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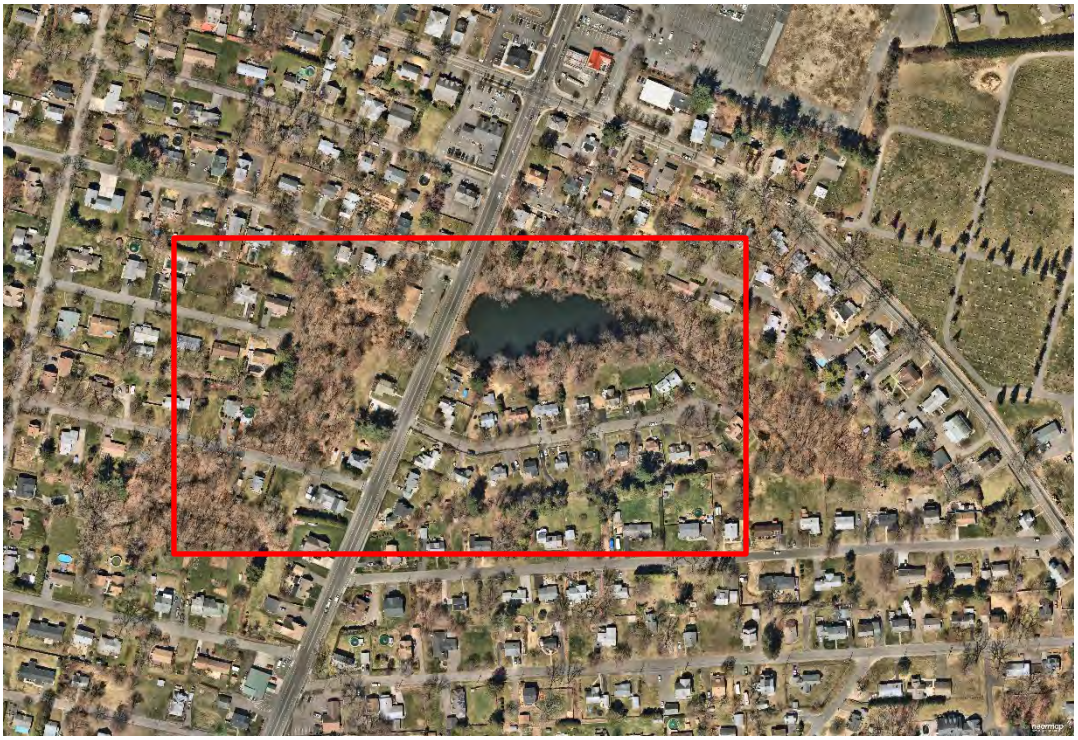
Hydrologic and Hydraulic Report



Buttery Brook Watershed Restoration

South Hadley, MA

March 2023

FUSS & O'NEILL

1550 Main Street, Suite 400
Springfield, MA 01103

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1 Executive Summary

The Town of South Hadley (Town) has been awarded a FY23 Municipal Vulnerability Preparedness Action Grant to fund the second phase of a multi-phase project. The first (FY22) planning and assessment phase evaluated options for the removal of Queensville Dam, located at Titus Pond on Newton Street, restoration and ecological enhancement of the Titus Pond impoundment, 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. The preferred alternative from the FY22 study includes removing the outlet control structure which maintains the depth of the Titus Pond impoundment but leaving the existing 24" outlet pipe to allow for stormwater conveyance under Route 116 and into the Tributary to Buttery Brook. By removing the outlet control structure, the impoundment can be restored to a wetland and recreational walking trail and additional stormwater retention capacity can be realized to reduce flooding of densely populated downstream neighborhoods. Additional improvements to the Buttery Brook watershed include replacing the culvert at Mountain Avenue with a 15' x 6'7" open-bottom arch culvert to provided better capacity for storm flows both now and under future precipitation conditions. Additionally, improvements will be made to the inlet to the buried pipe at Joffre Ave to reduce nuisance flooding and the existing wetlands between Joffre Avenue and Mountain Avenue will be enhanced to promote infiltration of stormwater. The purpose of this report is to summarize the hydrologic and hydraulic analyses completed to size and design Titus Pond restoration concepts and replace the stream crossing at Mountain Avenue based on Massachusetts Stream Crossing Standards while also addressing future climate conditions using the guidelines created by the Resilient Massachusetts Action Team (RMAT).

2 Project Description

2.1 Existing Conditions

The upstream portion of the project area consists of Titus Pond and Queensville Dam on Newton Street (State Route 116). 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 daylights 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 pipe of unknown size for roughly 650 feet under several residential properties before daylighting south of Joffre Avenue in a 24" pipe. 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. An 8" standpipe at the inlet has been set as an emergency measure.

2.2 Proposed Conditions

The preferred alternative for Titus Pond is to remove the existing outlet control structure that maintains the water level at Titus Pond and replace it with a headwall/wingwalls for the existing 24" culvert that conveys surface water under Route 116. With this modification, water will be able to flow unobstructed into the culvert that joins Buttery Brook, located approximately 200 feet west of Route 116. This will maintain the permanent drawdown of Titus Pond and, as a result, eliminate the dam's jurisdictional status by reducing the size of the impoundment to below the jurisdictional threshold of impounding 15 ac-ft during the 24-hour, 100-year storm. Restoration to Titus Pond area will include the creation of a meandering low-flow channel, grade-control structures and scour protection made from natural materials (including boulder or log vanes, rootwatds, etc), and a graduated series of wetland habitats planted with native wetland vegetation. The dam classification will be removed as it will be less than 15 ac-ft of impounded storage volume during a 24-hour, 100-year storm event. No changes are proposed to the culvert or earthen dam. A concept plan for proposed conditions for Titus Pond is presented in Figure 1.

Figure 1: Titus Pond Dam Removal and Restoration Concept

Further downstream, the culvert under Mountain Avenue will be replaced with a corrugated metal arch that provides better capacity for storm flows both now and under future precipitation conditions, addresses current structural deficiencies, and meets the Massachusetts Stream Crossing Standards. The proposed crossing will be installed to better align with Buttery Brook, which will be re-routed to enter the new inlet approximately 30 feet to the east-southeast of the existing inlet's location. At present, the brook forms a sharp bend of nearly 90 degrees to enter the 24" pipe. The proposed realignment of approximately 30 feet of stream channel will eliminate this sharp bend, better aligning the culvert with Buttery Brook and reducing the erosive conditions observed at the road embankment as well as the risk of clogging.

To satisfy the Massachusetts Stream Crossing Standards the proposed crossing structure will be a corrugated metal arch structure with open channel bottom, measuring 15' in width and 6-7' in height. Gradation analysis of samples taken from the natural streambed upstream and downstream of the existing structure will be used to construct a natural channel bottom through the new structure, matching the existing streambed.

Mountain Avenue is classified as an urban local road by MassDOT; Chapter 85 therefore requires the design flood frequency be based on the 10-year storm, a less stringent guideline than the design requirements determined by RMAT. Per the requirements of Chapter 85, the proposed design provides more than the required 2 feet of freeboard above the future projected 10-year WSEL to the low chord of the proposed box culvert.

Downstream of Mountain Avenue, the project proposes four (4) locations where large woody debris will be placed in the reach of the brook between Mountain Avenue and the repaired inlet. These nature-based structures will be permeable and constructed from logs, limbs, and/or root wads to be sourced from the project area. Three of the structures will be placed across the stream channel, at bankfull height, to promote aggradation in the streambed and to disperse and attenuate stream flows. For bank stabilization, the fourth structure will be a combination of wooden deflector vanes and root wads installed along an approximately 40-foot stretch of the river-left bank, located just downstream of the proposed stream crossing at Mountain Avenue. The specific location, installation, and materials used for these in-stream structures will be directed by the designer in the field based on ecological and geomorphic conditions.

The existing failed culvert inlet near Joffre Avenue, and the associated structure installed as a temporary repair at the collapsed inlet that begins the approximately 650-foot buried segment of Buttery Brook, will be repaired to reduce localized flooding and restore the hydraulic capacity of the existing culvert. Repairs include rebuilding the inlet headwall/wingwalls.

3 Data Collection

The project area was surveyed in January 2022 and October 2022 to collect topographic data for the hydraulic study. Survey data includes twelve cross sections of Buttery Brook with detailed channel geometry, culvert inlet and outlet invert elevations for the Titus Pond impoundment and Mountain Avenue crossing, detailed road survey data, and bathymetry data (top and bottom of sediment) for Titus Pond. The LiDAR data set used to supplement survey data was a 1-meter LiDAR based Digital Elevation Model (DEM) downloaded from NOAA Coastal Data Viewer (2015 USGS Lidar: Maine & Massachusetts QL1 & QL2). Additionally, 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 for the scour safety/stability analysis of Mountain Avenue.

4 Engineering Methods

4.1 Hydrologic Analysis

A hydrologic model for Buttery Brook was developed using the U.S Army Corps of Engineers HEC-HMS version 4.8 software and CivilGEO's proprietary GeoHECHMS software, a graphical user interface data wrapper to HEC-HMS. 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.

4.1.1 Watershed Characteristics

Two sub-watersheds were delineated for the project area in GeoHECHMS using a 1-meter LiDAR based DEM *(see Appendix A)*. The first outlet point was selected upstream of the outlet control structure in Titus Pond. The Titus Pond sub-watershed has an area of 0.11 sq mi. The second outlet was selected at the stream crossing of Joffre Avenue at Buttery Brook. The Joffre Avenue sub-watershed has an area of 0.07 sq mi.

To determine the Curve Numbers (CN) for each sub-watershed, soil and land use data were obtained from the USDA Natural Resources Conservation Service (NRCS) and the Land Cover Land Use Database (NLCD, 2019) was obtained from Multi-Resolution Land Characteristics Consortium (MLRC). 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 primary land use for both sub-watersheds is a mix of low density, medium density, and high-density development. The composite curve number for the Titus Pond sub-watershed was determined to be 59.73 and for the Joffre Ave sub-watershed was determined to be 67.96.

4.1.2 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:

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

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 (0.8 miles for Titus Pond sub-watershed and 0.3 miles for Joffre Ave sub-watershed) and centroidal flow path (0.3 miles for Titus

Pond sub-watershed and 0.15 miles for Joffre Ave sub-watershed) were then calculated for the watershed in GeoHMS.

4.1.3 Design Storms

Unit hydrographs for the 1-, 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. Table 2 demonstrates the peak discharge from the watershed through the Mountain Avenue culvert. It takes into account the storage attenuation at Titus Pond. Both present and future climactic conditions were considered in this analysis. The crossings were classified as Tier 2 based on the RMAT Climate Resilience Design Standards Tool. Per Tier 2 RMAT 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

Table 2
Summary of Mountain Avenue Peak Discharges

Design Storm	Present Climate Conditions	Future Climate Conditions
1-year	19.33	26.33
10-year	56.42	69.57
25-year	71.86	87.33
50-year	82.68	100.7
100-year	94.98	123.03

Appendix A contains supporting documentation used to develop the HEC-HMS model. Appendix B contains the summary of the HEC-HMS model.

4.1.4 Titus Pond Stage-Storage and Stage-Discharge Relationship

Stage-storage and stage-discharge relationships for Titus Pond were developed using HydroCAD (version 10.2) for both existing and proposed conditions. HEC-RAS does not have an accurate way of modeling the

existing outlet control structure in Titus Pond, whereas in HydroCAD it is possible to model a wide variety of stormwater infrastructure configurations. Surveyed bathymetry data of Titus Pond was used to create an existing conditions stage-storage relationship and proposed grading was used to create proposed stage-storage values in HydroCAD. For existing conditions, flow was routed through the outlet control structure and then the 24" RCP. For proposed conditions, the outlet control structure was removed. Unit hydrographs generated from HEC-HMS were imported into HydroCAD to determine the capacity of the existing 24" RCP under Newton Street, peak water surface elevations, and total storage in Titus Pond during all design storm events for both existing and proposed conditions. The volume and water surface elevations are summarized in Table 3 and 4 below for existing, proposed and proposed under future climate conditions. See Appendix C for a summary report of the HydroCAD model.

Table 3
Summary of Titus Pond Stage-Storage Relationship

Design Storm	Existing Conditions Storage[1]	Proposed Conditions Storage[1]; Current Climate Conditions	Proposed Conditions Storage[1]; Future Climate Conditions
1-year	7.64	0.48	0.64
10-year	9.48	2.01	3.29
25-year	10.58	3.6	6.01
50-year	11.98	5.23	8.43
100-year	14.0	7.34	12.98

1. Storage values are in acre-feet (above the normal pool elevation of 160.2)

Table 4
Summary of Titus Pond Stage-Discharge Relationship

Design Storm	Existing Conditions Peak WSE[1]	Proposed Conditions Peak WSE[1]; Current Climate Conditions	Proposed Conditions Peak WSE[1]; Future Climate Conditions
1-year	160.9	154.66	154.96
10-year	162.0	156.71	157.94
25-year	162.6	158.21	160.0
50-year	163.3	159.46	161.51
100-year	164.2	160.86	163.81

1. WSE values are in feet

4.2 Hydraulic Analysis

To analyze the impacts of the existing and proposed stream crossings at Newton Street and Mountain Avenue, a one-dimensional (1D) HEC-RAS model (version 6.1) was developed. Detailed cross sections for the 1D model were created using survey data for main channel geometry and LiDAR data for overbank geometry. 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 HEC-RAS model

begins approximately 270 feet downstream of the outlet of the conveyance pipe under Joffre Avenue and extends upstream to the upstream limit of Titus Pond. Normal depth was used as the downstream boundary conditions for both existing and proposed conditions. Appendix D contains supporting documentation used for the HEC-RAS hydraulic model. A summary report of the HEC-RAS hydraulic model is included in Appendix E.

4.2.1 Existing Conditions

The existing impoundment of Titus Pond was represented in HEC-RAS as a wide channel defined by cross sections developed from surveyed bathymetry and LiDAR data. As previously mentioned, HEC-RAS does not have an accurate way of representing the existing outlet control structure. To account for storage attenuation in Titus Pond, discharge values immediately upstream of the outlet control structure in HEC-RAS were changed to reflect the capacity of the culvert as calculated in HydroCAD. Additional flow was added downstream of Newton Street to account for runoff from the western side of the watershed to represent peak flows through Mountain Avenue.

Table 5 shows existing water surface elevation (WSEL) values at Newton Street and Mountain Avenue. WSEL values for Newton Street were taken from the HydroCAD model, while values for Mountain Avenue were taken from the HEC-RAS model. Newton Street slopes upward to the northeast and overtops on the southern end of the road crossing at 165'. Mountain Avenue overtops at 148'. Under existing conditions, Mountain Avenue is overtopping during 10-year and larger storm events.

Table 5
Existing Conditions Water Surface Elevations

Design Storm	Newton Street (HydroCAD)	Mountain Ave (HEC-RAS)
1-year	160.9	138.49
10-year	162.0	148.22
25-year	162.6	148.35
50-year	163.3	148.41
100-year	164.2	148.47

4.2.2 Proposed Conditions

The cross sections and channel centerline through Titus Pond were changed to reflect proposed grading through impoundment, which includes the creation of a meandering, low-flow channel and a graduated series of flatter terrain for wetland habitats. The proposed hydrology was modeled in the same manner as existing conditions. The capacity of the culvert without the outlet control structure calculated in HydroCAD was used as the outlet from Titus Pond and a flow change location was added downstream of the culvert outlet to represent the peak flows at Mountain Avenue during each design storm.

At Mountain Avenue, the channel centerline was altered to remove the sharp meander and better align the culvert with natural flow. The bounding downstream and upstream cross sections for the Mountain Avenue crossing were updated to reflect proposed grading of the channel realignment. The proposed culvert is a 15' by 6'7" corrugated metal arch sized to satisfy Massachusetts stream crossing standards for 1.2 and bankfull width and appropriate openness ratio. The upstream and downstream invert elevations of the proposed

culvert were also determined based on proposed grading. Table 6 compares WSEL values at Mountain Avenue for existing conditions, proposed conditions for current design storms (2022), and proposed conditions for future design storms (2070). This table demonstrates that the proposed changes will lower WSEL along Mountain Avenue even for future climactic conditions. Table 7 summarizes the channel velocities at Mountain Avenue.

Table 6
Mountain Ave Water Surface Elevations

Design Storm	Existing Conditions[1]	Proposed Design[1]; Existing Flows	Proposed Design[1]; 2070 Flows
1-year	138.49	136.26	136.39
10-year	148.22	136.81	136.97
25-year	148.35	136.99	137.13
50-year	148.41	137.09	137.23
100-year	148.47	137.20	137.40

1. Water surface elevation values in feet

Table 7
Mountain Ave Velocity Near Crossing

Design Storm	Existing Conditions[1]	Proposed Design[1]; Existing Flows	Proposed Design[1]; 2070 Flows
1-year	1.15	4.12	4.38
10-year	0.26	5.23	5.38
25-year	0.35	5.43	5.73
50-year	0.40	5.64	6.00
100-year	0.45	5.86	6.37

1. Maximum velocity near the bridge in ft/s

4.3 Scour Safety/Stability Analysis

Five grain size analyses were performed on the streambed material downstream of the Newton Street crossing and upstream of the conveyance pipe under Joffre 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 Tables 8 and 9.

Table 8
Summary of Calculated Scour for Existing Conditions[1]

Return Frequency (Year)	Scour Depth (h_s) (Feet)	Scour Width (W_s) (Feet)	Scour Length (L_s) (Feet)	Scour Volume (V_s) (Feet)	Location of Maximum Scour (L_m) (Feet)
25	4.67	27.65	43.50	5067.35	17.40
50	4.67	27.65	43.53	5074.25	17.41

1. 24" CMP

Table 9
Summary of Calculated Scour for Proposed Design[1]

Return Frequency (Year)	Total Abutment Scour[2] (ft)
25: **Design**	1.2
50: **Check**	1.6

1. 15' x 6-7' arch culvert
2. Total scour depth for a single abutment

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

5 Conclusions and Recommendations

5.1 Conclusions

Titus Pond suffers from chronic water quality impairments that are an environmental and public health concern. By removing the outlet control structure, the impoundment can be restored to a wetland and recreational walking trail and additional stormwater retention capacity can be realized to reduce flooding of densely populated downstream neighborhoods.

The existing 24" CMP culvert at Mountain is deteriorated. Hydraulic analysis shows the existing crossing at Mountain Avenue is undersized for Chapter 85 design flood requirements of 2 feet of freeboard for the 10-year flood event. The proposed replacement crossing provides more than the required 2 feet of freeboard above the future projected 10-year WSEL to the low chord of the proposed box culvert as well as meeting Massachusetts Stream Crossing Standards.

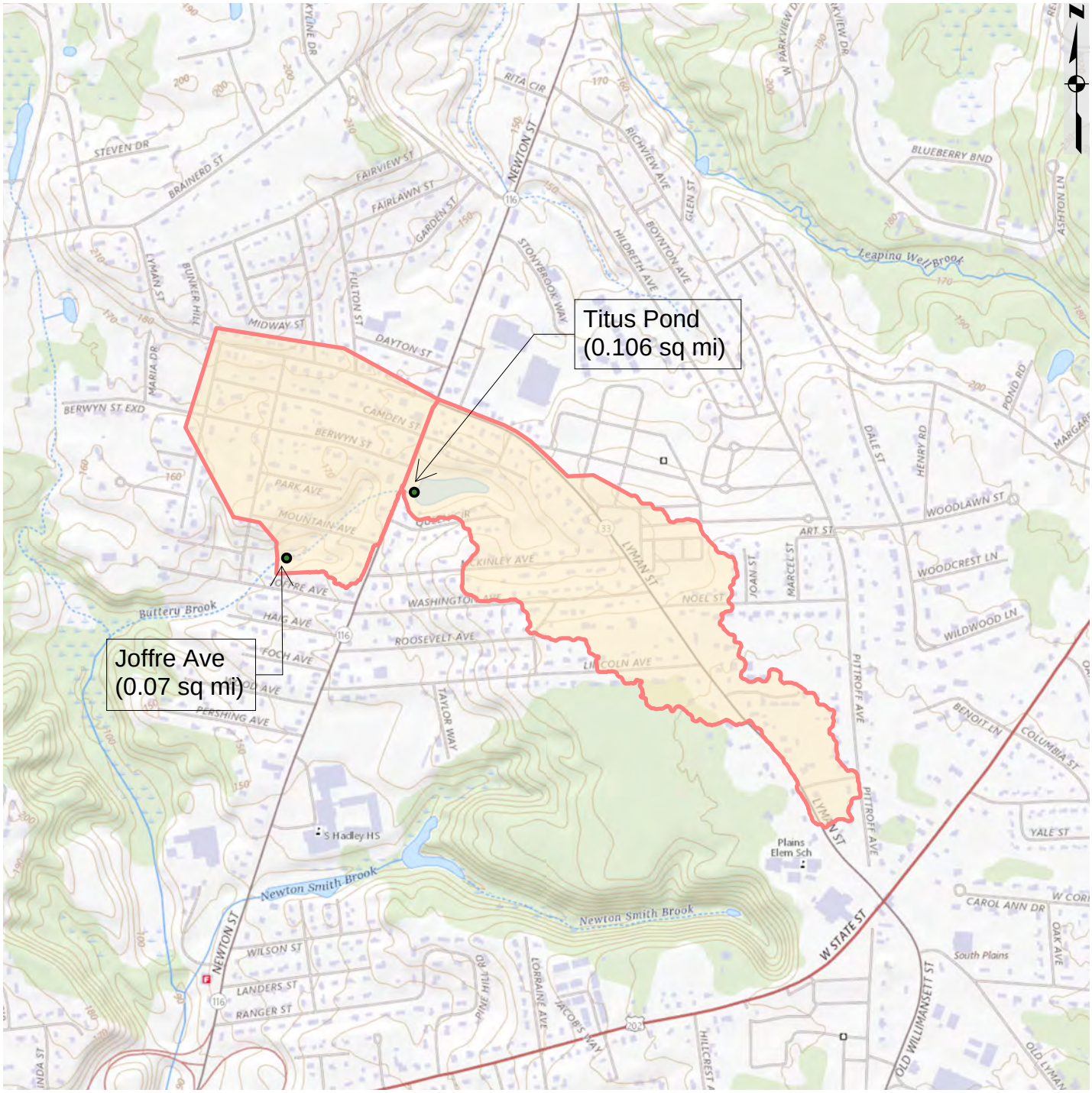
5.2 Recommendations

The preferred alternative for Titus Pond is to remove the existing outlet control structure and replace it with a headwall and wingwalls for the existing 24-inch culvert under Newton Street. This modification maintains the permanent drawdown of the impoundment and results in a storage volume of less than 15 acre-feet during a 24-hour, 100-year storm event, eliminating the dam's jurisdictional status under the Office of Dam Safety (MA DCR).

The preferred alternative for the crossing at Mountain Avenue is to replace the existing 24" CMP culvert with a corrugated metal open channel bottom arch, measuring 15' in width by 6'7" in height. It is recommended that the inlet of the proposed structure be relocated approximately 30 feet to the east-southeast of the existing inlet's locationto better align the culvert with Buttery Brook and reduce the erosive conditions observed at the road embankment.

Appendix A

Supporting Information for Hydrologic Model Development



MAP REFRENCE: USGS Topo
Accessed on : 2/27/2023
From: https://basemap.nationalmap.gov/arcgis/rest/services/USGSTopo/MapServer

USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed June, 2022.

Map Reference Location

0 500 1,000
GRAPHIC SCALE

SCALE: 1" = 1,000'

FUSS & O'NEILL

South Hadley, MA
SITE LOCATION MAP
Buttery Brook Restoration

PROJ No.: 20170390.V50
DATE: Feb 2023

FIGURE 1

Folder: K:\P2017\0390\V50\MXD\Watershed Delineation Figure\ Project: Watershed Delineation Figure Layout: clsc_8.5x11_Portrait_Bottom Map: Main Data Frame Map Frame
Date Exported: 2/27/2023 1:37 PM User: LCromer Date Saved: 2/27/2023 1:34 PM

NOAA Atlas 14, Volume 10, Version 3
Location name: South Hadley, Massachusetts, USA*
Latitude: 42.2339°, Longitude: -72.5841°
Elevation: 165.59 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

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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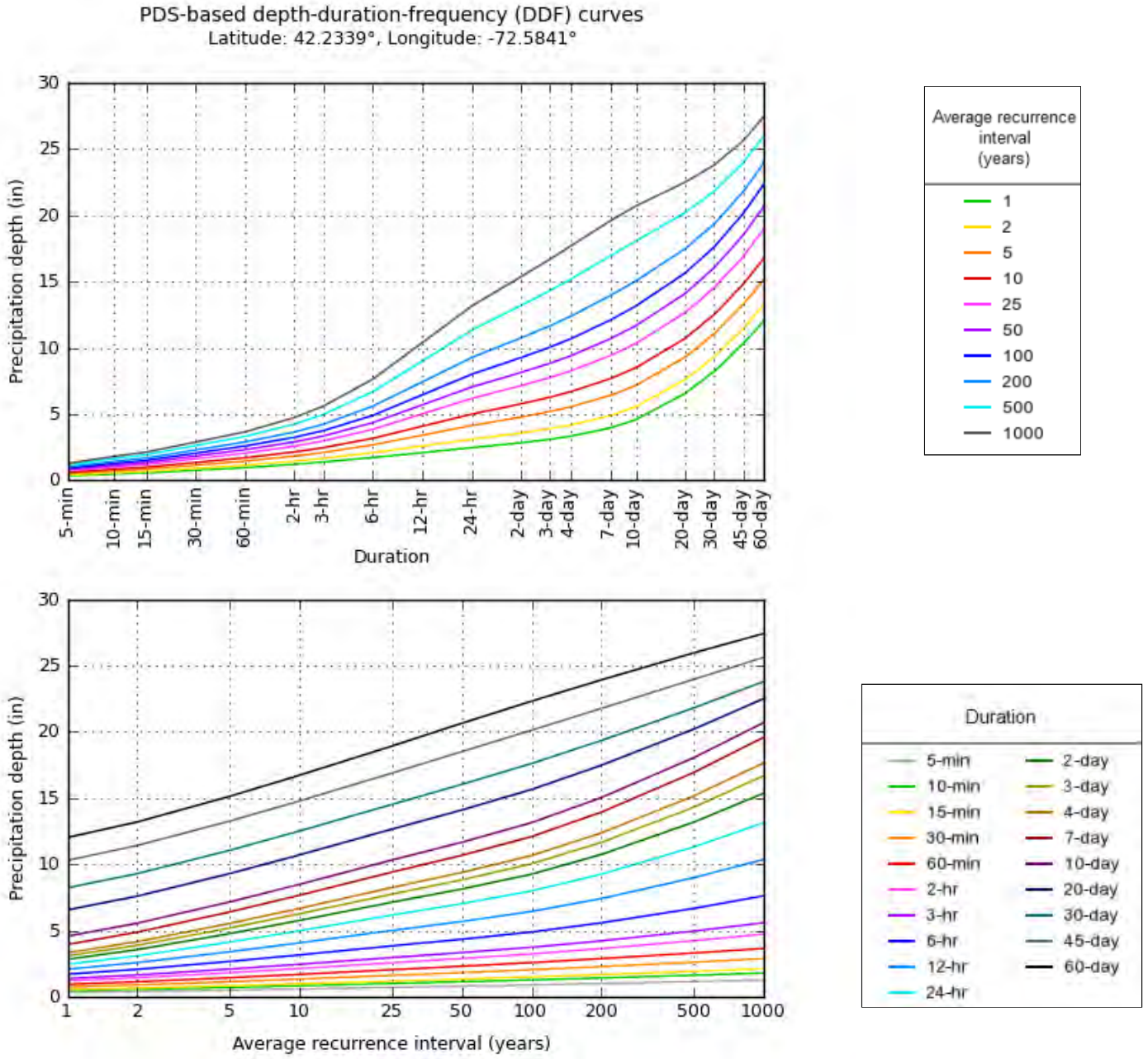
PF graphical



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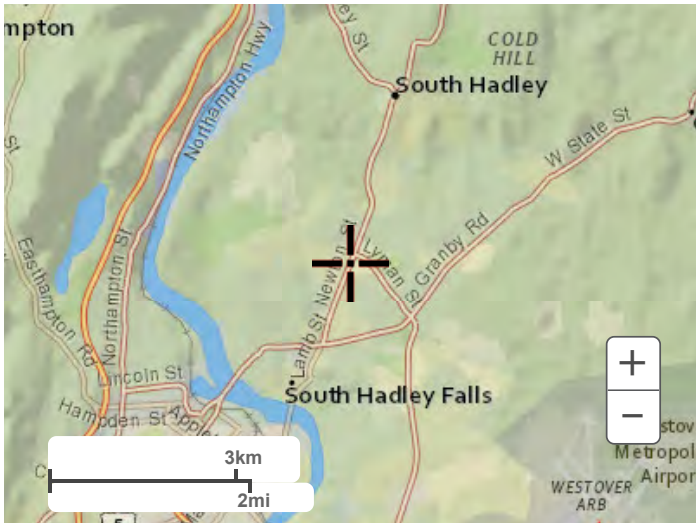
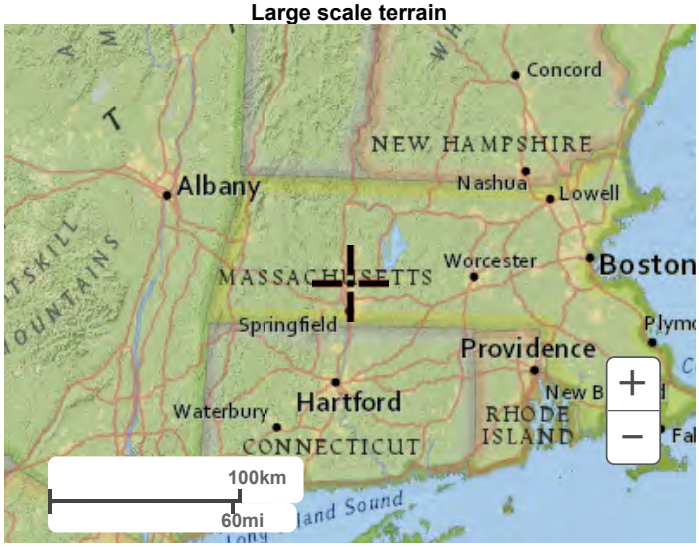
Maps & aerials

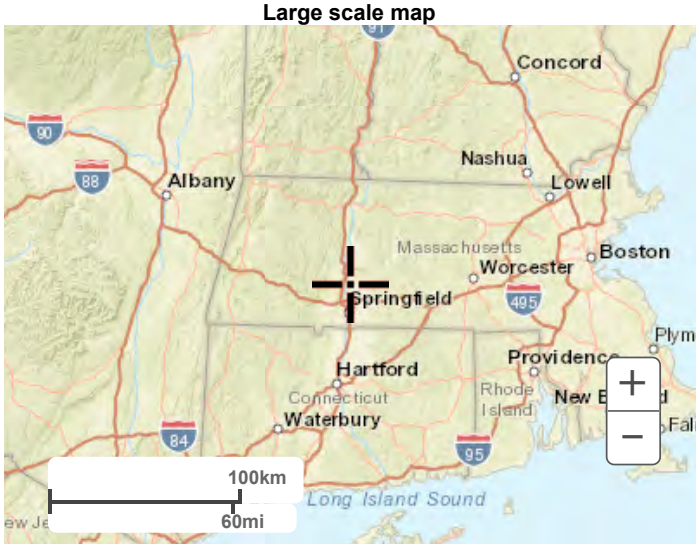
Small scale terrain



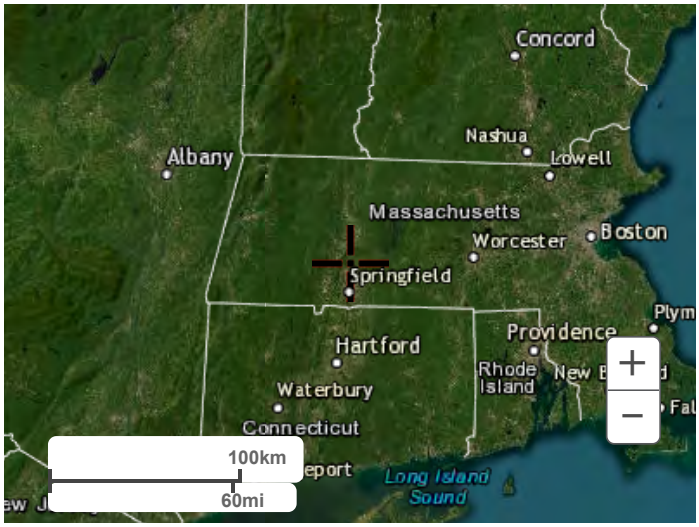
Large scale terrain



Large scale map



Large scale aerial



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US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

Snyder Parameters
South Hadley, MA
Project No. 20170390.V50

Sub-basin	Ct	L (miles)	Lc (miles)	tl (hours)	tl (min)
Titus Pond	2.2	0.79	0.21	1.28	77.04
Joffre Ave	2.2	0.31	0.21	0.97	58.28

tl = Ct(L*Lc)^0.3

Ct =	basin coefficient
L	longest flow path
Lc	distance from outlet to near centroid along river

Weighted Curve Number Calculations

Titus Pond Subbasin

Area (acres)	Area (%)	CN	Description
3.125	4.59	30	Undeveloped, Deciduous Forest
18.954	27.81	77.02	Developed, Medium Density
0.011	0.02	30	Undeveloped, Evergreen Forest
1.875	2.75	30	Undeveloped, Shrub/Scrub
0.611	0.9	39	Agricultural, Pasture/Hay
0.903	1.32	89	Developed, High Density
14.656	21.51	51.11	Developed, Open Space
0.121	0.18	30	Undeveloped, Mixed Forest
27.888	40.92	61.04	Developed, Low Density
68.145	**100**	**61.18**	**Weighted Average**

Joffre Ave Subbasin

Area (acres)	Area (%)	CN	Description
11.282	25.3	79.9	Developed, Medium Density
0.316	0.71	89	Developed, High Density
12.633	28.33	58.03	Developed, Open Space
20.354	45.65	67.18	Developed, Low Density
44.585	**100**	**67.96**	**Weighted Average**

Appendix B

HEC-HMS Hydraulic Model Summary Report

Existing 1-Year, 24-Hour Storm

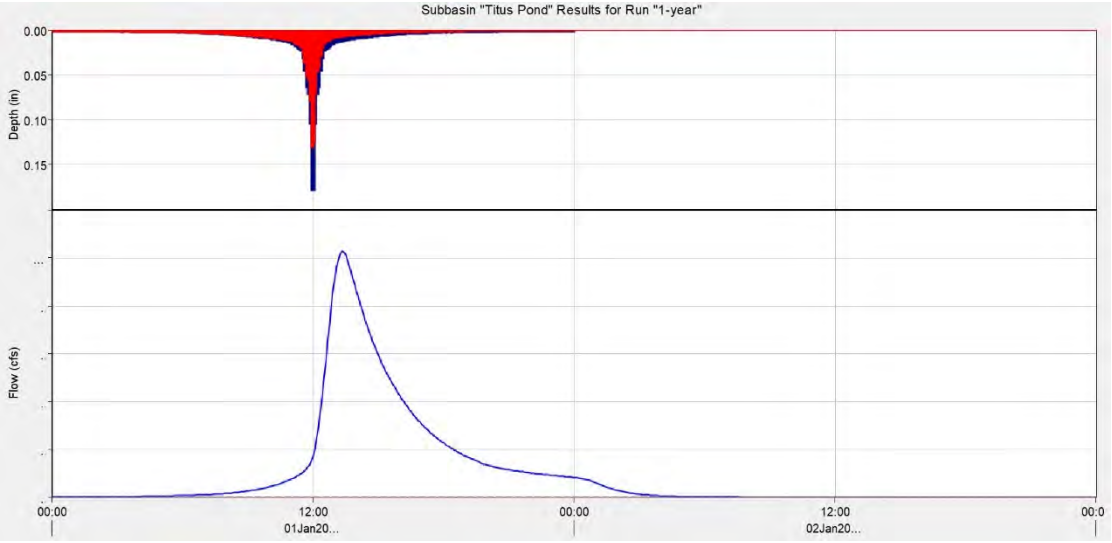
Project: QueensvilleDam_Updated Simulation Run: 1-year
Subbasin: Titus Pond

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	1-year
Compute Time:	31Jan2023, 14:31:00	Control Specifications:	Control 1

Volume Units: (•) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	10.3 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:20
Precipitation Volume:	2.46 (IN)	Direct Runoff Volume:	0.66 (IN)
Loss Volume:	1.80 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	0.66 (IN)	Discharge Volume:	0.66 (IN)



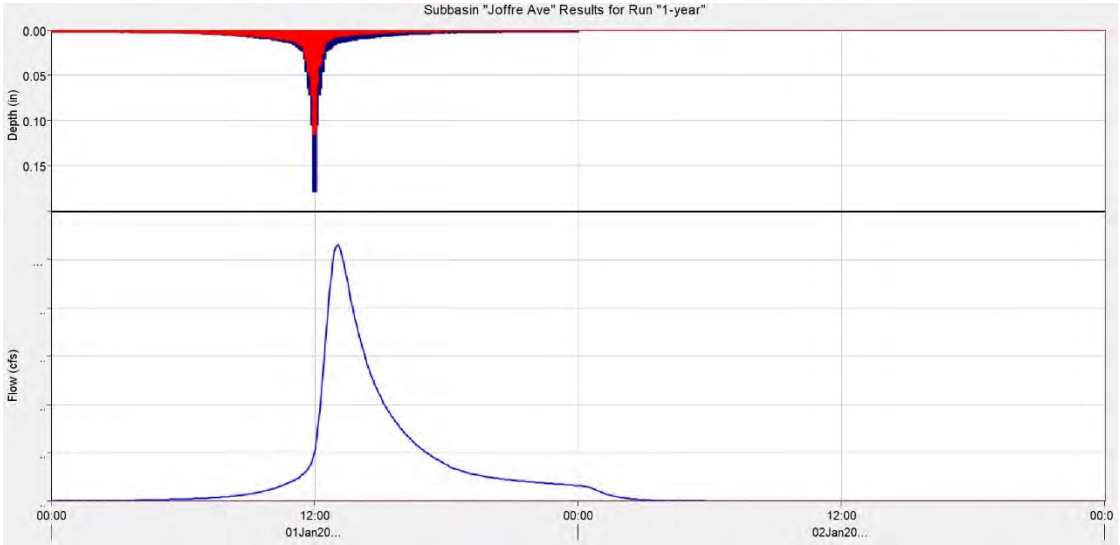
Project: QueensvilleDam_Updated Simulation Run: 1-year
Subbasin: Joffre Ave

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	1-year
Compute Time:	31Jan2023, 14:31:00	Control Specifications:	Control 1

Volume Units: (•) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	10.6 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:05
Precipitation Volume:	2.46 (IN)	Direct Runoff Volume:	0.84 (IN)
Loss Volume:	1.62 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	0.84 (IN)	Discharge Volume:	0.84 (IN)



Future (2070) 1-year, 24- Hour Storm

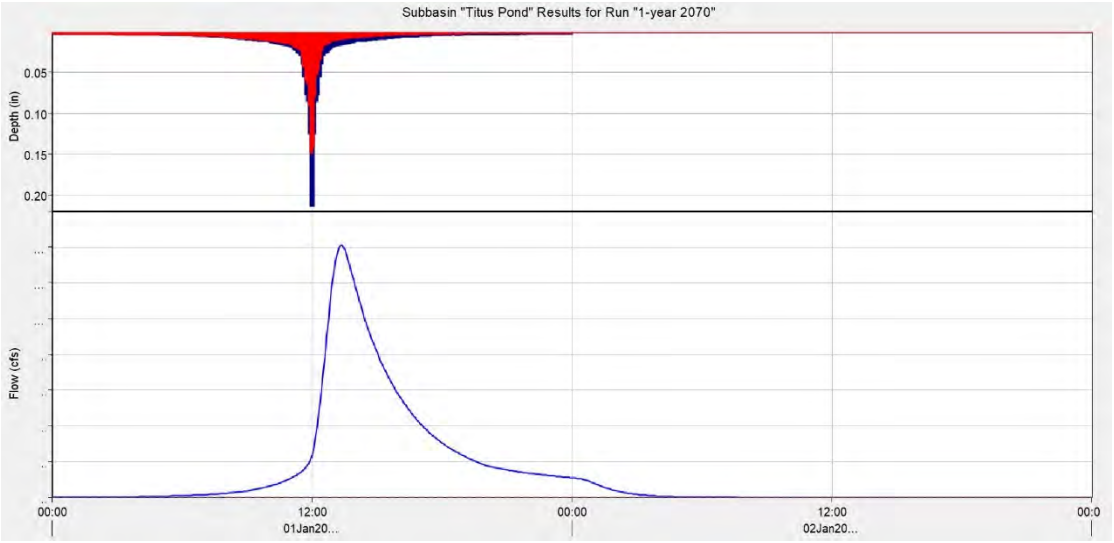
Project: QueensvilleDam_Updated Simulation Run: 1-year 2070
Subbasin: Titus Pond

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	1-year 2070
Compute Time:	31Jan2023, 14:31:16	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	14.1 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:20
Precipitation Volume:	2.95 (IN)	Direct Runoff Volume:	0.90 (IN)
Loss Volume:	2.05 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	0.90 (IN)	Discharge Volume:	0.90 (IN)



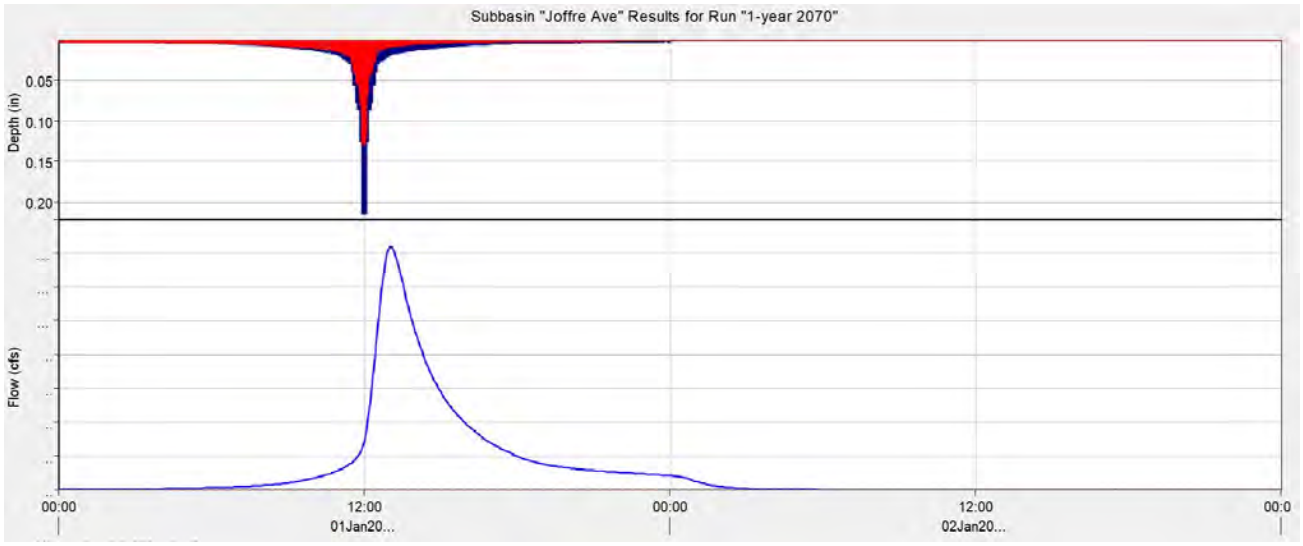
Project: QueensvilleDam_Updated Simulation Run: 1-year 2070
Subbasin: Joffre Ave

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	1-year 2070
Compute Time:	31Jan2023, 14:31:16	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	14.4 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:05
Precipitation Volume:	2.95 (IN)	Direct Runoff Volume:	1.14 (IN)
Loss Volume:	1.81 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	1.14 (IN)	Discharge Volume:	1.14 (IN)



Existing 10-Year, 24-Hour Storm

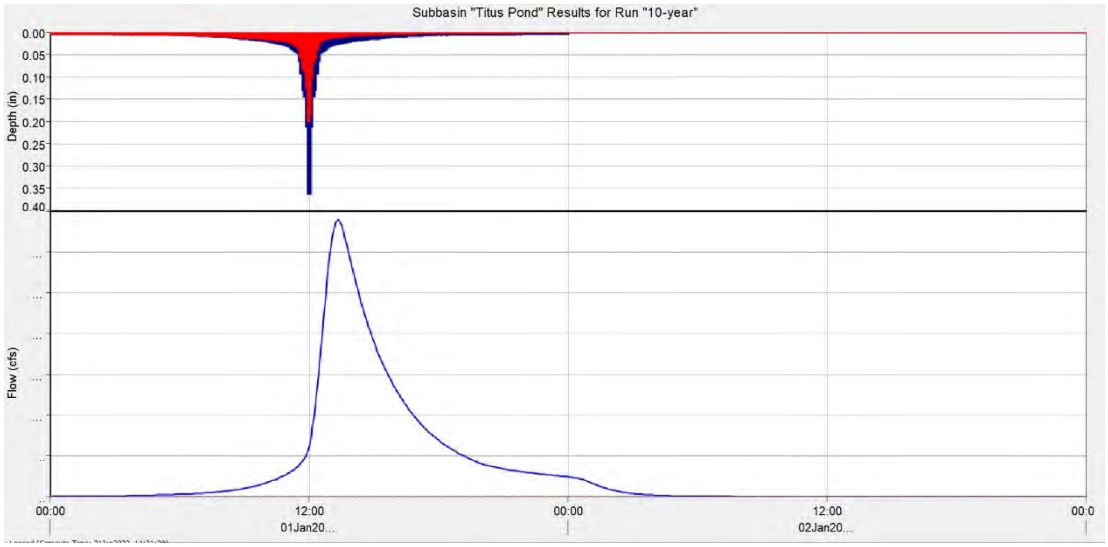
Project: QueensvilleDam_Updated Simulation Run: 10-year
Subbasin: Titus Pond

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	10-year
Compute Time:	31Jan2023, 14:31:30	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	34.0 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:20
Precipitation Volume:	4.98 (IN)	Direct Runoff Volume:	2.12 (IN)
Loss Volume:	2.86 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	2.12 (IN)	Discharge Volume:	2.12 (IN)



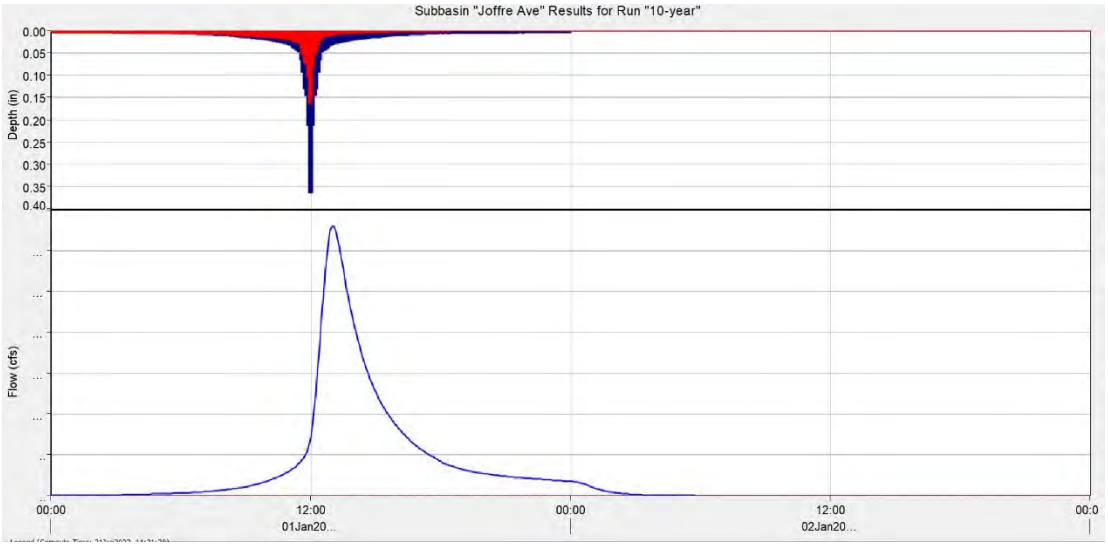
Project: QueensvilleDam_Updated Simulation Run: 10-year
Subbasin: Joffre Ave

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	10-year
Compute Time:	31Jan2023, 14:31:30	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	33.1 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:00
Precipitation Volume:	4.98 (IN)	Direct Runoff Volume:	2.56 (IN)
Loss Volume:	2.42 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	2.56 (IN)	Discharge Volume:	2.56 (IN)



Future (2070) 10-Year, 24-Hour Storm

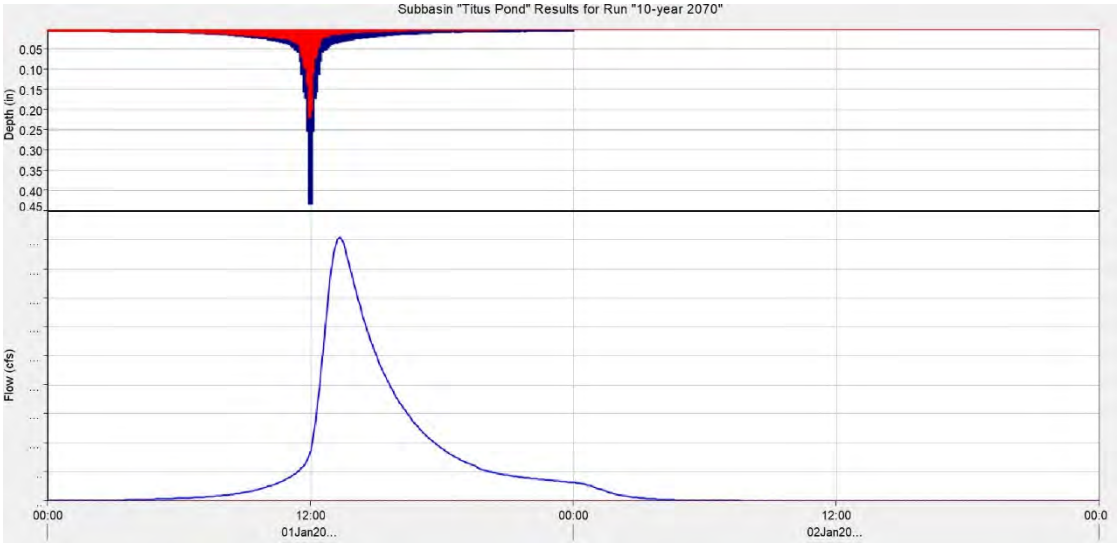
Project: QueensvilleDam_Updated Simulation Run: 10-year 2070
Subbasin: Titus Pond

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	10-year 2070
Compute Time:	31Jan2023, 14:31:45	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	45.4 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:20
Precipitation Volume:	5.98 (IN)	Direct Runoff Volume:	2.81 (IN)
Loss Volume:	3.17 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	2.81 (IN)	Discharge Volume:	2.81 (IN)



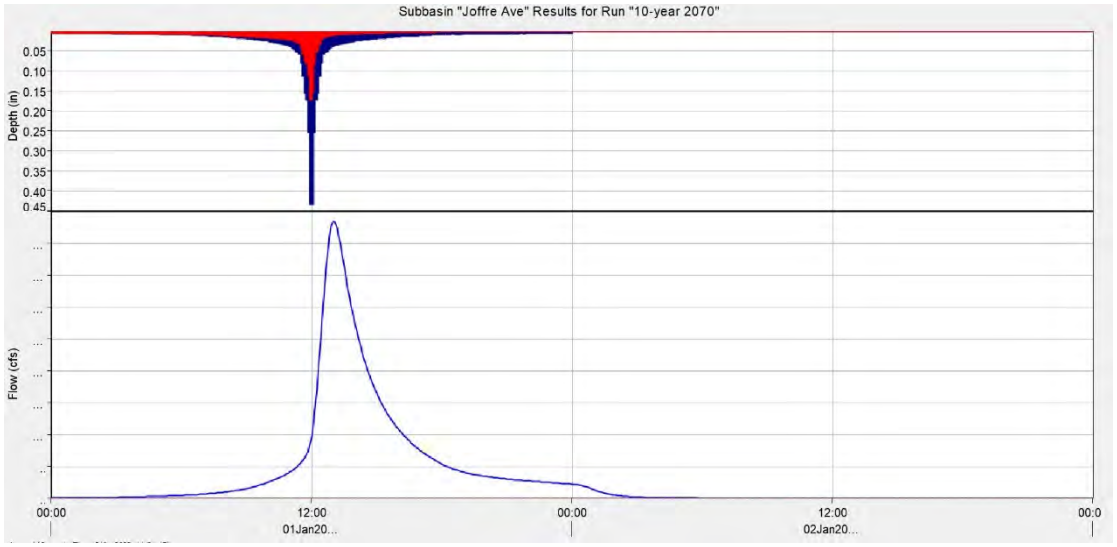
Project: QueensvilleDam_Updated Simulation Run: 10-year 2070
Subbasin: Joffre Ave

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	10-year 2070
Compute Time:	31Jan2023, 14:31:45	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	43.5 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:00
Precipitation Volume:	5.98 (IN)	Direct Runoff Volume:	3.34 (IN)
Loss Volume:	2.64 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	3.34 (IN)	Discharge Volume:	3.34 (IN)



Existing 25-Year, 24-Hour Storm

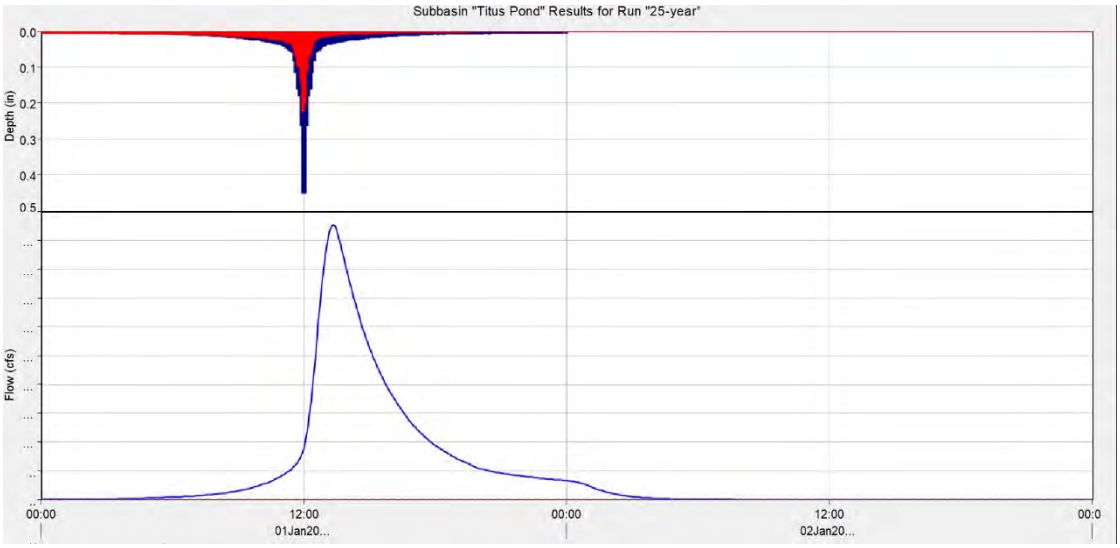
Project: QueensvilleDam_Updated Simulation Run: 25-year
Subbasin: Titus Pond

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	25-year
Compute Time:	31Jan2023, 14:33:28	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	47.7 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:20
Precipitation Volume:	6.17 (IN)	Direct Runoff Volume:	2.95 (IN)
Loss Volume:	3.22 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	2.95 (IN)	Discharge Volume:	2.95 (IN)



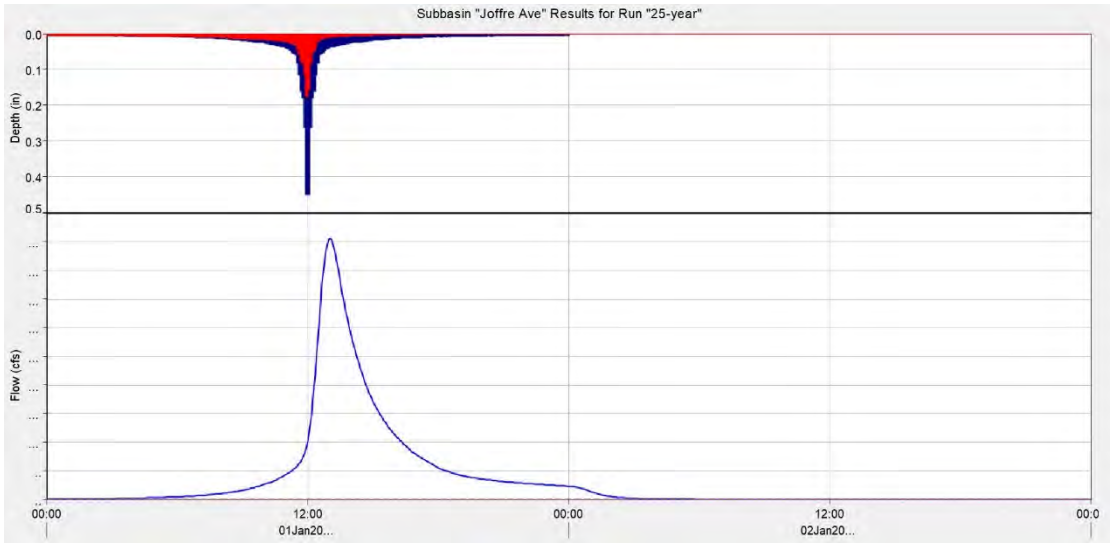
Project: QueensvilleDam_Updated Simulation Run: 25-year
Subbasin: Joffre Ave

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	25-year
Compute Time:	31Jan2023, 14:33:28	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	45.5 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:00
Precipitation Volume:	6.17 (IN)	Direct Runoff Volume:	3.50 (IN)
Loss Volume:	2.67 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	3.50 (IN)	Discharge Volume:	3.50 (IN)



Future (2070) 25-Year, 24-Hour Storm

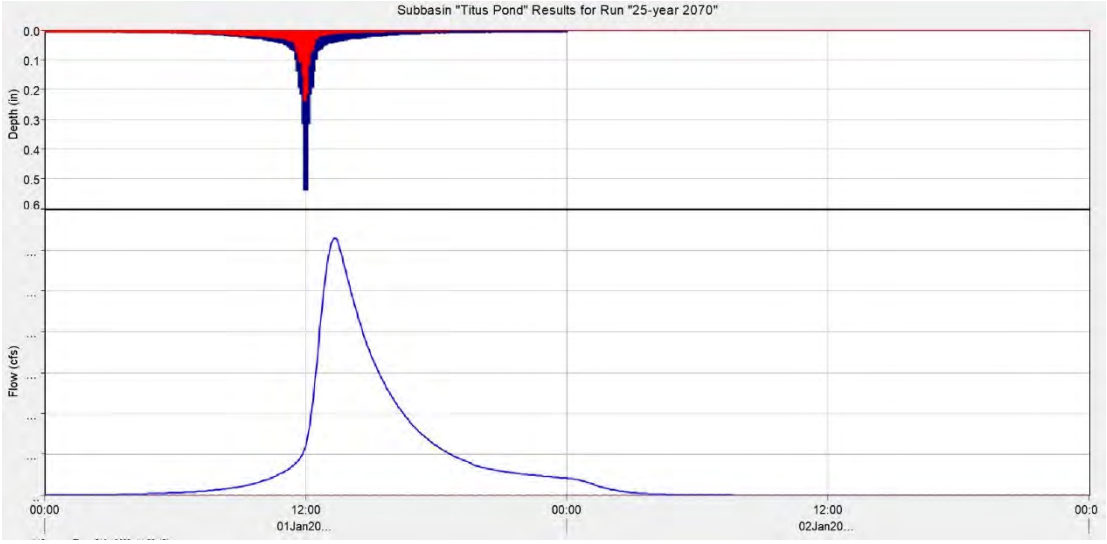
Project: QueensvilleDam_Updated Simulation Run: 25-year 2070
Subbasin: Titus Pond

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	25-year 2070
Compute Time:	31Jan2023, 14:33:43	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	63.1 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:20
Precipitation Volume:	7.40 (IN)	Direct Runoff Volume:	3.87 (IN)
Loss Volume:	3.53 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	3.87 (IN)	Discharge Volume:	3.87 (IN)



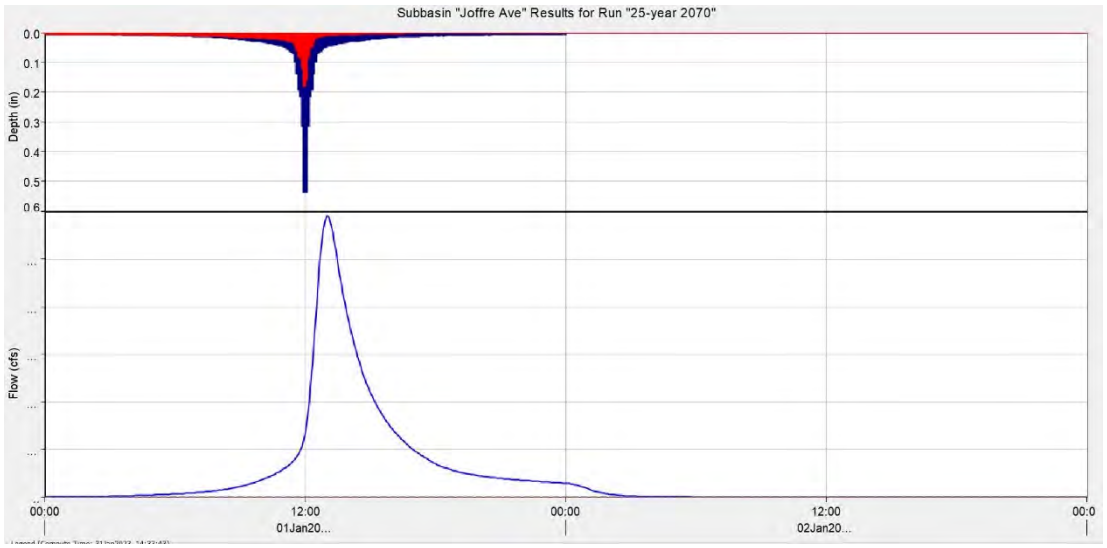
Project: QueensvilleDam_Updated Simulation Run: 25-year 2070
Subbasin: Joffre Ave

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	25-year 2070
Compute Time:	31Jan2023, 14:33:43	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	59.1 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:00
Precipitation Volume:	7.40 (IN)	Direct Runoff Volume:	4.52 (IN)
Loss Volume:	2.88 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	4.52 (IN)	Discharge Volume:	4.52 (IN)



Existing 50-Year, 24-Hour Storm

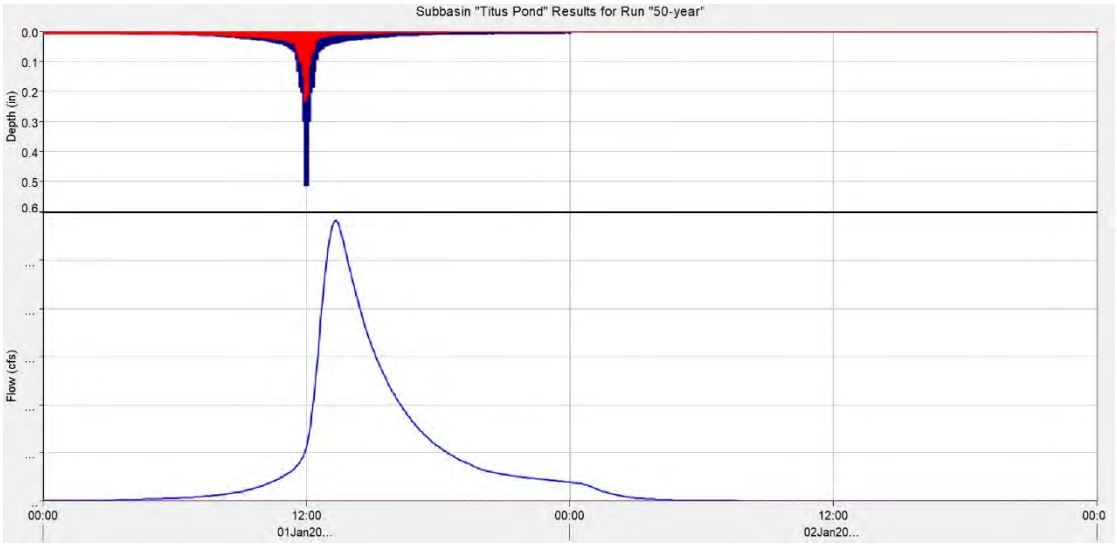
Project: QueensvilleDam_Updated Simulation Run: 50-year
Subbasin: Titus Pond

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	50-year
Compute Time:	31Jan2023, 14:34:27	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	58.3 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:20
Precipitation Volume:	7.03 (IN)	Direct Runoff Volume:	3.59 (IN)
Loss Volume:	3.44 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	3.59 (IN)	Discharge Volume:	3.59 (IN)



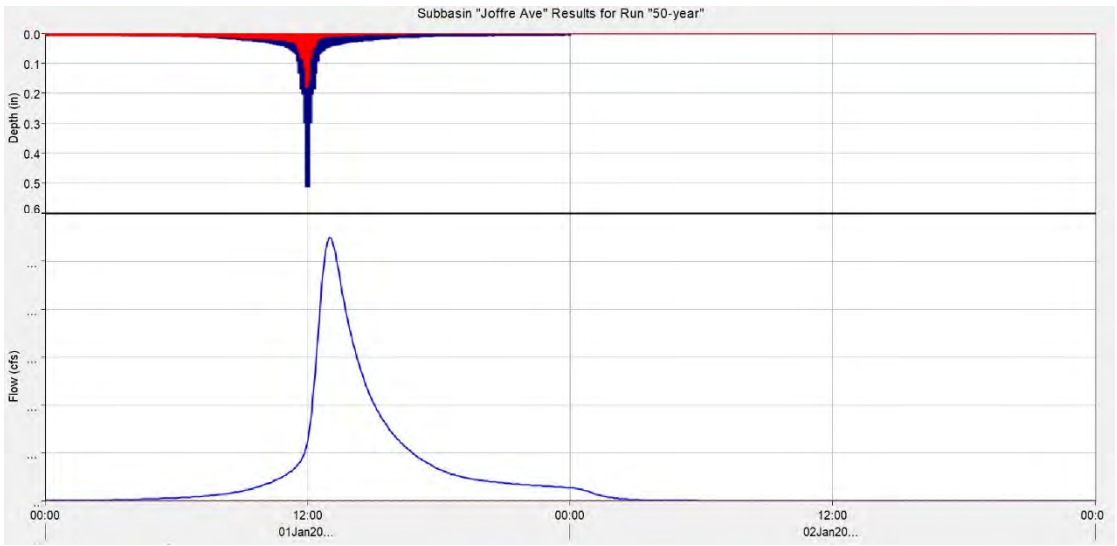
Project: QueensvilleDam_Updated Simulation Run: 50-year
Subbasin: Joffre Ave

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	50-year
Compute Time:	31Jan2023, 14:34:27	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	55.0 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:00
Precipitation Volume:	7.03 (IN)	Direct Runoff Volume:	4.21 (IN)
Loss Volume:	2.82 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	4.21 (IN)	Discharge Volume:	4.21 (IN)



Future 50-Year, 24-Hour Storm

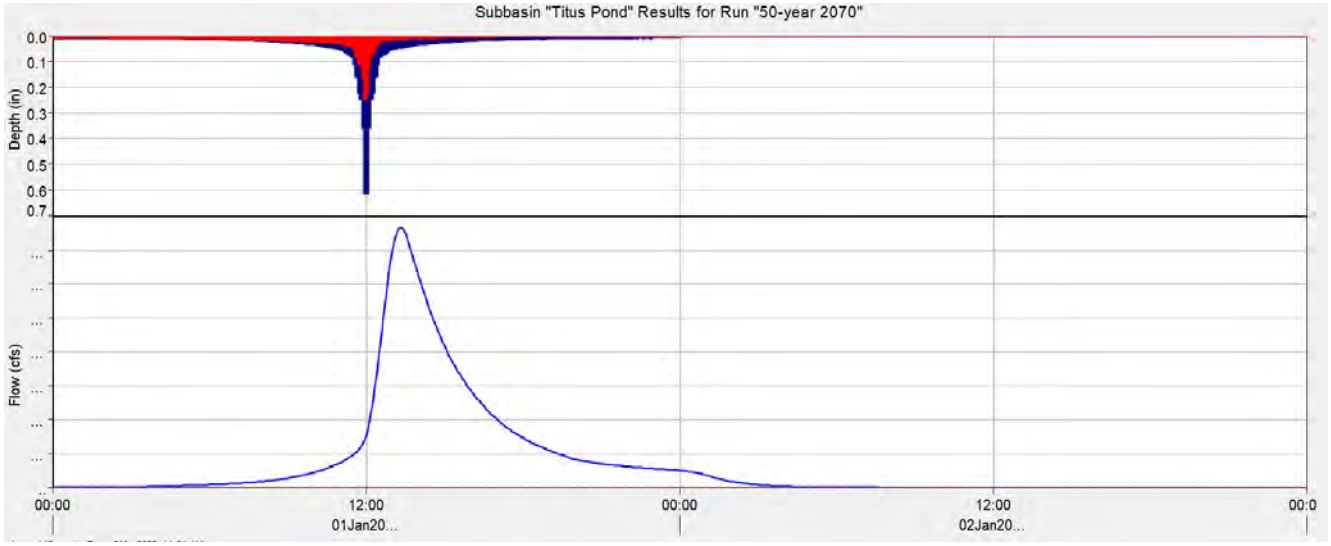
Project: QueensvilleDam_Updated Simulation Run: 50-year 2070
Subbasin: Joffre Ave

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	50-year 2070
Compute Time:	31Jan2023, 14:34:41	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	71.0 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:00
Precipitation Volume:	8.44 (IN)	Direct Runoff Volume:	5.42 (IN)
Loss Volume:	3.02 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	5.42 (IN)	Discharge Volume:	5.42 (IN)



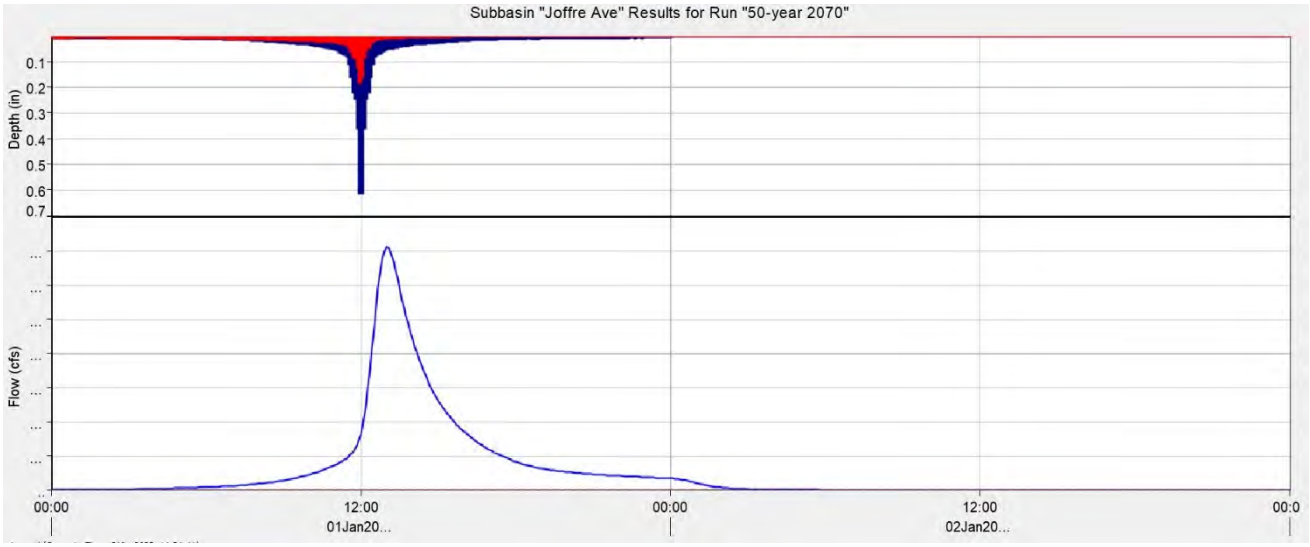
Project: QueensvilleDam_Updated Simulation Run: 50-year 2070
Subbasin: Titus Pond

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	50-year 2070
Compute Time:	31Jan2023, 14:34:41	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	76.7 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:20
Precipitation Volume:	8.44 (IN)	Direct Runoff Volume:	4.69 (IN)
Loss Volume:	3.75 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	4.69 (IN)	Discharge Volume:	4.69 (IN)



Existing 100-Year, 24-Hour Storm

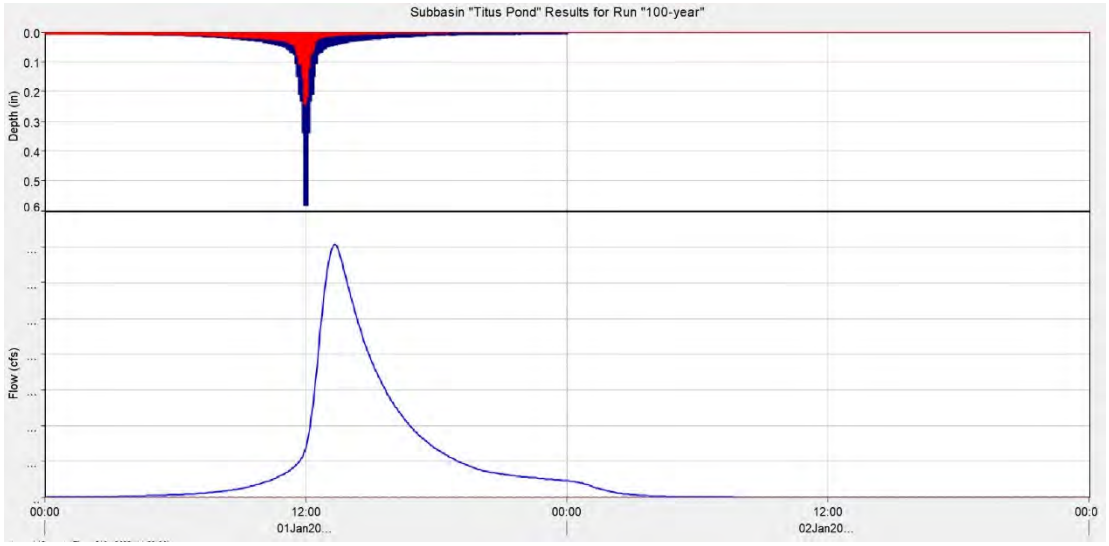
Project: QueensvilleDam_Updated Simulation Run: 100-year
Subbasin: Titus Pond

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	100-year
Compute Time:	31Jan2023, 14:32:00	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	70.8 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:20
Precipitation Volume:	7.99 (IN)	Direct Runoff Volume:	4.33 (IN)
Loss Volume:	3.66 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	4.33 (IN)	Discharge Volume:	4.33 (IN)



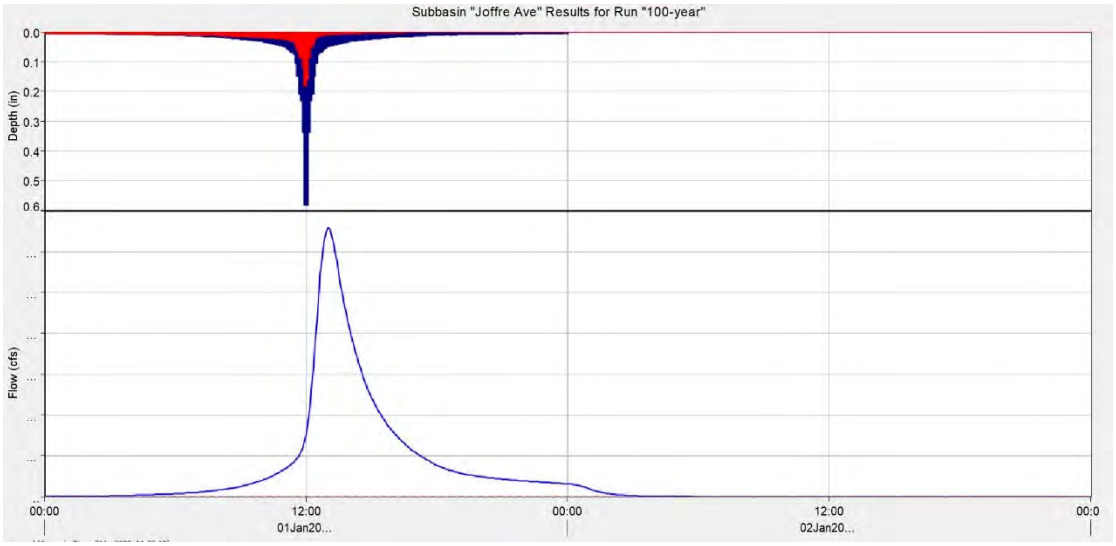
Project: QueensvilleDam_Updated Simulation Run: 100-year
Subbasin: Joffre Ave

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	100-year
Compute Time:	31Jan2023, 14:32:00	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	65.9 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:00
Precipitation Volume:	7.99 (IN)	Direct Runoff Volume:	5.02 (IN)
Loss Volume:	2.97 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	5.02 (IN)	Discharge Volume:	5.02 (IN)



Future (2070) 100-Year, 24-Hour Storm

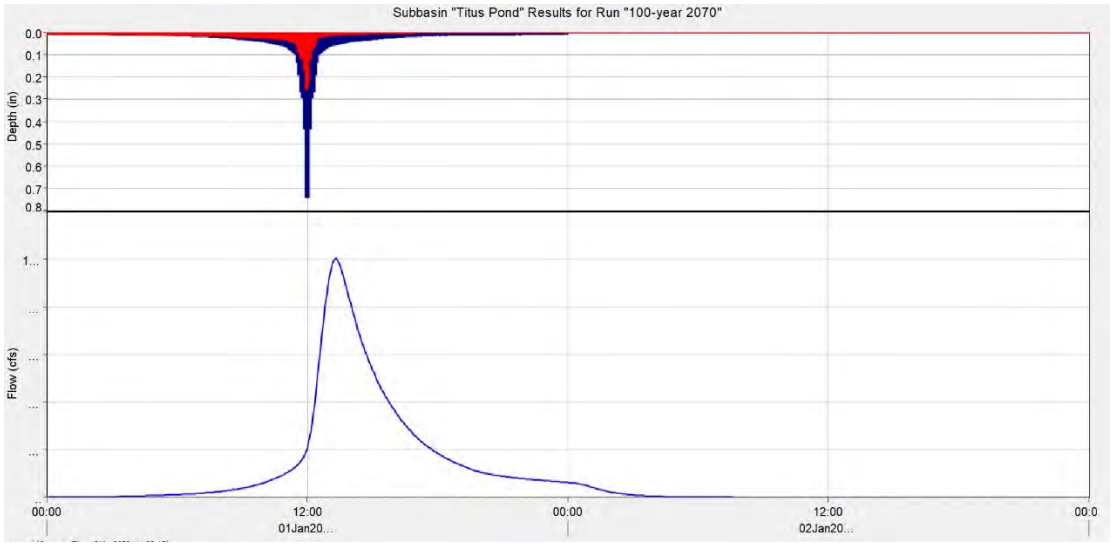
Project: QueensvilleDam_Updated Simulation Run: 100-year 2070
Subbasin: Titus Pond

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	100-year 2070
Compute Time:	31Jan2023, 14:32:15	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

Computed Results

Peak Discharge:	100.3 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:20
Precipitation Volume:	10.15 (IN)	Direct Runoff Volume:	6.10 (IN)
Loss Volume:	4.05 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	6.10 (IN)	Discharge Volume:	6.10 (IN)



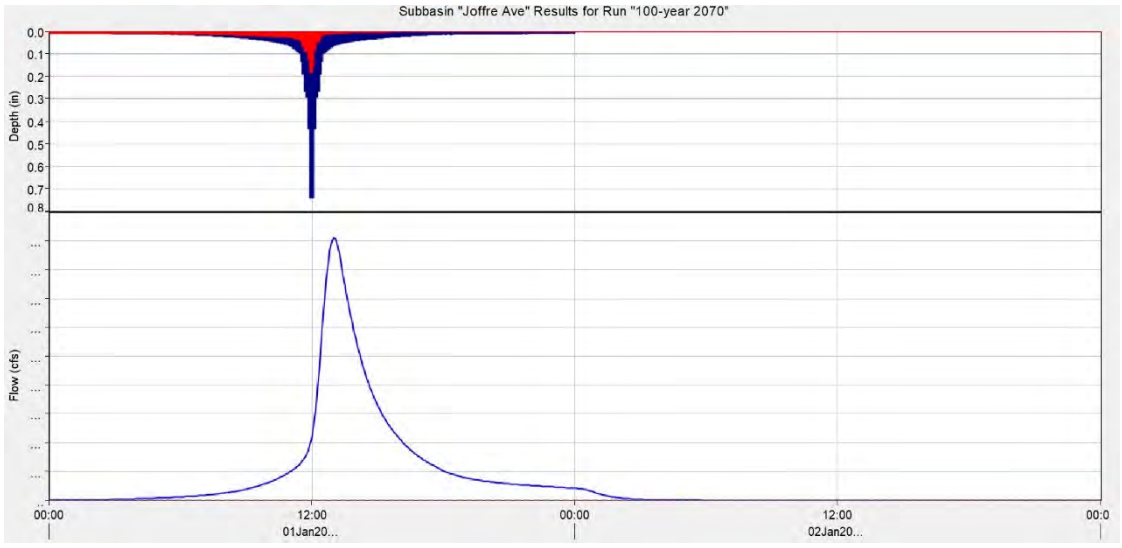
Project: QueensvilleDam_Updated Simulation Run: 100-year 2070
Subbasin: Joffre Ave

Start of Run:	01Jan2021, 00:00	Basin Model:	Basin 1
End of Run:	03Jan2021, 00:00	Meteorologic Model:	100-year 2070
Compute Time:	31Jan2023, 14:32:15	Control Specifications:	Control 1

Volume Units: (●) IN ( ) ACRE-FT

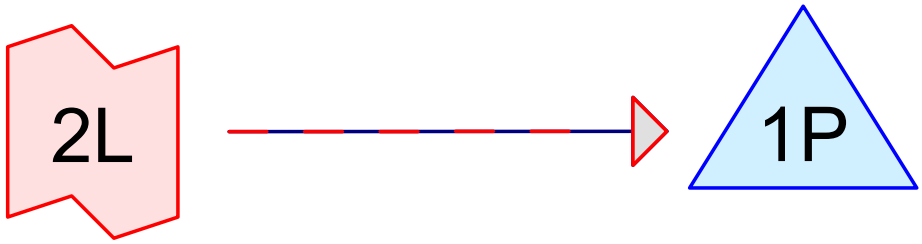
Computed Results

Peak Discharge:	91.2 (CFS)	Date/Time of Peak Discharge:	01Jan2021, 13:00
Precipitation Volume:	10.15 (IN)	Direct Runoff Volume:	6.93 (IN)
Loss Volume:	3.22 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	6.93 (IN)	Discharge Volume:	6.93 (IN)



Appendix C

HydroCAD Model Summary Report



HMS Hydrograph; Existing Conditions

Titus Pond; Existing Conditions

Subcat Reach Pond Link

Routing Diagram for Existing Conditions_2023027
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 1P: Titus Pond; Existing Conditions Peak Elev=160.92' Storage=7.644 af Inflow=10.28 cfs 3.710 af
Primary=5.91 cfs 3.697 af Secondary=0.00 cfs 0.000 af Outflow=5.91 cfs 3.697 af

Link 2L: HMS Hydrograph; 1-year Imported from Hydrograph.csv before 48.00 hrs Inflow=10.28 cfs 3.710 af
Primary=10.28 cfs 3.710 af Secondary=0.00 cfs 0.000 af

Summary for Pond 1P: Titus Pond; Existing Conditions

Inflow	=	10.28 cfs @	13.34 hrs,	Volume=	3.710 af
Outflow	=	5.91 cfs @	15.00 hrs,	Volume=	3.697 af, Atten= 43%, Lag= 100.0 min
Primary	=	5.91 cfs @	15.00 hrs,	Volume=	3.697 af
Secondary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Starting Elev= 160.20' Surf.Area= 1.505 ac Storage= 6.520 af
Peak Elev= 160.92' @ 15.00 hrs Surf.Area= 1.612 ac Storage= 7.644 af (1.124 af above start)
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.968 af (9.448 af above start)

Plug-Flow detention time= (not calculated: initial storage exceeds outflow)
Center-of-Mass det. time= 164.9 min (1,103.7 - 938.8)

Volume	Invert	Avail.Storage	Storage Description
#1	149.00'	18.632 af	**Custom Stage Data (Conic)** Listed below (Recalc)

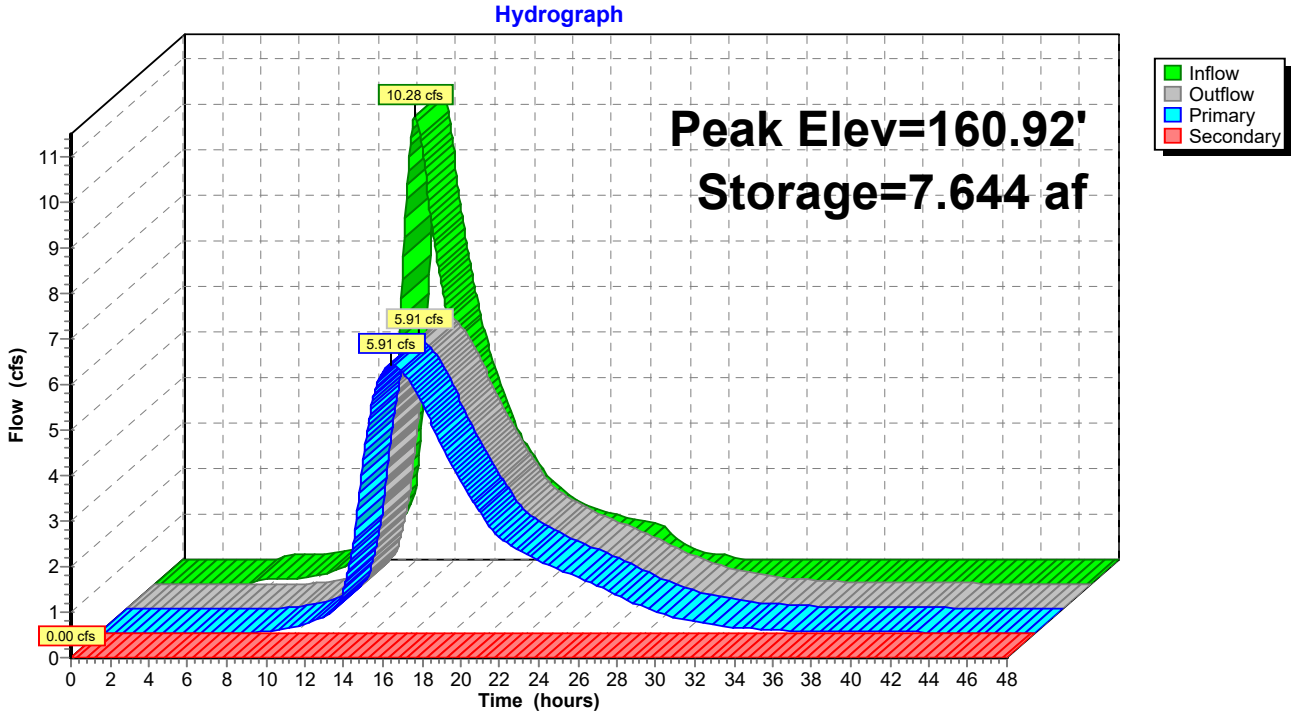
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
149.00	0.003	0.000	0.000	0.003
150.00	0.054	0.023	0.023	0.054
151.00	0.100	0.076	0.099	0.100
152.00	0.166	0.132	0.231	0.167
153.00	0.267	0.215	0.445	0.268
154.00	0.372	0.318	0.763	0.373
155.00	0.528	0.448	1.211	0.530
156.00	0.706	0.615	1.826	0.708
157.00	0.890	0.796	2.622	0.893
158.00	1.113	0.999	3.621	1.116
159.00	1.308	1.209	4.831	1.312
160.00	1.476	1.391	6.222	1.482
161.00	1.624	1.549	7.771	1.631
162.00	1.847	1.734	9.506	1.855
163.00	2.038	1.942	11.447	2.048
164.00	2.239	2.138	13.585	2.250
165.00	2.530	2.383	15.968	2.542
166.00	2.800	2.664	18.632	2.814

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Device 1	160.20'	**36.0" W x 36.0" H Vert. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=5.90 cfs @ 15.00 hrs HW=160.92' (Free Discharge)
└─**1=Culvert** (Passes 5.90 cfs of 29.14 cfs potential flow)
└─**2=Orifice/Grate** (Orifice Controls 5.90 cfs @ 2.73 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=160.20' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 1P: Titus Pond; Existing Conditions



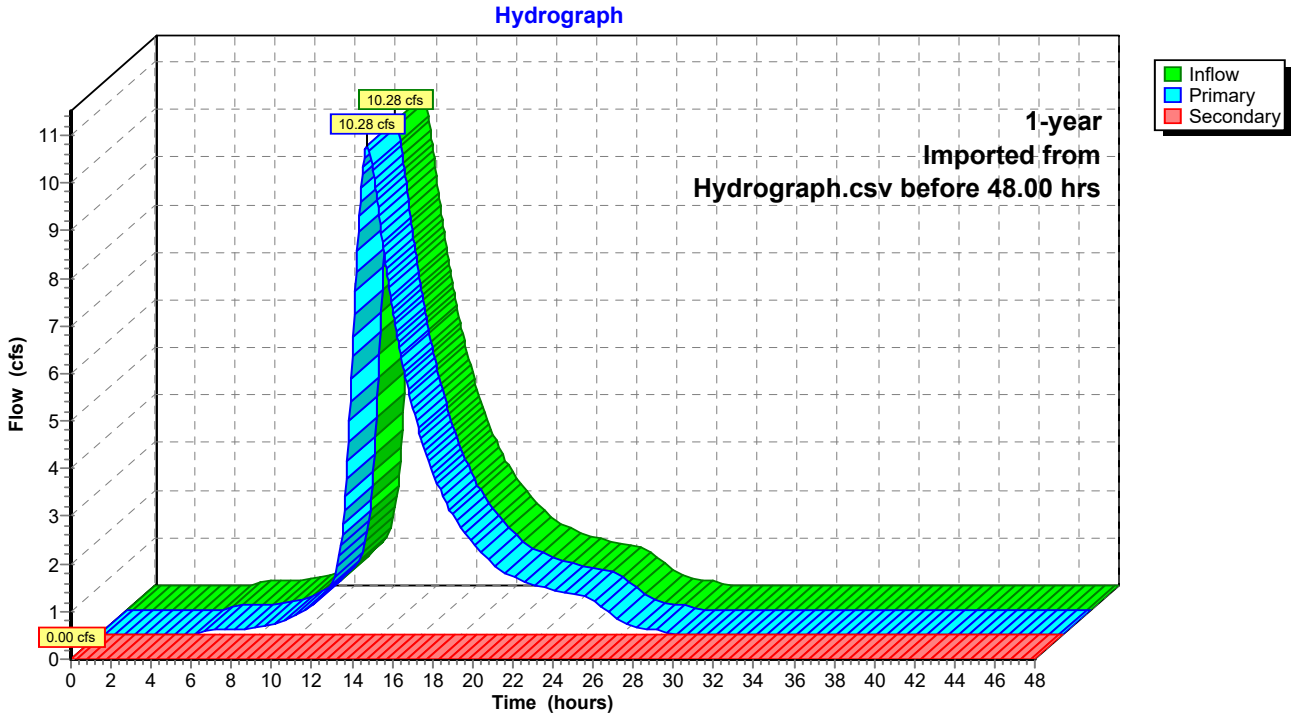
Summary for Link 2L: HMS Hydrograph; Existing Conditions

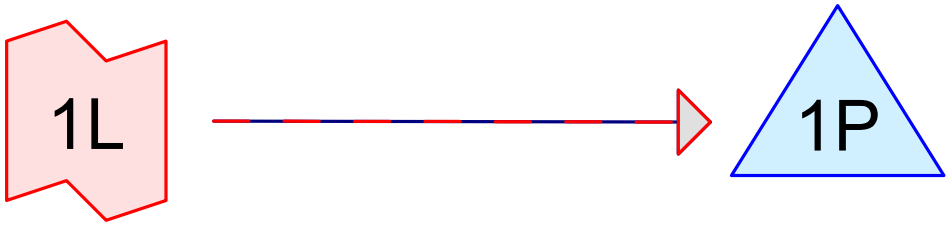
Inflow = 10.28 cfs @ 13.34 hrs, Volume= 3.710 af
Primary = 10.28 cfs @ 13.34 hrs, Volume= 3.710 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 1P : Titus Pond; Existing Conditions
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 1P : Titus Pond; Existing Conditions

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

1-year Imported from Hydrograph.csv

Link 2L: HMS Hydrograph; Existing Conditions





HMS Hydrograph

Titus Pond; Proposed Conditions

Subcat Reach Pond Link

Routing Diagram for Proposed Conditions
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 1P: Titus Pond; Proposed Conditions Peak Elev=154.66' Storage=0.481 af Inflow=10.28 cfs 3.710 af
Primary=8.73 cfs 3.688 af Secondary=0.00 cfs 0.000 af Outflow=8.73 cfs 3.688 af

Link 1L: HMS Hydrograph 1-year Imported from Hydrograph.csv before 48.00 hrs Inflow=10.28 cfs 3.710 af
Primary=10.28 cfs 3.710 af Secondary=0.00 cfs 0.000 af

Summary for Pond 1P: Titus Pond; Proposed Conditions

Inflow	=	10.28 cfs @	13.34 hrs,	Volume=	3.710 af
Outflow	=	8.73 cfs @	13.96 hrs,	Volume=	3.688 af, Atten= 15%, Lag= 37.6 min
Primary	=	8.73 cfs @	13.96 hrs,	Volume=	3.688 af
Secondary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 154.66' @ 13.96 hrs Surf.Area= 0.514 ac Storage= 0.481 af
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.779 af

Plug-Flow detention time= 51.5 min calculated for 3.688 af (99% of inflow)
Center-of-Mass det. time= 47.1 min (985.8 - 938.8)

Volume	Invert	Avail.Storage	Storage Description
#1	153.00'	18.443 af	**Custom Stage Data (Conic)** Listed below (Recalc)

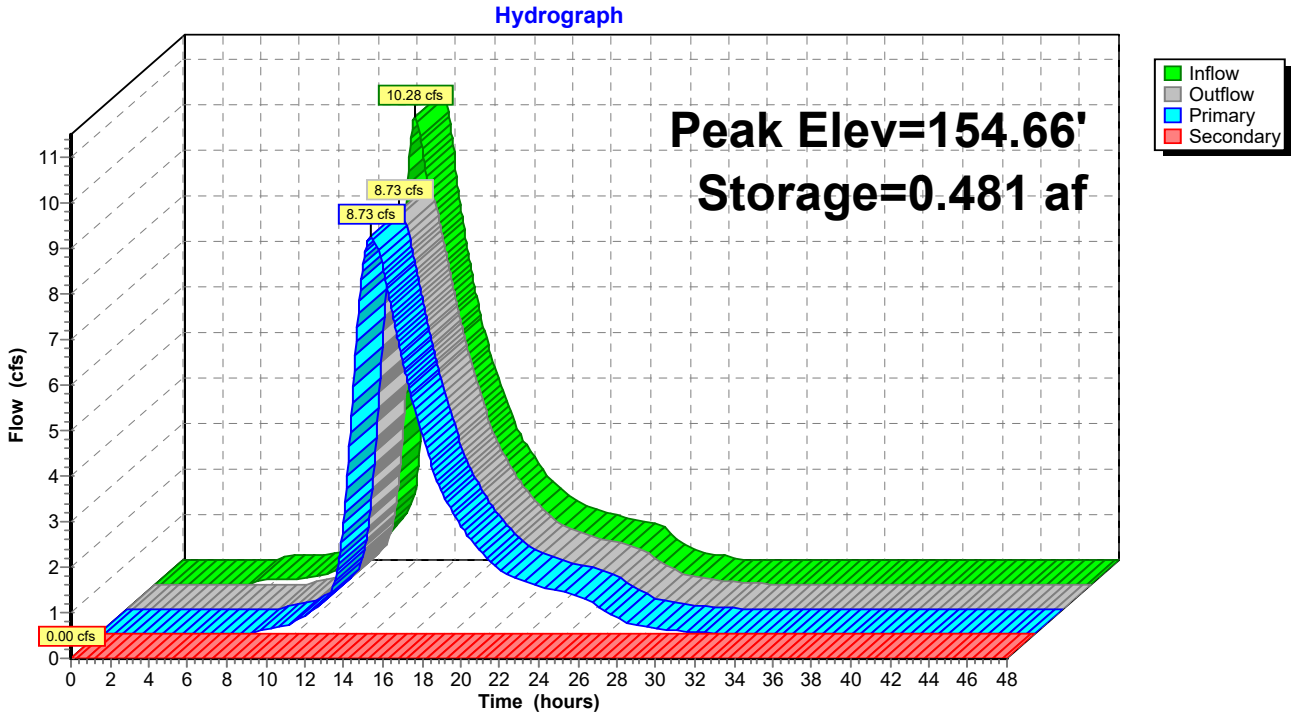
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
153.00	0.032	0.000	0.000	0.032
154.00	0.397	0.181	0.181	0.397
155.00	0.579	0.485	0.666	0.579
156.00	0.849	0.710	1.375	0.850
157.00	0.979	0.913	2.289	0.981
158.00	1.157	1.067	3.355	1.160
159.00	1.321	1.238	4.594	1.325
160.00	1.501	1.410	6.004	1.506
161.00	1.630	1.565	7.569	1.637
162.00	1.847	1.737	9.306	1.855
163.00	2.043	1.944	11.250	2.052
164.00	2.245	2.143	13.393	2.256
165.00	2.530	2.386	15.779	2.542
166.00	2.800	2.664	18.443	2.813

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=8.72 cfs @ 13.96 hrs HW=154.66' (Free Discharge)
1=Culvert (Inlet Controls 8.72 cfs @ 3.93 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=153.00' (Free Discharge)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Pond 1P: Titus Pond; Proposed Conditions



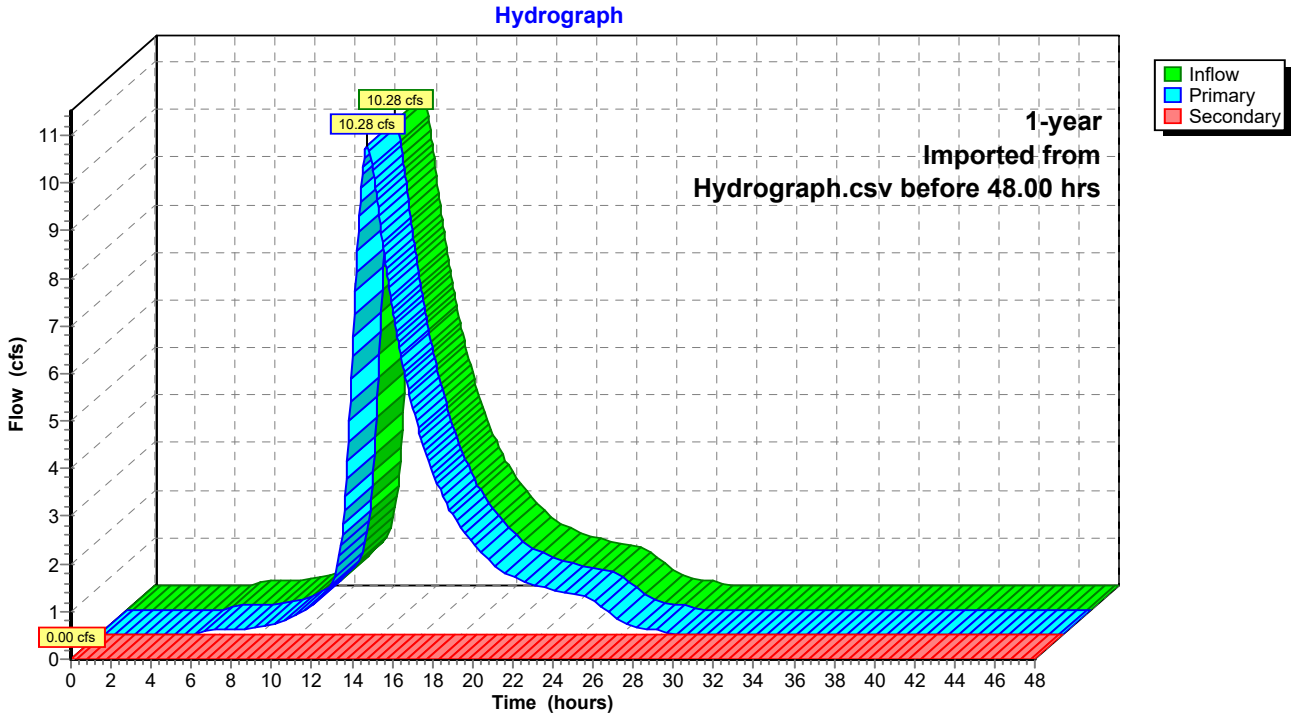
Summary for Link 1L: HMS Hydrograph

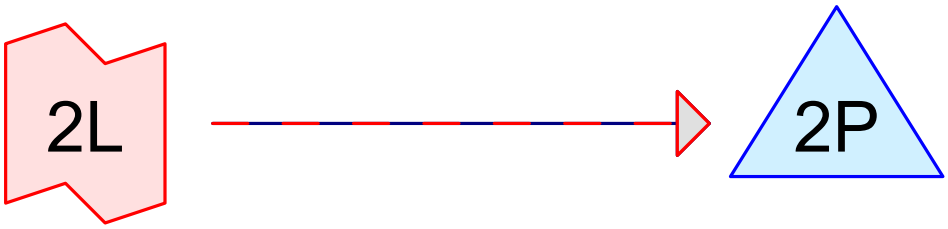
Inflow = 10.28 cfs @ 13.34 hrs, Volume= 3.710 af
Primary = 10.28 cfs @ 13.34 hrs, Volume= 3.710 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 1P : Titus Pond; Proposed Conditions
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 1P : Titus Pond; Proposed Conditions

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

1-year Imported from Hydrograph.csv

Link 1L: HMS Hydrograph





HMS Hydrograph 2070

Titus Pond; Proposed Conditions (2070 Climate)

Subcat Reach Pond Link

Routing Diagram for Proposed Conditions
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 2P: Titus Pond; Proposed Conditions Peak Elev=154.96' Storage=0.644 af Inflow=14.11 cfs 5.071 af
Primary=11.93 cfs 5.049 af Secondary=0.00 cfs 0.000 af Outflow=11.93 cfs 5.049 af

1-year Impound **Link** from F:\P2017\0390\V50\H&H\HydroCAD\Hydrograph 2070.csv before 48.00 hrs Inflow=14.11 cfs 5.071 af
Primary=14.11 cfs 5.071 af Secondary=0.00 cfs 0.000 af

Summary for Pond 2P: Titus Pond; Proposed Conditions (2070 Climate)

Inflow	=	14.11 cfs @	13.38 hrs,	Volume=	5.071 af
Outflow	=	11.93 cfs @	13.97 hrs,	Volume=	5.049 af, Atten= 15%, Lag= 35.9 min
Primary	=	11.93 cfs @	13.97 hrs,	Volume=	5.049 af
Secondary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 154.96' @ 13.97 hrs Surf.Area= 0.571 ac Storage= 0.644 af
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.779 af

Plug-Flow detention time= 47.4 min calculated for 5.044 af (99% of inflow)
Center-of-Mass det. time= 44.7 min (981.0 - 936.3)

Volume	Invert	Avail.Storage	Storage Description
#1	153.00'	18.443 af	**Custom Stage Data (Conic)** Listed below (Recalc)

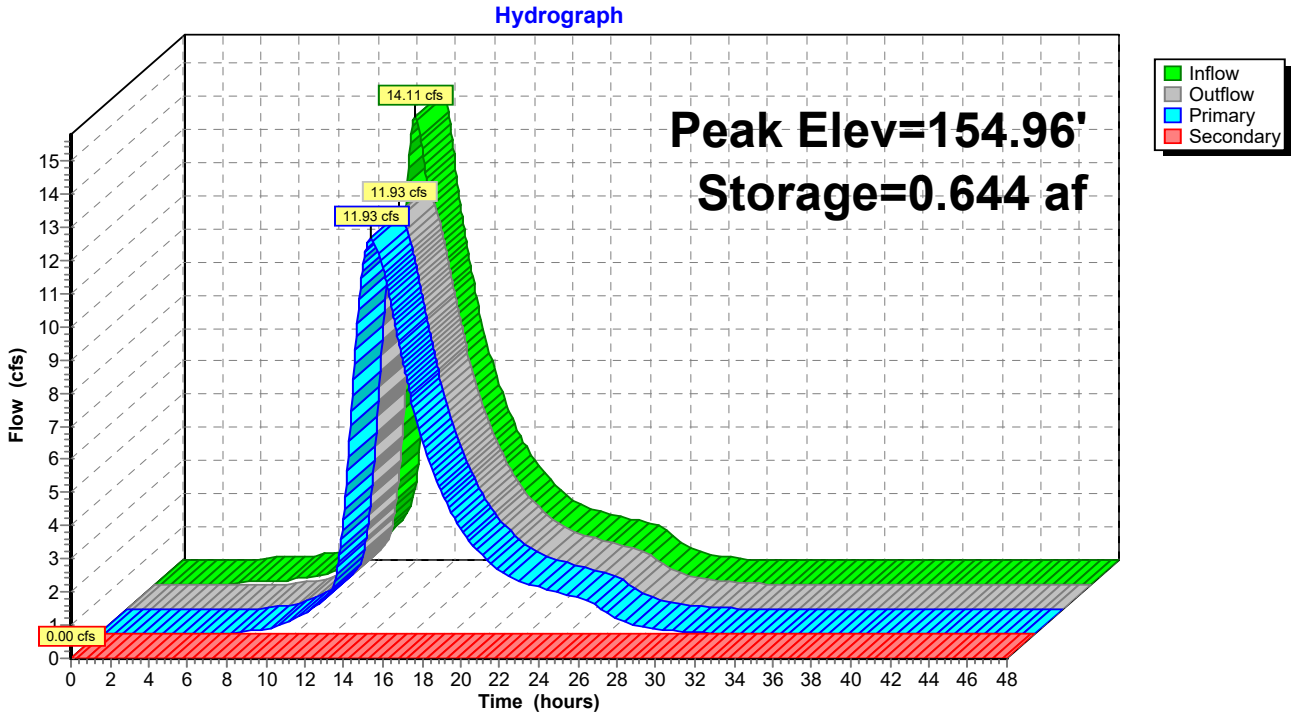
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
153.00	0.032	0.000	0.000	0.032
154.00	0.397	0.181	0.181	0.397
155.00	0.579	0.485	0.666	0.579
156.00	0.849	0.710	1.375	0.850
157.00	0.979	0.913	2.289	0.981
158.00	1.157	1.067	3.355	1.160
159.00	1.321	1.238	4.594	1.325
160.00	1.501	1.410	6.004	1.506
161.00	1.630	1.565	7.569	1.637
162.00	1.847	1.737	9.306	1.855
163.00	2.043	1.944	11.250	2.052
164.00	2.245	2.143	13.393	2.256
165.00	2.530	2.386	15.779	2.542
166.00	2.800	2.664	18.443	2.813

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=11.93 cfs @ 13.97 hrs HW=154.96' (Free Discharge)
1=Culvert (Inlet Controls 11.93 cfs @ 4.35 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=153.00' (Free Discharge)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Pond 2P: Titus Pond; Proposed Conditions (2070 Climate)



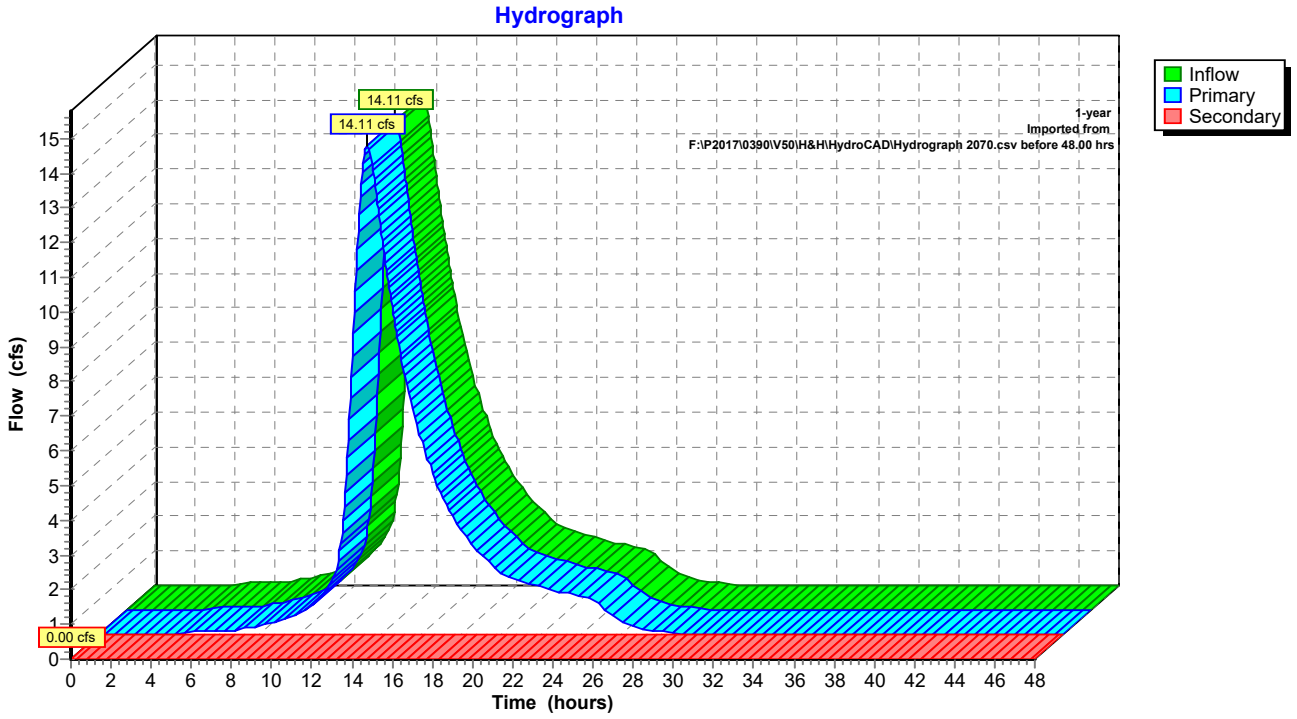
Summary for Link 2L: HMS Hydrograph 2070

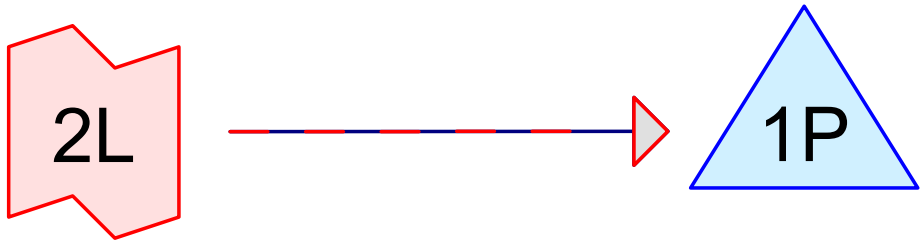
Inflow = 14.11 cfs @ 13.38 hrs, Volume= 5.071 af
Primary = 14.11 cfs @ 13.38 hrs, Volume= 5.071 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 2P : Titus Pond; Proposed Conditions (2070 Climate)
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 2P : Titus Pond; Proposed Conditions (2070 Climate)

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

1-year Imported from F:\P2017\0390\V50\H&H\HydroCAD\Hydrograph 2070.csv

Link 2L: HMS Hydrograph 2070





HMS Hydrograph; Existing Conditions

Titus Pond; Existing Conditions

Subcat Reach Pond Link

Routing Diagram for Existing Conditions_2023027
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 1P: Titus Pond; Existing Conditions Peak Elev=161.98' Storage=9.477 af Inflow=33.96 cfs 11.963 af
Primary=22.96 cfs 11.946 af Secondary=0.00 cfs 0.000 af Outflow=22.96 cfs 11.946 af

Link 2L: HMS 10-year Imported from Hydrograph.csv before 48.00 hrs Inflow=33.96 cfs 11.963 af
Primary=33.96 cfs 11.963 af Secondary=0.00 cfs 0.000 af

Summary for Pond 1P: Titus Pond; Existing Conditions

Inflow	=	33.96 cfs @	13.34 hrs,	Volume=	11.963 af
Outflow	=	22.96 cfs @	14.51 hrs,	Volume=	11.946 af, Atten= 32%, Lag= 69.7 min
Primary	=	22.96 cfs @	14.51 hrs,	Volume=	11.946 af
Secondary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Starting Elev= 160.20' Surf.Area= 1.505 ac Storage= 6.520 af
Peak Elev= 161.98' @ 14.51 hrs Surf.Area= 1.843 ac Storage= 9.477 af (2.957 af above start)
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.968 af (9.448 af above start)

Plug-Flow detention time= 487.6 min calculated for 5.421 af (45% of inflow)
Center-of-Mass det. time= 119.6 min (1,046.6 - 927.0)

Volume	Invert	Avail.Storage	Storage Description
#1	149.00'	18.632 af	**Custom Stage Data (Conic)** Listed below (Recalc)

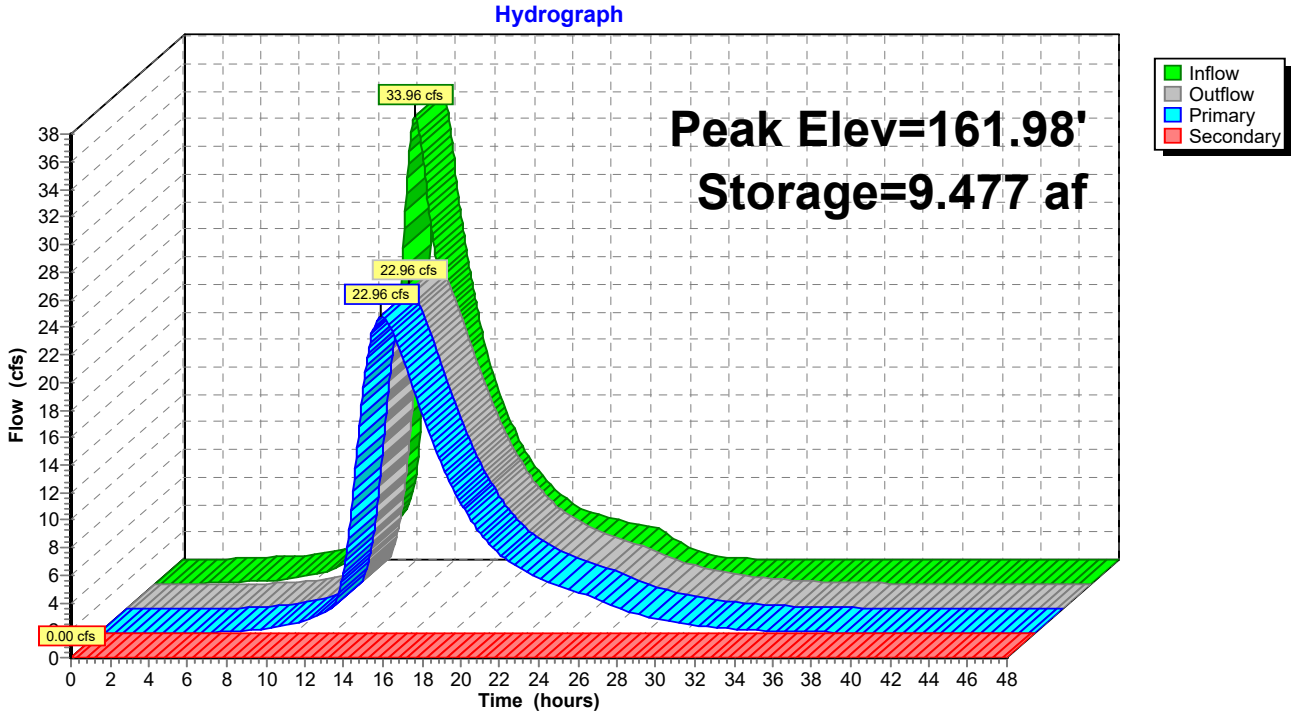
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
149.00	0.003	0.000	0.000	0.003
150.00	0.054	0.023	0.023	0.054
151.00	0.100	0.076	0.099	0.100
152.00	0.166	0.132	0.231	0.167
153.00	0.267	0.215	0.445	0.268
154.00	0.372	0.318	0.763	0.373
155.00	0.528	0.448	1.211	0.530
156.00	0.706	0.615	1.826	0.708
157.00	0.890	0.796	2.622	0.893
158.00	1.113	0.999	3.621	1.116
159.00	1.308	1.209	4.831	1.312
160.00	1.476	1.391	6.222	1.482
161.00	1.624	1.549	7.771	1.631
162.00	1.847	1.734	9.506	1.855
163.00	2.038	1.942	11.447	2.048
164.00	2.239	2.138	13.585	2.250
165.00	2.530	2.383	15.968	2.542
166.00	2.800	2.664	18.632	2.814

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Device 1	160.20'	**36.0" W x 36.0" H Vert. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=22.96 cfs @ 14.51 hrs HW=161.98' (Free Discharge)
└─**1=Culvert** (Passes 22.96 cfs of 30.16 cfs potential flow)
└─**2=Orifice/Grate** (Orifice Controls 22.96 cfs @ 4.29 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=160.20' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 1P: Titus Pond; Existing Conditions



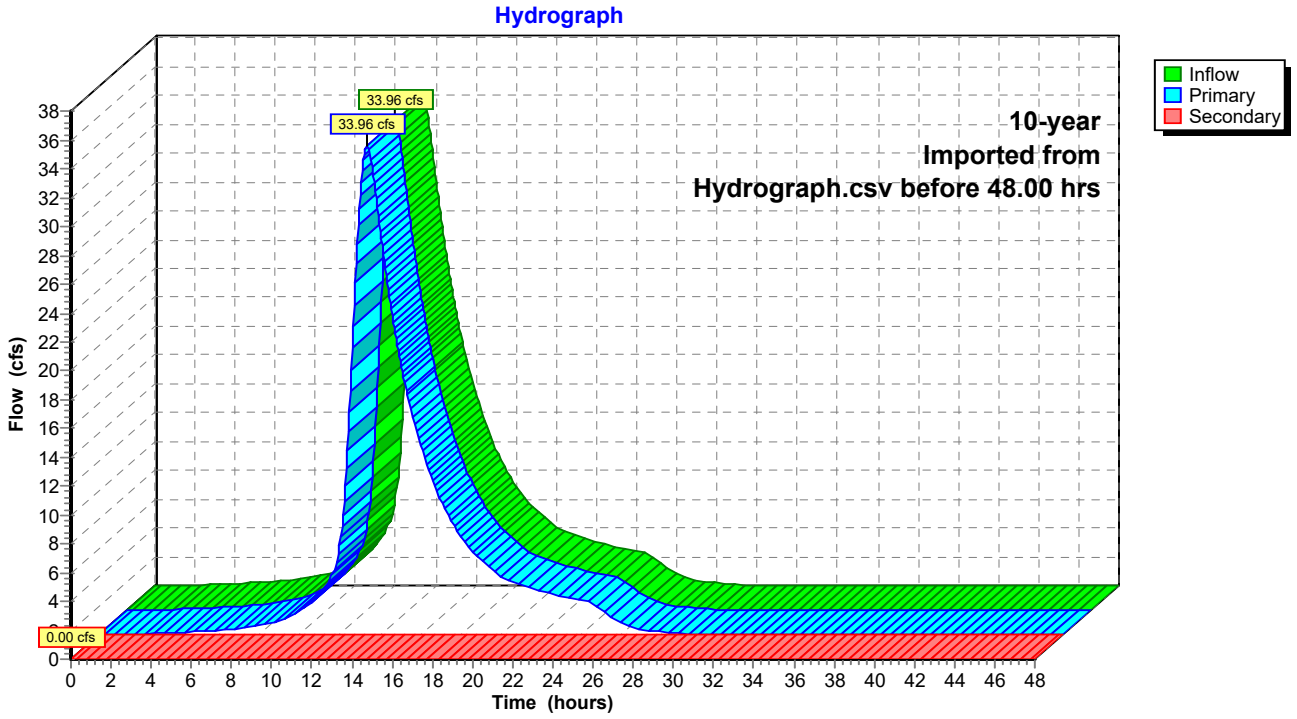
Summary for Link 2L: HMS Hydrograph; Existing Conditions

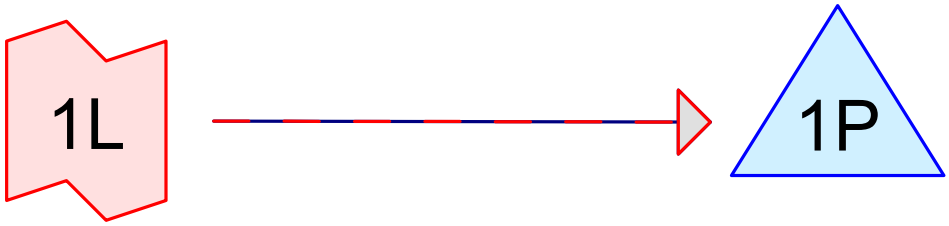
Inflow = 33.96 cfs @ 13.34 hrs, Volume= 11.963 af
Primary = 33.96 cfs @ 13.34 hrs, Volume= 11.963 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 1P : Titus Pond; Existing Conditions
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 1P : Titus Pond; Existing Conditions

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

10-year Imported from Hydrograph.csv

Link 2L: HMS Hydrograph; Existing Conditions





HMS Hydrograph

Titus Pond; Proposed Conditions

Subcat Reach Pond Link

Routing Diagram for Proposed Conditions
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 1P: Titus Pond; Proposed Peak Elev=156.71' Storage=2.008 af Inflow=33.96 cfs 11.963 af
Primary=23.32 cfs 11.941 af Secondary=0.00 cfs 0.000 af Outflow=23.32 cfs 11.941 af

Link 1L: HMS 10-year Imported from Hydrograph.csv before 48.00 hrs Inflow=33.96 cfs 11.963 af
Primary=33.96 cfs 11.963 af Secondary=0.00 cfs 0.000 af

Summary for Pond 1P: Titus Pond; Proposed Conditions

Inflow	=	33.96 cfs @	13.34 hrs,	Volume=	11.963 af
Outflow	=	23.32 cfs @	14.47 hrs,	Volume=	11.941 af, Atten= 31%, Lag= 67.3 min
Primary	=	23.32 cfs @	14.47 hrs,	Volume=	11.941 af
Secondary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 156.71' @ 14.47 hrs Surf.Area= 0.940 ac Storage= 2.008 af
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.779 af

Plug-Flow detention time= 52.7 min calculated for 11.941 af (100% of inflow)
Center-of-Mass det. time= 50.9 min (977.8 - 927.0)

Volume	Invert	Avail.Storage	Storage Description
#1	153.00'	18.443 af	**Custom Stage Data (Conic)** Listed below (Recalc)

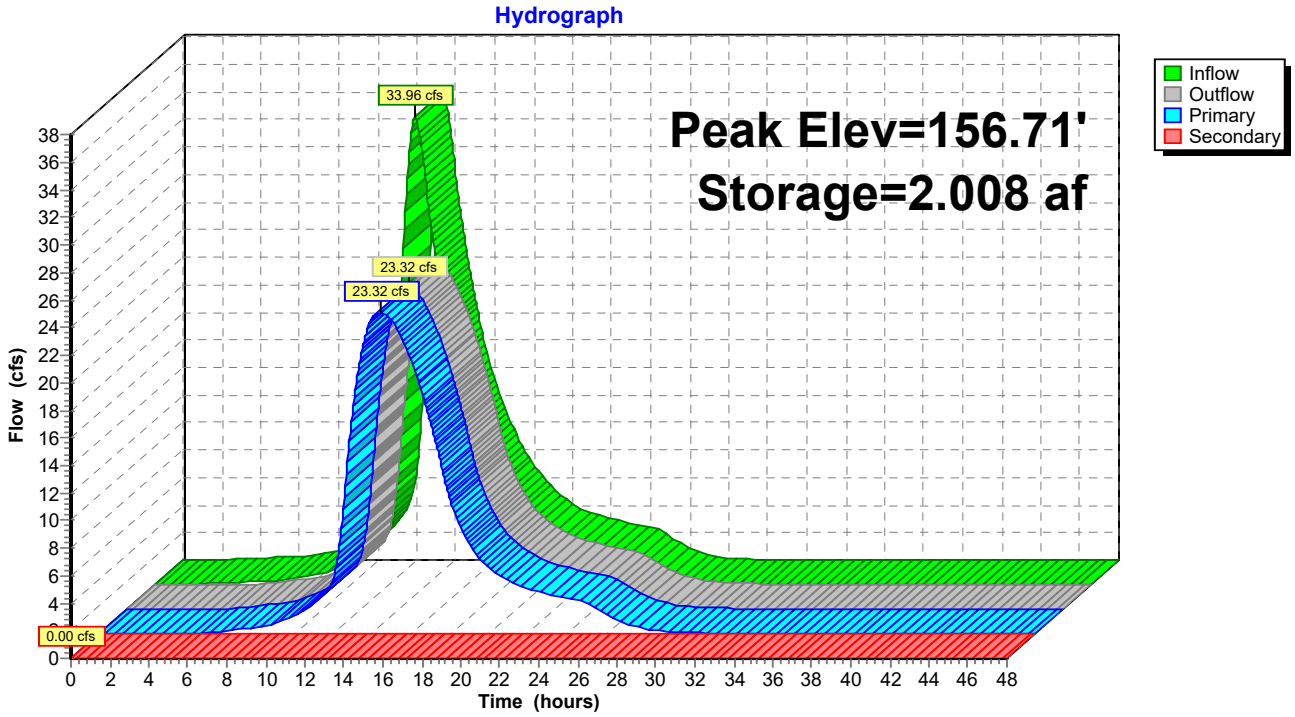
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
153.00	0.032	0.000	0.000	0.032
154.00	0.397	0.181	0.181	0.397
155.00	0.579	0.485	0.666	0.579
156.00	0.849	0.710	1.375	0.850
157.00	0.979	0.913	2.289	0.981
158.00	1.157	1.067	3.355	1.160
159.00	1.321	1.238	4.594	1.325
160.00	1.501	1.410	6.004	1.506
161.00	1.630	1.565	7.569	1.637
162.00	1.847	1.737	9.306	1.855
163.00	2.043	1.944	11.250	2.052
164.00	2.245	2.143	13.393	2.256
165.00	2.530	2.386	15.779	2.542
166.00	2.800	2.664	18.443	2.813

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=23.32 cfs @ 14.47 hrs HW=156.71' (Free Discharge)
1=Culvert (Inlet Controls 23.32 cfs @ 7.42 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=153.00' (Free Discharge)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Pond 1P: Titus Pond; Proposed Conditions



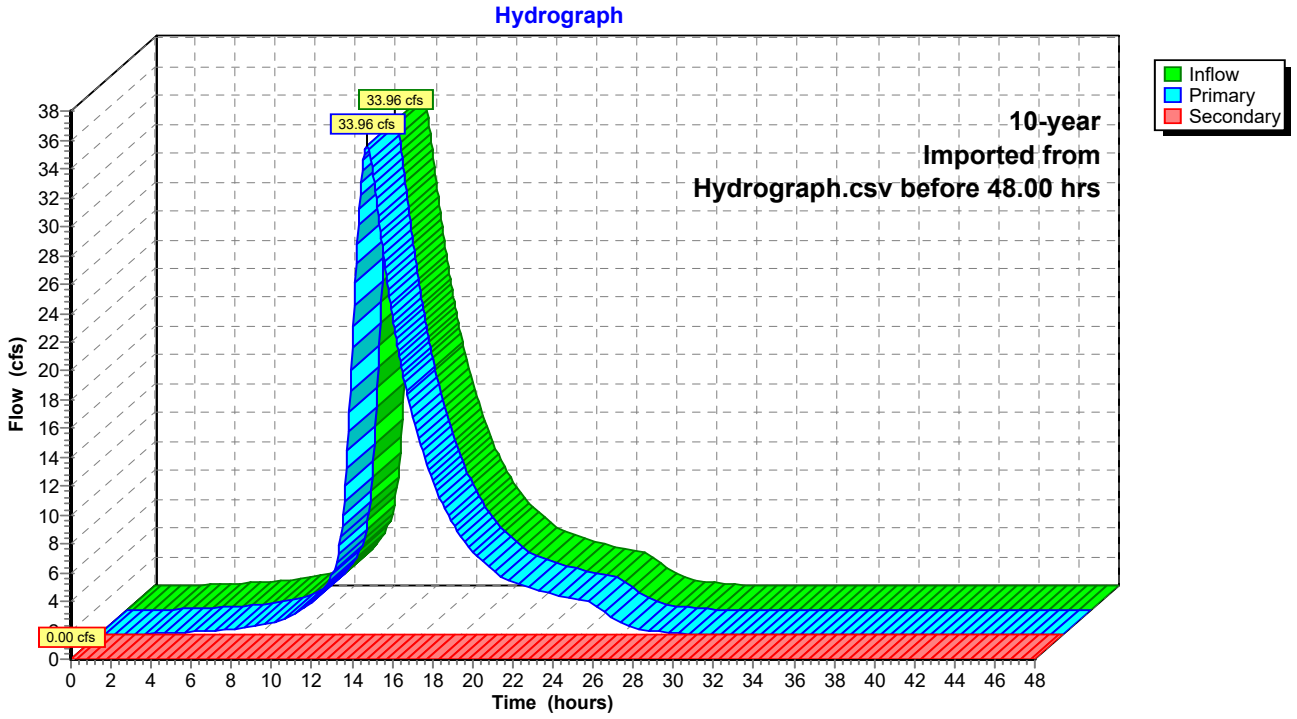
Summary for Link 1L: HMS Hydrograph

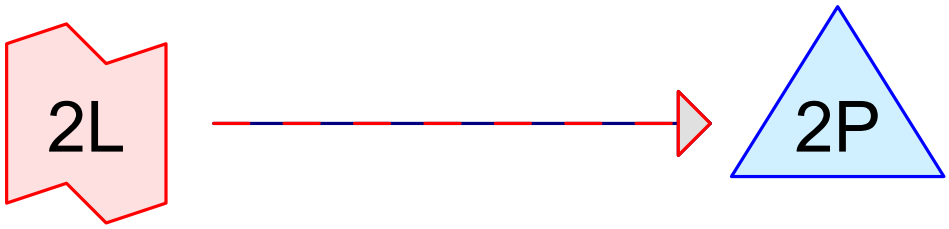
Inflow = 33.96 cfs @ 13.34 hrs, Volume= 11.963 af
Primary = 33.96 cfs @ 13.34 hrs, Volume= 11.963 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 1P : Titus Pond; Proposed Conditions
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 1P : Titus Pond; Proposed Conditions

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

10-year Imported from Hydrograph.csv

Link 1L: HMS Hydrograph





HMS Hydrograph 2070

Titus Pond; Proposed Conditions (2070 Climate)

Subcat Reach Pond Link

Routing Diagram for Proposed Conditions
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 2P: Titus Pond; Proposed Peak Elev=157.94' Storage=3.287 af Inflow=45.36 cfs 15.890 af
Primary=26.07 cfs 15.868 af Secondary=0.00 cfs 0.000 af Outflow=26.07 cfs 15.868 af

0-year Import from F:\P2017\0390\V50\H&H\HydroCAD\Hydrograph 2070.csv before 48.00 hrs Inflow=45.36 cfs 15.890 af
Link Primary=45.36 cfs 15.890 af Secondary=0.00 cfs 0.000 af

Summary for Pond 2P: Titus Pond; Proposed Conditions (2070 Climate)

Inflow = 45.36 cfs @ 13.34 hrs, Volume= 15.890 af
Outflow = 26.07 cfs @ 14.90 hrs, Volume= 15.868 af, Atten= 43%, Lag= 93.9 min
Primary = 26.07 cfs @ 14.90 hrs, Volume= 15.868 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 157.94' @ 14.90 hrs Surf.Area= 1.146 ac Storage= 3.287 af
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.779 af

Plug-Flow detention time= 64.6 min calculated for 15.851 af (100% of inflow)
Center-of-Mass det. time= 63.7 min (987.1 - 923.4)

Volume	Invert	Avail.Storage	Storage Description
#1	153.00'	18.443 af	**Custom Stage Data (Conic)** Listed below (Recalc)

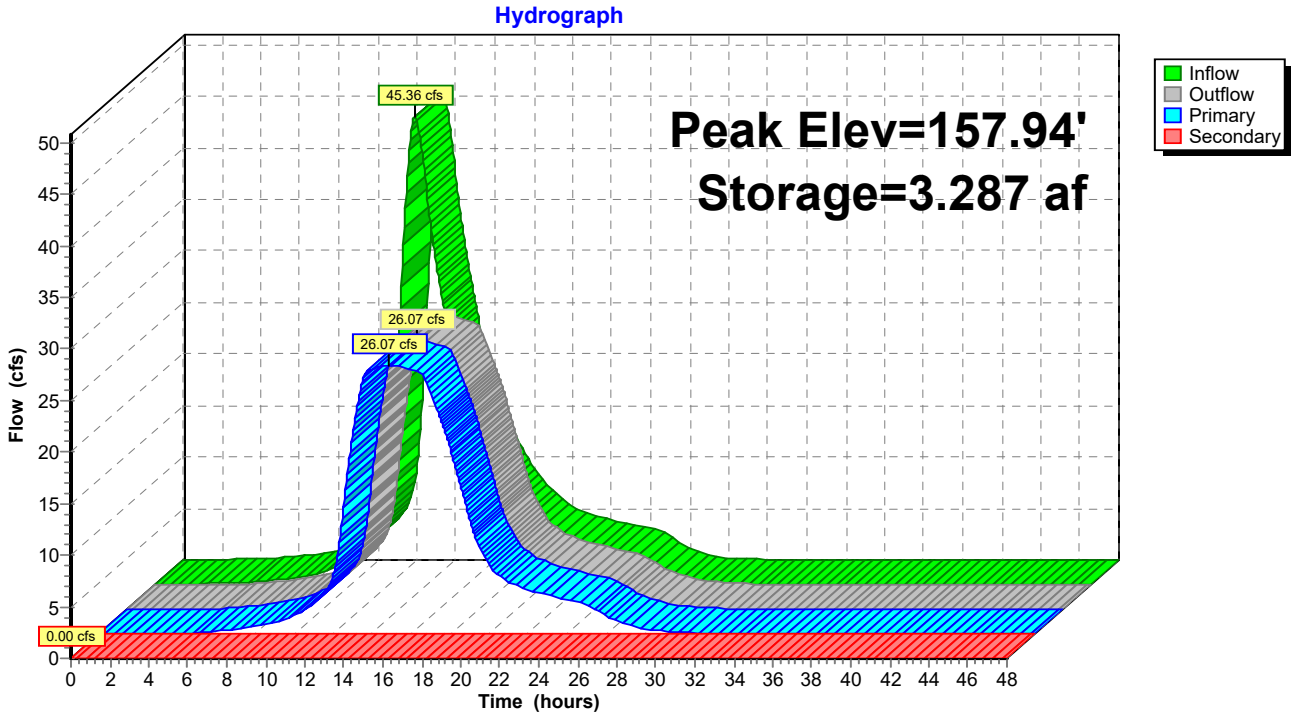
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
153.00	0.032	0.000	0.000	0.032
154.00	0.397	0.181	0.181	0.397
155.00	0.579	0.485	0.666	0.579
156.00	0.849	0.710	1.375	0.850
157.00	0.979	0.913	2.289	0.981
158.00	1.157	1.067	3.355	1.160
159.00	1.321	1.238	4.594	1.325
160.00	1.501	1.410	6.004	1.506
161.00	1.630	1.565	7.569	1.637
162.00	1.847	1.737	9.306	1.855
163.00	2.043	1.944	11.250	2.052
164.00	2.245	2.143	13.393	2.256
165.00	2.530	2.386	15.779	2.542
166.00	2.800	2.664	18.443	2.813

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=26.07 cfs @ 14.90 hrs HW=157.94' (Free Discharge)
1=Culvert (Barrel Controls 26.07 cfs @ 8.30 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=153.00' (Free Discharge)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Pond 2P: Titus Pond; Proposed Conditions (2070 Climate)



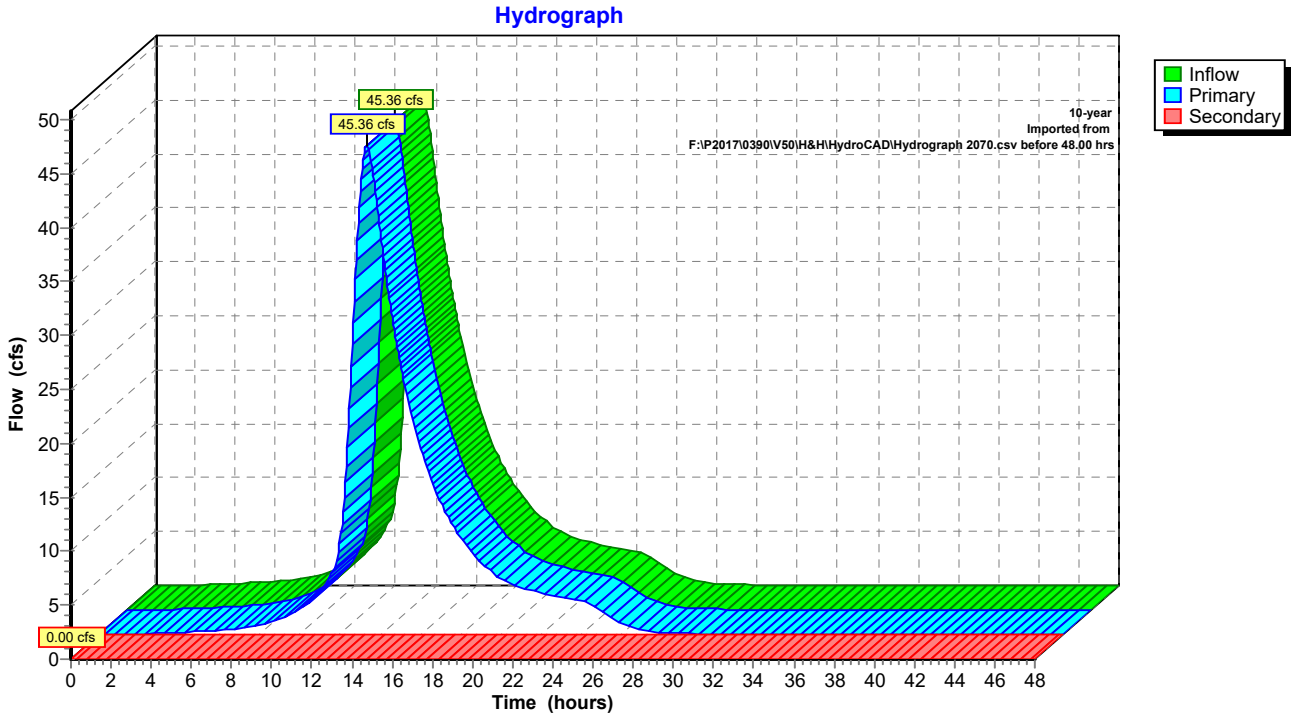
Summary for Link 2L: HMS Hydrograph 2070

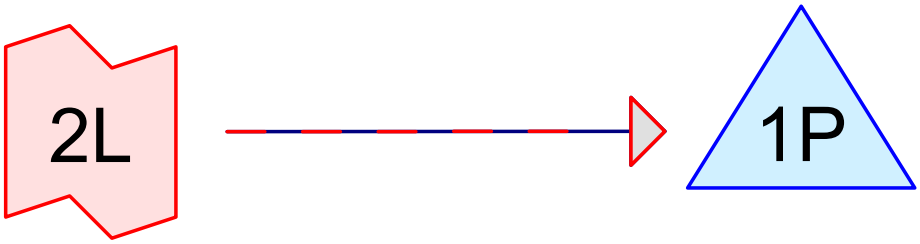
Inflow = 45.36 cfs @ 13.34 hrs, Volume= 15.890 af
Primary = 45.36 cfs @ 13.34 hrs, Volume= 15.890 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 2P : Titus Pond; Proposed Conditions (2070 Climate)
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 2P : Titus Pond; Proposed Conditions (2070 Climate)

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

10-year Imported from F:\P2017\0390\V50\H&H\HydroCAD\Hydrograph 2070.csv

Link 2L: HMS Hydrograph 2070





HMS Hydrograph; Existing Conditions

Titus Pond; Existing Conditions

Subcat Reach Pond Link

Routing Diagram for Existing Conditions_2023027
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 1P: Titus Pond; Existing Conditions Peak Elev=162.57' Storage=10.581 af Inflow=47.65 cfs 16.665 af
Primary=30.50 cfs 16.647 af Secondary=0.00 cfs 0.000 af Outflow=30.50 cfs 16.647 af

Link 2L: HMS 25-year Imported from Hydrograph.csv before 48.00 hrs Inflow=47.65 cfs 16.665 af
Primary=47.65 cfs 16.665 af Secondary=0.00 cfs 0.000 af

Summary for Pond 1P: Titus Pond; Existing Conditions

Inflow	=	47.65 cfs @	13.34 hrs,	Volume=	16.665 af
Outflow	=	30.50 cfs @	14.62 hrs,	Volume=	16.647 af, Atten= 36%, Lag= 76.8 min
Primary	=	30.50 cfs @	14.62 hrs,	Volume=	16.647 af
Secondary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Starting Elev= 160.20' Surf.Area= 1.505 ac Storage= 6.520 af
Peak Elev= 162.57' @ 14.62 hrs Surf.Area= 1.954 ac Storage= 10.581 af (4.061 af above start)
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.968 af (9.448 af above start)

Plug-Flow detention time= 370.1 min calculated for 10.117 af (61% of inflow)
Center-of-Mass det. time= 111.6 min (1,034.2 - 922.6)

Volume	Invert	Avail.Storage	Storage Description
#1	149.00'	18.632 af	**Custom Stage Data (Conic)** Listed below (Recalc)

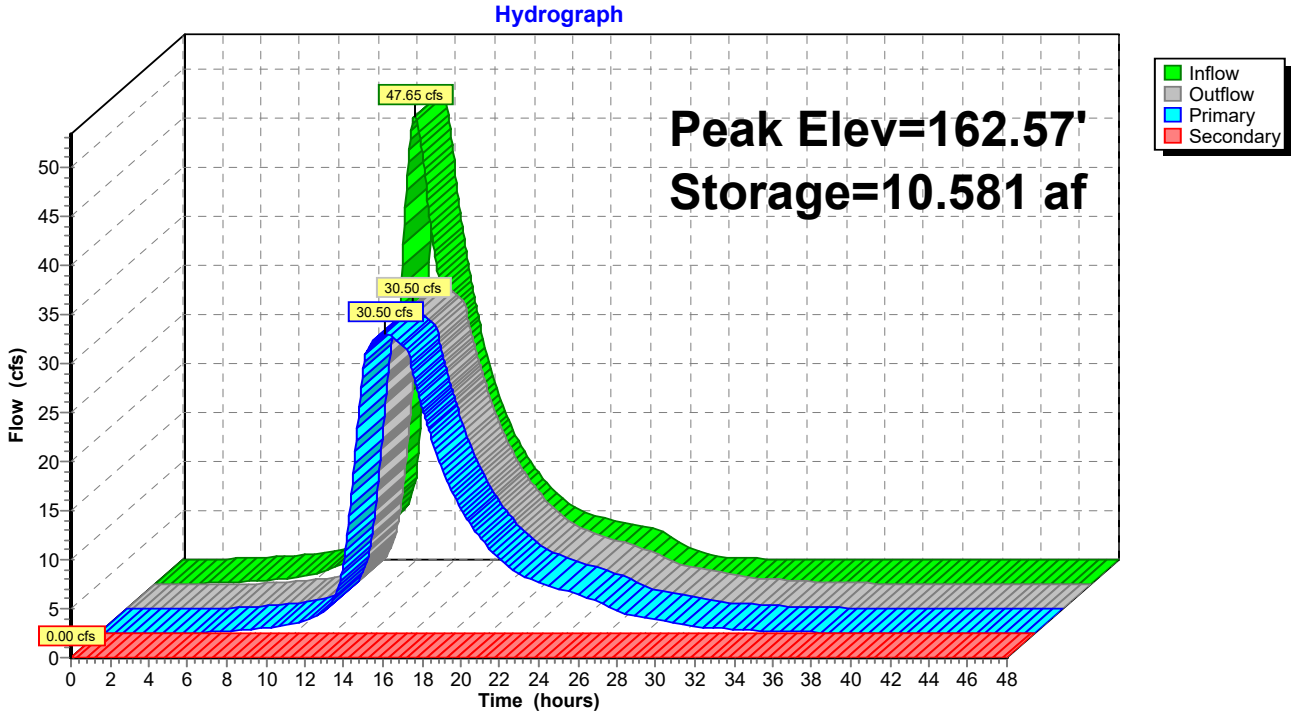
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
149.00	0.003	0.000	0.000	0.003
150.00	0.054	0.023	0.023	0.054
151.00	0.100	0.076	0.099	0.100
152.00	0.166	0.132	0.231	0.167
153.00	0.267	0.215	0.445	0.268
154.00	0.372	0.318	0.763	0.373
155.00	0.528	0.448	1.211	0.530
156.00	0.706	0.615	1.826	0.708
157.00	0.890	0.796	2.622	0.893
158.00	1.113	0.999	3.621	1.116
159.00	1.308	1.209	4.831	1.312
160.00	1.476	1.391	6.222	1.482
161.00	1.624	1.549	7.771	1.631
162.00	1.847	1.734	9.506	1.855
163.00	2.038	1.942	11.447	2.048
164.00	2.239	2.138	13.585	2.250
165.00	2.530	2.383	15.968	2.542
166.00	2.800	2.664	18.632	2.814

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Device 1	160.20'	**36.0" W x 36.0" H Vert. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=30.70 cfs @ 14.62 hrs HW=162.57' (Free Discharge)
└─**1=Culvert** (Barrel Controls 30.70 cfs @ 9.77 fps)
└─**2=Orifice/Grate** (Passes 30.70 cfs of 35.04 cfs potential flow)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=160.20' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 1P: Titus Pond; Existing Conditions



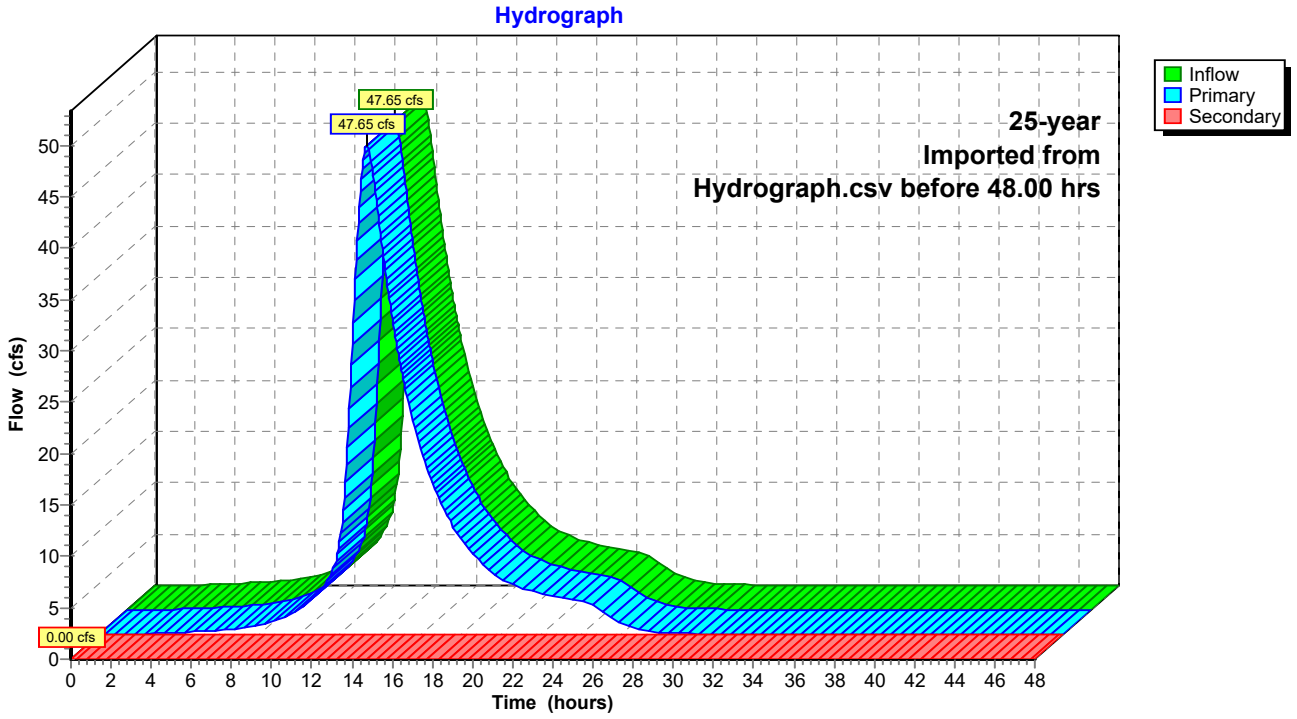
Summary for Link 2L: HMS Hydrograph; Existing Conditions

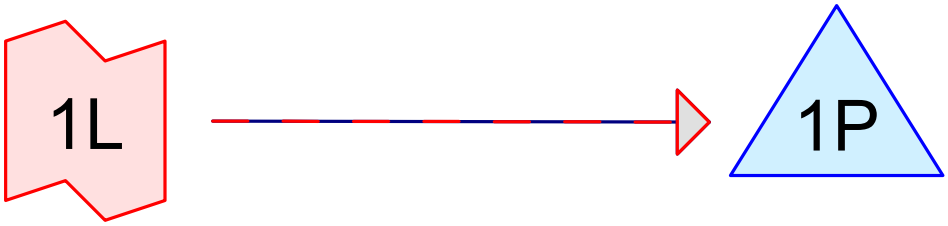
Inflow = 47.65 cfs @ 13.34 hrs, Volume= 16.665 af
Primary = 47.65 cfs @ 13.34 hrs, Volume= 16.665 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 1P : Titus Pond; Existing Conditions
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 1P : Titus Pond; Existing Conditions

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

25-year Imported from Hydrograph.csv

Link 2L: HMS Hydrograph; Existing Conditions





HMS Hydrograph

Titus Pond; Proposed Conditions

Subcat Reach Pond Link

Routing Diagram for Proposed Conditions
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 1P: Titus Pond; Proposed Peak Elev=158.21' Storage=3.602 af Inflow=47.65 cfs 16.665 af
Primary=26.36 cfs 16.643 af Secondary=0.00 cfs 0.000 af Outflow=26.36 cfs 16.643 af

Link 1L: HMS 25-year Imported from Hydrograph.csv before 48.00 hrs Inflow=47.65 cfs 16.665 af
Primary=47.65 cfs 16.665 af Secondary=0.00 cfs 0.000 af

Summary for Pond 1P: Titus Pond; Proposed Conditions

Inflow	=	47.65 cfs @	13.34 hrs,	Volume=	16.665 af
Outflow	=	26.36 cfs @	14.99 hrs,	Volume=	16.643 af, Atten= 45%, Lag= 99.4 min
Primary	=	26.36 cfs @	14.99 hrs,	Volume=	16.643 af
Secondary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 158.21' @ 14.99 hrs Surf.Area= 1.190 ac Storage= 3.602 af
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.779 af

Plug-Flow detention time= 69.0 min calculated for 16.643 af (100% of inflow)
Center-of-Mass det. time= 67.6 min (990.2 - 922.6)

Volume	Invert	Avail.Storage	Storage Description
#1	153.00'	18.443 af	**Custom Stage Data (Conic)** Listed below (Recalc)

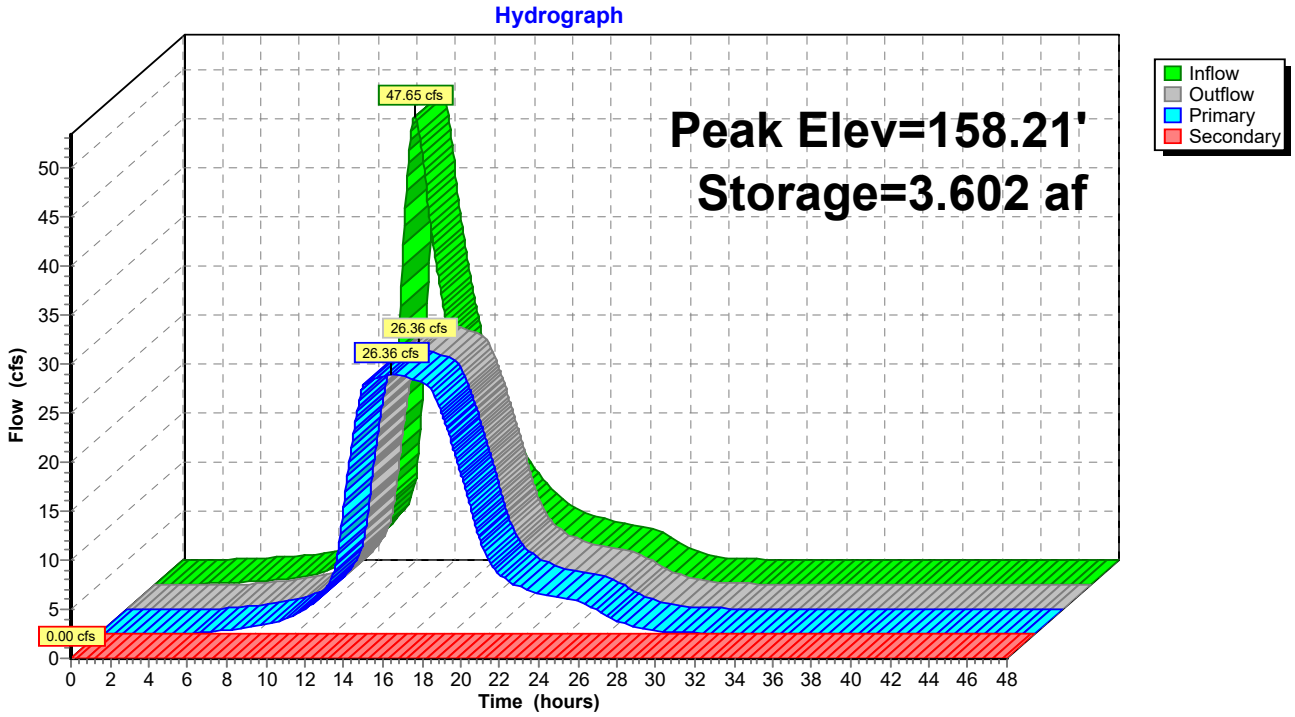
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
153.00	0.032	0.000	0.000	0.032
154.00	0.397	0.181	0.181	0.397
155.00	0.579	0.485	0.666	0.579
156.00	0.849	0.710	1.375	0.850
157.00	0.979	0.913	2.289	0.981
158.00	1.157	1.067	3.355	1.160
159.00	1.321	1.238	4.594	1.325
160.00	1.501	1.410	6.004	1.506
161.00	1.630	1.565	7.569	1.637
162.00	1.847	1.737	9.306	1.855
163.00	2.043	1.944	11.250	2.052
164.00	2.245	2.143	13.393	2.256
165.00	2.530	2.386	15.779	2.542
166.00	2.800	2.664	18.443	2.813

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=26.36 cfs @ 14.99 hrs HW=158.21' (Free Discharge)
1=Culvert (Barrel Controls 26.36 cfs @ 8.39 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=153.00' (Free Discharge)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Pond 1P: Titus Pond; Proposed Conditions



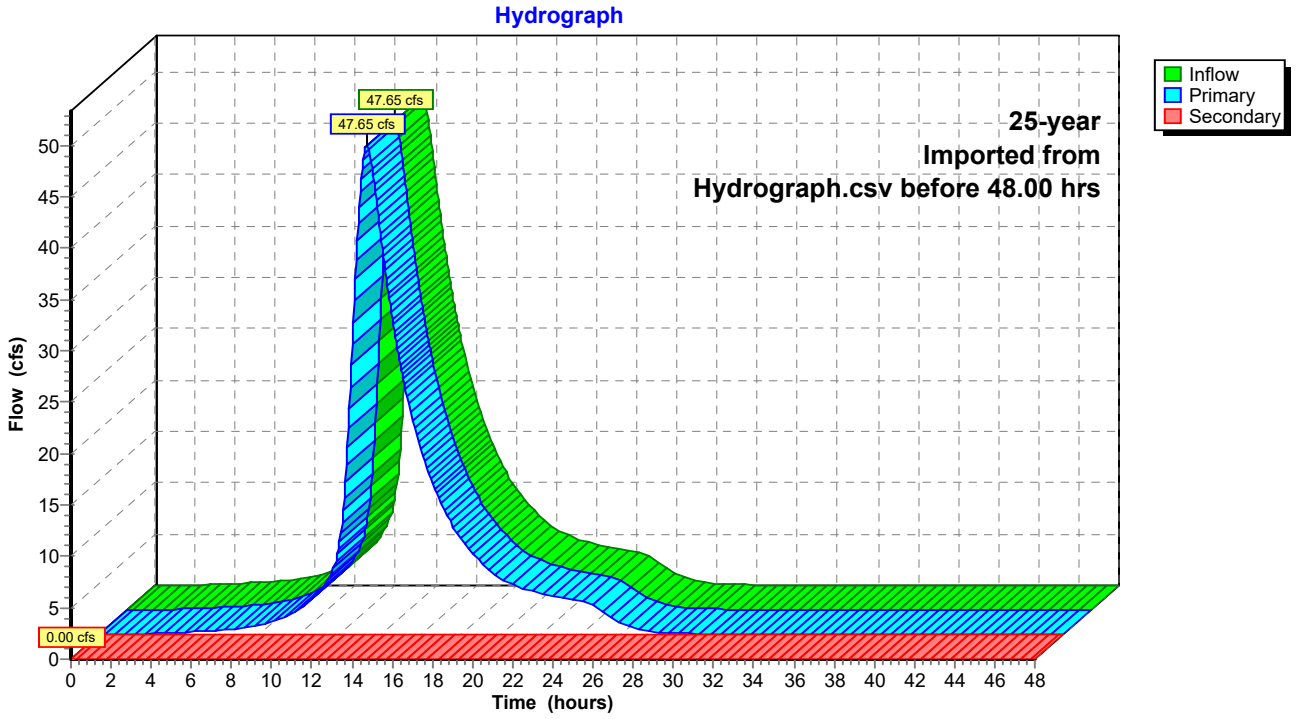
Summary for Link 1L: HMS Hydrograph

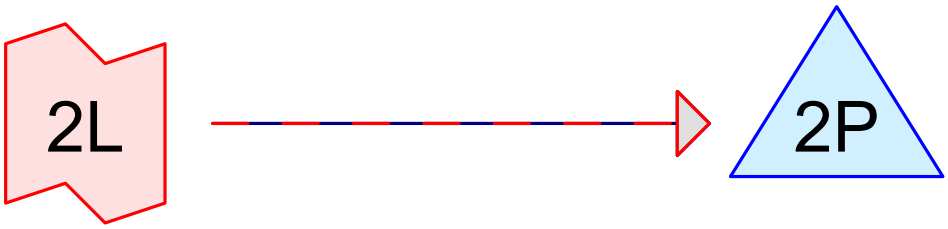
Inflow = 47.65 cfs @ 13.34 hrs, Volume= 16.665 af
Primary = 47.65 cfs @ 13.34 hrs, Volume= 16.665 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 1P : Titus Pond; Proposed Conditions
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 1P : Titus Pond; Proposed Conditions

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

25-year Imported from Hydrograph.csv

Link 1L: HMS Hydrograph





HMS Hydrograph 2070

Titus Pond; Proposed Conditions (2070 Climate)

Subcat Reach Pond Link

Routing Diagram for Proposed Conditions
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 2P: Titus Pond; Proposed Peak Elev=160.00' Storage=6.009 af Inflow=63.02 cfs 21.888 af
Primary=28.23 cfs 21.866 af Secondary=0.00 cfs 0.000 af Outflow=28.23 cfs 21.866 af

5-year Import from F:\P2017\0390\V50\H&H\HydroCAD\Hydrograph 2070.csv before 48.00 hrs Inflow=63.02 cfs 21.888 af
Link Primary=63.02 cfs 21.888 af Secondary=0.00 cfs 0.000 af

Summary for Pond 2P: Titus Pond; Proposed Conditions (2070 Climate)

Inflow = 63.02 cfs @ 13.33 hrs, Volume= 21.888 af
Outflow = 28.23 cfs @ 15.52 hrs, Volume= 21.866 af, Atten= 55%, Lag= 131.0 min
Primary = 28.23 cfs @ 15.52 hrs, Volume= 21.866 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 160.00' @ 15.52 hrs Surf.Area= 1.501 ac Storage= 6.009 af
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.779 af

Plug-Flow detention time= 99.2 min calculated for 21.866 af (100% of inflow)
Center-of-Mass det. time= 98.0 min (1,016.8 - 918.8)

Volume	Invert	Avail.Storage	Storage Description
#1	153.00'	18.443 af	**Custom Stage Data (Conic)** Listed below (Recalc)

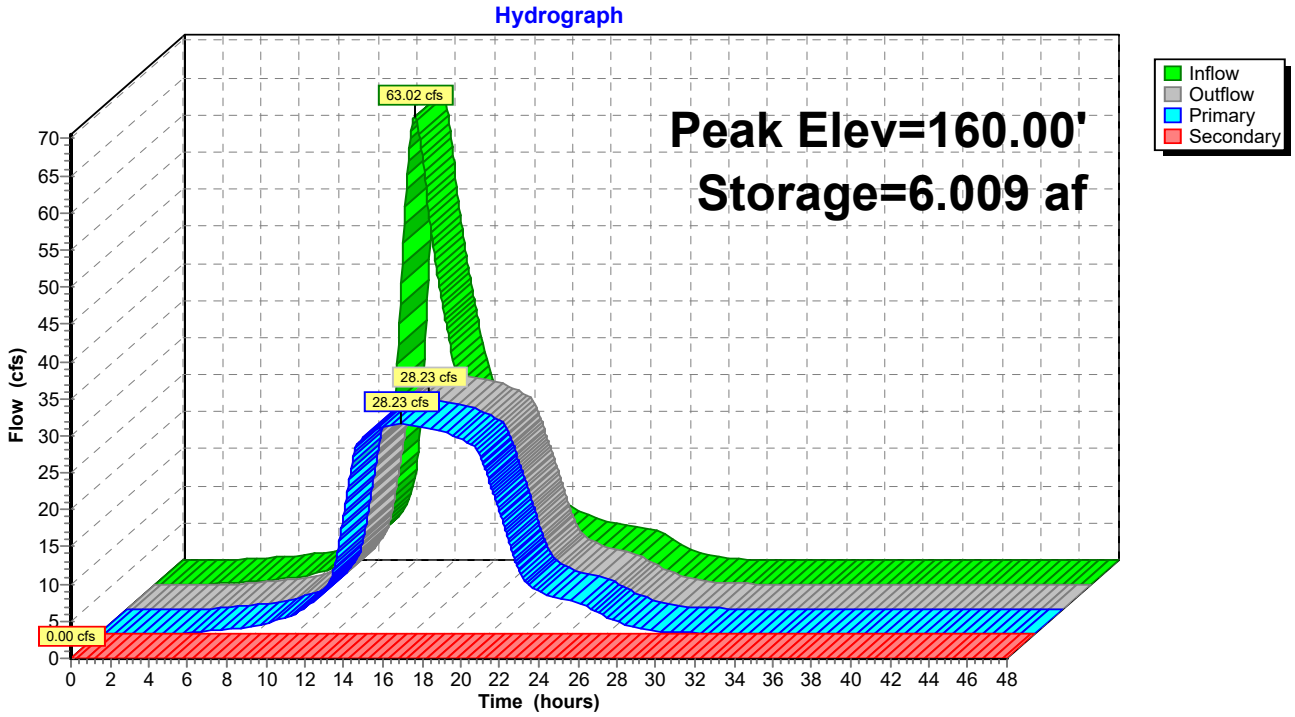
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
153.00	0.032	0.000	0.000	0.032
154.00	0.397	0.181	0.181	0.397
155.00	0.579	0.485	0.666	0.579
156.00	0.849	0.710	1.375	0.850
157.00	0.979	0.913	2.289	0.981
158.00	1.157	1.067	3.355	1.160
159.00	1.321	1.238	4.594	1.325
160.00	1.501	1.410	6.004	1.506
161.00	1.630	1.565	7.569	1.637
162.00	1.847	1.737	9.306	1.855
163.00	2.043	1.944	11.250	2.052
164.00	2.245	2.143	13.393	2.256
165.00	2.530	2.386	15.779	2.542
166.00	2.800	2.664	18.443	2.813

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=28.23 cfs @ 15.52 hrs HW=160.00' (Free Discharge)
1=Culvert (Barrel Controls 28.23 cfs @ 8.98 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=153.00' (Free Discharge)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Pond 2P: Titus Pond; Proposed Conditions (2070 Climate)



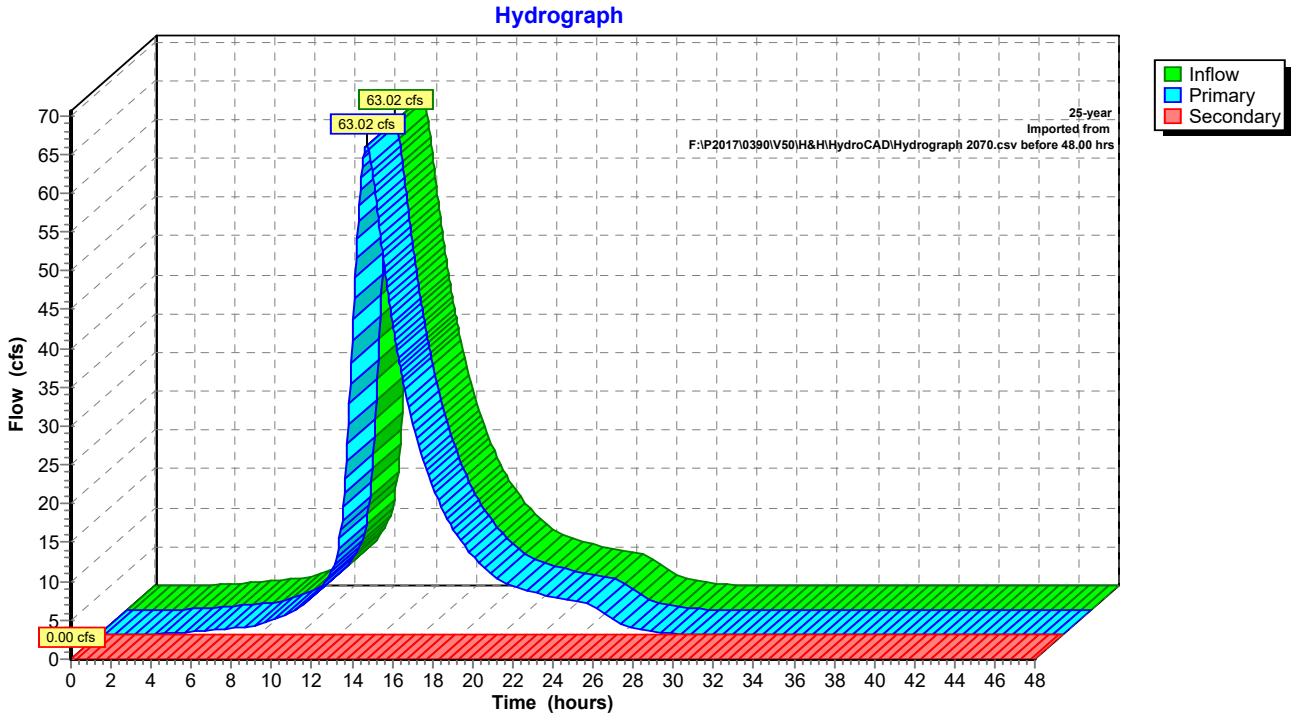
Summary for Link 2L: HMS Hydrograph 2070

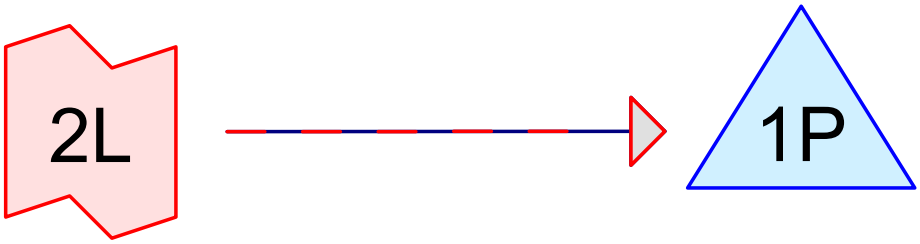
Inflow = 63.02 cfs @ 13.33 hrs, Volume= 21.888 af
Primary = 63.02 cfs @ 13.33 hrs, Volume= 21.888 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 2P : Titus Pond; Proposed Conditions (2070 Climate)
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 2P : Titus Pond; Proposed Conditions (2070 Climate)

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

25-year Imported from F:\P2017\0390\V50\H&H\HydroCAD\Hydrograph 2070.csv

Link 2L: HMS Hydrograph 2070





HMS Hydrograph; Existing Conditions

Titus Pond; Existing Conditions

Subcat Reach Pond Link

Routing Diagram for Existing Conditions_2023027
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 1P: Titus Pond; Existing Conditions Peak Elev=163.26' Storage=11.982 af Inflow=58.24 cfs 20.283 af
Primary=31.33 cfs 20.266 af Secondary=0.00 cfs 0.000 af Outflow=31.33 cfs 20.266 af

Link 2L: HMS 50-year Imported from Hydrograph.csv before 48.00 hrs Inflow=58.24 cfs 20.283 af
Primary=58.24 cfs 20.283 af Secondary=0.00 cfs 0.000 af

Summary for Pond 1P: Titus Pond; Existing Conditions

Inflow	=	58.24 cfs @	13.33 hrs,	Volume=	20.283 af
Outflow	=	31.33 cfs @	15.05 hrs,	Volume=	20.266 af, Atten= 46%, Lag= 102.9 min
Primary	=	31.33 cfs @	15.05 hrs,	Volume=	20.266 af
Secondary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Starting Elev= 160.20' Surf.Area= 1.505 ac Storage= 6.520 af
Peak Elev= 163.26' @ 15.05 hrs Surf.Area= 2.089 ac Storage= 11.982 af (5.462 af above start)
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.968 af (9.448 af above start)

Plug-Flow detention time= 338.0 min calculated for 13.746 af (68% of inflow)
Center-of-Mass det. time= 117.8 min (1,037.7 - 920.0)

Volume	Invert	Avail.Storage	Storage Description
#1	149.00'	18.632 af	**Custom Stage Data (Conic)** Listed below (Recalc)

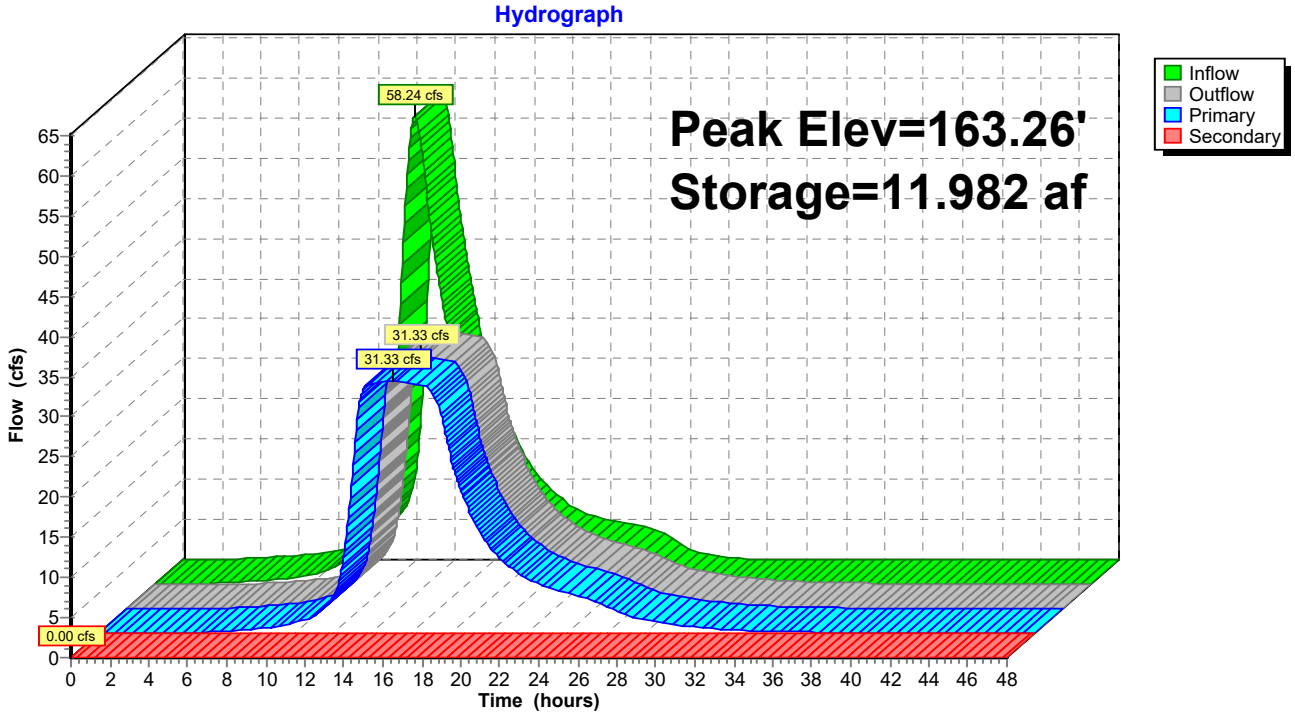
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
149.00	0.003	0.000	0.000	0.003
150.00	0.054	0.023	0.023	0.054
151.00	0.100	0.076	0.099	0.100
152.00	0.166	0.132	0.231	0.167
153.00	0.267	0.215	0.445	0.268
154.00	0.372	0.318	0.763	0.373
155.00	0.528	0.448	1.211	0.530
156.00	0.706	0.615	1.826	0.708
157.00	0.890	0.796	2.622	0.893
158.00	1.113	0.999	3.621	1.116
159.00	1.308	1.209	4.831	1.312
160.00	1.476	1.391	6.222	1.482
161.00	1.624	1.549	7.771	1.631
162.00	1.847	1.734	9.506	1.855
163.00	2.038	1.942	11.447	2.048
164.00	2.239	2.138	13.585	2.250
165.00	2.530	2.383	15.968	2.542
166.00	2.800	2.664	18.632	2.814

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Device 1	160.20'	**36.0" W x 36.0" H Vert. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=31.33 cfs @ 15.05 hrs HW=163.26' (Free Discharge)
└─**1=Culvert** (Barrel Controls 31.33 cfs @ 9.97 fps)
└─**2=Orifice/Grate** (Passes 31.33 cfs of 51.39 cfs potential flow)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=160.20' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 1P: Titus Pond; Existing Conditions



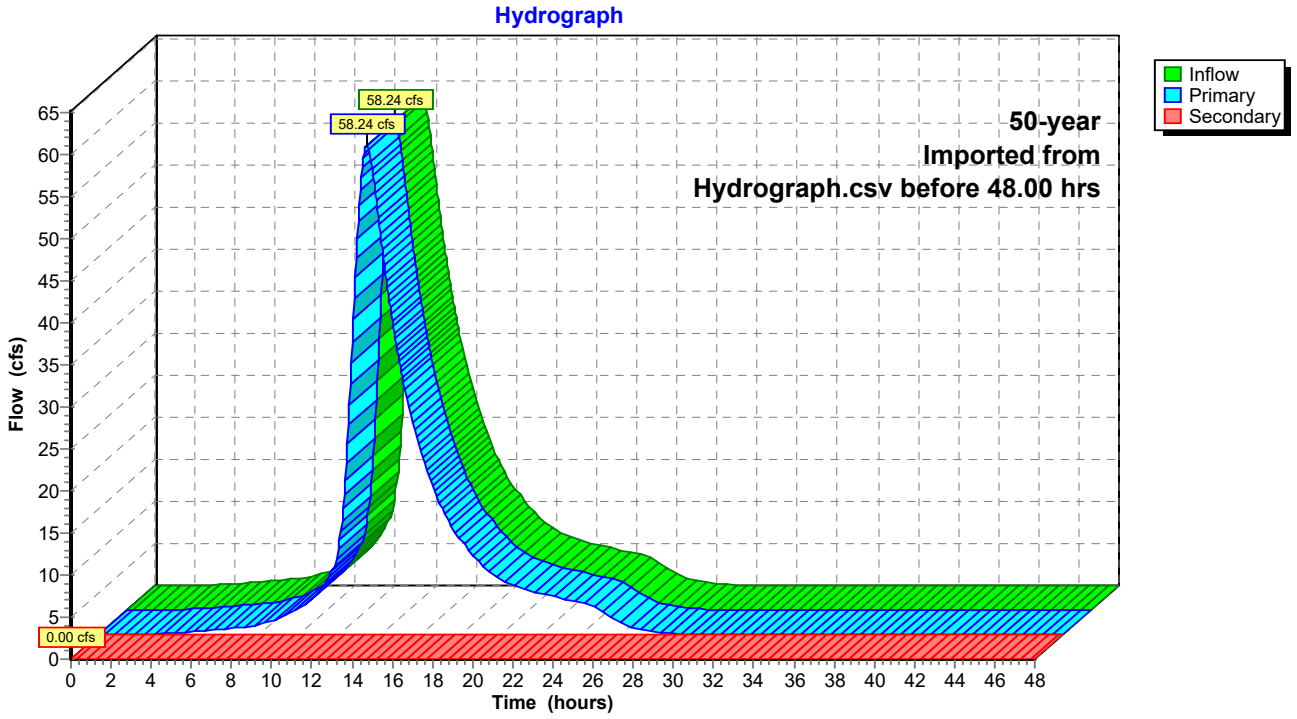
Summary for Link 2L: HMS Hydrograph; Existing Conditions

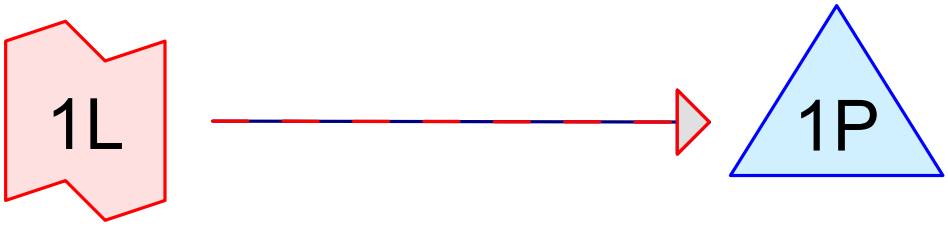
Inflow = 58.24 cfs @ 13.33 hrs, Volume= 20.283 af
Primary = 58.24 cfs @ 13.33 hrs, Volume= 20.283 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 1P : Titus Pond; Existing Conditions
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 1P : Titus Pond; Existing Conditions

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

50-year Imported from Hydrograph.csv

Link 2L: HMS Hydrograph; Existing Conditions





HMS Hydrograph

Titus Pond; Proposed Conditions

Subcat Reach Pond Link

Routing Diagram for Proposed Conditions
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 1P: Titus Pond; Proposed Peak Elev=159.46' Storage=5.227 af Inflow=58.24 cfs 20.283 af
Primary=27.68 cfs 20.262 af Secondary=0.00 cfs 0.000 af Outflow=27.68 cfs 20.262 af

Link 1L: HMS 50-year Imported from Hydrograph.csv before 48.00 hrs Inflow=58.24 cfs 20.283 af
Primary=58.24 cfs 20.283 af Secondary=0.00 cfs 0.000 af

Summary for Pond 1P: Titus Pond; Proposed Conditions

Inflow	=	58.24 cfs @	13.33 hrs,	Volume=	20.283 af
Outflow	=	27.68 cfs @	15.37 hrs,	Volume=	20.262 af, Atten= 52%, Lag= 122.4 min
Primary	=	27.68 cfs @	15.37 hrs,	Volume=	20.262 af
Secondary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 159.46' @ 15.37 hrs Surf.Area= 1.403 ac Storage= 5.227 af
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.779 af

Plug-Flow detention time= 89.3 min calculated for 20.262 af (100% of inflow)
Center-of-Mass det. time= 88.0 min (1,008.0 - 920.0)

Volume	Invert	Avail.Storage	Storage Description
#1	153.00'	18.443 af	**Custom Stage Data (Conic)** Listed below (Recalc)

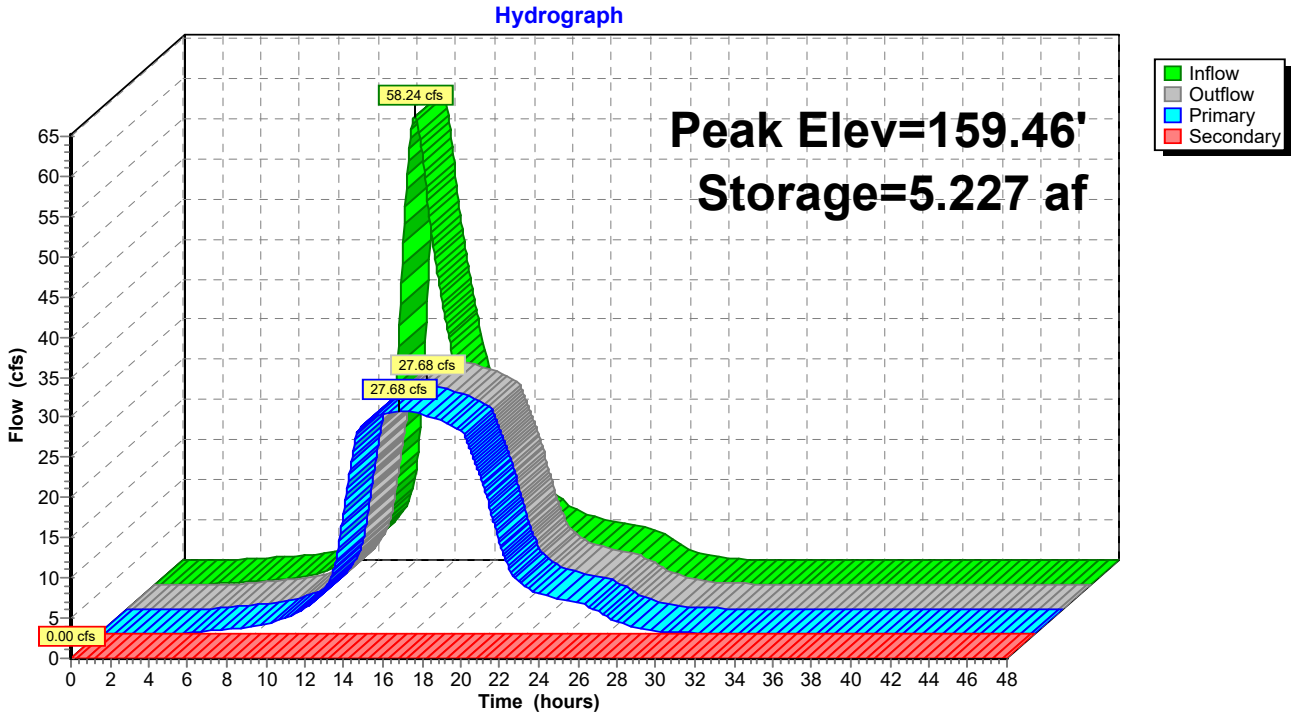
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
153.00	0.032	0.000	0.000	0.032
154.00	0.397	0.181	0.181	0.397
155.00	0.579	0.485	0.666	0.579
156.00	0.849	0.710	1.375	0.850
157.00	0.979	0.913	2.289	0.981
158.00	1.157	1.067	3.355	1.160
159.00	1.321	1.238	4.594	1.325
160.00	1.501	1.410	6.004	1.506
161.00	1.630	1.565	7.569	1.637
162.00	1.847	1.737	9.306	1.855
163.00	2.043	1.944	11.250	2.052
164.00	2.245	2.143	13.393	2.256
165.00	2.530	2.386	15.779	2.542
166.00	2.800	2.664	18.443	2.813

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=27.68 cfs @ 15.37 hrs HW=159.46' (Free Discharge)
1=Culvert (Barrel Controls 27.68 cfs @ 8.81 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=153.00' (Free Discharge)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Pond 1P: Titus Pond; Proposed Conditions



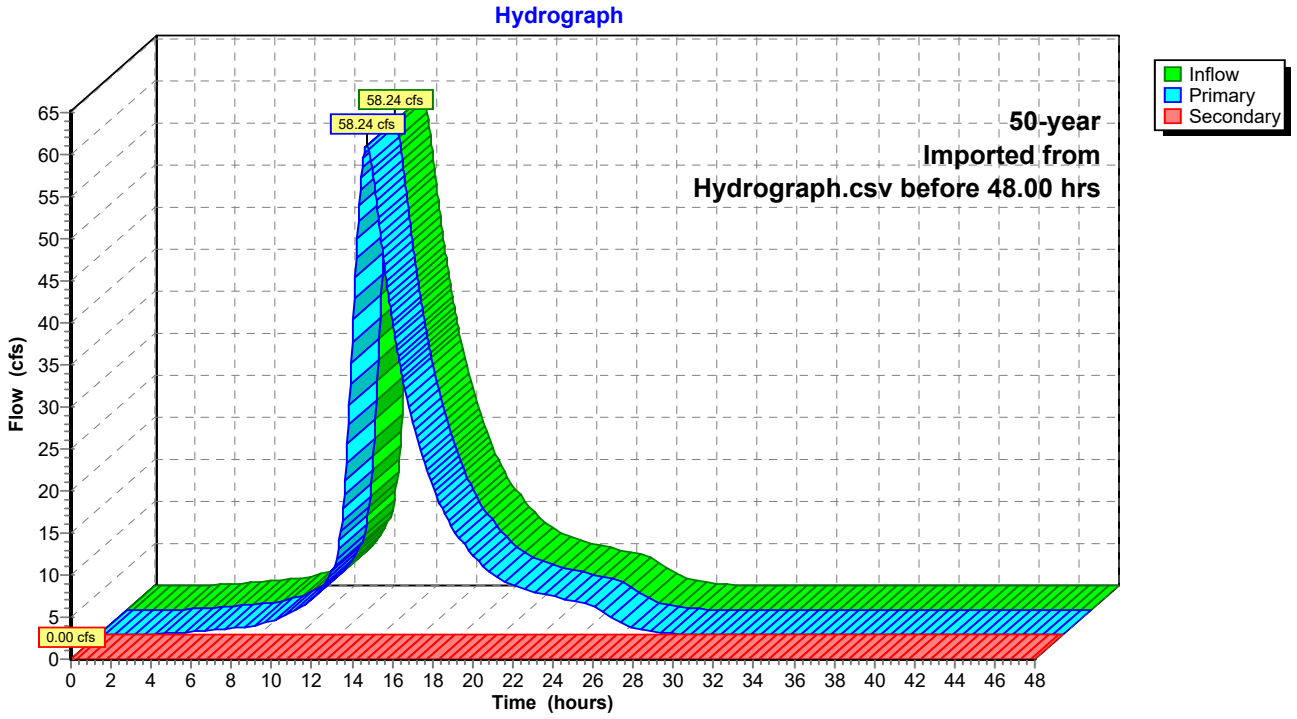
Summary for Link 1L: HMS Hydrograph

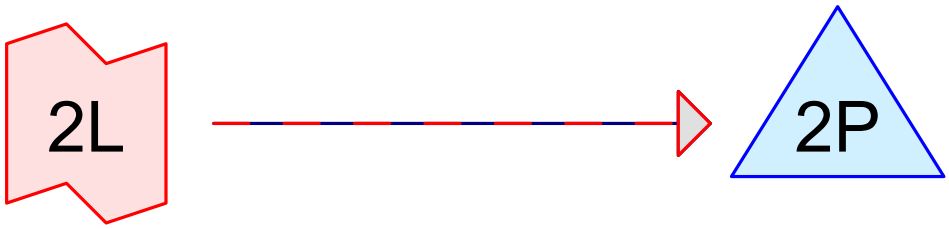
Inflow = 58.24 cfs @ 13.33 hrs, Volume= 20.283 af
Primary = 58.24 cfs @ 13.33 hrs, Volume= 20.283 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 1P : Titus Pond; Proposed Conditions
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 1P : Titus Pond; Proposed Conditions

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

50-year Imported from Hydrograph.csv

Link 1L: HMS Hydrograph





HMS Hydrograph 2070

Titus Pond; Proposed Conditions (2070 Climate)

Subcat Reach Pond Link

Routing Diagram for Proposed Conditions
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 2P: Titus Pond; Proposed Peak Elev=161.51' Storage=8.425 af Inflow=76.63 cfs 26.519 af
Primary=29.70 cfs 26.497 af Secondary=0.00 cfs 0.000 af Outflow=29.70 cfs 26.497 af

0-year Import from F:\P2017\0390\V50\H&H\HydroCAD\Hydrograph 2070.csv before 48.00 hrs Inflow=76.63 cfs 26.519 af
Link Primary=76.63 cfs 26.519 af Secondary=0.00 cfs 0.000 af

Summary for Pond 2P: Titus Pond; Proposed Conditions (2070 Climate)

Inflow	=	76.63 cfs @	13.33 hrs,	Volume=	26.519 af
Outflow	=	29.70 cfs @	15.89 hrs,	Volume=	26.497 af, Atten= 61%, Lag= 153.6 min
Primary	=	29.70 cfs @	15.89 hrs,	Volume=	26.497 af
Secondary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 161.51' @ 15.89 hrs Surf.Area= 1.739 ac Storage= 8.425 af
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.779 af

Plug-Flow detention time= 129.6 min calculated for 26.497 af (100% of inflow)
Center-of-Mass det. time= 128.5 min (1,044.5 - 915.9)

Volume	Invert	Avail.Storage	Storage Description
#1	153.00'	18.443 af	**Custom Stage Data (Conic)** Listed below (Recalc)

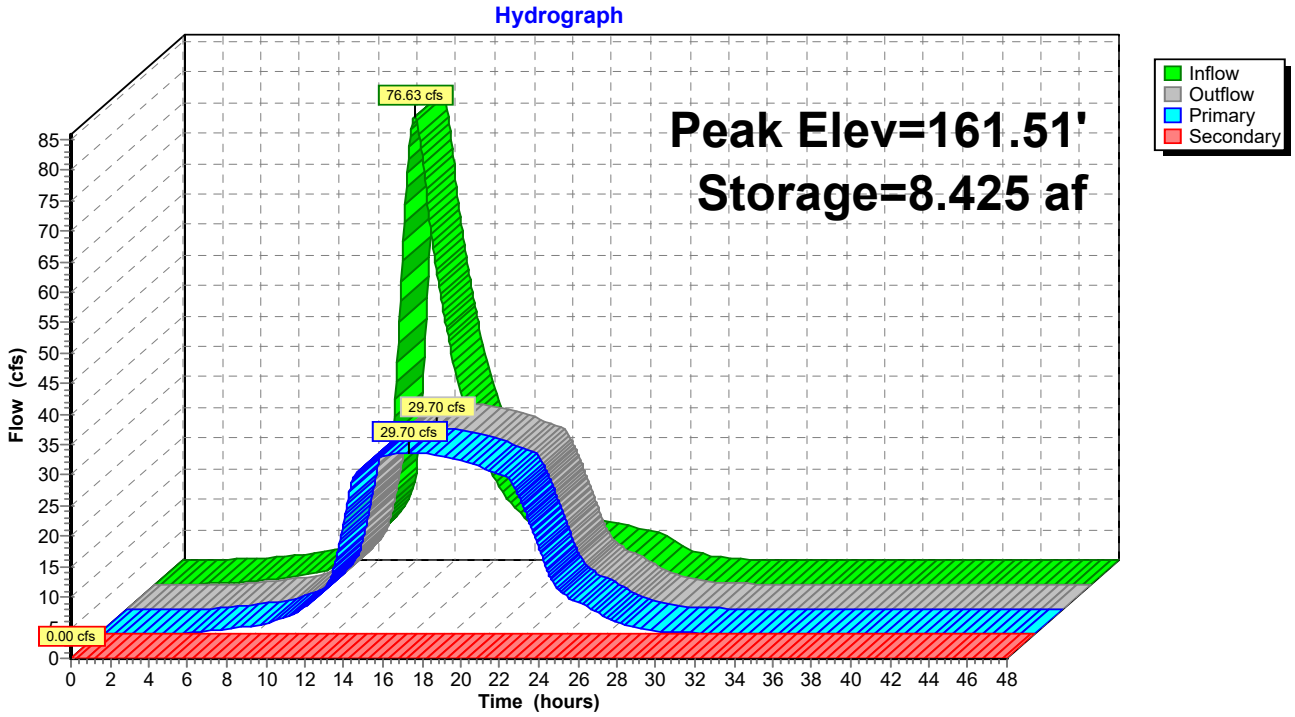
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
153.00	0.032	0.000	0.000	0.032
154.00	0.397	0.181	0.181	0.397
155.00	0.579	0.485	0.666	0.579
156.00	0.849	0.710	1.375	0.850
157.00	0.979	0.913	2.289	0.981
158.00	1.157	1.067	3.355	1.160
159.00	1.321	1.238	4.594	1.325
160.00	1.501	1.410	6.004	1.506
161.00	1.630	1.565	7.569	1.637
162.00	1.847	1.737	9.306	1.855
163.00	2.043	1.944	11.250	2.052
164.00	2.245	2.143	13.393	2.256
165.00	2.530	2.386	15.779	2.542
166.00	2.800	2.664	18.443	2.813

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=29.70 cfs @ 15.89 hrs HW=161.51' (Free Discharge)
1=Culvert (Barrel Controls 29.70 cfs @ 9.46 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=153.00' (Free Discharge)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Pond 2P: Titus Pond; Proposed Conditions (2070 Climate)



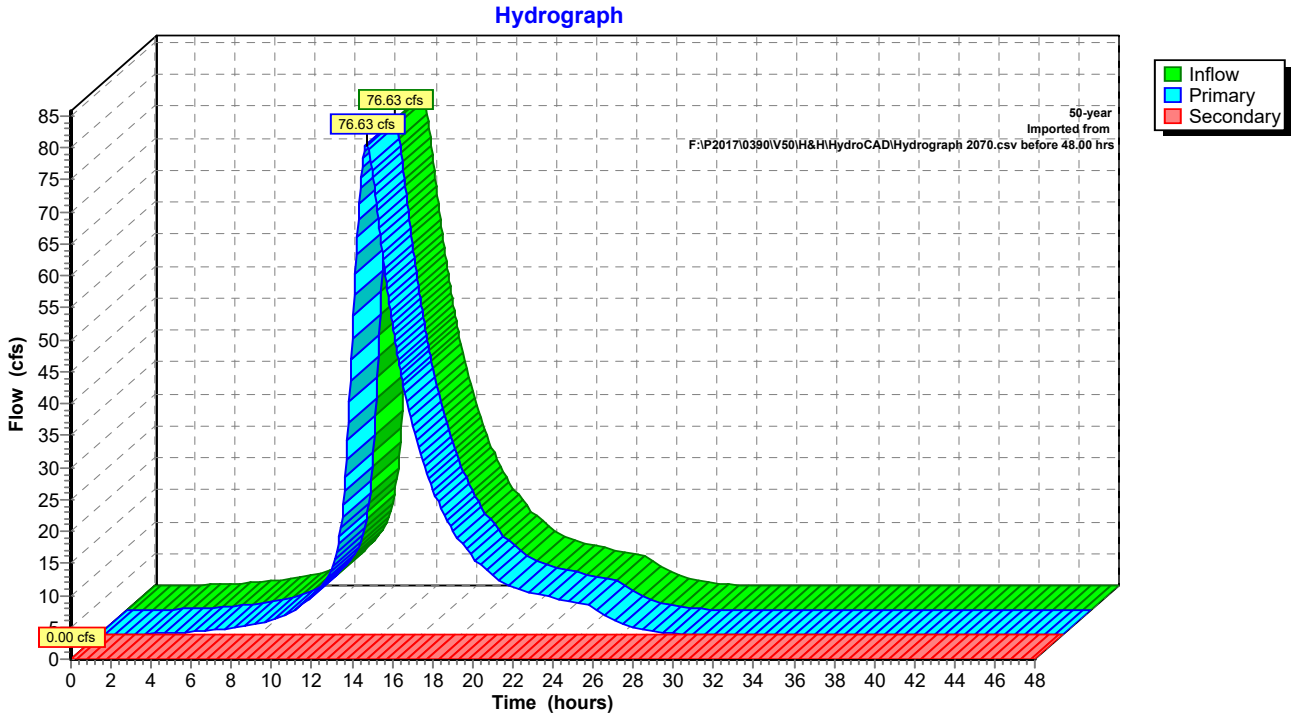
Summary for Link 2L: HMS Hydrograph 2070

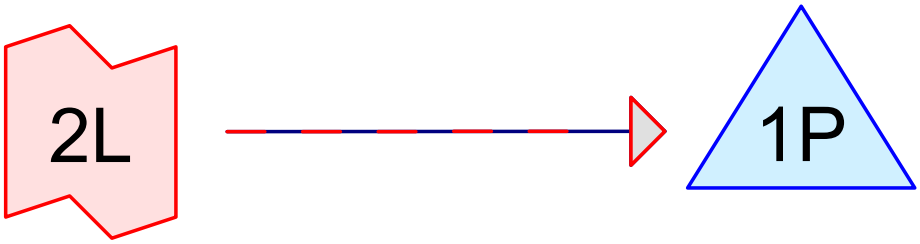
Inflow = 76.63 cfs @ 13.33 hrs, Volume= 26.519 af
Primary = 76.63 cfs @ 13.33 hrs, Volume= 26.519 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 2P : Titus Pond; Proposed Conditions (2070 Climate)
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 2P : Titus Pond; Proposed Conditions (2070 Climate)

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

50-year Imported from F:\P2017\0390\V50\H&H\HydroCAD\Hydrograph 2070.csv

Link 2L: HMS Hydrograph 2070





HMS Hydrograph; Existing Conditions

Titus Pond; Existing Conditions

Subcat Reach Pond Link

Routing Diagram for Existing Conditions_2023027
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 1P: Titus Pond; Existing Conditions Peak Elev=164.19' Storage=14.009 af Inflow=70.71 cfs 24.490 af
Primary=32.17 cfs 24.472 af Secondary=0.00 cfs 0.000 af Outflow=32.17 cfs 24.472 af

Link 2L: HMS 100-year Imported from Hydrograph.csv before 48.00 hrs Inflow=70.71 cfs 24.490 af
Primary=70.71 cfs 24.490 af Secondary=0.00 cfs 0.000 af

Summary for Pond 1P: Titus Pond; Existing Conditions

Inflow = 70.71 cfs @ 13.33 hrs, Volume= 24.490 af
Outflow = 32.17 cfs @ 15.46 hrs, Volume= 24.472 af, Atten= 55%, Lag= 127.9 min
Primary = 32.17 cfs @ 15.46 hrs, Volume= 24.472 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Starting Elev= 160.20' Surf.Area= 1.505 ac Storage= 6.520 af
Peak Elev= 164.19' @ 15.46 hrs Surf.Area= 2.292 ac Storage= 14.009 af (7.489 af above start)
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.968 af (9.448 af above start)

Plug-Flow detention time= 326.7 min calculated for 17.933 af (73% of inflow)
Center-of-Mass det. time= 134.7 min (1,051.8 - 917.2)

Volume	Invert	Avail.Storage	Storage Description
#1	149.00'	18.632 af	**Custom Stage Data (Conic)** Listed below (Recalc)

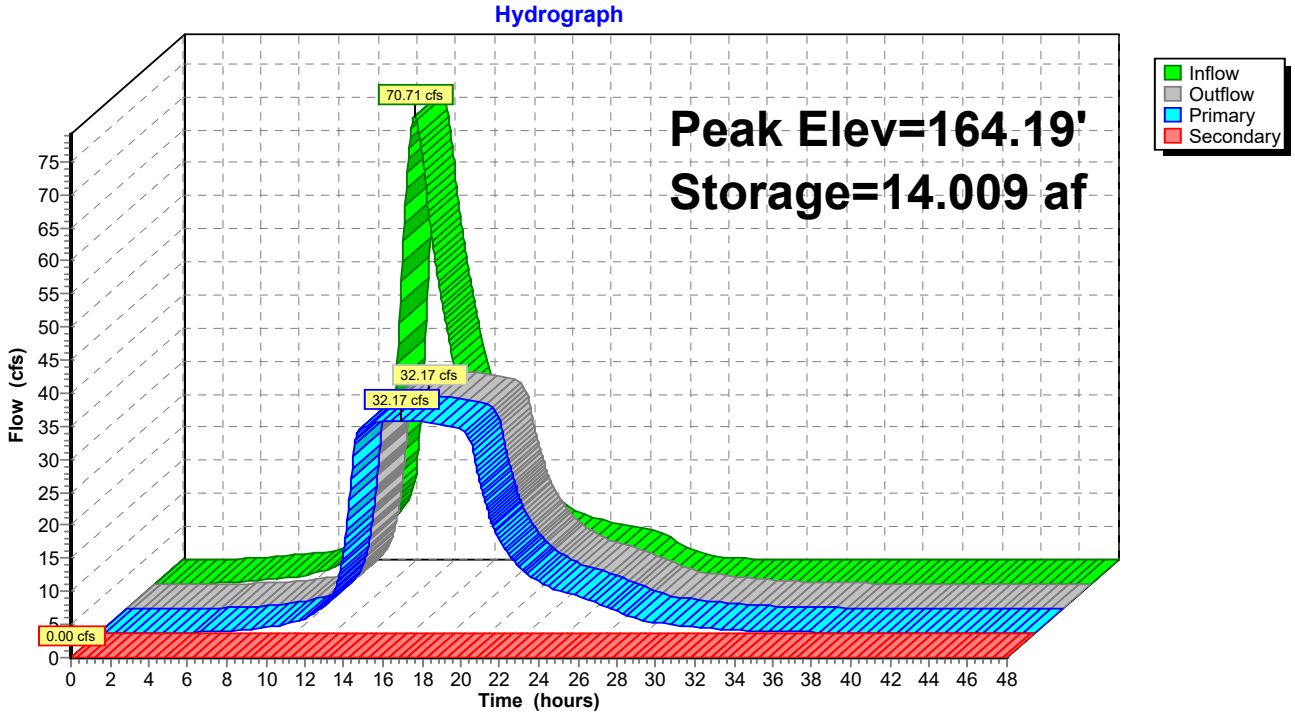
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
149.00	0.003	0.000	0.000	0.003
150.00	0.054	0.023	0.023	0.054
151.00	0.100	0.076	0.099	0.100
152.00	0.166	0.132	0.231	0.167
153.00	0.267	0.215	0.445	0.268
154.00	0.372	0.318	0.763	0.373
155.00	0.528	0.448	1.211	0.530
156.00	0.706	0.615	1.826	0.708
157.00	0.890	0.796	2.622	0.893
158.00	1.113	0.999	3.621	1.116
159.00	1.308	1.209	4.831	1.312
160.00	1.476	1.391	6.222	1.482
161.00	1.624	1.549	7.771	1.631
162.00	1.847	1.734	9.506	1.855
163.00	2.038	1.942	11.447	2.048
164.00	2.239	2.138	13.585	2.250
165.00	2.530	2.383	15.968	2.542
166.00	2.800	2.664	18.632	2.814

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Device 1	160.20'	**36.0" W x 36.0" H Vert. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=32.17 cfs @ 15.46 hrs HW=164.19' (Free Discharge)
└─**1=Culvert** (Barrel Controls 32.17 cfs @ 10.24 fps)
└─**2=Orifice/Grate** (Passes 32.17 cfs of 67.22 cfs potential flow)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=160.20' (Free Discharge)
└─**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 1P: Titus Pond; Existing Conditions



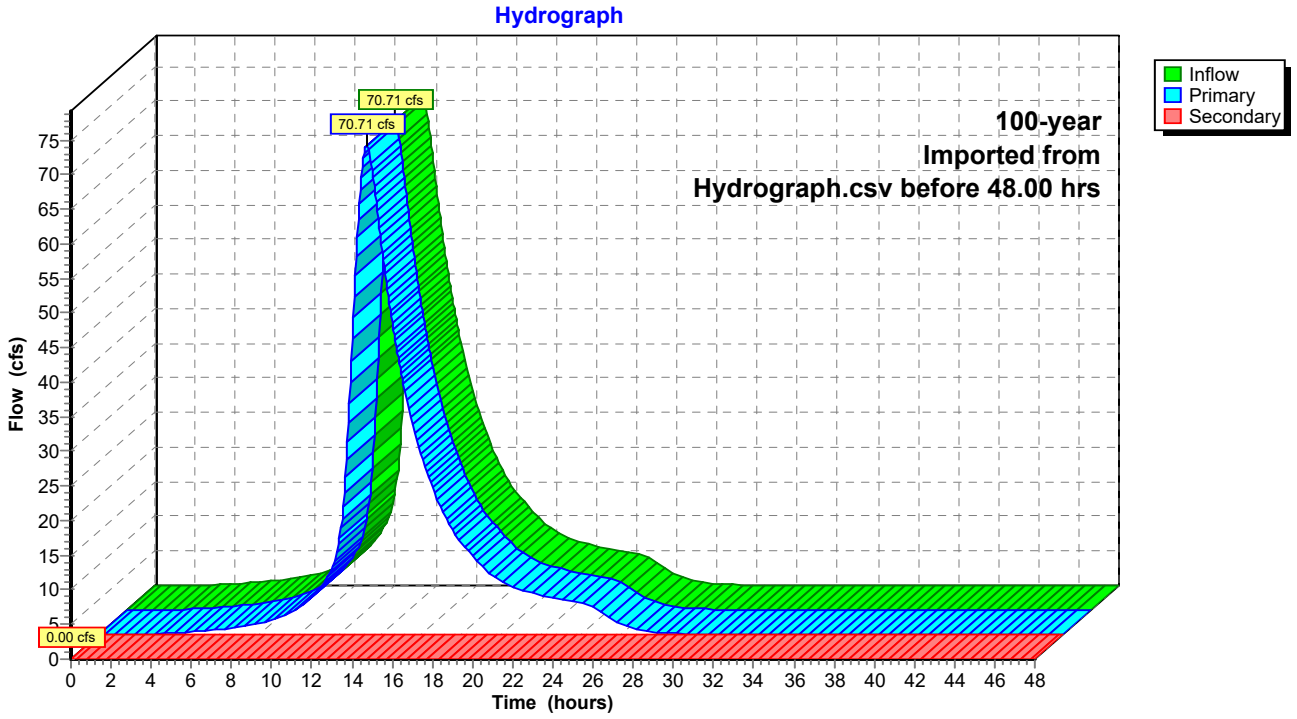
Summary for Link 2L: HMS Hydrograph; Existing Conditions

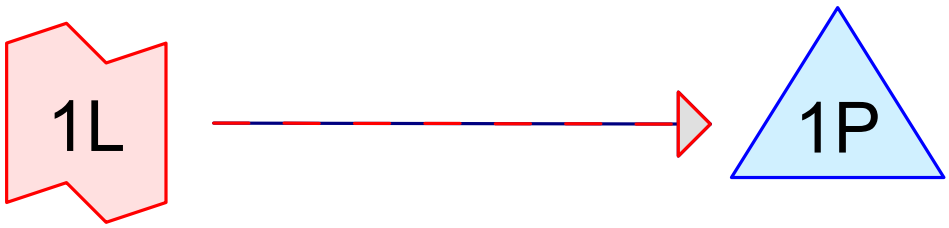
Inflow = 70.71 cfs @ 13.33 hrs, Volume= 24.490 af
Primary = 70.71 cfs @ 13.33 hrs, Volume= 24.490 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 1P : Titus Pond; Existing Conditions
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 1P : Titus Pond; Existing Conditions

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

100-year Imported from Hydrograph.csv

Link 2L: HMS Hydrograph; Existing Conditions





HMS Hydrograph

Titus Pond; Proposed Conditions

Subcat Reach Pond Link

Routing Diagram for Proposed Conditions
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 1P: Titus Pond; Proposed Peak Elev=160.86' Storage=7.343 af Inflow=70.71 cfs 24.490 af
Primary=29.08 cfs 24.468 af Secondary=0.00 cfs 0.000 af Outflow=29.08 cfs 24.468 af

Link 1L: HMS 100-year Imported from Hydrograph.csv before 48.00 hrs Inflow=70.71 cfs 24.490 af
Primary=70.71 cfs 24.490 af Secondary=0.00 cfs 0.000 af

Summary for Pond 1P: Titus Pond; Proposed Conditions

Inflow = 70.71 cfs @ 13.33 hrs, Volume= 24.490 af
Outflow = 29.08 cfs @ 15.73 hrs, Volume= 24.468 af, Atten= 59%, Lag= 144.2 min
Primary = 29.08 cfs @ 15.73 hrs, Volume= 24.468 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 160.86' @ 15.73 hrs Surf.Area= 1.612 ac Storage= 7.343 af
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.779 af

Plug-Flow detention time= 116.1 min calculated for 24.468 af (100% of inflow)
Center-of-Mass det. time= 114.9 min (1,032.1 - 917.2)

Volume	Invert	Avail.Storage	Storage Description
#1	153.00'	18.443 af	**Custom Stage Data (Conic)** Listed below (Recalc)

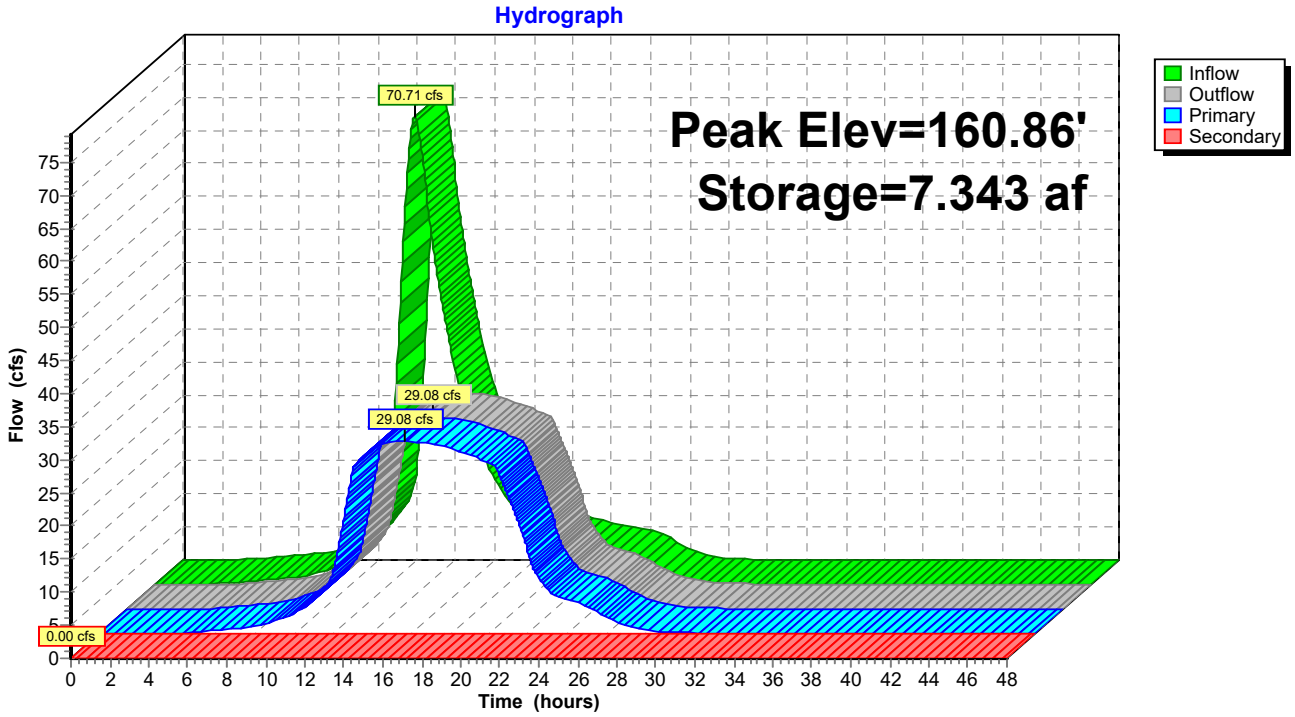
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
153.00	0.032	0.000	0.000	0.032
154.00	0.397	0.181	0.181	0.397
155.00	0.579	0.485	0.666	0.579
156.00	0.849	0.710	1.375	0.850
157.00	0.979	0.913	2.289	0.981
158.00	1.157	1.067	3.355	1.160
159.00	1.321	1.238	4.594	1.325
160.00	1.501	1.410	6.004	1.506
161.00	1.630	1.565	7.569	1.637
162.00	1.847	1.737	9.306	1.855
163.00	2.043	1.944	11.250	2.052
164.00	2.245	2.143	13.393	2.256
165.00	2.530	2.386	15.779	2.542
166.00	2.800	2.664	18.443	2.813

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=29.08 cfs @ 15.73 hrs HW=160.86' (Free Discharge)
1=Culvert (Barrel Controls 29.08 cfs @ 9.26 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=153.00' (Free Discharge)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Pond 1P: Titus Pond; Proposed Conditions



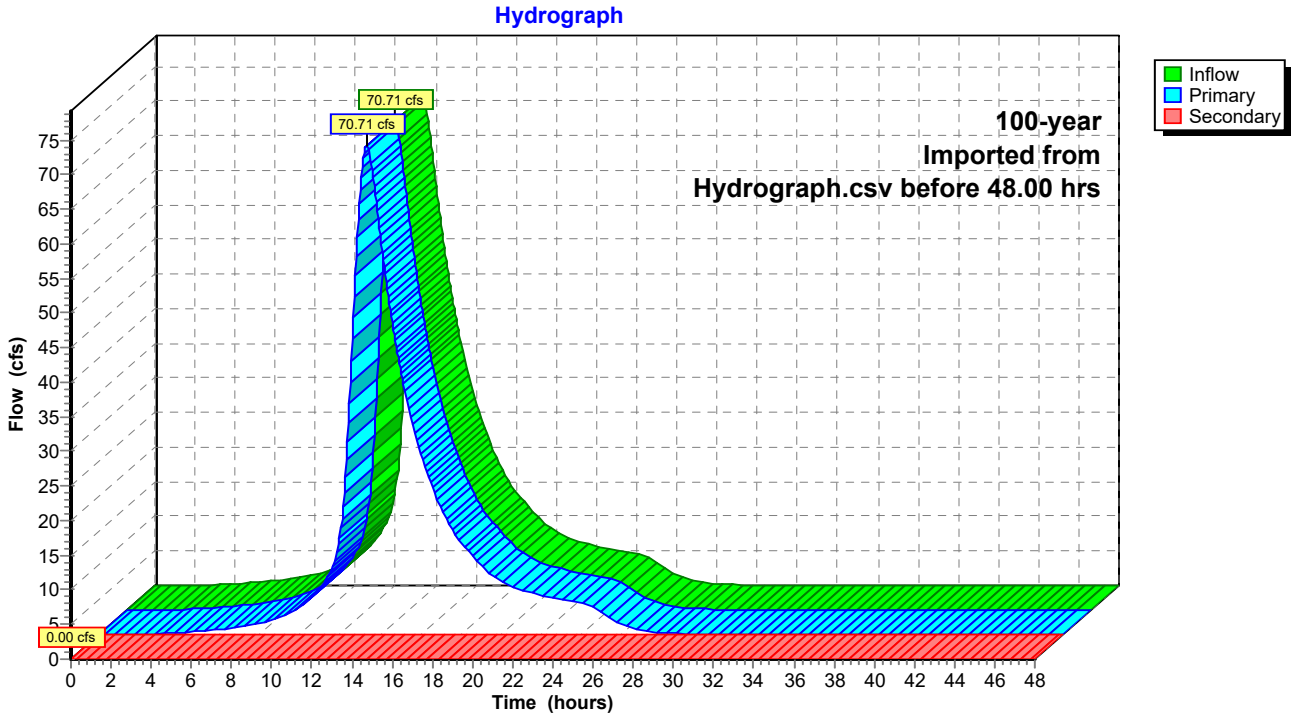
Summary for Link 1L: HMS Hydrograph

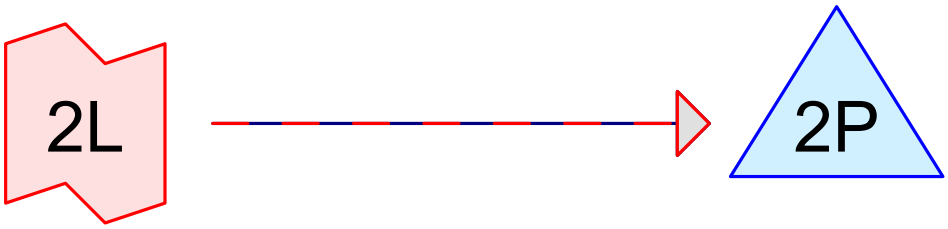
Inflow = 70.71 cfs @ 13.33 hrs, Volume= 24.490 af
Primary = 70.71 cfs @ 13.33 hrs, Volume= 24.490 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 1P : Titus Pond; Proposed Conditions
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 1P : Titus Pond; Proposed Conditions

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

100-year Imported from Hydrograph.csv

Link 1L: HMS Hydrograph





HMS Hydrograph 2070

Titus Pond; Proposed Conditions (2070 Climate)

Subcat Reach Pond Link

Routing Diagram for Proposed Conditions
Prepared by Fuss & O'Neill, Printed 2/27/2023

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Pond 2P: Titus Pond; Proposed Peak Elev=163.81' Storage=12.981 af Inflow=100.16 cfs 34.475 af
Primary=31.83 cfs 34.453 af Secondary=0.00 cfs 0.000 af Outflow=31.83 cfs 34.453 af

-year Imported from F:\P2017\0390\V50\H&H\HydroCAD\Hydrograph 2070.csv **Link** before 48.00 hrs Inflow=100.16 cfs 34.475 af
Primary=100.16 cfs 34.475 af Secondary=0.00 cfs 0.000 af

Summary for Pond 2P: Titus Pond; Proposed Conditions (2070 Climate)

Inflow	=	100.16 cfs @	13.32 hrs,	Volume=	34.475 af
Outflow	=	31.83 cfs @	16.39 hrs,	Volume=	34.453 af, Atten= 68%, Lag= 183.8 min
Primary	=	31.83 cfs @	16.39 hrs,	Volume=	34.453 af
Secondary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 163.81' @ 16.39 hrs Surf.Area= 2.207 ac Storage= 12.981 af
Flood Elev= 165.00' Surf.Area= 2.530 ac Storage= 15.779 af

Plug-Flow detention time= 185.1 min calculated for 34.418 af (100% of inflow)
Center-of-Mass det. time= 184.7 min (1,096.4 - 911.7)

Volume	Invert	Avail.Storage	Storage Description
#1	153.00'	18.443 af	**Custom Stage Data (Conic)** Listed below (Recalc)

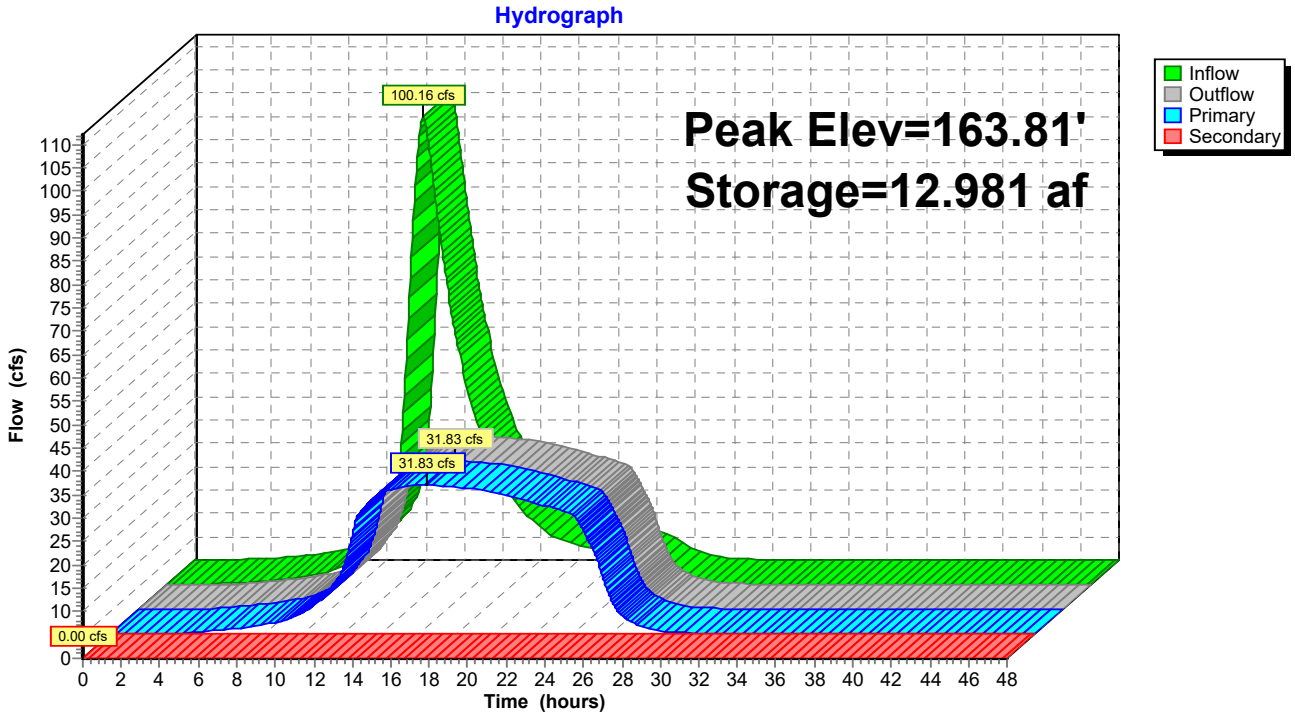
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
153.00	0.032	0.000	0.000	0.032
154.00	0.397	0.181	0.181	0.397
155.00	0.579	0.485	0.666	0.579
156.00	0.849	0.710	1.375	0.850
157.00	0.979	0.913	2.289	0.981
158.00	1.157	1.067	3.355	1.160
159.00	1.321	1.238	4.594	1.325
160.00	1.501	1.410	6.004	1.506
161.00	1.630	1.565	7.569	1.637
162.00	1.847	1.737	9.306	1.855
163.00	2.043	1.944	11.250	2.052
164.00	2.245	2.143	13.393	2.256
165.00	2.530	2.386	15.779	2.542
166.00	2.800	2.664	18.443	2.813

Device	Routing	Invert	Outlet Devices
#1	Primary	153.33'	**24.0" Round Culvert** L= 210.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 153.33' / 143.99' S= 0.0445 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf
#2	Secondary	165.00'	**100.0' long x 45.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=31.83 cfs @ 16.39 hrs HW=163.81' (Free Discharge)
└**1=Culvert** (Barrel Controls 31.83 cfs @ 10.13 fps)

Secondary OutFlow Max=0.00 cfs @ 0.00 hrs HW=153.00' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 2P: Titus Pond; Proposed Conditions (2070 Climate)



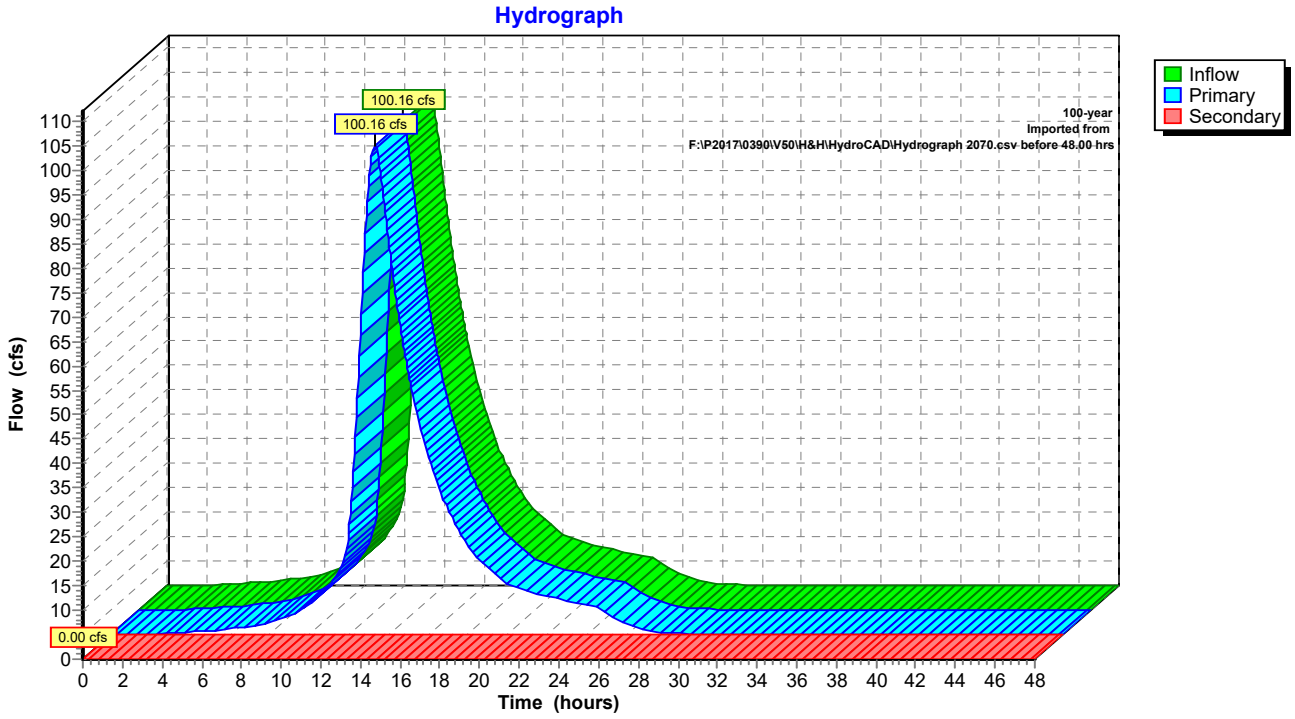
Summary for Link 2L: HMS Hydrograph 2070

Inflow = 100.16 cfs @ 13.32 hrs, Volume= 34.475 af
Primary = 100.16 cfs @ 13.32 hrs, Volume= 34.475 af, Atten= 0%, Lag= 0.0 min
Routed to Pond 2P : Titus Pond; Proposed Conditions (2070 Climate)
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af
Routed to Pond 2P : Titus Pond; Proposed Conditions (2070 Climate)

Primary outflow = Inflow before 48.00 hrs, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

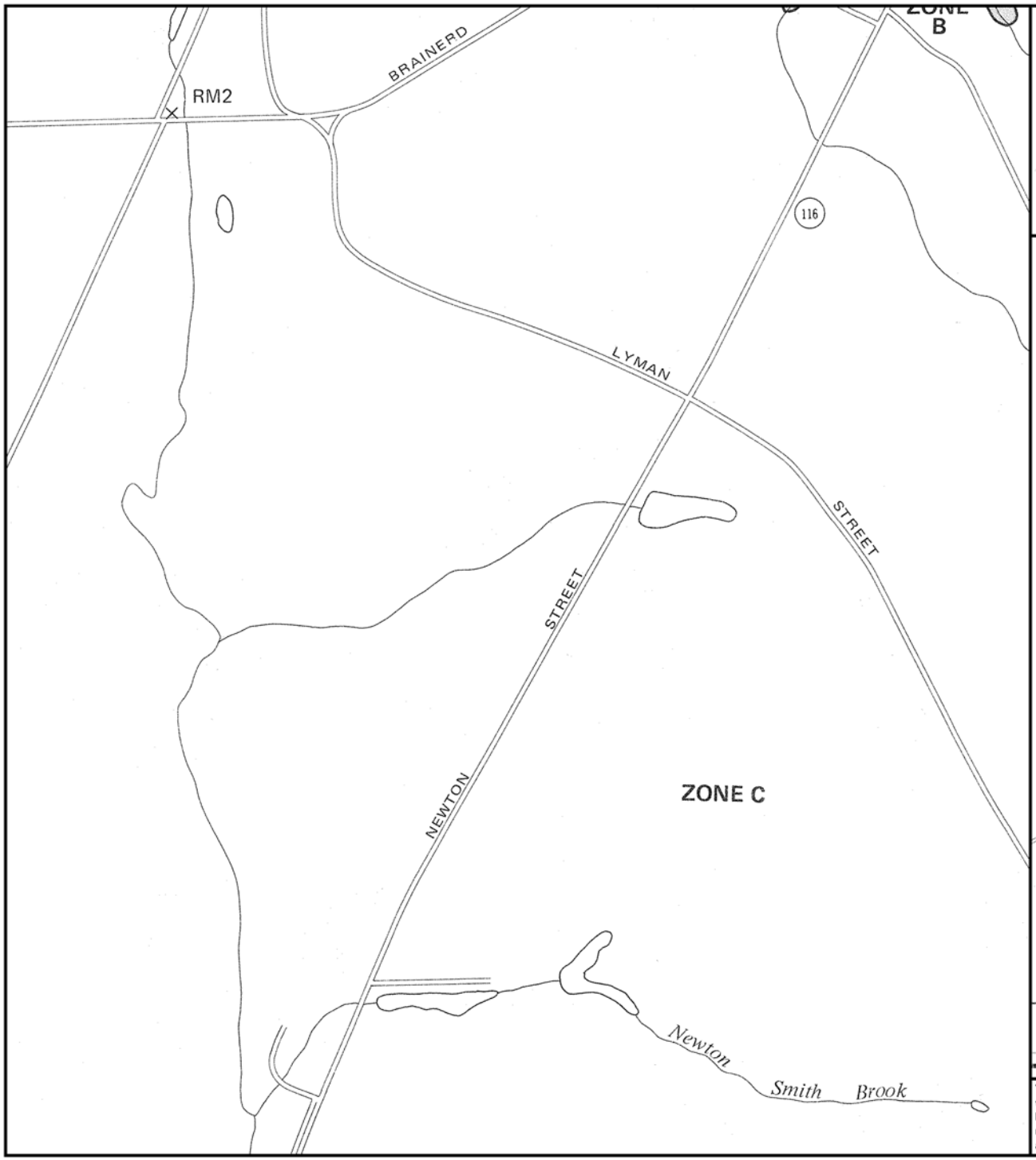
100-year Imported from F:\P2017\0390\V50\H&H\HydroCAD\Hydrograph 2070.csv

Link 2L: HMS Hydrograph 2070



Appendix D

Supporting Information for Hydraulic Model Development



Program, at (800) 638-6620, or (800)

APPROXIMATE

800 0

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

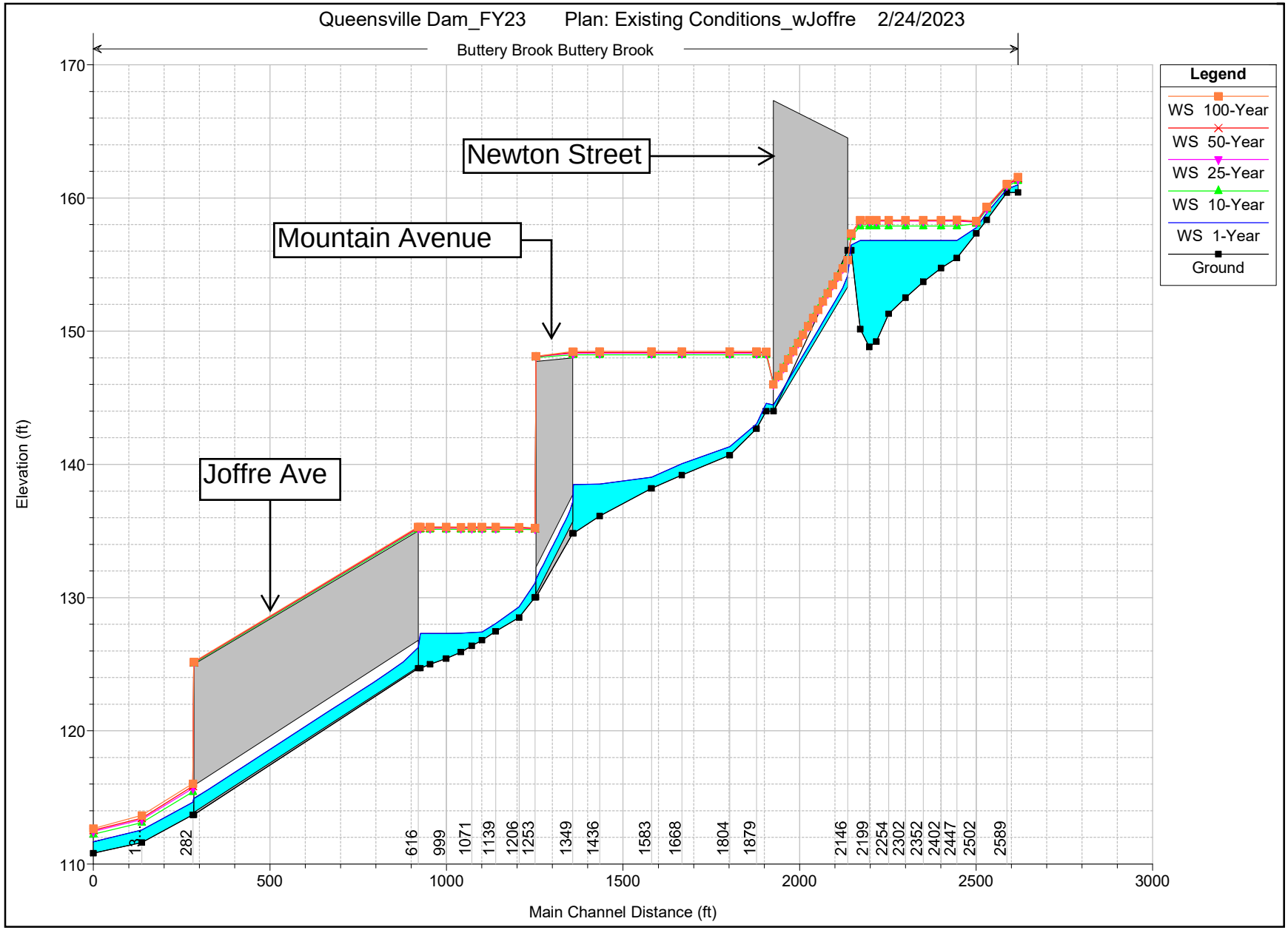
U.S. DEPARTMENT OF HOUSING
AND URBAN DEVELOPMENT
FEDERAL INSURANCE ADMINISTRATION

Mountain Avenue Openness Ratio Calculation
South Hadley, MA
20170390.V50

	Arch Culvert (15' span x 6-7' rise)
Crossing Length (ft)	91
Cross Sectional Area of Opening (ft^2)	74.7
Openness Ratio	0.82

Appendix E

HEC-RAS Hydraulic Model Summary Report


Queensville Dam_FY23 Plan: Existing Conditions_wJoffre 2/24/2023
Buttery Brook Buttery Brook
Newton Street
Mountain Avenue
Joffre Ave
Legend
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 1-Year
Ground
Elevation (ft)
Main Channel Distance (ft)
170
160
150
140
130
120
110
0
500
1000
1500
2000
2500
3000
282
616
999
1071
1139
1206
1253
1349
1436
1583
1668
1804
1879
2146
2199
2254
2302
2352
2402
2447
2502
2589

HEC-RAS Plan: Existing Conditions_wJoffre River: Buttery Brook Reach: Buttery Brook

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
Buttery Brook	2620.4	1-Year	10.30	160.42	160.99	0.52	19.70	58.16
Buttery Brook	2620.4	10-Year	34.00	160.42	161.30	0.87	39.30	64.78
Buttery Brook	2620.4	25-Year	47.70	160.42	161.41	1.02	46.82	65.48
Buttery Brook	2620.4	50-Year	58.30	160.42	161.49	1.12	52.04	65.98
Buttery Brook	2620.4	100-Year	70.80	160.42	161.57	1.24	57.30	66.48
Buttery Brook	2589	1-Year	10.30	160.40	160.67	2.17	4.74	27.51
Buttery Brook	2589	10-Year	34.00	160.40	160.86	2.94	11.55	44.62
Buttery Brook	2589	25-Year	47.70	160.40	160.95	2.99	15.96	52.32
Buttery Brook	2589	50-Year	58.30	160.40	160.99	3.26	17.88	54.63
Buttery Brook	2589	100-Year	70.80	160.40	161.04	3.39	20.87	59.53
Buttery Brook	2532	1-Year	10.30	158.35	158.88	0.96	10.68	47.60
Buttery Brook	2532	10-Year	34.00	158.35	159.13	1.30	26.07	70.23
Buttery Brook	2532	25-Year	47.70	158.35	159.21	1.53	31.11	71.17
Buttery Brook	2532	50-Year	58.30	158.35	159.27	1.62	36.06	71.91
Buttery Brook	2532	100-Year	70.80	158.35	159.34	1.73	41.00	72.64
Buttery Brook	2502	1-Year	10.30	157.34	157.78	2.70	3.81	16.65
Buttery Brook	2502	10-Year	34.00	157.34	158.07	3.09	11.01	38.59
Buttery Brook	2502	25-Year	47.70	157.34	158.19	2.94	16.24	48.47
Buttery Brook	2502	50-Year	58.30	157.34	158.22	3.28	17.78	51.54
Buttery Brook	2502	100-Year	70.80	157.34	158.26	3.51	20.20	55.27
Buttery Brook	2447	1-Year	10.30	155.49	156.81	0.16	65.71	78.00
Buttery Brook	2447	10-Year	34.00	155.49	157.89	0.21	164.02	102.76
Buttery Brook	2447	25-Year	47.70	155.49	158.27	0.23	204.25	109.33
Buttery Brook	2447	50-Year	58.30	155.49	158.31	0.28	208.76	110.01
Buttery Brook	2447	100-Year	70.80	155.49	158.35	0.33	213.28	110.63
Buttery Brook	2402	1-Year	10.30	154.73	156.81	0.09	111.73	81.23
Buttery Brook	2402	10-Year	34.00	154.73	157.89	0.16	212.69	105.98
Buttery Brook	2402	25-Year	47.70	154.73	158.27	0.19	254.50	114.59
Buttery Brook	2402	50-Year	58.30	154.73	158.31	0.22	259.15	115.20
Buttery Brook	2402	100-Year	70.80	154.73	158.35	0.27	263.79	115.78
Buttery Brook	2352	1-Year	10.30	153.70	156.81	0.06	182.71	95.57
Buttery Brook	2352	10-Year	34.00	153.70	157.89	0.11	296.58	115.86
Buttery Brook	2352	25-Year	47.70	153.70	158.27	0.14	341.70	122.38
Buttery Brook	2352	50-Year	58.30	153.70	158.31	0.17	346.63	123.07
Buttery Brook	2352	100-Year	70.80	153.70	158.35	0.20	351.54	123.76
Buttery Brook	2302	1-Year	10.30	152.51	156.81	0.03	347.82	131.42
Buttery Brook	2302	10-Year	34.00	152.51	157.89	0.07	501.09	152.32
Buttery Brook	2302	25-Year	47.70	152.51	158.27	0.09	560.19	159.94
Buttery Brook	2302	50-Year	58.30	152.51	158.31	0.10	566.63	160.68
Buttery Brook	2302	100-Year	70.80	152.51	158.35	0.12	573.01	161.39
Buttery Brook	2254	1-Year	10.30	151.30	156.81	0.02	506.24	160.62
Buttery Brook	2254	10-Year	34.00	151.30	157.89	0.05	689.00	178.95
Buttery Brook	2254	25-Year	47.70	151.30	158.27	0.06	758.22	184.97
Buttery Brook	2254	50-Year	58.30	151.30	158.31	0.08	765.65	185.38
Buttery Brook	2254	100-Year	70.80	151.30	158.35	0.09	773.01	185.79

HEC-RAS Plan: Existing Conditions_wJoffre River: Buttery Brook Reach: Buttery Brook (Continued)

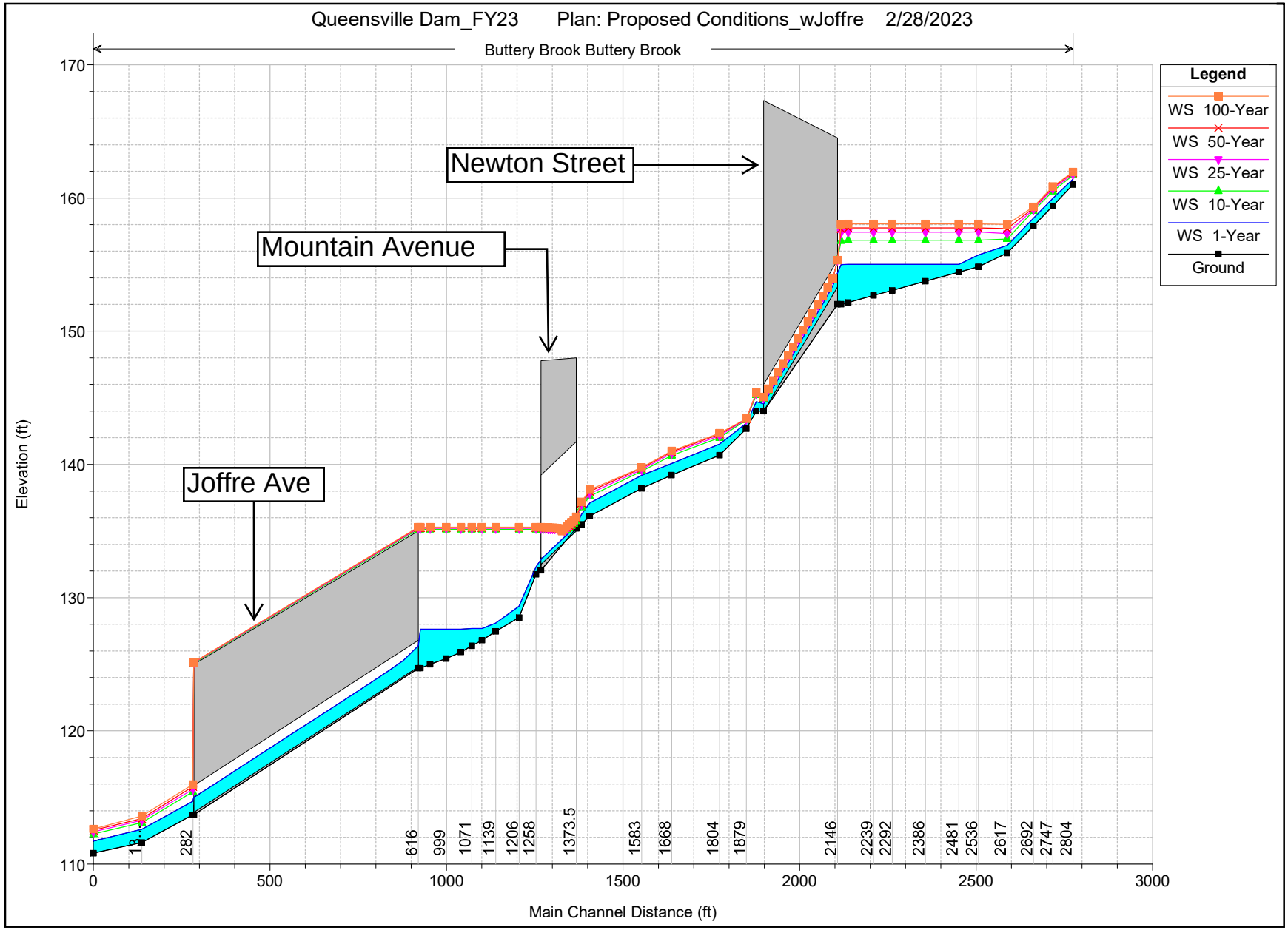
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
Buttery Brook	2219	1-Year	5.91	149.22	156.81	0.01	770.04	152.80
Buttery Brook	2219	10-Year	22.96	149.22	157.89	0.02	944.35	172.26
Buttery Brook	2219	25-Year	30.50	149.22	158.27	0.03	1010.65	176.93
Buttery Brook	2219	50-Year	31.33	149.22	158.31	0.03	1017.76	177.29
Buttery Brook	2219	100-Year	32.17	149.22	158.35	0.03	1024.80	177.63
Buttery Brook	2199	1-Year	5.91	148.82	156.81	0.01	725.78	143.14
Buttery Brook	2199	10-Year	22.96	148.82	157.89	0.03	889.59	162.19
Buttery Brook	2199	25-Year	30.50	148.82	158.27	0.03	952.06	167.10
Buttery Brook	2199	50-Year	31.33	148.82	158.31	0.03	958.78	167.54
Buttery Brook	2199	100-Year	32.17	148.82	158.35	0.03	965.43	167.99
Buttery Brook	2173	1-Year	5.91	150.14	156.81	0.01	497.60	126.99
Buttery Brook	2173	10-Year	22.96	150.14	157.89	0.04	643.94	145.12
Buttery Brook	2173	25-Year	30.50	150.14	158.27	0.04	700.09	151.76
Buttery Brook	2173	50-Year	31.33	150.14	158.31	0.04	706.19	152.42
Buttery Brook	2173	100-Year	32.17	150.14	158.35	0.05	712.25	153.02
Buttery Brook	2148	1-Year	5.91	156.07	156.48	3.65	1.62	99.60
Buttery Brook	2148	10-Year	22.96	156.07	157.08	5.69	4.04	108.85
Buttery Brook	2148	25-Year	30.50	156.07	157.29	6.26	4.87	115.23
Buttery Brook	2148	50-Year	31.33	156.07	157.31	6.32	4.96	115.87
Buttery Brook	2148	100-Year	32.17	156.07	157.34	6.38	5.05	116.62
Buttery Brook	2146		Culvert					
Buttery Brook	1907	1-Year	5.91	144.00	144.59	3.58	1.65	8.12
Buttery Brook	1907	10-Year	22.96	144.00	148.22	1.42	16.17	20.59
Buttery Brook	1907	25-Year	30.50	144.00	148.35	1.83	16.68	21.06
Buttery Brook	1907	50-Year	31.33	144.00	148.40	1.85	16.91	21.26
Buttery Brook	1907	100-Year	32.17	144.00	148.46	1.88	17.15	21.48
Buttery Brook	1879	1-Year	5.91	142.68	143.04	2.54	2.32	10.54
Buttery Brook	1879	10-Year	22.96	142.68	148.22	0.24	215.90	66.20
Buttery Brook	1879	25-Year	30.50	142.68	148.36	0.31	224.67	66.83
Buttery Brook	1879	50-Year	31.33	142.68	148.41	0.32	228.38	67.09
Buttery Brook	1879	100-Year	32.17	142.68	148.47	0.32	232.47	67.38
Buttery Brook	1804	1-Year	5.91	140.70	141.34	2.66	2.22	6.97
Buttery Brook	1804	10-Year	22.96	140.70	148.22	0.16	363.38	88.87
Buttery Brook	1804	25-Year	30.50	140.70	148.36	0.20	375.18	90.11
Buttery Brook	1804	50-Year	31.33	140.70	148.41	0.20	380.19	90.63
Buttery Brook	1804	100-Year	32.17	140.70	148.47	0.21	385.72	91.20
Buttery Brook	1668	1-Year	16.51	139.20	140.06	2.93	5.79	9.31
Buttery Brook	1668	10-Year	56.06	139.20	148.22	0.29	579.51	110.22
Buttery Brook	1668	25-Year	76.00	139.20	148.36	0.38	594.04	110.87
Buttery Brook	1668	50-Year	86.33	139.20	148.41	0.43	600.16	111.14
Buttery Brook	1668	100-Year	98.07	139.20	148.47	0.49	606.88	111.44
Buttery Brook	1583	1-Year	16.51	138.20	139.04	3.54	6.32	26.58
Buttery Brook	1583	10-Year	56.06	138.20	148.22	0.19	875.78	139.29

HEC-RAS Plan: Existing Conditions_wJoffre River: Buttery Brook Reach: Buttery Brook (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
Buttery Brook	1583	25-Year	76.00	138.20	148.36	0.26	894.17	140.31
Buttery Brook	1583	50-Year	86.33	138.20	148.41	0.29	901.92	140.74
Buttery Brook	1583	100-Year	98.07	138.20	148.47	0.33	910.43	141.21
Buttery Brook	1436	1-Year	16.51	136.12	138.52	0.42	101.86	81.59
Buttery Brook	1436	10-Year	56.06	136.12	148.22	0.15	1169.80	153.17
Buttery Brook	1436	25-Year	76.00	136.12	148.36	0.19	1189.98	153.78
Buttery Brook	1436	50-Year	86.33	136.12	148.41	0.22	1198.47	154.04
Buttery Brook	1436	100-Year	98.07	136.12	148.47	0.25	1207.77	154.32
Buttery Brook	1361	1-Year	16.51	134.82	138.49	1.15	14.30	29.33
Buttery Brook	1361	10-Year	56.06	134.82	148.22	0.26	557.37	73.90
Buttery Brook	1361	25-Year	76.00	134.82	148.35	0.35	567.27	77.64
Buttery Brook	1361	50-Year	86.33	134.82	148.41	0.40	571.58	82.14
Buttery Brook	1361	100-Year	98.07	134.82	148.47	0.45	576.55	83.94
Buttery Brook	1349		Culvert					
Buttery Brook	1253	1-Year	16.51	130.03	131.10	5.09	3.24	13.17
Buttery Brook	1253	10-Year	56.06	130.03	135.11	2.91	19.29	46.64
Buttery Brook	1253	25-Year	76.00	130.03	135.18	3.89	19.56	47.10
Buttery Brook	1253	50-Year	86.33	130.03	135.20	4.39	19.66	47.27
Buttery Brook	1253	100-Year	98.07	130.03	135.23	4.96	19.76	47.45
Buttery Brook	1206	1-Year	16.51	128.50	129.31	3.42	4.83	8.34
Buttery Brook	1206	10-Year	56.06	128.50	135.13	0.54	223.52	72.36
Buttery Brook	1206	25-Year	76.00	128.50	135.22	0.72	229.79	75.06
Buttery Brook	1206	50-Year	86.33	128.50	135.26	0.81	232.58	76.17
Buttery Brook	1206	100-Year	98.07	128.50	135.30	0.91	235.66	76.67
Buttery Brook	1139	1-Year	16.51	127.47	128.05	3.70	4.46	10.65
Buttery Brook	1139	10-Year	56.06	127.47	135.13	0.20	765.05	218.80
Buttery Brook	1139	25-Year	76.00	127.47	135.22	0.27	784.01	220.16
Buttery Brook	1139	50-Year	86.33	127.47	135.26	0.30	792.33	220.76
Buttery Brook	1139	100-Year	98.07	127.47	135.30	0.34	801.46	221.60
Buttery Brook	1100	1-Year	16.51	126.80	127.42	2.77	5.96	10.37
Buttery Brook	1100	10-Year	56.06	126.80	135.13	0.21	790.10	222.42
Buttery Brook	1100	25-Year	76.00	126.80	135.22	0.27	809.39	226.45
Buttery Brook	1100	50-Year	86.33	126.80	135.26	0.31	817.97	229.05
Buttery Brook	1100	100-Year	98.07	126.80	135.30	0.35	827.47	230.91
Buttery Brook	1071	1-Year	16.51	126.39	127.39	1.31	12.63	18.59
Buttery Brook	1071	10-Year	56.06	126.39	135.13	0.19	528.53	127.49
Buttery Brook	1071	25-Year	76.00	126.39	135.22	0.26	539.55	128.36
Buttery Brook	1071	50-Year	86.33	126.39	135.26	0.29	544.38	128.74
Buttery Brook	1071	100-Year	98.07	126.39	135.30	0.33	549.69	129.15
Buttery Brook	1040	1-Year	16.51	125.90	127.32	1.55	10.62	12.05
Buttery Brook	1040	10-Year	56.06	125.90	135.13	0.26	529.47	126.18
Buttery Brook	1040	25-Year	76.00	125.90	135.22	0.34	540.38	127.48
Buttery Brook	1040	50-Year	86.33	125.90	135.26	0.39	545.16	128.02
Buttery Brook	1040	100-Year	98.07	125.90	135.30	0.44	550.43	128.62

HEC-RAS Plan: Existing Conditions_wJoffre River: Buttery Brook Reach: Buttery Brook (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
Buttery Brook	999	1-Year	16.51	125.43	127.30	1.23	18.70	21.71
Buttery Brook	999	10-Year	56.06	125.43	135.13	0.26	689.66	131.34
Buttery Brook	999	25-Year	76.00	125.43	135.22	0.35	701.03	132.75
Buttery Brook	999	50-Year	86.33	125.43	135.26	0.39	706.02	133.36
Buttery Brook	999	100-Year	98.07	125.43	135.30	0.44	711.51	134.03
Buttery Brook	954	1-Year	16.51	125.00	127.31	0.34	62.78	49.25
Buttery Brook	954	10-Year	56.06	125.00	135.13	0.15	846.99	133.03
Buttery Brook	954	25-Year	76.00	125.00	135.22	0.20	858.47	133.49
Buttery Brook	954	50-Year	86.33	125.00	135.26	0.23	863.48	133.70
Buttery Brook	954	100-Year	98.07	125.00	135.30	0.26	868.98	133.92
Buttery Brook	926	1-Year	16.51	124.70	127.30	0.72	23.78	54.07
Buttery Brook	926	10-Year	56.06	124.70	135.13	0.15	876.36	139.86
Buttery Brook	926	25-Year	76.00	124.70	135.22	0.20	888.44	140.51
Buttery Brook	926	50-Year	86.33	124.70	135.26	0.23	893.72	140.80
Buttery Brook	926	100-Year	98.07	124.70	135.30	0.26	899.51	141.12
Buttery Brook	616		Culvert					
Buttery Brook	282	1-Year	16.51	113.69	114.64	3.98	4.15	14.74
Buttery Brook	282	10-Year	56.06	113.69	115.42	6.60	8.49	18.31
Buttery Brook	282	25-Year	76.00	113.69	115.69	7.58	10.02	19.52
Buttery Brook	282	50-Year	86.33	113.69	115.84	7.94	10.88	20.10
Buttery Brook	282	100-Year	98.07	113.69	116.02	8.28	11.85	20.69
Buttery Brook	137	1-Year	16.51	111.61	112.55	3.54	4.66	8.58
Buttery Brook	137	10-Year	56.06	111.61	113.11	5.39	10.60	12.88
Buttery Brook	137	25-Year	76.00	111.61	113.35	5.70	13.94	18.66
Buttery Brook	137	50-Year	86.33	111.61	113.46	5.85	16.34	26.97
Buttery Brook	137	100-Year	98.07	111.61	113.64	5.53	23.20	42.99
Buttery Brook	0	1-Year	16.51	110.81	111.67	1.91	9.08	19.00
Buttery Brook	0	10-Year	56.06	110.81	112.25	2.99	27.33	38.49
Buttery Brook	0	25-Year	76.00	110.81	112.45	3.33	36.21	46.12
Buttery Brook	0	50-Year	86.33	110.81	112.55	3.48	40.67	48.61
Buttery Brook	0	100-Year	98.07	110.81	112.65	3.64	45.71	51.65


Queensville Dam_FY23 Plan: Proposed Conditions_wJoffre 2/28/2023
Buttery Brook Buttery Brook
Newton Street
Mountain Avenue
Joffre Ave
Legend
WS 100-Year
WS 50-Year
WS 25-Year
WS 10-Year
WS 1-Year
Ground
Elevation (ft)
Main Channel Distance (ft)
110
120
130
140
150
160
170
0
500
1000
1500
2000
2500
3000
282
616
999
1071
1139
1206
1258
1373.5
1583
1668
1804
1879
2146
2239
2292
2386
2481
2536
2617
2692
2747
2804

HEC-RAS Plan: Proposed Conditions_wJoffre River: Buttery Brook Reach: Buttery Brook

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
Buttery Brook	2804	1-Year	10.30	161.01	161.41	2.69	6.20	22.21
Buttery Brook	2804	10-Year	34.00	161.01	161.71	4.22	13.07	24.17
Buttery Brook	2804	25-Year	47.70	161.01	161.79	5.09	15.21	24.52
Buttery Brook	2804	50-Year	58.30	161.01	161.87	5.54	17.07	24.82
Buttery Brook	2804	100-Year	70.80	161.01	161.95	6.01	19.16	25.15
Buttery Brook	2747	1-Year	10.30	159.41	159.98	3.41	3.02	7.35
Buttery Brook	2747	10-Year	34.00	159.41	160.52	4.18	10.05	31.66
Buttery Brook	2747	25-Year	47.70	159.41	160.68	4.36	16.44	40.53
Buttery Brook	2747	50-Year	58.30	159.41	160.77	4.61	20.10	43.01
Buttery Brook	2747	100-Year	70.80	159.41	160.86	4.87	24.05	45.13
Buttery Brook	2692	1-Year	10.30	157.90	158.48	3.35	3.07	7.38
Buttery Brook	2692	10-Year	34.00	157.90	159.04	3.83	12.94	41.11
Buttery Brook	2692	25-Year	47.70	157.90	159.16	4.30	17.69	42.06
Buttery Brook	2692	50-Year	58.30	157.90	159.23	4.61	20.82	42.68
Buttery Brook	2692	100-Year	70.80	157.90	159.33	4.77	25.07	43.46
Buttery Brook	2617	1-Year	10.30	155.87	156.45	3.37	3.05	7.31
Buttery Brook	2617	10-Year	34.00	155.87	156.92	4.74	7.49	15.96
Buttery Brook	2617	25-Year	47.70	155.87	157.34	3.82	18.38	40.07
Buttery Brook	2617	50-Year	58.30	155.87	157.69	2.98	34.93	54.75
Buttery Brook	2617	100-Year	70.80	155.87	158.03	2.49	56.30	69.78
Buttery Brook	2536	1-Year	10.30	154.84	155.72	1.87	5.52	9.15
Buttery Brook	2536	10-Year	34.00	154.84	156.84	0.85	81.53	88.18
Buttery Brook	2536	25-Year	47.70	154.84	157.45	0.69	136.97	94.48
Buttery Brook	2536	50-Year	58.30	154.84	157.73	0.69	164.56	97.51
Buttery Brook	2536	100-Year	70.80	154.84	158.05	0.70	196.34	101.23
Buttery Brook	2481	1-Year	10.30	154.44	155.02	3.40	3.12	13.43
Buttery Brook	2481	10-Year	34.00	154.44	156.83	0.49	130.78	103.10
Buttery Brook	2481	25-Year	47.70	154.44	157.44	0.45	195.90	111.39
Buttery Brook	2481	50-Year	58.30	154.44	157.73	0.48	228.57	115.72
Buttery Brook	2481	100-Year	70.80	154.44	158.05	0.50	266.41	120.29
Buttery Brook	2386	1-Year	10.30	153.75	155.02	0.16	93.53	101.44
Buttery Brook	2386	10-Year	34.00	153.75	156.83	0.17	314.41	133.14
Buttery Brook	2386	25-Year	47.70	153.75	157.44	0.20	397.71	140.44
Buttery Brook	2386	50-Year	58.30	153.75	157.73	0.22	438.59	143.90
Buttery Brook	2386	100-Year	70.80	153.75	158.05	0.25	485.31	147.76
Buttery Brook	2292	1-Year	10.30	153.06	155.02	0.26	84.60	100.23
Buttery Brook	2292	10-Year	34.00	153.06	156.83	0.23	285.20	121.23
Buttery Brook	2292	25-Year	47.70	153.06	157.44	0.26	372.85	155.51
Buttery Brook	2292	50-Year	58.30	153.06	157.73	0.29	418.26	160.30
Buttery Brook	2292	100-Year	70.80	153.06	158.05	0.31	470.44	165.49
Buttery Brook	2239	1-Year	10.30	152.69	155.02	0.07	249.70	140.13
Buttery Brook	2239	10-Year	34.00	152.69	156.83	0.12	519.85	158.25
Buttery Brook	2239	25-Year	47.70	152.69	157.44	0.14	618.08	164.29
Buttery Brook	2239	50-Year	58.30	152.69	157.73	0.16	665.73	167.09
Buttery Brook	2239	100-Year	70.80	152.69	158.05	0.18	719.76	170.35

HEC-RAS Plan: Proposed Conditions_wJoffre River: Buttery Brook Reach: Buttery Brook (Continued)

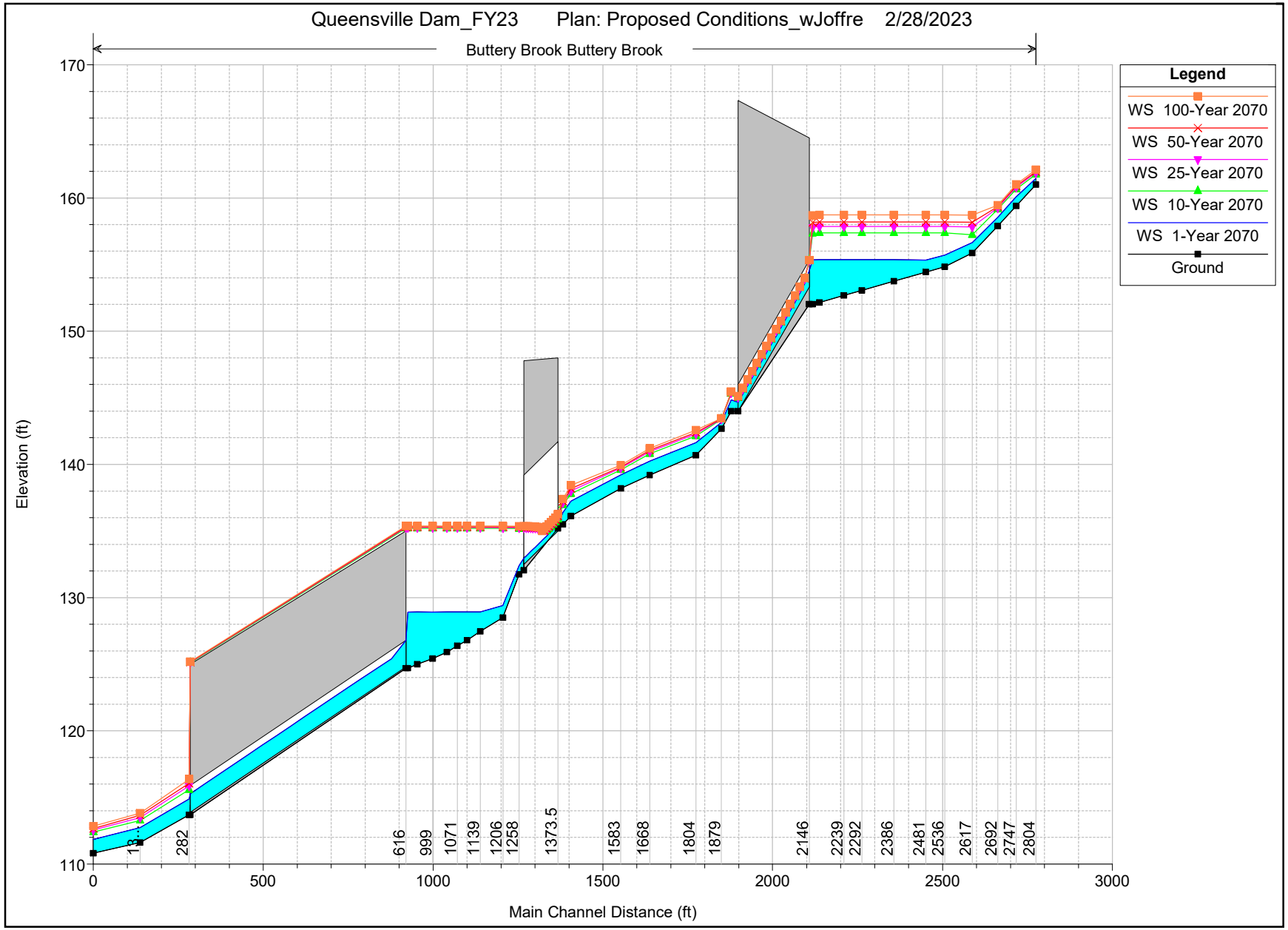
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
Buttery Brook	2168	1-Year	8.73	152.16	155.02	0.09	211.97	122.50
Buttery Brook	2168	10-Year	23.32	152.16	156.83	0.11	449.53	140.24
Buttery Brook	2168	25-Year	26.36	152.16	157.44	0.10	536.92	146.72
Buttery Brook	2168	50-Year	27.68	152.16	157.73	0.10	579.54	149.78
Buttery Brook	2168	100-Year	29.08	152.16	158.05	0.09	628.09	153.30
Buttery Brook	2147	1-Year	8.73	152.03	155.01	0.74	11.85	29.79
Buttery Brook	2147	10-Year	23.32	152.03	156.80	1.23	19.01	92.91
Buttery Brook	2147	25-Year	26.36	152.03	157.40	1.23	21.44	107.68
Buttery Brook	2147	50-Year	27.68	152.03	157.69	1.23	22.60	114.16
Buttery Brook	2147	100-Year	29.08	152.03	158.01	1.22	23.88	119.40
Buttery Brook	2146		Culvert					
Buttery Brook	1907	1-Year	8.73	144.00	144.72	4.29	2.17	8.51
Buttery Brook	1907	10-Year	23.32	144.00	145.23	6.01	4.21	10.07
Buttery Brook	1907	25-Year	26.36	144.00	145.33	6.21	4.61	10.37
Buttery Brook	1907	50-Year	27.68	144.00	145.36	6.33	4.75	10.48
Buttery Brook	1907	100-Year	29.08	144.00	145.41	6.42	4.92	10.61
Buttery Brook	1879	1-Year	8.73	142.68	143.10	2.93	2.98	11.29
Buttery Brook	1879	10-Year	23.32	142.68	143.35	4.05	6.05	13.41
Buttery Brook	1879	25-Year	26.36	142.68	143.39	4.22	6.64	13.78
Buttery Brook	1879	50-Year	27.68	142.68	143.41	4.28	6.90	13.93
Buttery Brook	1879	100-Year	29.08	142.68	143.43	4.35	7.17	14.10
Buttery Brook	1804	1-Year	8.73	140.70	141.53	2.32	3.77	9.18
Buttery Brook	1804	10-Year	23.32	140.70	142.01	2.59	9.05	12.15
Buttery Brook	1804	25-Year	26.36	140.70	142.15	2.46	10.86	12.61
Buttery Brook	1804	50-Year	27.68	140.70	142.25	2.33	12.12	12.91
Buttery Brook	1804	100-Year	29.08	140.70	142.35	2.22	13.45	13.23
Buttery Brook	1668	1-Year	19.33	139.20	140.07	3.38	5.88	9.44
Buttery Brook	1668	10-Year	56.42	139.20	140.67	4.92	18.12	27.24
Buttery Brook	1668	25-Year	71.86	139.20	140.83	5.41	22.44	29.34
Buttery Brook	1668	50-Year	82.68	139.20	140.92	5.75	25.11	30.57
Buttery Brook	1668	100-Year	94.98	139.20	141.02	6.04	28.34	31.99
Buttery Brook	1583	1-Year	19.33	138.20	139.18	3.10	10.29	29.59
Buttery Brook	1583	10-Year	56.42	138.20	139.49	5.27	20.37	36.49
Buttery Brook	1583	25-Year	71.86	138.20	139.61	5.69	24.98	39.33
Buttery Brook	1583	50-Year	82.68	138.20	139.69	5.90	28.37	41.31
Buttery Brook	1583	100-Year	94.98	138.20	139.77	6.21	31.61	43.10
Buttery Brook	1432	1-Year	19.33	136.12	137.10	3.66	6.45	31.95
Buttery Brook	1432	10-Year	56.42	136.12	137.62	3.62	35.75	64.33
Buttery Brook	1432	25-Year	71.86	136.12	137.82	3.51	49.01	69.05
Buttery Brook	1432	50-Year	82.68	136.12	137.96	3.44	58.72	71.49
Buttery Brook	1432	100-Year	94.98	136.12	138.11	3.39	69.43	74.10
Buttery Brook	1405	1-Year	19.33	135.50	136.26	4.12	4.69	9.30
Buttery Brook	1405	10-Year	56.42	135.50	136.81	5.23	10.80	13.44

HEC-RAS Plan: Proposed Conditions_wJoffre River: Buttery Brook Reach: Buttery Brook (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
Buttery Brook	1405	25-Year	71.86	135.50	136.99	5.43	14.13	26.29
Buttery Brook	1405	50-Year	82.68	135.50	137.09	5.64	16.14	75.95
Buttery Brook	1405	100-Year	94.98	135.50	137.20	5.86	18.32	76.24
Buttery Brook	1373.5		Culvert					
Buttery Brook	1258	1-Year	19.33	131.75	132.31	3.72	5.33	13.08
Buttery Brook	1258	10-Year	56.42	131.75	135.13	1.16	54.08	29.89
Buttery Brook	1258	25-Year	71.86	131.75	135.20	1.44	55.33	30.37
Buttery Brook	1258	50-Year	82.68	131.75	135.24	1.64	56.04	30.65
Buttery Brook	1258	100-Year	94.98	131.75	135.28	1.85	56.83	30.95
Buttery Brook	1206	1-Year	19.33	128.50	129.36	3.65	5.29	8.51
Buttery Brook	1206	10-Year	56.42	128.50	135.13	0.54	223.31	72.27
Buttery Brook	1206	25-Year	71.86	128.50	135.20	0.68	228.47	74.50
Buttery Brook	1206	50-Year	82.68	128.50	135.24	0.78	231.50	75.78
Buttery Brook	1206	100-Year	94.98	128.50	135.29	0.89	234.91	76.55
Buttery Brook	1139	1-Year	19.33	127.47	128.10	3.86	5.01	10.97
Buttery Brook	1139	10-Year	56.42	127.47	135.13	0.20	764.43	218.76
Buttery Brook	1139	25-Year	71.86	127.47	135.20	0.26	780.06	219.88
Buttery Brook	1139	50-Year	82.68	127.47	135.24	0.29	789.10	220.53
Buttery Brook	1139	100-Year	94.98	127.47	135.29	0.33	799.22	221.37
Buttery Brook	1100	1-Year	19.33	126.80	127.68	2.21	8.75	10.95
Buttery Brook	1100	10-Year	56.42	126.80	135.13	0.21	789.46	222.37
Buttery Brook	1100	25-Year	71.86	126.80	135.20	0.26	805.35	224.03
Buttery Brook	1100	50-Year	82.68	126.80	135.24	0.30	814.63	228.04
Buttery Brook	1100	100-Year	94.98	126.80	135.29	0.34	825.14	230.71
Buttery Brook	1071	1-Year	19.33	126.39	127.68	1.05	18.40	21.36
Buttery Brook	1071	10-Year	56.42	126.39	135.13	0.19	528.16	127.46
Buttery Brook	1071	25-Year	71.86	126.39	135.20	0.24	537.26	128.18
Buttery Brook	1071	50-Year	82.68	126.39	135.24	0.28	542.51	128.59
Buttery Brook	1071	100-Year	94.98	126.39	135.29	0.32	548.39	129.05
Buttery Brook	1040	1-Year	19.33	125.90	127.64	1.31	14.74	14.12
Buttery Brook	1040	10-Year	56.42	125.90	135.13	0.26	529.11	126.13
Buttery Brook	1040	25-Year	71.86	125.90	135.20	0.33	538.10	127.22
Buttery Brook	1040	50-Year	82.68	125.90	135.24	0.37	543.31	127.81
Buttery Brook	1040	100-Year	94.98	125.90	135.29	0.42	549.13	128.47
Buttery Brook	999	1-Year	19.33	125.43	127.62	1.15	26.74	28.34
Buttery Brook	999	10-Year	56.42	125.43	135.13	0.26	689.28	131.30
Buttery Brook	999	25-Year	71.86	125.43	135.20	0.33	698.66	132.46
Buttery Brook	999	50-Year	82.68	125.43	135.24	0.37	704.08	133.12
Buttery Brook	999	100-Year	94.98	125.43	135.29	0.43	710.16	133.86
Buttery Brook	954	1-Year	19.33	125.00	127.63	0.34	79.48	55.93
Buttery Brook	954	10-Year	56.42	125.00	135.13	0.15	846.61	133.02
Buttery Brook	954	25-Year	71.86	125.00	135.20	0.19	856.08	133.40
Buttery Brook	954	50-Year	82.68	125.00	135.24	0.22	861.54	133.62
Buttery Brook	954	100-Year	94.98	125.00	135.29	0.25	867.63	133.86

HEC-RAS Plan: Proposed Conditions_wJoffre River: Buttery Brook Reach: Buttery Brook (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
Buttery Brook	926	1-Year	19.33	124.70	127.62	0.73	27.61	60.76
Buttery Brook	926	10-Year	56.42	124.70	135.13	0.15	875.96	139.84
Buttery Brook	926	25-Year	71.86	124.70	135.20	0.19	885.92	140.37
Buttery Brook	926	50-Year	82.68	124.70	135.24	0.22	891.67	140.68
Buttery Brook	926	100-Year	94.98	124.70	135.29	0.25	898.09	141.04
Buttery Brook	616		Culvert					
Buttery Brook	282	1-Year	19.33	113.69	114.72	4.21	4.59	15.22
Buttery Brook	282	10-Year	56.42	113.69	115.42	6.62	8.52	18.33
Buttery Brook	282	25-Year	71.86	113.69	115.62	7.47	9.62	19.20
Buttery Brook	282	50-Year	82.68	113.69	115.79	7.81	10.59	19.92
Buttery Brook	282	100-Year	94.98	113.69	115.98	8.18	11.61	20.55
Buttery Brook	137	1-Year	19.33	111.61	112.61	3.74	5.17	8.98
Buttery Brook	137	10-Year	56.42	111.61	113.11	5.40	10.65	12.92
Buttery Brook	137	25-Year	71.86	111.61	113.29	5.72	13.03	14.28
Buttery Brook	137	50-Year	82.68	111.61	113.40	5.93	14.90	21.67
Buttery Brook	137	100-Year	94.98	111.61	113.61	5.52	21.95	41.21
Buttery Brook	0	1-Year	19.33	110.81	111.72	2.03	10.24	21.23
Buttery Brook	0	10-Year	56.42	110.81	112.25	3.00	27.49	38.60
Buttery Brook	0	25-Year	71.86	110.81	112.42	3.27	34.41	45.11
Buttery Brook	0	50-Year	82.68	110.81	112.52	3.43	39.10	47.67
Buttery Brook	0	100-Year	94.98	110.81	112.62	3.60	44.39	50.92


Queensville Dam_FY23 Plan: Proposed Conditions_wJoffre 2/28/2023
Buttery Brook Buttery Brook
Legend
WS 100-Year 2070
WS 50-Year 2070
WS 25-Year 2070
WS 10-Year 2070
WS 1-Year 2070
Ground
Elevation (ft)
Main Channel Distance (ft)
170
160
150
140
130
120
110
0
500
1000
1500
2000
2500
3000
282
616
999
1071
1139
1206
1258
1373.5
1583
1668
1804
1879
2146
2239
2292
2386
2481
2536
2617
2692
2747
2804

HEC-RAS Plan: Proposed Conditions_wJoffre River: Buttery Brook Reach: Buttery Brook

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
Buttery Brook	2804	1-Year 2070	14.10	161.01	161.47	3.02	7.57	22.86
Buttery Brook	2804	10-Year 2070	45.40	161.01	161.77	5.00	14.72	24.44
Buttery Brook	2804	25-Year 2070	63.10	161.01	161.90	5.73	17.87	24.95
Buttery Brook	2804	50-Year 2070	76.70	161.01	161.99	6.20	20.12	25.30
Buttery Brook	2804	100-Year 2070	100.30	161.01	162.12	6.96	23.51	25.83
Buttery Brook	2747	1-Year 2070	14.10	159.41	160.10	3.55	3.97	8.17
Buttery Brook	2747	10-Year 2070	45.40	159.41	160.67	4.29	15.66	39.99
Buttery Brook	2747	25-Year 2070	63.10	159.41	160.81	4.71	21.68	43.98
Buttery Brook	2747	50-Year 2070	76.70	159.41	160.90	4.99	25.70	45.71
Buttery Brook	2747	100-Year 2070	100.30	159.41	161.03	5.43	31.84	47.64
Buttery Brook	2692	1-Year 2070	14.10	157.90	158.55	3.89	3.63	7.82
Buttery Brook	2692	10-Year 2070	45.40	157.90	159.16	4.11	17.63	42.05
Buttery Brook	2692	25-Year 2070	63.10	157.90	159.26	4.75	22.09	42.92
Buttery Brook	2692	50-Year 2070	76.70	157.90	159.36	4.96	26.28	43.68
Buttery Brook	2692	100-Year 2070	100.30	157.90	159.46	5.61	30.83	45.15
Buttery Brook	2617	1-Year 2070	14.10	155.87	156.65	2.99	4.71	8.54
Buttery Brook	2617	10-Year 2070	45.40	155.87	157.25	4.12	15.01	36.02
Buttery Brook	2617	25-Year 2070	63.10	155.87	157.82	2.76	42.74	60.68
Buttery Brook	2617	50-Year 2070	76.70	155.87	158.18	2.29	67.26	72.11
Buttery Brook	2617	100-Year 2070	100.30	155.87	158.72	1.88	107.84	78.60
Buttery Brook	2536	1-Year 2070	14.10	154.84	155.72	2.58	5.47	9.11
Buttery Brook	2536	10-Year 2070	45.40	154.84	157.38	0.68	131.20	93.84
Buttery Brook	2536	25-Year 2070	63.10	154.84	157.86	0.70	176.72	98.82
Buttery Brook	2536	50-Year 2070	76.70	154.84	158.20	0.71	211.33	103.09
Buttery Brook	2536	100-Year 2070	100.30	154.84	158.73	0.73	267.37	109.26
Buttery Brook	2481	1-Year 2070	14.10	154.44	155.34	2.01	10.34	32.81
Buttery Brook	2481	10-Year 2070	45.40	154.44	157.38	0.45	189.10	110.34
Buttery Brook	2481	25-Year 2070	63.10	154.44	157.85	0.48	243.05	117.72
Buttery Brook	2481	50-Year 2070	76.70	154.44	158.20	0.50	284.22	122.33
Buttery Brook	2481	100-Year 2070	100.30	154.44	158.73	0.54	350.74	129.61
Buttery Brook	2386	1-Year 2070	14.10	153.75	155.37	0.16	131.61	117.63
Buttery Brook	2386	10-Year 2070	45.40	153.75	157.38	0.19	389.12	139.70
Buttery Brook	2386	25-Year 2070	63.10	153.75	157.85	0.23	456.53	145.39
Buttery Brook	2386	50-Year 2070	76.70	153.75	158.20	0.26	507.14	149.53
Buttery Brook	2386	100-Year 2070	100.30	153.75	158.73	0.29	587.79	155.89
Buttery Brook	2292	1-Year 2070	14.10	153.06	155.37	0.24	120.43	104.27
Buttery Brook	2292	10-Year 2070	45.40	153.06	157.38	0.25	363.35	154.50
Buttery Brook	2292	25-Year 2070	63.10	153.06	157.85	0.30	438.25	162.33
Buttery Brook	2292	50-Year 2070	76.70	153.06	158.20	0.32	494.91	167.70
Buttery Brook	2292	100-Year 2070	100.30	153.06	158.72	0.35	585.68	176.23
Buttery Brook	2239	1-Year 2070	14.10	152.69	155.37	0.08	299.36	143.47
Buttery Brook	2239	10-Year 2070	45.40	152.69	157.38	0.13	608.03	163.67
Buttery Brook	2239	25-Year 2070	63.10	152.69	157.85	0.17	686.52	168.32
Buttery Brook	2239	50-Year 2070	76.70	152.69	158.20	0.19	744.89	171.85
Buttery Brook	2239	100-Year 2070	100.30	152.69	158.72	0.22	836.99	176.91

HEC-RAS Plan: Proposed Conditions_wJoffre River: Buttery Brook Reach: Buttery Brook (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
Buttery Brook	2168	1-Year 2070	11.93	152.16	155.37	0.10	255.43	125.65
Buttery Brook	2168	10-Year 2070	26.07	152.16	157.38	0.10	527.95	146.08
Buttery Brook	2168	25-Year 2070	28.23	152.16	157.85	0.10	598.19	151.15
Buttery Brook	2168	50-Year 2070	29.70	152.16	158.20	0.09	650.71	154.85
Buttery Brook	2168	100-Year 2070	31.83	152.16	158.72	0.09	733.93	160.41
Buttery Brook	2147	1-Year 2070	11.93	152.03	155.35	0.90	13.23	38.08
Buttery Brook	2147	10-Year 2070	26.07	152.03	157.34	1.23	21.20	105.69
Buttery Brook	2147	25-Year 2070	28.23	152.03	157.82	1.22	23.09	116.12
Buttery Brook	2147	50-Year 2070	29.70	152.03	158.16	1.21	24.47	121.60
Buttery Brook	2147	100-Year 2070	31.83	152.03	158.69	1.20	26.58	130.25
Buttery Brook	2146		Culvert					
Buttery Brook	1907	1-Year 2070	11.93	144.00	144.85	4.75	2.70	8.92
Buttery Brook	1907	10-Year 2070	26.07	144.00	145.32	6.19	4.57	10.34
Buttery Brook	1907	25-Year 2070	28.23	144.00	145.38	6.37	4.82	10.53
Buttery Brook	1907	50-Year 2070	29.70	144.00	145.42	6.48	4.99	10.66
Buttery Brook	1907	100-Year 2070	31.83	144.00	145.48	6.63	5.22	10.84
Buttery Brook	1879	1-Year 2070	11.93	142.68	143.16	3.28	3.68	11.81
Buttery Brook	1879	10-Year 2070	26.07	142.68	143.39	4.20	6.59	13.74
Buttery Brook	1879	25-Year 2070	28.23	142.68	143.42	4.31	7.01	14.00
Buttery Brook	1879	50-Year 2070	29.70	142.68	143.44	4.38	7.29	14.17
Buttery Brook	1879	100-Year 2070	31.83	142.68	143.47	4.47	7.71	14.42
Buttery Brook	1804	1-Year 2070	11.93	140.70	141.64	2.48	4.80	10.43
Buttery Brook	1804	10-Year 2070	26.07	140.70	142.13	2.49	10.61	12.54
Buttery Brook	1804	25-Year 2070	28.23	140.70	142.29	2.28	12.64	13.04
Buttery Brook	1804	50-Year 2070	29.70	140.70	142.40	2.17	14.09	13.38
Buttery Brook	1804	100-Year 2070	31.83	140.70	142.58	2.01	16.73	17.19
Buttery Brook	1668	1-Year 2070	26.33	139.20	140.24	3.70	8.07	16.40
Buttery Brook	1668	10-Year 2070	69.57	139.20	140.80	5.34	21.80	29.04
Buttery Brook	1668	25-Year 2070	87.33	139.20	140.95	5.87	26.30	31.10
Buttery Brook	1668	50-Year 2070	100.70	139.20	141.06	6.19	29.72	32.58
Buttery Brook	1668	100-Year 2070	123.03	139.20	141.21	6.72	34.81	34.66
Buttery Brook	1583	1-Year 2070	26.33	138.20	139.23	3.84	11.62	30.52
Buttery Brook	1583	10-Year 2070	69.57	138.20	139.59	5.62	24.34	38.95
Buttery Brook	1583	25-Year 2070	87.33	138.20	139.73	6.01	29.70	42.05
Buttery Brook	1583	50-Year 2070	100.70	138.20	139.81	6.33	33.22	43.97
Buttery Brook	1583	100-Year 2070	123.03	138.20	139.94	6.72	39.47	47.18
Buttery Brook	1432	1-Year 2070	26.33	136.12	137.24	3.60	12.78	54.88
Buttery Brook	1432	10-Year 2070	69.57	136.12	137.79	3.54	46.80	68.41
Buttery Brook	1432	25-Year 2070	87.33	136.12	138.02	3.42	62.80	72.50
Buttery Brook	1432	50-Year 2070	100.70	136.12	138.18	3.36	74.86	75.38
Buttery Brook	1432	100-Year 2070	123.03	136.12	138.43	3.33	94.11	79.80
Buttery Brook	1405	1-Year 2070	26.33	135.50	136.39	4.38	6.01	10.18
Buttery Brook	1405	10-Year 2070	69.57	135.50	136.97	5.38	13.72	24.84
Buttery Brook	1405	25-Year 2070	87.33	135.50	137.13	5.73	16.98	76.06
Buttery Brook	1405	50-Year 2070	100.70	135.50	137.23	6.00	19.12	76.34

HEC-RAS Plan: Proposed Conditions_wJoffre River: Buttery Brook Reach: Buttery Brook (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
Buttery Brook	1405	100-Year 2070	123.03	135.50	137.40	6.37	22.63	76.81
Buttery Brook	1373.5		Culvert					
Buttery Brook	1258	1-Year 2070	26.33	131.75	132.41	4.07	6.70	13.88
Buttery Brook	1258	10-Year 2070	69.57	131.75	135.19	1.40	55.19	30.32
Buttery Brook	1258	25-Year 2070	87.33	131.75	135.26	1.72	56.40	30.79
Buttery Brook	1258	50-Year 2070	100.70	131.75	135.30	1.95	57.17	31.08
Buttery Brook	1258	100-Year 2070	123.03	131.75	135.37	2.34	58.37	31.55
Buttery Brook	1206	1-Year 2070	26.33	128.50	129.41	4.64	5.68	8.65
Buttery Brook	1206	10-Year 2070	69.57	128.50	135.19	0.66	227.89	74.25
Buttery Brook	1206	25-Year 2070	87.33	128.50	135.26	0.82	233.04	76.24
Buttery Brook	1206	50-Year 2070	100.70	128.50	135.31	0.94	236.38	76.79
Buttery Brook	1206	100-Year 2070	123.03	128.50	135.37	1.13	241.69	77.64
Buttery Brook	1139	1-Year 2070	26.33	127.47	128.93	1.61	16.35	16.19
Buttery Brook	1139	10-Year 2070	69.57	127.47	135.20	0.25	778.29	219.75
Buttery Brook	1139	25-Year 2070	87.33	127.47	135.27	0.31	793.67	220.85
Buttery Brook	1139	50-Year 2070	100.70	127.47	135.31	0.35	803.60	221.82
Buttery Brook	1139	100-Year 2070	123.03	127.47	135.38	0.42	819.50	227.13
Buttery Brook	1100	1-Year 2070	26.33	126.80	128.92	1.02	25.88	17.56
Buttery Brook	1100	10-Year 2070	69.57	126.80	135.20	0.25	803.55	223.74
Buttery Brook	1100	25-Year 2070	87.33	126.80	135.26	0.31	819.36	229.47
Buttery Brook	1100	50-Year 2070	100.70	126.80	135.31	0.36	829.69	231.09
Buttery Brook	1100	100-Year 2070	123.03	126.80	135.38	0.43	846.11	232.31
Buttery Brook	1071	1-Year 2070	26.33	126.39	128.93	0.51	52.68	33.41
Buttery Brook	1071	10-Year 2070	69.57	126.39	135.19	0.24	536.23	128.09
Buttery Brook	1071	25-Year 2070	87.33	126.39	135.26	0.29	545.17	128.80
Buttery Brook	1071	50-Year 2070	100.70	126.39	135.31	0.33	550.93	129.25
Buttery Brook	1071	100-Year 2070	123.03	126.39	135.38	0.40	560.08	129.96
Buttery Brook	1040	1-Year 2070	26.33	125.90	128.92	0.73	40.50	28.66
Buttery Brook	1040	10-Year 2070	69.57	125.90	135.19	0.32	537.08	127.10
Buttery Brook	1040	25-Year 2070	87.33	125.90	135.26	0.39	545.94	128.11
Buttery Brook	1040	50-Year 2070	100.70	125.90	135.31	0.45	551.65	128.75
Buttery Brook	1040	100-Year 2070	123.03	125.90	135.38	0.54	560.73	129.77
Buttery Brook	999	1-Year 2070	26.33	125.43	128.92	0.75	80.69	55.01
Buttery Brook	999	10-Year 2070	69.57	125.43	135.19	0.32	697.59	132.32
Buttery Brook	999	25-Year 2070	87.33	125.43	135.26	0.39	706.83	133.46
Buttery Brook	999	50-Year 2070	100.70	125.43	135.31	0.45	712.79	134.18
Buttery Brook	999	100-Year 2070	123.03	125.43	135.38	0.55	722.27	134.99
Buttery Brook	954	1-Year 2070	26.33	125.00	128.92	0.27	166.36	76.95
Buttery Brook	954	10-Year 2070	69.57	125.00	135.19	0.18	855.01	133.36
Buttery Brook	954	25-Year 2070	87.33	125.00	135.26	0.23	864.30	133.73
Buttery Brook	954	50-Year 2070	100.70	125.00	135.31	0.26	870.26	133.97
Buttery Brook	954	100-Year 2070	123.03	125.00	135.38	0.32	879.72	134.35
Buttery Brook	926	1-Year 2070	26.33	124.70	128.91	0.64	43.10	81.33
Buttery Brook	926	10-Year 2070	69.57	124.70	135.19	0.18	884.80	140.31

HEC-RAS Plan: Proposed Conditions_wJoffre River: Buttery Brook Reach: Buttery Brook (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
			(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
Buttery Brook	926	25-Year 2070	87.33	124.70	135.26	0.23	894.57	140.84
Buttery Brook	926	50-Year 2070	100.70	124.70	135.31	0.26	900.86	141.19
Buttery Brook	926	100-Year 2070	123.03	124.70	135.38	0.32	910.83	141.74
Buttery Brook	616		Culvert					
Buttery Brook	282	1-Year 2070	26.33	113.69	114.89	4.75	5.55	15.97
Buttery Brook	282	10-Year 2070	69.57	113.69	115.59	7.37	9.44	19.06
Buttery Brook	282	25-Year 2070	87.33	113.69	115.86	7.97	10.96	20.15
Buttery Brook	282	50-Year 2070	100.70	113.69	116.06	8.33	12.08	20.84
Buttery Brook	282	100-Year 2070	123.03	113.69	116.36	8.93	13.78	22.36
Buttery Brook	137	1-Year 2070	26.33	111.61	112.74	4.15	6.35	9.88
Buttery Brook	137	10-Year 2070	69.57	111.61	113.27	5.66	12.72	14.11
Buttery Brook	137	25-Year 2070	87.33	111.61	113.48	5.78	17.03	28.76
Buttery Brook	137	50-Year 2070	100.70	111.61	113.67	5.56	24.15	44.26
Buttery Brook	137	100-Year 2070	123.03	111.61	113.82	5.82	31.78	51.89
Buttery Brook	0	1-Year 2070	26.33	110.81	111.85	2.29	13.51	30.35
Buttery Brook	0	10-Year 2070	69.57	110.81	112.39	3.23	33.38	44.29
Buttery Brook	0	25-Year 2070	87.33	110.81	112.56	3.50	41.10	48.89
Buttery Brook	0	50-Year 2070	100.70	110.81	112.67	3.67	46.78	51.96
Buttery Brook	0	100-Year 2070	123.03	110.81	112.84	3.92	55.74	54.41

Appendix F

HEC-18 Scour Calculations

FUSS & O'NEILL	Prepared By	Date	Checked By	Date	Project No
	LKC	3/6/2023			Mountain Avenue; South Hadley, MA 20170390.V50

HEC-14 Scour Hole Geometry

Objective: Calculate total culvert outlet scour experienced by the **Existing 24" CMP**

Flow: **Q25 Flow - Scour Design Frequency**

Reference: HEC-14 Hydraulic Design of Energy Dissipators for Culverts and Channels, Third Ed., Section 5.1.1 Scour Hole Geometry

Culvert #1 - 36-Inch CMP

Q =	36.44	cfs	(discharge)	
g =	32.20	ft/s^2	(acceleration of gravity)	*(HEC 14)*
t =	30.00	min	(time)	*(HEC 14 Section 5.1.2)*
S =	0.05	ft/ft		
D_p =	2.00	ft	(pipe diameter)	
Inv. Out =	130.28	ft	(Invert Out Elevation)	
El_{min} =	130.03	ft	(minimum riverbed elevation at culvert outlet)	
R_c =	0.50	ft	(D_p/4, hydraulic radius at the end of the culvert (assuming full flow))	
H_d =	0.13	ft/ft	(drop height/Diameter)	

Table 5.2 Coefficient C_h for Outlets above Bed

H_d	Depth	Width	Length	Volume
0	1.00	1.00	1.00	1.00
0.13	**1.03**	**1.06**	**0.97**	**1.04**
1	1.22	1.51	0.73	1.28
2	1.26	1.54	0.73	1.47
4	1.34	1.66	0.73	1.55

Table 5.3 Coefficient C_s for Culvert Slope

Slope %	Depth	Width	Length	Volume
0	1.00	1.00	1.00	1.00
2	1.03	1.28	1.17	1.30
5	1.08	1.28	1.17	1.30
>7	1.12	1.28	1.17	1.30

	α	β	θ	C_s	C_h
Depth of Scour	2.27	0.39	0.06	1.08	1.03
Width of Scour	6.94	0.53	0.08	1.28	1.06
Length of Scour	17.1	0.47	0.1	1.17	0.97
Volume of Scour	127.08	1.24	0.18	1.30	1.04

FUSS & O'NEILL	Prepared By	Date	Checked By	Date	Project No
	LKC	3/6/2023			Mountain Avenue; South Hadley, MA 20170390.V50

HEC-14 Scour Hole Geometry	Sheet No
	2 of 2

σ = 6.86 ($(D_{84}/D_{16})^{0.5}$, material standard deviation)

D_{84} = 6.2760 mm

D_{16} = 0.1333 mm

Coefficients	Size	
85	6.5197	sample F642
84	**6.2760**	
60	0.427	sample F642

See Particle Size Analysis

Coefficients	Size	
30	0.2162	sample F623
16	**0.1333**	
15	0.1274	sample F623

See Particle Size Analysis

$$\left[\frac{h_s}{R_c}, \frac{W_s}{R_c}, \frac{L_s}{R_c}, \frac{V_s}{R_c^3}\right] = C_s C_h \left(\frac{\alpha}{\sigma^{1/3}}\right)\left(\frac{Q}{\sqrt{g}(R_c^{2.5})}\right)^{\beta}\left(\frac{t}{316}\right)^{\theta}$$

(HEC 14 Eqn. 5.1)

h_s = 4.67 ft (depth of scour)

W_s = 27.65 ft (width of scour)

L_s = 43.50 ft (length of scour)

V_s = 5067.35 ft (volume of scour)

L_s = 17.40 ft ($0.4L_s$, location of maximum scour downstream of culvert)

FUSS & O'NEILL	Prepared By	Date	Checked By	Date	Project No
	LKC	3/6/2023			Mountain Avenue; South Hadley, MA 20170390.V50

HEC-14 Scour Hole Geometry

Sheet No 1 of 2

Objective: Calculate total culvert outlet scour experienced by the **Existing 24" CMP**

Flow: **Q50 Flow - Scour Check Frequency**

Reference: HEC-14 Hydraulic Design of Energy Dissipators for Culverts and Channels, Third Ed., Section 5.1.1 Scour Hole Geometry

Culvert #1 - 36-Inch CMP

Q =	36.48	cfs	(discharge)	
g =	32.20	ft/s^2	(acceleration of gravity)	*(HEC 14)*
t =	30.00	min	(time)	*(HEC 14 Section 5.1.2)*
S =	0.05	ft/ft		
D_p =	2.00	ft	(pipe diameter)	
Inv. Out =	130.28	ft	(Invert Out Elevation)	
El_{min} =	130.03	ft	(minimum riverbed elevation at culvert outlet)	
R_c =	0.50	ft	(D_p/4, hydraulic radius at the end of the culvert (assuming full flow))	
H_d =	0.13	ft/ft	(drop height/Diameter)	

Table 5.2 Coefficient C_h for Outlets above Bed

H_d	Depth	Width	Length	Volume
0	1.00	1.00	1.00	1.00
0.13	**1.03**	**1.06**	**0.97**	**1.04**
1	1.22	1.51	0.73	1.28
2	1.26	1.54	0.73	1.47
4	1.34	1.66	0.73	1.55

Table 5.3 Coefficient C_s for Culvert Slope

Slope %	Depth	Width	Length	Volume
0	1.00	1.00	1.00	1.00
2	1.03	1.28	1.17	1.30
5	1.08	1.28	1.17	1.30
>7	1.12	1.28	1.17	1.30

	α	β	θ	C_s	C_h
Depth of Scour	2.27	0.39	0.06	1.08	1.03
Width of Scour	6.94	0.53	0.08	1.28	1.06
Length of Scour	17.1	0.47	0.1	1.17	0.97
Volume of Scour	127.08	1.24	0.18	1.30	1.04

FUSS & O'NEILL	Prepared By	Date	Checked By	Date	Project No
	LKC	3/6/2023			Mountain Avenue; South Hadley, MA 20170390.V50

HEC-14 Scour Hole Geometry	Sheet No
	2 of 2

σ = 6.86 ($(D_{84}/D_{16})^{0.5}$, material standard deviation)

D_{84} = 6.2760 mm

D_{16} = 0.1333 mm

Coefficients	Size	
85	6.5197	sample F642
84	**6.2760**	
60	0.427	sample F642

See Particle Size Analysis

Coefficients	Size	
30	0.2162	sample F623
16	**0.1333**	
15	0.1274	sample F623

See Particle Size Analysis

$$\left[\frac{h_s}{R_c}, \frac{W_s}{R_c}, \frac{L_s}{R_c}, \frac{V_s}{R_c^3}\right] = C_s C_h \left(\frac{\alpha}{\sigma^{1/3}}\right)\left(\frac{Q}{\sqrt{g}(R_c^{2.5})}\right)^{\beta}\left(\frac{t}{316}\right)^{\theta}$$

(HEC 14 Eqn. 5.1)

h_s = 4.67 ft (depth of scour)

W_s = 27.67 ft (width of scour)

L_s = 43.53 ft (length of scour)

V_s = 5074.25 ft (volume of scour)

L_s = 17.41 ft ($0.4L_s$, location of maximum scour downstream of culvert)

FUSS & O'NEILL	Prepared By	Date	Checked By	Date	Project No
	LKC	3/6/2023			Mountain Avenue; South Hadley, MA 20170390.V50

NCHRP 24-20 Abutment Scour Approach

Objective: Calculate total abutment scour experienced by the **Proposed Arch Culvert**

Flow: **Q25 Design Scour Frequency**

Reference: HEC-18 Evaluating Scour at Bridges, Fifth Ed., Section 8.6.3 NCHRP 24-20 Abutment Scour Approach

L/b_f = 100% Ratio of Embankment Length to Width of Floodplain, %

Assumptions:

If the projected length of the embankment is 75% or greater than the width of the floodplain, then the live-bed scour calculation is used. Otherwise, the clear-water scour calculations is use.

L/Bf >= 75%, Use Live-Bed Scour

Calculate Live-Bed Scour

$$y_c = y_1\left(\frac{q_{2c}}{q_1}\right)^{6/7}$$

q_b =	71.86	Total discharge in the bridge opening, ft^3/s
Wcs =	15	Width (clear span) of the bridge opening, ft
q_{2c} =	4.8	Unit discharge in the constricted opening accounting for non-uniform flow distribution, ft^2/s

Assume approach section is RS 1432

y_1 =	1.24	Upstream flow depth, ft	Hydraulic depth in main channel from RS 1432
v_1 =	3.51	Upstream velocity, ft/s	Average velocity in main channel from RS 1432
q_1 =	4.4	Upstream unit discharge, ft^2/s	
y_c =	1.3	Flow depth including contraction scour, ft	

$$y_{max} = \alpha_A y_c \qquad y_s = y_{max} - y_0$$

α_A =	1.63	Amplification Factor for live-bed conditions
y_{max} =	2.2	Maximum flow depth resulting from Abutment Scour, ft
y_0 =	1.01	Flow depth prior to scour, ft — Assume hydraulic depth at RS 1405
y_s =	1.2	Abutment Scour Depth, ft

FUSS & O'NEILL	Prepared By	Date	Checked By	Date	Project No
	LKC	3/6/2023			Mountain Avenue; South Hadley, MA 20170390.V50
NCHRP 24-20 Abutment Scour Approach					Sheet No 2 of 2

q_{2c}/q_1 = 1.10

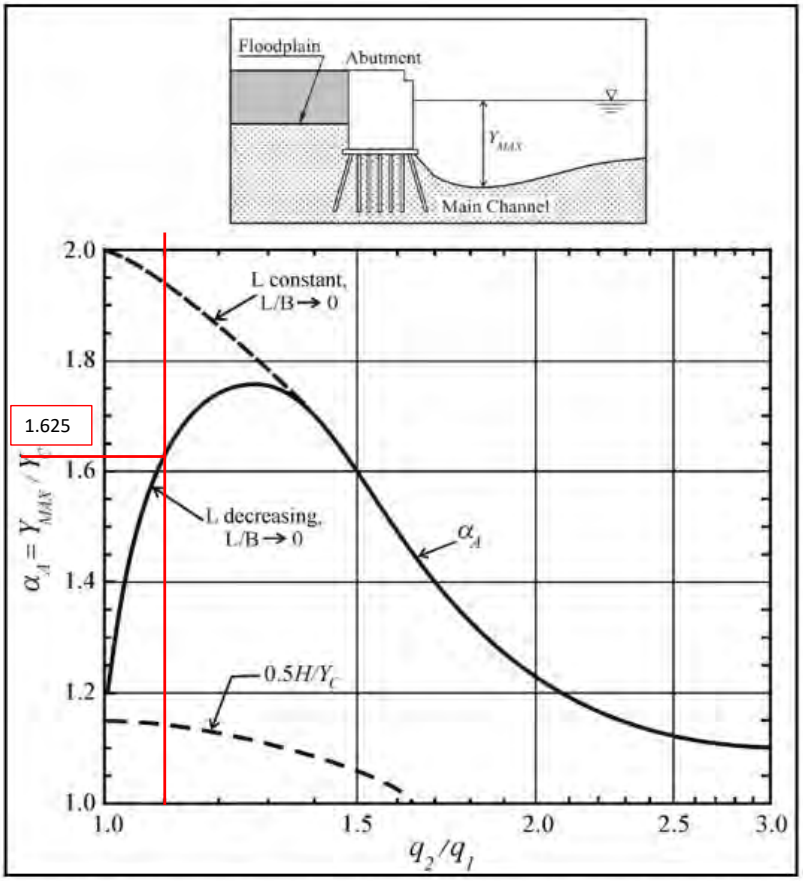


Figure 8.10. Scour amplification factor for wingwall abutments and live-bed conditions (NCHRP 2010b).

FUSS & O'NEILL	Prepared By	Date	Checked By	Date	Project No
	LKC	3/6/2023			Mountain Avenue; South Hadley, MA 20170390.V50

NCHRP 24-20 Abutment Scour Approach

Objective: Calculate total abutment scour experienced by the **Proposed Arch Culvert**

Flow: **Q25 (2070) Design Scour Frequency**

Reference: HEC-18 Evaluating Scour at Bridges, Fifth Ed., Section 8.6.3 NCHRP 24-20 Abutment Scour Approach

L/b_f = 100% Ratio of Embankment Length to Width of Floodplain, %

Assumptions:

If the projected length of the embankment is 75% or greater than the width of the floodplain, then the live-bed scour calculation is used. Otherwise, the clear-water scour calculations is use.

L/Bf >= 75%, Use Live-Bed Scour

Calculate Live-Bed Scour

$$y_c = y_1\left(\frac{q_{2c}}{q_1}\right)^{6/7}$$

q_b =	87.33	Total discharge in the bridge opening, ft^3/s
Wcs =	15	Width (clear span) of the bridge opening, ft
q_{2c} =	5.8	Unit discharge in the constricted opening accounting for non-uniform flow distribution, ft^2/s

Assume approach section is RS 1432

y_1 =	1.44	Upstream flow depth, ft	Hydraulic depth in main channel from RS 1432
v_1 =	3.42	Upstream velocity, ft/s	Average velocity in main channel from RS 1432
q_1 =	4.9	Upstream unit discharge, ft^2/s	
y_c =	1.7	Flow depth including contraction scour, ft	

$$y_{max} = \alpha_A y_c \qquad y_s = y_{max} - y_0$$

α_A =	1.73	Amplification Factor for live-bed conditions
y_{max} =	2.9	Maximum flow depth resulting from Abutment Scour, ft
y_0 =	1.15	Flow depth prior to scour, ft — Assume hydraulic depth at RS 1405
y_s =	1.7	Abutment Scour Depth, ft

FUSS & O'NEILL	Prepared By	Date	Checked By	Date	Project No
	LKC	3/6/2023			Mountain Avenue; South Hadley, MA 20170390.V50
NCHRP 24-20 Abutment Scour Approach					Sheet No 2 of 2

q_{2c}/q_1 = 1.18

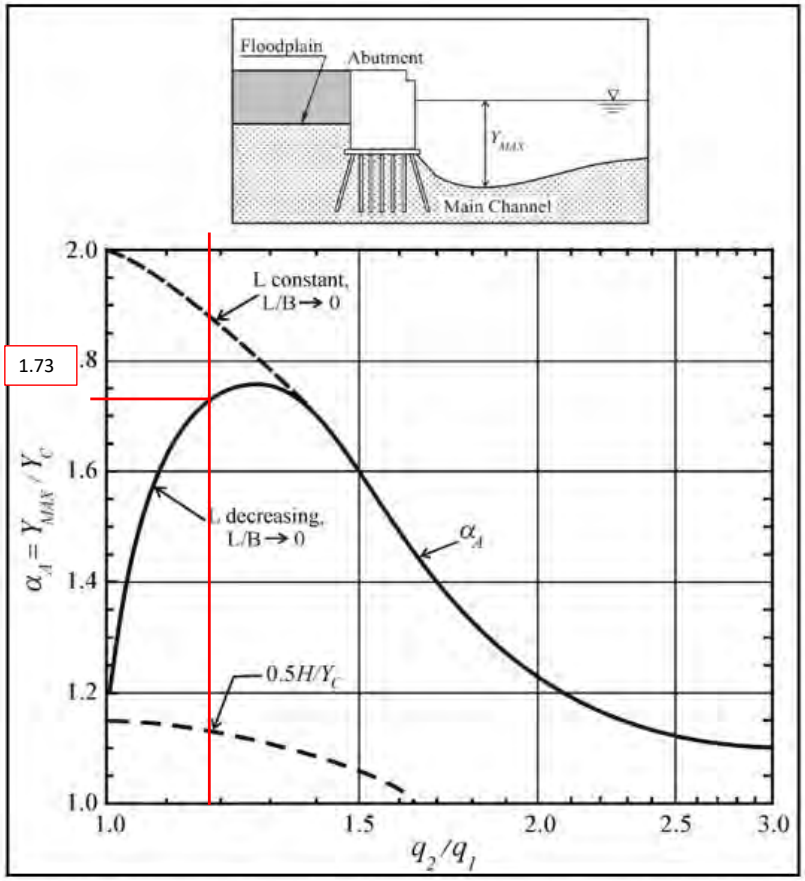


Figure 8.10. Scour amplification factor for wingwall abutments and live-bed conditions (NCHRP 2010b).

FUSS & O'NEILL	Prepared By	Date	Checked By	Date	Project No
	LKC	3/6/2023			Mountain Avenue; South Hadley, MA 20170390.V50

NCHRP 24-20 Abutment Scour Approach

Objective: Calculate total abutment scour experienced by the **Proposed Arch Culvert**

Flow: **Q50 Check Scour Frequency**

Reference: HEC-18 Evaluating Scour at Bridges, Fifth Ed., Section 8.6.3 NCHRP 24-20 Abutment Scour Approach

L/b_f = 100% Ratio of Embankment Length to Width of Floodplain, %

Assumptions:

If the projected length of the embankment is 75% or greater than the width of the floodplain, then the live-bed scour calculation is used. Otherwise, the clear-water scour calculations is use.

L/Bf >= 75%, Use Live-Bed Scour

Calculate Live-Bed Scour

$$y_c = y_1\left(\frac{q_{2c}}{q_1}\right)^{6/7}$$

q_b =	82.68	Total discharge in the bridge opening, ft^3/s
Wcs =	15	Width (clear span) of the bridge opening, ft
q_{2c} =	5.5	Unit discharge in the constricted opening accounting for non-uniform flow distribution, ft^2/s

Assume approach section is RS 1432

y_1 =	1.38	Upstream flow depth, ft	Hydraulic depth in main channel from RS 1432
v_1 =	3.44	Upstream velocity, ft/s	Average velocity in main channel from RS 1432
q_1 =	4.7	Upstream unit discharge, ft^2/s	
y_c =	1.6	Flow depth including contraction scour, ft	

$$y_{max} = \alpha_A y_c \qquad y_s = y_{max} - y_0$$

α_A =	1.74	Amplification Factor for live-bed conditions
y_{max} =	2.7	Maximum flow depth resulting from Abutment Scour, ft
y_0 =	1.11	Flow depth prior to scour, ft — Assume hydraulic depth at RS 1405
y_s =	1.62	Abutment Scour Depth, ft

FUSS & O'NEILL	Prepared By	Date	Checked By	Date	Project No
	LKC	3/6/2023			Mountain Avenue; South Hadley, MA 20170390.V50

NCHRP 24-20 Abutment Scour Approach

Sheet No 2 of 2

q_{2c}/q_1 = 1.2

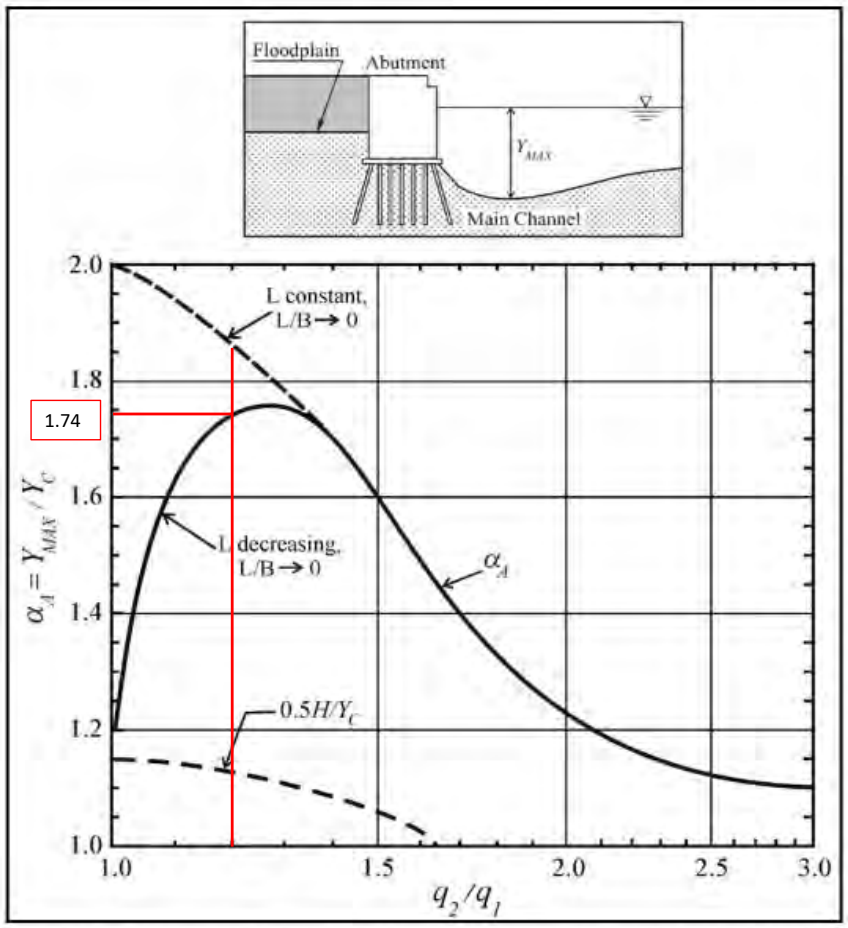


Figure 8.10. Scour amplification factor for wingwall abutments and live-bed conditions (NCHRP 2010b).

FUSS & O'NEILL	Prepared By	Date	Checked By	Date	Project No
	LKC	3/6/2023			Mountain Avenue; South Hadley, MA 20170390.V50

NCHRP 24-20 Abutment Scour Approach

Objective: Calculate total abutment scour experienced by the **Proposed Arch Culvert**

Flow: **Q50 (2070) Check Scour Frequency**

Reference: HEC-18 Evaluating Scour at Bridges, Fifth Ed., Section 8.6.3 NCHRP 24-20 Abutment Scour Approach

L/b_f = 100% Ratio of Embankment Length to Width of Floodplain, %

Assumptions:

If the projected length of the embankment is 75% or greater than the width of the floodplain, then the live-bed scour calculation is used. Otherwise, the clear-water scour calculations is use.

L/Bf >= 75%, Use Live-Bed Scour

Calculate Live-Bed Scour

$$y_c = y_1\left(\frac{q_{2c}}{q_1}\right)^{6/7}$$

q_b =	100.7	Total discharge in the bridge opening, ft^3/s
Wcs =	15	Width (clear span) of the bridge opening, ft
q_{2c} =	6.7	Unit discharge in the constricted opening accounting for non-uniform flow distribution, ft^2/s

Assume approach section is RS 1432

y_1 =	1.6	Upstream flow depth, ft	Hydraulic depth in main channel from RS 1432
v_1 =	3.36	Upstream velocity, ft/s	Average velocity in main channel from RS 1432
q_1 =	5.4	Upstream unit discharge, ft^2/s	
y_c =	1.9	Flow depth including contraction scour, ft	

$$y_{max} = \alpha_A y_c \qquad y_s = y_{max} - y_0$$

α_A =	1.74	Amplification Factor for live-bed conditions
y_{max} =	3.4	Maximum flow depth resulting from Abutment Scour, ft
y_0 =	1.25	Flow depth prior to scour, ft — Assume hydraulic depth at RS 1405
y_s =	2.12	Abutment Scour Depth, ft

q_{2c}/q_1 = 1.2

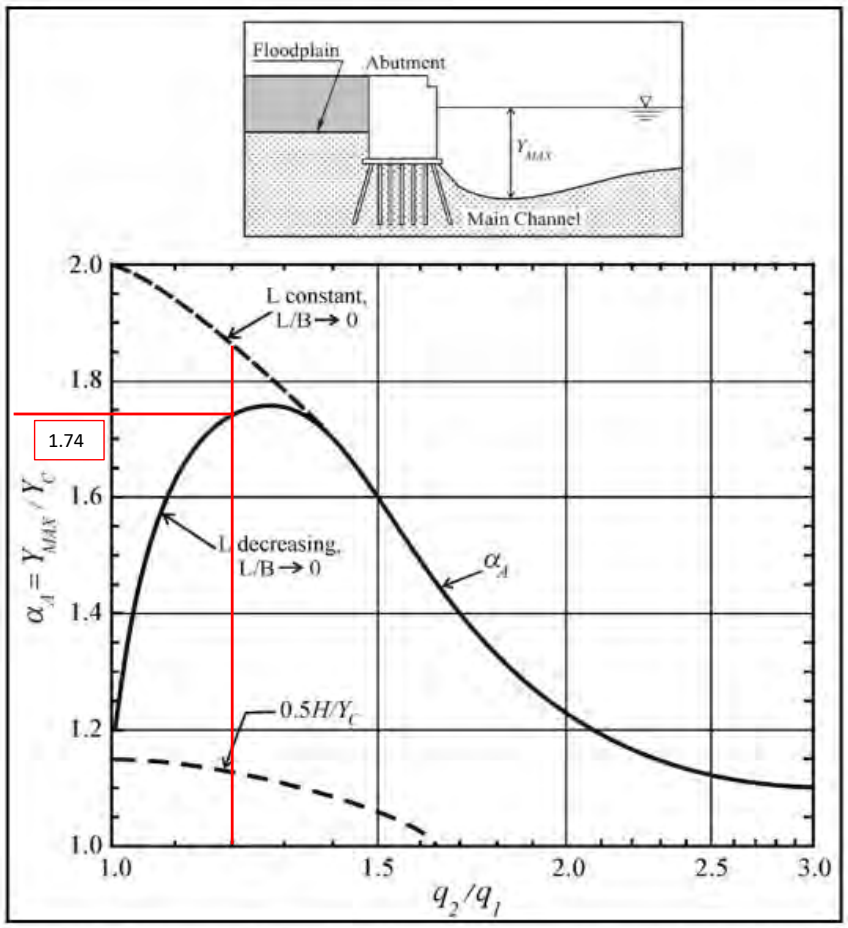


Figure 8.10. Scour amplification factor for wingwall abutments and live-bed conditions (NCHRP 2010b).