LGCI
Lahlaf Geotechnical Consulting, Inc.

December 9, 2019

Mr. Robert Para Jr., AIA
Lamoureux Pagano & Associates, Inc.
108 Grove Street, Suite 300
Worcester, MA 01605
Tel: (508) 752-2831
Fax: (508) 757-7769
E-mail: RPara@lpaa.com

Re: Preliminary Geotechnical Review Services
Proposed Doherty High School
Foley Stadium Site
Worcester, Massachusetts
LGCI Project No. 1922

Dear Mr. Para:

Lahlaf Geotechnical Consulting, Inc. (LGCI) has performed a site visit and completed a preliminary review of the geotechnical data available for the Commerce Bank Field at Foley Stadium (Foley Site) in relation to the proposed Doherty High School in Worcester, Massachusetts. Our services were performed in accordance with our proposal No. 19087 dated October 14, 2019. Ms. Kathryn Crockett of Lamoureux Pagano & Associates, Inc. (LPA) authorized our services by signing our proposal on November 13, 2019

This letter includes a summary of our field observations, a summary of the subsurface data we reviewed, our opinion about possible foundation issues during construction, and our recommendations for subsurface explorations.

1. Reviewed Documents

LGCI reviewed the following documents:

- "Custom Soil Resource Report for Worcester County, Massachusetts, Northeastern Part," (Soil Survey Report) National Cooperative Soil Survey/National Resources Conservation Services, USDA (Map and soil description printed November 15, 2019 from https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx).

- "Surficial Materials Map of the North Worcester, Massachusetts," prepared by Stone, J.R. and Stone, B.D. for U.S. Geological Survey, 2018, Scientific Investigation Map 3402, Quadrangle 126 – North Worcester.

- "Topographic Plan, Foley Stadium, Chandler Street, Worcester, Mass." (Site Plan) Prepared by R.E. Cameron A Associates, Inc. of Norwood, MA and provided to us via e-mail by LPA on October 31, 2019.

- Plan showing locations of borings performed at the site in 1963 (1963 Boring Location Plan), provided to us by LPA via e-mail on July 30, 2019.

- Logs of soil borings performed at the site in 1963 (1963 Boring Logs), provided to us by LPA via e-mail on July 30, 2019.

- Logs of borings advanced at the Foley Stadium in February 1963 and boring locations provided to us by LPA via e-mail on July 30, 2019.

- Plan showing locations of soil probes (Probe Location Plan), prepared by CDM, performed in 2006, provided to us by LPA via e-mail on August 23, 2019.

- Logs of probes prepared by CDM (2006 Probe Logs), provided to us by LPA via e-mail on August 23, 2019.

- Sketch showing concept plan titled: "3.3.3 - Final Evaluation of Alternatives, Preliminary Design Options, Option B.1 - New Construction on Foley Stadium Site (Proposed Scheme), provided to us by LPA via e-mail on December 6, 2019.

- Sketches showing preliminary grading (Preliminary Grading Plans) provided to us by LPA via e-mail December 6, 2019.

2. Site Location Description

We understand that one of the sites being considered for the proposed Doherty High School is the Foley Site located at 325 Chandler Street in Worcester, Massachusetts as shown in Figure 1. This is an active sports complex that includes a football field with track, a grandstand, a baseball field, a grass practice field, a garage, and a field house. The site has frontage on Chandler Street. The site is bordered by residential properties on northern side (Pleasant Street) side; by Norman Avenue, Abbott Street, and private properties on the eastern side; by residential properties on the western (Coolidge Road) side; and by Chandler Street (Route 122) on the southern side.

Based on the Site Plan, utilities at the site include drain lines and overhead wires. The Site Plan also shows an 84-inch drain line (Beaver Brook Culvert) crossing the site in a nearly north south direction. The Site Plan indicates that the grades at the site generally slope up gently from about El. 485 feet on the southern side near Chandler Street to El. 493 feet near the northernmost corner of the site and to about El. 501 feet on the eastern side near Abbott Street.

We understand that the site was constructed in 1927. Based on historical topographic maps, included in Attachment A, a river used to cross the site. The maps show that the site was filled sometime between 1908 and 1934. The existing culvert crossing the site channels the water from Beaver Brook. You indicated to us that the grandstands and nearby buildings are supported on piles.

3. Project Description

We understand that the City of Worcester is considering the Foley Site as one of three possible sites for the proposed Doherty High School. We understand that if the Foley Site is selected, the proposed construction would consist of a high school building on the southern side of the site near Chandler Street, i.e., within the area of the existing grandstands and football field.

Based on the Proposed Scheme, the proposed building will consist of two wings configured in a fan-shape and connected on their southern sides. Based on the Preliminary Grading Plans, the proposed building will have a footprint of between 155,000 and 160,000 square feet and will be five stories high. Based on the Site Plan, the existing grades range between about El. 185 feet on the southern side and El. 189 feet on the northern side of the proposed building footprint. Based on the Proposed Scheme and the Preliminary Grading Plans, we understand that the proposed floors will be configured as follows:

- The first floor of the proposed building will be partially below-ground and will extend over only a portion of the proposed building on the western side. The first floor will have a finished floor elevation (FFE) of El. 485 feet; thus, requiring cuts up to 4 feet to achieve the proposed FFE. The area east of the first floor will not be excavated.
- The second and third floors of the proposed building will extend over the entire footprint of the proposed building and will have FFEs of El. 500 feet and El. 520 feet, respectively.
- The fourth floor of the proposed building will extend over the northern portion of the proposed building footprint while its southern portion will be a roof. The fourth floor will have an FFE of El. 535 feet.
- The fifth floor of the proposed building will only extend over the northeastern portion of the proposed building footprint and will have an FFE of El. 550 feet.

The proposed athletic fields will be located on the northern side of the site, north of the proposed building.

Based on the Proposed Grading Plan, the proposed exterior grade will be about El. 490 feet around the proposed building and will gently rise to about El. 500 feet on the eastern side near Abbott Street. The proposed athletic fields will have finished grades at about El. 492 feet. Based on the proposed grades, little cuts and fill will be required to achieve the proposed grades.

Field Observations

An LGCI representative visited the site on December 5, 2019. The purpose of our visit was to observe site features such as wet areas, and other features that may impact construction. Photographs taken during our site visit are included in Attachment A.

The site was mostly covered with about one foot of snow at the time of our visit and site features were concealed by the snow.

The exposed surface visible at the time of our visit such as the parking lot on the western side of the grandstands and the concrete walkway just north of the grandstands showed no evidence of gross settlement. Cracks in the concrete slabs near the entrance were observed. We also did not observe evidence of settlement between the ground surface adjacent to the grandstands and the grandstands' foundation. It is not known whether the ground around the pile-supported grandstands was regraded over time as a result of settlement of ground. Photographs of the sites are included in Attachment B.

4. Summary of Existing Subsurface Data

Soil Survey Report – Based on the Soil Survey Report listed in Section 1, the soils at the site are classified primarily as Urban Land and Smoothed Udorthents. Urban Land is defined as excavated and filled land. Udorthents are defined as "made land over firm loamy basal till." The Soil Survey Report does not include the thickness of the A and B horizons. However, it includes a depth to groundwater that is deeper than 80 inches.

A copy of the Soil Survey Report and Map are included in Attachment C.

Surficial Geologic Map – The Surficial Geologic Map (listed in Section 1) indicates that the natural soils in the general vicinity of the site consist of swamp deposits and coarse deposits. Based on the Surficial Geologic Map, the swamp deposits consist of organic muck and peat that contain minor amounts of sand, silt, and clay. The Surficial Geologic Map indicates that the swamp deposits are present on the southern side of the site. The coarse deposits consist of gravel deposits, sand and gravel deposits, and sand deposits. These deposits are present on the northern side of the site.

The Surficial Geologic Map of the site is shown in Figure 2.

Previous Explorations – Based on the 1963 Boring Location Plan, fourteen (14) borings were advanced at the site in 1963. You provided us with the logs of nine (9) of the 1963 borings (Boring-1 to Boring-9). Borings Boring-1 to Boring-9 were advanced within and near the footprint of the existing grandstand and extended to depths ranging between 7 and 30 feet beneath the ground surface.

You also provided us with the logs of twenty-nine (29) probes that were advanced at the site by CDM in 2006. The locations of nineteen (19) of these probes (CDM-1 to CDM-19), advanced in the football field north of the existing grandstands, are shown in the Probe Location Plan. The locations of probes CDM-20 to CDM-29 are not shown on the Probe Location Plan. Probes CDM-1 to CDM-29 were advanced to depths ranging between 5 and 15 feet beneath the ground surface.

The locations of the 1963 borings and the 2006 probes, and the logs you provided to us are included in Attachment D.

The soil strata encountered in the borings and probes were as follows, starting at the ground surface.

Topsoil – A layer of topsoil was encountered at the ground surface in borings Boring-1 to Boring-9 and in probes CDM-1 to CDM-29. The topsoil extended to depths ranging between 0.5 and 3.8 feet beneath the ground surface. The topsoil was generally described as silt in the probes and as loam in the borings. The topsoil contained traces of roots.

Fill – A layer of fill was encountered at the ground surface or beneath the topsoil in borings Boring-1 to Boring-4, Boring-6, and Boring-8 and probes CDM-1 to CDM-28. The fill extended to the termination depth of boring Boring-2 and probes CDM-1, CDM-2 to CDM-5, CDM-7 to CDM-10, CDM-12 to CDM-14, CDM-16, CDM-17, and CDM-26 to CDM-29 at depths ranging between 5 and 7 feet beneath the ground surface. In Boring-1, Boring-3, Boring-4, Boring-6, and Boring-8 and in probes CDM-2, CDM-6, CDM-11, CDM-15, CDM-18 to CDM-25, the fill extended to the top of the silt, organic silt, and sand and gravel layers at depths ranging between 3.8 and 12.5 feet beneath the ground surface. In the borings, the fill was described as loose or firm fill. In the probes, the fill consisted of a heterogenous mixture of gravel, sand, silt, and clay and contained traces of silt, coal ash, ash, brick, and glass. In a few probes, the samples consisted mostly or entirely of coal ash and brick.

The standard penetration test (SPT) N-values in the fill ranged between 1 and 235 blows per foot (bpf), with most values ranging between 1 and 30 bpf, indicating mostly very loose to medium dense material. The high SPT N-values may have been caused by obstructions in the fill.

Silt/Organic Silt/Silty Clay/Sand and Gravel – Layers of interbedded silt, silty clay, sand, and gravel were encountered beneath the fill. The silt was described as organic silt in probes CDM-18 to CDM-21 and CDM-25. The organic silt extended to depths ranging between 12.5 and 14.8 feet beneath the ground surface. Two samples in probes CDM-18 and CDM-25 contained peat.

Where encountered, the sand and gravel extended to the probe and boring termination depths. The (SPT) N-values in the sand and gravel layer ranged between 16 and 330 bpf, with most values greater than 30 bpf, indicating mostly dense to very dense material.

Where encountered in the 1963 soil borings and in the 2006 probes, groundwater ranged between depths of 9 and 12 feet beneath the ground surface.

In addition to the exploration logs described above, you provided us with the logs and locations of ten (10) borings (P1-P4, A1, A3, B-4, B-6, C1, and C3), advanced at the existing Beaver Brook Park located across Chandler Street from the site, to depths ranging between 17 and 24 feet beneath the ground surface. These borings generally indicated fill, overlaying peat,

overlaying sand. The fill in borings P1, P4, A1, A3, B4, B6, C-1, and C3 was underlain by peat that extended to the termination depths of borings A1, A3, B4, B6, C-1, and C3, at 3 to 24 feet beneath the ground surface. Natural, very loose to medium dense sand was encountered beneath the fill or peat in the borings and extended to the boring termination depths. The Beaver Brook Park borings generally indicated subsurface conditions that were consistent with those observed in the borings and probes advanced at the site.

The subsurface conditions encountered at the site and at the Beaver Brook Park are consistent with the Surficial Geologic Map that indicated the presence of swamp deposits in the general area of the site.

5. Preliminary Recommendations

Please note that the review of available information summarized in this letter is not a substitute for a subsurface exploration program. The information gathered as part of this review may be incomplete and the recommendations derived therefrom are at best preliminary in nature and must be confirmed with actual subsurface explorations, laboratory testing, and geotechnical analyses.

The available subsurface data indicate the presence of fill that extends to depths of up to 12.5 feet beneath the ground surface. The previous borings indicated that the fill is very loose to medium dense. Existing fill that was not placed with strict moisture, density, and gradation control presents the risk of unpredictable settlements that may result in the poor performance of floor slabs and foundations. Organic silt was also encountered beneath the fill. The organic silt to depths of up to 14.8 feet beneath the ground surface. Organic silt left in place underneath the proposed foundations and slabs will result in larger than acceptable settlements. Due to these risks, the existing fill and organic silt are not suitable to support the proposed building.

The proposed building may be supported on deep foundations or on shallow footings bearing on improved ground as described below.

Deep Foundations – The proposed building may be supported on deep foundations. Feasible foundation types include H-piles, concrete-filled steel pipe piles, and pre-stressed concrete piles. H-piles would need to extend to the top of rock. Steel pipe piles and pre-stressed concrete piles could derive their capacity in friction and in end bearing in the sand layer. Micropiles installed with their bond zones in the sand layer are also feasible and offer the advantage of drilling through boulders. The selection of the pile type should be based on the proposed column loads, the subsurface conditions from deep borings, and on cost considerations. When considering a pile foundation, the cost of pile caps and a structural slab should be also be taken into account.

Ground Improvements – We believe that the existing fill and organic soil could be improved using aggregate piers (APs) or rigid inclusions.

APs are typically relatively short, stiff elements of compacted aggregate which improve the existing fill. These elements are typically installed by augering holes ranging from 20 inches to 36 inches in diameter. Aggregate (crushed stone or recycled concrete) is then introduced into the hole and is generally compacted in one-foot lifts by repeated penetrations with the vibrator, which can be mounted to a crane or tracked carrier. The vibratory or ramming energy densifies the aggregate in the element; thus, producing high modulus aggregate piers. The installation of APs also densifies the surrounding soil depending on the type of soil. These high modulus elements reinforce the treatment zone and increase the composite friction angle and stiffness of the reinforced soil mass. Due to the presence of organic soil, if used, the aggregate piers should be grouted to reduce the potential for bulging of the piers in the organic soil. The installation of grouted-APs is similar to conventional AP construction except that grout is introduced into the stone backfill during placement and compaction.

After the ground is improved, the proposed building may be supported on conventional shallow footings, and the proposed slab may be constructed as a slab-on-grade.

The final number, layout, size, and depth of the ground improvement are provided by a professional engineer engaged by the specialty contractor. A modulus test of each type of installed piers will be required before the start of production.

Rigid inclusions (RIs) are a ground improvement technique whereby rigid, cylindrical concrete elements are installed through a soil that is not suitable to support shallow foundations, such as the existing fill, organics, and loose sand and silt at the site. The concrete is installed using a bottom feed from a mandrel as the mandrel is extracted from the ground. After the ground is improved using rigid inclusions, the proposed structure may be supported on shallow foundations, and the slab may be constructed as a slab-on-grade.

6. Recommendations for Subsurface Explorations

We recommend performing additional explorations at the site if this site is selected. The additional explorations should include sixteen (16) to twenty (20) soil borings, including at least six (6) borings to rock, and two (2) groundwater observation wells. The geotechnical explorations should be coordinated with the work of an environmental engineer to pre-characterize the site soils generated from footing and utility excavations and from ground improvement soils, if any, that will need to be disposed of offsite.

7. Limitations

Our letter is based on project information provided to us at the time of this letter. If changes to the type, size, and location of the proposed structure or to the site grading are made, the recommendations contained in this letter shall not be considered valid unless the changes are reviewed, and the conclusions and recommendations modified in writing by LGCI. LGCI cannot accept responsibility for designs based solely on these preliminary recommendations.

It is not part of our scope to perform a more detailed site history; therefore, we have not explored for or researched the locations of buried utilities or other structures in the area of the proposed construction. Our scope did not include environmental services or services related to moisture, mold, or other biological contaminates in or around the site.

The recommendations in this letter are based in part on the data obtained from the review of existing subsurface data. The recommendations contained in this letter are at best preliminary in nature and must be confirmed with actual subsurface explorations, laboratory testing, and geotechnical analyses.

Our letter has been prepared in accordance with generally accepted engineering practices and in accordance with the terms and conditions set forth in our agreement. No other warranty, expressed or implied, is made. This report has been prepared for the exclusive use of Lamoureux Pagano & Associates, Inc. for the specific application to the proposed Foley Stadium Site at the Doherty High School in Worcester, Massachusetts as conceived at this time.

If you have any questions or need further assistance, please contact us at (978) 330-5912.

Very truly yours,

Lahlaf Geotechnical Consulting, Inc.

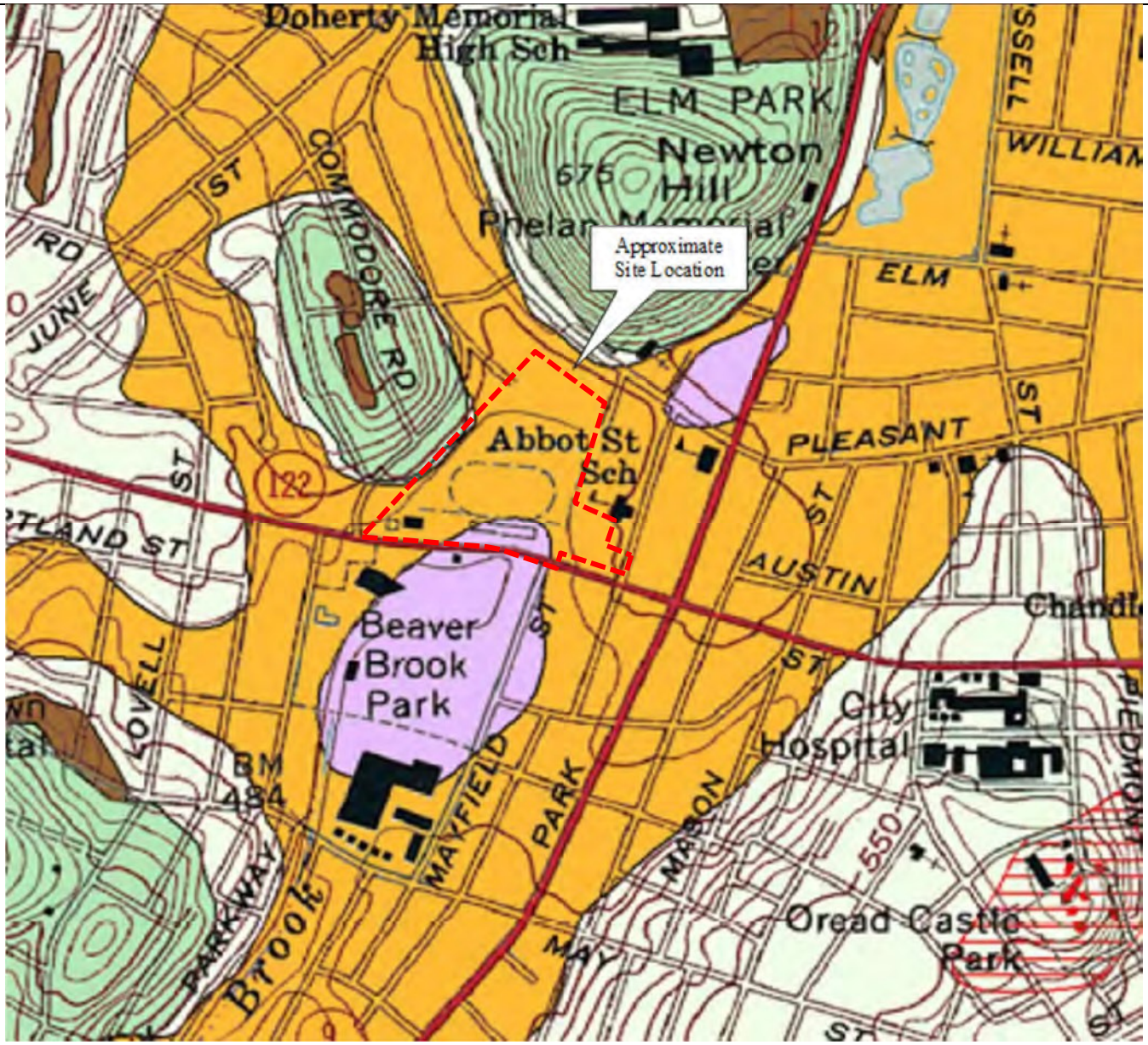
Abdelmadjid M. Lahlaf, Ph.D., P.E.
Principal Engineer

Attachments: Figure 1 – Site Location Map
Figure 2 – Surficial Geologic Map
Attachment A – Historical Topo Maps
Attachment B – Photographs
Attachment C – Excerpts of Soil Survey Report
Attachment D – Locations and Logs of Previous Borings and Probes

Contour Intervals: 3 meters

Figure based on USGS topographic map of Worcester, MA obtained from www.mytopo.com/maps

Client:	Project:	Figure 1 – Site Location Map (Foley Site)	
Lamoureux Pagano & Associates, Inc.	Proposed Doherty High School		
LGCI Lahlaf Geotechnical Consulting, Inc.	Project Location: Worcester, MA	LGCI Project No.: 1922	Date: Nov. 2019



N

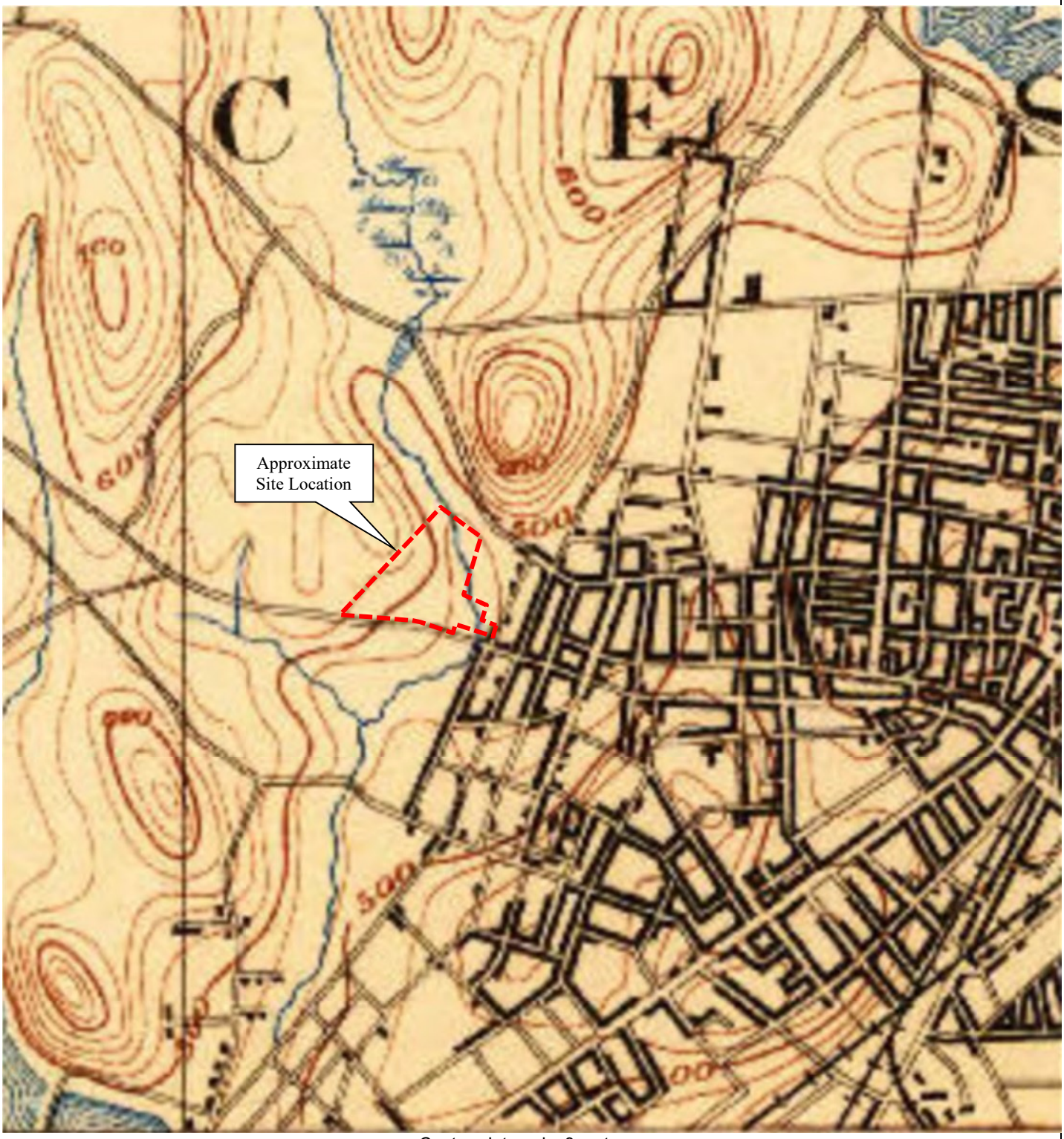
Swamp deposits—Organic muck and peat that contain minor amounts of sand, silt, and clay, are stratified and poorly sorted, and occur in swamps and freshwater marshes, in kettle depressions, or in poorly drained areas. Unit is shown only where deposits are estimated to be at least 3 ft thick; most deposits are less than 10 ft thick. Swamp deposits overlie glacial deposits or bedrock. They locally overlie glacial till even where they occur within thin glacial meltwater deposits

Coarse deposits consist of *gravel deposits*, *sand and gravel deposits*, and *sand deposits*, not differentiated in this report. *Gravel deposits* are composed of at least 50 percent gravel-size clasts; cobbles and boulders predominate; minor amounts of sand occur within gravel beds, and sand comprises a few separate layers. Gravel layers generally are poorly sorted, and bedding commonly is distorted and faulted due to postdepositional collapse related to melting of ice. *Sand and gravel deposits* occur as mixtures of gravel and sand within individual layers and as layers of sand alternating with layers of gravel. Sand and gravel layers generally range between 25 and 50 percent gravel particles and between 50 and 75 percent sand particles. Layers are well sorted to poorly sorted; bedding may be distorted and faulted due to postdepositional collapse. *Sand deposits* are composed mainly of very coarse to fine sand, commonly in well-sorted layers. Coarser layers may contain up to 25 percent gravel particles, generally granules and pebbles; finer layers may contain some very fine sand, silt, and clay

Figure based on map titled: "Surficial Materials Map of the North Worcester, Massachusetts," prepared by Stone, J.R. and Stone, B.D. for U.S. Geological Survey, 2018, Scientific Investigation Map 3402, Quadrangle 126 – North Worcester.

Client:	Project:	Figure 2 – Surficial Geologic Map (Foley Site)	
Lamoureux Pagano & Associates, Inc.	Proposed Doherty High School		
LGCI Lahlaf Geotechnical Consulting, Inc.	Project Location: Worcester, MA	LGCI Project No.: 1922	Date: Nov. 2019

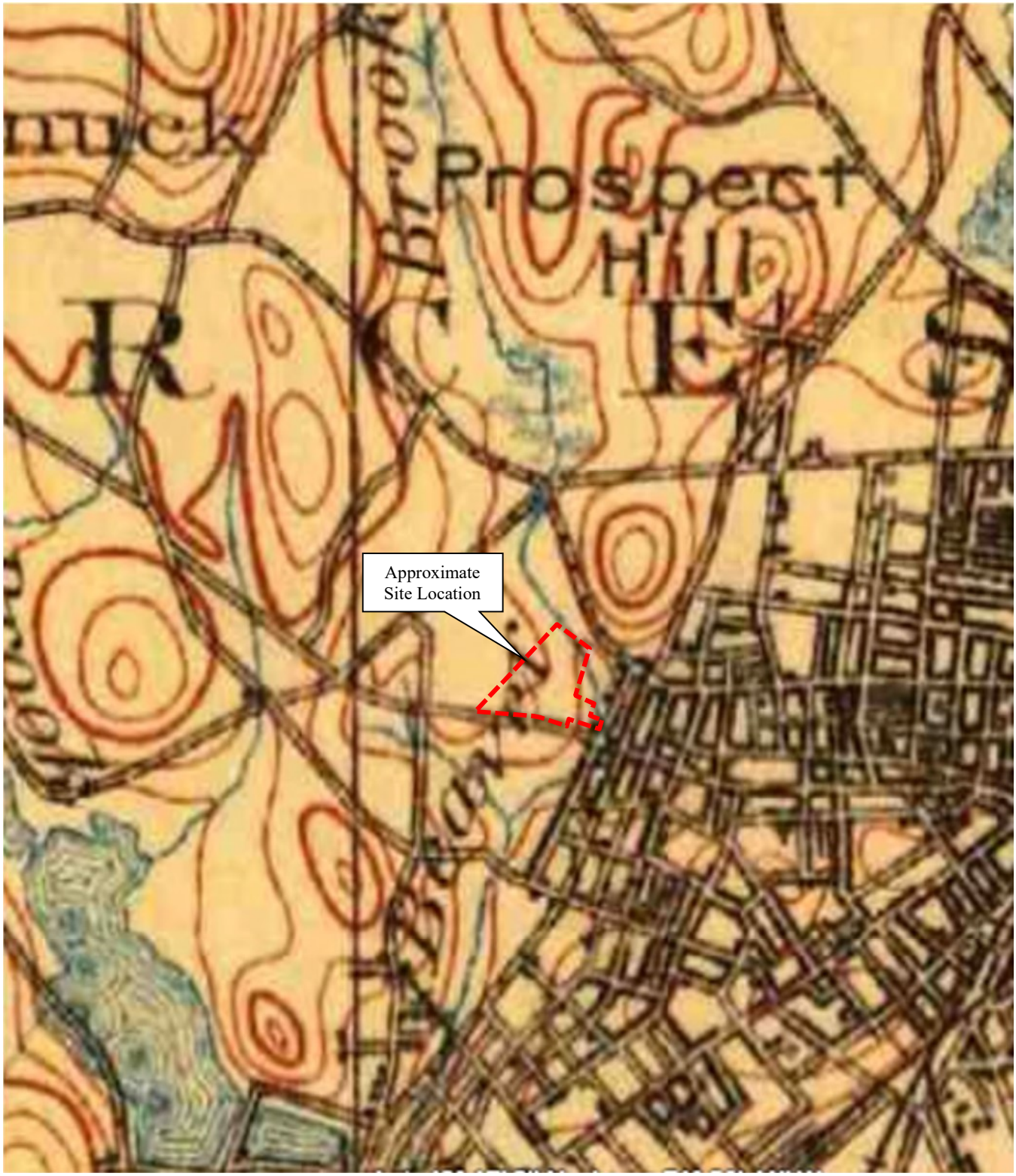
Attachment A – Historical Topo Maps



Contour Intervals: 3 meters

Figure based on USGS topographic map of Worcester, MA obtained from https://ngmdb.usgs.gov/topoview/

Client:	Project:	Figure A1 – 1886 Historical Topo Map (Foley Site)	
Lamoureux Pagano & Associates, Inc.	Proposed Doherty High School		
LGCI Lahlaf Geotechnical Consulting, Inc	Project Location: Worcester, MA	LGCI Project No.: 1922	Date: Nov. 2019



Contour Intervals: 3 meters

Figure based on USGS topographic map of Worcester, MA obtained from https://ngmdb.usgs.gov/topoview/

Client:	Project:	Figure A2 – 1908 Historical Topo Map (Foley Site)	
Lamoureux Pagano & Associates, Inc.	Proposed Doherty High School		
LGCI Lahlaf Geotechnical Consulting, Inc.	Project Location: Worcester, MA	LGCI Project No.: 1922	Date: Nov. 2019

Contour Intervals: 3 meters

Figure based on USGS topographic map of Worcester, MA obtained from https://ngmdb.usgs.gov/topoview/

Client:	Project:	Figure A3 – 1934 Historical Topo Map (Foley Site)	
Lamoureux Pagano & Associates, Inc.	Proposed Doherty High School		
LGCI Lahlaf Geotechnical Consulting, Inc.	Project Location: Worcester, MA	LGCI Project No.: 1922	Date: Nov. 2019

Attachment B – Photographs

Photo No. 1: Existing field covered with snow facing north

Photo No. 2: Existing field facing northeast

Photo No. 3: Existing field facing northwest

Photo No. 4: Panoramic View of the existing field

Photo No. 5: Plowed concrete walkway with no evidence of gross settlement

Photo No. 6: Existing crack near the entrance of the stadium