Wolverine Engineers & Surveyors, Inc.
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November 1, 2018

Mr. Paul Furtaw
Bergmann Associates PC
7050 West Saginaw Highway #200
Lansing, Michigan 48917

RE: Geotechnical Engineering Investigation
Proposed Redwood Living Development
Avon Road and Dequindre Road
Rochester Hills, Michigan
WESI Project No. 18-0122

Dear Mr. Furtaw:

Pursuant to your request, Wolverine Engineers and Surveyors, Inc. (Wolverine) performed a geotechnical investigation of the future location of the new Redwood Living Development proposed for Rochester Hills, Michigan. Please find attached to this letter, a report of our findings and geotechnical recommendations.

Wolverine appreciates the opportunity to provide our services to you and looks forward to working with you again in the future. Please feel free to contact us regarding any questions or concerns regarding our report.

Sincerely,
WOLVERINE ENGINEERS AND SURVEYORS, INC.,

Dan Wisinski
Project Manager

Donald B. Heck, P.E.
Principal Engineer

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1.0 Project Summary

Based on our conversations and email transmissions with Bergmann Associates PC (Bergmann), we understand that it is planned to construct several new residential buildings on an approximately 30-acre parcel of land located in Rochester Hills, Michigan. The new development, named Redwood Living, will consist of several, single-story residential condominiums, associated utilities and concrete drive areas.

The condominiums are anticipated to be a combination of wood and masonry block framing with concrete slabs-on-grade. The proposed finished floor elevations of the future buildings will roughly match the existing site grades that range from approximately 675 Feet MSL in the north and east portions of the site to 743 Feet MSL in the southwest portion of the site. The approximate site surface elevation was interpolated from imagery utilizing USGS topographic elevations. The project site is bordered by Avon Street to the north, Dequindre Street to the east, and vacant grass and woodlands to the south and west.

Based on or experience, we anticipate that the single-story buildings will require foundations to support maximum column loads on the order of 20 kips and maximum wall loads on the order of 3 kips per lineal foot. We also anticipate an approximately 10 to 15 feet either concrete or steel retaining wall to separate the higher southwest portion of the site from the remaining lower portions of the site.

At the time of our field investigation, the subject property was vacant and covered with tall grass. An orchard was located in the elevated area of the southwest portion of the site. A deep, heavily wooded ravine bisected the site into equal north and south portions. The site surface was relatively firm at the time of our field investigation and our ATV-mounted drill equipment experienced little difficulty accessing the boring locations.

Figure 1.0 Site Location Plan

2.0 Scope of Work

Wolverine contracted Strata Drilling to perform ten (10) soil borings to depths ranging from twenty (20) to fifty (55) feet below the existing ground surface. The borings were completed with an ATV-mounted tracked drilling rig utilizing 4-¼ inch hollow stem augers. The soil samples were collected during drilling in general accordance to ASTM D1586. Groundwater level measurements were taken during drilling operations and upon completion of the boring. After drilling the boreholes were backfilled with the excavated soils and the surface repaired to its preexisting condition. An abridged analysis of the collected samples was performed in our laboratory including visual classification, moisture content determination, and unconfined compressive strength estimates with a hand penetrometer. Two grab samples were collected and submitted to a laboratory for constant head permeability analysis. The boring logs and laboratory results can be found attached to this report following the boring location plan.

Figure 2.0 ATV-Mounted Drill Rig

3.0 Subsurface Soil Conditions

The observations from the field work indicate that the ground surface at the boring locations was covered with approximately 4 to 24 inches of **TOPSOIL**. The thickness of the topsoil should be expected to vary in depth and consistency across the project site in areas where we did not perform borings especially in the lower wet areas or areas that have been plowed. Detailed descriptions and observed depths of the topsoil material can be found on the boring logs attached to this report.

Beneath the aforementioned materials, fine to medium **SAND (SP) and SAND and GRAVEL** was generally encountered extending to a depth of approximately 4 to 10 feet below surface grades. The sand was then underlain by **SILTY CLAY (CL-ML)** which extended to the explored depth of the borings. The standard penetration values (N-values) of the granular soils (sands) averaged 5 blows per foot and ranged from 2 to greater than 50 blows per foot, indicating a very loose to very dense relative density. Estimates of the unconfined compressive strength of the silty clay soils ranged from 0.5 to greater than 4.5 tons per square foot which equates to a soft to hard consistency.

4.0 Groundwater Conditions

Groundwater was encountered at all the boring locations within the sand strata except for Boring 4. The groundwater depths ranged from 1.5 to 31 feet below site grades either during drilling operations or upon completion of the boring. The following table depicts the approximate shallowest depth of groundwater observed at each boring location.

Table 1.0 Approximate Groundwater Depths

Boring No.	Approx. Groundwater Depth (ft.)
1	1.5
2	5.0
3	5.5
4	-
5	12.5
6	5.0
7	4.0
8	3.5
9	30.0
10	31.0

5.0 Site Seismic Classification

Based on USGS geologic mapping of this portion of Oakland County and our experience in the area, we anticipate that the general subsurface conditions consist of glacial drift ranging from 75 to 150 feet in thickness overlying the Coldwater Shale Formation. This area of Oakland County is in the Central Stable Tectonic Region and in Seismic Zone 1 of the International Building Code (2015), Unified Building Code (UBC) and the Building Officials Congress of America. This Zone indicates that minor damages due to earthquakes might be expected in this area. Based on our findings and a review of other data sources, we recommend that the seismic design for this project be based on ***Site Class D***.

The 2009 USGS NEHRP probabilistic ground motion design values for a Site Class D located at these coordinates are detailed in the USGS Design Maps Summary Report included in the appendix of this Report.

6.0 Subgrade Preparation Recommendations

Based on the results of our field investigation, it appears that approximately 4 to 24 inches of topsoil is present at the site. These deposits appear to be surficial in nature; however, these materials could possibly extend to greater depths within the unexplored areas between boring locations, especially in low lying areas or areas that have been plowed. The topsoil materials should be considered unsuitable for any load bearing support and be completely stripped from the construction area. Groundwater could be problematic during the stripping of these materials and is addressed later in this report

Historical aerial imagery shows that several farm related buildings exist in the east portion of the site and are expected to be razed. It should be expected that materials related to these past structures may be encountered during site work activities. Any existing buried foundations/basement levels from previously demolished structures, abandoned and relocated utilities, etc. **must** be completely removed from the construction areas. Some of these materials may remain in place beneath pavements so long as the owner accepts the risk that damage could occur as a result of the consolidation of these unknown materials. If this risk is unacceptable to the owner, then these materials should be completely removed from the project site.

After removing any unsuitable soils and prior to placing engineered fill materials, the exposed subgrade surface should be observed by a representative of Wolverine to determine if areas of instability exist. The observation should take place immediately prior to fill placement or foundation installation. Dynamic Cone Penetrometers or other suitable testing equipment used in conjunction with hand augers should be suitable for identifying unstable areas. Areas exhibiting instability should be completely removed and replaced with engineered fill properly placed and compacted as outlined in our report. Again, groundwater could prove to be problematic and is discussed later in this report.

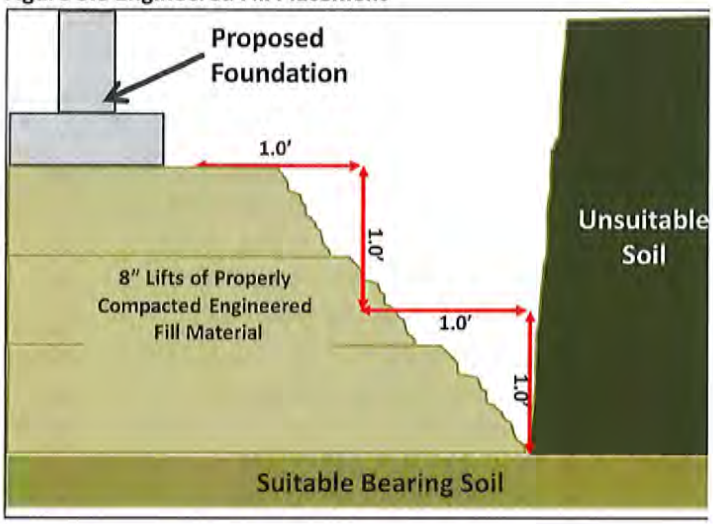
Where excavations are within the zone of influence of structure foundations, rigid pavements and other load bearing structures (*Figure 3.0*), the excavations must be backfilled with properly compacted MDOT Class II engineered fill. In areas where MDOT Class II fill would prove to be problematic (i.e. areas where it is difficult to drain or areas where there is a wet subgrade), properly placed and compacted MDOT 21AA aggregate may be utilized in place of MDOT Class II Fill. The use of larger, open graded aggregates (i.e. 1" x 3" crushed concrete) may also be utilized in areas that are exceedingly difficult to dry and stabilize. Prior to placing the 21AA or 1" by 3" stone in wet, unstable areas, a non-woven geotextile fabric and/or geogrid material should be installed per the manufacturer's recommendations.

All engineered fill and exposed subgrades should be free of organics, unfrozen, environmentally clean, and well-graded. The native soil at the bottom surface of the excavation should be dry and stabilized prior to placing fill as well as be completely free of organics. Wolverine should be

contacted to approve suitable engineered fill alternatives to MDOT Class II and MDOT 21AA engineered fill. Isolated impervious undercut areas should be accommodated with a gravity drainage system that will prevent the buildup of excess moisture.

Placement and compaction of any required engineered fills should be monitored by a representative of Wolverine or by a testing agency approved by Wolverine. The new materials should be placed in individual lifts not exceeding eight (8) inches in loose thickness. Each lift is to be compacted to 95 percent of the maximum dry density within three (3) percent of the optimum moisture content as determined in accordance with ASTM standard method D1557. As detailed in *Figure 3.0*, the compaction of the individual lifts should be extended 1 foot horizontally outside of the structure or pavement for every 1 foot in thickness between the intended bearing surface and the natural, suitable underlying soils to ensure a properly compacted lift. A sufficient number of in-place density tests should be performed by Wolverine or an approved testing agency on each lift of the fill. The tests should be performed in accordance with appropriate ASTM procedures.

Figure 3.0 Engineered Fill Placement



The engineered fill should be compacted with a smooth drum vibratory roller or excavator mounted plate compacter (i.e. hoe-pac). If the shallow ground water "wicks" or otherwise influences compactive efforts, a static smooth drum roller should be utilized, or the site dewatered as directed later in this report.

Fill materials placed immediately adjacent to below grade structures or piping should be compacted with light-weight compaction equipment such as jumping jacks or plate compactors to reduce the potential for damage. Fill soils compacted by walk-behind plate or other light weight soil compacting equipment should be tested more frequently since deep compaction is difficult to achieve with this type of equipment.

Where excavations are within greenbelt areas or other areas that will not be exposed to any type of loading or vehicle traffic, the backfill material is not required to be MDOT Class II material; however, it should consist of organic free, un-frozen, moisture conditioned soil sufficiently compacted to minimize consolidation.

6.1 Excavation Safety

To reduce the chances of collapsing the excavation, the materials removed from the excavation should not be stockpiled adjacent to the sidewalls of the excavation. All excavations, regardless of depth or use, should be constructed in accordance with the current OSHA guidelines. If temporary shoring of excavation sidewalls is performed, a professional engineer licensed in the State of Michigan must design it.

In accordance to OSHA Method ID-194 Version 2.0 Classification of Soils for Excavations, the near surface soils appear to be generally consistent with *Type C Granular Soils or Submerged Soils from which water is freely seeping.* The OSHA Soil Classification should be frequently confirmed by the contractor at each specific excavation location utilizing OSHA Method ID-194 Version 2.0 Classification of Soils for Excavations or the most current version available.

7.0 Foundation Recommendations

7.1 General Foundation Discussion

It appears that the native soils observed beneath the topsoil could be suitable for the support of the proposed Redwood Living building foundations if the site is sufficiently dewatered as directed in the following Section *8.0 Groundwater During Construction*. If the building sites are successfully dewatered and the foundation bearing surfaces are completely stabilized in accordance to our recommendations, shallow foundations may be utilized for the proposed development. The foundations may either be constructed on native soils or properly placed and compacted engineered fill placed over properly prepared and stable native soils. If conventional shallow foundations are utilized, they should be designed for a maximum allowable bearing capacity of **2,000 pounds per square foot**. The maximum allowable soil bearing capacity is contingent upon the bottom of the excavation consisting of dry, stabilized, and compacted native soil prior to fill and/or foundations being placed. Total foundation settlements are estimated to be less than 1 inch with differential settlement approximately ½ that value.

7.3 General Foundation Recommendations

The presence of shallow groundwater in the lower areas will make groundwater intrusion within a potential basement level a significant problem requiring waterproofing, redundant foundation draining and pumping systems, etc. Therefore, basement levels should be avoided if possible. Stabilizing the bottom of the foundation excavation and properly placing engineered fill would also prove to be very difficult in a basement level.

To resist punching, column footings bearing on native soils or properly placed engineered fill should have minimum dimensions of 24 inches and strip footings should have a minimum width of 18 inches. All excavations and foundation bearing surfaces must be compacted as directed in *Section 5.0 Subgrade Recommendations*. If unsuitable soils are removed, Wolverine or an approved testing agency should observe the bottom of excavations prior to placing any engineered fill and all foundation bearing surfaces immediately prior to placing concrete or reinforcing steel to verify its suitability. All foundations located in unheated areas must bear at a depth of at least 42 inches below final surface grades to guard against frost damage. If construction is to take place in the winter months, great care should be taken to protect all excavations from freezing as well. Slabs and pavements in located in unheated areas should incorporate a granular subgrade drainage layer and drainage structures as detailed in *Section 9.0 Pavement Section Recommendations* of this report.

The decision to extend the footings should be made by a representative of Wolverine at the time of construction. As depicted in Figure 3.0, any fill placed below the footings where soils are removed should extend 1 foot horizontally outside of the footing limits for every 1 foot in thickness between the intended bearing surface and the natural, suitable underlying soils. Wolverine should observe the bearing surfaces immediately prior to placing concrete or reinforcing steel to verify the bearing capacity. Prior to placing fill, the surface of the excavation must be properly compacted.

8.0 Groundwater During Construction

Suitable foundation materials will become unstable when exposed to water through groundwater infiltration, surface runoff, precipitation, or by other means. Therefore, the contractor should keep the excavations in a "dry condition" where water is encountered during construction. As indicated previously in this report, groundwater infiltration should be anticipated at this site where excavations approach the current static groundwater level in the lower areas of the site. Since it appears that the shallow groundwater is not isolated within small portions of the site, collection trenches, gravity drainage system, sump pumps, or other conventional minor dewatering procedures **will not** be sufficient to control groundwater infiltration if excavations extend deeper than the current static groundwater level in these areas.

Should excavations be planned to extend below the existing groundwater level, significant dewatering will need to take place before and during excavation activities. An experienced dewatering contractor should be contracted to dewater the work areas prior to work taking place. The dewatering contractor should be responsible for preparing a detailed dewatering plan based on the current site conditions. Since groundwater levels can fluctuate, the contractor should determine the actual water levels prior to preparing a dewatering plan. This plan should be provided to Wolverine for review prior to work taking place.

When compacting the exposed surface of the bottom of an excavation near groundwater with vibratory equipment, moisture may be wicked to the surface thus hindering the compaction efforts. Therefore; a static roller or other static compaction equipment should be utilized when compacting the surface of the excavations in close proximately to the water table.

9.0 Pavement Section Recommendations

Based on our analysis and our experience in the general site area with similar subgrade soils, we have made the following assumptions in our AASHTO design methods for flexible pavement based on a service life of 20 years.

- The subgrade is dry, stable, and has been properly prepared as outlined in this report
- All fill materials are compacted to 95 percent of the maximum dry density as determined by ASTM D 1557
- Stabilized Subgrade CBR = 5
- Reliability = 85%
- Standard Deviation = 0.49 Flexible, 0.35 Rigid
- Initial Serviceability Index = 4.2
- Terminal Serviceability Index = 2.0
- Estimated Traffic Volume (Light Duty) - 20,000 ESAL's (Construction and Service)
- Estimated Traffic Volume (Medium Duty) - 200,000 ESAL's (Construction and Service)

The CBR value should be field-verified when specific traffic frequencies and axle loading information is made available. The following "light duty" asphalt pavement section should be suitable for personal vehicle traffic only. The "heavy duty" asphalt section should be utilized in areas of high traffic or areas where larger vehicle traffic is anticipated (i.e. delivery trucks, garbage trucks). The "heavy duty" concrete section could be used as a substitute for asphalt pavement, especially in high traffic areas and should be installed in any dumpster pad/approach area and in heavy truck (i.e. tractor trailer) traffic areas.

Table 2.0 Pavement Sections

	Flexible Light Duty	Flexible Heavy Duty	Rigid Heavy Duty
Subgrade Reinforcement	*Geogrid fabric (If unstable)*	*Geogrid fabric (If unstable)*	*Geogrid fabric (If unstable)*
Aggregate Layer	10" MDOT 21AA	10" MDOT 21AA	3" MDOT 21AA
Leveling Course	2.5" MDOT 13A	3.0" MDOT 13A	---
Wearing Course	1.5" MDOT 36A	2.0" MDOT 36A	6" MDOT P1 Concrete

The Rigid (concrete) Heavy Duty pavement was provided by Redwood Development based on their experience with other Midwest project sites. If the subgrade is properly prepared and in excellent condition, the provided Rigid Heavy-Duty pavement section should be suitable, although the potential successful service life of the pavement would be largely dependent on the contractor's skill in preparing the subgrade and placing the pavement materials. We would typically recommend an aggregate thickness of ten (10) inches or more in this instance. Since MDOT 21AA can have a maximum aggregate size of almost 1½-inches, an area that contains an appreciable amount of these larger sized aggregates will not "lock up" and provide any structural support. Therefore, the concrete pavement would rely exclusively on the native subgrade for support. By increasing the aggregate section to ten (10) inches, areas of large aggregate will become less vulnerable to instability since the thicker section will result in an ample amount of binding material to stabilize the section and provide the proper support to the concrete pavement.

Periodic maintenance should be expected and performed on all pavements during the service life. All pavement materials and construction procedures should conform to MDOT or appropriate local requirements.

Prior to placing any road base materials, the exposed subgrade soils should be tested in accordance to the recommendations outlined in *Section 5.0 Subgrade Preparation*. Areas exhibiting deep instability not suitable for undercuts should be covered with a geogrid fabric properly installed to the product manufacturer's recommendations prior to placing engineered fill. Where geogrid is required, the backfill should consist of at least 10-inches of MDOT 21AA that is continued until the pavement bearing elevation is achieved. Wolverine should be provided the opportunity to approve the geogrid material prior to installation.

A concrete collar with a minimum width of three feet should be installed around catch basins to improve drainage. In addition, socked finger drains should be installed around catch basins and perimeter drainage should be incorporated into the pavement design. Inadequate drainage will result in significant distress to the pavement and a shortened service life.

Vehicle traffic or the loading of a partially constructed pavement section will likely cause premature pavement failure. All vehicle traffic or pavement loading should be restricted until the pavement section has been completely constructed or the partial pavement section must be designed for this purpose, particularly if construction traffic will use the partial pavement.

10.0 Slab-on-Grade Considerations

The subgrade soils utilized for the support of slabs-on-grade should be prepared as indicated in *Section 5.0 Subgrade Recommendations* of this report. Subgrade testing and observation, as discussed earlier in this report, should be performed to identify any soft or unsuitable soils, which should then be removed from the floor slab area prior to fill placement and/or floor slab construction. It may be necessary to utilize the pavement installation recommendations provided in the preceding section in areas that prove difficult to stabilize. A granular mat should be provided between the floor slab and the subgrade soil. It should be 4 inches or greater in thickness and be properly compacted as recommended in this report. The granular mat materials should comply with the current version of ACI 302.1.

Slabs should be suitably reinforced to make them as rigid as necessary. Proper joints should be provided at the junctions of the slab and the foundation system so that a small amount of independent movement can occur without causing damage. The floor areas should be provided with joints at frequent intervals to compensate for concrete volume changes during curing. If a vapor retarder/barrier will be utilized, placement should be in compliance with the current version of ACI 302.1, local building codes and the recommendations of the flooring manufacturer. A modulus of subgrade reaction for the native soils (or imported fills) specified and conditioned as described in this report of 100 psi/in may be used for the floor slab design. This value may be confirmed in the field by performing a 1-foot by 1-foot plate load test. However, depending on how the slab load is applied, the value will have to be geometrically modified.

11.0 Below Grade Walls

As stated previously in this report, below grade walls are not recommended in the lower portions of the site due to the shallow groundwater. In the southwest portion of the site where the groundwater is substantially deeper, the soil conditions should be suitable for basement levels and below grade walls. The below grade walls should be designed to resist lateral earth pressures as detailed in the following section. Lateral earth pressure is developed from soils present within a wedge formed by the vertical below-grade wall and an imaginary line extending up and away from the bottom of the wall at an approximate 45° angle. The lateral earth pressures are determined by multiplying the vertical applied pressure by the appropriate lateral earth pressure coefficient K. If the walls are rigidly attached to the structure and not free to rotate or deflect at the top, Wolverine recommends designing the walls for an "at-rest" lateral earth pressure condition using K_o. Walls that are permitted to rotate and deflect at the top can be designed for the active lateral earth pressure condition K_a. Passive pressure can be determined using K_p, with a factor of safety of 2.0. Recommended Parameters for use in below grade walls are as follows:

Table 3.0: Recommended Parameters for use in Below-Grade Wall Design

Material Type	Drained Friction Angle (Φ')		
1) Lean Clay (in-situ)	28°		
2) Lean Clay (conditioned and compacted)	22°		
3) Granular Soils (clean crushed limestone)	35°		
Total Soil Density (pcf)	125		
Cohesion for Clay Soils (psf) (undrained, Φ=0)	200		
Parameter specific to soil type	**1**	**2**	**3**
Friction Factor for Base	0.35	0.27	0.47
Coefficient of Active Pressure (Ka)	0.36	0.45	0.27
Coefficient of Passive Pressure (Kp)	2.77	2.2	3.69
Coefficient of At-Rest Pressure (Ko)	0.53	0.63	0.43

*These values may be used for design only if the crushed limestone backfill extends back from the wall certain distances. These are a horizontal distance approximately equal to or greater than the total height of the wall at the surface, and at least one-foot beyond the heel of the wall footing.
**Earth pressure coefficients valid for level backfill conditions with no surcharge

The values presented above were calculated based on positive foundation drainage being provided to prevent the buildup of hydrostatic pressure. If surface loads are placed near walls, such as traffic loads, they should be designed to resist and additional uniform lateral loads of one-half of the vertical surface loads. An "equivalent fluid" pressure can be obtained from the above chart by multiplying the appropriate K-factor times the total unit weight of the soil. This applies to unsaturated conditions only. If a saturated "equivalent fluid" pressure is needed, the effective unit weight (total unit weight minus unit weight of water) should be multiplied times the appropriate K-factor and the unit weight of water added to that resultant. However, Wolverine does not recommend that earth retaining wall be designed with a hydrostatic load and that drainage should be provided to relieve pressure.

The backfill materials should be placed in 8-inch thick loose layers and compacted to 95 percent of the maximum dry density according to ASTM D1557. We recommend that the backfill directly behind the walls be compacted with light, hand-held compactors. Heavy compactors and grading equipment should not be allowed to operate within 5 to 10 feet of the walls during backfilling to avoid developing excessive temporary or long-term lateral soil pressures. We recommend that a representative of Wolverine be present to monitor all foundation excavations and fill placement. Below grade walls should also be designed to resist adjoining surcharge loads from such items as foundations and/or equipment located in the vicinity of the wall.

As stated previously, it is recommended that all below grade walls and retaining walls be provided with a positive foundation drainage system. A typical below grade wall drain would consist of a 4-inch diameter or larger flexible or rigid perforated pipe protected by a proper filter medium (clean, coarse granular fill) and a non-woven geotextile fabric. The non-woven filter fabric is intended to encircle or wrap the entire system

12.0 Lateral Earth Pressures

We understand that it is planned to install retaining walls within the vicinity of Borings 6, 9, and 10. The lateral earth pressure for use in the design of retaining walls will vary depending on the type of wall, the type of backfill material, how the backfill is compacted, and drainage provisions. At the time of report preparation, the retaining wall type was not available. Regardless of the wall type, clean, granular soil is preferable as the backfill material against retaining structures to minimize lateral earth pressure. For free standing retaining walls, active earth pressure coefficients are used. For non-yielding walls, such as basement walls, at rest earth pressure coefficients should be used.

For backfill consisting of clean, granular soil, recommended lateral earth pressures for design of these walls are 60 pounds per square foot (psf) per foot of wall height for fixed-headed walls. For free-headed walls, an equivalent fluid pressure of 40 psf per foot of wall height should be used. These values are based on positive foundation drainage provided behind the wall to prevent buildup of hydrostatic pressure. These values do not include the influence of groundwater, structural compaction, and foundation and surface load in or adjacent to the wall backfill. If backfill against a non-yielding wall is well compacted, the equivalent fluid pressure should be in the range of 90 psf per foot of wall height. Below the groundwater table or if drainage is not provided, or if the possibility of water logging is suspected, the walls should be designed for additional hydrostatic pressure of 62.4 psf per foot of wall height.

As stated previously, we recommend the backfill of retaining walls consist of granular, free draining materials. Recommended design earth pressure coefficients for medium compacted sand are as follows:

Table 4.0 Earth Pressure Coefficients

Active Earth Pressure Coefficient, K_a	0.33
At Rest Earth Pressure Coefficient, K_o	0.5
Passive Earth Pressure Coefficient, K_p	3.0

If a clean, granular soil is not available for use as backfill, the backfill of foundation walls and retaining walls may consist of low plastic soils or mixed granular materials. If cohesive or poorly

draining soils are used as backfill, the minimum recommended lateral earth pressure values are 120 psf per foot of wall height for fixed-headed walls and 100 psf per foot of wall height for free-headed walls. These values are based on the assumption that the cohesive or poorly draining material will become fully saturated.

The backfill materials should be placed in 8-inch-thick loose layers and compacted to 95 percent of the maximum dry density according to ASTM D1557. We recommend that the backfill directly behind the walls be compacted with light, hand-held compactors. Heavy compactors and grading equipment should not be allowed to operate within 5 to 10 feet of the walls during backfilling to avoid developing excessive temporary or long-term lateral soil pressures. We recommend that a representative of the geotechnical engineer be present to monitor all foundation excavations and fill placement. Below grade walls should also be designed to resist adjoining surcharge loads from foundations and/or equipment located in the vicinity of the wall.

It is recommended that all below grade walls and retaining walls be provided with a positive foundation drainage system. A typical below grade wall drain would consist of a 4-inch diameter or larger flexible or rigid perforated pipe protected by a proper filter medium (clean, coarse granular fill) and a non-woven geotextile fabric. The non-woven filter fabric is intended to encircle or wrap the entire system

13.0 Limitations

The recommendations submitted for the proposed Redwood Living Development are based on the available project details furnished by Bergmann Associates, PC. If there are any revisions to the plans for this project or if deviations from the subsurface conditions noted in this report are encountered during construction, Wolverine must be notified immediately to determine if changes in the foundation recommendations are required. If Wolverine is not retained to perform these functions, Wolverine cannot be responsible for the impact of those conditions on the performance of the project.

Wolverine warrants that the findings, recommendations, specifications, or professional advice contained herein have been made in accordance with generally accepted professional geotechnical engineering practices in the local area. No other warranties are implied or expressed.

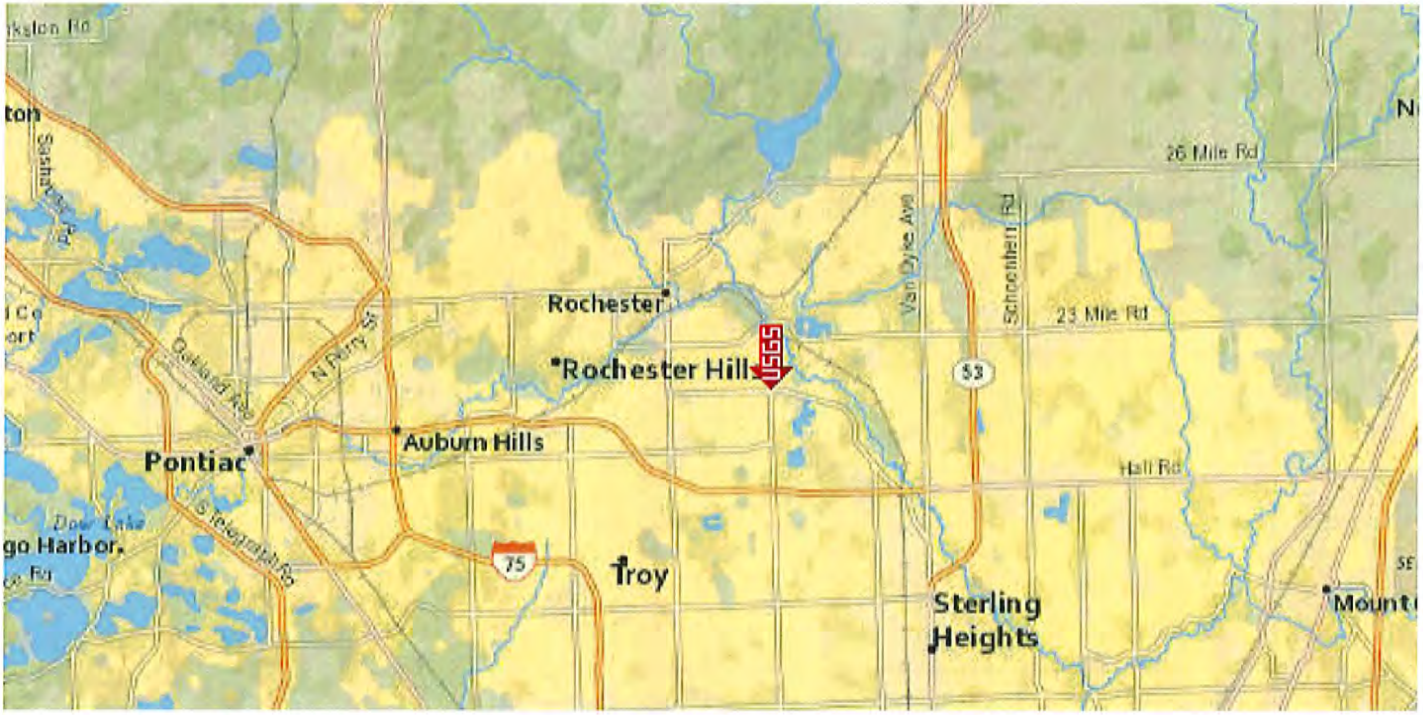
After the plans and specifications are complete, Wolverine should be retained to review the final design plans and specifications. This review is necessary to verify that the engineering recommendations are appropriate for the final configuration, and that they have been properly incorporated into the design documents. This report has been prepared for the exclusive use of Bergmann Associates PC, for specific application to the proposed Redwood Living Development to be constructed in Rochester Hills, Michigan.

Appendix

USGS Design Maps Summary Report

User–Specified Input

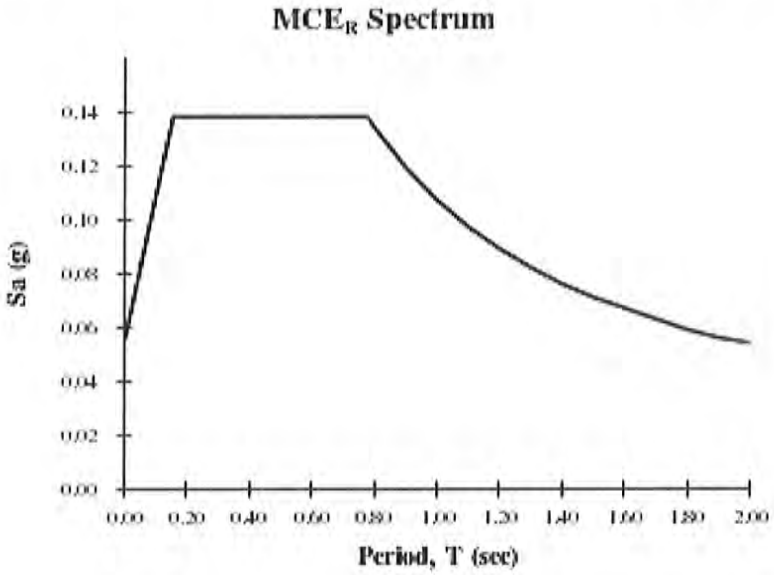
Report Title	Redwood Living Wed October 31, 2018 18:55:57 UTC
Building Code Reference Document	2009 NEHRP Recommended Seismic Provisions (which utilizes USGS hazard data available in 2008)
Site Coordinates	42.663°N, 83.093°W
Site Soil Classification	Site Class D – "Stiff Soil"
Risk Category	I/II/III

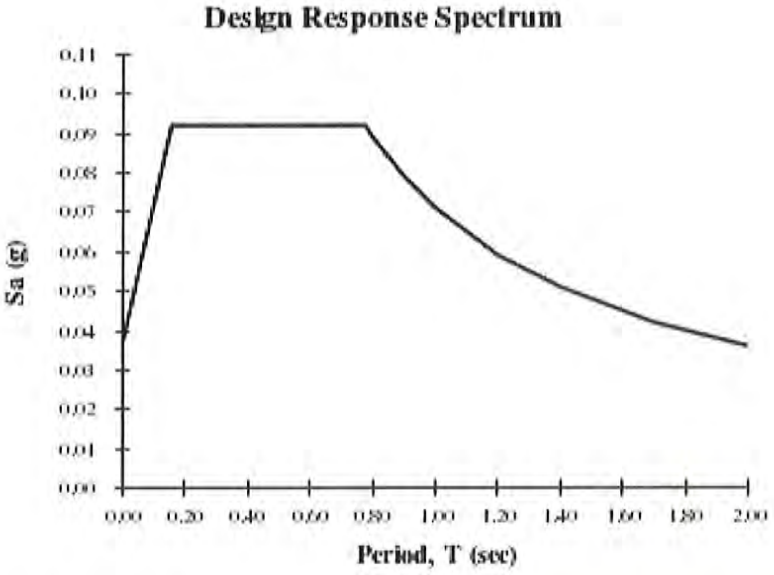


USGS–Provided Output

S_S =	0.086 g	S_{MS} =	0.138 g	S_{DS} =	0.092 g
S_1 =	0.045 g	S_{M1} =	0.107 g	S_{D1} =	0.071 g

For information on how the S_S and S_1 values above have been calculated from probabilistic (risk-targe deterministic ground motions in the direction of maximum horizontal response, please view the detail





For PGA_M, T_L, C_{RS}, and C_{R1} values, please view the detailed report.

Proposed Redwood Living Development
Avon and Dequindre Roads
Rochester Hills, Michigan

Drawing Not To Scale
Boring Locations are Approximate

WESI Job No.	18-0122
Date:	10/30/2018
Drawn By:	DJW
Checked By:	DJW

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BORING NUMBER B1

CLIENT Bergmann Associates Inc
PROJECT NAME Redwood Living
PROJECT NUMBER 18-0122
PROJECT LOCATION Rochester Hills, Michigan
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 682 ft **HOLE SIZE** 4 3/4"
DRILLING CONTRACTOR Strata Drilling
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Augers
▽ **AT TIME OF DRILLING** 2.00 ft / Elev 680.00 ft
LOGGED BY HTK **CHECKED BY** DJW
AT END OF DRILLING ---
NOTES
▽ **AFTER DRILLING** 1.50 ft / Elev 680.50 ft

DEPTH (ft)	ELEVATION (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)
0	680		1.2 Dark brown TOPSOIL (680.8)					
			2.0 (SP) Brown SANDY CLAY TOPSOIL, with gravel, moist (680.0)	SS		1-2-3 (5)	-	
			4.0 (SP) Loose, brown, fine to coarse SAND, with gravel, wet (678.0)	SS		3-5-7 (12)	2.0	
			(CL-ML) Very stiff, gray, SILTY CLAY, with occasional wet sand and gravel seams, moist	SS		6-7-9 (16)	3.25	
10	670			SS		6-11-14 (25)	4.5	
				SS		8-10-14 (24)	2.0	
20			20.0 (662.0)	SS		10-8-9 (17)	4.25	

Bottom of borehole at 20.0 feet.

▲ SPT N VALUE ▲
20 40 60 80
PL MC LL
20 40 60 80
☐ FINES CONTENT (%) ☐
20 40 60 80

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BORING NUMBER B2

CLIENT Bergmann Associates Inc
PROJECT NAME Redwood Living
PROJECT NUMBER 18-0122
PROJECT LOCATION Rochester Hills, Michigan
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 686 ft **HOLE SIZE** 4 3/4"
DRILLING CONTRACTOR Strata Drilling
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Augers
▽ **AT TIME OF DRILLING** 5.00 ft / Elev 681.00 ft
LOGGED BY HTK **CHECKED BY** DJW
AT END OF DRILLING ---
NOTES
▼ **AFTER DRILLING** 5.00 ft / Elev 681.00 ft

DEPTH (ft)	ELEVATION (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)
0			0.5 Dark brown TOPSOIL 685.5					
			(SM) Loose, brown, fine to medium SILTY SAND, with occasional wet gravel seams, moist to wet	SS		2-2-2 (4)	-	
			▽ 5.0 681.0	SS		2-2-3 (5)	-	
	680		(SP) Medium dense, fine to coarse SAND and					
			7.0 GRAVEL, wet 679.0	SS		5-9-6 (15)	-	
			(CL-ML) Very stiff, gray, SILTY CLAY, with occasional wet sand and gravel seams, moist					
10				SS		5-5-8 (13)	1.5	
				SS		4-7-7 (14)	1.0	
	670							
20			20.0 666.0	SS		4-8-9 (17)	0.5	

Bottom of borehole at 20.0 feet.

▲ SPT N VALUE ▲
20 40 60 80
PL MC LL
20 40 60 80
☐ FINES CONTENT (%) ☐
20 40 60 80

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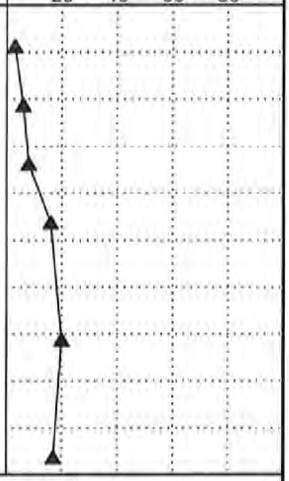
BORING NUMBER B3

CLIENT Bergmann Associates Inc
PROJECT NAME Redwood Living
PROJECT NUMBER 18-0122
PROJECT LOCATION Rochester Hills, Michigan
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 686 ft **HOLE SIZE** 4 3/4"
DRILLING CONTRACTOR Strata Drilling
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Augers
AT TIME OF DRILLING 6.00 ft / Elev 680.00 ft
LOGGED BY HTK **CHECKED BY** DJW
AT END OF DRILLING ---
NOTES
AFTER DRILLING 5.50 ft / Elev 680.50 ft

DEPTH (ft)	ELEVATION (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)
0			0.6 Dark brown TOPSOIL — 685.4					
			(SM) Very loose to loose, brown, SILTY SAND, moist	SS		2-1-2 (3)	-	
			5.0 — 681.0	SS		2-2-4 (6)	-	
	680		(SP) Loose to medium dense, brown, fine to coarse SAND, with gravel , moist to wet	SS		4-4-4 (8)	-	
10			10.0 — 676.0	SS		7-9-7 (16)	-	
			(CL-ML) Very stiff, brown, SILTY CLAY, moist					
			12.0 — 674.0					
			(CL-ML) Very stiff, gray, SILTY CLAY, with occasional wet sand and gravel seams, moist	SS		5-9-11 (20)	4.5	
	670							
20			20.0 — 666.0	SS		4-8-9 (17)	0.5	

Bottom of borehole at 20.0 feet.



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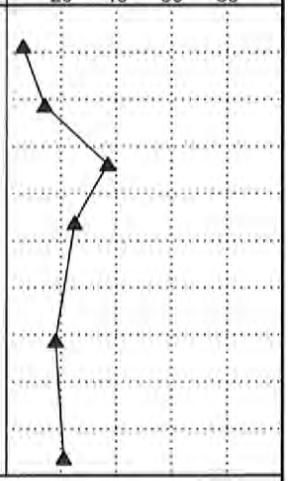
BORING NUMBER B4

CLIENT Bergmann Associates Inc
PROJECT NAME Redwood Living
PROJECT NUMBER 18-0122
PROJECT LOCATION Rochester Hills, Michigan
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 686 ft **HOLE SIZE** 4 3/4"
DRILLING CONTRACTOR Strata Drilling
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Augers
AT TIME OF DRILLING ---
LOGGED BY HTK **CHECKED BY** DJW
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	ELEVATION (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)
0			0.3 Dark brown TOPSOIL 685.7					
			(CL-ML) Very stiff, brown, SILTY CLAY, with occasional sand seams, moist	SS		3-3-3 (6)	-	
				SS		4-7-7 (14)	-	
	680			SS		15-16-21 (37)	4.5	
			7.5 678.5 (CL-ML) Very stiff, gray, SILTY CLAY, with occasional wet sand and gravel seams, moist					
10				SS		8-11-14 (25)	4.5	
				SS		6-7-11 (18)	4.5	
	670							
20			20.0 666.0	SS		8-9-12 (21)	4.5	

Bottom of borehole at 20.0 feet.

▲ SPT N VALUE ▲
20 40 60 80
PL MC LL
20 40 60 80
☐ FINES CONTENT (%) ☐
20 40 60 80



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BORING NUMBER B5

CLIENT Bergmann Associates Inc
PROJECT NAME Redwood Living
PROJECT NUMBER 18-0122
PROJECT LOCATION Rochester Hills, Michigan
DATE STARTED 10/18/18 **COMPLETED** 10/18/18
GROUND ELEVATION 744 ft **HOLE SIZE** 4 3/4"
DRILLING CONTRACTOR Strata Drilling
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Augers
AT TIME OF DRILLING ---
LOGGED BY HTK **CHECKED BY** DJW
AT END OF DRILLING ---
NOTES
AFTER DRILLING 12.50 ft / Elev 731.50 ft

DEPTH (ft)	ELEVATION (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	▲ SPT N VALUE ▲ 20 40 60 80 / PL MC LL 20 40 60 80 / ☐ FINES CONTENT (%) ☐ 20 40 60 80
0			0.9 Dark brown TOPSOIL — 743.1						
	740		(SC) Very loose, brown, fine to medium CLAYEY SAND, with occasional sand and gravel seams, moist	SS		1-1-1 (2)	-		
				SS		1-2-2 (4)	-		
			5.5 — 738.5 (SP) Medium dense, brown, fine to coarse SAND and GRAVEL, moist	SS		4-5-6 (11)	-		
10				SS		9-11-12 (23)	-		
	730		15.0 — 729.0 (SP) Medium dense, brown, fine SAND, with occasional gravel, moist	SS		7-10-13 (23)	-		
20			20.0 — 724.0	SS		5-6-8 (14)	-		

Bottom of borehole at 20.0 feet.

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BORING NUMBER B6

CLIENT Bergmann Associates Inc
PROJECT NAME Redwood Living
PROJECT NUMBER 18-0122
PROJECT LOCATION Rochester Hills, Michigan
DATE STARTED 10/18/18 **COMPLETED** 10/18/18
GROUND ELEVATION 704 ft **HOLE SIZE** 4 3/4"
DRILLING CONTRACTOR Strata Drilling
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Augers
▽ **AT TIME OF DRILLING** 5.00 ft / Elev 699.00 ft
LOGGED BY HTK **CHECKED BY** DJW
AT END OF DRILLING ---
NOTES
▼ **AFTER DRILLING** 16.00 ft / Elev 688.00 ft

DEPTH (ft)	ELEVATION (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)
0			0.7 Dark brown TOPSOIL 703.3					
			(SC) Loose, brown, fine to coarse CLAYEY	SS		4-3-4 (7)	-	
			3.0 SAND, moist 701.0					
	700		(CL-ML) Stiff, brown SILTY CLAY, trace sand,	SS		5-6-7 (13)	2.0	
			▽ 5.0 moist 699.0					
			(SM) Medium dense, brown fine SILTY SAND, with gravel, wet	SS		7-10-12 (22)	-	
10				SS		5-6-5 (11)	-	
	690			SS		5-7-6 (13)	-	
			▼					
			18.0 686.0					
20			(CL-ML) Very stiff, gray, SILTY CLAY, with occasional wet sand and gravel seams, moist	SS		5-7-7 (14)	1.25	
	680			SS		7-10-12 (22)	2.5	
30				SS		10-12-17 (29)	4.5	
	670			SS		9-10-14 (24)	3.5	
40				SS		9-13-17 (30)	4.5	
	660			SS		7-13-17 (30)	2.5	
50			50.0 654.0	SS		9-11-15 (26)	2.75	

Bottom of borehole at 50.0 feet.

▲ SPT N VALUE ▲ 20 40 60 80
PL MC LL 20 40 60 80
☐ FINES CONTENT (%) ☐ 20 40 60 80

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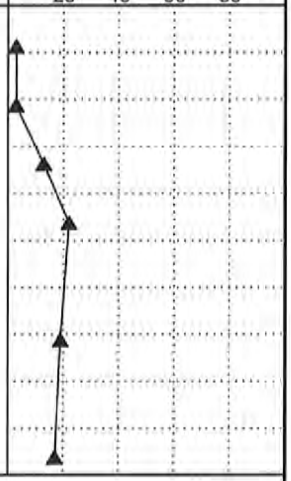
BORING NUMBER B7

CLIENT Bergmann Associates Inc
PROJECT NAME Redwood Living
PROJECT NUMBER 18-0122
PROJECT LOCATION Rochester Hills, Michigan
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 683 ft **HOLE SIZE** 4 3/4"
DRILLING CONTRACTOR Strata Drilling
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Augers
▽ **AT TIME OF DRILLING** 4.50 ft / Elev 678.50 ft
LOGGED BY HTK **CHECKED BY** DJW
AT END OF DRILLING ---
NOTES
▼ **AFTER DRILLING** 4.00 ft / Elev 679.00 ft

DEPTH (ft)	ELEVATION (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)
0			0.7 Dark brown TOPSOIL — 682.3					
	680		(SP) Very loose, brown, fine to coarse SAND and GRAVEL, moist to wet	SS		2-2-1 (3)	-	
				SS		2-1-2 (3)	-	
			6.0 — 677.0					
			7.0 (CL-ML) Stiff, brown, SILTY CLAY, with occasional wet sand and gravel seams, moist — 676.0	SS		5-6-7 (13)	2.25	
10			(CL-ML) Very stiff, gray, SILTY CLAY, with occasional wet sand and gravel seams, moist	SS		6-9-13 (22)	2.0	
	670			SS		5-9-10 (19)	1.25	
20			20.0 — 663.0	SS		5-8-9 (17)	4.5	

Bottom of borehole at 20.0 feet.

▲ SPT N VALUE ▲
20 40 60 80
PL MC LL
20 40 60 80
☐ FINES CONTENT (%) ☐
20 40 60 80



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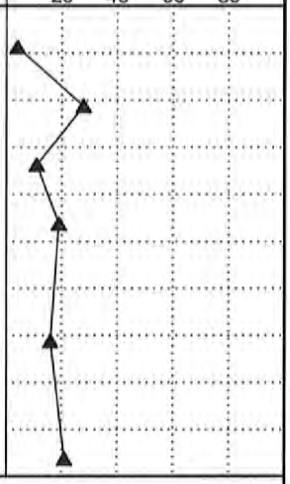
BORING NUMBER B8

CLIENT Bergmann Associates Inc
PROJECT NAME Redwood Living
PROJECT NUMBER 18-0122
PROJECT LOCATION Rochester Hills, Michigan
DATE STARTED 10/17/18 **COMPLETED** 10/17/18
GROUND ELEVATION 675 ft **HOLE SIZE** 4 3/4"
DRILLING CONTRACTOR Strata Drilling
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Augers
▽ **AT TIME OF DRILLING** 3.50 ft / Elev 671.50 ft
LOGGED BY HTK **CHECKED BY** DJW
AT END OF DRILLING ---
NOTES
▽ **AFTER DRILLING** 3.50 ft / Elev 671.50 ft

DEPTH (ft)	ELEVATION (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)
0			0.7 Dark brown TOPSOIL (674.3)					
			(SM) Loose, brown, fine SILTY SAND, moist	SS		1-2-2 (4)	-	
			▽ 3.5 (671.5)					
	670		(SP) Very loose, brown, fine to coarse SAND and GRAVEL, wet	SS		8-13-15 (28)	-	
			7.0 (668.0)	SS		4-7-4 (11)	4.5	
			7.2 (667.8) (CL-ML) Stiff, brown, SILTY CLAY, with occasional wet sand and gravel seams, moist					
10			(CL-ML) Very stiff, gray, SILTY CLAY, with occasional wet sand and gravel seams, moist	SS		6-8-11 (19)	4.0	
	660			SS		6-6-10 (16)	4.5	
20			20.0 (655.0)	SS		5-9-12 (21)	4.5	

Bottom of borehole at 20.0 feet.



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BORING NUMBER B9

CLIENT Bergmann Associates Inc
PROJECT NAME Redwood Living
PROJECT NUMBER 18-0122
PROJECT LOCATION Rochester Hills, Michigan
DATE STARTED 10/18/18 **COMPLETED** 10/18/18
GROUND ELEVATION 742 ft **HOLE SIZE** 4 3/4"
DRILLING CONTRACTOR Strata Drilling
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Augers
▽ **AT TIME OF DRILLING** 30.00 ft / Elev 712.00 ft
LOGGED BY HTK **CHECKED BY** DJW
AT END OF DRILLING ---
NOTES
▼ **AFTER DRILLING** 41.00 ft / Elev 701.00 ft

DEPTH (ft)	ELEVATION (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)
0	740	0.7 Dark brown TOPSOIL 741.3 (SP) Loose to medium dense, brown, fine to medium SAND, trace clay, moist	SS		2-2-2 (4)	-	
		4.0 738.0 (SP) Medium dense, brown, fine to coarse SAND and GRAVEL, moist	SS		10-12-13 (25)	-	
			SS		17-19-24 (43)	-	
		8.0 734.0 (SP) Medium dense, brown, fine SAND, moist	SS		10-8-10 (18)	-	
10	730	13.5 728.5 (SP) Medium dense, brown, fine to coarse SAND and GRAVEL, moist	SS		8-12-14 (26)	-	
			SS		8-13-16 (29)	-	
20	720	23.5 718.5 (SM) Dense to very dense, brown, SANDY SILT, with occasional wet seams, moist to wet	SS		17-25-35 (60)	-	
		▽	SS		23-32-37 (69)	-	
30	710		SS		21-45-50/3"	-	
		38.0 704.0 (CL-ML) Very stiff, gray, SILTY CLAY, with occasional wet sand and gravel seams, moist	SS		8-12-14 (26)	4.5	
40	700	▼	SS		7-12-16 (28)	4.5	
50		50.0 692.0 Bottom of borehole at 50.0 feet.	SS		7-11-14 (25)	4.5	

▲ SPT N VALUE ▲
20 40 60 80
PL MC LL
20 40 60 80
☐ FINES CONTENT (%) ☐
20 40 60 80

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BORING NUMBER B10

CLIENT Bergmann Associates Inc
PROJECT NAME Redwood Living
PROJECT NUMBER 18-0122
PROJECT LOCATION Rochester Hills, Michigan
DATE STARTED 10/18/18 **COMPLETED** 10/18/18
GROUND ELEVATION 738 ft **HOLE SIZE** 4 3/4"
DRILLING CONTRACTOR Strata Drilling
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Augers
AT TIME OF DRILLING 33.00 ft / Elev 705.00 ft
LOGGED BY HTK **CHECKED BY** DJW
AT END OF DRILLING ---
NOTES
AFTER DRILLING 31.00 ft / Elev 707.00 ft

DEPTH (ft)	ELEVATION (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)
0			0.8 Dark brown TOPSOIL 737.2					
			(SC) Very loose to loose, brown, fine to medium CLAYEY SAND, moist	SS		2-2-1 (3)	-	
				SS		2-2-2 (4)	-	
			6.0 732.0					
	730		(SP) Medium dense, brown, fine to coarse SAND and GRAVEL, moist	SS		6-7-10 (17)	-	
10				SS		4-6-9 (15)	-	
			13.0 725.0					
			(SP) Medium dense, brown, fine to coarse SAND, with gravel, moist	SS		4-7-8 (15)	-	
	720							
20				SS		10-20-28 (48)	-	
			24.0 714.0					
			(SM) Very dense, brown, fine SILTY SAND, moist to wet	SS		11-19-31 (50)	-	
	710							
30				SS		11-21-27 (48)	-	
			▽ 33.0 705.0					
			(CL-ML) Very stiff, gray, SILTY CLAY, with occasional wet sand and gravel seams, moist	SS		9-23-33 (56)	3.5	
	700							
40			40.0 698.0	SS		7-11-15 (26)	4.5	

Bottom of borehole at 40.0 feet.

▲ SPT N VALUE ▲
20 40 60 80
PL MC LL
20 40 60 80
☐ FINES CONTENT (%) ☐
20 40 60 80

WOLVERINE
Engineers & Surveyors, Inc.

BORING LOG TERMINOLOGY

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOIL (more than 50% of material is larger than No. 200 sieve size.)			
GRAVEL More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravel (Less than 5% fines)	GW	Well-graded gravel; gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravel; gravel-sand mixtures, little or no fines
	Gravel with fines (More than 12% fines)	GM	Silty gravel; gravel-sand-silt mixtures
		GC	Clayey gravel; gravel-sand-clay mixtures
SAND 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sand (Less than 5% fines)	SW	Well-graded sand; sand-gravel mixtures, little or no fines
		SP	Poorly graded sand; sand-gravel mixtures, little or no fines
	Sand with fines (More than 12% fines)	SM	Silty sand; sand-silt-gravel mixtures
		SC	Clayey sand; sand–clay-gravel mixtures
FINE-GRAINED SOIL (50% or more of material is smaller than No. 200 sieve size)			
SILT AND CLAY Liquid limit less than 50%		ML	Inorganic silt; sandy silt or gravelly silt with slight plasticity
		CL	Inorganic clay of low plasticity; lean clay, sandy clay, gravelly clay
		OL	Organic silt and organic clay of low plasticity
SILT AND CLAY Liquid limit 50% or greater		MH	Inorganic silt of high plasticity, elastic silt
		CH	Inorganic clay of high plasticity, fat clay
		OH	Organic silt and organic clay of high plasticity
HIGHLY ORGANIC SOIL		PT	Peat and other highly organic soil

OTHER MATERIAL SYMBOLS

Topsoil, Void, Sandstone, Asphalt, Glacial Till, Siltstone, Base, Coal, Limestone, Concrete, Shale, Fill

LABORATORY CLASSIFICATION CRITERIA

GW	$C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_C = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
GP	Not meeting all gradation requirements for GW	
GM	Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols
GC	Atterberg limits above "A" line with PI greater than 7	
SW	$C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_C = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
SP	Not meeting all gradation requirements for SW	
SM	Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols
SC	Atterberg limits above "A" line with PI greater than 7	

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

Less than 5 percent.....GW, GP, SW, SP
More than 12 percent.....GM, GC, SM, SC
5 to 12 percent.....Cases requiring dual symbols

- SP-SM or SW-SM (SAND with Silt or SAND with Silt and Gravel)
- SP-SC or SW-SC (SAND with Clay or SAND with Clay and Gravel)
- GP-GM or GW-GM (GRAVEL with Silt or GRAVEL with Silt and Sand)
- GP-GC or GW-GC (GRAVEL with Clay or GRAVEL with Clay and Sand)

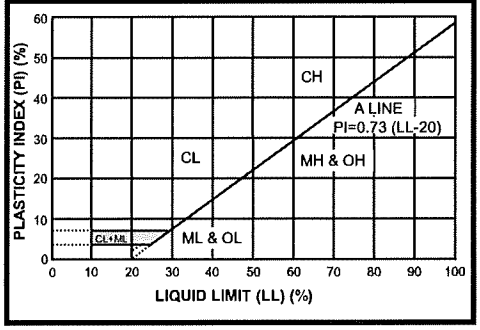
If the fines are CL-ML:

- SC-SM (SILTY CLAYEY SAND or SILTY CLAYEY SAND with Gravel)
- SM-SC (CLAYEY SILTY SAND or CLAYEY SILTY SAND with Gravel)
- GC-GM (SILTY CLAYEY GRAVEL or SILTY CLAYEY GRAVEL with Sand)
- GM-GC (CLAYEY SILTY GRAVEL or CLAYEY SILTY GRAVEL with Sand)

PARTICLE SIZES

Boulders	-	Greater than 12 inches
Cobbles	-	3 inches to 12 inches
Gravel- Coarse	-	3/4 inches to 3 inches
Fine	-	No. 4 to 3/4 inches
Sand- Coarse	-	No. 10 to No. 4
Medium	-	No. 40 to No. 10
Fine	-	No. 200 to No. 40
Silt and Clay	-	Less than (0.0074 mm)

PLASTICITY CHART



VISUAL MANUAL PROCEDURE

When laboratory tests are not performed to confirm the classification of soils exhibiting borderline classifications, the two possible classifications would be separated with a slash, as follows:

For soils where it is difficult to distinguish if it is a coarse or fine-grained soil:

- SC/CL (CLAYEY SAND to Sandy LEAN CLAY)
- SM/ML (SILTY SAND to SANDY SILT)
- GC/CL (CLAYEY GRAVEL to Gravelly LEAN CLAY)
- GM/ML (SILTY GRAVEL to Gravelly SILT)

For soils where it is difficult to distinguish if it is sand or gravel, poorly or well-graded sand or gravel; silt or clay; or plastic or non-plastic silt or clay:

- SP/GP or SW/GW (SAND with Gravel to GRAVEL with Sand)
- SC/GC (CLAYEY SAND with Gravel to CLAYEY GRAVEL with Sand)
- SM/GM (SILTY SAND with Gravel to SILTY GRAVEL with Sand)
- SW/SP (SAND or SAND with Gravel)
- GP/GW (GRAVEL or GRAVEL with Sand)
- SC/SM (CLAYEY to SILTY SAND)
- GM/GC (SILTY to CLAYEY GRAVEL)
- CL/ML (SILTY CLAY)
- ML/CL (CLAYEY SILT)
- CH/MH (FAT CLAY to ELASTIC SILT)
- CL/CH (LEAN to FAT CLAY)
- MH/ML (ELASTIC SILT to SILT)
- OL/OH (ORGANIC SILT or ORGANIC CLAY)

DRILLING AND SAMPLING ABBREVIATIONS

2ST	–	Shelby Tube – 2" O.D.
3ST	–	Shelby Tube – 3" O.D.
AS	–	Auger Sample
GS	–	Grab Sample
LS	–	Liner Sample
NR	–	No Recovery
PM	–	Pressure Meter
RC	–	Rock Core diamond bit. NX size, except where noted
SB	–	Split Barrel Sample 1-3/8" I.D., 2" O.D., except where noted
VS	–	Vane Shear
WS	–	Wash Sample

OTHER ABBREVIATIONS

WOH	–	Weight of Hammer
WOR	–	Weight of Rods
SP	–	Soil Probe
PID	–	Photo Ionization Device
FID	–	Flame Ionization Device

DEPOSITIONAL FEATURES

Parting	–	as much as 1/16 inch thick
Seam	–	1/16 inch to 1/2 inch thick
Layer	–	1/2 inch to 12 inches thick
Stratum	–	greater than 12 inches thick
Pocket	–	deposit of limited lateral extent
Lens	–	lenticular deposit
Hardpan/Till	–	an unstratified, consolidated or cemented mixture of clay, silt, sand and/or gravel, the size/shape of the constituents vary widely
Lacustrine	–	soil deposited by lake water
Mottled	–	soil irregularly marked with spots of different colors that vary in number and size
Varved	–	alternating partings or seams of silt and/or clay
Occasional	–	one or less per foot of thickness
Frequent	–	more than one per foot of thickness
Interbedded	–	strata of soil or beds of rock lying between or alternating with other strata of a different nature

CLASSIFICATION TERMINOLOGY AND CORRELATIONS

Cohesionless Soils

Relative Density	N-Value (Blows per foot)
Very Loose	0 to 4
Loose	4 to 10
Medium Dense	10 to 30
Dense	30 to 50
Very Dense	50 to 80
Extremely Dense	Over 80

Cohesive Soils

Consistency	N-Value (Blows per foot)	Undrained Shear Strength (kips/ft²)
Very Soft	0 - 2	0.25 or less
Soft	2 - 4	0.25 to 0.50
Medium	4 - 8	0.50 to 1.0
Stiff	8 - 15	1.0 to 2.0
Very Stiff	15 - 30	2.0 to 4.0
Hard	> 30	4.0 or greater

Standard Penetration 'N-Value' = Blows per foot of a 140-pound hammer falling 30 inches on a 2-inch O.D. split barrel sampler, except where noted.


WOLVERINE
Engineers & Surveyors, Inc.

Wolverine Engineers & Surveyors, Inc.
312 North Street • Mason, Michigan 48854 • 517.676.9200 • Fax 517.676.9396

November 19, 2018

Mr. Paul Furtaw
Bergmann Associates PC
7050 West Saginaw Highway #200
Lansing, Michigan 48917

RE: Permeability Testing Results
Proposed Redwood Living Development
Avon Road and Dequindre Road
Rochester Hills, Michigan
WESI Project No. 18-0122

Dear Mr. Furtaw:

Pursuant to your request, Wolverine Engineers and Surveyors, Inc. (Wolverine) performed two permeability analysis at the future location of the new Redwood Living Development proposed for Rochester Hills, Michigan. Please find the results of our analysis attached to this letter.

Wolverine appreciates the opportunity to provide our services to you and looks forward to working with you again in the future. Please feel free to contact us regarding any questions or concerns regarding our report.

Sincerely,
WOLVERINE ENGINEERS AND SURVEYORS, INC.,

Dan Wisinski
Project Manager

CONSTANT HEAD PERMEABILITY TESTING

PROJECT: ROCHESTER HILLS DEVELOPMENT

DATE: 10/30/2018

PROJECT NO.: 18-0122

SAMPLE: Boring 3

DEPTH: 1 to 6 Feet BGS

Sample Information
Diameter: 3.12 cm
Height: 15.0 cm
Area: 30.6 cm2
Volume: 460.2 cm3
Weight: 690.9 g
Dry density: 93.8 pcf

Permeability: **1.63 X 10-3 cm/s**

Soil Description: Fine to Medium SAND with Silt and Gravel - Brown – (SP-SM)

Remarks: The permeability test was performed in general accordance with ASTM D- 2434. The Standard is no longer supported by ASTM.

FALLING HEAD PERMEABILITY
ASTM D5084

PROJECT INFORMATION

Project:	Rochester Hills Development				
Wolverine Job #	18-0122	Date Started:	November 2, 2018	Permeameter Cell Number	6
		Engineer:	HK	Sample # B8 1-3.5 FT BGS	

SAMPLE IDENTIFICATION

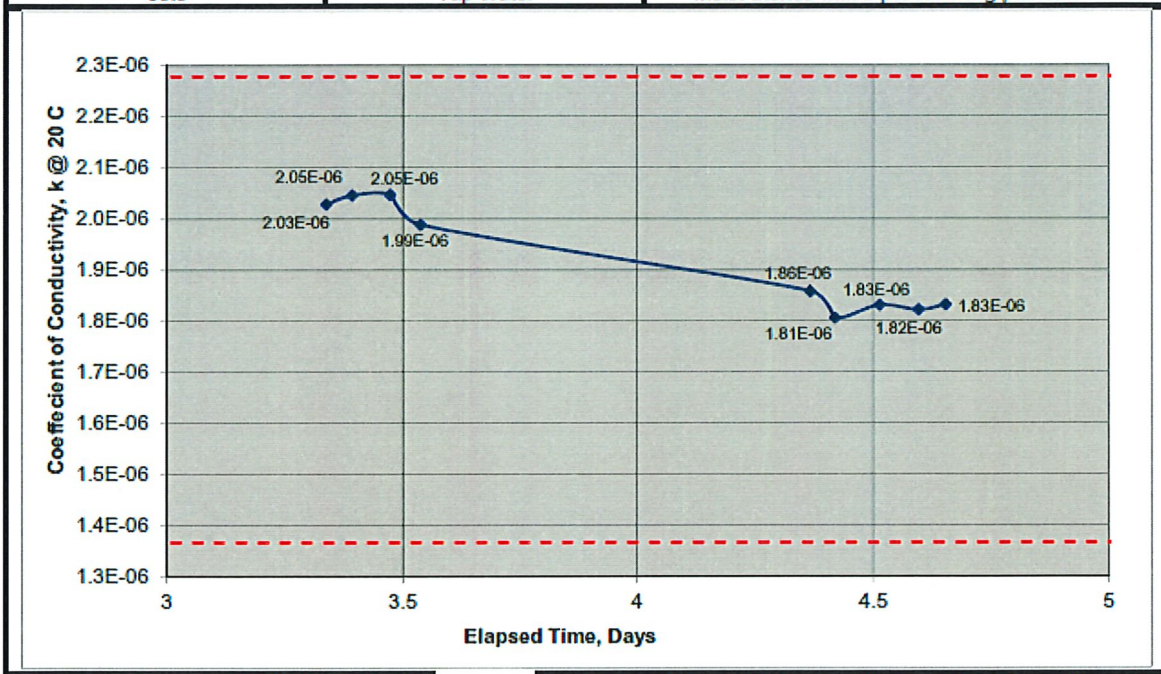
Sample Location	Type of Sample	Description
Onsite	Remolded	Brown SAND with fines

SAMPLE PREPARATION

Dry Unit Weight Maximum, pcf	Moisture Content Optimum, %	Actual Sample Compaction, %	Method of Compaction
---	---	---	3 lifts, scarred lower layer before compacting next lift

TEST CONDITIONS

Initial Head Height (inches)	Permeant Liquid	Initial Stone & Resevoir Water Conditions
60.5	Tap Water	Moist Stones with 5 psi confining pressure



	Initial	Final
Water Content, w%	18	16
Wet Unit Weight	128	125
Dry Unit Weight	109	109

Coefficient of Conductivity, k@20C, cm/sec Average of last 4 test cycles
0.0000018226
1.82E-06

CONSTANT HEAD PERMEABILITY TESTING

PROJECT: ROCHESTER HILLS DEVELOPMENT

DATE: 10/30/2018

PROJECT NO.: 18-0122

SAMPLE: Boring 6

DEPTH: 1 to 6 Feet BGS

Sample Information
Diameter: 3.12 cm
Height: 15.0 cm
Area: 30.6 cm2
Volume: 460.2 cm3
Weight: 690.9 g
Dry density: 93.8 pcf

Permeability: **1.63 X 10-3 cm/s**

Soil Description: Fine to Medium SAND with Silt and Gravel - Brown – (SP-SM)

Remarks: The permeability test was performed in general accordance with ASTM D- 2434. The Standard is no longer supported by ASTM.

FALLING HEAD PERMEABILITY
ASTM D5084

PROJECT INFORMATION

Project:	Rochester Hills Development				
Wolverine Job #	18-0122	Date Started:	November 2, 2018	Permeameter Cell Number	6
		Engineer:	HK	Sample #:	Boring 3 1 to 6 Feet BGS

SAMPLE IDENTIFICATION

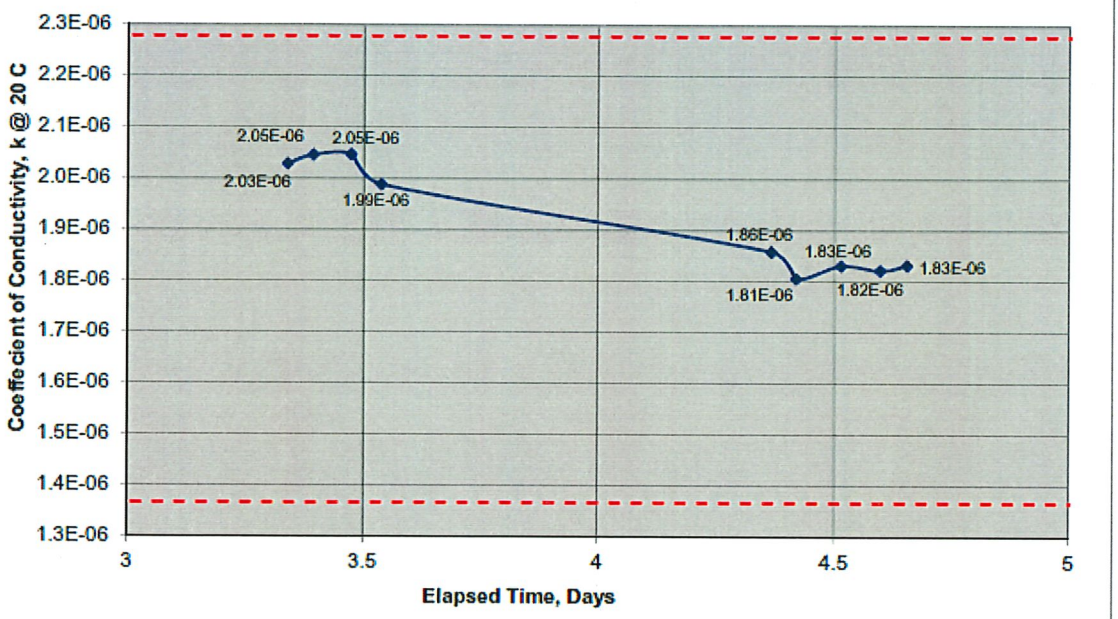
Sample Location	Type of Sample	Description
Onsite	Remolded	Brown SAND with fines

SAMPLE PREPARATION

Dry Unit Weight Maximum, pcf	Moisture Content Optimum, %	Actual Sample Compaction, %	Method of Compaction
---	---	---	3 lifts, scarred lower layer before compacting next lift

TEST CONDITIONS

Initial Head Height (inches)	Permeant Liquid	Initial Stone & Resevoir Water Conditions
60.5	Tap Water	Moist Stones with 5 psi confining pressure



	Initial	Final
Water Content, w%	18	16
Wet Unit Weight	128	125
Dry Unit Weight	109	109

Coefficient of Conductivity, k@20C, cm/sec Average of last 4 test cycles
0.0000018226
1.82E-06