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Municipal
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Site Hydrogeologic Study
White Oak Subtitle D Landfill
Haywood County, North Carolina

Project No. G 98010.5

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PURPOSE AND SCOPE OF STUDY

This study was undertaken to begin defining, with borings and piezometers, the soil and rock types and conditions of the uppermost aquifer regime at the proposed Haywood County Municipal Solid Waste Landfill (MSWLF) site. It is drafted to meet the requirements set forth by the North Carolina Department of Environment and Natural Resources in Solid Waste Management Rule 15A NCAC 13B.1623 (a).

SITE DESCRIPTION

The proposed Haywood County MSWLF site is located on 268 acres* that includes the existing White Oak Landfill (Plate 1). The site is 12 miles north of Waynesville at the Fines Creek Exit (Exit 15) off Interstate 40 almost 9 miles from the North Carolina-Tennessee state line.

The site lies within the Blue Ridge physiographic province characterized by mountainous topography. The site has a total relief of approximately 450 feet. The highest point is at 2700 feet above mean sea level (MSL) in the central-southern portion of the property. The lowest area is at an elevation of 2250 feet above MSL. This area is located along the Pigeon River reservoir on the northern property boundary†. On site slopes average 20%, though certain areas have considerably higher grades. Slopes that rise from the Pigeon River on the eastern border of the site have grades approaching 42%. Grades as low as 10% are found on shallow slopes between ridgelines in the central and western portion of the site. Three springs occur in the area where the water table intersects the land surface. The resulting waters drain north toward the Pigeon River. The property has historically been used as pasture and farmland. Several abandoned buildings occupy the clearing on the western side of the site. There are several paths that provide access for light vehicles. A General Site Plan is located on Plate 1.

*109 acres of the site have site suitability (Law Engineering, 1990).

†Walters Dam, located approximately 3.5 miles northwest of the site, was constructed along the Pigeon River for hydroelectric purposes. The resulting reservoir was named Waterville Lake (Walters lake on older USGS Quadrangles). However, for the purpose of this report, it will be referred to as the Pigeon River.

GEOLOGIC CONSIDERATIONS

The stratigraphy and structure of the southern Appalachian region have been the topic of many investigations and professional papers. In addition to previous observations by Law Engineering and Hatcher, MESCO personnel documented rock types and structure within the vicinity of the proposed landfill site. These observations were used in conjunction with extensive field reconnaissance performed by Hadley and Goldsmith to construct a geologic map outlining structures and lithologies within and surrounding the proposed site.[9] The derived geologic map and accompanying field notes are presented in Plate 2.

Regional Geology

Regionally the site lies near Ocoee series rocks that include both the older Snowbird Group and younger Great Smoky Group. The site itself overlies the Precambrian age basement complex that consists of metamorphosed plutonic rocks and the Carolina Gneiss.[9] Both units have experienced various degrees of polymetamorphism in both the Precambrian and Paleozoic where the original structure of the rocks was massively deformed, if not completely destroyed. The plutonic rocks, as described by Hadley and Goldsmith, stratigraphically overlie the Carolina Gneiss and are described as massive, often coarse textured rocks with varying textures and compositions. The composition of these meta-crystalline plutonic rocks (orthogneisses) suggests the parent materials were felsic igneous intrusions, namely granite and granodiorite. Though the underlying Carolina Gneiss is similar in texture and appearance, its composition suggests it was derived from very old meta-sedimentary units.[9] A non-conformity exists between the plutonic rocks of the basement complex and the overlying Thunderhead Sandstone that outcrops to the west and south of the site.

Structurally, the site is located very near the Cataloochee Divide Syncline between the kyanite and staurolite isograds. The degree of metamorphism increases to the south-southeast.[9] The Cataloochee Anticlinorium, located to the northwest of the site, is bounded by the Greenbrier Fault and bisected by the Cold Springs Fault. Located north-northwest of the site are small, high

angle reverse faults that roughly parallel the Cold Springs Fault. However, the lateral continuity of these faults is not established across the Pigeon River. Ridgeline orientation typically parallels structural features which trend northeast/southwest.

A stream trace analysis was performed within a 1 mile radius of the site. Structurally controlled features were traced from USGS 7.5 min Cove Creek Gap and Fines Creek Quadrangles. Dominant stream trends in the region are N5W to N25W and N35W to N45W, and minor trends are N5E to N30E and N75E to N85E. Field reconnaissance reveals major foliations trend N5W to N20W paralleling one of the dominant stream traces. Major joints trend N20W to N40W paralleling major stream traces. Other major foliation orientations (N9E to N20E) and joint orientations (N10E to N20E) parallel the minor stream traces. Stream traces do not appear to vary greatly between rock types, however, east of the Pigeon River stream traces trend N75W to east/west to N75E. This indicates a difference in fracturing on the opposite side of the Pigeon River which is likely following a major fracture system. Stream traces are presented on Plate 3. The Rose diagram on Plate 3B summarized the orientations of approximate straight line stream and drainage segments.

The site lies within a seismic impact zone defined as an area having greater than 10 percent probability that the maximum expected horizontal acceleration expressed as a percentage of the earth's gravitational pull (g) will exceed 0.10 g in 250 years.[1] There are no Holocene faults present within 200 feet of the landfill site.[12]

Site Specific Geology

Rock outcrop and core samples support the boundaries outlined by Hadley and Goldsmith.[9] Most of the core samples are layered, coarse-grained gneiss with varied degrees of fracturing and weathering. Some samples display granitic texture and good relict crystalline structure with only slight secondary orientation. Other samples show a typically gneissic texture that is massively foliated with interlayers of biotite mica and coarse-grained plagioclase and quartz. Although

changes in texture and composition are observed, the rocks underlying and outcropping within and directly adjacent to the site are classified as Precambrian plutonic basement rocks.

The most abundant on-site locations of rock outcrops are on the steep slopes that rise from the Pigeon River along the eastern and northern boundary of the site. Outcrop locations observed by Hatcher and Law Engineering were confirmed in the field by MESCO personnel. On-site outcrops consist of Precambrian basement granitoid gneiss with varying degrees of foliation. No faults are evident on site.

Small boulders of fine grained, white sandstone are found on the head of the slope where abandoned borehole P-8 is located. These are likely relicts of the overlying Thunderhead Sandstone. Soils weathered from the sandstone unit are not present in any borehole within the proposed site nor are there any sandstone outcrops within the site boundaries. The reported contact between the Thunderhead Sandstone and the basement complex lies west and south of the site as mapped by Hadley and Goldsmith.[9] The location of this contact was confirmed in the field by MESCO personnel.

FIELD INVESTIGATION

MESCO installed twenty-one borings for the site hydrogeologic study from March through May 1998, and nine borings from December 1999 through January 2000. Piezometers were installed in all borings that reached the water table and their locations were surveyed by MESCO in accordance with 15A NCAC 13B.1632. Boring B-8 reached neither the surface of intact rock nor the water table and was terminated and abandoned at a depth of 120 feet. Borings were drilled to provide both extended groundwater readings and subsurface data necessary for site characterization. Elevations from both the piezometers and monitoring wells will be used to define the potentiometric surface and groundwater flow characteristics. The locations of all borings and monitoring wells are provided on Plate 1. Water elevations and pertinent bore-hole and monitoring well depths are presented on Table 1.

Under the supervision of a MESCO geologist, Graham and Currie Well Drilling Company installed twenty temporary piezometers (P-1 through P-7, P-9 through P-19, P2-1 and P2-2) using a CME-850 truck mounted drill rig. Additionally, Engineering Tectonics installed piezometers P-1S, P-2S/D, P-3S/D, P-4S, P-6S/D and GWM-11D. Borings were augered with 4 1/4-inch ID hollow stem augers. Those borings extending below auger refusal were enlarged with 6 1/4-inch ID hollow stem augers to install a 4" casing for support of overburden soils during coring and/or air hammering. Piezometers screened in rock with two inch diameter PVC (P-1, P-2D, P-3, P-3D, P-5, P-6, P-6D, P-7, P-9, P-17, P-19 and GWM-11D) were installed with a 3 3/8-inch air hammer. Core samples were taken from ten borings (P-1, P-2D, P-3D, P-4, P-6D, P-9, P-14, P-18, P-19 and GWM-11D) using a 2-inch diameter core barrel. Borings P-4, P-14, and P-18 were installed with one inch diameter PVC in the core hole. Standard split-barrel samples of subsurface soils were taken at five foot intervals. Standard penetration tests were conducted in conjunction with split-barrel sampling in accordance with ASTM Test Procedure D 1586-84 using a 2-inch OD split-barrel sampler. Shelby tube samples were obtained of select cohesive soils for laboratory classification and *in situ* permeability testing. MESCO conducted slug tests in the field on July 6–8, 1998 and September 1, 1999 to measure hydraulic conductivity of select lithologic units.

Borings were logged in the field by a MESCO geologist and/or engineer according to the Unified Soil Classification System and sealed in containers for laboratory testing. Water levels were determined while drilling and were taken periodically after the piezometers were installed in each completed boring. Appendix A contains all relevant borings logs and construction records. The soil depths on the boring logs and depths of materials on the construction records are referenced by depth below existing ground surface.

SUBSURFACE CONDITIONS

Textural distinctions occur throughout the saprolite within the upper aquifer. Even though these variations are indicated on the boring logs, they do not imply the vertical or lateral extent of lithologies. The boring logs are divided into different soil lithologies only to add insight to the

type and gradation of soils to be encountered. Divisions on the logs are made based on expected hydrogeologic implications and how such variations are expected to influence the vertical and/or horizontal migration of groundwater.

The subsurface conditions at this particular site are best divided into three hydrogeologically distinct units. Boundaries for these units are made based on field inspection during installation, visual and laboratory sample analysis, and surrounding subsurface conditions. The uppermost portion of the site consists of saprolite defined as *in situ* chemically weathered crystalline rock. In this zone, a dense soil is found that grades slightly in composition, size, and degree of weathering depending on zonal variations in parent bedrock. Small scale structures are found in the saprolite that, upon visual inspection, are similar to underlying gneissic bedrock. Relict structures include foliations, thin fractures with iron-stains and clay replacement, broken quartz intrusions, phyllitic texture, and weathered crystals. Because the extent of chemical weathering of a rock depends largely upon the ease of access of water to the rock, a thick overburden (saprolite) layer can be an indication that the rock from which it is derived is abundantly fractured or has interstices of some type through which water can flow. A thick saprolite unit which is generally porous although not necessarily very permeable, serves as a reservoir to feed water into fractures.[14]

The second distinct unit is a zone of partially weathered rock (PWR). The PWR is highly fractured and stained with a large amount of soil filled fractures. This unit is often expected directly above bedrock as a transition zone between the overlying saprolite and underlying bedrock. In addition, however, the PWR unit in the mid-slope area is often found suspended in saprolite as a result of fracturing and weathering differences in the parent material. The presence of this material is indicated by slow advancement of the auger, abundant rock fragments in split spoon samples and auger cuttings, and blow counts approaching refusal. PWR produces low recovery (REC) and rock quality designation values (RQD) in core samples. In some instances, soil directly above zones of partially weathered rock becomes moist which may indicate the ability of PWR to inhibit vertical migration of groundwater and create a small, localized perched water table.

The third distinct unit is the underlying fractured gneissic bedrock. This unit, as previously described, is composed of meta-crystalline plutonic rocks. These orthogneisses vary in composition, texture, and structure. Fractures commonly parallel gneissic foliation at approximately 45 to 65° in core sample. The abundance of fractures within bedrock is often dependent on rock type. Strongly metamorphosed rock, such as that underlying the Haywood County site, develops planes of cleavage owing to the growth of micaceous minerals. Cleavage planes provide openings along which water may enter and flow.[14] Degree of fracturing is evident in an examination of core recovery (REC) and rock quality designation (RQD) values. The borings on ridgelines and toward the top of slopes (P-1, P-4, P-19 and GMW-11D) show higher average REC and RQD values. P-1, located on a broad ridgeline, has REC of 96% and RQD of 73%. REC and RQD values from P-4, which is located on a narrow ridge with steep slopes on either side, are 89% and 69% respectively. P-19 is located near the top of the steep slope rising from the Pigeon River. The average REC is 90% and average RQD is 71%. These high REC's and RQD's are an indication of intact and moderately fractured rock. Such high values can also provide reason for the existence of ridgelines, steep topography, and abundant outcrop in certain areas on-site. Conversely, borings located in valleys and toward the bottom of shallow slopes (P-9 and P2-1) display a decrease in REC and RQD values. REC and RQD values from P2-1, which was located midslope (before previous grading), are 84% and 48% respectively. P-9 is located very near a drainage feature. The average REC is 65% and the average RQD is 21%.

Along with supplying soil sample, standard penetration tests (SPT's) provide information to determine the relative *in situ* density of the saprolite unit. This information, when viewed in conjunction with other subsurface data, can help define weathering patterns and the presence of relict structures. A plot of average blows per foot (bpf) versus depth ratio of borings (Chart 1) indicates blow counts increase only slightly from ground surface through the majority of the boring.[‡] Average standard penetration values of saprolite fall between 10 and 40 bpf. However, toward auger refusal (80% to 100% depth), the standard penetration values increase rapidly. This sudden rise in *in situ* densities indicate an extensively and uniformly weathered overburden soil.

[‡]Data from P-1S, P-2S/D, P-3S/D, P-4S and P-6S/D are not included in the calculation of the average bpf.

Variations in the plot might account for zones of resistance such as partially weathered rock and broken quartz veins.

Groundwater was initially encountered in all three distinct units. Due to the general absence of subsurface structure that might influence groundwater movement (horizontal displacement, unweathered intrusions *etc.*), water elevations are largely a function of overlying topography. Water was initially encountered in saprolite in borings P-2S, P-3S/D, P-4S, P-6S/D, P-10, P-11, P-12, P-13, P-14, P-16 and GMW-11D. Groundwater was encountered initially in partially weathered rock in P-2, P-4, P-15, and P-18; and initial water elevations occurred in rock in the remaining borings (P-1, P-1S, P-3, P-5, P-6, P-7, P-9, P-17, P-19, P2-1, and P2-2). Of these, water in P-6, P2-1, and P2-2 was found just below the soil/rock interface as defined by auger refusal. Once allowed to stabilize after piezometer installation, the head in P-1S, P-2S/D, P-3S/D, P-4S, P-6, P-6S/D, P-9, P-10, P-11, P-12, P-13, P-15, P-16, and P-19 increased. Boring P-6 rose to the saprolite portion of the upper aquifer just above the soil/rock interface. Similarly, the head in P-1, P-2, P-4, P-14, and P-18 fell after stabilization. After installation, P-14 fell below the soil/rock interface. The remaining borings (P-3, P-5, P-7, P-17, P2-1, and P2-2) stabilized to levels comparable to those recorded while drilling. Stabilized water levels across the site indicate groundwater levels fall within 10 feet above or below the soil/rock interface.

Cross-sections are presented on Plates 5A through 5E. These sections display subsurface soil, rock, and groundwater conditions. The cross-sections show a somewhat uniform rock surface that generally follows the topography. Bedrock data were not available from all borings, therefore the bedrock surface under and between certain boreholes (B-8, P-10, P-13, and P-15) is interpretive. PWR occurs directly over the bedrock surface in most areas. It is most abundant on ridges and hills where it can be found in thick units on top of the rock surface as well as suspended in the saprolite unit. This is a result of reduced joints and fractures on the resistant hills and ridges. The saprolite remains thick, with larger zones of PWR. In the valleys and draws, saprolite tends to be thin, while the PWR unit often pinches out on either side of the draw.

The estimated long term seasonal high water table is presented on all cross-sections. The seasonal high surface generally occurs in the saprolite or PWR and tends to follow topographic and bedrock surface contours. Proposed subgrade elevations are also included on the cross-sections to show the four foot separation between the seasonal high water table elevations and subgrade elevations. The general profile presented on Plate 6 show sections B-B' and D-D' all the way to the river. The water table line shown on these is the single day line. The general profile shows the extreme topographic relief on-site as well as general hydrogeologic conditions. Cross-sections 5A-5E are more detailed and do not extend to the Pigeon River.

Hydraulic conductivities were determined using the Bouwer and Rice method.[3] This slug test method was developed as a bail-down test; that is, the water level is lowered by bailing so that the water flows from the aquifer into the well. The method can also be used when water is added to the well and heads in the casing fall, provided that the static level is above the well screen or open borehole.[6] It should be noted that Bouwer mentioned the occurrence of so-called "double straight line effect" when the water level is lowered below the top of the open section.[4] In case of such occurrence, two or more lines were drawn to fit the drawdown curve, and the line that best represents the aquifer characteristics in the vicinity of the piezometers was determined and used to compute the hydraulic conductivity. In some piezometers, the water level was initially above the top of the open section, and was lowered so far that it crossed the upper boundary of the open section. For those piezometers, multiple lines were expected, and the appropriate line for the determination of hydraulic conductivity was selected. A total of fourteen slug tests provided data to determine the hydraulic conductivities of the three distinct lithologic units comprising the uppermost aquifer.

Slug tests were performed on P-10, P-11, P-12, P-13, and P-16 which are screened in the saprolite portion of the upper aquifer. The average hydraulic conductivity for these wells is 1.50×10^{-4} cm/sec. This average value includes permeability tests run on five Shelby tubes taken from varying zones within the saprolite unit. Slug tests run on P-2 and P-15, which are screened in partially weathered rock, yield an average hydraulic conductivity of 6.81×10^{-5} cm/sec. Piezometers P-1,

P-5, P-6, P-7, P-17, and P-19 are screened in fractured gneissic bedrock. The average for this unit is 1.49×10^{-4} cm/sec.[§] A hydraulic consideration table and calculations are included in Appendix B.

LABORATORY RESULTS

Selected soil samples were tested in the laboratory in accordance with ASTM Standards to assist in classification and the estimation of engineering parameters. Laboratory tests included analysis of specific gravity, particle size through sieve analysis and hydrometer, and Atterberg limits. Tests on Shelby tube samples from P-8, P-9, P2-1, and P2-2 determined *in situ* hydraulic conductivities. Particle size plotted on textual classification triangles determined effective porosities for the overburden soils. Total and effective porosity values used in calculating flow rates are presented in Table 2. Table 3 summarizes the laboratory results and Appendix B includes all related documentation.

Atterberg limits (ASTM D-4318) were determined for twelve samples representative of variations within the saprolite unit. Liquid Limits ranged from 37% to 55% with an average of 44%. Plastic Limits ranged from 27% to 48% with an average of 35%. Plasticity Index ranged from 0 to 26% with an average of 11%. Test results for natural moisture content indicate an average of 23.6% with a range from 13.4% to 30.4%. By Unified Soil Classification System parameters, these soils are low plasticity inorganic silts and fine sands and slightly plastic clayey silts.

GROUNDWATER CONSIDERATIONS

Regionally, the upper aquifer occurs in regolith overlying fractured crystalline bedrock. Regolith is inclusive of all unconsolidated material that overlies intact bedrock. Most groundwater storage is located in the regolith because it has a higher porosity than fractured bedrock.[11] The approximate range in porosity for the saprolite and bedrock is shown in the following table.

[§]Values for P-9, P2-1 and P2-2 are not included in this calculation due to the unavailability of their revised slug test data. The wells P2-1 and P2-2 were abandoned during the construction of Cell 4. The value from the well P-9 is not included since a desirable amount of initial head change was not achieved during the slug test.

Rock type	Porosity (%)	K* (ft/day)
Saprolite	20–30	1–20
Bedrock	0.1–1	1–20

* K denotes hydraulic conductivity.

The above values suggest that the principal difference between saprolite and bedrock is in water-storage capacity.[10]

Infiltration occurs when precipitation reaches the land surface and penetrates the unsaturated soil. Water then moves laterally and downward through a temporary saturated zone. Ultimately, water will move into bedrock and be transported along interconnected fractures to points of discharge.[11]

On-site groundwater mainly occurs near the bedrock surface except on the crests of broad ridges underlain by thick saprolite and in deep draws, where the groundwater occurs in the saprolite. Plate 4 provides a single day potentiometric map generated from August 17, 1998 water level elevations. Groundwater flow is toward the main discharge feature, the Pigeon River.

There are several spring relief drains underneath the landfill. These drains were installed to remove spring water that was present at the time of construction. This drainage system was designed in such a way that all drained water travels to a drainage basin located to the north of the leachate pond. This drainage basin, however, stays dry to slightly moist throughout the seasons, indicating that water is rarely present along the drainage network. Hence it can be inferred that the water table stays mostly below these drains, and that the effect of "drainage" on levels of water table is marginal. The locations and elevations of the drainage pipes are provided in Plate 1.

Recharge areas occur on the tops of the largest ridges on the property (P-13, P-1, and B-8). Groundwater on the extreme southern portion of the site flows south and southeast from the proposed Phase 1 area.

As discussed above, the hydraulic conductivities for all three distinct units are very comparable. This is evidence to the fact that a change from saprolite or PWR to rock does not greatly affect flow within the aquifer. Groundwater is preferentially flowing along relict fractures and foliation

in the saprolite. Because fractures in core samples and outcrops parallel foliations, foliations are a zone of preferential groundwater flow in both the rock and the saprolite. Major stream traces also follow foliation and joint orientations observed in outcrop.

Groundwater flow rates for each distinct lithology are calculated using permeability and effective porosity data from Table 2 and vertical and horizontal gradients generated from potentiometric data. Saprolite and PWR generally have the lowest flow rates. This is largely because they have a higher effective porosity than gneiss. For two hydrogeologic units with the similar hydraulic conductivity, flow rate is controlled by effective porosity. In the flow rate equation, effective porosity is inversely proportional to flow rate; the lower the effective porosity, the higher the flow rate.¶ The average flow rate in saprolite is 145.57 ft/yr with a maximum of 233.04 ft/yr and minimum 8.01 ft/yr. Flow rates in the saprolite are greater than 200 ft/yr at P-12, GWM-1A, and GWM-8, all of which are located in draws. The minimum occurs at P-13 located on top of a ridge. Flow rates in PWR average 113.01 ft/yr, with the maximum of 200.00 ft/yr on a slope at P-18. The minimum flow rate (15.78 ft/yr) occurs on a ridge at P-15. Fractured gneiss contains higher flow rates averaging 544.82 ft/yr. The maximum flow rate for gneiss is 1905.52 ft/yr at P-6 on a ridge, while the minimum rate is 68.49 ft/yr at P-7 on a slope.

Vertical flow rates at five well nest locations GWM-2/2A, GWM-3/3D, GWM-5A/5D, GWM-7/7D, and TWD-10/10D are calculated from their hydraulic conductivities and effective porosities provided in Appendix B. For GWM-2/2A, GWM3/3D, GWM-5/5D and GWM-7/7D, the effective porosity and hydraulic conductivity of bedrock ($n_e = 0.05$ and $K = 1.49 \times 10^{-4}$ cm/sec, respectively) are used. For TWD-10/10D, the values for the saprolite unit ($n_e = 0.114$ and $K = 1.50 \times 10^{-4}$) are used for the calculation. The results are provided in Appendix B. Most notable is the GWM-3 nest which yields the average vertical flow rate of −1413.80 ft/yr, as opposed

¶Flow rate, *a.k.a.* average linear velocity, is defined by the equation

$$v_x = \frac{K}{n_e}\frac{dh}{dl}$$

where

v_x = average linear velocity (L/T)
K = hydraulic conductivity (L/T)
n_e = effective porosity
dh/dl = hydraulic gradient (L/L)[7]

to the average horizontal flow rate of 100.83 ft/yr at the same location. The GWM-2 nest, on the other hand, yields the average rate of 62.61 ft/yr, indicating an upward migration of groundwater. All other locations show slight to moderate amounts of downward flow gradient into the bedrock.

Plate 7 is an aerial photograph showing houses with wells within 2,000 feet of the landfill boundary. The nearest supply wells are located just south of the property. The wells are across a groundwater divide which occurs form P-14 to P-13 through TWD-10. Phase 1 limits cross this divide in the southeastern portion of Phase 1. The majority of groundwater under proposed waste cells will flow north toward the Pigeon River and discharge into the River or local streams which feed the river. A minimal amount of groundwater flows toward the supply wells south of the property. This localized southern flow can be easily monitored with monitoring wells. There is also a group of wells west of the site. Based on topography and the location of local streams, groundwater will flow north to northeast in the area of these wells, that is, groundwater will be flowing from these wells toward the landfill. Supply wells are also located north of the property, however, these wells are north of the Pigeon River and will not be affected by groundwater originating in the landfill area.

Effect of Pigeon River on Water Table

Water table fluctuations both at the monitoring points within the property and at the Pigeon River were obtained and evaluated for comparison. The lowest water table elevation within the property was recorded in the piezometer P-19 with the average elevation of 2407.82 feet over the period between 6/9/98 and 6/21/99 with the standard deviation[‖] of 2.85 feet. The average river elevation is 2252.06 feet over the same time period with the standard deviation of 6.12 feet.

[‖]By definition, standard deviation is the square of variance, and used to measure how spread out the individual values are around their mean value. It's defined by the equation

$$S.D. = \sqrt{\sum_{i=1}^{n} \frac{(x_i - \overline{x})^2}{n-1}}$$

where
n = total number of measurements
x_i = value of the ith measurement
$\overline{x}$ = mean value of all measurements

Elevations at each piezometer location were plotted against the river elevations to visualize the extent of linear correlations. A quick evaluation of the plots reveals little correlation between the river levels and the levels of water table in the landfill, which is also indicated by their low R^2 values (Appendix D). A summary of the computed R^2 values and Pearson correlation coefficients against the river levels is given in the table below.

	R*	R^2
Pigeon River	1.0000	1.0000
P-1	−0.0902	0.0081
P-2	0.3993	0.1595
P-3	0.1823	0.0332
P-4	−0.2059	0.0424
P-5	0.1097	0.0120
P-6	0.0218	0.0005
P-7	−0.1965	0.0386
P-9	0.0427	0.0018
P-10	0.1843	0.0340
P-11	−0.0014	0.0000
P-12	−0.3298	0.1088
P-13	−0.4454	0.1984
P-14	−0.4418	0.1952
P-15	−0.3640	0.1325
P-16	−0.1401	0.0196
P-17	−0.1524	0.0232
P-18	0.4624	0.2138
P-19	−0.0499	0.0025

* R denotes correlation coefficient.

By definition, the R^2 value is the square of correlation coefficient. It represents the percentage of the dependent variable that is explained by the independent variable, and is symmetrical *i.e.* the value is not influenced by flipping the dependent and independent variables. In this instance, the independent variable is the river level, and the dependent variable is the level of water table at each monitoring point. Correlation coefficient is the extent of linear relationship between two compared variables, and ranges from −1 to 1. If there is no linear relationship between the two variables, the correlation coefficient is close to 0. A negative value indicates the correlation is inversely linear.

The above presented evidence indicates that the effect of the river level changes on the water table elevations at the site is marginal. In addition, even the lowest recorded level at the site is

higher than the highest river elevation by at least 100 feet. This difference should be sufficient to encompass any future elevation changes.

Groundwater Flow in Fractured Bedrock

Observed hydraulic heads at four well nest locations were evaluated to characterize the downward component of groundwater flow within the site. The well nest GWM-2/2A, located directly off the gravel road on the east side of the property, shows a constant upward flow in this part of the aquifer. This confirms the initial speculation that groundwater discharges to the stream located directly downslope of the nest. The well nest GWM-3/3D, located to the north of the leachate lagoon, shows downward flow indicated by the head difference averaging 8 ft. over the observation period. Downward gradient is also present at the GWM-5/5D well nest location. The average head difference, however, is only 0.72 ft. over the 22-foot vertical separation, indicating that the downward flow is relatively minor in this portion of the aquifer. The well nest GWM-7/7D has a downward flow component similar to that at the GWM-5/5D nest.

Since each of the well nests consists of one well screened in the overburden saprolite and another screened in the bedrock, the presence of vertical flow between these depths suggests that those two lithologically distinct units are hydraulically connected. For each well nest, heads in the shallow well were plotted against those in the deep well to visualize the linear relationship between the trends of head changes at these two depth levels (Appendix D). Each plot was accompanied by a linear fit curve and the corresponding R^2 values are provided in the table below.

Well Nest	R^2 Value
GWM-2/2A	0.7244
GWM-3/3D	0.9126
GWM-5A/5D	0.9553
GWM-7/7D	0.6234

These large R^2 values indicate the similarities of head behaviors, which typically occurs when the compared measurement points are in the same hydraulic domain. Given that this trend is present over the entire property, it is apparent that the hydraulic systems both in the saprolite and the

bedrock are mutually dependent; changes in hydraulic potential in one system will likely affect the other.

Due to the complex nature of groundwater flow mechanisms in fractured rock media, it is not possible to determine precisely what paths groundwater takes from recharge to discharge. Less research has been done on this topic because of the complexity of solute transport in fractured media.[7] The requirement of having to determine the precise locations and characteristics of all fractures prohibits the development of fracture models.[2] Present approaches to describe flow and transport in fractured rock systems are:

1. fractured rock system as an equivalent porous medium (EPM), or
2. discrete fracture approach where channels are represented as channels with parallel sides and individual fractures are combined into fracture networks.[15]

Berkowitz *et al.* mentioned that application of an equivalent porous medium model was effective in the case of the formation possessing smaller fracture spacing, higher fracture connectivity, and higher block porosity, and that for sufficiently high fracture density, a single continuum conceptualization may, in fact, be sufficient for modeling contaminant transport problems of practical interest.[2] Schwartz and Smith also took a similar approach in characterization of groundwater flow in fractured media.[19] In their study, the average behavior of groundwater flow and mass transport in irregularly spaced fractures of finite length was successfully modeled based on the analytic model of *de Josselin de Jong and Way*, which was originally intended for the characterization of flow in regularly spaced fractures of infinite length and constant aperture.[19] For many different practical problems the continuum approach provides a feasible technique for evaluating transport in fractured systems of large extent.[18] Especially when the rock mass of interest contains many interconnecting fractures, it is appropriate to treat the fractured medium as an equivalent porous medium.[16]

Discrete fracture approach, on the other hand, focuses more on individual fractures. Several studies were conducted to characterize the groundwater flow in a single fracture. Sudicky and

Frind mentioned that as open fractures generally offer the path of least hydraulic resistance, direct transport of a contaminant entering a fractured rock system will be primarily along the fractures.[20] Fortunately, an important attenuation mechanism exists in the form of molecular diffusion into the solid matrix.[8] This mechanism acts to reduce contaminant concentrations in the fracture and thereby delays the migration of the contaminant.[21]

What differentiates a fractured bedrock unit as an equivalent porous medium from an actual porous medium is the directional dependency of hydraulic effective porosity**. When treated as an EPM, a fractured bedrock unit exhibited the tendency that effective porosity was directionally dependent and decreased well below the total porosity in certain directions. When the direction of hydraulic gradient was perpendicular to the overall orientation of a fracture set, it became non-conductive. In other directions the hydraulic effective porosity was equal to the total porosity.[5] This directional variances in hydraulic effective porosity make the directions of groundwater flow also directionally variant. This indicates that groundwater at a given location tends to flow in one fracture than the other, depending upon the availability of pore space. However, a dramatic drop in hydraulic effective porosity is unlikely to occur in random fracture systems because the irregular nature of the interconnected flow paths will inhibit abrupt changes in the conductive nature of the overall network.[5] Hence the average flow direction between two given points can be well represented by the difference in hydraulic heads.

The aquifer in the Haywood landfill site consists of three major lithologic units. The upper most aquifer occurs in saprolite unit, which sits on top of a zone of highly fractured crystalline bedrock. A zone of partially weathered rock (PWR) exists between these two units as a transition zone. The overburden saprolite is typically derived from the underlying parent bedrock by weathering, and has mineral compositions similar to those of the bedrock. As mentioned earlier, a thick overburden saprolite layer may well indicate the presence of abundant fractures in the parent rock from which it is derived. In fact, boring logs for all installed piezometers suggest moderate to high degrees of fractures present in the bedrock. Since the occurrence of single, isolated fractures is mainly

**Effective porosity, commonly denoted as n_e, is the porosity available for fluid flow.[6]

associated with faults, and no faults have been observed within the property, it is highly probable that the bedrock unit underneath the property contain moderate to high degrees of fracture networks.

Given the abundance of fracture networks and high connectivity of the two distinct lithologic units, the bedrock unit can be treated as an equivalent porous medium with properties different from those of the overlying layers at a macroscopic scale. To validate the applicability of this assumption, potentiometric maps were created for three independent measurement events. Each map consists of two layers, one based on the wells screened in the upper saprolite unit, and another based on the wells screened in the bedrock (Appendix D). Although some discrepancies exist due to the lack of equivalent number of observation points, the overall trends appear to be in good agreement, indicating the paralleling nature of equipotential lines across these two lithologic units.

With the above presented evidence, it is concluded that the layers of upper saprolite unit and underlying bedrock unit are hydraulically connected, and that the average hydraulic gradients in both units follow the overall trend of head distribution. The applicability of this assumption, however, has yet to be validated for the land south of the groundwater divide. Due to the proximity of the divide to the residential area south of the landfill property, the replacement of the fractured bedrock unit with an equivalent porous medium may not reasonably characterize the groundwater flow in that portion of the aquifer.

DELINEATION OF GROUNDWATER DIVIDE

Additional piezometers P-1S, P-2S/D, P-3S/D, P-4S, P-6S/D and GMW-11D (Plate 1) were installed in the vicinity of the ridgeline that extends in a northeast/southwest direction in the extreme south of the property. Hydraulic heads in these piezometers were measured and used to define the position of the groundwater divide. The shallow piezometers (P-1S, P-2S, P-3S, P-4S and P-6S) were installed so that the screened interval captures the water table within its expected

fluctuation range. The water table was encountered immediately above the saprolite/rock interface in wells P-2S, P-3S, and P-6S. In well P-1S, the water table was encountered approximately 5 ft. below the interface, while in well P-4S the water table was encountered at a depth in saprolite slightly above a zone of PWR. The deep wells (P-2D, P-3D, P-6D and GMW-11D) were installed in the fractured bedrock unit with a screen interval of 10 feet. Core samples taken from these wells exhibit a trend reflected by their physical locations. Core samples from well P-2D have relatively higher RQD values indicative of a zone of less fractured bedrock. This is typically observed in areas of topographical high where the rock is more resistant to weathering and erosion. Core samples from wells P-3D and P-6D which are located on the slope and toe of slope, respectively, depict relatively lower RQD values.

A potentiometric map was created based on the head values measured in the aforementioned piezometers (Plate 4B). Two piezometer nests P1-2S/D and P1-5S/D, which are intended for the design hydrogeologic study for the development of phase 1, were also used to create the potentiometric map. Head values from wells P-2D, P-3D, P-6D, P1-5D, GWM-7D and GWM-11D were not included as these wells are screened within bedrock beneath the water table and head elevations from these wells do not necessarily represent the actual water table elevations. The resulting map depicts the divide that approximately follows the ridgeline with the highest peak at GWM-11S. Well nests P1-5S/D, GWM-11S/D and GWM-7S/D reveal a slightly recharging condition which are likely associated with the presence of the groundwater divide. Well nest TWD-10/10D showed little vertical flow. This trend is not typically seen on the groundwater divide, as the groundwater tends to flow downward underneath the divide which in turn results in an apparent recharging condition. Well nests P-2S/D, P-3S/D, P-6S/D and P1-2S/D show a slightly discharging condition in contrast to the nests located on the estimated groundwater divide. All the above evidence suggests that the groundwater divide extends through P-1S, GWM-11S/D, P-4S, the area between TWD-10/10D and P-6S/D, and GWM-7/7D as indicated in Plate 4B.

Local Precipitation

Precipitation data from stations 319147 in Waynesville and 311564 in Cataloochee were evaluated in order to infer expected precipitation amounts at the site. Both stations showed the same 5 year and 30 year trend though the Cataloochee station showed slightly more abundant rainfall. Averages for a 30 year period from 1961 to 1990 are included as well as monthly data for the years 1993–1998. The 5-year data set closely follows the thirty year trend except for increased June precipitation amounts in the short term for both stations.

From 1961 through 1990, both areas experienced the highest average precipitation in March with the second highest in August. Lowest average precipitation occurred in October. All data were made available by the National Climatic Data Center and is expressed in tabular and graphical format in Appendix C.

Observation Well Data

Data from local USGS observation wells were used to track natural fluctuations in the regional water table. NC-40 is the closest currently maintained observation well. It is located approximately 20 miles to the southeast of the site along US 276. The well is 18-feet deep and is screened in saprolite of Precambrian gneiss. This is similar to the saprolite at the White Oak Landfill. The highest water level recorded during the 1997 water year was 2.71 feet below land surface in March. The low occurred in October, 1996 at 6.04 feet below land surface for a difference of 3.33 feet. Observation well NC-40 is a climatic effects well located in a valley. The maximum fluctuation recorded in this well is approximately 4 feet. NC-144 is located in Transylvania County just south of Haywood County in a moderately sloped area. The well is screened in saprolite of gneiss to 70 feet. The high for the 1997 water year occurred in May 1997 at 25.09 feet below land surface, while the low was 32.88 feet below land surface in November 1996 for a difference of 7.79 feet. Observation well NC-144 is a terrain effects well. The maximum fluctuation observed in NC-144 in one year was 12 feet. All observation well locations and data are provided in Appendix C.

Limited data are available for groundwater fluctuations at the landfill site. Water level elevations are available only since the boring program was completed. Data from the temporary piezometers were obtained during a period when groundwater levels were historically low. Taking into account fluctuations in terrain and climatic effects data provided by the USGS, 12 feet was added to the lowest reading on piezometers located in valleys and draws. This coincides with USGS data suggesting groundwater levels do not fluctuate as greatly in draws and valleys. The maximum expected fluctuation was added to be conservative for engineering design. The seasonal high estimation is summarized in Table 4, and all calculation and documentation is included in Appendix C.

SITE SUITABILITY

Overall the White Oak Landfill site is suitable for development as a subtitle D municipal solid waste landfill facility provided that the development be limited to the area north of the groundwater divide. The majority of the groundwater in this area flows toward a major discharge feature (Pigeon River). No faults, mines, lithologic contacts, or other geologic features which influence groundwater flow have been located on-site.

CLOSURE

This report was prepared to determine the site suitability of the proposed regional lined landfill and completes the requirements of Rule .1623 (a). Geological and hydrological data, information, and conclusions contained here and in reports of surrounding areas indicate no hindrance to developing a landfill at the White Oak site in Haywood County, North Carolina. The contents of this report discuss our investigations and conclusions of soil, rock, and groundwater conditions at the site. The scope of work is limited solely to the White Oak Landfill site and is not meant to infer conditions outside the study area.

All temporary piezometers installed during subsurface exploration and not converted to permanent monitoring wells will be abandoned in accordance with the procedures for permanent abandonment of wells as described in 15A NCAC Rule, 0113 (a)(2).

Respectfully submitted,
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Tables

Table 1. A summary of water table elevations in monitoring wells and piezometers at White Oak Landfill, Haywood County, North Carolina

Piezometer Number	Date Drilled	Completion Depth	Ground Elevation	Top of Rock	Top of Pipe	While Drilling	After Drilling	24 Hours After Drilling	7 Days After Drilling	6/9/98	7/7/98
P-1	05/20/98	2549.56	2629.56	2574.56	2632.34	2562.56	2559.09	2577.34	2558.19	2558.11	2558.47
P-1S	01/04/00	2577.75	2657.75	2589.45	2660.42	2592.19	-	-	-	-	-
P-2	04/02/98	2483.37	2520.37	2483.37	2523.82	2499.37	2494.17	2493.97	2496.54	2494.05	2492.34
P-2S	01/04/00	2555.52	2614.02	2555.52	2615.63	2562.67	-	-	-	-	-
P-2D	01/03/00	2534.53	2614.53	2556.53	2616.31	2562.07	-	-	-	-	-
P-3	05/19/98	2496.40	2564.00	2516.00	2566.64	2509.00	2509.01	2512.04	2512.07	2511.95	2511.40
P-3S	01/05/00	2563.02	2643.52	-	2645.92	2570.04	-	-	-	-	-
P-3D	01/05/00	2535.90	2643.73	2556.73	2645.95	2576.58	-	-	-	-	-
P-4	05/09/98	2490.66	2571.66	2512.66	2573.73	2509.66	2523.41	2507.23	2573.73	2503.83	2504.54
P-4S	12/23/99	2578.40	2661.90	-	2663.29	2588.50	-	-	-	-	-
P-5	05/25/98	2433.24	2485.54	2465.54	2488.38	2460.54	2449.54	2461.88	-	2462.70	2461.33
P-6	05/25/98	2526.69	2594.19	2536.19	2597.24	2535.19	2537.29	-	2538.57	2538.65	2538.80
P-6S	12/20/99	2557.90	2612.40	2557.90	2615.16	2560.90	-	-	-	-	-
P-6D	01/06/00	2536.04	2613.21	2556.04	2615.72	2560.32	-	-	-	-	-
P-7	05/25/98	2508.52	2550.52	2523.52	2553.15	2520.52	2528.52	2520.48	2553.15	2520.46	2519.23
P-9	05/21/98	2473.68	2520.98	2505.98	2524.12	2478.98	2486.62	2488.85	2524.12	2488.77	2488.12
P-10	03/19/98	2506.49	2579.49	-	2581.86	2527.49	2529.99	2530.16	2531.40	2534.05	2533.82
P-11	03/18/98	2526.87	2551.87	2526.87	2553.87	2534.37	2538.37	2537.75	2537.67	2536.07	2536.09
P-12	03/13/98	2537.38	2555.38	2537.38	2557.62	2547.38	2548.38	2550.20	2548.42	2549.47	2549.27
P-13	04/21/98	2575.66	2671.66	-	2675.69	2587.66	2589.56	2596.18	2598.97	2599.34	2599.82
P-14	05/12/98	2569.53	2650.93	2585.93	2654.13	2588.93	2605.53	-	-	2579.38	2579.86
P-15	03/28/98	2499.49	2603.49	-	2606.51	2512.49	2527.12	2527.10	-	2527.26	2527.38
P-16	03/29/98	2515.41	2557.91	2515.41	2560.57	2521.91	2535.14	2534.64	2534.98	2535.89	2536.04
P-17	05/21/98	2469.29	2559.29	2534.29	2562.25	2478.29	2478.22	2479.67	2480.41	2480.65	2481.35
P-18	05/10/98	2450.71	2491.71	2462.71	2495.26	2463.71	2469.26	2454.39	-	2452.06	2454.56
P-19	04/02/98	2380.52	2478.02	2455.02	2481.55	2402.02	2382.02	2411.18	2411.10	2411.13	2411.15
P1-2S	04/07/99	2548.50	2597.00	-	2604.01	2557.00	2559.66	2569.99	2569.86	-	-
P1-2D	04/07/99	2517.75	2597.00	2527.75	2604.98	2557.00	2558.52	2566.18	2565.93	-	-
P1-3	04/13/99	2562.50	2610.00	2574.00	2612.50	2586.00	2586.22	-	-	-	-
P1-4	04/12/99	2541.00	2613.00	2551.00	2613.42	2574.00	2573.90	-	-	-	-
P1-5S	03/25/99	2579.00	2637.00	2586.00	2636.07	2588.00	-	-	2583.19	-	-
P1-5D	03/24/99	2557.50	2636.00	2585.00	2635.45	2587.00	-	-	2581.46	-	-
P2-1	05/21/98	2520.24	2572.74	2538.74	2575.93	2535.74	2531.74	2533.63	2533.54	2533.53	2533.43
P2-2	05/21/98	2526.36	2573.66	2542.66	2574.13	2540.66	2531.66	2532.19	2531.93	2531.84	2531.53
GWM-1A	09/17/93	2491.97	2517.97	2491.97	2520.46	-	2501.97	-	-	2504.21	2503.77
GWM-2	09/16/93	2458.95	2494.45	2458.95	2497.00	-	-	-	-	2467.64	2467.20
GWM-2A	09/23/93	2439.35	2494.45	2457.55	2497.94	-	-	-	-	2467.44	2467.42
GWM-3	09/16/93	2414.20	2435.40	2414.20	2437.66	-	-	-	-	2430.10	2429.58
GWM-3D	09/23/93	2397.58	2434.58	2413.18	2436.90	-	-	-	-	2421.65	2421.62

Table 1. A

Piezome Numbe
GWM-4
GWM-5
GWM-5
GWM-6
GWM-
GWM-7
GWM-
GWM-1
GWM-1
TWD-1
TWD-1

Table 1. A summary of water table elevations in monitoring wells and piezometers at White Oak Landfill, Haywood County, North Carolina

Piezometer Number	8/17/98	9/25/98	10/27/98	12/2/98	1/13/99	2/11/99	6/21/99	8/10/99	1/12/00	Temporal High	Temporal Low	Difference
P-1	2558.48	2558.14	2557.67	2560.12	2556.47	2556.04	2555.02	2555.15	-	2560.12	2555.02	5.10
P-1S	-	-	-	-	-	-	-	-	2592.80	-	-	-
P-2	2490.10	2489.11	2488.42	2487.56	2486.74	2487.12	2490.08	2490.64	-	2494.05	2486.74	7.31
P-2S	-	-	-	-	-	-	-	-	2563.90	-	-	-
P-2D	-	-	-	-	-	-	-	-	2564.37	-	-	-
P-3	2510.62	2509.81	2509.21	2508.47	2507.72	2507.14	2507.87	2508.97	-	2511.95	2507.14	4.81
P-3S	-	-	-	-	-	-	-	-	2572.24	-	-	-
P-3D	-	-	-	-	-	-	-	-	2578.17	-	-	-
P-4	2504.80	2504.32	2503.71	2502.98	2502.11	2501.53	2500.20	2500.51	-	2504.80	2500.20	4.60
P-4S	-	-	-	-	-	-	-	-	2590.16	-	-	-
P-5	2460.32	2459.59	2459.12	2457.52	2458.18	2460.58	2459.45	2459.50	-	2462.70	2457.52	5.18
P-6	2538.68	2538.54	2538.20	2538.06	2537.58	2537.34	2537.63	2538.01	-	2538.80	2537.34	1.46
P-6S	-	-	-	-	-	-	-	-	2564.37	-	-	-
P-6D	-	-	-	-	-	-	-	-	2565.27	-	-	-
P-7	2520.05	2519.92	2519.74	2519.36	2518.95	2519.25	2519.12	2519.09	-	2520.46	2518.95	1.51
P-9	2487.82	2487.72	2487.87	2487.80	2487.20	2488.32	2487.48	2487.45	-	2488.77	2487.20	1.57
P-10	2532.81	2531.65	2531.03	2530.29	2529.79	2529.76	2530.00	2529.92	-	2534.05	2529.76	4.29
P-11	2535.98	2536.23	2535.88	2535.67	2536.07	2535.77	2536.15	2536.07	-	2536.23	2535.67	0.56
P-12	2548.89	2548.81	2548.37	2548.03	2547.99	2549.52	2546.85	2546.97	-	2549.52	2546.85	2.67
P-13	2600.48	2600.98	2601.31	2601.11	2600.57	2599.99	2598.15	2597.89	-	2601.31	2597.89	3.42
P-14	2580.78	2581.19	2580.82	2579.96	2579.05	2578.63	2577.61	2577.37	2576.83	2581.19	2576.83	4.36
P-15	2527.88	2527.87	2527.77	2527.45	2526.91	2526.61	2525.39	2525.02	2523.62	2527.88	2523.62	4.26
P-16	2536.29	2535.85	2535.45	2534.85	2534.19	2533.87	2533.31	2533.32	2532.14	2536.29	2532.14	4.15
P-17	2481.65	2480.75	2479.90	2479.18	2478.42	2478.05	2477.20	2476.81	-	2481.65	2476.81	4.84
P-18	2451.48	2451.32	2451.35	2451.23	2451.22	2451.06	2451.80	2452.35	-	2454.56	2451.06	3.50
P-19	2411.09	2409.59	2406.55	2405.52	2405.19	2405.05	2405.09	2405.65	-	2411.15	2405.05	6.10
P1-2S	-	-	-	-	-	-	2569.80	2569.91	2563.85	2569.91	2563.85	6.06
P1-2D	-	-	-	-	-	-	2565.64	2565.78	2564.36	2565.78	2564.36	1.42
P1-3	-	-	-	-	-	-	2589.10	2589.29	2586.81	2589.29	2586.81	2.48
P1-4	-	-	-	-	-	-	2575.89	2575.72	2576.27	2576.27	2575.72	0.55
P1-5S	-	-	-	-	-	-	2583.57	2583.78	2581.82	2583.78	2581.82	1.96
P1-5D	-	-	-	-	-	-	2582.02	2582.36	2580.81	2582.36	2580.81	1.55
P2-1	2532.95	2532.20	2531.40	2530.64	2530.12	-	-	-	-	2533.53	2530.12	3.41
P2-2	2530.93	2530.20	2529.83	2529.38	2528.95	-	-	-	-	2531.84	2528.95	2.89
GWM-1A	2503.13	2502.83	2502.58	2502.24	2502.23	2502.86	2502.66	2502.77	-	2504.21	2502.23	1.98
GWM-2	2466.43	2465.90	2465.82	2465.76	2466.00	2466.60	2467.06	2466.92	-	2467.64	2465.76	1.88
GWM-2A	2467.43	2466.14	2466.04	2465.98	2466.21	2466.74	2468.03	2467.88	-	2468.03	2465.98	2.05
GWM-3	2428.41	2427.31	2426.89	2426.31	2426.48	2428.26	2428.16	2428.55	-	2430.10	2426.31	3.79
GWM-3D	2420.59	2420.05	2419.75	2419.74	2419.51	2420.20	2420.23	2420.50	-	2421.65	2419.51	2.14

Table 1. A summary of water table elevations in monitoring wells and piezometers at White Oak Landfill, Haywood County, North Carolina

Piezometer Number	8/17/98	9/25/98	10/27/98	12/2/98	1/13/99	2/11/99	6/21/99	8/10/99	1/12/00	Temporal High	Temporal Low	Difference
GWM-4A	2463.71	2457.26	2461.17	2460.26	2459.85	2461.25	2462.82	2462.71	-	2464.37	2457.26	7.11
GWM-5A	2496.76	2496.43	2496.36	2496.15	2496.09	2497.76	2496.51	2496.80	-	2497.76	2496.09	1.67
GWM-5D	2496.07	2495.90	2495.88	2495.68	2495.75	2496.48	2495.82	2495.99	-	2496.62	2495.68	0.94
GWM-6A	2522.27	2522.21	2521.99	2521.92	2522.47	2523.52	2522.54	2522.67	-	2523.90	2521.92	1.98
GWM-7	2581.37	2580.67	2579.18	2579.48	2578.81	2578.64	2577.98	2580.14	2577.49	2581.92	2577.49	4.43
GWM-7D	2579.39	2578.67	2578.19	2577.50	2577.10	2576.62	2578.15	2577.12	2575.46	2579.80	2575.46	4.34
GWM-8	2446.23	2445.72	2445.46	2445.12	2445.01	2445.60	2445.05	2446.45	-	2447.08	2445.01	2.07
GWM-11S	-	-	-	-	-	-	-	-	2596.58	-	-	-
GWM-11D	-	-	-	-	-	-	-	-	2595.93	-	-	-
TWD-10	2586.48	2585.17	2584.20	2578.19	2584.74	2582.86	2584.06	2584.06	2581.15	2588.21	2578.19	10.02
TWD-10D	2586.33	2585.04	2584.08	2583.10	2583.41	2582.78	2584.41	2583.93	2581.03	2588.00	2581.03	6.97

Plates

Plates

(at end of file)

Appendix A

LOG OF BORING: P-1S

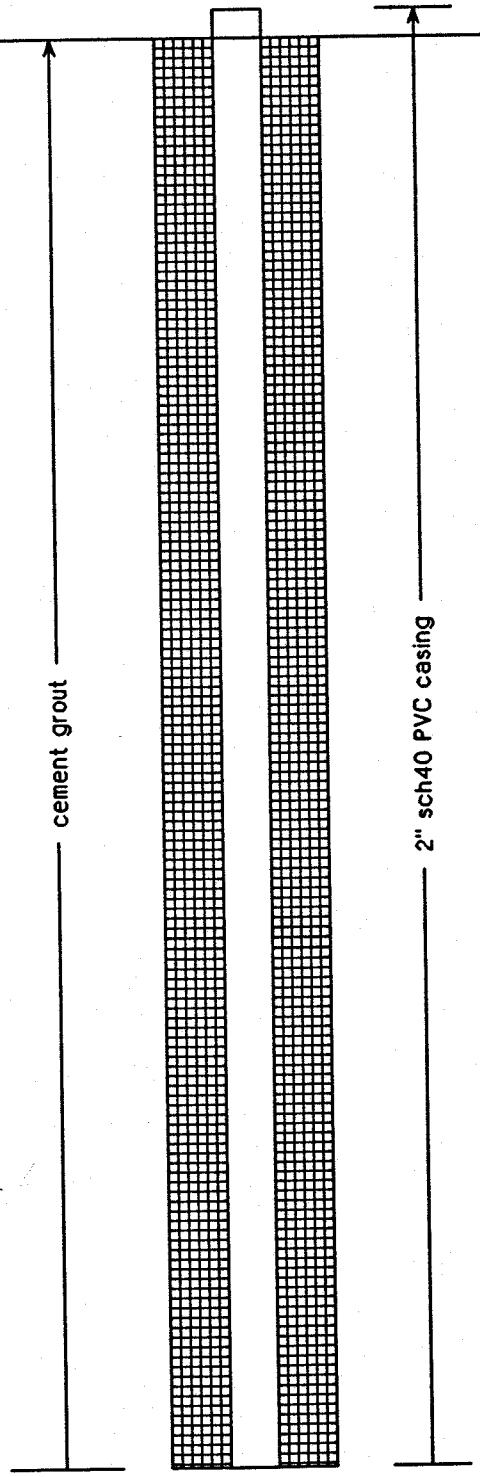
Project: Haywood County
Project No. G98010.5
Type: HSA SS

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2657.75ft
Top of Casing: 2660.42ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	21			- Light brown silty sand, some organic root matter, slightly micaceous; a few small white "talc" deposits. Low amount of zonal variation. No relic fractures.
5				
10				
	23			- Darker brown silty sand, slightly micaceous. No zonal variations or relic fractures. Cohesionless. Very small amount of scattered rust orange color intermixed.
15				
20				
	29			- Dark reddish brown silty sand, slightly micaceous. A few relic fractures. Slightly cohesive w/possible clay properties.
25				
30				- Harder drilling begins. - Considerable amount of gray dust blowing through termination.
	50/6"			Med gray silty sand. Large proportion of gritty white "talc" & a small amount of small white quartz fragments. Coarse w/ mica. A small proportion of iron orange stains.
35				
40				
	50/4"			- SAPROLITE; dark gray coarse silty sand. Slightly micaceous w/no fractures evident in the very small sample. Two hard fragments of weathered gneiss w/quartz lodged in the split spoon bit. A few orange specs as well as white "talc". Dry.
45				
50				

PIEZOMETER DIAGRAM



Completion Depth: 80.0 ft
DATE: 1/4/2000

Depth to Water: 73.24 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Signature of Field Agent

LOG OF BORING: P-1S

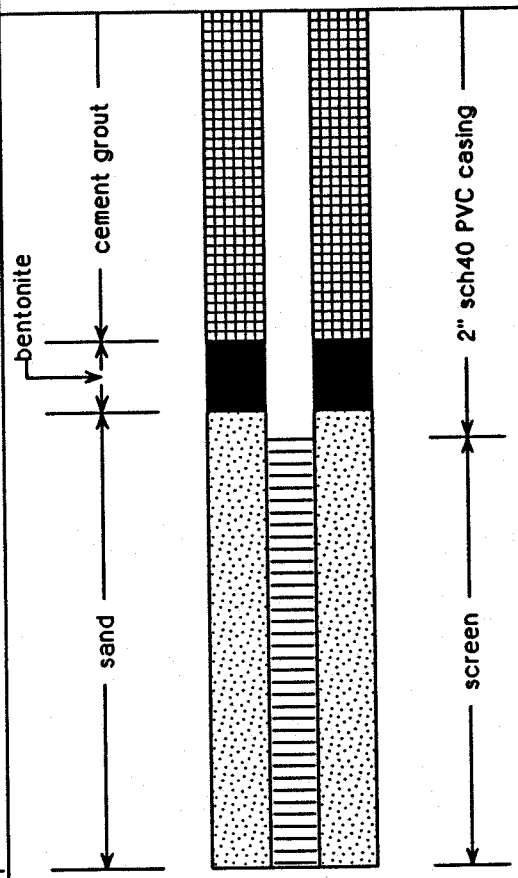
Project: Haywood County
Project No. G98010.5
Type: HSA SS

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2657.75ft
Top of Casing: 2660.42ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	50/4"			- SAPROLITE; dark brown sandy silt. Three relic fractures & no zonal variations. White & rust orange mottling. Micaceous. Two relic fractures evident. Dry.
55				- Harder drilling ends.
60				
	50/5"			- SAPROLITE; dark brown silty clay. Two relic fractures & no zonal variations.
65				Hit rock at 68.3 ft.
				GNEISS; weathered, fractured.
70				- Water when drilling at 73.24 ft.
75				
80				End of Boring at 80.0 feet
85				
90				
95				
100				

PIEZOMETER DIAGRAM



Completion Depth: 80.0 ft
DATE: 1/4/2000

Depth to Water: 73.24 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P-2D

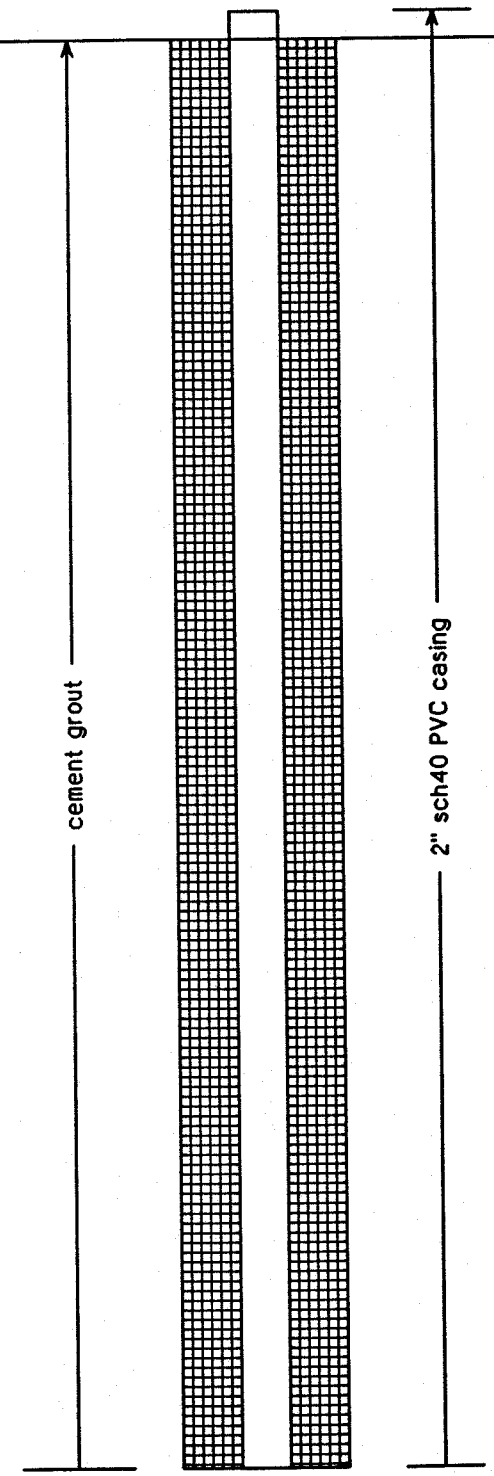
Project: Haywood County
Project No. 698010.5
Type: HSA AH

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2614.53ft
Top of Casing: 2616.31ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	9		X	- Orangish red cohesive clay w/vertical black specks. Very similar to exposed surface material. Moist.
5				
10				
	8		X	- SAPROLITE; orangish red cohesive clay w/black & white mottling. Two 30-degree relict fractures. Moist.
15				
20				
	11		X	- SAPROLITE; orange red cohesive clay w/black spots & finely intermixed white crystalline mottling. No fractures. Moist.
25				
30				
	16		X	- SAPROLITE; orange brown cohesive clay (less red than sample 1 & 3) w/black biotite & finely intermixed muscovite. Two fractures apparent. Moist.
35				
40				
	12		X	- SAPROLITE; light orangish brown lower cohesive clay. 3 relic fractures one of which had 2 smooth black sides on either side of the fracture. Also an 3" seam of pure white crystalline pulverized quartz with a consistency of wet sand. Micaceous & moist w/ white mottling. Coloring turning more brown w/depth.
45				
50				

PIEZOMETER DIAGRAM



Completion Depth: 80.0 ft
DATE: 12/29/1999

Depth to Water: 53.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P-2D

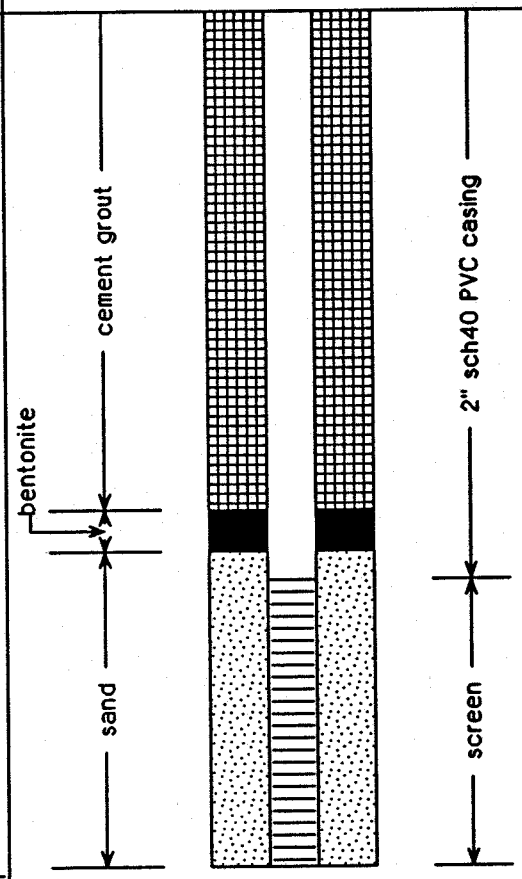
Project: Haywood County
Project No. G98010.5
[illegible]e: HSA AH

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2614.53ft
Top of Casing: 2616.31ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
				Rock/boulder ledge hit from 51.0' to 53.0' then soft until rock at 58.0.
				Hit water at 53.0 ft.
55				
				Hit rock at 58.0 ft.
60				REC=85%, RQD=23.85% Gneiss, dark greenish gray, disseminated and foliated quartz, muscovite and biotite. Breaks parallel to and along poorly developed foliation.
				60 degree iron stained fracture from 63.8 to 64.0 ft.
65				
70				REC=100%, RQD=87.64% Gneiss, same as above.
75				
				70 degree iron stained fracture from 79.25 to 79.60 ft.
80				End of Boring at 80.0 feet
85				
90				
95				
[illegible]0				

PIEZOMETER DIAGRAM



Completion Depth: 80.0 ft
DATE: 12/29/1999

Depth to Water: 53.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: _____
Signature of Field Agent

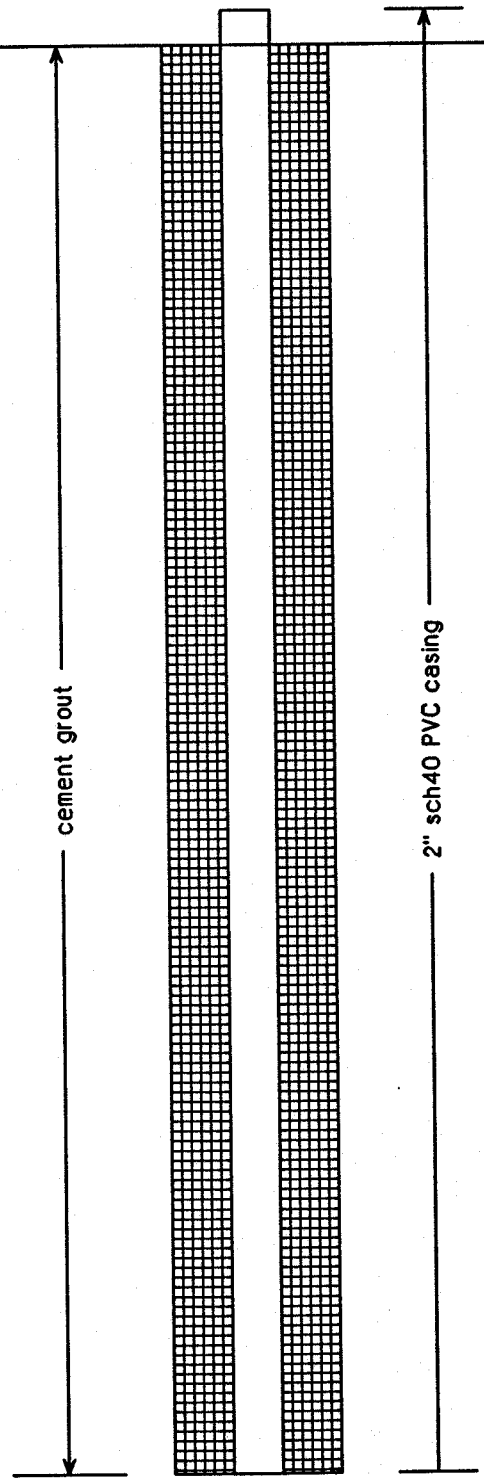
LOG OF BORING: P-2S

Project: Haywood County
Project No. G98010.5
Type: HSA AH

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2614.02ft
Top of Casing: 2615.63ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	PIEZOMETER DIAGRAM
				Air drilling w/o any sampling through termination	
5					
10					
15					
20					
25					
30					
35					
40					



Completion Depth: 58.5 ft
DATE: 1/4/2000

Depth to Water: 53.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yamol
Signature of Field Agent

LOG OF BORING: P-2S

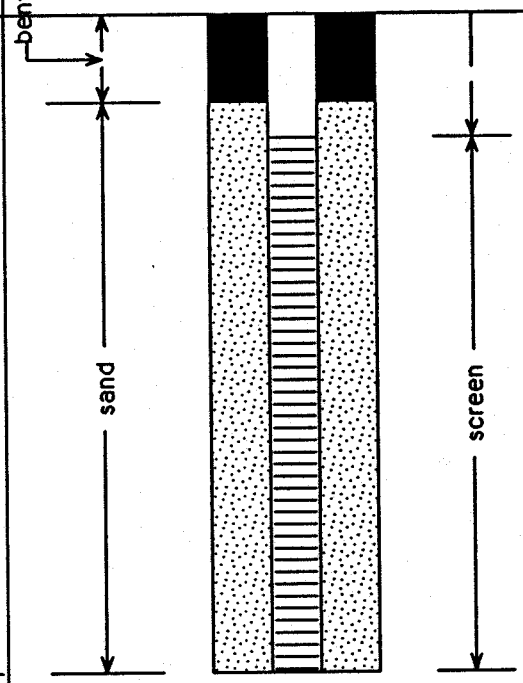
Project: Haywood County
Project No. G98010.5
Type: HSA AH

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2614.02ft
Top of Casing: 2615.63ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
				Easy smooth drilling
45				
50				No rock ledge evident as in P-2D
				- Hit water when drilling
55				
				End of Boring at Auger Refusal 58.5 feet
60				
65				
70				
75				
80				

PIEZOMETER DIAGRAM



Completion Depth: 58.5 ft
DATE: 1/4/2000

Depth to Water: 53.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P-3D

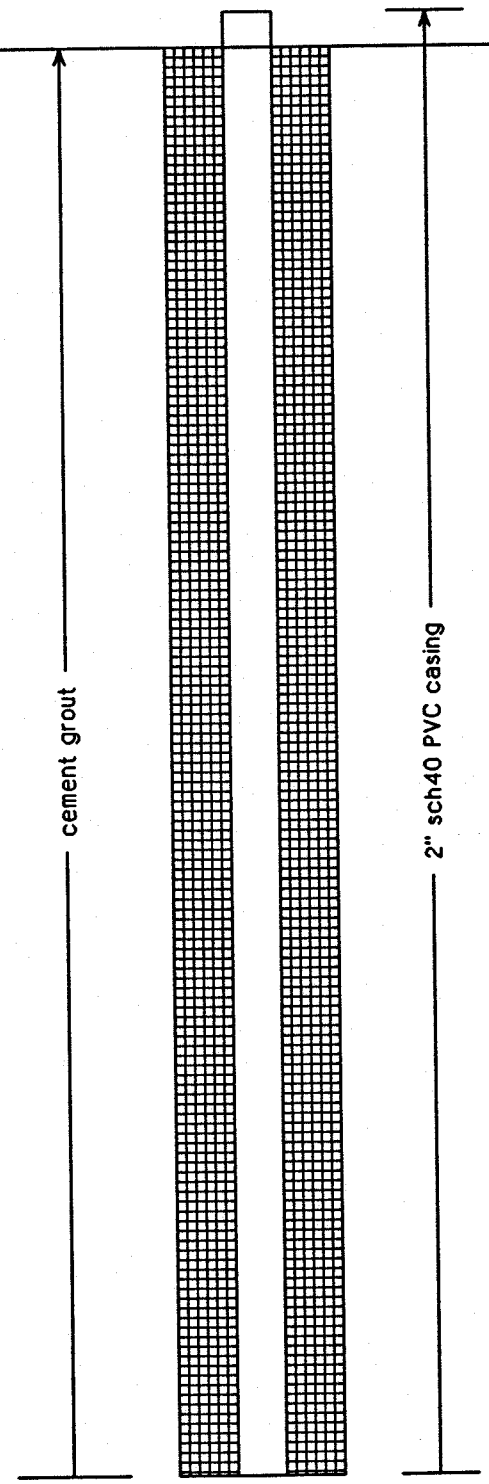
Project: Haywood County
Project No. G98010.5
Type: HSA RB

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2643.73ft
Top of Casing: 2645.95ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	10		X	- SAPROLITE; reddish tan silt w/trace amounts of sand, white & black mottling throughout. Slightly micaceous, trance amount of organic material. Very little cohesive properties. Moist.
5				
10				
	11		X	- A seam of soft white "talc" at 12.6 ft. - SAPROLITE; light reddish tan silt w/considerable amounts of red, black, orange & white striations or mottling. Moist.
15				
20				
	14		X	- SAPROLITE; light reddish tan silt w/a higher more cohesive clay consistency. the sample is more red than 1st and 2nd samples. A considerable amount of red, black, white & orange striations or mottling present. Black specs/minerals evident. Moist.
25				
30				
	16		X	- SAPROLITE; reddish tan silt, very similar to 1st sample. Some mottling & black specks w/considerable mica content. Moist.
35				
40				

PIEZOMETER DIAGRAM



Completion Depth: 107.83 ft
DATE: 12/28/1999

Depth to Water: 70.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: _____
Signature of Field Agent

LOG OF BORING: P-3D

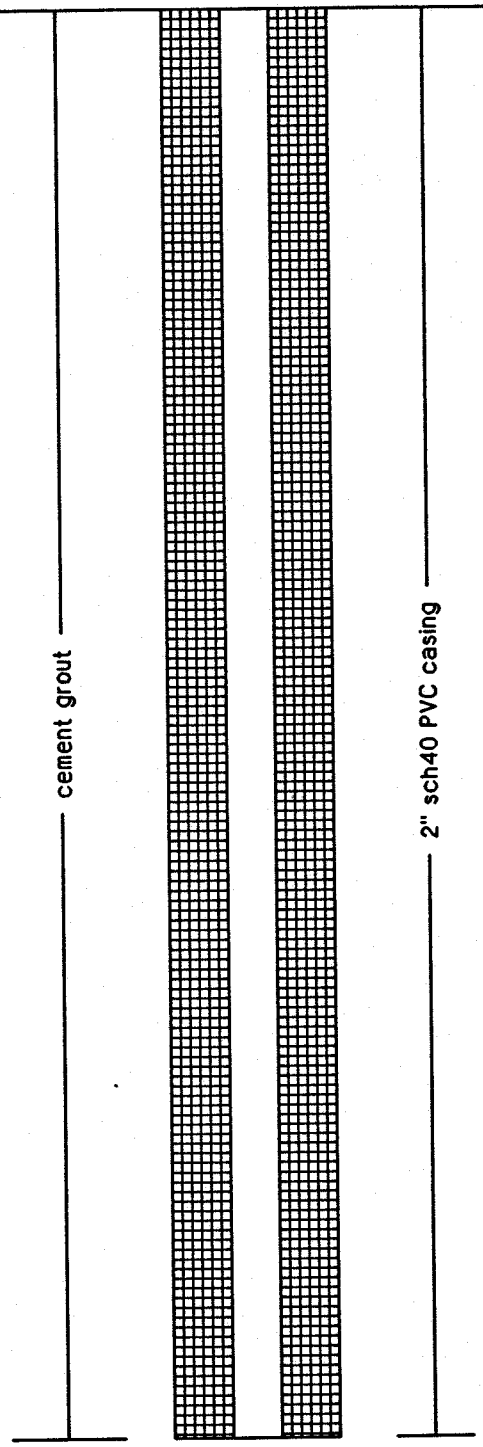
Project: Haywood County
Project No. G98010.5
Type: HSA RB

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2643.73ft
Top of Casing: 2645.95ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
45	20		X	- SAPROLITE; red orangeish tan silt w/considerable white seams w/orange & black mottling. No relic fractures evident. Sample staying intact except for a few mechanical fractures. Micaceous, moist.
50				
55	41		X	- SAPROLITE; sandy silt. A dark greenish gray w/white & black mottling. Very low amount of cohesive properties. Very soft.
60				
65	37		X	- SAPROLITE; a dark gray sandy silt w/white & black mottling. Micaceous w/some greenish particles evident. Single cohesive mass w/no fractures. Very soft & easily pulverized.
70				- Hit water.
75	40		X	- SAPROLITE; sandy silt. A dark gray w/white & black mottling. Only a small trace amount of "burnt Sienna" intermixed. Micaceous w/small quartz fragments. No fractures evident. Very similar to last two samples. Wet.
80				

PIEZOMETER DIAGRAM



Completion Depth: 107.83 ft
DATE: 12/28/1999

Depth to Water: 70.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P-3D

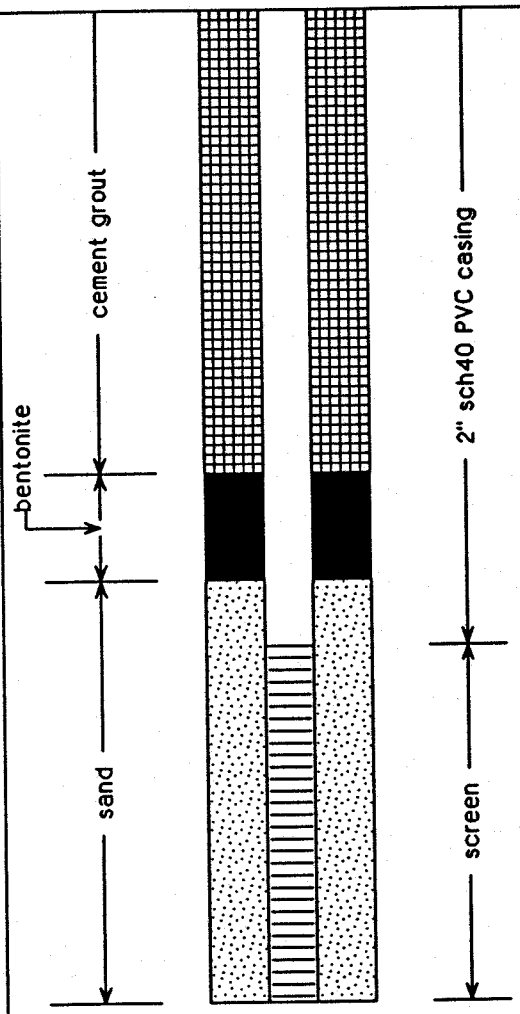
Project: Haywood County
Project No. G98010.5
Type: HSA RB

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2643.73ft
Top of Casing: 2645.95ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	61			- SAPROLITE; sandy silty clay with pure H20 in upper 12" of spoon, then a more consolidated dark gray w/white & rust colored "bands" w/mica & quartz. No large fractures evident. Sample wet.
85				- Hit rock at 87.0 ft.
90				REC=87.92%, RQD=7.5% Gneiss, dark gray with white bands, quartz, muscovite & biotite. 40 to 50 dip of foliation. Increasing quartz content downward. Breaks parallel to foliation.
95				
				REC=100%, RQD=29.06% Gneiss, same as above.
100				- 85 degree iron stained fracture from 99.33 to 99.93 ft.
				- Highly broken from 101.1 to 101.8 ft.
				- Highly broken from 103.3 to 103.9 ft.
105				- Near vertical fracture (partially annealed) from 104.53 to 104.83.
				- Another fracture w/features same as above from 106.83 to 107.03 ft.
110				Enf of Boring at 107.83 feet
115				
120				

PIEZOMETER DIAGRAM



Completion Depth: 107.83 ft
DATE: 12/28/1999

Depth to Water: 70.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P-3S

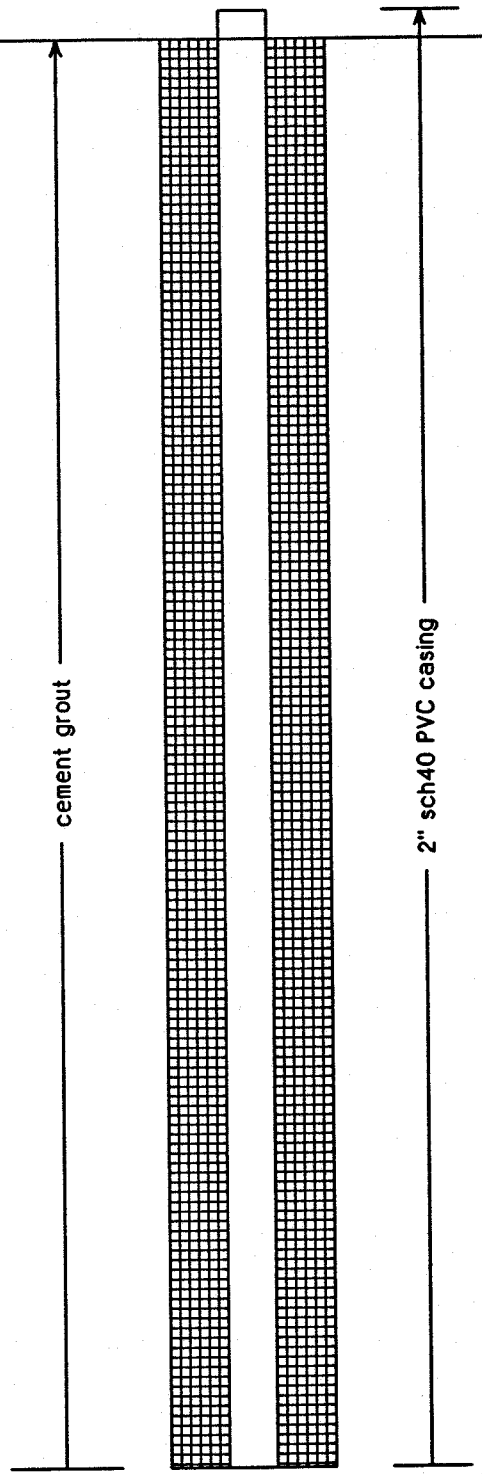
Project: Haywood County
Project No. G98010.5
Type: HSA RB

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2643.52ft
Top of Casing: 2645.92ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
				Air drilling w/o any sampling through termination.
5				
10				
15				Smooth, easy drilling the entire time.
20				
25				
30				
35				
40				
45				
				Smooth, easy drilling the entire time.
50				

PIEZOMETER DIAGRAM



Completion Depth: 80.5 ft
DATE: 1/5/2000

Depth to Water: 70.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: _____
Signature of Field Agent

LOG OF BORING: P-3S

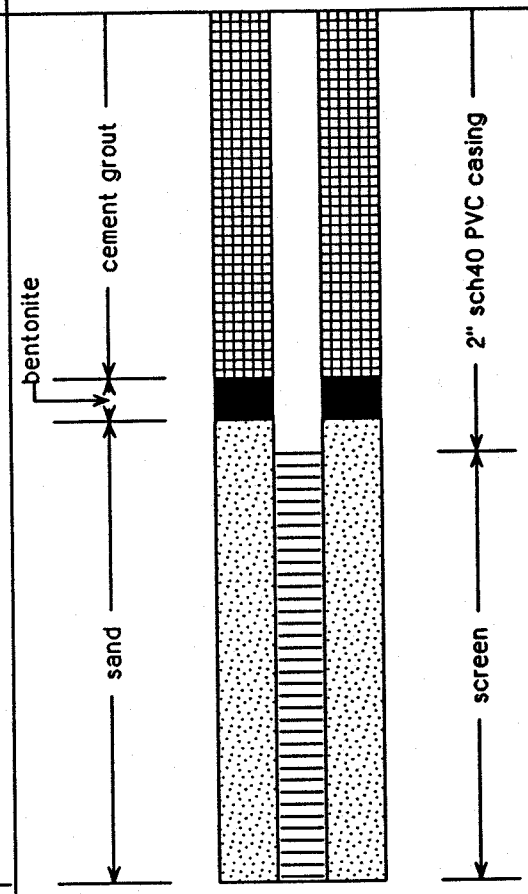
Project: Haywood County
Project No. G98010.5
Type: HSA RB

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2643.52ft
Top of Casing: 2645.92ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
55				
60				
65				
70				- Hit water at 70.0 ft.
75				
80				End of Boring at 80.5 feet
85				
90				
95				
100				

PIEZOMETER DIAGRAM



Completion Depth: 80.5 ft
DATE: 1/5/2000

Depth to Water: 70.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohe Yoshiol
Signature of Field Agent

LOG OF BORING: P-4S

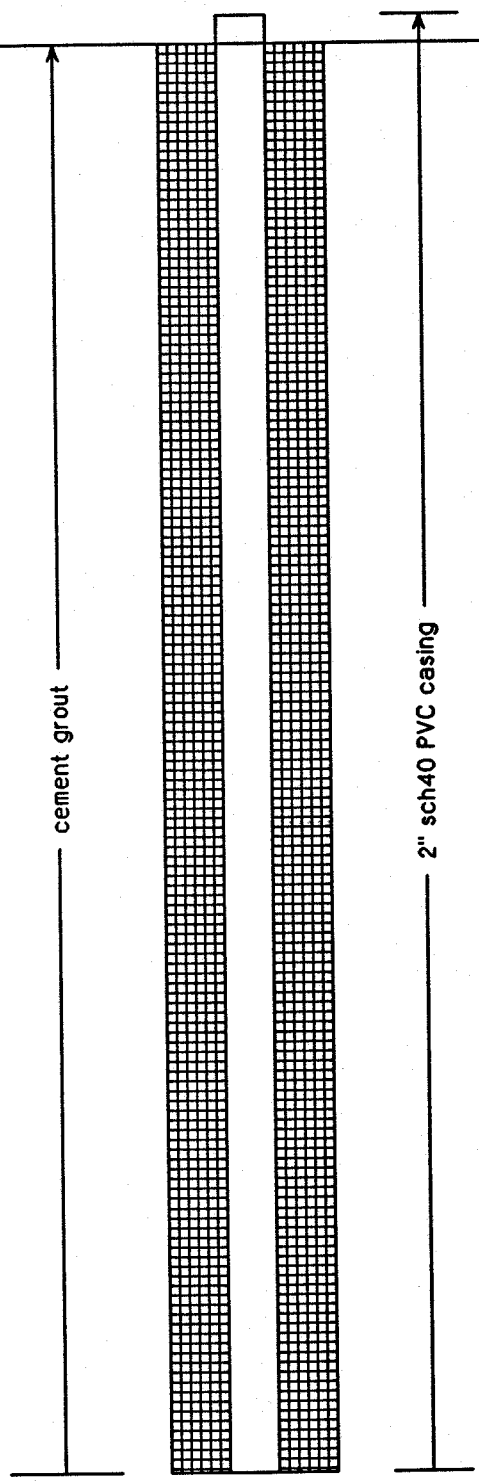
Project: Haywood County
Project No. G98010.5
Type: HSA RB

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2661.90ft
Top of Casing: 2663.69ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	22		☒	SAPROLITE; red-brown silt w/trace amount of sand & relict fracture. Moist.
5				
10				
	23		☒	SAPROLITE; red-brown, sandy silt w/mica, whitish, black specks & relic fracture. Moist.
15				
20				
	21		☒	SAPROLITE; red-brown-tan-white mottled sandy silt w/mica and black specks. Moist.
25				
30				
	27		☒	SAPROLITE; red-brown-tan-white mottled sandy silt w/mica, relic fractures (60 degrees) parallel to each other, and black specks. Moist.
35				
40				
	36		☒	SAPROLITE; orange-brown-tran-gray mottled sandy silt w/mica, relic fracture and black specks. Moist.
45				
50				

PIEZOMETER DIAGRAM



Completion Depth: 83.5 ft
DATE: 12/22/1999

Depth to Water: 73.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshiet
Signature of Field Agent

LOG OF BORING: P-4S

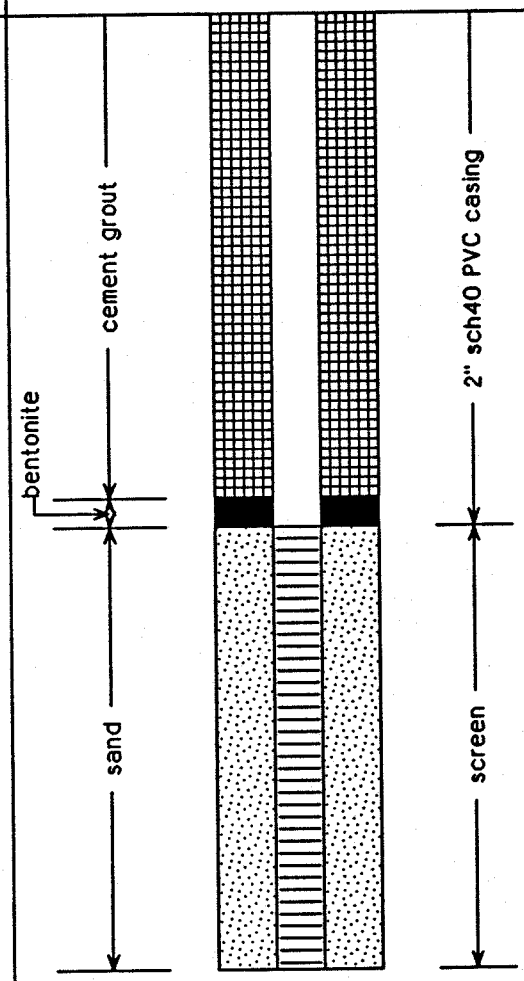
Project: Haywood County
Project No. G98010.5
Type: HSA RB

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2661.90ft
Top of Casing: 2663.69ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
55	65		X	SAPROLITE; brown-red-tan-white mottled sandy silt w/mica and relic fractures. Moist.
60				
65	44		X	SAPROLITE; tan-brown-gray-white mottled sandy silt w/mica, relic fracture, and black specks. Moist.
70				
75	67		X	SAPROLITE: tan-brown-gray-white mottled sandy silt w/mica, 45-60 degree beddings, relic fracture, and black specks. Moist. Outside spoon wet. Observed wet saprolite w/quartz fragments on the top inside the spoon. Possible water level.
80				
85	50/6"		X	Gray-tan-white mottled sandy silt coarse grained. Wet. Angled bedding (45 degrees) and black specks present. trace amount of quartz/PWR fragments.
				End of Boring at 83.5 feet
90				
95				
0				

PIEZOMETER DIAGRAM



Completion Depth: 83.5 ft
DATE: 12/22/1999

Depth to Water: 73.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: _____
Signature of Field Agent

LOG OF BORING: P-6D

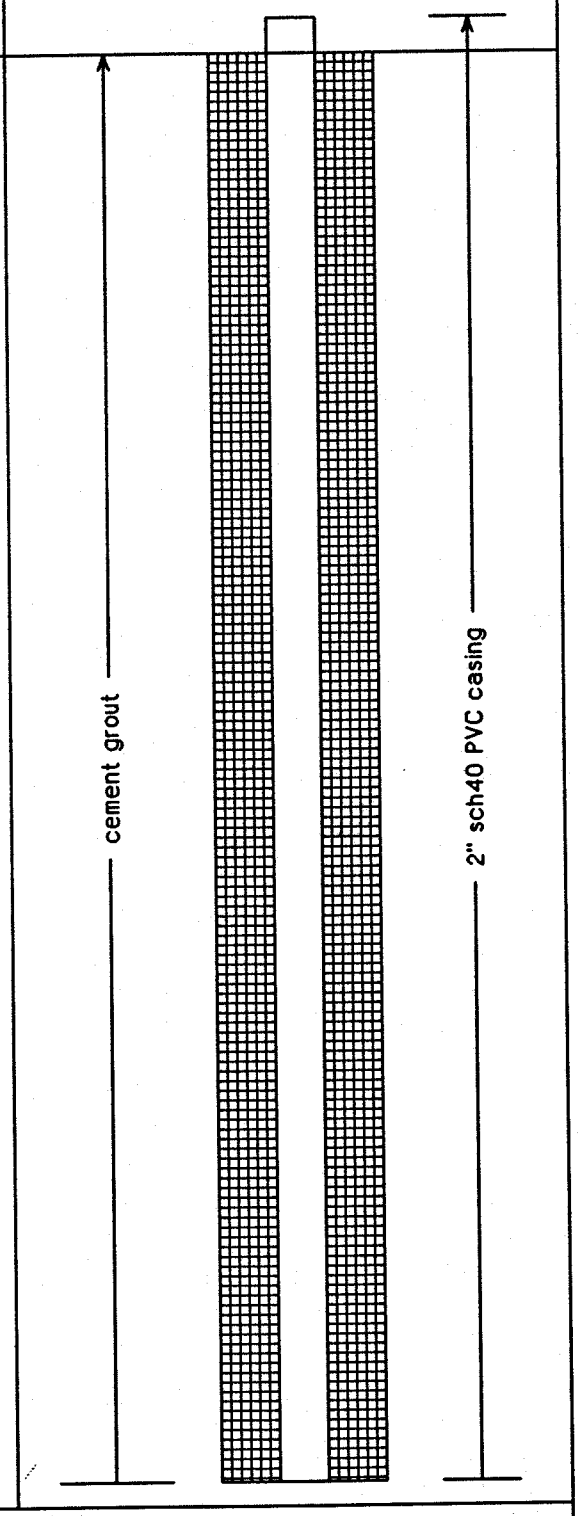
Project: Haywood County
Project No. G98010.5
Type: HSA RB

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2613.21ft
Top of Casing: 2615.72ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
				Air drilled w/o any sampling
5				
10				
15				
20				
25				
30				
35				
40				

PIEZOMETER DIAGRAM



Completion Depth: 77.17 ft
DATE: 1/6/2000

Depth to Water: 49.1 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kobe Yoshioka
Signature of Field Agent

LOG OF BORING: P-6D

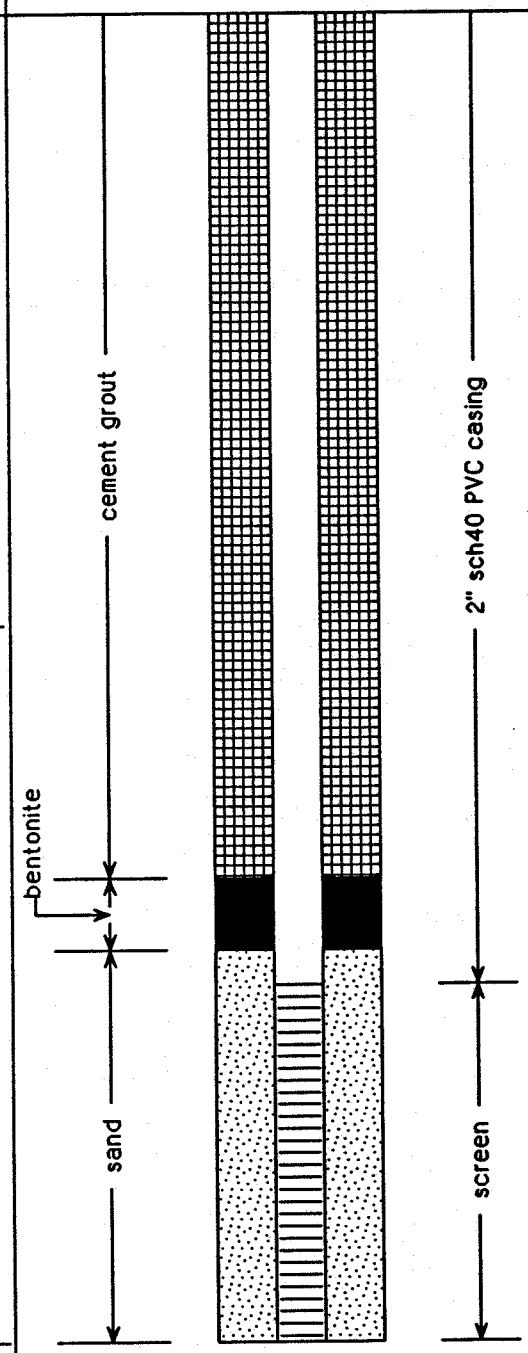
Project: Haywood County
Project No. G98010.5
Type: HSA RB

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2613.21ft
Top of Casing: 2615.72ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
45				
50				
55				Hit rock at 57.17 ft.
60				REC=91.875%, RQD=14.16% Gneiss, quartz, muscovite, biotite foliation. 40 degree dip increasing quartz content downward. Breaks along foliation. Iron stained. Slightly weathered from 57.2 to 64.7 ft.
65				
70				REC=91.875%, RQD=46.25% Gneiss, same as above.
75				
80				End of Boring at 77.17 feet

PIEZOMETER DIAGRAM



Completion Depth: 77.17 ft
DATE: 1/6/2000

Depth to Water: 49.1 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P-6S

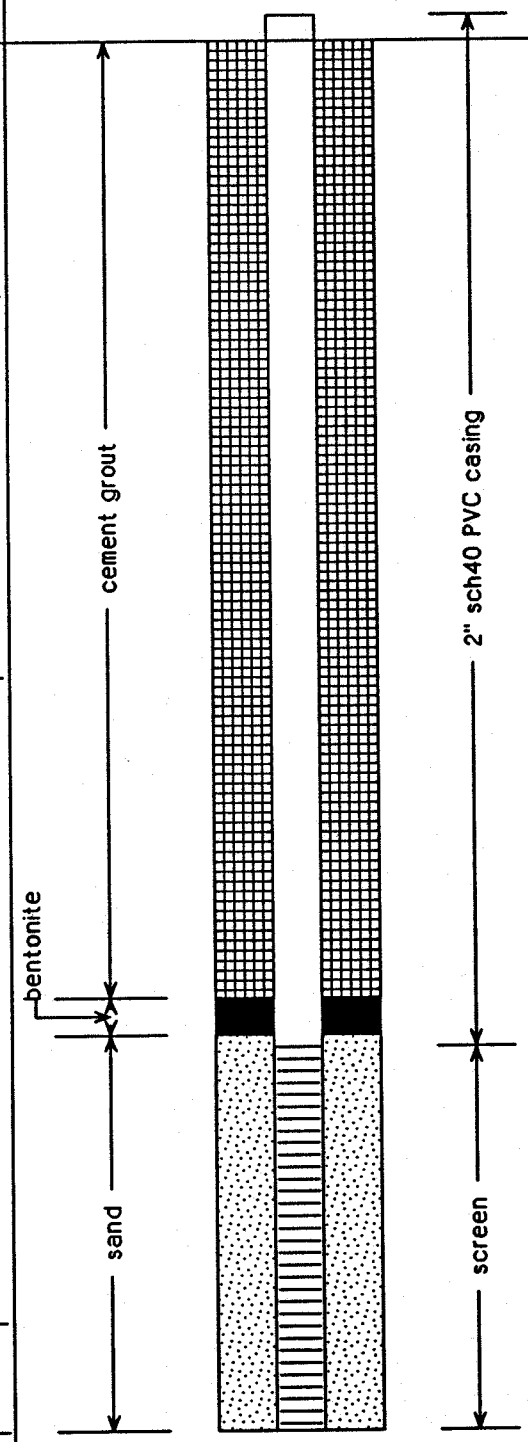
Project: Haywood County
Project No. G98010.5
Type: HSA RB

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2612.40ft
Top of Casing: 2615.15ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
5	24		X	SAPROLITE; orange-red silt w/some sand, micaceous, ferrous stains. Moist.
10	23		X	SAPROLITE; orange-brown sandy silt, micaceous, ferrous stains. Moist.
15	85		X	SAPROLITE; orange-brown-gray sandy silt, micaceous, ferrous stains & PWR fragments at the bottom of the sample.
20	50/4"		X	SAPROLITE; orange-gray-brown sandy micaceous silt w/PWR fragments. Moist. Ferrous stains in last 6" of the sample at the angle of 45 degrees.
25	38		X	SAPROLITE; gray-white-brown mottled silt w/some small black stained spots & mica. Moist. Some ferrous stained material in the middle of the sample.
30	35		X	Same as the last sample. Bedding observed at angle of 45 degrees. Moist.
35	50/5"		X	SAPROLITE; brown-tan micaceous silt w/some sand, iron/ferrous stains. Moist.
40	50/3"		X	SAPROLITE; brown-black or gray micaceous silt w/stains. Moist.
				- Hard drilling starts.
45	50/6"		X	SAPROLITE; brown, balck, tan micaceous silt w/sand & stains. Moist.
				- Water first observed while drilling.
50	50/5" 25/0"		X	Brown, black, orange sandy silt w/mica & PWR fragments. Wet.
55				End of Boring at Auger Refusal 54.5 feet

PIEZOMETER DIAGRAM



Completion Depth: 54.5 ft
DATE: 12/20/1999

Depth to Water: 49.1 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P1-2D

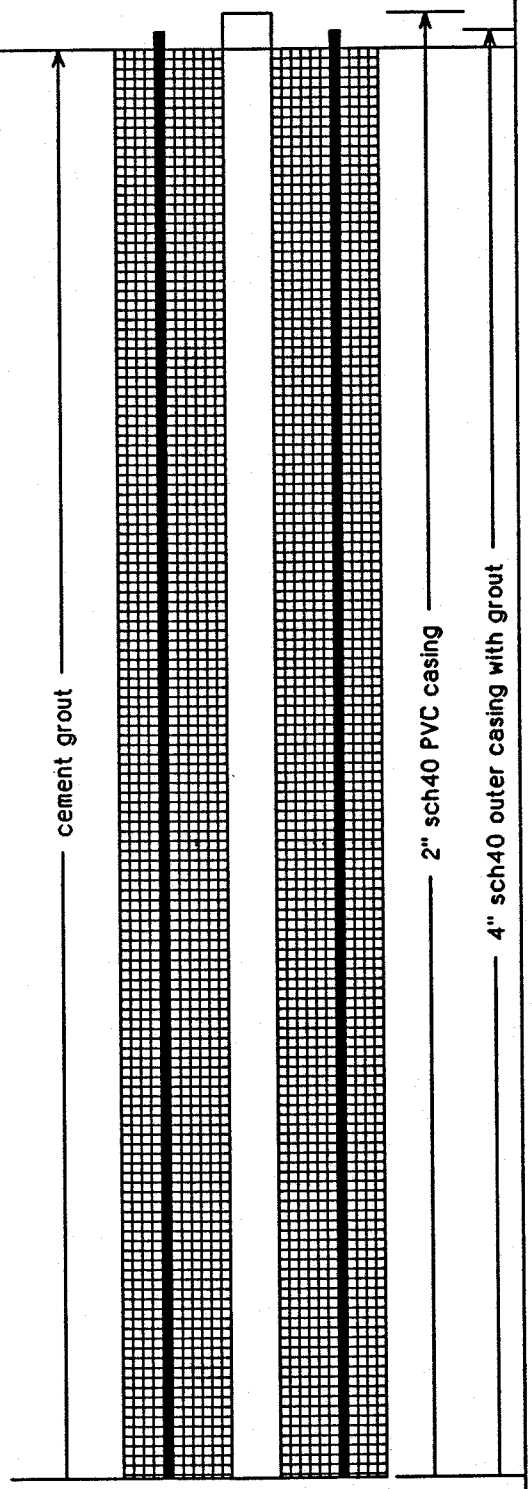
Project: Haywood County
Project No. G98010.6
[illegible]e: A/R,A/H,NX/NQ,SS

Drilling Contractor: Engineering Tectonics
Registration Number: 835

Surface Elevation: 2603.09ft
Top of Casing: 2604.98ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	9		X	Sandy Silt (ML); FILL MATERIAL, medium brown, no structure, few fragments
5	11		X	-FILL MATERIAL
10	15		X	-FILL MATERIAL
15	14		X	-FILL MATERIAL
20	13		X	-FILL MATERIAL
25	11		X	-FILL MATERIAL
30	13		X	-FILL MATERIAL, moist
35	10		X	-FILL MATERIAL
				SILT (ML), dark brown to black, some root debris, original ground elevation
[illegible]0	4		X	-medium brown, little structure, wet

PIEZOMETER DIAGRAM



Completion Depth: 79.25 ft
DATE: 4/7/99

Depth to Water: 39.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P1-2D

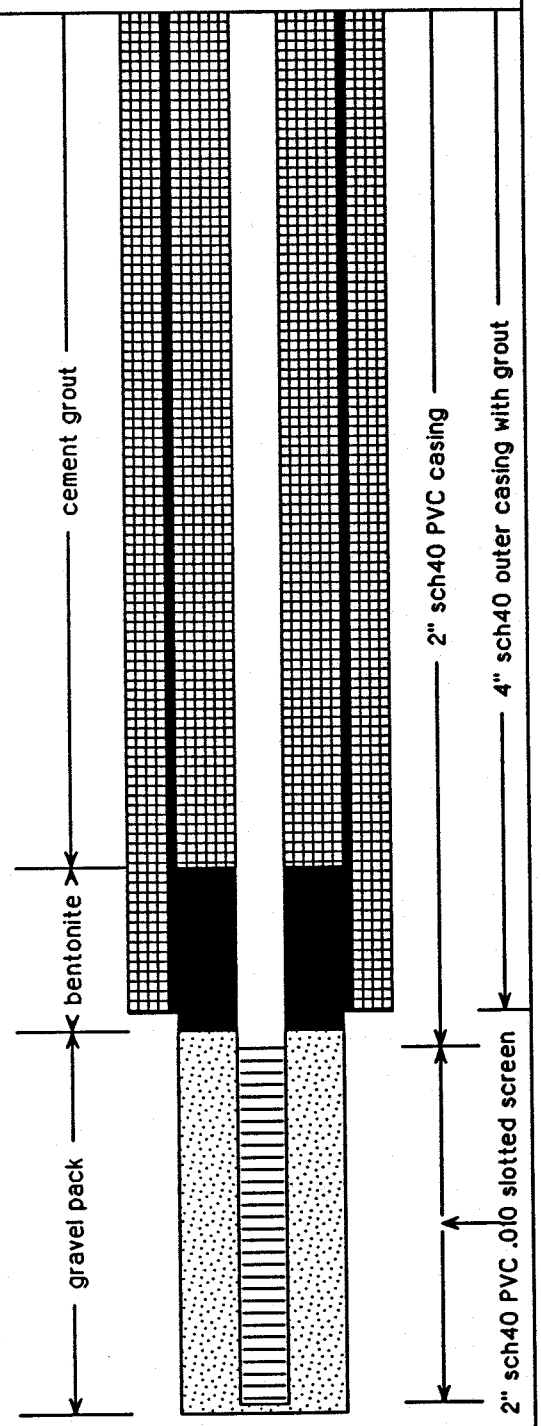
Project: Haywood County
Project No. G98010.6
Type: A/R,A/H,NX/NQ,SS

Drilling Contractor: Engineering Tectonics
Registration Number: 835

Surface Elevation: 2603.09ft
Top of Casing: 2604.98ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
45	8			
				SANDY SILT (ML); brown to gray, faint structure, abundant rust staining, small vertical fracture, some dark mica, wet
50	12			
55	24			-red-brown to gray, thinly layered weathered gneiss, some heavy rust staining, fine mica foliations
				-rocky zone
60	13			
65	17			
				Air Rotary Bit Refusal at 69.25 feet
70				REC=84.2% RQD=56.0% Gneiss; white, meta-granitic structure, weathered toward top, angled foliation
75				-zone of weathered saprolite, brown to yellow
80				End of Boring at 79.25 feet

PIEZOMETER DIAGRAM



Completion Depth: 79.25 ft
DATE: 4/7/99

Depth to Water: 39.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P1-2S

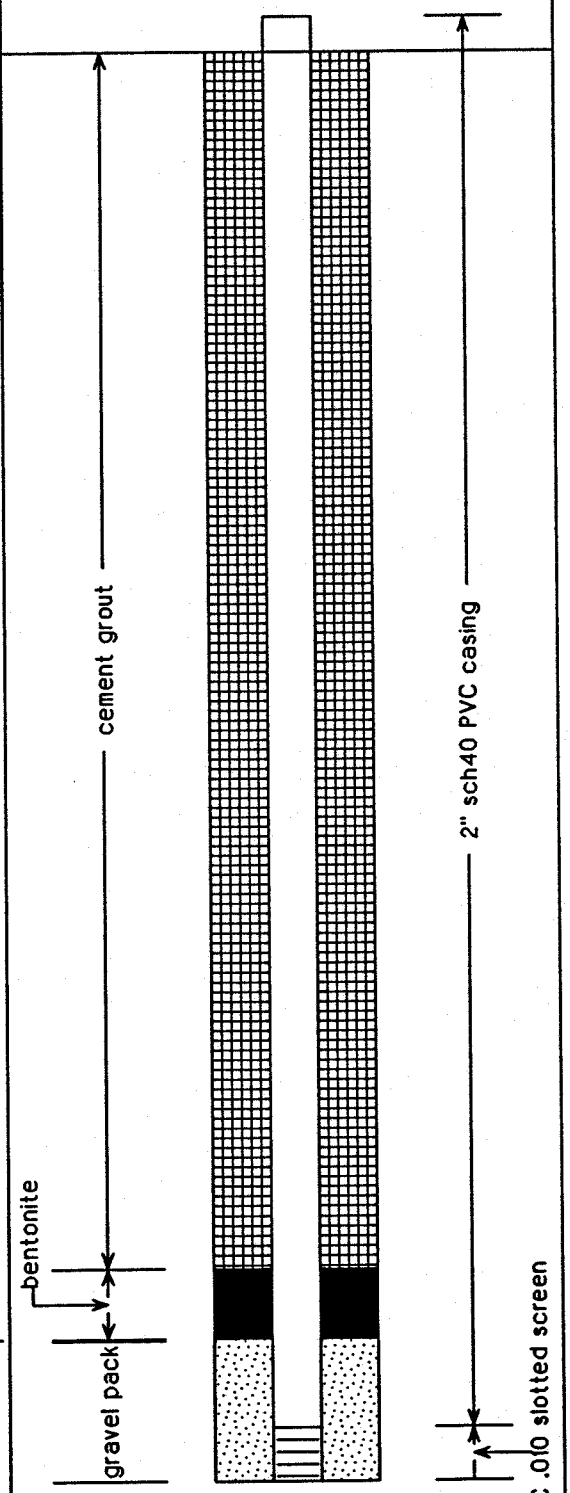
Project: Haywood County
Project No. G98010.6
[illegible]e: A/R,A/H,SS

Drilling Contractor: Engineering Tectonics
Registration Number: 835

Surface Elevation: 2602.48ft
Top of Casing: 2604.01ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	9		X	Sandy Silt (ML); FILL MATERIAL, medium brown, no structure, few fragments
5	11		X	-FILL MATERIAL
10	15		X	-FILL MATERIAL
15	14		X	-FILL MATERIAL
20	13		X	-FILL MATERIAL
25	11		X	-FILL MATERIAL
30	13		X	-FILL MATERIAL
35	10		X	-FILL MATERIAL
				SILT (ML), dark brown to black, some root debris, original ground elevation
40	4		X	-medium brown, little structure, wet

PIEZOMETER DIAGRAM



Completion Depth: 48.5 ft
DATE: 4/7/99

Depth to Water: 40.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P1-2S

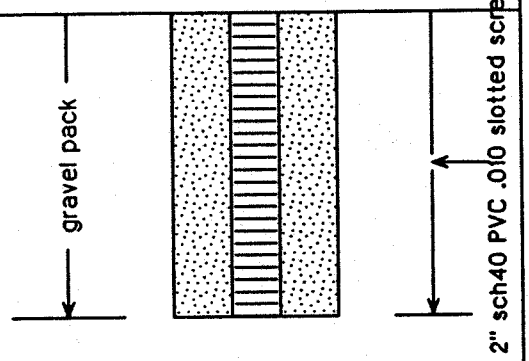
Project: Haywood County
Project No. G98010.6
Type: A/R,A/H,SS

Drilling Contractor: Engineering Tectonics
Registration Number: 835

Surface Elevation: 2602.48ft
Top of Casing: 2604.01ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
				-rocky zone from 40-41 feet
45	8			
				SANDY SILT (ML); brown to gray, faint structure, abundant rust staining, small vertical fracture, some dark mica, wet
50				End of Boring at 48.5 feet
55				
60				
65				
70				
75				
80				

PIEZOMETER DIAGRAM



Completion Depth: 48.5 ft
DATE: 4/7/99

Depth to Water: 40.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohe Yoshida
Signature of Field Agent

LOG OF BORING: P1-3

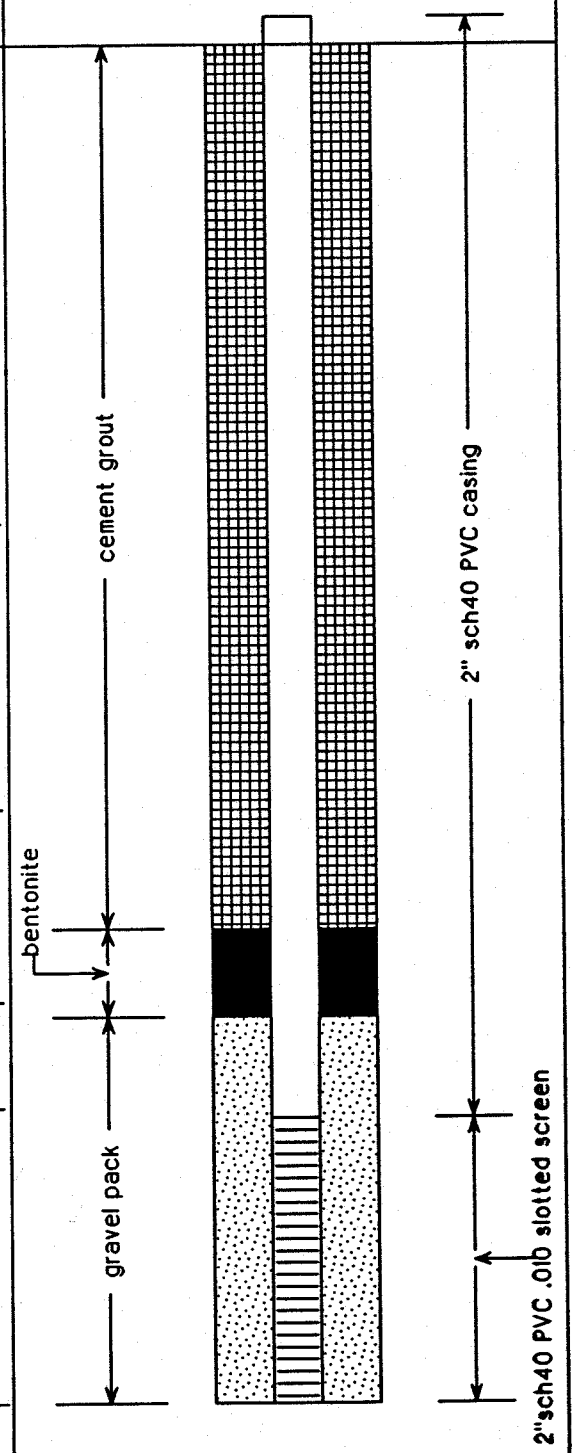
Project: Haywood County
Project No. G98010.6
Type: A/R,A/H,NX/NQ,SS

Drilling Contractor: Engineering Tectonics
Registration Number: 835

Surface Elevation: 2609.67ft
Top of Casing: 2612.35ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	4			CLAYEY SILT (ML); medium brown-red, relict structure, some root debris and mica, few rock fragments
5	22			SANDY SILT (SM); tan and pink, zones of medium-grained mica, thinly layered, saprolite of metacrystalline parent material
10	18			-thickly layered mica and white sand-silt, heavy iron staining, some rust staining
15	18			-faint layering, trace mica, relict fractures with good iron staining, rust staining abundant
20	50/5.5"			PARTIALLY WEATHERED ROCK; dark gray-green weathered schist, red clay and iron staining on relict foliations and fractures
25	50/2"			-layered mica, saturated
30	29			SANDY SILT (SM); medium brown, faint relict structure, wet
35	ref/0			PARTIALLY WEATHERED ROCK Air Rotary Bit Refusal at 36.0 feet
40				REC=80.4% RQD=34.7% grey w/regional white bandings, abundunt fractures typically parallel to foliation, highly weathered w/abundunt iron staining in upper 2 ft. of core sample
45				-noticable weathering -fracture parpendicular to foliation w/iron staining
50				End of Boring at 47.5 feet

PIEZOMETER DIAGRAM



Completion Depth: 47.5 ft
DATE: 4/13/99

Depth to Water: 24 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohe Yoshida
Signature of Field Agent

LOG OF BORING: P1-4

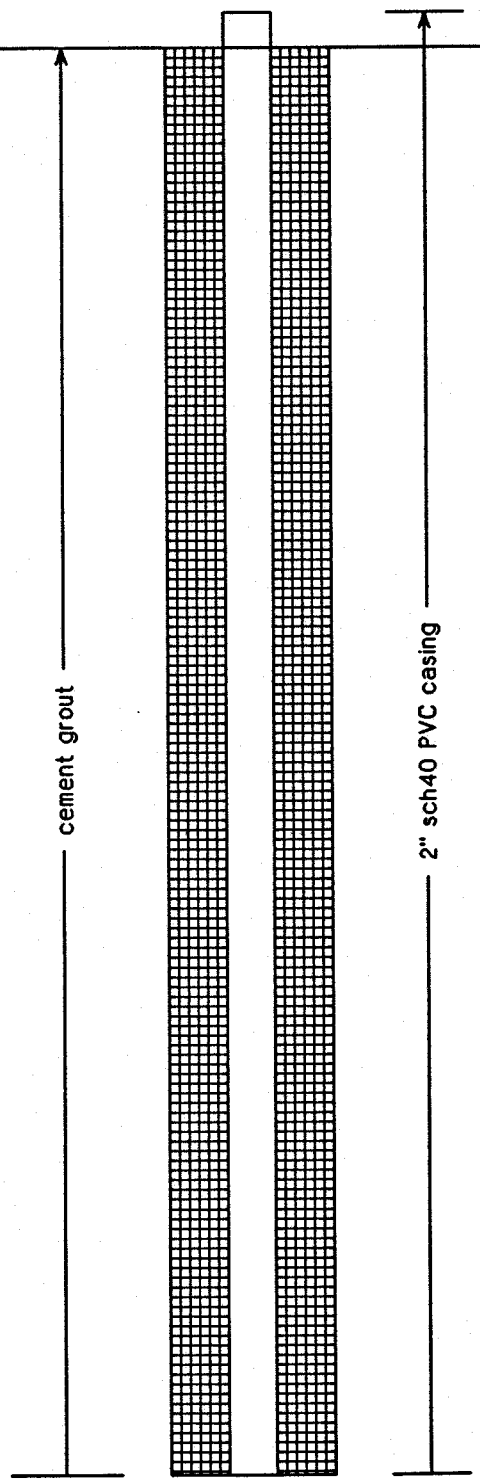
Project: Haywood County
Project No. G98010.6
Type: A/R,A/H,NX/NQ,SS

Drilling Contractor: Engineering Tectonics
Registration Number: 835

Surface Elevation: 2610.78ft
Top of Casing: 2613.42ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	4		X	SILT (ML); medium to dark brown, some medium and coarse sand, faint gneissic structure
	11		X	SANDY SILT (SM); tan to gray, some coarse sand, zonated with white silt and fine sand, faint relict structure
5				
	40		X	-tan to white, thin fracture with iron staining, zones of weathered mica schist
10				
	49		X	-dark brown, fine to medium sand, near vertical relict fractures with rust staining, weathered schist texture
15				
	28		X	-weathered massive metacrystalline, faint layering
20				
	46		X	-thick layered schist with iron and rust stains, zones of white medium sand and silt, moist
25				
	60		X	-some coarse sand, trace clay, moist
30				
	54		X	-less layering, moist
35				
	27		X	
40				

PIEZOMETER DIAGRAM



Completion Depth: 72.0 ft
DATE: 4/12/99

Depth to Water: 39.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P1-4

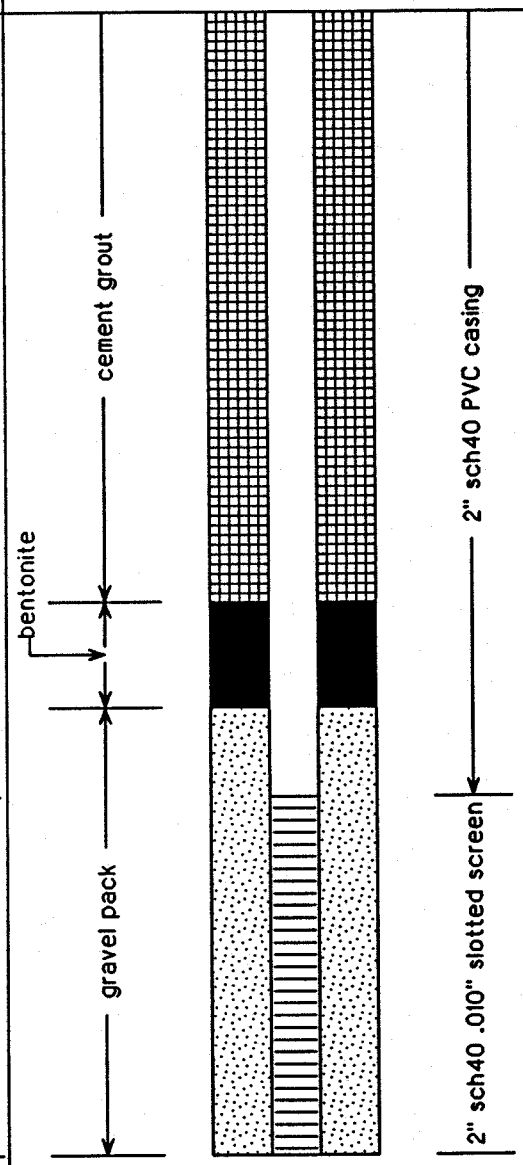
Project: Haywood County
Project No. G98010.6
Type: A/R,A/H,NX/NQ,SS

Drilling Contractor: Engineering Tectonics
Registration Number: 835

Surface Elevation: 2610.78ft
Top of Casing: 2613.42ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
				-rocky zone form 40-41 feet
	ref/4"			-few fragments, weathered gneiss
45				
50				
55				
60				Air Rotary Bit Refusal at 62.0 feet
				REC=100% RQD=70.0% gneiss; light-colored meta-granitic structure, angled micaceous foliation, mixture of lateral and angled fractures
65				-weathering w/trace amount of iron staining
				-high-angled fracture w/iron staining
70				
				End of Boring at 72.0 feet
75				
80				

PIEZOMETER DIAGRAM



Completion Depth: 72.0 ft
DATE: 4/12/99

Depth to Water: 39.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshioka
Signature of Field Agent

LOG OF BORING: P1-5D

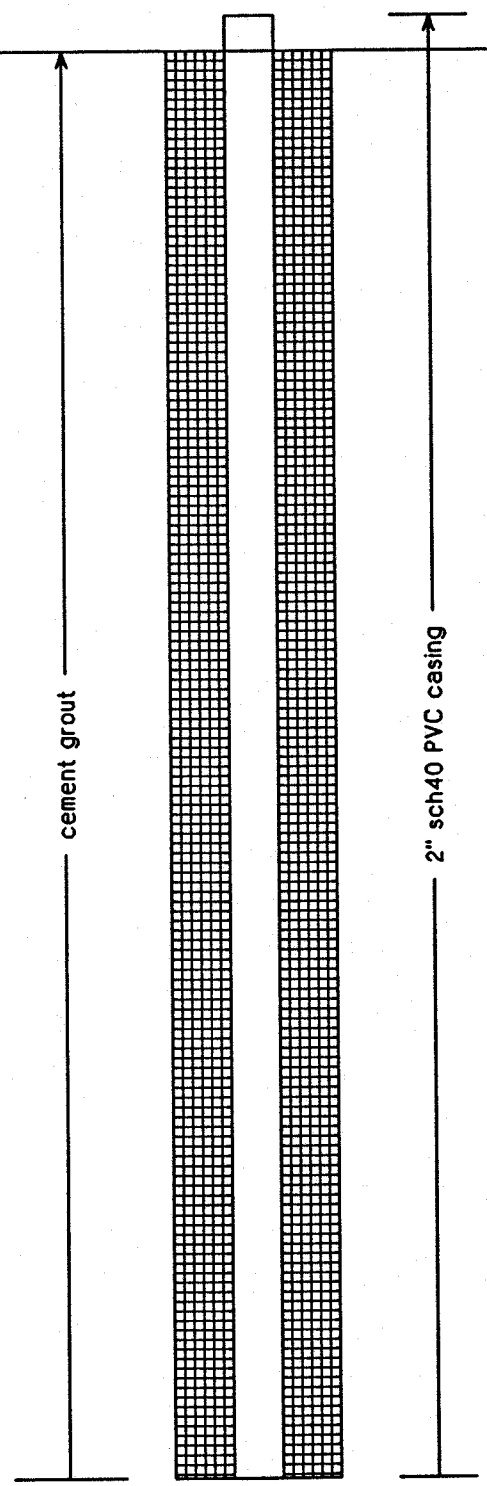
Project: Haywood County
Project No. G98010.6
Type: A/R,A/H,NX/NQ,SS

Drilling Contractor: Engineering Tectonics
Registration Number: 835

Surface Elevation: 2633.21ft
Top of Casing: 2635.45ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	5			CLAY (CL); red, with silt, some root debris, no structure
	9			SILT (ML); pink and white, with fine sand, trace clay, very faint relict structure
5				
	10			SAND (SM); white and gray, fine to medium grained, trace coarse, rust stained pits, faint gneissic structure
10				
	20			-grades with white sand, relict vein apparent, no structure
15				
				-hard drilling from 18-20 feet, rock fragments of metacrystalline and thick, fractured quartz
20				
	26			-white to yellow, medium to coarse grained, with trace rock fragments, grades to brown sand and silt with relict schistosity
25				
				-relict foliations at 30 to 45 degrees
	91			
30				
	19			SILT (ML); dark brown to yellow, rust staining throughout, faint relict structure, relict fracture at 45 degrees with iron and rust staining
35				
	71			-quartz vein from 39-41 feet
40				

PIEZOMETER DIAGRAM



Completion Depth: 78.5 ft
DATE: 3/24/99

Depth to Water: 49.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kobe Yoshioka
Signature of Field Agent

LOG OF BORING: P1-5D

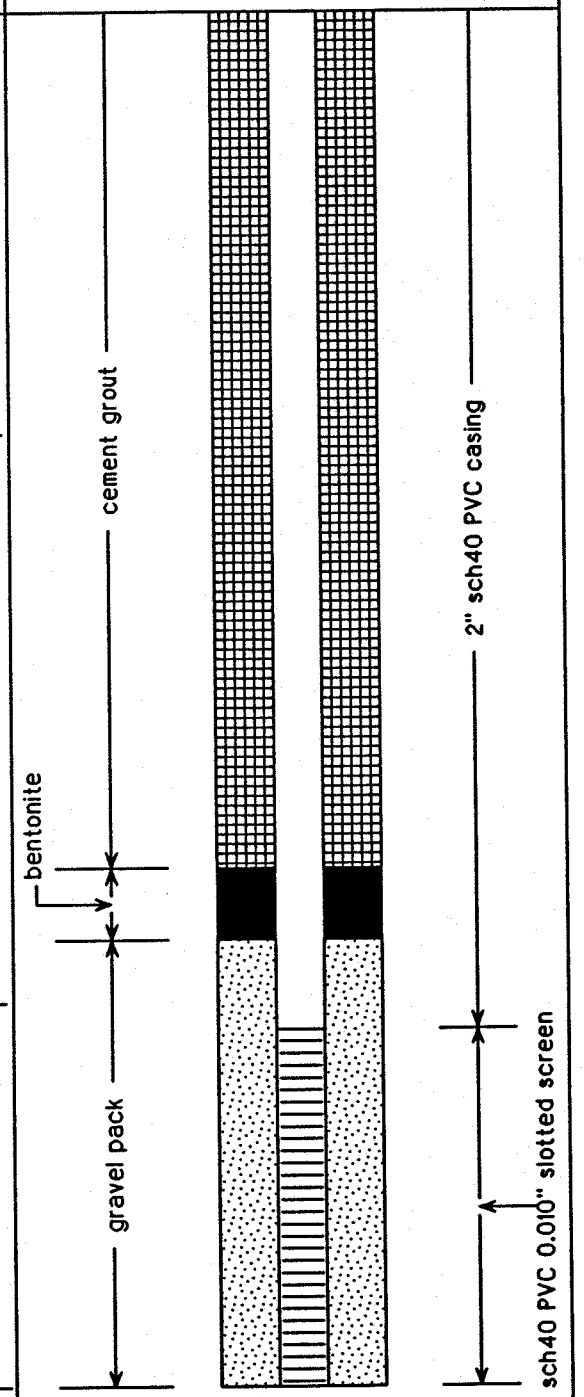
Project: Haywood County
Project No. G98010.6
Type: A/R,A/H,NX/NQ,SS

Drilling Contractor: Engineering Tectonics
Registration Number: 835

Surface Elevation: 2633.21ft
Top of Casing: 2635.45ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	27			
45				
	50/5"			-white to gray, dense, trace mica and fine sand, faint structure, wet
50				Air Rotary Bit Refusal at 51.0 feet
				-PWR, A/H irregular
55				-compentent rock, A/H constant
				-PWR, A/H irregular, with rust stained quart fragments
60				-competent rock, A/H constant
65				-quartz vein with rust staining
				REC=73.3% RQD=31.8% Gneiss; white w/regional grey layerings, zonal variation, meta-granitic structure, angled fractures throughout, heavily weathered in upper 2 ft.
70				-dark-colored, zone of schist and gneiss w/thin foliation
75				-angled fractures w/iron staining
				-dark-colored, zone of shist and gneiss w/thin foliation
80				End of Boring at 78.50 feet

PIEZOMETER DIAGRAM



Completion Depth: 78.5 ft
DATE: 3/24/99

Depth to Water: 49.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P1-5S

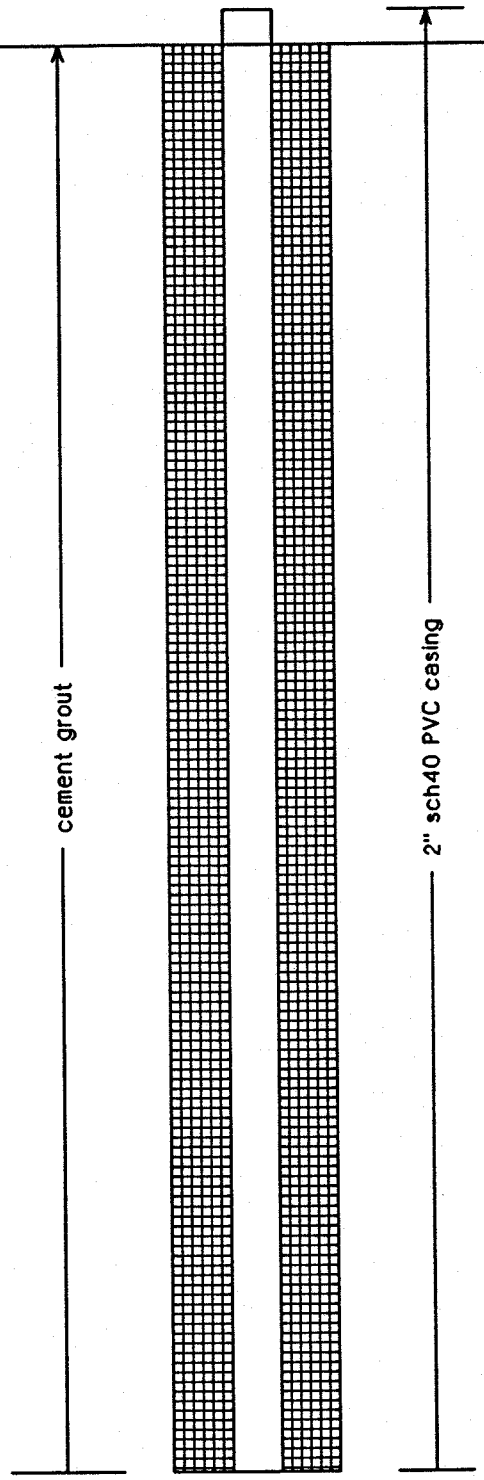
Project: Haywood County
Project No. G98010.6
[illegible]: A/R,A/H,SS

Drilling Contractor: Engineering Tectonics
Registration Number: 835

Surface Elevation: 2633.21ft
Top of Casing: 2636.07ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	5		X	CLAY (CL); red, with silt, some root debris, no structure
	9		X	SILT (ML); pink and white, with fine sand, trace clay, very faint relict structure
5				-hard drilling, rock fragments of metacrystalline and white quartz
	10		X	SAND (SM);white and gray, fine to medium grained, trace coarse, rust stained pits, faint gneissic structure
10				
	20		X	-grades with white sand, relict vein apparent, no structure
15				
				-hard drilling from 18-20 feet, rock fragments of metacrystalline and thick, fractured quartz
20				
	26		X	-white-yellow, medium to coarse grained, with trace rock fragments, grades to brown sand and silt with relict schistosity
25				
	91		X	-relict foliations at 30 to 45 degrees
30				
	19		X	SILT (ML); dark brown to yellow, rust staining throughout, faint relict structure, relcit fracture at 45 degrees with iron and rust staining
35				
	71		X	-quartz vein from 39-41 feet
40				

PIEZOMETER DIAGRAM



Completion Depth: 58.0 ft
DATE: 3/25/99

Depth to Water: 49.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

LOG OF BORING: P1-5S

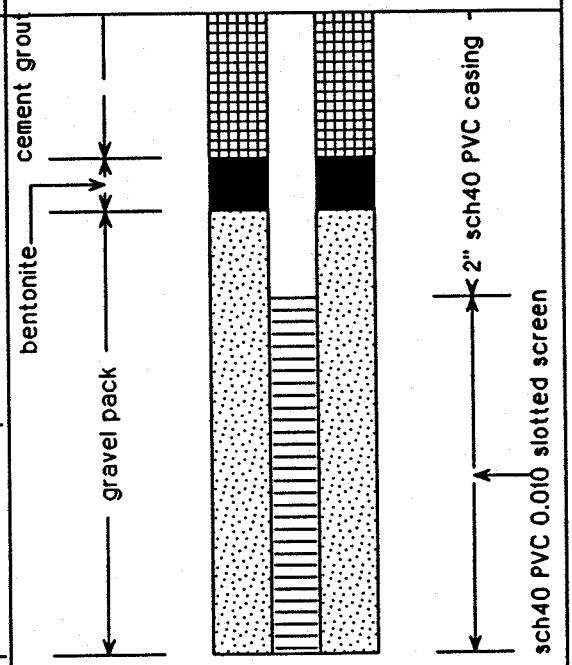
Project: Haywood County
Project No. G98010.6
Type: A/R,A/H,SS

Drilling Contractor: Engineering Tectonics
Registration Number: 835

Surface Elevation: 2633.21ft
Top of Casing: 2636.07ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	27			
45				
	50/5"			-white to gray, dense, trace mica and fine sand, faint structure, wet
50				-Air Rotary Bit Refusal at 51.0 feet
				-PWR, A/H irregular
55				-competent rock, A/H constant
				End of Boring at 58.0 feet
60				
65				
70				
75				
80				

PIEZOMETER DIAGRAM



Completion Depth: 58.0 ft
DATE: 3/25/99

Depth to Water: 49.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

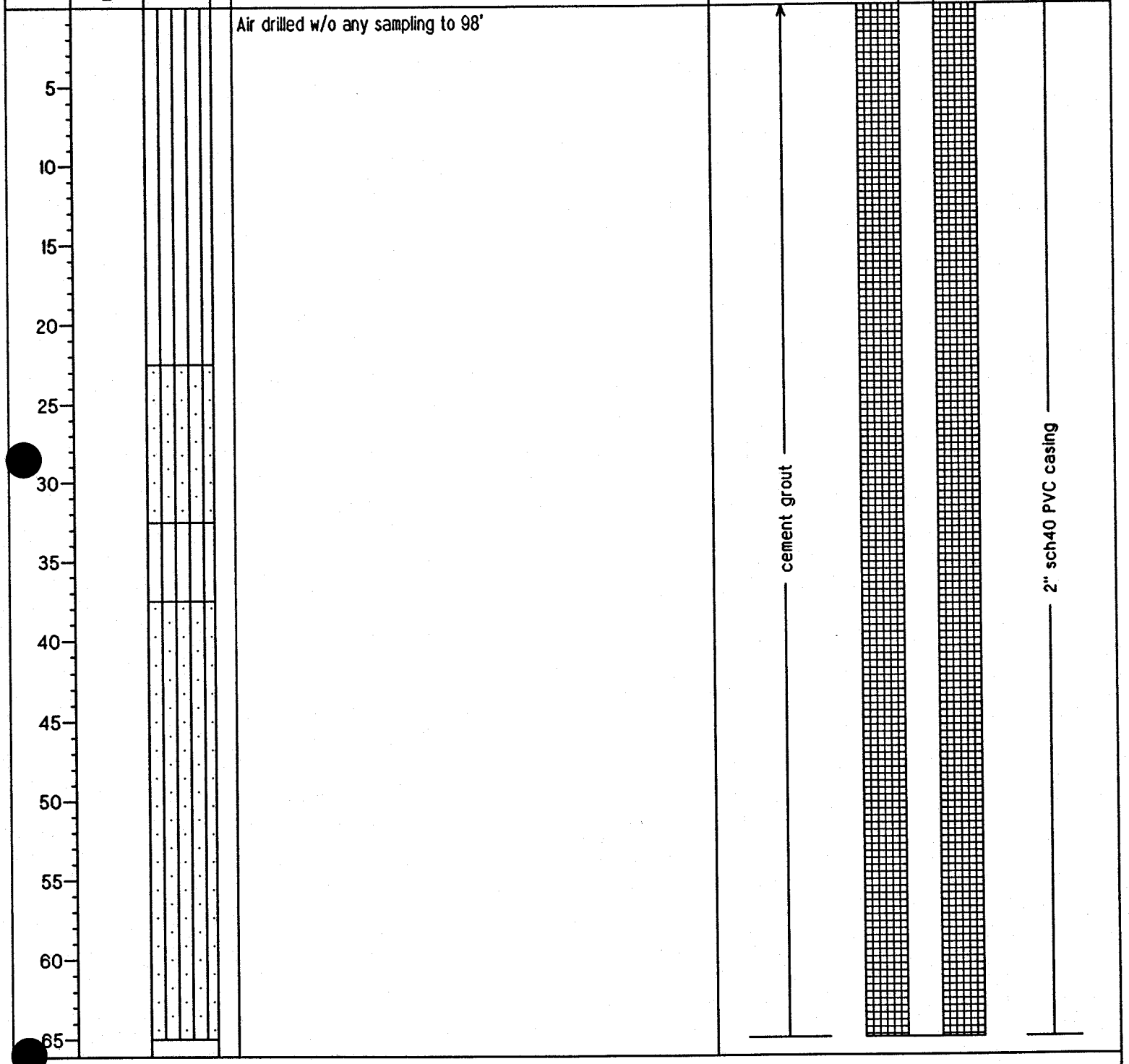
LOG OF BORING: GMW-11D

Project: Haywood County
Project No. G98010.5
Type: HSA RB

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2672.01ft
Top of Casing: 2675.21ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	PIEZOMETER DIAGRAM
				Air drilled w/o any sampling to 98'	



Completion Depth: 127.6 ft
DATE: 12/27/1999

Depth to Water: 98.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshioka
Signature of Field Agent

LOG OF BORING: GMW-11D

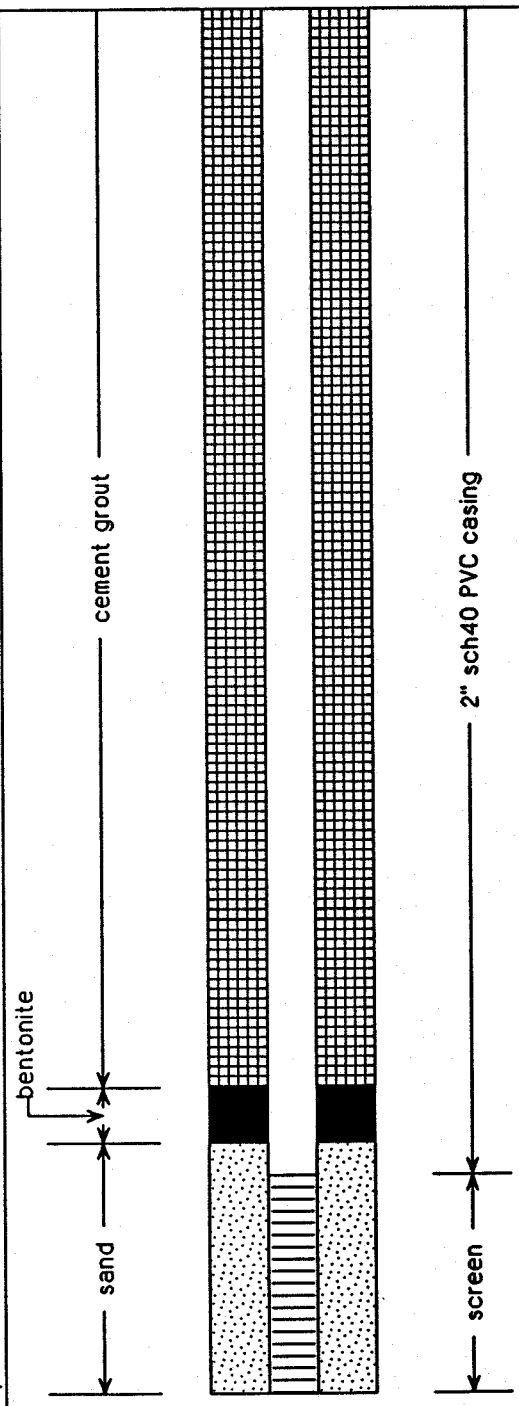
Project: Haywood County
Project No. G98010.5
Type: HSA RB

Drilling Contractor: Engineering Tectonics
Registration Number:

Surface Elevation: 2672.01ft
Top of Casing: 2675.21ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
70				
75				
80				
85				
90				
95				- Hard drilling starts. - Cuttings from borehole wet.
100				Highly fractured rock
105				
110				REC=97.1%, RQD=20.8% Gneiss, quartz, muscovite, biotite foliation. 40 to 50 degree dip of foliation. Breaks along foliation. - 70 degree iron stained fracture that crosses foliation from 114.1 to 114.4 ft.
115				
120				REC=100%, RQD=63.8% Gneiss, same as above.
125				
130				End of Boring at 127.6 feet

PIEZOMETER DIAGRAM



Completion Depth: 127.6 ft
DATE: 12/27/1999

Depth to Water: 98.0 ft WD

MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

I acknowledge that this record is true to the best of my knowledge: Kohei Yoshida
Signature of Field Agent

Appendix B

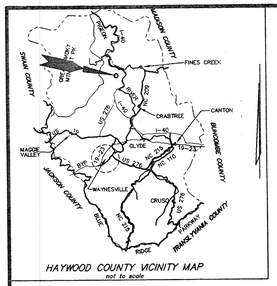
Summary of Construction Record of Monitoring Wells and Piezometers
White Oak Lined Landfill, Haywood County, North Carolina

Well	Total Depth	Stickup	L of Solid Section	L of Screen Interval	L of Tail	Depth to Top of Screen	Initial Depth to Water Table	Depth to Water Table at t = 0	Initial Head Change	Well Diameter (in.)	Gravel Pack Diameter (in.)	Radius of Well Casing	Radius of Gravel Pack	Initial Water Column	Trend Expected	Trend Observed
GWM-1A	26.0	2.5	10.4	15.0	0.6	12.9										
GWM-2	35.5	3.0	19.9	15.0	0.6	22.9										
GWM-2A	55.1	2.3	44.6	10.0	0.5	46.9										
GWM-3	21.2	2.5	5.6	15.0	0.6	8.1										
GWM-3D	37.0	2.6	26.5	10.0	0.5	29.1										
GWM-4A	100.3	2.5	85.2	15.0	0.1	87.7										
GWM-5A	20.1	2.5	4.5	15.0	0.6	7.0										
GWM-5D	36.2	1.6	25.7	10.0	0.5	27.3										
GWM-6A	18.5	2.9	3.4	15.0	0.1	6.3										
GWM-7	82.8	2.7	62.3	20.0	0.5	65.0										
GWM-7D	103.2	2.2	92.7	10.0	0.5	94.9										
GWM-8	42.0	2.5	31.0	10.0	1.0	33.5										
TWD-10	35.0	2.5	25.0	10.0	0.0	27.5										
TWD-10D	59.0	2.5	39.0	20.0	0.0	41.5										
P-1	80.0	1.5	65.0	15.0		66.5	73.37	75.05	1.68	2	3.375	0.0833	0.1406	8.13	double	double
P-2	37.0	1.0	27.0	10.0		28.0	31.48	37.20	5.72	2	4.250	0.0833	0.1771	6.52	double	r-multiple
P-3	67.6	1.5	52.6	15.0		54.1				2	3.375	0.0833	0.1406	69.10		
P-4	81.0	1.5	71.0	10.0		72.5				1	2.000	0.0417	0.0833	82.50		
P-5	52.3	1.5	42.3	10.0		43.8	27.05	38.20	11.15	2	3.375	0.0833	0.1406	26.75	single	single
P-6	67.5	1.5	57.5	10.0		59.0	58.44	58.65	10.12	2	3.375	0.0833	0.1406	9.81		
P-7	42.0	1.5	32.0	10.0		33.5	33.92	35.13	1.21	2	3.375	0.0833	0.1406	9.58	double	r-double
P-9	47.3	1.5	37.3	10.0		38.8	36.00	36.14	0.92‡	2	3.375	0.0833	0.1406	11.70		
P-10	73.0	1.0	63.0	10.0		64.0	48.04	50.45	2.41	2	4.250	0.0833	0.1771	25.96	single	single
P-11	25.0	1.0	14.0	10.0	1.0	15.0	16.20	17.75	1.55	2	4.250	0.0833	0.1771	8.80	double	double
P-12	18.0	1.0	8.0	10.0		9.0	8.35	12.00	3.65	2	4.250	0.0833	0.1771	10.65	multiple	r-double
P-13	96.0	1.0	86.0	10.0		87.0	75.87	84.00	8.13	2	4.250	0.0833	0.1771	21.13	single	single
P-14	81.3	1.5	71.3	10.0		72.8				1	2.000	0.0417	0.0833	82.80		
P-15	104.0	1.0	93.0	10.0	1.0	94.0	79.13	85.65	6.52	2	4.250	0.0833	0.1771	24.87	single	single
P-16	42.5	1.0	32.0	10.0	0.5	33.0	24.35	31.50	7.15	2	4.250	0.0833	0.1771	18.65	single	single
P-17	90.0	1.5	80.0	10.0		81.5	80.90	82.35	1.45	2	3.375	0.0833	0.1406	10.60	multiple	multiple
P-18	41.0	1.5	31.0	10.0		32.5				1	2.000	0.0417	0.0833	42.50		
P-19	97.5	1.5	87.5	10.0		89.0	70.40	79.85	9.45	2	3.375	0.0833	0.1406	28.60	single	single
P2-1	52.5	1.5	37.5	15.0		39.0	42.50	42.65	0.15‡	2	3.375	0.0833	0.1406	11.50		
P2-2	47.3	1.5	32.3	15.0		33.8	42.60	42.85	0.25‡	2	3.375	0.0833	0.1406	6.20		

* All lengths are expressed in feet unless indicated otherwise.

† The words "single", "double" and "multiple" mean that the plot shows single-line, double-line and multiple-line effects, respectively. The prefix "r" means the trend is reversed, *i.e.* the second line is steeper than the first one *etc*.

‡ Due to insufficient amounts of initial head changes, values of hydraulic conductivity for the wells P-9, P2-1 and P2-2 are not used for the calculations of flow rates.



HAYWOOD COUNTY VICINITY MAP
not to scale

LEGEND:

———	PROPERTY LINE
▬▬▬	300' BUFFER
- - - - -	PROPOSED ANCHOR TRENCH
·····	PROPOSED PHASE LIMITS
———	EXISTING LANDFILL
—·—·—	CELL 4
▥▥▥	SPRING RELIEF DRAINS
—·—·—	BRANCH OR STREAM
—x—x—x—x—	FENCE
⊕ P-14	EXISTING PIEZOMETER
⊡ B-8	EXISTING BORING
● GWM-1A	EXISTING GROUNDWATER MONITORING
△ SPRING	EXISTING SPRING

PLATE 1

Municipal Engineering Services Company, P.A.
P.O. BOX 549 BOONE, N.C. 28607 (828) 262-1767
P.O. BOX 97 GARNER, N.C. 27529 (919) 772-5393

MUNICIPAL SOLID WASTE LANDFILL FACILITY
HAYWOOD COUNTY NORTH CAROLINA

DATE	BY	REV.	DESCRIPTION
2/2/00	LCH	1	ADDED NEW PIEZOMETERS

SITE SUITABILITY STUDY
GENERAL SITE MAP

SCALE:	1"= 200'
DATE:	10/2/98
DRWN. BY:	L. HAMPTON
CHKD. BY:	W. SULLIVAN
PROJECT NUMBER	G98010
DRAWING NO.	GS
SHEET NO.	1 OF 1

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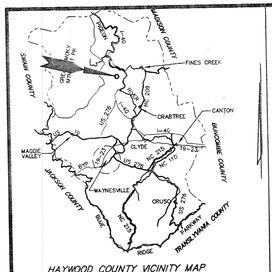
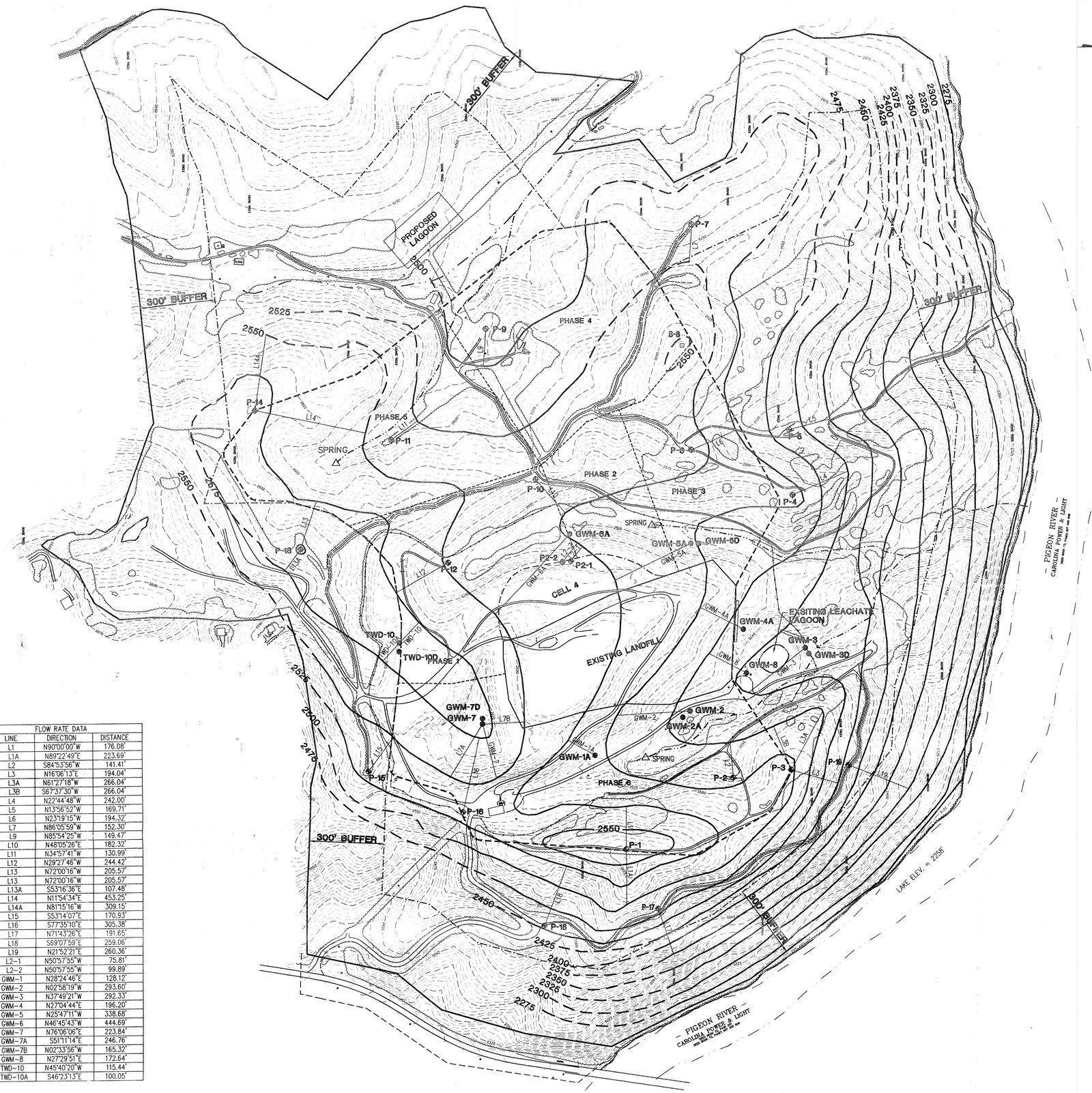


LEGEND:

- PROPERTY LINE
- 300' BUFFER
- PROPOSED ANCHOR TRENCH
- PROPOSED PHASE LIMITS
- EXISTING LANDFILL
- CELL 4
- BRANCH OR STREAM
- FENCE
- P-14 EXISTING PIEZOMETER
- B-8 EXISTING BORING
- GWM-1A EXISTING GROUNDWATER MONITORING
- SPRING EXISTING SPRING
- L11 P-11 FLOW RATE AND DIRECTION
- 2550 POTENTIOMETRIC CONTOUR AS OF 8/17/98
- 2550 INTERPOLATED POTENTIOMETRIC CONTOUR



GROUNDWATER ELEVATION DATA (FEET)			
PIEZOMETER	TOP OF PIPE	GROUND	8/17/98
P1	2632.34	2629.56	2558.48
P2	2523.82	2520.37	2490.10
P3	2566.64	2564.00	2510.62
P4	2573.73	2571.66	2504.80
P5	2488.38	2485.54	2460.32
P6	2597.24	2594.19	2538.68
P7	2553.15	2550.52	2520.05
P9	2524.12	2520.98	2487.82
P10	2581.86	2579.49	2532.81
P11	2553.87		2535.98
P12	2557.56	2555.29	2548.83
P13	2675.69	2671.66	2600.48
P14	2654.13	2650.93	2580.78
P15	2606.51	2603.49	2527.88
P16	2560.57	2557.91	2536.29
P17	2562.25	2559.29	2481.65
P18	2495.26	2491.71	2451.48
P19	2481.55	2478.02	2411.09
P2-1	2575.93	2572.74	2532.95
P2-2	2574.13	2573.66	2530.93
GWM-1A	2632.34	2629.56	2503.13
GWM-2	2497.00	2494.45	2466.43
GWM-3	2437.66	2435.40	2428.41
GWM-4A	2499.45	2496.19	2463.71
GWM-5A	2504.06	2502.47	2496.76
GWM-6A	2530.37	2527.88	2522.27
GWM-7	2644.82	2643.56	2581.37
GWM-8	2477.70	2475.13	2446.23
TWD-10	2617.16	2614.39	2586.48

FLOW RATE DATA		
LINE	DIRECTION	DISTANCE
L1	N90°00'00"W	176.08'
L1A	N89°22'49"E	223.69'
L2	S84°53'56"W	141.41'
L3	N16°06'13"E	194.04'
L3A	N61°27'18"W	266.04'
L3B	S67°37'30"W	266.04'
L4	N22°44'48"W	242.00'
L5	N13°56'52"W	169.71'
L6	N23°19'15"W	194.32'
L7	N86°05'59"W	152.30'
L9	N85°54'25"W	149.47'
L10	N48°05'26"E	182.32'
L11	N34°57'41"W	130.99'
L12	N29°27'46"W	244.42'
L13	N72°00'16"W	205.57'
L13	N72°00'16"W	205.57'
L13A	S53°16'36"E	107.48'
L14	N11°54'34"E	453.25'
L14A	N81°15'16"W	309.15'
L15	S53°14'07"E	170.93'
L16	S77°35'10"E	305.38'
L17	N71°43'26"E	191.65'
L18	S69°07'59"E	259.06'
L19	N21°52'21"E	260.36'
L2-1	N50°57'55"W	75.81'
L2-2	N50°57'55"W	99.89'
GWM-1	N28°24'46"E	128.12'
GWM-2	N02°58'19"W	293.60'
GWM-3	N37°49'21"W	292.33'
GWM-4	N27°04'44"E	196.20'
GWM-5	N25°47'11"W	338.68'
GWM-6	N46°45'43"W	444.69'
GWM-7	N76°06'06"E	223.84'
GWM-7A	S51°11'14"E	246.76'
GWM-7B	N02°33'56"W	165.32'
GWM-8	N27°29'51"E	172.64'
TWD-10	N45°40'20"W	115.44'
TWD-10A	S46°23'13"E	100.05'

PLATE 4A

Municipal Engineering Services Company, P.A.
P.O. BOX 349 BOONE, N.C. 28607 (828) 262-1767
P.O. BOX 67 GARNER, N.C. 27529 (919) 772-5393

MUNICIPAL SOLID WASTE LANDFILL FACILITY
HAYWOOD COUNTY NORTH CAROLINA

DATE	BY	REV.	DESCRIPTION
2/7/00	LCH	1	REVISED PLATE NUMBER

SITE SUITABILITY STUDY
SINGLE DAY WITH FLOW RATE DATA

SCALE: 1"= 200'
DATE: 8/31/98
DRWN. BY: L. HAMPTON
CHKD. BY: W. SULLIVAN
PROJECT NUMBER G98010
DRAWING NO. PM
SHEET NO. 1 OF 1

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