LIU & ASSOCIATES, INC.

Geotechnical Engineering | Engineering Geology | Earth Science

May 21, 2015

Mr. Lucas Kragt
KLN Construction, Inc.
19000 – 33rd Avenue West, Suite 200
Lynnwood, WA 98036

Dear Mr. Kragt:

Subject: Geotechnical Investigation
Bridlestone Estates
46xx – 116th Avenue NE
Kirkland, Washington
L&A Job No. 14-070

INTRODUCTION

We have completed a geotechnical investigation for the proposed subject development project, located at the above address in Kirkland, Washington. We understand that the proposed development is to plat the project site into 35 single-family residential building lots with supporting infrastructure. We also understand that onsite stormwater disposal by infiltration is being considered for the subject project.

The purpose of this investigation is to explore and characterize subsurface conditions of the site, evaluate feasibility of onsite stormwater disposal by infiltration, and provide geotechnical recommendations on onsite stormwater disposal, grading, site stabilization, surface and ground water drainage control, erosion mitigation, soil parameters for retaining wall design, and foundation support to buildings for the proposed development. Presented in this report are our findings, conclusion, and recommendations.

SITE CONDITIONS

Surface Condition

The general location of the project site is shown on Plate 1 – Vicinity Map. The site is situated on a gentle to moderately-steep, westerly-declining hillside. As shown on Plate 2 – Site and Exploration Location Plan, the site is clever-shaped land elongated in the east-west direction with a short handle at its southwest corner. It is bounded by 116th Avenue NE to its west, and adjoined by Bridle Trails State Park to its east and residential development to its north and south.

The terrain within the project site generally slopes down gently to moderately-steeply from the east down towards the west. The site has been graded into level benches on which barns, fenced corrals, and buildings and sheds are located, between moderately steep slopes, gravel roads and trails. The slopes in between the benches are mostly dotted with tall mature trees and covered by lawn grass.

Geologic Setting

The Geologic Map of King County, Washington, by Derek B. Booth, Kathy A. Troost and Aaron P. Wisher (2007) was referenced for the geologic and soil conditions at the property. According to this publication, the surficial soil units at and in the vicinity of the site are mapped as Vashon Till (Q_{vt}) deposits underlain by Advance Outwash (Q_{va}) deposits.

The geology of the Puget Sound Lowland has been modified by the advance and retreat of several glaciers in the past one million years and the subsequent deposits and erosion. The last glacier advanced to the Puget Sound Lowland is referred to as the Vashon Stade of the Fraser Glaciation, which occurred during the later stages of the Pleistocene Epoch and retreated from the region some 12,500 years ago.

The deposits of the Vashon till soil unit (Q_{vt}) were plowed directly under glacial ice during the most recent glacial period as the glacier advanced over an eroded, irregular surface of older formations and sediments. This soil unit is composed of a mixture of unsorted clay, silt, sand, gravel, and scattered cobbles and boulders. The Vashon till soil over the top two to three feet is normally weathered to a medium-dense state, and is moderately permeable and compressible. The underlying fresh till soil, commonly referred to as "hard pan", is very dense and weakly cemented. The fresh till soil possesses a compressive strength comparable to that of low-grade concrete and can remain stable on steep natural slopes or man-make cuts for a long period. The fresh till deposits are practically impervious to stormwater infiltration and can provide excellent foundation support with little or no settlement.

The advance outwash soil unit (Q_{va}), normally underlying the Vashon till soil unit, is composed of stratified sand and gravel with very minor amount of silt and clay, deposited by the meltwater of advancing glacial ice of the last glacier. Due to their generally granular composition, the advance outwash deposits are of moderately high permeability and drains fairly well. The advance outwash deposits had been glacially overridden and are generally dense to very-dense in their natural, undisturbed state, except the soils in the top 2 to 3 feet exposed on slopes which are normally weathered to a loose to medium-dense state. The underlying fresh advance outwash deposits can stand in steep cuts or natural slopes for extended period when undisturbed and properly drained. Where exposed on slopes, devoid of vegetation cover, and subject to storm runoff or groundwater seepage, the advance outwash deposits can be gradually eroded and may slough and redeposit to a flatter inclination. The fresh advance outwash deposits are also quite stable and capable of providing very good foundation support with little settlement.

Soil Condition

Subsurface conditions of the project site were explored with three test borings. A geotechnical engineer from our office was present during subsurface exploration, examined the soil and geologic conditions encountered, and completed logs of test borings. The locations of the test borings are shown on Plate 2 – Site and Exploration Location Plan. The test borings were drilled on July 15, 2014, with a tract-mounted drill rig, owned and operated by Davies Drilling of Seattle, Washington.

Soil samples obtained from each soil layer in the test borings were visually classified in general accordance with United Soil Classification System, a copy of which is presented on Plate 3. Detailed descriptions of soils encountered during site exploration are presented in test boring logs on Plates 4 through 6.

Standard Penetration Tests were conducted, in accordance with ASTM D-1586, in the bore holes using a standard split-spoon sampler of 2-inch outside diameter, driven with a 140-pound hammer that was raised and released for a 30-inch free fall. The number of blows required to advance the sampler a given distance is an indication of the density for granular soils or the consistency of cohesive soils. The sampler was advanced 18 inches and the total number of blows for the last 12 inches was recorded on the boring logs as N-values of the Standard Penetration Tests.

All three test borings encountered an advance outwash soil deposit with the top of this deposit at about 4.0 to 9.5 feet below existing ground surface. The advance outwash deposits are composed of brown to brown-gray to gray, medium-dense to dense, fine to medium sand. The density of this advance outwash soil unit generally increases with depth. Overlying the advance outwash soil unit is a layer or layers of weathered soil of loose to medium-dense, silty fine sand, with peat bedding and wood chips locally. A Lawton Clay soil unit of gray clayey silt was encountered at 15.5 feet, underlying the advance outwash deposit, in Test Boring B-2.

Groundwater Condition

Groundwater table was encountered in all three test borings at depths from 14.5 to 16.5 feet. This groundwater is perched on a Lawton clay soil unit of extremely low permeability underlying the advance outwash soil unit. The level of the groundwater table would fluctuate seasonally, depending on precipitation, surface runoff, ground vegetation cover, site utilization, and other factors. A groundwater monitoring well was installed in each test bore hole with a PVC stand pipe fit with a 5-foot piezometer tip inserted in drilled holes. The annular space in the bore holes was then packed with commercial silica sand and sealed with bentonite pallets. The wells were then capped with a well monument secured with a padlock. The monitoring wells will be used to determined winter high groundwater table, and the groundwater table data will be used in consideration of design of infiltration trenches or galleries.

GEOLOGIC HAZARDS AND MITIGATION

Erosion Hazard

The surficial topsoil and weathered soil are of low resistance against erosion, while the underlying dense advance outwash deposit is of moderately high resistance against erosion. The weaker surficial soils on the steeper areas of the site can be gradually eroded if they are devoid of vegetation cover and saturated. The erosion hazard may be mitigated by maintaining and protecting vegetation cover outside of construction areas. Exposed unpaved ground from construction activities should be covered with plastic tarps during construction and be re-seeded and re-vegetated as soon as possible. Concentrated stormwater should not be discharged uncontrolled onto the ground within the site. Stormwater over impervious surfaces, such as roofs and paved roadways, driveways and parking areas, should be captured by underground drain line systems connected to roof downspouts and catch basins installed in paved areas. Water collected into these drain line systems should be tightlined to discharge into a storm sewer or suitable stormwater disposal facilities, such as infiltration trenches.

Landslide Hazard

The project site is generally graded into nearly level benches and gentle slopes, disrupted by occasional steep slopes. The site is underlain by a dense advance outwash deposit with its surface at about 4 to 7 feet deep in the steeper east area and about 4 to 10 feet deep in the low-lying gently sloped west area of the site. The advance outwash deposit is of high shear strength and is highly resistant against slope failures. Therefore, the potential for deep-seated slides to occur within the site should be minimal if the recommendations in this report are fully implemented and observed.

Seismic Hazard

The Puget Sound region is in an active seismic zone. The project site is underlain at shallow depth by dense advance outwash deposits of high shear strength. Therefore, the potential for seismic hazards, such as landslides and lateral soil spreading, to occur on the site should be minimal if the erosion mitigation, drainage control, and site stabilization measures recommended in this report are fully implemented.

Seismic hazard can also be in the form of liquefaction which can cause soils to liquefy due to ground shaking from strong earthquakes. The type of soils most susceptible to liquefaction during a strong seismic event is a saturated, loose, fine sand to silty fine sand deposit coupled with high groundwater table. Such a loose deposit, when subjected to strong ground shaking, can be densified and decrease in volume. If water in the deposit is unable to drain quickly, pore water pressure in the deposit would increase. When the pore water pressure continues to build up by prolonged ground shaking, a "quick" condition will be reached when the pore water pressure equals the effective overburden soil pressure at some depths. Under this condition, the sand deposit will turn into a liquid state and lose its load bearing capacity and cause structures it supports to settle, tilt, or topple over.

Liquefaction Hazard Mitigation

Liquefaction potential can be mitigated by the following measures:

a) Over-Excavation and Backfilling

The loose to very-loose, fine sand to silty fine sand deposit down to about 13 feet which are prone to liquefaction may be over-excavated and backfill with free-draining pit-run granular soil or crushed rock compacted in lifts to a dense state. Conventional footing foundations may then be poured on the backfill to support proposed residences.

b) Shallow Excavation lined with Non-woven Filter Fabric

The building footprint excavation may be excavated to 3 to 4 feet deep and to 3 feet laterally beyond building limits of the residences. The soils at bottom of excavation should be compacted to a non-yielding state with a vibratory mechanical compactor. The bottom and side walls of excavation should then be lined with a layer of non-woven filter fabric, such as Mirafi 140 NS. The excavation is then backfilled with 2-to-4-inch rock spalls at least 2.0 feet thick, topped with a 6-inch layer of 2-inch crushed rock. The rock spall fill and the crushed rock base course should be placed in lifts, with each lift compacted to a non-yielding state with a vibratory mechanical compactor. Conventional footing foundations may then be constructed on the crushed rock base. The purpose of the non-woven filter fabric liner is to allow potential upwelling groundwater during strong earthquakes to flow into the voids in the rock spall fill while keep the soil underneath in place, and thus providing effective mitigation to liquefaction hazard.

c) Improvement Surficial Loose Soils

The permeability and density of surficial loose to very-loose fine sand to silty fine sand deposits may be improved to increase their resistance against liquefaction. Density increase may be achieved by vibro-floatation method. This method uses vibrofloat equipment to create voids in the loose sand or silty sand soil by vibration and fill the voids with densified sand. Permeability of loose sand and silty sand may be improved by stone columns. This method requires drilling holes in the ground through the loose sand into underlying dense or hard soil. The holes are then filled free-draining gravel or crushed rock into which groundwater can flow freely as pore water pressure in the loose sand deposits increases during strong earthquakes. Conventional footing foundations may then constructed on top of improved soils.

d) Deep Foundations

Deep foundations, such as augercast piles or driven piles, may be installed to penetrate through the surficial loose to very-loose sandy soils and seated into the underlying dense advance outwash sand deposit to support the residential buildings. Stability of buildings thus supported will not be compromised even if liquefaction occurs in the surficial loose to very-loose sandy soils.

The proposed residential buildings should be designed for seismic forces induced by strong earthquakes. Based on the soil conditions encountered by the test pits, it is our opinion that Seismic Use Group I and Site Class C should be used in the seismic design of the proposed residences in accordance with the 2012 International Building Code (IBC).

DISCUSSION AND RECOMMENDATIONS

GENERAL

Based on the soil conditions encountered by test borings drilled on the site, it is our opinion that the project site is suitable for the proposed development from the geotechnical engineering viewpoint, provided that the recommendations in this report are fully implemented and observed during and following completion of construction. Conventional footing foundations constructed on or into the underlying dense advance outwash soil may be used to support the proposed residential buildings, except in the southwest area at the west end of the site where liquefaction hazard exists. Unsuitable surficial topsoil and weathered soil should be stripped within footprint of roads, driveways, parking areas, and areas of structural fill.

The surficial topsoil and weathered soil contain a high percentage of fines and can be easily disturbed when saturated. Grading work in wet winter months may cause complication and difficulty. Therefore, grading and foundation construction work should be scheduled and completed between April 1 and October 31, if possible. Otherwise, erosion protection and drainage control measures recommended in this report should be implemented for site stabilization and to facilitate earthwork if it is to be carried out beyond the above dryer period.

TEMPORARY DRAINAGE AND EROSION CONTROL

The onsite surficial weak soils are sensitive to moisture and can be easily disturbed by construction traffic when saturated. A layer of clean, 2-to-4-inch quarry spalls should be placed over areas of frequent traffic, such as the entrances to the site, as required, to protect the subgrade soils from disturbance by construction traffic.

A silt fence should be installed along the downhill sides of construction areas to minimize transport of sediment by storm runoff onto neighboring properties or the street. The bottom of the filter cloth of the silt fences should be anchored in a trench filled with onsite soil.

Intercepting ditches or trench drains should be installed around the construction areas, as required, to intercept and drain away storm runoff and near-surface groundwater seepage. Water captured by such ditches or trench drains should be stored in temporary holding and settling pits onsite. Only clear and clean water may be discharged into wetlands within the site or into nearby storm inlet. The storm inlet into which collected stormwater is to be discharged should be covered with a non-woven filter fabric sock to prevent sediment from entering the storm sewer system. The filter sock should be cleaned frequently during construction to prevent clogging, and should be removed after completion of construction.

Spoil soils should be hauled off of the site as soon as possible. Spoil soils and imported structural fill material to be stored onsite should be stockpiled in areas where the ground is no steeper than 15% grade. Stockpiled spoil soils should be securely covered with plastic tarps, as required, for protection against erosion.

SITE PREPARATION AND GENERAL GRADING

Vegetation within construction limits should be cleared and grubbed. Existing structures to be demolished should also have their foundations removed. Loose topsoil and weak weathered soil should be completely stripped down to dense advance outwash soil within the building pads of proposed residences; while topsoil and unsuitable soil in the root zone should be stripped down to the medium-dense weathered soil and/or dense advance outwash soil within paved roads, driveways and parking areas. The exposed soils should be compacted to a non-yielding state with a mechanical compactor and proof-rolled with a piece of heavy earthwork equipment prior to roads, driveways, and parking area construction.

EXCAVATION AND FILL SLOPES

Under no circumstance should excavation slopes be steeper than the limits specified by local, state and federal safety regulations if workers have to perform construction work in or near excavated areas. Unsupported temporary cuts greater than 4 feet in height should be no steeper than 1H:1V in topsoil and weathered soil and no steeper than 1/2H:1V in the underlying dense advance outwash soils if the overall depth of cut does not exceed 15 feet. Otherwise, cut in advance outwash soils should be no steeper than 3/4H:1V. Permanent cut banks should be no steeper than 2-1/4H:1V in topsoil and weathered soil, and no steeper than 1-1/2H:1V in the underlying dense advance outwash soils. The soil units and the stability of cut slopes should be observed and verified by a geotechnical engineer during excavation.

Permanent fill embankments required to support structural or traffic load should be constructed with compacted structural fill placed over undisturbed, proof-rolled, firm, native soils after the surficial unsuitable soils are completely stripped. The slope of permanent fill embankments should be no steeper than 2-1/4H:1V. Upon completion, the sloping face of permanent fill embankments should be thoroughly compacted to a non-yielding state with a hoe-pack. Permanent fill embankments constructed over ground of slope at 20% or more should be structurally supported laterally. Ground of slope at 15% or more should step-cut with each vertical step not more than 3 feet high prior to construction of fill embankments.

The above recommended cut slopes and fill embankments are under the assumption that groundwater seepage would not be encountered during construction. If groundwater is encountered, the grading work should be immediately halted and the slope stability re-evaluated. The slopes may have to be flattened and other measures, such as dewatering wells, may have to be taken to stabilize the slopes. Stormwater should not be allowed to flow uncontrolled over cut slopes and fill embankments. Permanent cut slopes or fill embankments should be seeded and vegetated as soon as possible for erosion protection and long-term stability, and should be covered with clear plastic sheets, as required, to protect them from erosion until the vegetation is fully established.

STRUCTURAL FILL

Structural fill is the fill that supports structural or traffic load. Structural fill should consist of clean granular soils free of organic, debris and other deleterious substances and with particles not larger than three inches. Structural fill should have a moisture content within one percent of its optimum moisture content at the time of placement. The optimum moisture content is the water content in the soils that enable the soils to be compacted to the highest dry density for a given compaction effort. Onsite soils meeting the above requirements may be used as structural fill. Imported material to be used as structural fill should be clean, free-draining, granular soils containing no more than 5 percent by weight finer than the No. 200 sieve based on the fraction of the material passing No. 4 sieve, and should have individual particles not larger than three inches.

The ground over which structural fill is to be placed should be prepared in accordance with recommendations in the SITE PREPARATION AND GENERAL GRADING and EXCAVATION AND FILL SLOPES sections of this report. Structural fill should be placed in lifts no more than 10 inches thick in its loose state, with each lift compacted to a minimum percentage of the maximum dry density determined by ASTM D1557 (Modified Proctor Method) as follows:

Application	% of Maximum Dry Density
Within building pads and under foundations	95%
Roadway/driveway subgrade	95% for top 3 feet and 90% below
Retaining/foundation wall backfill	92%
Utility trench backfill	95% for top 4 feet and 90% below

In-situ density of structural fill should be tested with a nuclear densometer by a testing agency specialized in fill placement and construction work. Testing frequency should be one test per every 250 square feet per lift of fill.

BUILDING FOUNDATIONS

Conventional footing foundations may be used to support proposed residences. Special subgrade preparation per recommendations under the Liquefaction Hazard Mitigation section on Pages 8 and 9 of this report will be required if footing foundations are used to support residential buildings in the southwest area at the west end of the site where liquefaction hazard exists. The footing foundations should be constructed on or into the underlying, dense advance outwash soil, or on structural fill placed over this undisturbed competent basal soil. Water should not be allowed to accumulate in excavated footing trenches. Disturbed soils in footing trenches should be completely removed down to native, undisturbed, glacial till and/or advance outwash soil prior to pouring concrete for the footings.

If the above recommendations are followed, our recommended design criteria for footing foundations are as follows:

- The allowable soil bearing pressure for design of footing foundations, including dead and live loads, should be no greater than 3,000 psf if constructed on or into advance outwash soil, and no greater than 2,500 psf if constructed on structural fill placed over this competent basal soil. The footing bearing soils should be verified by a geotechnical engineer after the footing trenches are excavated and before the footings poured.
- The minimum depth to bottom of perimeter footings below adjacent final exterior grade should be no less than 18 inches. The minimum depth to bottom of the interior footings below top of floor slab should be no less than 12 inches.
- The minimum width should be no less than 16 inches for continuous footings, and no less than 24 inches for individual footings, except those footings supporting light-weight decks or porches.

A one-third increase in the above recommended allowable soil bearing pressure may be used when considering short-term, transitory, wind or seismic loads. For footing foundations designed and constructed per recommendations above, we estimate that the maximum total post-construction settlement of the buildings should be 3/4 inch or less and the differential settlement across building width should be 1/2 inch or less.

Lateral loads on the proposed buildings may be resisted by the friction force between the foundations and the subgrade soils or the passive earth pressure acting on the below-grade portion of the foundations. For the latter, the foundations must be poured "neat" against undisturbed soils or backfilled with a clean, free-draining, compacted structural fill. We recommend that an equivalent fluid density (EFD) of 275 pcf (pounds per cubic foot) for the passive earth pressure be used for lateral resistance. The above passive pressure assumes that the backfill is level or inclines upward away from the foundations for a horizontal distance at least twice the depth of the foundations below the final grade. A coefficient of friction of 0.55 between the foundations and the subgrade soils may be used. The above soil parameters are unfactored values, and a proper factor of safety should be used in calculating the resisting forces against lateral loads on the buildings.

SLAB-ON-GRADE FLOORS

Slab-on-grade floors, if used for proposed residences, should be placed on firm subgrade soil prepared as outlined in the SITE PREPARATION AND GENERAL EARTHWORK and the STRUCTURAL FILL sections of this report. Where moisture control is critical, the slab-on-grade floors should be placed on a capillary break which is in turn placed on the compacted subgrade. The capillary break should consist of a minimum four-inch-thick layer of clean, free-draining, 7/8-inch crushed rock, containing no more than 5 percent by weight passing the No. 4 sieve. A vapor barrier, such as a 6-mil plastic membrane, may be placed over the capillary break, as required, to keep moisture from migrating upwards.

CAST-IN-PLACE CONCRETE WALLS

Building foundation walls restrained at the top from lateral movement are considered unyielding and should be designed for a lateral soil pressure under the at-rest condition. Retaining walls unrestrained and free to move at the top may be designed for active soil pressure. We recommend that an at-rest soil pressure of 50 pcf EFD (equivalent fluid density) and an active soil pressure of 35 pcf EFD be used for the design of building foundation walls and retaining walls, respectively, with a level or descending backslope. For walls with ascending backslope, an additional pressure of 0.75 pcf per degree of the backslope angle above the horizontal should be added to the above design pressures. To counter the above active or at-rest pressure, a passive lateral soil pressure of 300 pcf EFD may be used. This passive pressure value is applicable only to walls with a level or ascending backslope for a horizontal distance at least 1.5 times the wall height. To resist against sliding, the friction force between the footings and the subgrade soils may be calculated based on a coefficient of friction of 0.55. The above soil parameters are ultimate values based on a fully drained condition of the walls. The walls should be designed for a factor of safety of 1.7 against sliding and 1.5 against overturning.

The building foundation walls and retaining walls should also be designed for seismic loading based on a 100-year seismic event. For seismic design, a pseudo uniform static soil pressure diagram of 8H psf should be added to the above static soil pressure, where H is the height of the wall (from bottom of footing to top of wall) plus one half of the thickness of the soil mass above the wall if applies. The factor of safety for design against seismic loading should be at least 1.15 against sliding failure and 1.2 against overturning failure. A one-third increase in the above recommended allowable soil bearing pressure may be used when considering seismic loading condition.

A drain line consisting of perforated, rigid PVC, drain pipes, at least 4 inches in diameter, should be installed at a few inches below bottom of retaining and foundation walls to intercept and drain away groundwater flowing towards the walls. The drain line should have sufficient slope (0.5 percent minimum) to generate flow by gravity, and water collected in the drain line should be tightlined to discharge into a storm sewer or suitable stormwater disposal facilities. The drain line should be wrapped in a layer of non-woven filter fabric, such as 140NS by Mirafi Inc., or approved equal, and completely embedded in clean washed gravel or crushed rock to within about 18 inches of the finish grade. A vertical drainage blanket at least 12 inches thick, consisting of clean, 3/4 to 1-1/2-inch, washed gravel or crushed rock, should be placed against the walls. Alternatively, a vertical drain mat, such as Miradrain 6000 by Mirafi Inc., or approved equal, may be placed against the walls as the vertical drainage blanket. The vertical drainage blanket or drain mat should be hydraulically connected to the drain lines at the base of the retaining and foundation walls.

PAVED ROADS DRIVEWAYS AND PARKING AREAS

Performance of roads, driveway and parking area pavement is critically related to the conditions of the underlying subgrade soils. We recommend that the subgrade soils under the roadways, driveways and parking areas be treated and prepared as described in the SITE PREPARATION AND GENERAL EARTHWORK section of this report. Prior to placing base material, the subgrade soils should be compacted to a non-yielding state with a vibratory roller compactor and proof-rolled with a piece of heavy construction equipment, such as a fully-loaded dump truck. Any areas with excessive flexing or pumping should be over-excavated and re-compacted or replaced with a structural fill or crushed rock placed and compacted in accordance with the recommendations provided in the STRUCTURAL FILL section of this report.

We recommend that a layer of compacted, 7/8-inch crushed rock base (CRB), be placed for the roadways, driveways, and parking areas. This crushed rock base should be at least 6 inches for the public roadways and 4 inches for the private driveways and parking areas. This crushed rock base should be overlain with a 3-inch asphalt treated base (ATB) topped by a 2-inch-thick Class B asphalt concrete (AC) surficial course for the public roads and overlain by a 3-inch-thick Class B asphalt concrete (AC) surficial course for private driveways and parking areas.

ONSITE STORMWATER DISPOSAL

See report titled "Onsite Stormwater Disposal, Bridle Trails, 46xx – 116th Avenue NE, Kirkland, Washington," dated August 11, 2014, by Liu & Associates, Inc.

DRAINAGE CONTROL

Building Footprint Excavation

Footprint excavation for the proposed residences, if encountering groundwater seepage, should have bottom of excavation sloped slightly and ditches excavated along bases of the cut banks to direct groundwater into sump pits from which water can be pumped out. A layer of 2-inch crushed rock should be placed over footing bearing subgrade soils, as required, to protect the soils from disturbance by construction traffic. This crushed rock base should be built to a few inches above groundwater level, but not less than 6 inches thick. The crush rock base should be compacted in 12-inch lifts to a non-yielding state with a vibratory mechanical compactor.

Runoff over Impervious Surfaces

Storm runoff over impervious surfaces, such as roofs and paved roads, driveways and parking areas, should be collected by underground drain line systems connected to downspouts and by catch basins installed in paved roads, driveways and parking areas. Stormwater thus collected should be tightlined to discharge into a storm sewer or suitable stormwater disposal facilities.

Building Footing Drains

A subdrain should be installed around the perimeter footings of each residential building. The subdrains should consist of a 4-inch-minimum-diameter, perforated, rigid, drain pipe, laid a few inches below bottom of the perimeter footings of the buildings. The trenches and the drain lines should have a sufficient gradient (0.5% minimum) to generate flow by gravity. The drain lines should be wrapped in a non-woven filter fabric sock and completely enclosed in clean washed gravel. The remaining trenches may be backfilled with clean onsite soils. Water collected by the perimeter footing subdrain systems should be tightlined, separately from the roof and surface stormwater drain lines, to discharge into a storm sewer or suitable stormwater disposal facilities.

Surface Drainage

Water should not be allowed to stand in any areas where footings, on-grade slabs, or pavement is to be constructed. Finish ground surface should be graded to direct surface runoff away from adjacent buildings. We recommend the finish ground be sloped at a gradient of 3 percent minimum for a distance of at least 10 feet away from buildings, except in the areas to be paved.

Cleanouts

Sufficient number of cleanouts at strategic locations should be provided for underground drain lines. The underground drain lines should be cleaned and maintained periodically to prevent clogging.

RISK EVALUATION STATEMENT

The subject site is underlain at shallow depth by dense advance outwash deposits. These deposits are of high shear strength and the site should be quite stable. It is our opinion that if the recommendations in this report are fully implemented and observed during and following completion of construction, the areas disturbed by construction will be stabilized and will remain stable, and will not increase the potential for soil movement. In our opinion, the risk for damages to the proposed development and from the development to adjacent properties from soil instability should be minimal.

LIMITATIONS

This report has been prepared for the specific application to the subject project for the exclusive use by KNL Construction, Inc., and its associates, representatives, consultants and contractors. We recommend that this report, in its entirety, be included in the project contract documents for the information of prospective contractors for their estimating and bidding purposes and for compliance with the recommendations in this report during construction. The conclusions and interpretations in this report, however, should not be construed as a warranty of the subsurface conditions. The scope of this study does not include services related to construction safety precautions and our recommendations are not intended to direct the contractor's methods, techniques, sequences or procedures, except as specifically described in this report for design considerations. All geotechnical construction work should be monitored by a geotechnical engineer during construction.

Our recommendations and conclusions are based on the geologic and soil conditions encountered in the test borings, and our experience and engineering judgment. The conclusions and recommendations are professional opinions derived in a manner consistent with the level of care and skill ordinarily exercised by other members of the profession currently practicing under similar conditions in this area. No warranty, expressed or implied, is made.

The actual subsurface conditions of the site may vary from those encountered by the test borings drilled on the site. The nature and extent of such variations may not become evident until construction starts. If variations appear then, we should be retained to re-evaluate the recommendations of this report, and to verify or modify them in writing prior to proceeding further with the construction of the proposed development of the site.

RESPONSES TO CODE 85.15

Required Information – Landslide Hazard and Seismic Hazard Areas

1. - a), b), c), and d) - to be provided by others
2. Geotechnical Investigation – presented above in this report
3. a. If the recommendations in this report are fully implemented and observed during and following completion of construction, the site will be more stable than under

its pre-developed condition. This is because storm runoff over impervious surfaces and near-surface underground water will be collected and safely disposed. Groundwater in the higher ground area will be lowered, erosion potential will be mitigated, and liquefaction potential in the low-lying southwest area of the west end of the site will be mitigated.

b. No evidence of Holocene or recent landsliding, soughing, or soil creep was observed during our site visit.

c. Other than seasonal runoff in the wetlands and the stream feeding the wetlands, there were no springs, seeps or surface expression of groundwater observed.

d. Our subsurface exploration and onsite observation did not encountered existing fill areas within the site.

e. See test boring logs on Plates 4 through 6 of his report for soil classification.

f. See test boring logs on Plates 4 through 6 of his report for depths to groundwater. Groundwater table during drilling test borings. Groundwater table in monitoring wells have also been measured and recorded by KLN Construction personnel.

4. a. Stability of the site during construction is discussed under the GEOLOGIC HAZARDS AND MITIGATION section on Pages 6 through 9 of this report. Impact of the development on stability of adjacent properties is presented under the RISK EVALUATION STATEMENT on Page 22 of this report.

b. See Plate 2 of this report for proposed buildings, roads, and other improvements.

c. Grading and earthwork recommendations are provided under SITE AND GENERAL GRADING, EXCAVATION AND FILL SLOPES, and STRUCTURAL FILL sections on Page 12 through 15 of this report.

d. See BUILDING FOUNDATIONS, SLAB-ON-GRADE FLOORS, AND CAST-IN-PLACE CONCRETE WALLS sections on Pages 15 through 19 of this report for foundation and retaining wall design criteria.

e. See the TEMPORARY DRAINAGE AND EROSION CONTROL section (Page 11) and the DRAINAGE CONTROL section (Page 20) of this report for surface and subsurface drainage requirements.

f. Seismic ground motion amplification in the loose to medium-dense sand to silty sand soils overlying the dense advance outwash deposits will be moderately high. Liquefaction potential of the southwest area at the west end of the site and its mitigation are presented under Seismic Hazard and Liquefaction Hazard Mitigation sections (Pages 7 through 10) of this report.

g. See the GEOLOGIC HAZARDS AND MITIGATION section (Pages 6 through 9) and the EXCAVATION AND FILL SLOPES section (Pages 12 through 14) of this report for other measures recommended to reduce risk of slope instability.

h. No additional information at this point.

RESPONSES TO CODE 85.25

Performance Standards – Landslide Hazard and Seismic Hazard Areas

1. To be provided by others.
2. To be arranged by others.
3. We recommend it, and will do if given this assignment.
4. To be responded by others.
5. To be performed by a structural engineer.

6. To be arranged by others.
7. Impact on slope stability will be kept to minimal if recommendations in this report are fully implemented and observed during and following completion of construction.
8. To be responded by others.

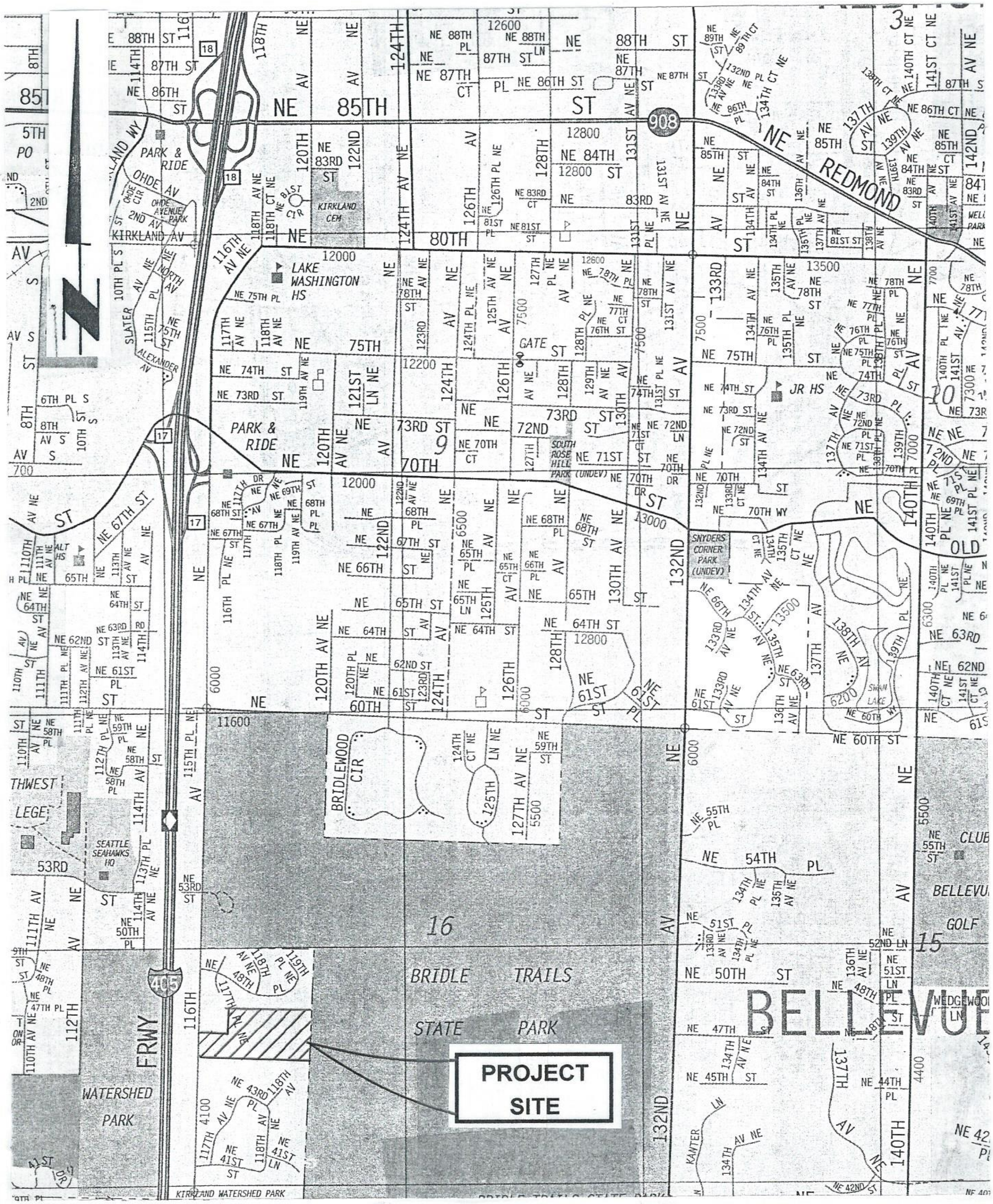
CLOSURE

We are pleased to be of service to you on this project. Please feel free to contact us if you have any questions regarding this report or need further consultation.

Yours very truly,
LIU & ASSOCIATES, INC.

J. S. (Julian) Liu, Ph.D., P.E.
Consulting Geotechnical Engineer

Six plates attached



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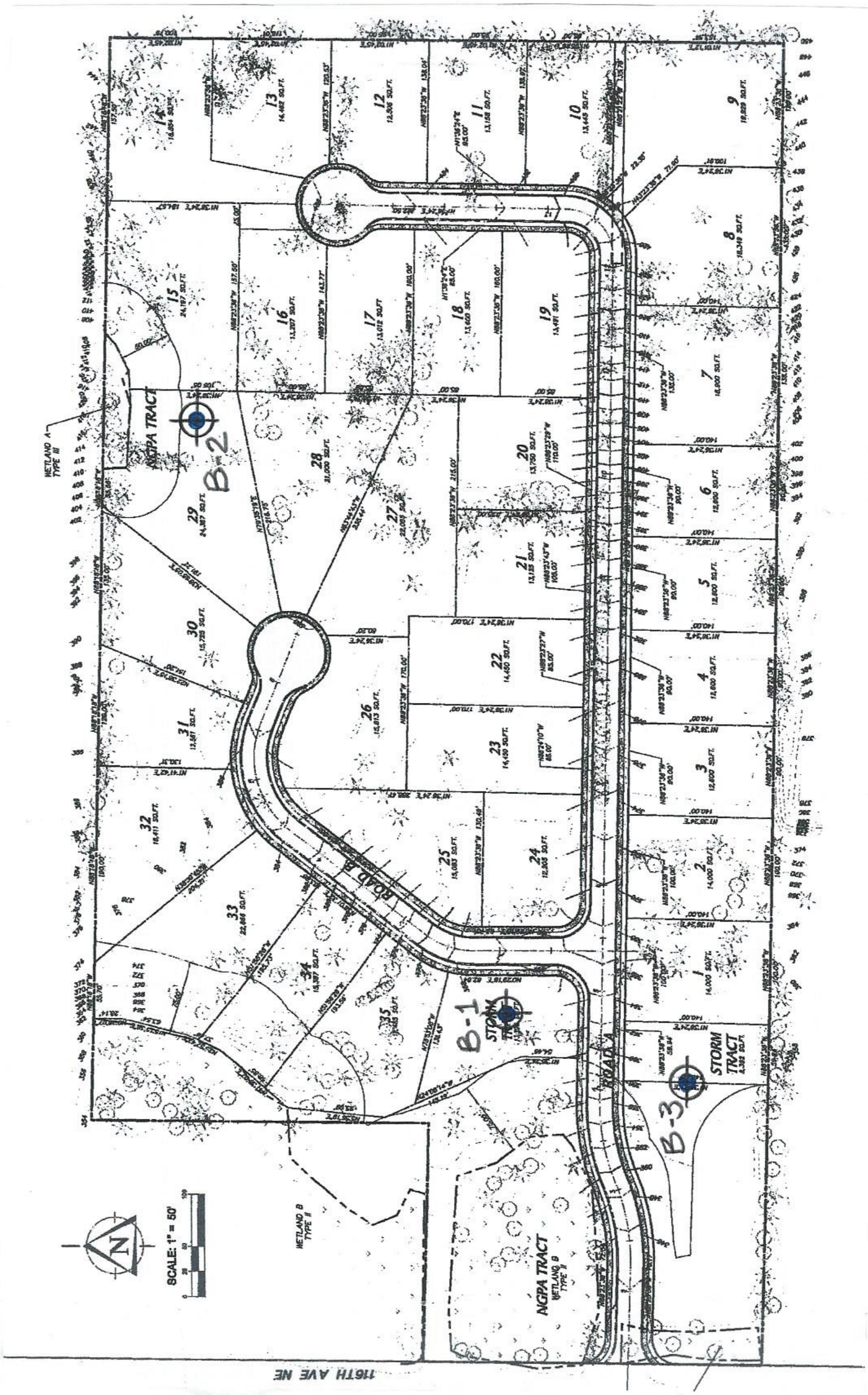
VICINITY MAP
BRIDLE TRAILS
46xx - 116TH AVENUE NE
BELLEVUE, WASHINGTON

JOB NO.	14-070	DATE	8/1/2014	PLATE	1



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SITE AND EXPLORATION LOCATION PLAN
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JOB NO. 14-070	DATE 8/1/2014	PLATE 2

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOL	GROUP NAME
COARSE-GRAINED SOILS MORE THAN 50% RETAINED ON THE NO. 200 SIEVE	GRAVEL MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVEL	GW	WELL-GRADED GRAVEL, FINE TO COARSE GRAVEL
			GP	POORLY-GRADED GRAVEL
		GRAVEL WITH FINES	GM	SILTY GRAVEL
			GC	CLAYEY GRAVEL
	SAND MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	CLEAN SAND	SW	WELL-GRADED SAND, FINE TO COARSE SAND
			SP	POORLY-GRADED SAND
		SAND WITH FINES	SM	SILTY SAND
			SC	CLAYEY SAND
FINE-GRAINED SOILS MORE THAN 50% PASSING ON THE NO. 200 SIEVE	SILT AND CLAY LIQUID LIMIT LESS THAN 50%	INORGANIC	ML	SILT
			CL	CLAY
		ORGANIC	OL	ORGANIC SILT, ORGANIC CLAY
	SILTY AND CLAY LIQUID LIMIT 50% OR MORE	INORGANIC	MH	SILT OF HIGH PLASTICITY, ELASTIC SILT
			CH	CLAY OF HIGH PLASTICITY, FAT CLAY
		ORGANIC	OH	ORGANIC SILT, ORGANIC SILT
HIGHLY ORGANIC SOILS			PT	PEAT AND OTHER HIGHLY ORGANIC SOILS

<u>NOTES</u>:

1. FIELD CLASSIFICATION IS BASED ON VISUAL EXAMINATION OF SOIL IN GENERAL ACCORDANCE WITH ASTM D2488-83.
2. SOIL CLASSIFICATION USING LABORATORY TESTS IS BASED ON ASTM D2487-83.
3. DESCRIPTIONS OF SOIL DENSITY OR CONSISTENCY ARE BASED ON INTERPRETATION OF BLOW-COUNT DATA, VISUAL APPEARANCE OF SOILS, AND/OR TEST DATA.

<u>SOIL MOISTURE MODIFIERS</u>:

DRY - ABSENCE OF MOISTURE, DUSTY, DRY TO THE TOUCH

SLIGHTLY MOIST - TRACE MOISTURE, NOT DUSTY

MOIST - DAMP, BUT NO VISIBLE WATER

VERY MOIST - VERY DAMP, MOISTURE FELT TO THE TOUCH

WET - VISIBLE FREE WATER OR SATURATED, USUALLY SOIL IS OBTAINED FROM BELOW WATER TABLE

LIU & ASSOCIATES, INC. Geotechnical Engineering · Engineering Geology · Earth Science	UNIFIED SOIL CLASSIFICATION SYSTEM
	PLATE 3

BORING NO. B-1

Logged By: JSL   7/15/2014   Ground Elev. ±

Depth ft.	USCS	Soil Description	Sample Type	Sample No.	(N) Blows/ft.	W %	Other Test
	OL	Dark-brown, fine SAND, silty, loose, organic, moist	SS	1	13		
	SM	Light-brown, fine SAND, slightly silty, loose, slightly moist					
5	SP	Brown, fine SAND, medium-dense, slightly moist (ADVANCE OUTWASH)	SS	2	31		
	SP	Brown-gray, fine SAND, medium-dense to dense, slightly moist to moist (ADVANCE OUTWASH)	SS	3	24		
10			SS	4	22		
15	SP	Gray, fine SAND, dense to very-dense, very moist to wet medium-dense to dense, very moist (ADVANCE OUTWASH)	SS	5	31		
20			SS	6	35		
25		Test boring terminated at 21.5 ft; groundwater table @ 16.5 ft.					
30							
35							

LEGEND: SS - 2" O.D. Split-Spoon Sample
ST - 3" O.D. Shelby-Tube Sample
B - Bulk Sample

GROUNDWATER: Seal
Water Level
Observation Well Tip

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BORING LOG
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JOB NO. 14-070   DATE 7/15/2014   PLATE 4

BORING NO. B-2

Logged By: JSL　　7/15/2014　　Ground Elev. ±

Depth ft.	USCS	Soil Description	Sample Type	Sample No.	(N) Blows/ ft.	W %	Other Test
	OL	Dark-brown, fine SAND, silty, loose, organic, moist	SS	1	13		
	SP	Brown-gray, fine SAND, moist					
5	SP	Gray, fine SAND, silty, with peat bedding, medium-dense, moist	SS	2	17		
	SP	Brown-gray, fine SAND, slightly silty, medium-dense to dense, moist to very moist (ADVANCE OUTWASH)	SS	3	27		
10			SS	4	31		
15	▽						
			SS	5	34		
	SP	Gray, SILT, clayey, hard, very moist to wet (LAWTON CLAY)					
20		- Becomes light-brown to light-gray	SS	6	43		
		Test boring terminated at 21.5 ft; groundwater table @ 14.5 ft.					
25							
30							
35							

LEGEND: SS - 2" O.D. Split-Spoon Sample
ST - 3" O.D. Shelby-Tube Sample
B - Bulk Sample

GROUNDWATER: Seal
Water Level
Observation Well Tip

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BORING LOG
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BELLEVUE, WASHINGTON

JOB NO. 14-070　DATE 7/15/2014　PLATE 5

BORING NO. B-3

Logged By: JSL   7/15/2014   Ground Elev. ±

Depth ft.	USCS	Soil Description	Sample Type	Sample No.	(N) Blows/ft.	W %	Other Test
	OL	Dark-brown, silty fine SAND, loose, organic, moist	SS	1	7		
	SM	Brown to brown-gray, fine SAND, silty, loose, slightly moist					
5	SP/SM	Gray, fine SAND, silty to slightly silty, very loose, with wood chips and peaty bedding, moist to very moist	SS	2	2		
			SS	3	6		
10	SP	Gray, fine to medium SAND, loose, very moist (ADVANCE OUTWASH)	SS	4	9		
15	SP	Gray, fine to medium SAND, medium-dense to dense, very moist to wet (ADVANCE OUTWASH)	SS	5	18		
20			SS	6	32		
25		Test boring terminated at 21.5 ft; groundwater table @ 16.5 ft.					
30							
35							

LEGEND: SS - 2" O.D. Split-Spoon Sample
ST - 3" O.D. Shelby-Tube Sample
B - Bulk Sample

GROUNDWATER: Seal
Water Level
Observation Well Tip

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BORING LOG
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JOB NO. 14-070 | DATE 7/15/2014 | PLATE 6