LUNA Engineering Inc.

GEOTECHNICAL INVESTIGATION REPORT

230 EAST CENTRAL STREET

Franklin, MA

Prepared for:

Taj Estates of Franklin II, LLC.
95 East Main Street, Suite 100
Westborough, MA 01581

Submitted by:

LUNA Engineering, Inc.
148 Pioneer Drive
Leominster, MA 01453

Project Reference No. MAO221221

18 January 2023

LUNA Engineering Inc.
info@lunaengineering.us
+1 (978) 840-0391

January 18, 2023

Taj Estates of Franklin II, LLC.
95 East Main Street, Suite 100
Westborough, MA 01581

Attention: Mr. Mirajuddin Ahmed

RE: GEOTECHNICAL INVESTIGATION REPORT
230 EAST CENTRAL STREET
Franklin, MA
Project Ref. No.: MAO22121

Dear Mr. Mirajuddin Ahmed:

LUNA Engineering Inc. has completed the geotechnical investigation on the site located at 230 East Central Street in Franklin, MA. Presented herein and attached are our review of the of the site subsurface investigation and our recommendations concerning to design and construction of the foundations, ground floor slab, retaining wall and other geotechnical aspects of the project.

We appreciate the opportunity to participate on the site investigation and look forward to work with you on this project through its completion. Please do not hesitate to contact us if you have any question or require additional information.

Sincerely,

COMMONWEALTH OF MASSACHUSETTS
SEVERINO
LUNA
50532
REGISTERED
PROFESSIONAL ENGINEER

Severino Luna, PE
LUNA Engineering, Inc.

SL/cdl

LUNA Engineering Inc.
info@lunaengineering.us
+1 (978) 840-0391

GEOTECHNICAL INVESTIGATION REPORT

230 EAST CENTRAL STREET

FRANKLIN, MA

REPORT TOPICS

ATTACHMENTS

GEOTECHNICAL REPORT
230 EAST CENTRAL STREET
FRANKLIN, MA

1.0 INTRODUCTION

LUNA Engineering, Inc. (LUNA) is pleased to present this *Geotechnical Investigation Report* for the site located at 230 East Central Street in Franklin, MA. The geotechnical explorations and engineering evaluations were conducted in accordance with our proposed scope of services and in general conformance with the applicable requirements of the current edition of the *Massachusetts State Building Code* (MA-Code).

Reference is made to the following documents:

- *Massachusetts Amendments to the International Building Code (IBC).*
- *The Commonwealth of Massachusetts Standard Specifications for Highways and Bridges, current publication of the Massachusetts Highway Department.*
- Project Boring Logs Prepared by Soil X, Corp.
- Project Site Plan Prepared by Guerriere & Halnon, Inc. dated 9/11/2022.

The purpose of this geotechnical report is reviewing the soil exploration on the subject site to determine relevant parameters and to provide geotechnical engineering recommendations to support the planning, repair, design, and/or construction of the foundations or any structural element necessary for the project.

This report does NOT include any environmental assessment relative to oil, gasoline, solid waste, and/or other hazardous materials. Similarly, this evaluation did not include review of site design or construction issues such as infiltration systems, underground utilities, protection of existing structures, and/or other site/temporary design issues unless specifically addressed herein.

Geotechnical explorations were performed at subjected site on December 22, 2022. This report summarizes the available project information, presents the geotechnical exploration, describes the subsurface conditions encountered, and provides geotechnical engineering recommendations. The contents of this report are subject to the attached Limitations.

2.0 PROJECT INFORMATION

2.1 Site Location and Description

The property is an irregular shaped parcel with approximately 1.01 acres identified as Property No. 285-069-000-000 on the public available Massachusetts Interactive Property Map Website.

The property is located at the south side of East Central Street (Route 140) on a mixed residential and commercial area. It is boarded by residential properties, but commercial buildings were observed north and along the street.

Currently the parcel is vacant with approximately 115-feet frontage along East Central Street. The property was relatively cleaned and flattened with some material piled and an excavator on site at the time of the execution of the borings. The subject appears at the shoulder of small hill with the property slightly slope down towards the east. Rock outcrops were observed on the west properties.

2.2 Proposed Development

We understand that the proposed design development is on-going and conceptual plans are being evaluated. Based on the available information, the project consists of a mixed used 3-story building and parking lot.

Project-specific structural loading is not available, but we understand that no cellar or other below grade space is planned, and the foundation loads are expected to be light and concentrated at the perimeter of the building.

Project Architectural, Structural and/or other disciplines plans were not available to prepare this report.

3.0 GEOTECHNICAL CHARACTERIZATION

Soil X Corp. perform geotechnical test borings on 22 of December 2022 to determine the subsurface conditions. The boreholes were designated as B-1 through B-4. LUNA Engineering, Inc. (LUNA) directed the drilling, sampling activities and logged the subsurface conditions encountered at each boring location.

The boring locations were selected in relation to the existing site features and proposed development, and under the constraints of drill rig access. Subsequently, the relative location of each boring was established via measurements from existing site features and scaling the dimensions onto the provided conceptual plan. The attached Test Boring Location Plan depicts the approximate boring locations.

All borings were performed by a Track Rig using continuous flight hollow stem auger techniques while the soil samples were obtained using standard split-spoon samplers driven by a 140-pound automatic hammer in general accordance with ASTM D1586 *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling Soils*. The test borings were advanced from the existing ground surface and upon completion of each borehole, groundwater observations were recorded. Detailed records of the drilling, sampling and the soil and groundwater conditions observed at each test boring location are provided on the attached Test Boring Logs.

LUNA Engineering, Inc. (LUNA) review of the "Surficial Geologic Map of the Franklin Quadrangle, Massachusetts" which indicates the native soils consist chiefly of Glacial Till and consist of dark to light gray to olive gray poorly sorted moderately compact mixture of sand, gravel, and boulders, with minor amounts of silt. The glacial till underlies nearly all upland areas and probably exists beneath the stratified drift at lower elevations. Lenses of sand and gravel occur locally within the till. The layers are characteristically parallel to the topographic surface and may represent slight sorting within the till mass. The thickness of the till is extremely variable, ranging from 0 to 15 feet in upland areas and to 30 feet or more in the valleys.

LUNA Engineering, Inc. (LUNA) review of the "Bedrock Geologic Map of the Holliston and Medfield Quadrangles, Middlesex, Norfolk, and Worcester Counties, Massachusetts" (Volkmann, 1977) indicates the bedrock consist predominantly of greenschist, greenstone, felsite, and quartzite commonly enveloped in granite.

4.0 SUBSURFACE CONDITIONS

A generalized subsurface condition based on the test borings information are summarized in the following subsections.

4.1 Soils

The conditions exposed in the borings show the soil types and stratigraphy is generally uniform to the depths investigated and reflects the local geology as well as the historical developments at the site. Based on the borings, the generalized subsurface profile can be briefly described as:

4.1.1 FILL & ORGANICS

Fill materials were encountered at the ground surface at all boring locations. The fill consists of poorly graded fine to coarse SAND and organic silt. The fill ranges from 2- to 5-feet below grade surface and is underlain by;

4.1.2 SAND DEPOSITS

Native glaciofluvial stratified deposits were encountered beneath the Fill & Organics. This stratum consists of fine to coarse SAND with varying proportions of silt and gravel; and can be described as loose to dense based on the SPT N-values. It is typical of outwash terraces and moraines landforms and should extend to the top of the bedrock.

4.2 Bedrock

Bedrock was not confirmed (via rock coring) at any of the test boring locations. However, practical refusal to further penetration of the auger and/or split-spoon sampler occurred on borings B-1 and B3. Based on the topographic and geologic characteristics of the area, it estimated to be the top of the bedrock.

4.3 Groundwater

Groundwater was encountered on test borings B-2 and B-4 at approximately 15 feet below grade surface (BGS). It is observed that the subsurface soils have a very high hydraulic conductivity and are excessive drained (granular soils). Groundwater levels vary and are influenced by seasonal changes, local climatic conditions, precipitation, and other environmental factors. Short-term water levels observed in test borings should be considered approximate.

5.0 GEOTECHNICAL ANALYSIS & RECOMMENDATIONS

The evaluation of the site and the proposed development was based on the review of the subsurface conditions encountered on the test borings; and the assumed structural loading conditions, as described herein.

Fill and/or organic matter materials are NOT suitable for direct load support. Granular fill, if clean and without organic material, loam, snow/ice, or other objectionable material, can be used and/or prepared to support foundations or as base of pavement structure. Appropriated testing is needed to evaluate material to be used as structural fill.

Based on the results of the subsurface investigation, the proposed building can be designed and constructed using shallow foundations. The foundations shall bear directly on the top of the bedrock, the dense natural sand and/or structural fill or crushed stone built-up from the properly prepared native soil or rock strata; provide that the design and construction recommendations presented herein are satisfied. The existing surficial fill shall not be considered for any type of foundation.

Bedrock may impact the proposed construction. Final grades shall be studied to accommodate the existing rock elevation, otherwise rock removal should be expected, and a variety of removal methods should be anticipated and budgeted for (obtain unit costs), including mechanical excavation, ripping, hoe-ram, and blasting.

The structural plans were not available for studying. Depending on the proposed structural elements, the assumptions may change.

It is anticipated the bottom of excavation (BOE) will be within the natural dense sand stratum at about 6 feet below grade surface (BGS). Groundwater was encountered at 15 feet below grade surface (BGS) and is not anticipated to affect the construction. However, temporary water control shall be anticipated and assure all work be executed in dry conditions.

Safe temporary excavation and/or fill slopes are the responsibility of the Contractor. All excavations must be conducted in accordance OSHA requirements or following local, state, and federal regulations. If an excavation cannot be properly sloped or benched due to space limitations, adjacent structures, and/or seepage, the Contractor must install an engineered shoring system to support the temporary excavation.

5.1 Seismic Considerations

Earthquake loadings must be considered under requirements of the current edition of the Massachusetts State Building Code (MA-Code) which refer to the International Building Code (IBC) and applicable amendments. ASCE/SEI 7 Table 20.3-1 is used to establish the site class based on the average density, and hence the ability of the soil to transmit shear waves during a seismic event. The average density is based on the material, both soil and rock, within 100 feet below the building. The site classification is then used to determine the site coefficient and mapped spectral response for a given structure. The response to earthquake loading is controlled by the presence of the dense sand and the rock. Based on the requirements of the Code, the site is classified as:

Site Class C: Dense Soil and Rock Profile.

Liquefaction refers to the loss of strength in saturated cohesionless soils due to the buildup of pore water pressures during cyclic or seismic loading. Based on the conditions encountered at the test boring locations, the site is not considered to be susceptible to liquefaction.

5.2 Site Preparation

All unsuitable materials which include but are not limited to organic soils, loam, snow, ice, frozen soils, and other objectionable materials as bituminous or asphalt components shall be completely removed from the proposed building footprint and parking lots.

Any loose, soft, wet, and/or otherwise unsuitable soils (typically evidenced by rutting, pumping, and/or deflection of the subgrade) should be over-excavated to expose suitable soils or rock, or other remedial measures should be taken, as approved by the on-site geotechnical engineer. Any over-excavations should be backfilled with properly placed and compacted structural fill.

Any unstable areas that cannot be stabilized by additional compaction should be excavated to competent material and the area backfilled with compacted structural fill or ¾” stone.

5.3 Rock Excavation

Depending on the rock type and conditions, rock excavation may occur by fragmenting with conventional excavating equipment instead of blasting. Fragmenting must be done using mechanical means which include hoe rams or breakers, drilling and splitting, or drilling and chemical expansive agents. Since any means of rock removal will generate potentially damaging ground vibrations, measures shall be taken to limit the potential for damage, including:

- Developing project specifications to provide guidelines for rock removal procedures and providing performance criteria.
- Performing vibration monitoring during rock removal operations so that the contractor's procedures can be modified in the field if monitoring data indicate vibrations approach or exceed threshold limits.

The exposed bedrock must be scraped clean of soil and any loose material should be removed. The footing subgrade should be approximately level and bedrock surfaces that exceed 6H:1V slope should be step-serrated or suitably benched.

5.4 Spread Footings and Ground Slab-on-Grade

Foundations for the new building can be designed and constructed as typical shallow spread footings with a floor slab-on-grade with the following design recommendations:

- Fill materials should be completely removed from the proposed building footprint, plus adequate working distance of at least 3 feet laterally.
- The shallow spread footings shall be sized using an allowable bearing pressure of 4,000-psf (pounds per square foot).
- Design bearing pressures may be increased by one-third (⅓) when considering seismic and or transient wind loading conditions.
- Continuous wall footings should have a minimum width of 2.0 feet when placed on top of rock or competent natural soil and 2.5 feet if placed on top of built-up structural fill. Isolated column footings should have a minimum width of 3 feet.
- A Modulus of Vertical Subgrade Reaction (k_{vi}) of 200 psi/in (pounds per square inch per inch) should be available for structural design of floor slabs-on-grade.
- The floor slab should be isolated structurally from foundation walls and columns/piers to allow for differential movement. Slab-on-grade built on top of competent compacted soil or built-up structural fill is considered structurally isolated of the building foundations. Slabs that are supported by the foundations are structurally dependent and shall be reinforced.
- Total post-construction settlements are estimated to be on the order of 0.50 inches or less.
- Differential settlements are estimated to be on the order of 0.35 inches or less.
- Exterior footings should be founded at least four (4) feet below the lowest adjacent grade to provide adequate frost protection. If competent Bedrock is encountered during excavations for exterior footings, the footings can be founded on top of clean competent Bedrock, provided that the condition of the Bedrock is reviewed by the on-site geotechnical engineer.
- Foundation drains are recommended for the exterior of the footings building. Foundation drains should consist of 4-inch diameter perforated pipe encased in at least 6 inches of ¾-inch stone protected with a filter fabric. The drains should be graded to positively drain to a suitable discharge point away from the proposed structure. Drains should not be connected to surface or roof drain discharge points. Clean-outs should be located at bends and no greater than 150 feet on-center. It is recommended that a backflow preventer be installed at the outlet of the drains to reduce the impact of potential surcharges.

The estimated settlements and resulting angular distortion are anticipated to be within the allowable limits for this type of structure. Post-construction settlements should be complete shortly after construction is finished.

Foundation subgrade soils should be protected against physical disturbance, precipitation, and/or frost throughout construction. Surface water run-on/run-off should be diverted away from open foundation excavations. The Contractor shall ultimately be responsible for the means and methods to protect the foundation subgrade during construction.

The need/desire to provide a moisture/vapor barrier beneath ground floor slab should be evaluated by the architect, based on the building's specific interior usage requirements.

During construction, we expect that much of the building footprint will be excavated or disturbed during site preparation and grading, excavations for shallow foundations, and/or excavations for new underground utilities or due demolition. It is imperative that the subgrade beneath the floor slab-on-grade be reinstated with properly placed and compacted structural fill.

Recommendations for shallow foundation subgrade preparation/construction and foundation backfilling are provided as follows:

- A geotechnical engineer or his/her representative should directly observe foundation subgrade preparation activities.
- The work shall proceed in dry conditions, if wet conditions are present or anticipated due to groundwater seepage, perched groundwater; the foundation subgrade should be protected with a 6-inch (minimum) thick layer of ¾-inch minus crushed stone. In this case, the crushed stone shall be placed immediately upon exposure of the native foundation subgrade soils and densify with a plate compactor until exhibiting stable conditions.
- If undocumented fill and/or any unsuitable soils/materials are encountered at the foundation subgrade, over-excavations should remove all fill and/or unsuitable soils within the footing zone of influence, which is defined as the area extending laterally 1 foot from edges of the footing and then outward and downward in a slope of 1:1.5 (horizontal to vertical) until a suitable native subgrade soil is encountered.
- Any over-excavations should be backfilled with properly placed and compacted Structural Fill or Crushed Stone as approved by the on-site geotechnical engineer.
- Prior to placing concrete, a geotechnical engineer should directly observe footing subgrades.
- Footing subgrades should be level or suitably benched and free of standing water and/or debris.
- Loose, soft, wet, frozen, or otherwise unsuitable soils should either be re-compacted or

over-excavated to a suitable subgrade, as approved by the on-site geotechnical engineer.

- Foundation subgrade soils should be protected against physical disturbance, precipitation, and/or frost throughout construction. Surface water run-on/run-off should be diverted away from open foundation excavations. The Contractor shall ultimately be responsible for the means and methods to protect the foundation subgrade during construction.
- Backfill for footings, should be placed in uniform horizontal lifts having a maximum loose lift thickness of 9 inches and compacted to 95% of the modified Proctor maximum dry density as determined by ASTM D1557. Thinner lifts may be required in order to achieve the required compaction criteria.
- To minimize the potential for foundation wall damage during the backfill and compaction activities, it is recommended that foundation wall backfill be placed in a manner that maintains a balanced fill height on both sides of the wall (up to the final exterior grade).

Following excavation and removal of unsuitable materials, the exposed subgrade should be compacted with multiple passes of a vibratory plate compactor. However, proof-rolling should not be performed if/when the exposed subgrade soils are wet (i.e., due to presence of groundwater, stormwater, perched water, etc.) because this may result in soil pumping and instability. Therefore, the proof-rolling efforts, including the number of passes and whether to employ static or vibratory methods, should be directed by the on-site geotechnical engineer.

Any loose, soft, wet, and/or otherwise unsuitable soils (typically evidenced by rutting, pumping, and/or deflection of the subgrade) should be over-excavated to expose suitable soils, or other remedial measures should be taken, as approved by the on-site geotechnical engineer. Any over-excavations should be backfilled with properly placed and compacted structural fill.

5.5 Re-Use of Site Soils

The granular material encountered at the exploration locations may be suitable for re-use contingent on careful inspection and testing.

They shall be appropriately segregated from any subsoil, silt or organic material and are free of any urban materials (asphalt, construction debris, plastics, etc). All material shall be tested and shall be submitted to the geotechnical engineer for approval prior any re-use.

5.6 Backfill and Compaction Requirements

Select backfill or structural fill should consist of granular soils free of cinder, brick, asphalt, ash, and other unsuitable materials. Such material should not contain any boulders or cobbles larger than about 3 inches across and should have less than 10% fines content (material passing the No. 200 sieve). The subgrade underneath the backfill should be properly prepared.

All backfill should be placed in lifts not exceeding 9-inches in loose thickness. Backfill placed beneath shallow foundations (e.g., footings, mat) should be compacted to a minimum of 95% of the maximum dry density. In-situ density testing should be performed to confirm that 95% compaction has been achieved. Special inspection of backfill placed beneath slabs-on-grade, behind below-grade walls, and underneath sidewalks is not required because it does not affect the performance of the building; however, it is recommended that the backfill be compacted to a minimum of 90% of the maximum dry density to reduce the potential for settlement of the backfill.

Table 2: Fill Material Types.

Fill Type [1]	USCS Classification	Acceptable Location for Placement
Structural Fill [2]	GW, GW-GM, SW, SW-SM, SP, GP	All locations and elevations
Pavement Subbase	GW, GW-GM, SW, SW-SM, SP, GP	Selected fill beneath pavement
Common Fill [3]	Varies	Used for general site grading. Not to be used under settlement or frost-sensitive structures
Crushed Stone	GP	Used on wet subgrades, and as drainage fill. Should be uniform ¾-inch angular crushed stone.
Lean Concrete	Not Applicable	Used to level subgrades between foundations and native soils

1. Compacted fill should consist of approved materials that are free of organic matter and debris. Frozen material should not be used. Fill should not be places on a frozen subgrade.
2. Imported Structural Fill should consist of inorganic, readily compactable, well-graded granular soils with a maximum particle size of 6 Inches and no more than 10 percent by weight passing the US No. 200 sieve.
3. Common Fill should have a maximum particle size of 6 inches and no more than 20 percent by weight passing the US No. 200 sieve.

Table 3: Recommended Soil Gradation for **Structural Fill**.

Sieve Size	Percent Passing
3-inch	100
½-inch	50 - 85
No. 4	40 - 75
No. 50	8 - 28
No. 200	0 - 10

Notes:

1. For use as structural load support below foundations and within the building footprint.
2. Structural Fill placed beneath building foundations should include the Footing Zone of Influence which is defined as that area extending laterally one foot from the edge of the footing then outward and downward at a 1:1.5 (H:V) splay.
3. Structural Fill should be free of construction and demolition debris, frozen soil, organic soil, peat, stumps, brush, trash, and refuse.
4. Structural Fill should not be placed on soft, saturated, or frozen subgrade soils.
5. Structural Fill should be placed in lifts not exceeding 12 inches for heavy vibratory rollers and 9 inches for vibratory plate compactors.
6. Place and compact within ± 3% of optimum moisture content.
7. Compact to at least 95% standard density compaction per ASTM D1557.
8. The adequacy of the compaction efforts should be verified by field density testing.

Table 4: Recommended Soil Gradation for **Clean Granular Fill**.

Sieve Size	Percent Passing
3-inch	100
¾-inch	60 - 90
No. 4	20 - 70
No. 200	2 - 8

Notes:

1. For use as base below floor slab-on-grade
2. For minimum 18-inch base for exterior concrete slabs exposed to frost.
3. For minimum 24-inch base at exterior ramps, aprons, and loading bays adjacent to entrances/exit ways.
4. For use as backfill behind unbalanced foundation/retaining walls.
5. Place in lifts not exceeding 12 inches for heavy vibratory rollers and 9 inches for vibratory plate compactors.
6. Place and compact within ± 3% of optimum moisture content.
7. Compact to at least 95% standard density compaction per ASTM D1557.
8. Compaction efforts should be verified by field density testing.

5.7 Flexible Pavements

Flexible pavement design for light and heavy-duty pavement sections are based on the AASHTO Guide for Design of Pavement Structures. The thickness of each course depends on subgrade strength, traffic, design life, drainage, serviceability factors and frost susceptibility. Reference is made to the Commonwealth of Massachusetts Department of Public Works (MADPW) specifications for Bridge and Highway Construction, 1988 Edition.

The following is a summary of our minimum recommended flexible pavement structures for a 15-year design life, based on the subgrade soil conditions at the test boring locations and the assumed traffic intensity/loading conditions:

Pavement Course/Material		***Standard-Duty***	***Heavy-Duty***
Bituminous Concrete Top Course MA DPW M3.11.03 Table A		1 inch	1 inch
Bituminous Concrete Binder Course MA DPW M3.11.03 Table A		2 inches	3 inches
Processed Gravel for Subbase Course MA DPW M1.03.1		9 inches	12 inches
	TOTAL:	**12 inches**	**16 inches**

NOTES:

1. Standard-duty pavement areas are strictly for vehicular parking.
2. Heavy-duty pavement areas are associated with access drives, entrances, main roadways, loading bays, etc.

Table 5: Recommended Soil Gradation for **Processed Gravel for Subbase**.

Sieve Size	Percent Passing
3-inch	100
1½-inch	70 - 100
No. 4	30 - 60
No. 200	0 - 10

Additional design recommendations for the flexible pavements are provided as follows:

- The prevention of storm water infiltration into the subgrade is essential for the successful performance of the pavement. Both the subgrade and the pavement surface should have a minimum slope of 1/4-quarter inch per foot with suitable catch basins and associated storm drain piping to promote surface drainage and minimize infiltration into pavement base, subbase, and subgrade soils. At the edges of pavement, the subbase and base courses should extend laterally beyond the limits of pavement to side ditches and/or perimeter drainpipes should be provided to drain any infiltrated water.
- The recommended pavement structures should not be construed as adequate for support of haul roads, staging areas, and other construction traffic. The design and maintenance of such temporary construction roads shall be reviewed by the Contractor.
- Processed Gravel must consist of inert material that is hard, durable stone and coarse sand, free from loam and clay, surface coatings and other deleterious materials. The coarse aggregate should have a percentage of wear of not more than 50 when tested by the Los Angeles Abrasion Test. See Table 5: Recommended Soil Gradation for Processed Gravel for Subbase.

Recommendations for pavement subgrade preparation and construction are provided as follows:

- In cut areas, the exposed subgrade should be proof-rolled with a large (10-ton) smooth-drum roller as directed by the on-site geotechnical engineer.
- In fill areas, the pavement subgrade should consist of Structural Fill built up from properly prepared subgrade soils.
- Gravel Base should be placed in uniform horizontal lifts having a maximum lift thickness of 12 inches and compacted to at least 95% of the modified maximum dry density as determined by ASTM D1557 or AASHTO T-99. In-place field density tests should be performed to confirm that the specified compaction is achieved.
- Bituminous concrete should be placed and constructed in accordance with the MADPW, latest edition. Bituminous concrete should be compacted to 92 to 97% of the Maximum Theoretical Density (MTD) within the specified temperature range. Placement temperatures of bituminous concrete mixes, in general, range between 270- and 310-degrees Fahrenheit.
- A tack coat shall be placed between successive layers of the bituminous concrete. Specifically, a tack coat shall be placed atop the binder course pavement prior to placing the top course. Similarly, an asphalt jointing-compound should be applied to any cold joints, if applicable.

Based on our observations, the existing grade was constructed on top of subsoil which might have organic matter. Removal and/or replacement of the material can be onerous. On the parking lot and driveways, the cost of annual maintenance and occasional repairs shall be considered in lieu of replacement of material.

If the option of maintain the present fill is considered, to reduce any settlements, we recommend that the entire area be heavily proof rolled using at least eight passes of a 20-ton vibratory roller operating at maximum amplitude. Where fill is required to attain the proposed grade, structural fill or processed gravel for subbase should be used. The fill should be placed in lifts not exceeding 12 inches loose measure and should be compacted to 95% modified density.

5.8 Construction Monitoring

It is recommended that a geotechnical engineer familiar with the subsurface conditions and foundation design criteria, review and approve the foundation contractors' procedures and provide inspection services during excavation and foundation construction. Geotechnical related inspection services should include:

- Observation and documentation of all phases of excavation and foundation construction.
- Quality control testing and review of monitoring data.

Professional judgments were necessary in relation to determining stratigraphy and soil properties from the subsurface investigations. Such judgments were based partly on the evaluation of the technical information gathered, and partly on our experience with similar projects. If further investigation reveals differences in the subsurface conditions and/or groundwater level, or if the proposed building elevations or design are different from those indicated herein, it is recommended that we be given the opportunity to review this new information and modify our recommendations, if deemed appropriate.

5.9 Additional Considerations

Additional recommendations are provided as follows:

- Roof drains or similar features should be provided to collect roof run-off and prevent ponding near the building. Roof drains and other stormwater controls should not discharge to foundation drains.
- The exterior ground surface adjacent to the building should be sloped away from the building to provide positive drainage. Similarly, the final surface materials adjacent to the building should be relatively impermeable to reduce the volume of precipitation infiltrating into the subsurface proximate to building foundations. Such impermeable materials include concrete, bituminous concrete, and/or vegetated silty/clayey topsoil.
- Permanent fill or cut slopes should have a maximum slope of 3h:1v (horizontal to vertical) or flatter unless a properly designed surface slope stabilization system is provided.
- Safe temporary excavation and/or fill slopes are the responsibility of the Contractor.

Excavations should be conducted in accordance with local, state, and federal (OSHA) requirements, at a minimum. If an excavation cannot be properly sloped or benched due to space limitations, adjacent structures, and/or seepage, the Contractor should install an engineered shoring system to support the temporary excavation.

- Subgrade conditions will be influenced by excavation methods, precipitation, stormwater management, groundwater control(s), and/or construction activities. Most of the site soils are moisture-sensitive and considered susceptible to disturbance when exposed to wet conditions and construction activities. As such, the Contractor shall be aware of these conditions and must take precautions to minimize subgrade disturbance. Such precautions may include diverting storm run-off away from construction areas, reducing traffic in sensitive areas, minimizing the extent of exposed subgrade if inclement weather is forecast, backfilling excavations and footings as soon as practicable, and maintaining an effective dewatering program, as necessary.
- All slopes should be protected from erosion during (and after) construction.

6.0 LIMITATIONS

Explorations

1. The analyses and recommendations presented in this report are based on based in part upon the data obtained from widely spaced subsurface explorations. Subsurface conditions between exploration locations may vary from those encountered at the exploration locations. The nature and extent of variations between explorations may not become evident until construction. If variations appear, it will be necessary to re-evaluate the recommendations of this report.
2. The generalized soil profile described in the text is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized and have been developed by interpretation of widely spaced explorations and samples; actual strata transitions are probably more gradual. For specific information, refer to the individual test pit and/or boring logs.
3. Water level readings have been made in the test pits and/or test borings under conditions stated on the logs. These data have been reviewed and interpretations have been made in the text of this report. However, it must be noted that fluctuations in the level of the groundwater may occur due to variations in rainfall, temperature, and other factors differing from the time the measurements were made.

Review

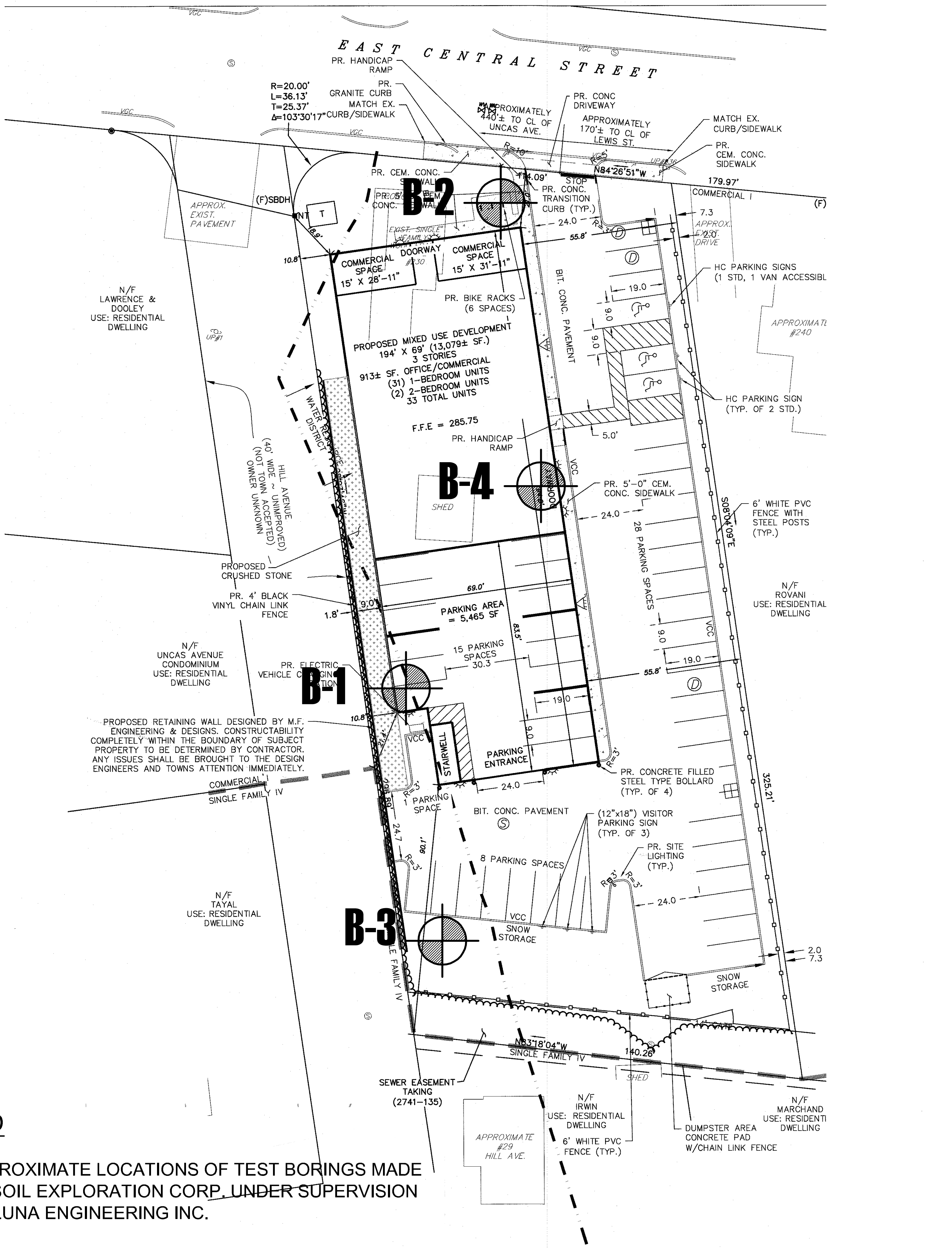
4. In the event that any changes in the nature, design, or location of the proposed structure or areas planned, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed, and conclusions of the report modified or verified in writing. It is recommended that this firm be provided the opportunity for a general review of final design and specifications in order that earthwork and foundation recommendations may be properly interpreted and implemented in the design and specifications.

Construction

5. LUNA Engineering, Inc. may be retained to provide geotechnical engineering services during the installation phases of the work. This is to observe compliance with the design concepts, specifications, and recommendations and to allow design changes if subsurface conditions differ from those anticipated prior to the start of construction.

Use of Report

6. This report has been prepared for the exclusive use of *Taj Estates of Franklin II, LLC*. for the specific application to the project located at *230 EAST CENTRAL STREET in Franklin, Massachusetts*. All considerations are based on the available information and are in accordance with generally accepted soil and foundation engineering practices. No other warranty, expressed or implied, is made.
7. This report was completed for design purposes and may be limited in its scope to complete an accurate bid.



LEGEND

B-N APPROXIMATE LOCATIONS OF TEST BORINGS MADE BY SOIL EXPLORATION CORP. UNDER SUPERVISION OF LUNA ENGINEERING INC.

LUNA Engineering Inc.
info@lunaengineering.us

LOCATION PLAN

230 East Central St
Franklin, Massachusetts

Project No.	Sheet No.
MAO221231	FIGURE 1

Date	Drawn By	Drawing No.
13 JAN 2023	fs	LOC-1

Scale	Checked By
NOT TO SCALE	SL

LUNA Engineering Inc.	**SOIL X, Corp.** 148 Pioneer Drive, Leominster, MA 01453 (978) 840-0391	Boring No. **B-1** Scale: N.T.S.

City / Town: Franklin	Assignment: N/A	Project File No. MAO221027	Contract No. N/A
Location: 230 East Central Street		Date and Time Started: 12/22/2022	Total Hours:
Groundwater Depth: NO	Date & Time:	Date and Time Completed: 12/22/2022	
Coordinates: N: N/A	E: N/A	Driller's Name: Edwin	Helper's Name: Justin / Connor
Ground Elevation: N/A	Inspector's Name (Print): Fred	Inspector's Signature: N/A	Inspector's Company: N/A

Sample Number	Depth Range (Feet)	Blows per 6 Inches / Coring Times (Min/Ft)	Recovery (inches)	Field Description	Strata Changes
1	0'0"-2'0"	1-1-2-4	20"	Dry, brown, very loose, medium to fine SAND and organic silt, some gravel.	
2	2'0"-4'0"	2-4-9-20	16"		3'0"
3	5'0"-7'0"	10-12-12-16	14"	Dry, tan, medium dense to very dense, medium to fine SAND, some gravel.	
4	7'0"-9'0"	18-14-26-33	20"		
5	10'0"-10'11"	44-50/5"	8"	End of Exploration at 10'11". Refusal. Groundwater not encountered	

Remarks:
NO = Not Observed after completion

Protective Device: Stand: Box:
Well Depth: Solid Pipe:
Stick Up Pipe: Screen Pipe:

Type of Drill Rig:

Penetration Resistance (N) Guide

Cohesionless Soils (Sands, Gravels)		Cohesive Soils (Silts, Clays)	
Relative Density:	Penetration Resistance:	Consistency	Penetration Resistance
Very Loose	0 – 4	Very Soft	0 – 2
Loose	4 - 10	Soft	2 – 4
Medium Dense	10 - 30	Medium Stiff	4 – 8
Dense	30 - 50	Stiff	8 – 15
Very Dense	Over 50	Very Stiff	15 – 30
		Hard	Over 30

N = Sum of Second and Third 6" Blow Counts

Terms Used for Second Entry of Descriptions: and = 40–50% Some = 10–40% trace = 10% or less

Casing Type: Size:
Depth: Fall:
Hammer Weight:

Sampler Type: Size:
Automatic Hammer Weight: 140lbs
Safety Hammer Weight:
Donut Hammer Weight:
Fall: 30"

Core Barrel Type: Size:

LUNA Engineering Inc.	SOIL X, Corp. 148 Pioneer Drive, Leominster, MA 01453 (978) 840-0391	Boring No. **B-2** Scale: N.T.S.

City / Town: Franklin | Assignment: N/A | Project File No. MAO221027 | Contract No. N/A

Location: 230 East Central Street | Date and Time Started: 12/22/2022 | Total Hours:

Groundwater Depth: 15-ft BG | Date & Time: | Date and Time Completed: 12/22/2022

Coordinates: N: N/A E: N/A | Driller's Name: Edwin | Helper's Name: Justin / Connor

Ground Elevation: N/A | Inspector's Name (Print): Fred | Inspector's Signature: N/A | Inspector's Company: N/A

Sample Number	Depth Range (Feet)	Blows per 6 Inches / Coring Times (Min/Ft)	Recovery (inches)	Field Description	Strata Changes
1	0'0"-2'0"	1-1-1-1	14"	Dry, brown, very loose, medium to fine SAND and organic silt, some gravel.	
2	2'0"-4'0"	1-3-9-15	16"		3'0"
3	5'0"-7'0"	9-9-8-12	16"		
4	7'0"-9'0"	14-11-11-13	16"	Dry, tan, loose to medium dense, coarse to fine SAND, some gravel.	
5	10'0"-12'0"	4-5-6-8	20"		
6	15'0"-17'0"	3-8-8-8	18"		
7	20'0"-22'0"	2-4-5-6	14"		25'0"
8	25'0"-27'0"	4-8-18-28	20"	Wet, tan, medium dense, coarse to fine SAND and gravel.	
				End of Exploration at 27'0".	
				Groundwater at 15-ft below grade	

Remarks:

Protective Device: Stand: Box:
Well Depth: Solid Pipe:
Stick Up Pipe: Screen Pipe:

Penetration Resistance (N) Guide

Cohesionless Soils (Sands, Gravels)		Cohesive Soils (Silts, Clays)	
Relative Density:	Penetration Resistance:	Consistency	Penetration Resistance
Very Loose	0 – 4	Very Soft	0 – 2
Loose	4 - 10	Soft	2 – 4
Medium Dense	10 - 30	Medium Stiff	4 – 8
Dense	30 - 50	Stiff	8 – 15
Very Dense	Over 50	Very Stiff	15 – 30
		Hard	Over 30

N = Sum of Second and Third 6" Blow Counts

Terms Used for Second Entry of Descriptions: and = 40–50% Some = 10–40% trace = 10% or less

Type of Drill Rig:

Casing Type: Size:
Depth: Fall:
Hammer Weight:

Sampler Type: Size:
Automatic Hammer Weight: 140lbs
Safety Hammer Weight:
Donut Hammer Weight:
Fall: 30"

Core Barrel Type: Size:

LUNA Engineering Inc.	SOIL X, Corp. 148 Pioneer Drive, Leominster, MA 01453 (978) 840-0391	Boring No. B-3 Scale: N.T.S.

City / Town: Franklin	Assignment: N/A	Project File No. MAO221027	Contract No. N/A
Location: 230 East Central Street		Date and Time Started: 12/22/2022	Total Hours:
Groundwater Depth: NO	Date & Time:	Date and Time Completed: 12/22/2022	
Coordinates: N: N/A	E: N/A	Driller's Name: Edwin	Helper's Name: Justin / Connor
Ground Elevation: N/A	Inspector's Name (Print): Fred	Inspector's Signature: N/A	Inspector's Company: N/A

Sample Number	Depth Range (Feet)	Blows per 6 Inches / Coring Times (Min/Ft)	Recovery (inches)	Field Description	Strata Changes
1	0'0"-2'0"	1-2-3-6	24"	Dry, brown, very loose, medium to fine SAND and organic silt, some gravel.	
2	2'0"-4'0"	10-13-12-14	16"	Dry, tan, medium dense to very dense, medium to fine SAND, some gravel.	2'0"
3	5'0"-7'0"	15-15-16-15	18"		
4	7'0"-7'8"	35-50/2"	8"		
				End of Exploration at 7'8". Refusal.	
				Groundwater not encountered	

Remarks: NO = Not Observed after completion	Protective Device: Stand: Box: Well Depth: Solid Pipe: Stick Up Pipe: Screen Pipe:

Penetration Resistance (N) Guide

Cohesionless Soils (Sands, Gravels)		Cohesive Soils (Silts, Clays)	
Relative Density:	Penetration Resistance:	Consistency	Penetration Resistance
Very Loose	0 – 4	Very Soft	0 – 2
Loose	4 - 10	Soft	2 – 4
Medium Dense	10 - 30	Medium Stiff	4 – 8
Dense	30 - 50	Stiff	8 – 15
Very Dense	Over 50	Very Stiff	15 – 30
		Hard	Over 30

N = Sum of Second and Third 6" Blow Counts

Terms Used for Second Entry of Descriptions: and = 40–50% Some = 10–40% trace = 10% or less

Type of Drill Rig:

Casing Type: Size:
Depth: Fall:
Hammer Weight:

Sampler Type: Size:
Automatic Hammer Weight: 140lbs
Safety Hammer Weight:
Donut Hammer Weight:
Fall: 30"

Core Barrel Type: Size:

LUNA Engineering Inc.	SOIL X, Corp. 148 Pioneer Drive, Leominster, MA 01453 (978) 840-0391	Boring No. B-4
		Scale: N.T.S.

City / Town: Franklin	Assignment: N/A	Project File No MAO221027	Contract No. N/A
Location: 230 East Central Street		Date and Time Started: 12/22/2022	Total Hours:
Groundwater Depth: 15-ft BG Date & Time:		Date and Time Completed: 12/22/2022	
Coordinates: N: N/A E: N/A		Driller's Name: Edwin	Helper's Name: Justin / Connor
Ground Elevation: N/A	Inspector's Name (Print): Fred	Inspector's Signature: N/A	Inspector's Company: N/A

Sample Number	Depth Range (Feet)	Blows per 6 Inches / Coring Times (Min/Ft)	Recovery (inches)	Field Description	Strata Changes
1	0'0"-2'0"	4-2-2-2	16"	Dry, brown, very loose, medium to fine SAND and organic silt, some gravel.	
2	2'0"-4'0"	3-4-5-14	24"		3'0"
3	5'0"-7'0"	15-15-16-15	18"		
4	7'0"-9'0"	22-19-20-16	16"	Dry, tan, loose to medium dense, coarse to fine SAND, some gravel.	
5	10'0"-12'0"	6-5-6-8	20"		
					15'0"
6	15'0"-17'0"	15-16-15-10	24"	Wet, tan, dense to very dense, coarse to fine SAND and gravel.	
7	20'0"-22'0"	26-22-25-28	16"		
				End of Exploration at 22'0".	
				Groundwater at 15-ft below grade	

Remarks:	Protective Device: Stand: Box: Well Depth: Solid Pipe: Stick Up Pipe: Screen Pipe:
Penetration Resistance (N) Guide	Type of Drill Rig:

Cohesionless Soils (Sands, Gravels)		Cohesive Soils (Silts, Clays)		
Relative Density:	Penetration Resistance:	Consistency	Penetration Resistance	Casing Type: Size: Depth: Fall: Hammer Weight:
Very Loose	0 – 4	Very Soft	0 – 2	Sampler Type: Size:
Loose	4 - 10	Soft	2 – 4	Automatic Hammer Weight: 140lbs
Medium Dense	10 - 30	Medium Stiff	4 – 8	Safety Hammer Weight:
Dense	30 - 50	Stiff	8 – 15	Donut Hammer Weight:
Very Dense	Over 50	Very Stiff	15 – 30	
		Hard	Over 30	
N = Sum of Second and Third 6" Blow Counts				Fall: 30"
Terms Used for Second Entry of Descriptions: and = 40–50% Some = 10–40% trace = 10% or less				Core Barrel Type: Size: