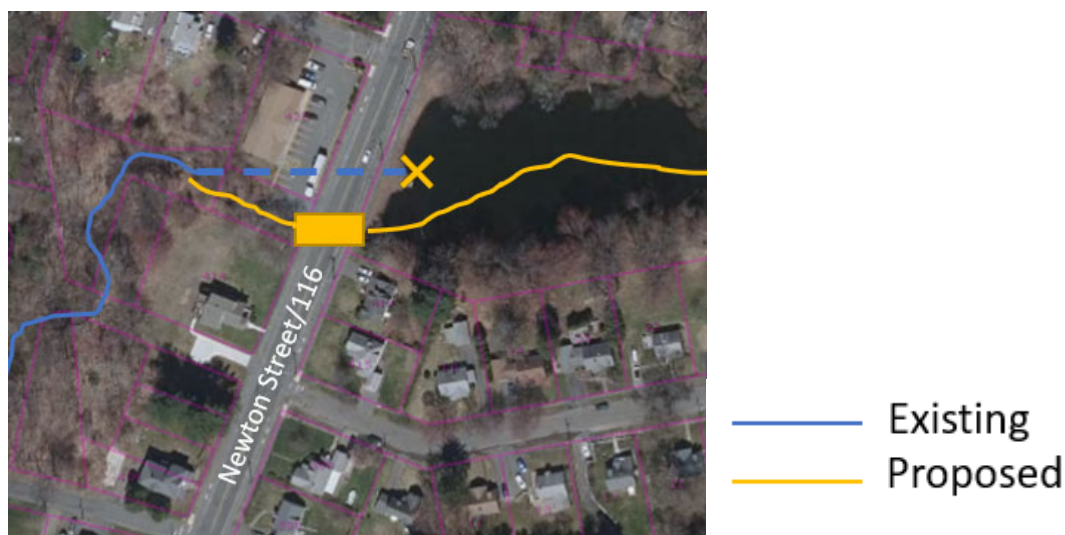


Figure 1: Alternative 1 Dam Removal Concept

The second alternative is to remove the concrete outlet control structure and retain the existing 24" RCP under Newton Street. This would permit water to enter the culvert at lower flood stages, allowing Titus Pond to drain and the channel to reestablish naturally over time. Newton Street would still experience overtopping during the 50- and 100-year storm events, but the storage volume within Titus Pond would be less than 15 ac-ft, removing the dam classification of Queensville Dam. Alternative 2 is depicted on Figure 2 below.



Figure 2: Alternative 2 Dam Removal Concept

The third alternative is to remove the concrete outlet control structure and retain the existing 24" RCP under Newton Street similar to Alternative 2. Alternative 3 would actively restore Buttery Brook through Titus Pond to a more defined meandering channel, which would increase floodwater and/or stormwater attenuation. The Titus Pond area would be graded with step-pool structures, meanders and riffles, native wetland vegetation would be planted, and green stormwater management techniques would be installed for runoff entering the area. Like Alternative 2, Newton Street would still experience overtopping during the 50- and 100-year storm events, but the dam classification could be removed as it would be less than 15 ac-ft of storage volume. Alternative 3 is depicted on Figure 3 below.

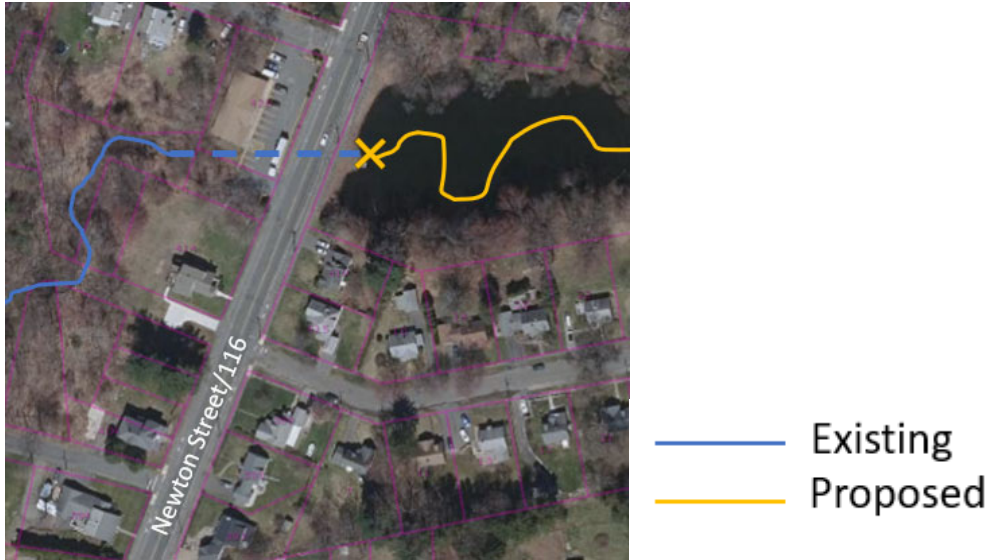


Figure 3: Alternative 3 Dam Removal Concept

Further downstream, Mountain Avenue crossing is proposed to be replaced to meet the requirements of the Massachusetts Stream Crossing Standards. The 24" CMP will be replaced with a 14-foot span x 5-foot rise three-sided frame with an open bottom that will be realigned to match existing stream geometry. At present, the channel bends approximately 90 degrees to the west before flowing south under Mountain Avenue. The proposed design would realign the channel to reduce erosion and restore the natural stream function.

After reviewing parcel maps and easements, it was determined that it is not feasible to daylight the conveyance pipe under Joffre Avenue. The pipe runs under several constructed residential properties and open private land which would need to be purchased to daylight Buttery Brook along this stretch. Additionally, the length of the buried pipe would require the construction of an unfeasibly large structure to meet Massachusetts Stream Crossing Standards. Instead of removal and construction of a new pipe, the Town will film the conveyance pipe during the Spring of 2022 to determine its condition and recommendations will be made during final engineering for improvements at the conveyance pipe inlet north of Joffre Avenue.

3 Hydrologic Analysis

A hydrologic model for Buttery Brook was developed using the U.S Army Corps of Engineers HEC-HMS version 4.8 software. The Soil Conservation Service (SCS) Curve Number (CN) methodology was used to represent the hydrologic losses for each sub-watershed. The Snyder Unit Hydrograph method was used to simulate the excess rainfall-runoff response of the watershed. Details of the development of the hydrologic model are presented in the following sections.

3.1 Watershed Delineation

The Buttery Brook watershed was delineated using the USGS StreamStats online webtool, a commonly used program developed by the United States Geological Survey (USGS). The outlet point was selected at the stream crossing of Joffre Avenue at Buttery Brook. The total watershed has an area of 0.41 sq mi.

3.2 Curve Number Development

To determine the Curve Numbers (CN) for the watershed, soil and land use data were obtained from the USDA Natural Resources Conservation Service (NRCS) Web Soil Survey (WSS) Database (SSURGO 2.2) and the Land Cover Land Use data (2016) was obtained from Massmapper (run by MassGIS).

The NRCS classifies soils into four hydrologic groups represented as Type A, B, C, and D soils. Type A soils have high infiltration capacity and typically consist of coarse sands, while Type D soils have very low infiltration capacity, typically due to a restrictive layer or clay content. Some soils are classified as two types, such as A/D, B/D, and C/D, which reflect areas with a shallow groundwater table and infiltration capacity that is dependent on the antecedent moisture condition. These soil groups were conservatively treated as Type D in the Curve Number (CN) calculation since the hydrologic analysis is based on extreme precipitation events. Curve numbers were assigned to the combined soil land use dataset using guidance from the USDA Urban Hydrology for Small Watersheds TR-55 document. The composite curve number for the Buttery Brook watershed was determined to be 60.2.

3.3 Snyder Methodology

The HEC-HMS model uses two parameters to define the runoff characteristics of a watershed when using the Snyder Unit Hydrograph methodology: Standard Lag (T_L) and the Peaking Coefficient (C_P).

The Standard Lag Time (T_L) was computed using the Snyder watershed lag equation:

$$T_L = C_T(L \times L_{ca})^{0.3}$$

Where:

C_T = Coefficient representing variations in watershed topography

L = Longest Flow Path along main stream to basin divide (mi)

L_{ca} = Centroidal Flow Path Length along main stream to watershed centroid (mi)

Based on guidance from the HEC-HMS technical manual, which presents typical ranges for C_T to be from 1.8 to 2.2, a value of 2.0 was used as an average typical value for C_T . The longest flow path (2.1 miles) and centroidal flow path (1 mile) were then calculated for the watershed in GIS.

3.4 Design Storms

Unit hydrographs for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year storm events were determined using HEC-HMS. The meteorological model in HEC-HMS was set up for a hypothetical storm using an SCS Type 3 distribution. Precipitation depth values were obtained from NOAA Atlas 14 for the 24-hour storm events and are shown in Table 1. Both present and future climactic conditions were considered in this analysis. The crossing was classified as Tier 2 based on the RMA2 Climate Resilience Design Standards Tool. Per Tier 2 RMA2 methodology, present baseline precipitation depths from NOAA Atlas 14 were scaled by 27% for the 100-year design storm and 20% for more frequent design storms.

**Table 1
NOAA Atlas 14 Precipitation Depths for Present and Late Century**

Design Storm	Present Baseline Precipitation Depth (in)	Late Century (2070/2090) Precipitation Depth (in)
1-year	2.46	2.95
10-year	4.98	5.98
25-year	6.17	7.40
50-year	7.03	8.44
100-year	7.99	10.15

The peak unit hydrographs were input into the HEC-RAS hydraulic model. Appendix A contains supporting documentation used to develop the HEC-HMS model. Appendix B contains the summary of the HEC-HMS model.

3.5 Recommended Next Steps

The hydrologic modeling methodology presented in this report was developed for this preliminary analysis. When the proposed alternative is taken to final design, the hydrology will be amended to include a stage-storage volume relationship for Titus Pond.

4 Hydraulic Analysis

To analyze the impacts of the existing and proposed stream crossings at Newton Street, Mountain Avenue, and Joffre Avenue, a one-dimensional (1D) HEC-RAS model (version 6.1) was developed. The project site was surveyed in January 2022. Survey data includes twelve cross sections with detailed channel geometry, culvert inlet and outlet invert elevations for the Titus Pond impoundment and Mountain Avenue crossing, and detailed road survey data. Detailed cross sections for the 1D model were developed using survey data for main channel geometry and LiDAR data for overbank geometry. The LiDAR data set used was a 1-meter LiDAR based Digital Elevation Model (DEM) downloaded from NOAA Coastal Data Viewer (2015 USGS Lidar: Maine & Massachusetts QL1 & QL2). Manning's n values for the main channel and overbank areas were determined through photographs taken by Fuss and O'Neill during the wetland resources area delineation. The model begins at the upstream end of

Titus Pond and terminates approximately 270 feet downstream of the outlet of the conveyance pipe under Joffre Avenue.

4.1 Existing Conditions

The longitudinal profile of the channel was drawn in ArcGIS Pro using topographical survey. Cross sections were created from survey and LiDAR data. The road crossings at Newton Street and Mountain Avenue were developed using site survey data. The upstream invert elevation for the conveyance pipe under Joffre Avenue was estimated based on topographical survey data and the downstream invert elevation was determined using LiDAR data.

The storage area in Titus Pond was represented as a wide channel defined by five cross sections developed from LiDAR data. Since Manning's n values increase with depth, the Manning's n values for the main channel of the pond cross sections were increased to reflect sluggish, deep conditions.

Table 2 shows existing water surface elevation (WSEL) values at Newton Street and Mountain Avenue. Newton Street slopes upward to the northeast and overtops on the southern end of the road crossing at 165'. Mountain Avenue overtops at 148'. Currently, Newton Street is overtopping during 10-year and larger storms and Mountain Avenue is overtopping during 10-year and larger storm events.

Table 2
Existing Conditions Water Surface Elevations

Design Storm	Newton Street	Mountain Ave
1-year	163.71	140.3
10-year	165.51	148.4
25-year	165.68	148.6
50-year	165.78	148.7
100-year	165.88	148.8

4.2 Proposed Conditions

The following modifications were made to the HEC-RAS model for the Mountain Avenue crossing and each dam removal alternative.

Mountain Avenue

At Mountain Avenue, the channel centerline was redrawn in ArcGIS Pro to remove the sharp meander and better align the culvert with natural flow. Cross section (XS) 5 and XS 6 are the bounding downstream and upstream cross sections for the Mountain Avenue road crossing and were updated to reflect proposed grading of the channel realignment. The upstream and downstream invert elevations of the proposed culvert were also determined based on proposed grading. Table 3 compares WSEL values at Mountain Avenue for existing conditions, proposed conditions for current design storms (2022), and proposed conditions for future design storms (2070). The table demonstrates that the proposed changes will lower WSEL along Mountain Avenue even for future climactic conditions.

**Table 3
Mountain Ave Water Surface Elevations**

Design Storm	Existing Conditions	Proposed Design; Existing Flows	Proposed Design; 2070 Flows
1-year	140.3	133.8	134.0
10-year	148.4	135.4	135.6
25-year	148.6	135.6	135.9
50-year	148.7	135.8	136.1
100-year	148.8	136.0	136.6

Alternative 1

The channel centerline at the upstream end of the reach was redrawn in ArcGIS Pro to move the inlet for the proposed box culvert at Titus Pond approximately 60 feet southwest of the existing outlet control structure. The upstream invert of the proposed 14' x 5' box culvert was lowered eight feet to 152' to reflect the removal of the outlet control structure. XS 10-12 were replaced with artificial cross sections that incorporated the presence of a 10-foot retaining wall and channel grading immediately downstream of the proposed culvert. The cross sections through Titus Pond were adjusted to create a more defined channel that mimics downstream conditions and reflects the removal of the storage area.

This alternative accommodates the 100-year storm events for both present and future climactic conditions. It also reduces the velocity immediately downstream of the culvert, significantly reducing the potential for scour and erosion.

Alternative 2 & 3

For this feasibility study, the hydraulics of alternatives 2 and 3 for dam removal were modeled in the same way. In Alternative 2, the outlet control structure will be removed and BATTERY Brook through Titus Pond will be allowed to reestablish naturally over time. In Alternative 3, the outlet control structure will be removed and nature-based solutions such as step pools, riffles and meanders will be added to BATTERY Brook through Titus Pond to allow the restored wetland to better attenuate stormwater. For both alternatives, the outlet control structure was removed and the existing 24" RCP was used as the culvert under Newton Street. The cross sections through Titus Pond were adjusted to create a more defined channel that mimics downstream conditions and reflects the removal of the dam. Under Alternatives 2 and 3, Newton Street is still partially overtopped during 10-year and larger flow events.

Appendix C contains supporting documentation used for the HEC-RAS hydraulic model. A summary report of the HEC-RAS hydraulic model is included in Appendix D.

5 Scour Safety/Stability Analyses

Five grain size analyses were performed on the streambed material downstream of the Newton Street crossing and upstream of the conveyance pipe under Joffrey Avenue to determine the streambed D_{50} particle size in preparation for the development of the scour calculations for Mountain Avenue. The D_{50} particle size was 0.323 mm.

A scour safety assessment was performed utilizing values obtained from the 1D HEC-RAS Model. Froehlich's Abutment Scour Equation in HEC-18 was used to calculate local abutment scour depth. Per MassDOT standards, the design frequency used to estimate total abutment scour is the 25-year storm event, and the check scour frequency is the 50-year storm event. A summary of calculated abutment scour depths are found in Table 4.

Table 4
Summary of Calculated Scour

Return Frequency (Year)	Design Abutment Scour Depth (ft)
25	3.6
50	2.7

Scour analysis calculations and supporting documentation is included in Appendix E.

Appendix A

Supporting Information for Hydrologic Model Development



NOAA Atlas 14, Volume 10, Version 3
Location name: South Hadley, Massachusetts,
USA*

Latitude: 42.234°, Longitude: -72.5829°
Elevation: 160.25 ft**

* source: ESRI Maps
 ** source: USGS



POINT PRECIPITATION FREQUENCY ESTIMATES

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NOAA, National Weather Service, Silver Spring, Maryland

[PF_tabular](#) | [PF_graphical](#) | [Maps_&_aerials](#)

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)¹										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.331 (0.255-0.422)	0.396 (0.305-0.506)	0.502 (0.385-0.644)	0.590 (0.450-0.762)	0.712 (0.527-0.964)	0.804 (0.583-1.11)	0.900 (0.634-1.30)	1.00 (0.675-1.49)	1.15 (0.746-1.78)	1.27 (0.803-2.00)
10-min	0.469 (0.361-0.598)	0.561 (0.431-0.717)	0.712 (0.546-0.913)	0.837 (0.638-1.08)	1.01 (0.746-1.37)	1.14 (0.826-1.58)	1.27 (0.898-1.84)	1.42 (0.955-2.11)	1.63 (1.06-2.51)	1.80 (1.14-2.84)
15-min	0.551 (0.424-0.704)	0.660 (0.508-0.843)	0.838 (0.642-1.08)	0.985 (0.752-1.27)	1.19 (0.878-1.61)	1.34 (0.972-1.86)	1.50 (1.06-2.16)	1.67 (1.12-2.48)	1.92 (1.24-2.96)	2.12 (1.34-3.34)
30-min	0.748 (0.576-0.955)	0.896 (0.689-1.15)	1.14 (0.873-1.46)	1.34 (1.02-1.73)	1.62 (1.19-2.19)	1.82 (1.32-2.53)	2.04 (1.44-2.94)	2.28 (1.53-3.38)	2.61 (1.69-4.03)	2.88 (1.82-4.54)
60-min	0.945 (0.728-1.21)	1.13 (0.871-1.45)	1.44 (1.10-1.85)	1.69 (1.29-2.19)	2.04 (1.51-2.77)	2.31 (1.67-3.20)	2.58 (1.82-3.72)	2.88 (1.94-4.28)	3.31 (2.14-5.10)	3.65 (2.31-5.75)
2-hr	1.21 (0.938-1.52)	1.44 (1.12-1.82)	1.82 (1.41-2.31)	2.13 (1.64-2.73)	2.57 (1.92-3.46)	2.89 (2.12-3.99)	3.24 (2.31-4.67)	3.64 (2.46-5.36)	4.23 (2.75-6.49)	4.73 (3.00-7.41)
3-hr	1.38 (1.08-1.73)	1.65 (1.29-2.07)	2.09 (1.63-2.64)	2.46 (1.90-3.13)	2.96 (2.23-3.97)	3.34 (2.46-4.60)	3.74 (2.69-5.39)	4.22 (2.86-6.20)	4.96 (3.23-7.58)	5.59 (3.56-8.73)
6-hr	1.71 (1.35-2.13)	2.07 (1.64-2.58)	2.67 (2.10-3.34)	3.16 (2.48-3.98)	3.84 (2.93-5.13)	4.34 (3.25-5.96)	4.89 (3.57-7.06)	5.58 (3.79-8.15)	6.67 (4.36-10.1)	7.62 (4.86-11.8)
12-hr	2.08 (1.67-2.57)	2.58 (2.06-3.18)	3.40 (2.70-4.21)	4.07 (3.22-5.08)	5.00 (3.85-6.64)	5.68 (4.29-7.77)	6.44 (4.76-9.28)	7.42 (5.06-10.8)	8.99 (5.89-13.6)	10.4 (6.64-16.0)
24-hr	2.46 (1.99-3.00)	3.09 (2.50-3.78)	4.13 (3.32-5.06)	4.99 (3.99-6.16)	6.17 (4.79-8.13)	7.03 (5.36-9.56)	7.99 (5.96-11.5)	9.26 (6.34-13.3)	11.3 (7.43-17.0)	13.1 (8.43-20.1)
2-day	2.83 (2.31-3.41)	3.56 (2.91-4.31)	4.76 (3.88-5.79)	5.76 (4.66-7.05)	7.14 (5.60-9.33)	8.14 (6.26-11.0)	9.26 (6.97-13.2)	10.7 (7.40-15.4)	13.2 (8.70-19.6)	15.4 (9.89-23.4)
3-day	3.09 (2.54-3.71)	3.89 (3.19-4.67)	5.19 (4.25-6.26)	6.27 (5.10-7.62)	7.75 (6.11-10.1)	8.83 (6.83-11.9)	10.0 (7.59-14.3)	11.7 (8.05-16.6)	14.3 (9.46-21.2)	16.7 (10.8-25.3)
4-day	3.32 (2.75-3.97)	4.16 (3.44-4.98)	5.54 (4.55-6.66)	6.68 (5.45-8.08)	8.25 (6.53-10.7)	9.39 (7.29-12.6)	10.7 (8.08-15.1)	12.4 (8.56-17.6)	15.2 (10.0-22.4)	17.7 (11.4-26.7)
7-day	3.95 (3.29-4.68)	4.88 (4.07-5.79)	6.40 (5.31-7.63)	7.67 (6.32-9.21)	9.41 (7.50-12.1)	10.7 (8.33-14.1)	12.1 (9.18-16.9)	13.9 (9.70-19.7)	16.9 (11.3-24.9)	19.6 (12.7-29.5)
10-day	4.58 (3.84-5.39)	5.56 (4.66-6.56)	7.16 (5.98-8.49)	8.49 (7.04-10.1)	10.3 (8.26-13.1)	11.7 (9.12-15.3)	13.1 (9.98-18.2)	15.0 (10.5-21.1)	18.1 (12.0-26.4)	20.7 (13.4-31.0)
20-day	6.56 (5.57-7.65)	7.60 (6.44-8.88)	9.30 (7.85-10.9)	10.7 (8.98-12.7)	12.7 (10.2-15.8)	14.1 (11.1-18.2)	15.7 (11.8-21.1)	17.5 (12.3-24.3)	20.2 (13.5-29.3)	22.5 (14.6-33.5)
30-day	8.23 (7.03-9.54)	9.30 (7.94-10.8)	11.1 (9.40-12.9)	12.5 (10.6-14.7)	14.5 (11.7-18.0)	16.0 (12.6-20.4)	17.6 (13.3-23.4)	19.4 (13.7-26.7)	21.8 (14.7-31.5)	23.8 (15.5-35.3)
45-day	10.3 (8.86-11.9)	11.4 (9.82-13.2)	13.3 (11.3-15.4)	14.8 (12.6-17.3)	16.9 (13.7-20.7)	18.5 (14.6-23.3)	20.1 (15.1-26.4)	21.8 (15.5-29.9)	24.0 (16.2-34.4)	25.6 (16.7-37.9)
60-day	12.0 (10.4-13.8)	13.2 (11.4-15.2)	15.1 (13.0-17.5)	16.7 (14.3-19.5)	18.9 (15.4-23.0)	20.6 (16.3-25.8)	22.3 (16.8-29.0)	23.9 (17.1-32.7)	26.0 (17.6-37.1)	27.4 (17.9-40.4)

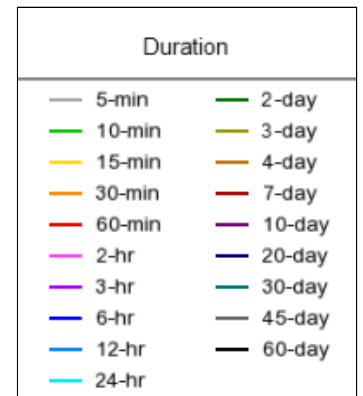
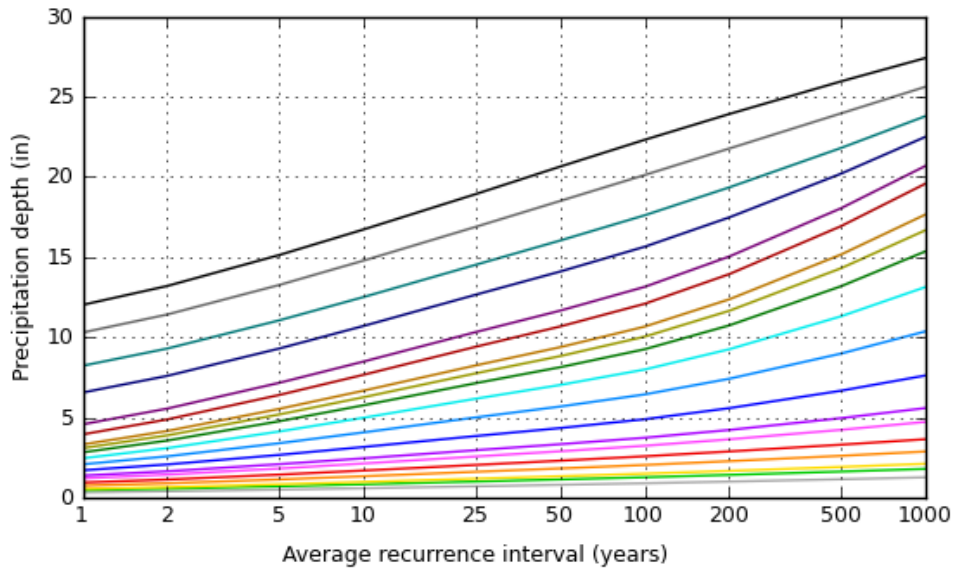
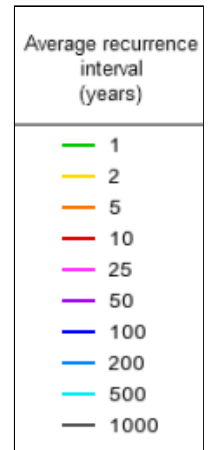
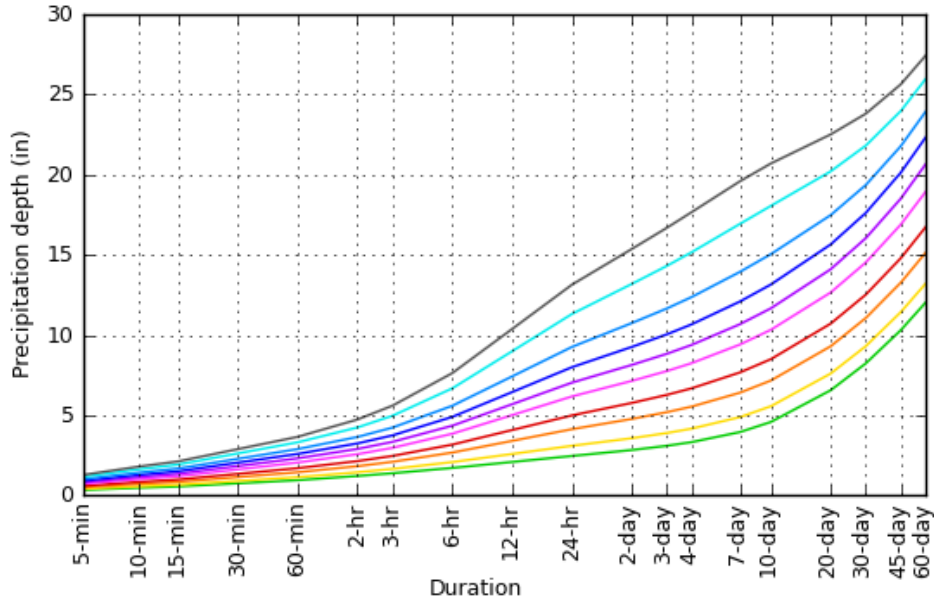
¹ Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS). Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values. Please refer to NOAA Atlas 14 document for more information.

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PF graphical

PDS-based depth-duration-frequency (DDF) curves

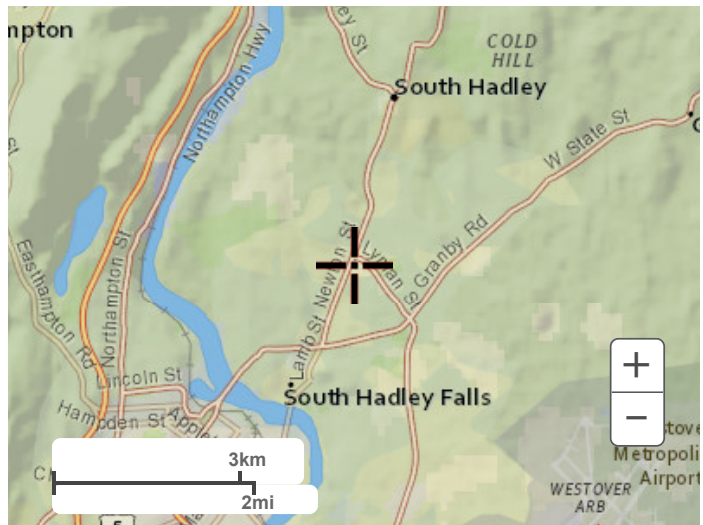
Latitude: 42.2340°, Longitude: -72.5829°



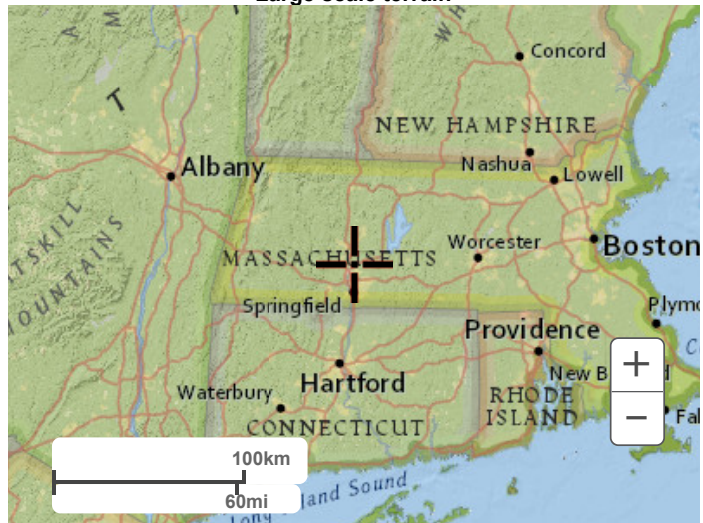
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Maps & aerials

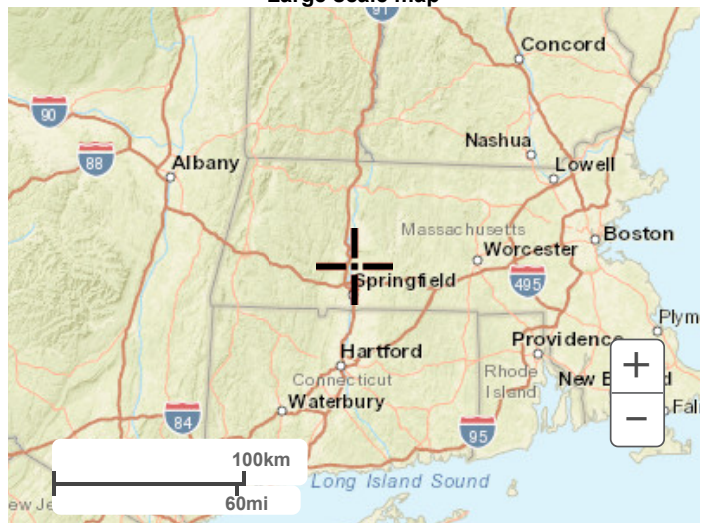
Small scale terrain



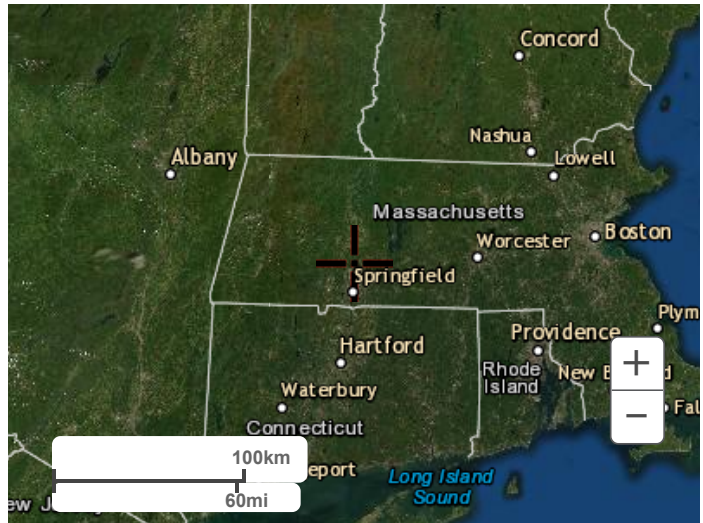
Large scale terrain



Large scale map



Large scale aerial



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1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

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Queensville Dam

Sub-basin	L (miles)	Lc (miles)	tl (hours)	CN
1	2.1	1	2.5	60.2

$$tl = Ct(L * Lc)^{0.3}$$

Ct = 2 basin coefficient

L longest flow path

Lc distance from outlet to near centroid along river

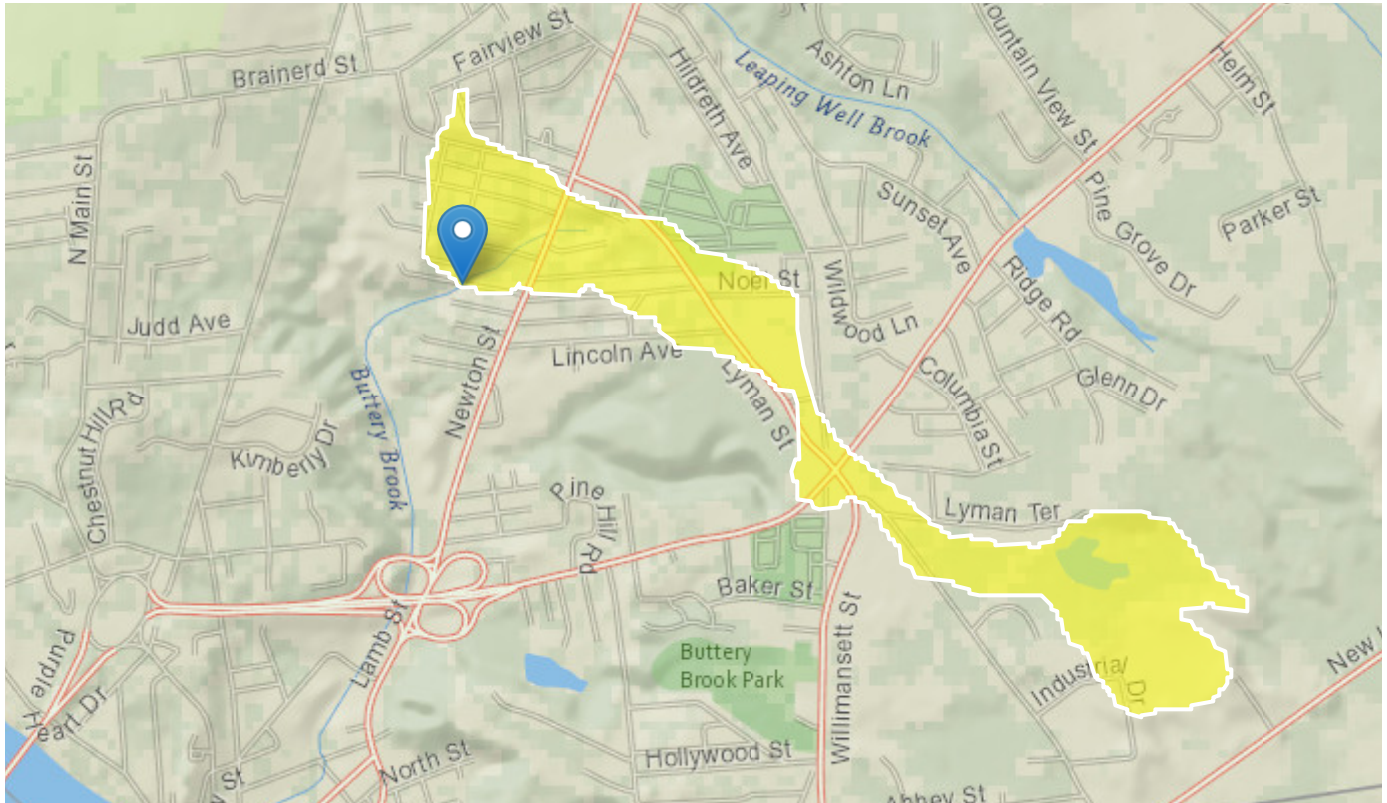
StreamStats Report

Region ID: MA

Workspace ID: MA20220307202932459000

Clicked Point (Latitude, Longitude): 42.23203, -72.58802

Time: 2022-03-07 15:29:54 -0500



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	0.41	square miles
ELEV	Mean Basin Elevation	219	feet
LC06STOR	Percentage of water bodies and wetlands determined from the NLCD 2006	13	percent
DRFTPERSTR	Area of stratified drift per unit of stream length	1.13	square mile per mile
MAREGION	Region of Massachusetts 0 for Eastern 1 for Western	1	dimensionless

Parameter Code	Parameter Description	Value	Unit
BSLDEM250	Mean basin slope computed from 1:250K DEM	0.932	percent
BSLDEM10M	Mean basin slope computed from 10 m DEM	3.917	percent
PCTSNDGRV	Percentage of land surface underlain by sand and gravel deposits	79.32	percent
FOREST	Percentage of area covered by forest	16.31	percent
ACRSDFE	Area underlain by stratified drift	0.41	square miles
CAT1ROADS	Length of interstates lmtd access highways and ramps for lmtd access highways, includes cloverleaf interchanges (USGS Ntl Transp Dataset)	0	miles
CAT2ROADS	Length of sec hwy or maj connecting roads; main arteries & hwys not lmtd access, usually in the US Hwy or State Hwy systems (USGS Ntl Transp Dataset)	0.15	miles
CAT3ROADS	Length of local connecting roads; roads that collect traffic from local roads & connect towns, subdivisions & neighborhoods (USGS Nat Transp Dataset)	0.9	miles
CAT4ROADS	Length of local roads; generally paved street, road, or byway that usually have single lane of traffic in each direction (USGS Ntnl Transp Dataset)	4.9	miles
CENTROIDX	Basin centroid horizontal (x) location in state plane coordinates	111460	meters
CENTROIDY	Basin centroid vertical (y) location in state plane units	886940	meters
CROSCOUNT1	Number of intersections between streams and roads, where the roads are interstate, limited access highway, or ramp (CAT1ROADS)	0	dimensionless
CROSCOUNT2	Number of intersections between streams and roads, where the roads are secondary highway or major connecting road (CAT2ROADS)	0	dimensionless
CROSCOUNT3	Number of intersections between streams and roads, where roads are local connecting roads (CAT3ROADS)	1	dimensionless
CROSCOUNT4	Number of intersections between streams and roads, where roads are local roads (CAT4ROADS)	2	dimensionless
CRSDFE	Percentage of area of coarse-grained stratified drift	79.32	percent

Parameter Code	Parameter Description	Value	Unit
CSL10_85	Change in elevation divided by length between points 10 and 85 percent of distance along main channel to basin divide - main channel method not known	52.2	feet per mi
LAKEAREA	Percentage of Lakes and Ponds	2.7	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	66.2	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	23.2	percent
LFPLENGTH	Length of longest flow path	2.39	miles
MAXTEMPC	Mean annual maximum air temperature over basin area, in degrees Centigrade	15.2	degrees C
OUTLETX	Basin outlet horizontal (x) location in state plane coordinates	110185	feet
OUTLETY	Basin outlet vertical (y) location in state plane coordinates	887415	feet
PRECPRI00	Basin average mean annual precipitation for 1971 to 2000 from PRISM	45.8	inches
STRMTOT	total length of all mapped streams (1:24,000-scale) in the basin	0.36	miles
WETLAND	Percentage of Wetlands	5.45	percent

Peak-Flow Statistics Parameters [Peak Statewide 2016 5156]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.41	square miles	0.16	512
ELEV	Mean Basin Elevation	219	feet	80.6	1948
LC06STOR	Percent Storage from NLCD2006	13	percent	0	32.3

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

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	Plu	ASEp
50-percent AEP flood	16.3	ft ³ /s	8.25	32.2	42.3
20-percent AEP flood	27.6	ft ³ /s	13.8	55.4	43.4
10-percent AEP flood	36.8	ft ³ /s	17.9	75.7	44.7
4-percent AEP flood	50.1	ft ³ /s	23.5	107	47.1
2-percent AEP flood	61.2	ft ³ /s	27.8	135	49.4
1-percent AEP flood	73.1	ft ³ /s	32.1	166	51.8
0.5-percent AEP flood	86	ft ³ /s	36.7	202	54.1
0.2-percent AEP flood	105	ft ³ /s	42.7	258	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	0.41	square miles	1.61	149
DRFTPERSTR	Stratified Drift per Stream Length	1.13	square mile per mile	0	1.29
MAREGION	Massachusetts Region	1	dimensionless	0	1
BSLDEM250	Mean Basin Slope from 250K DEM	0.932	percent	0.32	24.6

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

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

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

Statistic	Value	Unit
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Statistic	Value	Unit
50 Percent Duration	0.385	ft ³ /s
60 Percent Duration	0.307	ft ³ /s
70 Percent Duration	0.333	ft ³ /s
75 Percent Duration	0.306	ft ³ /s
80 Percent Duration	0.313	ft ³ /s
85 Percent Duration	0.23	ft ³ /s
90 Percent Duration	0.216	ft ³ /s
95 Percent Duration	0.116	ft ³ /s
98 Percent Duration	0.0899	ft ³ /s
99 Percent Duration	0.0632	ft ³ /s

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	0.41	square miles	1.61	149
BSLDEM250	Mean Basin Slope from 250K DEM	0.932	percent	0.32	24.6
DRFTPERSTR	Stratified Drift per Stream Length	1.13	square mile per mile	0	1.29
MAREGION	Massachusetts Region	1	dimensionless	0	1

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

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

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

Statistic	Value	Unit
7 Day 2 Year Low Flow	0.117	ft ³ /s
7 Day 10 Year Low Flow	0.0632	ft ³ /s

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	0.41	square miles	1.61	149
BSLDEM250	Mean Basin Slope from 250K DEM	0.932	percent	0.32	24.6
DRFTPERSTR	Stratified Drift per Stream Length	1.13	square mile per mile	0	1.29
MAREGION	Massachusetts Region	1	dimensionless	0	1

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

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

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

Statistic	Value	Unit
August 50 Percent Duration	0.286	ft ³ /s

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	0.41	square miles	0.6	329
BSLDEM10M	Mean Basin Slope from 10m DEM	3.917	percent	2.2	23.9

Bankfull Statistics Parameters [Appalachian Highlands D Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.41	square miles	0.07722	940.1535

Bankfull Statistics Parameters [New England P Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.41	square miles	3.799224	138.999861

Bankfull Statistics Parameters [USA Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.41	square miles	0.07722	59927.7393

Bankfull Statistics Disclaimers [Bankfull Statewide SIR2013 5155]

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

Bankfull Statistics Flow Report [Bankfull Statewide SIR2013 5155]

Statistic	Value	Unit
Bankfull Width	9.54	ft
Bankfull Depth	0.678	ft
Bankfull Area	6.37	ft ²
Bankfull Streamflow	12	ft ³ /s

Bankfull Statistics Flow Report [Appalachian Highlands D Bieger 2015]

Statistic	Value	Unit
Bieger_D_channel_width	10.5	ft

Statistic	Value	Unit
Bieger_D_channel_depth	0.868	ft
Bieger_D_channel_cross_sectional_area	9.2	ft ²

Bankfull Statistics Disclaimers [New England P Bieger 2015]

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

Bankfull Statistics Flow Report [New England P Bieger 2015]

Statistic	Value	Unit
Bieger_P_channel_width	19.7	ft
Bieger_P_channel_depth	1.13	ft
Bieger_P_channel_cross_sectional_area	22	ft ²

Bankfull Statistics Flow Report [USA Bieger 2015]

Statistic	Value	Unit
Bieger_USA_channel_width	9.05	ft
Bieger_USA_channel_depth	0.997	ft
Bieger_USA_channel_cross_sectional_area	10.6	ft ²

Bankfull Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
Bankfull Width	9.54	ft
Bankfull Depth	0.678	ft
Bankfull Area	6.37	ft ²
Bankfull Streamflow	12	ft ³ /s
Bieger_D_channel_width	10.5	ft
Bieger_D_channel_depth	0.868	ft
Bieger_D_channel_cross_sectional_area	9.2	ft ²
Bieger_P_channel_width	19.7	ft
Bieger_P_channel_depth	1.13	ft

Statistic	Value	Unit
Bieger_P_channel_cross_sectional_area	22	ft ²
Bieger_USA_channel_width	9.05	ft
Bieger_USA_channel_depth	0.997	ft
Bieger_USA_channel_cross_sectional_area	10.6	ft ²

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/>)

Bieger, Katrin; Rathjens, Hendrik; Allen, Peter M.; and Arnold, Jeffrey G., 2015, Development and Evaluation of Bankfull Hydraulic Geometry Relationships for the Physiographic Regions of the United States, Publications from USDA-ARS / UNL Faculty, 17p. (https://digitalcommons.unl.edu/usdaarsfacpub/1515?utm_source=digitalcommons.unl.edu%2Fusdaarsfacpub%2F1515&utm_medium=PDF&utm_can)

Probability Statistics Parameters [Perennial Flow Probability]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.41	square miles	0.01	1.99
PCTSNDGRV	Percent Underlain By Sand And Gravel	79.32	percent	0	100
FOREST	Percent Forest	16.31	percent	0	100
MAREGION	Massachusetts Region	1	dimensionless	0	1

Probability Statistics Flow Report [Perennial Flow Probability]

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

Statistic	Value	Unit	PC
Probability Stream Flowing Perennially	0.96	dim	71

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: 4.7.0

StreamStats Services Version: 1.2.22

NSS Services Version: 2.1.2

Appendix B

HEC-HMS Hydraulic Model Summary Report



HEC-HMS Hydrologic Model Summary

Existing 1-year, 24-hour storm

Project: QueensvilleDam Simulation Run: 1-year
Subbasin: Subbasin-1

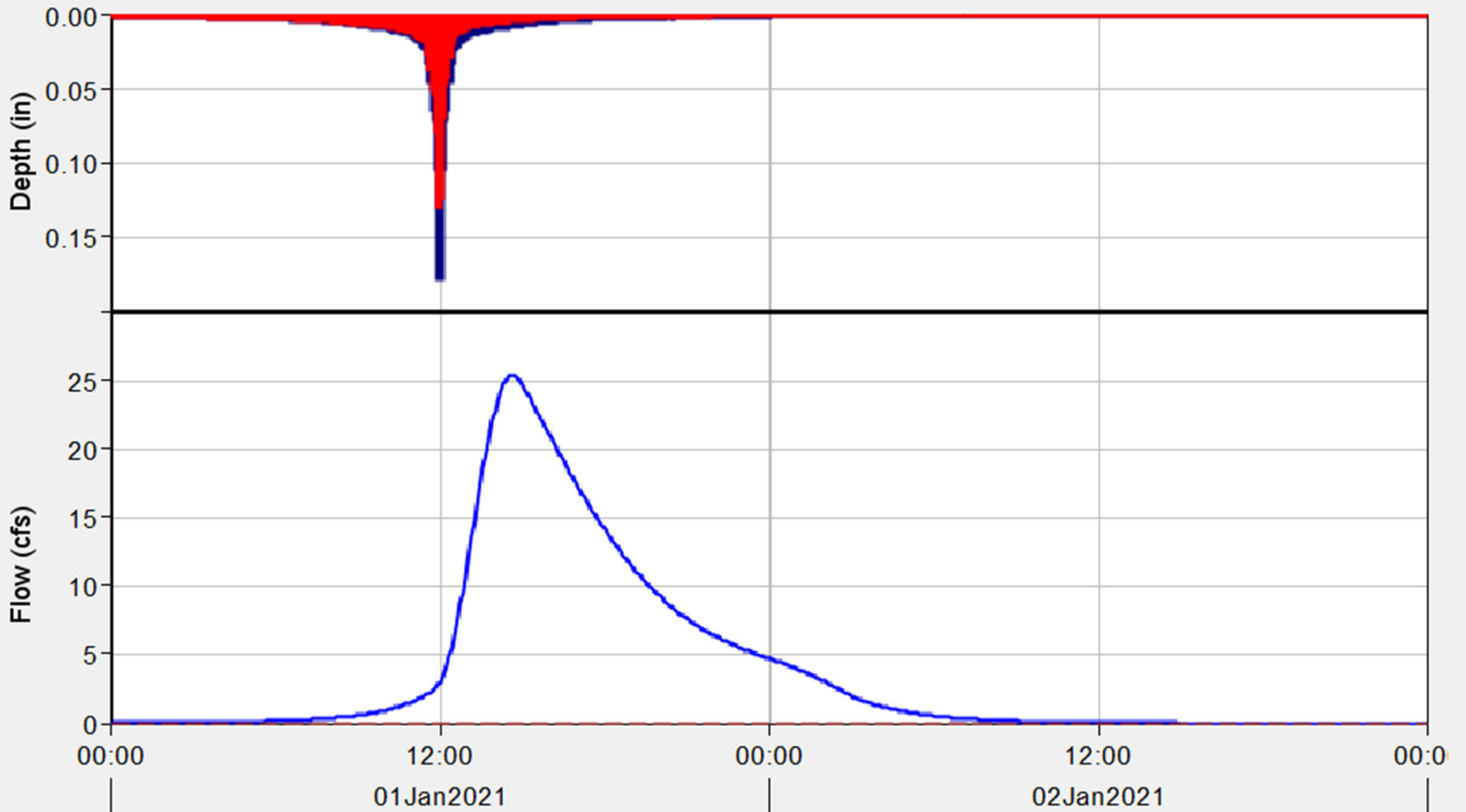
Start of Run: 01Jan2021, 00:00	Basin Model: Basin 1
End of Run: 03Jan2021, 00:00	Meteorologic Model: 1-year
Compute Time: 31Jan2022, 08:15:40	Control Specifications: Control 1

Volume Units: IN ACRE-FT

Computed Results

Peak Discharge: 25.4 (CFS)	Date/Time of Peak Discharge: 01Jan2021, 14:40
Precipitation Volume: 2.46 (IN)	Direct Runoff Volume: 0.67 (IN)
Loss Volume: 1.79 (IN)	Baseflow Volume: 0.00 (IN)
Excess Volume: 0.67 (IN)	Discharge Volume: 0.67 (IN)

Subbasin "Subbasin-1" Results for Run "1-year"



Legend (Compute Time: 31Jan2022, 08:15:40)

— Run: 1-year Element: Subbasin-1 Result: Precipit...
— Run: 1-year Element: Subbasin-1 Result: O...

— Run: 1-year Element: Subbasin-1 Result: Precipitation ...
- - - Run: 1-year Element: Subbasin-1 Result: Bas...

Future (2070) 1-year, 24-hour storm

Project: QueensvilleDam Simulation Run: 1-year 2070
 Subbasin: Subbasin-1

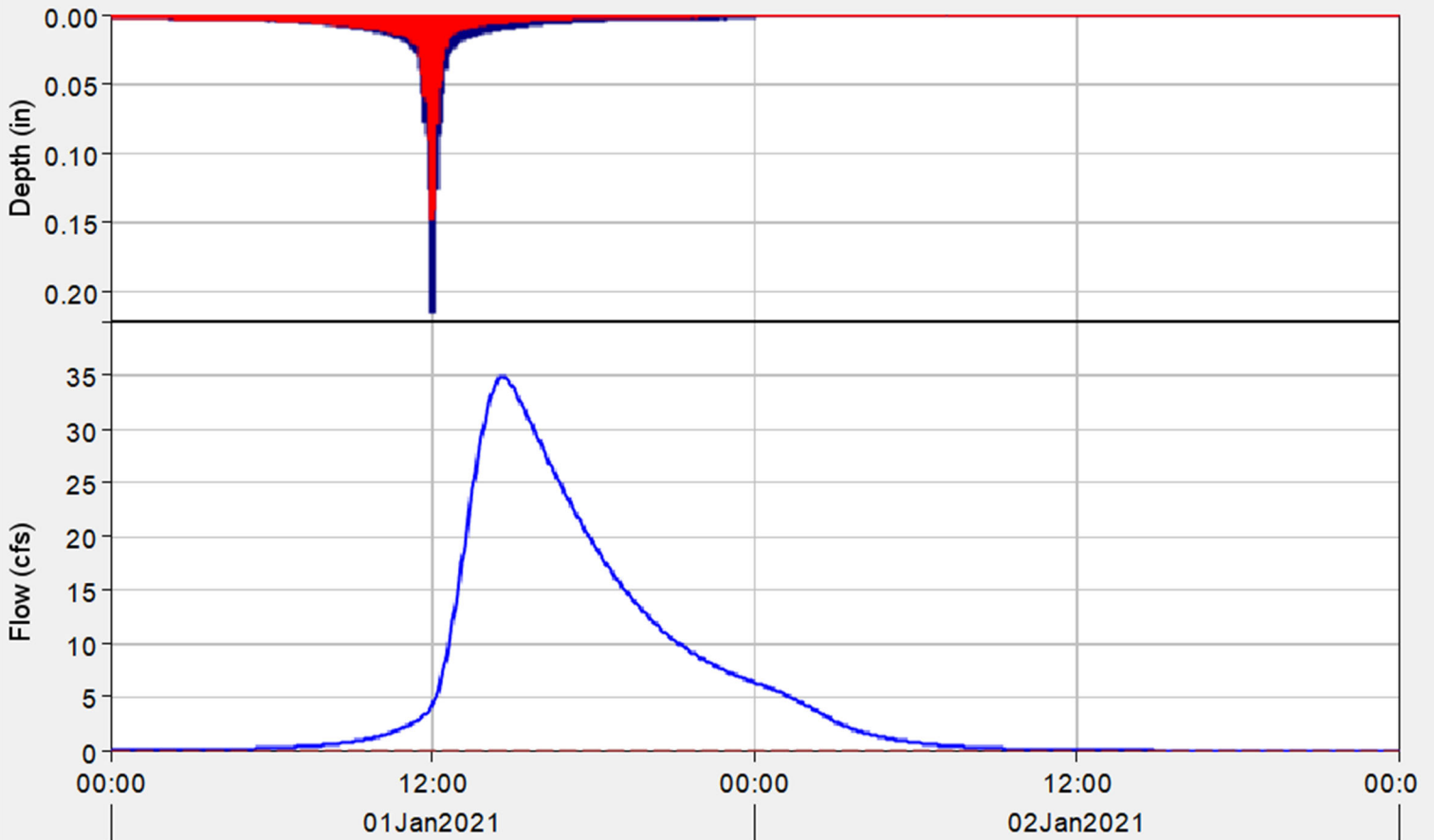
Start of Run: 01Jan2021, 00:00 Basin Model: Basin 1
 End of Run: 03Jan2021, 00:00 Meteorologic Model: 1-year 2070
 Compute Time: 31Jan2022, 08:34:43 Control Specifications: Control 1

Volume Units: IN ACRE-FT

Computed Results

Peak Discharge: 34.9 (CFS)	Date/Time of Peak Discharge: 01Jan2021, 14:35
Precipitation Volume: 2.95 (IN)	Direct Runoff Volume: 0.91 (IN)
Loss Volume: 2.04 (IN)	Baseflow Volume: 0.00 (IN)
Excess Volume: 0.91 (IN)	Discharge Volume: 0.91 (IN)

Subbasin "Subbasin-1" Results for Run "1-year 2070"



Legend (Compute Time: 31Jan2022, 08:34:43)

- █ Run:1-year 2070 Element:Subbasin-1 Result:Precipit...
- █ Run:1-year 2070 Element:Subbasin-1 Result:Precipitation ...
- █ Run:1-year 2070 Element:Subbasin-1 Result:O...
- - - Run:1-year 2070 Element:Subbasin-1 Result:Bas...

Existing 10-year, 24-hour storm

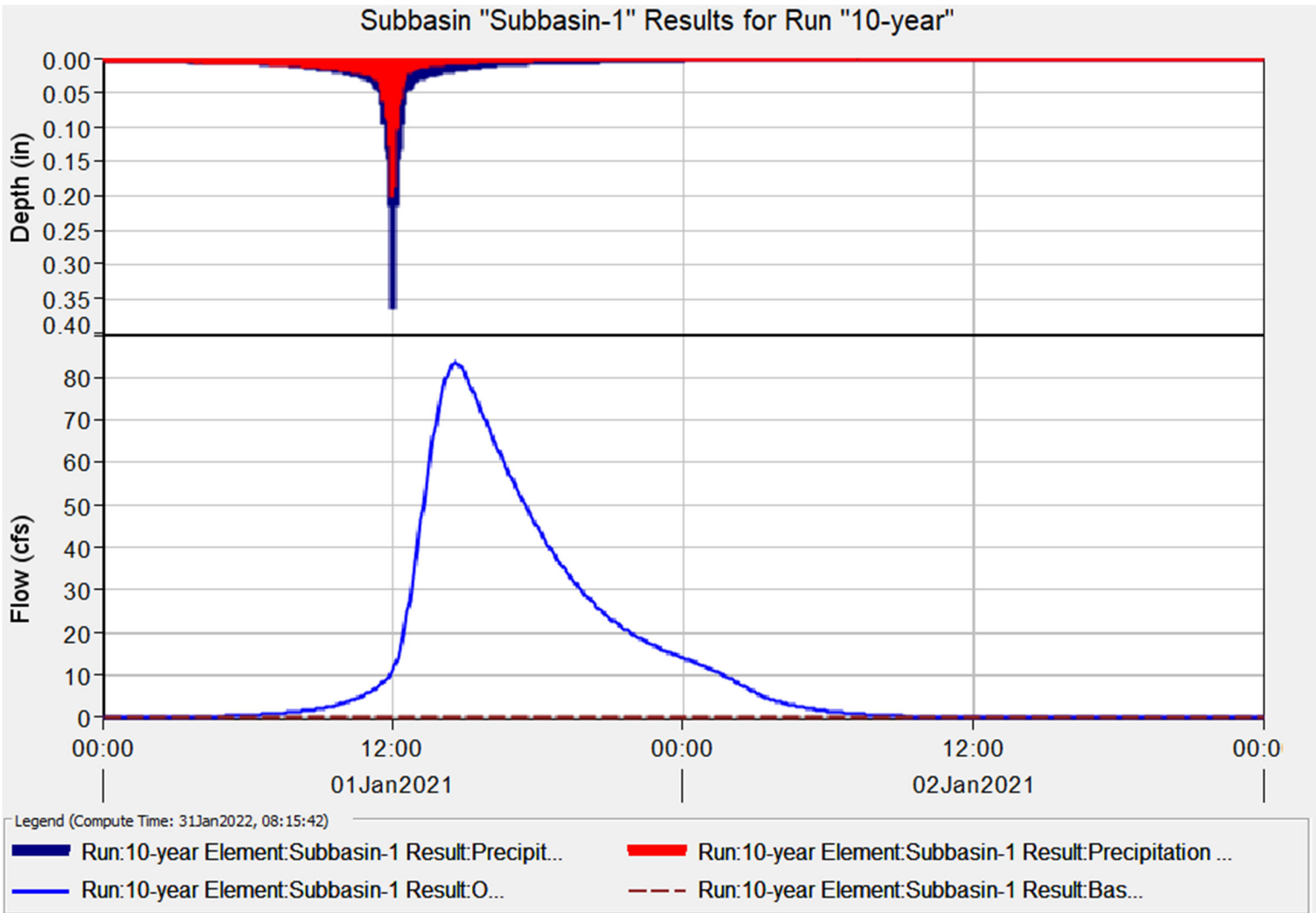
Project: QueensvilleDam Simulation Run: 10-year
Subbasin: Subbasin-1

Start of Run: 01Jan2021, 00:00	Basin Model: Basin 1
End of Run: 03Jan2021, 00:00	Meteorologic Model: 10-year
Compute Time: 31Jan2022, 08:15:42	Control Specifications: Control 1

Volume Units: IN ACRE-FT

Computed Results

Peak Discharge: 83.5 (CFS)	Date/Time of Peak Discharge: 01Jan2021, 14:35
Precipitation Volume: 4.98 (IN)	Direct Runoff Volume: 2.14 (IN)
Loss Volume: 2.84 (IN)	Baseflow Volume: 0.00 (IN)
Excess Volume: 2.14 (IN)	Discharge Volume: 2.14 (IN)



Future (2070) 10-year, 24-hour storm

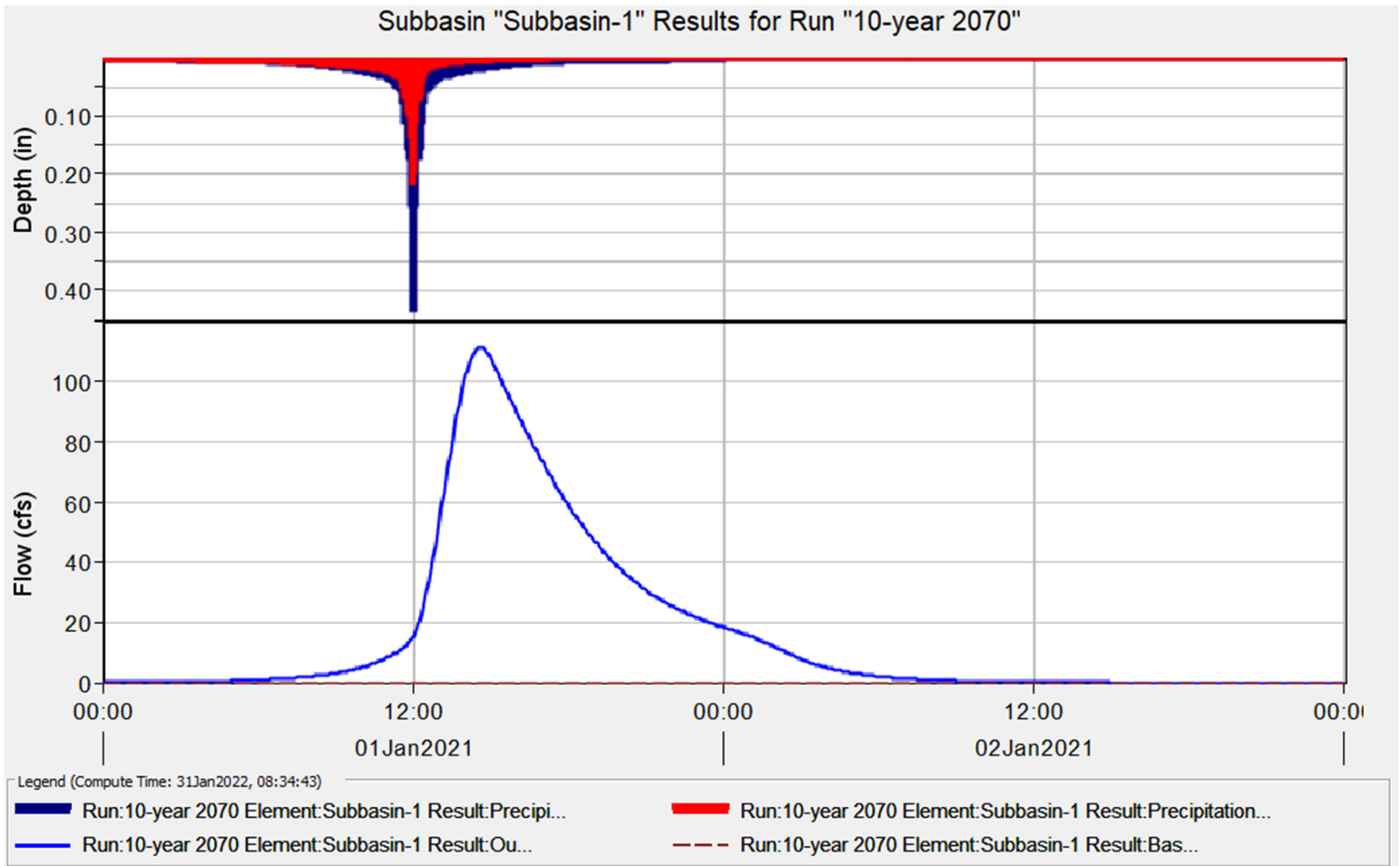
Project: QueensvilleDam Simulation Run: 10-year 2070
 Subbasin: Subbasin-1

Start of Run: 01Jan2021, 00:00	Basin Model: Basin 1
End of Run: 03Jan2021, 00:00	Meteorologic Model: 10-year 2070
Compute Time: 31Jan2022, 08:34:43	Control Specifications: Control 1

Volume Units: IN ACRE-FT

Computed Results

Peak Discharge: 111.6 (CFS)	Date/Time of Peak Discharge: 01Jan2021, 14:35
Precipitation Volume: 5.98 (IN)	Direct Runoff Volume: 2.84 (IN)
Loss Volume: 3.14 (IN)	Baseflow Volume: 0.00 (IN)
Excess Volume: 2.84 (IN)	Discharge Volume: 2.84 (IN)



25-year, 24-hour storm

Project: QueensvilleDam Simulation Run: 25-year
 Subbasin: Subbasin-1

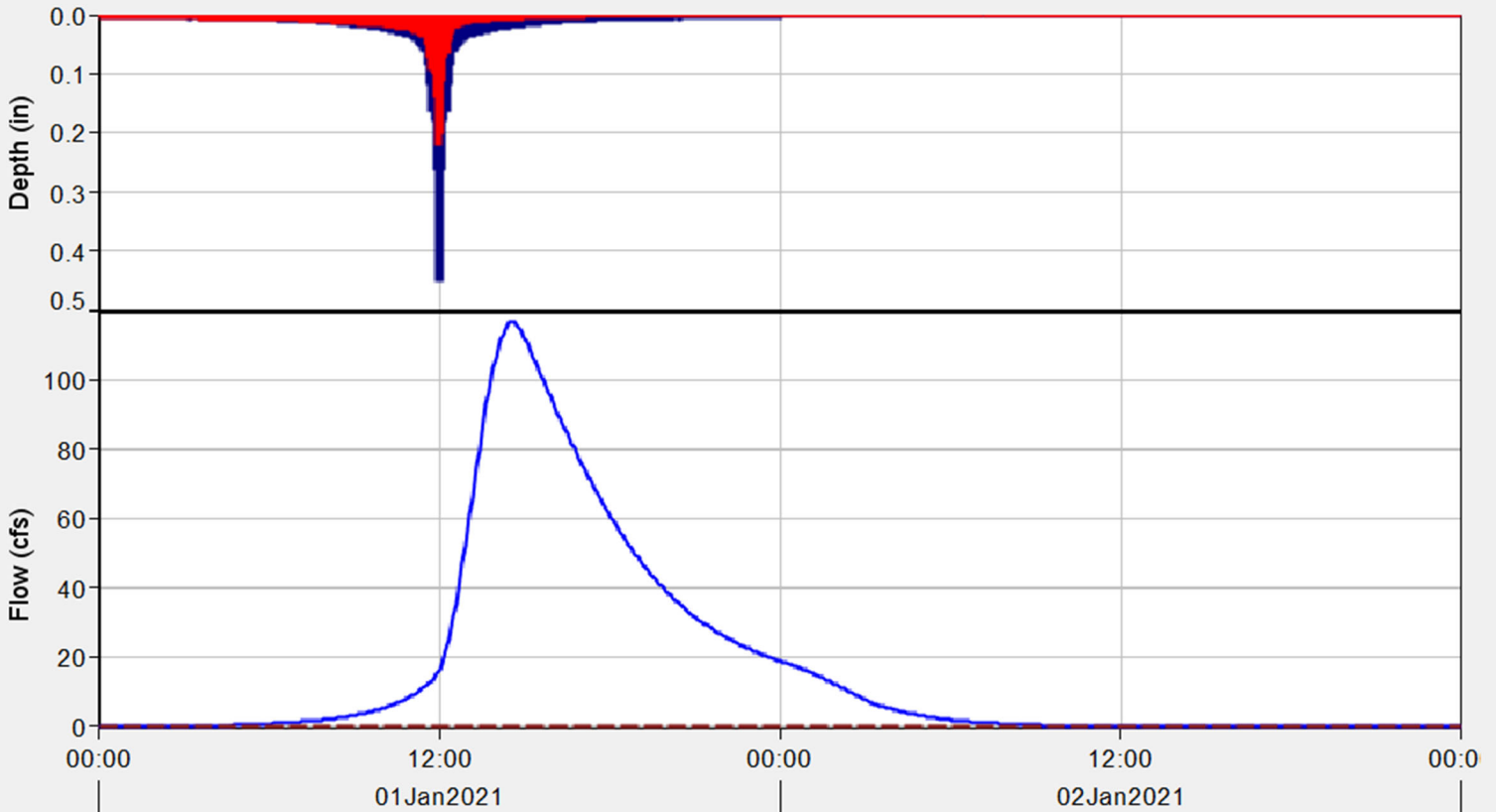
Start of Run: 01Jan2021, 00:00 Basin Model: Basin 1
 End of Run: 03Jan2021, 00:00 Meteorologic Model: 25-year
 Compute Time: 31Jan2022, 08:15:49 Control Specifications: Control 1

Volume Units: IN ACRE-FT

Computed Results

Peak Discharge:	117.1 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 14:35
Precipitation Volume:	6.17 (IN)	Direct Runoff Volume:	2.98 (IN)
Loss Volume:	3.19 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	2.98 (IN)	Discharge Volume:	2.98 (IN)

Subbasin "Subbasin-1" Results for Run "25-year"



Legend (Compute Time: 31Jan2022, 08:15:49)

- █ Run:25-year Element:Subbasin-1 Result:Precipit...
- █ Run:25-year Element:Subbasin-1 Result:Precipitation ...
- Run:25-year Element:Subbasin-1 Result:O...
- - - Run:25-year Element:Subbasin-1 Result:Bas...

Future (2070) 25-year, 24-hour storm

Project: QueensvilleDam Simulation Run: 25-year 2070
Subbasin: Subbasin-1

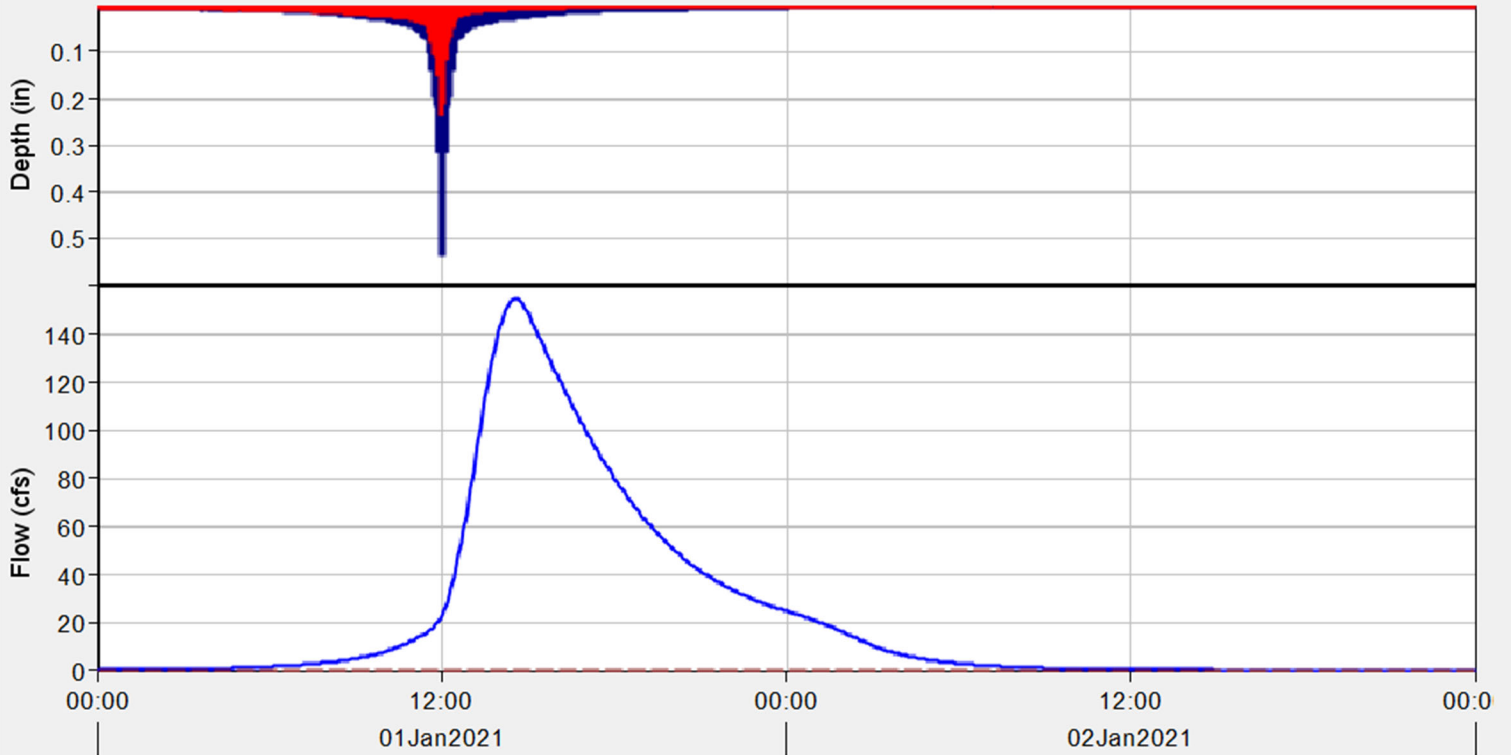
Start of Run: 01Jan2021, 00:00	Basin Model: Basin 1
End of Run: 03Jan2021, 00:00	Meteorologic Model: 25-year 2070
Compute Time: 31Jan2022, 08:34:45	Control Specifications: Control 1

Volume Units: IN ACRE-FT

Computed Results

Peak Discharge: 154.6 (CFS)	Date/Time of Peak Discharge: 01Jan2021, 14:35
Precipitation Volume: 7.40 (IN)	Direct Runoff Volume: 3.91 (IN)
Loss Volume: 3.49 (IN)	Baseflow Volume: 0.00 (IN)
Excess Volume: 3.91 (IN)	Discharge Volume: 3.91 (IN)

Subbasin "Subbasin-1" Results for Run "25-year 2070"



Legend (Compute Time: 31Jan2022, 08:34:45)

— Run:25-year 2070 Element:Subbasin-1 Result:Precipi...	— Run:25-year 2070 Element:Subbasin-1 Result:Precipitation...
— Run:25-year 2070 Element:Subbasin-1 Result:Ou...	- - - Run:25-year 2070 Element:Subbasin-1 Result:Bas...

50-year, 24-hour storm

Project: QueensvilleDam Simulation Run: 50-year
Subbasin: Subbasin-1

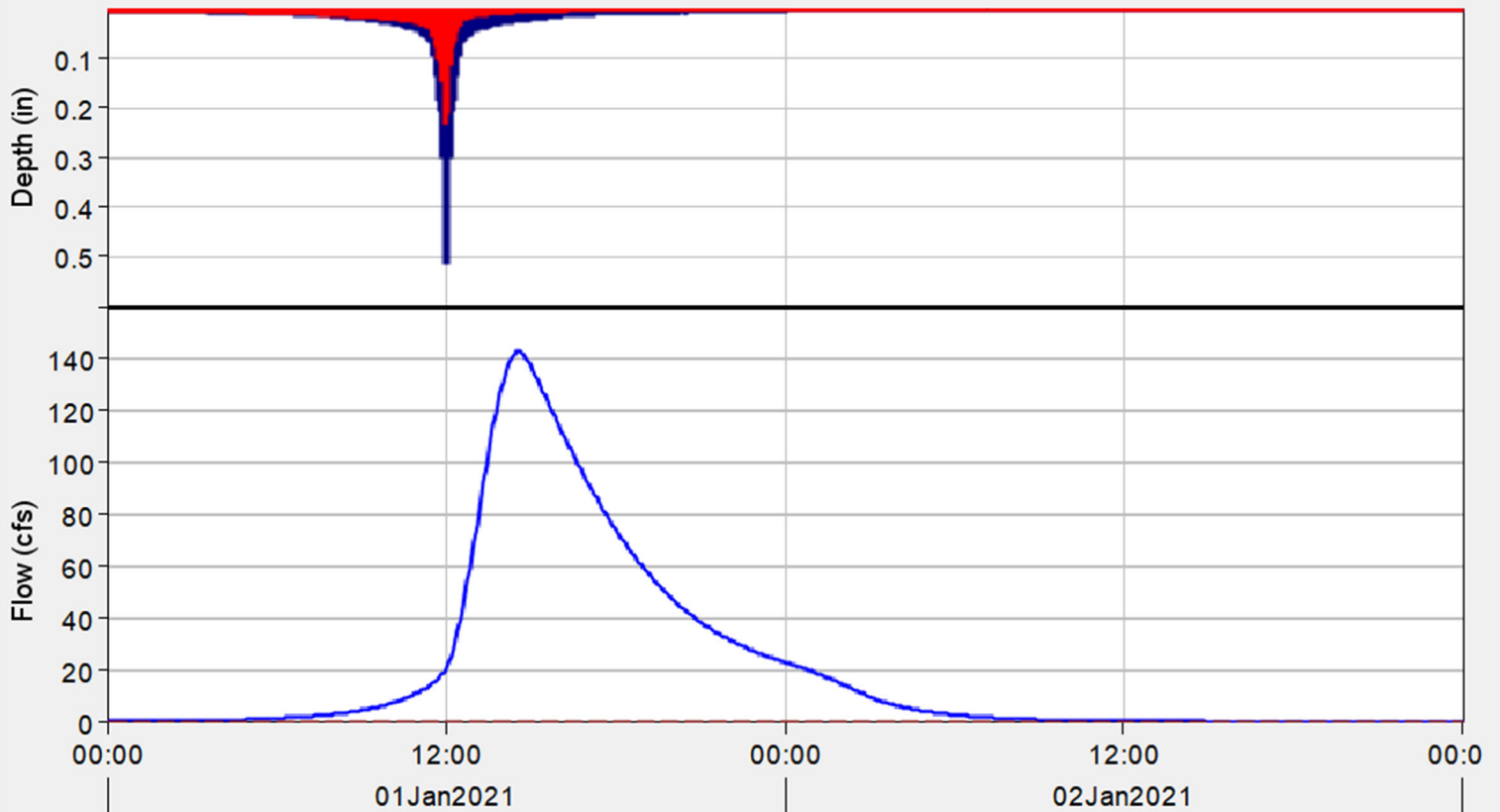
Start of Run: 01Jan2021, 00:00	Basin Model: Basin 1
End of Run: 03Jan2021, 00:00	Meteorologic Model: 50-year
Compute Time: 31Jan2022, 08:15:53	Control Specifications: Control 1

Volume Units: IN ACRE-FT

Computed Results

Peak Discharge: 143.1 (CFS)	Date/Time of Peak Discharge: 01Jan2021, 14:35
Precipitation Volume: 7.03 (IN)	Direct Runoff Volume: 3.62 (IN)
Loss Volume: 3.41 (IN)	Baseflow Volume: 0.00 (IN)
Excess Volume: 3.62 (IN)	Discharge Volume: 3.62 (IN)

Subbasin "Subbasin-1" Results for Run "50-year"



Legend (Compute Time: 31Jan2022, 08:15:53)

- █ Run:50-year Element:Subbasin-1 Result:Precipitation
- █ Run:50-year Element:Subbasin-1 Result:Precipitation Loss
- Run:50-year Element:Subbasin-1 Result:Outflow
- - - Run:50-year Element:Subbasin-1 Result:Baseflow

Future (2070) 50-year, 24-hour storm

Project: QueensvilleDam Simulation Run: 50-year 2070
Subbasin: Subbasin-1

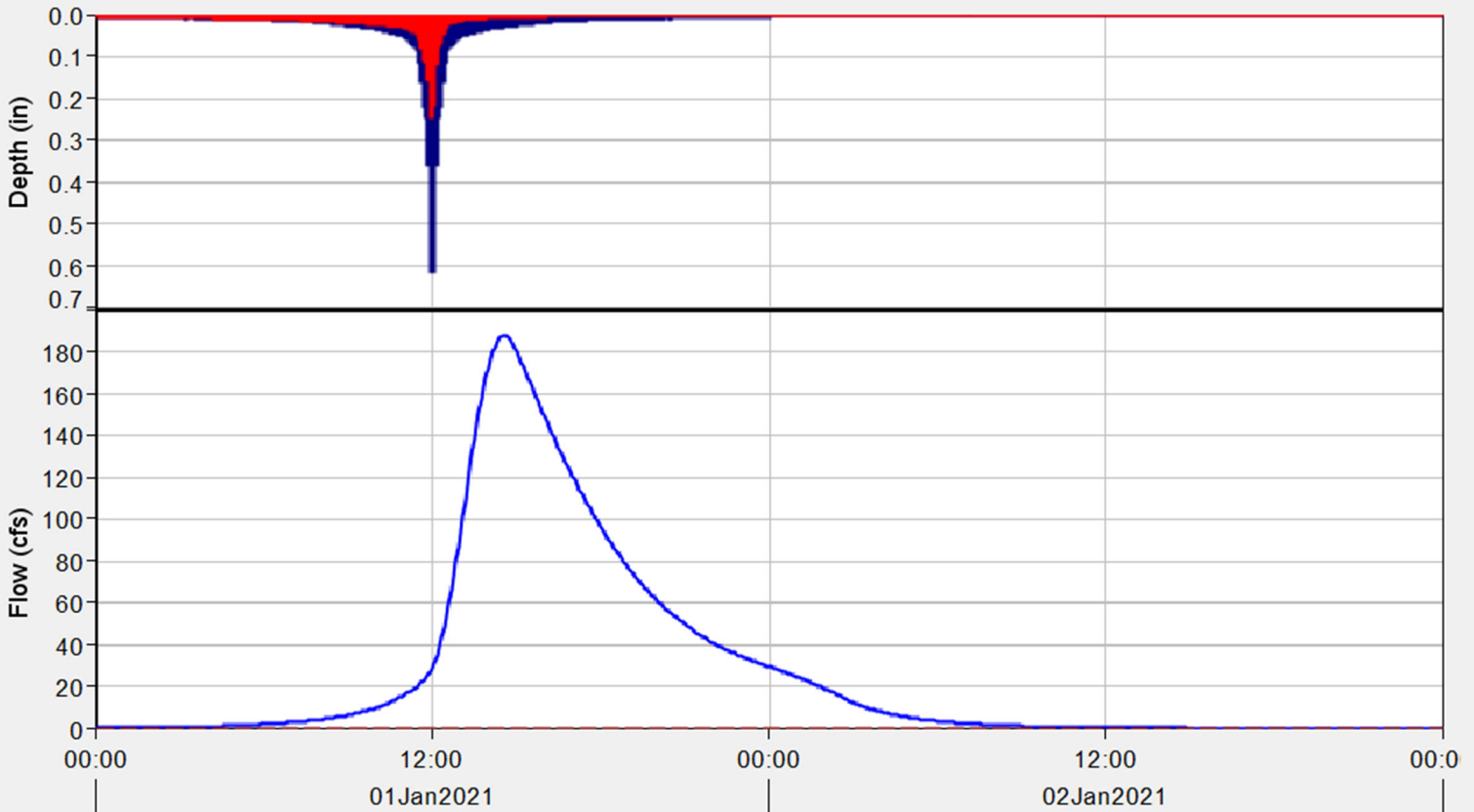
Start of Run: 01Jan2021, 00:00	Basin Model: Basin 1
End of Run: 03Jan2021, 00:00	Meteorologic Model: 50-year 2070
Compute Time: 31Jan2022, 08:34:45	Control Specifications: Control 1

Volume Units: IN ACRE-FT

Computed Results

Peak Discharge: 187.9 (CFS)	Date/Time of Peak Discharge: 01Jan2021, 14:35
Precipitation Volume: 8.44 (IN)	Direct Runoff Volume: 4.73 (IN)
Loss Volume: 3.71 (IN)	Baseflow Volume: 0.00 (IN)
Excess Volume: 4.73 (IN)	Discharge Volume: 4.73 (IN)

Subbasin "Subbasin-1" Results for Run "50-year 2070"



Legend (Compute Time: 31Jan2022, 08:34:45)

- █ Run:50-year 2070 Element:Subbasin-1 Result:Precipit...
- █ Run:50-year 2070 Element:Subbasin-1 Result:Precipitation ...
- Run:50-year 2070 Element:Subbasin-1 Result:O...
- - - Run:50-year 2070 Element:Subbasin-1 Result:Bas...

100-year, 24-hour storm

Project: QueensvilleDam Simulation Run: 100-year
 Subbasin: Subbasin-1

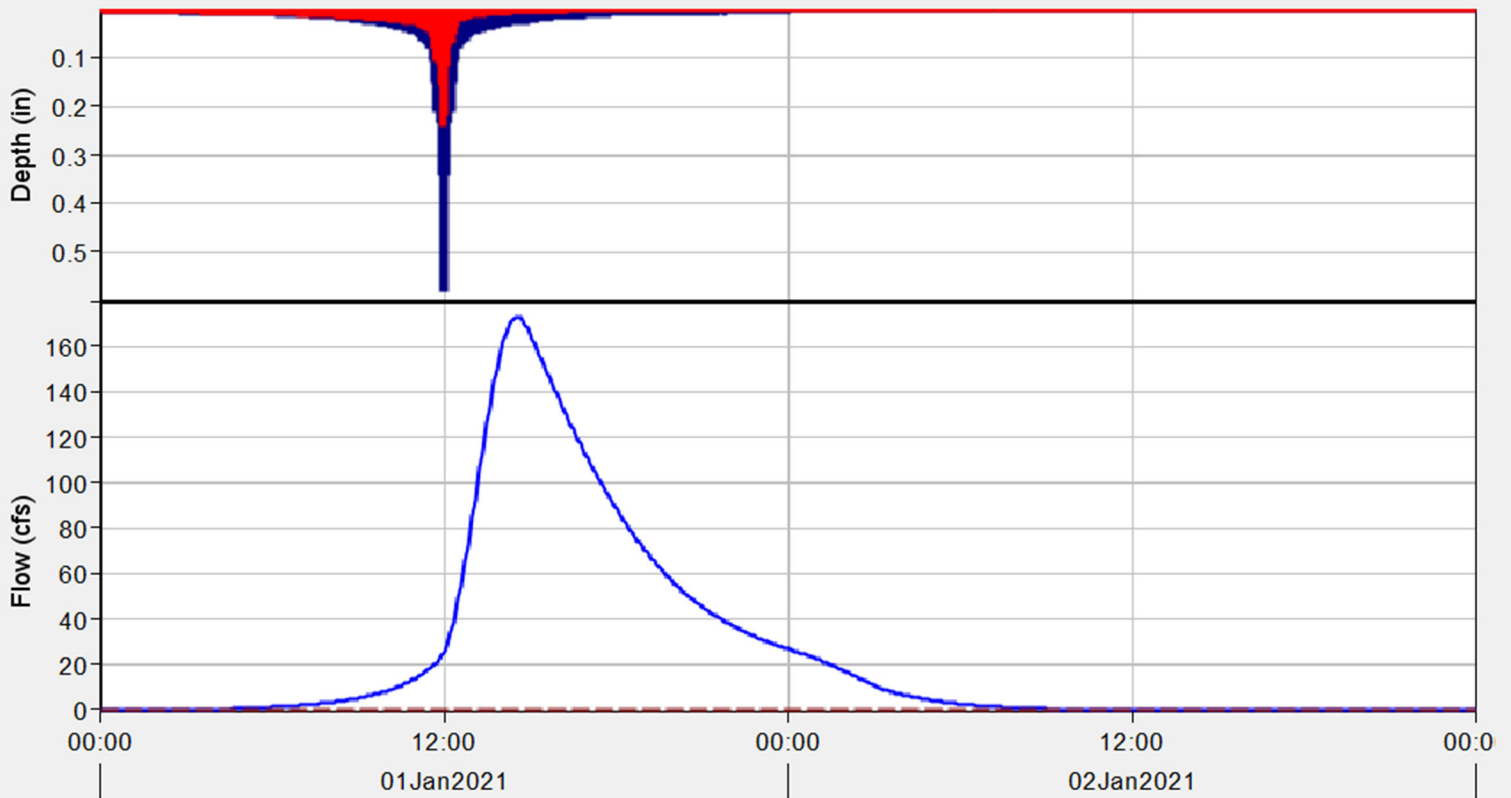
Start of Run: 01Jan2021, 00:00 Basin Model: Basin 1
 End of Run: 03Jan2021, 00:00 Meteorologic Model: 100-year
 Compute Time: 31Jan2022, 08:15:44 Control Specifications: Control 1

Volume Units: IN ACRE-FT

Computed Results

Peak Discharge:	173.3 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 14:35
Precipitation Volume:	7.99 (IN)	Direct Runoff Volume:	4.37 (IN)
Loss Volume:	3.62 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	4.37 (IN)	Discharge Volume:	4.37 (IN)

Subbasin "Subbasin-1" Results for Run "100-year"



Legend (Compute Time: 31Jan2022, 08:15:44)

- █ Run:100-year Element:Subbasin-1 Result:Precipit...
- █ Run:100-year Element:Subbasin-1 Result:Precipitation ...
- █ Run:100-year Element:Subbasin-1 Result:O...
- - - Run:100-year Element:Subbasin-1 Result:Bas...

Future (2070) 100-year, 24-hour storm

Project: QueensvilleDam Simulation Run: 100-year 2070
Subbasin: Subbasin-1

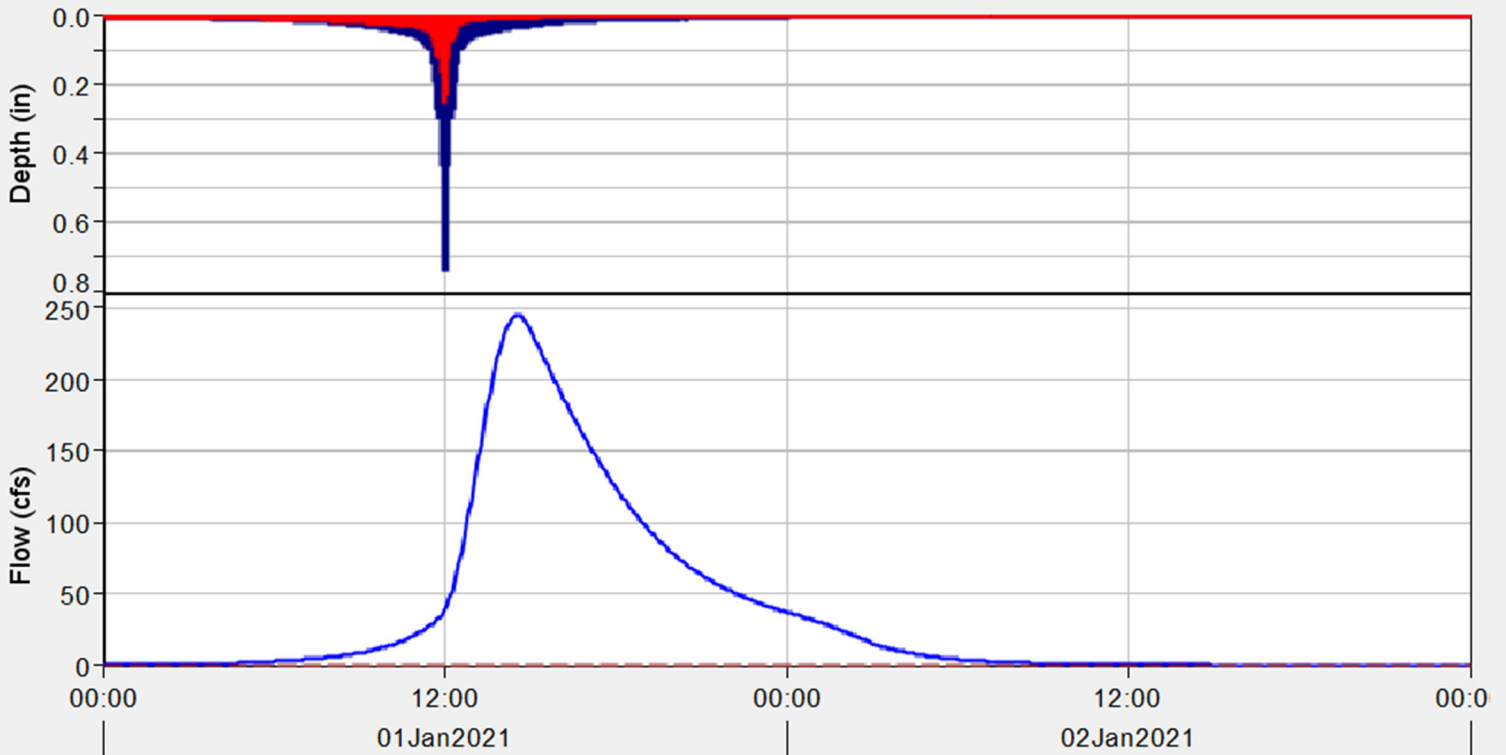
Start of Run: 01Jan2021, 00:00	Basin Model: Basin 1
End of Run: 03Jan2021, 00:00	Meteorologic Model: 100-year 2070
Compute Time: 31Jan2022, 08:34:44	Control Specifications: Control 1

Volume Units: IN ACRE-FT

Computed Results

Peak Discharge: 245.1 (CFS)	Date/Time of Peak Discharge: 01Jan2021, 14:35
Precipitation Volume: 10.15 (IN)	Direct Runoff Volume: 6.15 (IN)
Loss Volume: 4.00 (IN)	Baseflow Volume: 0.00 (IN)
Excess Volume: 6.15 (IN)	Discharge Volume: 6.15 (IN)

Subbasin "Subbasin-1" Results for Run "100-year 2070"

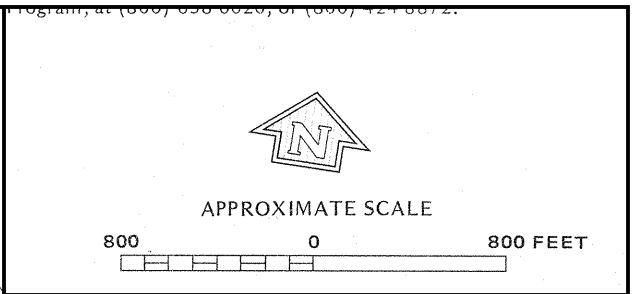
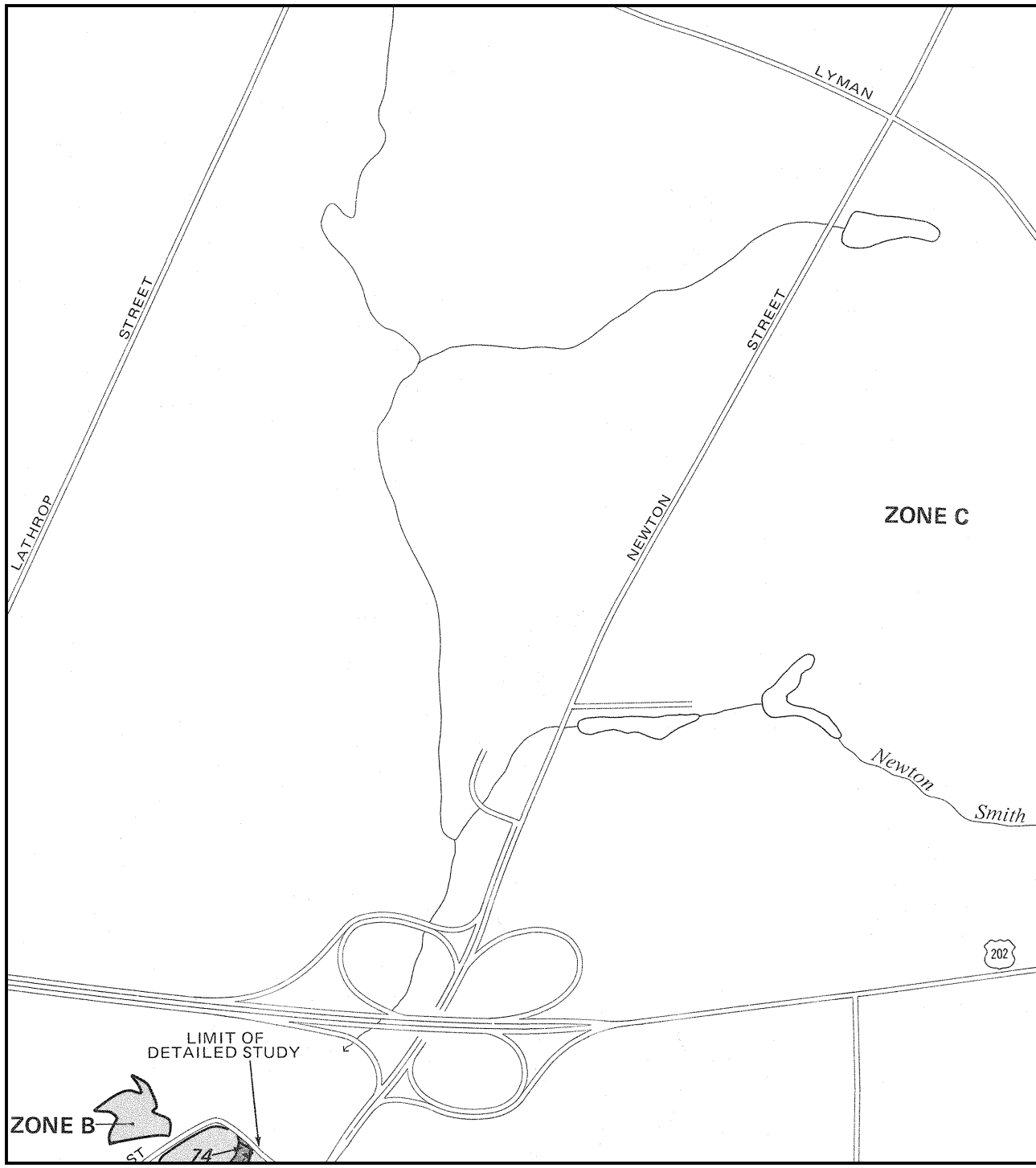


Legend (Compute Time: 31Jan2022, 08:34:44)

- █ Run:100-year 2070 Element:Subbasin-1 Result:Precipit...
- █ Run:100-year 2070 Element:Subbasin-1 Result:Precipitation ...
- █ Run:100-year 2070 Element:Subbasin-1 Result:O...
- - - Run:100-year 2070 Element:Subbasin-1 Result:Bas...

Appendix C

Supporting Information for Hydraulic Model Development



NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

TOWN OF
SOUTH HADLEY,
MASSACHUSETTS
HAMPSHIRE COUNTY

PANEL 10 OF 10
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
250170 0010 A

EFFECTIVE DATE:
AUGUST 15, 1979

U.S. DEPARTMENT OF HOUSING
AND URBAN DEVELOPMENT
FEDERAL INSURANCE ADMINISTRATION

This is an official FIRMette showing a portion of the above-referenced flood map created from the MSC FIRMette Web tool. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For additional information about how to make sure the map is current, please see the Flood Hazard Mapping Updates Overview Fact Sheet available on the FEMA Flood Map Service Center home page at <https://msc.fema.gov>.

Titus Pond/Buttery Brook
South Hadley, MA
Openness Ratio Calculation

	Newton Street (Alternative 1)	Mountain Avenue
Crossing Length (ft)	86	84
Cross Sectional Area of Opening (ft ²)	70	70
Openness Ratio	1.23	1.20

Appendix D

HEC-RAS Hydraulic Model Summary Report

HEC-RAS Hydraulic Model Summary

Existing Culvert at Newton Road

Culvert Group: **Culvert #1**

Solution Criteria: **Computed Flow Control**

Shape: **Circular** Span: **2** Diameter: **2**

Chart #: **1 - Concrete Pipe Culvert**

Scale #: **3 - Groove end entrance; pipe projecting from fill**

Distance to Upstrm XS: **2**

Culvert Length: **210**

Entrance Loss Coeff: **0.5**

Exit Loss Coeff: **1**

Manning's n for Top: **0.012**

Manning's n for Bottom: **0.012**

Depth to use Bottom n: **0**

Depth Blocked: **0**

Upstream Invert Elev: **160.2**

Downstream Invert Elev: **144**

Culvert Barrel Data

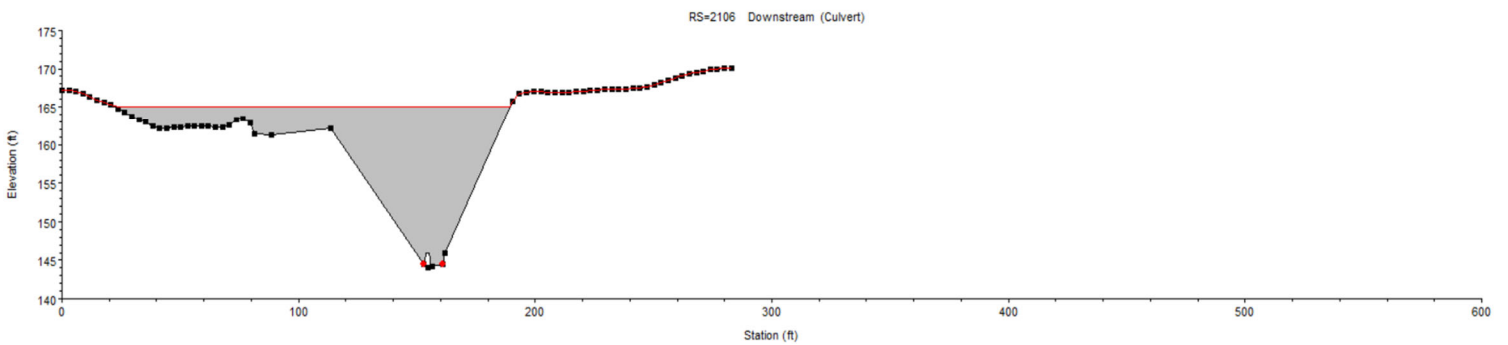
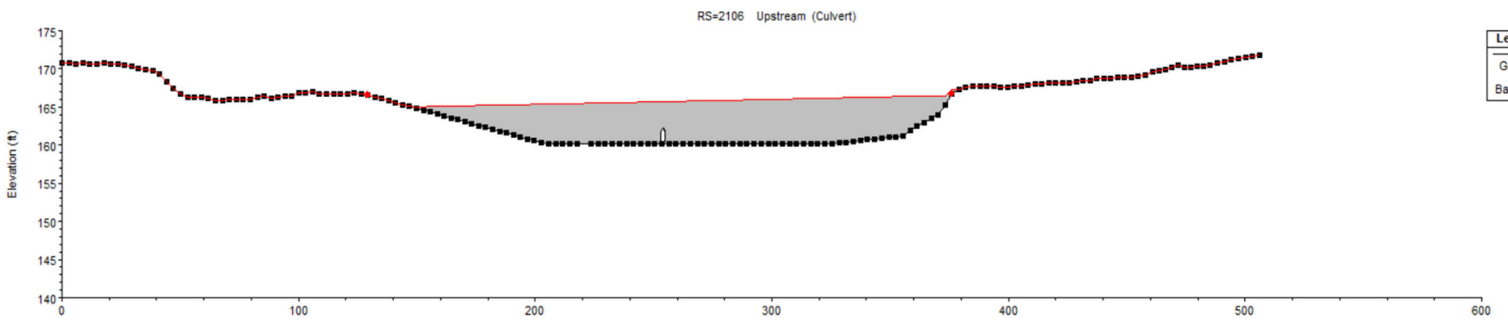
Barrel Centerline Stations # Barrels: **1**

	Barrel Name	US Sta	DS Sta
1	barrel 1	254	154.5
2			
3			
4			
5			

Barrel GIS Data: barrel 1 Length: 0

	X	Y
1		
2		
3		
4		
5		

Individual Barrel Centerlines ... Show on Map OK Cancel Help



Proposed Culvert at Newton Road (Alternative 1)

Culvert Group: **Culvert #1**

Solution Criteria: **Computed Flow Control**

Shape: **Box** Span: **14** Rise: **5**

Chart #: **8 - flared wingwalls**

Scale #: **1 - Wingwall flared 30 to 75 deg.**

Distance to Upstrm XS: **2**

Culvert Length: **86**

Entrance Loss Coeff: **0.5**

Exit Loss Coeff: **1**

Manning's n for Top: **0.012**

Manning's n for Bottom: **0.04**

Depth to use Bottom n: **0**

Depth Blocked: **0**

Upstream Invert Elev: **152**

Downstream Invert Elev: **150.05**

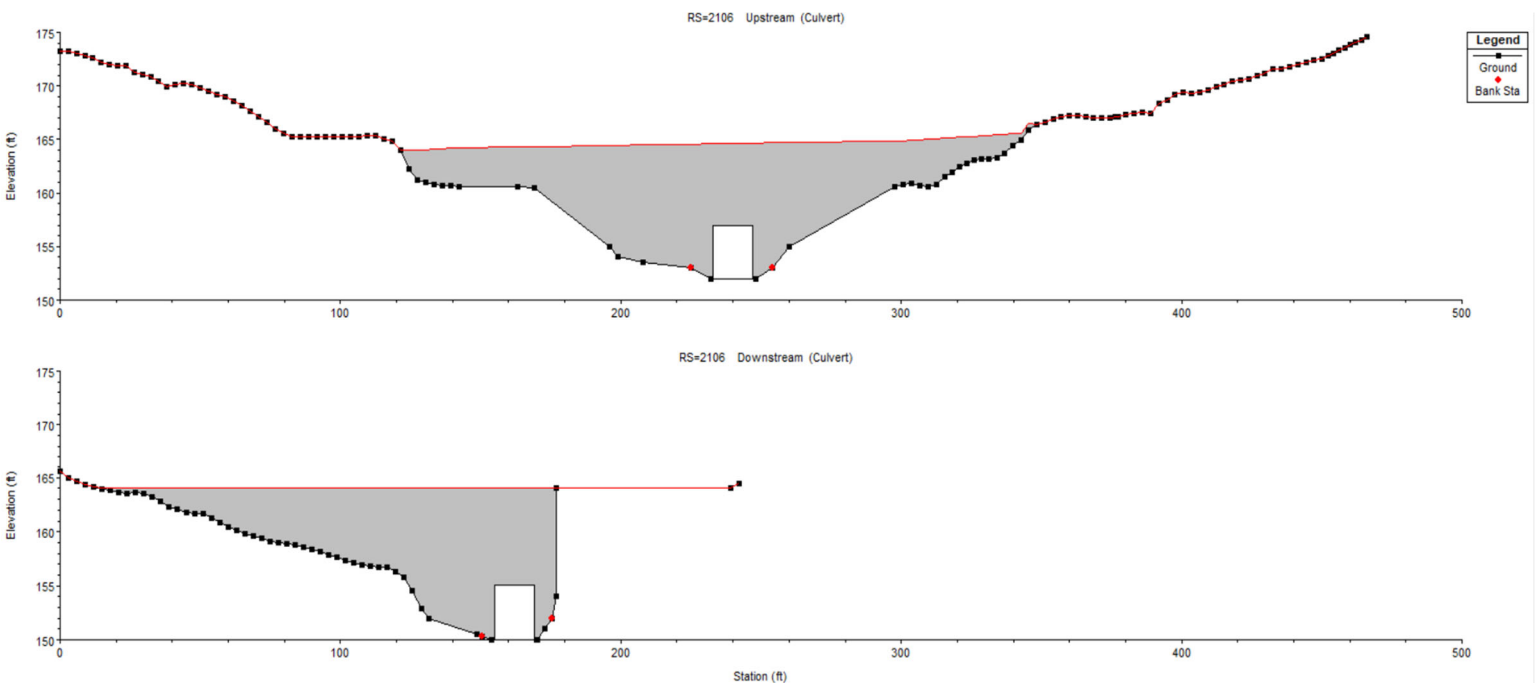
Culvert Barrel Data

Barrel Centerline Stations				# Barrels :
	Barrel Name	US Sta	DS Sta	
1	barrel 1	240	162	▲
2				
3				
4				
5				

Barrel GIS Data: barrel 1
Length: 0

	X	Y	
1			▲
2			
3			
4			
5			

Individual Barrel Centerlines ... Show on Map OK Cancel Help



Proposed Culvert at Newton Road (Alternatives 2 & 3)

Culvert Group: **Culvert #1**

Solution Criteria: **Computed Flow Control**

Shape: **Circular** Span: **2** Diameter: **2**

Chart #: **1 - Concrete Pipe Culvert**

Scale #: **3 - Groove end entrance; pipe projecting from fill**

Distance to Upstrm XS: **2**

Culvert Length: **210**

Entrance Loss Coeff: **0.5**

Exit Loss Coeff: **1**

Manning's n for Top: **0.012**

Manning's n for Bottom: **0.012**

Depth to use Bottom n: **0**

Depth Blocked: **0**

Upstream Invert Elev: **152**

Downstream Invert Elev: **144**

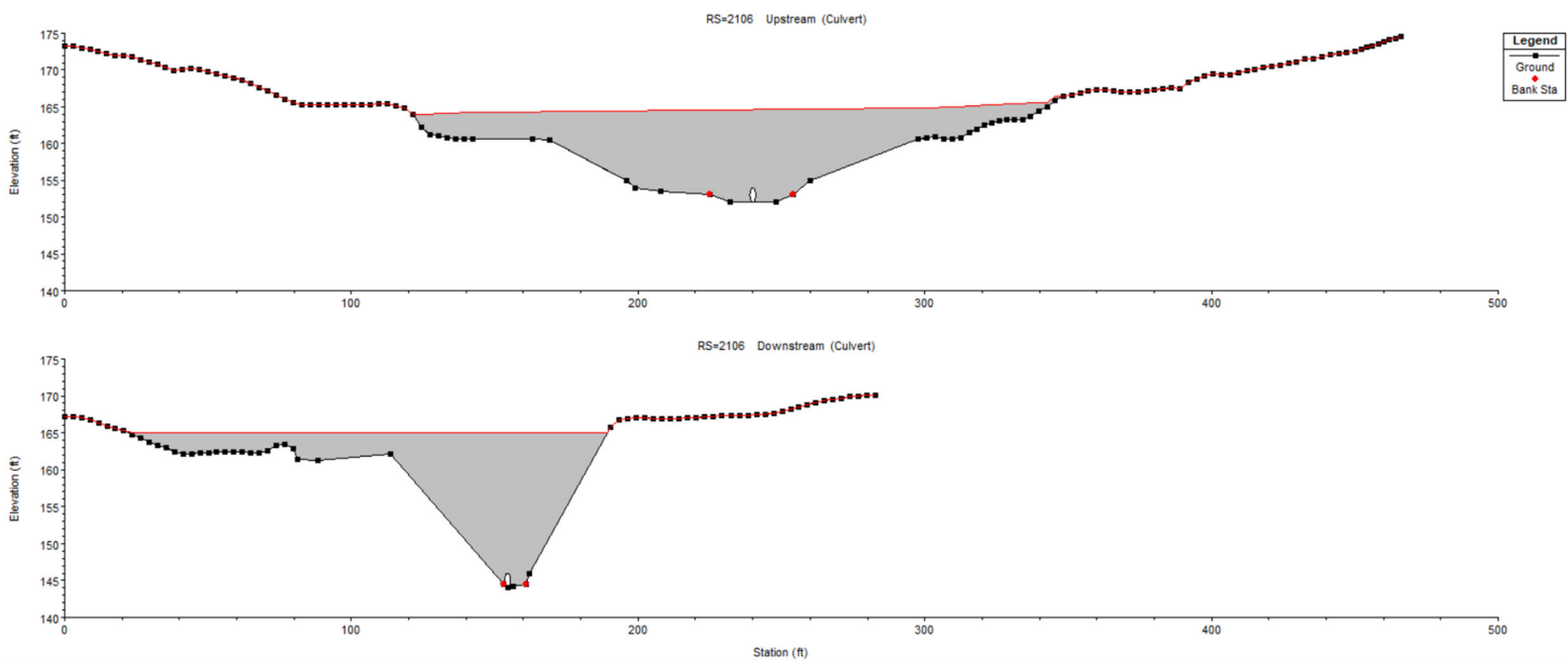
Culvert Barrel Data

Barrel Centerline Stations				# Barrels :
	Barrel Name	US Sta	DS Sta	
1	barrel 1	240	154.5	
2				
3				
4				
5				

Barrel GIS Data: barrel 1
Length: 0

	X	Y
1		
2		
3		
4		
5		

Individual Barrel Centerlines ... Show on Map OK Cancel Help



Existing Culvert at Mountain Avenue

Culvert Group: **Culvert #1**

Solution Criteria: **Computed Flow Control**

Shape: **Circular** Span: **2** Diameter: **2**

Chart #: **2 - Corrugated Metal Pipe Culvert**

Scale #: **3 - Pipe projecting from fill**

Distance to Upstrm XS: **2**

Culvert Length: **104**

Entrance Loss Coeff: **0.5**

Exit Loss Coeff: **1**

Manning's n for Top: **0.024**

Manning's n for Bottom: **0.024**

Depth to use Bottom n: **0**

Depth Blocked: **0**

Upstream Invert Elev: **135.7**

Downstream Invert Elev: **130.05**

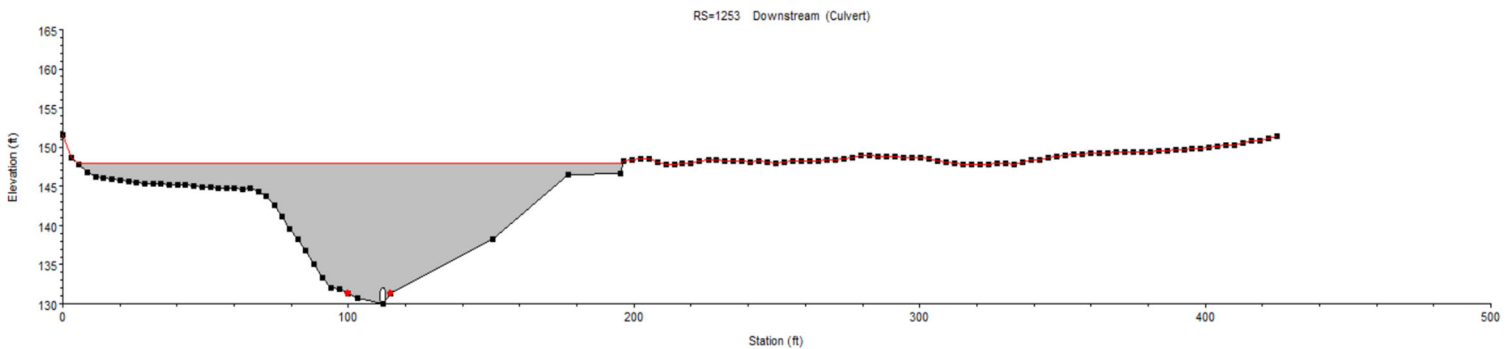
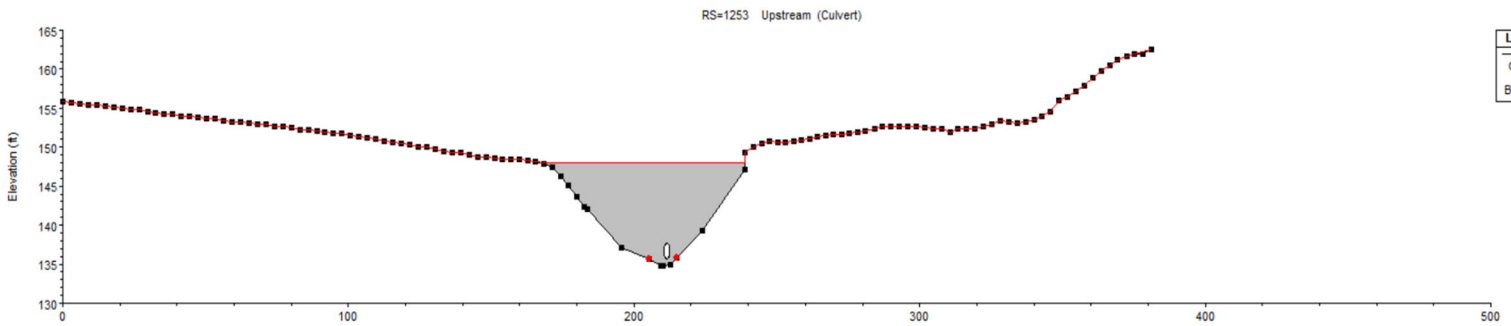
Culvert Barrel Data

Barrel Centerline Stations				# Barrels :
	Barrel Name	US Sta	DS Sta	
1	barrel 1	211.48	112	1
2				
3				
4				
5				

Barrel GIS Data: barrel 1
 Length: 0

	X	Y
1		
2		
3		
4		
5		

Individual Barrel Centerlines ... Show on Map OK Cancel Help



Proposed Culvert at Mountain Avenue

Culvert Group: **Culvert #1**

Solution Criteria: **Computed Flow Control**

Shape: **Box** Span: **14** Rise: **5**

Chart #: **8 - flared wingwalls**

Scale #: **1 - Wingwall flared 30 to 75 deg.**

Distance to Upstrm XS: **2**

Culvert Length: **84**

Entrance Loss Coeff: **0.5**

Exit Loss Coeff: **1**

Manning's n for Top: **0.024**

Manning's n for Bottom: **0.04**

Depth to use Bottom n: **0**

Depth Blocked: **0**

Upstream Invert Elev: **133**

Downstream Invert Elev: **131**

—Culvert Barrel Data

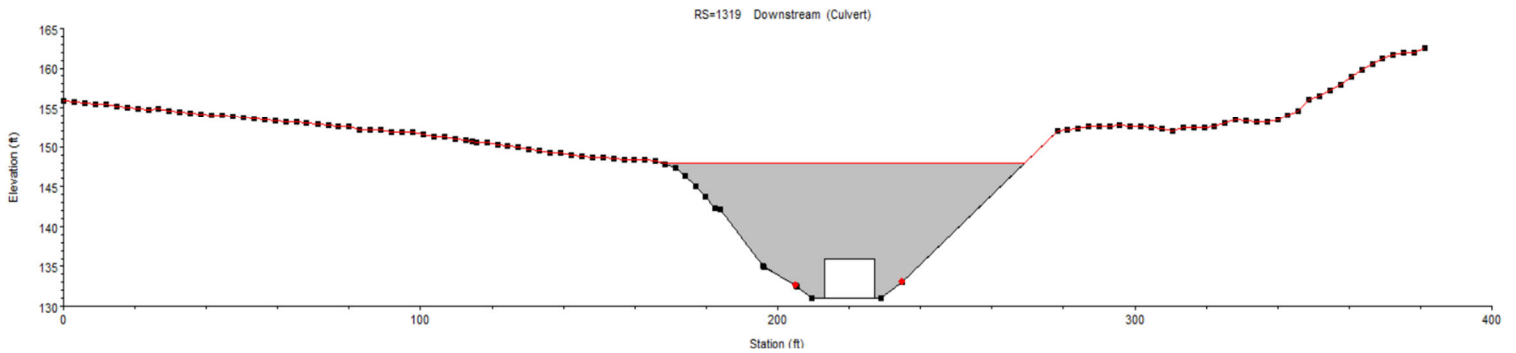
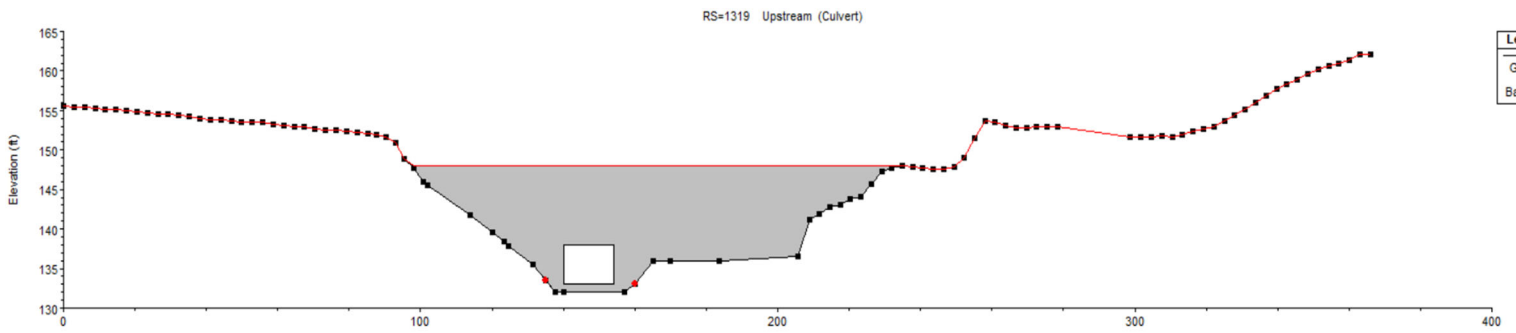
Barrel Centerline Stations # Barrels : **1**

	Barrel Name	US Sta	DS Sta
1	barrel 1	147	220
2			
3			
4			
5			

Barrel GIS Data: barrel 1
Length: 0

	X	Y
1		
2		
3		
4		
5		

Individual Barrel Centerlines ... Show on Map OK Cancel Help



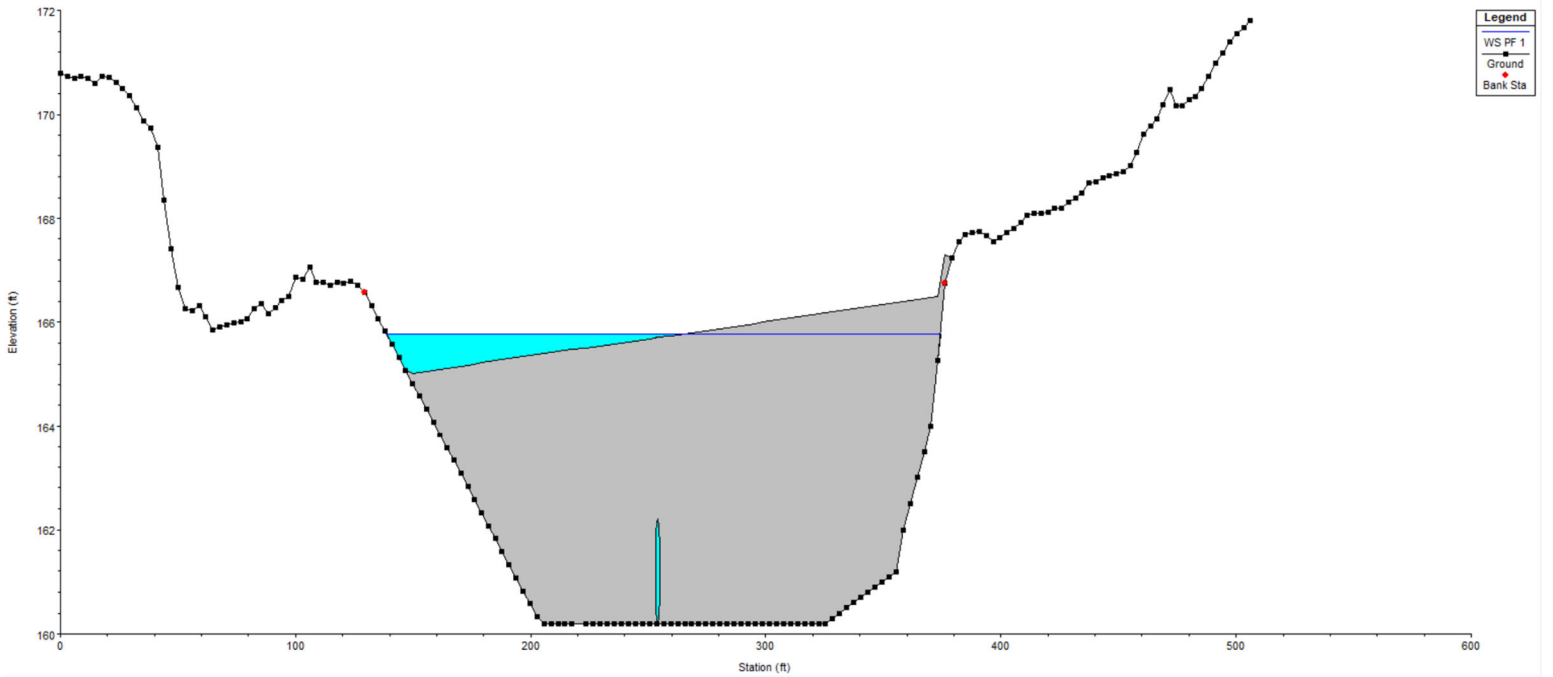
WSEL Summary Tables

Road Crossing	Flow Event	Existing Conditions WSEL (ft)	Proposed Alternative 1 (2022) WSEL (ft)	Proposed Alternative 1 (2070) WSEL (ft)	Proposed Alternative 2/3 (2022) WSEL (ft)	Proposed Alternative 2/3 (2070) WSEL (ft)
Newton Road (overtops at 165')	1-year existing	163.7	152.8	153.0	155.5	157.3
	10-year existing	165.5	153.8	154.1	165.0	165.0
	25-year existing	165.7	154.2	154.7	165.0	165.0
	50-year existing	165.8	154.5	155.1	165.0	165.0
	100-year existing	165.9	154.9	155.7	165.0	165.0

Road Crossing	Flow Event	Existing Conditions WSEL (ft)	Proposed Conditions (2022) WSEL (ft)	Proposed Conditions (2070) WSEL (ft)
Mountain Avenue (overtops at 148')	1-year existing	140.3	133.8	134.0
	10-year existing	148.4	135.4	135.6
	25-year existing	148.6	135.6	135.9
	50-year existing	148.7	135.8	136.1
	100-year existing	148.8	136.0	136.6

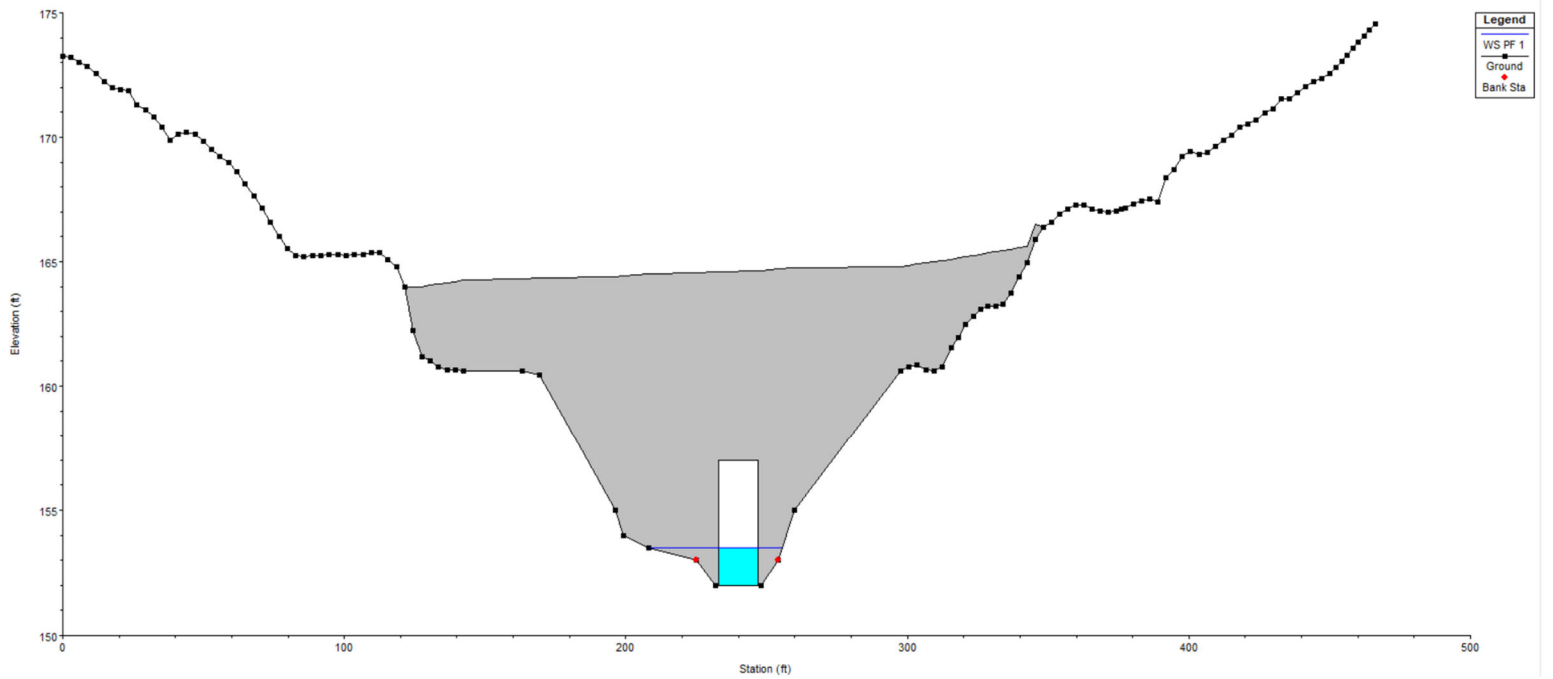
Newton Avenue; Existing Conditions WSEL (50-year storm)

SouthHadley Plan: 1) 50-year existing 3/4/2022
RS = 2106 Culv

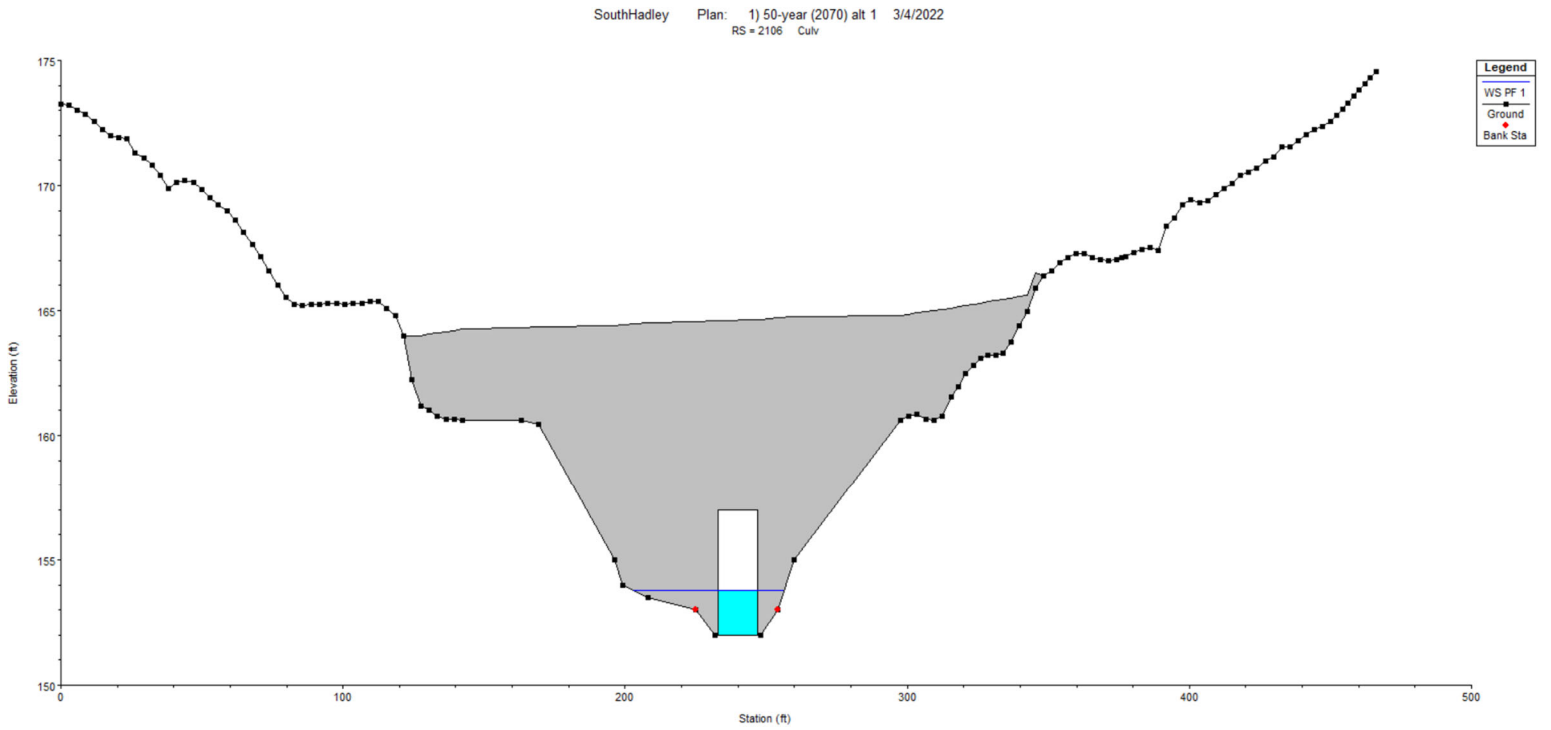


Newton Avenue; Proposed Alternative 1 WSEL (2022, 50-year storm)

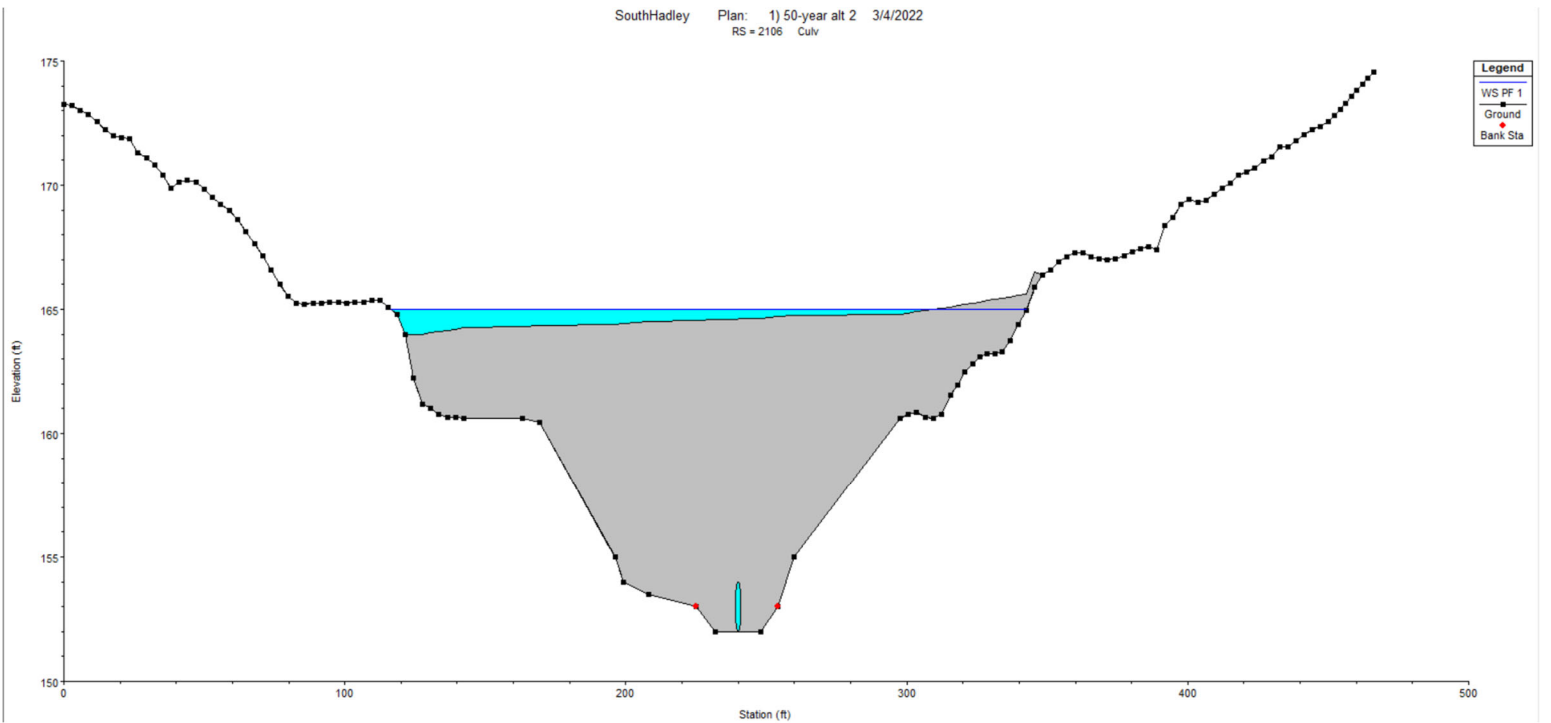
SouthHadley Plan: 1) 50-year alt 1 3/4/2022
RS = 2106 Culv



Newton Avenue; Proposed Alternative 1 WSEL (2070, 50-year storm)

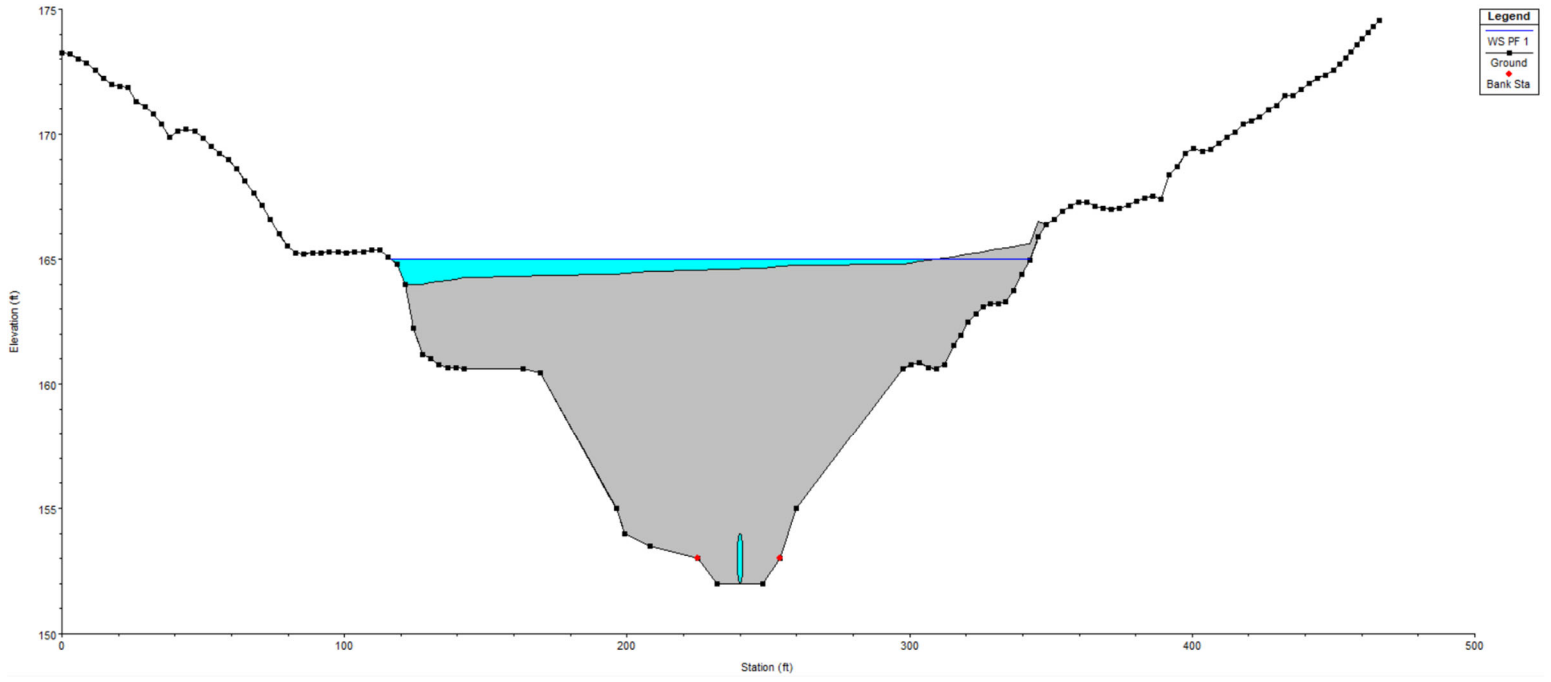


Newton Avenue; Proposed Alternative 2 WSEL (2022, 50-year storm)



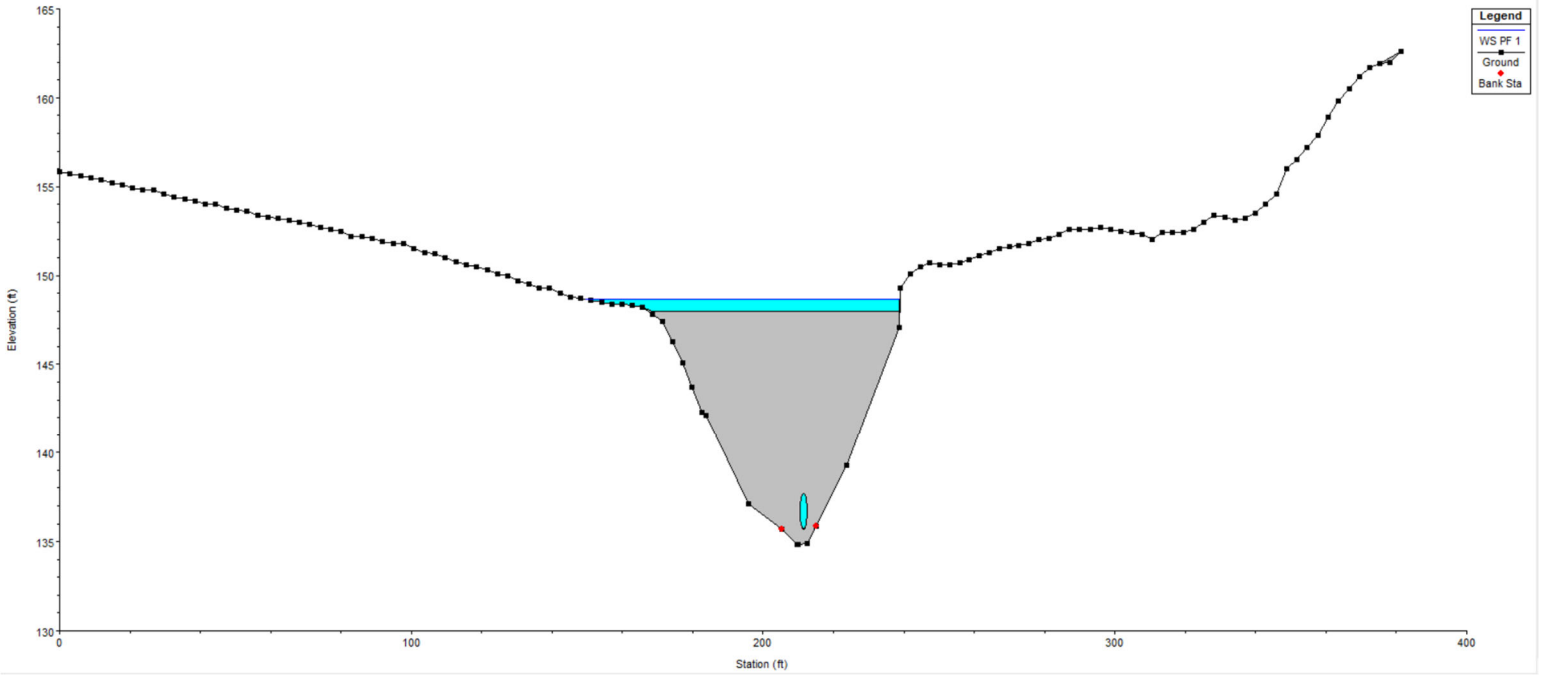
Newton Avenue; Proposed Alternative 2 WSEL (2070, 50-year storm)

SouthHadley Plan: 1) 50-year (2070) alt2 3/4/2022
RS = 2106 Culv



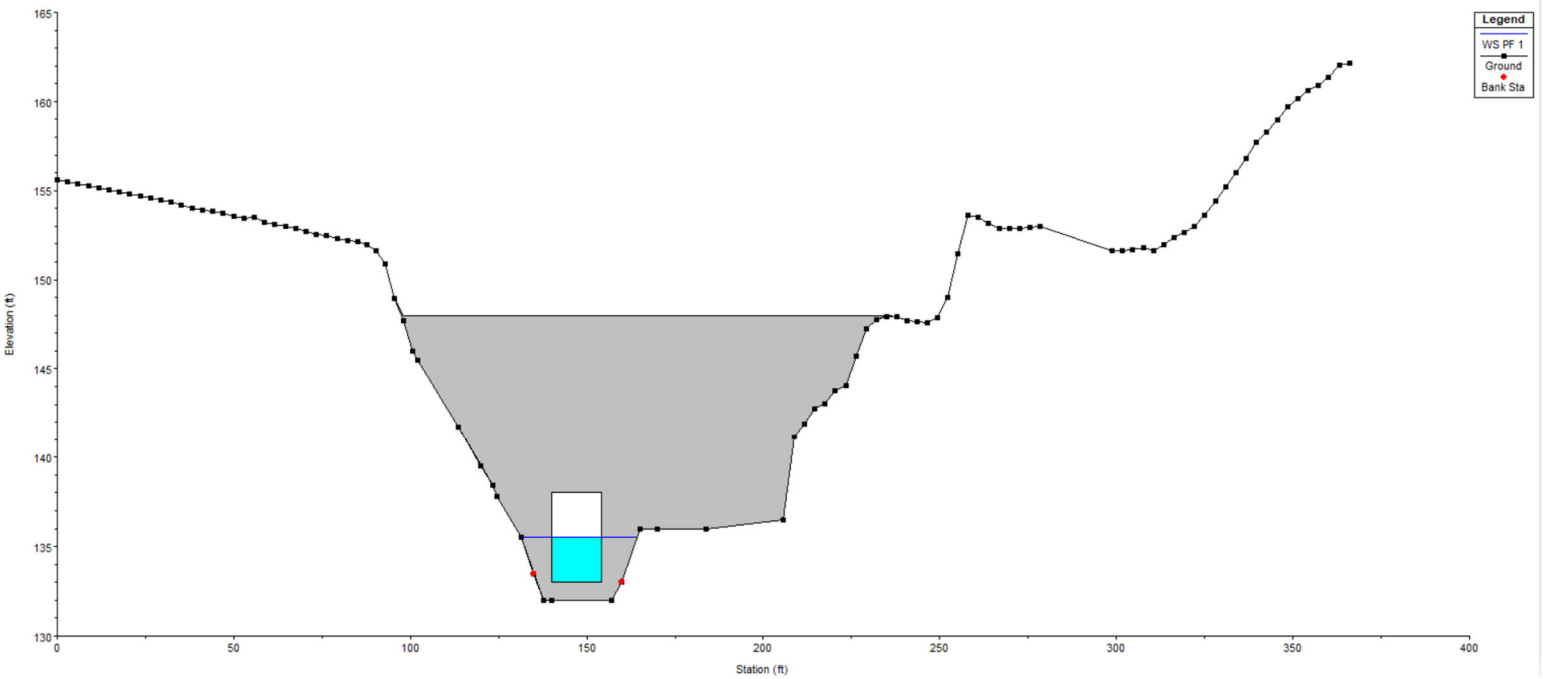
Mountain Avenue; Existing WSEL (50-year storm)

SouthHadley Plan: 1) 50-year existing 3/4/2022
RS = 1253 Culv



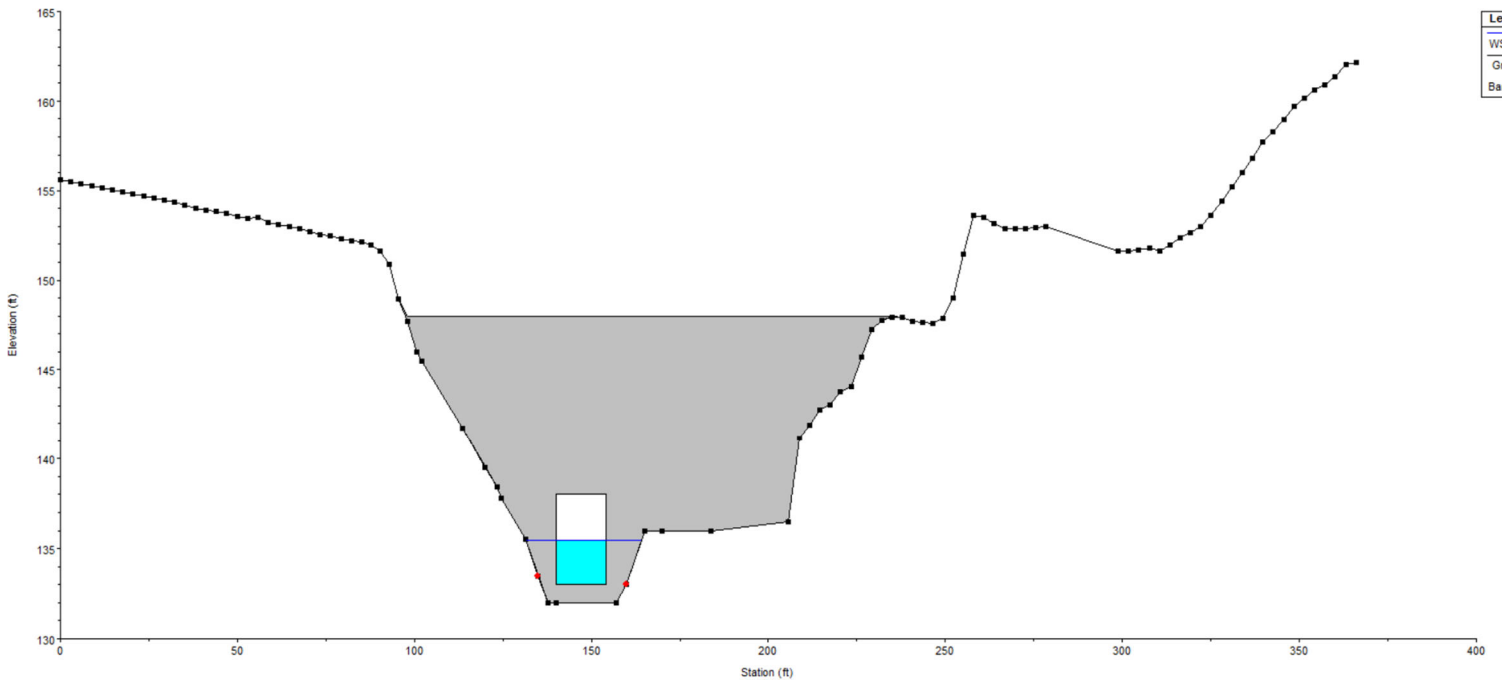
Mountain Avenue; Proposed Conditions WSEL (2022, 50-year storm)

SouthHadley Plan: 1) 50-year (2070) alt 1 3/4/2022
RS = 1319 Culv



Mountain Avenue; Proposed Conditions WSEL (2070, 50-year storm)

SouthHadley Plan: 1) 50-year alt 1 3/4/2022
RS = 1319 Culv



Appendix E

HEC-18 Scour Calculations



195 Frances Avenue
 Cranston RI, 02910
 Phone: (401)-467-6454
 Fax: (401)-467-2398
thielsch.com
Let's Build a Solid Foundation

Client Information:
 Fuss & O'Neill
 Springfield, MA
 PM: Julianne Busa
 Assigned By: Juliane Busa
 Collected By: Michael Soares

Project Information:
Queensville Dam Removal Feasibility Study
South Hadley, MA
 F&ON Project Number: 20170390.V30
 Summary Page: 1 of 1
 Report Date: 11.17.21

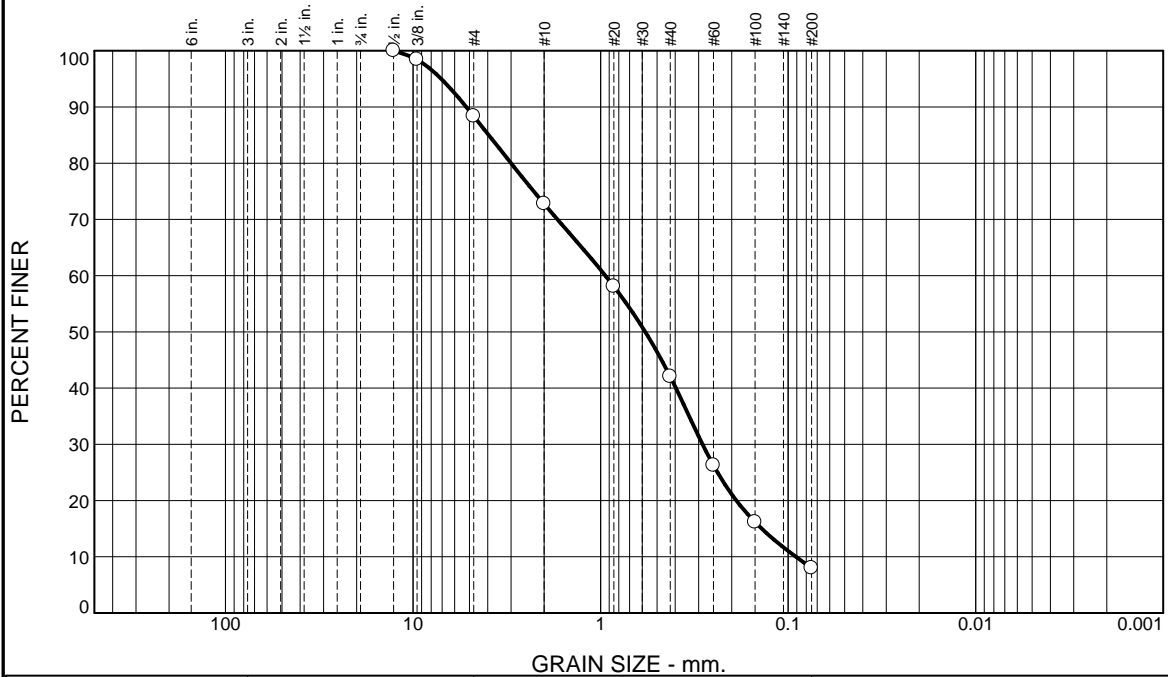
LABORATORY TESTING DATA SHEET, Report No.: 7421-L-132

Source	Sample No.	Depth (Ft)	Laboratory No.	Identification Tests								Proctor / CBR / Permeability Tests							Laboratory Log and Soil Description	
				As Received Moisture Content %	LL %	PL %	Gravel %	Sand %	Fines %	Org. %	G _s	Dry unit wt. pcf	Test Moisture Content %	γ _d MAX (pcf) W _{opt} (%)	γ _d MAX (pcf) W _{opt} (%) (Corr.)	Target Test Setup as % of Proctor	CBR @ 0.1"	CBR @ 0.2"		Permeability cm/sec
				D2216	D4318		D6913			D2974	D854			D1557						
Sediment	20211022-E510	-	21-S-4308				11.6	80.4	8.0											Brown poorly graded sand with silt
Sediment	20211022-E552	-	21-S-4309				9.1	49.3	41.6											Brown silty sand
Sediment	20211022-F623	-	21-S-4310				0.8	88.0	11.2											Brown poorly graded sand with silt
Sediment	20211022-F642	-	21-S-4311				21.0	26.5	52.5											Brown sandy silt with gravel
Sediment	20211022-G702	-	21-S-4312				6.8	87.2	6.0											Brown poorly graded sand with silt

Date Received: 11.10.17 Reviewed By:  Date Reviewed: 11.17.21

This report only relates to items inspect and/or tested. No warranty, expressed or implied, is made.
 This report shall not be reproduced, except in full, without prior written approval from the Agency, as defined in ASTM E329.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	11.6	15.6	30.8	34.0	8.0	

Test Results (D6913 & ASTM D 1140)			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
0.5"	100.0		
0.375"	98.4		
#4	88.4		
#10	72.8		
#20	58.1		
#40	42.0		
#60	26.3		
#100	16.2		
#200	8.0		

* (no specification provided)

Material Description

Brown poorly graded sand with silt

Atterberg Limits (ASTM D 4318)

PL= NP LL= NV PI= NP

Classification

USCS (D 2487)= SP-SM AASHTO (M 145)= A-1-b

Coefficients

D ₉₀ = 5.2043	D ₈₅ = 3.9463	D ₆₀ = 0.9437
D ₅₀ = 0.5778	D ₃₀ = 0.2859	D ₁₅ = 0.1383
D ₁₀ = 0.0909	C _u = 10.38	C _c = 0.95

Remarks

Date Received: 11.10.17 Date Tested: 11.17.21

Tested By: SL

Checked By: Steven Accetta

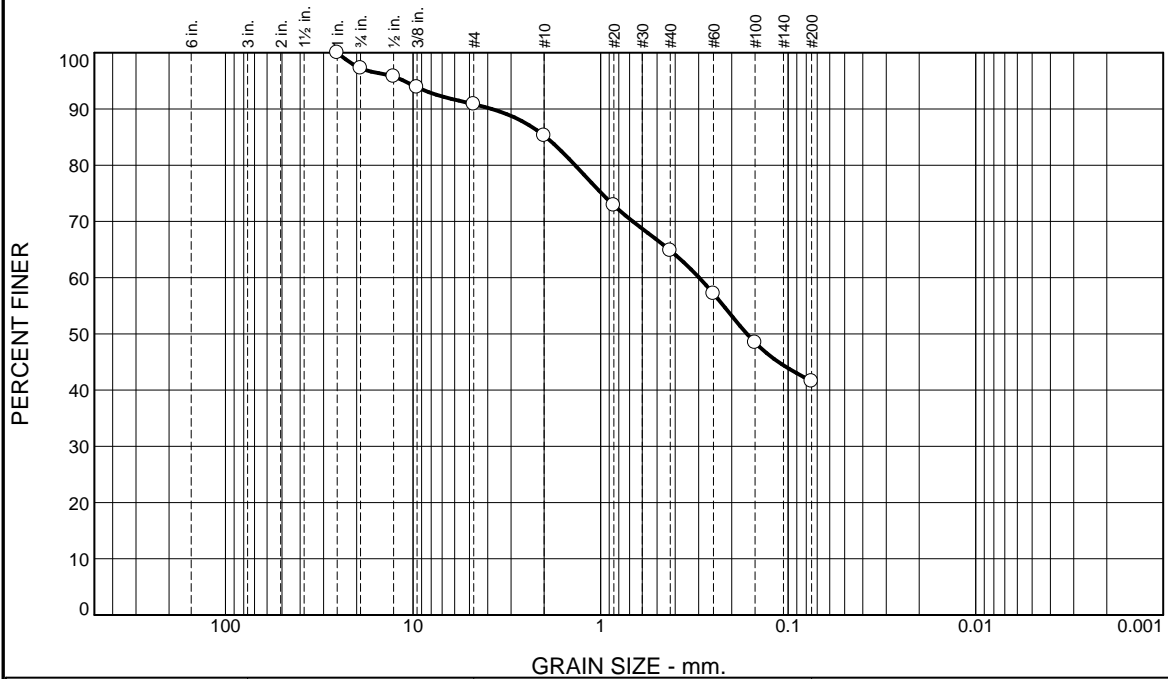
Title: Laboratory Coordinator

Source of Sample: Sediment
Sample Number: 20211022-E510

Date Sampled:

<p>Thielsch Engineering Inc.</p> <p style="text-align: center;">Cranston, RI</p>	<p>Client: Fuss & O'Neill</p> <p>Project: Queensville Dam Removal Feasibility Study South Hadley, MA</p> <p>Project No: 20170390.V30</p>
<p>Figure 21-S-4308</p>	

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	2.8	6.3	5.6	20.5	23.2	41.6	

Test Results (D6913 & ASTM D 1140)			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
0.75"	97.2		
0.5"	95.8		
0.375"	93.9		
#4	90.9		
#10	85.3		
#20	72.9		
#40	64.8		
#60	57.2		
#100	48.5		
#200	41.6		

* (no specification provided)

Material Description

Brown silty sand

Atterberg Limits (ASTM D 4318)

PL= 31 LL= 39 PI= 8

Classification

USCS (D 2487)= SM AASHTO (M 145)= A-4(1)

Coefficients

D₉₀= 3.7992 D₈₅= 1.9553 D₆₀= 0.2982
D₅₀= 0.1658 D₃₀= D₁₅=
D₁₀= C_u= C_c=

Remarks

Sample visually classified as plastic. Sample rolled to 1/8".

Date Received: 11.10.17 Date Tested: 11.17.21

Tested By: SL

Checked By: Steven Accetta

Title: Laboratory Coordinator

Source of Sample: Sediment
Sample Number: 20211022-E552

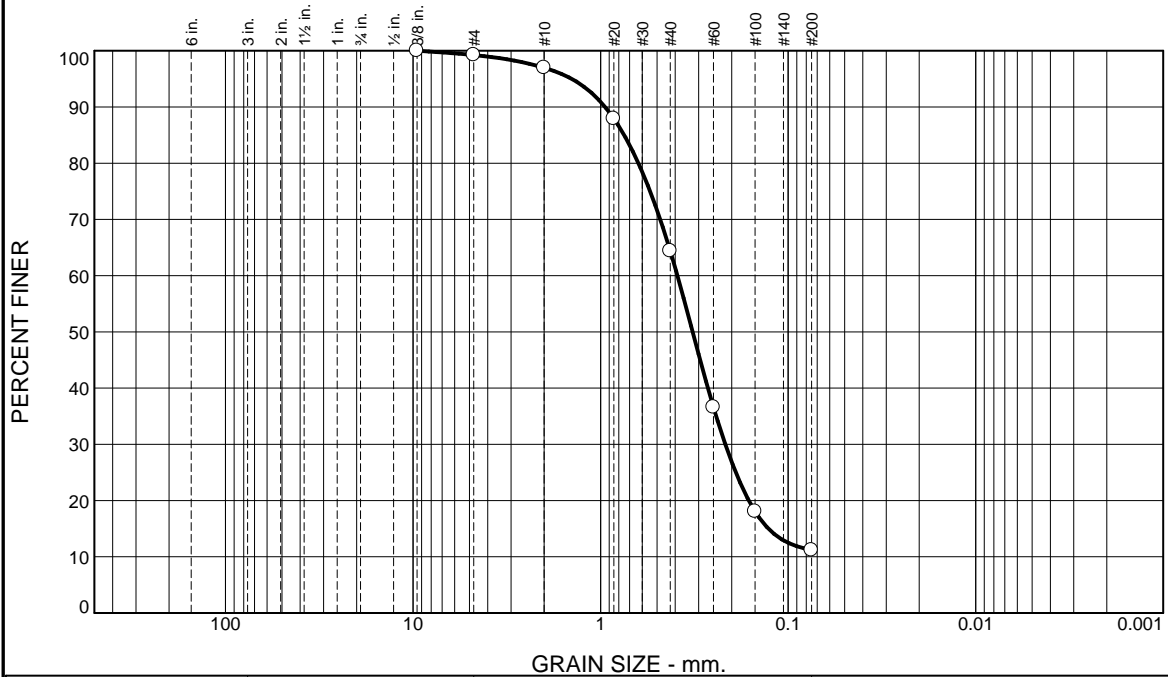
Date Sampled:

Thielsch Engineering Inc.
Cranston, RI

Client: Fuss & O'Neill
Project: Queensville Dam Removal Feasibility Study
South Hadley, MA
Project No: 20170390.V30

Figure 21-S-4309

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.8	2.2	32.6	53.2	11.2	

Test Results (D6913 & ASTM D 1140)			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
0.375"	100.0		
#4	99.2		
#10	97.0		
#20	87.9		
#40	64.4		
#60	36.6		
#100	18.1		
#200	11.2		

* (no specification provided)

Material Description

Brown poorly graded sand with silt

Atterberg Limits (ASTM D 4318)

PL= NP LL= NV PI= NP

Classification

USCS (D 2487)= SP-SM AASHTO (M 145)= A-2-4(0)

Coefficients

D₉₀= 0.9468 D₈₅= 0.7488 D₆₀= 0.3894
D₅₀= 0.3230 D₃₀= 0.2162 D₁₅= 0.1274
D₁₀= C_u= C_c=

Remarks

Date Received: 11.10.21 Date Tested: 11.17.21

Tested By: SL

Checked By: Steven Accetta

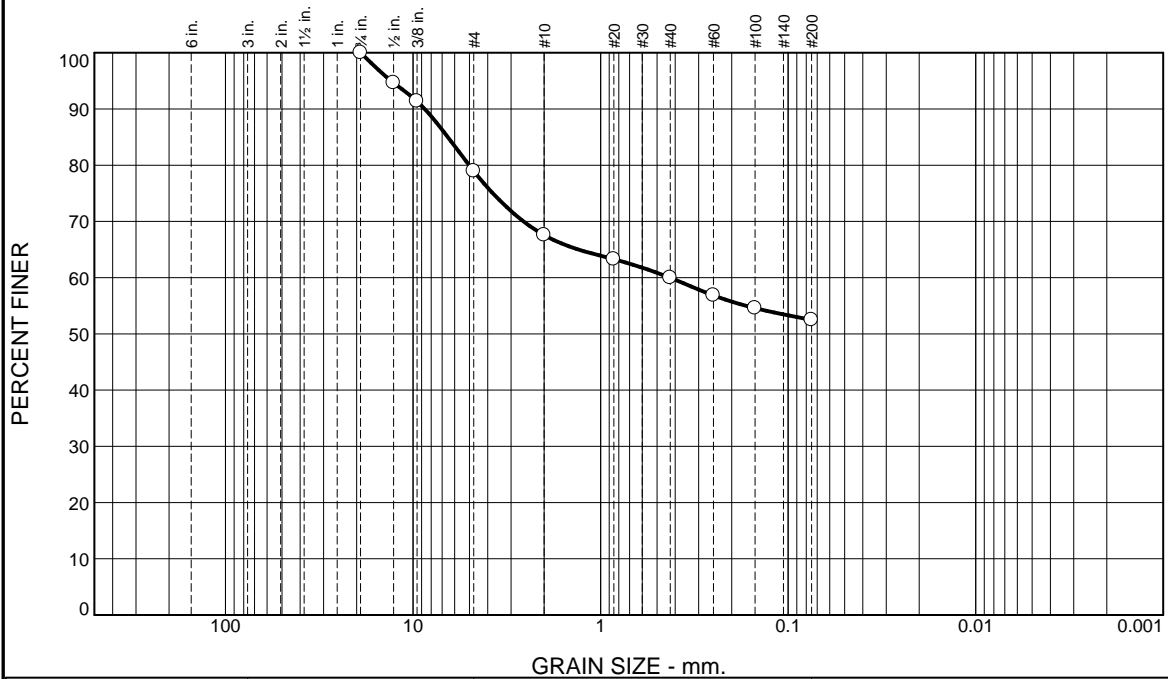
Title: Laboratory Coordinator

Source of Sample: Sediment
Sample Number: 20211022-F623

Date Sampled:

Thielsch Engineering Inc. Cranston, RI	Client: Fuss & O'Neill Project: Queensville Dam Removal Feasibility Study South Hadley, MA Project No: 20170390.V30
Figure 21-S-4310	

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	21.0	11.4	7.6	7.5	52.5	

Test Results (D6913 & ASTM D 1140)			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
0.75"	100.0		
0.5"	94.7		
0.375"	91.4		
#4	79.0		
#10	67.6		
#20	63.3		
#40	60.0		
#60	56.8		
#100	54.6		
#200	52.5		

Material Description

Brown sandy silt with gravel

Atterberg Limits (ASTM D 4318)

PL= NP LL= NV PI= NP

Classification

USCS (D 2487)= ML AASHTO (M 145)= A-4(0)

Coefficients

D₉₀= 8.6611 D₈₅= 6.5197 D₆₀= 0.4270
D₅₀= D₃₀= D₁₅=
D₁₀= C_u= C_c=

Remarks

Sample visually classified as non-plastic.

Date Received: 11.10.21 Date Tested: 11.17.21

Tested By: SL

Checked By: Steven Accetta

Title: Laboratory Coordinator

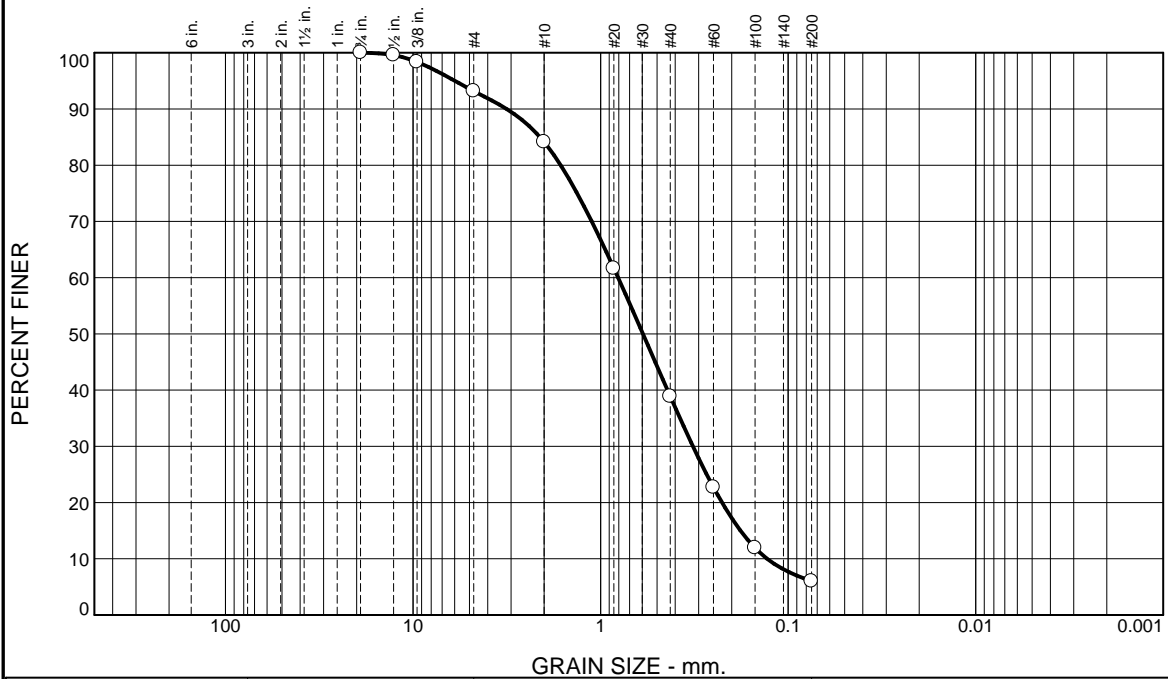
* (no specification provided)

Source of Sample: Sediment
Sample Number: 20211022-F642

Date Sampled:

Thielsch Engineering Inc. Cranston, RI	Client: Fuss & O'Neill Project: Queensville Dam Removal Feasibility Study South Hadley, MA Project No: 20170390.V30
Figure 21-S-4311	

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	6.8	9.1	45.2	32.9	6.0	

Test Results (D6913 & ASTM D 1140)			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
0.75"	100.0		
0.5"	99.6		
0.375"	98.4		
#4	93.2		
#10	84.1		
#20	61.7		
#40	38.9		
#60	22.7		
#100	11.9		
#200	6.0		

* (no specification provided)

Material Description

Brown poorly graded sand with silt

Atterberg Limits (ASTM D 4318)

PL= NP LL= NV PI= NP

Classification

USCS (D 2487)= SP-SM AASHTO (M 145)= A-1-b

Coefficients

D ₉₀ = 3.1695	D ₈₅ = 2.1053	D ₆₀ = 0.8071
D ₅₀ = 0.5946	D ₃₀ = 0.3218	D ₁₅ = 0.1794
D ₁₀ = 0.1293	C _u = 6.24	C _c = 0.99

Remarks

Date Received: 11.10.21 Date Tested: 11.17.21

Tested By: SL

Checked By: Steven Accetta

Title: Laboratory Coordinator

Source of Sample: Sediment
 Sample Number: 20211022-G702

Date Sampled:

Thielsch Engineering Inc.
Cranston, RI

Client: Fuss & O'Neill
 Project: Queensville Dam Removal Feasibility Study
 South Hadley, MA
 Project No: 20170390.V30

Figure 21-S-4312

JOB	South Hadley, MA		
SHEET NO.		OF	
CALCULATED BY	LC	DATE	3/10/2022
CHECKED BY		DATE	

SUBJECT Proposed Scour at Mountain Avenue (14'x5')

References: "Evaluating Scour at Bridges", HEC-18, 4/2012

Local Abutment Scour:

Froehlich's Eqn: $Y_s/Y_a = 2.27 K_1 K_2 (L/Y_a)^{0.43} FR^{0.61} + 1$ (HEC 18, Eqn. 8.1)

$K_2 = (\theta/90)^{0.13}$ (HEC 18, Eqn. 8.1)

$V_e = Q_e / A_e$ (HEC 18, Eqn. 8.1)

$L = A_e / Y_a$ (HEC 18, Eqn. 8.1)

$L' = L \sin\theta$ (if $\theta \leq 90$)

$L' = L \sin(180 - \theta)$ (if $\theta > 90$)

$FR = V_e / (32.2 Y_a)^{1/2}$ (HEC 18, Eqn. 8.1)

Left Abutment:

$K_1 =$	0.82 (coefficient for abutment shape)	(HEC 18, Table 8.1)
$\theta =$	46.00 (embankment angle to flow)	
$K_2 =$	0.92 (coefficient for embankment angle to flow)	

	Q25	Q50	
Y_a (ft) =	1.09	1.17	(depth of flow at abutment face) (HEC-RAS)
A_e (sq ft) =	5.12	6.36	(flow area obstructed by embankment) (HEC-RAS)
Q_e (cfs) =	1.35	1.95	(flow in flow area, A_e) (HEC-RAS)
V_e (fps) =	0.26	0.31	(velocity in flow area)
L (ft) =	4.70	5.44	(abut. length normal to flow)
L' (ft) =	3.38	3.91	(adjusted abut. length normal to flow)
$FR =$	0.04	0.05	(Froude number)

Y_s (ft) = 1.54 1.71 (avg. scour depth)

Assumes all overbank flow is blocked by bridge - Conservative.

JOB	South Hadley, MA		
SHEET NO.		OF	
CALCULATED BY	LC	DATE	3/10/2022
CHECKED BY		DATE	

SUBJECT Proposed Scour at Mountain Avenue (14'x5')

References: "Evaluating Scour at Bridges", HEC-18, 4/2012

Local Abutment Scour:

Froehlich's Eqn: $Y_s/Y_a = 2.27 K_1 K_2 (L/Y_a)^{0.43} FR^{0.61} + 1$ *(HEC 18, Eqn. 8.1)*
 $K_2 = (\theta/90)^{0.13}$ *(HEC 18, Eqn. 8.1)*
 $V_e = Q_e / A_e$ *(HEC 18, Eqn. 8.1)*
 $L = A_e / Y_a$ *(HEC 18, Eqn. 8.1)*
 $L' = L \sin\theta$ (if $\theta \leq 90$)
 $L' = L \sin(180 - \theta)$ (if $\theta > 90$)
 $FR = V_e / (32.2 Y_a)^{1/2}$ *(HEC 18, Eqn. 8.1)*

Right Abutment:

$K_1 = 0.82$ (coefficient for abutment shape) *(HEC 18, Table 8.1)*
 $\theta = 135.00$ (embankment angle to flow)
 $K_2 = 1.05$ (coefficient for embankment angle to flow)

	Q25	Q50	
Y_a (ft) =	1.45	0.38	(depth of flow at abutment face) <i>(HEC-RAS)</i>
A_e (sq ft) =	6.98	11.19	(flow area obstructed by embankment) <i>(HEC-RAS)</i>
Q_e (cfs) =	2.18	1.70	(flow in flow area, A_e) <i>(HEC-RAS)</i>
V_e (fps) =	0.31	0.15	(velocity in flow area)
L (ft) =	4.81	29.45	(abut. length normal to flow)
L' (ft) =	3.40	20.82	(adjusted abut. length normal to flow)
FR =	0.05	0.04	(Froude number)

Y_s (ft) = **2.08** **1.00** (avg. scour depth)

Assumes all overbank flow is blocked by bridge - Conservative.

Total Scour Depth (ft):	3.62	2.70
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Fuss & O'Neill

1550 Main St #400
 Springfield, MA 01103
 Tel.: 413.452.0445

JOB South Hadley, MA
 SHEET NO. _____ OF _____
 CALCULATED BY LC DATE 3/10/2022
 CHECKED BY _____ DATE _____

SUBJECT Proposed Scour at Mountain Avenue (14'x5')

References: "Evaluating Scour at Bridges", HEC-18, 4/2012

HEC-RAS River: south hadley Reach: 1 Profile: PF 1											
River Sta	Profile	Plan	Flow Area Ch (sq ft)	Flow Area L (sq ft)	Flow Area R (sq ft)	Q Channel (cfs)	Q Left (cfs)	Q Right (cfs)	Hydr Depth C (ft)	Hydr Depth L (ft)	Hydr Depth R (ft)
1363	PF 1	25-year (2070) proposed alt 1	93.91	5.12	6.98	151.07	1.35	2.18	3.76	1.09	1.45
1363	PF 1	50-year (2070) alt 1	99.99	6.36	11.19	184.26	1.94	1.70	4.00	1.17	0.38
1319			Culvert								

Mountain Avenue culvert

