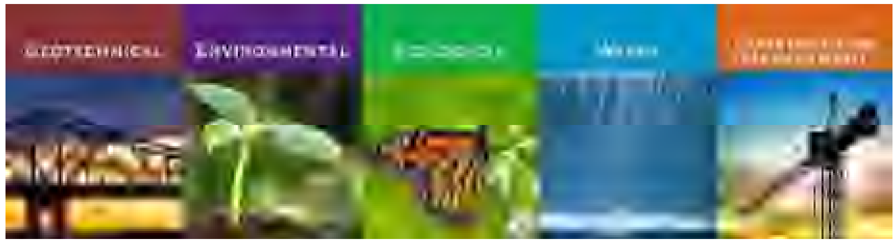

PHASE II REPORT FOR BULLOUGHS POND DAM

Newton, MA

May 22, 2020
File No. 01.0174021.00

PREPARED FOR:
City of Newton

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Bulloughs Pond Dam MA03414
City of Newton
Newton, Massachusetts

Phase II Engineering Evaluation and Alternatives Analysis

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1.0 INTRODUCTION

1.1 Authority

GZA GeoEnvironmental, Inc. (GZA) of Norwood, Massachusetts, was contracted by the City of Newton (City) to perform a Phase II dam safety evaluation involving a number of engineering tasks preliminary to the design of repairs and rehabilitations to the Bulloughs Pond Dam. GZA was authorized to proceed by the City on December 10, 2018. This report is subject to the Limitations contained in **Appendix A**.

1.2 Purpose

The overall purpose of our services was to perform Phase II inspections and Investigations as required by the Massachusetts Department of Conservation and Recreation, Office of Dam Safety (DCR or ODS) Certificate of Non-Compliance and Dam Safety Order dated July 16, 2018. The Dam Safety Order was issued as a result of Pare Corporation inspections that determined the dam to be **STRUCTURALLY DEFICIENT** and in **POOR** condition.

GZA's approach for this Phase II assessment was to design and execute a limited exploratory field program and to conduct engineering analyses to address the following technical issues:

- Characterize the embankment and foundation soils and estimate the seepage (phreatic) surface and stability of the earthen portion of the dam embankment;
- Conduct a detailed hydrologic and hydraulic (H&H) analysis to evaluate whether the dam can pass the Spillway Design Flood (SDF) for the dam, which is the 100-year storm; and
- Develop alternatives to mitigate identified deficiencies.

Unless otherwise noted, elevations used in this report are referenced to the North American Vertical Datum of 1988 (NAVD88).

1.3 Scope of Services

As part of our Phase II efforts, GZA performed the following scope of services:

- Compiled available information. As part of this initial task, GZA visited the dam site and conducted a Follow-up inspection as required by the Dam Safety Order. GZA referenced inspection guidelines and standard document formats presented on the ODS website. GZA compiled and reviewed original engineering design drawings and available on-line resources;
- Planned, coordinated and observed a subsurface exploration program consisting of four test borings to obtain information that was used in seepage and stability analyses. Observation wells were installed in two of the four completed borings;
- Performed five laboratory gradation analyses on representative embankment and foundation soil samples;
- Performed seepage and stability analyses to evaluate performance of the dam with respect to embankment safety;

- Conducted preliminary geotechnical design evaluations of proposed embankment modifications to address seepage and stability performance;
- Conducted follow-up inspections on January 15, 2019, July 19, 2019, and April 6, 2020;
- Performed a detailed hydrologic and hydraulic (H&H) analysis of the existing dam and reservoir system in accordance with Massachusetts Dam Safety Regulations and current engineering practice.
- Conducted preliminary evaluations of proposed dam and spillway modifications to safely pass the SDF;
- Based on the above-performed tasks and to assist Client in decision making, developed recommendations and preliminary cost estimates for selected remedial repair alternatives to address deficiencies identified during our investigation and analyses specifically with respect to safely passing the SDF, replacing the existing low-level outlet gates, repairing the spillway and training walls, regrading and protecting the embankment; and
- Prepared this report summarizing our investigations and engineering analyses, conclusions and recommendations.

Subsequent to GZA's initiation of Phase II efforts, the City of Newton engaged GZA to develop an Emergency Action Plan (EAP) for Bulloughs Pond Dam. The EAP is being submitted under separate cover. The results of the EAP suggest that the dam may be reclassified by DCR as a ***High Hazard Potential (Class I)*** dam. In addition, our Phase II evaluations indicate that the Bulloughs Pond Dam is an ***Intermediate-size*** structure. ***Dam Size and Hazard classification should be considered during final design of the selected alternative, particularly with respect to hydrology and hydraulics analyses, stability evaluations, and the selected repair alternative.*** Refer to Sections 2.3, 2.4, and 9.3.6 for additional discussion.

2.0 SITE DESCRIPTION

2.1 File Review

Based on GZA's review of existing files, some type of dam/impoundment structure has been present at the site since about 1664. The Bulloughs Pond Association's research[1] indicates that the structure was replaced sometime around 1926 with the configuration present today.

Pertinent information on the dam's construction was garnered from our review of drawings prepared between 1897 and 1922 (Historic Drawings) when the dam underwent a major reconstruction to its present configuration. These drawings were provided by the City of Newton Engineering Department and are included in Appendix B.

2.2 Description of Dam and Appurtenances

Bulloughs Pond Dam is an approximately 225-foot long, 14.5-foot high earthen embankment. The top of embankment (at approximately elevation 92) is asphalt-paved Dexter Road with a bridge over the spillway. The

[1] The History of Bullough's Pond" webpage, researched and prepared by the Bullough's Pond Association, http://www.bulloughspond.org/the-history-of-bulloughs-pond.html

paved roadway is flanked by a stone dust walkway on the upstream side and grassy shoulder on the downstream side. The upstream and downstream slopes are grassed and heavily vegetated with woody brush and trees. The embankment side slopes are approximately 2 horizontal to 1 vertical (2H:1V) on both the upstream and downstream sides, with locally steeper upstream slopes where scarping has occurred near the normal pool level.

The water level in Bulloughs Pond (historically also referred to as Spring's Pond or Pearl Lake) is maintained via an uncontrolled 35-foot-long spillway located upstream of the Dexter Road bridge, with an additional downstream weir located below the bridge. The vee-shaped upstream weir elevation is 85.94 feet, and the downstream weir elevation is 84.95 feet with a central lower throat at elevation 81.9 feet. The downstream weir appears to follow the contours of the bedrock beneath the bridge.

Low flows can be passed via two gated 24-inch diameter low-level outlets, located toward the left (west) end of the embankment. The outlet pipes are cast iron, with downstream inverts around elevation 77 feet. The gates valves are located in a vault in the upstream slope and reportedly exercised on a yearly basis.

According to the historic drawings (see **Appendix B**) made available to GZA, a concrete core wall is present along the length of the dam embankment. The top of core wall is shown on historic drawings approximately 3½ to 5½ feet below proposed 1897 grades. It is likely that roadway work has modified grades over the past century. As described below, the core wall was encountered during the subsurface exploration program about 5 feet below current grade. The core wall alignment varies from upstream to downstream along the length of the embankment. The core wall is reportedly 2.5 feet wide at the top tapering to 3.5 feet wide at the base.

2.3 Dam Size Classification

The dam is currently classified by DCR as a **Small** size structure, likely due to information contained in the National Inventory of Dams (NID) database[2]. According to the NID database, Bulloughs Pond Dam has a maximum height of approximately 9 feet and an estimated maximum storage capacity of about 30.8 acre-feet.

The dam height surveyed by the City of Newton (refer to **Appendix C**) indicates that maximum embankment height of Bulloughs Pond Dam is about 14.5 feet. The results of the hydrology and hydraulics evaluations described in Section 6 indicate that the dam has a maximum storage of about 63 acre-ft. Therefore, in accordance with Department of Conservation and Recreation Office of Dam Safety classification, under Commonwealth of Massachusetts Dam Safety rules and regulations stated in 302 CMR 10.00 as amended by Chapter 330 of the Acts of 2002, Bulloughs Pond Dam is an **Intermediate** size structure (due to a height exceeding 6-feet, but less than 15-feet and a maximum storage capacity exceeding 50 acre-feet, but less than 100 acre-feet).

2.4 Dam Hazard Classification

The dam is currently classified by DCR as having a **Significant Hazard** (Class II) potential. Significant Hazard is defined as: "Dams located where failure may cause loss of life and damage to home(s), industrial or commercial facilities, secondary highway(s) or railroad(s) or cause interruption of use or service of relatively important facilities."

[2] https://nid.sec.usace.army.mil/ords/f?p=105:113:10544599320348::NO:113,2:P113_RECORDID:31354

Massachusetts Dam Safety Regulations now require an Emergency Action Plan (EAP) for all Significant Hazard dams in Massachusetts. GZA is currently developing an Emergency Action Plan for this dam, which will be submitted to ODS under separate cover. The results of this evaluation suggest that DCR may consider reclassification of Bulloughs Pond Dam as a High Hazard Potential (Class I) structure.

3.0 DAM SAFETY INSPECTIONS

3.1 Summary of Previous Inspections by Others

Pare Corporation personnel visited the site in May 2017, December 2017, and June 2018 to conduct Follow-up dam inspections. Based on these inspections, Pare recommended a **POOR** condition for Bulloughs Pond Dam, as defined in 302 CMR 10.03.

3.2 Summary of GZA Inspections

Follow-up inspections were performed by GZA on January 15, 2019, July 19, 2019, and April 6, 2020. Based on our inspections, we observed that the dam condition was generally unchanged from the prior inspections by others.

3.3 Summary of Previously Identified Deficiencies

The following is a brief summary of deficiencies/issues identified during previous inspections/evaluations:

1. Unwanted vegetation in areas of the dam including large trees along the downstream slope;
2. Scarping along the upstream slope and bare soils prone to erosion along the downstream slope;
3. Deterioration/potentially unstable headwall at the downstream end of the low-level outlet with observed scour/displaced riprap within the channel;
4. Areas of scour along the downstream channel including at the low-level outlet and along the left and right banks. If erosion of the left bank continues, it could encroach on the toe of the downstream slope;
5. Mortar missing from some joints of the spillway training walls; and,
6. Additional maintenance deficiencies and dam safety concerns. *{Unspecified in 2018 Pare Follow-up}*

GZA did not observe significant changes to the above-noted deficiencies during our follow-up inspections. During the April 2020 inspection, GZA observed eroded footpaths on the upstream and downstream slopes.

3.4 Summary of Dam Safety Orders

Based on the reported Poor condition of the dam, ODS issued a Certificate of Non-Compliance and Dam Safety Order dated July 16, 2018. The order requires that the City:

- Conduct follow-up inspections at six-month intervals (Follow-up Inspection reports were submitted to ODS as referenced in **Appendix D**);
- Conduct a Phase II Inspection and Investigation; and,
- Bring the dam into compliance and complete repair work.

ODS also issued Orders related to preparation of an Emergency Action Plan (EAP) as follows:

- An Order to Prepare an Emergency Action Plan for Significant Hazard Potential Dams, Bulloughs Pond Dam, Newton, MA03414, Significant Hazard, dated December 10, 2018 (with December 17, 2018 Correction to Recent Emergency Action Plan Order); and
- A request for status update concerning December 10, 2018 Order to Prepare an Emergency Action Plan for Significant Hazard Potential Dams, Bulloughs Pond Dam, Newton, MA03414, Significant Hazard, dated march 3, 2020.

On behalf of the City, GZA requested and received extensions to the deadlines in these Dam Safety Orders. Refer to **Appendix E** for Dam Safety Orders and extension correspondence.

4.0 PHASE II INVESTIGATIONS

A subsurface exploration program including lab testing for select samples was developed and performed by GZA. Topographic and bathymetric surveys and natural resource delineations were performed by the City to support the Phase II investigations.

4.1 Test Borings

Four test borings (GZ-1 through GZ-4) were completed on February 25 and 26, 2019 by New England Boring Contractors, Inc. of Brockton, Massachusetts. Test boring locations were chosen to provide information about the dam embankment to support our seepage and stability evaluations and to help confirm presence of a core wall. The borings were located near the dam maximum section between the spillway and low-level outlet. The test borings were performed at the locations shown in Appendix F as located in the field by City topographic survey subsequent to the explorations.

Borings were advanced via drive-and-wash methods using flush-jointed HW (4-inch-diameter) casing to depths ranging from about 11.5 to 23 feet below the existing ground surface. Split spoon sampling was generally performed on a continuous basis, with larger spacing for two of the sample intervals to help increase production. Split spoon sampling and Standard Penetration Tests (SPTs) were performed in general accordance with ASTM D1586 wherein a 2-inch-outside diameter split spoon is driven up to 24 inches with a 140-pound safety hammer falling 30 inches. The number of blows required to drive the sampler for each 6-inch increment was recorded and the Standard Penetration Resistance (N-value) was computed as the sum of the blows over the middle 12 inches of penetration. Representative soil samples were collected and stored in jars for later review and laboratory testing.

Upon completion, borings GZ-2 and GZ-3 were each completed as an observation well (OW). OW GZ-2 was screened in embankment soils from 6 to 11 feet below existing ground surface (GZ-2-OW) and OW GZ-3 was screened in in the embankment soils from 6.5 to 11.5 feet below the existing ground surface (GZ-3-OW). The wells were backfilled with filter sand extending to about one foot above the screened interval. Up to 1 foot of bentonite chips was installed above the screen sections. Close to the ground surface, a thin layer of sand was placed to provide bedding for the concrete collar for flush-mounted roadboxes, which were installed at each well. Each road box was grouted in place. Borings GZ-1 and GZ-4 were backfilled with a cement/bentonite grout.

A GZA representative observed the explorations, visually classified the soil samples using the modified Burmister Classification system, and prepared the logs included in **Appendix F**.

4.2 Geotechnical Laboratory Testing

Geotechnical laboratory gradation (sieve) tests were performed on two of the embankment soil samples and three of the foundation soil samples obtained from the test boring program. The tests were performed in accordance with American Society of Testing and Materials (ASTM D-422) by Thielsch Engineering in Cranston, Rhode Island. The testing was performed to help confirm visual field classifications and assign engineering parameters to the soils for use in the seepage and stability modeling. Laboratory results are attached as **Appendix G**.

4.3 Natural Resource Delineation

The City flagged bordering vegetated wetlands (BVW) and bank location. The resource flagging was performed by Jennifer Steel, Senior Environmental Planner for the City of Newton. Wetland flag locations were surveyed by City personnel as described below and are shown in **Appendix C**.

4.4 Topographic and Bathymetric Survey

The City conducted a topographic and bathymetric survey of Bulloughs Pond Dam and the immediately surrounding areas[3]. The topographic survey included abutments, low-level outlet intake and outlet structures, pipe inverts, spillway crest and downstream apron, upstream and downstream slope angles, bridge deck and abutments, roadway drainage structures, manholes, upstream edge of water and top/bottom of bank for outlet channel, boring locations, property lines, natural resource boundaries, spot elevations of key site features and one-foot contours. The topographic survey was referenced to the Massachusetts State Plane Coordinate System horizontal datum, and North American Vertical Datum of 1988 (NAVD88) vertical datum. Refer to **Appendix C** for the topographic and bathymetric survey plan.

5.0 INTERPRETATION OF SUBSURFACE CONDITIONS

5.1 Soil Strata

Subsurface conditions as interpreted from GZA's test borings generally consist of embankment fill over natural soil or bedrock. A summary of the subsurface conditions encountered at each test boring is presented below:

- Topsoil: An approximately 2-foot thick surficial layer of topsoil was encountered in the grassed area near the downstream edge of the top of embankment (crest) in boring GZ-3. This strata was not encountered in borings GZ-1, GZ-2, or GZ-3 which were performed in paved areas. The topsoil was loose and generally consisted of a dark brown, fine to coarse sand with between 20 and 35 percent silt, up to 10 percent gravel, and up to 5 percent roots.
- Asphalt and Road Base: An approximately 6-inch thick surficial layer of asphalt was encountered in borings GZ-1, GZ-2, and GZ-4. An approximately 1½-foot thick layer of road base soil was encountered below the asphalt paving in boring GZ-1. Samples of roadway base soils were not attempted in borings GZ-2 and GZ-4. Where

[3] "Existing Conditions Topographic Plan of Bulloughs Pond Dam Spillway Culvert in Newton, MA" Prepared for City of Newton, MA by the City of Newton Engineering Department, dated October 7, 2019.

sampled, the road base material generally consisted of brown, fine to coarse sand, with between 20 and 35 percent gravel and 10 to 20 percent silt.

- Embankment Fill: Embankment fill was encountered in each boring below the road base or topsoil. The embankment fill generally consisted of a brown to reddish brown mixture of gravel, sand, silt, and clayey silt with consistencies varying from loose to medium dense or stiff. Where fully penetrated, the embankment fill extended to depths below ground surface (bgs) of about 10.5 feet in GZ-3 to 14 feet in GZ-2.
- Core Wall: According to the typical cross-section depicted on historical drawings provided from the City of Newton, the dam was reportedly constructed in a zoned fashion with a soil shell and a concrete core. The top of core wall is shown on historic drawings approximately 3½ to 5½ feet below proposed 1897 grades. It is likely that roadway work has modified grades over the past century. Evidence of a core wall was encountered in boring GZ-1, where reddish-brown concrete was encountered and cored from about 5- to 12 feet bgs, or below approximate elevation 87 feet. The concrete was fresh to slightly weathered with moderately spaced to close fractures.
- Fine-Grained Foundation Soils: A fine grained natural foundation soil layer was encountered immediately below the embankment fill layer in borings GZ-3 and GZ-4. Where encountered, the fine-grained foundation soil generally consisted of a loose, gray to grayish brown fine to medium sand with about 10 to 35 percent gravel.
- Bedrock: Sound bedrock was encountered at approximately 14-feet bgs in boring GZ-2 and inferred from casing and roller bit refusals at depths of at 11.5 and 13-feet below ground surface at GZ-3 and GZ-4, respectively. These depths correspond to approximate top of bedrock elevations of 78 to 81 feet. The bedrock cored in boring GZ-2 generally consisted of hard, slightly weathered, amorphous to medium-grained, greenish gray Argillite with very thin, moderately dipping foliation, and smooth, planar, and close to moderately close sub-horizontal joints. Core recovery ranged from 80 to 92 percent with Rock Quality Designation[4] (RQD) ranging from 77 to 83 percent. This lithology is consistent with published regional bedrock geologic mapping[5].

5.2 Groundwater

Groundwater was encountered during drilling in borings GZ-2, GZ-3, and GZ-4 at depths between 6 and 7 feet bgs, corresponding to approximate elevation 85 to 86 feet. The reservoir water elevation during drilling was approximately 1 to 2-inches over the spillway crest (corresponding to approximate elevation 86 feet). Due to drilling disturbance and the use of drilling fluids, these measurements are not considered stabilized readings.

Monitoring wells were installed in borings GZ-2 and GZ-3 (GZ-2OW and GZ-3OW) to allow stabilized groundwater level measurements. After six weeks of stabilization time, the measured water levels were 9.86 feet bgs (approximate elevation 82.0) in GZ-2OW, and 10.9 feet bgs (approximate elevation 81.3 feet) in GZ-3OW. The reservoir level was at approximately normal pool (elevation 86 feet) when the stabilized groundwater levels were measured. The core wall is located between GZ-1/GZ-4 and GZ-3OW, indicating an approximate 4 to 5 foot head drop across the core wall.

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[4] RQD is defined as the sum of the lengths of rock core pieces measuring >4-inches divided by the length of core run, expressed in percent

[5] "Bedrock Geologic Maps of the Boston North, Boston South, and Newtown Quadrangles, Massachusetts Sheet 1 of 2" by Clifford A. Kaye dated 1980

Please note that fluctuations in groundwater levels will occur due to variations in season, rainfall, site features, and other factors different from those existing at the time of the explorations and measurements.

6.0 HYDROLOGIC AND HYDRAULIC (H&H) ANALYSES

6.1 Objectives

GZA conducted hydrologic and hydraulic (H&H) analyses of the Bulloughs Pond Dam. The initial objective of the analysis was to assess the spillway capacity and embankment overtopping potential. The dam's spillway adequacy was evaluated for the spillway design flood (SDF). Per DCR Dam Safety Regulation 302 CMR 10.14, the SDF for the Bulloughs Pond Intermediate-sized, Significant Hazard dam is a 100-year recurrence interval design storm. Future design should consider the higher SDF associated with a High Hazard structure, if so designated by DCR. The results of our H&H analyses were subsequently used to evaluate spillway adequacy for the alternatives analysis. Computer model input/output for the hydrology and hydraulics analyses are contained in **Appendix H**.

GZA used the US Army Corps of Engineers Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) computer program to estimate the flow generated by the 100-year flood SDF. This flow was routed through the dam/reservoir system. Inflow and outflow hydrographs were generated for the current spillway configuration, and then the model was used to study potential design alternatives for passing the SDF.

6.2 Methodology and Inputs

GZA used the Spillway Design Flood (SDF) criteria specified in the Massachusetts Dam Safety Regulations (302 CMR 10.14(6)) for an existing Intermediate-sized, Significant Hazard dam. Refer to Sections 2.3 and 2.4 for discussion of size and hazard classification. Hazard re-classification will increase the SDF per Massachusetts Dam Safety regulations. For this Phase II evaluation, per the current Significant Hazard classification and Intermediate size, the SDF for Bulloughs Pond Dam is the 100-year flood.

GZA simulated the rainfall/runoff process using the HEC-HMS computer program. Inflow hydrographs were generated for the 100-year storm event using a 24-hour, nested rainfall distribution and Dimensionless Unit Hydrograph methodology.

Precipitation

GZA developed the rainfall distributions for the 100-year storm using a nested approach based on the Natural Resources Conservation Service (NRCS) National Engineering Handbook, Part 630: Hydrology, Chapter 4: Storm Rainfall Depth and Distribution guidance document (NRCS, 2015). GZA used the nested method to develop the 24-hour rainfall distribution, which includes nested storms of smaller duration from 5-minutes through 24-hours in a single rainfall hyetograph (i.e., time series). GZA developed the distribution from National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation depths for New England and New York. The precipitation depth estimates are provided below.

Table 6.1: Precipitation Depth Estimates

Event	Precipitation Total (in)
2-Year, 24-Hour	3.3
5-Year, 24-Hour	4.3
10-Year, 24-Hour	5.1
25-Year, 24-Hour	6.3
50-Year, 24-Hour	7.2
100-Year, 24-Hour	8.1

According to published rainfall data for the Northeast Regional Climate Center Bedford Station[6], the largest regional rainfall intensity between 1957 and 2008 was 7.83 inches over 24 hours, on October 20, 1998. No other storms during that time period exceeded 6 inches of precipitation. We understand from the City of Newton that the embankment has not overtopped since they started keeping records in 1992.

Watershed Characteristics

GZA delineated the total contributing drainage area of approximately 3.15 square miles using the USGS StreamStats web application and 2013-2014 USGS Sandy LiDAR data published by Massachusetts Geographic Information System (MassGIS). The LiDAR data had a resolution of 1 meter. GZA subdivided the watershed into six sub-watersheds which are shown in **Figure 3**. The watershed is characterized by a varying range of runoff potential soils as well as commercial, residential, and recreational (parks) land uses. The City of Newton is densely populated with a large amount of impervious area and the impervious areas are considered connected as its runoff flows directly into a drainage system, as defined in Chapter 9 of the NRCS National Engineering Handbook (NEH) Part 630 Hydrology (NRCS, 2004). The characterization of soil types within the drainage area is shown in **Figure 4**.

The Curve Number (CN) Method was used to model infiltration. The CN is assigned based on hydrologic soil group (A, B, C or D, from lowest to highest runoff potential) and land cover type based on guidance in Chapter 9 of the NRCS NEH Part 630 Hydrology (NRCS, 2004). The hydrologic soil group classification was obtained from the 2017 Norfolk and Suffolk Counties Soil Data GIS shapefile available from the NRCS Web Soil Survey. The land cover data was obtained from the 2005 Massachusetts Land Use GIS shapefile available on the MassGIS website. The resultant CN for the subwatersheds are provided in **Table 6.2** below. The land use categories within the watershed are shown in **Figure 5**. Curve number computations are included in **Appendix H**.

The watershed time of concentration (Tc) and lag time were calculated for each of the subwatersheds based on guidelines included in Chapter 15 of the NRCS Part 630 Hydrology NEH (NRCS, 2010). The estimated watershed lag times are provided in **Table 6.2**. The alignment of the flow paths identified for the time of concentration calculations are shown in **Figure 6**. The input and outputs of the time of concentration calculations are included in **Appendix H**. Note that the curve number and time of concentration were ultimately revised using calibration, which is discussed below.

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[6] "Partial Duration Series (by Station), Station ID #190535 – BEDFORD", period of record 1957 through 2008, http://precip.eas.cornell.edu/

Table 6.2: Watershed Characteristics

Watershed	Area (sq. mi)	Curve Number	Lag Time (min)	Calibrated Curve Number	Calibrated Lag Time (min)
A – Newton Cemetery	1.22	66	66	56	76
B – Newton Centre Playground	0.22	76	33	65	38
C – Commonwealth Avenue	0.33	80	33	68	38
D – Below Hammond Pond	0.8	72	54	61	62
E – Hammond Pond	0.4	76	38	76	62
G – Bulloughs Pond	0.18	73	16	62	18

Reservoir Stage Area Curve

GZA developed a stage surface area relationship for Bulloughs Pond and the upstream pond adjacent to Newton City Hall using 2014 LiDAR data. GZA computed stage-area relationships in Bulloughs Pond at 1-foot intervals with a minimum elevation of 85 feet, which is below the spillway weir and the approximate lowest elevation included in the LiDAR Digital Elevation Model in Bulloughs Pond. GZA computed stage-area relationships in the City Hall Pond at 1-foot intervals with a minimum elevation of 89 feet.

Stage-area information for both impoundments below the normal pool was estimated based on the assumed depth of the impoundment based on the structural height of Bulloughs Pond Dam and the elevation of the weir at the upstream City Hall Pond. The city indicated that prior to large storm events they typically lower the pool level at City Hall Pond, however, it is unlikely that the pond has sufficient storage to attenuate the peak flow of the design storm. Thus, City Hall Pond was not included in the final HMS model used by GZA. The stage-area relationship for Bulloughs Pond computed using ArcGIS tools and the 2014 LiDAR is provided in the table below. Elevations over 92.5-ft (top of dam) are included in the table as these values were required to run the model in HEC-HMS.

Table 6.3: Stage-Area Relationships

Bulloughs Pond	
Elevation (ft-NAVD88)	**Area (acres)**
85	6.9
86	7.2
87	7.4
88	7.7
89	7.8
90	8.0
91	8.4
92	9.0
93	9.4
94	9.7
95	10.0

Outflow Hydraulics

Spillway and dam geometry (i.e. length) were based on survey data from September 2019, supplied by the City of Newton. Terrain in the vicinity of the dam were estimated and available LiDAR data from MassGIS (USGS,2014).

In GZA's opinion, the hydraulics of Bulloughs Pond Dam are influenced in a domino fashion by 1) culvert capacity of the culvert under Walnut St (315 feet downstream of Bulloughs Pond Dam), 2) resulting headwater upstream of the culvert under Walnut St, 3) culvert capacity of the secondary weir under Dexter Rd (20 feet downstream of the v-shaped spillway weir), 4) resulting headwater upstream of the secondary weir, immediately downstream of the v-shaped spillway weir (noted as the "Plunge Pool", and 5) spillway capacity.

GZA developed a hydraulic model of the dam, spillway, and downstream culverts using HY-8 version 7.5 to estimate tailwater conditions for use in developing a rating curve for Bulloughs Pond Dam. To incorporate the limiting factors in order, the rating curve developed for each structure was used as the tailwater rating curve for the structure upstream of it. For example, the rating curve developed for the culvert under Walnut Street was used as a tailwater rating curve in developing the rating curve for the secondary spillway under Dexter Road.

The tailwater data entered for the culvert under Walnut Street was based on available LiDAR data, and on photographs from a site visit. The tailwater flows in a rectangular channel that was approximate 4 feet wide, with a slope of 0.006 ft/ft and an invert at 68.6 feet. The culvert was modeled as a 138-inch wide and 87-inch-high concrete pipe arch with a slope of 0.004ft/ft, an inlet elevation of 68.7 feet, and a crest elevation of 87 feet.

The tailwater data entered for the secondary spillway under Dexter Road was the rating curve developed for the culvert under Walnut Street. The secondary spillway was modeled as a concrete box culvert, with a span of 19.5 feet and a height of 5.5 feet. The elevation of a small weir within the culvert was set as the culvert channel bottom. The inlet elevation set at 85 feet and the crest elevation was set at 91.5 feet (lowest elevation of roadway along top of dam). The manning's n was set to 0.012 and the slope of the culvert was 0.005 ft/ft.

The rating curve developed for the secondary spillway culvert under Dexter Road was brought into the HEC-HMS model to create a rating curve for the Bulloughs Pond Dam vee-shaped spillway. The HEC-HMS software computes spillway submergence if the user specifies tailwater conditions. The spillway and top of dam geometry were input in the HMS "Outflow Structures" subroutine. The dam top was set at elevation 92.5 feet (based on topographic survey data supplied by the City of Newton) with a length of 225 feet and a weir coefficient of 3.0. The spillway crest was set at elevation 85.9 feet, with a length of 35 feet and a weir coefficient of 3.0. Weir coefficients were estimated by GZA using a broad-crested weir coefficient look up table, based on weir crest breadth and head, developed by Brater and King (1976). Using a "Source" node, GZA passed flows varying from 100 cubic feet per second (cfs) to 5,500 cfs and extracted the computed reservoir elevation to develop a rating curve to be used in the Bulloughs Pond Dam HMS model.

For all modeling, the low-level outlet was assumed to be closed. The USGS StreamStats application estimated a 100-year peak inflow to the dam of 564 cfs (approximately 182 cfs per square mile of drainage area). The HMS model created by GZA estimated a 100-year peak inflow of 2500 cfs (806 cfs per square mile of drainage area).

The City of Newton indicated that the dam has not overtopped in the past 28 years. In order to calibrate the model based on this observation, GZA acquired maximum rainfall totals at in the Greater Boston area for durations between 1-hour to 24-hours. According to published U.S Hourly Precipitation Data available from the Blue Hill Weather

Station, the largest regional rainfall intensity over the past 28 years was 5.96 inches over 6 hours, on June 13, 1996. GZA used the available hourly rainfall data as the precipitation input for the existing model. the time of concentration and curve numbers from this were calibrated such that the resulting inflow (1,500 cfs) was at the top of the dam.

The computed outflow rating curve for Bulloughs Pond Dam used in the model is shown below in the following table**.**

Table 6.4: Outflow Rating Curve

Reservoir Elevation (feet-NAVD88)	Discharge (cfs)
85.94 (spillway crest)	0.0
87.0	100
89.2	500
91.9	968
92.5	1000
93.3	1500
93.9	2000
94.9	2500

Note: Considers weir tailwater submergence. See text above.

6.3 Results

GZA used HEC-HMS to model and route the 100-year peak inflows to Bulloughs Pond Dam and evaluate the spillway capacity and embankment overtopping potential.

The top of dam is approximately elevation 92.5 based on topographic survey. The HEC-HMS results for the 100-year flood are provided in **Table 6.5.** Outputs from HEC-HMS are included in **Appendix H**.

Table 6.5: HEC-HMS Results for 100-Year Spillway Design Flood

Peak Inflow	Peak Outflow	Peak Water Surface Elevation	Overtopping Depth	Overtopping Duration	Percent of SDF Passed Without Overtopping
1,630 cfs	1,570 cfs	92.7 feet	0.2 feet	0.6 hours	91%

Note: Initial water surface in Bulloughs Pond modelled as normal pool elevation 85.9 feet.

The results of the HEC-HMS flood analysis indicate that the current configuration of Bulloughs Pond Dam is not able to pass the 100-year SDF without overtopping. Overtopping of the embankment in its current configuration could lead to erosion, embankment failure, and resulting release of the impoundment. The analyses indicate remedial measures are required to safely pass the SDF.

Please note that the calculated peak water surface elevation will inundate areas to the right of the dam along Dexter Road and Bullough Park Road. These inundated areas will convey floodwater to the right groin and spillway outlet channel along the right downstream side of the dam. In this area, there is a relatively steep slope upward from the outlet channel to the adjoining 96 Dexter Road property. We understand the property line is approximately 22 feet from the outlet channel. The floodwater conveyed from these areas to the right of the dam will concentrate on these steep slopes with the possibility of erosion and loss of the spillway right abutment. In addition to remedial measures to safely pass the SDF, remedial measures will be required to prevent erosion at the right groin and right side of the downstream channel.

7.0 SEEPAGE ANALYSES

GZA evaluated the seepage of the embankment portion of the Bulloughs Pond Dam. The evaluation considered the maximum section of the embankment in the vicinity of the low-level outlet pipe on the left side of the embankment approximately 75 feet left of the spillway. Calculations along with the seepage analysis assumptions and loading conditions are presented in **Appendix I**.

7.1 Seepage Model

GZA used GEO-SLOPE International, Ltd.'s computer program, SEEP/W 2019 R2 (a two-dimensional, finite element seepage analysis package), to simulate the pore pressures at finite element nodes, exit gradients, and seepage quantity (flux) for the existing conditions at the dam. Seepage through and under the dam was evaluated through a typical section near the low-level outlet using SEEP/W. Representative headwater and tailwater conditions were modelled based on the H&H analyses.

For the purpose of a steady-state seepage analysis, the model was first calibrated using the impoundment elevation (normal pool) and measured groundwater elevations. During GZA's subsurface investigations, the groundwater profile dropped in elevation from the upstream-most to the downstream-most borings. The core wall was possibly encountered and cored at GZ-1. Based on the groundwater measurements, the apparent core wall causes a drop of approximately 3 feet in head. These conditions were taken as representative of average seepage conditions over the full length of the embankment. GZA then used the SEEP/W computer model to estimate seepage gradients and flux through and under a unit width of the embankment.

7.2 Soil Characteristics

Permeability (i.e. hydraulic conductivity) coefficients for the various materials modeled in the seepage analysis were estimated based on published correlations to the gradation analysis of the tested samples and on engineering judgment. Permeability, as well as soil strengths values were assigned according to the table below.

Table 7.1: Assumed Soil Material Properties for Seepage and Stability Analyses

Soil	Saturated Unit Weight[1]	Cohesion	Friction Angle[2]	Permeability (Saturated) [1]
Embankment Fill	125 pcf	0 ksf	31°	6.0×10^{-5} cm/sec
Fine-Grained Foundation Soil	130 pcf	0 ksf	29°	7.0×10^{-4} cm/sec
Core Wall	140 pcf	288 ksf	0°	2.6×10^{-4} cm/sec
Bedrock	Impenetrable			3.0×10^{-10} cm/sec

1. Unit weight approximated based on Table 2-1 in *An Introduction to Geotechnical Engineering* by Roberts D. Holtz and William D. Kovacs.
2. Permeability approximated based Federal Highway Administration[7] and Justin-Hinds[8] methodologies.
3. Friction angle approximated based on Table 35.12 in the *Civil Engineering Reference Manual* by Michael R. Lindeburg.

7.3 Seepage Analyses Results

The SEEP/W seepage analyses indicate that under maximum pool conditions with the upstream water surface level at elevation 92.6 feet and the downstream water surface at 87.5 feet, the maximum exit gradient of water in the embankment is about 0.59 (foot/foot), just above the tailwater elevation. Taking the critical gradient (which is the gradient slope at which soil transport and thus potential piping failure is assumed to begin) as 1.0, as is typically done for these analyses, the computed exit gradient is lower than the critical gradient, indicating that soil transport is likely not a concern at the dam, in GZA's opinion.

Due to the significant uncertainties inherent in such calculations, the recommended factor of safety against seepage failure ranges from 2.5 to 3.0 (Cedergran 1977). The factor of safety equation against seepage (piping) failure through the embankment is:

$$F.S. = i_c/i$$

The calculated factor of safety against seepage instability for the Bulloughs Pond Dam embankment is approximately **1.8** at maximum pool. This factor of safety against seepage instability is considered insufficient and remedial measures are considered necessary.

The seepage model is only applicable to general conditions at the dam. It should be noted that isolated anomalies in the embankment are not captured by this analysis.

8.0 STABILITY ANALYSES

8.1 Liquefaction

Liquefaction potential susceptibility was evaluated per the Massachusetts State Building Code (MSBC)[9] Section 1806.4.1. Using the SPT results measured during drilling, Seismic Site Class was established following IBC[10] Section

[7] FHWA IF-02-034, Originally published by GeoSyntec Consultants, Inc. (1991). Geotextile Filter Design Manual.
[8] Justin, Hinds and Creager, "Engineering for Dams"; Vol. III; John Wiley & Sons.
[9] Ninth Edition of the MA State Building Code 780 CMR Amendments to the 2015 IBC International Codes published by the International Code Council (IBC).

1613.5.5. Liquefaction potential screening using MSBC Figure 1804.6.b, indicated the site is not considered susceptible to liquefaction. A more rigorous evaluation using the "Seed and Idriss" demand-capacity approach[11] was used to confirm the MSBC screening and estimate vertical settlements during a seismic event. The demand-capacity evaluations estimated seismically-induced vertical settlements of less than about ¼-inch and confirmed the MSBC liquefaction potential screening results.

8.2 Slope Stability

GZA performed a two-dimensional stability analysis at the maximum section of the Bulloughs Pond Dam embankment. The analyses were performed in general accordance with Massachusetts Dam Safety Regulations (302 CMR 10.14(9)) as well as other industry standards from the United States Bureau of Reclamation, United States Army Corp of Engineers, and Federal Energy Regulatory Commission.

Slope stability for an embankment dam is an important factor in the overall safety of the structure. Both the upstream and downstream slopes of an embankment must have sufficient capacity to resist sliding under a variety of loading conditions. The slope stability safety factors are a measure of an earthfill dam's capacity to meet the stability requirements mandated by Massachusetts Dam Safety Regulations (302 CMR 10.14(9(c)) and sound engineering practice. The safety factors are a function of several different parameters including soil type, slope height and angle, soil density, phreatic surface location, and loading condition.

A limit equilibrium-based computer code, GEO-SLOPE International, Ltd.'s SLOPE/W 2019 R2, was used for the slope stability assessment. The general representative cross section was the seepage analysis cross section. Pore water pressure values obtained from the seepage analysis were incorporated in the SLOPE/W simulation. Input parameters for the stability analyses are shown in **Table 7.1** above. Using the SLOPE/W program to assist the analyses, factors of safety against slope failure were estimated for various loading conditions. Estimated and recommended minimum factors of safety for existing conditions are shown below. Output from the SLOPE/W program is contained in **Appendix I**.

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[10] 2015 International Codes published by the International Code Council (IBC)

[11] Idriss, I.M. and Boulanger, R.W. (2008). Soil Liquefaction During Earthquakes. Earthquake Engineering Research Institute. Oakland, California. EERI Publication No. MNO-12.

Table 8.2: Slope Stability Results – Existing Conditions

Loading Condition	Dam Face	Slope Stability Factor of Safety	
		Minimum (302 CMR 10.14)	Existing Conditions – Slope Stability
Rapid Drawdown from Normal Pool (85.94 feet)	Upstream	1.2	1.2
Rapid Drawdown from Flood Pool (92.6 feet)	Upstream	>1.1	1.3
Steady Seepage at Normal Pool (Elev. 85.94 feet)	Upstream	1.5	1.5
	Downstream	1.5	1.5
Steady Seepage at Flood Pool (Elev. 92.6 feet)	Upstream	1.4	1.7
	Downstream	1.4	***1.0***
Earthquake (pseudo-static, 0.218g)	Upstream	>1.0	***0.9***
	Downstream	>1.0	***0.9***

The analyses indicated unacceptable factors of safety on the downstream slope under flood pool, and both slopes during earthquake loading. Based on the overall results of the stability assessment, stability-related corrective actions are required.

9.0 ALTERNATIVES ANALYSIS

Based on our Phase II analyses we have developed a suite of alternative approaches to address the identified deficiencies related to inadequate spillway capacity, embankment slope and seepage instability, presence of trees and related heavy vegetation on the embankment, scour in the downstream channel, and missing mortar in spillway training wall joints.

As discussed in Sections 1.3 and 2.4, DCR may reclassify Bulloughs Pond Dam as a High Hazard potential, dam. This reclassification would increase the Spillway Design Flood (SDF) per Massachusetts Dam safety regulations. ***Hazard Classification and SDF should be re-evaluated during final design.***

As a part of our Phase II engineering investigations, GZA performed preliminary analysis of possible alternatives for correcting the deficiencies identified during the Phase I visual inspection and confirmed by the engineering assessments performed as part of our Phase II services. Advantages and disadvantages of the various alternatives are presented as necessary.

9.1 No Action

The “No Action” alternative is not considered a viable option due to the observed safety deficiencies at the dam. Failure to address the identified deficiencies would be a violation of Massachusetts Law (G.L c. 253, § 44-49 as amended by Chapter 330 of the Acts of 2002) and Massachusetts Dam Safety Regulations (302 CMR 10.00) which require an Owner to properly maintain their dam such that it meets minimum dam safety standards. Failure to correct the dam safety deficiencies identified at the Bulloughs Pond Dam could endanger downstream public safety and property.

9.2 Dam Breach/Removal

The option to breach or fully remove the Bulloughs Pond Dam was considered. However, Bulloughs Pond serves as an important recreational asset for the City of Newton. Thus breaching the dam is not considered a viable alternative.

9.3 Repair the Dam

As the Bulloughs Pond Dam is very likely to remain, it will need to be repaired to bring it into compliance with the latest Massachusetts Dam Safety Regulations. Repairs are necessary to remediate the following deficiencies:

- Inadequate minimum freeboard during the SDF and the potential for embankment overtopping.
- Inadequate calculated factors of safety for embankment seepage stability and slope stability.
- Unwanted vegetation in areas of the dam including large trees along the downstream slope.
- Scarping along the upstream slope and bare soils prone to erosion along the downstream slope.
- Deterioration/potentially unstable headwall at the downstream end of the low-level outlet.
- Areas of scour along the downstream channel including at the low-level outlet and along the left and right banks. If erosion of the left bank continues, it could encroach on the toe of the downstream slope.
- Mortar missing from some of the spillway training wall joints.

GZA evaluated alternatives for remedying each of these deficiencies and provides the following conceptual recommendations. A conceptual design sketch depicting pertinent features of the each of the alternatives is included as **Figures 7A** through **7E**.

There are several repair scope items that are common to all repair alternatives, including

- Protection and/or flattening of slopes to help address slope instability. Conceptually, the upstream slope would be protected against seismic loading by placement of several feet of riprap at the toe and up the slope;
- Upward extension of the core wall to help address seepage instability. Note that the location of the most critical exit gradient is just above the tailwater during the SDF. We infer that the location of the critical exit gradient will change for lesser storms when the tailwater is lower. Toe drains were therefore not considered as part of the alternatives analysis and the slope flattening should include a drainage feature such as a blanket to properly filter and collect seepage;
- Armoring of the downstream channel, including the right groin and right downstream outlet channel to mitigate off-dam floodwater erosion;
- Lining (or replacement) of the two outlet pipes. Since lining is economically desirable and technically feasible, it is preferred over pipe replacement;
- Regrading upstream slope and placement of riprap on the upstream slope to mitigate scarping;
- Repointing of existing training walls; and
- Removal of trees and vegetation on the upstream and downstream slopes.

It is acknowledged by the dam safety engineering community that trees and woody plants that are allowed to grow on and immediately along and downstream of the toe of earthen dams can hinder safety inspections, interfere with safe operations, or can even cause dam failure via piping or blow-down. Therefore remedial repairs should include removal of trees, brush and associated woody vegetation from the crest, embankment slopes, and in the area immediately downstream of the embankment toe along the entire downstream length of the dam per the latest DCR-ODS policy of "Trees on Dams". Concurrent with tree/brush removal, remove all roots/root balls associated with trees and vegetation and backfill resulting voids with compacted sand/gravel. Thereafter establish a uniform, healthy grass cover within the cleared areas.

Note that in addition to final engineering and design, each alternative will require additional studies to facilitate permitting. Additionally, local conservation commission, state, and federal ecological requirements would need to be adhered to for each alternative.

9.3.1 - Alternative 1: Raise the Dam Embankment and Dexter Road to Provide Additional Storage

Raising the top of the dam and Dexter Road to approximate elevation 95 feet would allow the dam to store and safely retain the 100-year SDF. The length of the raising would extend from Walnut Street eastward across dam to either:

1) Across Bullough Park Road onto private property where natural grades are above the peak water surface elevation, or

2) Along Dexter Road on the right side of the dam. This would not fully contain the SDF and would allow flow around the right side of the raised embankment.

As part of this work, the roadway, bridge, and training walls would have to be raised or replaced at a higher elevation. Slopes would need to be extended upstream and downstream, with areas of retaining walls to reduce encroachment on adjoining private properties. Driveway ramps to between one and three residences along Dexter Road would be required to maintain vehicular access, depending on the length of Dexter Road raised. We estimate that two to six nearby residences would be severely impacted by the embankment raising.

The estimated cost of this alternative ranges from around $900,000 to $1,000,000, excluding bridge modifications. Based on the Federal Highway Administration[12] information, bridge modifications would be on the order of $600,000 to $800,000 depending on the level needed.

9.3.2 -Alternative 2: Parapet Walls to Provide Additional Storage

Similar to the Alternative 1, construction of one- to four-foot-high parapet walls to elevation 95 feet would be used to provide additional storage and help retain the 100-year flood. The length of these walls would also extend from Walnut Street to the west and to Bullough Park on the right.

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[12] "Bridge Replacement Unit Costs 2017" United States Department of Transportation Federal Highway Administration. http://www.fhwa.dot.gov/bridge/nbi/sd2017.cfm

This alternative would allow bypass flow around the right side of the parapet wall near Bullough Park Road. This bypass flow would require armoring of the right downstream groin and outlet channel to mitigate erosion. A gap in the wall would be required at the 69 Dexter Road driveway to allow vehicular access. The approximately 1.5-foot high gap in the wall would need to be closed by sandbags or flood barriers prior to overtopping events. The roadway grading and bridge elevations would not be affected by the parapet walls. However, the bridge would have to be evaluated by a structural engineer and modified to tie in with the parapet wall and withstand the additional loading. Views of the pond will be impacted, which could degrade recreational usage.

The estimated cost of this alternative is around $850,000 to $950,000, exclusive of bridge modifications. Based on the Federal Highway Administration information, bridge modifications would be on the order of $400,000 to $600,000 depending on the level needed.

9.3.3 -Alternative 3: Lower Impoundment and Construct Parapet Wall to Augment Spillway Outflow and Provide Additional Storage

A third option is to permanently lower the spillway weir and construct a relatively lower parapet wall. These actions will increase storage while providing additional outlet capacity. The spillway weir would be lowered by about 6 feet to approximate elevation 80 feet, with a parapet wall up to about 1.5-feet high. This alternative would lower the normal pool by about 6 feet, which would impact recreational usage of the pond. The lowering of the weir would require demolition and training wall repairs or rebuilding. The bridge would need to be evaluated for modifications or replacement. Similar to alternative 2, bypass flow would occur around the right side of the parapet wall near Bullough Park Road. This bypass flow would require armoring of the right downstream groin and outlet channel to mitigate erosion.

The estimated cost of this alternative is around $850,000 to $950,000, exclusive of bridge modifications. Based on the Federal Highway Administration information, bridge modifications would be on the order of $400,000 to $600,000 depending on the level needed.

GZA understands from discussions with the City that lowering the impoundment would not be a preferred alternative due to the scenic and recreational benefits that the pond provides.

9.3.4 -Alternative 4: Widen Spillway to Augment Spillway Outflow

The fourth option involves widening the spillway to approximately 60 feet to safely pass the SDF through the spillway. The spillway weir would remain at the same elevation and the normal pool elevation would be retained. Roadway grade modifications would not be required, however the bridge and training walls would have to be rebuilt. Since the full SDF outflow would be passed through the spillway, bypass flow to the right of the dam would be mitigated. The estimated cost of this alternative is over $1.4 million excluding bridge costs. Based on the Federal Highway Administration information, bridge modifications would be above $1.5 million.

9.3.5 - Alternative 5: Armor Downstream Slope to Provide Overtopping Protection

This alternative includes armoring of the embankment to allow overtopping during the SDF while mitigating potential erosion and scour failure of the embankment. Under existing and proposed conditions, the dam would be overtopped by approximately 0.2 feet. There are different methods of slope armoring available, all of which have the same goal: to protect the earth from the flow and turbulence of flood water that tends to erode the embankment, thus leading to dam failure. There are three main categories of slope armoring:

1. Pre-cast, Articulated Concrete Blocks (ACB)
2. Stone Riprap
3. Turf Reinforcement Mats (TRM)
4. Gabions

All of these are proven methods for overtopping protection. They are selected based on the depth of overtopping, flow velocities, and duration of overtopping. Each of these armor alternatives comes in different sizes and strengths, depending on individual site constraints. Since upstream slope protection is envisioned under all five alternatives, the upstream and downstream slopes could be designed to use the same armoring and would appear similar.

Placing riprap on the slope is a natural and low-labor solution. Stones would be dumped downslope and chinked into place using smaller stones. The riprap also helps to establish a stable slope; however, public access would be difficult due to irregular footing. In addition, maintenance of the riprap would likely be needed as the stones may be displaced over time or by vandalism, especially in public areas. Gabions could be used to armor the slope in a stepped fashion. During final design, it is likely that the gabions will require concrete facing of horizontal surfaces to resist scour. A filter or drainage layer would likely be needed for either riprap or gabions.

Unlike riprap, ACBs provide a physically flexible option for erosion protection. They are not intended for slope stabilization and slope stability must be established before implementing and ACB system. ACB systems are composed of pre-formed concrete blocks that are interconnected by cables. The blocks conform to changes in the subgrade and provide protective cover. Topsoil can be placed in and over open-cell ACBs to allow vegetation to be established, which can improve aesthetic appeal. In an ACB system, the contact between the ACB's and the subgrade is paramount. A filter or drainage layer is needed in the design of ACB systems. Flow beneath the armor layer can cause uplift pressure and separate the blocks from the subgrade.

Turf Reinforcement Mats (TRMs) are generally not as erosion-resistant as riprap or ACBs, but have been used and approved by ODS in the past as embankment dam overtopping protection. TRMs are a permanent, cost effective and environmentally friendly alternative to hard armor erosion protection solutions. TRMs essentially consist of ultraviolet light and chemical resistant synthetic polyolefins manufactured to create a flexible three-dimensional matrix. Seed and soil are held in place within the matrix. As the vegetation matures, roots and stems inter-twine with the matrix, creating a "Biotechnical Composite" that is permanently anchored to the soil greatly enhancing the turfs' ability to withstand high shear stresses and flow velocities. With adequate care, a visitor to the site would see only a grassed slope within a growing season. At the upstream water level, a different material such as riprap would be necessary to resist scour. This alternative would also require repointing of the spillway training walls.

The conceptual cost estimate for armor using either TRM or ACBs is $700,000 to $800,000. Armoring using riprap would be on the order of $850,000 to $950,000. In GZA's opinion, armoring the downstream slope to allow it to withstand the SDF is the preferred alternative.

9.3.6 Additional Repair Considerations

As discussed in Sections 1.3 and 2.4, DCR may reclassify Bulloughs Pond Dam as a High Hazard potential, dam. This reclassification would increase the Spillway Design Flood (SDF) per Massachusetts Dam safety regulations. ***Hazard Classification and SDF should be re-evaluated during final design.*** Each of the first four alternatives is not scalable in that if additional storage or outflow capacity is required after construction, significant dam modifications could be required. The preferred (fifth) alternative is scalable in that additional or more robust overtopping protection could be considered in the final design and installed at the present time to accommodate future changes in SDF outflow.

The following additional construction and contractual items may be necessary to support final design, depending on the selected alternative.

- Replacement of the two 24-inch diameter gate valves. The current valves are functional, but may be nearing the end of their service life.
- A property line survey will be required for final design.
- Traffic impact studies may be necessary, depending on the alternative chosen.
- Temporary or permanent easement agreement(s) with nearby property owners for temporary access to work areas or location of permanent features to be constructed on adjoining properties.

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

Bulloughs Pond Dam has been found by others to be in “Poor” condition, it exhibits deficiencies that directly impact the long term performance of the structure. Our studies also indicate that the size classification should be changed from Small to Intermediate size. Parallel development of an EAP indicates that Bulloughs Pond Dam may be re-classified as High Hazard. GZA has undertaken preliminary engineering analyses with respect to evaluating and mitigating the following deficiencies:

- Inadequate minimum freeboard during the SDF and the potential for embankment overtopping.
- Inadequate calculated factors of safety for embankment seepage stability and slope stability.
- Unwanted vegetation in areas of the dam including large trees along the downstream slope.
- Scarping along the upstream slope and bare soils prone to erosion along the downstream slope.
- Deterioration/potentially unstable headwall at the downstream end of the low-level outlet.
- Areas of scour along the downstream channel including at the low-level outlet and along the left and right banks. If erosion of the left bank continues, it could encroach on the toe of the downstream slope.
- Mortar missing from some of the spillway training wall joints.

10.2 Recommendations

To bring the structure into compliance with Massachusetts Dam Safety Regulations and current engineering practice, GZA recommends the following:

- Resurface the upstream embankment with stone rip-rap protection.
- Re-grade the downstream embankment to a uniform and stable slope by extending the toe five to ten feet. Place armor over the downstream slope to address potential for crest overtopping and erosion of the downstream slope. The downstream slope should be designed to incorporate an appropriate filter blanket to collect and filter seepage and confine locations of maximum seepage gradients under flood conditions.
- Clear vegetation, trees and woody vegetation from the embankments, crest and downstream toe area. Additionally, remove all roots/root balls associated with trees and vegetation and backfill resulting voids with compacted sand/gravel
- Repoint training walls.
- Slipline the low level outlet pipes and construct new headwall at extended toe of slope.
- Armor the downstream channel.

These recommendations should be confirmed during final design, especially if DCR increases the Hazard classification for the dam.

10.3 Permitting

We anticipate the following permits will be required for the repairs:

- Order of Conditions under the Massachusetts Wetlands Protection Act (Newton Conservation Commission).
- Chapter 253 Dam Safety Permit (DCR-ODS).
- Section 106 Historical Notification (Mass. Heritage Commission).
- Chapter 91 license review by the Massachusetts Department of Environmental Protection (MADEP).
- Water Quality Certification by MADEP under Section 401.
- Review by the U.S. Army Corps of Engineers under Section 404.
- Environmental Notification Form for Massachusetts Environmental Policy Act Office.

Permitting requirements should be confirmed during final design

10.4 Preliminary Conceptual Cost Estimates

The preliminary conceptual cost estimate for the concept design developed for the preferred remedial repairs discussed herein is between $700,000 and $950,000, depending on the selected slope armoring material. A detailed breakdown of the estimate is presented in **Appendix K.** This estimate was generated based on prices for similar projects updated to reflect 2020 construction prices. Actual construction and other costs will vary based on final design and other circumstances.

It must be noted that the recent climate for construction in Massachusetts has seen significant increases in the cost of fuel, concrete, steel, and other construction materials. This has led to very high bids on a number of recent projects. Recent discussions with contractors who are engaged in dam repair work indicate that higher than average cost inflation may continue. We also believe that economic uncertainty related the COVID-19 pandemic may have large impacts on bid prices depending on the timing of procurement and construction. This could lead to actual bid costs above those estimated by GZA. Accordingly, we recommend that a larger than usual contingency be applied. In GZA's experience, bids for water control at dam repair project sites have recently been higher than expected, which appears to reflect contractor concern about the risk involved with this item. It is also important to recognize that costs for environmental mitigations may exceed the estimate above depending upon the extent of work required under permit conditions.

We estimate that the engineering costs for construction oversight services by an engineering consultant will range between approximately $80,000 and $120,000.

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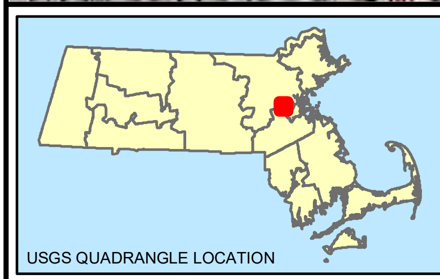
Figures



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SCALE IN FEET

Data Supplied by : USGS

N W E S

PROJ. MGR.: LAG
DESIGNED BY: DEM
REVIEWED BY: CWC
OPERATOR: DEM
DATE: 3/11/2020

LOCUS PLAN

BULLOUGHS POND DAM
NEWTON, MASSACHUSETTS

JOB NO. 01.174021.00

FIGURE NO. 1

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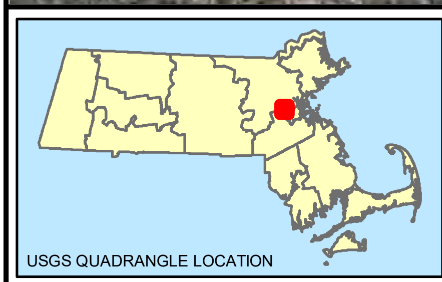

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SCALE IN FEET

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PROJ. MGR.: LAG
DESIGNED BY: DEM
REVIEWED BY: CWC
OPERATOR: DEM
DATE: 1-25-2019

AERIAL LOCUS PLAN

BULLOUGHS POND DAM
NEWTON, MASSACHUSETTS

JOB NO.
01.174021.00

FIGURE NO.
2

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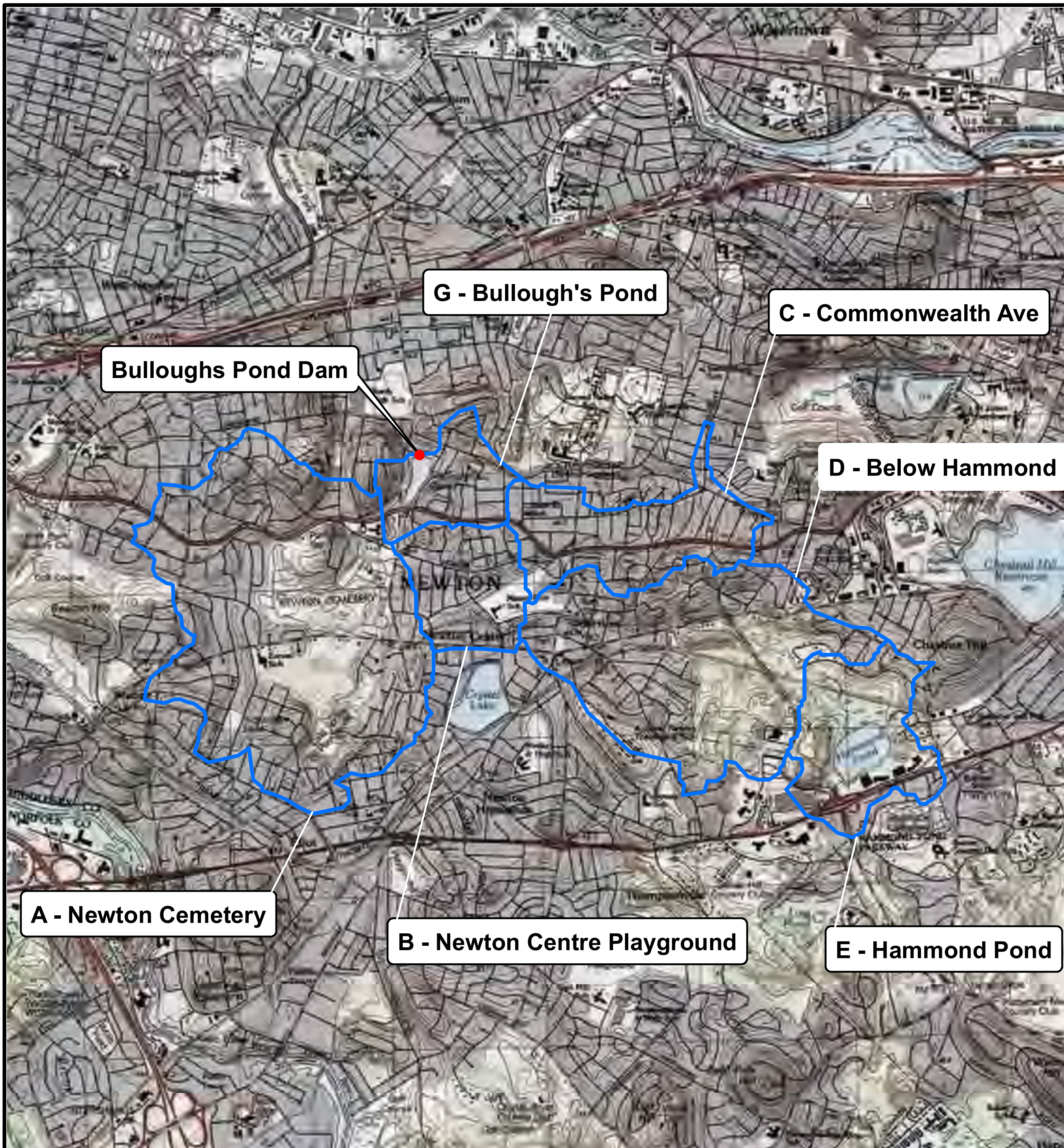
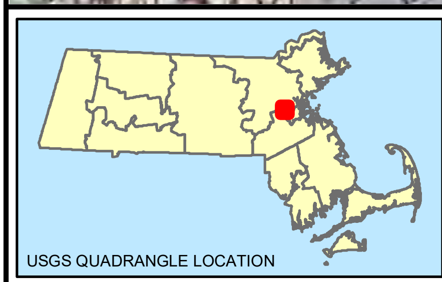




THIS MAP PRESENTS LAND COVER IMAGERY FOR THE WORLD AND DETAILED TOPOGRAPHIC MAPS FOR THE UNITED STATES. THE MAP IS PARTOF SEAMLESS, SCANNED IMAGES OF UNITED STATES GEOLOGICAL SURVEY (USGS) PAPER TOPOGRAPHIC MAPS.

Data Supplied by : USGS

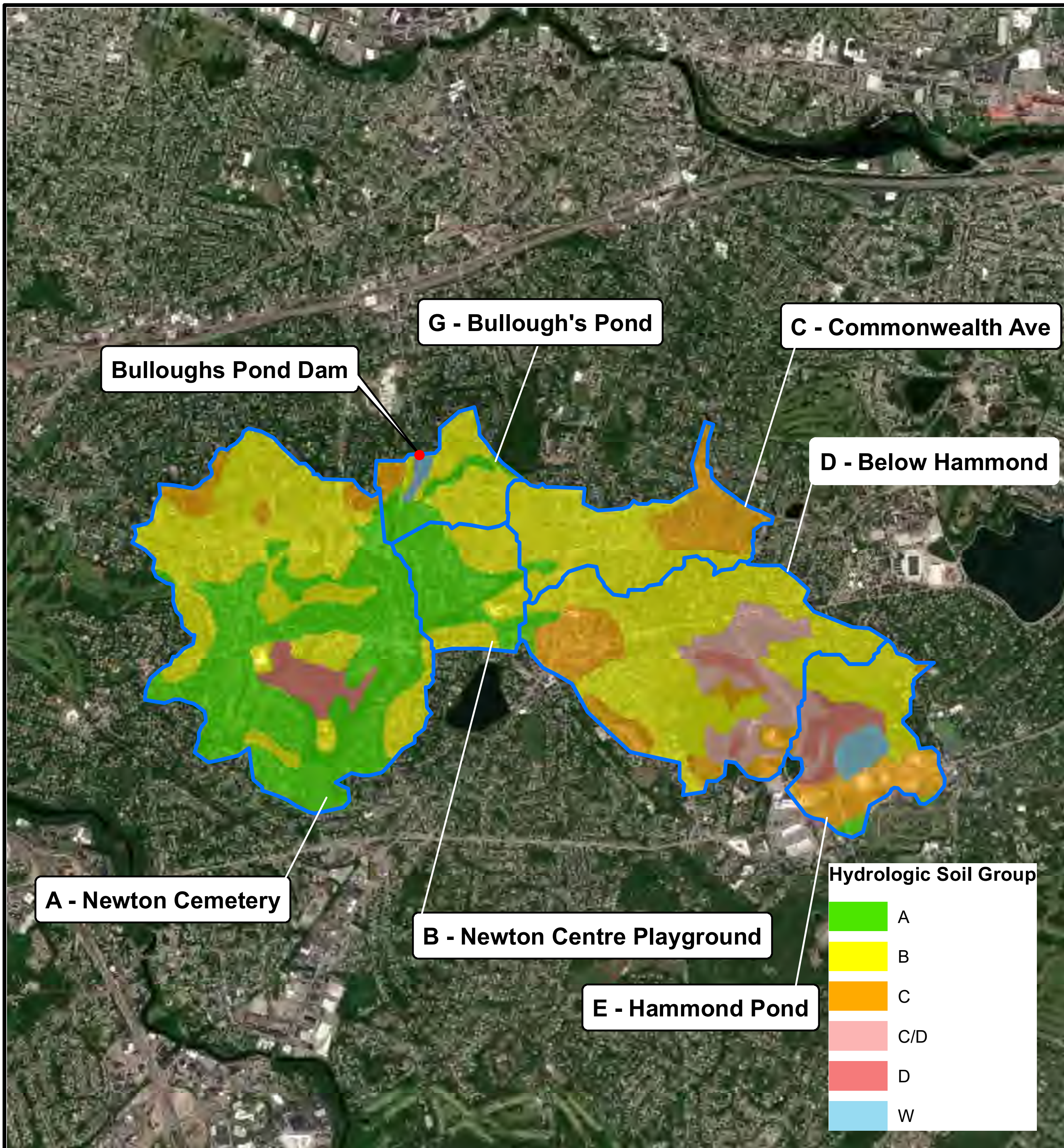
0 500 1,000 2,000 3,000

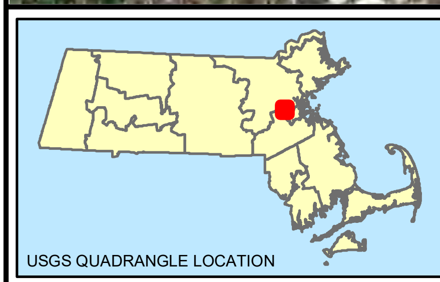
SCALE IN FEET

N W E S

GZA	PROJ. MGR.: LAG DESIGNED BY: DEM REVIEWED BY: CWC OPERATOR: DEM DATE: 3/11/2020	WATERSHED PLAN	JOB NO. 01.174021.00
		BULLOUGHS POND DAM NEWTON, MASSACHUSETTS	FIGURE NO. 3

© 2020 - GZA GeoEnvironmental, Inc., J:\170,000-179,999\174021\174021-00.LAG\Phase II Report\Figures\mxd\Figure 3 - WATERSHED PLAN.mxd, 3/11/2020, 11:48:26 AM, daniel.mcgraw





THIS MAP CONTAINS AERIAL IMAGERY FROM ESRI, 2017.
SOIL DATA WAS OBTAINED FROM THE USDA/NRCS
WEB SOIL SURVEY (WSS), ACCESSED SEPTEMBER, 2019

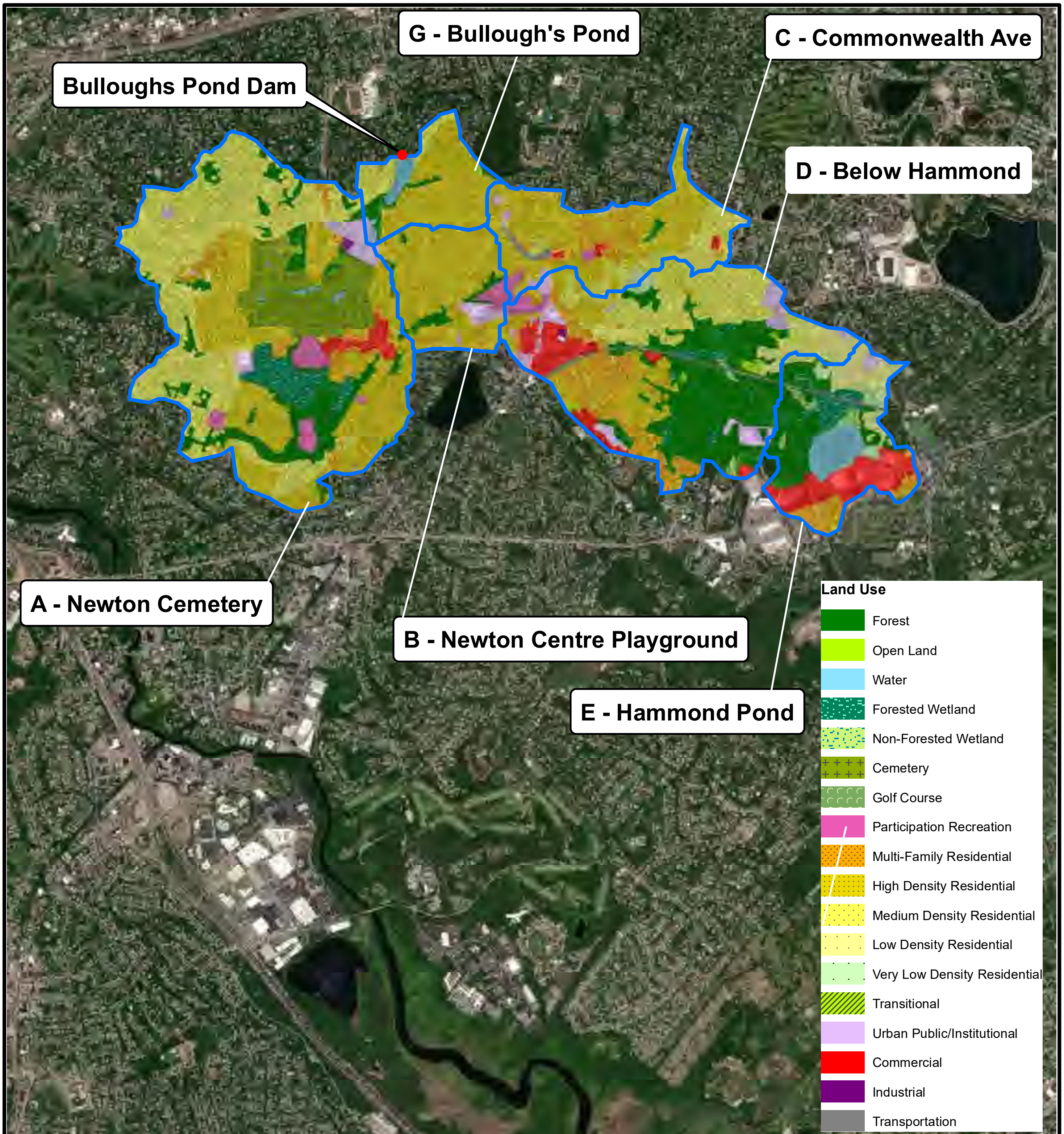
Data Supplied by : USGS

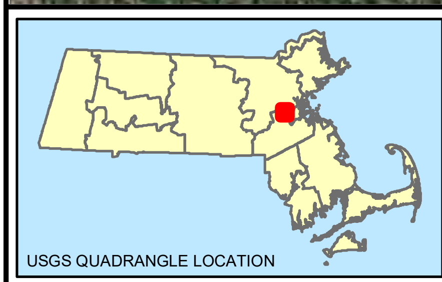
0 1,000 2,000 3,000
SCALE IN FEET

N W E S

GZA	PROJ. MGR.: LAG DESIGNED BY: DEM REVIEWED BY: CWC OPERATOR: DEM DATE: 3/11/2020	SOILS MAP	JOB NO. 01.174021.00
		BULLOUGHS POND DAM NEWTON, MASSACHUSETTS	FIGURE NO. **4**

© 2020 - GZA GeoEnvironmental, Inc., J:\170,000-179,999\174021\174021-00.LAG\Phase II Report\Figures\mxd\Figure 4 - SOILS MAP.mxd, 3/11/2020, 11:51:52 AM, daniel.mcgraw





THIS MAP CONTAINS AERIAL IMAGERY FROM ESRI, 2017.
LAND USE DATA WASA RETRIEVED FROM MASS GIS, PUBLISHED IN 2005

Data Supplied by : USGS

0 1,000 2,000 3,000
SCALE IN FEET

N W E S

PROJ. MGR.: LAG
DESIGNED BY: DEM
REVIEWED BY: CWC
OPERATOR: DEM
DATE: 3/11/2020

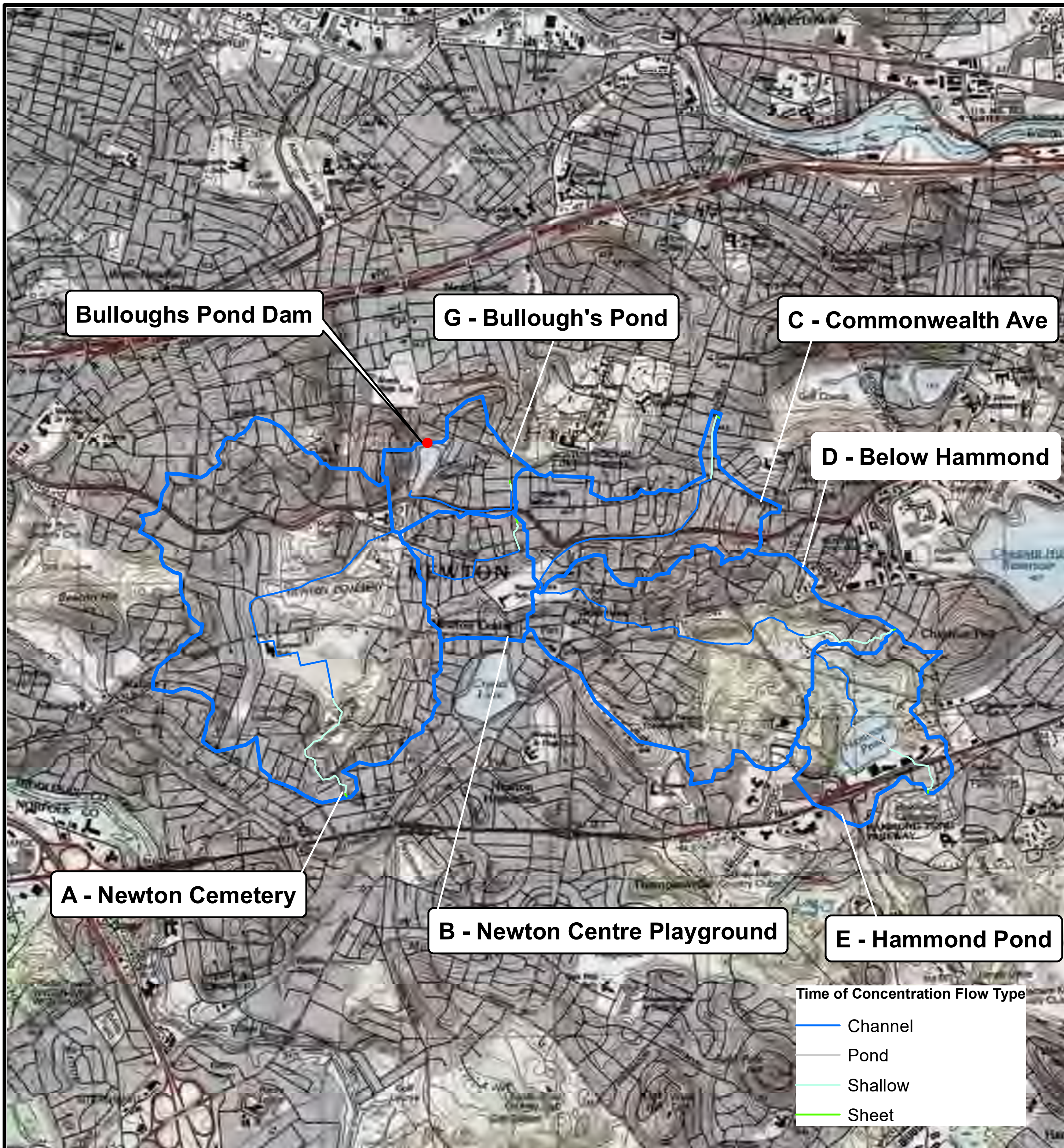
LAND USE MAP

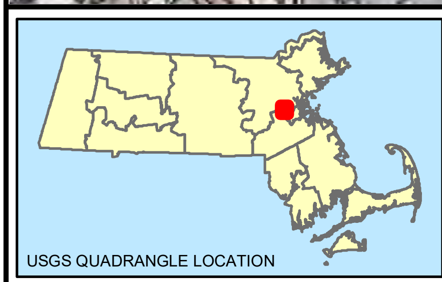
BULLOUGHS POND DAM
NEWTON, MASSACHUSETTS

JOB NO. 01.174021.00

FIGURE NO. 5

© 2020 - GZA GeoEnvironmental, Inc., J:\170,000-179,999\174021\174021-00.LAG\Phase II Report\Figures\mxd\Figure 5 - LAND USE MAP.mxd, 3/11/2020, 11:52:51 AM, daniel.mcgraw





THIS MAP CONTAINS AERIAL IMAGERY FROM ESRI, 2017.
LAND USE DATA WASA RETRIEVED FROM MASS GIS, PUBLISHED IN 2005

Data Supplied by : USGS

0 1,000 2,000 3,000
SCALE IN FEET

N W E S

GZA	PROJ. MGR.: LAG DESIGNED BY: DEM REVIEWED BY: CWC OPERATOR: DEM DATE: 3/11/2020	FLOW PATH MAP	JOB NO. 01.174021.00
		BULLOUGHS POND DAM NEWTON, MASSACHUSETTS	FIGURE NO. 6

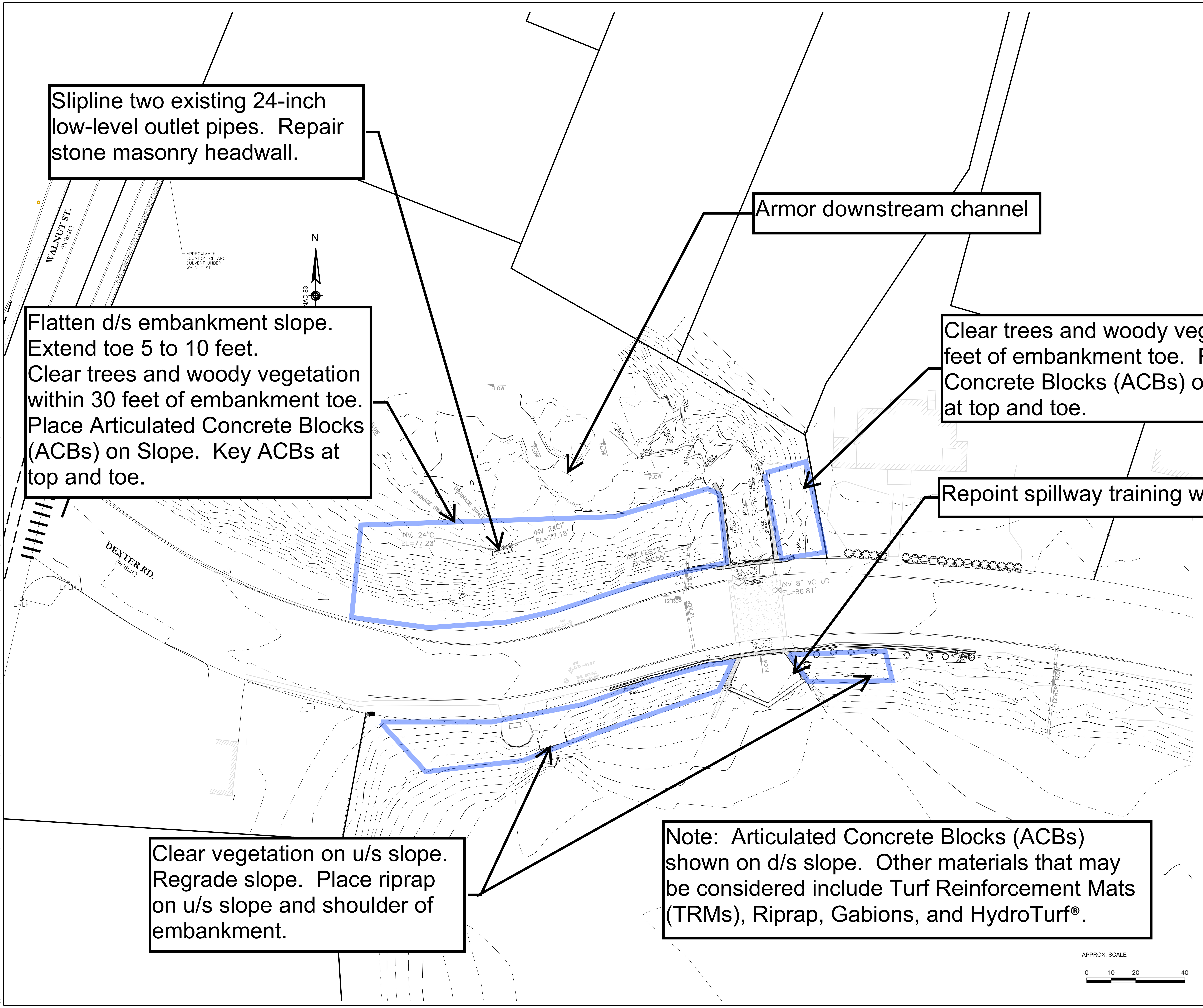
© 2020 - GZA GeoEnvironmental, Inc., J:\170,000-179,999\174021\174021-00.LAG\Phase II Report\Figures\mxd\Figure 6 - TOC MAP.mxd, 3/11/2020, 11:56:36 AM, daniel.mcgraw


Armor downstream channel
Slipline two existing 24-inch low-level outlet pipes. Repair stone masonry headwall.
Repoint spillway training walls. Extend upward to retain raised embankment.
Clear trees and woody vegetation within 30 feet of embankment toe. Place erosion protection such as riprap, ACBs or TRM.
Raise dam embankment to El. 95' to retain 100 year flood. Extend raised area left (west) to Walnut Street and east (right) to Bullough Park to reduce flow around ends. Raise roadway, bridge, and training walls. Provide retaining walls or extend slopes on u/s and d/s embankments.
Flatten d/s embankment slope. Extend toe 5 to 10 feet. Clear trees and woody vegetation within 30 feet of embankment toe. Loam & seed slope.
Clear vegetation on u/s slope. Regrade slope. Place riprap on u/s slope and shoulder of embankment.
WALNUT ST. (PUBLIC)
DEXTER RD. (PUBLIC)
N
NAD 83
FLOW
APPROX. SCALE
0 10 20 40
NO. ISSUE/DESCRIPTION BY DATE
BULLOUGH'S POND DAM
NEWTON, MASSACHUSETTS
ALTERNATIVE 1: RAISE DAM EMBANKMENT
PREPARED BY:
GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com
PREPARED FOR:
PROJ MGR: LAG
REVIEWED BY: JDA
CHECKED BY: PFS
DESIGNED BY: LAG
DRAWN BY: City of Newton
SCALE: N.T.S
DATE: 04-01-2020
PROJECT NO. 01.0174021.00
REVISION NO.
FIGURE 7A


Armor downstream channel
Slipline two existing 24-inch low-level outlet pipes. Repair stone masonry headwall.
Repoint spillway training walls.
Clear trees and woody vegetation within 30 feet of embankment toe. Place erosion protection such as riprap, ACBs or TRM.
Flatten d/s embankment slope. Extend toe 5 to 10 feet. Clear trees and woody vegetation within 30 feet of embankment toe. Loam & seed slope.
Construct masonry or concrete parapet wall to El. 95' to retain 100 year flood (1 to 4'). Extend parapet wall (west) to Walnut Street and east (right) to Bullough Park to reduce flow around ends.
Flood would flow around ends of the parapet wall, requiring temporary closure at driveway.
Clear vegetation on u/s slope. Regrade slope. Place riprap on u/s slope and shoulder of embankment.
WALNUT ST. (PUBLIC)
DEXTER RD. (PUBLIC)
N
NAD 83
APPROX. SCALE
0 10 20 40
NO. ISSUE/DESCRIPTION BY DATE
UNLESS SPECIFICALLY STATED BY WRITTEN AGREEMENT, THIS DRAWING IS THE SOLE PROPERTY OF GZA GEOENVIRONMENTAL, INC. (GZA). THE INFORMATION SHOWN ON THE DRAWING IS SOLELY FOR USE BY GZA'S CLIENT OR THE CLIENT'S DESIGNATED REPRESENTATIVE FOR THE SPECIFIC PROJECT AND LOCATION IDENTIFIED ON THE DRAWING. THE DRAWING SHALL NOT BE TRANSFERRED, REUSED, COPIED, OR ALTERED IN ANY MANNER FOR USE AT ANY OTHER LOCATION OR FOR ANY OTHER PURPOSE WITHOUT THE PRIOR WRITTEN CONSENT OF GZA. ANY TRANSFER, REUSE, OR MODIFICATION TO THE DRAWING BY THE CLIENT OR OTHERS, WITHOUT THE PRIOR WRITTEN EXPRESS CONSENT OF GZA, WILL BE AT THE USER'S SOLE RISK AND WITHOUT ANY RISK OR LIABILITY TO GZA.
BULLOUGH'S POND DAM
NEWTON, MASSACHUSETTS
ALTERNATIVE 2: CONSTRUCT PARAPET WALL
PREPARED BY:
GZA GeoEnvironmental, Inc.
Engineers and Scientists
www.gza.com
PREPARED FOR:
PROJ MGR: LAG
REVIEWED BY: JDA
CHECKED BY: PFS
DESIGNED BY: LAG
DRAWN BY: City of Newton
SCALE: N.T.S
DATE: 04-01-2020
PROJECT NO. 01.0174021.00
REVISION NO.
FIGURE 7B

© 2013 – GZA GeoEnvironmental, Inc.

Slipline two existing 24-inch low-level outlet pipes. Repair stone masonry headwall.
Armor downstream channel
Flatten d/s embankment slope. Extend toe 5 to 10 feet. Clear trees and woody vegetation within 30 feet of embankment toe. Loam & seed slope.
Clear trees and woody vegetation within 30 feet of embankment toe. Loam & seed slope.
Widen spillway to approx. 60 feet (±40 feet wider). Rebuild bridge and training walls.
Clear vegetation on u/s slope. Regrade slope. Place riprap. Loam and seed.
WALNUT ST. (PUBLIC)
DEXTER RD. (PUBLIC)
N
APPROX. SCALE
0 10 20 40
BULLOUGH'S POND DAM
NEWTON, MASSACHUSETTS
ALTERNATIVE 4: WIDEN SPILLWAY
GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com
PROJ MGR: LAG
DESIGNED BY: LAG
DATE: 04-01-2020
REVIEWED BY: JDA
PROJECT NO. 01.0174021.00
CHECKED BY: PFS
SCALE: N.T.S
FIGURE 7D



NO.	ISSUE/DESCRIPTION	BY	DATE

UNLESS SPECIFICALLY STATED BY WRITTEN AGREEMENT, THIS DRAWING IS THE SOLE PROPERTY OF GZA GEOENVIRONMENTAL, INC. (GZA). THE INFORMATION SHOWN ON THE DRAWING IS SOLELY FOR USE BY GZA'S CLIENT OR THE CLIENT'S DESIGNATED REPRESENTATIVE FOR THE SPECIFIC PROJECT AND LOCATION IDENTIFIED ON THE DRAWING. THE DRAWING SHALL NOT BE TRANSFERRED, REUSED, COPIED, OR ALTERED IN ANY MANNER FOR USE AT ANY OTHER LOCATION OR FOR ANY OTHER PURPOSE WITHOUT THE PRIOR WRITTEN CONSENT OF GZA. ANY TRANSFER, REUSE, OR MODIFICATION TO THE DRAWING BY THE CLIENT OR OTHERS, WITHOUT THE PRIOR WRITTEN EXPRESS CONSENT OF GZA, WILL BE AT THE USER'S SOLE RISK AND WITHOUT ANY RISK OR LIABILITY TO GZA.

BULLOUGH'S POND DAM

NEWTON, MASSACHUSETTS

ALTERNATIVE 5: ARMOR DOWNSTREAM SLOPE

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com

PREPARED FOR:

PROJ MGR: LAG	REVIEWED BY: JDA	CHECKED BY: PFS	FIGURE
DESIGNED BY: LAG	DRAWN BY: City of Newton	SCALE: N.T.S	7E
DATE: 04-01-2020	PROJECT NO. 01.0174021.00	REVISION NO.	

© 2013 – GZA GeoEnvironmental, Inc. GZA-C:\Users\daniel.mcgraw\Documents\1.CompanionFolder\174021-00\BULLOUGHS_POND_DAM – Alt Figure.dwg [SHEET] April 01, 2020 – 3:31pm daniel.mcgraw

Appendix A
Limitations

DAM ENGINEERING REPORT LIMITATIONS

Use of Report

1. GZA GeoEnvironmental, Inc. (GZA) prepared this report on behalf of, and for the exclusive use of City of Newton (Client) for the stated purpose(s) and location(s) 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 we do not accept any responsibility for the consequences of such use(s). Further, reliance by any party not identified in the agreement, for any use, without our prior written permission, shall be at that party's sole risk, and without any liability to GZA.

Standard of Care

2. Our findings and conclusions are based on the work conducted as part of the Scope of Services set forth in the Report and/or 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(s).
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 property. No warranty, expressed or implied, is made.

Subsurface Conditions

4. If presented, the generalized soil profile(s) and description, along with the conclusions and recommendations provided in our Report, are based in part on widely-spaced subsurface explorations by GZA and/or others, with a limited number of soil and/or rock samples and groundwater /piezometers data and are intended only to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and were based on our assessment of subsurface conditions. The composition of strata, and the transitions between strata, may be more variable and more complex than indicated. For more specific information on soil conditions at a specific location refer to the exploration logs. The nature and extent of variations between these explorations may not become evident until further exploration or construction. If variations or other latent conditions then appear evident, it will be necessary to reevaluate the conclusions and recommendations of this report.

5. Water level readings have been made in test holes (as described in the Report), monitoring wells and piezometers, at the specified times and under the stated conditions. These data have been reviewed and interpretations have been made in this Report. Fluctuations in the groundwater and piezometer levels, however, occur due to temporal or spatial variations in areal recharge rates, soil heterogeneities, reservoir and tailwater levels, the presence of subsurface utilities, and/or natural or artificially induced perturbations.

General

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

7. In preparing this report, GZA relied on certain information provided by the Client, state and local officials, and other parties referenced therein available to GZA at the time of the evaluation. GZA did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this evaluation.

8. Any GZA hydrologic analysis presented herein is for the rainfall volumes and distributions stated herein. For storm conditions other than those analyzed, the response of the site's spillway, impoundment, and drainage network has not been evaluated. This analysis also relies on anecdotal data on overtopping frequency provided by the Client.

9. Observations were made of the site and of structures on the site as indicated within the report. Where access to portions of the structure or site, or to structures on the site was unavailable or limited, GZA 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 and elsewhere and/or flow over the spillway may have limited GZA's ability to make observations of underwater portions of the structure. Excessive vegetation, when present, also inhibits observations.

10. 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 along with data made available to GZA. It is important to note 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 care can there be any chance that unsafe conditions be detected.

Compliance with Codes and Regulations

11. 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.

12. This scope of work does not include an assessment of the need for fences, gates, no-trespassing signs, repairs to existing fences and railings 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 also excluded.

Cost Estimates

13. Unless otherwise stated, our cost estimates are for comparative, or general planning purposes. These estimates may 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 may vary over time and could be significantly more, or less, than stated in the Report.

Additional Services

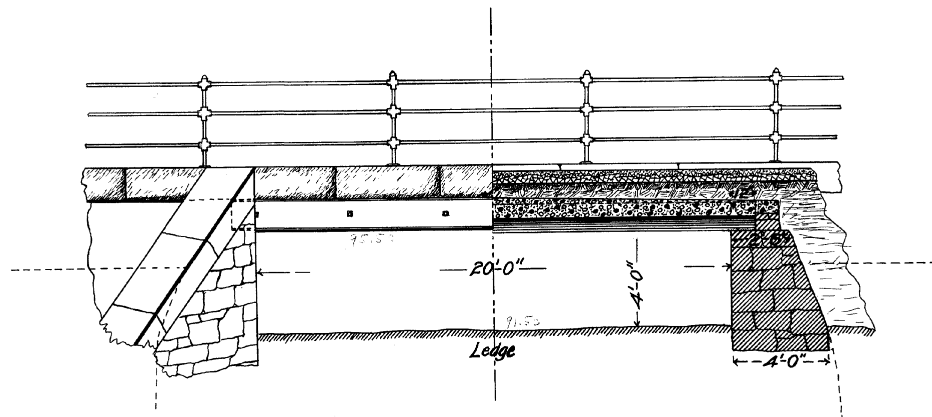
14. It is recommended that GZA be retained to provide services during any future: site observations, explorations, evaluations, design, implementation activities, construction and/or implementation of remedial measures recommended in this Report. This will allow us the opportunity to: i) observe conditions 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.

Appendix B
Historic Drawings

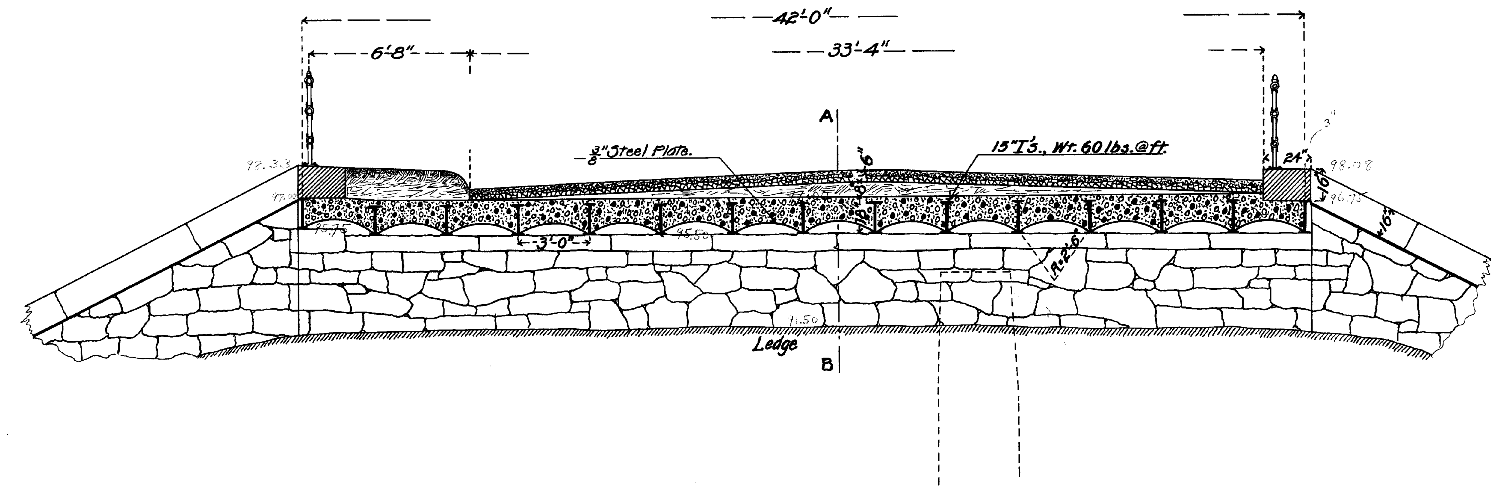
7587

Bk 109 D2

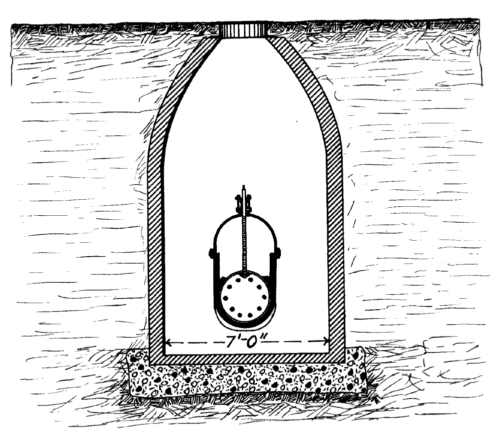
END ELEVATION OF CULVERT. HALF SECTION ON A-B.



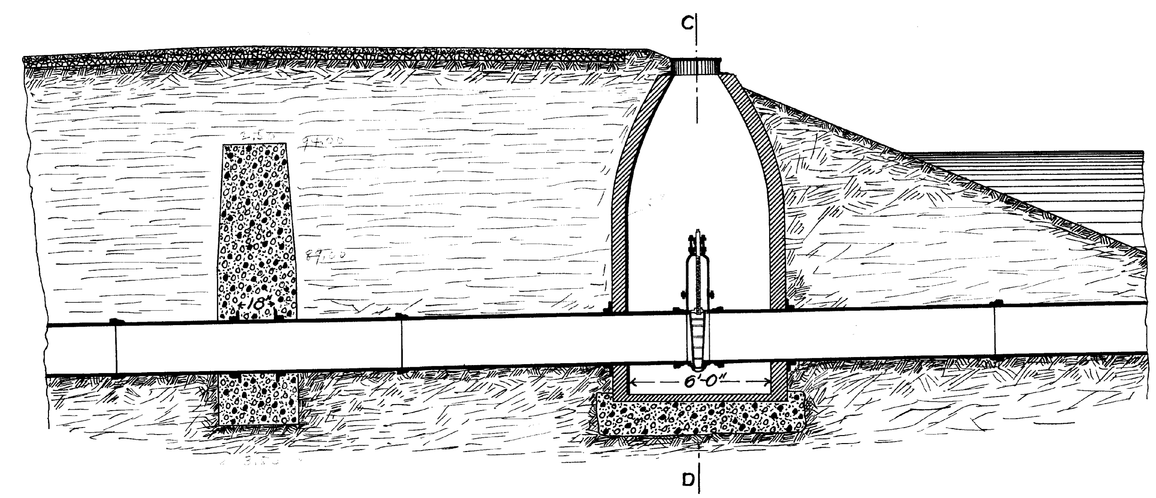
SECTION THROUGH OVERFLOW CULVERT.



SECTION ON C-D.



SECTION THROUGH WASTE PIPE AND GATE CHAMBER.



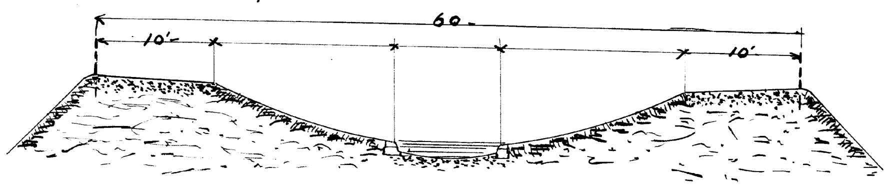
DETAILS OF
CULVERT AND WASTE PIPE
BULLOUGHS POND IMPROVEMENTS

SCALE 4 FT. = 1 IN.

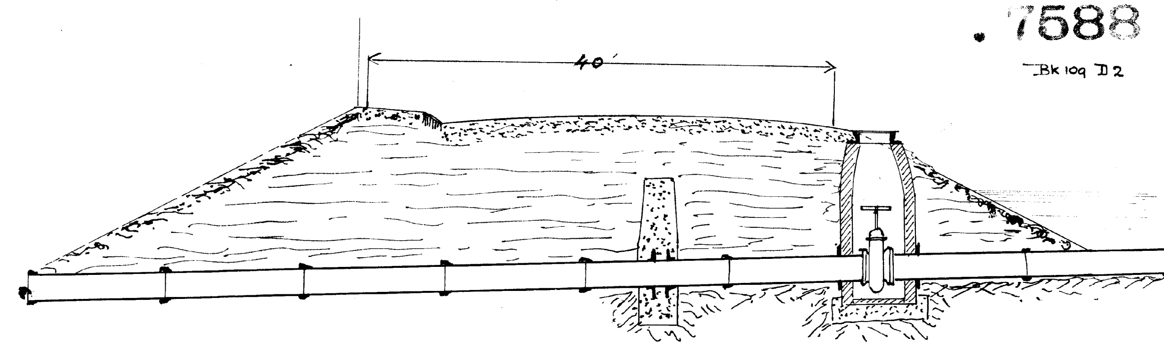
NEWTON, MASS.
SEPT. 1897.

H.D. WOODS,
CITY ENGINEER.

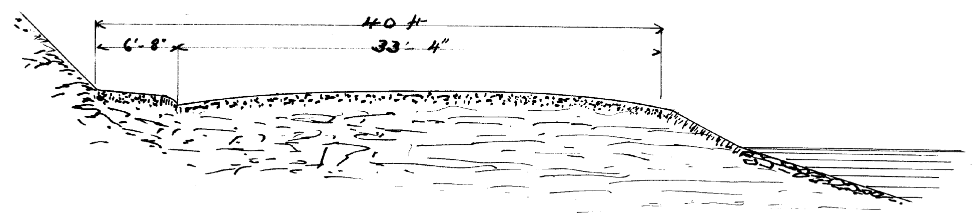
. 7588
Bk 109 D 2



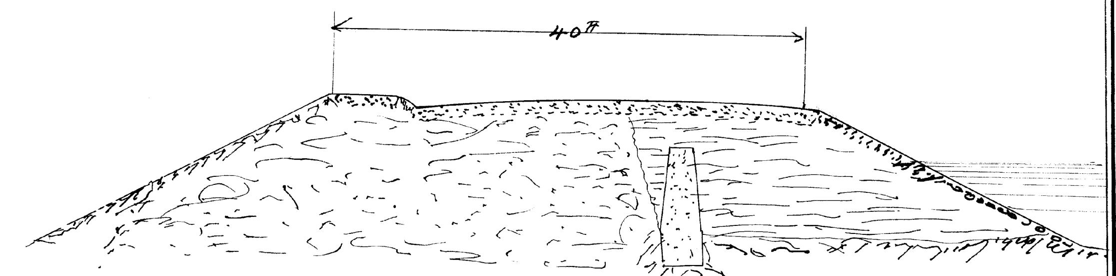
Section of Brookway.



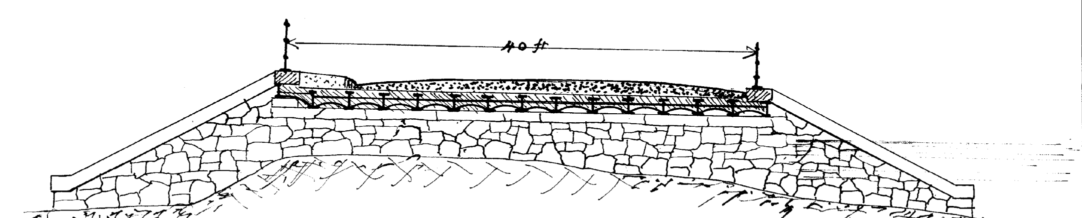
Section of Dam and Waste-pipe.



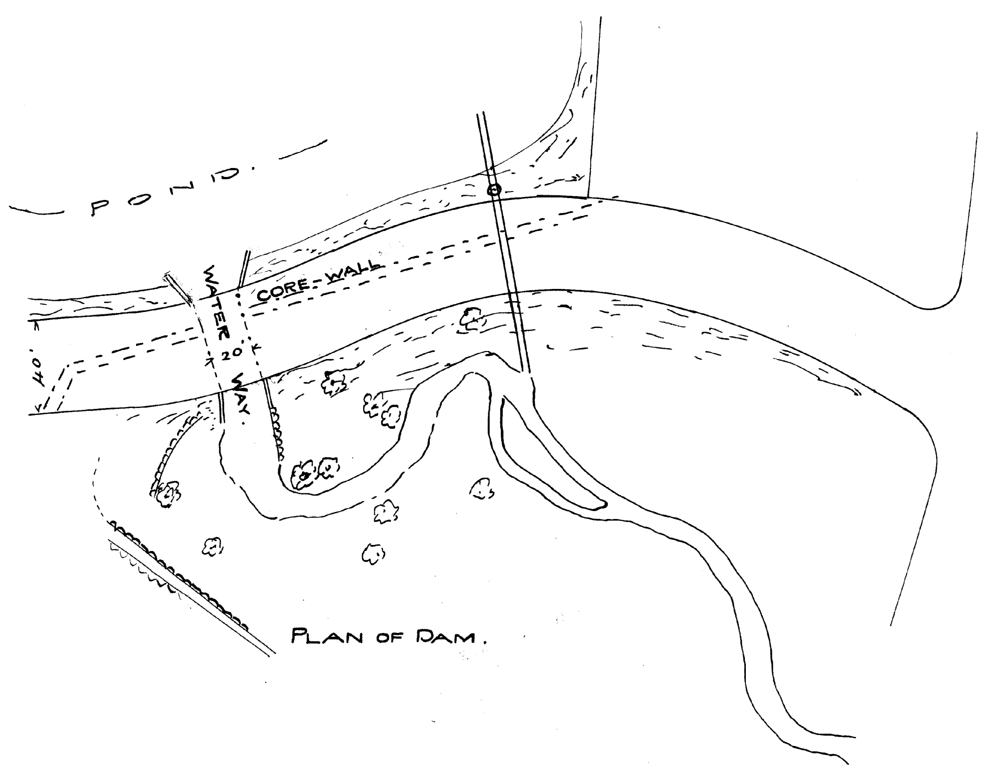
Section of Driveway.



General Section of Dam.



Section at Bridge and Overflow.



Plan of Dam.

Plan of

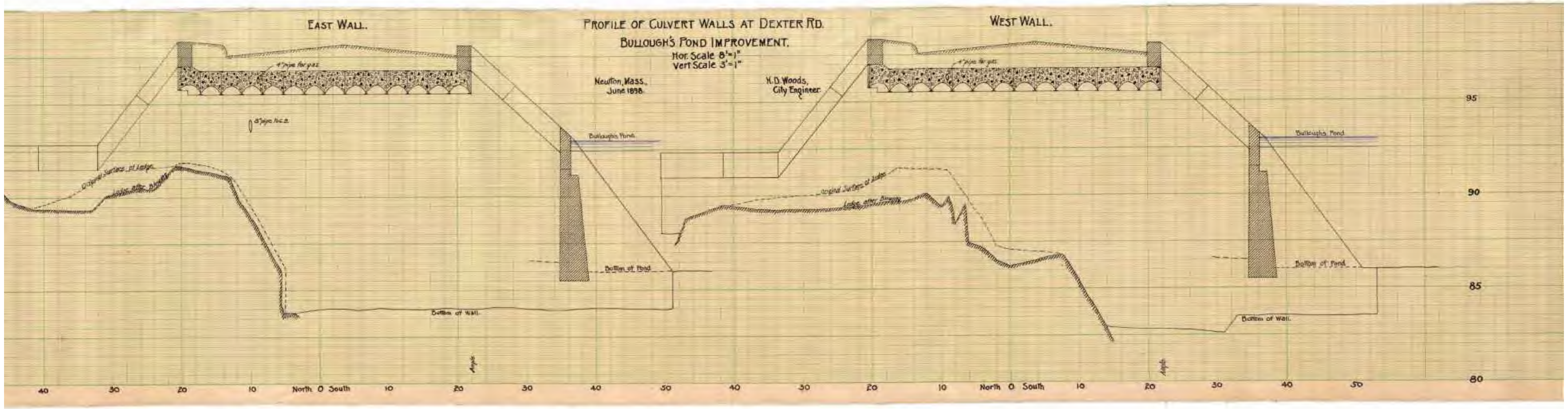
Proposed Sections of Roadways and Dam.

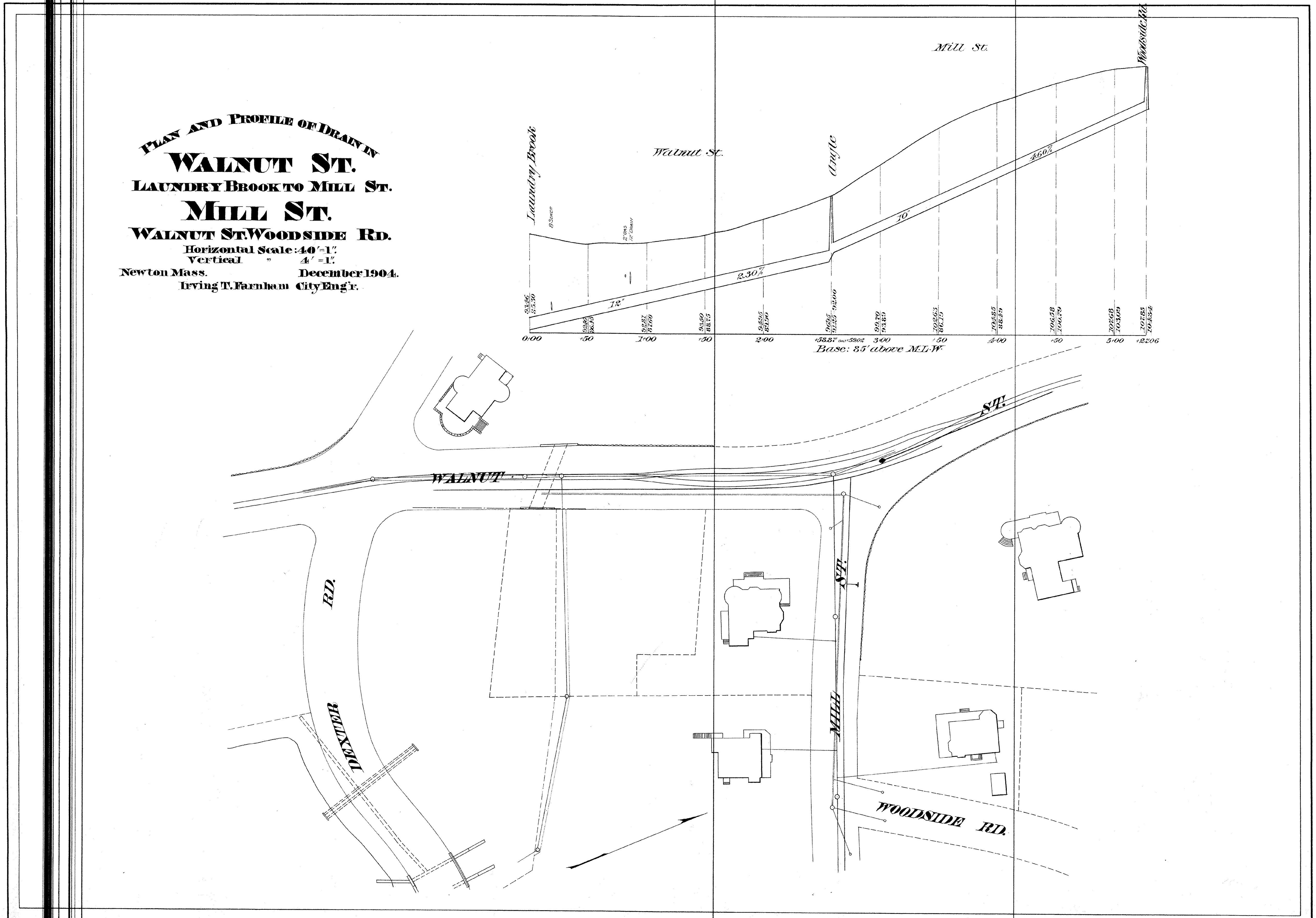
Bulloughs Pond Improvements.

Scale 8 Feet = 1 Inch.

Newton, Mass., Aug. 1897.

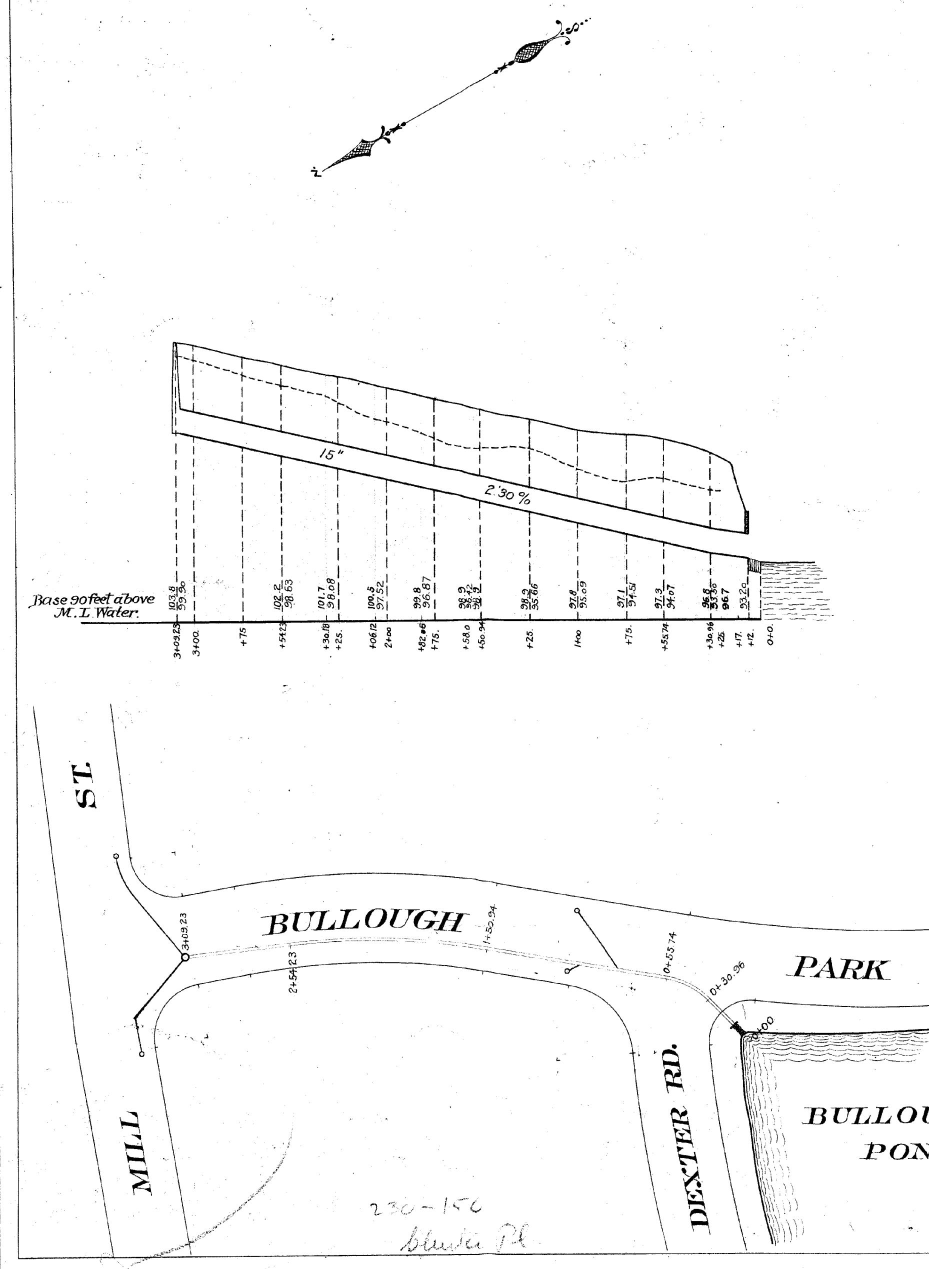
H. D. Woods. City Eng'r.


EAST WALL.
PROFILE OF CULVERT WALLS AT DEXTER RD.
BULLOUGH'S POND IMPROVEMENT.
Hor. Scale 8'=1"
Vert Scale 3'=1"
Newton, Mass.,
June 1898.
H.D. Woods,
City Engineer.
WEST WALL.
Bullough's Pond
Bottom of Pond
Bottom of Wall
North 0 South



10648
P-16

10648
P-16



PLAN AND PROFILE
of
BULLOUGH PARK DRAIN
FROM BULLOUGH'S POND TO MILL ST.

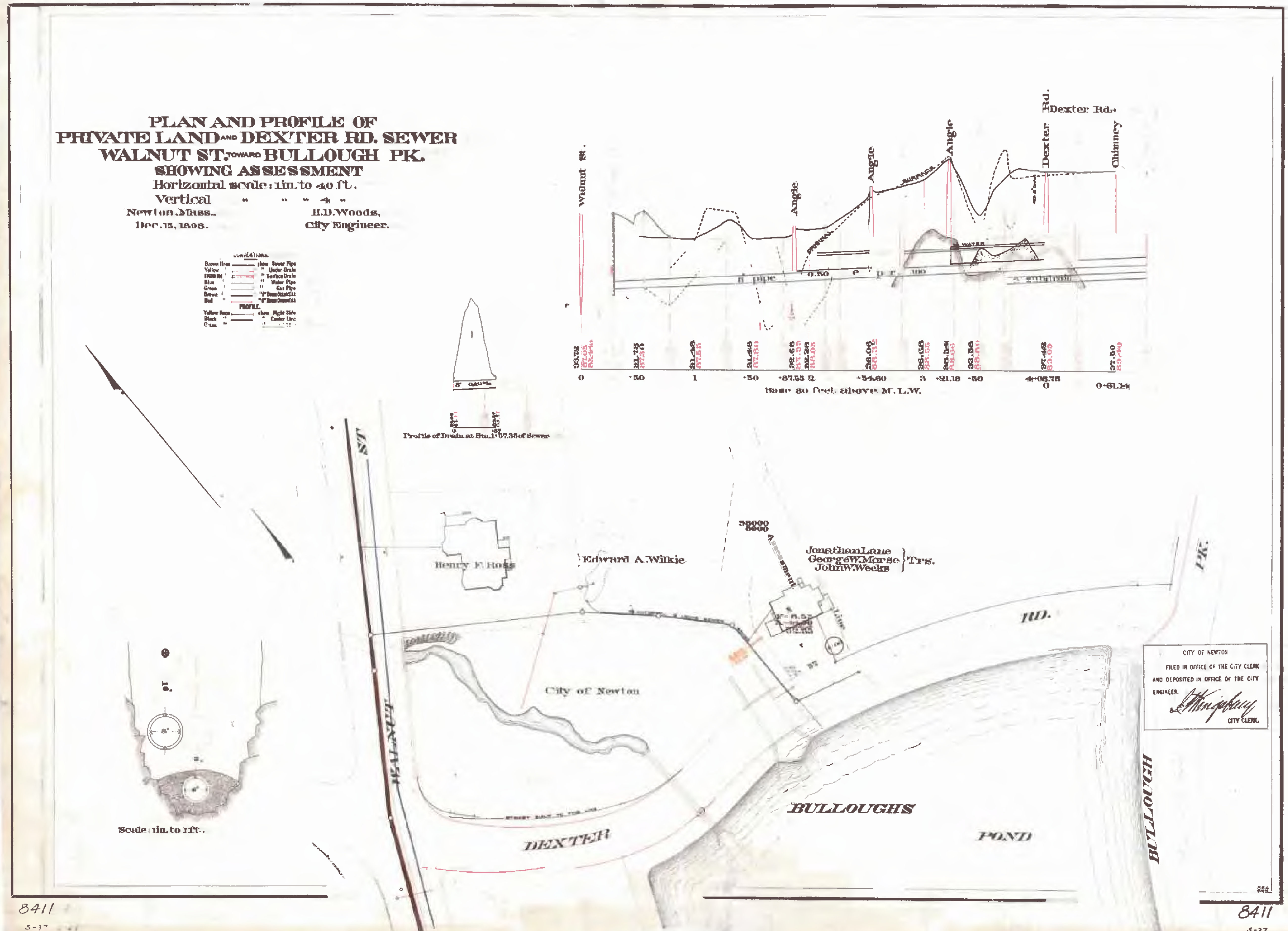
Horizontal Scale 40 feet to an inch.
Vertical " 4 " " " "

Newton, Mass.
June, 1898.

H. D. Woods.
City Engineer.

11568
P-19

11568
P-19


PLAN AND PROFILE OF
PRIVATE LAND AND DEXTER RD. SEWER
WALNUT ST. TOWARD BULLOUGH PK.
SHOWING ASSESSMENT
Horizontal scale: 1in. to 40 ft.
Vertical " " " 4 "
Newton Mass.
Dec. 15, 1898.
H.D. Woods,
City Engineer.
Walnut St.
Angle
Angle
Angle
Dexter Rd.
Dexter Rd.
Chimney
Surface
Water
pipe
subdrain
Base 80 feet above M.L.W.
Profile of Drain at Sta.1+07.35 of Sewer
Scale: 1in. to 1ft.
Henry F. Ross
Edward A. Wilkie
Jonathan Lane
George W. Morse
John W. Weeks
Trs.
City of Newton
Assessment
WALNUT ST
DEXTER RD.
BULLOUGHS POND
BULLOUGH PK.
CITY OF NEWTON
FILED IN OFFICE OF THE CITY CLERK AND DEPOSITED IN OFFICE OF THE CITY ENGINEER.
CITY CLERK.
8411
S-37
8411
S-37

17407

17407

CITY OF NEWTON

MASSACHUSETTS

DEXTER ROAD

BULLOUGH PK. WESTERLY

PLAN AND PROFILE SHOWING
SEWER AND SEWER ASSESSMENT

Horizontal Scale: 40' to an inch
Vertical " 6' " " "

February 6, 1922.

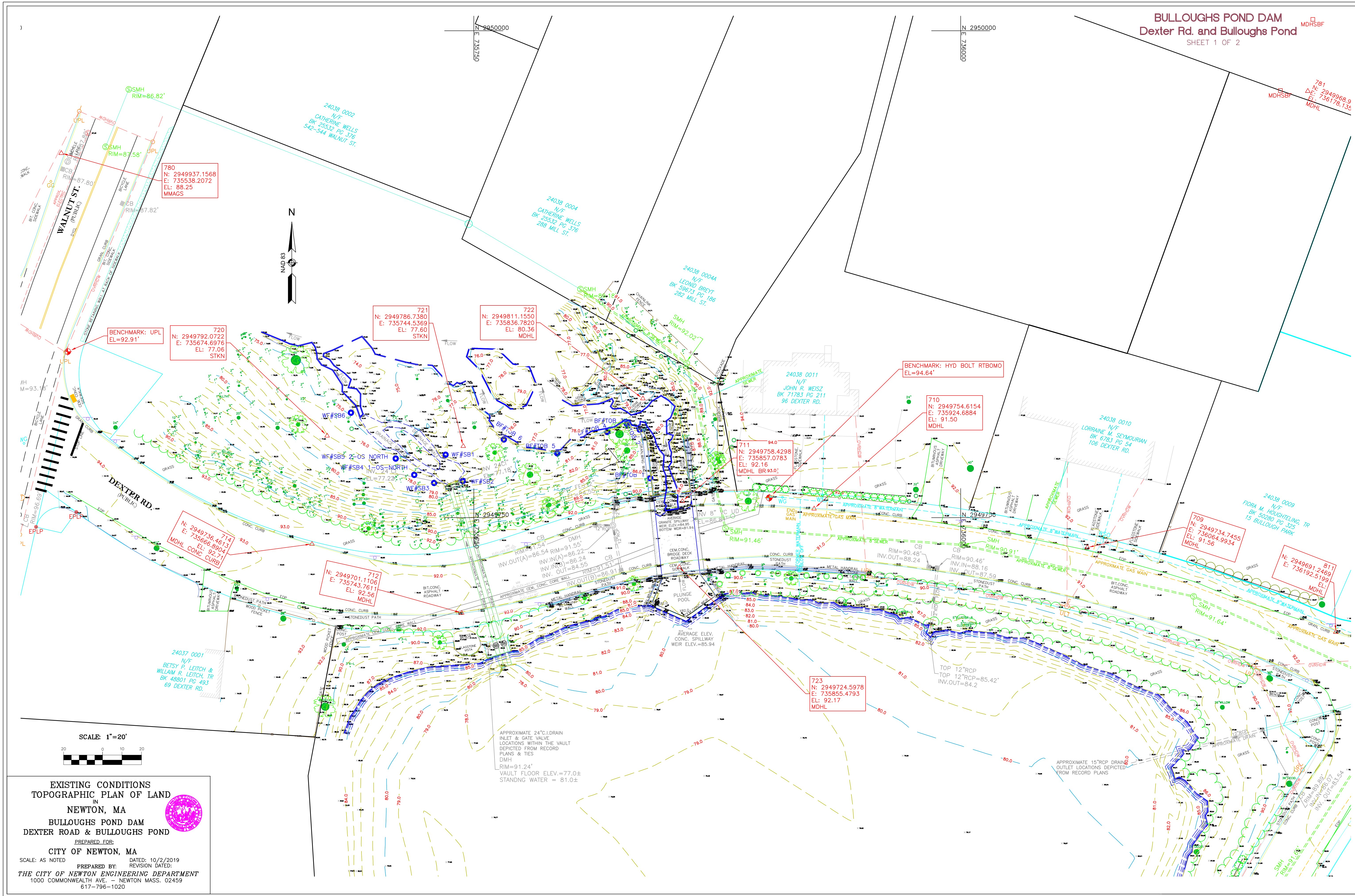
Edwin W. Rogers
CITY ENGINEER.

17407

17407
5-49

5-49

Appendix C
Topographic Survey



BULLOUGHS POND DAM
Dexter Rd. and Bulloughs Pond
SHEET 1 OF 2
EXISTING CONDITIONS
TOPOGRAPHIC PLAN OF LAND
IN
NEWTON, MA
BULLOUGHS POND DAM
DEXTER ROAD & BULLOUGHS POND
PREPARED FOR:
CITY OF NEWTON, MA
SCALE: AS NOTED
DATED: 10/2/2019
REVISION DATED:
PREPARED BY:
THE CITY OF NEWTON ENGINEERING DEPARTMENT
1000 COMMONWEALTH AVE. – NEWTON MASS. 02459
617-796-1020
SCALE: 1"=20'
N
NAD 83
WALNUT ST. (PUBLIC)
DEXTER RD. (PUBLIC)
BENCHMARK: UPL EL=92.91'
BENCHMARK: HYD BOLT RTBOMO EL=94.64'
780 N: 2949937.1568 E: 735538.2072 EL: 88.25 MMAGS
720 N: 2949792.0722 E: 735674.6976 EL: 77.06 STKN
721 N: 2949786.7380 E: 735744.5369 EL: 77.60 STKN
722 N: 2949811.1550 E: 735836.7820 EL: 80.36 MDHL
710 N: 2949754.6154 E: 735924.6884 EL: 91.50 MDHL
711 N: 2949758.4298 E: 735857.0783 EL: 92.16 MDHL
712 N: 2949701.1106 E: 735743.7611 EL: 92.56 MDHL
714 N: 2949736.4613 E: 735666.8904 EL: 92.71 MDHL CONC CURB
723 N: 2949724.5978 E: 735855.4793 EL: 92.17 MDHL
709 N: 2949734.7455 E: 736064.9934 EL: 91.56 MDHL
811 N: 2949691.2469 E: 736192.5199 EL: MDHL
781 N: 2949968.9 E: 736178.135 EL: MDHL
24038 0002 N/F CATHERINE WELLS BK 25532 PG 376 542-544 WALNUT ST.
24038 0004 N/F CATHERINE WELLS BK 25532 PG 376 288 MILL ST.
24038 0004A N/F LEONID BREYT BK 59673 PG 186 282 MILL ST.
24038 0011 N/F JOHN R. WEISZ BK 71783 PG 211 96 DEXTER RD.
24038 0010 N/F LORRAINE M. SEYMOURIAN BK 6783 PG 54 106 DEXTER RD.
24038 0009 N/F FIORA M. HOUGHTELING, TR BK 50280 PG 325 15 BULLOUGH PARK
24037 0001 N/F BETSY P. LEITCH & WILLIAM R. LEITCH, TR BK 48801 PG 493 69 DEXTER RD.
N 2950000
N 2949750
E 735750
E 736000
AVERAGE ELEV. CONC. SPILLWAY WEIR ELEV.=85.94
PLUNGE POOL
APPROXIMATE 24"C.I.DRAIN INLET & GATE VALVE LOCATIONS WITHIN THE VAULT DEPICTED FROM RECORD PLANS & TIES
DMH RIM=91.24' VAULT FLOOR ELEV.=77.0± STANDING WATER = 81.0±
APPROXIMATE 15"RCP DRAIN OUTLET LOCATIONS DEPICTED FROM RECORD PLANS
TOP 12"RCP TOP 12"RCP=85.42' INV.OUT=84.2
APPROXIMATE GAS MAIN

NOTES:

1. LOCATIONS OF UTILITIES SHOWN WERE PLOTTED FROM (1) RECORD DATA PROVIDED BY THE CITY OF NEWTON, MA OR THE RESPECTIVE UTILITY OR (2) BY LOCATION IN THE FIELD. LOCATIONS AND ELEVATIONS OF ALL UTILITIES ARE APPROXIMATE ONLY. THE CONTRACTOR SHALL NOTIFY DIG SAFE AND DETERMINE THE EXACT LOCATIONS IN THE FIELD PRIOR TO ANY WORK PER MASSACHUSETTS GENERAL LAW CHAPTER 82 SECTIONS 40A - 40E, AS AMENDED. THIS PLAN DOES NOT WARRANTY NOR GUARANTEE THE LOCATION OF ALL UTILTIES EITHER DEPICTED OR NOT DEPICTED, THIS PLAN MAY OR MAY NOT SHOW ALL THE UTILITIES SERVICING OR EXISTING AT THIS SITE; ABOVE GROUND OR BELOW, IN SERVICE OR ABANDONED, UNRECORDED OR OF RECORD. ANY LABEL IDENTIFYING A UTILITY STRUCTURE IS BASED ON FIELD INSPECTION AND/OR FROM AVAILABLE PLANS AND SHOULD NOT BE CONSIDERED AS A DEFINITIVE DESCRIPTION OF EITHER THE UTILITY OR USAGE OF THE STRUCTURE.

2. THIS PLAN IS NOT A CERTIFICATION TO TITLE OR OWNERSHIP OF PROPERTY SHOWN, OWNERS OF ADJOINING PROPERTIES ARE ACCORDING TO CURRENT ASSESSOR'S RECORDS.

3. THIS PLAN DOES NOT SHOW ANY RECORDED, UNRECORDED OR UNWRITTEN EASEMENTS WHICH MAY EXIST.

4. THIS PLAN WAS PREPARED FOR THE CITY OF NEWTON ENGINEERING DIVISION FOR THE FOLLOWING PURPOSES: EXISTING CONDITIONS TOPOGRAPHIC PLAN OF A PORTION OF BULLOUGHS POND, BULLOUGH PARK, DEXTER RD. & BULLOUGHS POND DAM, TO BE USED FOR INSPECTION, EVALUATION AND DESIGN IMPROVEMENT & REPAIRS. THIS PLAN IS THE RESULT OF TOPOGRAPHIC DETAIL SURVEY AND RIGHT OF WAY RETRACEMENT SURVEY PERFORMED BY THE CITY OF NEWTON ENGINEERING DIVISION.

5. THE HORIZONTAL SURVEY CONTROL WAS BASED ON SURVEY CONTROL ESTABLISHED ON THE GROUND BY THE CITY OF NEWTON ENGINEERING DIVISION, SURVEY SECTION BY PERFORMING A CLOSED LOOP TRAVERSE AND TRAVERSE ADJUSTMENT, CONTROL WAS FURTHER EXTENDED BY MEANS OF TRAVERSING RADIALLY FROM CLOSED LOOP TRAVERSE OUTWARD TO LOCATE STREET MONUMENTS (RADIAL TRAVERSE INCORPORATED CLOSING THE HORIZON ANGULARLY ALONG ANY EXTENSIONS FROM CLOSED TRAVERSE LOOP). THE COORDINATES OF THIS PROJECT ARE DERIVED FROM GEODETIC POSITIONING USING REAL TIME KINEMATIC (RTK) GLOBAL POSITIONING SYSTEM (GPS) NETWORK ROVER THAT RECEIVED ON THE FLY POSITIONAL CORRECTIONS FROM THE MAINE TECHNICAL SOURCE COOPERATIVE NATIONAL GEODETIC SURVEY (NGS) CONTINUALLY OPERATING REFERENCE SYSTEM (CORS) BASED ON THE NORTH AMERICAN DATUM OF 1983 (2011) (NAD83) (CORS2011) (EPOCH 2010) HORIZONTAL DATUM (MASSACHUSETTS MAINLAND STATE PLANE COORDINATE SYSTEM ZONE 2001). COORDINATE VALUES OBTAINED WERE AVERAGED FROM MULTIPLE OBSERVATIONS TAKEN AT DIFFERENT TIMES ON DIFFERENT DAYS (SEPTEMBER 22 & 23, 2017) AT FOUR OF THE HORIZONTAL CONTROL TRAVERSE LOCATIONS. RTK GPS DERIVED NAD83 STATE PLANE COORDINATE SYSTEM ZONE 2001 MASSACHUSETTS MAINLAND, THE AVERAGE COMBINED SCALE FACTOR FOR THIS PROJECT SITE IS 0.99996736, AND THE UNITS OF THE COORDINATES, DISTANCES AND MEASURE DEPICTED HEREON ARE U.S. SURVEY FEET.

6. LOCATIONS AND OTHER UNDERGROUND UTILITIES I.E.: WATER MAINS, GAS MAINS, SEWER LINES, DRAIN LINES, ELECTRIC LINES, COMMUNICATION LINES LOCATIONS DEPICTED HEREON ARE TAKEN FROM A COMBINATION OF PLANS OF RECORD, FIELD LOCATIONS FROM DIG SAFE MARKINGS & STRUCTURE LOCATIONS, AND FROM DIGITIZING THE LOCATIONS FROM SCANNED PLANS THAT CONTAIN GRAPHICAL REPRESENTATIONS OF THE LOCATION WITHOUT DIMENSIONAL INFORMATION. AS SUCH THE LOCATION OF UNDERGROUND UTILITIES AND THE DAM CORE WALL LOCATIONS DEPICTED HEREON ARE APPROXIMATE IN NATURE AS RECREATING THE EXACT LOCATIONS IS BEYOND THE SCOPE OR NECESSITY OF THIS PROJECT, THEY ARE FOR ILLUSTRATIVE PURPOSES ONLY.

7. THE VERTICAL CONTROL ELEVATIONS DEPICTED HEREON ARE BASED ON THE ELEVATIONS OF THE NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD29) THAT WERE CONVERTED FROM NGVD29 TO THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 1988) REFERENCING THE MASS HIGHWAY SURVEY MANUAL DATUM PLANE RELATIONS TABLE. VERTICAL CONTROL AT THIS SITE WAS OBTAINED BY PERFORMING CLOSED LOOP DIFFERENTIAL LEVELING THROUGH THE PUBLISHED BENCHMARK AND THE LOCAL SITE BENCHMARKS AND TRAVERSE POINTS DEPICTED HEREON FROM PUBLISHED BENCH MARK MassDOT ID:4421, STATION #10033, A MASS. GEODETIC SURVEY DISK ON CONC. PEDESTAL ON GROUNDS OF NEWTON CITY HALL, CITY OF NEWTON ENGINEERING DIVISION FIELD BOOK 988 & 993.

NOTES (CONTINUED):

8. THIS PLAN IS THE ORIGINAL WORK OF THE CITY OF NEWTON ENGINEERING DEPARTMENT. IT IS A VIOLATION OF LAW FOR ANYONE TO REPRESENT THIS PLAN AS THEIR OWN ORIGINAL WORK, WITH OR WITHOUT EDITING. IT IS A VIOLATION OF LAW TO EDIT THIS PLAN AND CONTINUE TO REPRESENT IT AS THE ORIGINAL WORK OF THE CITY OF NEWTON ENGINEERING DEPARTMENT.

9. BY VISUAL REVEIW AND SCALE, DEXTER RD AND BULLOUGHS POND IS NOT LOCATED WITHIN FLOOD ZONE X (AREAS OUTSIDE TH E0.02% ANNUAL CHANCE FLOODPLAIN) NOR FLOOD ZONE X (AREAS OF 0.2% ANNUAK CHANCE FLOOD) AS SHOWN ON NATIONAL FLOOD INSURANCE PROGRAM (NFIP) FLOOD INSURANCE RATE MAP (FIRM) NUMBER 25017C0554E WITH AN EFFECTIVE DATE OF JUNE 4, 2010.

10. THE BORDERING VEGETATIVE WETLANDS (BVW) & BANK LOCATION FLAGS SHOWN HEREON WERE LOCATED IN THE FIELD. THE WETLAND FLAGS WERE HUNG BY JENNIFER STEELE, THE SENIOR ENVIRONMENTAL PLANNER FOR THE CITY OF NEWTON, TO DELINEATE THE EDGE OF BORDERING VEGETATED WETLANDS AND THE BANK.

11. THE COLD SPRING BROOK, COLEMAN BROOK, HAMMOND BROOK DRAINAGE CULVERTS AND ROADWAY DRAINAGE ARE THE SOURCE FOR THE WATER PASSING THROUGH BULLOUGHS POND AND THE BULLOUGHS POND SPILLWAY.

12. THE RIGHT OF WAY LINES DEPICTED HEREON REPRESENT A RETRACEMENT OF THE DEXTER ROAD AND BULLOUGH PARK THE RIGHTS OF WAY.

13. THIS PLAN DOES NOT SHOW ANY RECORDED, UNRECORDED OR UNWRITTEN EASEMENTS WHICH MAY EXIST. A REASONABLE AND DILIGENT ATTEMPT HAS BEEN MADE TO OBSERVE ANY APPARENT VISIBLE USES OF THE LAND; HOWEVER, THIS DOES NOT CONSTITUTE A GUARANTEE THAT NO SUCH EASEMENTS EXIST.

LEGEND

SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
DH/SB	DRILL HOLE/ STONE BOUND	C.B.	CATCH BASIN		BENCHMARK
D.H.	DRILL HOLE	(D) D.M.H.	DRAIN MANHOLE	CTRL.CAB.	CONTROL CABINET (TRAFFIC)
I.R	IRON ROD	(S) S.M.H.	SEWER MANHOLE	PB	PULL BOX
I.P.	IRON PIPE	(W)	WATERMAIN MANHOLE	VAR.	VARIABLE
C.B.	CONCRETE BOUND	M.W.R.A.	MA WATER RESOURCES AUTHORITY	X 106.02	EXISTNG SPOT GRADE
CTR./S.B.	CENTER/ STONE BOUND	(T)	TELEPHONE MANHOLE	APPR.	APPROXIMATE
CRNR./S.B.	CORNER/ STONE BOUND	(E)	ELECTRIC MANHOLE	UGU	UNDERGROUND UTILITIES
E.P./L.P.	ESCUTCHEON PIN/LEAD PLUG	(OT)	MANHOLE OTHER	PKWY.	PARKWAY
I.P./C.B.	IRON PIPE/CONCRETE BOUND		SIGN	BK.	BOOK
BIT.	BITUMINOUS	WV	WATER GATE	PG.	PAGE
CONC.	CONCRETE	WG	WATER GATE	S.D.	SOUTH DISTRICT
B.G.	BELOW GRADE	ULT	UTILITY POLE W/ LIGHT	M.C.R.D.	MIDDLESEX COUNTY REGISTRY OF DEEDS
GRAN.	GRANITE		UTILITY POLE	SPCS	STATE PLANAR COORDINATE SYSTEM
S.	SET	UPL	UTILITY POLE	BLDG.	BUILDING
F.	FOUND	GW	GUY	PL.BK.	PLAN BOOK
N/F	NOW OR FORMERLY		HYDRANT	EOP	EDGE OF PAVEMENT
CLF	CHAIN LINK FENCE		LIGHT	DYCL	DOUBLE YELLOW CENTER LINE
GG	GAS GATE	OVRHDW	OVERHEAD WIRES	CEM.	CEMENT
PS	PARKING SPACE	UGE	UNDERGROUND ELECTRIC WIRES	CONC.	CONCRETE

SCALE: 1"=20'

20 0 10 20

EXISTING CONDITIONS
TOPOGRAPHIC PLAN OF LAND
IN
NEWTON, MA

BULLOUGHS POND DAM
DEXTER ROAD & BULLOUGHS POND

PREPARED FOR:

CITY OF NEWTON, MA

SCALE: AS NOTED
DATED: 10/2/2019
REVISION DATED:

PREPARED BY:

THE CITY OF NEWTON ENGINEERING DEPARTMENT
1000 COMMONWEALTH AVE. – NEWTON MASS. 02459
617–796–1020

Appendix D

References

PREVIOUS REPORTS AND REFERENCES

The following is a list of reports that were located during the file review, or were referenced in previous reports.

1. GZA GeoEnvironmental, Inc., Follow Up Inspection/Evaluation Report, April 2020.

2. "Existing Conditions Topographic Plan of Bulloughs Pond Dam Spillway Culvert in Newton, MA" Prepared for City of Newton, MA by the City of Newton Engineering Department, dated October 7, 2019.

3. GZA GeoEnvironmental, Inc., Follow Up Inspection/Evaluation Report, July 2019.

4. GZA GeoEnvironmental, Inc., Follow Up Inspection/Evaluation Report, January 2019.

5. Pare Corporation., Follow Up Inspection/Evaluation Report, June 2018.

6. Ninth Edition of the MA State Building Code 780 CMR Amendments to the 2015 IBC International Codes published by the International Code Council (IBC).

7. 2015 International Codes published by the International Code Council (IBC)

8. The History of Bullough's Pond" webpage, researched and prepared by the Bullough's Pond Association, http://www.bulloughspond.org/the-history-of-bulloughs-pond.html

9. National Inventory of Dams (NID) database, https://nid.sec.usace.army.mil/ords/f?p=105:113:10544599320348::NO:113,2:P113_RECORDID:31354

10. "Partial Duration Series (by Station), Station ID #190535 – BEDFORD", period of record 1957 through 2008, http://precip.eas.cornell.edu/

11. Idriss, I.M. and Boulanger, R.W. (2008). Soil Liquefaction During Earthquakes. Earthquake Engineering Research Institute. Oakland, California. EERI Publication No. MNO-12.

12. "Bridge Replacement Unit Costs 2017" United States Department of Transportation Federal Highway Administration. http://www.fhwa.dot.gov/bridge/nbi/sd2017.cfm

13. Department of Conservation and Recreation Dam Detail Sheet, September 2006.

14. FHWA IF-02-034, Originally published by GeoSyntec Consultants, Inc. Geotextile Filter Design Manual, 1991.

15. "Bedrock Geologic Maps of the Boston North, Boston South, and Newtown Quadrangles, Massachusetts Sheet 1 of 2" by Clifford A. Kaye dated 1980

16. Cedergren, H.R., Seepage, Drainage and Flow Nets, 1977.

17. Justin, Hinds and Creager, "Engineering for Dams"; Vol. III; John Wiley & Sons. 1961.

18. “Plan and Profile Showing Sewer and Showing Assessment”, City of Newton, February 6, 1922.

19. “Plan and Profile of Drain in Walnut Street, Laundry Brook to Mill Street, Mill Street, Walnut Street, Woodside Road”, City of Newton., December 1904.

20. “Plan and Profile of Private Land and Dexter Road Sewer, Walnut Street Toward Bullough Park, Showing Assessment”, City of Newton, December 15, 1898.

21. “Profile of Culvert Walls at Dexter Road, Bulloughs Pond Improvements”, City of Newton, June 1898.

22. “Plan and Profile of Bullough Park Drain from Bullough’s Pond to Mill St.”, Bulloughs Pond Improvements”, City of Newton, June 1898.

23. “Details of Culvert and Waste Pipe, Bulloughs Pond Improvements”, City of Newton, September 1897.

24. “Plan of Proposed Sections of Roadways and Dam, Bulloughs Pond Improvements”, City of Newton, August 1897.

The following references were utilized during the preparation of this report and the development of the recommendations presented herein.

25. Commonwealth of Massachusetts Regulations, 302 CMR 10.00 – Dam Safety, Effective 10/30/2017.

Appendix E
Dam Safety Orders

dcr
Massachusetts

July 16, 2018
Certified Mail No. 7017 2620 0000 7578 6800
Return Receipt Requested

City of Newton
c/o the Honorable Ruthanne Fuller
1000 Commonwealth Ave
Newton, MA 02459

Subject: **CERTIFICATE OF NON-COMPLIANCE and DAM SAFETY ORDER**

Dam Name:	Bulloughs Pond Dam
Location:	Newton
National ID No:	MA03414
Known Condition:	Poor
Hazard Potential:	Significant
Middlesex Registry of Deeds:	Book 2618, Page 2

Dear Mayor Fuller:

In accordance with 302 CMR 10.08, the Department of Conservation and Recreation (DCR), Office of Dam Safety (ODS) has determined that Bulloughs Pond Dam does not meet accepted dam safety standards and is a potential threat to public safety. Therefore, DCR hereby issues a **CERTIFICATE OF NON-COMPLIANCE and DAM SAFETY ORDER**.

ODS records indicate that the City of Newton is the Owner of the Bulloughs Pond Dam, National Inventory of Dams No. MA03414. ODS classifies the dam as a **Small Size, Significant Hazard Potential** Structure. Significant Hazard Potential Dams are dams that may cause the loss of life and property damage in the event of dam failure.

On May 2, 2017, and more recently on June 7, 2018, inspections of the Bulloughs Pond Dam were performed by engineering consultants PARE Corp., at the expense of the ODS. As a result of these inspections, the dam was determined to be **STRUCTURALLY DEFICIENT** and in **POOR** condition. The dam has been found to be in need of repair, breaching or removal to bring the dam into compliance with dam safety regulations.

The CERTIFICATE OF NON-COMPLIANCE is based on the above-referenced inspection report results which listed the observance of many deficiencies, including but not limited to:

- Unwanted vegetation in areas of the dam including large trees along the downstream slope;
- Scarping along the upstream slope and bare soils prone to erosion along the downstream slope;
- Deterioration/potential unstable headwall at the downstream end of the low-level outlet with observed scour/displaced riprap within the channel;
- Areas of scour along the downstream channel including at the low-level outlet and along the left and right banks. If erosion of the left bank continues, it could encroach on the toe of the downstream slope;
- Mortar is missing from some joints of the spillway training walls; and
- Additional maintenance deficiencies and dam safety concerns.

These foregoing deficiencies compromise the structural integrity of the dam and present a potential threat to public safety. ODS has determined that the dam needs to be repaired, breached or removed in order to bring the dam into compliance with dam safety regulations.

G.L. c. 253, Sections 44-48 and 302 CMR 10.00 set forth the jurisdiction for ODS and its authority to take action and order actions to be taken. For your information a copy of the Dam Safety Regulations, 302 CMR 10.00 Dam Safety, can be found on the ODS website.

DAM SAFETY ORDER:

In accordance with the authority of G.L. c. 253, Section 47, 302 CMR 10.07 and 10.08 you are hereby **ORDERED** to comply with the following:

1) **Conduct Follow-up Inspections:** You shall complete follow-up visual inspections at six (6)-month intervals, conducted by a registered professional civil engineer qualified to conduct dam inspections, at your cost, until adequate repairs are made or the dam is adequately breached. You shall submit the first Follow-up inspection to ODS no later than **December 7, 2018**.

   Follow-up inspections are to be summary in format and shall provide a written description, including photographs, of any changes in condition. Your engineer is to use the attached ODS Poor Condition Dam Follow-up Inspection Form to report follow-up inspection findings. The form is also available electronically on the ODS web site. Your engineer shall include a cover letter on engineering firm letterhead that briefly summarizes the current follow-up inspection and findings.

You shall submit one (1) hard copy printed double-sided and one (1) electronic pdf copy of all completed follow-up visual inspection reports to ODS within thirty (30) days of the date of follow-up inspection field work.

2) **Conduct Phase II Inspection and Investigations**. You shall hire at your cost, a qualified registered professional engineer with dam engineering experience (engineer) to conduct a Phase II Inspection and Investigation of the dam to evaluate the structural integrity and spillway hydraulic adequacy of your dam and to develop/implement a plan to bring the dam into compliance with dam safety regulations by adequately repairing, breaching or removing the dam (see attached Phase II Investigation Outline).

   a. You shall commence the Phase II Inspection and Investigation no later than **October 16, 2018**. The Phase II Inspection and Investigation is to conform to the attached Phase II Investigation Outline. You are to, in a letter to ODS, no later than **October 2, 2018,** identify your selected engineer and inform ODS of the start date of the Phase II work.

   b. The Phase II Inspection and Investigation is to be completed, signed and stamped by your engineer and copies of the Phase II final report are to be delivered to ODS no later than **January 16, 2019**.

   You shall include a cover letter with the submitted Phase II report which describes your selected alternative to bring the dam into compliance with dam safety regulations. The owner shall submit a statement of your intent to implement inspection report recommendations to address structural and operational deficiencies to ODS upon submission of the required Phase II Inspection and Investigation completed by your engineer.

3) **Bring the dam into compliance and complete all repair, breach or removal work no later than January 16, 2020.** With your Phase II submittal, you must also provide a proposed timeline to design, permit and construct the selected alternative to repair, breach or remove the dam. The selected alternative must be completed, and the dam brought into compliance with Dam Safety regulations, by January 16, 2020.

4) **Additional Requirements:**
   a. You shall furnish copies of all required submittals listed above via certified mail.

   b. In order to maintain compliance with the Commonwealth's Wetlands Protection Laws you may have to seek requisite approval from your local Conservation Commission in accordance with G.L. c. 131, §40. You are obligated to contact and maintain communication with the Newton Conservation Commission and any other local, state or federal permitting agency the ensure compliance with the Wetlands Protection Act and any other regulatory requirements.

c. You must inform the following parties about the condition of the dam and your developing plans to bring the dam into compliance with dam safety regulations: all abutters of the impoundment upstream; property owners within one-half mile downstream of the Bulloughs Pond Dam; Northeast District, Division of Fisheries & Wildlife, 85 Fitchburg Rd, Ayer, MA 01432; Regional Director, Department of Environmental Protection, Northeast Region, 205B Lowell St, Wilmington, MA 01887; Conservation Commission, 1000 Commonwealth Ave, Newton, MA 02459; Emergency Management Director, 1164 Centre St, Newton, MA 02459.

Please be advised that in accordance with G.L. c. 253, § 47, "any person who fails to comply with the provisions of this chapter or of any order, regulation or requirement of the department relative to dam safety, shall be fined an amount not to exceed $5,000 for each offense, to be fixed by the court." Furthermore, each violation shall be regarded as a separate and distinct offense and, in case of a continuing violation, each day's continuance thereof shall be deemed to be a separate and distinct offense.

Nothing in this order releases the owner from the requirements of any prior Dam Safety Order issued for this dam.

In accordance with 302 CMR 10.08, this CERTIFICATE OF NON-COMPLIANCE and DAM SAFETY ORDER will be recorded by the DCR at the Registry of Deeds in the county where the dam lies. Issuance of a Certificate of Compliance following adequate repair or breaching of the dam will be required to discharge the CERTIFICATE OF NON-COMPLIANCE and DAM SAFETY ORDER.

Please direct any technical questions, correspondence, or submittals to Emily Caruso, Department of Conservation and Recreation, Office of Dam Safety, 180 Beaman Street, West Boylston, MA 01583 or Emily.Caruso@state.ma.us. Other questions regarding process and administration of Dam Safety regulations should be directed to Bill Salomaa, Director of Office of Dam Safety, at William.Salomaa@state.ma.us. Additional dam safety information can be found at the DCR-ODS website: http://www.mass.gov/eea/agencies/dcr/conservation/dam-safety/.

Thank you for your cooperation.

Sincerely,

Leo Roy
Commissioner, DCR

Enclosure: June 2018 Follow-Up Inspection

CC: Senator Cynthia Stone Creem
Representative Kay Khan
Newton Emergency Management Director
Newton Conservation Commission
Barbara Newman, U.S. Army Corps
Northeast Region, DEP
Deirdre Buckley, MEPA
Northeast District, DFW
Rob Lowell, DCR
William Salomaa, DCR
Ariana Johnson, Esq., DCR
Nick Wildman, DER

Department of Conservation and Recreation
Office of Dam Safety
Phase II Inspection and Investigation Outline

I.	**Review of existing information..**
II.	**Updated Detailed Phase I surface inspection in compliance with Office of Dam Safety Phase I Inspection format..**
III.	**Subsurface Investigations – borings, sampling, analysis..................**
IV.	**Topographic Survey, wetlands flagging/delineation, of sufficient detail to support not only the Phase II effort, but sufficient for the future implementation of design phase...**
V.	**Stability and seepage analyses – Seismic and static stability evaluation of dam (upstream and downstream slopes, internal materials), seepage potential, internal erosion potential, piping potential..................**
VI.	**Hydrologic/Hydraulic Analysis and spillway inadequacy resolution...**
VII.	**Alternatives analysis and presentation of conceptual designs and associated estimated design, permitting and construction costs to bring the dam structure into compliance with Chapter 253 Section 44-48 and 302 CMR 10.00 Dam Safety Regulations by either executing selected repair plan or breach plan......................**
VIII.	**Final Report Presented to the Office of Dam Safety..**

Commonwealth of Massachusetts
Department of Conservation and Recreation
Office of Dam Safety Poor Condition Dam Follow-up Inspection Form

(Complete this inspection form and provide a cover letter on consulting firm letterhead that briefly summarizes the current follow-up inspection and findings. The cover letter shall be signed and stamped by the Registered Professional Engineer in charge of the inspection)

Dam Name:
Dam Owner:
Nat. ID Number:
Hazard Potential:
Location of Dam (town):
Coordinate location (lat, long):
Date of Inspection:
Weather:

Consultant Inspector(s): firm name and name of Registered Professional Engineer in charge of inspection.

Others in Attendance at Field Inspection: include list of names, affiliation and phone numbers.

Attachments: **Updated site sketch with photo locations, Updated photos, and copy of locus map from Phase I report and other applicable attachments.**

I. **Previous Inspection date/Overall Condition:**
- Date of most recent formal Phase I Inspection Report:
- List the overall condition reported in most recent Phase I Inspection Report:

II. **Previous Inspection Deficiencies:**
- List identified deficiencies in the most recent Phase I Inspection Report:

III. **Overall Condition of Dam at the Time of the Current Follow-up Inspection:**
  a. **State the current condition**
  b. **Have conditions changed since the previous inspection? Yes or no.**

IV. **Comparison of Current Conditions to Condition Listed in Previous Phase I Inspection Report:**
  a. **Have any of the deficiencies listed in the previous Phase I Inspection Report worsened?**
  b. **If yes, list the changes.**
  c. **Are there any additional deficiencies that have been identified in the current inspection?**

d. **If yes, list the deficiencies and describe.**

V. Dam Safety Orders:

- **List dam safety orders that have been issued to the dam owner pertaining to this dam.**

VI. Maintenance:

1. Indicate if there exists an operation and maintenance plan for the dam.
2. Indicate if it appears the dam is being maintained.

VII. Recommendations:

VIII. Other Comments or Observations:

IX. Updated Site Sketch with Photo Locations:

X. Updated Photos:

XI. Copy of Locus Map from Phase I Report:

XII. Other applicable attachment:

Laurie Gibeau

From:	Caruso, Emily (DCR) <emily.caruso@state.ma.us>
Sent:	Tuesday, March 3, 2020 10:12 AM
To:	Laurie Gibeau
Cc:	Jonathan Andrews; Louis M. Taverna
Subject:	RE: Bulloughs Pond Dam, Newton

Hi Laurie.

That extension is no problem at all. Please let us know if you need anything else.

Emily

Emily Caruso
DAM SAFETY ENGINEER
OFFICE OF DAM SAFETY

dcr MASSACHUSETTS DEPARTMENT OF CONSERVATION AND RECREATION

180 BEAMAN STREET | WEST BOYLSTON, MA | 01583
PH: (508) 792-7716 EXT. 41827

Email: Emily.Caruso@mass.gov
Website: www.mass.gov/dcr

From: Laurie Gibeau [mailto:Laurie.Gibeau@gza.com]
Sent: Tuesday, March 03, 2020 10:01 AM
To: Caruso, Emily (DCR)
Cc: Jonathan Andrews; Louis M. Taverna
Subject: Bulloughs Pond Dam, Newton

Hi, Emily-

Thanks for taking the time to chat with me on the phone. I appreciate that you will be giving the City of Newton an extension to complete the Phase II for Bulloughs Pond Dam. Based on discussions with the City and preliminary results of our evaluations, we should be able to get the Phase II to you by the beginning of May.

Please let me know if you have any questions.

Laurie A. Gibeau, P.E. (MA, CT, NY)
Project Manager | Dams Engineering
GZA | 249 Vanderbilt Avenue | Norwood, MA 02062
o: 781.278.5848 | c: 413.530.7540 | laurie.gibeau@gza.com | www.gza.com | LinkedIn

GEOTECHNICAL | ENVIRONMENTAL | ECOLOGICAL | WATER | CONSTRUCTION MANAGEMENT
Known for excellence. Built on trust.

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For information about GZA GeoEnvironmental, Inc. and its services, please visit our website at www.gza.com.

Appendix F
Soil Boring Logs

LEGEND

SOIL BORING BY NEW ENGLAND BORING CONTRACTORS AND OBSERVED BY GZA ON FEBRUARY 25 AND 26, 2020. GZA-1, GZ-2, AND GZ-3 SURVEYED BY CITY OF NEWTON. GZ-4 WAS LOCATED BASED ON LINE OF SIGHT TO EXISTING SITE FEATURES.

NO.	ISSUE/DESCRIPTION	BY	DATE

UNLESS SPECIFICALLY STATED BY WRITTEN AGREEMENT, THIS DRAWING IS THE SOLE PROPERTY OF GZA GEOENVIRONMENTAL, INC. (GZA). THE INFORMATION SHOWN ON THE DRAWING IS SOLELY FOR USE BY GZA'S CLIENT OR THE CLIENT'S DESIGNATED REPRESENTATIVE FOR THE SPECIFIC PROJECT AND LOCATION IDENTIFIED ON THE DRAWING. THE DRAWING SHALL NOT BE TRANSFERRED, REUSED, COPIED, OR ALTERED IN ANY MANNER FOR USE AT ANY OTHER LOCATION OR FOR ANY OTHER PURPOSE WITHOUT THE PRIOR WRITTEN CONSENT OF GZA. ANY TRANSFER, REUSE, OR MODIFICATION TO THE DRAWING BY THE CLIENT OR OTHERS, WITHOUT THE PRIOR WRITTEN EXPRESS CONSENT OF GZA, WILL BE AT THE USER'S SOLE RISK AND WITHOUT ANY RISK OR LIABILITY TO GZA.

BULLOUGH'S POND DAM

NEWTON, MASSACHUSETTS

BORING LOCATION PLAN

PREPARED BY:

GZA GeoEnvironmental, Inc.
Engineers and Scientists
www.gza.com

PREPARED FOR:

PROJ MGR: LAG	REVIEWED BY: JDA	CHECKED BY: PFS	FIGURE
DESIGNED BY: LAG	DRAWN BY: City of Newton	SCALE: N.T.S	F1
DATE: 04-01-2020	PROJECT NO. 01.0174021.00	REVISION NO.	

© 2013 – GZA GeoEnvironmental, Inc. GZA-C:\Users\daniel.mcgraw\Documents\1.CompanionFolder\174021-00\BULLOUGHS_POND_DAM – Alt Figure.dwg [SHEET] April 01, 2020 – 3:31pm daniel.mcgraw

TEST BORING LOG

GZA GeoEnvironmental, Inc. *Engineers and Scientists*	**City of Newton DPW** **Bulloughs Pond Dam Phase II** **Dexter Road** **Newton, Massachusetts**	**BORING NO.:** GZ-1 **SHEET:** 1 of 1 **PROJECT NO:** 01.0174021.00 **REVIEWED BY:**

Drilling Co.: New England Boring Contractors **Foreman:** Gary Twombley **Logged By:** Cody Gibb	**Type of Rig:** Truck **Rig Model:** CME 75 **Drilling Method:** Drive & Wash	**Boring Location:** See Plan **Ground Surface Elev. (ft.):** 91.82 **Final Boring Depth (ft.):** 12 **Date Start - Finish:** 2/25/2019 - 2/25/2019	**H. Datum:** See Plan **V. Datum:** NAVD88

Auger/Casing Type: HW **I.D/O.D.(in):** 4"/4.5" **Hammer Weight (lb.):** 300 **Hammer Fall (in.):** 24 **Other:** Safety Hammer	**Sampler Type:** Split Spoon **I.D./O.D. (in.):** 1.375"/2" **Sampler Hmr Wt (lb):** 140 **Sampler Hmr Fall (in):** 30 **Other:** Auto Hammer

Groundwater Depth (ft.)

Date	Time	Water Depth	Casing	Stab. Time
Not	encountered.			

Depth (ft)	Casing Blows (ft/min)	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows (per 6 in.)	SPT Value	Sample Description and Identification (Modified Burmister Procedure)	Remark	Field Test Data	Stratum Description
									1		0.5 ASPHALT 91.3'
		S-1	1-3	24	12	21 10 9 7	19	S-1: (Top 6") Medium dense, brown to dark gray, fine to coarse SAND, some Gravel, little Silt. S-1: (Bottom 6") Medium dense, brown, fine to coarse SAND, some Silt, little Gravel.			ROAD SUBBASE 2 89.8'
		S-2	3-5	21	3	8 10 9 100/3"	19	S-2: Medium dense, reddish brown, GRAVEL, some fine to coarse Sand, little Silt.			EMBANKMENT FILL
5									2		5 86.8'
	14.25 9.5	C-1	7-12	60	56			C-1: Reddish brown CONCRETE, fresh to slightly weathered, moderately spaced to close fractures	3		CONCRETE STRUCTURE [POSSIBLE CORE WALL]
10	11.75 8.5 10.25										12 79.8'
								Bottom of boring at 12 feet.	4		
15											
20											
25											
30											

REMARKS

1. Ground surface elevation estimated from topographic survey by the City of Newton dated October 2, 2019.
2. Casing refusal encountered at 5 feet below ground surface (bgs).
3. Rollerbit refusal encountered at 7 feet bgs.
4. Boring backfilled with grout and bentonite to 0.25 feet bgs. Backfilled with cement to ground surface.

See Log Key for explanation of sample description and identification procedures. Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Boring No.: GZ-1

TEST BORING LOG

GZA GeoEnvironmental, Inc.
Engineers and Scientists

City of Newton DPW
Bulloughs Pond Dam Phase II
Dexter Road
Newton, Massachusetts

BORING NO.: GZ-2
SHEET: 1 of 1
PROJECT NO: 01.0174021.00
REVIEWED BY:

Drilling Co.: New England Boring Contractors	**Type of Rig:** Truck	**Boring Location:** See Plan	**H. Datum:** See Plan
Foreman: Gary Twombley	**Rig Model:** CME 75	**Ground Surface Elev. (ft.):** 91.87	
Logged By: Cody Gibb	**Drilling Method:** Drive & Wash	**Final Boring Depth (ft.):** 23	
		Date Start - Finish: 2/25/2019 - 2/25/2019	**V. Datum:** NAVD88

Auger/Casing Type: HW	**Sampler Type:** Split Spoon
I.D/O.D.(in): 4"/4.5"	**I.D./O.D. (in.):** 1.375"/2"
Hammer Weight (lb.): 300	**Sampler Hmr Wt (lb):** 140
Hammer Fall (in.): 24	**Sampler Hmr Fall (in):** 30
Other: Safety Hammer	**Other:** Auto Hammer

Groundwater Depth (ft.)

Date	Time	Water Depth	Casing	Stab. Time
2/25/19	0300	7		
2/26/19	0710	7.5		
2/26/19	1420	6.5		

Depth (ft)	Casing Blows (ft/min)	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows (per 6 in.)	SPT Value	Sample Description and Identification (Modified Burmister Procedure)	Remark	Field Test Data	Stratum Depth (ft.)	Stratum Description	Elev. (ft.)
									1		0.5	ASPHALT	91.4'
									2				
5		S-1	5-7	24	6	5 4 6 5	10	S-1: Stiff, brown, fine to medium SAND and SILT & CLAY, little fine Gravel.					
		S-2	7-9	24	5	4 6 5 8	11	S-2: Stiff, brown, Clayey SILT, some fine to coarse Sand, little Gravel.				EMBANKMENT FILL	
10		S-3	9-11	24	0	7 4 2 2	6	S-3: No recovery.					
		S-4	11-13	24	0	3 3 6 3	9	S-4: No recovery. Gravel in split spoon.					
		S-5	13-14	14	4	1 4 100/2"	R				14		77.9'
15	13.5, 11.5, 13.5, 27.5	C-1	14-18	48	44			C-1: Hard, slightly weathered, amorphous to medium grained, greenish gray, ARGILLITE, with very thin, moderately dipping foliation and smooth, planar, close to moderately close, subhorizontal jointing.	3				
20	12, 9.25, 10.75, 11, 9.5	C-2	18-23	60	48			C-2: Hard, slightly weathered, amorphous to medium grained, greenish gray, ARGILLITE, with very thin, moderately dipping foliation and smooth, planar, close to moderately close, subhorizontal jointing.	4		23	BEDROCK	68.9'
25								Bottom of boring at 23 feet.	5				
30													

REMARKS

1. Ground surface elevation estimated from topographic survey by the City of Newton dated October 2, 2019.
2. Blind drill from 0 to 5 feet below ground surface (bgs).
3. Casing refusal at 14 feet bgs. Rollerbit refusal encountered at 14 feet bgs.
4. Core barrel jammed at 18 feet bgs. Terminated core.
5. Boring converted to observation well at completion of drilling.

See Log Key for explanation of sample description and identification procedures. Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Boring No.: GZ-2

TEST BORING LOG

GZA GeoEnvironmental, Inc.
Engineers and Scientists

City of Newton DPW
Bulloughs Pond Dam Phase II
Dexter Road
Newton, Massachusetts

BORING NO.: GZ-3
SHEET: 1 of 1
PROJECT NO: 01.0174021.00
REVIEWED BY:

Drilling Co.: New England Boring Contractors
Foreman: Gary Twombley
Logged By: Cody Gibb

Type of Rig: Truck
Rig Model: CME 75
Drilling Method: Drive & Wash

Boring Location: See Plan
Ground Surface Elev. (ft.): 92.2
Final Boring Depth (ft.): 11.5
Date Start - Finish: 2/26/2019 - 2/28/2019

H. Datum: See Plan
V. Datum: NAVD88

Auger/Casing Type: HW
I.D/O.D.(in): 4"/4.5"
Hammer Weight (lb.): 300
Hammer Fall (in.): 24
Other: Safety Hammer

Sampler Type: Split Spoon
I.D./O.D. (in.): 1.375"/2"
Sampler Hmr Wt (lb): 140
Sampler Hmr Fall (in): 30
Other: Auto Hammer

Groundwater Depth (ft.)

Date	Time	Water Depth	Casing	Stab. Time
2/26/19	1420	7		

Depth (ft)	Casing Blows (ft/min)	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows (per 6 in.)	SPT Value	Sample Description and Identification (Modified Burmister Procedure)	Remark	Field Test Data	Stratum Depth (ft.)	Stratum Description	Stratum Elev. (ft.)
		S-1	0-2	24	11	3 2 6 6	8	S-1: Loose, dark brown, fine to coarse SAND, some Silt, little Gravel, moist.	1			TOPSOIL	
											2		90.2'
		S-2	2-4	24	12	10 4 3 3	7	S-2: Medium stiff, brown, fine to medium SAND and SILT, little fine Gravel, moist.	2				
5		S-3	4-6	24	12	7 4 3 3	7	S-3: Medium stiff, brown, fine to medium SAND and SILT, little fine Gravel.					
		S-4	6-8	24	10	6 6 13 11	19	S-4: Very stiff, brown, fine to medium SAND and SILT, little fine Gravel.				EMBANKMENT FILL	
		S-5	8-10	24	5	15 7 3 2	10	S-5: Stiff, brown, fine to medium SAND and SILT, some fine to coarse Gravel.					
10		S-6	10-11.5	11	8	24 100/5"	R	S-6: (Top 5") Brown, fine to medium SAND, some Silt, little coarse Gravel.	3		10.5		81.7'
								S-6: (Bottom 3") Gray, SILT, little fine Sand, trace Gravel.	4 5		11.5	FINE GRAINED FOUNDATION SOIL	80.7'
								Bottom of boring at 11.5 feet.					
15													
20													
25													
30													

REMARKS

1. Ground surface elevation estimated from topographic survey by the City of Newton dated October 2, 2019.
2. Color change from dark brown to brown was observed in wash return at 2 feet below ground surface (bgs).
3. Casing encountered refusal at 10.5 feet bgs.
4. Rollerbit encountered refusal at 11.5 feet bgs.
5. Boring was converted to observation well at completion of drilling.

See Log Key for explanation of sample description and identification procedures. Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Boring No.: GZ-3

174021 BULLOUGHS POND DAM PHASE II.GPJ; STRATUM ONLY; 4/22/2020

TEST BORING LOG

GZA GeoEnvironmental, Inc.
Engineers and Scientists

City of Newton DPW
Bulloughs Pond Dam Phase II
Dexter Road
Newton, Massachusetts

BORING NO.: GZ-4
SHEET: 1 of 1
PROJECT NO: 01.0174021.00
REVIEWED BY:

Drilling Co.: New England Boring Contractors	**Type of Rig:** Truck	**Boring Location:** See Plan	**H. Datum:** See Plan
Foreman: Gary Twombley	**Rig Model:** CME 75	**Ground Surface Elev. (ft.):** 91.8	
Logged By: Cody Gibb	**Drilling Method:** Drive & Wash	**Final Boring Depth (ft.):** 13	
		Date Start - Finish: 2/26/2019 - 2/26/2019	**V. Datum:** NAVD88

Auger/Casing Type: HW	**Sampler Type:** Split Spoon
I.D/O.D.(in): 4"/4.5"	**I.D./O.D. (in.):** 1.375"/2"
Hammer Weight (lb.): 300	**Sampler Hmr Wt (lb):** 140
Hammer Fall (in.): 24	**Sampler Hmr Fall (in):** 30
Other: Safety Hammer	**Other:** Auto Hammer

Groundwater Depth (ft.)

Date	Time	Water Depth	Casing	Stab. Time
2/26/19	1330	6		

Depth (ft)	Casing Blows (ft/min)	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows (per 6 in.)	SPT Value	Sample Description and Identification (Modified Burmister Procedure)	Remark	Field Test Data	Stratum Depth (ft.)	Stratum Description	Elev. (ft.)
									1		0.5	ASPHALT	91.3'
									2				
									3				
5												EMBANKMENT FILL	
		S-1	7-9	24	3	23 16 12 19	28	S-1: Very stiff, brown, SILT, some fine to coarse Sand, little Gravel.					
10		S-2	9-11	24	3	45 22 8 9	30	S-2: Medium dense, brown, fine to coarse SAND, some Gravel, trace Silt. (Gravel stuck in spoon tip.)			11		80.8'
		S-3	11-13	24	6	10 6 3 2	9	S-3: Loose, brown, fine to medium SAND, some fine to coarse Gravel, little Sand.			13	FINE GRAINED FOUNDATION SOIL	78.8'
								Bottom of boring at 13 feet.	4, 5				
15													
20													
25													
30													

REMARKS

1. Ground surface elevation estimated from topographic survey by the City of Newton dated October 2, 2019.
2. Probe from 0 to 6 feet below ground surface (bgs).
3. Blind drill from 0 to 7 feet bgs.
4. Casing and rollerbit encountered refusal at 13 feet bgs.
5. Boring backfilled with bentonite grout to 0.25 feet bgs. Backfilled with cement to ground surface.

See Log Key for explanation of sample description and identification procedures. Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Boring No.: GZ-4

Appendix G
Geotechnical Laboratory Test Results

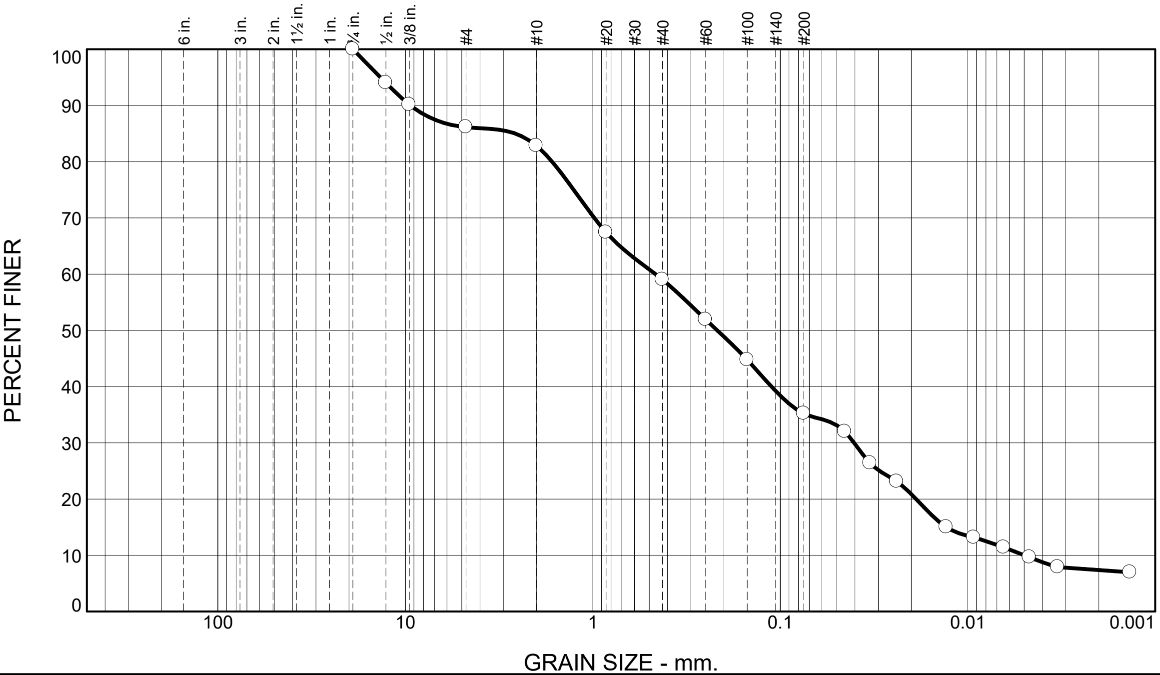
THIELSCH ENGINEERING	195 Frances Avenue Cranston RI, 02910 Phone: (401)-467-6454 Fax: (401)-467-2398 thielsch.com *Let's Build a Solid Foundation*	Client Information: GZA GeoEnvironmental Norwood, MA PM: Lauries Gibeau Assigned By: Cody Gibb Collected By: Cody Gibb	Project Information: **Bulloughs Pond Dam Phase II** **Newton, Massachusetts** GZA Project Number: 01.0174021.00 Summary Page: 1 of 1 Report Date: 03.13.19

LABORATORY TESTING DATA SHEET

				Identification Tests								Proctor / CBR / Permeability Tests								
Boring	Sample No.	Depth (ft)	Laboratory No.	As Received Water Content %	LL %	PL %	Gravel %	Sand %	Fines %	Org. %	G_s	Dry unit wt. pcf	Test Water Content %	γ_d MAX (pcf) W_{opt} (%)	γ_d MAX (pcf) W_{opt} (%) (Corr.)	Target Test Setup as % of Proctor	Thermal Resistivity @ 1.5% Moisture (°C*cm/W)	Thermal Resistivity @ Optimum Moisture (°C*cm/W)	Thermal Resistivity Oven Dried (°C*cm/W)	Laboratory Log and Soil Description
				D2216	D4318		D6913			D2874	D854			D1557			D5334			
GZ-2	S-1	5-7	S-1				13.9	50.9	35.2											Brown f-m SAND and SILT & CLAY, little fine Gravel
GZ-3	S-3	4-6	S-2				12.0	54.8	33.2											Brown f-m SAND and SILT, little fine Gravel
GZ-3	S-5	8-10	S-3				25.0	42.5	32.5											Brown f-m SAND and SILT, some f-c Gravel
GZ-3	S-6A	10-11	S-4				12.3	58.3	29.4											Brown f-m SAND, some Silt, little coarse Gravel
GZ-4	S-3	11-13	S-5				34.8	50.8	14.4											Brown f-m SAND, some f-c Gravel, little Silt

Date Received *03.06.19* Reviewed By: [signature] Date Reviewed: *03.13.2019*

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	13.9	3.2	23.9	23.8	27.8	7.4

Test Results (D7928 & ASTM D 1140)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
0.75"	100.0		
0.5"	94.0		
0.375"	90.2		
#4	86.1		
#10	82.9		
#20	67.4		
#40	59.0		
#60	51.9		
#100	44.8		
#200	35.2		
0.0453 mm.	32.0		
0.0332 mm.	26.4		
0.0239 mm.	23.1		
0.0130 mm.	15.0		
0.0093 mm.	13.2		
0.0064 mm.	11.4		
0.0047 mm.	9.6		
0.0033 mm.	7.9		
0.0014 mm.	7.0		

* (no specification provided)

Material Description

Brown f-m SAND and SILT & CLAY, little fine Gravel

Atterberg Limits (ASTM D 4318)

PL= **LL=** **PI=**

Classification

USCS (D 2487)= SC **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 9.3954 D_{85}= 2.5904 D_{60}= 0.4628
D_{50}= 0.2169 D_{30}= 0.0404 D_{15}= 0.0130
D_{10}= 0.0050 C_u= 92.65 C_c= 0.71

Remarks

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

Date Received: 03.06.19 **Date Tested:** 03.13.19

Tested By: RR / MN

Checked By: Steven Accetta

Title: Laboratory Coordinator

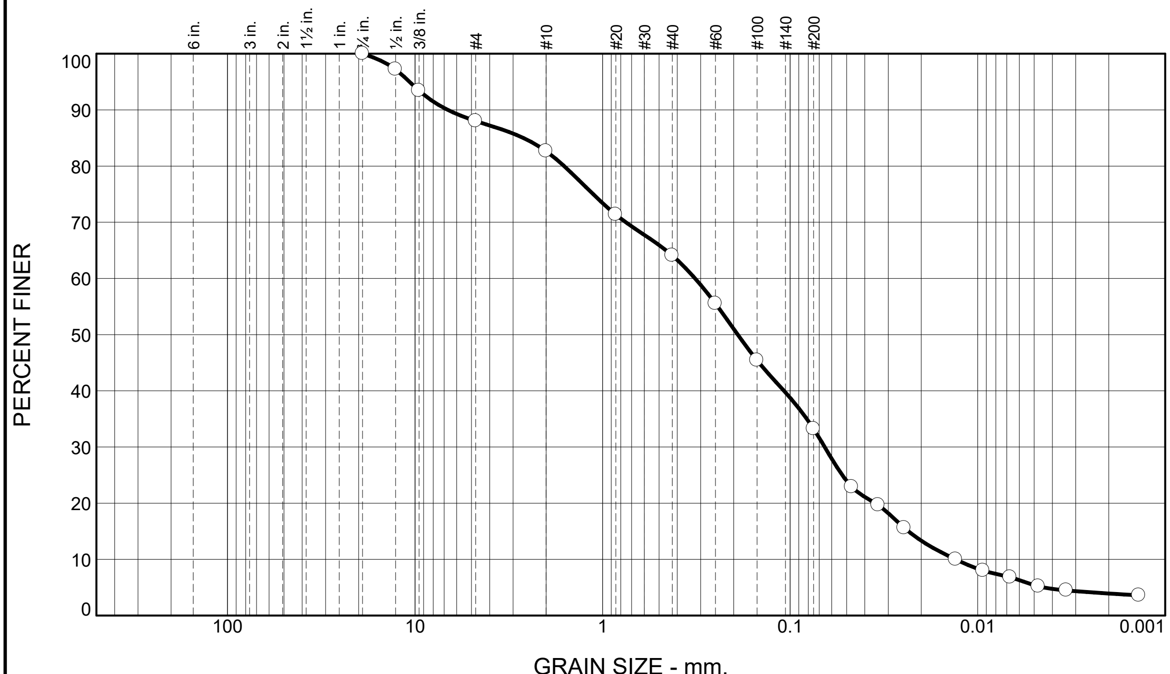
Source of Sample: Borings **Depth:** 5-7' **Date Sampled:**
Sample Number: GZ-2 / S-1

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: Bulloughs Pond Dam Phase II
Newton, Massachusetts
Project No: 01.0174021.00 **Figure** S-1

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	12.0	5.4	18.5	30.9	29.3	3.9

Test Results (D7928 & ASTM D 1140)			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
0.75"	100.0		
0.5"	97.2		
0.375"	93.4		
#4	88.0		
#10	82.6		
#20	71.4		
#40	64.1		
#60	55.5		
#100	45.4		
#200	33.2		
0.0469 mm.	22.9		
0.0339 mm.	19.6		
0.0246 mm.	15.6		
0.0131 mm.	10.0		
0.0094 mm.	8.0		
0.0067 mm.	6.8		
0.0047 mm.	5.2		
0.0034 mm.	4.5		
0.0014 mm.	3.6		

* (no specification provided)

Material Description

Brown f-m SAND and SILT, little fine Gravel

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

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

Coefficients

D_{90}= 6.6874 D_{85}= 2.6419 D_{60}= 0.3210
D_{50}= 0.1901 D_{30}= 0.0654 D_{15}= 0.0234
D_{10}= 0.0131 C_u= 24.52 C_c= 1.02

Remarks

Sample visually classified as non-plastic.

Date Received: 3.06.19 **Date Tested:** 3.13.19

Tested By: RR / MN

Checked By: Steven Accetta

Title: Laboratory Coordinator

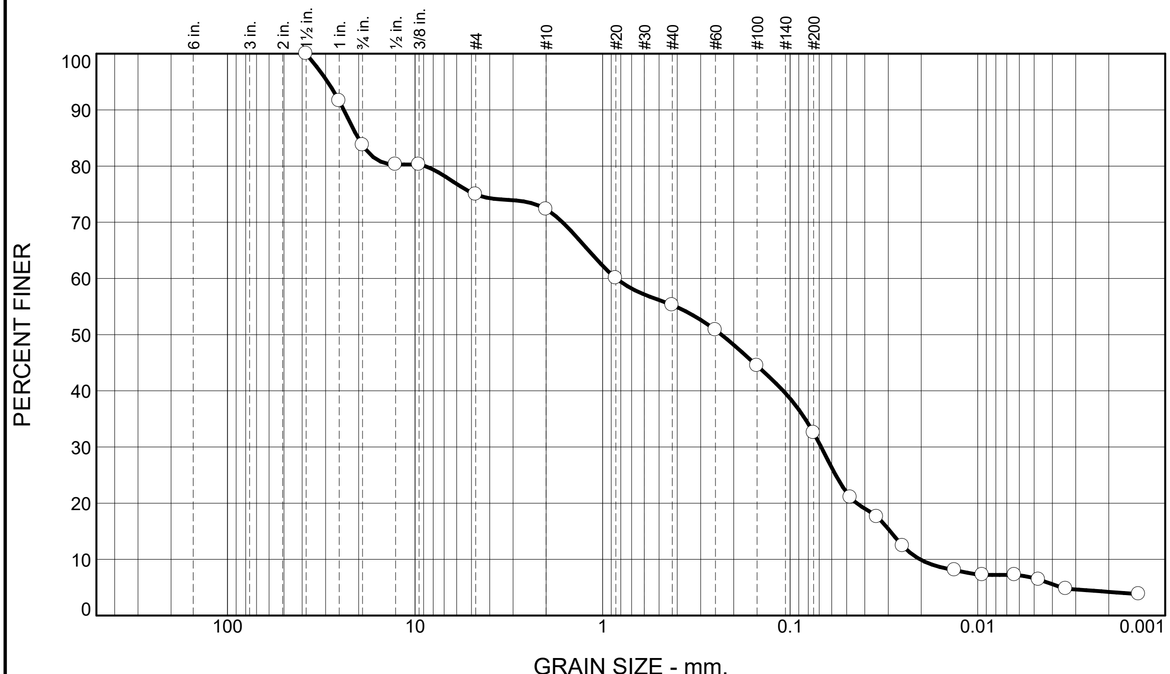
Source of Sample: Borings **Depth:** 4-6' **Date Sampled:**
Sample Number: GZ-3 / S-3

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: Bulloughs Pond Dam Phase II
Newton, Massachusetts
Project No: 01.0174021.00 **Figure** S-2

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	16.3	8.7	2.7	17.0	22.8	28.3	4.2

Test Results (D7928 & ASTM D 1140)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1-1/2"	100.0		
1"	91.6		
3/4"	83.7		
1/2"	80.3		
3/8"	80.3		
#4	75.0		
#10	72.3		
#20	60.1		
#40	55.3		
#60	50.8		
#100	44.5		
#200	32.5		
0.0478 mm.	21.0		
0.0345 mm.	17.6		
0.0251 mm.	12.4		
0.0133 mm.	8.1		
0.0094 mm.	7.2		
0.0064 mm.	7.2		
0.0047 mm.	6.4		
0.0034 mm.	4.8		
0.0014 mm.	3.8		

* (no specification provided)

Material Description

Brown f-m SAND and SILT & CLAY, some f-c Gravel

Atterberg Limits (ASTM D 4318)

PL= **LL=** **PI=**

Classification

USCS (D 2487)= SC **AASHTO (M 145)=** A-2-4(0)

Coefficients

D_{90}= 23.9757 D_{85}= 20.1028 D_{60}= 0.8450
D_{50}= 0.2325 D_{30}= 0.0683 D_{15}= 0.0293
D_{10}= 0.0203 C_u= 41.58 C_c= 0.27

Remarks

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

Date Received: 03.06.19 **Date Tested:** 3.13.19

Tested By: RR / MN

Checked By: Steven Accetta

Title: Laboratory Coordinator

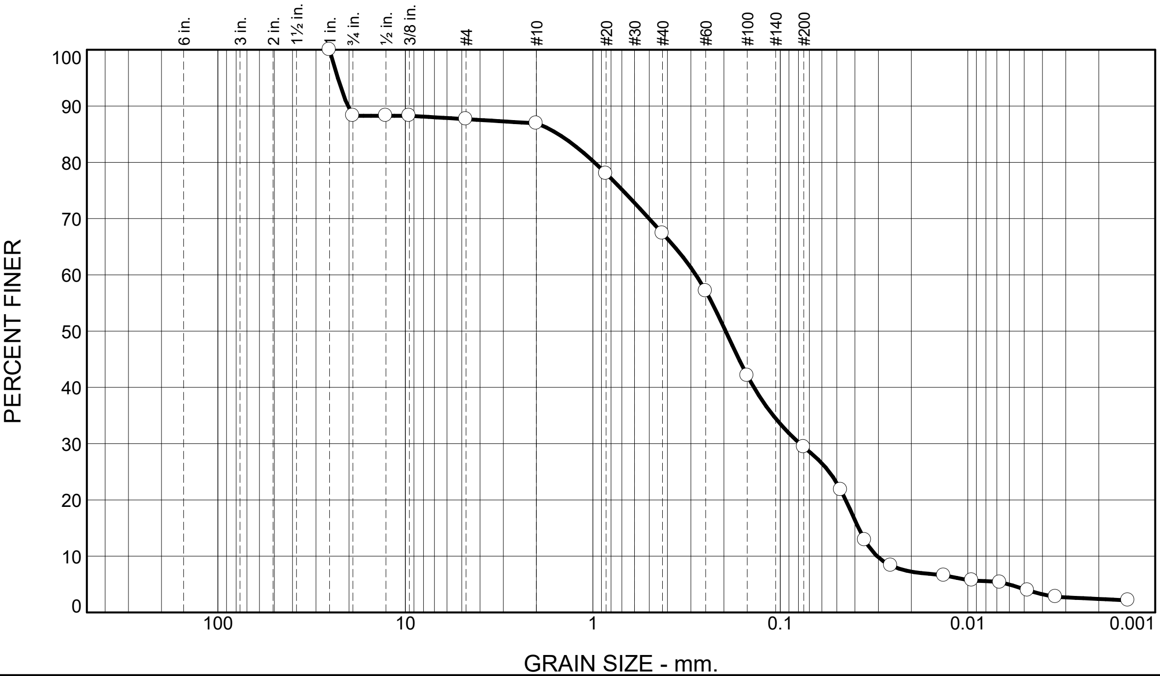
Source of Sample: Borings **Depth:** 8-10' **Date Sampled:**
Sample Number: GZ-3 / S-5

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: Bulloughs Pond Dam Phase II
Newton, Massachusetts
Project No: 01.0174021.00 **Figure** S-3

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	11.7	0.6	0.8	19.5	38.0	27.0	2.4

Test Results (D7928 & ASTM D 1140)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1"	100.0		
0.75"	88.3		
0.5"	88.3		
0.375"	88.3		
#4	87.7		
#10	86.9		
#20	78.0		
#40	67.4		
#60	57.1		
#100	42.1		
#200	29.4		
0.0476 mm.	21.8		
0.0354 mm.	12.9		
0.0257 mm.	8.4		
0.0134 mm.	6.6		
0.0095 mm.	5.7		
0.0067 mm.	5.3		
0.0048 mm.	3.9		
0.0034 mm.	2.8		
0.0014 mm.	2.2		

* (no specification provided)

Material Description

Brown f-m SAND, some Silt, little coarse Gravel

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

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

Coefficients

D_{90}= 20.2671 D_{85}= 1.5249 D_{60}= 0.2819
D_{50}= 0.1956 D_{30}= 0.0786 D_{15}= 0.0383
D_{10}= 0.0305 C_u= 9.25 C_c= 0.72

Remarks

Sample visually classified as non-plastic.

Date Received: 3.06.19 **Date Tested:** 03.13.19

Tested By: RR / MN

Checked By: Steven Accetta

Title: Laboratory Coordinator

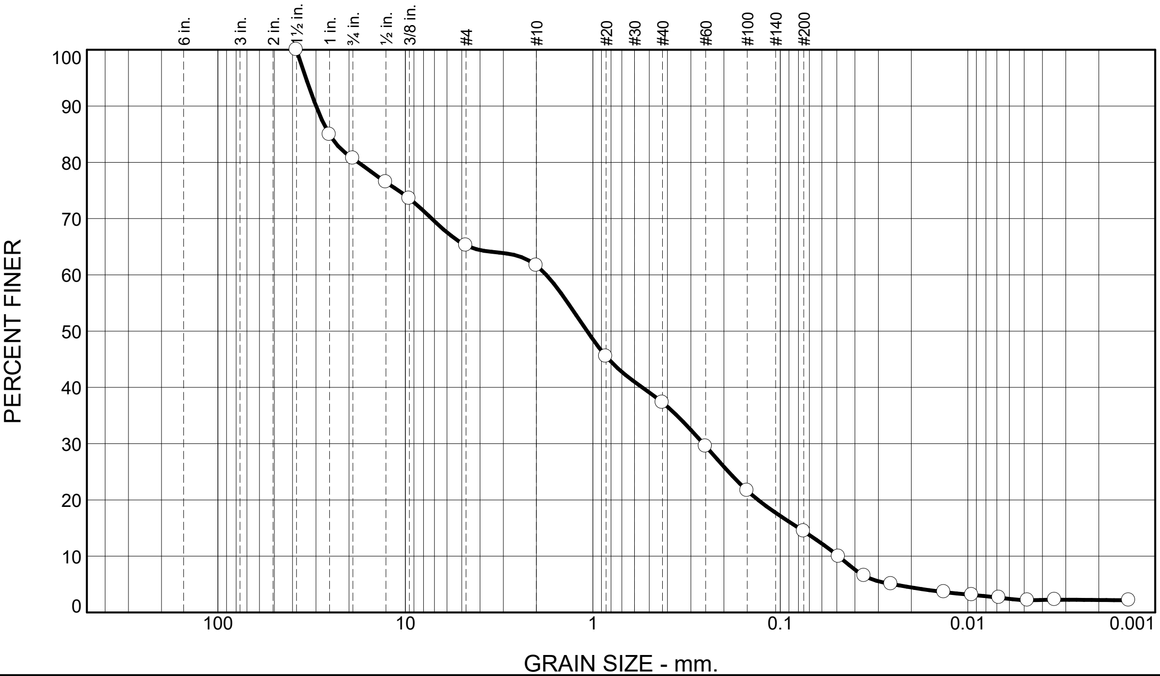
Source of Sample: Borings **Depth:** 10-11' **Date Sampled:**
Sample Number: GZ-3 / S-6A

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: Bulloughs Pond Dam Phase II
Newton, Massachusetts
Project No: 01.0174021.00 **Figure** S-4

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	19.3	15.5	3.5	24.4	22.9	12.2	2.2

Test Results (D7928 & ASTM D 1140)			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1-1/2"	100.0		
1"	84.9		
3/4"	80.7		
1/2"	76.5		
3/8"	73.6		
#4	65.2		
#10	61.7		
#20	45.5		
#40	37.3		
#60	29.5		
#100	21.6		
#200	14.4		
0.0488 mm.	9.9		
0.0357 mm.	6.5		
0.0256 mm.	5.1		
0.0134 mm.	3.6		
0.0095 mm.	3.1		
0.0068 mm.	2.6		
0.0048 mm.	2.2		
0.0034 mm.	2.3		
0.0014 mm.	2.2		

* (no specification provided)

Material Description

Brown f-m SAND, some f-c Gravel, little Silt

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

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

Coefficients

D_{90}= 29.9246 D_{85}= 25.4671 D_{60}= 1.7706
D_{50}= 1.0736 D_{30}= 0.2572 D_{15}= 0.0796
D_{10}= 0.0490 C_u= 36.14 C_c= 0.76

Remarks

Date Received: 3.06.19 **Date Tested:** 3.13.19

Tested By: RR / MN

Checked By: Steven Accetta

Title: Laboratory Coordinator

Source of Sample: Borings **Depth:** 11-13' **Date Sampled:**
Sample Number: GZ-4 / S-3

Thielsch Engineering Inc.

Cranston, RI

Client: GZA GeoEnvironmental
Project: Bulloughs Pond Dam Phase II
Newton, Massachusetts
Project No: 01.0174021.00 **Figure** S-5

Appendix H
Hydrologic & Hydraulic Analyses – Existing Conditions

Project Name: Bullough's Pond Dam Phase II H&H Analysis

Project Number: 01.0174021.00

File Name: HMS_Tc_CN_Calculations

Data Source: Tc lines drawn using USGS topo maps (1:24k scale), elevation data (contours and LiDAR) from MassGIS, and aerial photography downloaded form MassGIS

Date: 3/10/2020

Purpose: To calculate Tc and lag times for subbasins within the study area, as well as curve numbers for subbasins within study area

Notes:

Performed By: Daniel McGraw, E.I.T

Reviewed By: Christine E. Suhonen, P.E.

Review Date: 1/14/2020

Updates:

Date	Action/Comment	Performed by?	Check required?	Checked by	Checked date
4/2/2020	Original calculations	DEM			
11/15/2019	Updates to calculations	DEM	X	CES	1/14/2020
1/14/2020	Checked by Christine Suhonen				
1/15/2020	Updates to Christine Suhonen's comments	DEM			

Time of Concentration/Lag Time Calculations[1]

	Sheet flow (Eq. 15-8):								Shallow concentrated flow (Table 15-3)[5]:								Open Channel / Piped / Open Water Flow (Eq. 15-10 or Eq. 15-11)[6,6b]											TC	
Subwatershed	Len.[2] ft	Elev. Up ft	Elev. Down ft	Slope ft/ft	Surface Description	'n'[3]	P2[4] in	Travel Time hrs	Len. ft	Elev. Up ft	Elev. Down ft	Slope ft/ft	Surface Description	'n'	Vel. ft/s	Travel Time hrs	Len. ft	Elev. Up ft	Elev. Down ft	Slope ft/ft	Flow Type	Description	'n'	Dep. ft	Width ft	Vel. ft/s	Travel Time hrs	hrs	min
Bulloughs Dam	52.9	159.3	159.2	0.003	Smooth Surfaces	0.011	3.30	0.026	190	159.2	158.2	0.005	Paved	0.025	1.46	0.036	722	158.2	150.3	0.011	Piped Flow	Corrugated Metal Pipe	0.024	1	1	2.00	0.10	0.16	9.8
																	211	150.3	148.3	0.009	Piped Flow	Corrugated Metal Pipe	0.024	2	2	2.00	0.03	0.03	1.8
																	736	148.3	142.6	0.008	Piped Flow	Corrugated Metal Pipe	0.024	2	2	2.00	0.10	0.10	6.1
																	1029	142.6	85.8	0.055	Piped Flow	Corrugated Metal Pipe	0.024	2	2	2.00	0.14	0.14	8.6
Newton Centre Playground	74.6	166.4	164.8	0.021	Woods Light Underbrush	0.400	3.30	0.273	650	164.8	143.5	0.033	Short grass	0.073	1.26	0.143	1352	143.5	113.7	0.022	Piped Flow	Corrugated Metal Pipe	0.024	2	2	2.00	0.19	0.60	36.2
																	2162	113.7	88.9	0.011	Open Channel	Main Channel Straight Some Stones	0.035	5	11	2.00	0.30	0.30	18.0
Below Hammond	62.5	211.3	207.6	0.059	Prairie Grass Short	0.150	3.30	0.071	1345	207.6	173.8	0.025	Short grass	0.073	1.10	0.339	6064	165.8	120.6	0.007	Open Channel	Main Channel Straight Some Stones	0.035	4	8	2.00	0.84	1.25	75.1
									864	173.8	165.8	0.009	Paved	0.025	1.96	0.123	900	120.6	115.1	0.006	Open Channel	Main Channel Straight Some Stones	0.035	2	6	2.00	0.13	0.25	14.9
Commonwealth	74.8	220.4	217.0	0.045	Prairie Grass Short	0.150	3.30	0.092	1365	217.0	192.6	0.018	Paved	0.025	2.72	0.140	1524	192.6	154.9	0.025	Piped Flow	Corrugated Metal Pipe	0.024	2	2	2.00	0.21	0.44	26.6
																	1104	154.9	140.4	0.013	Piped Flow	Corrugated Metal Pipe	0.024	3	3	2.00	0.15	0.15	9.2
																	1655	140.4	124.8	0.009	Open Channel	Main Channel Straight Some Stones	0.035	3	6	2.00	0.23	0.23	13.8
																	721	124.8	114.3	0.015	Open Channel	Main Channel Straight Some Stones	0.035	3	6	2.00	0.10	0.10	6.0
Newton Cemetery	56.8	153.2	152.8	0.007	Prairie Grass Short	0.150	3.30	0.155	1611.6	152.8	134.0	0.012	Paved	0.025	2.20	0.204	2435.0	101.6	99.4	0.001	Open Channel	Main Channel Weeds/Stones	0.050	5	12	1.75	0.39	0.75	44.7
									1556.2	134.0	101.6	0.021	Short grass	0.073	1.00	0.430	2341.1	106.8	102.8	0.002	Open Channel	Main Channel Straight Some Stones	0.035	5	7	2.00	0.33	0.76	45.3
																	891.47	102.8	97.11	0.005	Open Channel	Main Channel Straight Some Stones	0.035	5	7	2.00	0.12	0.12	7.4
																	1451.4	97.1	89.1	0.006	Open Channel	Main Channel Straight Some Stones	0.035	5	7	2.00	0.20	0.20	12.1
Hammond Pond	76.2	188.6	184.6	0.053	Prairie Grass Short	0.150	3.30	0.087	1530.7	184.6	164.5	0.013	Paved	0.025	2.33	0.183	929.4	164.5	164.5	0.000	Body of Water	Main Channel Straight Some Stones	0.035	2	4	2.00	0.13	0.40	24.0
																	2175.0	164.5	163.4	0.001	Open Channel	Main Channel Sluggish Reach	0.070	4	15	0.91	0.67	0.67	40.0
HammondPond to Park1																	3378	163.4	137.4	0.008	Open Channel	Main Channel Sluggish Reach	0.070	2	10	2.00	0.47	0.47	28.2
HammondPond to Park2																	3469	137.4	114.5	0.007	Open Channel	Main Channel Straight Some Stones	0.035	2	8	2.00	0.48	0.48	28.9
Combined Park to City Hall																	3587	114.5	88.8	0.007	Open Channel	Main Channel Straight Some Stones	0.035	4	10	2.00	0.50	0.50	29.9
City Hall to Bullough's																	373	88.5	87.9	0.002	Open Channel	Main Channel Straight Some Stones	0.035	2	6	2.00	0.05	0.05	3.1

	TC		Lag
Subwatershed	hrs	min	min
Bulloughs Dam	0.44	26	16
Newton Centre Playground	0.90	54	33
Below Hammond	1.50	90	54
Commonwealth	0.93	56	33
Newton Cemetery	1.83	110	66
Hammond Pond	1.07	64	38

[1] Travel time was determined using the Nation Engineering Handbook (NEH) Section 630.1502 Methods for estimating time of concentration [(b) Velocity Method]
[2] Maximum sheet flow length guidance outlined in Eq. 15-9 and in Table 15-2
[3] Manning's roughness from Table 15-1 - Manning's roughness coefficients for sheet flow (flow depth generally ≤ 0.1 ft)
[4] P2 is the 2-year, 24-hour rainfall in inches obtained using the NOAA Atlas 14.
[5] Travel time for shallow concentrated flow calculated using Figure 15-4 / Table 15-3 from NEH-630.1502 (USDA NRCS, May 2010).
[6] Travel time for open channel flow was calculated assuming rectangular channel shape and assumed channel dimensions
[6-b] Channel depth and width estimated based on bankful dimensions as estimated using Stream Stats (or regression estimates)

				Unconnected Impervious Areas					Connected Impervious Areas	
					CN				CN	
Row Labels	**Sum of CN*Area**	**Sum of Area_ac**	**Sum of Imperv Area**	**% Imperv**	**Pervious**	**Composite[1]**	**R**	**tial Abstract[2]**	**Composite[1]**	**Initial Abstract[2]**
NewtonCentrePark	10655.5	140.91	78.1	55.4%	76	85	0.5	0.353	88	0.273
Below Hammond	36948.1	512.24	170.4	33.3%	72	78	0.5	0.564	81	0.469
Bulloughs Pond Dam	8519.8	116.25	57.1	49.1%	73	82	0.5	0.439	85	0.353
Commonwealth Ave	17036.7	213.44	123.3	57.8%	80	88	0.5	0.273	90	0.222
Newton Cemetery/Cold Spring Park	51529.5	780.48	266.7	34.2%	66	74	0.5	0.703	77	0.597
Hammond Pond	15566.1	204.42	68.1	33.3%	76	81	0.5	0.469	83	0.410
(blank)				#DIV/0!	#DIV/0!	#DIV/0!	0.5	#DIV/0!	#DIV/0!	#DIV/0!
Grand Total	**140255.8**	**1967.75**	**763.6**							

Row Labels	Sum of Area_ac
Below Hammond	512.24
Bulloughs Pond Dam	116.25
Commonwealth Ave	213.44
Hammond Pond	204.42
Newton Cemetery/Cold Spring Park	780.48
NewtonCentrePark	140.91
(blank)	
Grand Total	**1967.75**

Row Labels	Sum of Area_ac
3	309.42
4	10.17
6	4.36
7	37.12
11	585.07
12	440.34
13	53.02
15	98.18
16	1.87
17	0.13
20	33.16
31	67.62
37	57.87
38	13.37
10	146.18
18	14.01
34	95.66
26	0.20
(blank)	
Grand Total	**1967.75**

(2) Unconnected impervious areas

If runoff from impervious areas occurs over a pervious area as sheet flow prior to entering the drainage system, the impervious area is unconnected. To determine CN when all or part of the impervious area is not directly connected to the drainage system:

- use equation 9–2 or figure 9–4 if the total impervious area is less than 30 percent of the total area or
- use equation 9–1 or figure 9–3 if the total impervious area is equal to or greater than 30 percent of the total area, because the absorptive capacity of the remaining pervious areas will not significantly affect runoff.

$$CN_c = CN_p + \left(\frac{P_{imp}}{100}\right)(98 - CN_p)(1 - .05R) \quad (9\text{-}2)$$

where:
CN_c = composite runoff curve number
CN_p = pervious runoff curve number
P_{imp} = percent imperviousness
R = ratio of unconnected impervious area to total impervious area

When impervious area is less than 30 percent, obtain the composite CN by entering the right half of figure 9–4 with the percentage of total impervious area and the ratio of total unconnected impervious area to total impervious area. Then move left to the appropriate pervious CN and read down to find the composite CN.

Note: The equation incorrectly indicates 0.05R, whereas it should be 0.5R (see example problem and chart)

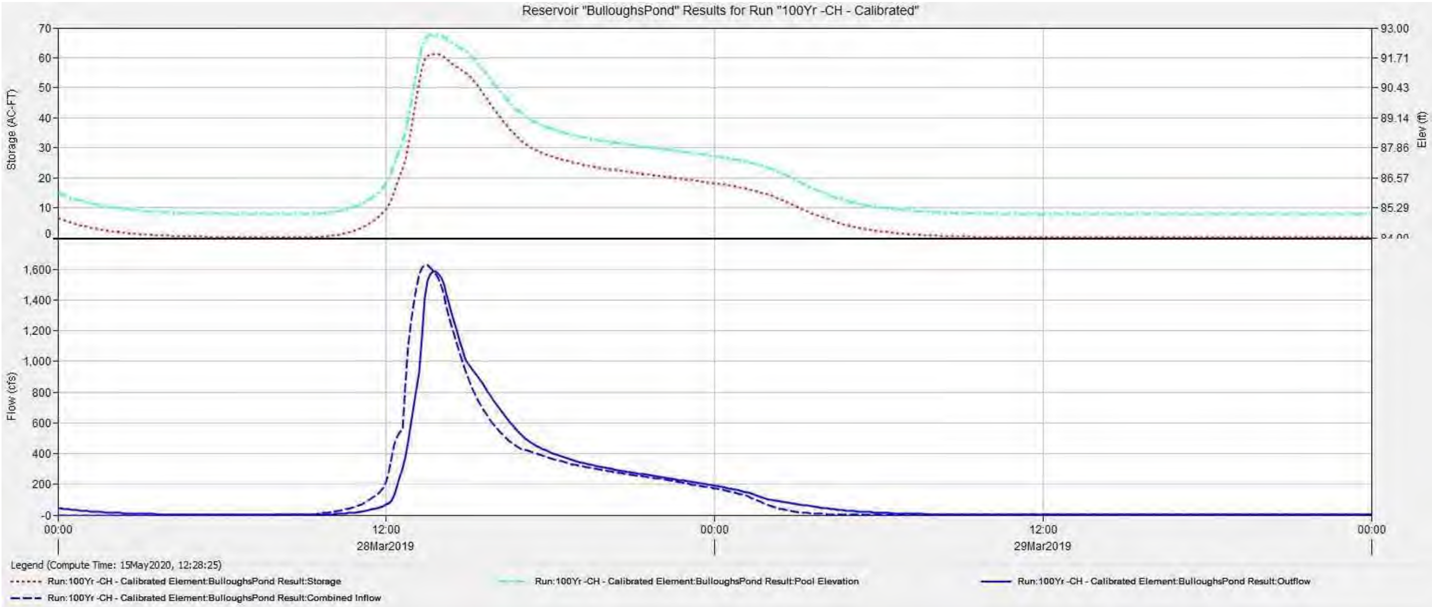
(1) Connected impervious areas

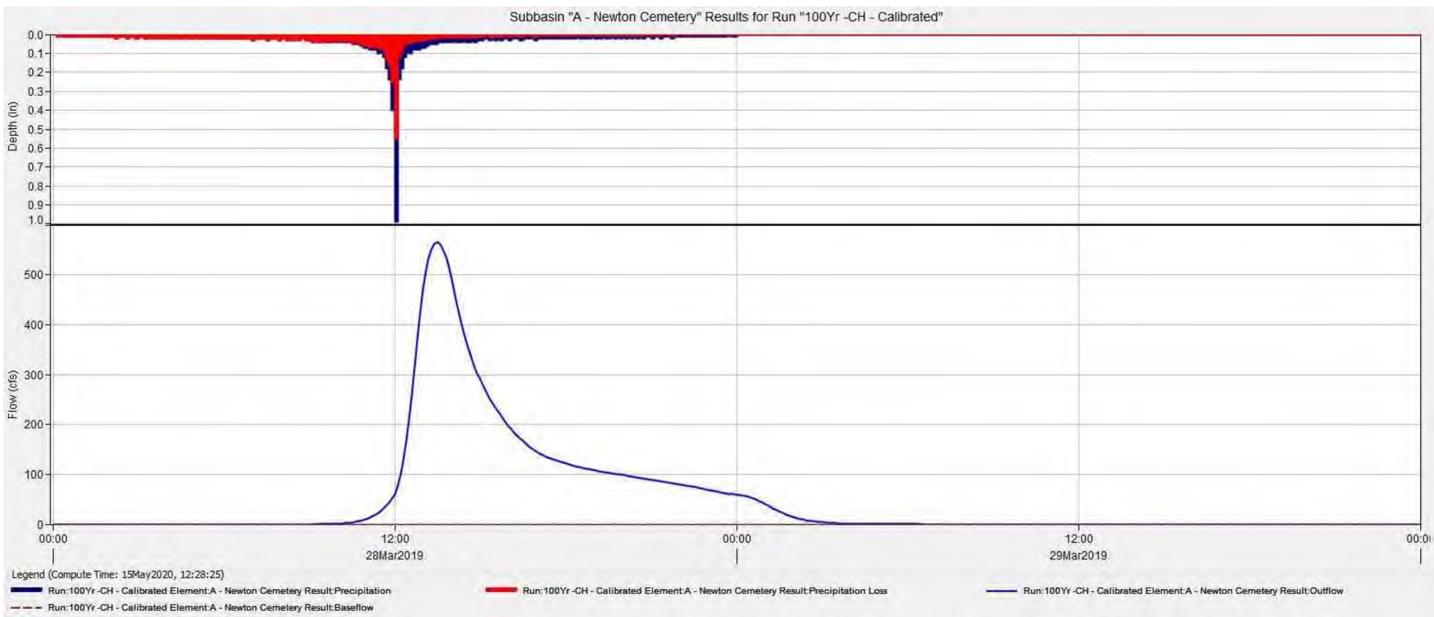
An impervious area is considered connected if runoff from it flows directly into the drainage system. It is also considered connected if runoff from it occurs as shallow concentrated flow that runs over a pervious area and then into a drainage system.

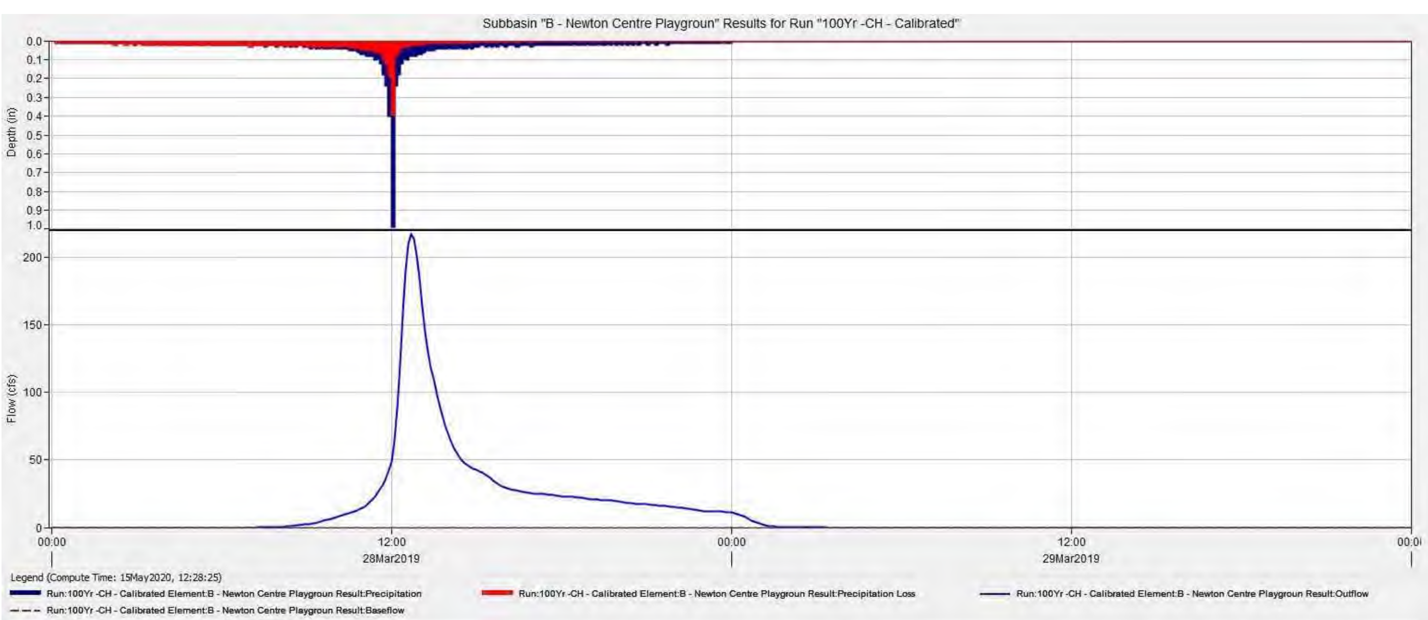
If all of the impervious area is directly connected to the drainage system, but the impervious area percentages in table 9–5 or the pervious land use assumptions are not applicable, use equation 9–1 or figure 9–3 to compute a composite CN.

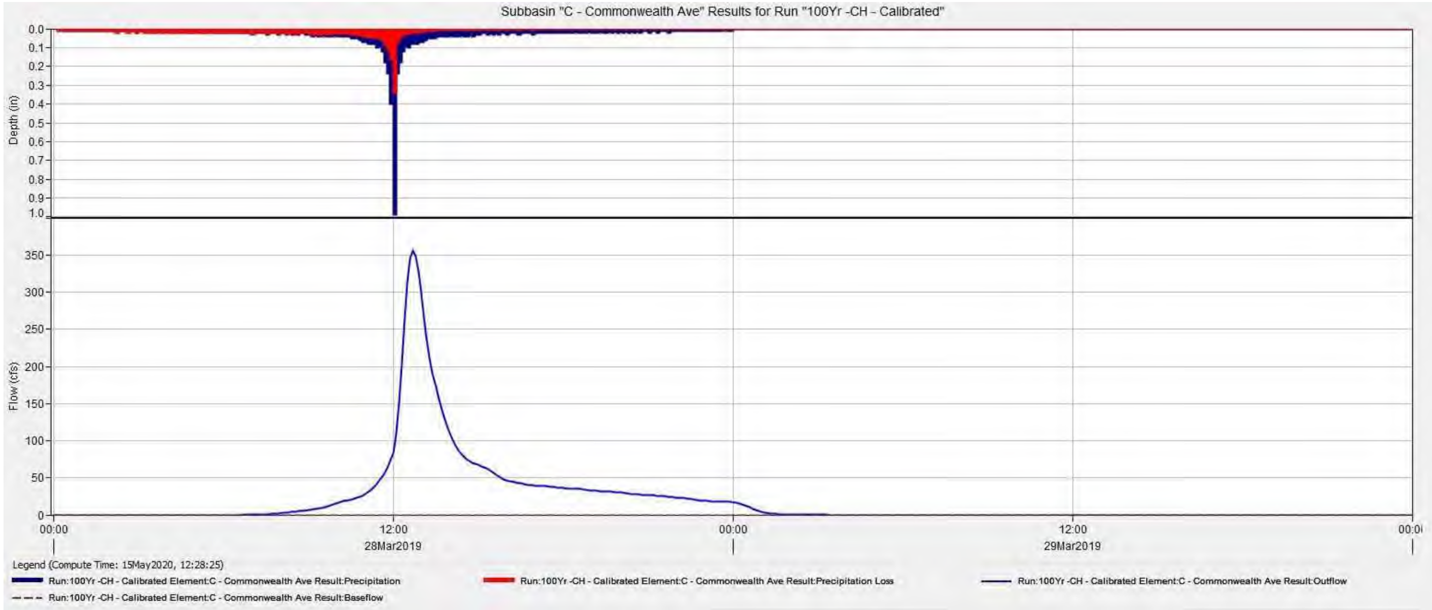
$$CN_c = CN_p + \left(\frac{P_{imp}}{100}\right)(98 - CN_p) \quad (9\text{-}1)$$

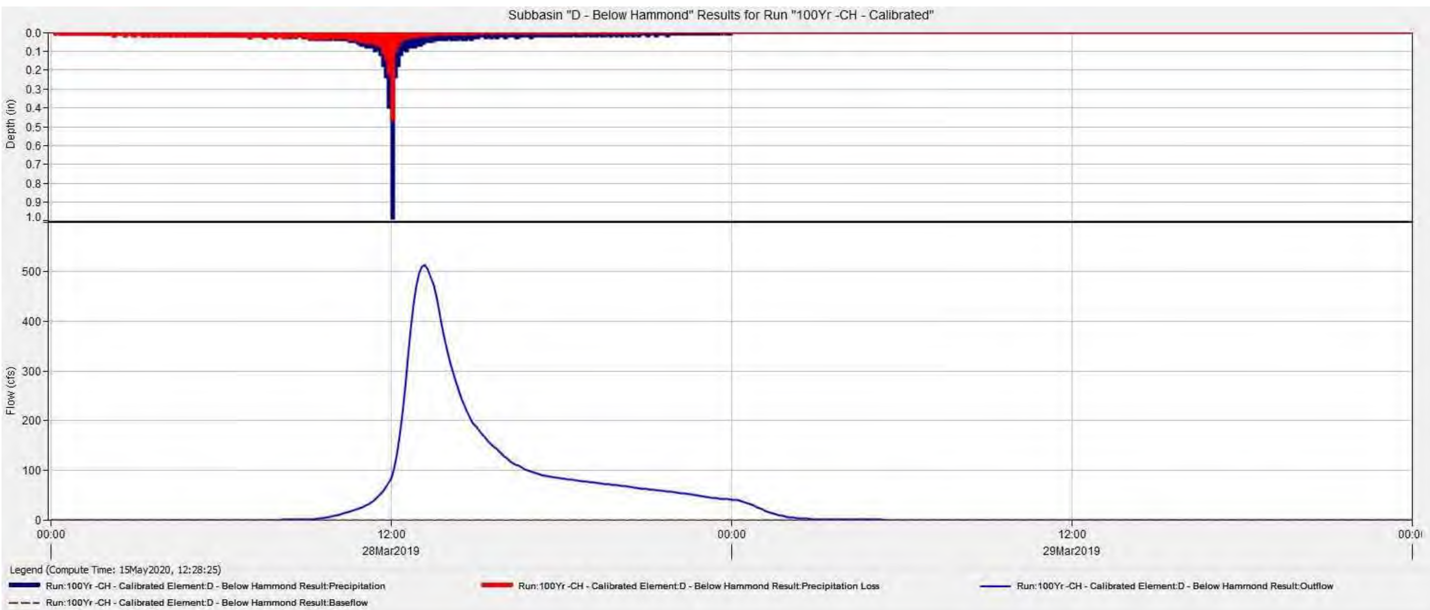
where:
CN_c = composite runoff curve number
CN_p = pervious runoff curve number
P_{imp} = percent imperviousness

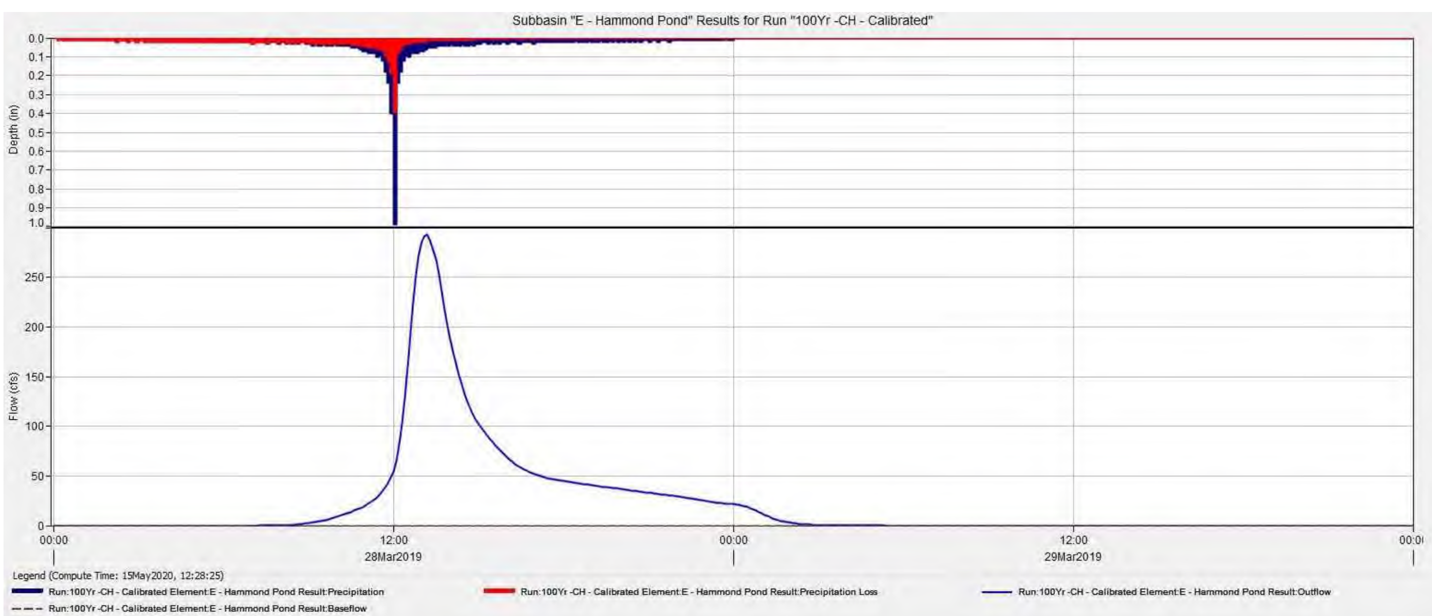

Reservoir "BulloughsPond" Results for Run "100Yr -CH - Calibrated"
Storage (AC-FT)
Elev (ft)
Flow (cfs)
28Mar2019
29Mar2019
Legend (Compute Time: 15May2020, 12:28:25)
Run:100Yr -CH - Calibrated Element:BulloughsPond Result:Storage
Run:100Yr -CH - Calibrated Element:BulloughsPond Result:Pool Elevation
Run:100Yr -CH - Calibrated Element:BulloughsPond Result:Outflow
Run:100Yr -CH - Calibrated Element:BulloughsPond Result:Combined Inflow

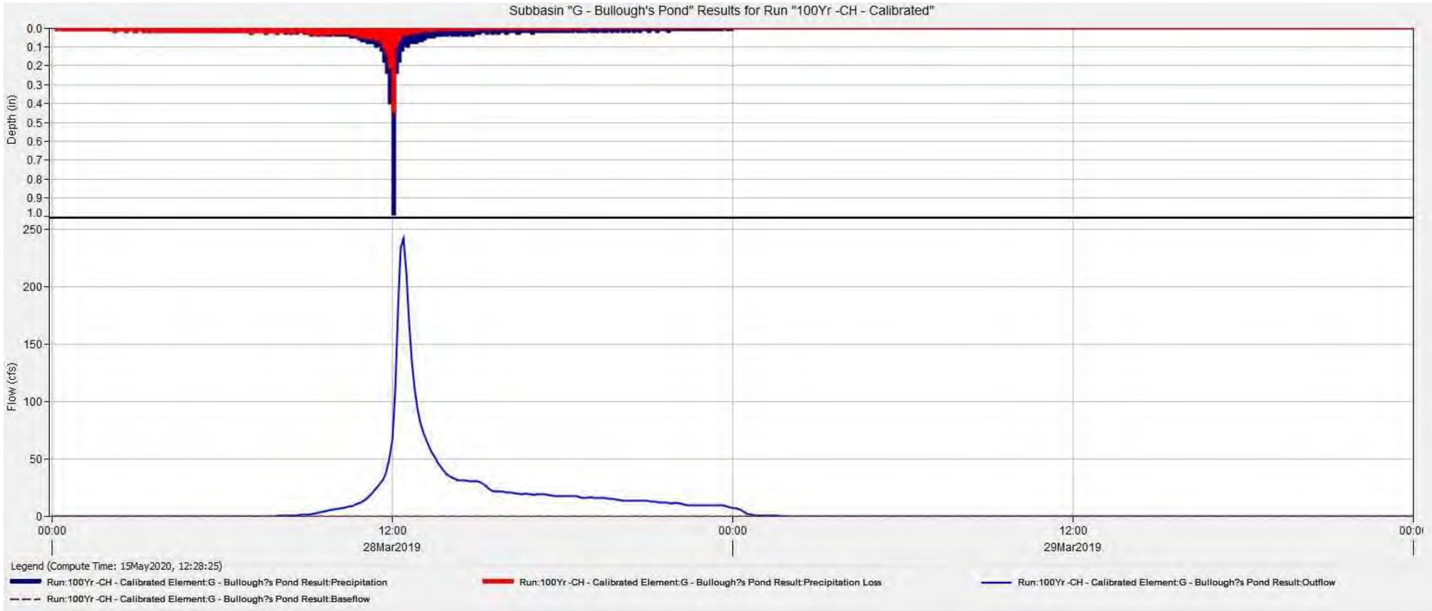

Subbasin "A - Newton Cemetery" Results for Run "100Yr -CH - Calibrated"
Depth (in)
Flow (cfs)
28Mar2019
29Mar2019
Legend (Compute Time: 15May2020, 12:28:25)
Run:100Yr -CH - Calibrated Element:A - Newton Cemetery Result:Precipitation
Run:100Yr -CH - Calibrated Element:A - Newton Cemetery Result:Precipitation Loss
Run:100Yr -CH - Calibrated Element:A - Newton Cemetery Result:Outflow
Run:100Yr -CH - Calibrated Element:A - Newton Cemetery Result:Baseflow


Subbasin "B - Newton Centre Playgroun" Results for Run "100Yr -CH - Calibrated"
Depth (in)
Flow (cfs)
28Mar2019
29Mar2019
Legend (Compute Time: 15May2020, 12:28:25)
Run:100Yr -CH - Calibrated Element:B - Newton Centre Playgroun Result:Precipitation
Run:100Yr -CH - Calibrated Element:B - Newton Centre Playgroun Result:Precipitation Loss
Run:100Yr -CH - Calibrated Element:B - Newton Centre Playgroun Result:Outflow
Run:100Yr -CH - Calibrated Element:B - Newton Centre Playgroun Result:Baseflow


Subbasin "C - Commonwealth Ave" Results for Run "100Yr -CH - Calibrated"
Depth (in)
Flow (cfs)
00:00
12:00
28Mar2019
00:00
12:00
29Mar2019
Legend (Compute Time: 15May2020, 12:28:25)
Run:100Yr -CH - Calibrated Element:C - Commonwealth Ave Result:Precipitation
Run:100Yr -CH - Calibrated Element:C - Commonwealth Ave Result:Precipitation Loss
Run:100Yr -CH - Calibrated Element:C - Commonwealth Ave Result:Outflow
Run:100Yr -CH - Calibrated Element:C - Commonwealth Ave Result:Baseflow


Subbasin "D - Below Hammond" Results for Run "100Yr -CH - Calibrated"
Depth (in)
Flow (cfs)
00:00
12:00
28Mar2019
00:00
12:00
29Mar2019
Legend (Compute Time: 15May2020, 12:28:25)
Run:100Yr -CH - Calibrated Element:D - Below Hammond Result:Precipitation
Run:100Yr -CH - Calibrated Element:D - Below Hammond Result:Precipitation Loss
Run:100Yr -CH - Calibrated Element:D - Below Hammond Result:Outflow
Run:100Yr -CH - Calibrated Element:D - Below Hammond Result:Baseflow


Subbasin "E - Hammond Pond" Results for Run "100Yr -CH - Calibrated"
Depth (in)
Flow (cfs)
00:00
12:00
28Mar2019
00:00
12:00
29Mar2019
Legend (Compute Time: 15May2020, 12:28:25)
Run:100Yr -CH - Calibrated Element:E - Hammond Pond Result:Precipitation
Run:100Yr -CH - Calibrated Element:E - Hammond Pond Result:Precipitation Loss
Run:100Yr -CH - Calibrated Element:E - Hammond Pond Result:Outflow
Run:100Yr -CH - Calibrated Element:E - Hammond Pond Result:Baseflow



Subbasin "G - Bullough's Pond" Results for Run "100Yr -CH - Calibrated"
Depth (in)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Flow (cfs)
250
200
150
100
50
0
00:00
12:00
28Mar2019
00:00
12:00
29Mar2019
Legend (Compute Time: 15May2020, 12:28:25)
Run:100Yr -CH - Calibrated Element:G - Bullough?s Pond Result:Precipitation
Run:100Yr -CH - Calibrated Element:G - Bullough?s Pond Result:Precipitation Loss
Run:100Yr -CH - Calibrated Element:G - Bullough?s Pond Result:Outflow
Run:100Yr -CH - Calibrated Element:G - Bullough?s Pond Result:Baseflow

Appendix I
Seepage and Stability Analyses

GZA
GeoEnvironmental, Inc.
249 Vanderbilt Ave
Norwood, MA 02062
781-278-3700
FAX 781-278-5701
http://www.gza.com

Engineers and Scientists

JOB	01.0174021.00 Bulloughs Pond Dam		
SHEET NO.	1	**OF**	2
CALCULATED BY	CMG/MFJ	**DATE**	9/1/2019- 4/22/2020
CHECKED BY	LAG	**DATE**	4/22/2020
SCALE	N/A		

Objective: To assess stability of the Bulloughs Pond Dam in Newton, MA

Method:

1) Develop typical cross section of dam at approximate maximum section (See attached figure).
2) Determine material parameters from test borings, laboratory testing, and typical values of similar materials.
3) Calculate location of phreatic surface within dam for normal and flood conditions, using SEEP/W. Calculate factor of safety against piping failure. Evaluate effect of rapid drawdown on phreatic surface within dam.
4) Using pore water data from SEEP/W, calculate factors of safety against slope failure for the following load cases defined by requirements of 302 CMR 10.14 (9(c)). Factors of safety calculated for both upstream and downstream slopes using Spencer method.

Case #2 - Rapid drawdown from flood pool to low level outlet
Case #3 - Rapid drawdown from normal pool to low level outlet
Case #4 - Steady seepage at normal pool
Case #5 - Steady seepage with maximum (flood) pool
Case #6 - Earthquake (pseudo-static) at normal pool

Subsurface Information:

- Test borings GZ-1 through GZ-4 by GZA (Feb 2019)
- Observation wells installed in GZ-2 and GZ-3 by GZA (Feb 2019)
- Grain size distributions from samples collected by GZA
- Water levels based on piezometer readings taken on 7/19/19 and groundwater levels measured within boreholes at time of drilling

Assumptions:

- Horizontal acceleration for pseudo-static seismic analysis is **0.216g**, per ASCE7-16 (Modified peak acceleration with 2% probability of exceedance in 50 years)
- Configuration of embankment based on interpretation of strata from test borings, actual configuration may vary from that used in calculations

Material Properties:

Strata	Total Unit Weight, γ_t (pcf)	Cohesion, c (psf)	Friction Angle, ϕ°	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ'°	Saturated Permeability, k_{sat}	Notes
Embankment Fill	125	0	31	0	31	2.0E-06 ft/s, 6.0E-05 cm/s	(1),(2)
Fine Sand	130	0	29	0	29	2.3E-05 ft/s, 7.0E-04 cm/s	(1),(2)
Core Wall	140	288000	0	288000	0	8.5E-06 ft/s, 2.6E-04 cm/s	(3)
Bedrock	Impenetrable					1.0E-11 ft/s, 3.0E-10 cm/s	(3)

(1) - Permeabilities for granular materials encountered in borings estimated from Hazen equation.
(2) - Phi value of granular soils determined by analysis of SPT-N values from the test borings (Attachment D)
(3) - Assumed parameters based on similar material

Analysis Results:

SEEPAGE ANALYSIS RESULTS - EXISTING CONDITIONS

Case	Pool Elevation	Unit Flowrate, Q (2) (through dam face)	Exit Gradient, i_e (2)	Critical Gradient, i_{cr} (3)	FS, i_{cr}/i_e	Required FS (4)
1	Normal (El. 85.94)	0 ft^3/s/ft	No Exit	1.0	N/A	2.5-3.0
2	100-year Flood(El. 92.6)	3.2E-05 ft^3/s/ft	0.59	1.0	***1.7***	2.5-3.0

- Note: Factor of safety values less than recommended values are shown in italics
(1) - Elevations for Normal and 1/2 PMF pools from GZA's detailed H&H Analysis
(2) - Flow and exit gradient obtained from results of SEEP/W analysis using the maximum section of the dam
(3) - i_{cr}: critical gradient, typical value for sand = 1.0
(4) - Cedergren, 1977

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http://www.gza.com

Engineers and Scientists

JOB	01.0174021.00 Bulloughs Pond Dam		
SHEET NO.	2	OF	2
CALCULATED BY	CMG/MFJ	DATE	9/1/2019- 4/22/2020
CHECKED BY	LAG	DATE	4/22/2020
SCALE	N/A		

SLOPE STABILITY ANALYSIS RESULTS

Load Case	Loading Condition	Dam Face	Factor of Safety		Comments / Notes
			Minimum	Existing	
1	End of Construction	Upstream	1.3	Not Applicable	
		Downstream			
2	Sudden drawdown from maximum pool (Flood)	Upstream	1.1	1.2	Figure G-1
3	Sudden drawdown from spillway/top of gates (Normal)	Upstream	1.2	1.3	Figure G-2
4	Steady-state seepage at maximum storage pool (Normal)	Upstream	1.5	1.5	Figure G-3
		Downstream		1.5	Figure G-4
5	Steady-state seepage at surcharge pool (Flood)	Upstream	1.4	1.7	Figure G-5
		Downstream		***1.0***	Figure G-6
6	Earthquake[(2)] (Steady-state seepage at normal pool)	Upstream	1.0	***0.9***	Figure G-7
		Downstream		***0.9***	Figure G-8

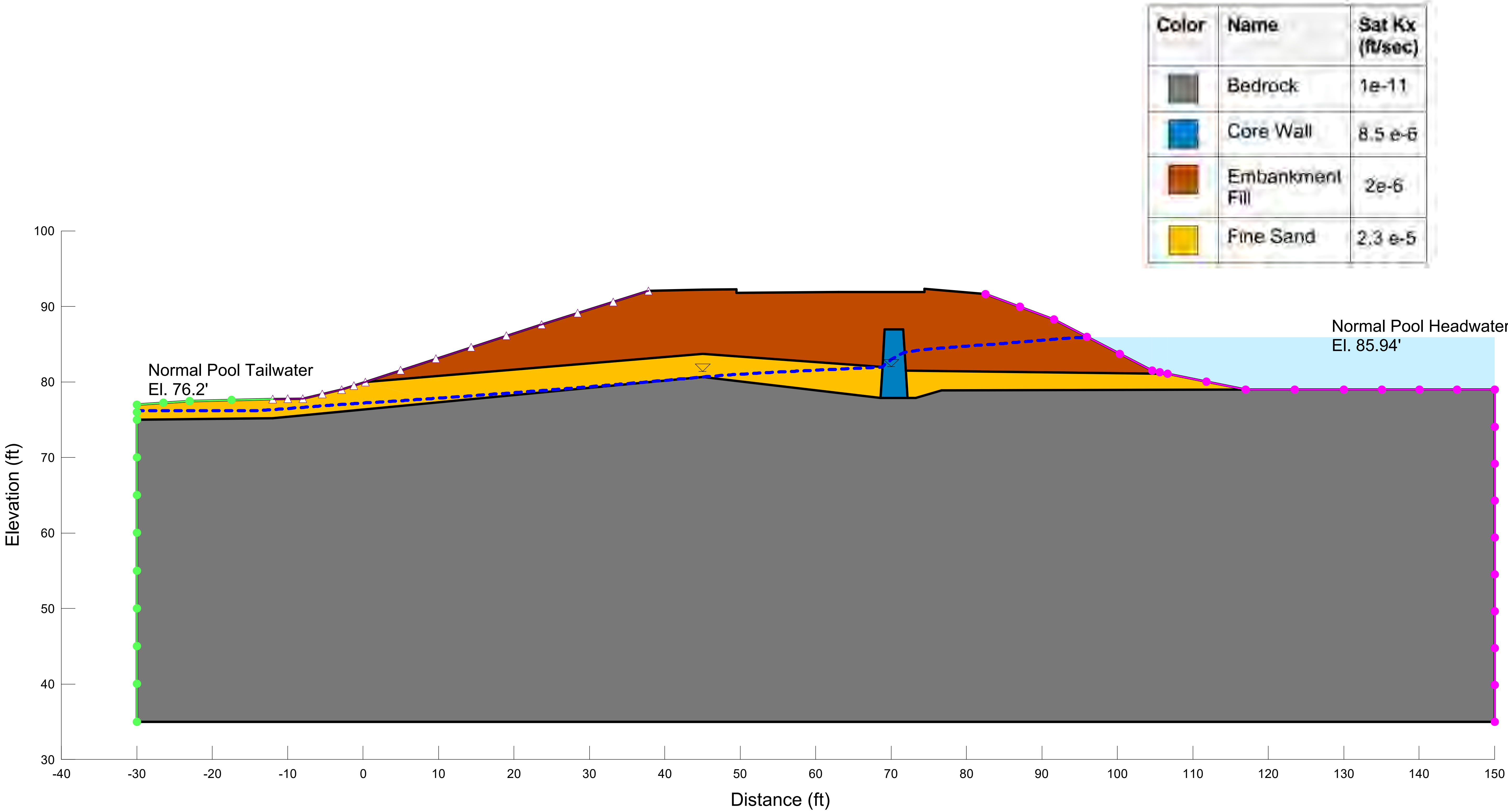
- Note: Factor of safety values less than recommended values are shown in bold and italics
(1) - Low level outlet invert is at elevation 58.9, per H&H analysis
(2) - Earthquake loading applied as a lateral load using seismic coefficient

- Refer to Attachment A for SLOPE/W slope stability analysis graphical results

- Refer to Attachment B for Liquefaction Analysis

ATTACHMENT A

SLOPE W GRAPHICAL RESULTS

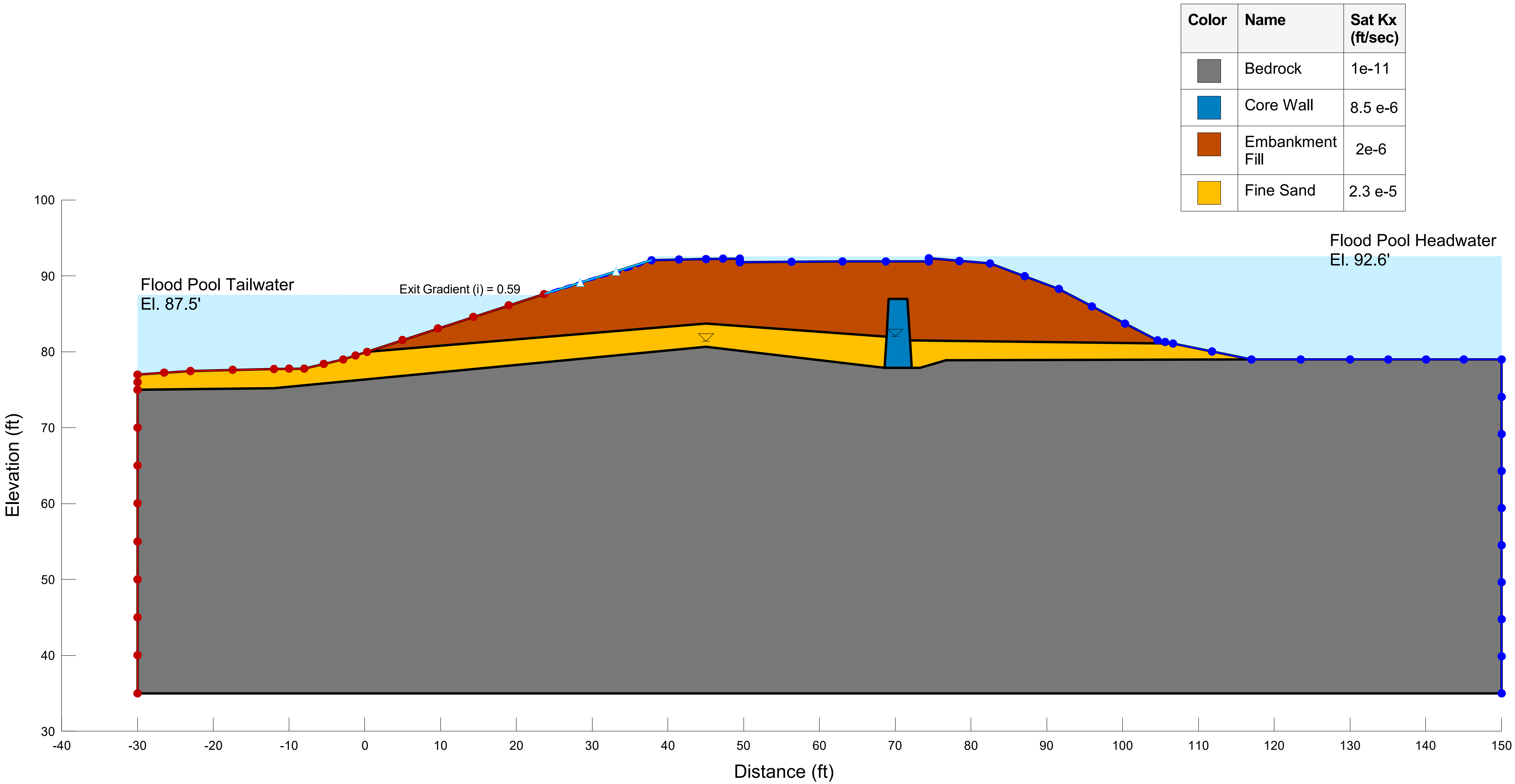


05/19/2020

Phase II For Bulloughs Pond Dam
Newton, MA

Seepage Analysis - Normal Pool

FIGURE



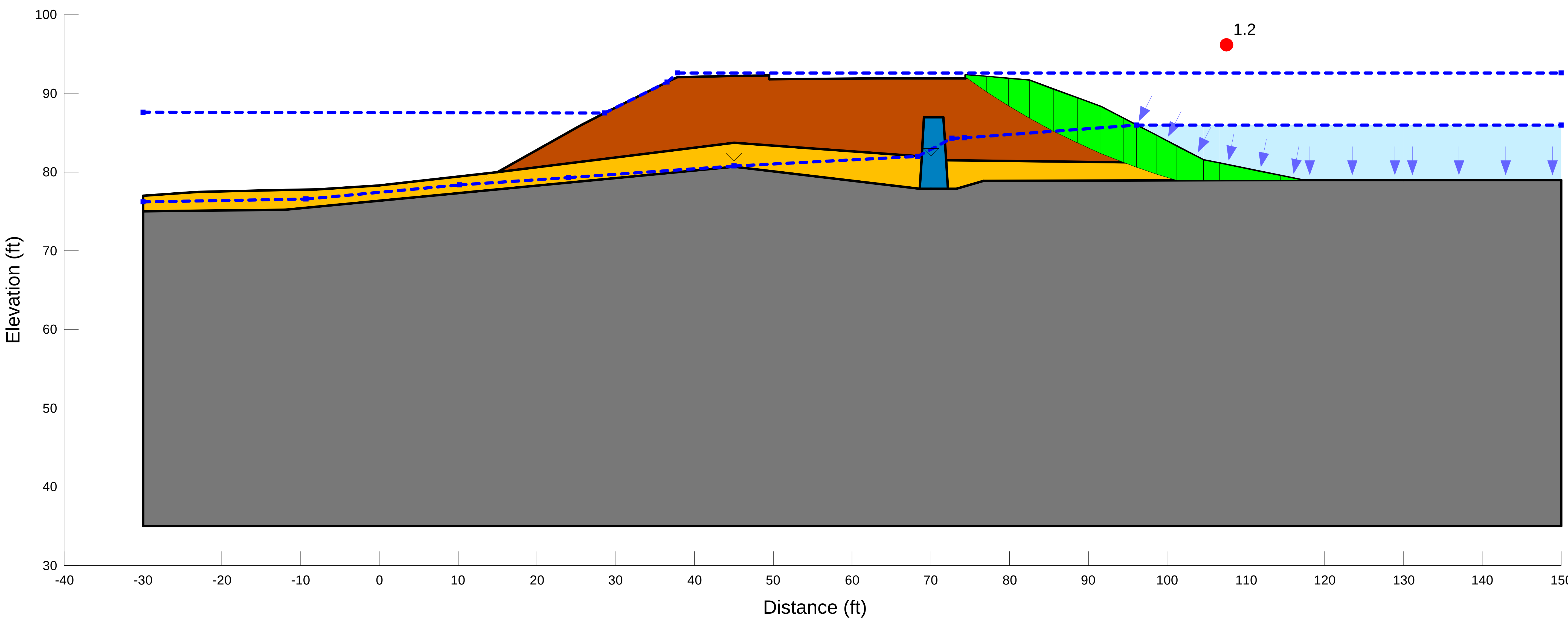
05/19/2020

Phase II For Bulloughs Pond Dam
Newton, MA

Seepage Analysis - Flood Pool

FIGURE

Color	Name	Unit Weight	Cohesion'	Phi'
(gray)	Bedrock			
(blue)	Core Wall	140	288,000	0
(brown)	Embankment Fill	125	0	31
(yellow)	Fine Sand	120	0	29



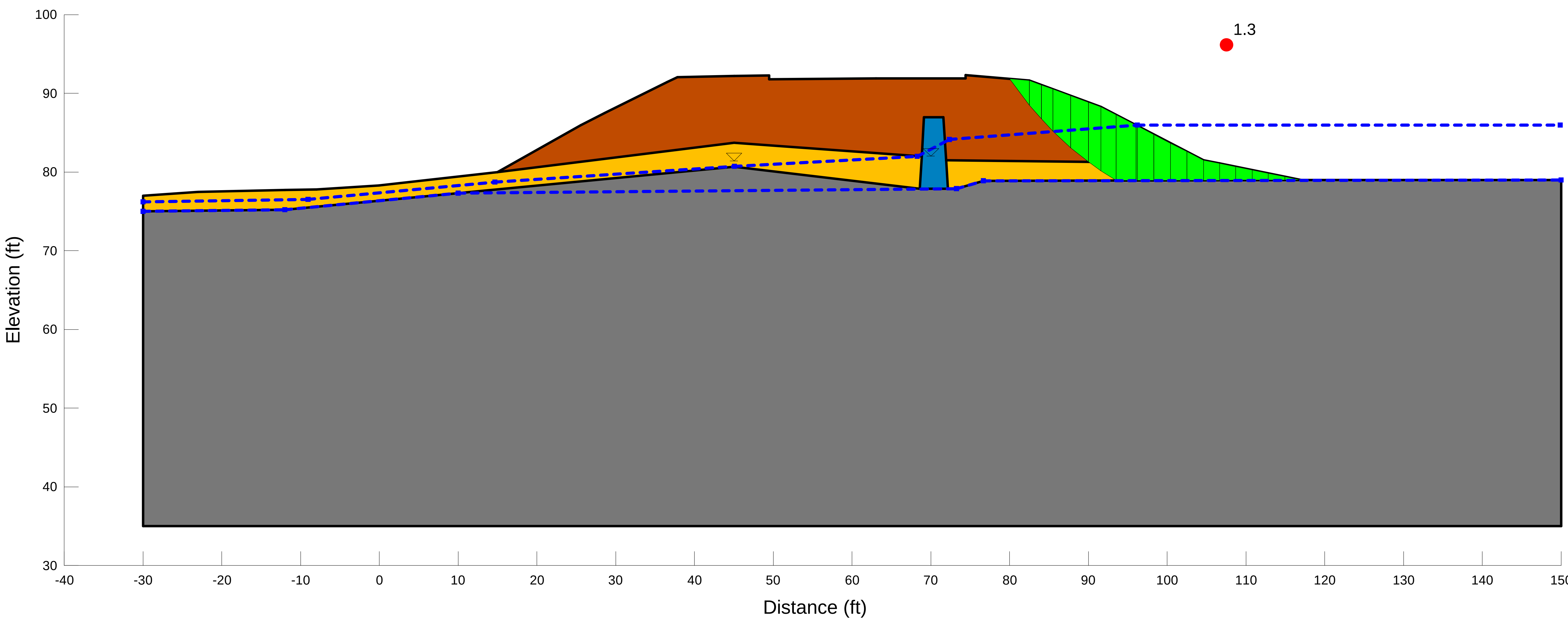
04/22/2020

Phase II For Bulloughs Pond Dam
Newton, MA

Upstream Stability - Rapid Drawdown from Flood Pool

FIGURE G-1

Color	Name	Unit Weight	Cohesion'	Phi'
	Bedrock			
	Core Wall	140	288,000	0
	Embankment Fill	125	0	31
	Fine Sand	120	0	29



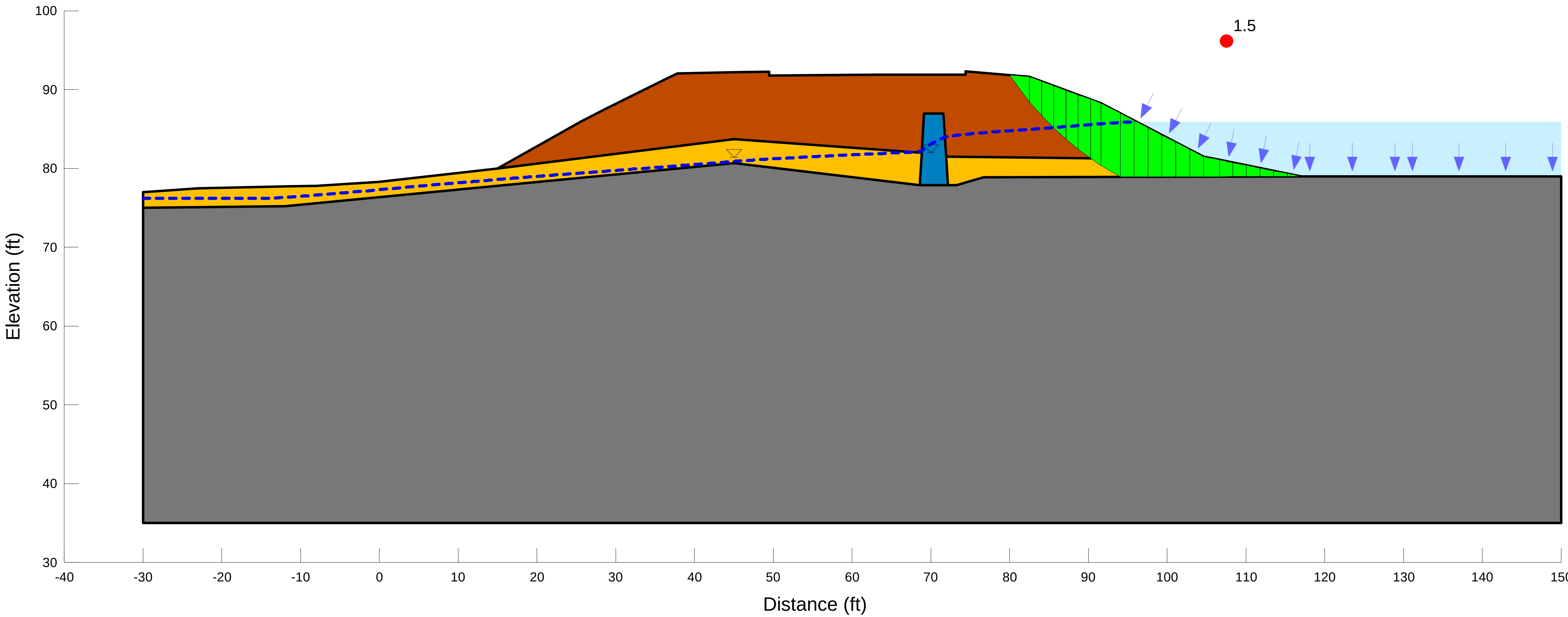
04/22/2020

Phase II For Bulloughs Pond Dam
Newton, MA

Upstream Stability - Rapid Drawdown from Normal Pool

FIGURE G-2

Color	Name	Unit Weight	Cohesion'	Phi'
	Bedrock			
	Core Wall	140	288,000	0
	Embankment Fill	125	0	31
	Fine Sand	120	0	29



04/22/2020

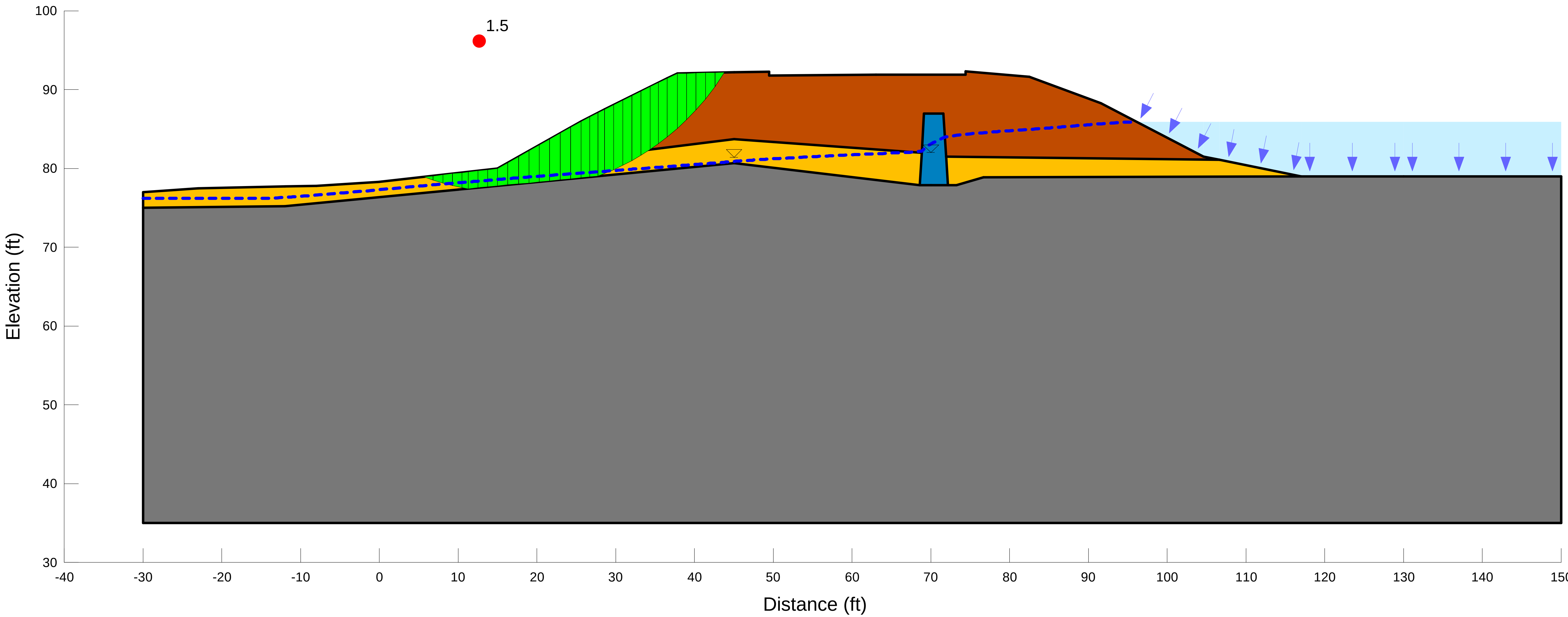
Phase II For Bulloughs Pond Dam

Newton, MA

Upstream Stability - Normal Pool

FIGURE **G-3**

Color	Name	Unit Weight	Cohesion'	Phi'
	Bedrock			
	Core Wall	140	288,000	0
	Embankment Fill	125	0	31
	Fine Sand	120	0	29



04/22/2020

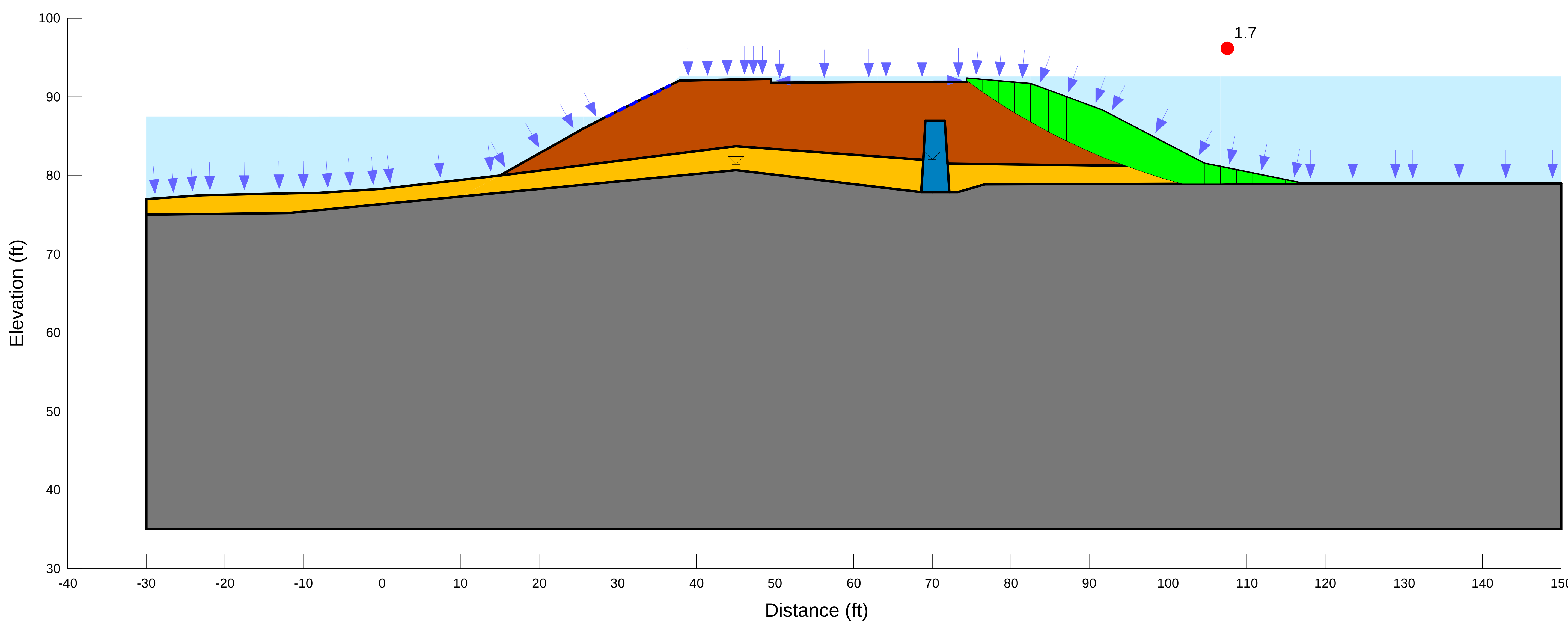
Phase II For Bulloughs Pond Dam

Newton, MA

Downstream Stability - Normal Pool

FIGURE G-4

Color	Name	Unit Weight	Cohesion'	Phi'
	Bedrock			
	Core Wall	140	288,000	0
	Embankment Fill	125	0	31
	Fine Sand	120	0	29



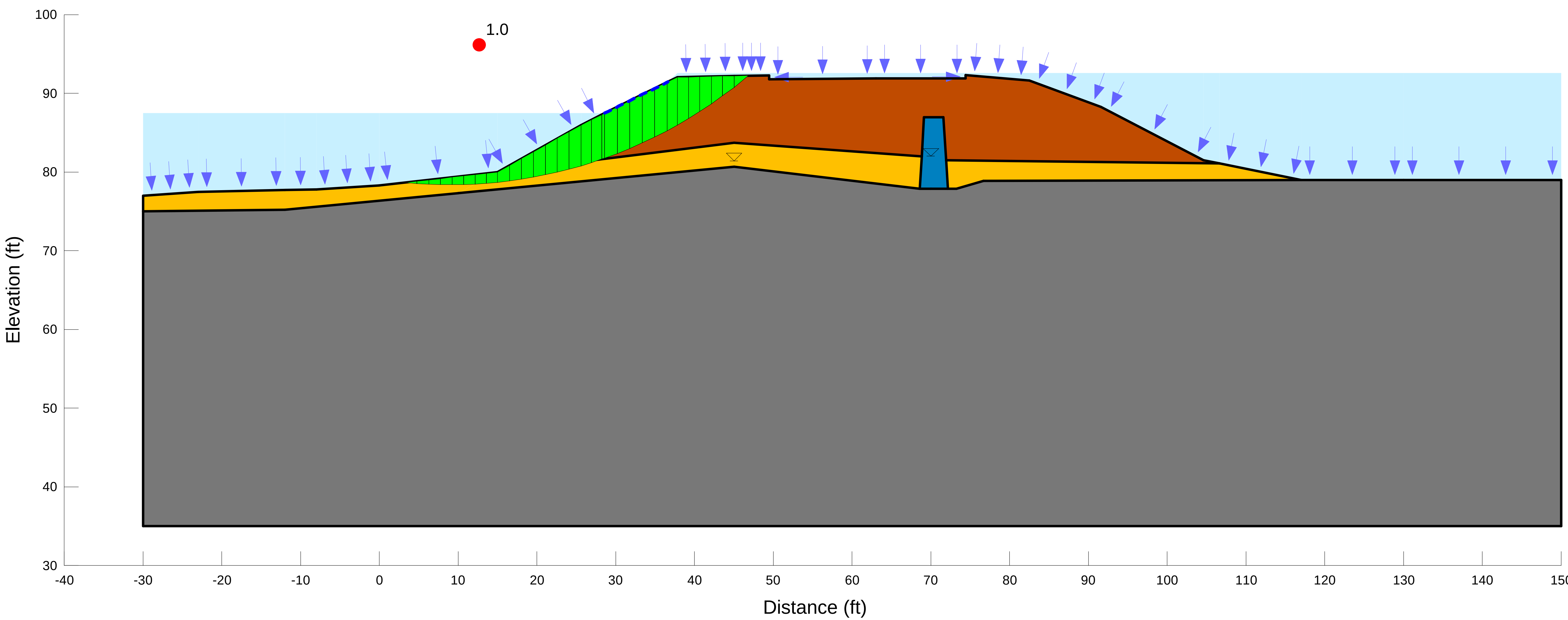
04/22/2020

Phase II For Bulloughs Pond Dam
Newton, MA

Upstream Stability - Flood Pool

FIGURE G-5

Color	Name	Unit Weight	Cohesion'	Phi'
	Bedrock			
	Core Wall	140	288,000	0
	Embankment Fill	125	0	31
	Fine Sand	120	0	29



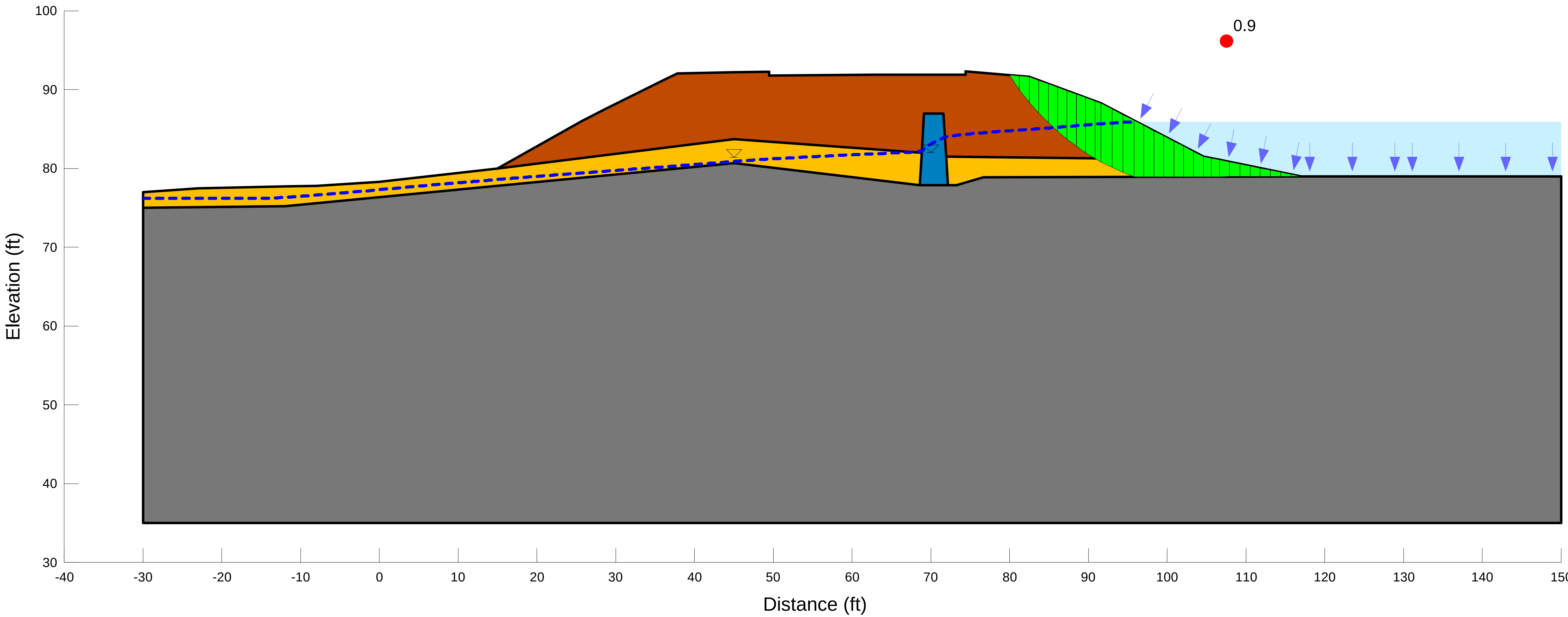
04/22/2020

Phase II For Bulloughs Pond Dam
Newton, MA

Downstream Stability - Flood Pool

FIGURE **G-6**

Color	Name	Unit Weight	Cohesion'	Phi'
	Bedrock			
	Core Wall	140	288,000	0
	Embankment Fill	125	0	31
	Fine Sand	120	0	29



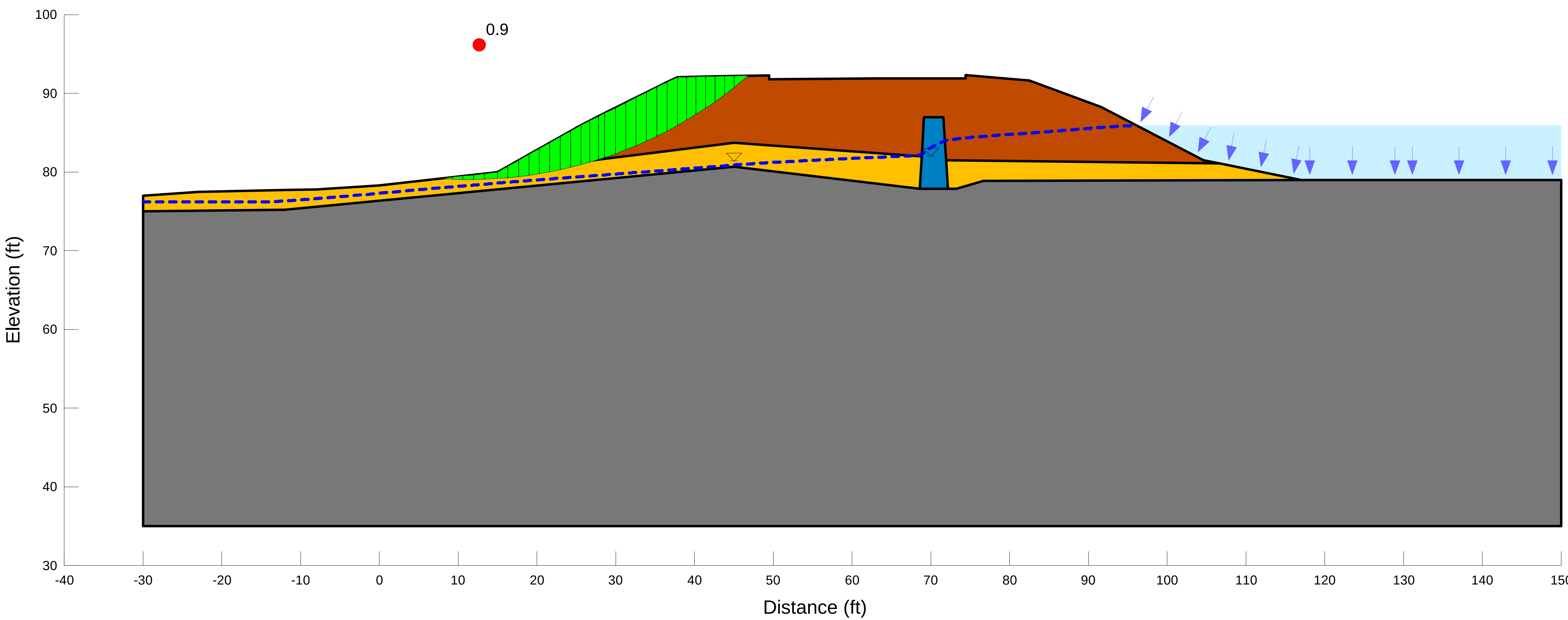
04/22/2020

Phase II For Bulloughs Pond Dam
Newton, MA

Upstream Stability - Flood Pool (Psuedo-static Ag = 0.216)

FIGURE G-7

Color	Name	Unit Weight	Cohesion'	Phi'
(gray)	Bedrock			
(blue)	Core Wall	140	288,000	0
(brown)	Embankment Fill	125	0	31
(yellow)	Fine Sand	120	0	29



04/22/2020

Phase II For Bulloughs Pond Dam
Newton, MA

Downstream Stability - Normal Pool (Psuedo-static Ag = 0.216)

FIGURE **G-8**

ATTACHMENT B

LIQUEFACTION ANALYSIS

SPT-Based Liquefaction Susceptibility Evaluation

Project:	Bulloughs Pond Dam Phase II	**Project No.:**	01.0174021.00
Location:	Newton, Massachusetts		
Evaluated By:	CMG	**Date:**	2/27/2019
Checked By:		**Date:**	

Purpose: Estimate exploration-specific factor of safety against liquefaction and liquefaction induced settlement.

Reference:
1) Idriss, I.M. and Boulanger, R.W. (2008). Soil *Liquefaction During Earthquakes.* Earthquake Engineering Research Institute. Oakland, California. EERI Publication No. MNO-12.
2) Idriss, I.M. and Boulanger, R.W. (2004). *Semi-Empirical Procedures for Evaluating Liquefaction Potential During Earthquakes* . Proceedings of the Joint International Conference on Soil Dynamics & Earthquake Engineering and International Conference on Earthquake Geotechnical Engineering. Berkeley, California. January, 2004. pp.32-56

Approach:
1) Boring GZ-2, GZ-3, and GZ-4 analyzed
2) Create and modify evaluation and plot worksheet tabs to accommodate depths within Boring GZ-2, GZ-3, and G
3) Enter input parameters for boring GZ-2, GZ-3, and GZ-4.
4) Input data from boring (depths, N, estimated fines content, and interpreted soil strata).
5) Check plots for accuracy and update as necessary.
6) If required, spot-check approximations using the MathCAD calculation verification form.
7) Add summary of results below.

Summary of Results: Based on the boring data provided, samples were screened for liquefaction susceptibility using the following criteria:

- Samples whose fines conent (% silt- and clay-sized particles) exceeded 35% were assumed not suscpetible to liquefaction
- Samples whose corrected blow count, $(N_1)_{60\text{-}cs}$, was greater than 30 were assumed not susceptible to liquefaction

Boring ID:	**GZ-2**	**GZ-3**	**GZ-4**
Minimum Factor of Safety:	1.69	2.05	1.54
Elevation of Minimum Factor of Safety (ft, MDC):	90	91	88

Recommendations: Based on the factors of safety against liquefaction presented above, we recommend the site not be considered susceptible to liquefaction.

SPT-Based Liquefaction Susceptibility & Induced Settlement Evaluation

oughs Pond Dam Pha **Newton, Massachusetts**

01.0174021.00

Reference: Idriss & Boulanger (2008)

Calculated By: CMG Date: 2/27/2019

Checked By: 0.00 Date: 1/0/1900

Exploration ID: GZ-2

Input

Elevation Data:
- Ground Surface Elevation: 100.0 ft
- Water Elevation: 93.5 ft

SPT Correction Factors:
- Split Spoon Type: I.D.=1-3/8 in - Standard Sampler
- Hammer Type: Auto Hammer
- Typical rod stickup during SPT: 3 ft
- Borehole Diameter: ≤4.5 in

Material Properties:
- Assumed Soil Unit Weight Above Water Table, γ = 120 pcf
- Assumed Soil Unit Weight Below Water Table, γ_{sat} = 120 pcf
- Atmospheric Pressure, P_a = 2088 psf

Seismic Assumptions
- Maximum Acceleration at Ground Surface, a_{max} = 0.184
- Design Earthquake Magnitude, M = 5.55
- (see attached USGS Deaggregation for more information)

Equations

Overburden and Hammer Energy Corrected Blow Count, $(N_1)_{60} = N_m C_N C_E C_B C_S C_R$

where:

N_m = Field Blow Count

Overburden Correction Factor, $C_N = (P_a/\sigma'_v)^{0.784-0.0768\sqrt{(N_1)_{60}}} \quad \le 1.7$

Borehole Diameter Correction Factor,

C_B = 1.0 (2.5"-4.5" diameter), 1.05 (6" diam.), 1.10 (8" diam.)

Sampling Method Correction Factor, C_S

= 1.0 (Standard Sampler or Sampler with liners)

OR, when sampler with room for liners is used without liners;

$= 1.1 \quad \text{for} \quad (N_1)_{60} \le 10$

$= 1.0 + \frac{(N_1)_{60}}{100} \quad \text{for} \quad 10 < (N_1)_{60} \le 30$

$= 1.3 \quad \text{for} \quad (N_1)_{60} \ge 30$

Rod Length Correction Factor,

C_R = 0.75 (0-3m), 0.80 (3-4m), 0.85 (4-6m), 0.95 (6-10m), 1.0 (>10m)

Hammer Energy Correction Factor, C_e:

C_e = 0.75 (Donut Hammer), 1.0 (Safety Hammer), 1.2 (Auto Hammer)

Factor of Safety, $F_s = \frac{CRR_{corr}}{CSR}$

Cyclic Stress Ratio, $CSR = 0.65 a_{max} \left(\frac{\sigma_v}{\sigma'_v}\right) r_d$

where:

Depth Reduction Factor, $r_d = \exp[\alpha(z) + M * \beta(z)]$

$\alpha(z) = -1.012 - 1.126 \sin\left(\frac{z}{11.73} + 5.133\right)$ (z = depth in meters)

$\beta(z) = 0.106 + 0.118 \sin\left(\frac{z}{11.28} + 5.142\right)$ (z = depth in meters)

Clean – Sand Corrected Blow Count, $(N_1)_{60-CS} = (N_1)_{60} + \Delta(N_1)_{60}$

where: $\Delta(N_1)_{60} = e^{\left[1.63 + \frac{9.7}{FC+0.01} - \left(\frac{15.7}{FC+0.01}\right)^2\right]}$

FC = Fines Content (%)

For use in liquefaction-induced strain estimates: $N_1 = (N_1)_{60} \cdot 0.833$

Cyclic Resistance Ratio, CRR =

$$\exp\left[\frac{(N_1)_{60-CS}}{14.1} + \left(\frac{(N_1)_{60-CS}}{126}\right)^2 - \left(\frac{(N_1)_{60-CS}}{23.6}\right)^3 + \left(\frac{(N_1)_{60-CS}}{25.4}\right)^4 - 2.8\right]$$

Corrected Cyclic Resistance Ratio, $CRR_{corr} = CRR \cdot MSF \cdot K_\sigma$

where:

Magnitude Scaling Factor, $MSF = 6.9 \exp\left(\frac{-M}{4}\right) - 0.058 \quad \le 1.8$

Overburden Correction Factor, $K_\sigma = 1 - C_\sigma \ln\left(\frac{\sigma'_v}{P_a}\right) \quad \le 1.1$

$C_\sigma = \frac{1}{18.9 - 2.55\sqrt{(N_1)_{60}}} \quad \le 0.3$

Limiting Shear Strain, $\gamma_{lim} = 1.859\left(1.1 - \sqrt{\frac{(N_1)_{60cs}}{46}}\right)^3 \quad \ge 0.0$

Maximum Shear Strain, γ_{max}:

$\gamma_{max} = 0$ when $F_s \ge 2.0$

$\gamma_{max} = \gamma_{lim}$ when $F_s \le F_\alpha$

$\gamma_{max} = \min\left[\gamma_{lim},\ 0.035(2 - F_s)\left(\frac{1 - F_\alpha}{F_s - F_\alpha}\right)\right]$ when $2.0 > F_s > F_\alpha$

where $F_\alpha = 0.032 + 0.69\sqrt{(N_1)_{60cs}} - 0.13(N_1)_{60cs}$

Vertical Strain, $\varepsilon_v = 1.5 e^{-0.369\sqrt{(N_1)_{60cs}}} \cdot \min(0.08,\ \gamma_{max})$

$LDI = \Delta H \cdot \gamma_{max}$

Vertical Settlement, $s = \Delta H \cdot \varepsilon_v$

Legend
- Liquefaction Likely (Fs < 1.1)
- Possible Flow Liquefaction Or Cyclic Strain Softening (1.1 ≤ Fs < 1.4)

Approximation

Depth bgs (mid-SPT interval)	Elevation	Depth	Total Stress, σ_v	Effective Stress, σ'_v	N (field)	C_R	C_N	C_s	$(N_1)_{60}$	Fines Content	$(N_1)_{60CS}$	CRR	MSF	C_σ	K_σ	CRR_{corr}	r_d	CSR	F_s	Limiting Shear Strain, γ_{lim}	Parameter F_α	Max Shear Strain, γ_{max}	Layer Thickness, ΔH	LDI (layer)	LDI (cumulative)	Vertical Strain, ε_v	Vertical Settlement (Layer)	Vertical Settlement (Cumulative)	Interpreted Soil Strata	Comments
ft	ft	m	psf	psf						%													ft	ft	ft		in	in		
6.0	94.0	1.83	720	720	10	0.75	1.68	1.00	15	30	20	0.21	1.66	0.11	1.10	0.39	0.98	0.12	3.32	0.15	0.49	0.000	6	0	0.00	0.000	0.000	0.019	Fill	
8.0	92.0	2.44	960	866	11	0.80	1.52	1.00	16	30	21	0.22	1.66	0.12	1.10	0.41	0.96	0.13	3.22	0.14	0.44	0.000	2	0	0.00	0.000	0.000	0.019		
10.0	90.0	3.05	1200	982	6	0.80	1.52	1.00	9	15	12	0.13	1.66	0.09	1.07	0.24	0.95	0.14	1.69	0.38	0.86	0.002	2	0.003585	0.00	0.001	0.018	0.019	Fine Sand	
12.0	88.0	3.66	1440	1097	9	0.85	1.39	1.00	13	15	16	0.16	1.66	0.10	1.07	0.29	0.94	0.15	1.99	0.25	0.71	0.000	2	0.000231	0.00	0.000	0.001	0.001		
14.0	86.0	4.27	1680	1212	100	0.85	1.00	1.00	102	*Not considered susceptible to liquefaction (N-value > 30 bpf)*																				

Bedrock observed below 14 feet bgs. Not considered susceptible to liquefaction.

SPT-Based Liquefaction Susceptibility & Induced Settlement Evaluation

oughs Pond Dam Pha Newton, Massachusetts
01.0174021.00
Reference: Idriss & Boulanger (2008)

Calculated By: CMG Date: 2/27/2019
Checked By: 0.00 Date: 1/0/1900

Exploration ID: GZ-3

Input

Elevation Data:
- Mudline Elevation 100.0 ft
- Water Elevation 93.0 ft

SPT Correction Factors:
- Split Spoon Type: I.D.=1-3/8 in - Standard Sampler
- Hammer Type: Donut Hammer
- Typical rod stickup during SPT: 3 ft
- Borehole Diameter: ≤4.5 in

Material Properties:
- Assumed Soil Unit Weight Above Water Table, γ = 120 pcf
- Assumed Soil Unit Weight Below Water Table, γ_{sat} = 120 pcf
- Atmospheric Pressure, P_a = 2088 psf

Seismic Assumptions
- Maximum Acceleration at Ground Surface, a_{max} = 0.184
- Design Earthquake Magnitude, M = 5.55
- (see attached USGS Deaggregation for more information)

Equations

Overburden and Hammer Energy Corrected Blow Count, $(N_1)_{60} = N_m C_N C_E C_B C_S C_R$

where:

N_m = Field Blow Count

Overburden Correction Factor, $C_N = (P_a/\sigma'_v)^{0.784-0.0768\sqrt{(N_1)_{60}}} \quad \le 1.7$

Borehole Diameter Correction Factor,

$C_B = 1.0$ (2.5"-4.5" diameter), 1.05 (6" diam.), 1.10 (8" diam.)

Sampling Method Correction Factor, C_S

= 1.0 (Standard Sampler or Sampler with liners)

OR, when sampler with room for liners is used without liners;

$= 1.1$ for $(N_1)_{60} \le 10$

$= 1.0 + \frac{(N_1)_{60}}{100}$ for $10 < (N_1)_{60} \le 30$

$= 1.3$ for $(N_1)_{60} \ge 30$

Rod Length Correction Factor,

C_R = 0.75 (0-3m), 0.80 (3-4m), 0.85 (4-6m), 0.95 (6-10m), 1.0 (>10m)

Hammer Energy Correction Factor, C_e:

C_e = 0.75 (Donut Hammer), 1.0 (Safety Hammer), 1.2 (Auto Hammer)

Factor of Safety, $F_s = \frac{CRR_{corr}}{CSR}$

Cyclic Stress Ratio, $CSR = 0.65 a_{max} \left(\frac{\sigma_v}{\sigma'_v}\right) r_d$

where:

Depth Reduction Factor, $r_d = \exp[\alpha(z) + M * \beta(z)]$

$\alpha(z) = -1.012 - 1.126 \sin\left(\frac{z}{11.73} + 5.133\right)$ (z = depth in meters)

$\beta(z) = 0.106 + 0.118 \sin\left(\frac{z}{11.28} + 5.142\right)$ (z = depth in meters)

Clean – Sand Corrected Blow Count, $(N_1)_{60-CS} = (N_1)_{60} + \Delta(N_1)_{60}$

where: $\Delta(N_1)_{60} = e^{\left[1.63 + \frac{9.7}{FC+0.01} - \left(\frac{15.7}{FC+0.01}\right)^2\right]}$

FC = Fines Content (%)

For use in liquefaction-induced strain estimates: $N_1 = (N_1)_{60} \cdot 0.833$

Cyclic Resistance Ratio, CRR =

$$\exp\left[\frac{(N_1)_{60-CS}}{14.1} + \left(\frac{(N_1)_{60-CS}}{126}\right)^2 - \left(\frac{(N_1)_{60-CS}}{23.6}\right)^3 + \left(\frac{(N_1)_{60-CS}}{25.4}\right)^4 - 2.8\right]$$

Corrected Cyclic Resistance Ratio, $CRR_{corr} = CRR \cdot MSF \cdot K_\sigma$

where:

Magnitude Scaling Factor, $MSF = 6.9 \exp\left(\frac{-M}{4}\right) - 0.058 \quad \le 1.8$

Overburden Correction Factor, $K_\sigma = 1 - C_\sigma \ln\left(\frac{\sigma'_v}{P_a}\right) \quad \le 1.1$

$C_\sigma = \frac{1}{18.9 - 2.55\sqrt{(N_1)_{60}}} \quad \le 0.3$

Limiting Shear Strain, $\gamma_{lim} = 1.859\left(1.1 - \sqrt{\frac{(N_1)_{60cs}}{46}}\right)^3 \ge 0.0$

Maximum Shear Strain, γ_{max}:

$\gamma_{max} = 0$ when $F_s \ge 2.0$

$\gamma_{max} = \gamma_{lim}$ when $F_s \le F_\alpha$

$\gamma_{max} = \min\left[\gamma_{lim},\ 0.035(2 - F_s)\left(\frac{1 - F_\alpha}{F_s - F_\alpha}\right)\right]$ when $2.0 > F_s > F_\alpha$

where $F_\alpha = 0.032 + 0.69\sqrt{(N_1)_{60cs}} - 0.13(N_1)_{60cs}$

Vertical Strain, $\varepsilon_v = 1.5 e^{-0.369\sqrt{(N_1)_{60cs}}} \cdot \min(0.08,\ \gamma_{max})$

$LDI = \Delta H \cdot \gamma_{max}$

Vertical Settlement, $s = \Delta H \cdot \varepsilon_v$

Legend
- Liquefaction Likely (Fs < 1.1)
- Possible Flow Liquefaction Or Cyclic Strain Softening (1.1 ≤ Fs < 1.4)

Approximation

Depth below mudline (mid-SPT interval)	Elevation	Depth	Total Stress, σ_v	Effective Stress, σ'_v	N (field)	C_R	C_N	C_s	$(N_1)_{60}$	Fines Content	$(N_1)_{60CS}$	CRR	MSF	C_σ	K_σ	CRR_{corr}	r_d	CSR	F_s	Limiting Shear Strain, γ_{lim}	Parameter F_α	Max Shear Strain, γ_{max}	Layer Thickness, ΔH	LDI (layer)	LDI (cumulative)	Vertical Strain, ε_v	Vertical Settlement (Layer)	Vertical Settlement (Cumulative)	Interpreted Soil Strata	Comments
ft	ft	m	psf	psf						%													ft	ft	ft		in	in		
1.0	99.0	0.30	120	120	8	0.75	1.70	1.00	8	30	13	0.14	1.66	0.08	1.10	0.26	1.00	0.12	2.14	0.34	0.83	0.000	2	0	0.00	0.000	0.000	0.000	Topsoil	
3.0	97.0	0.91	360	360	7	0.75	1.70	1.00	7	30	12	0.13	1.66	0.08	1.10	0.24	0.99	0.12	2.05	0.38	0.86	0.000	2	0	0.00	0.000	0.000	0.000	Fill	
5.0	95.0	1.52	600	600	7	0.75	1.70	1.00	7	30	12	0.13	1.66	0.08	1.10	0.24	0.98	0.12	2.07	0.38	0.86	0.000	2	0	0.00	0.000	0.000	0.000		
7.0	93.0	2.13	840	840	19	0.80	1.53	1.00	17	30	23	0.25	1.66	0.12	1.10	0.45	0.97	0.12	3.87	0.12	0.37	0.000	2	0	0.00	0.000	0.000	0.000		
9.0	91.0	2.74	1080	955	10	0.80	1.54	1.00	9	30	15	0.15	1.66	0.09	1.07	0.27	0.96	0.13	2.10	0.29	0.77	0.000	1.75	0	0.00	0.000	0.000	0.000		
10.5	89.5	3.20	1260	1042	100	0.85	1.10	1.00	70	*Not considered susceptible to liquefaction (N-value > 30 bpf)*																			Fine Sand	

Bedrock observed below 10.5 feet bgs. Not considered susceptible to liquefaction.

SPT-Based Liquefaction Susceptibility & Induced Settlement Evaluation

oughs Pond Dam Pha **Newton, Massachusetts**

01.0174021.00

Reference: Idriss & Boulanger (2008)

Calculated By: CMG Date: 2/27/2019
Checked By: 0.00 Date: 1/0/1900

Exploration ID: GZ-4

Input

Elevation Data:
- Mudline Elevation: 100.0 ft
- Water Elevation: 93.5 ft

SPT Correction Factors:
- Split Spoon Type: I.D.=1-3/8 in - Standard Sampler
- Hammer Type: Donut Hammer
- Typical rod stickup during SPT: 3 ft
- Borehole Diameter: ≤4.5 in

Material Properties:
- Assumed Soil Unit Weight Above Water Table, γ = 120 pcf
- Assumed Soil Unit Weight Below Water Table, γ_{sat} = 120 pcf
- Atmospheric Pressure, P_a = 2088 psf

Seismic Assumptions
- Maximum Acceleration at Ground Surface, a_{max} = 0.184
- Design Earthquake Magnitude, M = 5.55
- (see attached USGS Deaggregation for more information)

Equations

Overburden and Hammer Energy Corrected Blow Count, $(N_1)_{60} = N_m C_N C_E C_B C_S C_R$

where:

N_m = Field Blow Count

Overburden Correction Factor, $C_N = (P_a/\sigma'_v)^{0.784-0.0768\sqrt{(N_1)_{60}}} \quad \leq 1.7$

Borehole Diameter Correction Factor,

C_B = 1.0 (2.5"-4.5" diameter), 1.05 (6" diam.), 1.10 (8" diam.)

Sampling Method Correction Factor, C_S

= 1.0 (Standard Sampler or Sampler with liners)

OR, when sampler with room for liners is used without liners;

$= 1.1$ for $(N_1)_{60} \leq 10$

$= 1.0 + \frac{(N_1)_{60}}{100}$ for $10 < (N_1)_{60} \leq 30$

$= 1.3$ for $(N_1)_{60} \geq 30$

Rod Length Correction Factor,

C_R = 0.75 (0-3m), 0.80 (3-4m), 0.85 (4-6m), 0.95 (6-10m), 1.0 (>10m)

Hammer Energy Correction Factor, C_e:

C_e = 0.75 (Donut Hammer), 1.0 (Safety Hammer), 1.2 (Auto Hammer)

Factor of Safety, $F_s = \frac{CRR_{corr}}{CSR}$

Cyclic Stress Ratio, $CSR = 0.65 a_{max} \left(\frac{\sigma_v}{\sigma'_v}\right) r_d$

where:

Depth Reduction Factor, $r_d = \exp[\alpha(z) + M * \beta(z)]$

$\alpha(z) = -1.012 - 1.126 \sin\left(\frac{z}{11.73} + 5.133\right)$ (z = depth in meters)

$\beta(z) = 0.106 + 0.118 \sin\left(\frac{z}{11.28} + 5.142\right)$ (z = depth in meters)

Clean – Sand Corrected Blow Count, $(N_1)_{60-CS} = (N_1)_{60} + \Delta(N_1)_{60}$

where: $\Delta(N_1)_{60} = e^{\left[1.63 + \frac{9.7}{FC+0.01} - \left(\frac{15.7}{FC+0.01}\right)^2\right]}$

FC = Fines Content (%)

For use in liquefaction - induced strain estimates: $N_1 = (N_1)_{60} \cdot 0.833$

Cyclic Resistance Ratio, $CRR =$

$$\exp\left[\frac{(N_1)_{60-CS}}{14.1} + \left(\frac{(N_1)_{60-CS}}{126}\right)^2 - \left(\frac{(N_1)_{60-CS}}{23.6}\right)^3 + \left(\frac{(N_1)_{60-CS}}{25.4}\right)^4 - 2.8\right]$$

Corrected Cyclic Resistance Ratio, $CRR_{corr} = CRR \cdot MSF \cdot K_\sigma$

where:

Magnitude Scaling Factor, $MSF = 6.9 \exp\left(\frac{-M}{4}\right) - 0.058 \quad \leq 1.8$

Overburden Correction Factor, $K_\sigma = 1 - C_\sigma \ln\left(\frac{\sigma'_v}{P_a}\right) \quad \leq 1.1$

$C_\sigma = \frac{1}{18.9 - 2.55\sqrt{(N_1)_{60}}} \quad \leq 0.3$

Limiting Shear Strain, $\gamma_{lim} = 1.859\left(1.1 - \sqrt{\frac{(N_1)_{60cs}}{46}}\right)^3 \geq 0.0$

Maximum Shear Strain, γ_{max}:

$\gamma_{max} = 0$ when $F_s \geq 2.0$

$\gamma_{max} = \gamma_{lim}$ when $F_s \leq F_\alpha$

$\gamma_{max} = \min\left[\gamma_{lim},\ 0.035(2 - F_s)\left(\frac{1 - F_\alpha}{F_s - F_\alpha}\right)\right]$ when $2.0 > F_s > F_\alpha$

where $F_\alpha = 0.032 + 0.69\sqrt{(N_1)_{60cs}} - 0.13(N_1)_{60cs}$

Vertical Strain, $\varepsilon_v = 1.5 e^{-0.369\sqrt{(N_1)_{60cs}}} \cdot \min(0.08,\ \gamma_{max})$

$LDI = \Delta H \cdot \gamma_{max}$

Vertical Settlement, $s = \Delta H \cdot \varepsilon_v$

Legend
- Liquefaction Likely (Fs < 1.1)
- Possible Flow Liquefaction Or Cyclic Strain Softening (1.1 ≤ Fs < 1.4)

Approximation

Depth below mudline (mid-SPT interval)	Elevation	Depth	Total Stress, σ_v	Effective Stress, σ'_v	N (field)	C_R	C_N	C_s	$(N_1)_{60}$	Fines Content	$(N_1)_{60CS}$	CRR	MSF	C_σ	K_σ	CRR_{corr}	r_d	CSR	F_s	Limiting Shear Strain, γ_{lim}	Parameter F_α	Max Shear Strain, γ_{max}	Layer Thickness, ΔH	LDI (layer)	LDI (cumulative)	Vertical Strain, ε_v	Vertical Settlement (Layer)	Vertical Settlement (Cumulative)	Interpreted Soil Strata	Comments
ft	ft	m	psf	psf						%													ft	ft	ft		in	in		
8.0	92.0	2.44	960	866	28	0.80	1.43	1.00	24	20	29	0.41	1.66	0.16	1.10	0.74	0.96	0.13	5.82	0.06	0.01	0.000	8	0	0.01	0.000	0.000	0.031	Fill	
10.0	90.0	3.05	1200	982	30	0.80	1.36	1.00	24	20	29	0.42	1.66	0.16	1.10	0.78	0.95	0.14	5.58	0.05	-0.02	0.000	2	0	0.01	0.000	0.000	0.031		
12.0	88.0	3.66	1440	1097	9	0.85	1.44	1.00	8	15	12	0.13	1.66	0.09	1.06	0.23	0.94	0.15	1.54	0.40	0.88	0.003	2	0.006052	0.01	0.001	0.031	0.031	Fine Sand	

Bedrock observed below 10.5 feet bgs. Not considered susceptible to liquefaction.

Appendix J
Cost Estimate for Preferred Alternatives

BULLOUGH'S POND DAM REHABILITATION PROJECT
NEWTON, MA
GZA GeoEnvironmental, Inc.
File No. 174021
CONCEPTUAL COST ESTIMATE - Alternative 5 (Riprap)

ITEM #	DESCRIPTION	ESTIMATED QUANITY	UNIT	GZA UNIT PRICE	GZA TOTAL PRICE
		ONE TIME COST			
01740.01	Site Restoration	1	LS	$10,000.00	$10,000.00
01900.01	Mobilization and Demobilization	1	LS	$25,000.00	$25,000.00
02065.03	Removal and Legal Disposal of Miscellaneous Debris and Items	1	LS	$5,000.00	$5,000.00
	Slipeline 24-inch Outlet Pipes	1	LS	$225,000.00	$225,000.00
	Repair Stone Masonry Headwall				
11010.02	Repoint Spillway Training Walls	210	LF	$25.00	$5,250.00
	Grout Pump	3	day	$70.00	$210.00
		UPSTREAM SLOPE			
	Clearing, Grubbing , Stripping - Upstream Slope Face	470	SY	$10.00	$4,700.00
	Tree Clearing - Upstream Slope	10	Ea.	$160.00	$1,600.00
02270.01	Furnishing and Placement of Crushed Stone Material Riprap Bedding	423	ton	$60.00	$25,380.00
02270.02	Furnishing and Placement of Upstream Slope Stone Riprap	1410	CY	$100.00	$141,000.00
		DOWNSTREAM SLOPE			
	Clearing, Grubbing , Stripping - Downstream Slope Face	222	SY	$10.00	$2,222.22
	Tree Clearing - Downstream Slope	9	Ea.	$160.00	$1,440.00
02200.01	Common Excavation for Slope Repairs	266.7	CY	$25.00	$6,666.67
02270.01	Furnishing and Placement of Crushed Stone Material Riprap Bedding	804	ton	$60.00	$48,240.00
02270.02	Furnishing and Placement of Downstream Slope Stone Riprap	893	CY	$90.00	$80,400.00
		DOWNSTREAM CHANNEL			
02270.02	Furnishing and Placement Riprap at Downstream Channel	122	SY	$10.00	$1,222.22
				Sub-Total Cost:	**$583,300.00**
				50% Contingency:	**$291,700.00**
				Total Cost:	**$875,000.00**

BULLOUGH'S POND DAM REHABILITATION PROJECT
NEWTON, MA
GZA GeoEnvironmental, Inc.
File No. 174021
CONCEPTUAL COST ESTIMATE - Alternative 5 (TRM)

ITEM #	DESCRIPTION	ESTIMATED QUANITY	UNIT	GZA UNIT PRICE	GZA TOTAL PRICE
	ONE TIME COST				
01740.01	Site Restoration	1	LS	$10,000.00	$10,000.00
01900.01	Mobilization and Demobilization	1	LS	$25,000.00	$25,000.00
02065.03	Removal and Legal Disposal of Miscellaneous Debris and Items	1	LS	$5,000.00	$5,000.00
	Slipeline 24-inch Outlet Pipes	1	LS	$225,000.00	$225,000.00
	Repair Stone Masonry Headwall				
11010.02	Repoint Spillway Training Walls	210	LF	$25.00	$5,250.00
	Grout Pump	3	day	$70.00	$210.00
	UPSTREAM SLOPE				
	Clearing, Grubbing , Stripping - Upstream Slope Face	470	SY	$9.00	$4,230.00
	Tree Clearing - Upstream Slope	10	Ea.	$160.00	$1,600.00
02270.01	Furnishing and Placement of Crushed Stone Material Riprap Bedding	423	ton	$60.00	$25,380.00
02270.02	Furnishing and Placement of Upstream Slope Stone Riprap	1410	CY	$90.00	$126,900.00
	DOWNSTREAM SLOPE				
	Clearing, Grubbing , Stripping - Downstream Slope Face	222	SY	$10.00	$2,222.22
	Tree Clearing - Downstream Slope	9	Ea.	$160.00	$1,440.00
02200.01	Common Excavation for Slope Repairs	266.7	CY	$25.00	$6,666.67
	Furnishing and Placement of Turf Reinforcement Mat	893.3	SY	$11.00	$9,830.00
02930.02	Furnishing and Placement of Loam from Off-Site Sources	148.9	CY	$50.00	$7,444.44
02930.03	Seeding	893.3	SY	$5.00	$4,466.67
	DOWNSTREAM CHANNEL				
02270.02	Furnishing and Placement Riprap at Downstream Channel	122	SY	$10.00	$1,222.22
				Sub-Total Cost:	**$461,900.00**
				50% Contingency:	**$231,000.00**
				Total Cost:	**$692,900.00**

BULLOUGH'S POND DAM REHABILITATION PROJECT
NEWTON, MA
GZA GeoEnvironmental, Inc.
File No. 174021
CONCEPTUAL COST ESTIMATE - Alternative 5 (ACB)

ITEM #	DESCRIPTION	ESTIMATED QUANITY	UNIT	GZA UNIT PRICE	GZA TOTAL PRICE
ONE TIME COST					
01740.01	Site Restoration	1	LS	$10,000.00	$10,000.00
01900.01	Mobilization and Demobilization	1	LS	$25,000.00	$25,000.00
02065.03	Removal and Legal Disposal of Miscellaneous Debris and Items	1	LS	$5,000.00	$5,000.00
	Slipeline 24-inch Outlet Pipes	1	LS	$225,000.00	$225,000.00
	Repair Stone Masonry Headwall				
11010.02	Repoint Spillway Training Walls	210	LF	$25.00	$5,250.00
	Grout Pump	3	day	$70.00	$210.00
UPSTREAM SLOPE					
	Clearing, Grubbing , Stripping - Upstream Slope Face	470	SY	$9.00	$4,230.00
	Tree Clearing - Upstream Slope	10	Ea.	$200.00	$2,000.00
02270.01	Furnishing and Placement of Crushed Stone Material Riprap Bedding	423	ton	$60.00	$25,380.00
02270.02	Furnishing and Placement of Upstream Slope Stone Riprap	1410	CY	$90.00	$126,900.00
DOWNSTREAM SLOPE					
	Clearing, Grubbing , Stripping - Downstream Slope Face	222	SY	$10.00	$2,222.22
	Tree Clearing - Downstream Slope	9	Ea.	$200.00	$1,800.00
02200.01	Common Excavation for Slope Repairs	266.7	CY	$25.00	$6,666.67
	Place ACBs downstream Slope	2000.0	SF	$11.00	$22,000.00
DOWNSTREAM CHANNEL					
02270.02	Furnishing and Placement Riprap at Downstream Channel	122	SY	$10.00	$1,222.22
				Sub-Total Cost:	**$462,900.00**
				50% Contingency:	**$231,500.00**
				Total Cost:	**$694,400.00**

GZA GeoEnvironmental, Inc.