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

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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 trace 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 in March through May 1998. 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. 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-3, P-5, P-6, P-7, P-9, P-17, and P-19) were installed with a 3 3/8-inch air hammer. Core samples were taken from six borings (P-1, P-4, P-9, P-14, P-18, and P-19) 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 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 is 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, and P-19) 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. 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-10, P-11, P-12, P-13, P-14, and P-16. 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-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-6, 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 results 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-9, P-17, and P-19 are screened in fractured gneissic bedrock. The average for this unit is 2.26×10^{-4} cm/sec.[‡] A hydraulic consideration table and calculations are included in Appendix B.

[‡]Values for P2-1 and P2-2 are not included in this calculation due to the unavailability of their revised slug test data. These two piezometers were abandoned during the construction of Cell 4.

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.

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 737.98 ft/yr. The maximum flow rate for gneiss is 2064 ft/yr at P-3 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 $K = 2.26 \times 10^{-4}$ 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 -2144.43 ft/yr, as opposed 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 94.96 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

[§]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]

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.

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.

[¶]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

	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 associated with faults, and no faults have been observed within the property, the bedrock unit underneath the property most likely contains a high degree of fracture networks.

Because of 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 large scale. To validate this assumption, potentiometric

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

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.

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. The majority of the groundwater flows toward a major discharge feature (Pigeon River). Because Haywood County owns the property to this point, the site will be easily monitored. The portion of groundwater flowing southward from the recharge area will be monitored by several nested monitoring wells, which will be proposed for installation for the groundwater monitoring plan developed for the design phase. 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,
MUNICIPAL ENGINEERING SERVICES COMPANY, P.A.

Kohei Yoshida
Hydrogeologist

Edward S. Custer, Jr., Ph.D., P.G.
Professional Geologist

NORTH CAROLINA LICENSED SEAL 730 GEOLOGIST EDWARD S. CUSTER, JR.

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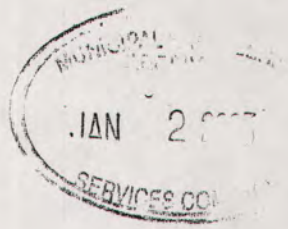
[23] U.S. Geological Survey, 1967, Fines Creek 7.5 minute quadrangle.

Plates

44-07

EDWARD S. CUSTER, JR. Ph.D., L.G.
730 ELM STREET
BARBOURSVILLE, WV 25504 USA
December 30, 2002



Mr. Wayne Sullivan
Municipal Engineering Services Co. PA
PO Box 97
Garner, NC 27529

Re: Geologic Conditions C & D Landfill

Dear Mr. Sullivan:

At your request, I visited the Haywood County C & D Landfill on December 27, 2002. The purpose of the inspection was to investigate some rock encountered during the excavation of the remaining area of the Phase 1 portion of the site. The site had been excavated, reportedly down to grade, except for a partially excavated area measuring approximately 120 by 70 feet located near the center of the site. Partially weathered quartzose gneiss was present on both the south and north sides of the partially excavated area, while partially weathered interbedded gneiss and mica schist occurred between the harder quartzose gneiss. The zone of rock was approximately six feet above grade on the southern side and ten feet above grade on the northern side. This area appears to be a pinnacle of rock that did not completely chemically weather to saprolite and soil that are present throughout the remainder of the site. No water was observed within the rock area or standing on the grade surface.

I discussed the excavation of the site with the Landfill manager and he stated that the excavation contractor only had a D-8 bulldozer and was not able to rip out this area, because of the hardness of the quartzose gneiss. I observed some potential rippable zones, but their removal would probably result in several odd shaped areas that would be more difficult to build berms around. Removal of the entire rock area will probably require some blasting to remove the harder quartzose gneiss beds.

Once this area is surveyed, the appropriate decision concerning either removal or building the appropriate regulatory separation berms around and above this rock can be determined.

In my professional opinion, I believe that the presence of this pinnacle rock area will not impact our ability to monitor the groundwater for the site using the existing groundwater monitoring plan.

Sincerely,

Edward S. Custer, Jr., Ph.D., L.G.

MUNICIPAL SOLID WASTE LANDFILL

FACILITY PERMIT

COUNTY OF HAYWOOD

is hereby issued a PERMIT to CONSTRUCT a

MUNICIPAL SOLID WASTE LANDFILL FACILITY

CONSTRUCTION & DEMOLITION UNIT

located at 3898 Fines Creek Road, SR 1338, Haywood County, North Carolina in accordance with Article 9, Chapter 130A, of the General Statutes of North Carolina and all rules promulgated thereunder and subject to the conditions set forth in this permit. The facility is located and described by the attached legal description of the site.

_____

James C. Coffey, Acting Chief
Solid Waste Section

ATTACHMENT 1

Approved Documents

PART I: GENERAL FACILITY CONDITIONS

PART II: MUNICIPAL SOLID WASTE LANDFILL CONDITIONS

PART III: CONSTRUCTION AND DEMOLITION LANDFILL CONDITIONS

1. *Site Hydrogeologic Study, Haywood County Construction & Demolition Landfill, Waynesville, North Carolina*, prepared by Municipal Engineering, dated June 4, 2001.

PART IV: LAND CLEARING AND INERT DEBRIS LANDFILL CONDITIONS

PART V: YARD WASTE CONDITIONS

PART VI: MISCELLANEOUS TREATMENT AND PROCESSING FACILITIES CONDITIONS

ATTACHMENT 2

PART I: GENERAL FACILITY CONDITIONS

FACILITY CONSTRUCTION CONDITIONS

FACILITY PRE-OPERATIVE CONDITIONS

PART II: MUNICIPAL LANDFILL UNIT SPECIFIC CONDITIONS

PRE-OPERATIONAL CONDITIONS

CONSTRUCTION CONDITIONS

PART III: CONSTRUCTION AND DEMOLITION DEBRIS UNIT SPECIFIC CONDITIONS

1. This permit approves the development and construction of the Construction and Demolition debris landfill unit and the on-site environmental management and protection facilities as described in the approved plans.

2. Buffer zones are as established in the approved plans. Division approval is required for use of buffer zones other than as described in the approved plans.

3. Haywood County must obtain a Permit to Operate for this facility prior to acceptance and disposal of construction and demolition debris in this unit.

4. Ground water monitoring wells and surface water sampling locations shall be sampled in accordance with the approved plans prior to issuing a Permit to Operate.

5. The owner's geologist shall examine the cell excavation and note any pertinent geologic features exposed during the construction process and shall notify the Solid Waste Section Hydrogeologist of the findings.

6. The owner's geologist shall be in the field to supervise all well installations. Any modifications to the approved water quality monitoring plan require approval by the Section Hydrogeologist. Documentation of all changes to the approved monitoring plan shall be submitted with the well construction records.

7. For each monitoring well constructed, a well construction record, well schematic, boring log, and a description of well development activities shall be submitted to the Section within 30 days upon well completion.

PART IV: LAND CLEARING AND INERT DEBRIS UNIT SPECIFIC CONDITIONS

PART V: YARD WASTE UNIT SPECIFIC CONDITIONS

PART VI: MISCELLANEOUS UNIT SPECIFIC CONDITIONS

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NCDENR
North Carolina Department of Environment and Natural Resources

FACILITY COMPLIANCE AUDIT REPORT
Division of Waste Management
Solid Waste Section

UNIT TYPE: (check all that apply to this audit with same Permit number)												
Lined MSWLF		LCID		YW		Transfer		Compost		SLAS		COUNTY: Haywood
Closed MSWLF		HHW		White goods		Incin		T&P		FIRM		PERMIT NO.: 44-07
CDLF	X	Tire T&P / Collection		Tire Monofill		Industrial Landfill		DEMO		SDTF		FILE TYPE: COMPLIANCE

Date of Audit: 1/10/03 (first inspection) Date of Last Audit: N/A

FACILITY NAME AND ADDRESS:
Haywood County Construction and Demolition Landfill
SR 1338
Waynesville, NC 28786

FACILITY CONTACT NAME AND PHONE NUMBER:
Bobby Cogdill, Haywood County Solid Waste Director
Telephone: 828-627-8042

FACILITY CONTACT ADDRESS (IF DIFFERENT):
Bobby Cogdill, Director
Haywood County Solid Waste Department
278 Recycle Drive
Clyde, NC 28721

AUDIT PARTICIPANTS:
Jim Patterson, N.C. Solid Waste Section
Bobby Cogdill and Jeremy Parker, Haywood County Solid Waste Department

STATUS OF PERMIT:
Permit to operate issued on 11/18/02.

PURPOSE OF AUDIT:
Inspection of construction and demolition landfill.

NOTICE OF VIOLATION(S) (citation and explanation):
No violations noted.

You are hereby advised that, pursuant to N.C.G.S. 130A-22, an administrative penalty of up to $5,000 per day may be assessed for each violation of the Solid Waste Statute or Regulations. If the violation(s) noted here continue, you may be subject to enforcement actions including penalties, injunction from operation of a solid waste management facility or a solid waste collection service and any such further relief as may be necessary to achieve compliance with the North Carolina Solid Waste Management Act and Rules.

STATUS OF PAST NOTED VIOLATIONS (List all noted last audit):
N/A

OTHER COMMENTS /SUGGESTIONS:

(1) Large outcropping of rock observed in cell upgradient of the operating working face.

(2) This is the first inspection at this landfill.

Please contact me if you have any questions or concerns regarding this audit report.

James E Patterson (signature) Phone: 828-251-6784.
Regional Representative

Distribution: original signed copy to facility -- signed copy to compliance officer -- e-mail or copy to super

Delivered on : 01/14/03 **by**		hand delivery	x	US Mail		Certified No. [_]

cc: Mark Poindexter
Brent Rockett

Municipal Services
Garner, N.C.

Engineering Company, P.A.
Boone, N.C.

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

Project No. G 98010.5

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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	5/20/1998	2549.56	2629.56	2574.56	2632.34	2562.56	2559.09	2577.34	2558.19	2558.11	2558.47
P-2	4/2/1998	2483.37	2520.37	2483.37	2523.82	2499.37	2494.17	2493.97	2496.54	2494.05	2492.34
P-3	5/19/1998	2496.40	2564.00	2516.00	2566.64	2509.00	2509.01	2512.04	2512.07	2511.95	2511.40
P-4	5/9/1998	2490.66	2571.66	2512.66	2573.73	2509.66	2523.41	2507.23	2573.73	2503.83	2504.54
P-5	5/25/1998	2433.24	2485.54	2465.54	2488.38	2460.54	2449.54	2461.88	-	2462.70	2461.33
P-6	5/25/1998	2526.69	2594.19	2536.19	2597.24	2535.19	2537.29	-	2538.57	2538.65	2538.80
P-7	5/25/1998	2508.52	2550.52	2523.52	2553.15	2520.52	2528.52	2520.48	2553.15	2520.46	2519.23
P-9	5/21/1998	2473.68	2520.98	2505.98	2524.12	2478.98	2486.62	2488.85	2524.12	2488.77	2488.12
P-10	3/19/1998	2506.49	2579.49	-	2581.86	2527.49	2529.99	2530.16	2531.40	2534.05	2533.82
P-11	3/18/1998	2526.87	2551.87	2526.87	2553.87	2534.37	2538.37	2537.75	2537.67	2536.07	2536.09
P-12	3/13/1998	2537.38	2555.38	2537.38	2557.62	2547.38	2548.38	2550.20	2548.42	2549.47	2549.27
P-13	4/21/1998	2575.66	2671.66	-	2675.69	2587.66	2589.56	2596.18	2598.97	2599.34	2599.82
P-14	5/12/1998	2569.53	2650.93	2585.93	2654.13	2588.93	2605.53	-	-	2579.38	2579.86
P-15	3/28/1998	2499.49	2603.49	-	2606.51	2512.49	2527.12	2527.10	-	2527.26	2527.38
P-16	3/29/1998	2515.41	2557.91	2515.41	2560.57	2521.91	2535.14	2534.64	2534.98	2535.89	2536.04
P-17	5/21/1998	2469.29	2559.29	2534.29	2562.25	2478.29	2478.22	2479.67	2480.41	2480.65	2481.35
P-18	5/10/1998	2450.71	2491.71	2462.71	2495.26	2463.71	2469.26	2454.39	-	2452.06	2454.56
P-19	4/2/1998	2380.52	2478.02	2455.02	2481.55	2402.02	2382.02	2411.18	2411.10	2411.13	2411.15
P2-1	5/21/1998	2520.24	2572.74	2538.74	2575.93	2535.74	2531.74	2533.63	2533.54	2533.53	2533.43
P2-2	5/21/1998	2526.36	2573.66	2542.66	2574.13	2540.66	2531.66	2532.19	2531.93	2531.84	2531.53
GWM-1A	9/17/1993	2491.97	2517.97	2491.97	2520.46	-	2501.97	-	-	2504.21	2503.77
GWM-2	9/16/1993	2458.95	2494.45	2458.95	2497.00	-	-	-	-	2467.64	2467.20
GWM-2A	9/23/1993	2439.35	2494.45	2457.55	2497.94	-	-	-	-	2467.44	2467.42
GWM-3	9/16/1993	2414.20	2435.40	2414.20	2437.66	-	-	-	-	2430.10	2429.58
GWM-3D	9/23/1993	2397.58	2434.58	2413.18	2436.90	-	-	-	-	2421.65	2421.62
GWM-4A	9/29/1993	2395.89	2496.19	2468.19	2499.45	-	-	-	-	2460.35	2464.37
GWM-5A	9/25/1993	2482.37	2502.47	2482.37	2504.06	-	-	-	-	2497.70	2497.04
GWM-5D	9/29/1993	2466.27	2502.47	2482.47	2503.28	-	-	-	-	2496.62	2496.23
GWM-6A	9/24/1993	2509.38	2527.88	-	2530.52	-	-	-	-	2523.90	2522.82
GWM-7	7/12/1993	2560.76	2643.56	2560.76	2645.74	-	-	-	-	2581.50	2581.92
GWM-7D	9/30/1993	2540.36	2643.56	-	2644.82	-	-	-	-	2579.62	2579.80
GWM-8	-	2433.13	2475.13	-	2477.70	-	-	-	-	2447.08	2446.87
TWD-10	-	2579.39	2614.39	-	2617.16	-	-	-	-	2588.21	2587.74
TWD-10D	-	2555.39	2614.39	-	2617.48	-	-	-	-	2588.00	2587.57

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	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-2	2490.10	2489.11	2488.42	2487.56	2486.74	2487.12	2490.08	2490.64	2494.05	2486.74	7.31
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-4	2504.80	2504.32	2503.71	2502.98	2502.11	2501.53	2500.20	2500.51	2504.80	2500.20	4.60
P-5	2460.32	2459.59	2459.12	2457.52	2458.18	2460.58	2459.45	2459.5	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-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	2598.15	3.16
P-14	2580.78	2581.19	2580.82	2579.96	2579.05	2578.63	2577.61	2577.37	2581.19	2577.61	3.58
P-15	2527.88	2527.87	2527.77	2527.45	2526.91	2526.61	2525.39	2525.02	2527.88	2525.39	2.49
P-16	2536.29	2535.85	2535.45	2534.85	2534.19	2533.87	2533.31	2533.32	2536.29	2533.31	2.98
P-17	2481.65	2480.75	2479.90	2479.18	2478.42	2478.05	2477.20	2476.81	2481.65	2477.20	4.45
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
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	2420.5	2421.65	2419.51	2.14
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	2496.8	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	2581.92	2577.98	3.94
GWM-7D	2579.39	2578.67	2578.19	2577.50	2577.10	2576.62	2578.15	2577.12	2579.80	2576.62	3.18
GWM-8	2446.23	2445.72	2445.46	2445.12	2445.01	2445.60	2445.05	2446.45	2447.08	2445.01	2.07
TWD-10	2586.48	2585.17	2584.20	2578.19	2584.74	2582.86	2584.06	2584.06	2588.21	2578.19	10.02
TWD-10D	2586.33	2585.04	2584.08	2583.10	2583.41	2582.78	2584.41	2583.93	2588.00	2582.78	5.22

Table 2. Hydrologic properties of lithologic units. White Oak Lined Landfill, Haywood County, North Carolina

Lithologic Unit	Average Hydraulic Conductivity (cm/sec)	Total Porosity (%)	Effective Porosity (%)	Average Flow Rate (ft/yr)
Saprolite	1.50E-04	27.00	11.40	145.57
Partially Weathered Rock	6.81E-05	10.00	10.00	113.01
Fractured Gneiss	2.26E-04	5.00	5.00	737.98

* Data and calculations for all properties are provided in Appendix B.

Table 3. Lab results for soil samples. White Oak Lined Landfill, Haywood County, North Carolina

Boring	Depth (ft.)	Soil Description	Liquid Limit	Plastic Limit	Plasticity Index	Percent Gravel (%)	Percent Sand (%)	Percent Silt (%)	Percent Clay (%)	Permeability ASTM D 5084 (cm/sec)	Specific Gravity	Natural Moisture Content (%)
P2-1*	1-5'	SaCl	55	29	26	2.4	43.5	26.4	27.7	-	2.71	24.0
P2-1*	6-10'	SaCl	48	27	21	3.5	45.1	24.6	26.8	-	2.69	22.9
P2-1	10-12'	SiSa	39	40	NP	1.6	57.0	23.5	17.9	2.20E-06	2.71	22.1
P2-1	21-23'	SaSi	37	NP	-	0.3	39.5	36.2	24.0	1.30E-06	2.72	30.4
P2-2	3-5'	SiSa	44	34	10	8.4	47.6	28.2	15.8	2.00E-07	2.75	21.5
P-1	3-5'	SiSa	NP	NP	NP	0.0	47.7	39.2	13.1	-	2.83	21.7
P-8	39-40'	SiSa	48	48	0	0.0	58.4	26.3	15.3	2.20E-05	2.73	26.3
P-8	44-46'	ClSi	44	41	3	0.1	31.3	47.5	21.1	-	2.74	23.6
P-9	0-2'	SaCl	47	28	19	0.5	35.5	15.3	48.8	-	2.68	26.6
P-9	8-10'	SiSa	37	36	1	0.0	51.2	34.3	14.5	1.50E-04	2.72	22.2
P-14	0-2'	ClSi	40	36	4	0.0	34.1	45.7	20.0	-	2.75	28.3
P-15	13-15'	SaSi	NP	NP	NP	0.0	42.6	45.0	12.4	-	2.65	13.4

* denotes composite sample.

Table 4. Seasonal high estimation. White Oak Lined Landfill, Haywood County, North Carolina

Piezometer	Low Reading	Topographic Setting	Expected Fluctuation	Estimated High
P-1	2555.02	Ridge	12	2567.02
P-2	2486.74	Slope	12	2498.74
P-3	2507.14	Ridge	12	2519.14
P-4	2500.20	Ridge	12	2512.20
P-5	2457.52	Draw	8	2465.52
P-6	2537.34	Ridge	12	2549.34
P-7	2518.95	Slope	12	2530.95
P-9	2487.20	Valley	8	2495.20
P-10	2529.76	Ridge	12	2541.76
P-11	2535.67	Draw	8	2543.67
P-12	2546.85	Draw	8	2554.85
P-13	2598.15	Ridge	12	2610.15
P-14	2577.61	Ridge	12	2589.61
P-15	2525.39	Ridge	12	2537.39
P-16	2533.31	Slope	12	2545.31
P-17	2477.20	Slope	12	2489.20
P-18	2451.06	Slope	12	2463.06
P-19	2405.05	Slope	12	2417.05
P2-1	2530.12	Slope	12	2542.12
P2-2	2528.95	Slope	12	2540.95
GWM-1A	2502.23	Draw	8	2510.23
GWM-2	2465.76	Draw	8	2473.76
GWM-2A	2465.98	Draw	8	2473.98
GWM-3	2426.31	Draw	8	2434.31
GWM-3D	2419.51	Draw	8	2427.51
GWM-4A	2457.26	Slope	12	2469.26
GWM-5A	2496.09	Draw	8	2504.09
GWM-5D	2495.68	Draw	8	2503.68
GWM-6A	2521.92	Draw	8	2529.92
GWM-7	2577.98	Ridge	12	2589.98
GWM-7D	2576.62	Ridge	12	2588.62
GWM-8	2445.01	Draw	8	2453.01
TWD-10	2578.19	Ridge	12	2590.19
TWD-10D	2582.78	Ridge	12	2594.78

- Fluctuations for slopes and ridges were taken from the maximum fluctuations for USGS terrain effects observation wells.
- Fluctuations for draws and valleys was taken from the maximum fluctuations for USGS climatic effects observation wells.
- All observation well data are included in Appendix C.

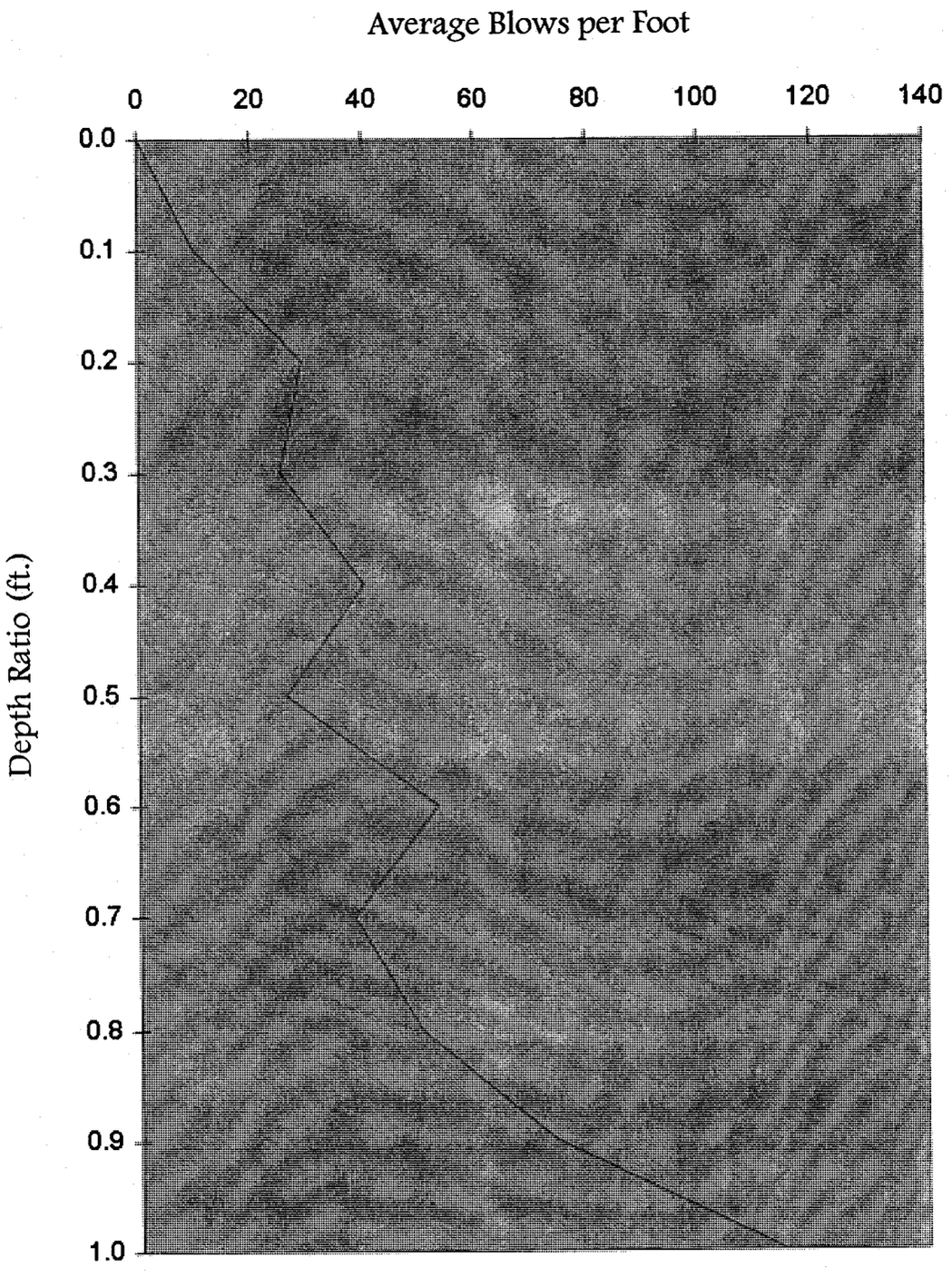


Chart 1. Standard Penetration Test

Appendix A

LOG OF BORING: P-2

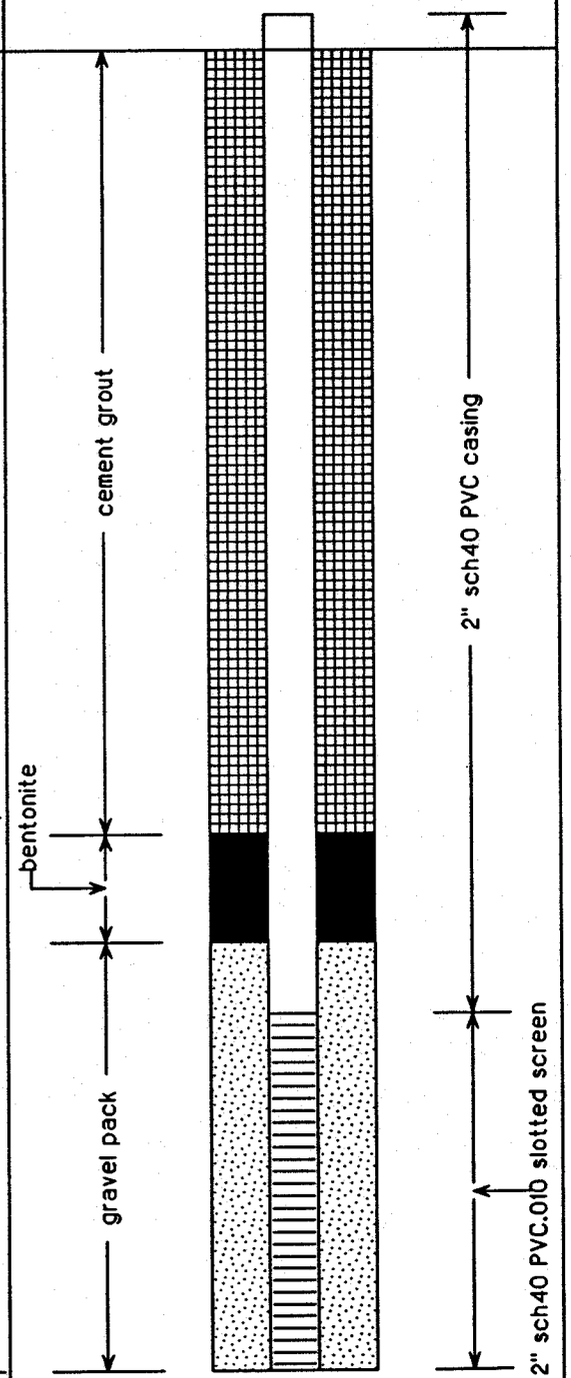
Project: Haywood County
Project No. 698010.5
Type: HSA SS

Drilling Contractor: Graham & Currie
Registration Number: 537

Surface Elevation: 2520.37ft
Top of Casing: 2523.82ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
0	7			SILTY CLAY (CL); brown, firm, damp, grades with coarse sand, trace root debris near surface, damp
	8			-grades with mica, relict structure
5				
	8			SILT (ML); brown, firm, micaceous, grades with fine sand and clay
10				
	7			-grades light brown, relict stucture
15				
	12			
20				
	50/5			PARTIALLY WEATHERED ROCK; gray-green fragments with microcrystalline texture, some silt and coarse sand, clay on fracture surfaces
25				
	ref/5			-grades brown, saturated, iron minerlization between relict layers mineralization between relict layers
30				
	ref/2.5			-dark gray-green, gneissic layering, rust stains on fractures, zones of clayey silt
35				
				End of Boring at Auger Refusal 37.0 feet
40				

PIEZOMETER DIAGRAM



Completion Depth: 37.0 ft
DATE: 4/2/98

Depth to Water: 21.0 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: B-8

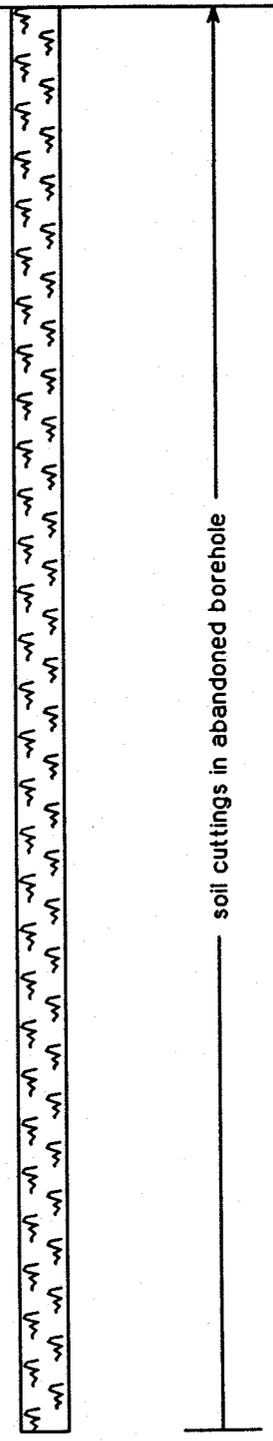
Project: Haywood County
Project No. G98010.5
Type: HSA SS

Drilling Contractor: Graham & Currie
Registration Number: 537

Surface Elevation: N/Aft
Top of Casing: N/Aft

DEPTH (ft)	BLOWS PER FOOT	DESCRIPTION OF MATERIAL
	4	Topsoil top 2"
		SILTY CLAY (CL); red-brown, soft, few angular pebbles and coarse grains
	22	
5		SILT (ML); gray to white, very stiff, pebbles of fine grain white sandstone
	9	
10		
	8	
15		-orange-red, with medium grained sand, trace clay and coarse grains
20	14	-grades stiff, purple-orange, relict structure
25	17	-grades red, some fine to medium sand
30	16	-grades with white and orange layers, trace fine sand and mica, trace clay
35	20	-grades red-purple, very stiff, with yellow veins
		SILTY SAND (SM); trace gravel
40		

PIEZOMETER DIAGRAM



Completion Depth: 120 ft
DATE: 4/21/98

Depth to Water: dry 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: B-8

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

Drilling Contractor: Graham & Currie
Registration Number: 537

Surface Elevation: N/Aft
Top of Casing: N/Aft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
				CLAYEY SILT (ML) grades tan-yellow to brown, relict structure, well sorted
45	20			
				SILT (ML);grades purple with white mottles, some clay, relict stucture
50	30			
55	31			
60	23			-grades orange brown, trace mediume sand, trace mica
65	32			-grades with some clay
70	28			-grades with some mica, relict veins with iron staining
75	37			-grades red-brown with yellow mottles, micaceous
80	27			

PIEZOMETER DIAGRAM

soil cuttings in abandoned borehole

Completion Depth: 120 ft
DATE: 4/21/98

Depth to Water: dry 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: B-8

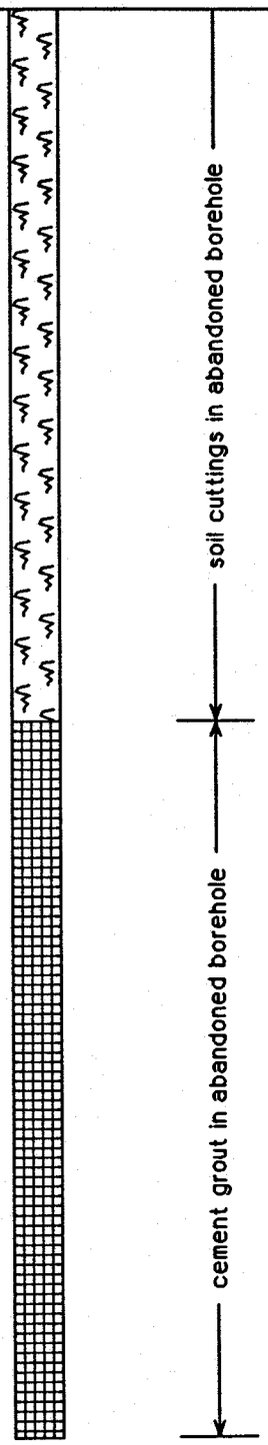
Project: Haywood County
Project No. G98010.5
Type: HSA SS

Drilling Contractor: Graham & Currie
Registration Number: 537

Surface Elevation: N/Aft
Top of Casing: N/Aft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
85	40			-grades pink to red with white mottles, hard, with angular coarse pebbles
90	30			SANDY SILT (ML); brown to red, dense, dry, white highly weathered crystals, black mottles, some mica, relict structure
95	34			-grades light brown to yellow, zones of rust staining
100	30			SILT (ML); light brown, dense, trace medium and coarse grains, micaceous, relict stucture
105	24			-grades damp, with weathered mica and sand layers,
110	40			SANDY SILT (ML); brown with tan layers, dense, moist, black and red banding, trace clay
115	34			-grades with zones of dark brown to black, layers of yellow-tan silt and fine sand, relict structure
120	45			SILT (ML); brown, dense, moist, abundant fine mica, trace medium and coarse grains, zones of iron mineralization

PIEZOMETER DIAGRAM



Completion Depth: 120 ft
DATE: 4/21/98

Depth to Water: dry 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-11

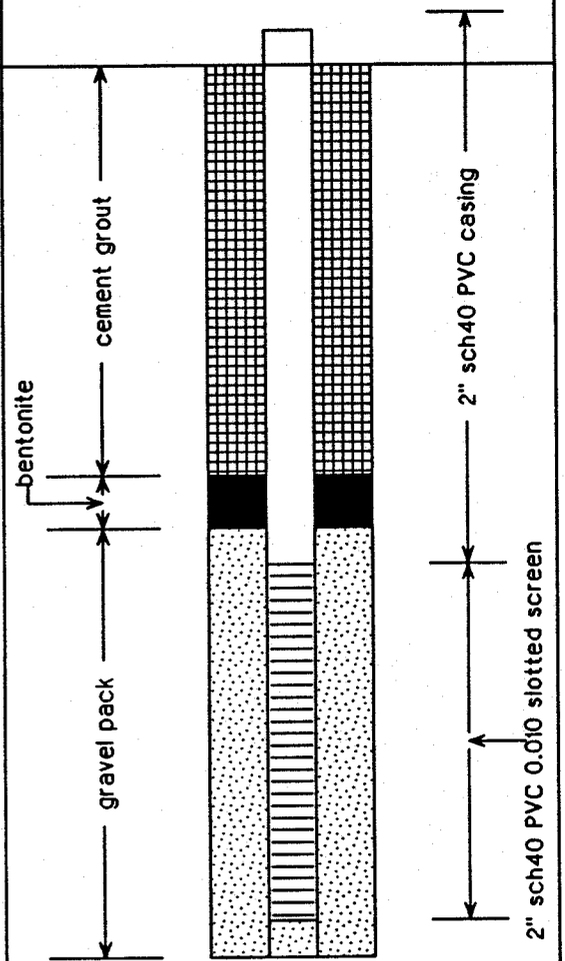
Project: Haywood County
Project No. 698010.5
Type: HSA,SS

Drilling Contractor: Graham & Currie
Registration Number: 537

Surface Elevation: 2551.87ft
Top of Casing: 2553.87ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	4			SILTY CLAY (CL); Medium brown, moist, soft, with medium to coarse sand
5	3			CLAYEY SILT (ML); Brown, moist, soft, some root debris, trace coarse sand and mica
	11			SILT (ML); dark brown, stiff, saprolitic, with mica and fine sand layers, some clay, rust stained relict foliation
10				
15	16			SANDY SILT (ML); black/white gneissic banding, moist, very stiff, saprolitic, some coarse quartz grains
20	50/1			-grades dark brown with tan and orange layers, saturated, very dense, micaceous
25	ref/3			-grades with few rock fragments, some coarse grains, trace mica
				End of Boring at Auger Refusal 25.0 feet
30				
35				
40				

PIEZOMETER DIAGRAM



Completion Depth: 25.0 ft
DATE: 3/18/98

Depth to Water: 17.5 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-12

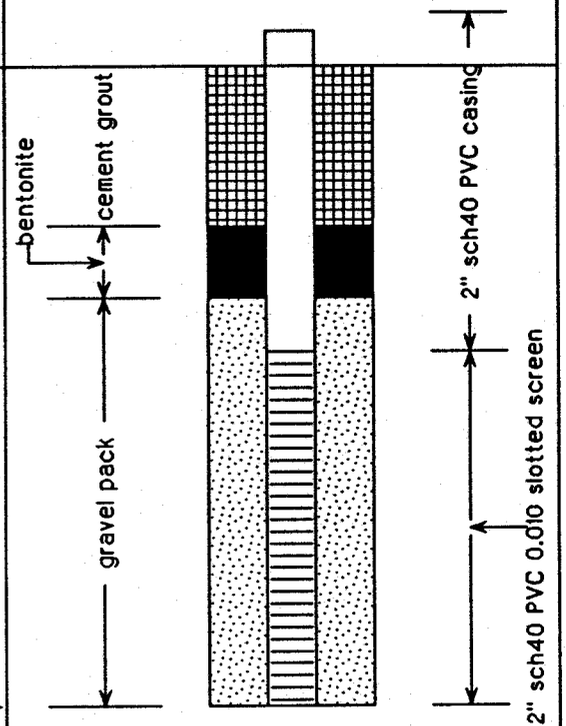
Project: Haywood County
Project No. G98010.5
Type: HSA,SS

Drilling Contractor: Graham & Currie
Registration Number: 537

Surface Elevation: 2555.38ft
Top of Casing: 2557.62ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	7			SILTY CLAY (CL): Dark brown, damp, firm, some coarse sand, trace fine mica
5	12			SILT (ML): Tan to brown, moist, stiff, faint relict structure, some fine mica and coarse sand, trace clay
	8			-grades medium to dark brown, saturated, firm, with medium and coarse sand, 1" layer of gravel at 8'
10				
	12			SILTY SAND (SM): brown with yellow-orange mottles, saturated, stiff, relict gneissic banding, coarse grained
15				
20				End of Boring at Auger Refusal 18.0 feet
25				
30				
35				
40				

PIEZOMETER DIAGRAM



Completion Depth: 18.0 ft
DATE: 3/13/98

Depth to Water: 8.0 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-16

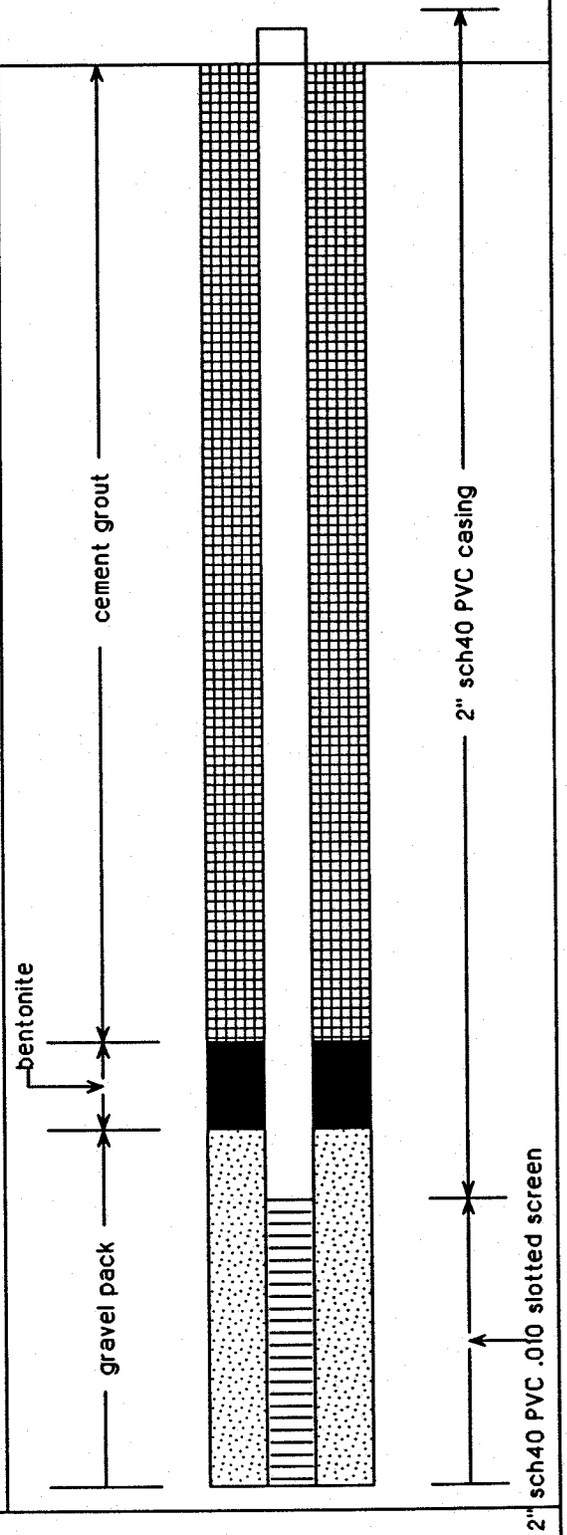
Project: Haywood County
Project No. G98010.5
Type: HSA SS

Drilling Contractor: Graham & Currie
Registration Number: 537

Surface Elevation: 2557.91ft
Top of Casing: 2560.57ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	8			CLAYEY SILT (ML); brown, firm, with fine to medium grained sand, some angular rock fragments
5	7			SANDY SILT (ML); orange-white, loose, fine grained, trace mica, faint relict structure
10	9			-grades with fine to medium grade sand; some mica
	48			SILT (ML); dark brown, saprolite, very hard, relict fractures, micaceous
20	9			-grades white and brown, firm, relict structure, zones of staining
25	18			-grades brown, very stiff, white and black mottles, trace clay, trace rock fragments
30	14			-grades with red and black mottles, damp
35	15			-grades greenish brown, damp, trace clay and sand
40	50/3			-grades with relict phyllitic texture, saturated

PIEZOMETER DIAGRAM



Completion Depth: 42.5 ft
DATE: 3/29/98

Depth to Water: 36.0 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-16

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

Drilling Contractor: Graham & Currie
Registration Number: 537

Surface Elevation: 2557.91ft
Top of Casing: 2560.57ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	PIEZOMETER DIAGRAM
					gravel pack; 2" sch40 PVC .010 slotted screen
				End of Boring at Auger Refusal 42.5 feet	
45					
50					
55					
60					
65					
70					
75					
80					

Completion Depth: 42.5 ft
DATE: 3/29/98

Depth to Water: 36.0 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: P2-1

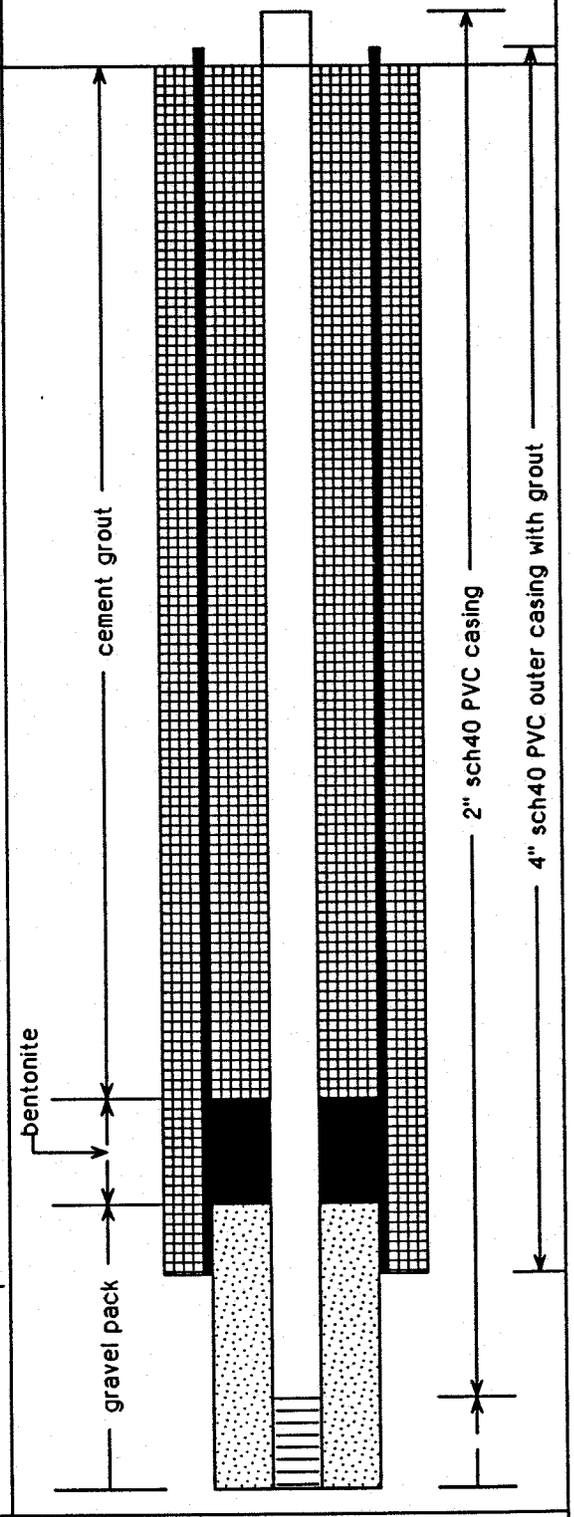
Project: Haywood County
Project No. G98010.5
Type: HSA SS NQ AH

Drilling Contractor: Graham & Currie
Registration Number: 537

Surface Elevation: 2572.74ft
Top of Casing: 2575.93ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL
	6			SILTY SAND (SM); brown to dark brown, some clay, root debris
5	7			-brown, with medium grained sand, some mica and trace clay, some root debris
	11			-grades stiff, with medium to coarse grained sand and mica
10				
15	24			-red to brown, very stiff, grades with more coarse grained sand, relict foliations, zones of clayey sand
20	26			-grades with less sand, trace clay
				-grades olive brown, silty, some clay
25	39			-salt and pepper color, dense, medium to coarse grained, some gravel, near vertical clay-filled fracture, saprolite
30	57			-grades very dense, rock fragments, gneissic structure, grades to orange weathered rock, quartz grains with sand and silt, biotite layer
				Auger Refusal at 34.0 feet
35				GNEISS; quartz, plagioclase, and mafic minerals, faint banding fractures at 30 degrees, REC=92%, RQD=79%
				-highly weathered zone, REC=59%, RQD=0%
40				

PIEZOMETER DIAGRAM



Completion Depth: 52.5 ft
DATE: 5/21/98

Depth to Water: 37 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: P2-1

Project: Haywood County
ect No. 698010.5
Type: HSA SS NQ AH

Drilling Contractor: Graham & Currie
Registration Number: 537

Surface Elevation: 2572.74ft
Top of Casing: 2575.93ft

DEPTH (ft)	BLOWS PER FOOT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	PIEZOMETER DIAGRAM
45				-REC=85%, RQD=52% -slightly weathered, fractures parallel to banding at 30 degrees REC=100%, RQD=92%	gravel pack; 2" sch40 PVC .010 slotted screen
50					
				End of Boring at 52.5 feet	
55					
60					
65					
70					
75					
80					

Completion Depth: 52.5 ft
DATE: 5/21/98

Depth to Water: 37 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

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	8.1	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	6.5	double	r-multiple
P-3	67.6	1.5	52.6	15.0		54.1				2	3.375	0.0833	0.1406	69.1		
P-4	81.0	1.5	71.0	10.0		72.5				1	2.000	0.0417	0.0833	82.5		
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	26.8	single	single
P-6	67.5	1.5	57.5	10.0		59.0	58.44	58.65	0.21	2	3.375	0.0833	0.1406	9.8		
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	9.6	double	r-double
P-9	47.3	1.5	37.3	10.0		38.8	36.00	36.14	0.14	2	3.375	0.0833	0.1406	11.7		
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	26.0	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	8.8	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	10.7	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	21.1	single	single
P-14	81.3	1.5	71.3	10.0		72.8				1	2.000	0.0417	0.0833	82.8		
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	24.9	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	18.7	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	10.6	multiple	multiple
P-18	41.0	1.5	31.0	10.0		32.5				1	2.000	0.0417	0.0833	42.5		
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	28.6	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	11.5		
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	6.2		

* 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*.

Flow Rates and Directions
White Oak Lined Landfill, Haywood County, North Carolina

Piezometer	Geomorphology	Lithology	Screen Interval (ft.-ft.)	Hydraulic Conductivity (cm/sec) *	Effective Porosity (%)	Δh (ft.)	Δl (ft.)	Δh / Δl	Flow Rate (ft./yr.) **	Flow Direction
P-1	ridge	Gneiss	65.0-80.0	1.25E-04	5.00%	33.48	176.08	0.190	493.77	N90W
P-2	draw	PWR	27.0-37.0	1.24E-04	10.00%	15.10	141.41	0.107	137.48	S85W
P-3	ridge	Gneiss	52.6-67.6	2.26E-04	5.00%	85.62	194.04	0.441	2064.53	N16E
P-4	ridge	Gneiss	71.0-81.0	2.26E-04	5.00%	54.80	242.00	0.226	1059.50	N23W
P-5	draw	Gneiss	42.3-52.3	1.67E-04	5.00%	35.32	169.71	0.208	717.24	N14W
P-6	slope	Gneiss	57.5-67.5	4.63E-04	5.00%	38.68	194.32	0.199	1905.52	N23W
P-7	slope	Gneiss	32.0-42.0	1.02E-04	5.00%	4.95	152.30	0.033	68.49	N86W
P-9	valley	Gneiss	37.3-47.3	6.87E-04	5.00%	12.18	149.47	0.081	1158.98	N86W
P-10	ridge	Saprolite	63.0-73.0	2.82E-04	11.40%	7.81	182.32	0.043	109.61	N48E
P-11	draw	Saprolite	14.0-24.0	1.95E-04	11.40%	10.98	130.99	0.084	147.99	N35W
P-12	draw	Saprolite	8.0-18.0	2.35E-04	11.40%	26.17	244.42	0.107	228.44	N29W
P-13	ridge	Saprolite	86.0-96.0	7.12E-06	11.40%	25.48	205.57	0.124	8.01	N72W
P-14	head of slope	Gneiss	71.3-81.3	2.26E-04	5.00%	30.78	453.25	0.068	317.74	N12E
P-15	ridge	PWR	93.0-103.0	1.18E-05	10.00%	22.12	170.93	0.129	15.78	S53E
P-16	slope	Saprolite	32.5-42.5	1.66E-04	11.40%	38.71	305.83	0.127	190.79	S78E
P-17	slope	Gneiss	80.0-90.0	7.54E-06	5.00%	106.65	191.65	0.556	86.81	N72E
P-18	slope	PWR	31.0-41.0	6.81E-05	10.00%	73.52	259.06	0.284	200.00	S69E
P-19	slope	Gneiss	87.5-97.5	3.14E-05	5.00%	86.09	260.36	0.331	214.81	N22E
P2-1	head of slope	Gneiss	37.5-52.5	2.26E-04	5.00%	7.95	75.81	0.105	490.66	N51W
P2-2	head of slope	Gneiss	32.3-47.3	2.26E-04	5.00%	5.93	99.89	0.059	277.76	N51W
GWM-1A	slope	Saprolite	10.4-25.4	1.50E-04	11.40%	21.87	128.12	0.171	233.04	N28E
GWM-2	draw	Saprolite	19.9-34.9	1.50E-04	11.40%	33.57	293.60	0.114	156.10	N03W
GWM-3	draw	Saprolite	5.6-20.6	1.50E-04	11.40%	21.59	292.33	0.074	100.83	N38W
GWM-4A	slope	Gneiss	85.2-100.2	2.26E-04	5.00%	36.29	196.20	0.185	865.42	N27E
GWM-5A	draw	Saprolite	4.5-19.5	1.50E-04	11.40%	28.24	338.68	0.083	113.83	N26W
GWM-6A	draw	Saprolite	3.4-18.4	1.50E-04	11.40%	27.73	444.69	0.062	85.13	N47W
GWM-7	ridge	PWR	62.3-82.3	6.81E-05	10.00%	31.37	223.84	0.140	98.77	N76E
GWM-8	draw	Saprolite	31.0-41.0	1.50E-04	11.40%	28.77	172.64	0.167	227.51	N27E

* Underlined values are calculated means from each lithology.

** Underlined values are estimated values based on mean hydraulic conductivities.

Hydraulic considerations
White Oak Lined Landfill, Haywood County, North Carolina

Piezometer	Geomorphology	Lithology	Hydraulic Conductivity (cm/sec) **	Test Method
P-1	ridge	Gneiss	7.45E-04	Bail-Down
P-2	draw	PWR	2.25E-04	Bail-Down
P-3	ridge	Gneiss	2.26E-04	
P-4	ridge	Gneiss	2.26E-04	
P-5	draw	Gneiss	2.32E-04	Bail-Down
P-6	slope	Gneiss	1.39E-05	Bail-Down
P-7	slope	Gneiss	2.26E-04	Bail-Down
P-8	ridge	Saprolite	1.50E-04	
P-9	valley	Gneiss	6.86E-05	Bail-Down
P-10	ridge	Saprolite	2.05E-04	Bail-Down
P-11	draw	Saprolite	1.64E-04	Bail-Down
P-12	draw	Saprolite	8.10E-04	Bail-Down
P-13	ridge	Saprolite	2.40E-06	Bail-Down
P-14	head of slope	Gneiss	2.26E-04	
P-15	ridge	PWR	1.06E-05	Bail-Down
P-16	slope	Saprolite	1.35E-04	Bail-Down
P-17	slope	Gneiss	7.42E-06	Bail-Down
P-18	slope	PWR	6.81E-05	
P-19	slope	Gneiss	1.03E-06	Bail-Down
P2-1	head of slope	Gneiss	7.71E-04	Bail-Down
P2-2	head of slope	Gneiss	8.24E-05	Bail-Down

Lithology	Piezometer Tested	Hydraulic Conductivity (cm/sec)	Descriptive Statistics	
Saprolite	P-10	2.82E-04	Mean:	1.50E-04
	P-11	1.95E-04	Standard Error:	3.89E-05
	P-12	2.35E-04	Median:	1.66E-04
	P-13	7.12E-06	Mode:	#N/A
	P-16	1.66E-04	Standard Deviation:	1.03E-04
	B-8 @ 39 ft.†	2.22E-05	Minimum:	7.12E-06
	P-9 @ 8 ft.†	1.46E-04	Maximum:	2.82E-04
PWR	P-2	1.24E-04	Mean:	6.81E-05
	P-15	1.18E-05	Standard Error:	5.63E-05
Fractured Gneissic Bedrock	P-1	1.25E-04	Mean:	2.26E-04
	P-5	1.67E-04	Standard Error:	9.56E-05
	P-6	4.63E-04	Median:	1.25E-04
	P-7	1.02E-04	Mode:	#N/A
	P-9	6.87E-04	Standard Deviation:	2.53E-04
	P-17	7.54E-06	Minimum:	7.54E-06
	P-19	3.14E-05	Maximum:	6.87E-04
	P2-1	-		
	P2-2	-		

* All hydraulic conductivity values were calculated from field data using the Bouwer and Rice (1976) method.

** Underlined values are calculated means from each lithology.

† Values are derived from laboratory run in-situ permeability tests

Average of flow rates and effective porosity for lithologic units
White Oak Lined Landfill, Haywood County, North Carolina

Saprolite	Effective Porosity (%)
P-1	15.5
P-8	14.5
P-8	8.0
P-9	1.0
P-9	16.0
P-14	9.5
P-15	15.5
P2-1	13.0
P2-1	6.0
P2-2	14.5
average:	11.4

PWR	Effective Porosity (%)*
P-2	10.0
P-15	10.0
P-18	10.0
average:	10.0

Gneiss	Effective Porosity (%)*
default:	5.0

Saprolite	Flow Rate (ft./yr.)
P-10	109.61
P-11	147.99
P-12	228.44
P-13	8.01
P-16	190.79
GWM-1A	233.04
GWM-2	156.1
GWM-3	100.83
GWM-5A	113.83
GWM-6A	85.13
GWM-8	227.51
total:	1601.28
average:	145.57

Gneiss	Flow Rate (ft./yr.)
P-1	493.77
P-3	2064.53
P-4	1059.50
P-5	717.24
P-6	1905.52
P-7	68.49
P-9	1158.98
P-14	317.74
P-17	86.81
P-19	214.81
P2-1	490.66
P2-2	277.76
total:	8855.81
average:	737.98

PWR	Flow Rate (ft./yr.)
P-2	137.48
P-15	15.78
P-18	200.00
GWM-7	98.77
total:	452.03
average:	113.01

* Effective porosity values for PWR and fractured gneiss are default values based on porosity of fractured crystalline rocks (Fetter, 1994) and degree of fracturing in core samples.

Total Porosity Calculations
White Oak Lined Landfill, Haywood County, North Carolina

Total porosity (n) is defined as the ratio of void volume to total volume and may range from a small fraction to about 0.90.

$$n_p = \frac{V_v}{V} = \frac{V - V_m}{V} = 1 - \frac{V_m}{V} = 1 - \frac{q_d}{q_w G_s}$$

where

n_p = porosity
V_V = volume of voids
V = total volume of sample
V_m = volume of the soil (material)
q_w = unit weight of water (62.4 lb/cf)

Saprolite	Gs
P2-1	2.71
P2-1	2.69
P2-1	2.71
P2-1	2.72
P2-2	2.75
P-1	2.83
P-8	2.73
P-8	2.74
P-9	2.68
P-9	2.72
P-14	2.75
P-15	2.65
average:	2.72

Saprolite*	Dry Density (q_d)	123.55
	Specific Gravity (G_s)	2.72
	Total Porosity (n_p)	**27%**

* Values derived from Table1.4 by Peck, Hanson and Thornburn, 1973.

Vertical Flow Rates
White Oak Lined Landfill, Haywood County, North Carolina

Date	GWM-2	GWM-2A	dh†	V_z* (ft/yr)	Descriptive Statistics	
06/09/98	2467.64	2467.44	-0.20	-47.72	Mean:	94.96
07/07/98	2467.20	2467.42	0.22	52.49	Standard Error:	31.66
08/17/98	2466.43	2467.43	1.00	238.60	Median:	52.49
09/25/98	2465.90	2466.14	0.24	57.26	Mode:	52.49
10/27/98	2465.82	2466.04	0.22	52.49	Standard Deviation:	100.13
12/02/98	2465.76	2465.98	0.22	52.49	Kurtosis:	-0.994
01/13/99	2466.00	2466.21	0.21	50.11	Skewness:	0.609
02/11/99	2466.60	2466.74	0.14	33.40	Range:	286.32
06/21/99	2467.06	2468.03	0.97	231.44	Minimum:	-47.72
08/10/99	2466.92	2467.88	0.96	229.06	Maximum:	238.60

Date	GWM-3	GWM-3D	dh†	V_z* (ft/yr)	Descriptive Statistics	
06/09/98	2430.10	2421.65	-8.45	-2377.69	Mean:	-2144.43
07/07/98	2429.58	2421.62	-7.96	-2239.81	Standard Error:	53.09
08/17/98	2428.41	2420.59	-7.82	-2200.42	Median:	-2215.90
09/25/98	2427.31	2420.05	-7.26	-2042.85	Mode:	#N/A
10/27/98	2426.89	2419.75	-7.14	-2009.08	Standard Deviation:	167.89
12/02/98	2426.31	2419.74	-6.57	-1848.69	Kurtosis:	-0.831
01/13/99	2426.48	2419.51	-6.97	-1961.24	Skewness:	0.514
02/11/99	2428.26	2420.20	-8.06	-2267.95	Range:	529.00
06/21/99	2428.16	2420.23	-7.93	-2231.37	Minimum:	-2377.69
08/10/99	2428.55	2420.50	-8.05	-2265.14	Maximum:	-1848.69

Date	GWM-5A	GWM-5D	dh†	V_z* (ft/yr)	Descriptive Statistics	
06/09/98	2497.70	2496.62	-1.08	-313.71	Mean:	-208.56
07/07/98	2497.04	2496.23	-0.81	-235.28	Standard Error:	26.72
08/17/98	2496.76	2496.07	-0.69	-200.43	Median:	-200.43
09/25/98	2496.43	2495.90	-0.53	-153.95	Mode:	-200.43
10/27/98	2496.36	2495.88	-0.48	-139.43	Standard Deviation:	84.51
12/02/98	2496.15	2495.68	-0.47	-136.52	Kurtosis:	0.101
01/13/99	2496.09	2495.75	-0.34	-98.76	Skewness:	-0.773
02/11/99	2497.76	2496.48	-1.28	-371.80	Range:	273.04
06/21/99	2496.51	2495.82	-0.69	-200.43	Minimum:	-371.80
08/10/99	2496.80	2495.99	-0.81	-235.28	Maximum:	-98.76

Vertical Flow Rates
White Oak Lined Landfill, Haywood County, North Carolina

Date	GWM-7	GWM-7D	dh†	V_z* (ft/yr)	Descriptive Statistics	
06/09/98	2581.50	2579.62	-1.88	-430.98	Mean:	-401.87
07/07/98	2581.92	2579.80	-2.12	-486.00	Standard Error:	60.52
08/17/98	2581.37	2579.39	-1.98	-453.91	Median:	-453.91
09/25/98	2580.67	2578.67	-2.00	-458.49	Mode:	-453.91
10/27/98	2579.18	2578.19	-0.99	-226.95	Standard Deviation:	191.39
12/02/98	2579.48	2577.50	-1.98	-453.91	Kurtosis:	3.128
01/13/99	2578.81	2577.10	-1.71	-392.01	Skewness:	1.292
02/11/99	2578.64	2576.62	-2.02	-463.07	Range:	731.29
06/21/99	2577.98	2578.15	0.17	38.97	Minimum:	-692.32
08/10/99	2580.14	2577.12	-3.02	-692.32	Maximum:	38.97

Date	TWD-10	TWD-10D	dh†	V_z* (ft/yr)	Descriptive Statistics	
06/09/98	2588.21	2588.00	-0.21	-11.91	Mean:	16.68
07/07/98	2587.74	2587.57	-0.17	-9.64	Standard Error:	30.07
08/17/98	2586.48	2586.33	-0.15	-8.51	Median:	-7.37
09/25/98	2585.17	2585.04	-0.13	-7.37	Mode:	-7.37
10/27/98	2584.20	2584.08	-0.12	-6.81	Standard Deviation:	95.08
12/02/98	2578.19	2583.10	4.91	278.51	Kurtosis:	8.414
01/13/99	2584.74	2583.41	-1.33	-75.44	Skewness:	2.757
02/11/99	2582.86	2582.78	-0.08	-4.54	Range:	353.96
06/21/99	2584.06	2584.41	0.35	19.85	Minimum:	-75.44
08/10/99	2584.06	2583.93	-0.13	-7.37	Maximum:	278.51

* V_z denotes vertical flow rate, and is defined by the equation

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

where
V_z = vertical flow rate (ft/yr)
K = hydraulic conductivity (cm/sec)
n_e = effective porosity
dh = head difference (ft.)
dl = vertical separation (ft.)

† Negative dh values indicate downward flow gradient.

Bail-Down Test Piezometer P-13

Project Name White Oak Landfill - Haywood County

Initial Depth to Water (feet) **(Ho)** 75.87
Depth to Water (feet) at to **(H)** 84
Initial Change in Head (feet), **(yo)** 8.13

Time (h:mm:ss)	Time (mm:ss)	Time (sec)	Time Elapsed (sec)	DTW (ft) [H]	Change (ft) [H-Ho]
12:28:40	0	0	0	84.00	8.13
12:28:51	00:11	11	11	83.98	8.11
12:28:58	00:07	7	18	83.96	8.09
12:29:05	00:07	7	25	83.94	8.07
12:29:16	00:11	11	36	83.92	8.05
12:29:27	00:11	11	47	83.90	8.03
12:29:54	00:27	27	74	83.85	7.98
12:30:12	00:18	18	92	83.80	7.93
12:30:49	00:37	37	129	83.75	7.88
12:31:24	00:35	35	164	83.70	7.83
12:32:05	00:41	41	205	83.65	7.78
12:32:42	00:37	37	242	83.60	7.73
12:33:17	00:35	35	277	83.55	7.68
12:34:00	00:43	43	320	83.50	7.63
12:34:49	00:49	49	369	83.45	7.58
12:35:27	00:38	38	407	83.40	7.53
12:36:00	00:33	33	440	83.35	7.48
12:36:40	00:40	40	480	83.30	7.43
12:37:22	00:42	42	522	83.25	7.38
12:38:02	00:40	40	562	83.20	7.33
12:38:51	00:49	49	611	83.15	7.28
12:39:52	01:01	61	672	83.10	7.23
12:41:04	01:12	72	744	83.05	7.18
12:42:10	01:06	66	810	83.00	7.13
12:44:45	02:35	155	965	82.90	7.03
12:47:06	02:21	141	1106	82.80	6.93
12:49:28	02:22	144	1250	82.70	6.83
12:51:54	02:26	146	1396	82.60	6.73
12:54:28	02:34	154	1550	82.50	6.63
12:57:07	02:39	159	1709	82.40	6.53
12:59:50	02:43	163	1872	82.30	6.43
13:02:34	02:44	164	2036	82.20	6.33
13:05:38	03:04	184	2220	82.10	6.23
13:08:09	02:31	151	2371	82.00	6.13
13:11:07	02:58	178	2549	81.90	6.03
13:13:58	02:51	171	2720	81.80	5.93
13:17:14	03:16	196	2916	81.70	5.83
13:20:20	03:06	186	3102	81.60	5.73
13:23:36	03:16	196	3298	81.50	5.63
14:43:10	19:34	4774	8072	79.48	3.61

14:43:30	00:20	20	8092	79.47	3.60
14:44:30	01:00	60	8152	79.45	3.58
14:47:22	02:52	172	8324	79.40	3.53
14:50:22	03:00	180	8504	79.35	3.48
14:52:32	02:10	130	8634	79.30	3.43
14:55:15	02:43	163	8797	79.25	3.38
14:57:46	02:31	151	8948	79.20	3.33
15:00:37	02:51	171	9119	79.15	3.28
15:03:33	02:56	176	9295	79.10	3.23
15:06:23	02:50	170	9465	79.05	3.18
15:09:09	02:46	166	9631	79.00	3.13
15:11:15	02:06	126	9757	78.95	3.08
15:14:51	03:36	216	9973	78.90	3.03
15:17:59	03:08	188	10161	78.85	2.98
15:21:10	03:11	191	10352	78.80	2.93
15:23:55	02:45	165	10517	78.75	2.88
15:26:25	02:30	150	10667	78.70	2.83
15:30:00	03:35	215	10882	78.65	2.78
15:33:24	03:24	204	11086	78.60	2.73
15:36:48	03:24	204	11290	78.55	2.68
15:40:01	03:13	213	11503	78.50	2.63

Bail-Down Calculations Piezometer P-13

Project Name: White Oak Landfill - Haywood County

Lithology: Sandy Silt

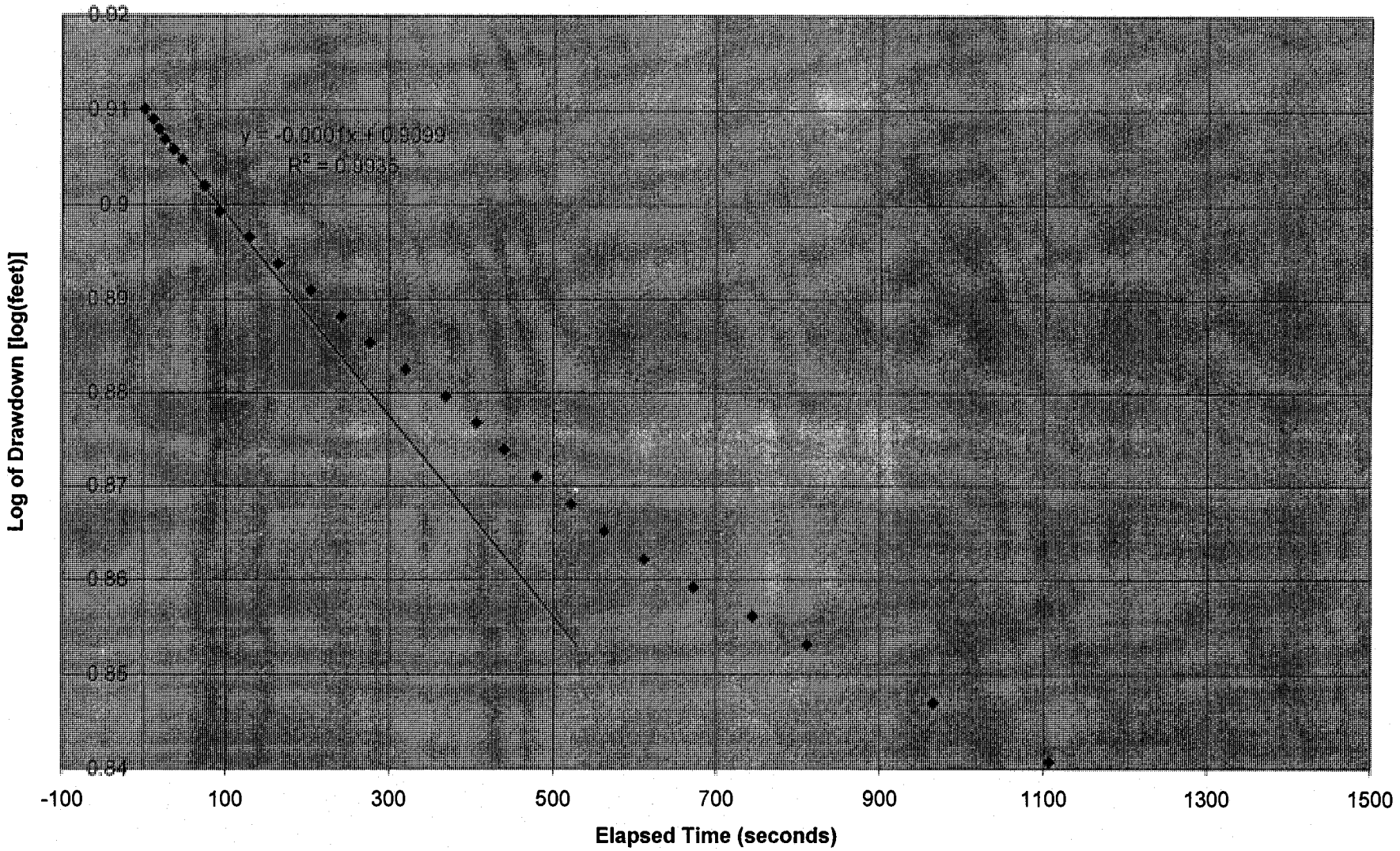
Hydraulic Conductivity by Bouwer and Rice (1976)

	K	hydraulic conductivity
0.0833	**rc**	radius of the well casing (feet)
0.1771	**rw**	radius of the gravel pack (feet)
	Re	effective radius over which head is dissipated (feet)
10	**Le**	the open section of the well through which water can enter (feet)
8.12	**yo**	drawdown at time = 0 (seconds)
7.88	**yt**	drawdown time at t = t (seconds)
129	**t**	elapsed time between yo and yt
3.20	**A**	dimensionless parameter
0.55	**B**	dimensionless parameter
21.1	**Lw**	initial water column in well

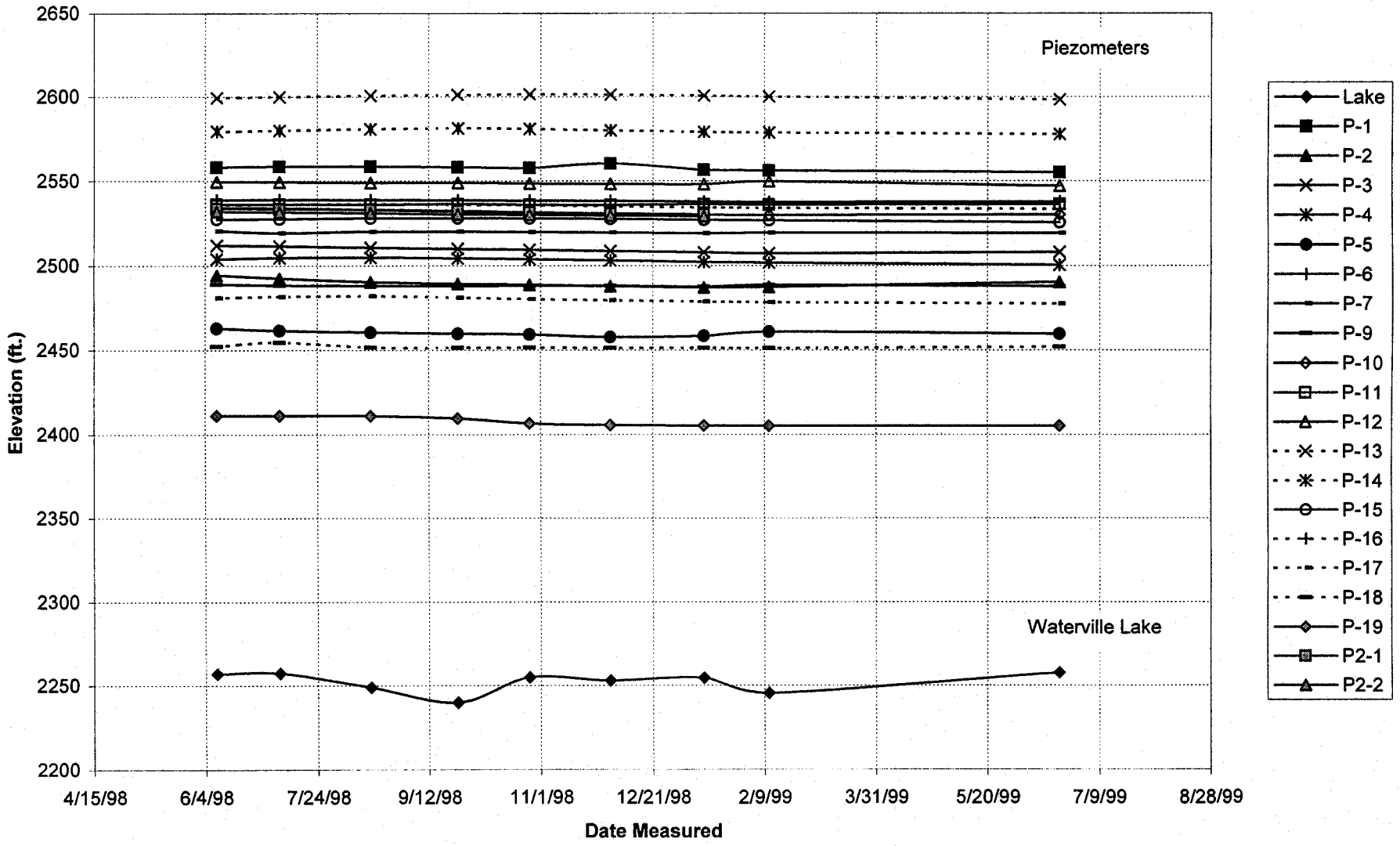
ln(Re/rw)= 2.8967

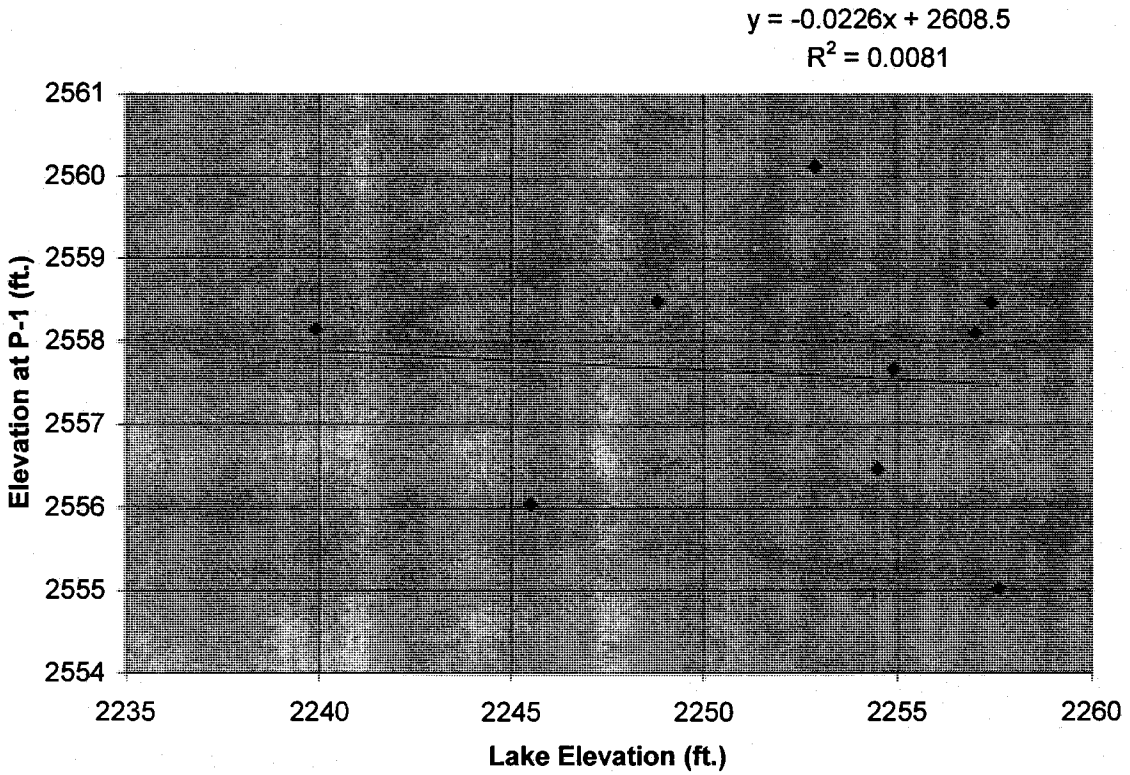
K=	2.34E-07	feet/sec
	7.12E-06	cm/sec
	7.37	feet/year
	2.25	meter/year

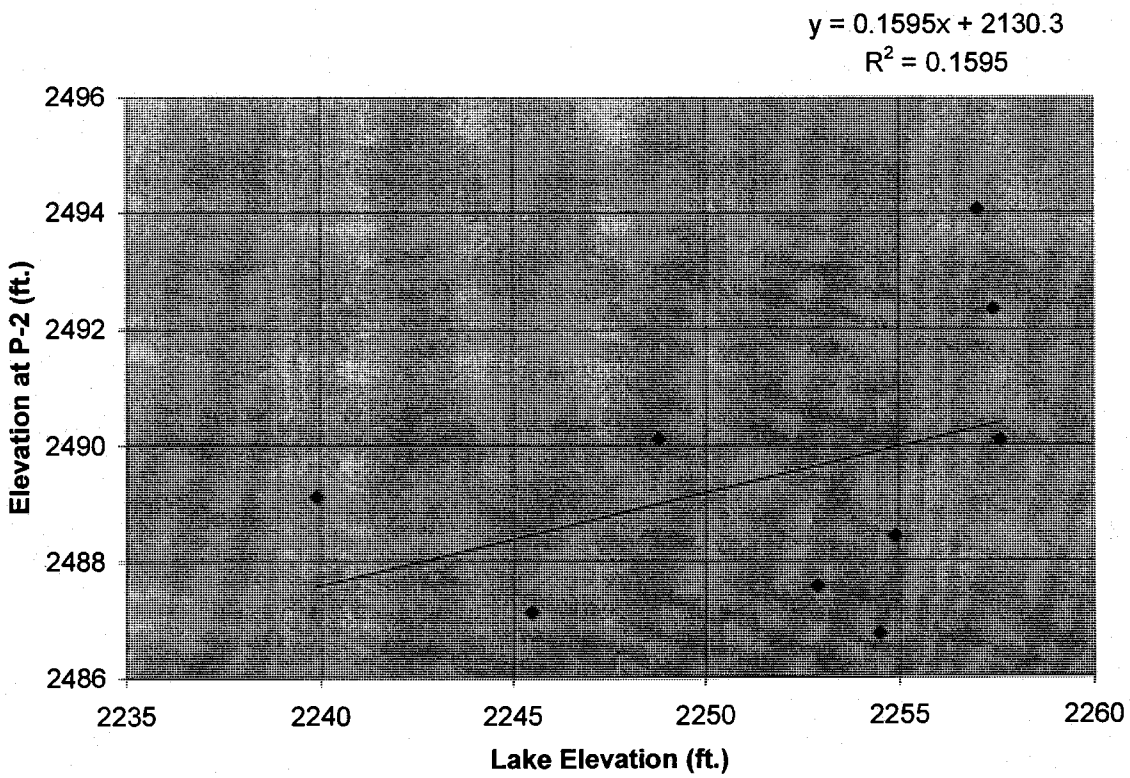
Bail-Down Test P-13 (t = 0 to 1500)

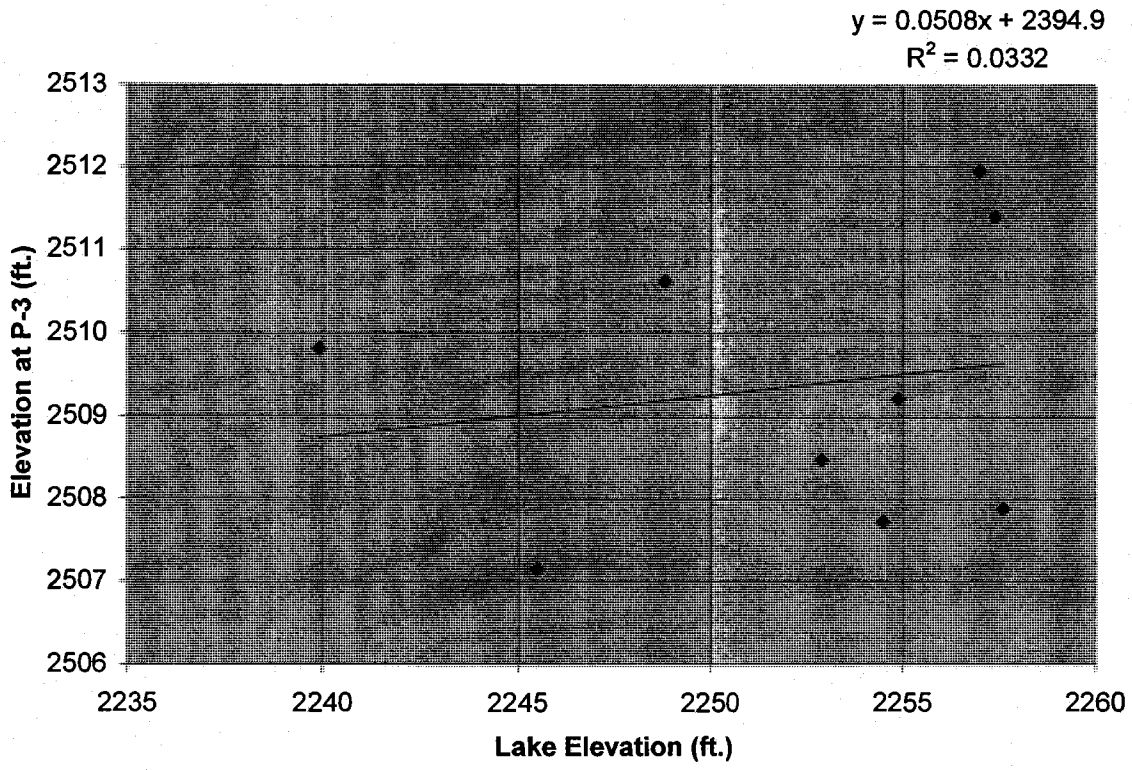


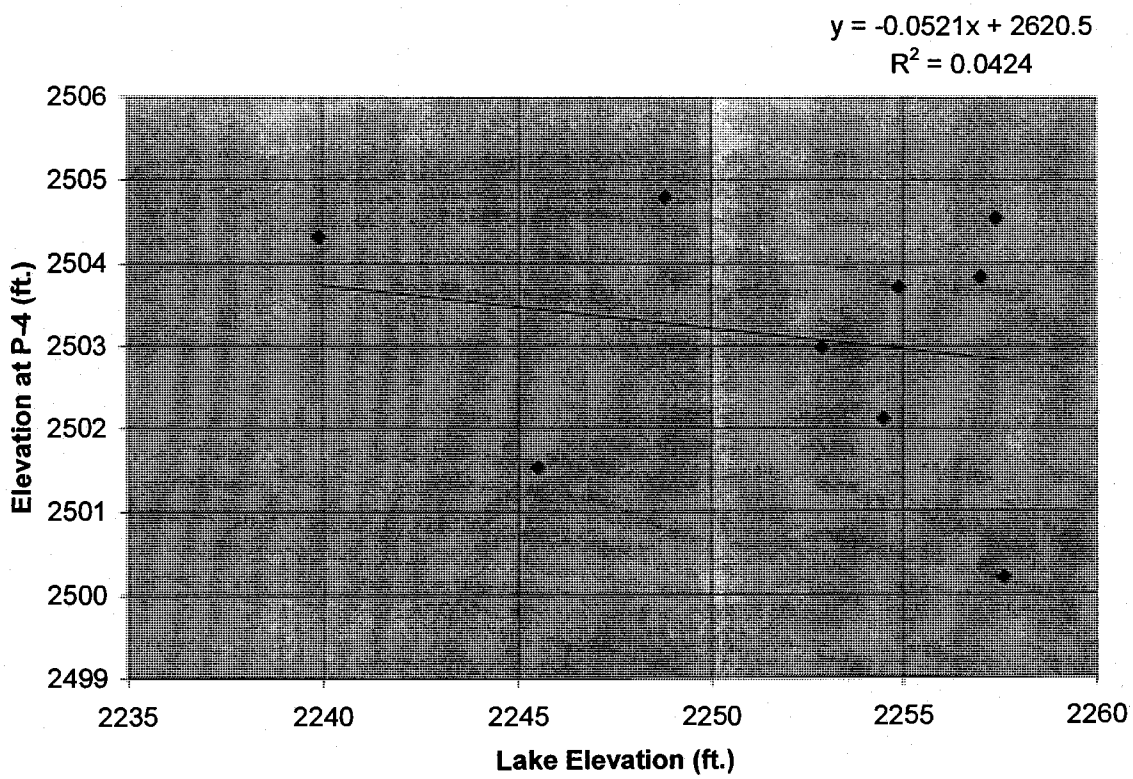
Water Table Elevations - White Oak Lined Landfill, Haywood County, North Carolina

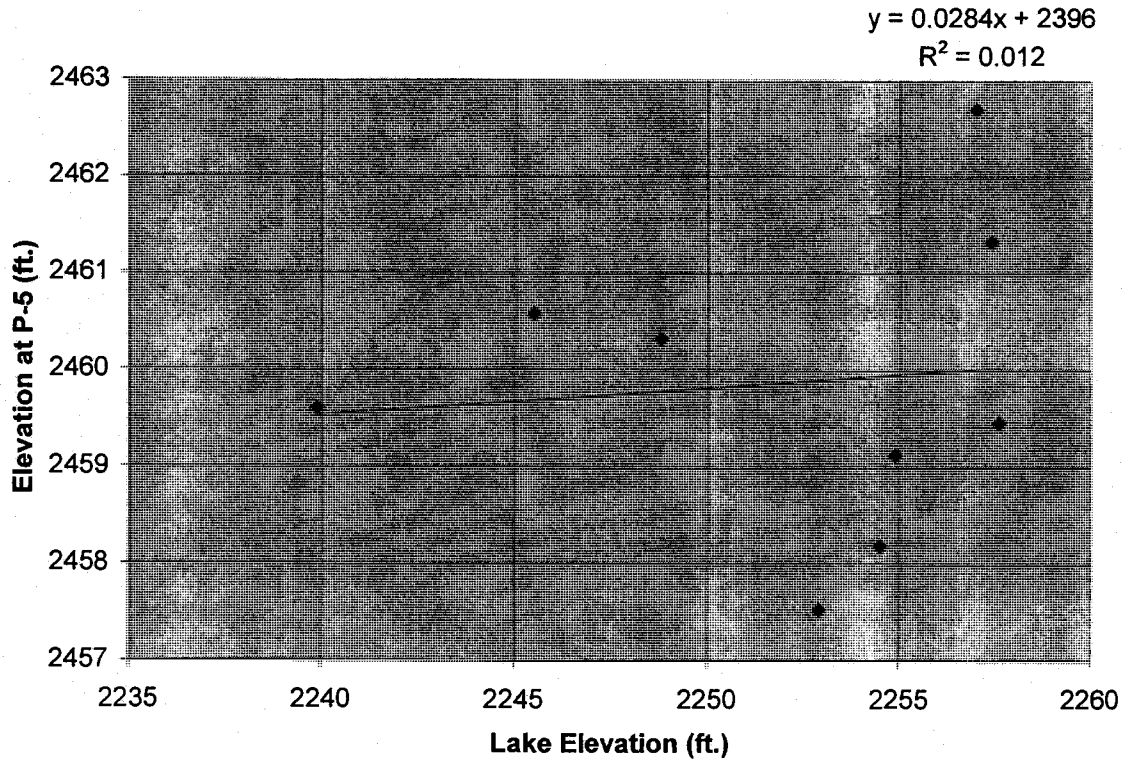


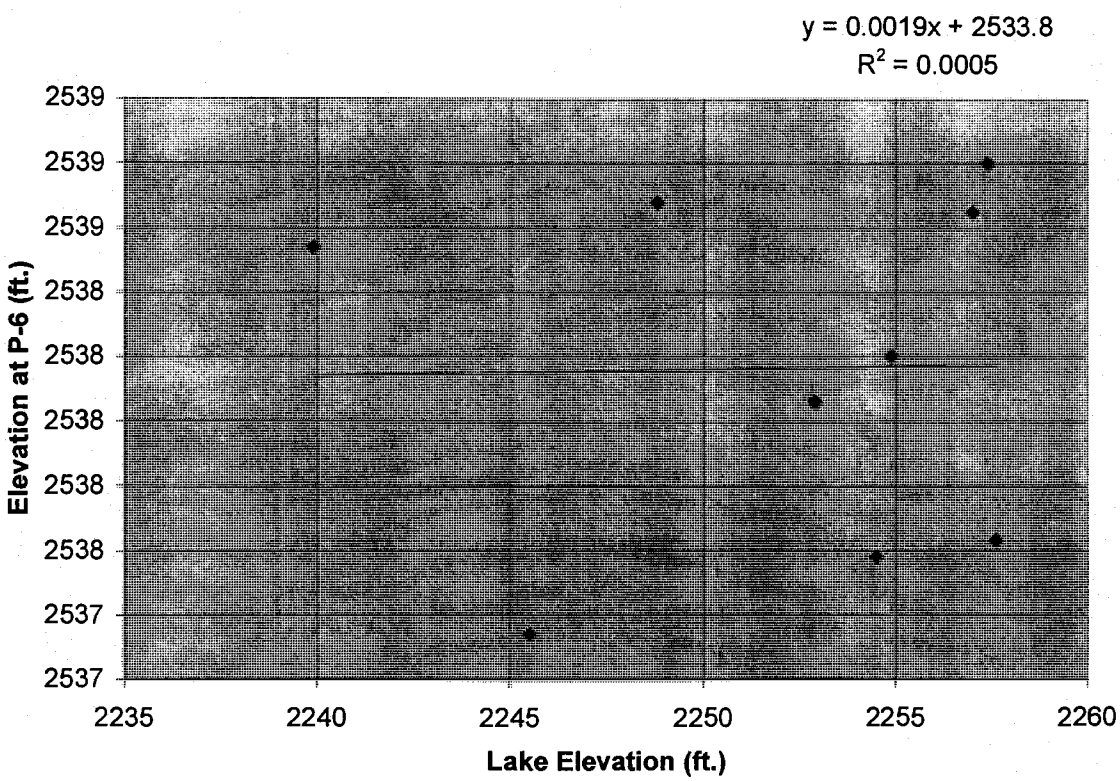

y = -0.0226x + 2608.5
R2 = 0.0081
Elevation at P-1 (ft.)
2561
2560
2559
2558
2557
2556
2555
2554
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

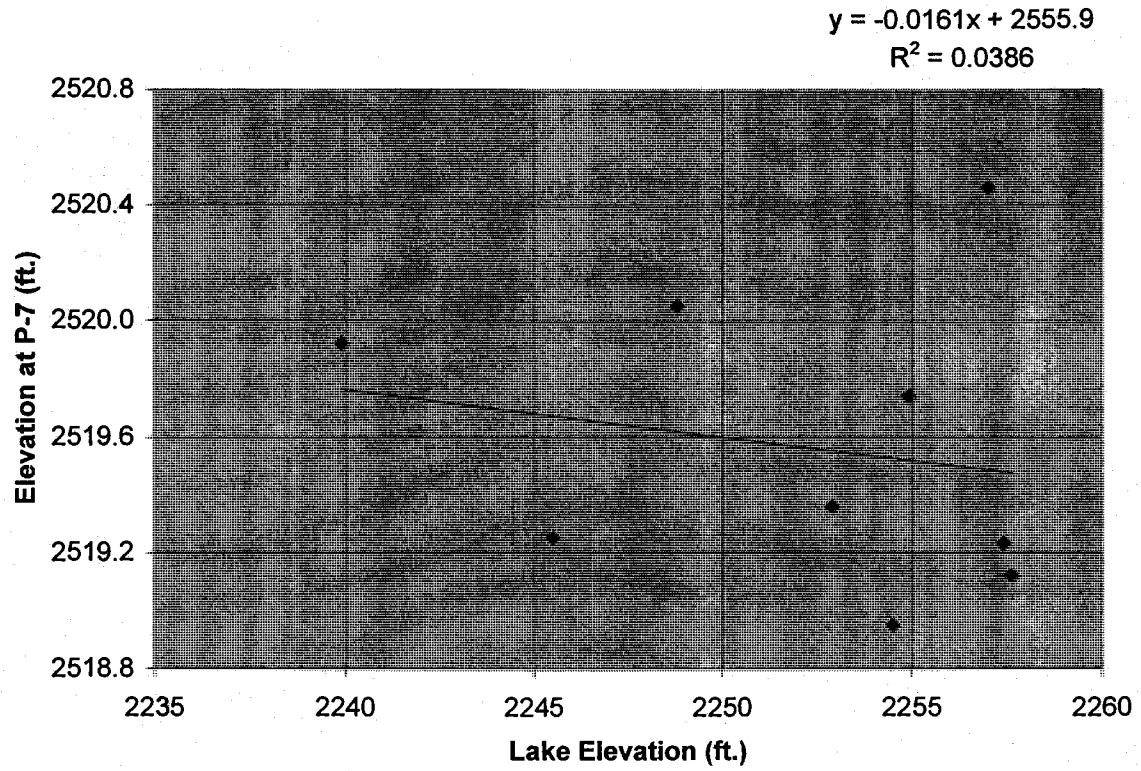

y = 0.1595x + 2130.3
R2 = 0.1595
Elevation at P-2 (ft.)
2496
2494
2492
2490
2488
2486
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

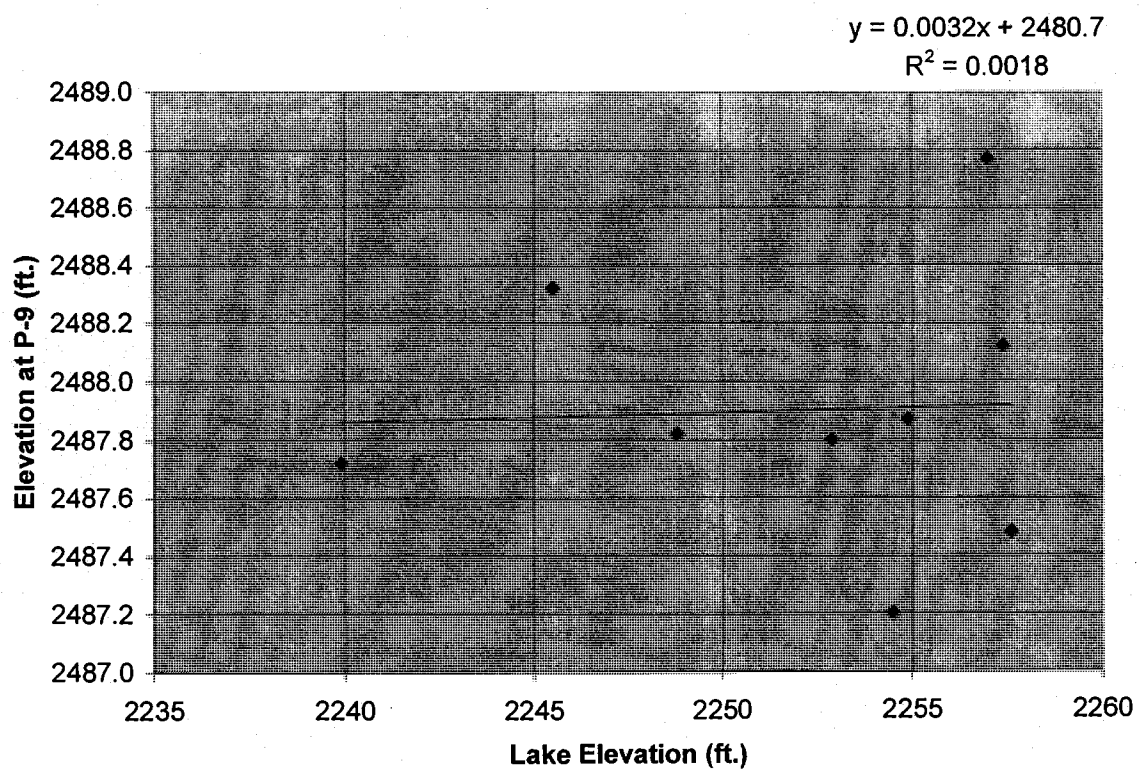

y = 0.0508x + 2394.9
R² = 0.0332
Elevation at P-3 (ft.)
2513
2512
2511
2510
2509
2508
2507
2506
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

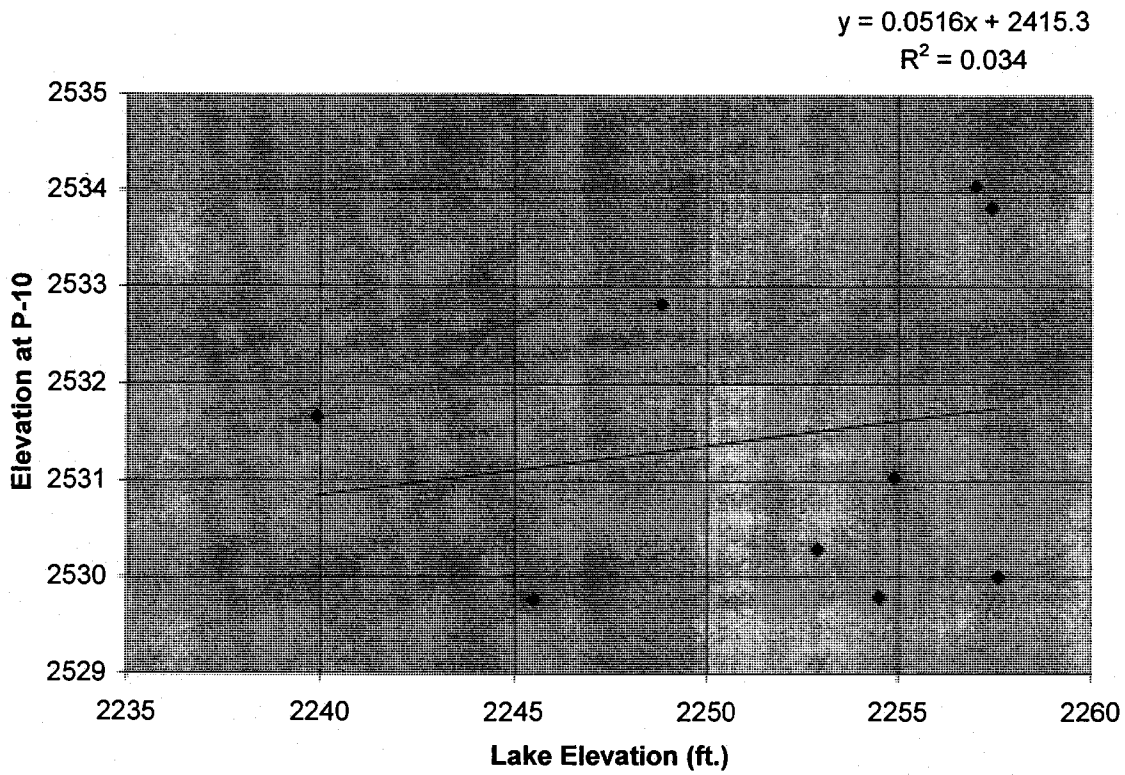

y = -0.0521x + 2620.5
R² = 0.0424
Elevation at P-4 (ft.)
2506
2505
2504
2503
2502
2501
2500
2499
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

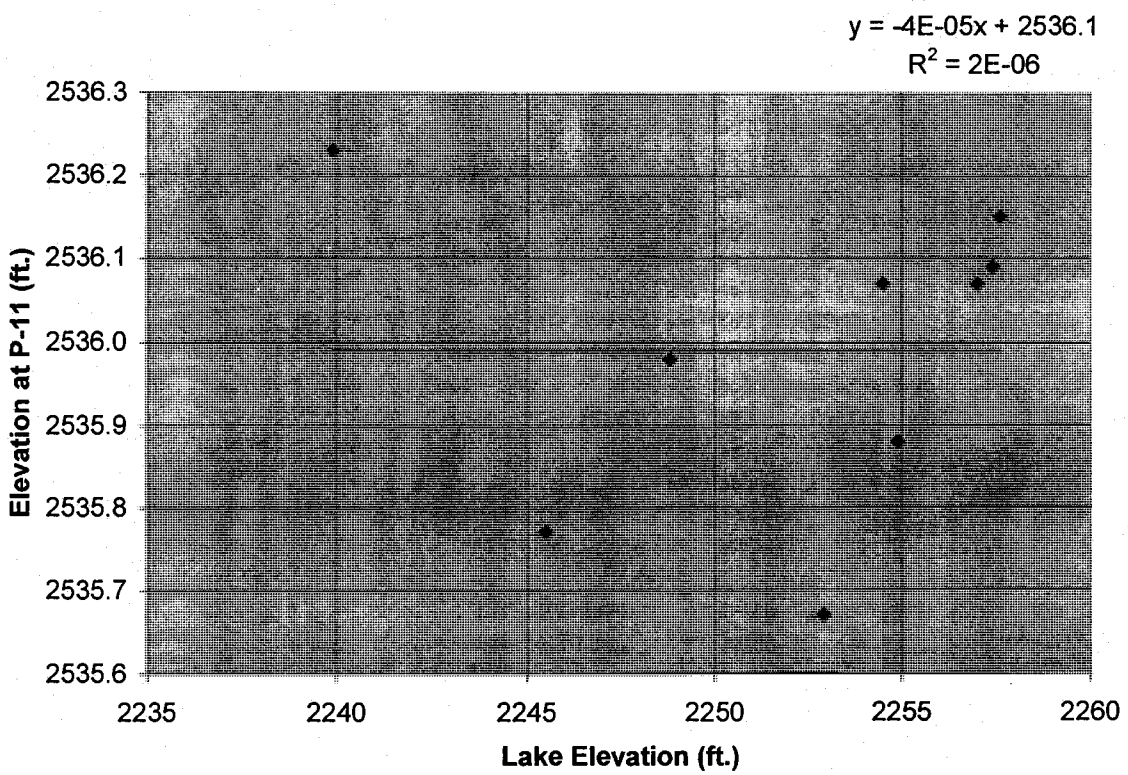

y = 0.0284x + 2396
R² = 0.012
Elevation at P-5 (ft.)
2463
2462
2461
2460
2459
2458
2457
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

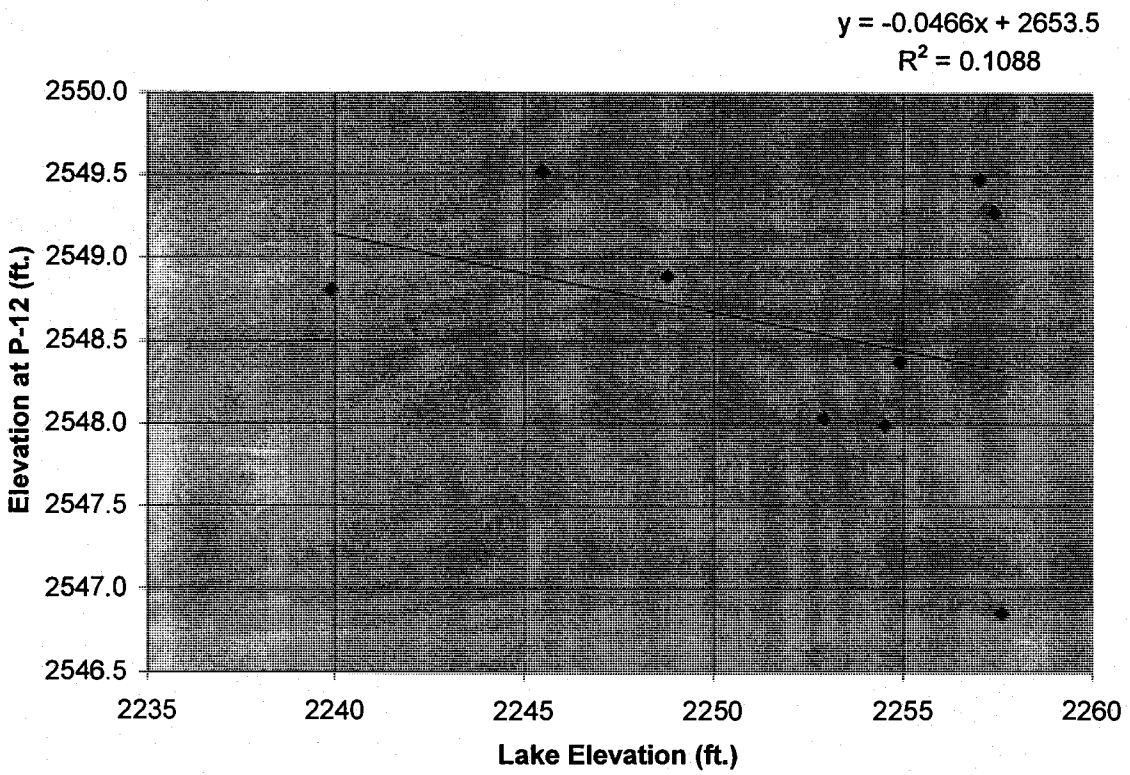

y = 0.0019x + 2533.8
R² = 0.0005
Elevation at P-6 (ft.)
2539
2539
2539
2538
2538
2538
2538
2538
2537
2537
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

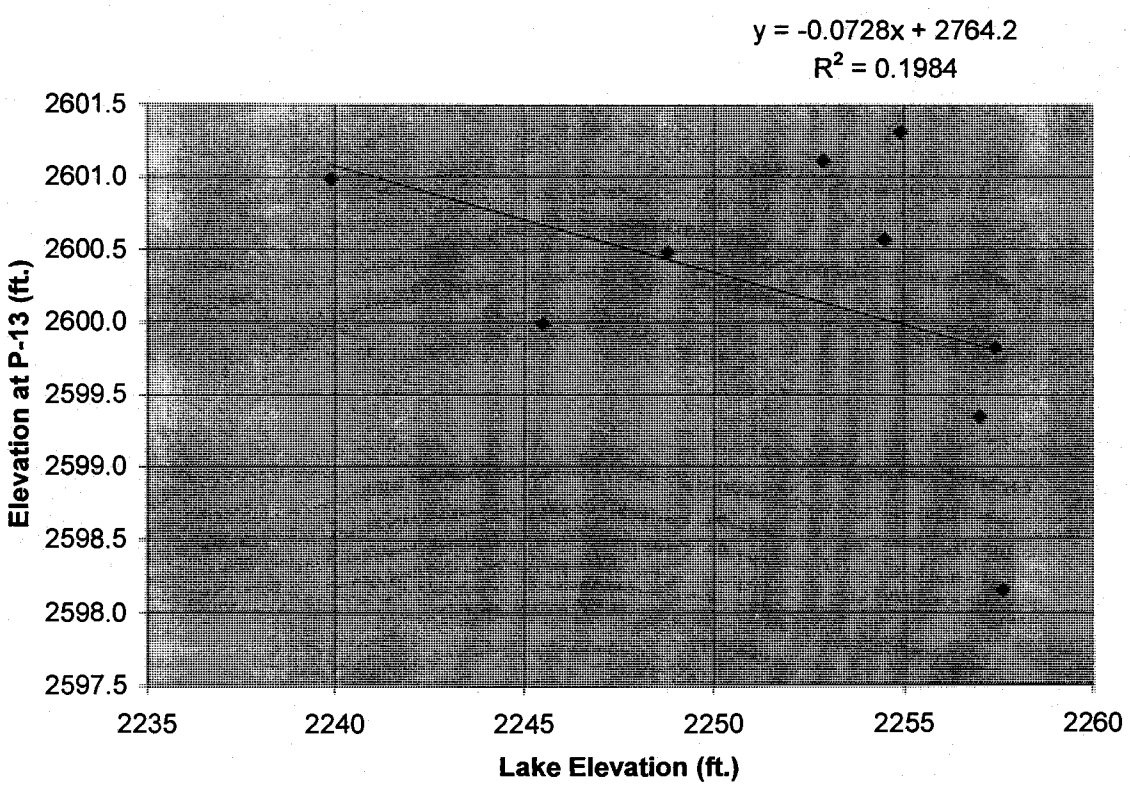

y = -0.0161x + 2555.9
R^2 = 0.0386
2520.8
2520.4
2520.0
2519.6
2519.2
2518.8
Elevation at P-7 (ft.)
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

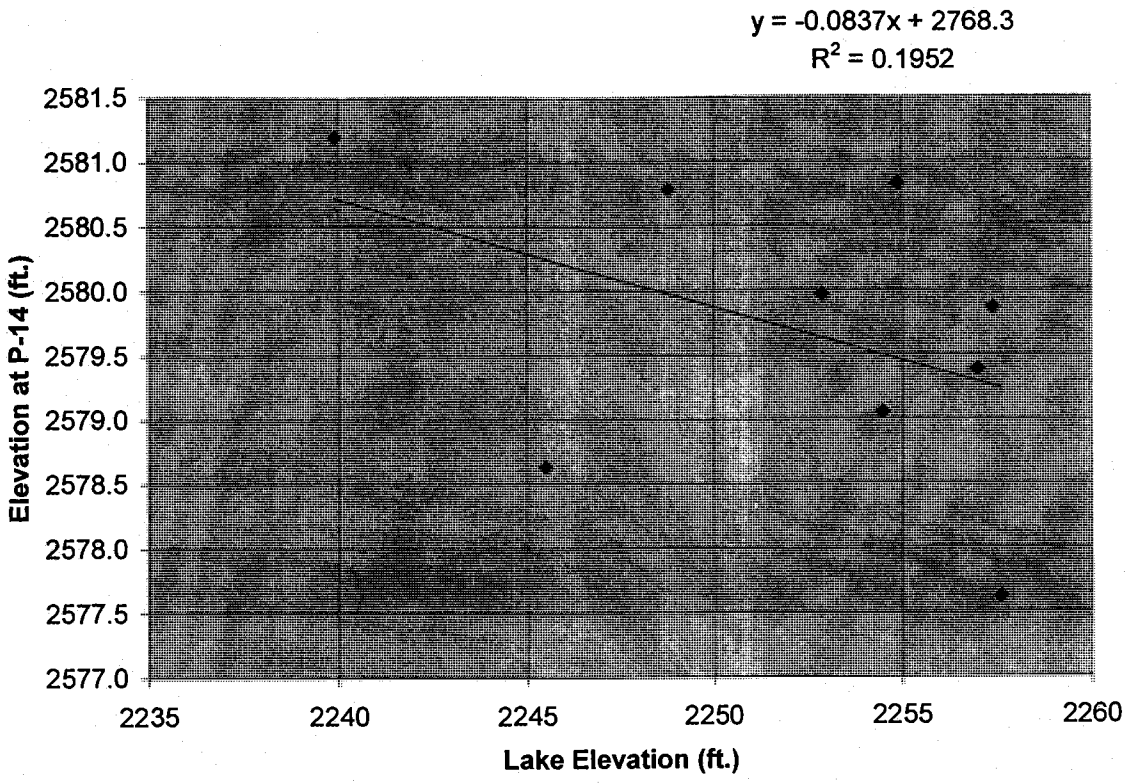

y = 0.0032x + 2480.7
R^2 = 0.0018
2489.0
2488.8
2488.6
2488.4
2488.2
2488.0
2487.8
2487.6
2487.4
2487.2
2487.0
Elevation at P-9 (ft.)
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

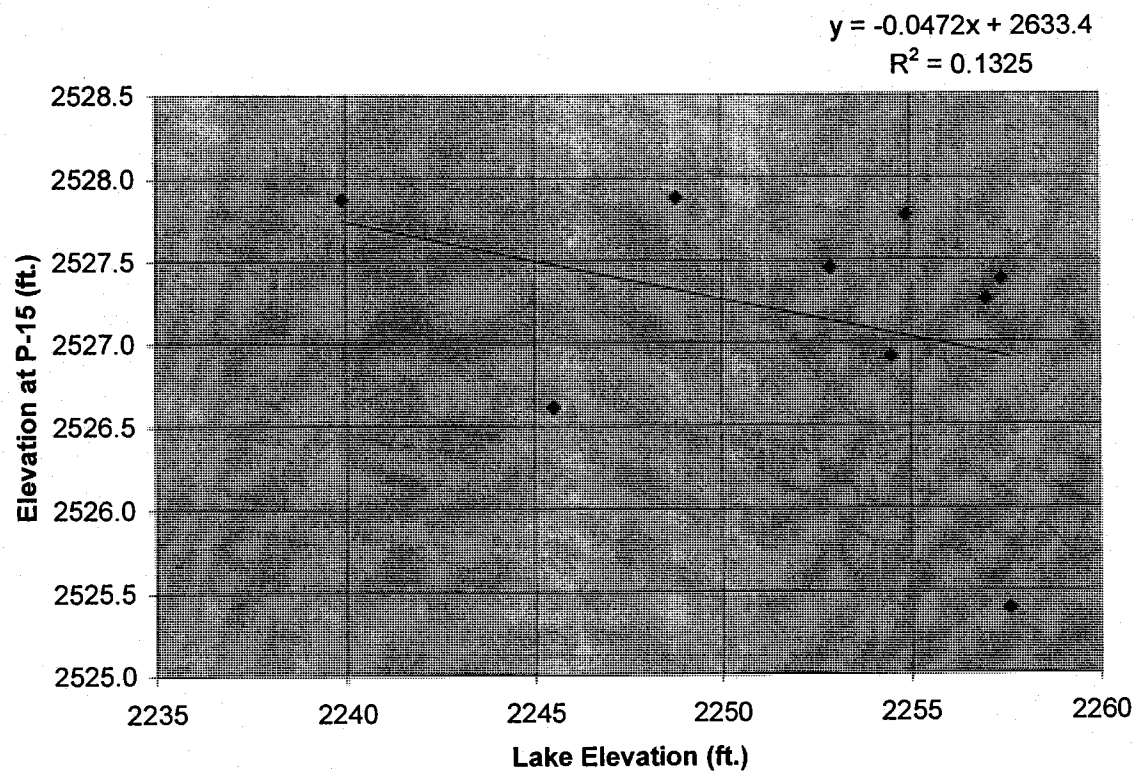

y = 0.0516x + 2415.3
R2 = 0.034
2535
2534
2533
2532
2531
2530
2529
Elevation at P-10
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

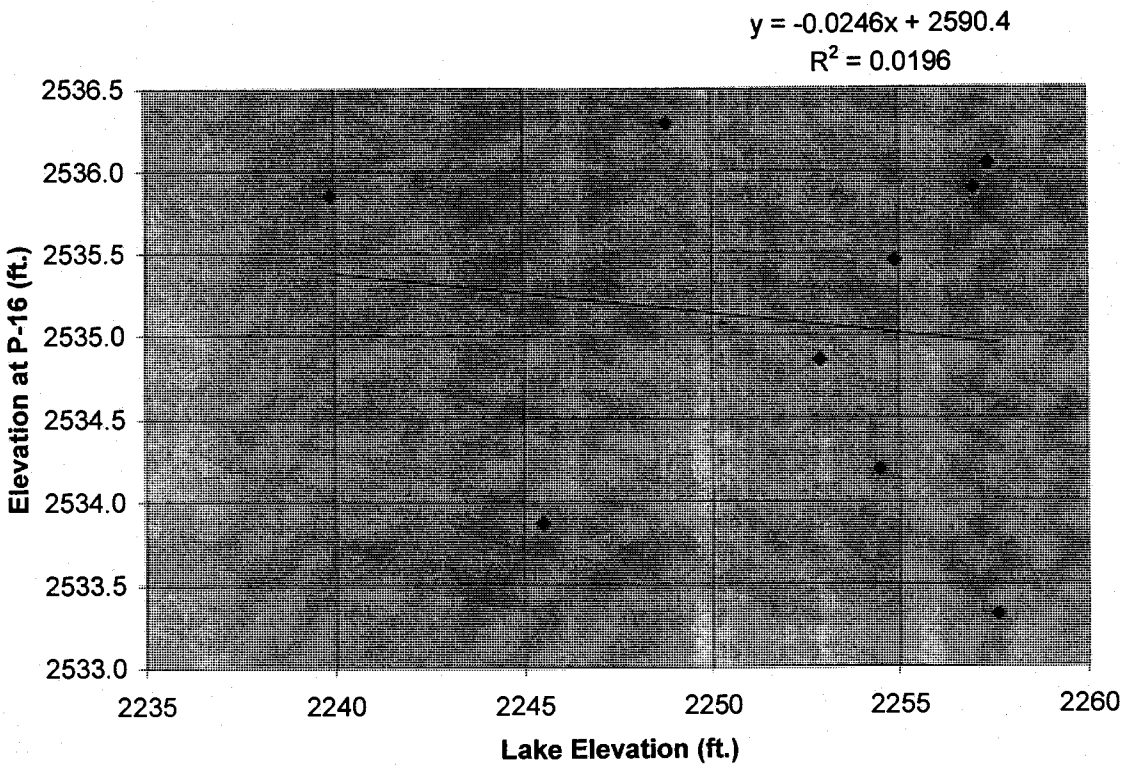

y = -4E-05x + 2536.1
R2 = 2E-06
2536.3
2536.2
2536.1
2536.0
2535.9
2535.8
2535.7
2535.6
Elevation at P-11 (ft.)
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

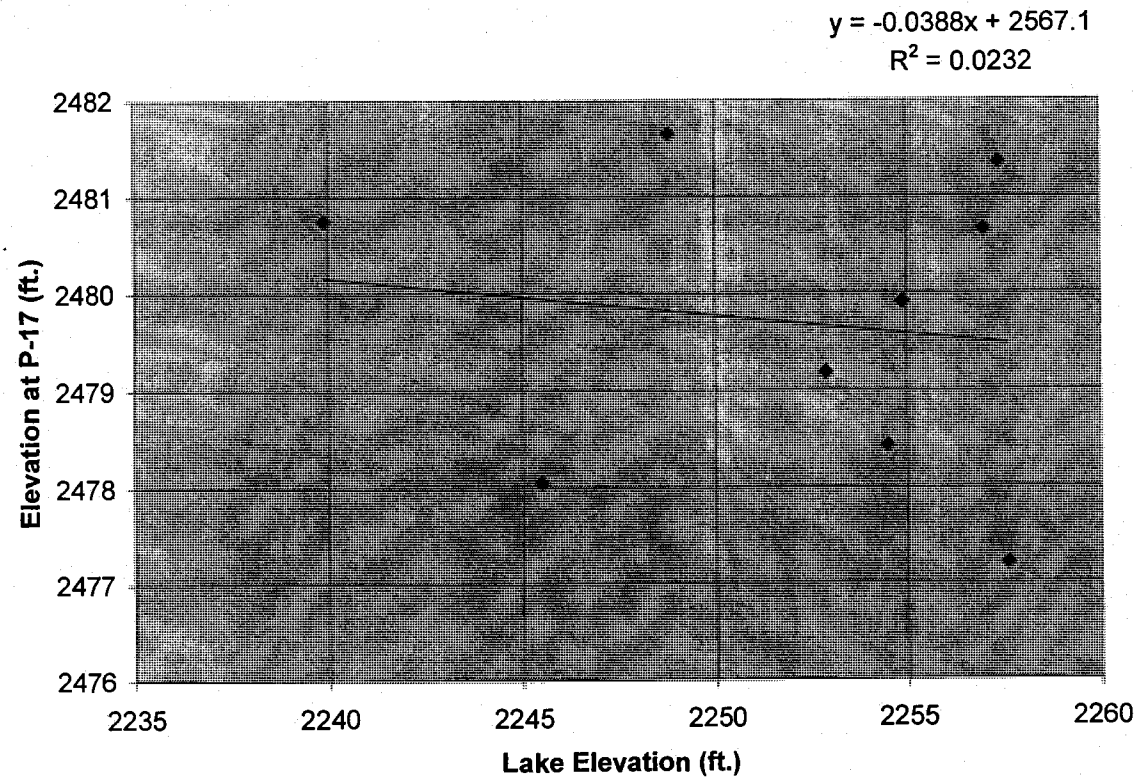

y = -0.0466x + 2653.5
R2 = 0.1088
Elevation at P-12 (ft.)
2550.0
2549.5
2549.0
2548.5
2548.0
2547.5
2547.0
2546.5
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

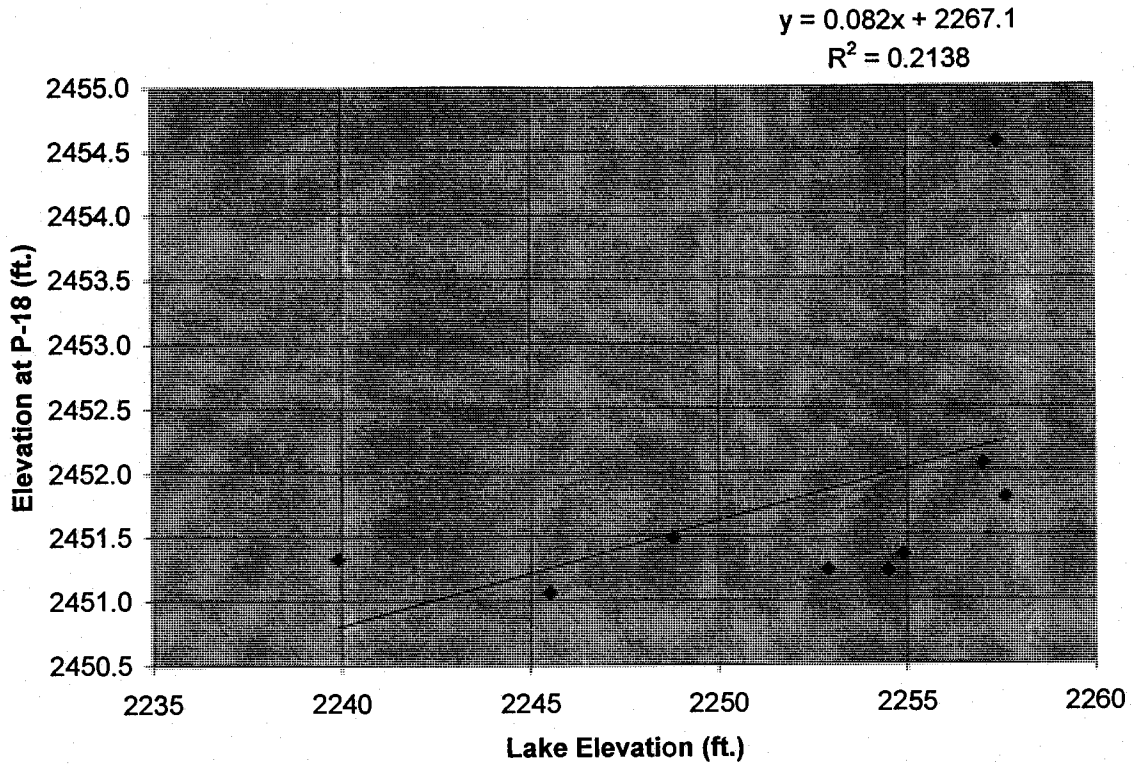

y = -0.0728x + 2764.2
R2 = 0.1984
Elevation at P-13 (ft.)
2601.5
2601.0
2600.5
2600.0
2599.5
2599.0
2598.5
2598.0
2597.5
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

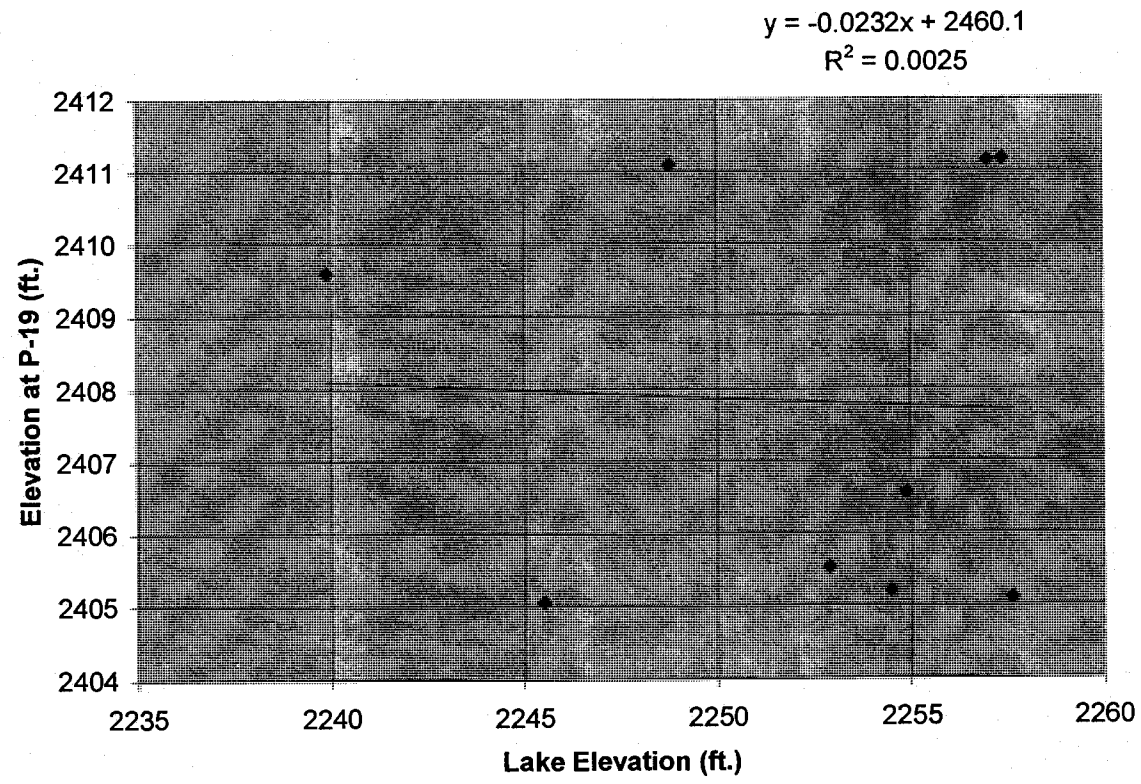

y = -0.0837x + 2768.3
R2 = 0.1952
Elevation at P-14 (ft.)
2581.5
2581.0
2580.5
2580.0
2579.5
2579.0
2578.5
2578.0
2577.5
2577.0
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

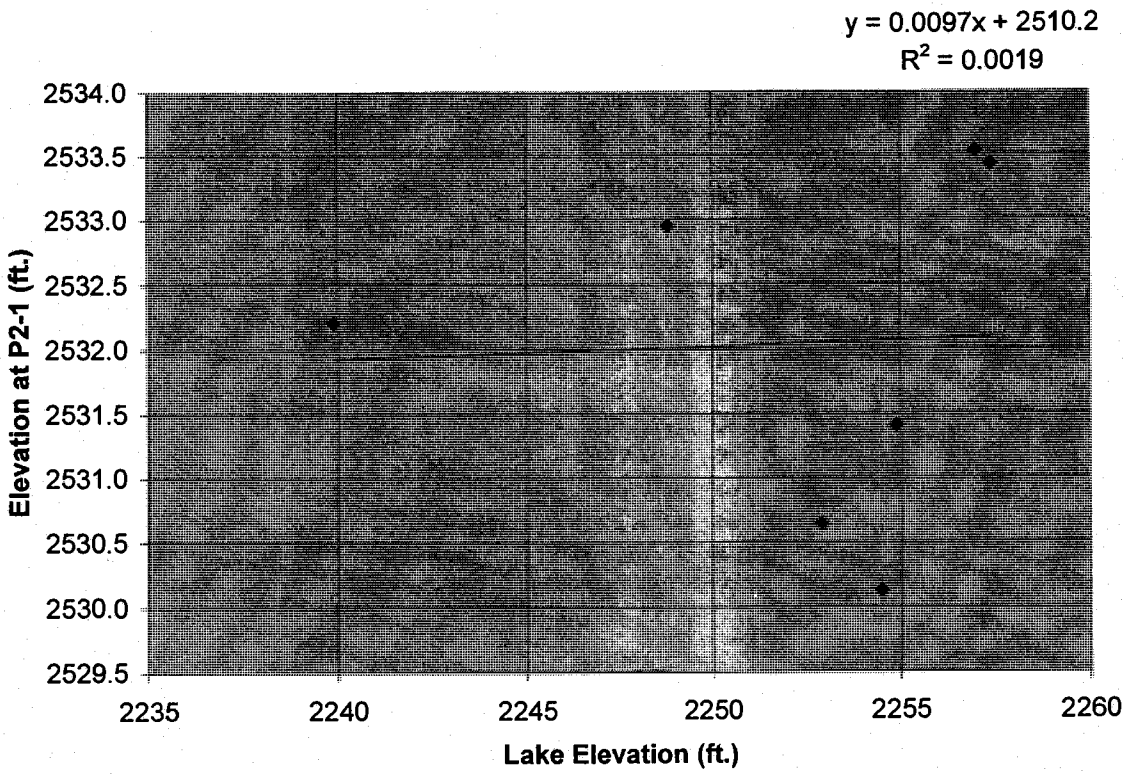

y = -0.0472x + 2633.4
R2 = 0.1325
Elevation at P-15 (ft.)
2528.5
2528.0
2527.5
2527.0
2526.5
2526.0
2525.5
2525.0
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

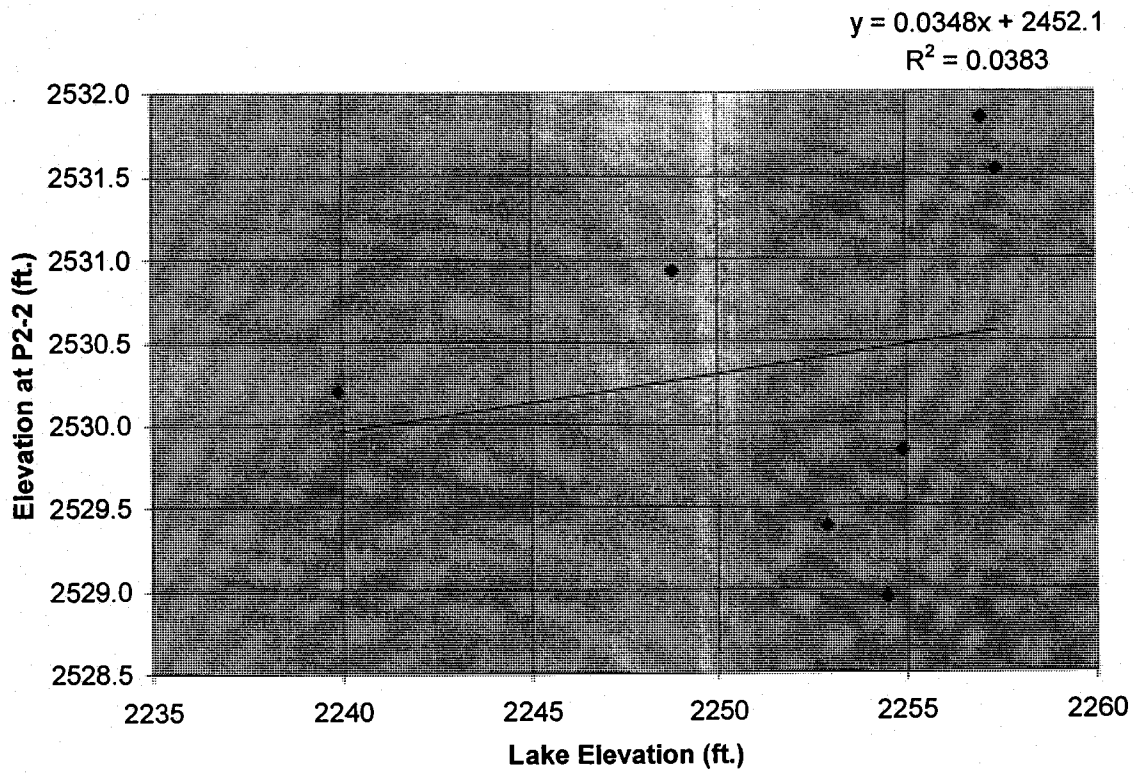

y = -0.0246x + 2590.4
R2 = 0.0196
Elevation at P-16 (ft.)
2536.5
2536.0
2535.5
2535.0
2534.5
2534.0
2533.5
2533.0
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

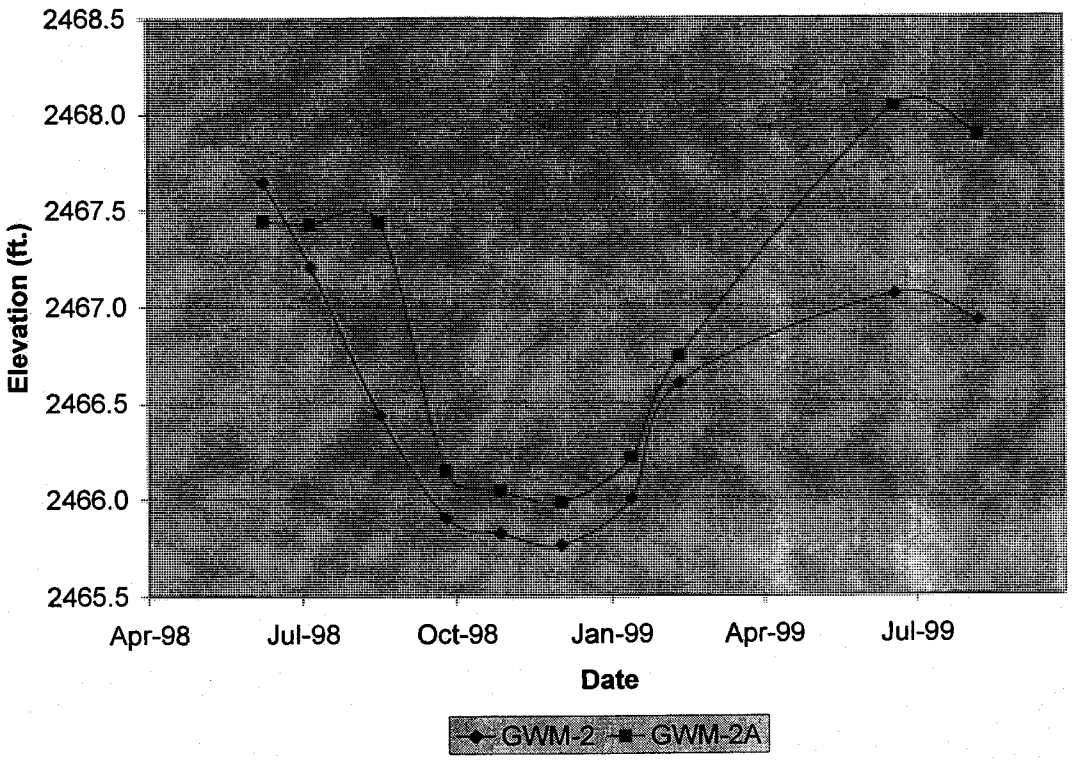

y = -0.0388x + 2567.1
R2 = 0.0232
Elevation at P-17 (ft.)
2482
2481
2480
2479
2478
2477
2476
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

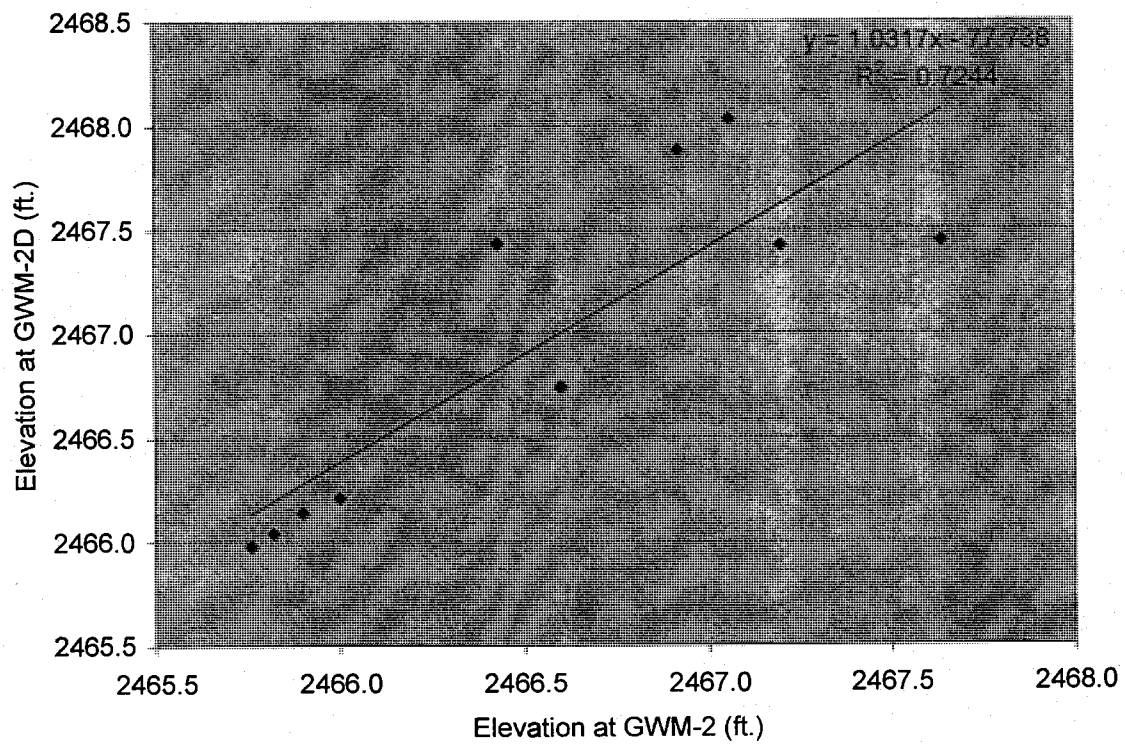

y = 0.082x + 2267.1
R² = 0.2138
Elevation at P-18 (ft.)
2455.0
2454.5
2454.0
2453.5
2453.0
2452.5
2452.0
2451.5
2451.0
2450.5
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

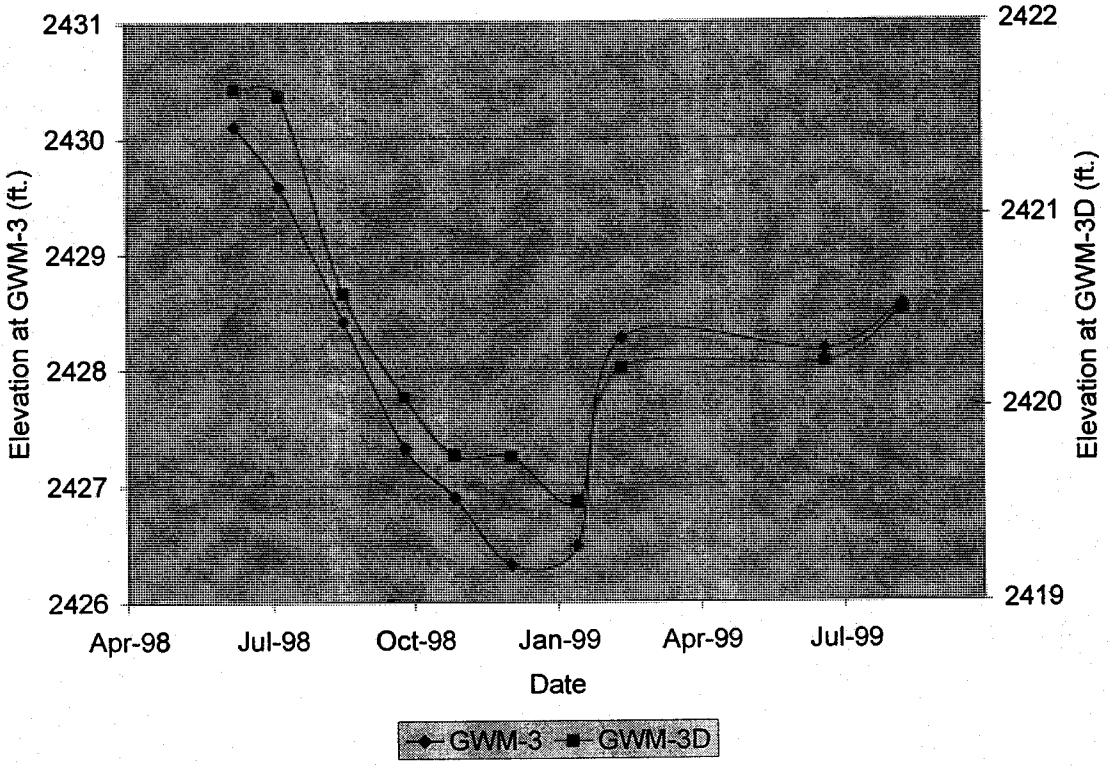

y = -0.0232x + 2460.1
R² = 0.0025
Elevation at P-19 (ft.)
2412
2411
2410
2409
2408
2407
2406
2405
2404
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

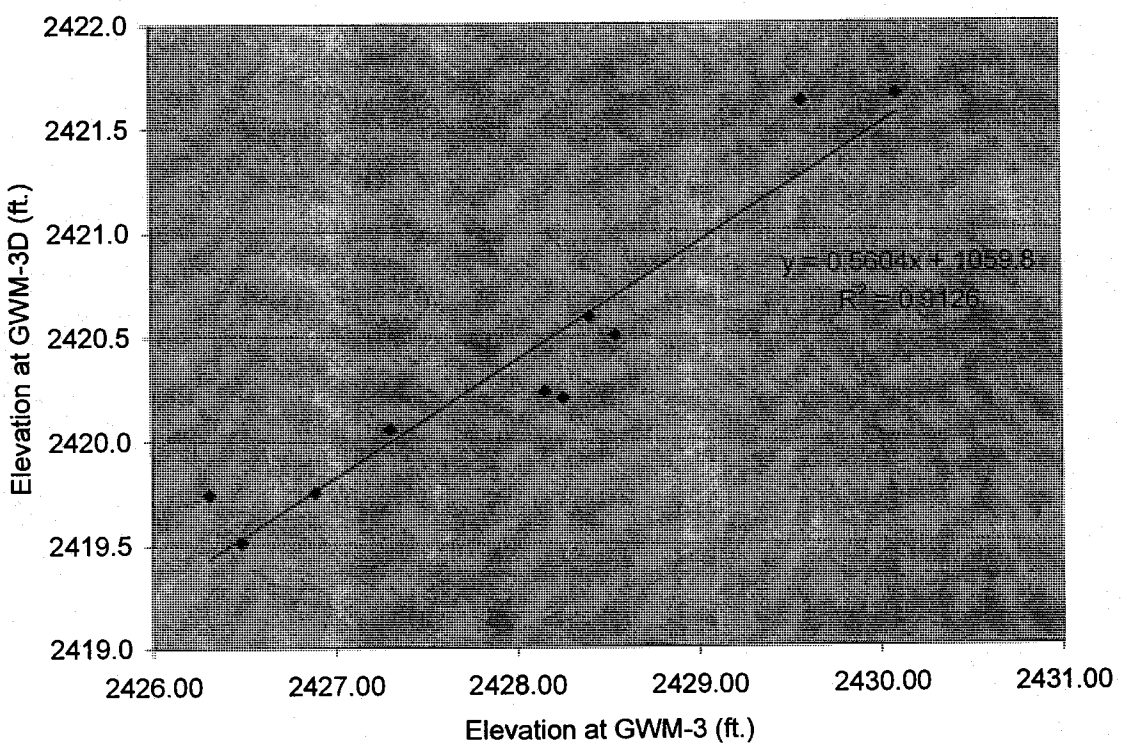

y = 0.0097x + 2510.2
R^2 = 0.0019
2534.0
2533.5
2533.0
2532.5
2532.0
2531.5
2531.0
2530.5
2530.0
2529.5
Elevation at P2-1 (ft.)
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

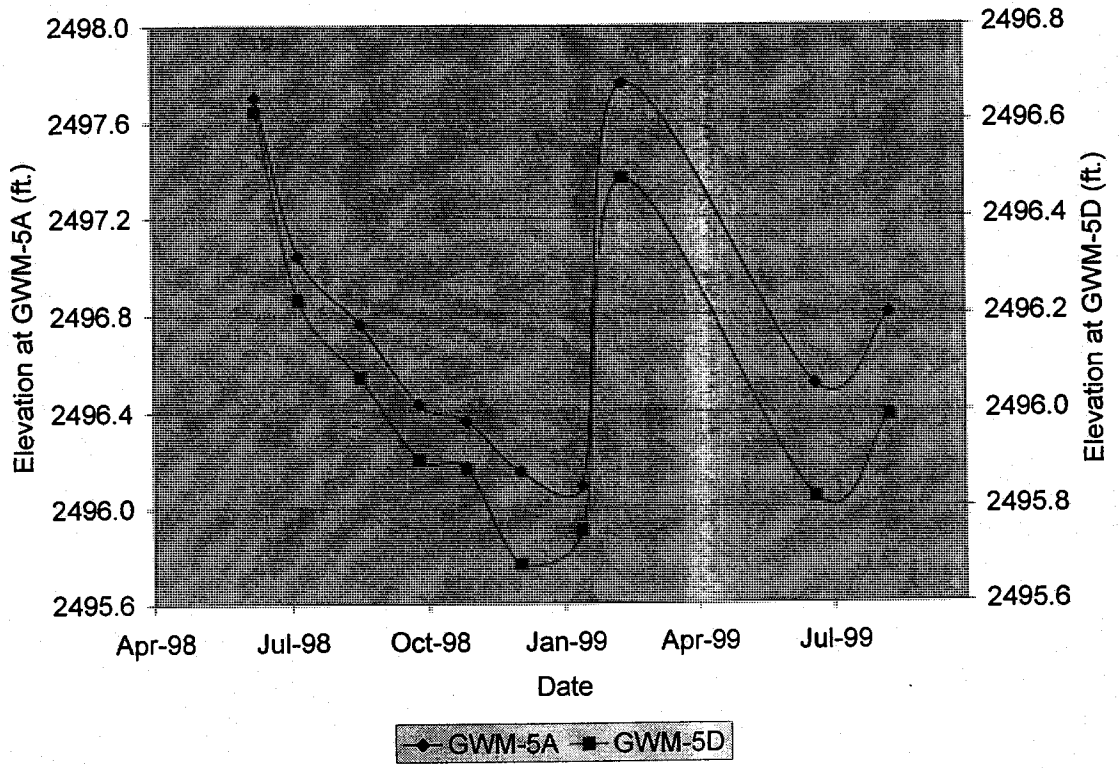

y = 0.0348x + 2452.1
R^2 = 0.0383
2532.0
2531.5
2531.0
2530.5
2530.0
2529.5
2529.0
2528.5
Elevation at P2-2 (ft.)
2235
2240
2245
2250
2255
2260
Lake Elevation (ft.)

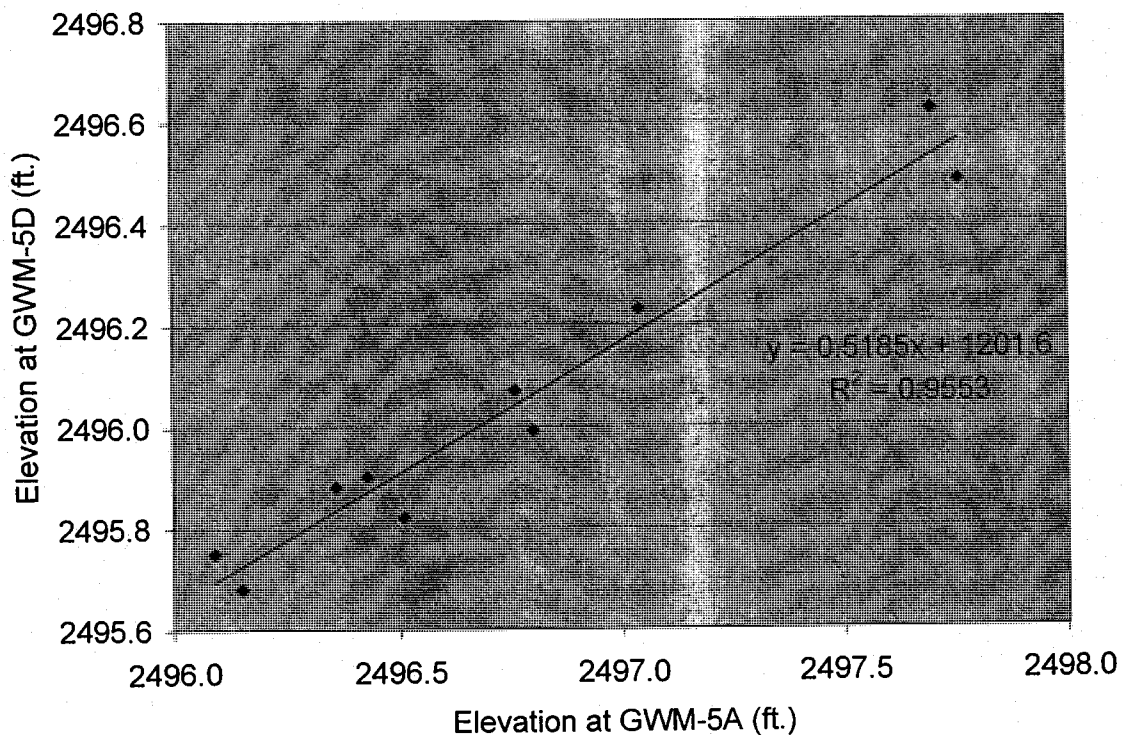

2468.5
2468.0
2467.5
2467.0
2466.5
2466.0
2465.5
Elevation (ft.)
Apr-98
Jul-98
Oct-98
Jan-99
Apr-99
Jul-99
Date
GWM-2
GWM-2A

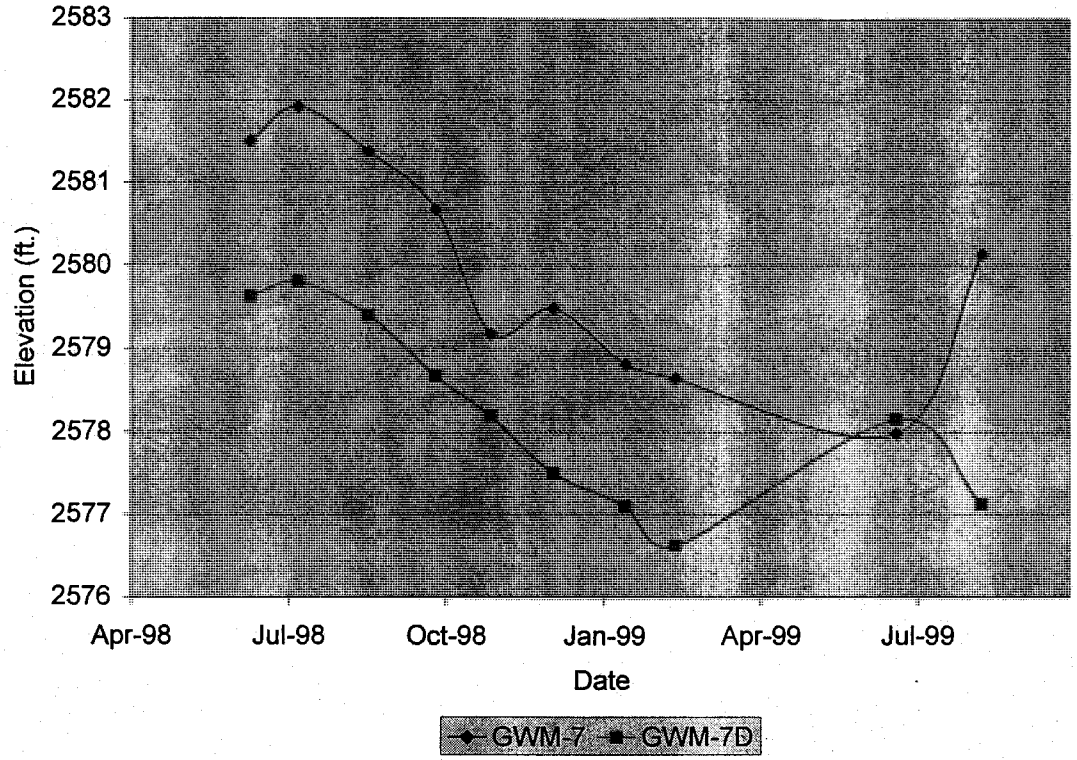

y = 1.0317x - 77.736
R² = 0.7244
2468.5
2468.0
2467.5
2467.0
2466.5
2466.0
2465.5
Elevation at GWM-2D (ft.)
2465.5
2466.0
2466.5
2467.0
2467.5
2468.0
Elevation at GWM-2 (ft.)

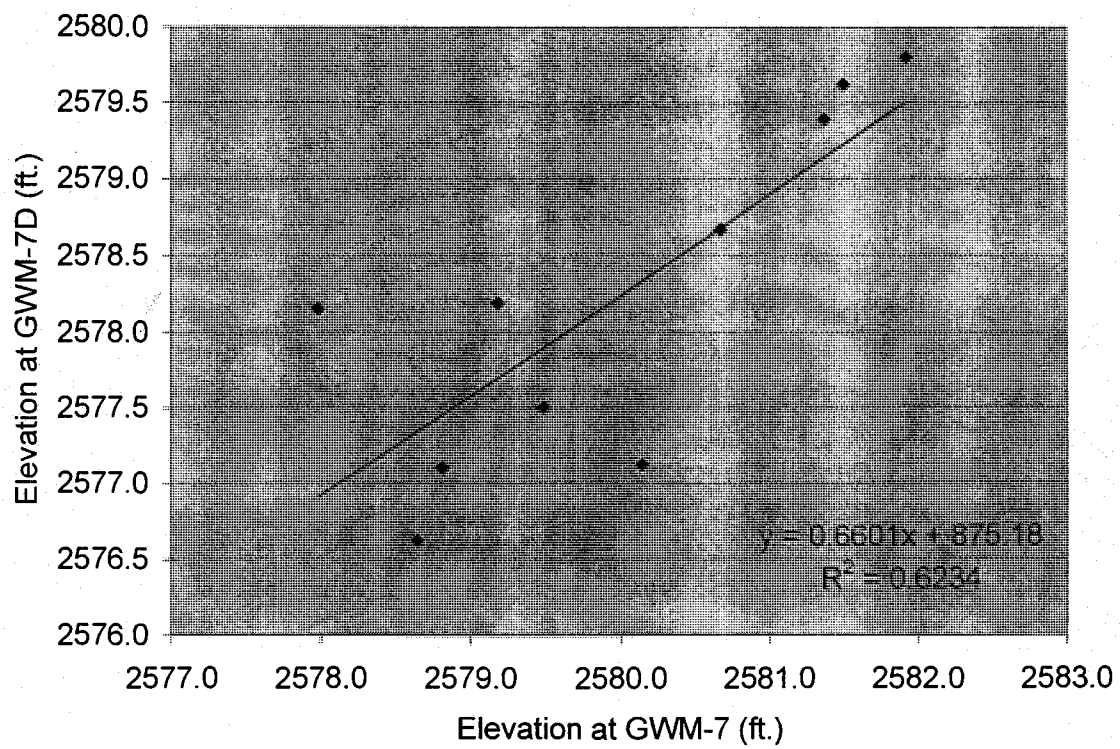

2431
2430
2429
2428
2427
2426
Elevation at GWM-3 (ft.)
2422
2421
2420
2419
Elevation at GWM-3D (ft.)
Apr-98
Jul-98
Oct-98
Jan-99
Apr-99
Jul-99
Date
GWM-3
GWM-3D


2422.0
2421.5
2421.0
2420.5
2420.0
2419.5
2419.0
Elevation at GWM-3D (ft.)
y = 0.6604x + 1059.8
R² = 0.3126
2426.00
2427.00
2428.00
2429.00
2430.00
2431.00
Elevation at GWM-3 (ft.)

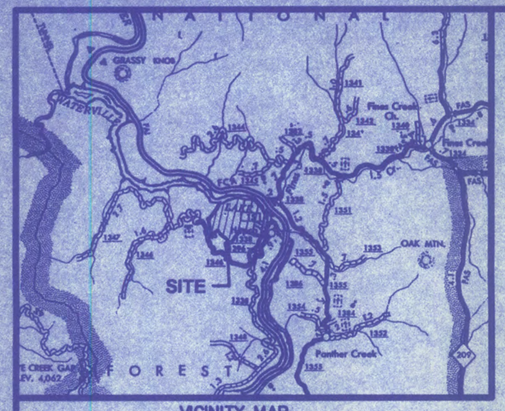

2498.0
2497.6
2497.2
2496.8
2496.4
2496.0
2495.6
Elevation at GWM-5A (ft.)
2496.8
2496.6
2496.4
2496.2
2496.0
2495.8
2495.6
Elevation at GWM-5D (ft.)
Apr-98
Jul-98
Oct-98
Jan-99
Apr-99
Jul-99
Date
GWM-5A
GWM-5D


2496.8
2496.6
2496.4
2496.2
2496.0
2495.8
2495.6
Elevation at GWM-5D (ft.)
y = 0.5185x + 1201.6
R² = 0.9553
2496.0
2496.5
2497.0
2497.5
2498.0
Elevation at GWM-5A (ft.)


2583
2582
2581
2580
2579
2578
2577
2576
Elevation (ft.)
Apr-98
Jul-98
Oct-98
Jan-99
Apr-99
Jul-99
Date
GWM-7
GWM-7D


2580.0
2579.5
2579.0
2578.5
2578.0
2577.5
2577.0
2576.5
2576.0
Elevation at GWM-7D (ft.)
2577.0
2578.0
2579.0
2580.0
2581.0
2582.0
2583.0
Elevation at GWM-7 (ft.)
y = 0.6601x + 875.18
R² = 0.6234

Drawings



VICINITY MAP

NOTES:

1. THIS IS NOT A BOUNDARY SURVEY, THIS IS A TOPOGRAPHIC MAP.

LEGEND

— — —	EXISTING MAJOR CONTOUR
— — —	EXISTING MINOR CONTOUR
—(2560)—	AS-BUILT CONTOURS
— — — —	LINES NOT SURVEYED
• EIP	EXISTING IRON PIN
• NIP	NEW IRON PIN

North Carolina
WAKE County

I, D. WAYNE SULLIVAN, certify that this plat was drawn under my supervision from an actual survey made under my supervision, deed description recorded in Book _____ page _____, that the boundaries not surveyed are clearly indicated as drawn from information found in Book _____ page _____; that the ratio of precision as calculated is 1: 10,000; that this plat was prepared in accordance with G.S. 47-30 as amended. Witness my original signature, registration number and seal, this 20 day of Feb, A.D., 2003.

SEAL OR STAMP — NORTH CAROLINA PROFESSIONAL SEAL L-2525 LAND SURVEYOR D. WAYNE SULLIVAN

D. Wayne Sull
Professional Land Surveyor

L-2525
Registration Number

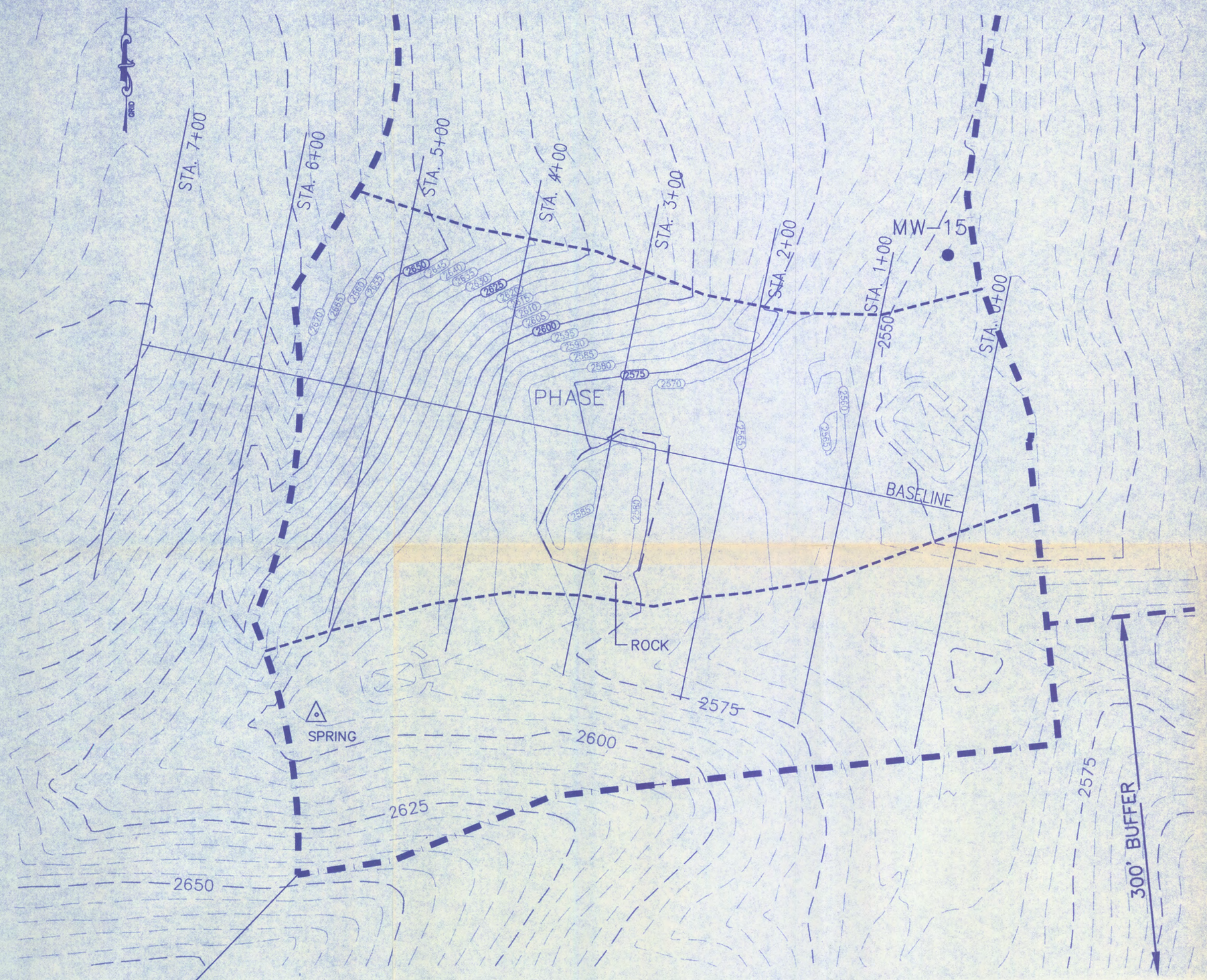
TYPE OF PLAT

I, D. WAYNE SULLIVAN, a Professional Land Surveyor, Reg. No. L-2525 certify to one or more of the following as checked below:

- ☐ A. That this plat is of a survey that creates a subdivision of land within an area of a county or municipality that has an ordinance that regulates parcels of land.
- ☐ B. That this plat is of a survey that is located in such portion of a county or municipality that is unregulated as to an ordinance that regulates parcels of land.
- ☐ C. That this plat is of a survey of an existing parcel or parcels of land.
- ☒ D. That this plat is of a survey of another category, such as the recombination of existing parcels, a court-ordered survey or other exception to the definition of a subdivision.
- ☐ E. That the information available to this surveyor is such that I am unable to make a determination to the best of my professional ability as to provisions contained in (A) through (D) above.

D. Wayne Sull
D. Wayne Sullivan, Professional Land Surveyor, Reg. No. L-2525

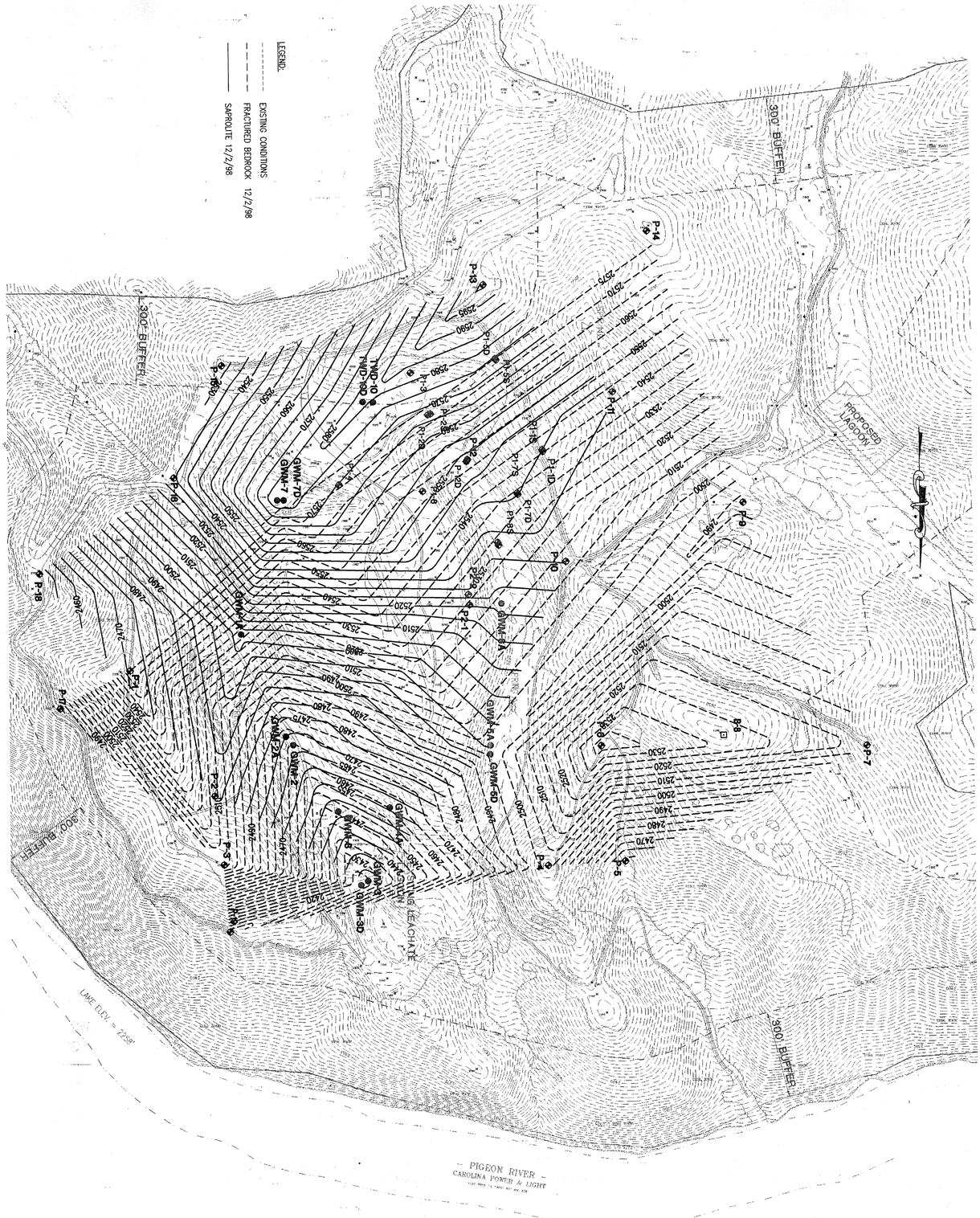
Recorded in Book of Maps _____ Vol. _____ Pg. _____



Permit 44-07

REVISIONS	AS-BUILT as of 01/03/03 HAYWOOD COUNTY CONSTRUCTION AND DEMOLITION LANDFILL		MUNICIPAL ENGINEERING SERVICES, CO., PA CONSULTING ENGINEERS GARNER, N.C. BOONE, N.C.		
	TOWNSHIP: ----------	COUNTY: HAYWOOD	DATE: 02/20/03	SURVEYED BY: T.I.	FIELD BOOK
60 30 0 60 SCALE	TOWN: ----------	STATE: NORTH CAROLINA	SCALE: 1"=60'	DRAWN BY: L.C.H.	DRAWING NO.
	ZONE: ---------- TAX MAP: ----- PARCEL: -----		CHECKED & CLOSURE BY: D.W.S.		G00009

C:\dwgs\haywood\hydro\98010kh2.dwg Tue Oct 05 16:05:02 1999 LCH



Permit No. 44-07

DATE	BY	REV.	DESCRIPTION	

POTENTIOMETRIC MAPS FOR TWO LITHOLOGIC UNITS (12/2/98)

MUNICIPAL SOLID WASTE LANDFILL FACILITY
HAYWOOD COUNTY
WAYNESVILLE, NC

SCALE: 1" = 200'
DATE: 10/5/99
DRWN. BY: L. HAMPTON
CHKD. BY: K. YOSHIDA
PROJECT NUMBER: G98010.5
DRAWING NO.: H2
SHEET NO.: 1 OF 1

Municipal Services
P.O. BOX 97 GARNER, N.C. 27529
(919) 772-5393

Engineering Company, P.A.
P.O. BOX 349 BOONE, N.C. 28607
(828) 262-1767

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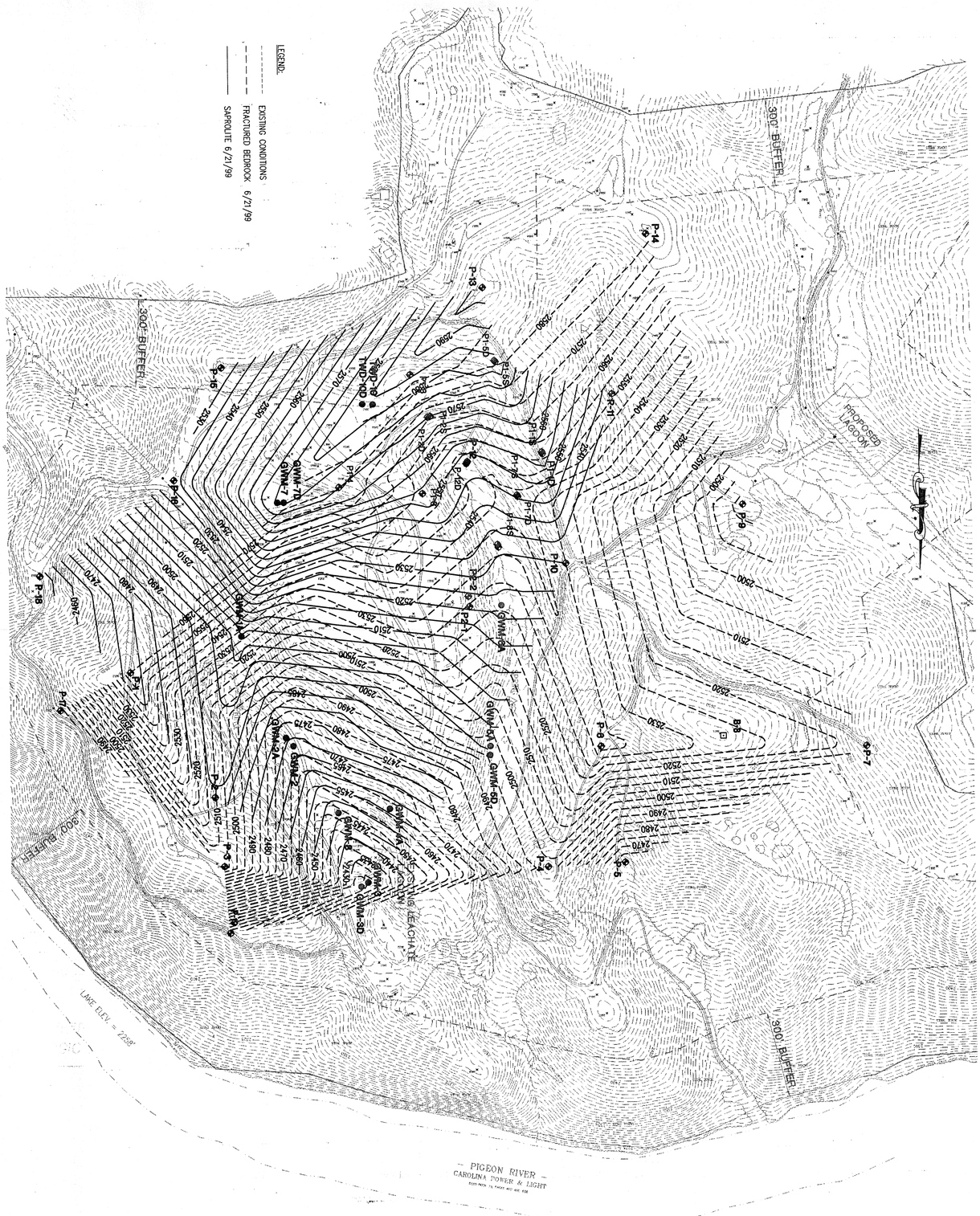

Permit No. 44-07

DATE	BY	REV.	DESCRIPTION	

SCALE: 1" = 200'
DATE: 10/5/99
DRWN BY: L. HAMPTON
CHKD BY: K. YOSHIDA
PROJECT NUMBER: 98010.5
DRAWING NO.: H3
SHEET NO.: 1 OF 1

POTENTIOMETRIC MAPS FOR TWO LITHOLOGIC UNITS (6/21/99)

MUNICIPAL SOLID WASTE LANDFILL FACILITY
HAYWOOD COUNTY
WAYNESVILLE, NC

Municipal Services
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