Tighe&Bond
Engineers | Environmental Specialists

17.1490011.02
July 12, 2017

Mr. Matthew Mainville, Executive Director
Holyoke Housing Authority
475 Maple Street
Holyoke, MA 01040

Re: **Geotechnical Evaluation for Holyoke Urban Agenda Grant**

Dear Mr. Mainville:

Tighe & Bond is pleased to present this geotechnical evaluation for the proposed housing units being considered on multiple properties on Clemente Street, South East Street, Hamilton Street, and South Bridge Street in Holyoke, MA. A Site Locus is presented as Figure 1 of Appendix A. This evaluation was completed in accordance with our Task Order #4 dated May 19, 2011. The vertical datum referenced in this report is the North American Vertical Datum of 1988 (NAVD88).

Executive Summary

In general, subsurface conditions consisted of approximately 2 to 9 inches of topsoil in most areas, overlying 1 to 7 feet of fill, overlying stratified sands and silts, overlying glacial till. Fill may extend as deep as approximately 10 to 12 feet below the existing ground surface on parcels 010, 011, and 012 on South East Street, but is likely less than 10 feet thick in this area. Portions of the fill contained brick, asphalt, coal and coal ash, concrete, plastic, wood, and trash. Remnants of former building foundations, foundation walls, and/or basement floor slabs were observed in some test pits and extended as deep as approximately 8 feet below the existing ground surface. Groundwater was encountered approximately 8 feet to 11 feet below the existing ground surface northwest of Clemente Street, corresponding to elevations ranging from approximately 68 to 70 feet. Southeast of South East Street, groundwater was encountered approximately 15 to 17 feet below the existing ground surface, corresponding to elevations ranging from approximately 60 to 62 feet.

The existing fill soils are not considered suitable for foundation or floor slab support for new buildings. It is anticipated that most of the existing fill, as well as remnant foundations, foundation walls, floor slabs and utility piping will be removed during excavation for new basements, which are assumed to be full basements extending 6 to 8 feet below finished site grades, and foundations. It is possible that several feet of existing fill may still be present below proposed basement floor slab and bottom of foundation level on South East Street parcels 010, 011, and 012. If existing fill, remnant structures, or utilities to be abandoned are encountered at floor slab or foundation subgrade level, they should be completely removed from the footprint of the proposed structure and within foundation bearing zones, and replaced with compacted Granular Fill, Gravel Borrow, or Crushed Stone wrapped in a non-woven geotextile separation fabric. The foundation bearing zone is defined by a 1H:1V plane extending downward and outward from one foot beyond the edge of foundation.

The new residential buildings may be supported by conventional spread footing foundations. A net allowable bearing pressure of 1 ton per square foot (tsf) is recommended for footings bearing on undisturbed native soils, or on placed and compacted Granular Fill, Gravel Borrow, or Crushed Stone wrapped in a non-woven geotextile separation fabric, placed over proof compacted native soil subgrades. Foundation and underslab drainage with damp-proofing is recommended for new buildings northwest of Clemente Street.

Site Conditions

Existing – The eighteen properties which may be redeveloped include parcels 001, 005, 006, 007, and 008 on Clemente Street, parcels 009, 010, 011, 012, 013, 016, 017, 018, and 019 on South East Street, parcels 006 and 007 on South Bridge Street, and parcels 001 and 006 on Hamilton Street. Except for parcels 001 and 008 on Clemente Street, 009 and 013 on South East Street, and 006 on South Bridge Street, the remaining parcels are currently owned by the City. A one-story brick building exists on South Bridge Street parcel 006. The remaining parcels are vacant and the former buildings have been demolished.

Existing topography is relatively flat across the project area. Existing site grades range from approximately elevation 75 feet to 77 feet on the South East Street and South Bridge Street parcels, and parcel 001 on Hamilton Street. Existing site grades range from approximately elevation 76 feet to 81 feet on the Clemente Street parcels, and parcel 006 on Hamilton Street. Our understanding of the existing conditions is based on the "Existing Conditions Survey" prepared by WSP USA Inc. and dated June 27, 2017.

Proposed – It is anticipated that the new residential structures will be two-story, duplex style houses with full basements. Proposed finished floor levels and finished site grades are not known at this time. However, it is assumed that finished site grades will likely be within a foot of existing site grades, and basement floor levels will be about 6 to 8 feet below finished site grades.

Subsurface Conditions

The generalized subsurface conditions described in the text below summarize trends observed in the explorations. The boundaries between soil strata are approximate, and are based on interpretations of widely spaced explorations and samples. Actual conditions could be more variable.

Test Borings – Seven geotechnical test borings (B-1 through B-6, and B-1A) were drilled on City owned parcels by Seaboard Drilling, Inc. of Springfield, MA on June 12 and 13, 2017. Test borings B-1 through B-6 were advanced with 4.25-inch inner diameter hollow-stem augers to depths ranging from 22 to 27 feet below the existing ground surface. Boring B-1A was advanced with 3-inch inner diameter flush joint casing and drive and wash methods to a depth of 47 feet below the existing ground surface. Split-spoon sampling and Standard Penetration Tests (SPTs) were conducted at maximum 5 foot intervals. Test borings were terminated in native soils.

Borings were backfilled upon completion with cuttings. Approximate boring locations are shown on Figure 2, of Appendix A. Test boring logs are included in Appendix B.

Test Pits – Thirteen test pits (TP-1 through TP-13) were excavated by Seaboard Drilling, Inc. of Springfield, MA on June 14 and 15, 2017 with a Komatsu PC40 excavator. Test pit depths ranged from 8 to 10 feet below the existing ground surface. Test pits were terminated in native soils, except for possibly test pits TP-6 and TP-8 which may have been terminated in fill, as discussed in the subsurface conditions summary below. Test pits were backfilled with excavated material placed in lifts and compacted with the heel of the bucket. Approximate test pit locations are shown on the Subsurface Exploration Plan. Test pit logs are included in Appendix B.

Laboratory Testing – Laboratory tests were performed to aid in soil classifications, evaluate liquefaction potential, and evaluate soil re-use potential. Five mechanical Particle Size

Analysis tests (ASTM D422), and one Atterberg limits test (ASTM D4318) were performed on samples taken during the explorations. Laboratory test results are included in Appendix C.

Summary of Subsurface Conditions – In general, subsurface conditions observed in the explorations consisted of approximately 2 to 9 inches of topsoil in most areas, overlying 1 to 7 feet of fill, overlying 16 to 40 feet of stratified sands and silts, where they were fully penetrated, overlying glacial till which was penetrated 1 to 5 feet before the explorations were terminated. At boring B-2, fill was observed in the sample obtained from a depth of 4 to 6 feet, and fragments of brick were stuck in the tip of the spit-spoon sampler driven from a depth of 10 to 12 feet which resulted in no sample recovery from that depth interval. At adjacent test pits TP-6 and TP-8, no clear distinction was made between sands which may have either been fill or native soils. Based on these observations, it is possible that fill may extend as deep as approximately 10 to 12 feet below the existing ground surface around boring B-2 and test pits TP-6 and TP-8. However, based upon the inconclusive observations and the thickness of fill observed in other areas, it is likely that fill is less than 10 feet thick in this area.

In general, the fill observed varied in composition and relative density, and does not appear to have been systematically placed and compacted. Portions of the fill contained brick, asphalt, coal and coal ash, concrete, plastic, wood, and trash. Remnants of former building foundations, foundation walls, and/or basement floor slabs were observed in test pits TP-1, TP-3, TP-5, TP-7, TP-11, and TP-13, and extended as deep as approximately 8 feet below the existing ground surface. Former utility piping was observed approximately 4 to 6 feet below the ground surface at test pits TP-8, TP-11 and TP-12. Based on these observations, the former structures do not appear to have been completely demolished and removed.

Table 1 below presents the general stratigraphy encountered during the subsurface exploration program in descending depth from below the surficial topsoil, or below the ground surface where topsoil was absent.

Groundwater was encountered approximately 8 feet to 11 feet below the existing ground surface at explorations advanced northwest of Clemente Street, corresponding to elevations ranging from approximately 68 to 70 feet. Southeast of South East Street, groundwater was encountered approximately 15 to 17 feet below the existing ground surface, corresponding to elevations ranging from approximately 60 to 62 feet. Water levels were taken during or immediately after drilling, and during test pit excavation, and may not reflect stabilized conditions. Water levels can fluctuate with season, precipitation, and nearby construction or other below grade activities, such as excavation, dewatering, wells, infiltration basins, etc.

Table 1
Description of Subsurface Conditions Encountered

Strata (In Descending Depth)	General Description
FILL	Loose to medium dense, brown to black to red, fine to coarse SAND with up to 50% Silt, 50% Brick and Asphalt, 35% Gravel, 35% Coal and Coal Ash, and 20% Concrete and Plastic. Wood and trash were also observed at some test pit locations.

SANDS	Loose to medium dense, brown, fine to coarse SAND with up to 50% Gravel and 10% Silt, varying to loose to medium dense, brown to gray, fine SAND with up to 50% Silt
SILTS	Loose, brown to grey SILT with up to 50% fine Sand, varying to grey to brown SILT & CLAY (B-1A only)
GLACIAL TILL	Dense to very dense, purple/grey SILT with up to 50% Gravel and 20% fine to coarse Sand, varying to medium dense, purple/brown, fine to coarse SAND with up to 35% Silt and 35% Gravel

Geotechnical Evaluation and Recommendations

The analyses and recommendations submitted in this evaluation are based upon the data obtained from the relatively widely spaced subsurface explorations. The nature and extent of variations between explorations may not become evident until construction. If significant variations from these descriptions appear during construction, it will be necessary to re-evaluate these recommendations.

Subsurface explorations were not conducted on parcels 001 and 008 on Clemente Street, 009 and 013 on South East Street, and 006 on South Bridge Street as they are not currently owned by the City. Therefore, the subsurface conditions at these parcels are not currently known. If these parcels are purchased by the City, then subsurface explorations should be performed to determine if the subsurface conditions are similar to those observed on nearby parcels, and verify that the geotechnical design recommendations presented below are appropriate.

The environmental concerns noted in the Phase I Environmental Site Assessment for the subject site dated June 2017 may represent a cost premium associated with the excavation and replacement of fill materials, as recommended above. In consideration of these environmental concerns and the observed remnant foundations, the practicality of full basements should be reevaluated during design.

Geotechnical Design Recommendations

Foundation and Slab Design – Due to the variable composition and relative density of the existing fill materials, they are not considered suitable for foundation or floor slab support for new buildings. It is anticipated that most of the existing fill, as well as remnant foundations, foundation walls, floor slabs and utility piping will likely be removed during excavation for new basements and foundations. Depending upon finished floor levels, it is possible that several feet of existing fill may still be present below basement floor slab and bottom of foundation level in the area of boring B-2 and test pits TP-6 and TP-8 on South East Street parcels 010, 011, and 012. If existing fill, remnant structures, or utilities to be abandoned are encountered at floor slab or foundation subgrade level, they should be completely removed from the footprint of the proposed structure and within foundation bearing zones, and replaced with compacted Granular Fill, Gravel Borrow, or Crushed Stone wrapped in a non-woven geotextile separation fabric. The foundation bearing zone is defined by a 1H:1V plane extending downward and outward from one foot beyond the edge of foundation. Where loose sands and fill materials are over-excavated and shallow foundations are constructed over properly compacted Granular Fill, Gravel Borrow, or Crushed Stone wrapped in a non-woven geotextile

separation fabric, placed over proof compacted native soil subgrades; allowable bearing pressures higher than 1 TSF may be achievable.

Following the removal of all vegetation, topsoil and subsoil, and the recommended over-excavation and replacement of the materials described above, the new residential buildings may be supported by conventional spread footing foundations. A net allowable bearing pressure of 1 ton per square foot (tsf) is recommended for footings bearing on undisturbed native soils, or on placed and compacted Granular Fill, Gravel Borrow, or Crushed Stone wrapped in a non-woven geotextile separation fabric, placed over proof compacted native soil subgrades.

The net allowable bearing pressure applies to footings having a minimum lateral dimension of at least 3 feet. For smaller footings, the recommended allowable bearing pressure must be reduced by the ratio of actual minimum footing size to 3 feet. At the recommended bearing pressure, total and differential settlements are anticipated to be less than 1 inch and ½ inch, respectively. Most settlement will occur during construction as dead load is applied.

Per the Massachusetts State Building Code, footings should bear a minimum of 4 feet below adjacent ground surface exposed to freezing temperatures for frost protection. Interior footings not exposed to freezing temperatures should bear a minimum of 1.5 feet below the slab; however, possible building shut downs or power failures should be considered.

A coefficient of friction equal to 0.30 ($\delta = 17$ degrees) should be used for concrete on native soils or compacted Granular Fill, 0.55 ($\delta = 29$ degrees) should be used for concrete on compacted Gravel Borrow or compacted Crushed Stone.

The floor slab may be designed as a slab-on-grade bearing on 1-foot of a compacted Gravel Borrow base course, or on a 1-foot compacted Crushed Stone base course where underslab drainage is recommended in the report section below, placed after proof compaction of the subgrade.

Subgrades and required fill to achieve proposed grade should be prepared, placed, and compacted as recommended later in this letter.

Foundation and Underslab Drainage – Groundwater was encountered as high as 8 feet below the existing ground surface northwest of Clemente Street, corresponding to elevation 70 feet. In addition, it is anticipated that seasonal fluctuations in groundwater levels could be higher. Based on this information and the assumption that basement floor levels will be approximately 6 feet below existing site grades, foundation and underslab drainage with damp-proofing is recommended for new buildings northwest of Clemente Street. Groundwater was encountered approximately 15 to 17 feet below the existing ground surface southeast of South East Street, corresponding to elevations ranging from approximately 60 to 62 feet. Therefore, underslab or foundation drainage is not required for new buildings located southeast of Southeast Street.

The underslab drainage blanket should include a minimum 12-inch thick layer of Crushed Stone wrapped in a non-woven geotextile filter fabric that extends beneath the entire floor slab, with a series of perforated PVC pipes bedded within the stone. The minimum pipe diameter and maximum pipe spacing should be at least 4-inch, and 20 feet, respectively, but should be determined based on the elevation of the drainage system in relation to the water table. The perimeter foundation drains should be a 6-inch diameter perforated PVC pipe surrounded by at least 6 inches of Crushed Stone wrapped in a non-woven filter fabric. Water collected in pipes should be conveyed to properly filtered sump pumps for discharge, or daylighted by gravity, if possible.

Retaining Wall Design – Lateral pressures for design of braced walls have been included for use in design of below grade foundation walls. It is recommended that braced foundation walls be designed for the following lateral loads:

- Static: 61 psf/ft as an equivalent fluid pressure
- Surcharge: 0.47 times the vertical surcharge load uniformly distributed over the height of the wall. The minimum vertical surcharge should be equivalent to an H-20 vehicular load, if vehicles (including construction equipment) will be allowed above the wall within a distance of the 1.5 times the wall height.
- Seismic: $7.5H^2$ distributed as an inverse triangle over the height of the wall

These design values were calculated using Rankine Theory with a soil unit weight of 130 pounds per cubic foot (pcf) and a friction angle of 32 degrees, assuming the use of three feet of Gravel Borrow or Crushed Stone wrapped in non-woven filter fabric placed behind the wall as part of a drainage system to prevent buildup of hydrostatic pressures. Additional fill needed behind the wall should consist of Granular Fill within 0.55 times the height of the wall. The design values above do not include hydrostatic loads. Where the calculated lateral earth pressure is less than 200 pounds per square foot (psf), it should be increased to 200 psf to account for compaction induced stresses.

Modulus of Subgrade Reaction - The recommended modulus of subgrade reaction, k_1, is 30 lbs per cubic inch. This value was determined based upon the available SPT data collected during the subsurface exploration program, and is not based upon a plate load test, or other type of direct test.

Seismic Design - Based on data from the borings, the site is assigned to Site Class E, according to the Massachusetts State Building Code. The design spectral response accelerations at short periods (S_{DS}) and at 1-second periods (S_{D1}) are 0.383 and 0.154 respectively. These values were calculated based on mapped spectral response accelerations and the appropriate magnification factors for Site Class E. The Seismic Design Category should be determined by the structural engineer based upon the seismic use groups presented in the building code.

Based on standard penetration test N-values, groundwater levels measured at the site, and gradation of the soils observed in the explorations, soils encountered in the borings are not considered susceptible to liquefaction.

Geotechnical Construction Recommendations

This section provides comments related to foundation construction, earthwork, and other geotechnical aspects of the project that will aid those responsible for preparing construction specifications.

Excavation and Fill – Conventional heavy construction equipment should be suitable for excavation in existing soil materials. Excavation should conform to OSHA excavation regulations contained in 29 CFR Part 1926, latest edition. Exposure to the observed contaminated subsurface materials may present an environmental health and safety risk; please refer to the Phase I Environmental Site Assessment for the subject site dated June 2017. Subgrades should be excavated in such a way to minimize disturbance, such as using a smooth faced bucket. Crushed Stone wrapped in a non-woven geotextile filter fabric should be used for the underslab drainage blanket. Gravel Borrow or Crushed Stone wrapped in a non-woven geotextile filter fabric should be used for the slab base course where underslab drainage is not required. Other fill needed below the structure, if any, should consist of

compacted Granular Fill, Gravel Borrow, or Crushed Stone wrapped in a non-woven geotextile filter fabric. Table 2 presents the required gradations for imported materials.

Table 2
Gradation Requirements for Borrow Materials

Sieve Size	Percent Finer by Weight		
	Granular Fill	**Gravel Borrow**	**1-1/2" Crushed Stone**
2/3rd lift thickness	100		
2 inch	--	100	100
1½ inch	--	--	95-100
1 inch	--	--	35-70
¾ inch	--	--	0-25
½ inch	--	50-85	--
No. 4	--	40-75	--
No. 10	30-95	--	--
No. 40	10-70	--	--
No. 50	--	8-28	--
No. 200	0-15	0-10	--

All backfill should be placed in 12-inch maximum lifts and should be compacted to 92 percent of the maximum dry density as determined by the Modified Proctor laboratory test (ASTM D1557). Thinner lifts may be needed depending on the material placed and the type of compactor used. Crushed Stone should be placed in loose lift thicknesses of less than 12 inches and be compacted with heavy compaction equipment to achieve an unyielding subgrade.

Dewatering – Groundwater might be encountered during foundation excavation for new buildings located northwest of Clemente Street. If dewatering becomes necessary it can likely be accomplished by pumping from properly filtered sumps and be discharged according to federal, state, and local regulations. The groundwater level should be temporarily lowered at least two feet below excavations to limit potential "boils", loss of fines, or softening of the ground. Surface water entering the construction area should be diverted away from excavations.

Bearing Surface Preparation – Excavated subgrades should be proof compacted with either 10 passes of a 10-ton vibratory drum roller for open excavations or 6 passes of a large, reversible, walk behind vibratory compactor capable of exerting a minimum force of 2,000 lbs in trench or pit excavations. Any subgrades that are soft or yielding under proof compaction

efforts should be removed below the footprint of the structure as well as in the footing bearing zone which is defined by a 1H:1V plane extending downward and outward from one foot beyond the edge of footing and replaced with compacted Granular Fill, Gravel Borrow, or Crushed Stone wrapped in a non-woven geotextile. If proof compaction will prove detrimental to the surface due to the presence of groundwater, static rolling may be allowed at the discretion of the Engineer.

Due to the high fines (silt) content, some of the bearing surfaces may be easily disturbed during foundation construction activities should they become wet from precipitation or groundwater. If desired, the bearing surfaces may be over-excavated by 6 to 12 inches and replaced by a layer of compacted Crushed Stone wrapped in a separation geotextile to provide a stable working surface.

Time between final excavation and placement of footings should be minimized to limit disturbance and groundwater induced softening of the subgrade. Soil bearing surfaces should be protected against freezing and the elements before and after concrete placement. If construction is performed during freezing weather, footings and foundation walls should be backfilled as soon as possible after they are constructed. Alternatively, insulating blankets or other means may be used for protection against freezing.

Reuse of Existing Soils – Existing subsurface materials, excluding topsoil, may be re-used as Granular Fill, regardless of its gradation, provided it is environmentally appropriate, free of organics, debris, trash, stones greater than two thirds the lift thickness in diameter, or other unsuitable material, and they are placed to the required degree of compaction. It should be noted that some of the existing site soils have a relatively high fine grained content, which could make them difficult to place and compact to the required degree of compaction when excessively wet. If existing fills containing brick are proposed for reuse, it is recommended that the brick be blended with a sufficient volume of soil, as needed, to reduce the brick concentration to 10 percent or less prior to placement and compaction.

Existing site soils may not be re-used as Gravel Borrow or Crushed Stone unless it meets the gradation requirements presented above, which is unlikely. Existing topsoil/subsoil may be reused in landscaped areas but should be tested for pH, percent organics, and nutrient content and modified as needed to support vegetative growth. Refer to Tighe & Bond's Phase I Environmental Site Assessment dated June 2017 for the limited subsrurface investigation findings related to the potential for soil contamination and suitability for reuse under the Massachusetts Contingency Plan (MCP) regulations.

Closing

The preceding recommendations provided herein are for specific application to the proposed housing units on parcels 001, 005, 006, 007, and 008 on Clemente Street, parcels 009, 010, 011, 012, 013, 016, 017, 018, and 019 on South East Street, parcels 006 and 007 on South Bridge Street, and parcels 001 and 006 on Hamilton Street in Holyoke, MA, in accordance with generally accepted soil and foundation engineering practices. No warranty, expressed or implied, is made. In the event that any changes in the design or location of the proposed structure are made, the conclusions and recommendations in this report should not be considered valid unless verified in writing. This report is for design purposes only and may not be sufficient to prepare accurate quantity take-offs. It is discouraged that this report in its entirety be included in the construction documents or be provided to a contractor. Rather, the construction recommendations should be incorporated appropriately into the construction specifications as well as exploration locations, exploration logs, and laboratory test results for the contractor's use under informational purposes only.

Thank you for the opportunity to provide these services. Please contact David Brogan at (603) 433-8818 if you should have any questions, comments, or require additional information.

Very truly yours,

TIGHE & BOND, INC.

Francis J. Hoey III, P.E., LEED AP
Senior Vice President

David R. Brogan, P.E.
Senior Engineer

Enclosures:

Appendix A – Figures
Appendix B – Exploration Logs
Appendix C – Laboratory Test Results

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