# Geotechnical Evaluation Report

**The Church of Jesus Christ of Latter-day Saints**
**850 South Ox Road Woodstock, VA**
**LDS Church Property Number**

Prepared For:
Corporation of the Presiding Bishop of the Church of Jesus Christ of Latter-day Saints
3944 Wilcoxson Drive, Fairfax, VA

TRIAD ENGINEERING, INC.
www.triadeng.com

Prepared by **Triad Engineering**
11-17-2016

COMMONWEALTH OF VIRGINIA
RANDY L. MOULTON
Lic. No. 019214
PROFESSIONAL ENGINEER


200 Aviation Dr., Winchester, VA, Phone (540)-667-9300, Fax (540)-667-2260, Email Address RStrother@Triadeng.com

November 17, 2016

Mr. Gordon S. Daines, Project Manager
The Church of Jesus Christ of Latter-day Saints
3944 Wilcoxson Drive
Fairfax, Virginia 22031

RE: Report for Geotechnical Exploration
Addition to Woodstock Ward
Woodstock, Virginia
Triad Report No. 07-16-0294

Dear Mr. Daines:

Triad Engineering, Inc. (Triad) has completed a geotechnical exploration at the planned Woodstock Ward Addition in Woodstock, Shenandoah County, Virginia. The geotechnical scope of services was authorized by our client Mr. Gordon S. Daines and completed in substantial conformance with our proposal dated October 17, 2016 and authorized by mutual acceptance of the consultant agreement on October 28, 2016.

The subsurface exploration was performed to evaluate the subsurface conditions encountered in the footprint of the planned building addition for the limited purposes of preparing design and construction recommendations for geotechnical aspects of the project. It is emphasized that subsurface conditions may vary dramatically between borings, and Triad makes no representations as to subsurface conditions other than those encountered at the specific boring locations.

This report has been prepared for the exclusive use of The Church of Jesus Christ of Latter-day Saints for specific application to the design of the church addition in Woodstock, Virginia. Triad's responsibilities and liabilities are limited to our Client and apply only to their use of our report for the purposes described above. To observe compliance with design concepts and specifications, and to facilitate design changes in the event that subsurface conditions differ from those anticipated prior to construction, it is recommended that Triad be retained to provide continuous engineering and testing services during the earthwork and foundation construction phases of the work.

We appreciate the opportunity to provide our services during the design phase of the project. If you should have any questions concerning this report, or if you require any additional information, please do not hesitate to contact us.

Sincerely,

**TRIAD ENGINEERING, INC.**

Matthew W. Beck
Staff Geologist

Randy L. Moulton, P.E.
Principal Engineer

# TABLE OF CONTENTS

# REPORT OF GEOTECHNICAL EXPLORATION

# ADDITION TO WOODSTOCK WARD
# WOODSTOCK, VIRGINIA

# TRIAD PROJECT NO. 07-16-0294

## EXECUTIVE SUMMARY

### Earthwork Considerations

- The in-situ soils are fine-grained and highly susceptible to moisture fluctuations and can be difficult to work during the wet fall, winter and early spring months. For this reason, it will be important to construct the roof of the addition prior to floor slab construction or sequence slab construction so that concrete is placed immediately after the subgrade has been tested and approved. Alternatively, a 2 to 3-inch “mud mat” can be placed on the subgrade surface after approval so it does not de-stabilize under wet weather.

### Foundations

- Based on the boring results and our understanding of the project, we believe that the proposed addition can be supported on conventional spread foundations bearing at minimal depths. We recommend that a maximum allowable bearing pressure of 2,500 psf be utilized for design of spread footings. Minimum dimensions of 2 feet and 3 feet should be observed for continuous and isolated footings, respectively. Exterior foundations should bear at least 30 inches below the final outside grade for frost protection. Footings within permanently heated areas can bear at minimum depths below the finished floor.

### Settlement Considerations

- Based on the assumed structural loads and results of the exploration, it is estimated that total settlements for isolated foundations bearing on approved soils will be 1 inch or less. Differential settlements are expected to be half of the total settlements, or in this case, a nominal 0.5 inch, while differential settlements of continuous wall footings are not expected to exceed an angular distortion of 0.0015 inch/inch.

### Floor Slabs

- We recommend that a modulus of subgrade reaction, "k," equal to 120 pci be adopted for analysis and design of the slabs-on-grade which will bear on suitable in-situ soil or controlled fill consisting of compacted soil.

# FOREWORD

This report has been prepared for the exclusive use of The Church of Jesus Christ of Latter-day Saints for specific application to the design of the church addition located in Woodstock, Shenandoah County, Virginia. The work has been performed in accordance with generally accepted geotechnical engineering practices. No other warranty, expressed or implied, is made.

This report should not be used for estimation of construction quantities and/or costs, and contractors should conduct their own investigation of site conditions for these purposes. Please note that Triad is not responsible for any claims, damages or liability associated with any other party's interpretation of the data or re-use of these data or engineering analyses without the express written authorization of Triad. Additionally, this report must be read in its entirety. Individual sections of this report may cause the reader to draw incorrect conclusions if considered in isolation from each other.

The conclusions and recommendations contained in this report are based, in part, upon our field observations and data obtained from the borings at the site. The nature and extent of variations may not become evident until construction. If variations then appear evident, it may be necessary to re-evaluate the recommendations presented herein. Similarly, in the event that any changes in the nature, design, or location of the facilities are planned, the conclusions and recommendations contained herein shall not be considered valid unless the changes are reviewed and the conclusions are modified or verified in writing by Triad.

It is recommended that we be provided the opportunity to review the final grading plan and specifications so that earthwork recommendations may be properly interpreted and implemented. If we are not afforded the privilege of making this review, we will not assume responsibility for misinterpretation of our recommendations, as our recommendations are strictly limited to conditions represented to Triad at the time this report was issued.

# SITE AND PROJECT DESCRIPTION

The site for the proposed addition is situated on the northwestern side of the existing Church of Jesus Christ of Latter-day Saints located at 850 South Ox Road in Woodstock, Shenandoah County, Virginia. Based on the provided information and our site reconnaissance, the parcel consists of flat to slightly sloping grass, asphalt and mulch covered terrain with a few isolated pockets of mature trees. The approximate site location is illustrated on Figure No. A-1 in Appendix A.

The provided concept plan indicates that the addition will include a 1,800 square foot extension to the northwestern side of the existing building to accommodate moving the existing rostrum area into the new addition and remodeling the chapel floor space. In addition, we understand that four additional rooms will be added on either side of the rostrum area that will include construction of connecting hallways. We assume that the structure will be comprised of metal framing, masonry walls with a brick veneer and a concrete slab-on-grade. Based on our previous experience, buildings of this type are typically lightly loaded, and we assume that maximum column and wall loads will be on the order of 50 to 60 kips and 2 to 4 kips per linear foot or less, respectively. **The structural engineer of record should verify that the assumed maximum wall and column loads are consistent with the actual design loads for the project.**

The finished floor elevation (FFE) of the new addition was not provided. However, according to the provided concept plan, the FFE is scheduled to match that of the existing building which has been established at an arbitrary elevation of 110.33. Based on the provided site plan and the provided arbitrary elevations, the site generally ranges from elevation 102 to 112. Based on the provided site plan and Google Earth, existing grades at the site generally range from 905 to 913 Mean Sea Level (MSL). Based on the existing grades and our understanding of the project, we anticipate maximum cuts and fills will be on the order of 5 feet or less. At this time, we are not aware of any below grade or retaining walls or stormwater management areas that are planned for the project.

## GEOLOGY

### General

According to the Geologic Map of the Woodstock, Wolf Gap, Conicville and Edinburg Quadrangles of Virginia, the site is located in an area of karst terrain. Specifically, the site contains alluvial (terrace deposits) materials of Quaternary Age at the surface, and these are underlain by the Beekmantown Formation of Ordovician Age. The terrace deposits are generally comprised of pebbles and cobbles of sandstone and quartzite in a sand, silt and clay matrix. The general lithology of the Beekmantown formation is generally described as light to dark colored limestone with finely crystalline gray dolomite. Residual soils weathered from the parent carbonate bedrock generally consist of low to high plasticity silty clay and clayey silt with varying amounts of sand and rock fragments.

Karst terrain is characterized by caves, internal drainage, lack of surface streams, and topographic features such as sinkholes. These features are the result of the dissolution of soluble bedrock, such as limestone or dolomite, by groundwater. As groundwater enters fractures and bedding planes in soluble carbonate bedrock, it slowly dissolves the rock and enlarges the fractures. This results in the formation of solution channels or underground streams or ravines.

### Development in Karst Areas

The carbonate rock at the site is moderately solution-prone, highly calcareous and weathers differentially to produce a pinnacled or "sawtooth" top of rock profile. The degree of weathering or dissolution within the limestone bedrock is controlled by joint orientation and frequency and to some degree bedrock structure. Where joints intersect or where rock is highly fractured, dissolution is intensified typically creating topographically low areas and weathered rock seams that are generally filled with residual clay soils. Conversely, topographically high areas generally represent more competent, slightly to non-weathered rock that is often coarse grained and only slightly solution prone.

Sinkholes are created by the subsidence of unconsolidated materials (soils) into underlying voids such as solution channels or caves. Usually, subsidence occurs slowly and steadily over geologic time. Many sinkholes, however, are caused by a sudden collapse of a solution cave when the roof of the cave becomes too thin to support the overburden materials. Sinkholes recently created by such a collapse can usually be identified by the presence of freshly broken rock outcrops around the rim or throat of the sinkhole.

Based on our site reconnaissance and review of the topographic mapping for the project site, we did not observe any apparent sinkholes at the exploration locations. It is important to note, however, that sinkholes and other types of solution features are very common in the immediate geographic area, and there are certain risks that an owner must accept when developing in these karst areas. These risks can include groundwater contamination, subsidence and flooding. In all these instances, water is the primary cause of the problem. The levels of these risks cannot be clearly or completely defined since they are partially controlled by nature. A geophysical study can be conducted to help better define the level of risk associated with potential future sinkhole activity, if desired.

It is important to note that alterations in the ground surface, particularly in cut areas, during construction can impact the natural drainage within the site, and it is common to have some solutioning features develop in these areas as a result of construction. Also, normal blasting required to remove hard rock can create micro-fractures within the bedrock that will allow greater surface water infiltration into areas that may normally not receive water and, in turn, disturb old solutioning features and/or possibly create new features. These features can develop during and/or after construction and they will result in some minor construction delays and unanticipated costs for repairs. Certain design and construction measures can and should be implemented to help reduce potential risks associated with future sinkhole development within the site. All of these suggested measures are associated with implementing proper site drainage, minimizing water infiltration, and reducing groundwater fluctuation during and after construction. These additional measures include the following:

- Wells should not be constructed within the project site.

- Positive slopes should be maintained away from the building and pavement areas during and subsequent to construction.

- All downspout drains should be contained in pipes and routed to discharge points far away from the buildings into stormwater management (SWM) areas.

- Do not locate any new deep utilities within the building areas, if possible. Also, new utility trenches along the perimeter of the buildings should be located outside the zone of influence of new foundations. Utility trenches are common routes along which subsurface water can travel, and this can increase the risk of future subsidence.

- Maintain positive slopes around footing excavations and the building footprints prior to and after placement of concrete.

## FIELD EXPLORATION

The field exploration for the project included drilling three (3) test borings within and just outside the proposed footprint of the new addition as requested. The approximate boring locations are shown on Figure No. A-2 in Appendix A. The boring locations were selected by others and located in the field by Triad. The surface elevations were estimated by Google Earth for a general elevation and by interpolation of the contours on the provided site plan for the datum-based elevation. Based upon the conditions encountered within borings B-1 through B-3 at the time of drilling, the on-site structural engineer determined that the potential fourth boring was not required along the northern wall.

The test borings included Standard Penetration Testing (SPT) and split barrel sampling (ASTM D 1586) at regular intervals to planned termination depth of 20 feet below existing grades or auger refusal whichever occurred first. An engineering geologist from our office was present full time during the drilling to direct the drill crew, log all recovered soil samples and observe groundwater and rock conditions. The recovered soil samples were transported to our laboratory for further testing. Detailed descriptions of materials encountered in the borings are contained on the logs in Appendix B. Figure No. 1 in Appendix B contains a description of the classification system and terminology utilized.

## SUBSURFACE CONDITIONS

The materials encountered in the borings are generally described below. Stratification lines indicated on the boring logs represent the approximate boundaries between material types, and the actual transitions may be gradual.

**Surface Materials:** Approximately 3 to 4 inches of topsoil was encountered at the surface of all the borings. Thicker zones of topsoil are likely in lower lying areas and adjacent to large root balls. The topsoil generally consisted of light to dark brown organic silt/clay with an appreciable surface root mat.

**Old Fill:** Old fill material was encountered in all of the borings and ranged in depth from 2.5 to 4 feet below existing grades. The fill material primarily consisted of brown lean clay with varying amounts of sand and rock fragments. SPT N-values obtained in the fill ranged from 16 to 20 blows per foot which indicated stiff consistencies to medium dense relative densities. The majority of the N-values obtained within the old fill indicated very stiff conditions.

**Alluvial Soils:** Alluvial soil consisting of terrace deposits was encountered below the old fill in all the borings. The alluvium was present to the planned termination depth or refusal on hard rock. Auger refusal was encountered on apparent hard rock at a depth of 16.5 feet below existing grade in boring B-2 and 19.4 feet in boring B-3. In general, the alluvial soils consisted of orange-brown fat clay with minor amounts of sand and rock fragments. SPT N-values obtained in the alluvium ranged from 5 to greater than 50 blows per foot indicating a medium stiff consistency to very dense relative density. The sample exhibiting medium stiff conditions was isolated to the 13.5 to 15 feet sample in B-3 and is attributed to the higher moisture contents observed in the samples. N-values obtained in the alluvium generally exhibited stiff consistencies.

**Groundwater Observations:** The borings were checked for the presence of groundwater both during and upon completion of the drilling. We did not detect an apparent static groundwater level in any of the borings during and upon completion of the drilling. It is important to note that fluctuations in perched water and groundwater levels may occur due to variations in environmental conditions, surface drainage and other factors which may not have been evident at the time measurements were made and reported herein. Therefore, the earthwork contractor should be prepared to implement dewatering measures during the earthwork phase of the project.

## LABORATORY TESTING

Laboratory tests were performed to supplement the field classifications, assess potential volume change characteristics and establish geotechnical design criteria. All laboratory tests were completed in accordance with appropriate ASTM standard test methods. Detailed results of the laboratory tests are contained in Appendix C. A summary of the test results is presented below.

| TEST TYPE | TEST RESULTS |
|---|---|
| Natural Moisture Contents | 13.6 to 34.9 % |
| Atterberg Limits: Liquid Limit<br>Plasticity Index | 26<br>10 |
| Percent Passing No. 200 Sieve | 68 |
| USCS Soil Classification | CL |

## RECOMMENDATIONS FOR DESIGN

### Foundations

Based on the boring results and our understanding of the project, we believe that the proposed addition can be supported on conventional spread foundations bearing at minimal depths. We recommend that a maximum allowable bearing pressure of 2,500 psf be utilized for design of spread footings. Minimum dimensions of 2 feet and 3 feet should be observed for continuous and isolated footings, respectively. Exterior foundations should bear at least 30 inches below the final outside grade for frost protection. Footings within permanently heated areas can bear at minimum depths below the finished floor.

Based on the assumed structural loads and results of the exploration, it is estimated that total settlements for isolated foundations bearing on approved soils will be 1 inch or less. Differential settlements are expected to be half of the total settlements, or in this case, a nominal 0.5 inch, while differential settlements of continuous wall footings are not expected to exceed an angular distortion of 0.0015 inch/inch.

In general, new foundation elements constructed adjacent to existing foundations should bear at the same elevation as the existing foundations. In the event that new foundations will be placed at lower levels than adjacent existing foundations, we recommend that a minimum 1H:1V slope be maintained between the bottom of the existing foundation and the new foundation excavation. This measure is required to help prevent undermining of the bearing soils beneath the existing foundations. Alternatively, the existing foundations could be conventionally underpinned by placement of concrete beneath the existing foundation to extend down to the new bearing elevation. The designer should carefully consider the appropriate method and chronology for underpinning to prevent undermining excessive lengths of the existing foundation at once (i.e., underpinning should be conducted in alternating sections with maximum lengths on the order of four feet or less). In addition, we recommend that non-shrink grout be dry-packed in any gap remaining between the underpinning and the existing foundation.

As mentioned previously, old fill material was encountered in all of the borings that ranged in depth from 2.5 to 4 feet below existing grades. Based on the assumed grading for the project and thickness of the encountered fill, we anticipate that the majority of the fill within the foundation footprints will be removed during footing excavations. The fill appeared to generally be in a stiff to very stiff condition and capable of providing the required bearing support. Nevertheless, we recommend that extensive testing and evaluation of foundation bearing soils be conducted during construction to verify that the fill soils are suitable throughout the building footprint. If any unsuitable materials extend to significant depths, alternative measures such as partial over-excavation, densification and replacement could possibly be considered. However, the appropriateness of these measures will need to be evaluated by a qualified representative from our office at the time of construction.

## Seismic Site Classification

The project site is located in Woodstock, Shenandoah County, Virginia which is considered to be a low seismic risk region. We recommend that site class “D” be utilized for seismic design of foundations. This recommendation is for the designer utilizing the International Building Code (IBC) 2012 guidelines. Liquefaction potential of the on-site soils is considered to be negligible.

## Floor Slabs

We assume the structure will include concrete slabs supported on grade. We recommend that a modulus of subgrade reaction, "k", equal to 120 pci be adopted for analysis and design of the slabs-on-grade. Based on the planned use of the addition, we do not anticipate any heavily loaded slabs. Therefore, the floor slabs may be underlain by a 4-inch thick layer of uniformly graded aggregate such as ASTM #57 stone. Concrete slabs upon which VCT, carpeting, quarry tile, or other flooring products will be placed should be underlain by a conventional polyethylene vapor barrier. If possible, it is recommended that the roof of the structure be substantially completed prior to floor slab construction. This measure will reduce potential construction problems associated with unstable subgrade impacted by adverse weather conditions and heavy construction equipment.

The slab subgrade should be properly sloped or crowned to prevent ponding of water within the base stone prior to concrete placement. Joints should be provided in the floor slabs in accordance with the recommendations specified by the Portland Cement Association (PCA) or American Concrete Institute (ACI).

# CONSTRUCTION RECOMMENDATIONS

## Site Preparation

Initial site clearing and grubbing should include removal of the topsoil, trees, brush, concrete, stone and any other deleterious materials within the new structure footprint, controlled fill areas and extending five (5) feet beyond their perimeters. Any existing utilities located within the new addition should be relocated and properly abandoned as part of the project. The old utility alignments should be backfilled with new controlled fill placed in accordance with the recommendations provided in the Controlled Fill section of the report. It should be noted that greater lateral extension of stripping in deeper fill areas may be required to accommodate adequate fill slopes.

After removal of the unsuitable surface materials, the subgrade soils should be heavily proof-rolled with approved construction equipment to locate isolated soft spots or areas of excessive "pumping" which are too wet to accommodate compacted fill or building construction. These areas should be either scarified, air-dried to a sufficient moisture content and re-compacted prior to fill placement or excavated to the level of stable soils. The exposed subgrade should be examined and verified by a representative from our office prior to placement of compacted fill.

## Excavation Areas

Because carbonate bedrock is present throughout the site, and it generally exhibits an irregular top of rock, it is impossible to predict where rock will be encountered at locations between specific exploration points. In general, the in-situ soils present can be excavated with conventional earth moving equipment such as backhoes and tracked loaders. Although not anticipated, decomposed rock encountered can possibly be removed to a very limited extent with a ripper. This layer, however, is typically thin and the transition from soil to hard rock is somewhat abrupt. Hard rock was not encountered in any of the test locations at or near the planned bearing elevations. Therefore, we do not anticipate hard rock will be encountered during construction. However, if hard bedrock or large boulders are encountered, hoe ramming or hydraulic splitting may be necessary for effective removal. Blasting should be strictly prohibited at the site to prevent any damage to the existing structure. All cut areas should be sloped and/or supported in accordance with current Occupational Safety and Health Administration (O.S.H.A.) Guidelines. Excavations should be completed on an unclassified basis, where the contractor will assume the risk of determining the percentage of rock in the overall excavations. Contractors should be required to submit unit prices for unanticipated unsuitable materials, should they be encountered during the project.

Considering that some of the soil originating from on-site cuts may be wetter than the optimum for compaction, proper drainage of excavation areas will be very important in overall construction progress. During excavation operations, dry conditions should be maintained within the cut areas at all times in order to reduce the need for additional undercutting or aeration of soils. The contractor should be prepared to implement, if necessary, temporary de-watering measures in these areas during construction. These measures can include sloping the cut areas to appropriate sump pit(s) and pumping accumulated surface runoff from precipitation. All cut areas should be sealed at the end of each day, to the extent which construction practicality will permit, to help prevent infiltration of precipitation and subsequent unsuitable soil conditions.

## Controlled Fill

### Satisfactory Soils

On-site in-situ materials excavated from cut areas can generally be used for fill provided that compaction criteria are strictly maintained. Based on results of the moisture content testing, we anticipate that the on-site materials may have to be wetted or dried on the order of 5 to 10% to attain a satisfactory moisture content that is within a satisfactory level to obtain proper compaction. ***Due to the fine-grained soils at the site, construction during the winter and spring months is often futile. This will be very dependent upon seasonal conditions at the time of earthwork construction. Also, the medium to high plasticity silty clays are relatively sensitive to moisture fluctuations and typically can be effectively placed and compacted only during drier seasons. Depending upon the anticipated construction schedule and actual field conditions, treatment of the soils with either lime or Portland cement can be considered to allow for earthwork construction to progress at an appropriate pace. Therefore, we recommend that the bidding contractors provide unit rates in the event these treatments are deemed necessary during construction.***

Fill materials should not contain any debris, waste, or frozen materials and they should contain less than two (2) percent vegetation-organic materials by weight. Also, materials classified as OL, OH, or Pt are not suitable for use as structural fill. The on-site high plasticity soils are generally suitable for re-use as structural fill provided that proper drainage, grading and sloping away from the structure is maintained both during and after construction. Although not anticipated for this project, blasted or "shot" limestone rock can be utilized for fill provided that certain construction procedures are observed. These procedures include maintaining the maximum particle size of the rock, prohibiting nesting of boulders, and mixing sufficient amounts of soil fines with the rock to fill in open voids between the rock particles. These procedures include maintaining the maximum particle size of the rock, prohibiting nesting of boulders, and mixing sufficient amounts of soil fines with the rock to fill in open voids between the rock particles.

Controlled fill placed in the zones for the structure should be free of rock or gravel larger than four (4) inches in any dimension. All proposed fill materials should be approved by a geotechnical engineer prior to placement as controlled fill, and representative samples should be obtained one week prior to placement of that material to allow time for completion of the necessary laboratory tests.

**Placement and Compaction**

Prior to compaction, the moisture content of each layer should be adjusted, as necessary, to obtain the required moisture content to achieve the specified compaction level. Each layer should be compacted to the required percentage of maximum dry density. Fill should not be placed on surfaces that are muddy or frozen, or have not been approved by testing and/or proof-rolling. Free water should be prevented from appearing on the surface during or subsequent to compaction operations.

Soil material which is removed because it is too wet to permit proper compaction can be spread and allowed to dry. Drying can be facilitated by discing or harrowing until the moisture content is reduced to an acceptable level. When the soil is too dry, water should be applied uniformly to the subgrade surface or to the layer to be compacted.

In general, all sloping areas upon which fill is to be placed should be benched or "notched" so that a smooth interface between existing ground and new fill will not be present. Each layer of fill should be benched into the existing ground a minimum of 3 feet horizontally and the depth of one fill layer. Controlled fill slopes constructed of on-site soils should be constructed at 2.5H:1V slopes or flatter.

All fill material compacted by heavy compaction equipment should be placed in maximum 9-inch loose lifts. In areas where larger rock is utilized, the size of the loose lift will be dependent on the quantity of rock within the overall fill matrix, and this can be evaluated at the time of actual placement. All fill material compacted by hand-operated tampers or light compaction equipment should be placed in maximum 4-inch loose lifts. Fill material placed within structure footprint and extending five (5) feet beyond the addition perimeter should be compacted to at least 100 percent of the laboratory maximum dry density as determined by the Standard Proctor method (ASTM D 698). The moisture content of the soils should be at or within three (3) percentage points above the optimum moisture content for structural fill. In areas where mixtures of shot rock and soil fill are placed, minimum passes with compaction equipment should be established during construction, and all areas should be proof-rolled with approved equipment for acceptance of compaction where in-place moisture-density tests are not feasible.

## Foundation Construction

We anticipate that conventional earth excavation equipment such as a backhoe or trackhoe can be utilized to excavate the in-situ soils for foundation construction. Although not anticipated, hard rock removal will require hoe-ram chipping. We recommend that any loose materials present at the bottom of footing excavations as a result of excavation work be re-compacted or completely removed by hand in order to reduce differential settlements. In any areas where hard rock is encountered at the bottom of proposed footing levels, the rock should be over-excavated 12 inches below the planned bearing level and replaced with on-site soils compacted in accordance with the specification herein.

Foundation concrete should be placed the same day that excavations are completed to reduce the potential for softening due to precipitation and/or runoff. In areas where backfill adjacent to wall construction has not been placed prior to precipitation events, any ponded water that accumulates in these areas should be pumped out immediately to help prevent softening and deterioration of the surrounding soils. In addition, all rough grades around the structure should be sloped away from the structure both during and after construction such that water from precipitation does not build up or pond adjacent to the building perimeters.

Any underground utilities which are located below or adjacent to new foundations should be backfilled with approved, compacted well-graded crushed aggregate, lean mix concrete or flowable fill grout to grades which are at or above the design bearing levels. In addition, minimal thicknesses of bedding stone should be utilized beneath the utility lines in order to help prevent significant accumulation of water from precipitation developing within the utility trench area.

## Floor Slab Construction

Prior to placement of crushed stone for the floor slabs, the subgrade soil within the limits of the structure should be proof-rolled in order to detect any soft, wet "pumping" areas. Any unsuitable areas should be either scarified, aerated to an approved moisture content, and re-compacted or undercut and replaced with controlled fill. The subgrade should be properly sloped to allow water from precipitation to drain from the stone prior to slab placement. Water should not be allowed to pond within the stone prior to placement of concrete.

As indicated previously, it is recommended that the roof of the addition be constructed prior to floor slab construction. This measure will reduce potential construction problems associated with unstable subgrade impacted by adverse weather conditions and heavy construction equipment. If the roof is not erected prior to floor slab construction, in order to reduce the potential for construction delays, we recommend that the sequence and timing of floor construction be coordinated such that slab concrete will be placed within a very short time, i.e., within a few days or less, after placement and compaction of the aggregate base course. Alternatively, we recommend utilizing a 2 to 3-inch “mud mat” to protect the subgrade soils after approval if the roof cannot be erected prior to floor slab work and sequencing does not allow the slab to be placed in a short time after placement and compaction of the base course. This measure will help protect the subgrade soils destabilizing after precipitation events, especially during the wetter seasons for the region.

## Utility Construction

In general, we anticipate that conventional excavation equipment such as a backhoe or trackhoe can be used for utility excavations in the in-situ soils and controlled fill. Any excavations which encounter large rock will likely require heavy ripping or hoe-ram chipping with a trackhoe to attain scheduled invert elevations. Blasting should be prohibited on site to prevent damage to construction in progress and to the existing structure. All utility trenches should be sloped and/or supported in accordance with current O.S.H.A. requirements.

## Construction Observations

We recommend that the geotechnical engineering firm of record, Triad, be retained to observe the construction activities to verify that the field conditions are consistent with the findings of our exploration. Construction observation services should be performed on a full-time and/or intermittent basis, as required, to:

- observe removal of all deleterious materials and observe proof-rolling of original subgrade material prior to initial fill placement.

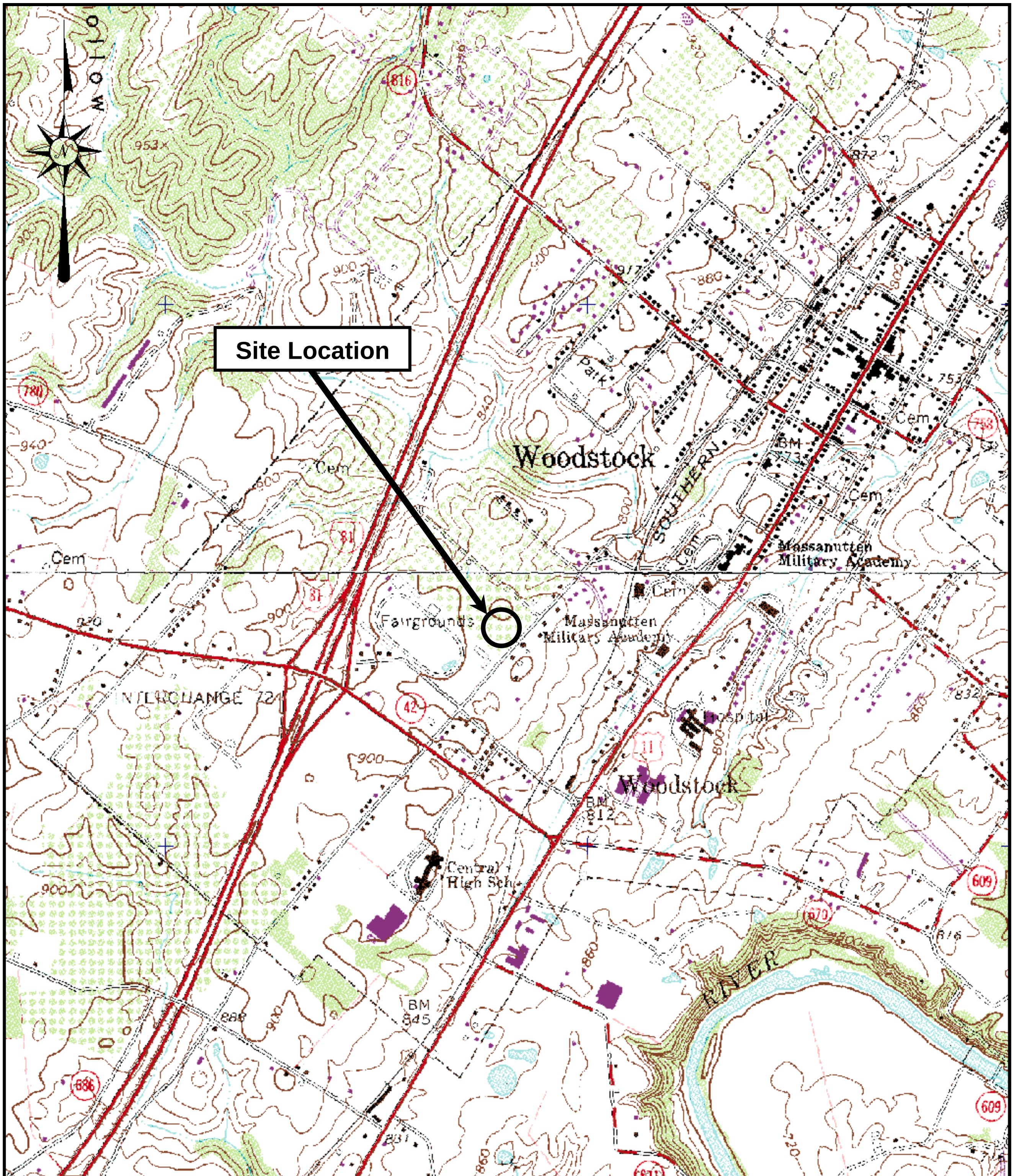
- observe and test controlled fill construction. Field density tests should be performed in accordance with ASTM D 6938 (nuclear method). A minimum of three field density tests should be performed for each lift of fill placed or at a frequency determined to be sufficient by the testing agency based on the amount of fill being placed to confirm the required soil compaction.

- examine all foundation bearing levels and slab subgrade, foundation depths and reinforcing steel size, amount and placement for the proposed structure. The inspection should be performed by a professional engineer or qualified representative working under the direct supervision of the professional engineer from our office. All foundation bearing levels should be tested immediately prior to placing reinforcing steel and concrete to confirm that the required bearing support is available.

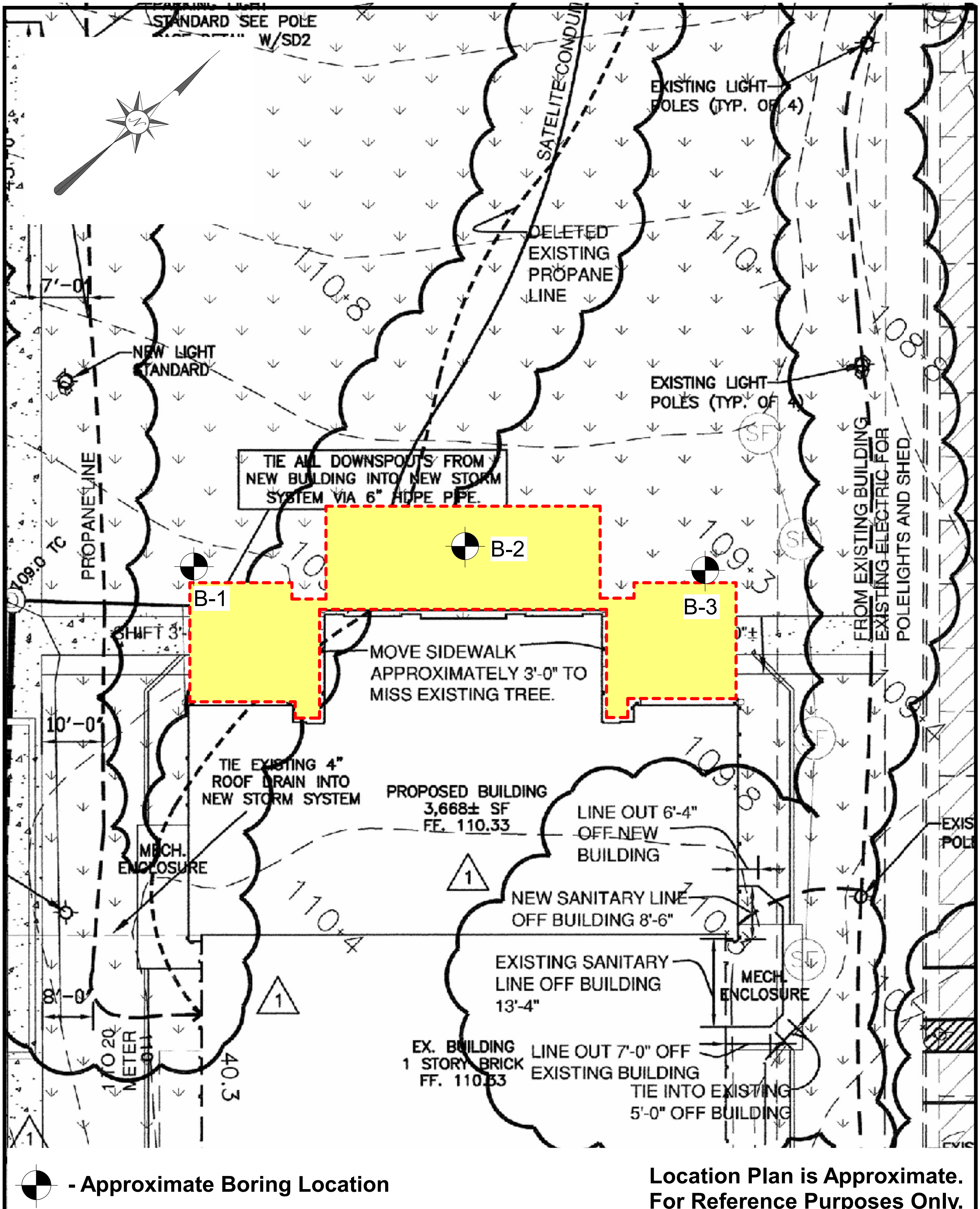
TRIAD ENGINEERING, INC.

# APPENDIX A

## *Illustrations*




| | | |
|---|---|---|
| SOURCE: USGS 7.5<br>Edinburg (VA) 1984;<br>Topographic Maps | **ADDITION TO WOODSTOCK WARD**<br>**WOODSTOCK, VIRGINIA** | TRIAD<br>TRIAD ENGINEERING, INC.<br>www.triadeng.com |
| DRAWN BY: MWB / CHECKED BY: RLM | **SITE VICINITY PLAN** | |
| DATE: 11-03-2016 / SCALE: 1"= 2000' | **TRIAD PROJECT NO. 07-16-0294** | **FIGURE NO.: A-1** |




**Location Plan is Approximate. For Reference Purposes Only.**

| | | | |
|---|---|---|---|
| Base Map Provided By: Hayes Design Group | | ADDITION TO WOODSTOCK WARD<br>WOODSTOCK, VIRGINIA | TRIAD ENGINEERING, INC.<br>www.triadeng.com |
| DRAWN BY: MB | CHECKED BY: RLM | TEST LOCATION PLAN | |
| DATE: 11-03-2016 | SCALE: 1"=20' | TRIAD PROJECT NO: 07-16-0294 | FIGURE NO.: A-2 |

TRIAD ENGINEERING, INC.

# APPENDIX B

## *Field Exploration*

# FIELD EXPLORATION

The subsurface conditions at the site were explored by drilling three (3) test borings with Standard Penetration Testing (SPT) and sampling. The borings were drilled by Recon Drilling utilizing a track-mounted rig equipped with hollow stem augers. The field exploration was supervised by an engineering geologist from our office.

SPT and sampling was performed in accordance with ASTM D 1586. The SPT's were performed to depths indicated on the attached boring logs using a split barrel sampler with an outside diameter of two (2) inches and an inside diameter of one and three-eighths (1-3/8) inches. The split barrel sampler was driven eighteen (18) inches with a hammer weighing approximately 140 pounds and falling thirty (30) inches. The number of blows required to drive the split barrel sampler at six (6) inch increments was recorded on the boring logs. The method utilized to classify the soils is defined in Figure No. 1, Key To Identification Of Soils And Weathered Rock Samples.

## TRIAD ENGINEERING, INC.

**KEY TO IDENTIFICATION OF SOIL AND WEATHERED ROCK SAMPLES**

The material descriptions on the logs indicate the visual identification of the soil and rock recovered from the exploration and are based on the following criteria. Major soil components are designated by capital letters and minor components are described by terms indicating the percentage by weight of each component. Standard Penetration Testing (SPT) and sampling was conducted in accordance with ASTM D1586. N-values in blows per foot are used to describe the *relative density* of coarse-grained soils or the *consistency* of fine-grained soils.

| The MAJOR components constitute more than 50% of the sample and have the following size designation. | | The MINOR components have the following percentage designation. | |
|---|---|---|---|
| **COMPONENT** | **PARTICLE SIZE** | **ADJECTIVE** | **PERCENTAGE** |
| Boulders | 12 inches plus | | |
| Cobbles | 3 to 12 inches | and | 35 - 50 |
| Gravel -coarse | ¾ to 3 inches | | |
| -fine | #4 to ¾ inches | some | 20 - 35 |
| Sand -coarse | #10 to #4 | | |
| -medium | #40 to #10 | little | 10 - 20 |
| -fine | #200 to #40 | | |
| Silt or Clay | Minus #200 (fine-grained soil) | trace | 0 - 10 |

| **Relative Density – Coarse-grained Soils** | | **Consistency – Fine-grained Soils** | |
|---|---|---|---|
| ***Term*** | ***N-Value*** | ***Term*** | ***N-Value*** |
| Very Loose | ≤4 | ery Soft | ≤ 2 |
| Loose | 5 to 10 | Soft | 3 to 4 |
| Medium Dense | 11 to 30 | Medium Stiff | 5 to 8 |
| Dense | 31 to 50 | Stiff | 9 to 16 |
| Very Dense | >50 | Very Stiff | >16 |

| **Soil Plasticity** | **Plasticity Index (PI)** | **Rock Hardness** | |
|---|---|---|---|
| None | Nonplastic | ***Term*** | ***N-Value*** |
| Low | 1 to 5 | Very Weathered | ≤ 50/.5 |
| Medium | 5 to 20 | Weathered | 50/.4 |
| High | 20 to 40 | Soft | 50/.3 |
| Very High | over 40 | Medium hard | 50/.2 to 50/.1 |
| | | Hard | Auger Refusal |

| **Moisture Description** |
|---|
| Dry - Dusty, dry to touch |
| Slightly Moist - damp |
| Moist - no visible free water |
| Wet - visible free water, saturated |

**FIGURE NO. 1**

TRIAD ENGINEERING, INC.

# TEST BORING LOG



Project Number: 07-16-0294 | Project Name: Addition to Woodstock Ward | Boring No.: B-1
Logger: MB | Boring Location: See Figure No. A-2
Date Started: 10/31/16 | Drill/Method: DIEDRICH D-50T
Date Completed: 10/31/16 | Driller: RECON | Ground Elev.: 109

Legend: Shelby Tube; Standard Split Spoon; Core Sample; Auger Probe

| Depth (feet) | Sample No. | Sample Type | Blow Counts | Recovery (%) | RQD (RUN) | Strata Depth (ft) | MATERIAL DESCRIPTION | RQD (Strata) | Water Level | Graphic Log | Strata Elevation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | S-1 | Split Spoon | 7-6-10 | 56% | | 2.5 | 4" TOPSOIL<br>Brown lean **CLAY**, little sand, trace rock fragments, medium plasticity, stiff, moist<br>PP=2.00 tsf<br>-FILL- | | | | 106.5 |
| 5.0 | S-2 | Split Spoon | 12-10-8 | 78% | | | Brown sandy lean **CLAY**, trace rock fragments, medium plasticity, very stiff, moist<br>PP=2.75 tsf | | | | |
| | S-3 | Split Spoon | 4-3-5 | 67% | | 9.0 | -medium stiff, moist<br>PP=2.25 tsf<br>-ALLUVIUM- | | | | 100.0 |
| 10.0 | S-4 | Split Spoon | 5-6-8 | 100% | | | Brown fat **CLAY**, trace sand and rock fragments, high plasticity, medium stiff, moist<br>PP=2.25 tsf | | | | |
| 15.0 | S-5 | Split Spoon | 4-6-10 | 100% | | | -stiff, moist<br>PP=3.50 tsf | | | | |
| 20.0 | S-6 | Split Spoon | 4-6-8 | 100% | | 20.0 | -stiff, moist<br>PP=2.75 tsf<br>-ALLUVIUM- | | | | 89.0 |

-BORING TERMINATED AT 20.0 FEET-

TRIAD_C 07-16-0294 BORINGS.GPJ TRIAD 3.GDT 11/17/16

TRIAD ENGINEERING, INC.
200 Aviation Drive
Winchester, VA
P: 540.667.9300
F: 540.667.2260

Remarks: No groundwater encountered during or upon completion of drilling. Cave in at 1.5 feet. Surface elevation is approximate.

# TEST BORING LOG



Project Number: **07-16-0294** Project Name: **Addition to Woodstock Ward** Boring No.: **B-2**
Logger: MB Boring Location: See Figure No. A-2
Date Started: 10/31/16 Drill/Method: DIEDRICH D-50T
Date Completed: 10/31/16 Driller: RECON Ground Elev.: 109.5

Legend: Shelby Tube; Standard Split Spoon; Core Sample; Auger Probe

| Depth (feet) | Sample No. | Sample Type | Blow Counts | Recovery (%) | RQD (RUN) | Strata Depth (ft) | MATERIAL DESCRIPTION | RQD (Strata) | Water Level | Graphic Log | Strata Elevation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | S-1 | Standard Split Spoon | 11-11-9 | 56% | | | 3" TOPSOIL<br>Brown sandy lean **CLAY**, trace rock fragments, medium plasticity, very stiff, moist<br>PP Not Possible | | | | |
| | S-2 | Standard Split Spoon | 6-6-10 | 100% | | 4.0 | -stiff, moist<br>PP=1.75 tsf<br>-FILL- | | | | 105.5 |
| 5.0 | S-3 | Standard Split Spoon | 7-8-10 | 100% | | | Brown sandy lean **CLAY**, trace rock fragments, very stiff, moist<br>PP=3.00 tsf | | | | |
| 10.0 | S-4 | Standard Split Spoon | 4-6-9 | 100% | | 9.5 | -ALLUVIUM- | | | | 100.0 |
| | | | | | | | Brown fat **CLAY**, trace sand and rock fragments, high plasticity, stiff, moist<br>PP=4.50 tsf | | | | |
| 15.0 | S-5 | Standard Split Spoon | 4-4-7 | 45% | | 16.5 | -stiff, moist<br>PP=3.25 tsf<br>-ALLUVIUM- | | | | 93.0 |
| 20.0 | | | | | | | -AUGER REFUSAL AT 16.5 FEET- | | | | |

TRIAD_C 07-16-0294 BORINGS.GPJ TRIAD 3.GDT 11/17/16

TRIAD ENGINEERING, INC.
200 Aviation Drive
Winchester, VA
P: 540.667.9300
F: 540.667.2260

Remarks: No groundwater encountered during or upon completion of drilling. Cave in at 1.4 feet. Surface elevation is approximate.

# TEST BORING LOG



Project Number: **07-16-0294** Project Name: **Addition to Woodstock Ward** Boring No.: **B-3**
Logger: MB Boring Location: See Figure No. A-2
Date Started: 10/31/16 Drill/Method: DIEDRICH D-50T
Date Completed: 10/31/16 Driller: RECON Ground Elev.: 109

Legend: Shelby Tube; Standard Split Spoon; Core Sample; Auger Probe

| Depth (feet) | Sample No. | Sample Type | Blow Counts | Recovery (%) | RQD (RUN) | Strata Depth (ft) | MATERIAL DESCRIPTION | RQD (Strata) | Water Level | Graphic Log | Strata Elevation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | S-1 | Standard Split Spoon | 7-9-9 | 67% | | | 3" TOPSOIL<br>Brown lean **CLAY**, little sand, trace rock fragments, medium plasticity, very stiff, moist<br>PP=2.75 tsf<br>-FILL- | | | | |
| | | | | | | 2.5 | | | | | 106.5 |
| | S-2 | Standard Split Spoon | 5-4-5 | 44% | | | Brown sandy lean **CLAY**, trace rock fragments, medium plasticity, stiff, moist<br>PP=3.00 tsf | | | | |
| 5.0 | S-3 | Standard Split Spoon | 5-6-8 | 89% | | | -stiff, moist<br>PP=4.00 tsf<br>-ALLUVIUM- | | | | |
| | | | | | | 8.5 | | | | | 100.5 |
| | S-4 | Standard Split Spoon | 6-5-6 | 100% | | | Brown lean **CLAY**, trace sand, high plasticity, stiff, moist<br>PP=1.50 tsf | | | | |
| 10.0 | | | | | | | | | | | |
| | S-5 | Standard Split Spoon | 2-2-3 | 100% | | | -medium stiff, moist<br>PP=2.25 tsf | | | | |
| 15.0 | | | | | | | | | | | |
| | S-6 | Standard Split Spoon | 2-50/4" | 40% | | | -very stiff, moist<br>PP=2.25 tsf<br>-ALLUVIUM- | | | | |
| | | | | | | 19.4 | | | | | 89.6 |
| 20.0 | | | | | | | -AUGER REFUSAL AT 19.4 FEET- | | | | |

TRIAD_C 07-16-0294 BORINGS.GPJ TRIAD 3.GDT 11/17/16

TRIAD ENGINEERING, INC.
**200 Aviation Drive**
**Winchester, VA**
**P: 540.667.9300**
**F: 540.667.2260**

Remarks: No groundwater encountered during or upon completion of drilling. Cave in at 2.4 feet. Surface elevation is approximate.

TRIAD ENGINEERING, INC.

# Appendix C

## *Laboratory Testing*

# LABORATORY TESTING

The soil samples obtained during the field exploration were visually classified in the field by geotechnical engineering personnel from Triad. The recovered soils were further evaluated by laboratory testing. Laboratory soil tests were conducted in accordance with applicable ASTM Standards as listed below:

1) Moisture content tests were performed in accordance with ASTM D 2216.

2) Atterberg Limits tests, consisting of the liquid limit, plastic limit, and plasticity index, were performed in accordance with ASTM D 4318.

3) Sieve analysis with washed No. 200 sieve tests were performed in accordance with ASTM D 422.

A summary and details of the laboratory tests are included on the following pages of this appendix.

## TRIAD ENGINEERING, INC.

SOIL DATA SUMMARY

| SAMPLE NO. | SAMPLE DEPTH (ft) | SAMPLE TYPE | NATURAL MOISTURE (%) | ATTERBERG LIMITS | | | GRADATION | | | USCS SOIL CLASS. | PROCTOR | | ADDITIONAL TESTS CONDUCTED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LL | PL | PI | % GRAVEL | % SAND | % FINES | | MAX. DD (pcf) | OPT. M (%) | |
| B-1 | 2.5-4 | SS | 13.6 | | | | | | | | | | |
| B-1 | 5-6.5 | SS | 29.6 | | | | | | | | | | |
| B-1 | 8.5-10 | SS | 24.3 | | | | | | | | | | |
| B-1 | 13.5-15 | SS | 23.7 | | | | | | | | | | |
| B-1 | 18.5-20 | SS | 20.5 | | | | | | | | | | |
| B-2 | 0-1.5 | SS | 14.5 | | | | | | | | | | |
| B-2 | 2.5-4 | SS | 15.9 | 26 | 16 | 10 | 5 | 27 | 68 | CL | | | |
| B-2 | 5-6.5 | SS | 14.7 | | | | | | | | | | |
| B-2 | 8.5-10 | SS | 16.1 | | | | | | | | | | |
| B-2 | 13.5-15 | SS | 29.7 | | | | | | | | | | |
| B-3 | 2.5-4 | SS | 25.8 | | | | | | | | | | |
| B-3 | 5-6.5 | SS | 23.8 | | | | | | | | | | |
| B-3 | 8.5-10 | SS | 31.5 | | | | | | | | | | |
| B-3 | 13.5-15 | SS | 34.9 | | | | | | | | | | |
| B-3 | 18.5-19.5 | SS | 34.2 | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

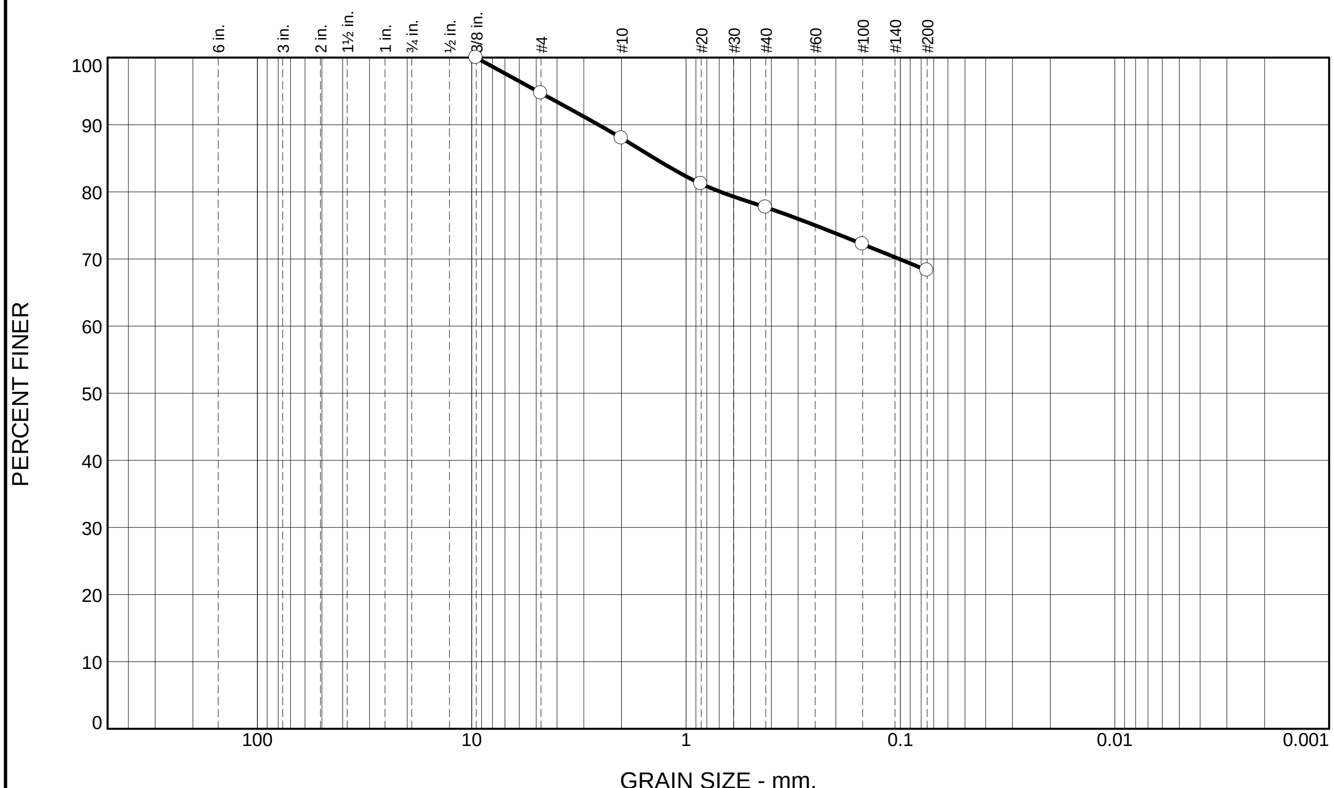
TRIAD ENGINEERING, INC.

Notes:
1) Soil tests performed in accordance with recognized ASTM testing standards.
2) SS = Split Spoon; UD = Undisturbed

PROJECT NUMBER: 07-16-0294
PROJECT NAME: Addition to Woodstock Ward
LOCATION: Woodstock, VA

FIGURE C-1

# Particle Size Distribution Report




| % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|
| | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| 0.0 | 0.0 | 5.3 | 6.7 | 10.3 | 9.4 | 68.3 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| 3/8 | 100.0 | | |
| #4 | 94.7 | | |
| #10 | 88.0 | | |
| #20 | 81.2 | | |
| #40 | 77.7 | | |
| #100 | 72.2 | | |
| #200 | 68.3 | | |

* (no specification provided)

**Soil Description**

Brown sandy lean CLAY, trace gravel

**Atterberg Limits**

PL= 16 LL= 26 PI= 10

**Coefficients**

$D_{90}$= 2.5628 $D_{85}$= 1.4022 $D_{60}$=
$D_{50}$= $D_{30}$= $D_{15}$=
$D_{10}$= $C_u$= $C_c$=

**Classification**

USCS= CL AASHTO= A-4(4)

**Remarks**

Natural Moisture - 14.6%

**Source of Sample:** B-2 **Depth:** 2.5 ft. - 6.5 ft.
**Sample Number:** B-2

**Date:** 11-01-2016

**Triad Engineering, Inc.**

**Client:** The Church of Jesus Christ of Latter-day Saints
**Project:** Addition to Woodstock Ward
Woodstock, VA
**Project No:** 07-16-0294 **Figure** C-2

**Tested By:** KBA **Checked By:** RAS