GEOTECHNICAL ENGINEERING STUDY
MARTIN ROAD PARK LAKE EXPANSION
MARTIN ROAD AT DALE STREET
AMARILLO, TEXAS

Presented To:

Alan Plummer Associates, Inc.

July 2013

PROJECT NO. 425-13-32

CMJ ENGINEERING, INC.
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July 9, 2013
Report No. 425-13-32

Alan Plummer Associates, Inc.
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Attn: Mr. George Farah, P.E.

GEOTECHNICAL ENGINEERING STUDY
MARTIN ROAD PARK LAKE EXPANSION
MARTIN ROAD AT DALE STREET
AMARILLO, TEXAS

Dear Mr. Farah:

Submitted here are the results of the geotechnical engineering services for the referenced project. This study was performed in general accordance with CMJ Proposal No. 13-4070 dated January 16, 2013. The geotechnical services were authorized on May 30, 2013 by Mr. George Farah, P.E.

Engineering analyses and recommendations are contained in the text section of the report. Results of our field and laboratory services are included in the appendix of the report. We would appreciate the opportunity to be considered for providing the materials engineering and geotechnical observation services during the construction phase of this project.

We appreciate the opportunity to be of service to Alan Plummer Associates, Inc. Please contact us if you have any questions or if we may be of further service at this time.

Respectfully submitted,
CMJ ENGINEERING, INC.
TEXAS FIRM REGISTRATION NO. F-9177

STATE OF TEXAS
JAMES P. SAPPINGTON, IV
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LICENSED
PROFESSIONAL ENGINEER
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APPENDIX A

1.0 INTRODUCTION

1.1 General

The project, as currently planned, consists of expanding and adding storage to the existing lake at Martin Road Park in Amarillo, Texas for flood control purposes. The existing lake is comprised of two distinct reservoirs connected by RCP; one on the east and west sides of Martin Road located north of Dale Street and south of NE 15th Avenue. The larger reservoir is west of Martin Road, with approximate dimensions of 700 feet by 800 feet. The smaller reservoir is approximately 120 feet by 350 feet. The lake is relatively shallow, with depths on the order of 5 to 10 feet maximum. Bank slopes are less than 4H:1V. Expansion is planned to consist mainly of enlarging the lake area, with only minor deepening. Consideration is being given to combining the two reservoir areas into one large lake, thus removing Martin Road. In addition, moderate erosion of the bank and two inlet channels is noted at the south and southwestern portions of the western reservoir. Several inlet structures may also be repaired or replaced. As bank slopes are not planned to be steeper than 4H:1V, slope stability analyses are not included in the work scope herein. Plate A.1, Plan of Borings, depicts the project vicinity and locations of the exploration borings.

1.2 Purpose and Scope

The purpose of this geotechnical engineering study has been to determine subsurface conditions, evaluate the engineering characteristics of the subsurface materials encountered, develop recommendations for the type or types of foundations, and provide earthwork recommendations.

To accomplish its intended purposes, the study has been conducted in the following phases: (1) drilling sample borings to determine the general subsurface conditions and to obtain samples for testing; (2) performing laboratory tests on appropriate samples to determine pertinent engineering properties of the subsurface materials; and (3) performing engineering analyses, using the field and laboratory data, to develop geotechnical recommendations for the proposed construction.

The design is currently in progress and the locations and/or elevations of structures could change. Once the final design is near completion (80- to 90-percent stage), it is recommended that CMJ Engineering, Inc. be retained to review those portions of the construction documents pertaining to the geotechnical recommendations, as a means to determine that our recommendations have been interpreted as intended.

1.3 Report Format

The text of the report is contained in Sections 1 through 7. All plates and large tables are contained in Appendix A. The alpha-numeric plate and table numbers identify the appendix in which they appear. Small tables of less than one page in length may appear in the body of the text and are numbered according to the section in which they occur.

Units used in the report are based on the English system and may include tons per square foot (tsf), kips (1 kip = 1,000 pounds), kips per square foot (ksf), pounds per square foot (psf), pounds per cubic foot (pcf), and pounds per square inch (psi).

2.0 FIELD EXPLORATION AND LABORATORY TESTING

2.1 Field Exploration

Subsurface materials at the project site were explored by six (6) borings drilled to depths of 25 to 30 feet. The borings were drilled using truck mounted drilling equipment at the approximate locations shown on the Plan of Borings, Plate A.1. The boring logs are included on Plates A.4 through A.9, and keys to classifications and symbols used on the logs are provided on Plates A.2 and A.3.

Undisturbed samples of cohesive soils were obtained with nominal 3-inch diameter thin-walled (Shelby) tube samplers at the locations shown on the logs of borings. The Shelby tube sampler consists of a thin-walled steel tube with a sharp cutting edge connected to a head equipped with a ball valve threaded for rod connection. The tube is pushed into the soil by the hydraulic pulldown of the drilling rig. The soil specimens were extruded from the tube in the field, logged, tested for consistency with a hand penetrometer, sealed, and packaged to limit loss of moisture.

The consistency of cohesive soil samples was evaluated in the field using a calibrated hand penetrometer. In this test a 0.25-inch diameter piston is pushed into the relatively undisturbed sample at a constant rate to a depth of 0.25 inch. The results of these tests, in tsf, are tabulated at respective sample depths on the logs. When the capacity of the penetrometer is exceeded, the value is tabulated as 4.5+.

Ground-water observations during and after completion of the borings are shown on the upper right of the boring log. Upon completion of the borings, the bore holes were backfilled with soil cuttings and plugged at the surface by hand tamping.

2.2 Laboratory Testing

Laboratory soil tests were performed on selected representative samples recovered from the borings. In addition to the classification tests (liquid limits, plastic limits, and gradations), moisture content, unconfined compressive strength, and unit weight tests were performed. Results of the laboratory classification tests, moisture content, unconfined compressive strength, and unit weight conducted for this project are included on the boring logs. Gradation analyses are presented on Plates A.10 through A.13.

The above laboratory tests were performed in general accordance with applicable ASTM procedures or generally accepted practice.

3.0 SUBSURFACE CONDITIONS

3.1 Soil Conditions

Specific types and depths of subsurface strata encountered at the boring locations are shown on the boring logs in Appendix A. The generalized subsurface stratigraphy encountered in the borings are discussed below. Note that depths on the borings refer to the depth from the existing grade or ground surface present at the time of the investigation, and the boundaries between the various soil types are approximate.

Possible fill materials are noted in Borings B-1 and B-2 above 10 and 2 feet, respectively. The possible fills consist of brown, light brown, and reddish brown silty clays and sandy silty clays. Natural soils encountered consist of dark brown, brown, light brown, reddish brown, and light reddish brown silty clays, sandy silty clays, silty sandy clays, and sandy clayey silts.

The clay soils encountered are stiff to hard in consistency (soil basis), with pocket penetrometer values of 2.5 to over 4.5 tsf. The various soils encountered in the borings had tested Liquid Limits (LL) ranging from 34 to 73 with Plasticity Indices (PI) ranging from 18 to 48 and are classified as CL, ML and CH by the USCS. Tested unit weight and unconfined compressive strength values range from 100 to 114 pcf and 3,590 to 20,020 psf, respectively.

The Atterberg Limits tests indicate the various clays encountered at this site are moderately active to highly active with respect to moisture induced volume changes. Active clays can experience volume changes (expansion or contraction) with fluctuations in their moisture content.

3.2 Ground-Water Observations

The borings were drilled using continuous flight augers in order to observe ground-water seepage during drilling. Ground-water seepage was not encountered during drilling and all borings were dry at completion. While it is not possible to accurately predict the magnitude of subsurface water fluctuation that might occur based upon these short-term observations, it should be recognized that ground-water conditions will vary with fluctuations in rainfall.

Fluctuations of the ground-water level can occur due to seasonal variations in the amount of rainfall; site topography and runoff; hydraulic conductivity of soil strata; and other factors not evident at the time the borings were performed. The possibility of ground-water level fluctuations should be considered when developing the design and construction plans for the project. Ground water may occur in more granular/sandy zones.

4.0 FOUNDATION RECOMMENDATIONS

4.1 General Foundation Considerations

Two independent design criteria must be satisfied in the selection of the type of foundation to support the proposed inlet structures. First, the ultimate bearing capacity, reduced by a sufficient factor of safety, must not be exceeded by the bearing pressure transferred to the foundation soils. Second, due to consolidation or expansion of the underlying soils during the operating life of the structures, total and differential vertical movements must be within tolerable limits.

4.2 Foundations

Foundations for the inlet structures may be mat-type founded a minimum of 2 feet below the thalweg of the channel situated within hard dark brown, brown, light brown, or reddish brown silty clays. Proper identification of the bearing material by qualified geotechnical personnel during construction is vital; therefore, the foundation bearing depth may be deeper, depending on materials encountered. The foundations may be designed for an allowable bearing pressure of 4.0 ksf. Excavation for the footing base could require dewatering to keep the excavation free of excess water. The water table, if encountered, should be lowered to a depth of 2 feet below the proposed excavation. It should be noted that wall foundations are typically subjected to non-uniform pressure across the foundation, and possibly negative pressure (separation of foundation from soil) under a portion of the foundation, due to the overturning moment induced by the lateral earth pressures. The allowable foundation pressures given above are for the maximum pressure induced by the foundation loads, and not the average pressure under the foundation base.

The horizontal bases of the footings will develop resistance to sliding by means of friction. Given the nature of the foundation materials, an ultimate friction factor of 0.35 may be used to calculate sliding resistance of the footings. Passive earth pressure resistance should be neglected in the channel bottom.

Foundations designed in accordance with these recommendations will have a minimum factor of safety of 3 with respect to a bearing capacity failure, and should experience a total settlement of 1 inch or less and a differential settlement of ½ inch or less, after construction.

4.3 Mat Type Foundation Construction

Mat type foundation construction should be monitored by a representative of the geotechnical engineer to observe, among other things, the following items:

- Identification of bearing material
- Adequate penetration of the foundation excavation into the bearing layer
- The base and sides of the excavation are clean of loose cuttings
- When seepage is encountered, whether it is of sufficient amount to require the use of excavation dewatering methods

The footing excavations should be neat vertical cuts and maintained throughout construction. Precautions should be taken during the placement of reinforcing steel and concrete to prevent loose, excavated soil from falling into the excavation. Concrete should be placed as soon as practical after completion of the excavating, cleaning, reinforcing steel placement and observation. Excavation for a mat type foundation should be filled with concrete before the end of the workday, or sooner if required, to prevent deterioration of the bearing material. Prolonged exposure or inundation of the bearing surface with water will result in change in strength and compressibility characteristics. If delays occur, the excavation should be deepened as necessary and cleaned, in order to provide a fresh bearing surface. If more than 24 hours of exposure of the bearing surface is anticipated in the excavations, a "mud slab" should be used to protect the bearing surfaces. If a mud slab is used, the foundation excavations should initially be over-excavated by approximately 4 inches and a lean concrete mud slab of approximately 4 inches in thickness should be placed in the bottom of the excavations immediately following exposure of the bearing surface by excavation. The mud slab will protect the bearing surface, maintain more uniform moisture in the subgrade, facilitate dewatering of excavations if required, and provide a working surface for the placement of formwork and reinforcing steel.

The concrete should be placed in a manner that will prevent the concrete from striking the reinforcing steel or the sides of the excavation in a manner that would cause segregation of the concrete.

4.4 Design Considerations

Undercutting due to erosion must be prevented in order for the inlet structures to be successful. In addition to providing the embedment depth recommended above, the addition of a 12-inch thick gabion mattress or similar erosion protection structure at the wall toe should be considered for scour protection. The mattress should be at least 6 feet in length. The upstream end of the gabions should be protected from erosion by angling a return into the bank using either a gabion mattress or suitable rip-rap.

PVC coated gabions should be used, particularly as the base of the structure will be inundated by water. Detailed specifications should be provided for gabion construction including proper tying method, inner tie wire method, cutting and retying of the gabions to form angles and curves, passage of pipes through gabions, tapering and transitioning of gabions, etc. The contractor or subcontractor selected should have prior acceptable experience in gabion construction.

4.5 Lateral Earth Pressures

4.5.1 *General*

The below grade walls must be designed for lateral pressures including, but not necessarily limited to, earth, water, surcharge, swelling, and vibration. In addition, the lateral pressures will be influenced by whether the backfill is drained or undrained, and above or below the ground-water table.

4.5.2 *Equivalent Fluid Pressures*

Lateral earth pressures on below grade and retaining walls will depend on a variety of factors, including the type of soils behind the wall, the condition of the soils, and the drainage conditions behind the wall. Recommended lateral earth pressures expressed as equivalent fluid pressures, per foot of wall height, are presented in Table 4.5.2-1 for a wall with a level backfill behind the top of the wall. The equivalent fluid pressure for an undrained condition should be used if a drainage system is not present to remove water trapped in the backfill and behind the wall. Pressures are provided for at-rest and active earth pressure conditions. Rigid walls are not anticipated to develop enough movement to mobilize active earth pressures. In order to allow for an active condition the top of the wall(s) must deflect on the order of 0.4 percent.

TABLE 4.5.2-1 – Equivalent Fluid Pressures

Backfill Material	At-Rest Equivalent Fluid Pressure (pcf)		Active Equivalent Fluid Pressure (pcf)	
	Drained	Undrained	Drained	Undrained
Excavated on-site soils or clay fill material	100	110	90	100
Select fill / flowable fill / on-site soils meeting material specifications	75	100	55	90
Free draining granular backfill material	55	90	35	80

For the select fill or free draining granular backfill, these values assume that a "full" wedge of the material is present behind the wall. The wedge is defined where the wall backfill limits extend outward at least 2 feet from the base of the wall and then upward on a 1H:2V slope. For narrower backfill widths of granular or select fill soils, the equivalent fluid pressures for the on-site soils should be used.

4.5.3 *Additional Lateral Pressures*

The location and magnitude of permanent surcharge loads (if present) should be determined, and the additional pressure generated by these loads such as the weight of construction equipment and vehicular loads that are used at the time the structures are being built must also be considered in the design. The effect of this or any other surcharge loading may be accounted for by adding an additional uniform load to the full depth of the side walls equivalent to one-half of the expected vertical surcharge intensity for select backfill materials, or equal to the full vertical surcharge intensity for clay backfill. The equivalent fluid pressures, given here, do not include a safety factor. Analysis of surcharge loads (if any) should be performed on a case-by-case basis. This is not included in the scope of this study. These services can be provided as additional services upon request.

4.6 Wall Backfill Material Requirements

On-Site Clay Backfill: For wall backfill areas with site-excavated materials or similar imported materials, all oversized fragments larger than four inches in maximum dimension should be removed from the backfill materials prior to placement. The backfill should be free of all organic and deleterious materials, and should be placed in maximum 8-inch compacted lifts at a minimum of 95 percent of Standard Proctor density (ASTM D 698) within a moisture range of plus to minus 3 percentage points of optimum moisture. Compaction within five feet of the walls should be accomplished using hand compaction equipment, and should be between 90 and 95 percent of the Standard Proctor density.

Select Fill Backfill: All wall select backfill should consist of clayey sand and/or sandy clay material with a Plasticity Index between 4 and 16, with a Liquid Limit not exceeding 35. The select fill should be placed in maximum 8-inch lifts and compacted to between 95 and 100 percent of Standard Proctor density (ASTM D 698) within a moisture range of plus to minus 3 percentage points of the optimum moisture. Compaction within five feet of the walls should be accomplished using hand compaction equipment and should be compacted between 90 and 95 percent of the Standard Proctor density.

Flowable Backfill: Item 401, Texas Department of Transportation Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, 2004 Edition.

Free Draining Granular Backfill: All free draining granular wall backfill material should be a crushed stone, sand/gravel mixture, or sand/crushed stone mixture. The material should have less than 3 percent passing the No. 200 sieve and less than 30 percent passing the No. 40 sieve. The minus No. 40 sieve material should be non-plastic. Granular wall backfill should not be water jetted during installation.

4.7 Drainage Requirements

In order to achieve the "drained" condition for low-permeability walls (concrete, masonry, etc.), a vertical drainage blanket or geocomposite drainage member must be installed adjacent to the wall on the backfill side. The drainage must be connected to an outlet drain at the base of the wall. Drainage could be provided using a collector pipe or weep holes near the base of the abutment. Drains should be properly filtered to minimize the potential for erosion through these drains, and/or the plugging of drain lines. Design or specific recommendations for drainage members is beyond the scope for this study. These services can be provided as an additional service upon request.

5.0 EARTHWORK

5.1 Site Preparation

The subgrade should be firm and able to support the construction equipment without displacement. Soft or yielding subgrade should be corrected and made stable before construction proceeds. The subgrade should be proof rolled to detect soft spots, which if exist, should be reworked to provide a firm and otherwise suitable subgrade. Proof rolling should be performed using a heavy pneumatic tired roller, loaded dump truck, or similar piece of equipment. The proof rolling operations should be observed by the project geotechnical engineer or his/her representative. Prior to fill placement, the subgrade should be scarified to a minimum depth of 8 inches, its moisture content adjusted, and recompacted to the moisture and density recommended for fill.

5.2 Placement and Compaction

Fill material should be placed in loose lifts not exceeding 8 inches in uncompacted thickness. The uncompacted lift thickness should be reduced to 4 inches for structure backfill zones requiring hand-operated power compactors or small self-propelled compactors. The fill material should be uniform with respect to material type and moisture content. Clods and chunks of material should be broken down and the fill material mixed by disking, blading, or plowing, as necessary, so that a material of uniform moisture and density is obtained for each lift. Water required for sprinkling to bring the fill material to the proper moisture content should be applied evenly through each layer.

The on-site soils are suitable for use in site grading. Imported fill material should be clean soil with a Liquid Limit less than 60 and no rock greater than 4 inches in maximum dimension. The fill materials should be free of vegetation and debris.

The fill material should be compacted to a minimum of 95 percent of the maximum dry density determined by the Standard Proctor test, ASTM D 698. In conjunction with the compacting operation, the fill material should be brought to the proper moisture content. The moisture content for general earth fill should range from 2 percentage points below optimum to 5 percentage points above optimum (-2 to +5). These ranges of moisture contents are given as maximum recommended ranges. For some soils and under some conditions, the contractor may have to maintain a more narrow range of moisture content (within the recommended range) in order to consistently achieve the recommended density.

Field density tests should be taken as each lift of fill material is placed. As a guide, one field density test per lift for each 5,000 square feet of compacted area is recommended. For small areas or critical areas the frequency of testing may need to be increased to one test per 2,500 square feet. A minimum of 2 tests per lift should be required. The earthwork operations should be observed and tested on a continuing basis by an experienced geotechnician working in conjunction with the project geotechnical engineer.

Each lift should be compacted, tested, and approved before another lift is added. The purpose of the field density tests is to provide some indication that uniform and adequate compaction is being obtained. The actual quality of the fill, as compacted, should be the responsibility of the contractor and satisfactory results from the tests should not be considered as a guarantee of the quality of the contractor's filling operations.

5.3 Channel / Bank Slope Recommendations

Where existing channels have eroded and require reconstruction, and in new lake bank areas, special site preparation procedures will be imperative to reduce the possibility of slope sliding, settlement of fill soils, and otherwise undue soil movements. In addition, cuts and fills will be required along the channels/banks to properly blend new fill materials to existing fill materials. These procedures are outlined below, but generally consist of proper removal of existing vegetation, proof rolling the site area to receive fill, benching new fill into the existing fill to prevent a direct slide plane at this interface, and general grading at existing, specific erosion and drainage areas.

Specific recommended procedures are provided in this report section to emphasize the importance of these procedures. If these procedures are adhered to during the construction phase, the potential for slides, undue settlement, and otherwise problematic soil movements are greatly reduced. Attention is called to Section 5.7 regarding the need for channel / bank erosion protection as necessary. The following specific recommendations are provided:

1. Grub all areas in which earth fill operations will take place. This requires the proper removal and disposal of all trees, brush, and vegetation. It also requires the grubbing of all roots in excess of 1 inch and disposing of them properly away from the site.

2. All organic topsoil, trash, debris, or other deleterious materials should be removed from the fill. Any rock fragments larger than 6-inch size should likewise be removed.

3. In areas to receive fill, the surface should be proof rolled to locate any soft or compressible materials. Should said materials be encountered, they should be removed and backfilled with acceptable soil materials.

4. The fill materials should be placed from the bottom leading upwards. The surface soils should be lightly scarified to allow bonding of new fill to either natural soils or existing fill. The initial lift of fill should be at least 12 feet wide and placed on a horizontal plane. As additional fill is placed, the fill should be benched into the natural soil for every 1-foot thickness of fill placed. The benches should continue to work uphill to prevent a continuous plane from occurring at the new fill/old fill/natural soil interface.

The onsite soil may be used as fill for the proposed slopes. Clean sands, silts, gravels, and highly plastic clays should be discarded. In addition, fill materials should be placed, pulverized as required, uniformly moistened as required, compacted to those standards listed above and reiterated in Section 5.2, and each lift tested to assure proper compaction. Any fill not meeting specifications should be reworked/recompacted as necessary. In addition, light scarification should be performed on the surface of the accepted fill prior to placing the next lift of fill in order to bond the fill lifts satisfactorily.

5.4 Lake Expansion Comments

Clay soils with a Plasticity Index of 25 or greater are considered to be relatively impervious and would normally be considered to provide adequate protection against large seepage losses. A majority of the soils encountered in the borings are considered to have Plasticity Indices in excess of 25 and are generally considered amenable for water retention. Particle size analyses of on-site materials with Plasticity Indices less than 25 (Boring B-4 below 7 feet) indicate a relatively high silt and clay fraction, thus seepage losses would occur rather slowly. Therefore, deepening of the lake, and/or combining the two lake areas is feasible and should not result in excess water seepage losses. Highly sandy, permeable zones were not encountered in the exploration borings.

5.5 Excavation

The soils encountered in the borings can easily be excavated using conventional earthwork equipment. No major hard rock units were encountered in the borings through completion depth. In the case that excavations occur through granular soils or submerged soils, it will be necessary to either slope the excavation sidewalls or provide temporary bracing to control excavation wall instability.

The side slopes of excavations through the overburden soils should be made in such a manner to provide for their stability during construction. Existing structures, pipelines or other facilities, which are constructed prior to or during the currently proposed construction and which require excavation, should be protected from loss of end bearing or lateral support.

Temporary construction slopes and/or permanent embankment slopes should be protected from surface runoff water. Site grading should be designed to allow drainage at planned areas where erosion protection is provided, instead of allowing surface water to flow down unprotected slopes.

Permanent slopes at the site should be as flat as practical to reduce creep and occurrence of shallow slides. The following slope angles are recommended as maximums. The presented angles refer to the total height of a slope. Site improvement should be maintained away from the top of the slope to reduce the possibility of damage due to creep or shallow slides.

Height (ft.)	Horizontal to Vertical
0 – 3	1:1
3 – 6	2:1
6 – 9	3:1
> 9	4:1

Trench safety recommendations are beyond the scope of this report. The contractor must comply with all applicable safety regulations concerning trench safety and excavations including, but not limited to, OSHA regulations.

5.6 Soil Corrosion Potential

Specific testing for soil corrosion potential was not included in the scope of this study. However, based upon past experience on other projects in the vicinity, the soils at this site may be corrosive. Standard construction practices for protecting metal pipe and similar facilities in contact with these soils should be used.

5.7 Erosion and Sediment Control

All disturbed areas should be protected from erosion and sedimentation during construction, and all permanent slopes and other areas subject to erosion or sedimentation should be provided with permanent erosion and sediment control facilities. All applicable ordinances and codes regarding erosion and sediment control should be followed.

Soils encountered are considered moderately erosive. Generally speaking, maximum permissible velocities of these soils in non-vegetated waterways vary from approximately 2½ to 4 feet per second. Should higher velocities be expected in the channels, erosion control features would be recommended to reduce water velocities and/or reduce the potential for slope and bottom channel soils erosion. Plates A.10 through A.13 present sieve/hydrometer grain size analyses for typical onsite soils. The following table provides grain size values for erosion analyses.

Table 5.7-1 Grain Size Values

		Grain Size (mm)	
Boring No.	**Depth (Ft.)**	D_{50}	D_{95}
B-1	7 – 8	0.0019	0.1139
B-2	3 – 4	0.0076	0.1396
B-4	4 – 5	0.0109	0.1359
B-4	9 – 10	0.0287	0.1366
B-5	2 – 3	0.0040	0.9348

6.0 CONSTRUCTION OBSERVATIONS

In any geotechnical investigation, the design recommendations are based on a limited amount of information about the subsurface conditions. In the analysis, the geotechnical engineer must assume the subsurface conditions are similar to the conditions encountered in the borings. However, quite often during construction, anomalies in the subsurface conditions are revealed. Therefore, it is recommended that CMJ Engineering, Inc. be retained to observe any additional earthwork and perform materials evaluation during the construction phase of the project. This enables the geotechnical engineer to stay abreast of the project and to be readily available to evaluate unanticipated conditions, to conduct additional tests if required and, when necessary, to recommend alternative solutions to unanticipated conditions.

It is proposed that construction phase observation and materials observation commence by the project geotechnical engineer at the outset of the project. Experience has shown that the most suitable method for procuring these services is for the owner or the owner's design engineers to contract directly with the project geotechnical engineer. This results in a clear, direct line of communication between the owner and the owner's design engineers and the geotechnical engineer.

7.0 REPORT CLOSURE

The locations and elevations of the borings should be considered accurate only to the degree implied by the methods used in their determination. The boring logs shown in this report contain information related to the types of soil encountered at specific locations and times and show lines delineating the interface between these materials. The logs also contain our field representative's interpretation of conditions that are believed to exist in those depth intervals between the actual samples taken. Therefore, these boring logs contain both factual and interpretive information. Laboratory soil classification tests were also performed on samples from selected depths in the borings. The results of these tests, along with visual-manual procedures, were used to generally classify each stratum. Therefore, it should be understood that the classification data on the logs of borings represent visual estimates of classifications for those portions of each stratum on which the full range of laboratory soil classification tests were not performed. It is not implied that these logs are representative of subsurface conditions at other locations and times.

With regard to ground-water conditions, this report presents data on ground-water levels as they were observed during the course of the field work. In particular, water level readings have been made in the borings at the times and under conditions stated in the text of the report and on the boring logs. It should be noted that fluctuations in the level of the ground-water table can occur with passage of time due to variations in rainfall, temperature and other factors. Also, this report does not include quantitative information on rates of flow of ground water into excavations, on pumping capacities necessary to dewater the excavations, or on methods of dewatering excavations.

Unanticipated soil conditions at a construction site are commonly encountered and cannot be fully predicted by mere soil samples, test borings or test pits. Such unexpected conditions frequently require that additional expenditures be made by the owner to attain a properly designed and constructed project. Therefore, provision for some contingency fund is recommended to accommodate such potential extra cost.

The analyses, conclusions and recommendations contained in this report are based on site conditions as they existed at the time of our field investigation and further on the assumption that the exploratory borings are representative of the subsurface conditions throughout the site; that is, the subsurface conditions everywhere are not significantly different from those disclosed by the borings at the time they were completed. If, during construction, different subsurface conditions from those encountered in our borings are observed, or appear to be present in excavations, we must be advised promptly so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between submission of this report and the start of the work at the site, if conditions have changed due either to natural causes or to construction operations at or adjacent to the site, or if structure locations, structural loads or finish grades are changed, we urge that we be promptly informed and retained to review our report to determine the applicability of the conclusions and recommendations, considering the changed conditions and/or time lapse.

Further, it is urged that CMJ Engineering, Inc. be retained to review those portions of the plans and specifications for this particular project that pertain to earthwork as a means to determine whether the plans and specifications are consistent with the recommendations contained in this report. In addition, we are available to observe construction, particularly the compaction of structural fill, or backfill as recommended in the report, and such other field observations as might be necessary.

The scope of our services did not include any environmental assessment or investigation for the presence or absence of wetlands or hazardous or toxic materials in the soil, surface water, ground water or air, on or below or around the site. The scope of services also did not include any assessment of the site for suitability for the proposed construction or use, related to items or conditions other than those specifically addressed in this report.

This report has been prepared for use in developing an overall design concept. Paragraphs, statements, test results, boring logs, diagrams, etc. should not be taken out of context, nor utilized without a knowledge and awareness of their intent within the overall concept of this report. The reproduction of this report, or any part thereof, supplied to persons other than the owner, should indicate that this study was made for design purposes only and that verification of the subsurface conditions for purposes of determining difficulty of excavation, trafficability, etc. are responsibilities of the contractor.

This report has been prepared for the exclusive use of the Alan Plummer Associates, Inc. for specific application to design of this project. The only warranty made by us in connection with the services provided is that we have used that degree of care and skill ordinarily exercised under similar conditions by reputable members of our profession practicing in the same or similar locality. No other warranty, expressed or implied, is made or intended.

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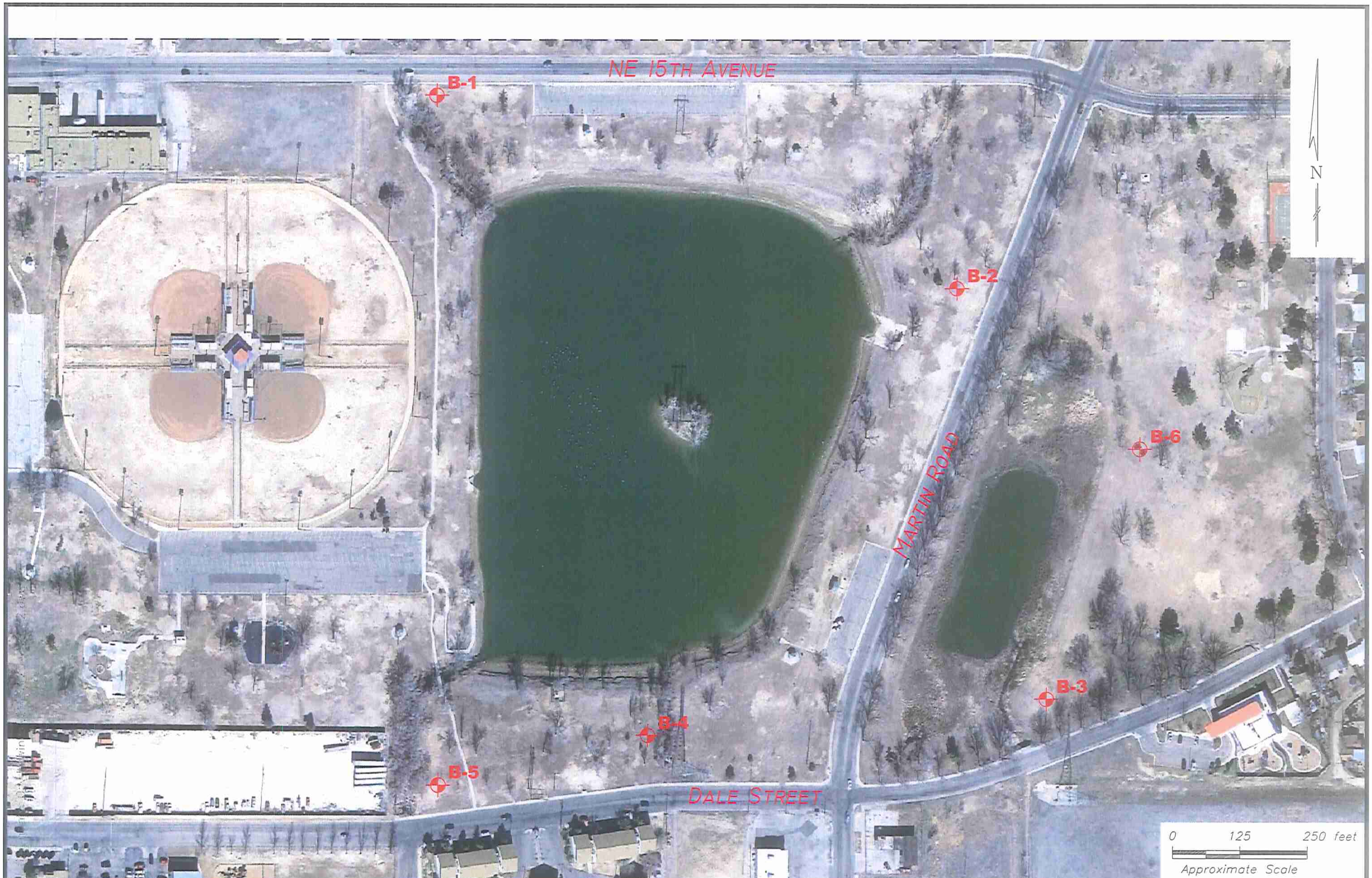


Plan of Borings

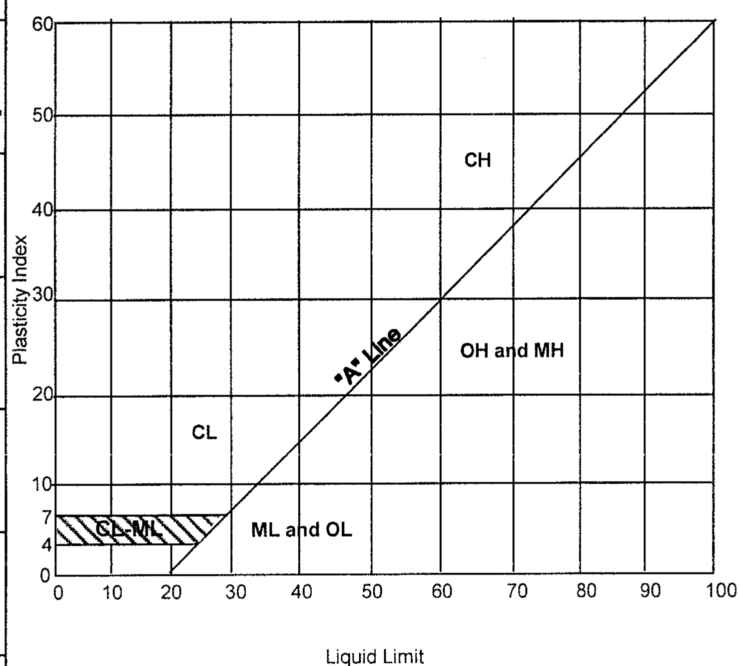
Martin Road Park Lake Expansion
Amarillo, Texas

CMJ Engineering, Inc.

CMJ Project No. 425-13-32

Plate A.1

Major Divisions			Grp. Sym.	Typical Names	Laboratory Classification Criteria		
Coarse-grained soils (more than half of the material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5 percent............GW, GP, SW, SP More than 12 percent............GM, GC, SM, SC 5 to 12 percent............*Borderline* cases requiring dual symbols	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4: $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures		Liquid and Plastic limits below "A" line or P.I. greater than 4	Liquid and plastic limits plotting in hatched zone between 4 and 7 are borderline cases requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Liquid and Plastic limits above "A" line with P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ greater than 6: $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	Poorly graded sands; gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures		Liquid and Plastic limits below "A" line or P.I. less than 4	Liquid and plastic limits plotting between 4 and 7 are borderline cases requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Liquid and Plastic limits above "A" line with P.I. greater than 7	
Fine-grained soils (More than half of material is smaller than No. 200 sieve)	Silts and clays (Liquid limit less than 50)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity	Plasticity Chart (see below)		
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, and lean clays			
			OL	Organic silts and organic silty clays of low plasticity			
	Silts and clays (Liquid limit greater than 50)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts			
			CH	Inorganic clays of high plasticity, fat clays			
			OH	Organic clays of medium to high plasticity, organic silts			
Highly Organic soils			Pt	Peat and other highly organic soils			

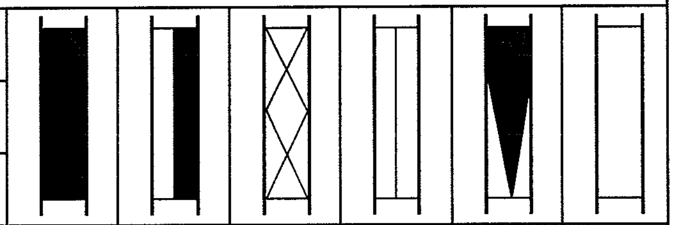


Plasticity Chart

UNIFIED SOIL CLASSIFICATION SYSTEM **PLATE A.2**

SOIL OR ROCK TYPES

GRAVEL	LEAN CLAY	LIMESTONE
SAND	SANDY	SHALE
SILT	SILTY	SANDSTONE
CLAYEY	HIGHLY PLASTIC CLAY	CONGLOMERATE



Shelby Tube	Auger	Split Spoon	Rock Core	Cone Pen	No Recovery

TERMS DESCRIBING CONSISTENCY, CONDITION, AND STRUCTURE OF SOIL

Fine Grained Soils (More than 50% Passing No. 200 Sieve)

Descriptive Item	Penetrometer Reading, (tsf)
Soft	0.0 to 1.0
Firm	1.0 to 1.5
Stiff	1.5 to 3.0
Very Stiff	3.0 to 4.5
Hard	4.5+

Coarse Grained Soils (More than 50% Retained on No. 200 Sieve)

Penetration Resistance (blows/foot)	Descriptive Item	Relative Density
0 to 4	Very Loose	0 to 20%
4 to 10	Loose	20 to 40%
10 to 30	Medium Dense	40 to 70%
30 to 50	Dense	70 to 90%
Over 50	Very Dense	90 to 100%

Soil Structure

Calcareous	Contains appreciable deposits of calcium carbonate; generally nodular
Slickensided	Having inclined planes of weakness that are slick and glossy in appearance
Laminated	Composed of thin layers of varying color or texture
Fissured	Containing cracks, sometimes filled with fine sand or silt
Interbedded	Composed of alternate layers of different soil types, usually in approximately equal proportions

TERMS DESCRIBING PHYSICAL PROPERTIES OF ROCK

Hardness and Degree of Cementation

Very Soft or Plastic	Can be remolded in hand; corresponds in consistency up to very stiff in soils
Soft	Can be scratched with fingernail
Moderately Hard	Can be scratched easily with knife; cannot be scratched with fingernail
Hard	Difficult to scratch with knife
Very Hard	Cannot be scratched with knife
Poorly Cemented or Friable	Easily crumbled
Cemented	Bound together by chemically precipitated material; Quartz, calcite, dolomite, siderite, and iron oxide are common cementing materials. and iron oxide are common cementing materials.

Degree of Weathering

Unweathered	Rock in its natural state before being exposed to atmospheric agents
Slightly Weathered	Noted predominantly by color change with no disintegrated zones
Weathered	Complete color change with zones of slightly decomposed rock
Extremely Weathered	Complete color change with consistency, texture, and general appearance approaching soil

KEY TO CLASSIFICATION AND SYMBOLS **PLATE A.3**

Project No. 425-13-32	Boring No. B-1	Project: Martin Road Park Lake Expansion, Amarillo, Texas
Location: See Plate A.1		Water Observations: Dry during drilling; dry at completion
Completion Depth: 25.0'	Completion Date: 7-1-13	
Surface Elevation:		Type: B-47, w/ CFA

Stratum Description

0 – 10 ft: **SILTY CLAY**, brown to light brown, very stiff to hard (possible fill)

10 – 25 ft: **SILTY CLAY**, dark brown to brown, very stiff to hard

Stratum	REC %	RQD %	Blows/Ft. or Pen Reading, T.S.F.	Passing No 200 Sieve, %	Liquid Limit, %	Plastic Limit, %	Plasticity Index	Moisture Content, %	Unit Dry Wt. Lbs./Cu. Ft.	Unconfined Compression Pounds/Sq. Ft.
SILTY CLAY, brown to light brown (possible fill)			3.75					26		
			4.0	60	51	17	34	24		
			3.5					27	100	4480
			3.0					22		
			4.0					28		
			3.5	91	69	24	45	24		
			4.5+					16	105	3590
SILTY CLAY, dark brown to brown			3.25	93	73	25	48	34		
			3.5		72	25	47	33		
			4.5					29		

LOG OF BORING 425-13-32.GPJ CMJ.GDT 7/9/13

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Project No.	Boring No.	Project
425-13-32	B-2	Martin Road Park Lake Expansion Amarillo, Texas
Location: See Plate A.1		Water Observations: Dry during drilling; dry at completion
Completion Depth: 25.0'	Completion Date: 7-1-13	
Surface Elevation:	Type: B-47, w/ CFA	

Depth, Ft.	Stratum Description	REC %	RQD %	Blows/Ft. or Pen Reading, T.S.F.	Passing No 200 Sieve, %	Liquid Limit, %	Plastic Limit, %	Plasticity Index	Moisture Content, %	Unit Dry Wt. Lbs./Cu. Ft.	Unconfined Compression Pounds/Sq. Ft.
0	**SANDY SILTY CLAY**, brown and reddish brown, stiff to very stiff (possible fill)			2.5	55	48	18	30	28		
				3.0					23		
2	**SANDY SILTY CLAY / SILTY CLAY**, brown to dark brown, very stiff to hard			3.0					22		
				4.5+	78	50	18	32	19		
				4.5+					27		
5											
				4.5+					27		
				4.5+					24		
10											
				4.5+					24		
15											
19	**SILTY CLAY**, brown and reddish brown, hard			4.5+	80	72	24	48	21		
20											
				4.5+					13		
25											

CMJ ENGINEERING INC

Project No.	Boring No.	Project
425-13-32	B-3	Martin Road Park Lake Expansion Amarillo, Texas

Location	Water Observations
See Plate A.1	Dry during drilling; dry at completion

Completion Depth	Completion Date	Surface Elevation	Type
25.0'	7-1-13		B-47, w/ CFA

Stratum Description

Depth, Ft.	Stratum Description	REC %	RQD %	Blows/Ft. or Pen Reading, T.S.F.	Passing No 200 Sieve, %	Liquid Limit, %	Plastic Limit, %	Plasticity Index	Moisture Content, %	Unit Dry Wt. Lbs./Cu. Ft.	Unconfined Compression Pounds/Sq. Ft.
0	**SILTY SANDY CLAY**, brown, very stiff to hard			4.5+					23		
				4.5+					14		
				4.5+					18		
				3.0					31		
				4.5+					15		
7				4.5+	68	36	18	18	17		
9				4.5+					13		
10	**SANDY SILTY CLAY**, brown to light brown, hard										
14				4.5+	73	46	15	31	13		
16	**SANDY SILTY CLAY**, reddish brown, w/ calcareous nodules and calcareous seams, hard										
19				4.5+					15		
24				4.5+					17		
25											

LOG OF BORING 425-13-32.GPJ CMJ.GDT 7/9/13

LOG OF BORING NO. **B-3**

PLATE A.6

CMJ ENGINEERING INC

Project No.	Boring No.	Project
425-13-32	B-4	Martin Road Park Lake Expansion Amarillo, Texas

Location	Water Observations
See Plate A.1	Dry during drilling; dry at completion

Completion Depth	Completion Date	Surface Elevation	Type
30.0'	7-1-13		B-47, w/ CFA

Stratum Description

Depth, Ft.	Stratum Description
0 – 7	**SANDY SILTY CLAY**, brown to dark brown, w/ calcareous nodules, hard
7 – 21	**SANDY SILTY CLAY / SANDY CLAYEY SILT**, brown and reddish brown, hard
21 – 30	**SANDY SILTY CLAY**, light brown and reddish brown, w/ calcareous nodules and calcareous seams, hard

Depth, Ft.	REC %	RQD %	Blows/Ft. or Pen Reading, T.S.F.	Passing No 200 Sieve, %	Liquid Limit, %	Plastic Limit, %	Plasticity Index	Moisture Content, %	Unit Dry Wt. Lbs./Cu. Ft.	Unconfined Compression Pounds/Sq. Ft.
0–1			4.5+					20		
1–2			4.5+					12		
2–3			4.5+					15		
3–4			4.5+					18		
4–5			4.5+	77	48	17	31	16		
7–8			4.5+					14	107	13880
9–10			4.5+	80	34	16	18	13		
14–15			4.5+					14		
19–20			4.5+					13		
24–25			4.5+					13	114	20020
29–30			4.5+					15		

CMJ ENGINEERING INC

Project No.	Boring No.	Project
425-13-32	B-5	Martin Road Park Lake Expansion, Amarillo, Texas

Location: See Plate A.1

Water Observations: Dry during drilling; dry at completion

Completion Depth: 30.0'

Completion Date: 7-1-13

Surface Elevation:

Type: B-47, w/ CFA

Depth, Ft.	Stratum Description	REC %	RQD %	Blows/Ft. or Pen Reading, T.S.F.	Passing No 200 Sieve, %	Liquid Limit, %	Plastic Limit, %	Plasticity Index	Moisture Content, %	Unit Dry Wt. Lbs./Cu. Ft.	Unconfined Compression Pounds/Sq. Ft.
0	**SILTY CLAY**, dark brown to brown, hard			4.5+					23		
				4.5+					21		
				4.5+	88	61	20	41	19		
				4.5+					17		
				4.5+					19	104	11260
6	**SILTY CLAY**, reddish brown, hard			4.5+	85	41	16	25	14		
				4.5+					14	108	15200
12	**SANDY SILTY CLAY**, light reddish brown, hard			4.5+					15		
				4.5+					13		
22	**SILTY SANDY CLAY**, light brown to brown, w/ calcareous nodules and calcareous seams, hard			4.5+					13		
				4.5+					12		
30											

LOG OF BORING 425-13-32.GPJ CMJ.GDT 7/9/13

CMJ ENGINEERING INC

Project No: 425-13-32
Boring No: B-6
Project: Martin Road Park Lake Expansion, Amarillo, Texas
Location: See Plate A.1
Water Observations: Dry during drilling; dry at completion
Completion Depth: 25.0'
Completion Date: 7-1-13
Surface Elevation:
Type: B-47, w/ CFA

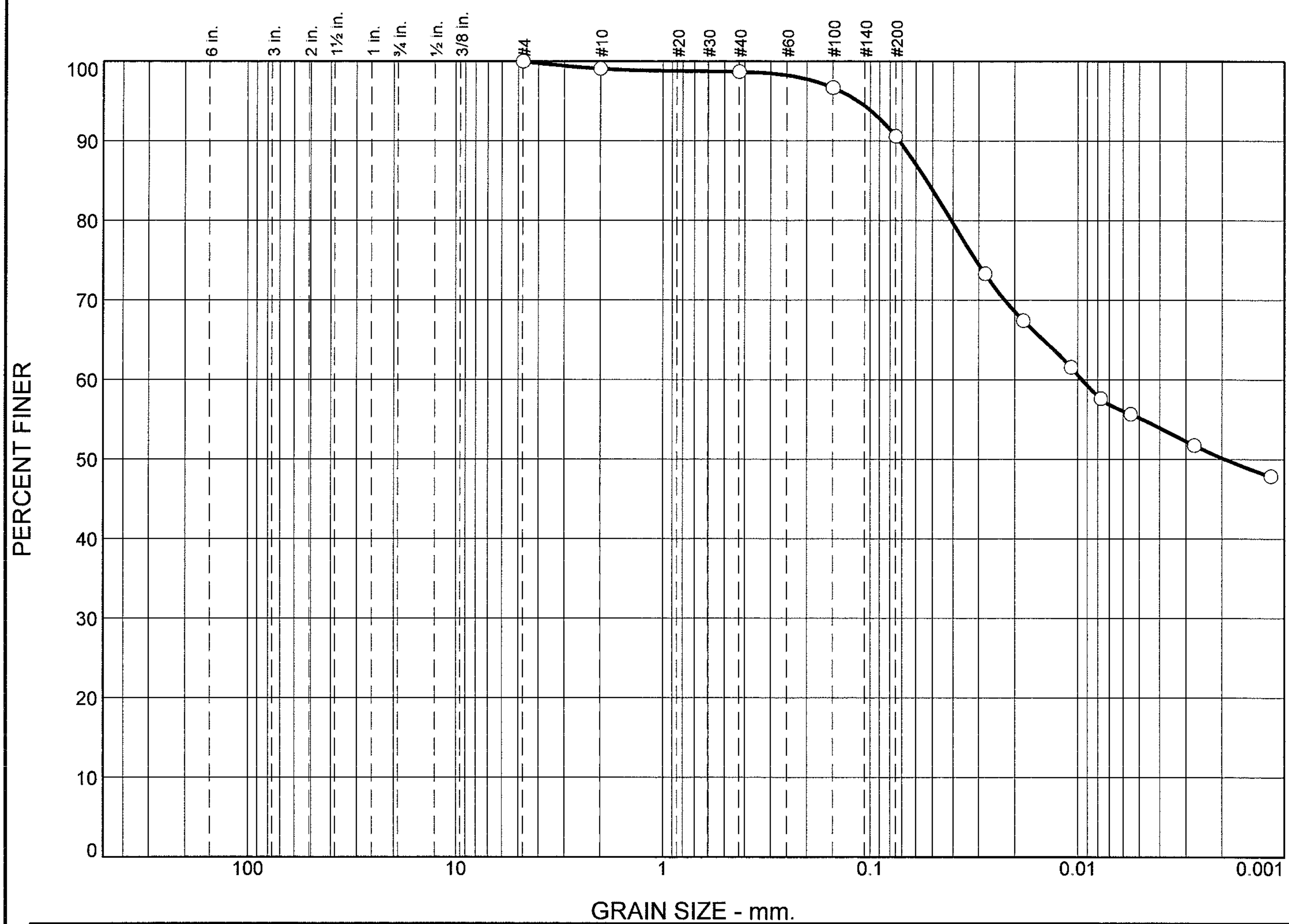
Stratum Description

0' – 16': **SILTY CLAY**, dark brown, hard
-w/ calcareous nodules, 4' to 16'

16' – 25': **SILTY CLAY / SANDY SILTY CLAY**, light brown and light reddish brown, w/ calcareous nodules and calcareous seams, hard

REC %	RQD %	Blows/Ft. or Pen Reading, T.S.F.	Passing No 200 Sieve, %	Liquid Limit, %	Plastic Limit, %	Plasticity Index	Moisture Content, %	Unit Dry Wt. Lbs./Cu. Ft.	Unconfined Compression Pounds/Sq. Ft.
		4.5+					20		
		4.5+	71	53	17	36	17		
		4.5+					16		
		4.5+					16		
		4.5+					16		
		4.5+					14		
		4.5+	84	51	17	34	14		
		4.5+					13		
		4.5+					18		
		4.5+					19		

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.9	0.4	8.1	35.4	55.2

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	69	45	0.0532	0.0095	0.0019					

Material Description	USCS	AASHTO
○		

Project No. 425-13-32 **Client:** Alan Plummer Associates, Inc.

Project: Martin Road Park Lake Expansion

○ **Location:** B-1 **Depth:** 7-8

Remarks:

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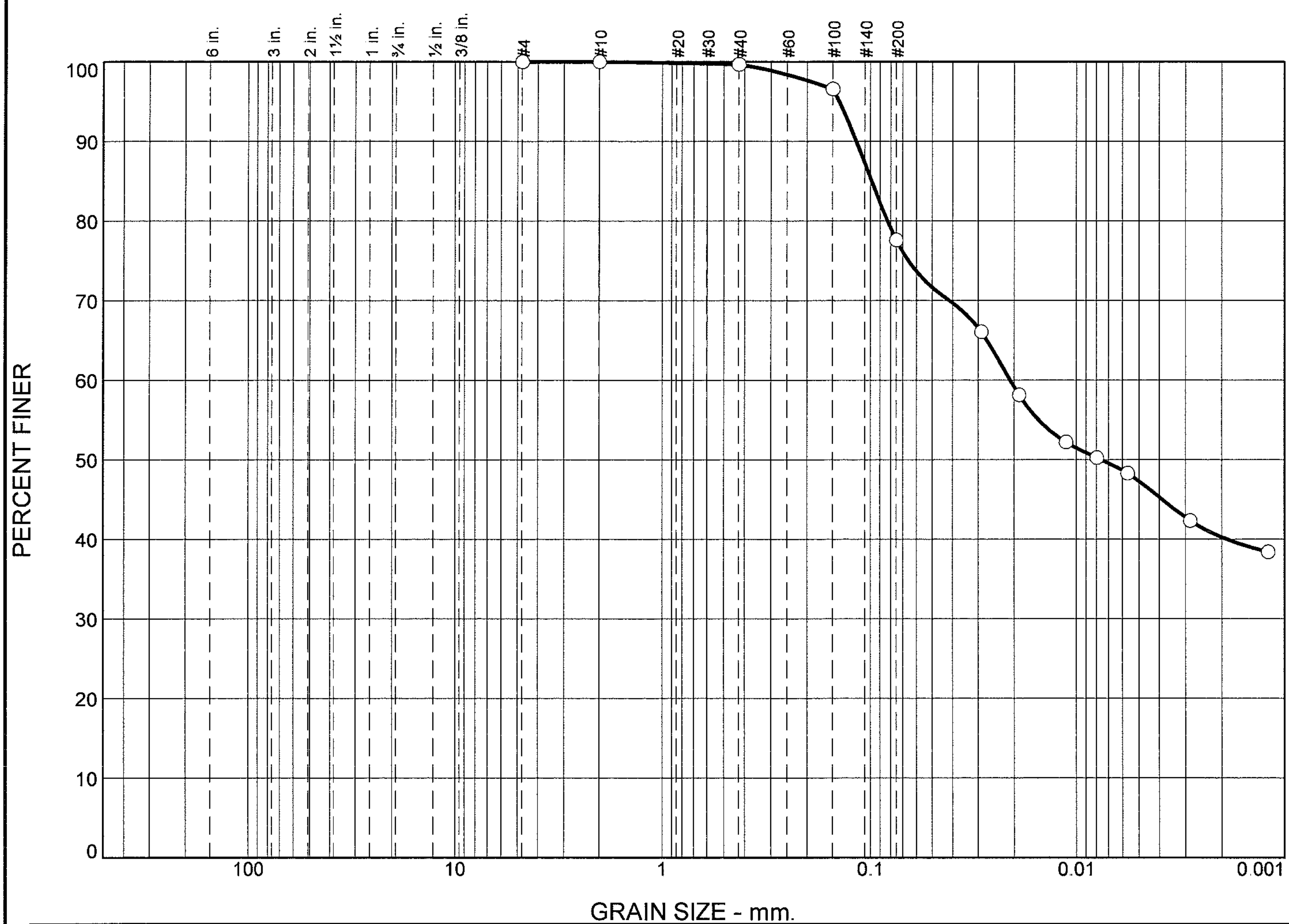
Fort Worth, Texas

PLATE A.10

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.0	0.3	22.1	30.3	47.3

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	50	32	0.0985	0.0209	0.0076					

Material Description	USCS	AASHTO
○		

Project No. 425-13-32 **Client:** Alan Plummer Associates, Inc.

Project: Martin Road Park Lake Expansion

○ **Location:** B-2 **Depth:** 3-4

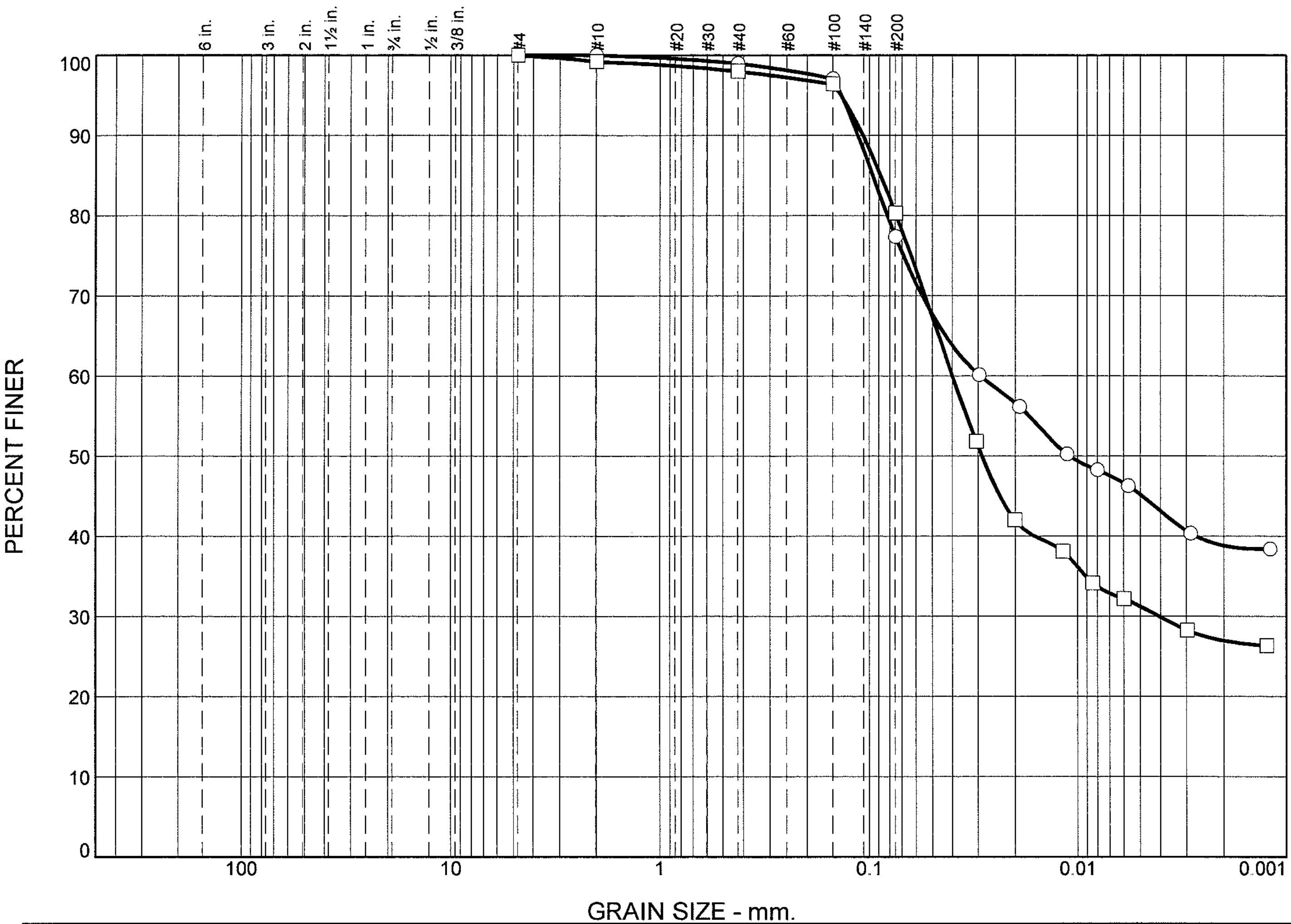
Remarks:

CMJ ENGINEERING, INC.

Fort Worth, Texas

PLATE A.11

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.0	1.0	21.6	32.2	45.2
□	0.0	0.0	0.0	0.8	1.2	17.7	49.0	31.3

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	48	31	0.0960	0.0292	0.0109					
□	34	18	0.0881	0.0399	0.0287	0.0041				

Material Description	USCS	AASHTO
○		
□		

Project No. 425-13-32 **Client:** Alan Plummer Associates, Inc.
Project: Martin Road Park Lake Expansion

○ **Location:** B-4 **Depth:** 4-5
□ **Location:** B-4 **Depth:** 9-10

Remarks:

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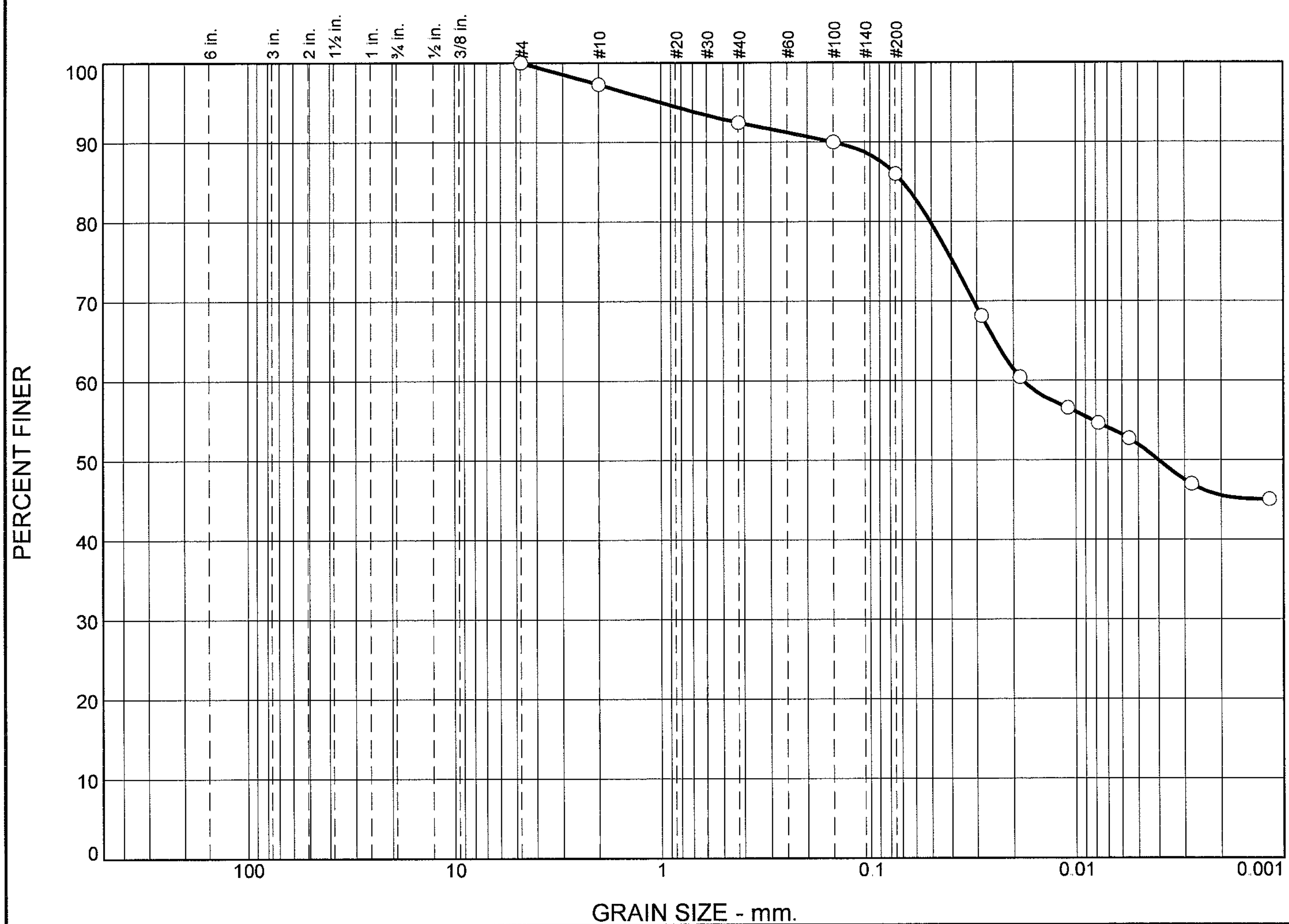
Fort Worth, Texas

PLATE A.12

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	2.7	4.8	6.5	34.0	52.0

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	61	41	0.0691	0.0179	0.0040					

Material Description	USCS	AASHTO
○		

Project No. 425-13-32 **Client:** Alan Plummer Associates, Inc.

Project: Martin Road Park Lake Expansion

○ **Location:** B-5 **Depth:** 2-3

Remarks:

CMJ ENGINEERING, INC.

Fort Worth, Texas

PLATE A.13