Hydraulic/Hydrologic Study

for

RILEY POND DAM

Northbridge, MA

Date: December 18, 2014

Project No. W-2979

Prepared By:
Guerriere & Halnon, Inc.
1029 Providence Road
Whitinsville, Massachusetts 01588

Prepared for:
Town of Northbridge Department of Public Works
P.O. Box 88
Whitinsville, MA 01588

Guerriere & Halnon, Inc.

SITE LOCATION AND DESCRIPTION

Riley Pond is located in the Town of Northbridge Massachusetts, off of Castle Hill Road in the south central portion of Northbridge and is approximately 6.4 acres in size. The tributary area to Riley Pond encompasses approximately 147± acres of land in the Towns of Northbridge (59± acres), Uxbridge (84± acres) and Sutton (4± acres). Only a small portion of this land (13± acres) has been developed with residential homes and a farm. The remaining land is pasture (57± acres) and woodland (70.0± acres).

The high point of the tributary area is on Sutton Street in Uxbridge, Massachusetts. From this point, the topography slopes down to the north and northeast to small valley. This valley slopes down to the northeast and ultimately discharges into a Riley Pond.

The topography for the tributary area was obtained from various sources. A detailed ground survey of the dam, outlet structure and immediate downstream area was performed by Guerriere & Halnon, Inc. (G&H)

Refer to Figures 1 through 4 attached and Figure 5, the survey plan of the dam entitled "Topographic Plan of Dan and Immediate Vicinity Riley Pond Dam" prepared by Guerriere & Halnon, Inc. dated November 21, 2014.

DAM CLASSIFICATON

As part of our analysis, the Size Classification and Hazard Potential Classification for Riley Pond Dam were determined. 302 CMR 10.00 Dam Safety, Section 10.06 specifies the size and hazard classifications for dams in the State.

The Size Classification is based on the height of the dam and its storage capacity and is broken down into four (4) categories: "Non-jurisdictional", "Small", "Intermediate", and "Large". The height of the dam is established based on the maximum water storage elevation which is defined as the reservoir elevation reached during the spillway design flood. The storage capacity of the dam is the volume of water contained in the impoundment at maximum water storage elevation. Based on a maximum water depth of 12.7 feet and a storage capacity of approximately 44 acre-feet, Riley Dam falls in the "Small" category. The "Small" category is defined as a height $\geq$ 6 feet and $<$ 15 feet and a storage capacity of $\geq$ 15 acre-feet and $<$ 50 acre feet.

The Hazard Classification is based on the potential for loss of human life or property damage in the event of failure of the dam and is broken down into three (3) categories: "High Hazard", "Significant Hazard", and "Low Hazard". As a loss of life in not expected, and there are limited buildings or roads downstream, Riley Dam falls in the "Low Hazard" category which is defined as "Dams located where failure may cause minimal property damage to others. Loss of life is not expected."

SPILLWAY ANALYSIS

Although no size changes are proposed for the dam and its spillway, an analysis was performed to ensure that the existing spillway has sufficient capacity to pass the design storm for the dam. At the dam outlet, the spillway is approximately 7.5 feet wide and 14 feet long with granite block sides 2.5 feet tall. The spillway then narrows and slopes down to a stone culvert 2.5 feet wide, and 3 feet tall and approximately 90 feet long. The culvert runs under the parking lot below the dam, under Castle Hill Road and then discharges into a low lying swampy area. From this location, it flows cross country to another small pond,

then through a 30 inch concrete culvert that flows under Douglas Road and discharges into the Mumford River.

302 CMR 10.00 Dam Safety, Section 10.14 (6) specifies the Spillway Design Flood Design Storms for existing and new dams for all hazard and size classifications. For "Low Hazard", "Small" dams such as Riley Dam, the spillway shall be designed to pass the flow resulting from a 50-year storm for existing dams and from a 100-year storm for new dams. Although the only criteria required for Riley Pond Dam is to pass a 50-year storm, we performed two additional analyses for the spillway operation; one for the 100-year storm and the other for a storm that would fill Riley Pond to the top of the dam, but not overtop. Calculations were conducted using USDA SCS *Urban Hydrology for Small Urban Watersheds (TR-20 & TR-55)* and HydroCAD 7.1 software. The results for the three modeled storms are as follows:

	Storm Event			
	Normal El.	50-Year	100-Year	Pond Filling
Rainfall Depth (in)	n/a	5.90	7.00	8.85
Pond Inflow (cfs)	n/a	69.63	97.44	148.29
Pond Discharge (cfs)	n/a	31.22	49.63	85.35
Pond Elevation (ft)	342.19	343.44	343.87	344.60
Pond Volume (af)	35.5	44.0	47.0	52.3
Dam Freeboard (ft)	2.41	1.16	0.73	0.00

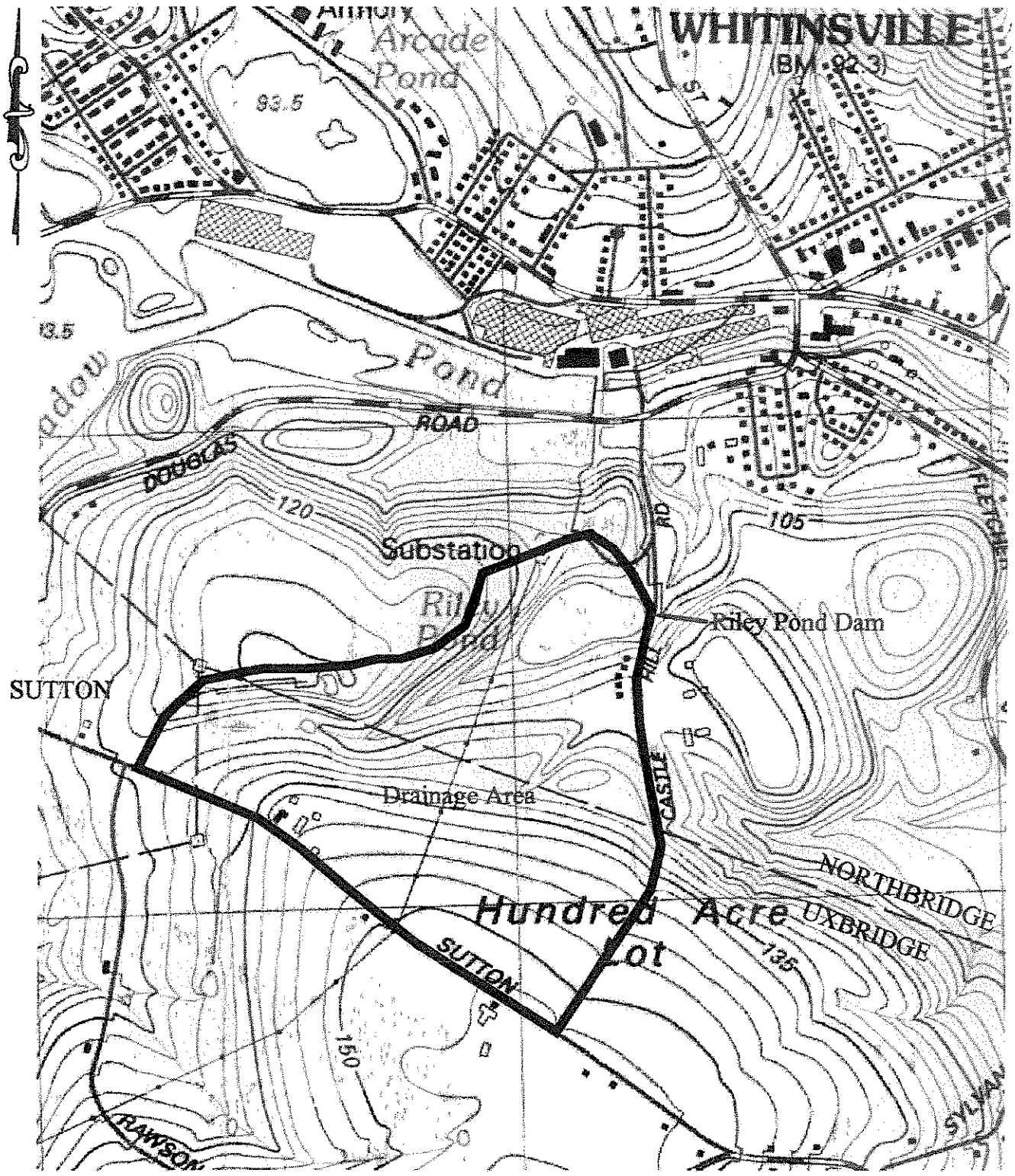
All storms were modeled as Type III, 24-hour storms with the total rainfall depths noted. The Pond Inflow is the calculated peak instantaneous flow into Riley Pond from the 147± acre tributary area. The Pond Discharge is the calculated peak instantaneous flow out of Riley Pond, flowing through the spillway and the stone culvert in series. The Pond Elevation is the calculated peak water elevation in Riley Pond during a particular storm. The Pond Volume is the volume of water stored in the pond at the peak elevation during a particular storm. The Dam Freeboard is the distance between the Pond Elevation and the top of Riley Pond Dam.

The calculations model both the spillway and the stone culvert under Castle Hill Road in series. The capacity of the stone culvert under free flow conditions is approximately 86.7 cfs. Under pond full conditions, the spillway passes 85.32 cfs, which would equate to the ultimate capacity of the spillway. Based on the calculations, the spillway and stone culvert combination in series has sufficient capacity to pass not only the 50-year spillway design storm, but also the 100-year and pond filling storms.

SUMMARY

In summary, Riley Pond Dam is classified under Dam Safety Regulations as a Small, Low Hazard dam with a spillway design capacity that exceeds the requirements for both existing and new dams.

HYDRAULIUC CALCULATIONS



Data Source: Mass GIS
USGS: Uxbridge Quadrangle

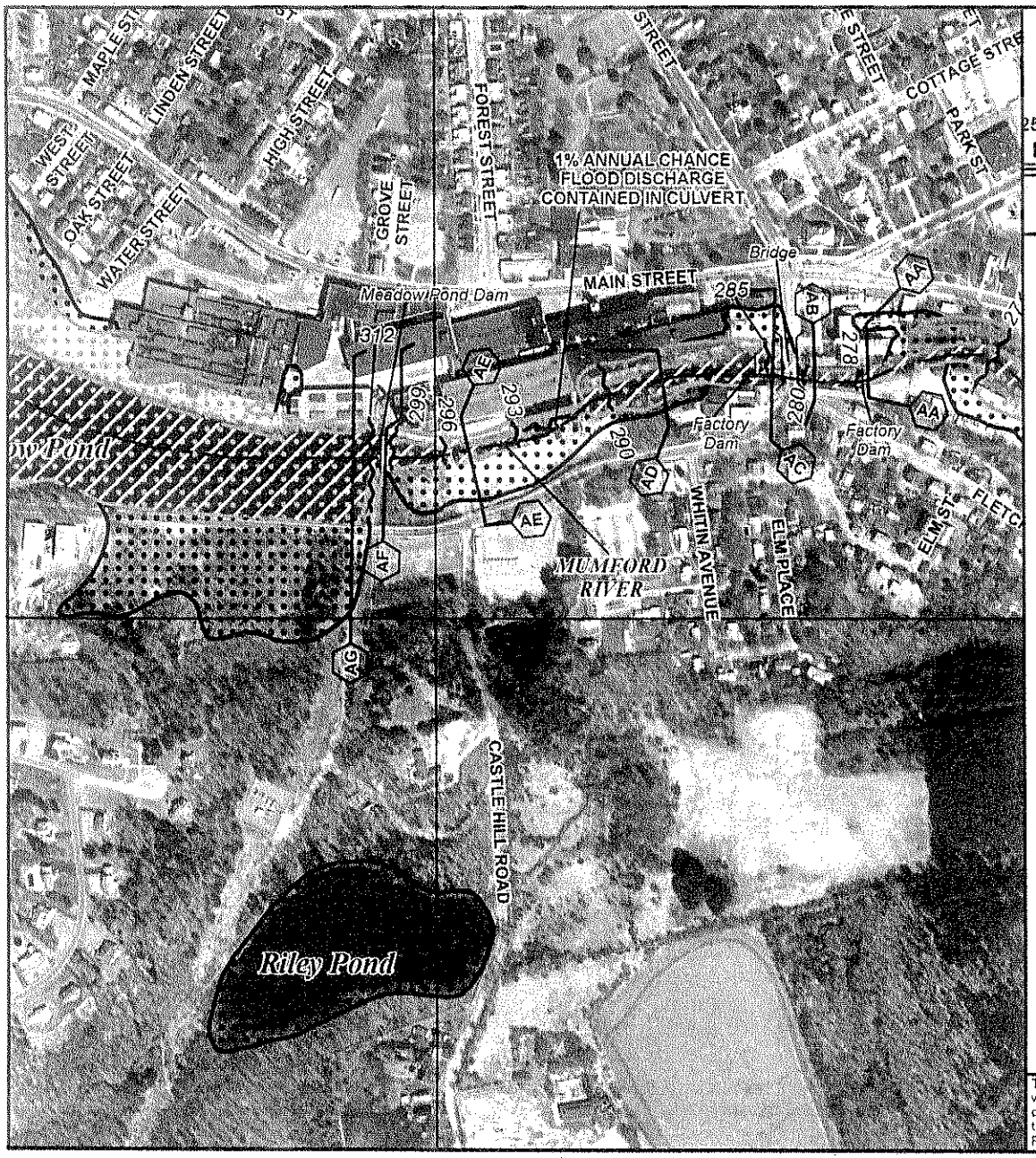
Drainage Area: 0.23 sq. mi.

FIGURE 3
DRAINAGE AREA PLAN
RILEY POND DAM
NID ID# MA02862
MA ID# 3-14-216-9
42° 08' 17" N - 71° 40' 07" W

NORTHBRIDGE, MASSACHUSETTS

DATE: NOVEMBER 20, 2014 SCALE: 1"=1,000' JOB NO. W-2979

Guerriere & Halnon, Inc.
ENGINEERING & LAND SURVEYING
1029 PROVIDENCE ROAD, WHITINSVILLE, MASS. 01588
(508) 234-6834 FAX: (508) 234-6723
WWW.GUERRIEREANDHALNON.COM



MAP SCALE 1" = 500'

250 0 500 1000

FEET

METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 1006E

FIRM

FLOOD INSURANCE RATE MAP

WORCESTER COUNTY, MASSACHUSETTS

(ALL JURISDICTIONS)

PANEL 1006 OF 1075

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

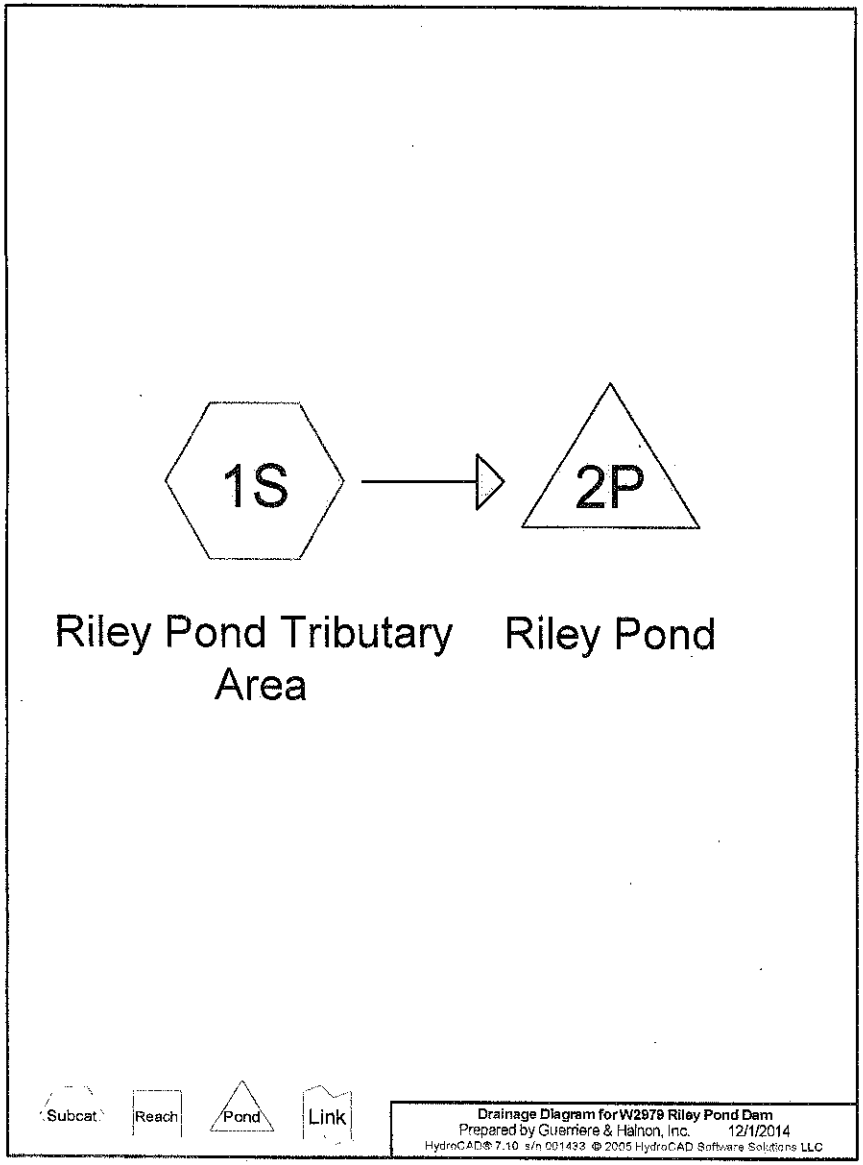
COMMUNITY	NUMBER	PANEL	SUFFIX
NORTHBRIDGE, TOWN OF	250332	1006	E
SUTTON, TOWN OF	250338	1006	E
UXBRIDGE, TOWN OF	250341	1006	E

Notice to User: **The Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
25027C1006E

EFFECTIVE DATE
JULY 4, 2011

Federal Emergency Management Agency



Subcatchment 1S: Riley Pond Tributary Area

Runoff = 69.63 cfs @ 14.38 hrs, Volume= 26.798 af, Depth= 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.10 hrs
Type III 24-hr 50-year Rainfall=5.90"

Area (ac)	CN	Description
5.460	39	Pasture/grassland/range, Good, HSG A
26.210	30	Woods, Good, HSG A
3.500	98	Paved parking & roofs
51.800	74	Pasture/grassland/range, Good, HSG C
43.740	70	Woods, Good, HSG C
9.530	74	>75% Grass cover, Good, HSG C
6.440	80	Riley Pond
146.680	64	Weighted Average

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
44.8	300	0.0300	0.1		**Sheet Flow, A** Grass: Bermuda n= 0.410 P2= 3.20"
22.7	1,150	0.0600	0.8		**Lag/CN Method,**
102.8	3,200	0.0150	0.5		**Lag/CN Method,**
170.3	4,650	Total			

Pond 2P: Riley Pond

Inflow Area = 146.680 ac, Inflow Depth = 2.19" for 50-year event
Inflow = 69.63 cfs @ 14.38 hrs, Volume= 26.798 af
Outflow = 31.22 cfs @ 16.88 hrs, Volume= 22.758 af, Atten= 55%, Lag= 150.0 min
Primary = 31.22 cfs @ 16.88 hrs, Volume= 22.758 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.10 hrs
Peak Elev= 343.44' @ 16.88 hrs Surf.Area= 7.010 ac Storage= 12.390 af
Plug-Flow detention time= 364.4 min calculated for 22.758 af (85% of inflow)
Center-of-Mass det. time= 295.5 min (1,301.0 - 1,005.5)

Volume	Invert	Avail.Storage	Storage Description
#1	341.60'	28.230 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
341.60	6.430	0.000	0.000
342.60	6.740	6.585	6.585
343.60	7.060	6.900	13.485
344.60	7.370	7.215	20.700
345.60	7.690	7.530	28.230

Device	Routing	Invert	Outlet Devices
#1	Primary	336.20'	**2.50' W x 3.00' H x 92.0' long Culvert** Box, headwall w/3 rounded edges, Ke= 0.200 Outlet Invert= 332.09' S= 0.0447 '/' Cc= 0.900 n= 0.025 Rubble masonry, cemented
#2	Device 1	342.20'	**7.5' long (Profile 5) Broad-Crested Rectangular Weir** Head (feet) 0.49 0.98 1.48 Coef. (English) 2.79 2.93 3.06
#3	Primary	344.60'	**160.0' long x 20.0' 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=31.22 cfs @ 16.88 hrs HW=343.44' (Free Discharge)
- **1=Culvert** (Passes 31.22 cfs of 86.93 cfs potential flow)
  - **2=Broad-Crested Rectangular Weir** (Weir Controls 31.22 cfs @ 3.3 fps)
- **3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Subcatchment 1S: Riley Pond Tributary Area

Runoff = 97.44 cfs @ 14.31 hrs, Volume= 36.687 af, Depth= 3.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.10 hrs
Type III 24-hr 100-year Rainfall=7.00"

Area (ac)	CN	Description
5.460	39	Pasture/grassland/range, Good, HSG A
26.210	30	Woods, Good, HSG A
3.500	98	Paved parking & roofs
51.800	74	Pasture/grassland/range, Good, HSG C
43.740	70	Woods, Good, HSG C
9.530	74	>75% Grass cover, Good, HSG C
6.440	80	Riley Pond
146.680	64	Weighted Average

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
44.8	300	0.0300	0.1		**Sheet Flow, A** Grass: Bermuda n= 0.410 P2= 3.20"
22.7	1,150	0.0600	0.8		**Lag/CN Method,**
102.8	3,200	0.0150	0.5		**Lag/CN Method,**
170.3	4,650	Total			

Pond 2P: Riley Pond

Inflow Area = 146.680 ac, Inflow Depth = 3.00" for 100-year event
Inflow = 97.44 cfs @ 14.31 hrs, Volume= 36.687 af
Outflow = 49.63 cfs @ 16.38 hrs, Volume= 32.643 af, Atten= 49%, Lag= 124.2 min
Primary = 49.63 cfs @ 16.38 hrs, Volume= 32.643 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.10 hrs
Peak Elev= 343.87' @ 16.38 hrs Surf.Area= 7.144 ac Storage= 15.419 af
Plug-Flow detention time= 302.4 min calculated for 32.598 af (89% of inflow)
Center-of-Mass det. time= 251.7 min (1,247.8 - 996.1)

Volume	Invert	Avail.Storage	Storage Description
#1	341.60'	28.230 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
341.60	6.430	0.000	0.000
342.60	6.740	6.585	6.585
343.60	7.060	6.900	13.485
344.60	7.370	7.215	20.700
345.60	7.690	7.530	28.230

Device	Routing	Invert	Outlet Devices
#1	Primary	336.20'	**2.50' W x 3.00' H x 92.0' long Culvert** Box, headwall w/3 rounded edges, Ke= 0.200 Outlet Invert= 332.09' S= 0.0447 '/' Cc= 0.900 n= 0.025 Rubble masonry, cemented
#2	Device 1	342.20'	**7.5' long (Profile 5) Broad-Crested Rectangular Weir** Head (feet) 0.49 0.98 1.48 Coef. (English) 2.79 2.93 3.06
#3	Primary	344.60'	**160.0' long x 20.0' 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=49.62 cfs @ 16.38 hrs HW=343.87' (Free Discharge)
└1=**Culvert** (Passes 49.62 cfs of 89.13 cfs potential flow)
└2=**Broad-Crested Rectangular Weir** (Weir Controls 49.62 cfs @ 4.0 fps)
└3=**Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Subcatchment 1S: Riley Pond Tributary Area

Runoff = 148.29 cfs @ 14.24 hrs, Volume= 54.639 af, Depth= 4.47"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.10 hrs
Type III 24-hr Pond Full Rainfall=8.85"

Area (ac)	CN	Description
5.460	39	Pasture/grassland/range, Good, HSG A
26.210	30	Woods, Good, HSG A
3.500	98	Paved parking & roofs
51.800	74	Pasture/grassland/range, Good, HSG C
43.740	70	Woods, Good, HSG C
9.530	74	>75% Grass cover, Good, HSG C
6.440	80	Riley Pond
146.680	64	Weighted Average

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
44.8	300	0.0300	0.1		**Sheet Flow, A** Grass: Bermuda n= 0.410 P2= 3.20"
22.7	1,150	0.0600	0.8		**Lag/CN Method,**
102.8	3,200	0.0150	0.5		**Lag/CN Method,**
170.3	4,650	Total			

Pond 2P: Riley Pond

Inflow Area = 146.680 ac, Inflow Depth = 4.47" for Pond Full event
Inflow = 148.29 cfs @ 14.24 hrs, Volume= 54.639 af
Outflow = 85.35 cfs @ 15.93 hrs, Volume= 50.591 af, Atten= 42%, Lag= 101.5 min
Primary = 85.35 cfs @ 15.93 hrs, Volume= 50.591 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.10 hrs
Peak Elev= 344.60' @ 15.93 hrs Surf.Area= 7.370 ac Storage= 20.702 af
Plug-Flow detention time= 246.0 min calculated for 50.521 af (92% of inflow)
Center-of-Mass det. time= 210.0 min (1,194.5 - 984.5)

Volume	Invert	Avail.Storage	Storage Description
#1	341.60'	28.230 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
341.60	6.430	0.000	0.000
342.60	6.740	6.585	6.585
343.60	7.060	6.900	13.485
344.60	7.370	7.215	20.700
345.60	7.690	7.530	28.230

Device	Routing	Invert	Outlet Devices
#1	Primary	336.20'	**2.50' W x 3.00' H x 92.0' long Culvert** Box, headwall w/3 rounded edges, Ke= 0.200 Outlet Invert= 332.09' S= 0.0447 '/' Cc= 0.900 n= 0.025 Rubble masonry, cemented
#2	Device 1	342.20'	**7.5' long (Profile 5) Broad-Crested Rectangular Weir** Head (feet) 0.49 0.98 1.48 Coef. (English) 2.79 2.93 3.06
#3	Primary	344.60'	**160.0' long x 20.0' 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=85.32 cfs @ 15.93 hrs HW=344.60' (Free Discharge)
└**1=Culvert** (Passes 85.32 cfs of 92.75 cfs potential flow)
└**2=Broad-Crested Rectangular Weir** (Weir Controls 85.32 cfs @ 4.7 fps)
└**3=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

DAM ENGINEERING REPORT LIMITATIONS

Use of Report

1. Guerriere & Halnon, Inc. (G&H) prepared this report on behalf of, and for the exclusive use of our client, the Town of Northbridge, and the Commonwealth of Massachusetts Department of Conservation and Recreation. This Report is limited to the Riley Pond Dam and the stated purpose and locations identified in the Report. Use of this report, in whole or in part, at other locations, or for other purposes, may lead to inappropriate conclusions; and G&H does not accept any responsibility for the consequences of such use. Further, reliance by any party not identified in the agreement, for any use, without G&H's prior written permission, shall be at that party's sole risk, and without any liability to G&H.

Standard of Care

2. G&H's findings and conclusions are based on the work conducted as part of the Scope of Services set forth in the Report and proposal, and reflect our professional judgment. These findings and conclusions must be considered not as scientific or engineering certainties, but rather as our professional opinions concerning the limited data gathered during the course of our work. Conditions other than described in this report may be found at the subject location.

3. Our services were performed using the degree of skill and care ordinarily exercised by qualified professionals performing the same type of services at the same time, under similar conditions, at the same or a similar facility. No warranty, expressed or implied, is made.

General

4. The observations described in this report were made under the conditions stated herein. The conclusions presented were based solely upon the services described in this report, and not on scientific tasks or procedures beyond the scope of described services or the time and budgetary constraints imposed by the Client.

5. In preparing this report, G&H relied on certain information provided by the Client and state and local officials, and other parties referenced herein available to G&H at the time of the evaluation. G&H did not attempt to independently verify the accuracy or completeness of any information reviewed or received during the course of this evaluation.

6. The G&H hydrologic and hydraulic analysis presented is for the rainfall volumes and distributions stated in the analysis. For storm conditions other than those analyzed, the

response of the site's spillway, impoundment, and drainage network has not been evaluated.

7. Observations were made of the site and of structures on the site as indicated within this report. Where access to portions of the structure or site, or to structures on the site was unavailable or limited, G&H renders no opinion as to the condition of that portion of the site or structure. In particular, it is noted that water levels in the impoundment has limited G&H's ability to make observations of underwater portions of the structure.

8. In reviewing this Report, it should be realized that the reported condition of the dam is based on observations of field conditions during the course of this study (November/December 2014). It is important to understand that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued inspection and maintenance can unsafe conditions be detected in the future.

Compliance with Codes and Regulations

9. We used reasonable care in identifying and interpreting applicable codes and regulations. These codes and regulations are subject to various, and possibly contradictory, interpretations. Compliance with codes and regulations by other parties is beyond our control.

10. This scope of work does not include an assessment of the need for fences, gates, no-trespassing signs, and other items which may be needed to minimize trespass and provide greater security for the facility and safety to the public. An evaluation of the project for compliance with OSHA rules and regulations is not included in our report.

Cost Estimates

11. Unless otherwise stated, out cost estimates are for comparative, or general planning purposes only. These estimates involve approximate quantity evaluations and may not be sufficiently accurate to develop construction bids, or to predict the actual cost of work addressed in this Report. Further, since we have no control over the labor and material costs required to plan and execute the anticipated work, our estimates were made using our experience and readily available information. Actual costs will vary over time and could be significantly more, or less, than stated in the Report.

Additional Services

12. It is recommended that G&H be retained to provide continuity of services during any future site observations, explorations, evaluations, design, construction and/or implementation of remedial measures recommended in this Report. This will allow us the opportunity to: i) observe conditions and compliance with our design concepts and opinions; ii) allow for changes in the event that conditions are other than anticipated; iii) provide modifications to our design; and iv) assess the consequences of changes in technologies and/or regulations.