GEOTECHNICAL INVESTIGATION
NEW NORTHSTAR BATTERY MANUFACTURING FACILITY
SPRINGFIELD, MISSOURI

Prepared For

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INTRODUCTION

This is the report of the geotechnical investigation performed at the site planned for construction of a new Northstar Battery Manufacturing Facility located south of State Route EE (Division) along Alliance Avenue in Springfield, Missouri. This investigation was authorized by a letter proposal dated January 16, 2008 and signed by Joel Gibson, representing Marshall Waters Woody Associates. It is understood that the proposed new development will include construction of a single-story building with precast walls and slab-on-grade construction measuring approximately 308,000 sq ft in plan dimension. It is also understood that there are several concrete pits over 10 feet deep planned within the southeast portions of the building. Pavement for light vehicular parking and entrance drives as well as pavement for tractor trailers is also planned. Foundation loads for the building are anticipated to be moderate, while floor slab loads are anticipated to be moderate to heavy.

The purpose of this investigation is to provide information for the design of safe and economical foundations and to aid in site development. To accomplish the intended purposes, a three-phase study program was conducted which included: a) a field investigation consisting of sample borings; b) a laboratory testing program designed to evaluate the engineering properties and strength characteristics of the subgrade and foundation soils; and c) an engineering analysis of the information developed in the field and laboratory studies with recommendations for foundation support, subgrade preparation and pavement thickness.

WORK PERFORMED

On-Site Borings: Subsurface conditions at the site were investigated by drilling a total of fifteen (15) sample borings. Borings B1 through B-10 were drilled within the proposed building areas while Borings P-1 through P-5 were drilled within proposed pavement areas. Building borings were discontinued on limestone at depths ranging from 9.5 to 14.3 feet below existing ground surface, while pavement borings were discontinued in clay at depths of 4.5 to 5 feet. Boring locations were selected and staked in the field by Palmerton and Parrish, Inc., using a total station and information provided by the client. The Missouri One-Call System was notified prior to the investigation to assist in locating buried utilities. A site plan presenting boring locations was prepared and included with this report as Appendix I. Logs of the borings showing descriptions of soil and rock units encountered as well as results of field and laboratory tests are presented in Appendix II.

Borings were drilled February 5 through February 7, 2008 using 4.5-inch diameter continuous flight augers powered by a track-mounted CME-55 drill rig. Relatively undisturbed soil samples were obtained from the borings using thin wall (Shelby) tube samplers pushed hydraulically into the soil in advance of drilling. This sampling, which is considered to be undisturbed, was performed in accordance with the requirements of ASTM D 1587. This type of sample is considered best for the testing if "in situ" soil properties such as natural density and strength characteristics. The use of this sampling method is basically restricted to soil containing little to no chert fragments and to softer shale deposits.

The second soil sample type was the split spoon sample which was obtained while performing the Standard Penetration Test. This test, described in ASTM D 1586, consists of driving a 2-inch diameter split spoon sampler using a weight of 140 pounds with free fall of 30 inches. The number of blows required to drive the sampler each of three successive 6 inch increments of depth or fraction thereof, in advance of drilling was recorded. The sum of the last two blow count determinations is normally taken as the penetration expressed in blows per 12 inches (N-values) and is presented on the boring log at sample depth. The soil sample obtained is considered disturbed and is useful primarily for strata identification and the determination of natural moisture content and Atterberg Limit values.

The conventional method used to obtain disturbed samples in the field was typically derived by the use of a safety hammer operated by company personnel with a cat head and rope. However, use of an automatic hammer allows a greater mechanical efficiency to be achieved in the field by performing a standard penetration resistance test based upon automatic hammer efficiencies calibrated using dynamic testing techniques.

Laboratory Testing: All samples were transported to the laboratory for further evaluation and visual examination. Laboratory soil testing included determination of natural soil moisture content and dry unit weight, unconfined compressive strength, pocket penetrometer strength and Atterberg Limit values. Laboratory test results are recorded on the boring logs at sample depth.

SITE GEOLOGY

The general site area is underlain at depth by the Mississippian Age Burlington Limestone Formation. This unit characteristically consists of coarse grained gray limestone which is nearly pure calcium carbonate. Isolated chert nodules and discontinuous chert layers are present throughout the formation. The upper surface of this limestone unit is generally irregular due to the effects of differential vertical weathering and solution activity. Limestone pinnacles, some of which are 10 to 15 feet high are common in the general area. In upland areas, overburden soils are usually composed of red clay and chert and are residual having developed from physical and chemical weathering of the parent limestone. The chert fragments were interbedded with the limestone, but are much more resistant to weathering and retain rock-like properties. The contact between comparatively unweathered bedrock and the residual soils is usually abrupt.

The general site area is located within the Ozarks Physiographic Region of Missouri which is characterized by rugged to rolling hill terrain, meandering streams and karst topography. Karst topography forms over areas of carbonate bedrock where groundwater has solutionally enlarged openings to form a subsurface drainage system. Springs, caves, losing streams and sinkholes are common in karst areas. Sinkholes are defined as a depression in the landscape with an internal drainage system.

To investigate karst activity at the project site, a cursory reconnaissance survey was performed. Available geographic information system (GIS) data found on the Center for Agricultural, Resources and Environmental Systems (CARES) website indicates that no USGS or MoDNR mapped sinkholes or sinkhole areas are located on the property.

GENERAL SITE AND SUBSURFACE CONDITIONS

The project site is currently an open, gently sloping, grass covered agricultural field with poor to fair surface drainage. Surficial soils encountered across the site consist of approximately 9 to 12 inches of grass covered topsoil. Due to recent precipitation, these surficial soils were relatively unstable at the time of drilling requiring four-wheel drive support vehicles and track-mounted drilling equipment that produced significant rutting or deflection.

Underlying topsoil, shallow soils encountered in the borings consisted of moist and soft to firm brown and reddish brown lean clay with chert quantities on the order of a trace to 20 percent. Soft soils encountered were generally within the upper 1 to 1.5 feet in the borings and exhibited low shear strength, probably due to recent precipitation and cold winter months. These lean clays exhibit low plasticity and classify as CL according to Unified Soil Classification System (USCS) criteria and extend to depths of 2.5 to 4.0 feet. Cohesion values ranging from 1505 to 2523 psf, as well as pocket penetrometer strengths ranging from 2 to 4 tsf were recorded for the lean clays below 1 foot depths indicating moderate shear strength.

Lean clays at this site generally above 2.5 to 4 ft, typically above 2 ft, often contain little or no chert. Based upon the on-site conditions during drilling, these soils will probably undergo significant loss of shear strength and related subgrade stability upon increase in soil moisture, especially when disturbed with heavy construction equipment. These lean clays may

also have a relatively narrow range of moisture content at which satisfactory compacted density and subgrade stability may be achieved. This soil behavior makes compaction difficult if construction is initiated during wet weather when precipitation exceeds evaporation rates.

Deeper foundation soils encountered in the borings consisted of a moist and firm to stiff reddish brown fat clay with chert quantities on the order of 0 to 30 percent. It should be noted that soft soils were encountered in Borings B-2 and B-8, generally within a few feet above limestone bedrock. Soft soils are common immediately above limestone in the Springfield area. These fat clays exhibit high plasticity classifying as CH according to USCS criteria and extend to boring completion or top of limestone in the borings. The significant soil shrinkage and/or swell commonly associated with CH clays is not considered likely due to the low dry unit weight, high natural moisture content relative to the plastic limit and dilution effect of chert as well as past experience by this firm in the Springfield area. Cohesion values ranging from 1032 to 2248 psf, Standard Penetration N-values ranging from 9 to 56 blows per foot as well as pocket penetrometer strengths ranging from 1 to 3.5 tsf were recorded for the deeper fat clays indicating moderate shear strength. Exceptions were encountered in soft clays above limestone, such as Borings B-2 and B-8, where recorded N-values of 5 and 6 blows per foot indicate low shear strength.

Limestone was encountered in all building Borings at depths ranging from 6.3 to 10.9 feet below existing ground surface with corresponding elevations from 1277.7 to 1290.3. A summary of ground surface elevations, depths to limestone and corresponding limestone surface elevations for the building borings are presented below (Table 1).

Table 1			
Boring	Ground Surface Elevation	Depth to Limestone, ft	Limestone Surface Elevation
B-1	1281.0	10.9	1270.1
B-2	1280.4	9.5	1270.9
B-3	1279.4	8.0	1271.4
B-4	1282.0	9.0	1273.0
B-5	1285.6	8.3	1277.3
B-6	1282.6	6.3	1276.3
B-7	1286.3	9.0	1277.3
B-8	1287.7	10.0	1277.7
B-9	1290.2	10.5	1279.7
B-10	1290.3	10.0	1280.3

According to boring elevation data and site grading plans, limestone bedrock should remain below excavation depths required for the project, except in areas where deep pits are planned. In these areas, limestone encountered during excavation will be highly resistant to machine excavation techniques, requiring the use of blasting techniques or a pneumatic breaker for removal.

No shallow groundwater was observed within borings at the time of drilling. However, shallow perched groundwater is considered possible at the site.

SUMMARY OF SITE TERRAIN, GEOLOGIC AND SUBSURFACE CONDITIONS

The site terrain, geologic and subsurface conditions considered pertinent to foundation design and site development are:

1. The gentle sloping topography and poor to fair surface drainage at the site;
2. The presence of approximately 9 to 12 inches of topsoil across the site;
3. The karst condition of the general site area, but absence of apparent sinkhole depressions on the property based upon a cursory site reconnaissance and conditions encountered in the borings;

4. The moderate shear strength of shallow lean clays encountered in the borings 1 to 1.5 feet below existing grade and the low shear strength encountered in soft soils generally above 1 to 1.5 feet. **These soils contained little to no chert and should be expected to undergo significant loss of shear strength and related subgrade stability upon increase in soil moisture, especially if disturbed by construction equipment;**
5. The generally moderate shear strength of deeper CH clays encountered across the site. Soft soils were encountered in Borings B-2 and B-8, generally within a few feet above limestone bedrock. Soft soils are common immediately above limestone in the Springfield area and should be anticipated at this site;
6. The anticipated low shrink/swell potential of the CH clays at the site;
7. The presence of limestone encountered in all building Borings at depths ranging from 6.3 to 10.9 feet below existing ground surface with corresponding elevations from 1277.7 to 1290.3. A summary of ground surface elevations, depths to bedrock and corresponding bedrock surface elevations for the building borings are presented in Table 1;
8. The absence of shallow groundwater observed within borings at the time of drilling, but the possibility of shallow perched groundwater developing at the site.

FOUNDATION RECOMMENDATIONS

Foundation design for all structures must consider two primarily soil related factors. Foundations should be designed so that maximum possible stresses transmitted to foundation soils and rock will not exceed allowable bearing pressures as computed from reliable shear strength information of the soil mass. In addition, foundations should be sized to limit the maximum anticipated total or differential movements to magnitudes which can be tolerated by the planned structural system. Construction factors such as installation of foundation units, excavation and fill placement difficulties and surface and groundwater conditions must also be considered. These factors along with the previously discussed surface conditions were influential in preparation of the following recommendations.

As previously mentioned, the proposed new development will include construction of a single-story building with precast walls and slab-on-grade construction measuring approximately 308,000 sq ft in plan dimension. It is also understood that there are several concrete pits over 10 feet deep planned within the southeast portions of the building. Pavement for light vehicular parking and entrance drives as well as pavement for tractor trailers is also planned. Foundation loads for the building are anticipated to be moderate, while floor slab loads are anticipated to be moderate to heavy. According to site grading plans, estimated finish floor elevation for the building is 1286. This will require fill depths ranging up to 7 feet or more for the northern two-thirds of the building footprint and cut depths transitioning to 5 feet or more for the southern one-third to provide finish subgrade elevations.

Based upon subsurface conditions encountered in the borings, the use of shallow spread footings founded on firm to stiff natural soils or well compacted controlled fill is considered permissible. **If footings are to be founded on compacted fill, subgrade preparation and fill placement should be performed under controlled conditions in strict accordance with the following section of this report.** Footings bearing on natural soils should be founded at least 1.5 feet below existing grade. **However, the requirement of deepening of some footings to penetrate subgrade soils that may become softened due to the wet weather should be anticipated and recognized in contract documents.** To limit the effects of frost penetration and seasonal variation of soil moisture, all exterior footings should be founded at least 2.5 feet below final exterior grade.

Footings founded as outlined above on controlled fill or firm to stiff natural soils may be sized using net allowable bearing pressures of 2500 and 3000 psf for continuous and individual footings, respectively. Minimal footing widths of 1.5 feet for continuous and 2.5 feet for individual footings are recommended to prevent localized shear failure. These bearing pressures should provide a factor of safety against bearing capacity failure on the order of 3.0 with respect to the average minimum shear strength properties anticipated for well compacted controlled fill and determined for natural soils during this study.

Seismic Considerations: The IBC 2000 code allows a method for determining the appropriate site class of a site with distinctly different subsurface strata. This method was utilized by assigning an appropriate shear wave velocity for each general strata at the site (lean clays, fat clays and limestone). Shear wave velocity approximations for the clays were based upon empirical relationships whereas shear wave velocity for the limestone formation was based upon past actual measurements conducted by this firm in similar rock formation. Based upon this analysis, it is believed that a site Class C should be assigned to this project site.

SITE DEVELOPMENT

According to site grading plans, estimated finish floor elevation for the building is 1286. This will require fill depths ranging up to 7 feet or more for the northern two-thirds of the building footprint and cut depths transitioning to 5 feet or more for the southern one-third to provide finish subgrade elevations. It is anticipated that building floor slabs will often be subjected to moderate storage, equipment and wheel loads. Pavement areas along the south and east portions of the building will be subjected to frequent tractor trailer traffic, while pavement areas to the north and west will be subjected to light vehicular traffic.

Subgrade Preparation: The initial phase of site preparation should include clearing and grubbing of all vegetative matter and topsoil. Topsoil stripping on the order of 9 to 12 inches should be anticipated. Once this preliminary work is complete, a method of subgrade improvement within the slab and heavy-duty pavement areas should be selected. As previously described, existing subgrade soils above 1.5 feet are topsoil or lean clays containing little or no chert fragments and presently exhibiting low shear strength. Even after adjusting to near optimum moisture and compaction, these soils do not provide a good quality subgrade over design life of pavements and slabs. To improve subgrade support characteristics and avoid the design of overly thick pavement sections, one of the following subgrade improvement measures should be implemented.

1. **General Removal and Replacement:** Lean clays containing little or no chert, commonly found at this site should be generally undercut from beneath all building floor slabs, as well as pavements subjected to frequent truck wheel loads, to depths on the order of 1.5 feet. **Lean clays in shallow undercuts may be excessively wet and soft during periods of prolonged rainfall. If this condition is exposed, deeper undercutting or other methods of stabilizing the undercut bottoms will be warranted.**

2. **Removal and Replacement with Select Fill:** In addition to general undercutting described above under Item 1, the slab and pavement areas may be undercut sufficient to provide at least 2 feet of select fill below slabs and heavy duty pavements. This will allow use of a higher CBR value in pavement analysis. Select fill should consist of clayey chert gravel, gravelly clay or lean clay containing at least 30 percent sand and gravel retained on the No. 200 sieve. Soil moisture within this zone below slabs and truck pavements should be controlled within 2 percent of optimum.

3. **Installation of Rock Fill Sub-Base:** Removal of the top 1.5-ft of existing lean clays may be performed to enable the placement of rock fill. A rock fill sub-base consisting of 4 to 8 inch top-size rock may be placed in full 18-inch lift thickness ahead of

construction activity and compacted by a self-propelled vibratory roller. A CBR of 12 may be assumed for subgrades improved in this manner for preliminary pavement design. Again, if excessively soft or wet undercut bottoms occur during periods of prolonged precipitation, deeper undercutting and/or thicker rock fill sub-base will be required.

Earth Fill: Controlled earth fill for this project should consist of inorganic low plasticity lean clay or clayey gravel classifying as CL or GC. Higher plasticity CH clays should be used for fill only if containing at least 35 percent chert fragments retained on the No. 4 sieve or if placed at least 2 ft below pavements, slabs and footings. Large size rock greater than 6 inches should be generally excluded from controlled fills. Surficial soils may contain excessive moisture during wet weather and drying by aeration or manipulation is usually difficult during cool wet weather. Deeper CH clays should be used for controlled fill only if complying with above criteria for placement location or chert content.

Controlled fill should be placed in no greater than 8 inch loose lifts and compacted to at least 95 percent of maximum density as determined by Standard Proctor Procedures (ASTM D 698). Soil moisture should be as required to achieve specified compacted density. **However, within 2 ft of finish subgrade in building slab and heavy duty pavement areas, earth fill should be compacted to at least 98 percent of maximum Standard Proctor Density (ASTM D 698) within 2 percent of optimum for CL or GC soil types and 0 to 4 percent above optimum for CH soil types containing appreciable chert.** Adequate field density and moisture content tests should be performed to ensure compliance with project specifications. Subgrade inspection and fill testing under controlled conditions is considered essential if footings are to be founded in fill. A testing frequency of at least one (1)field density test for each 2500 sq ft of fill lift, but no less than three (3) tests per lift is recommended within building areas. In pavement areas, the testing frequency may be relaxed to one (1) field density test per 5000 sp ft of fill lift, but again no less than three (3) tests per lift.

Retaining Walls: In view of the possible development of perched groundwater at the project site, it is recommended that retaining wall structures be designed and constructed recognizing the possibility of shallow groundwater. A drainage system constructed with coarse free-draining gravel and perforated pipe is considered adequate. Groundwater collected by the drain should be removed to free-discharge by gravity flow or by weep holes through the base of wall.

Retaining wall backfill should consist of free-draining crushed stone or alternatively, may consist of lean clay or higher plasticity clay containing appreciable chert fragments. Crushed stone, if selected, must be imported from a quarry source whereas on-site soils suitable for wall backfill could probably be segregated and stockpiled during basement excavation. Depending upon the type of backfill selected and degree of wall restraint, the following table of lateral earth pressures are considered appropriate for wall design.

TABLE 1 EQUIVALENT FLUID PRESSURES (Drained Backfill Only)

Type of Backfill	Level Backfill		Sloped Backfill (2H:1V)*	
	Restrained Walls	Unrestrained Walls	Restrained Walls	Unrestrained Walls
Compacted Lean Clay (CL) or Cherty Clay >40%+No. 4 Sieve	70 pcf	45 pcf	80 pcf	55 pcf
Clean Crushed Stone	50 pcf	35 pcf	60 pcf	45 pcf
Rock Fill (Free-Draining)	50 pcf	35 pcf	60 pcf	45 pcf

For backfill sloped other than 2H:1V, interpolate between values given in Table 1 for level and sloped backfill.
NOTE: Structural design of unrestrained walls should permit wall rotation oat top of wall equal to 1/240th of wall height.

If crushed stone backfill is selected and wall design in accordance with the above equivalent fluid pressures, the crushed stone backfill should be placed within a boundary projecting 30 degrees from the vertical commencing at a point 1 foot out from the base of wall. Storage loads placed upon floor slabs adjacent to retaining walls will increase lateral stress against walls. Storage loads placed immediately adjacent to dock walls should be multiplied by 0.25 to compute lateral stress increase.

Floor Slabs: Slab-on-grade or slab-on-fill type construction is considered appropriate at the project site with subgrade preparation in accordance with the above recommendations. Placement of 5 or more inches of compacted free-draining granular base course below slabs as recommended by the American Concrete Institute is preferred to limit moisture rise through slabs and to improve slab support, particularly at joints. If slab areas are planned which will be sensitive to slab moisture due to the intended use, it is recommended that a 10 mil impervious moisture barrier or equivalent be provided below slabs.

PAVEMENT ANALYSIS

Three different subgrade/sub-base alternatives were examined when performing the pavement analysis for the project site. These alternatives include the use of existing soils as a natural subgrade after general undercuts of 1- to 1.5-foot depths, removal and replacement with select earth fill, and the construction of a rock fill sub-base. For existing soils compacted in accordance with this report, a CBR value of 3.0 was used in the pavement analysis. For select fill subgrade, the CBR value was increased to 6.0. If the rock fill sub-base alternative was chosen, the CBR value was increased to 12.0.

Paving Materials: Two different paving materials were analyzed, which included asphaltic concrete and concrete pavement. If asphaltic paving is selected, the aggregate base may be a granular compacted crushed limestone with a gradation and quality conforming to the requirements of the Missouri Department of Transportation, Standard Specification 1007 for either Type 1 or Type 5 aggregates. The maximum lift thickness for the granular base is 4 inches. Granular base thicknesses in excess of 4 inches should be placed in multiple lifts with each lift being of approximate equal thickness. The granular base should be compacted to at least 100 percent of Standard Proctor Compaction (ASTM D-698). The base may also be a bituminous base.

Asphaltic concrete should conform to the requirements of MoDOT Standard Specification 401. Asphaltic concrete should be compacted to 92 to 96 percent of Maximum Theoretical Gravity (ASTM D-2041). Ninety-five percent (95%) of 50-Blow Marshall compaction is also accepted as a minimum compaction if the void content (Va) is within the specification value range. Substitution of an appropriate Superpave Mix Design (MoDOT Section 403) is permitted. SP 190C or SP 250C can be used in place of the bituminous base. SP 190C or SP 125C may be used for the surface. All bituminous mix designs should have been prepared or verified within six (6) months of the date of placement on this project.

If rigid concrete paving is selected a minimum 4-inch thickness granular base compacted to 100 percent of Standard Proctor should be placed on the prepared subgrade. The Portland Cement Concrete mix should have a minimum 28-day compressive strength of 4000 psi. Concrete should be placed at a low slump (1 to 3 inches) and have an entrained air content of 5 to 7 percent. If an increased slump is desired, use of Super Plasticizer is recommended. The use of 6x6 inch welded wire mesh placed throughout the slab is recommended for reinforcement.

Traffic Frequency and ESAL's: The following traffic frequency for Type II and Type III paving areas was provided by Northstar Battery and used in pavement design. Using a traffic frequency of 14 tractor trailers per day with a gross weight of 72,000 pounds and a 2 percent annual growth factor, the followings ESAL's were computed. A design life for asphalt and concrete paving of 20 years was used in the pavement design below.

TYPE II & TYPE III PAVING								
Unit Type	Avg. Daily Traffic	Gross Wt. (kips)	Reliability (%)	Deviation, Rigid (Flexible)	Initial Serviceability, Rigid (Flexible)	Terminal Serviceability	Rigid ESALs	Flexible ESALs
Tractor Trailers (5 single axles)	14	72	85	0.35 (0.45)	4.5 (4.2)	2.0	304,073	184,456

The following daily traffic frequency for Type I paving areas were computed by multiplying the number of available parking spaces by three, plus one delivery truck per day, and used in pavement design. An annual growth rate of 2 percent was also used in the design of the pavement sections.

TYPE I PAVING							
Unit Type	Avg. Daily Traffic	Gross Wt. (kips)	Reliability (%)	Deviation, Flexible	Initial Serviceability, Flexible	Terminal Serviceability	Flexible ESALs
Autos	1,968	4.0	85	0.45	4.2	2.0	7,919
Box Truck (2 single axles)	1	24.0	85	0.45	4.2	2.0	8,977
						Total =	16,897

Recommended Pavement Sections: The recommended pavement sections (thicknesses) are based upon the above wheel loadings (ESALs) and subgrade support properties previously described for the differing methods of subgrade preparation. This analysis was performed using computer software provided by the American Concrete Pavement Association and based upon the 1993 AASHTO publication "Guide to Design of Pavement Structures". Please note that some of the recommended thicknesses were altered slightly based upon experience.

ALTERNATE 1: Subgrade Using On-Site Soils
(after general undercutting, soil moisture adjustment and compaction)

CBR=3.0 (Flexible - Type I Paving)		
Asphaltic Surface Course, (in)	Asphaltic Base Course, (in)	Aggregate Base, (in)
3.0	0	6.0

CBR=3.0 (Flexible - Type II Paving)		
Asphaltic Surface Course, (in)	Asphaltic Base Course, (in)	Aggregate Base, (in)
2.0	4.5	6.0

CBR=3.0 (Rigid - Type III Paving)	
Portland Cement Concrete, (in)	Aggregate Base, (in)
6.0	4.0

ALTERNATE 2: Select Earth Fill

CBR=6.0 (Flexible - Type II Paving)		
Asphaltic Surface Course, (in)	Asphaltic Base Course, (in)	Aggregate Base, (in)
2.0	3.0	6.0

CBR=6.0 (Rigid - Type III Paving)	
Portland Cement Concrete, (in)	Aggregate Base, (in)
5.5	4.0

ALTERNATE 3: Rock Fill Sub-Base

CBR=12.0 (Flexible - Type II Paving)		
Asphaltic Surface Course, (in)	Asphaltic Base Course, (in)	Aggregate Base, (in)
2.0	2.0	6.0

CBR=12.0 (Rigid - Type III Paving)	
Portland Cement Concrete, (in)	Aggregate Base, (in)
5.0	4.0

The above pavement thicknesses may be revised to produce an equivalent pavement thickness using appropriate substitution ratios, such as replacing asphaltic surface and base courses for aggregate base. The thickness of aggregate base may also be reduced through incorporation of a geogrid. It should be noted that in the Type I Paving areas (light vehicles), subgrade improvement measures, beyond soil moisture adjustment and compaction, do not decrease the pavement thicknesses, due to the recommended minimum pavement section thickness and expected light wheel loadings in this area.

ADDITIONAL RECOMMENDATIONS

1. Bearing Surfaces at the bottom of excavations should be protected from either inundation or drying out during the excavation process. Providing good surface drainage during construction will prevent many problems.
2. All loose soils or soils softened due to moisture collection in the trench after excavation should be removed prior to concreting.
3. Careful inspection of footing excavations should be performed during construction to detect any unanticipated conditions which may affect structure performance. If such conditions are detected, they should be reported to the Geotechnical Engineer before proceeding with construction.
4. **Delay of construction until drier summer months should reduce subgrade preparation difficulties and associated costs.**

Report Limitations: This report has been prepared in accordance with generally accepted practices of other consultants undertaking similar studies at the same time and in the same geographical area. Palmerton & Parrish, Inc., observed that degree of care and skill generally exercised by other consultants under similar circumstances and conditions. Palmerton & Parrish's findings and conclusions must be considered not as scientific certainties, but as opinions based on our professional judgement concerning the significance of the data gathered during the course of this investigation. Other than this, no warranty is implied or intended.

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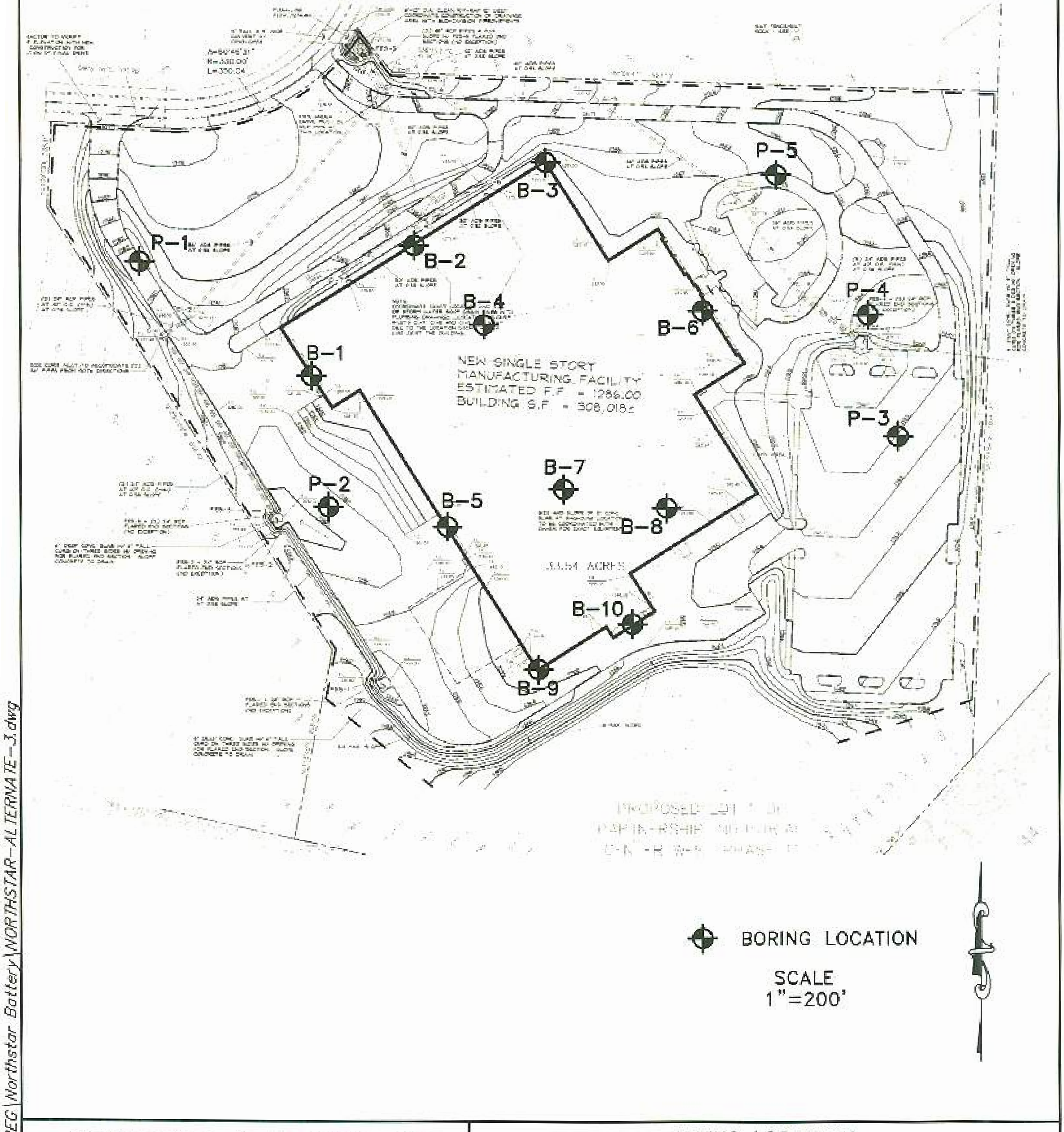
APPENDIX I

SITE PLAN



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BORING LOCATIONS
NORTHSTAR BATTERY, SPRINGFIELD, MO

CLIENT: MARSHALL, WATERS, WOODY ASSOCIATES
PROJECT NO.: 181772 DATE: 1/28/2008

APPENDIX II

BORING LOGS & LEGEND

PALMERTON & PARRISH, INC.

Civil, Geotechnical & Materials Engineers
*Testing Laboratories * Core Drilling*

4168 West Kearney
Springfield, MO 65803
(417) 864-6000

3416 East 13th Street
Joplin, MO 64801
(417) 624-2005

BORING LOG

BORING NO.: B-1

CLIENT: MARSHALL WATERS WOODY ASSOCIATES

SHEET 1 OF 1

PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY

DATE DRILLED 2-07-06

LOCATION: SPRINGFIELD, MISSOURI

JOB NO: 181772

DRILL RIG '05 CME55

DRILLER EP/MR

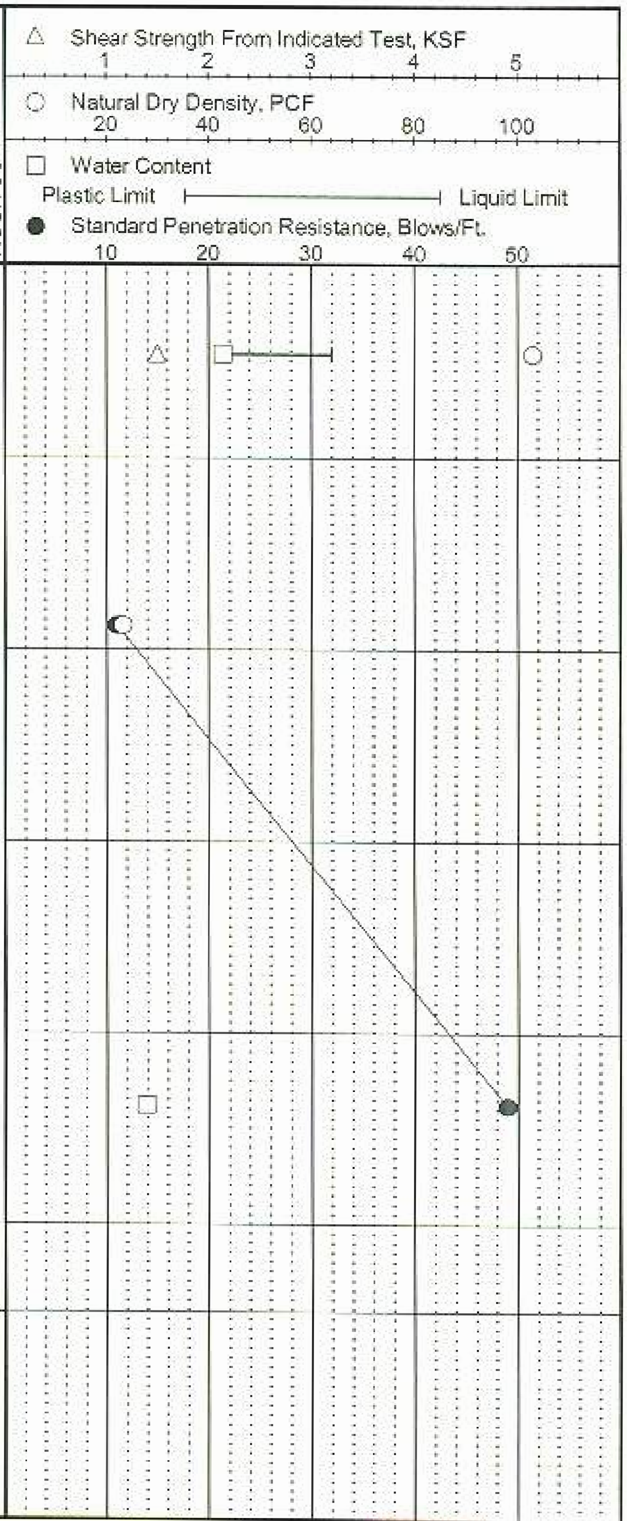
COMPLETION DEPTH 10.92 FT.

BORING METHOD 4.5" DIA. CFA

ROCK CORE DIAMETER N/A IN.

SURFACE ELEVATION 1281.0 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (9")						
	MOIST & SOFT TO FIRM & BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT					2.25	
2	MOIST & FIRM REDDISH BROWN FAT CLAY W/ 0-10% CHERT						
				11		2.25	
4	- 10-30% CHERT BELOW 4'0"						
6							
8							
				49			
10							
	DISCONTINUED DRILLING ON LIMESTONE @ 10'11"						
12							



WATER LEVEL OBSERVATIONS

DURING DRILLING NONE FT.

AT COMPLETION NONE FT.

AFTER ______ HRS. ______ FT.

NOTES

LIMESTONE BEDROCK ELEVATION = 1270.1

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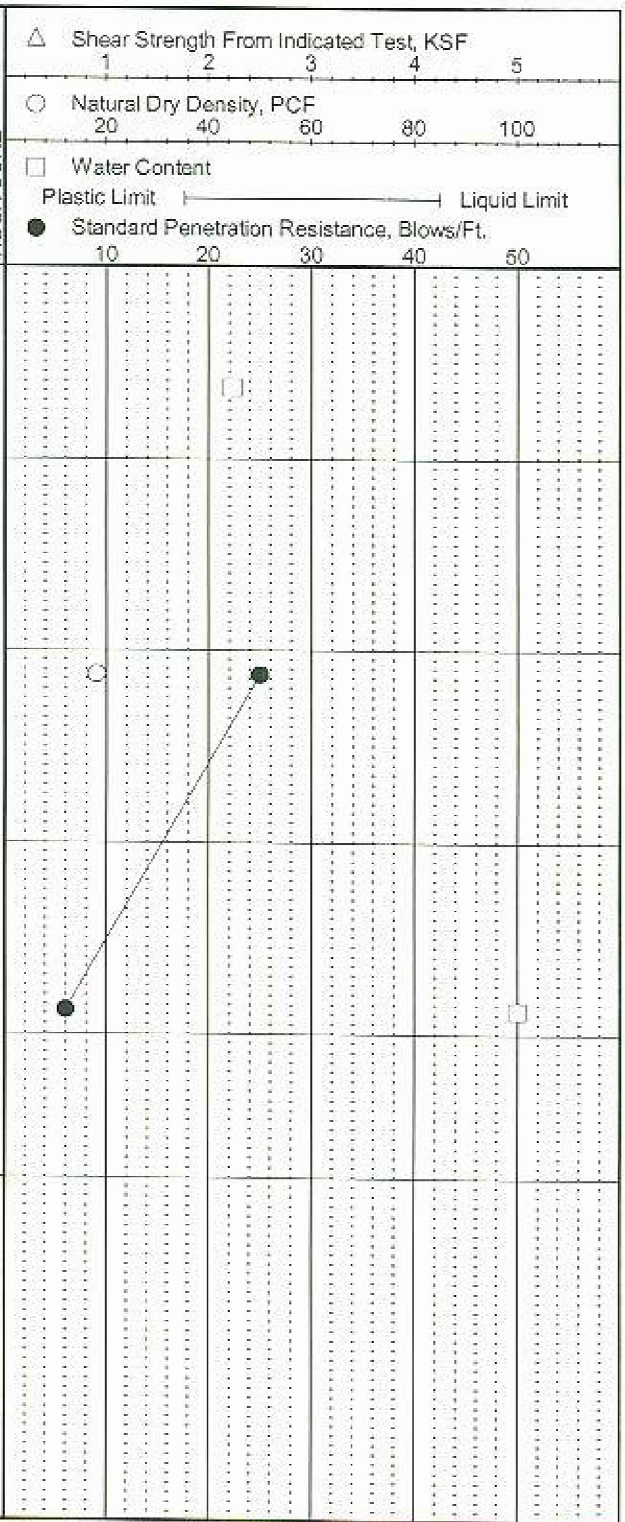
BORING LOG

BORING NO.: B-2
CLIENT: MARSHALL WATERS WOODY ASSOCIATES
SHEET 1 OF 1
PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY
DATE DRILLED 2-06-08
LOCATION: SPRINGFIELD, MISSOURI
JOB NO: 181772
DRILL RIG '05 CME55
DRILLER EP/MR

COMPLETION DEPTH 9.5 FT.
BORING METHOD 4.5" DIA. CFA
ROCK CORE DIAMETER N/A IN.
SURFACE ELEVATION 1280.4 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (9")				■		
	MOIST & SOFT TO FIRM & BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT - 10-20% CHERT BELOW 1'6"				■	2.0	
2							
	MOIST & FIRM REDDISH BROWN FAT CLAY W/ 10-20% CHERT						
4			■	25		2.25	
6							
	- FIRM TO SOFT BELOW 7'6"						
8			■	6		1.25	
	DISCONTINUED DRILLING ON LIMESTONE @ 9'6"						
10							
12							



WATER LEVEL OBSERVATIONS		
DURING DRILLING	NONE	FT.
AT COMPLETION	NONE	FT.
AFTER ___ HRS.		FT.

NOTES

LIMESTONE BEDROCK ELEVATION = 1270.9

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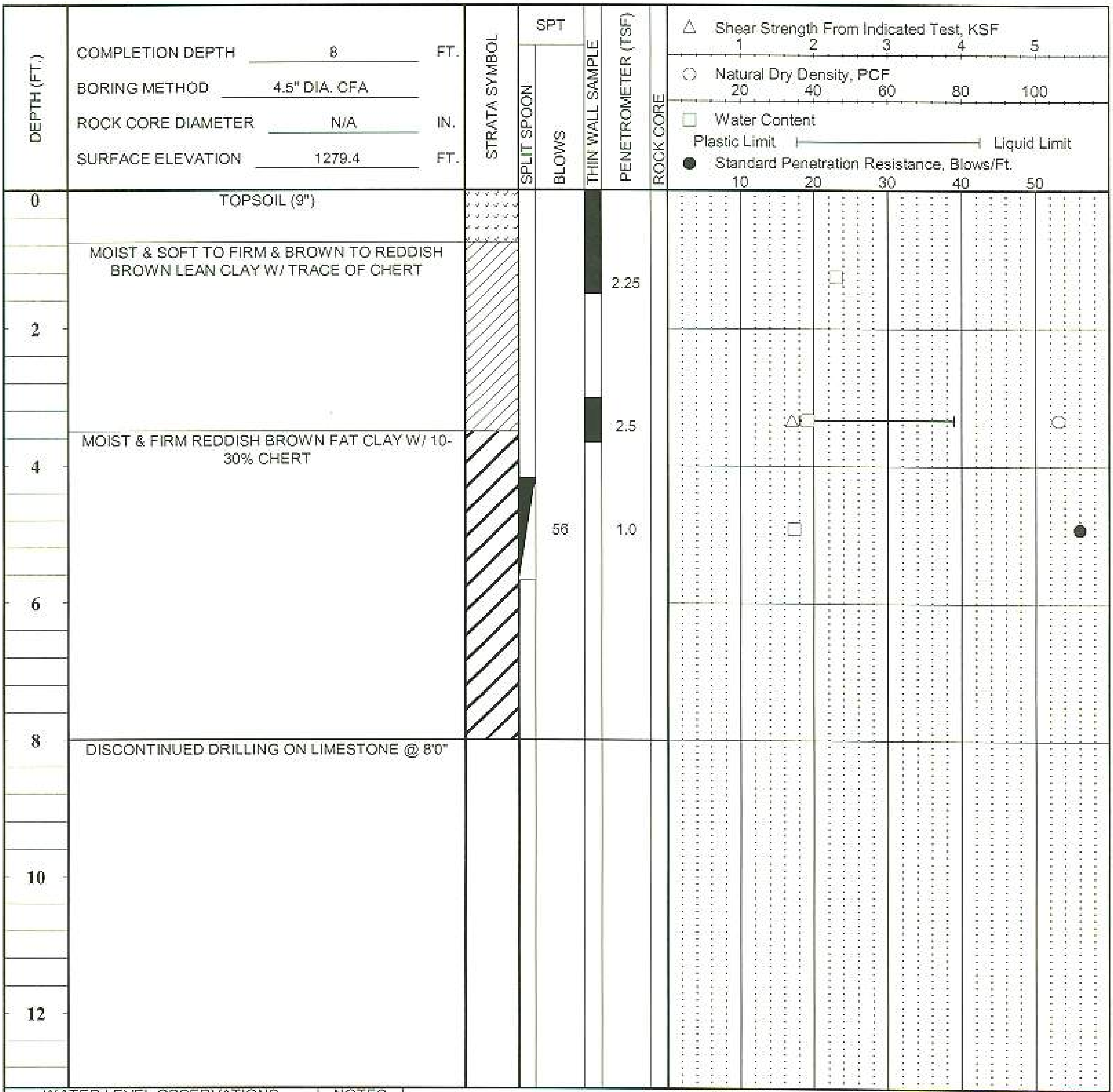
BORING LOG

BORING NO.: B-3
SHEET 1 OF 1

CLIENT: MARSHALL WATERS WOODY ASSOCIATES
PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY
DATE DRILLED: 2-06-08
LOCATION: SPRINGFIELD, MISSOURI
JOB NO: 181772
DRILL RIG: '05 CME55
DRILLER: EP/MR

COMPLETION DEPTH: 8 FT.
BORING METHOD: 4.5" DIA. CFA
ROCK CORE DIAMETER: N/A IN.
SURFACE ELEVATION: 1279.4 FT.



TOPSOIL (9")

MOIST & SOFT TO FIRM & BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT

MOIST & FIRM REDDISH BROWN FAT CLAY W/ 10-30% CHERT

DISCONTINUED DRILLING ON LIMESTONE @ 8'0"

WATER LEVEL OBSERVATIONS

DURING DRILLING: NONE FT.
AT COMPLETION: NONE FT.
AFTER ______ HRS. ______ FT.

NOTES

LIMESTONE BEDROCK ELEVATION = 1271.4

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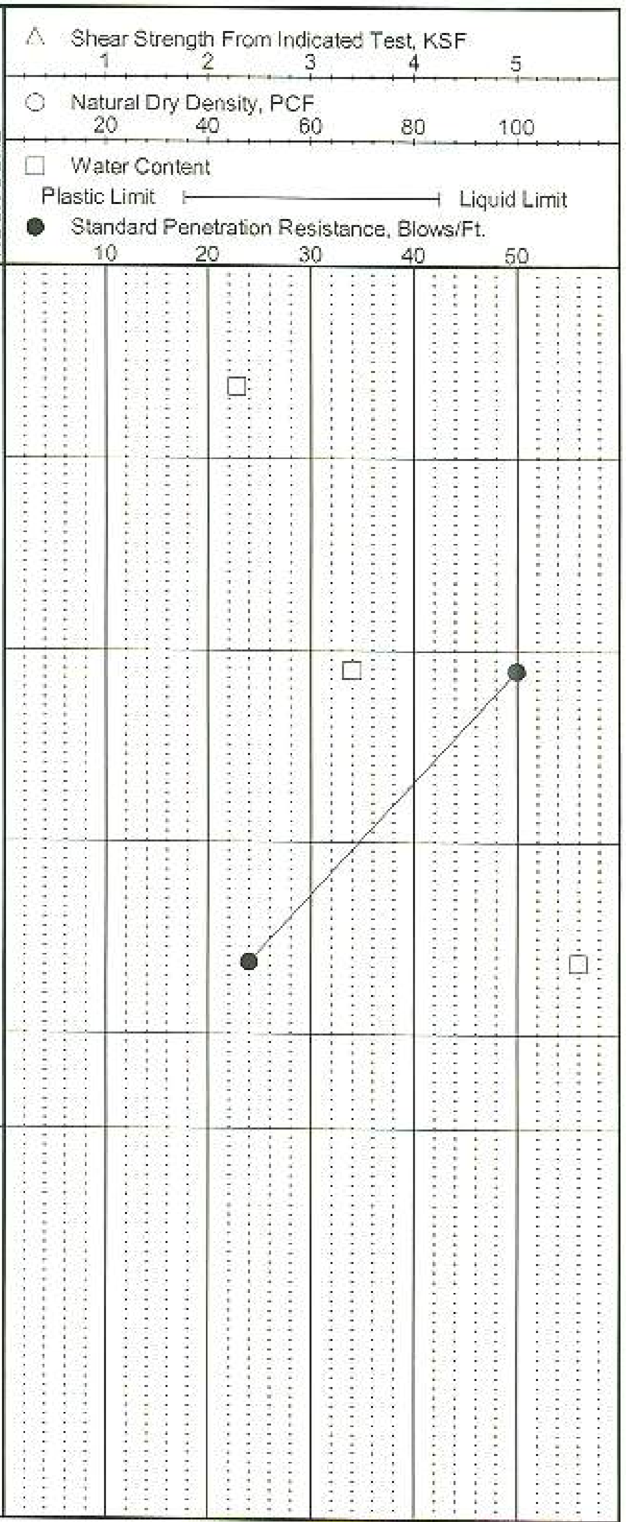
BORING LOG

BORING NO.: B-4
CLIENT: MARSHALL WATERS WOODY ASSOCIATES
SHEET 1 OF 1
PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY
DATE DRILLED 2-06-08
LOCATION: SPRINGFIELD, MISSOURI
JOB NO: 181772
DRILL RIG '05 CME55
DRILLER EP/MR

COMPLETION DEPTH 9 FT.
BORING METHOD 4.5" DIA. CFA
ROCK CORE DIAMETER N/A IN.
SURFACE ELEVATION 1282.0 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (9")						
	MOIST & SOFT TO FIRM & BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT					2.5	
2	- 10-20% CHERT BELOW 1'6"						
	MOIST & FIRM REDDISH BROWN FAT CLAY W/ 10-20% CHERT						
4				50/5		2.5	
	- OCCASIONAL CHERT SEAM BELOW 5'0"						
6				24		1.75	
8							
	DISCONTINUED DRILLING ON LIMESTONE @ 9'0"						
10							
12							



WATER LEVEL OBSERVATIONS		
DURING DRILLING	NONE	FT.
AT COMPLETION	NONE	FT.
AFTER ___ HRS.		FT.

NOTES

LIMESTONE BEDROCK ELEVATION = 1273.0

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BORING LOG

BORING NO.: B-5

SHEET 1 OF 1

CLIENT: MARSHALL WATERS WOODY ASSOCIATES

PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY

DATE DRILLED 2-05-08

LOCATION: SPRINGFIELD, MISSOURI

JOB NO: 181772

DRILL RIG '05 CME55

DRILLER EP/MR

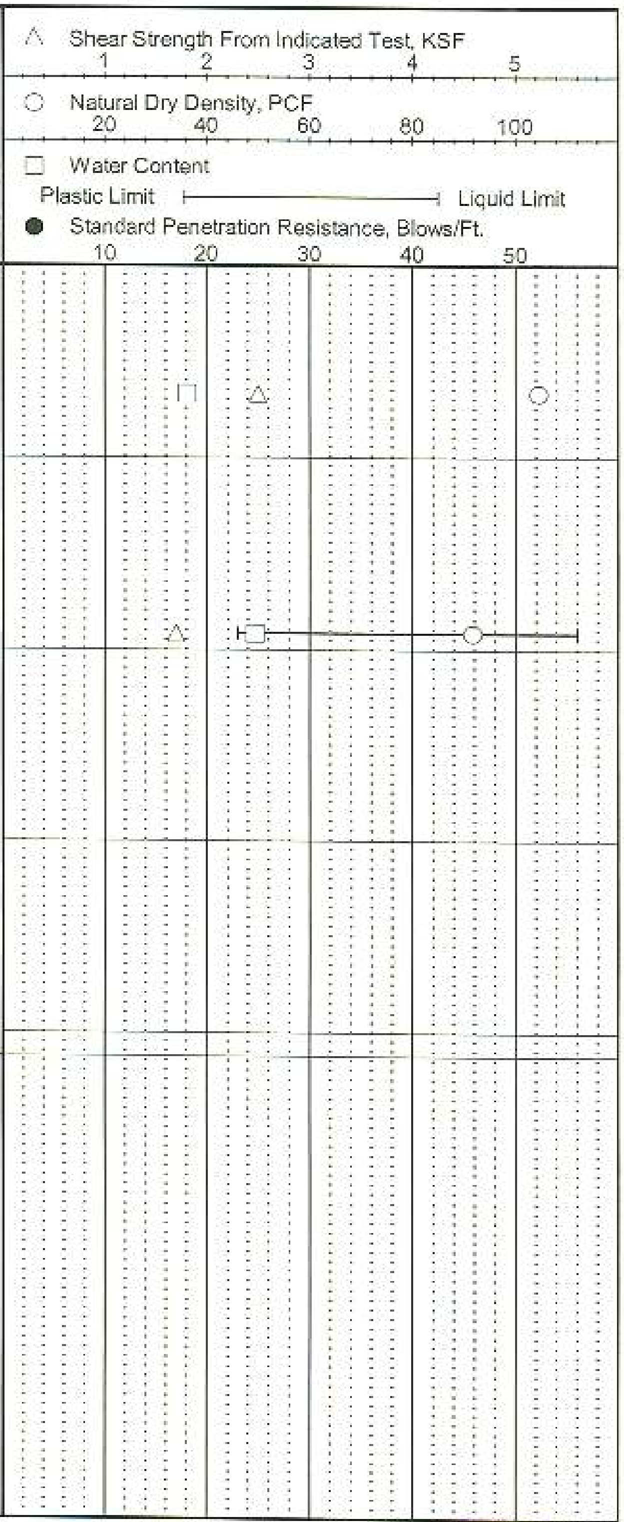
COMPLETION DEPTH 8.25 FT.

BORING METHOD 4.5" DIA. CFA

ROCK CORE DIAMETER N/A IN.

SURFACE ELEVATION 1285.6 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (9")				■		
	MOIST & SOFT TO FIRM & BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT	▨			■	3.25	
2							
	MOIST & FIRM TO STIFF REDDISH BROWN FAT CLAY W/ 0-10% CHERT	▨			■		
4						2.75	
	- OCCASIONAL CHERT SEAM BELOW 5'6"						
6							
8	DISCONTINUED DRILLING ON LIMESTONE @ 8'3"						
10							
12							



WATER LEVEL OBSERVATIONS

DURING DRILLING NONE FT.

AT COMPLETION NONE FT.

AFTER ______ HRS. ______ FT.

NOTES

LIMESTONE BEDROCK ELEVATION = 1277.3

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BORING LOG

BORING NO.: B-6

CLIENT: MARSHALL WATERS WOODY ASSOCIATES

SHEET 1 OF 1

PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY

DATE DRILLED 2-06-08

LOCATION: SPRINGFIELD, MISSOURI

JOB NO: 181772

DRILL RIG '05 CME55

DRILLER EP/MR

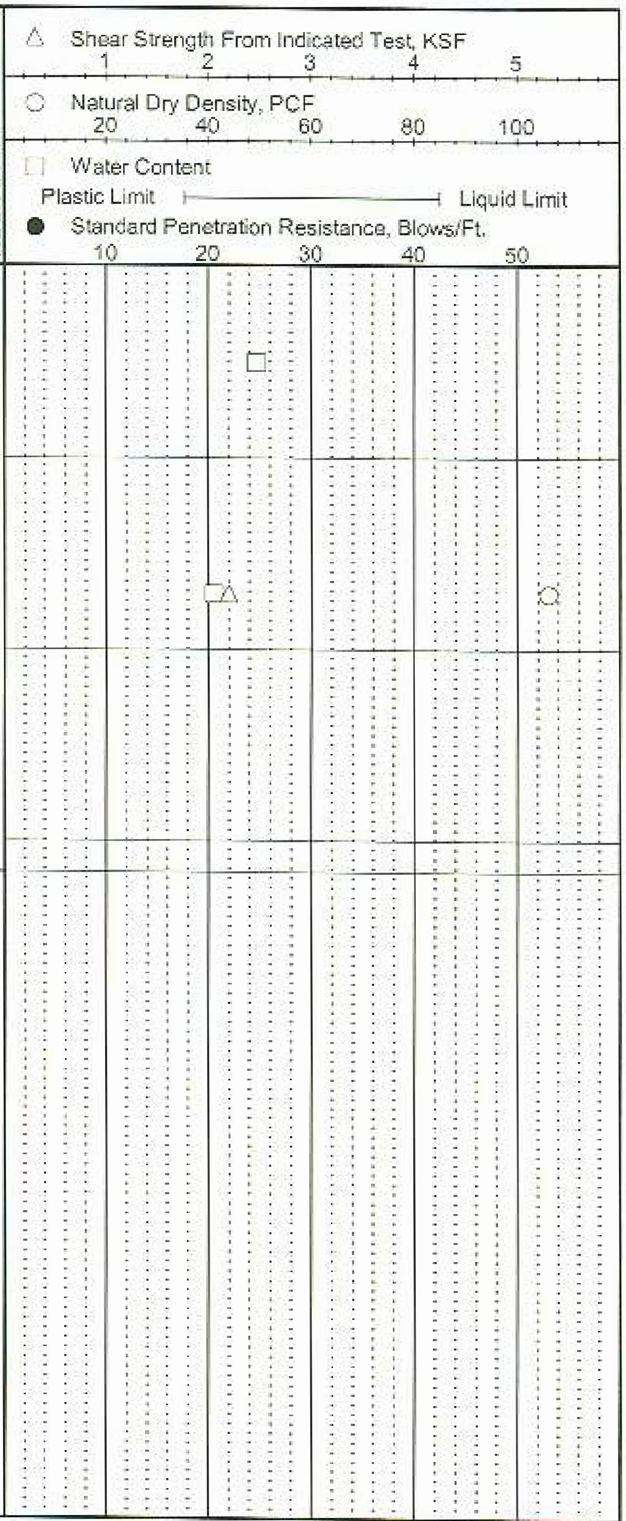
COMPLETION DEPTH 6.33 FT.

BORING METHOD 4.5" DIA. CFA

ROCK CORE DIAMETER N/A IN.

SURFACE ELEVATION 1282.6 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (9")				■		
	MOIST & SOFT TO FIRM & BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT				■	3.5	
2							
	MOIST & FIRM REDDISH BROWN FAT CLAY W/ 10-20% CHERT				■	2.5	
4							
6							
	DISCONTINUED DRILLING ON LIMESTONE @ 6'4"						
8							
10							
12							



WATER LEVEL OBSERVATIONS

DURING DRILLING NONE FT.

AT COMPLETION NONE FT.

AFTER ______ HRS. ______ FT.

NOTES

LIMESTONE BEDROCK ELEVATION = 1276.3

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BORING LOG

BORING NO.: B-7
SHEET 1 OF 1

CLIENT: MARSHALL WATERS WOODY ASSOCIATES

PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY

DATE DRILLED 2-05-08

LOCATION: SPRINGFIELD, MISSOURI

JOB NO: 181772

DRILL RIG '05 CME55

DRILLER EP/MR

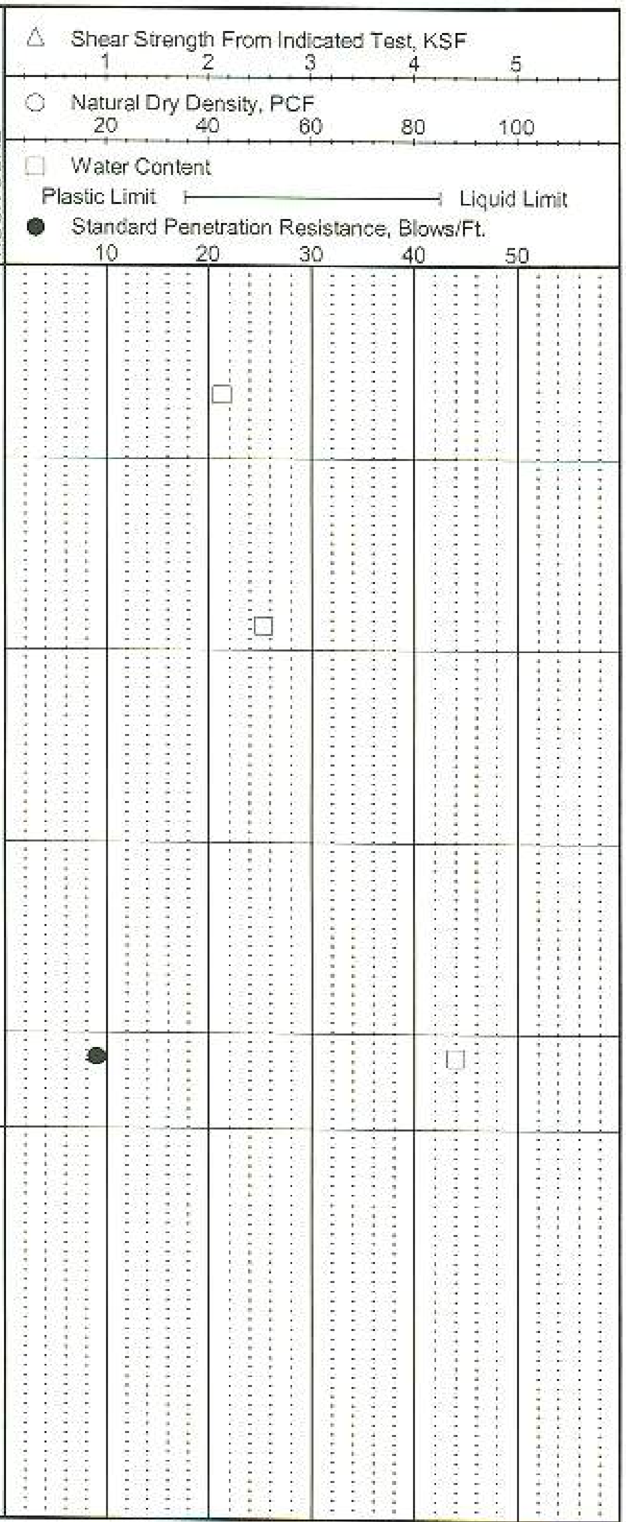
COMPLETION DEPTH 9 FT.

BORING METHOD 4.5" DIA. CFA

ROCK CORE DIAMETER N/A IN.

SURFACE ELEVATION 1286.3 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (9")				■		
	MOIST & SOFT TO FIRM & BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT	▨			■	2.0	
2		▨					
	MOIST & FIRM REDDISH BROWN FAT CLAY W/ 0-10% CHERT	▨			■	3.25	
4		▨					
6		▨					
8		▨	■	9			
	DISCONTINUED DRILLING ON LIMESTONE @ 9'0"						
10							
12							



WATER LEVEL OBSERVATIONS		
DURING DRILLING	NONE	FT.
AT COMPLETION	NONE	FT.
AFTER ______ HRS.		FT.

NOTES

LIMESTONE BEDROCK ELEVATION = 1277.3

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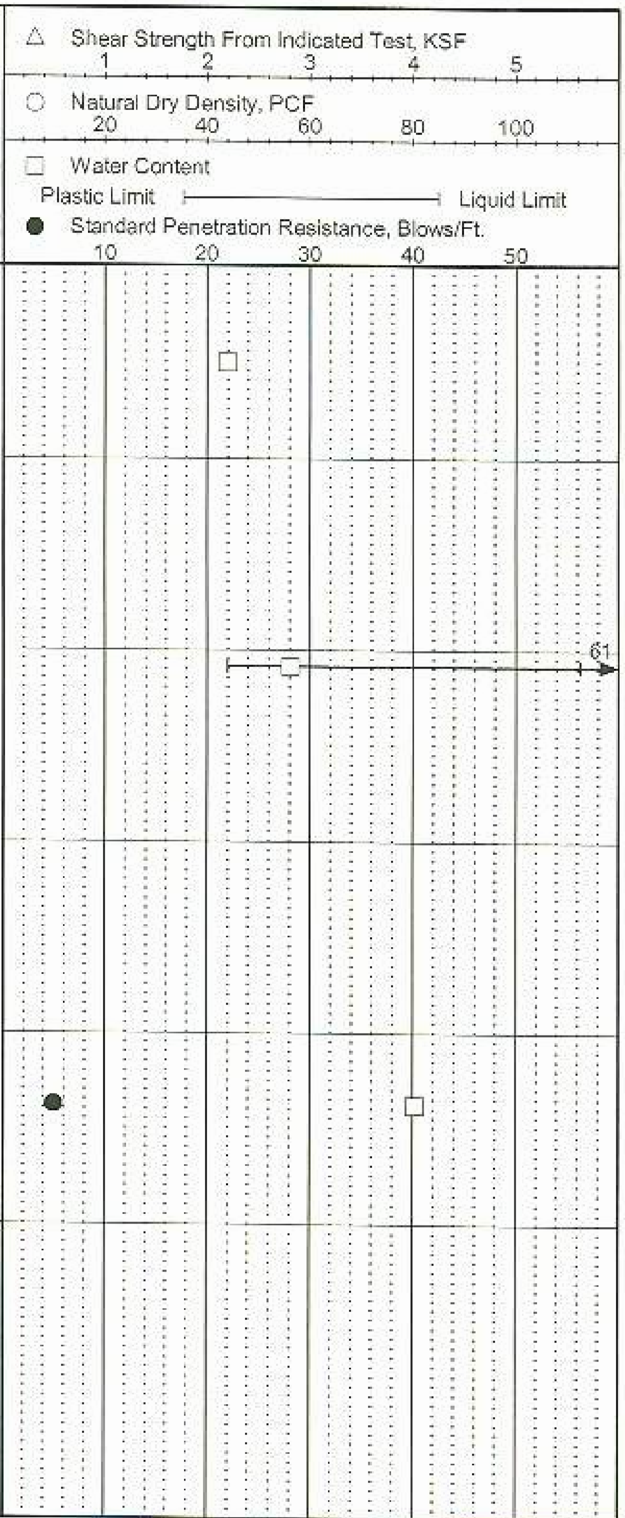
BORING LOG

BORING NO.: B-8
CLIENT: MARSHALL WATERS WOODY ASSOCIATES
SHEET 1 OF 1
PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY
DATE DRILLED 2-05-08
LOCATION: SPRINGFIELD, MISSOURI
JOB NO: 181772
DRILL RIG '05 CME55
DRILLER EP/MR

COMPLETION DEPTH 10 FT.
BORING METHOD 4.5" DIA. CFA
ROCK CORE DIAMETER N/A IN.
SURFACE ELEVATION 1287.7 FT.

DEPTH (FT.)		SPT BLOWS	PENETROMETER (TSF)
0	TOPSOIL (9")		
	MOIST & SOFT TO FIRM & BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT		3.0
2			
4	MOIST & FIRM REDDISH BROWN FAT CLAY W/ 0-10% CHERT		3.25
6			
8	- SOFT TO FIRM BELOW 8'0"	5	
10	DISCONTINUED DRILLING ON LIMESTONE @ 10'0"		
12			



WATER LEVEL OBSERVATIONS
DURING DRILLING NONE FT.
AT COMPLETION NONE FT.
AFTER ______ HRS. ______ FT.

NOTES

LIMESTONE BEDROCK ELEVATION = 1277.7

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BORING LOG

BORING NO.: B-9

CLIENT: MARSHALL WATERS WOODY ASSOCIATES

SHEET 1 OF 1

PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY

DATE DRILLED 2-05-08

LOCATION: SPRINGFIELD, MISSOURI

JOB NO: 181772

DRILL RIG '05 CME55

DRILLER EP/MR

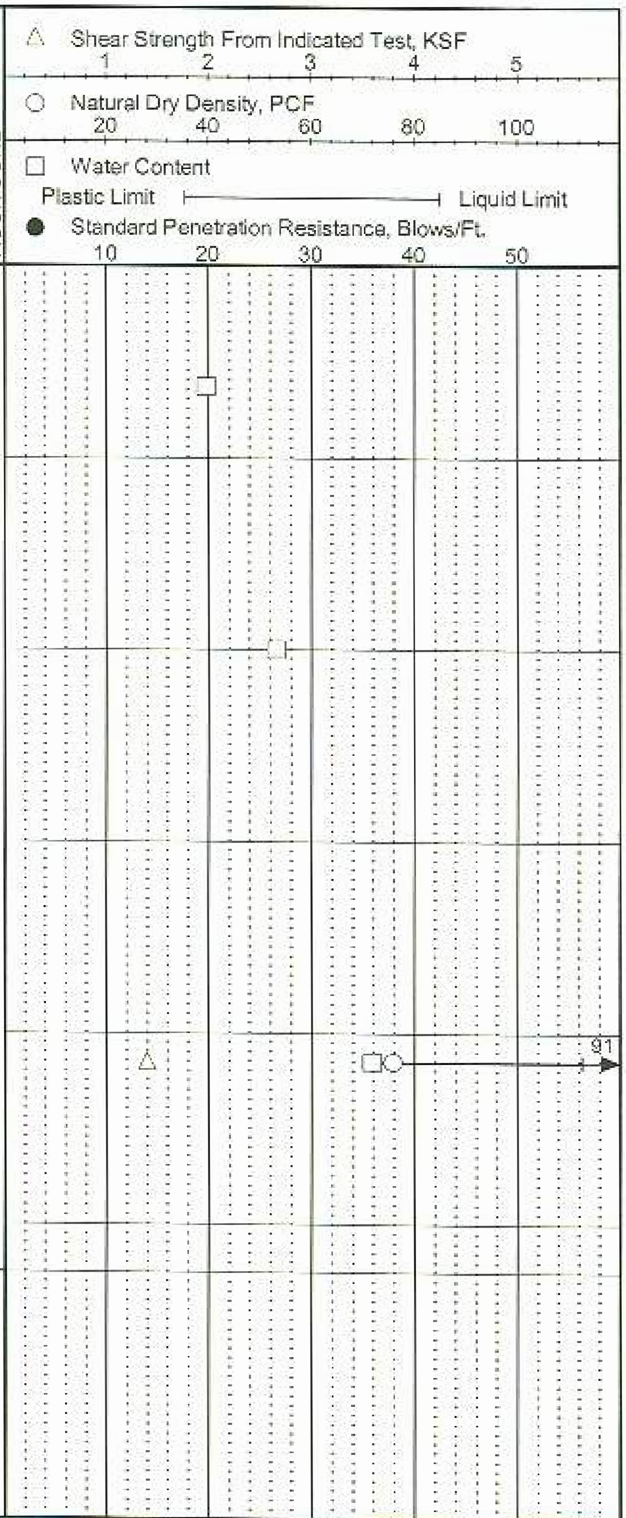
COMPLETION DEPTH 10.5 FT.

BORING METHOD 4.5" DIA. CFA

ROCK CORE DIAMETER N/A IN.

SURFACE ELEVATION 1290.2 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (12")				■		
	MOIST & FIRM & BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT	▨			■	3.25	
2							
	MOIST & FIRM TO STIFF REDDISH BROWN FAT CLAY W/ 0-10% CHERT	▨			■		
4						3.5	
6							
8					■	2.25	
10							
	DISCONTINUED DRILLING ON LIMESTONE @ 10'6"						
12							



WATER LEVEL OBSERVATIONS		
DURING DRILLING	NONE	FT.
AT COMPLETION	NONE	FT.
AFTER ___ HRS.		FT.

NOTES

LIMESTONE BEDROCK ELEVATION = 1279.7

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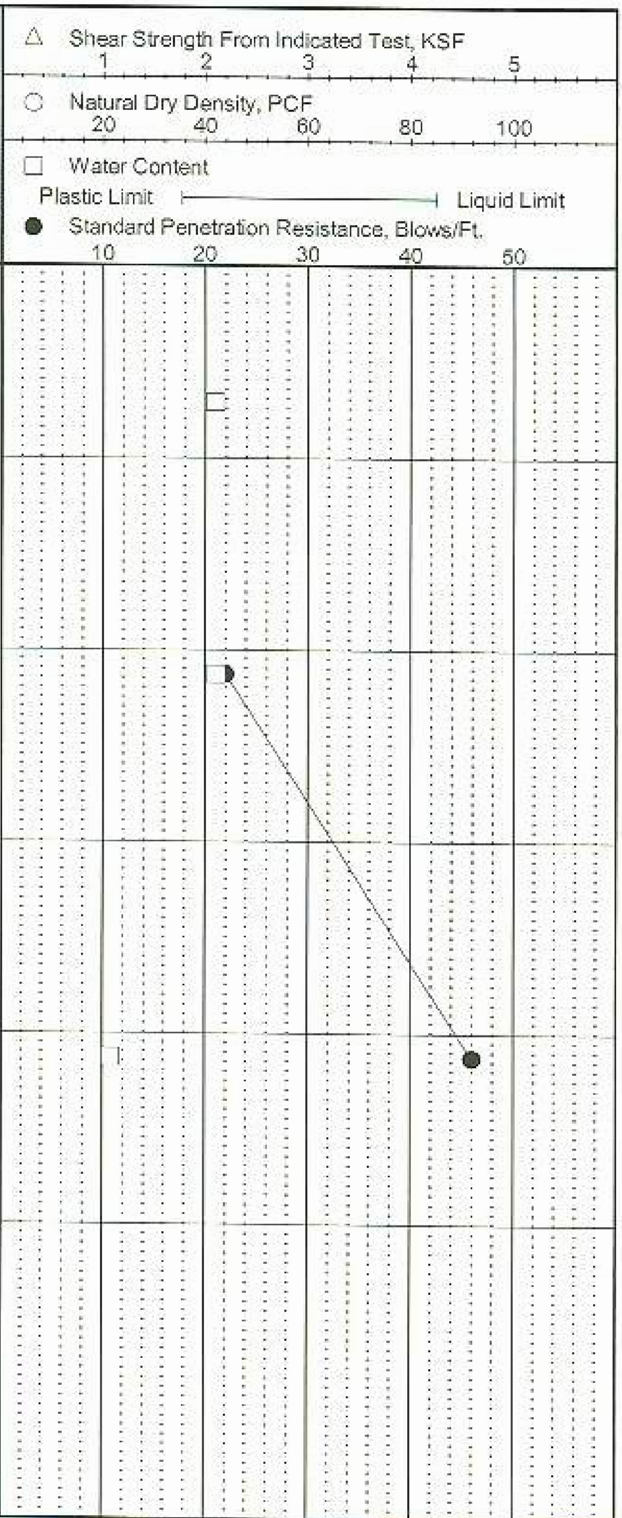
BORING LOG

BORING NO.: B-10
CLIENT: MARSHALL WATERS WOODY ASSOCIATES
SHEET 1 OF 1
PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY
DATE DRILLED 2-05-08
LOCATION: SPRINGFIELD, MISSOURI
JOB NO: 181772
DRILL RIG '05 CME55
DRILLER EP/MR

COMPLETION DEPTH 10 FT.
BORING METHOD 4.5" DIA. CFA
ROCK CORE DIAMETER N/A IN.
SURFACE ELEVATION 1290.3 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (12")				■		
	MOIST & FIRM & BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT				■	2.75	
2							
	- 10-20% CHERT BELOW 3'6"						
4	MOIST & FIRM REDDISH BROWN FAT CLAY W/ 10-30% CHERT & OCCASIONAL CHERT SEAM		■	22		2.5	
6							
8			■	46			
10	DISCONTINUED DRILLING ON LIMESTONE @ 10'0"						
12							



WATER LEVEL OBSERVATIONS
DURING DRILLING NONE FT.
AT COMPLETION NONE FT.
AFTER ______ HRS. ______ FT.

NOTES

LIMESTONE BEDROCK ELEVATION = 1280.3

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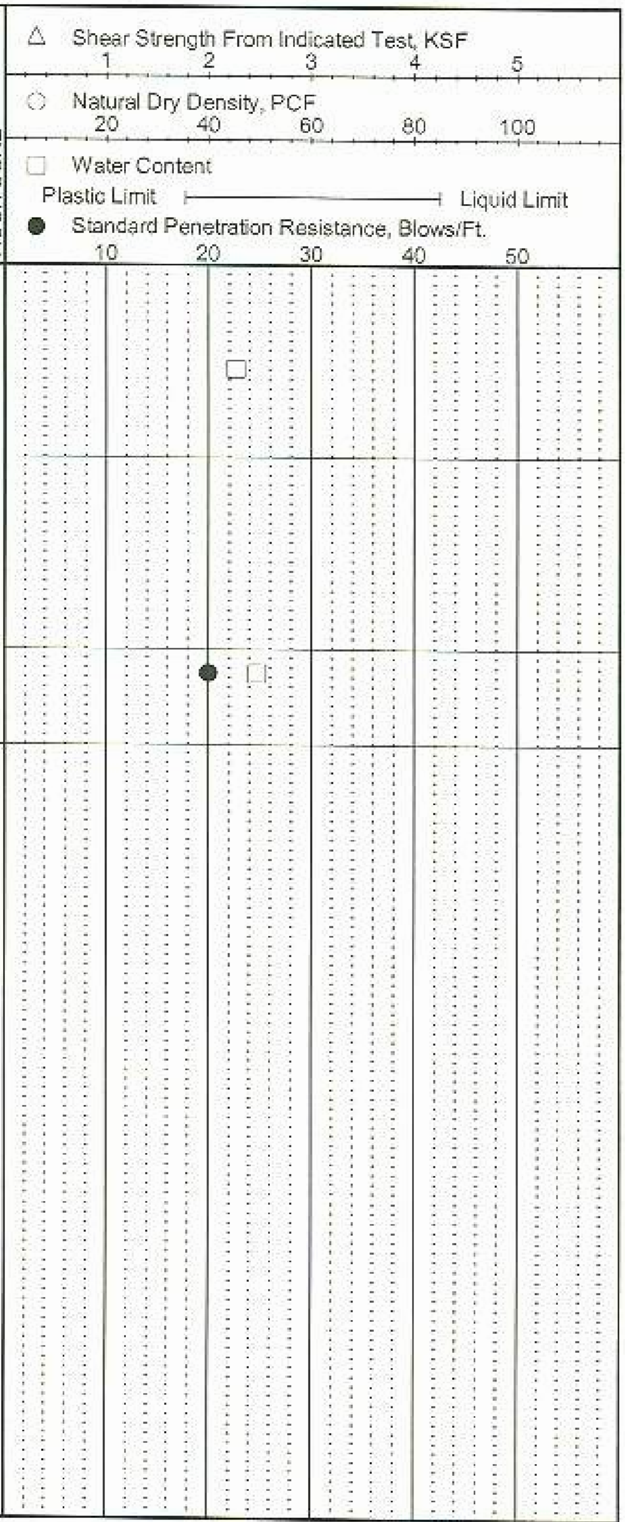
BORING LOG

BORING NO.: P-1
CLIENT: MARSHALL WATERS WOODY ASSOCIATES
SHEET 1 OF 1
PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY
DATE DRILLED 2-07-08
LOCATION: SPRINGFIELD, MISSOURI
JOB NO: 181772
DRILL RIG '05 CME55
DRILLER EP/MR

COMPLETION DEPTH 5 FT.
BORING METHOD 4.5" DIA. CFA
ROCK CORE DIAMETER N/A IN.
SURFACE ELEVATION 1277.7 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (9")				■		
	MOIST & SOFT TO FIRM BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT	▨			■	4.0	
2 4	MOIST & FIRM REDDISH BROWN FAT CLAY W/ 10-30% CHERT	▨	■	20		1.0	
6 8 10 12	DISCONTINUED DRILLING @ 5'0"						



WATER LEVEL OBSERVATIONS
DURING DRILLING NONE FT.
AT COMPLETION NONE FT.
AFTER ______ HRS. ______ FT.

NOTES

LIMESTONE BEDROCK ELEVATION BELOW 1272.7

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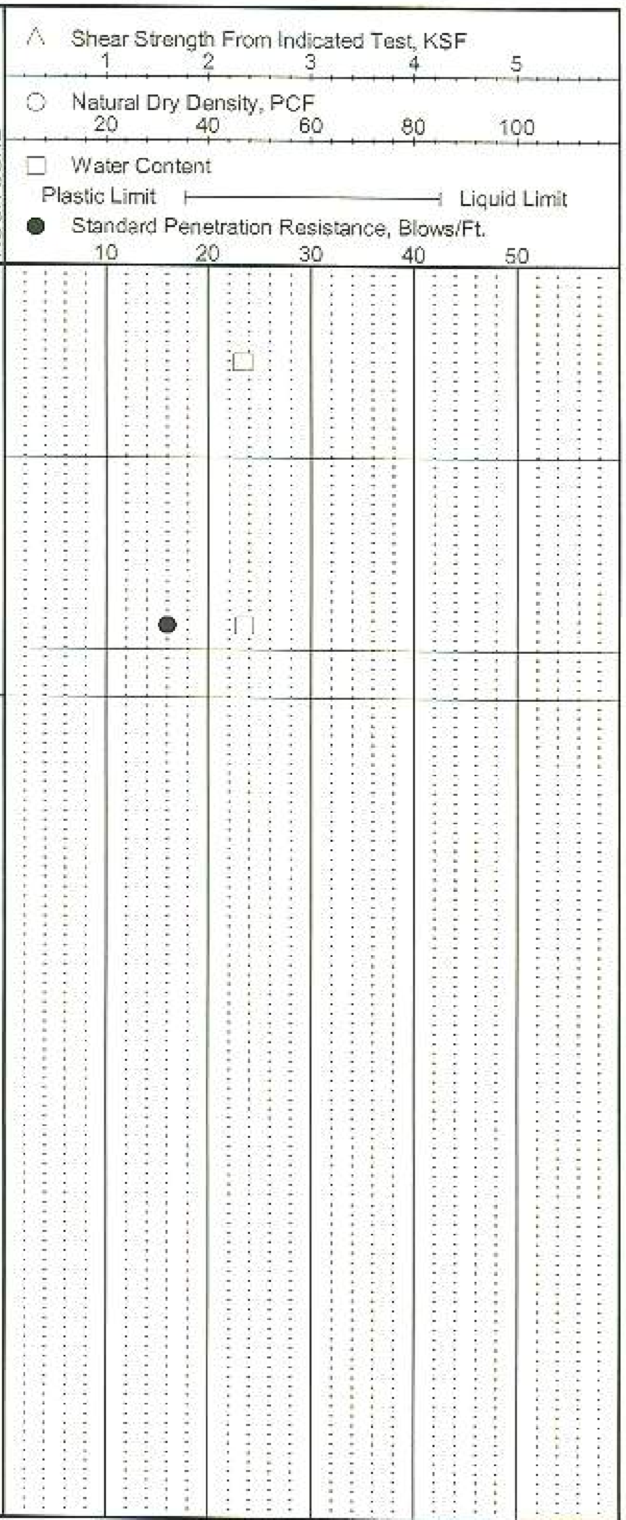
BORING LOG

BORING NO.: P-2
CLIENT: MARSHALL WATERS WOODY ASSOCIATES
SHEET 1 OF 1
PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY
DATE DRILLED 2-07-08
LOCATION: SPRINGFIELD, MISSOURI
JOB NO: 181772
DRILL RIG '05 CME55
DRILLER EP/MR

COMPLETION DEPTH 4.5 FT.
BORING METHOD 4.5" DIA. CFA
ROCK CORE DIAMETER N/A IN.
SURFACE ELEVATION 1282.6 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (9")						
	MOIST & SOFT TO FIRM BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT					3.25	
2							
4	MOIST & FIRM REDDISH BROWN FAT CLAY W/ 0-10% CHERT			16		1.75	
	DISCONTINUED DRILLING @ 4'6"						
6							
8							
10							
12							



WATER LEVEL OBSERVATIONS
DURING DRILLING NONE FT.
AT COMPLETION NONE FT.
AFTER ______ HRS. ______ FT.

NOTES

LIMESTONE BEDROCK ELEVATION BELOW 1278.1

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BORING LOG

BORING NO.: P-3

CLIENT: MARSHALL WATERS WOODY ASSOCIATES

SHEET 1 OF 1

PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY

DATE DRILLED 2-07-08

LOCATION: SPRINGFIELD, MISSOURI

JOB NO: 181772

DRILL RIG '05 CME55

DRILLER EP/MR

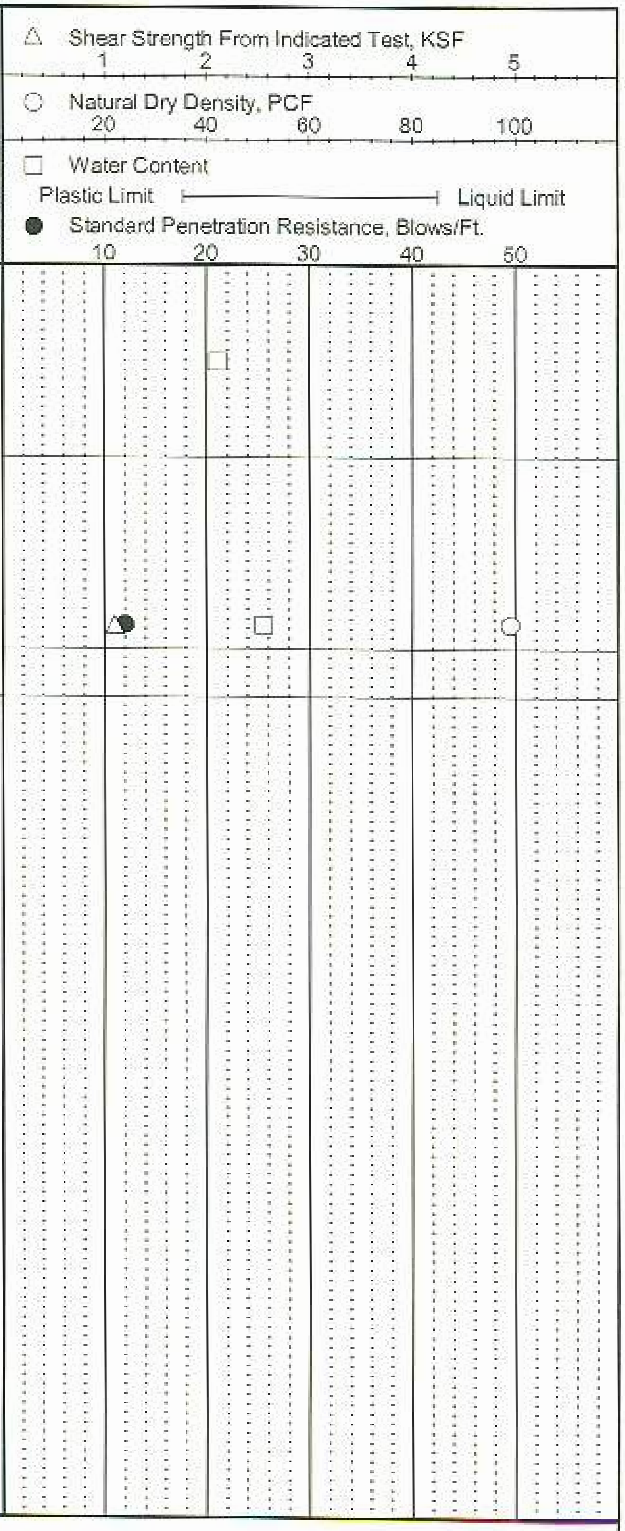
COMPLETION DEPTH 4.5 FT.

BORING METHOD 4.5" DIA. CFA

ROCK CORE DIAMETER N/A IN.

SURFACE ELEVATION 1285.5 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (9")				■		
	MOIST & SOFT TO FIRM BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT	▨			■	2.75	
2							
	MOIST & FIRM REDDISH BROWN FAT CLAY W/ 0-10% CHERT	▨	■	12		1.25	
4							
	DISCONTINUED DRILLING @ 4'6"						
6							
8							
10							
12							



WATER LEVEL OBSERVATIONS		
DURING DRILLING	NONE	FT.
AT COMPLETION	NONE	FT.
AFTER ______ HRS.		FT.

NOTES

LIMESTONE BEDROCK ELEVATION BELOW 1281.0

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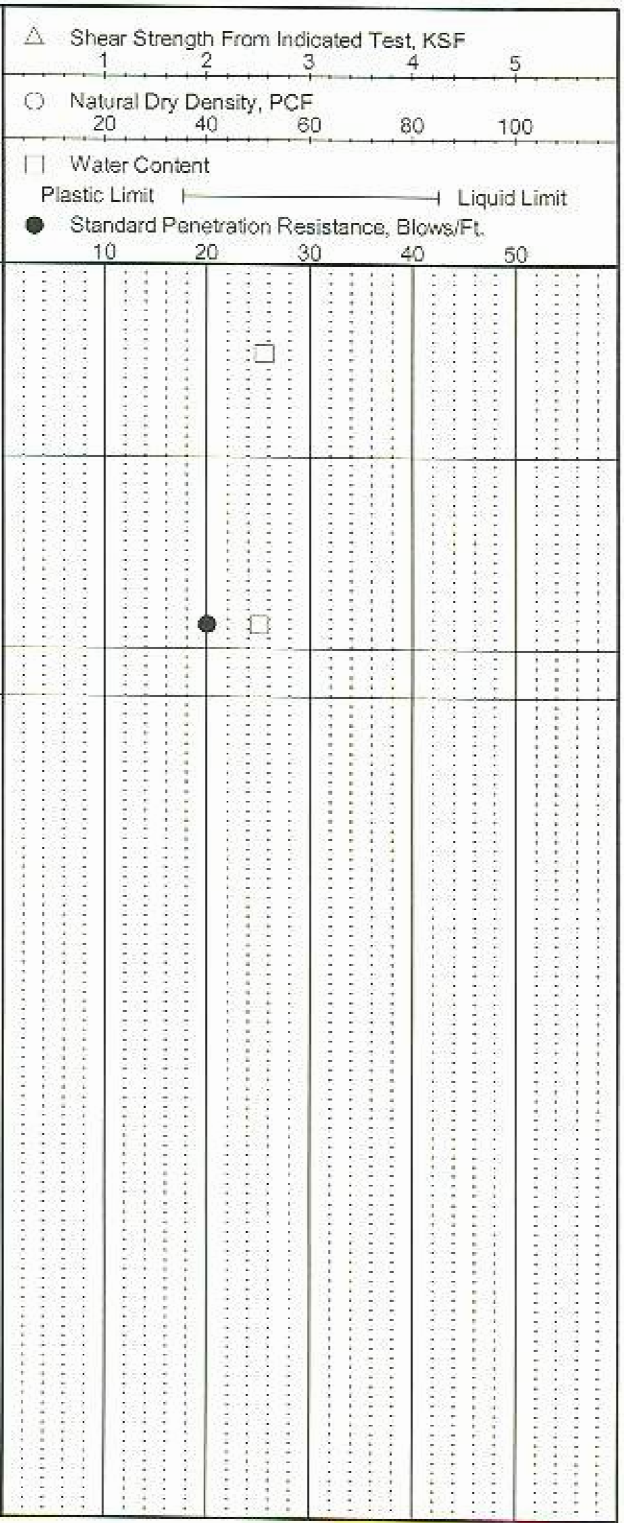
BORING LOG

BORING NO.: P-4
CLIENT: MARSHALL WATERS WOODY ASSOCIATES
SHEET 1 OF 1
PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY
DATE DRILLED 2-07-08
LOCATION: SPRINGFIELD, MISSOURI
JOB NO: 181772
DRILL RIG '05 CME55
DRILLER EP/MR

COMPLETION DEPTH 4.5 FT.
BORING METHOD 4.5" DIA. CFA
ROCK CORE DIAMETER N/A IN.
SURFACE ELEVATION 1284.4 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (10")				■		
	MOIST & FIRM BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT					2.25	
2							
	MOIST & FIRM REDDISH BROWN FAT CLAY W/ 0-20% CHERT		■				
4				20		1.25	
	DISCONTINUED DRILLING @ 4'6"						
6							
8							
10							
12							



WATER LEVEL OBSERVATIONS
DURING DRILLING NONE FT.
AT COMPLETION NONE FT.
AFTER ______ HRS. ______ FT.

NOTES

LIMESTONE BEDROCK ELEVATION BELOW 1279.9

PALMERTON & PARRISH, INC.

Civil, Geotechnical & Materials Engineers
*Testing Laboratories * Core Drilling*

4168 West Kearney
Springfield, MO 65803
(417) 864-6000

3416 East 13th Street
Joplin, MO 64801
(417) 624-2005

BORING LOG

BORING NO.: P-5

CLIENT: MARSHALL WATERS WOODY ASSOCIATES

SHEET 1 OF 1

PROJECT: NORTHSTAR BATTERY - NEW MANUFACTURING FACILITY

DATE DRILLED 2-07-08

LOCATION: SPRINGFIELD, MISSOURI

JOB NO: 181772

DRILL RIG '05 CME55

DRILLER EP/MR

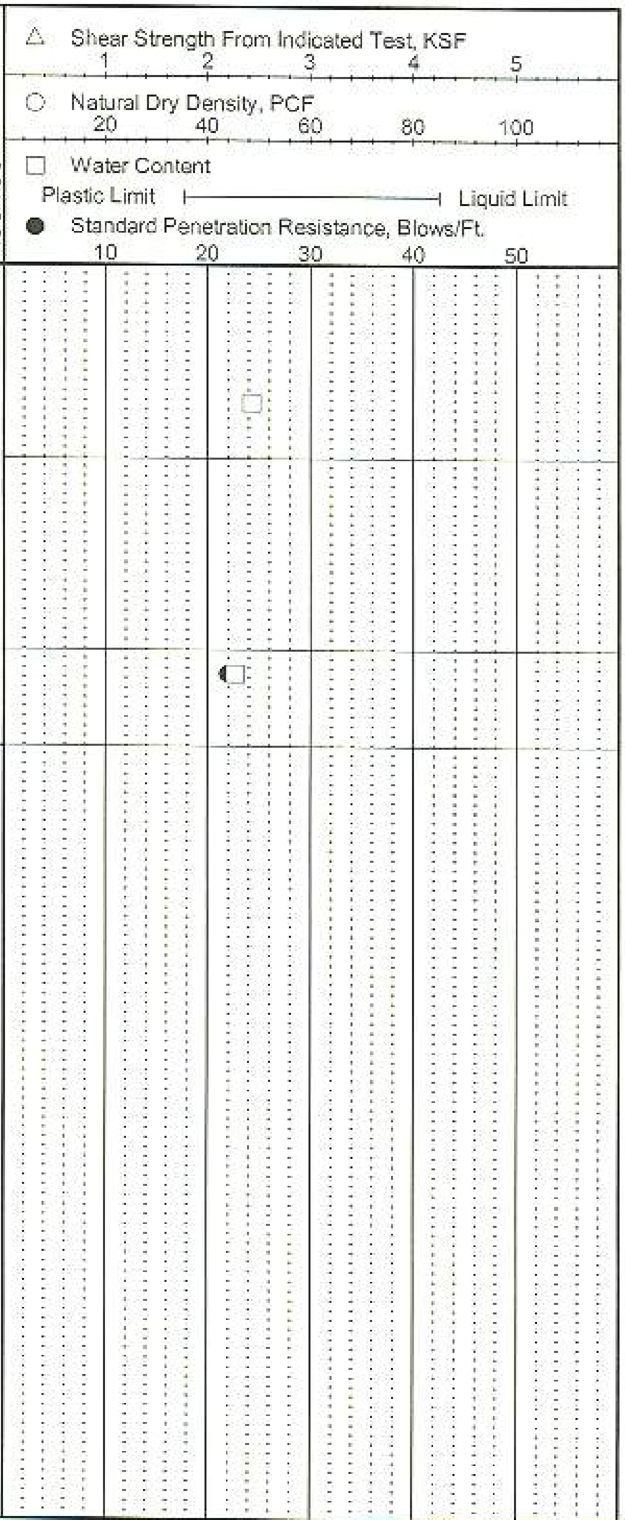
COMPLETION DEPTH 5 FT.

BORING METHOD 4.5" DIA. CFA

ROCK CORE DIAMETER N/A IN.

SURFACE ELEVATION 1283.1 FT.

DEPTH (FT.)		STRATA SYMBOL	SPT SPLIT SPOON	SPT BLOWS	THIN WALL SAMPLE	PENETROMETER (TSF)	ROCK CORE
0	TOPSOIL (12")						
	MOIST & FIRM BROWN TO REDDISH BROWN LEAN CLAY W/ TRACE OF CHERT					2.0	
2							
	MOIST & FIRM REDDISH BROWN FAT CLAY W/ 10-20% CHERT						
4				22		1.75	
	DISCONTINUED DRILLING @ 5'0"						
6							
8							
10							
12							



WATER LEVEL OBSERVATIONS

DURING DRILLING NONE FT.

AT COMPLETION NONE FT.

AFTER ______ HRS. ______ FT.

NOTES

LIMESTONE BEDROCK ELEVATION BELOW 1278.1

PALMERTON & PARRISH, INC.
BORING LOG LEGEND

SOIL/ROCK TYPES

▥	SILT
▨	LEAN CLAY
▨	FAT CLAY
░	SAND
●	GRAVEL
⁘	TOPSOIL
▩	FILL OR POSSIBLE FILL
▦	LIMESTONE
▤	DOLOMITE
▤	SHALE
☐	SANDSTONE
▽	CHERT

SAMPLER TYPES

░	SHELBY TUBE (3" ø)
◩	SPLIT SPOON SAMPLER (2" O.D.)
▥	ROCK CORE (NQ2)
▦	CONTINUOUS SAMPLER
☒	BULK SAMPLE

RQD (%)	ROCK QUALITY
0-25	VERY POOR
25-50	POOR
50-75	FAIR
75-90	GOOD
90-100	EXCELLENT

MAJOR COMPONENT OF SAMPLE	SIZE RANGE
BOULDERS	OVER 12" (>300 MM)
COBBLES	12" TO 3" (300MM TO 75MM)
GRAVEL	3" TO #4 SIEVE (75MM TO 4.75MM)
SAND	#4 TO #200 SIEVE (4.75MM TO 0.05MM)
SILT	PASSING #200 SIEVE (0.074MM TO 0.002MM)
CLAY	PASSING #200 SIEVE (<0.002MM)

SOIL STRENGTH CHARACTERISTICS

COHESIVE SOILS			NON-COHESIVE SOILS	
CONSISTENCY	SPT BLOWS/FT (N)	UNCONFINED COMPRESSIVE STRENGTH (KSF)	RELATIVE DENSITY	SPT BLOWS/FT (N)
VERY SOFT	0-2	0-0.5	VERY LOOSE	0-4
SOFT	3-4	0.5-1.0	LOOSE	5-10
FIRM	5-8	1.0-2.0	MEDIUM DENSE	11-30
STIFF	9-15	2.0-4.0	DENSE	31-50
VERY STIFF	16-30	4.0-8.0	VERY DENSE	51+
HARD	31+	8.0+		

DEGREE OF PLASTICITY	PI (LIQUID LIMIT - PLASTIC LIMIT)
NONE TO SLIGHT	0-4
SLIGHT	5-10
MEDIUM	11-30
HIGH TO VERY HIGH	31+

DESCRIPTION	CRITERIA
DRY	ABSENCE OF MOISTURE, DUSTY, DRY TO TOUCH
MOIST	DAMP, BUT NO VISIBLE WATER
WET	VISIBLE FREE WATER, SOIL USUALLY BELOW WATER TABLE

WATER LEVEL MEASUREMENTS

WATER LEVELS INDICATED ON THE LOG FORMS ARE THE LEVELS MEASURED AT THE TIMES INDICATED. IN PERVIOUS SOILS, THE INDICATED LEVELS MAY REFLECT THE LOCATION OF GROUNDWATER. IN LOW PERMEABILITY SOILS, THE ACCURATE DETERMINATION OF GROUNDWATER LEVELS IS NOT POSSIBLE WITH SHORT TERM OBSERVATIONS.

DESCRIPTIVE TERMS

SLICKENSIDED	HAVING INCLINED PLANES OF WEAKNESS THAT ARE SLICK AND GLOSSY IN APPEARANCE.
FISSURED	CONTAINING SHRINKAGE CRACKS, FREQUENTLY FILLED WITH FINE SAND OR SILT.
LAMINATED	COMPOSED OF THIN (6mm OR LESS) PARTINGS OF VARYING COLOR AND TEXTURE.
INTERBEDDED	COMPOSED OF ALTERNATE LAYERS OF DIFFERENT SOIL/ROCK TYPES.
CALCAREOUS	CONTAINING APPRECIABLE QUANTITIES OF CALCIUM CARBONATE.
WELL GRADED	HAVING UNIFORM DISTRIBUTION FROM COARSE TO FINE PARTICLES.
POORLY GRADED	HAVING SIMILAR SIZE PARTICLES WITH NO SIGNIFICANT VARIANCE.
ARGILLACEOUS	HAVING A NOTABLE PORTION OF CLAY.
MOTTLED	IRREGULARLY MARKED WITH SPOTS OF DIFFERENT COLORS.

SYMBOL	DEFINITION
CFA	CONTINUOUS FLIGHT AUGER
HSA	HOLLOW STEM AUGER
DDC	DRILLING DISCONTINUED
RQD	ROCK QUALITY DESIGNATION
△	COHESIVE SHEAR STRENGTH (KSF)
□	NATURAL MOISTURE CONTENT (%)
○	NATURAL DRY DENSITY (PCF)
●	STANDARD PENETRATION N-VALUE (BLOWS/FT)

* SOIL CLASSIFICATION CRITERIA IN ACCORDANCE WITH ASTM D 2488.

APPENDIX III

PAVEMENT ANALYSIS RESULTS

WinPAS

Pavement Thickness Design According to

1993 AASHTO Guide for Design of Pavements Structures

American Concrete Pavement Association

Flexible Design Inputs

Agency:	
Company:	Marshall Waters Woody Associates
Contractor:	Palmerton & Parrish, Inc
roject Description:	New Northstar Battery Facility - Type I Paving (CBR=3)
Location:	Springfield, MO

Flexible Pavement Design/Evaluation

Structural Number	2.10		**Soil Resilient Modulus**	4,118.20	**psi**
Design ESALs	16,897		**Initial Serviceability**	4.20	
Reliability	85.00	**percent**	**Terminal Serviceability**	2.00	
Overall Deviation	0.45				

Layer Pavement Design/Evaluation

Layer Material	Layer Coefficient	Drainage Coefficient	Layer Thickness	Layer SN
Asphalt Cement Concrete	0.40	1.00	3.00	1.20
Crushed Stone Base	0.12	1.00	6.00	0.72
	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00
			ΣSN	1.92

Monday, February 18, 2008 4:11:30PM

Engineer:Gregory Swift

WinPAS

Pavement Thickness Design According to

1993 AASHTO Guide for Design of Pavements Structures

American Concrete Pavement Association

Flexible Design Inputs

Agency:
Company: Marshall Waters Woody Associates
Contractor: Palmerton & Parrish, Inc
roject Description: New Northstar Battery Facility - Type II Paving (CBR=3)
Location: Springfield, MO

Flexible Pavement Design/Evaluation

Structural Number	3.06		**Soil Resilient Modulus**	4,118.20	**psi**
Design ESALs	184,456		**Initial Serviceability**	4.20	
Reliability	85.00	**percent**	**Terminal Serviceability**	2.00	
Overall Deviation	0.45				

Layer Pavement Design/Evaluation

Layer Material	**Layer Coefficient**	**Drainage Coefficient**	**Layer Thickness**	**Layer SN**
Asphalt Cement Concrete	0.40	1.00	2.00	0.80
Asphalt Treated Agg. Base	0.35	1.00	4.50	1.58
Crushed Stone Base	0.12	1.00	6.00	0.72
	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00
			ΣSN	3.10

Monday, February 18, 2008 4:13:58PM

Engineer:Gregory Swift

WinPAS

Pavement Thickness Design According to

1993 AASHTO Guide for Design of Pavements Structures

American Concrete Pavement Association

Rigid Design Inputs

Agency:
Company: Marshall Waters Woody Associates
Contractor: Palmerton & Parrish, Inc
Project Description: New Northstar Battery Facility - Type III Paving (CBR=3)
Location: Springfield, MO

Rigid Pavement Design/Evaluation

PCC Thickness	4.96	**inches**	**Load Transfer, J**	3.20	
Design ESALs	304,073		**Mod. Subgrade Reaction, k**	212	**psi/in**
Reliability	85.00	**percent**	**Drainage Coefficient, Cd**	1.00	
Overall Deviation	0.35		**Initial Serviceability**	4.50	
Modulus of Rupture	650	**psi**	**Terminal Serviceability**	2.00	
Modulus of Elasticity	4,387,500	**psi**			

Modulus of Subgrade Reaction (k-value) Determination

Resilient Modulus of the Subgrade	4,118.2	**psi**
Resilient Modulus of the Subbase	0.0	**psi**
Subbase Thickness	4.00	**inches**
Depth to Rigid Foundation	0.00	**feet**
Loss of Support Value (0,1,2,3)	0.0	

Modulus of Subgrade Reaction	212.30	**psi/in**

Monday, February 18, 2008 4:16:11PM

Engineer: Gregory Swift

WinPAS

Pavement Thickness Design According to

1993 AASHTO Guide for Design of Pavements Structures

American Concrete Pavement Association

Flexible Design Inputs

Agency:
Company: Marshall Waters Woody Associates
Contractor: Palmerton & Parrish, Inc
roject Description: New Northstar Battery Facility - Type II Paving (CBR=6)
Location: Springfield, MO

Flexible Pavement Design/Evaluation

Structural Number	2.58		**Soil Resilient Modulus**	6,618.50	**psi**
Design ESALs	184,456		**Initial Serviceability**	4.20	
Reliability	85.00	**percent**	**Terminal Serviceability**	2.00	
Overall Deviation	0.45				

Layer Pavement Design/Evaluation

Layer Material	Layer Coefficient	Drainage Coefficient	Layer Thickness	Layer SN
Asphalt Cement Concrete	0.40	1.00	2.00	0.80
Asphalt Treated Agg. Base	0.35	1.00	3.00	1.05
Crushed Stone Base	0.12	1.00	6.00	0.72
	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00
			ΣSN	2.57

Monday, February 18, 2008 4:19:05PM Engineer:Gregory Swift

WinPAS

Pavement Thickness Design According to

1993 AASHTO Guide for Design of Pavements Structures

American Concrete Pavement Association

Rigid Design Inputs

Agency:
Company: Marshall Waters Woody Associates
Contractor: Palmerton & Parrish, Inc
Project Description: New Northstar Battery Facility - Type III Paving (CBR=6)
Location: Springfield, MO

Rigid Pavement Design/Evaluation

PCC Thickness	4.50	inches	**Load Transfer, J**	3.20	
Design ESALs	304,073		**Mod. Subgrade Reaction, k**	341	psi/in
Reliability	85.00	percent	**Drainage Coefficient, Cd**	1.00	
Overall Deviation	0.35		**Initial Serviceability**	4.50	
Modulus of Rupture	650	psi	**Terminal Serviceability**	2.00	
Modulus of Elasticity	4,387,500	psi			

Modulus of Subgrade Reaction (k-value) Determination

Resilient Modulus of the Subgrade	6,618.5	psi
Resilient Modulus of the Subbase	0.0	psi
Subbase Thickness	4.00	inches
Depth to Rigid Foundation	0.00	feet
Loss of Support Value (0,1,2,3)	0.0	

Modulus of Subgrade Reaction	341.20	psi/in

Monday, February 18, 2008 4:20:50PM

Engineer: Gregory Swift

WinPAS

Pavement Thickness Design According to

1993 AASHTO Guide for Design of Pavements Structures

American Concrete Pavement Association

Flexible Design Inputs

Agency:
Company: Marshall Waters Woody Associates
Contractor: Palmerton & Parrish, Inc
roject Description: New Northstar Battery Facility - Type II Paving (CBR=12)
Location: Springfield, MO

Flexible Pavement Design/Evaluation

Structural Number	2.17		**Soil Resilient Modulus**	10,636.60	**psi**
Design ESALs	184,456		**Initial Serviceability**	4.20	
Reliability	85.00	**percent**	**Terminal Serviceability**	2.00	
Overall Deviation	0.45				

Layer Pavement Design/Evaluation

Layer Material	Layer Coefficient	Drainage Coefficient	Layer Thickness	Layer SN
Asphalt Cement Concrete	0.40	1.00	2.00	0.80
Asphalt Treated Agg. Base	0.35	1.00	2.00	0.70
Crushed Stone Base	0.12	1.00	6.00	0.72
	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00
			ΣSN	2.22

Friday, February 15, 2008 2:16:52PM

Engineer:Gregory Swift

WinPAS

Pavement Thickness Design According to

1993 AASHTO Guide for Design of Pavements Structures

American Concrete Pavement Association

Rigid Design Inputs

Agency:
Company: Marshall Waters Woody Associates
Contractor: Palmerton & Parrish, Inc
Project Description: New Northstar Battery Facility - Type III Paving (CBR=12)
Location: Springfield, MO

Rigid Pavement Design/Evaluation

PCC Thickness	4.00	**inches**	**Load Transfer, J**	3.20	
Design ESALs	304,073		**Mod. Subgrade Reaction, k**	484	**psi/in**
Reliability	85.00	**percent**	**Drainage Coefficient, Cd**	1.00	
Overall Deviation	0.35		**Initial Serviceability**	4.50	
Modulus of Rupture	650	**psi**	**Terminal Serviceability**	2.00	
Modulus of Elasticity	4,387,500	**psi**			

Modulus of Subgrade Reaction (k-value) Determination

Resilient Modulus of the Subgrade	9,388.7	**psi**
Resilient Modulus of the Subbase	0.0	**psi**
Subbase Thickness	4.00	**inches**
Depth to Rigid Foundation	0.00	**feet**
Loss of Support Value (0,1,2,3)	0.0	

Modulus of Subgrade Reaction	484.00	**psi/in**

Friday, February 15, 2008 2:27:45PM

Engineer: Gregory Swift