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Maricopa Casa Grande Highway
Santa Cruz Wash Crossing Improvements

62953157

GEOTECHNICAL EVALUATION
MARICOPA-CASA GRANDE HIGHWAY
CROSSING IMPROVEMENTS
PINAL COUNTY, ARIZONA

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December 17, 2013
Project No. 604034001

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Mr. Berwyn Wilbrink, P.E.
Jacobs
101 North 1st Avenue, Suite 3100
Phoenix, Arizona 85003

Subject: Geotechnical Evaluation
Maricopa-Casa Grande Highway Crossing Improvements
Pinal County, Arizona

Dear Mr. Wilbrink:

In accordance with your authorization and our proposal dated November 15, 2012, we have performed a geotechnical evaluation for the above-referenced project. This report presents our findings, conclusions, and recommendations for the project.

We appreciate the opportunity to be of service to you during this phase of the project.

Sincerely,
NINYO & MOORE

Registered Professional Engineer (Civil)
CERTIFICATE NO. 41716
KEVIN L. PORTER
Date Signed 12-17-13
ARIZONA U.S.A.
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1. INTRODUCTION

In accordance with our proposal dated November 15, 2012, and your authorization, we have performed a geotechnical evaluation for the proposed Maricopa-Casa Grande Highway Crossing Improvements in Pinal County, Arizona. The purpose of our evaluation was to assess the subsurface conditions at the project site in order to formulate geotechnical recommendations for design and construction. This report presents the results of our evaluation and our geotechnical conclusions and recommendations regarding the proposed construction.

2. SCOPE OF SERVICES

The scope of our services for the project generally included:

- Conducting a visual reconnaissance of the project area and reviewing available geologic literature and aerial photographs of the project site.
- Obtaining a right-of-way permit from Pinal County to perform the work, including arranging for traffic control.
- Drilling, logging, and sampling nine hollow-stem auger borings using a truck-mounted, two-wheel drive drill rig. Six borings extended approximately 15 feet deep (two at each box culvert crossing), and three borings extended approximately 5 feet deep (subgrade). The boring logs are provided in Appendix A.
- Conducting laboratory testing of selected samples obtained from the borings to evaluate in-situ moisture and dry density, sieve analysis, Atterberg limits, consolidation, and corrosivity characteristics (including pH, minimum electrical resistivity, and sulfate and chloride contents). The results of our laboratory testing are provided in Appendix B.
- Preparing a Pavement Design Summary with recommendations for asphalt concrete pavement sections in general accordance with the (Arizona Department of Transportation) ADOT Preliminary Engineering & Design (PE&D) Manual. This report is submitted under separate cover.
- Preparing this report presenting our findings, conclusions, and recommendations regarding the design and construction of the proposed improvements.

Our scope of services did not include environmental consulting services, such as hazardous waste sampling or analytical testing, at the site. A detailed scope of services and estimated fee for such services can be provided upon request.

3. SITE/PROJECT DESCRIPTION

The project site is located on Maricopa-Casa Grande Highway, roughly between Murphy Road and 1,500 feet northwest of Murphy Road in Pinal County, Arizona. The approximate location of the site is depicted on Figure 1.

Presently, the existing roadway is a two-lane, asphalt concrete (AC) paved roadway trending in a northwest-southeast direction and is surrounded by undeveloped and agricultural lands. The roadway is generally at grade and crosses the Santa Cruz Channel. There is an existing railroad line located west of, and generally parallel to, the roadway near the project site. The railroad line is elevated above the surrounding grade in this area and has three box culverts that allow channel flows beneath the rail line. Scattered vegetation and rip rap, generally consisting of large cobbles and boulders, were observed adjacent to the roadway within the channel.

According to the *Stanfield, Arizona-Pinal County, 7.5-Minute United States Geological Survey (USGS) Topographic Quadrangle Map (2011),* the elevation at the project site is approximately 1,241 feet relative to mean sea level (MSL). The topography in the vicinity of the site generally slopes from the southeast down to the northwest. According to the plans obtained from your office, the roadway elevation ranges from approximately 1,240 to 1,245 feet MSL within the project limits.

Ten aerial photographs from Google Earth™ were reviewed for this project. The available aerial photographs from 1996, 2003, 2005, 2006, 2007, 2010, 2011, and 2012 depicted the site as being similar to its current condition. Several topographic maps and aerial photographs were reviewed for this project from the HistoricAerials.com website (NETR, 2013), including topographic maps from the period between 1924 and 1995. The topographic maps from 1924 to 1959 depict the railroad alignment crossing several washes. The topographic maps from 1967 to 1994 depict the

roadway and the intersection with Murphy Road and also depicts the channelization of Santa Cruz Wash with levees.

We understand that the roadway will be reconstructed within the project limits and placed on up to approximately five feet of grade-raise engineered fill with three concrete box culverts allowing the flow of the Santa Cruz Channel beneath the elevated roadway. We understand the planned improvements will be constructed following Maricopa Association of Governments (MAG) Specifications. In addition, a pipe culvert is planned beneath Murphy Road. We understand that the concrete box culverts will be on the order of 10 feet by 6 feet in dimension and will consist of 6 to 18 barrels.

4. FIELD EXPLORATION AND LABORATORY TESTING

On September 26, 2013, Ninyo & Moore conducted a subsurface exploration for the proposed project. The exploration was conducted in order to evaluate the existing subsurface conditions and to collect soil samples for laboratory testing. Our exploration consisted of logging and sampling nine exploratory borings. Six of the nine borings were to a depth of approximately 15 feet and three borings extended to a depth of approximately 5 feet below the ground surface. Bulk and relatively undisturbed soil samples were collected at selected intervals from the exploratory borings. Descriptions of the soils encountered are presented on the boring logs in Appendix A. The general locations of the borings are depicted on Figure 2.

The samples obtained during the fieldwork were visually classified, placed into appropriate containers, and transported to our laboratory in Phoenix for geotechnical testing. The laboratory testing included in-situ moisture content and dry density, sieve analysis, Atterberg limits, consolidation, and corrosivity characteristics (including pH, minimum electrical resistivity, and sulfate and chloride contents). The results of the in-situ moisture content and dry density tests are presented on the boring logs in Appendix A. A description of each laboratory test method and the remainder of the test results are presented in Appendix B.

5. GEOLOGY AND SUBSURFACE CONDITIONS

The geology and subsurface conditions at the site are described in the following sections.

5.1. Geologic Setting

The project site is located in the Sonoran Desert Section of the Basin and Range physiographic province, which is typified by broad alluvial valleys separated by steep, discontinuous, subparallel mountain ranges. The mountain ranges generally trend north-south and northwest-southeast. The basin floors consist of alluvium with thickness extending to several thousands of feet.

The basins and surrounding mountains were formed approximately 10 to 18 million years ago during the mid- to late-Tertiary. Extensional tectonics resulted in the formation of horsts (mountains) and grabens (basins) with vertical displacement along high-angle normal faults. Intermittent volcanic activity also occurred during this time. The surrounding basins filled with alluvium from the erosion of the surrounding mountains as well as from deposition from rivers. Coarser-grained alluvial material was deposited at the margins of the basins near the mountains.

The surficial geology along the project alignment is described as modern channel and terrace deposits composed of sand, silt, and clay. Areas southeast of the Santa Cruz wash have been mapped as undifferentiated Holocene alluvium (Klawon et al. 1998).

5.2. Subsurface Conditions

Our knowledge of the subsurface conditions at the project site is based on our field exploration and laboratory testing, and our understanding of the general geology of the area. Alluvium was encountered at the ground surface of our borings. The alluvium generally consisted of clayey sand, silty sand, and sandy clay with varying amounts of gravel in our borings. In addition, scattered caliche filaments and nodules were also observed within the

alluvium. More detailed descriptions and thickness of the materials encountered are presented on the boring logs.

5.3. Groundwater

Groundwater was not encountered in our borings. Based on well data from the Arizona Department of Water Resources (ADWR), the approximate depth to regional groundwater may be 95 feet below the surface or deeper at the site. Groundwater levels can fluctuate due to seasonal variations, groundwater withdrawal or injection, flows within nearby washes or drainages, irrigation, and other factors. Due to presence of clayey soils, perched groundwater and/or zones of very wet soils might be present at some locations, particularly during periods of wet weather.

6. GEOLOGIC HAZARDS

The following sections describe potential geologic hazards at the site, including land subsidence and earth fissures and faulting and seismicity.

6.1. Land Subsidence and Earth Fissures

Groundwater depletion, due to groundwater pumping, has caused land subsidence and earth fissures in numerous alluvial basins in Arizona. It has been estimated that subsidence has affected more than 3,000 square miles and has caused damage to a variety of engineered structures and agricultural land (Schumann and Genualdi, 1986). From 1948 to 1983, excessive groundwater withdrawal has been documented in several alluvial valleys where groundwater levels have been reportedly lowered by up to 500 feet. With such large depletions of groundwater, the alluvium has undergone consolidation resulting in large areas of land subsidence.

In Arizona, earth fissures are generally associated with land subsidence and pose an on-going geologic hazard. Earth fissures generally form near the margins of geomorphic basins

where significant amounts of groundwater depletion have occurred. Reportedly, earth fissures have also formed due to tensional stress caused by differential subsidence of the unconsolidated alluvial materials over buried bedrock ridges and irregular bedrock surfaces (Schumann and Genualdi, 1986).

Based on our field reconnaissance and review of the referenced material, groundwater levels have dropped 200 to 400 feet and there are no documented earth fissures present at the surface of the subject site. However, the closest documented earth fissure to this site is approximately 1,200 feet to the northwest. Continued groundwater withdrawal in the area may result in subsidence of the valley and the formation of new fissures or the extension of existing fissures. Because of the unpredictable nature of earth fissures, as well as the difficulty of observing fissures that are not yet projected to the surface, earth fissures may be a constraint to the design and construction of the project. If an earth fissure or soil cracking is encountered during construction, specifically during the earthwork operations, Ninyo & Moore should be notified immediately for further recommendations.

6.2. Faulting and Seismicity

The site lies within the Sonoran zone, which is a relatively stable tectonic region located in southwestern Arizona, southeastern California, southern Nevada, and northern Mexico (Euge et al., 1992). This zone is characterized by sparse seismicity and few Quaternary faults. Based on our field observations, review of pertinent geologic data, and analysis of aerial photographs, faults are not located on or adjacent to the property. The closest fault to the site is the Sand Tank fault zone, located approximately 37 miles to the west of the site (Pearthree, 1998). Approximately 2 meters of displacement has occurred along this fault within middle to upper Pleistocene deposits, but the latest Pleistocene and Holocene alluvium are not faulted. Seismic design parameters are provided in Section 8.3.

7. CONCLUSIONS

Based on the results of our subsurface evaluation, laboratory testing, and data analysis, it is our opinion that the proposed construction is feasible from a geotechnical standpoint, provided that the recommendations of this report are incorporated into the design and construction of the proposed project, as appropriate. Geotechnical considerations include the following:

- The on-site soils encountered along the project alignment should generally be excavatable to the anticipated depths with earthmoving or excavating equipment in good working condition. However, gravel, cobbles, and possible boulders were observed at the site and in our borings, which could be more difficult to excavate and could slow the rate of excavation.
- Imported soils and soils generated from on-site excavation activities that exhibit low plasticity and very low to low expansion potential may be used as engineered fill during backfilling operations.
- Our borings revealed potentially collapsible soils in the vicinity of the box culverts. Mitigation to reduce the hydrocollapse potential should be considered.
- We estimate an earthwork (shrinkage) factor of about 10 to 20 percent for this project. This estimate is based on the results of the in-situ dry density testing and an assumed maximum density.
- Groundwater was not observed in our exploratory borings; however, this could fluctuate depending on other factors. In addition, perched groundwater may be present at some locations, particularly during periods of wet weather, due to the presence of clayey soils.
- There is a reported earth fissure located approximately 1,200 feet from the project limits. Because of the unpredictable nature of earth fissures, as well as the difficulty of observing fissures that are not yet projected to the surface, earth fissures may be a constraint to the design and construction of the project.
- Corrosivity test results indicate that some of the soils at the site may be corrosive to ferrous metals and the sulfate content of the soils presents a negligible sulfate exposure to concrete.

8. RECOMMENDATIONS

The following sections present our geotechnical recommendations for the proposed construction. If the proposed construction is changed from that discussed in this report, Ninyo & Moore should be contacted for additional recommendations.

8.1. Earthwork

The following sections provide our earthwork recommendations. The earthwork specifications contained in Maricopa Association of Governments (MAG) Uniform Standard Specifications and Details for Public Works Construction are expected to apply, except as noted.

8.1.1. Site Preparation

Construction areas should be cleared of deleterious materials, including vegetation (if present), asphalt pavement, construction debris, and any other material that might interfere with the performance or progress of the work. These materials, if found anywhere along the project alignment, should be disposed of at a legal dumpsite.

It may be desirable to recognize utilities, underground structures, or other features that are near the planned construction and to survey or document (e.g., photographs, video, official documentation, etc.) their pre-construction condition. The findings of the survey could be used to document any damage that might result from this project.

8.1.2. Excavation

Our evaluation of the excavation characteristics of the on-site materials is based on the results of nine exploratory borings, our site observations, and our experience on similar projects. In our opinion, excavation of many of the on-site materials encountered can be accomplished to the anticipated depths with earthmoving or excavating equipment in good operating condition. However, gravel, cobbles, and possible boulders were observed at the site and in our borings, which could be more difficult to excavate and could slow the rate of excavation.

8.1.3. Temporary Slope Stability

The sides of any excavation should be stabilized in order to minimize damage to adjacent structures resulting from vertical or lateral movement of the soil. The sides of trenches may be stabilized by sloping back the sides and/or by using bracing. However,

trench sidewalls may be difficult to stabilize in areas where loose, low cohesion, granular soils exist on site. These soils could have a potential for caving and sloughing during excavation, especially if the soils are wet or saturated. Additionally, vibrations caused by nearby traffic or construction equipment could accelerate sloughing. We recommend that slopes be no steeper than 1.5:1 (horizontal:vertical), as discussed in the following paragraph.

The contractor should provide safely sloped excavations or an adequately constructed and braced shoring system, in compliance with the project specifications and/or OSHA regulations, for employees working in excavations that may expose them to the danger of moving ground. Reducing the inclination of the sidewalls of the excavations, where feasible, may increase the stability of the excavations. If construction or earth material is stored or equipment is operated near an excavation, flatter slope geometry or stronger shoring should be used during construction. The OSHA regulations provide trench sloping and shoring design parameters for trenches up to 20 feet deep based on the soil types encountered. Trenches over 20 feet deep should be designed by the contractor's engineer based on alignment-specific geotechnical analyses. For planning purposes and according to OSHA soil classifications, a "Type C" soil should be considered due to the presence of granular soils and the anticipated roadway vibrations. Upon making the excavations, soil classification and excavation performance should be evaluated in the field by the geotechnical consultant in accordance with the OSHA regulations.

Temporary excavations that encounter groundwater seepage, if any, or surface runoff may need shoring or may be stabilized by placing sandbags or gravel along the base of the seepage zone. Excavations encountering groundwater seepage should be evaluated on a case-by-case basis. Flatter slopes or bracing should be used if excessive sloughing or raveling is observed. If material is stored or equipment is operated near an excavation, stronger shoring should be used to resist the extra pressure due to superimposed loads.

8.1.4. Bottom Stability

Based on the proposed invert depths, the excavation for new culverts is not anticipated to encounter groundwater (with the exception of possible surface run-off) or soft materials at the base. Therefore, excavation bottom stability problems during construction are not anticipated. However, if the excavation is open during a heavy rain event, the excavation bottom might become saturated and unstable. This scenario should be evaluated on a case-by-case basis.

8.1.5. Grading, Fill Placement, and Compaction

Vegetation and debris from the clearing operation should be removed from the site and disposed of at a legal dumpsite. Demolition debris, if any, should also be removed from the site and disposed of at a legal dumpsite. Obstructions that extend below finish grade, if present, should be removed and the resulting holes filled with compacted soil.

The geotechnical consultant should carefully evaluate any areas of soft or wet soils prior to placement of grade-raise fill or other construction. Drying or overexcavation of some materials may be appropriate.

On-site and imported soils that exhibit relatively low plasticity indices (PI) and very low to low expansive potential are generally suitable for re-use as engineered fill. Relatively low plasticity indices are defined as a plasticity index (by the American Society for Testing and Materials [ASTM] D4318) value of 20 or less. Very low to low expansive potential soils are defined as having an Expansion Index [EI] by ASTM D 4829) of 50 or less. The Atterberg limits test performed for this project indicated that the PI of the samples tested ranged from 12 to 17. As such, many of the on-site soils may be suitable for re-use as engineered fill for this project. Additional field sampling and laboratory testing should be conducted by the contractor to better delineate the limits of any unacceptable on-site soils, if encountered.

In addition, suitable fill should not include construction debris, organic material, cinders, or other non-soil fill materials. Rock particles and clay lumps should not be larger than 6 inches in dimension. Unsuitable material should be disposed of off-site or in non-structural areas. If on-site material is deemed suitable for re-use, we estimate an earthwork (shrinkage) factor of 10 to 20 percent for these soils.

Based on information from our exploratory borings, some of the near-surface soils exhibit significant hydrocollapse potential. These soils may collapse upon inundation with water under relatively light loads and cause significant settlement of the culvert foundation. In addition, the soils bearing the culvert base slab may become disturbed or loosened during the earthwork operations. As such, mitigation of these soils to reduce the potential for hydrocollapse related settlements should be considered.

Beneath the culvert foundations, the existing soils may be overexcavated to a depth of up to about 8 feet and replaced with moisture-conditioned and compacted engineered fill. The overexcavated zone should extend the same distance horizontally (beyond the base slab footprint) as it extends below the bottom of the base slab. Engineered fill should be placed in lifts not exceeding 8 inches, moisture-conditioned, and compacted by appropriate mechanical methods to a relative compaction of 95 percent as evaluated by ASTM D 698 at a moisture content generally slightly above the optimum. As an alternative to overexcavation, the site soils may be inundated and surcharged to reduce the hydrocollapse potential. However, this method is usually not as effective as overexcavation.

As an alternative to the possible mitigations noted above, increased maintenance of the roadway and/or culverts may be contemplated. We recommend that in preparation for the placement of grade-raise fill for the roadway (i.e., outside of the culvert areas), the existing soils be scarified to a depth of 12 inches, moisture-conditioned, and compacted by appropriate mechanical methods to a relative compaction of 95 percent as evaluated by ASTM D 698 at a moisture content generally slightly above the optimum.

The limits of scarification and compaction in the roadway areas should extend laterally to a distance of 1 or more feet horizontally beyond the embankment footprint.

Following the overexcavation as described above, and prior to the placement of any new fill, the resulting exposed surface should be carefully evaluated by the geotechnical consultant. This evaluation could consist of proof-rolling, soil probing, visual assessment, and/or additional laboratory testing. Based on this evaluation, additional remediation may be needed. This additional remediation, if needed, should be addressed by the geotechnical consultant during the earthwork operations.

Imported fill, if utilized, should consist of granular material with a very low to low expansion potential. Import material in contact with ferrous metals should also have low corrosion potential (minimum resistivity more than 2,000 ohm-cm, and chloride content less than 25 parts per million [ppm]). Import material in contact with concrete should have a soluble sulfate content of less than 0.1 percent. The geotechnical consultant should evaluate such materials and details of their placement prior to importation.

8.1.6. Constructed Slopes

Based on the subsurface information obtained from our borings and our experience with similar projects, we recommend that temporary cut slopes associated with this project be constructed no steeper than 1.5:1 (horizontal:vertical) and that permanent fill slopes associated with this project be constructed no steeper than 2.5:1 (horizontal:vertical). New embankment fills should be benched into existing embankments, where appropriate. Benches should be level and wide enough to allow operation of, and compaction by, construction equipment. Fill slopes should be constructed in a manner (e.g., overfilling and cutting to grade) such that the recommended degree of compaction is achieved to the finished slope face. Cut and fill slopes should be protected from erosion.

8.2. Seismic Design Considerations

Design of the proposed improvements should be performed in accordance with the requirements of the governing jurisdictions and applicable building codes. Table 1 presents the seismic design parameters for the site in accordance with the 2012 International Building Code (IBC) guidelines and adjusted maximum considered earthquake (MCE) spectral response acceleration parameters evaluated using the United States Geological Survey (USGS, 2013) ground motion calculator (web-based). Seismic design parameters according to the 2012 International Building Code (IBC) are presented in the following table.

Table 1 – 2012 International Building Code Seismic Design Criteria

Site Coefficients and Spectral Response Acceleration Parameters	Value
Site Class	D
Site Coefficient, F_a	1.6
Site Coefficient, F_v	2.4
Mapped Spectral Acceleration at 0.2-second Period, S_s	0.166 g
Mapped Spectral Acceleration at 1.0-second Period, S_1	0.056 g
Spectral Acceleration at 0.2-second Period Adjusted for Site Class, S_{MS}	0.266 g
Spectral Acceleration at 1.0-second Period Adjusted for Site Class, S_{M1}	0.134 g
Design Spectral Response Acceleration at 0.2-second Period, S_{DS}	0.177 g
Design Spectral Response Acceleration at 1.0-second Period, S_{D1}	0.089 g

8.3. Culvert Foundations

As discussed above, the site soils exhibited varying consistencies and some of these soils could be collapsible upon inundation with water. In addition, the culvert base slab bearing soils may become disturbed or loosened during the earthwork operations. Accordingly, we recommend that the existing soils be overexcavated to a depth of up to 8 feet and replaced with moisture-conditioned and compacted engineered fill as described in Section 8.1.5 above. We recommend an allowable gross soil bearing pressure of up to 2,500 psf for the culvert base slab founded on engineered fill. A coefficient of friction of 0.35 may be used to resist sliding between the culvert base slab and engineered fill soils. A modulus of subgrade

reaction, k, of 150 pounds per cubic inch (pci) may be used for designing the culvert base slab. We estimate that the box culvert may experience a total settlement of approximately 1 inch. This settlement estimate is based on the anticipated loading conditions and the available subsurface soil information. Differential settlement will depend on the stiffness of the base slab.

8.4. Corrosion

The corrosion potential of the on-site materials was analyzed to evaluate its potential effect on the underground utilities and structures. Corrosion potential was evaluated using the results of laboratory testing of a sample obtained during our subsurface evaluation that was considered representative of soils at the subject site.

Laboratory testing consisted of pH, minimum electrical resistivity, and chloride and soluble sulfate contents. The pH and minimum electrical resistivity tests were performed in general accordance with Arizona Test 236b, while sulfate and chloride tests were performed in accordance with Arizona Tests 733 and 736, respectively. The results of the corrosivity tests are presented in Appendix B.

The soil pH value of the sample tested from our boring was 8.0, representing a mildly alkaline environment. The electrical resistivity value measured in the laboratory was about 1,380 ohm-cm. The chloride content value was 110 ppm. The results indicate a mildly corrosive environment to ferrous metals. The soluble sulfate content of the soil sample was measured to be 0.010 percent, which represents a negligible sulfate exposure for concrete.

The results of the laboratory testing indicate that some of the on-site soils could be corrosive to ferrous metals. Therefore, special consideration should be given to the use of heavy gauge, corrosion protected, steel pipes. As an alternative, plastic pipe or reinforced concrete pipe could be considered.

To minimize corrosion of buried metallic utilities, if any, we recommend that topsoil, organic soils, existing fill soils, and mixtures of sand and clay not be placed adjacent to buried metallic utilities. Also, buried utilities of different metallic construction should be electrically isolated from each other to minimize galvanic corrosion problems. In addition, new piping should be electrically isolated from old piping so that the old metal will not increase the corrosion rate of the new metal. A corrosion specialist should be consulted for further recommendations.

8.5. Concrete

Laboratory chemical test performed on a sample of the on-site soils indicated sulfate content of about 0.010 percent. Based on the following American Concrete Institute (ACI) table, the on-site soils are considered to have a negligible sulfate exposure to concrete.

Table 2 – ACI Requirements for Concrete Exposed to Sulfate-Containing Soil

Sulfate Exposure	Water-Soluble Sulfate (SO_4) in Soil, Percentage by Weight	Cement Type	Water-Cementitious Materials Ratio, by Weight, Normal-Weight Aggregate Concrete[1]	f'_c, Normal-Weight and Lightweight Aggregate Concrete, psi x 0.00689 for MPa
Negligible	0.00 - 0.10	--	--	--
Moderate[2]	0.10 - 0.20	II, IP(MS), IS (MS)	0.50, or less	4,000, or more
Severe	0.20 - 2.00	V	0.45, or less	4,500, or more
Very severe	Over 2.00	V plus pozzolan[3]	0.45, or less	4,500, or more

Notes:
[1] A lower water-cementitious materials ratio or higher strength may be needed for low permeability or for protection against corrosion of embedded items or freezing and thawing (Table 4.2.2).
[2] Seawater.
[3] Pozzolan that has been evaluated by test or service record to improve sulfate resistance when used in concrete containing Type V cement.

Notwithstanding the sulfate test results, and due to the limited number of chemical tests performed, as well as our experience with similar soil conditions and local practice, we recommend that "Type II" cement be used for the construction of concrete structures at this site. Due to potential uncertainties as to the use of reclaimed irrigation water, or topsoil that may contain higher sulfate contents, pozzolan or admixtures designed to increase sulfate resistance may be considered.

The concrete should have a water-cementitious materials ratio no more than 0.5 by weight for normal weight aggregate concrete. The structural engineer should ultimately select the concrete design strength based on the project specific loading conditions. However, higher strength concrete may be selected for increased durability and resistance to shrinkage cracking.

8.6. Site Drainage

Surface drainage should be provided to divert water away from the new excavation. Positive drainage is defined as a slope of 2 percent or more over a distance of 5 feet or more away from the excavation.

8.7. Pre-Construction Conference

We recommend that a pre-construction conference be held. Representatives of the owner, the civil engineer, the geotechnical consultant, and the contractor should be in attendance to discuss the project plans and schedule. Our office should be notified if the project description included herein is incorrect, or if the project characteristics are significantly changed.

8.8. Construction Observation and Testing

During construction operations, we recommend that a qualified geotechnical consultant perform observation and testing services for the project. These services should be performed to evaluate exposed subgrade conditions, including the extent and depth of overexcavation,

to evaluate the suitability of proposed borrow materials for use as fill, and to observe and test placement of compacted fill soils. If another geotechnical consultant is selected to perform observation and testing services for the project, we request that the selected consultant provide a letter to the owner, with a copy to Ninyo & Moore, indicating that they fully understand our recommendations and that they are in full agreement with the recommendations contained in this report. Qualified subcontractors utilizing appropriate techniques and construction materials should perform construction of the proposed improvements.

9. LIMITATIONS

The field evaluation, laboratory testing, and geotechnical analyses presented in this geotechnical report have been conducted in general accordance with current practice and the standard of care exercised by geotechnical consultants performing similar tasks in the project area. No warranty, expressed or implied, is made regarding the conclusions, recommendations, and opinions presented in this report. There is no evaluation detailed enough to reveal every subsurface condition. Variations may exist and conditions not observed or described in this report may be encountered during construction. Uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration. Additional subsurface evaluation will be performed upon request. Please also note that our evaluation was limited to assessment of the geotechnical aspects of the project, and did not include evaluation of structural issues, environmental concerns, or the presence of hazardous materials.

This document is intended to be used only in its entirety. No portion of the document, by itself, is designed to completely represent any aspect of the project described herein. Ninyo & Moore should be contacted if the reader requires additional information or has questions regarding the content, interpretations presented, or completeness of this document.

This report is intended for design purposes only. It does not provide sufficient data to prepare an accurate bid by contractors. It is suggested that the bidders and their geotechnical consultant

perform an independent evaluation of the subsurface conditions in the project areas. The independent evaluations may include, but not be limited to, review of other geotechnical reports prepared for the adjacent areas, site reconnaissance, and additional exploration and laboratory testing.

Our conclusions, recommendations, and opinions are based on an analysis of the observed site conditions. If geotechnical conditions different from those described in this report are encountered, our office should be notified and additional recommendations, if warranted, will be provided upon request. It should be understood that the conditions of a site could change with time as a result of natural processes or the activities of man at the subject site or nearby sites. In addition, changes to the applicable laws, regulations, codes, and standards of practice may occur due to government action or the broadening of knowledge. The findings of this report may, therefore, be invalidated over time, in part or in whole, by changes over which Ninyo & Moore has no control.

This report is intended exclusively for use by the client. Any use or re-use of the findings, conclusions, and/or recommendations of this report by parties other than the client is undertaken at said parties' sole risk.

10. REFERENCES

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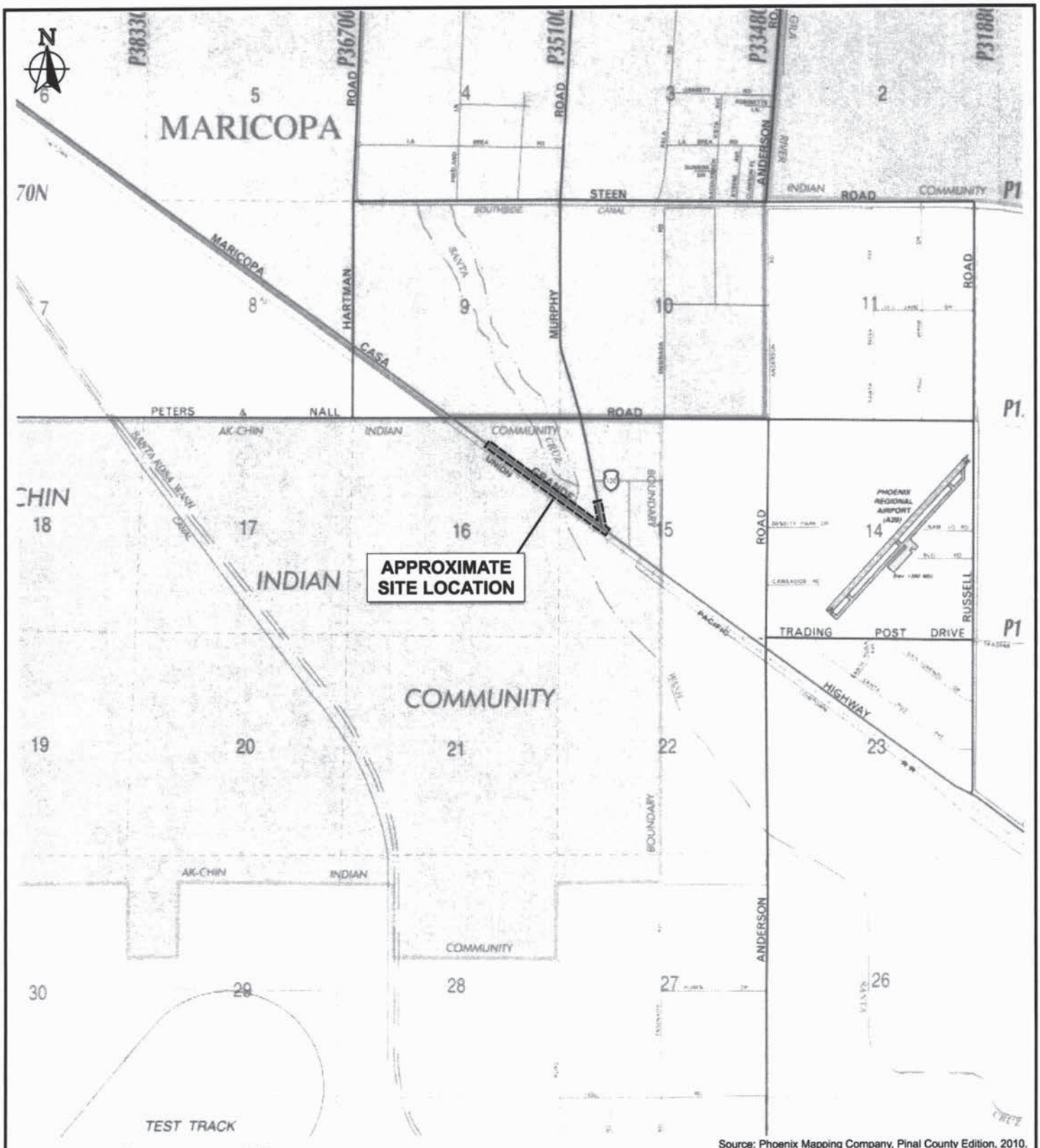
Reference Aerial Photographs

Source	Photo Date
Google Earth™	1996, 2003, 2005, 2006, 2007,2010,2011,2012
Historic Aerials	1924, 1956, 1959, 1967, 1972, 1983, 1994, 1995

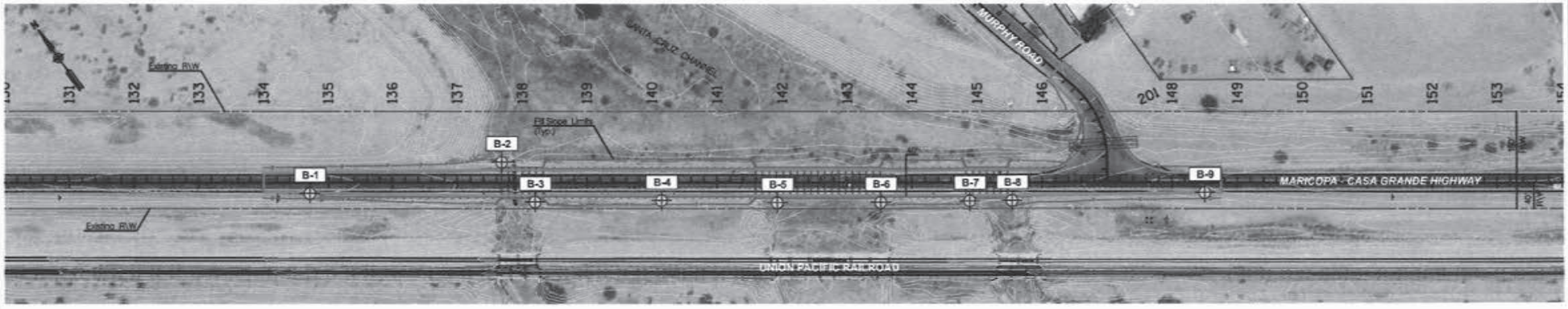


Source: Phoenix Mapping Company, Pinal County Edition, 2010.

Note: Dimensions, directions, and locations are approximate.

Ninyo & Moore	SITE LOCATION	FIGURE
PROJECT NO: 604034001 / DATE: 12/13	MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS PINAL COUNTY, ARIZONA	1

file no: 4034vmap1013



LEGEND

B-9 Boring Location

Note: Dimensions, directions, and locations are approximate.

Ninyo & Moore	BORING LOCATIONS	FIGURE
PROJECT NO: 604034001 / DATE: 12/13	MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS PINAL COUNTY, ARIZONA	2

file no: 40346m1013

APPENDIX A

BORING LOGS

Field Procedure for the Collection of Disturbed Samples

Disturbed soil samples were obtained in the field using the following methods.

Bulk Samples

Bulk samples of representative earth materials were obtained from the exploratory borings. The samples were bagged and transported to the laboratory for testing.

The Standard Penetration Test (SPT) Sampler

Disturbed drive samples of earth materials were obtained by means of a Standard Penetration Test sampler. The sampler is composed of a split barrel with an external diameter of 2 inches and an unlined internal diameter of 1-3/8 inches. The sampler was driven into the ground 12 to 18 inches with a 140-pound hammer falling freely from a height of 30 inches in general accordance with ASTM D 1586. The blow counts were recorded for every 6 inches of penetration; the blow counts reported on the logs are those for the last 12 inches of penetration. Soil samples were observed and removed from the sampler, bagged, sealed and transported to the laboratory for testing.

Field Procedure for the Collection of Relatively Undisturbed Samples

Relatively undisturbed soil samples were obtained in the field using the following methods.

The Modified Split-Barrel Drive Sampler

The sampler, with an external diameter of 3.0 inches, was lined with 1-inch long, thin brass rings with inside diameters of approximately 2.4 inches. The sampler barrel was driven into the ground with the weight of a hammer or the kelly bar of the drill rig in general accordance with ASTM D 3550. The driving weight was permitted to fall freely. The approximate length of the fall, the weight of the hammer or bar, and the number of blows per foot of driving are presented on the boring logs as an index to the relative resistance of the materials sampled. The samples were removed from the sampler barrel in the brass rings, sealed, and transported to the laboratory for testing.

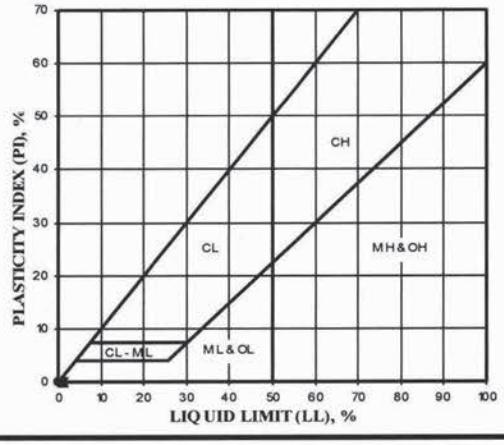
U.S.C.S. METHOD OF SOIL CLASSIFICATION

MAJOR DIVISIONS		SYMBOL	TYPICAL NAMES
COARSE-GRAINED SOILS (More than 1/2 of soil > No. 200 Sieve Size)	GRAVELS (More than 1/2 of coarse fraction > No. 4 sieve size	GW	Well graded gravels or gravel-sand mixtures, little or no fines
		GP	Poorly graded gravels or gravel-sand mixtures, little or no fines
		GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS (More than 1/2 of coarse fraction < No. 4 sieve size	SW	Well graded sands or gravelly sands, little or no fines
		SP	Poorly graded sands or gravelly sands, little or no fines
		SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (More than 1/2 of soil < No. 200 sieve size)	SILTS & CLAYS Liquid Limit <50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
	SILTS & CLAYS Liquid Limit >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 silty clays, organic silts
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils

GRAIN SIZE CHART

CLASSIFICATION	RANGE OF GRAIN	
	U.S. Standard Sieve Size	Grain Size in Millimeters
BOULDERS	Above 12"	Above 305
COBBLES	12" to 3"	306 to 76.2
GRAVEL	3" to No. 4	76.2 to 4.76
Coarse	3" to 3/4"	76.2 to 19.1
Fine	3/4" to No. 4	19.1 to 4.76
SAND	No. 4 to No. 200	4.76 to 0.075
Coarse	No. 4 to No. 10	4.76 to 2.00
Medium	No. 10 to No. 40	2.00 to 0.420
Fine	No. 40 to No. 200	0.420 to 0.075
SILT & CLAY	Below No. 200	Below 0.075

PLASTICITY CHART



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U.S.C.S. METHOD OF SOIL CLASSIFICATION

Updated Nov. 2011

BORING LOG EXPLANATION SHEET

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	
0	■							Bulk sample.
		■						Modified split-barrel drive sampler.
		☒						No recovery with modified split-barrel drive sampler.
		▮						Sample retained by others.
		◥						Standard Penetration Test (SPT).
5		◺						No recovery with a SPT.
		▯	XX/XX					Shelby tube sample. Distance pushed in inches/length of sample recovered in inches.
		◺						No recovery with Shelby tube sampler.
		▤						Continuous Push Sample.
				♀				Seepage.
10				▽				Groundwater encountered during drilling.
				▼				Groundwater measured after drilling.
						▦	SM	MAJOR MATERIAL TYPE (SOIL): Solid line denotes unit change.
						▨	CL	Dashed line denotes material change.
15								Attitudes: Strike/Dip b: Bedding c: Contact j: Joint f: Fracture F: Fault cs: Clay Seam s: Shear bss: Basal Slide Surface sf: Shear Fracture sz: Shear Zone sbs: Shear Bedding Surface
20								The total depth line is a solid line that is drawn at the bottom of the boring.

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BORING LOG

Explanation of Boring Log Symbols

PROJECT NO.	DATE	FIGURE

Updated Nov. 2011

DATE DRILLED 9/26/13 BORING NO. B-1

GROUND ELEVATION 1,245' ± (MSL) SHEET 1 OF 1

METHOD OF DRILLING CME-75, 8" Diameter Hollow-Stem Auger (Enviro Drill Inc.)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DM LOGGED BY DM REVIEWED BY JSR

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	■						CL	ALLUVIUM: Brown, damp, very stiff, sandy CLAY.
	■		16	9.6	90.1			
	■		23					Hard.
5								Total Depth = 5 feet. Groundwater not encountered during drilling. Backfilled on 9/26/13 shortly after completion of drilling.
								Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
10								
15								
20								

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BORING LOG

MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS
PINAL COUNTY, ARIZONA

PROJECT NO.	DATE	FIGURE
604034001	12/13	A-1

DATE DRILLED 9/26/13 BORING NO. B-2

GROUND ELEVATION 1,243' ± (MSL) SHEET 1 OF 1

METHOD OF DRILLING CME-75, 8" Diameter Hollow-Stem Auger (Enviro Drill Inc.)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DM LOGGED BY DM REVIEWED BY JSR

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						GC	FILL: Brown, damp, dense, clayey GRAVEL with sand; scattered asphalt debris.
		23					
						SM	ALLUVIUM: Brown, damp, medium dense, silty SAND; few gravel.
		23					
5						SC	Brown, damp, dense, clayey SAND; trace gravel.
		24					
		45					Scattered caliche nodules.
10							
		36					Very dense; few gravel.
15							Total Depth = 15 feet. Groundwater not encountered during drilling. Backfilled on 9/26/13 shortly after completion of drilling.
							Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
20							

Ninyo & Moore

BORING LOG

MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS
PINAL COUNTY, ARIZONA

PROJECT NO.	DATE	FIGURE
604034001	12/13	A-2

DATE DRILLED 9/26/13 BORING NO. B-3

GROUND ELEVATION 1,243' ± (MSL) SHEET 1 OF 1

METHOD OF DRILLING CME-75, 8" Diameter Hollow-Stem Auger (Enviro Drill Inc.)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DM LOGGED BY DM REVIEWED BY JSR

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						SC	ALLUVIUM: Brown, damp, medium dense, clayey SAND; trace gravel.
		38					
		19					Scattered caliche filaments.
5							
		44					Dense.
		49					Very dense; trace gravel.
10							
		75/11"					
15							Total Depth = 14.4 feet. Groundwater not encountered during drilling. Backfilled on 9/26/13 shortly after completion of drilling.
							Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
20							

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BORING LOG

MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS
PINAL COUNTY, ARIZONA

PROJECT NO.	DATE	FIGURE
604034001	12/13	A-3

DATE DRILLED 9/26/13 BORING NO. B-4

GROUND ELEVATION 1,242' ± (MSL) SHEET 1 OF 1

METHOD OF DRILLING CME-75, 8" Diameter Hollow-Stem Auger (Enviro Drill Inc.)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DM LOGGED BY DM REVIEWED BY JSR

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							CL	ALLUVIUM: Brown, damp, stiff, sandy CLAY; trace gravel.
			7					
			8	12.3	103.6			
5								Total Depth = 5 feet. Groundwater not encountered during drilling. Backfilled on 9/26/13 shortly after completion of drilling. Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
10								
15								
20								

Ninyo & Moore

BORING LOG

MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS
PINAL COUNTY, ARIZONA

PROJECT NO.	DATE	FIGURE
604034001	12/13	A-4

DATE DRILLED 9/26/13 BORING NO. B-5

GROUND ELEVATION 1,242' ± (MSL) SHEET 1 OF 1

METHOD OF DRILLING CME-75, 8" Diameter Hollow-Stem Auger (Enviro Drill Inc.)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DM LOGGED BY DM REVIEWED BY JSR

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						SC	ALLUVIUM: Brown, damp, dense, clayey SAND; trace gravel; scattered caliche filaments.
		61					
		25					
5						SM	Brown, damp, medium dense, silty SAND; trace gravel; scattered caliche filaments.
		29	5.4	97.4			
		34					Very dense.
10							
		86/11"					
15							Total Depth = 14.9 feet. Groundwater not encountered during drilling. Backfilled on 9/26/13 shortly after completion of drilling. Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
20							

Ninyo & Moore

BORING LOG

MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS
PINAL COUNTY, ARIZONA

PROJECT NO.	DATE	FIGURE
604034001	12/13	A-5

DATE DRILLED 9/26/13 BORING NO. B-6

GROUND ELEVATION 1,242' ± (MSL) SHEET 1 OF 1

METHOD OF DRILLING CME-75, 8" Diameter Hollow-Stem Auger (Enviro Drill Inc.)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DM LOGGED BY DM REVIEWED BY JSR

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						SC	ALLUVIUM: Brown, damp, medium dense, clayey SAND.
		11					
		27					
5							
		19					
		77/11"					Very dense.
10							
		40					Trace to few gravel.
15							Total Depth = 15 feet. Groundwater not encountered during drilling. Backfilled on 9/26/13 shortly after completion of drilling.
							Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
20							

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BORING LOG

MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS
PINAL COUNTY, ARIZONA

PROJECT NO.	DATE	FIGURE
604034001	12/13	A-6

DATE DRILLED 9/26/13 BORING NO. B-7

GROUND ELEVATION 1,242' ± (MSL) SHEET 1 OF 1

METHOD OF DRILLING CME-75, 8" Diameter Hollow-Stem Auger (Enviro Drill Inc.)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DM LOGGED BY DM REVIEWED BY JSR

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						SC	ALLUVIUM: Brown, damp, medium dense, clayey SAND; scattered caliche nodules.
		38					
		16					
5						SM	Brown, damp, medium dense, silty SAND; trace gravel.
		19					
		27					Dense.
10							
		97/9"					Very dense; trace gravel.
15							Total Depth = 14.8 feet. Groundwater not encountered during drilling. Backfilled on 9/26/13 shortly after completion of drilling.
							Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
20							

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BORING LOG

MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS
PINAL COUNTY, ARIZONA

PROJECT NO.	DATE	FIGURE
604034001	12/13	A-7

DATE DRILLED 9/26/13 BORING NO. B-8

GROUND ELEVATION 1,242' ± (MSL) SHEET 1 OF 1

METHOD OF DRILLING CME-75, 8" Diameter Hollow-Stem Auger (Enviro Drill Inc.)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DM LOGGED BY DM REVIEWED BY JSR

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	■						SC	ALLUVIUM: Brown, damp, medium dense, clayey SAND; few gravel.
	■	■	13					
	■							
	■							
	■	■	26					
5								
		■	23				SM	Brown, damp, dense, silty SAND.
							SC	Brown, damp, very dense, clayey SAND.
		■	85/11"					
10								
		■	16					Medium dense.
15								Total Depth = 15 feet. Groundwater not encountered during drilling. Backfilled on 9/26/13 shortly after completion of drilling.
								Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
20								

Ninyo & Moore

BORING LOG

MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS
PINAL COUNTY, ARIZONA

PROJECT NO.	DATE	FIGURE
604034001	12/13	A-8

DATE DRILLED 9/26/13 BORING NO. B-9

GROUND ELEVATION 1,245' ± (MSL) SHEET 1 OF 1

METHOD OF DRILLING CME-75, 8" Diameter Hollow-Stem Auger (Enviro Drill Inc.)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DM LOGGED BY DM REVIEWED BY JSR

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	■					▒	SC	ALLUVIUM: Brown, damp, medium dense, clayey SAND.
	■	■	29	6.1	97.3	▒		
	■	□				▒		
	■	□				▒		
	■	■	26			▒		Dense.
5								Total Depth = 5 feet. Groundwater not encountered during drilling. Backfilled on 9/26/13 shortly after completion of drilling.
								Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
10								
15								
20								

Ninyo & Moore

BORING LOG

MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS
PINAL COUNTY, ARIZONA

PROJECT NO.	DATE	FIGURE
604034001	12/13	A-9

APPENDIX B

LABORATORY TESTING

Classification

Soils were visually and texturally classified in accordance with the Unified Soil Classification System (USCS) in general accordance with ASTM D 2488. Soil classifications are indicated on the logs of the exploratory borings in Appendix A.

In-Place Moisture and Density Tests

The moisture content and dry density of relatively undisturbed samples obtained from the exploratory borings were evaluated in general accordance with ASTM D 2937. The test results are presented on the log of the exploratory borings in Appendix A.

Gradation Analysis

Gradation analysis tests were performed on selected representative soil samples in general accordance with ASTM D 422. The grain-size distribution curves are shown on Figures B-1through B-4. These test results were utilized in evaluating the soil classifications in accordance with the USCS.

Atterberg Limits

Tests were performed on selected representative fine-grained soil samples to evaluate the liquid limit, plastic limit, and plasticity index in general accordance with ASTM D 4318. These test results were utilized to evaluate the soil classification in accordance with the USCS. The test results and classifications are shown on Figure B-5.

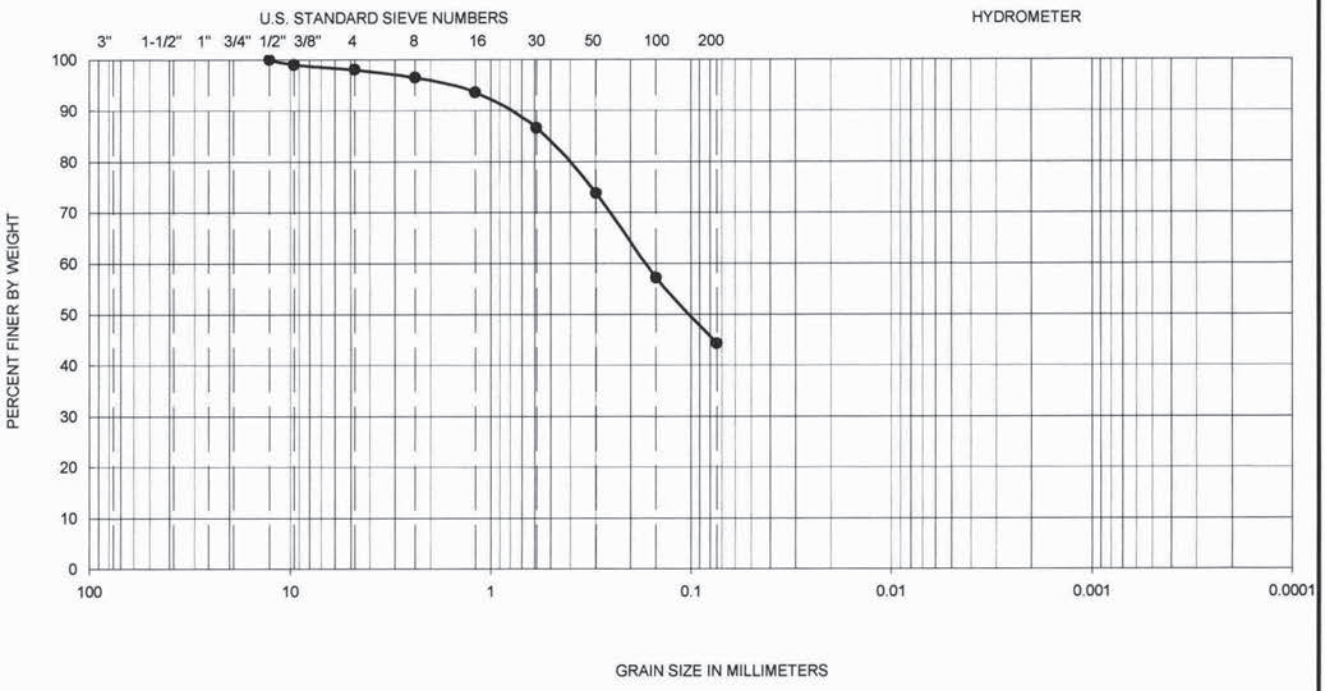
Consolidation Test

Consolidation test was performed on a selected relatively undisturbed soil sample in general accordance with ASTM D 2435. The sample was inundated during testing to represent adverse field conditions. The percent of consolidation for each load cycle was recorded as a ratio of the amount of vertical compression to the original height of the sample. The results of the test are summarized on Figure B-6.

Soil Corrosivity Tests

Soil pH and minimum resistivity tests were performed on representative samples in general accordance with Arizona Test 236b. Soluble sulfate and chloride content tests were also performed on these samples in general accordance with Arizona Test 733 and 736, respectively. The test results are presented on Figure B-7.

GRAVEL		SAND			FINES	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

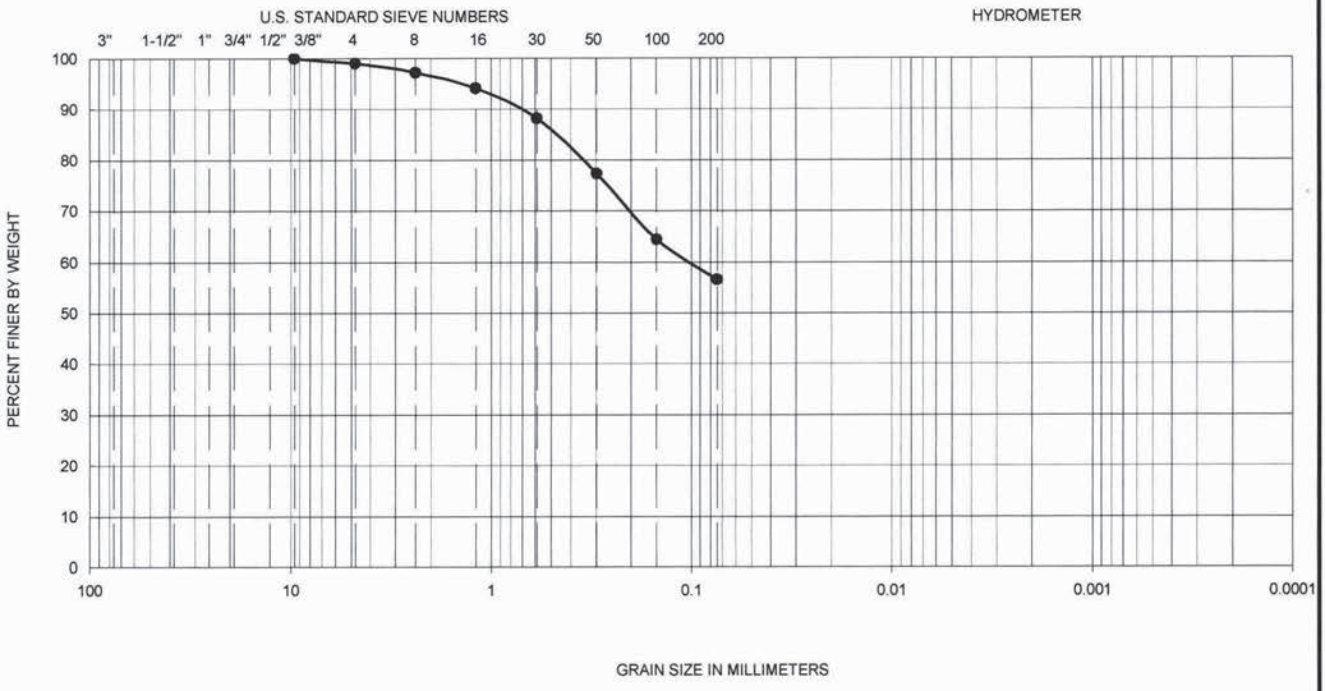


Symbol	Hole No.	Depth (ft)	Liquid Limit	Plastic Limit	Plasticity Index	D_{10}	D_{30}	D_{60}	C_u	C_c	Passing No. 200 (%)	U.S.C.S
●	B-3	0.0-5.0	31	15	16	--	--	--	--	--	44	SC

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 422

Ninyo & Moore	GRADATION TEST RESULTS	FIGURE
PROJECT NO. / DATE	MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS PINAL COUNTY, ARIZONA	B-1
604034001 / 12/13		

GRAVEL		SAND			FINES	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

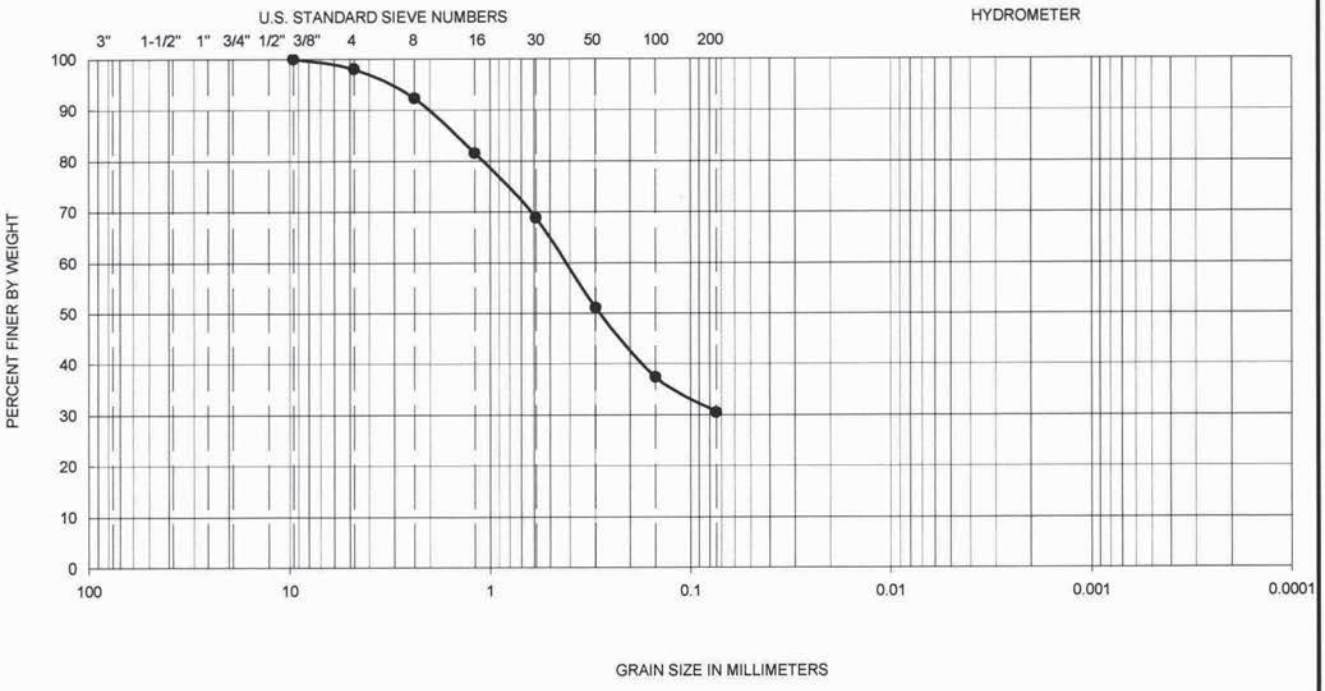


Symbol	Hole No.	Depth (ft)	Liquid Limit	Plastic Limit	Plasticity Index	D_{10}	D_{30}	D_{60}	C_u	C_c	Passing No. 200 (%)	U.S.C.S
●	B-4	0.0-5.0	34	17	17	--	--	--	--	--	57	CL

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 422

Ninyo & Moore	GRADATION TEST RESULTS	FIGURE
PROJECT NO. / DATE	MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS PINAL COUNTY, ARIZONA	B-2
604034001 / 12/13		

GRAVEL		SAND			FINES	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

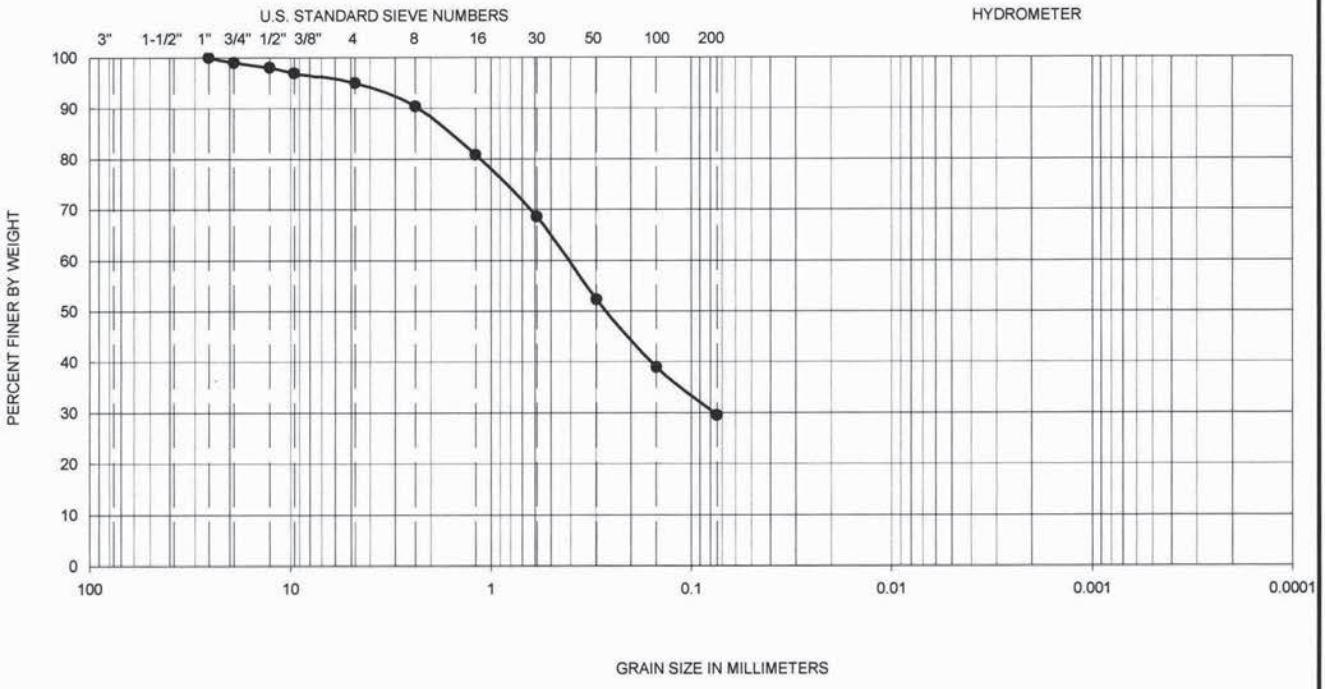


Symbol	Hole No.	Depth (ft)	Liquid Limit	Plastic Limit	Plasticity Index	D_{10}	D_{30}	D_{60}	C_u	C_c	Passing No. 200 (%)	U.S.C.S
●	B-5	0.0-5.0	28	15	13	--	--	--	--	--	30	SC

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 422

Ninyo & Moore	GRADATION TEST RESULTS	FIGURE
PROJECT NO. / DATE	MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS PINAL COUNTY, ARIZONA	B-3
604034001 / 12/13		

GRAVEL		SAND			FINES	
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay

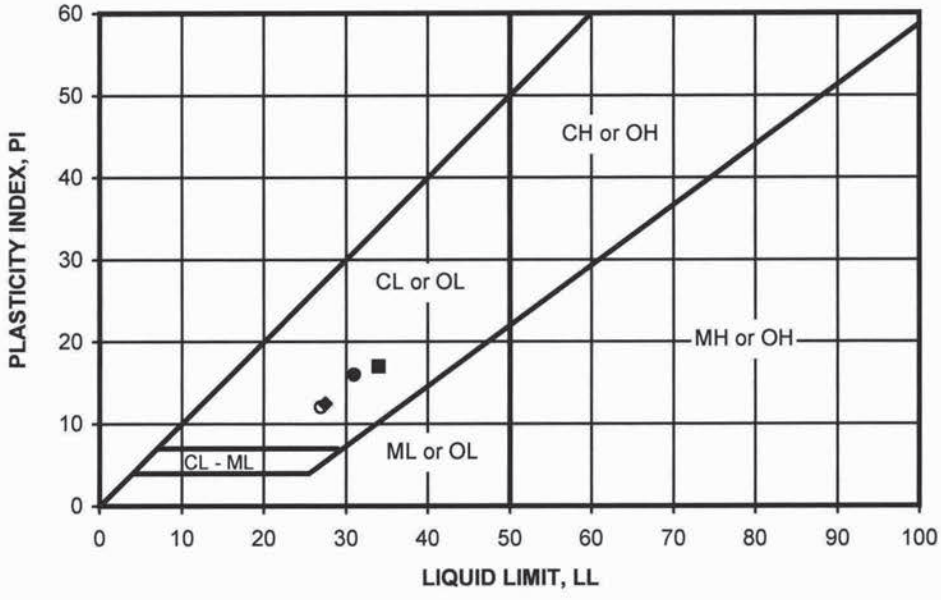


Symbol	Hole No.	Depth (ft)	Liquid Limit	Plastic Limit	Plasticity Index	D_{10}	D_{30}	D_{60}	C_u	C_c	Passing No. 200 (%)	U.S.C.S
●	B-8	0.0-5.0	27	15	12	--	--	--	--	--	29	SC

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 422

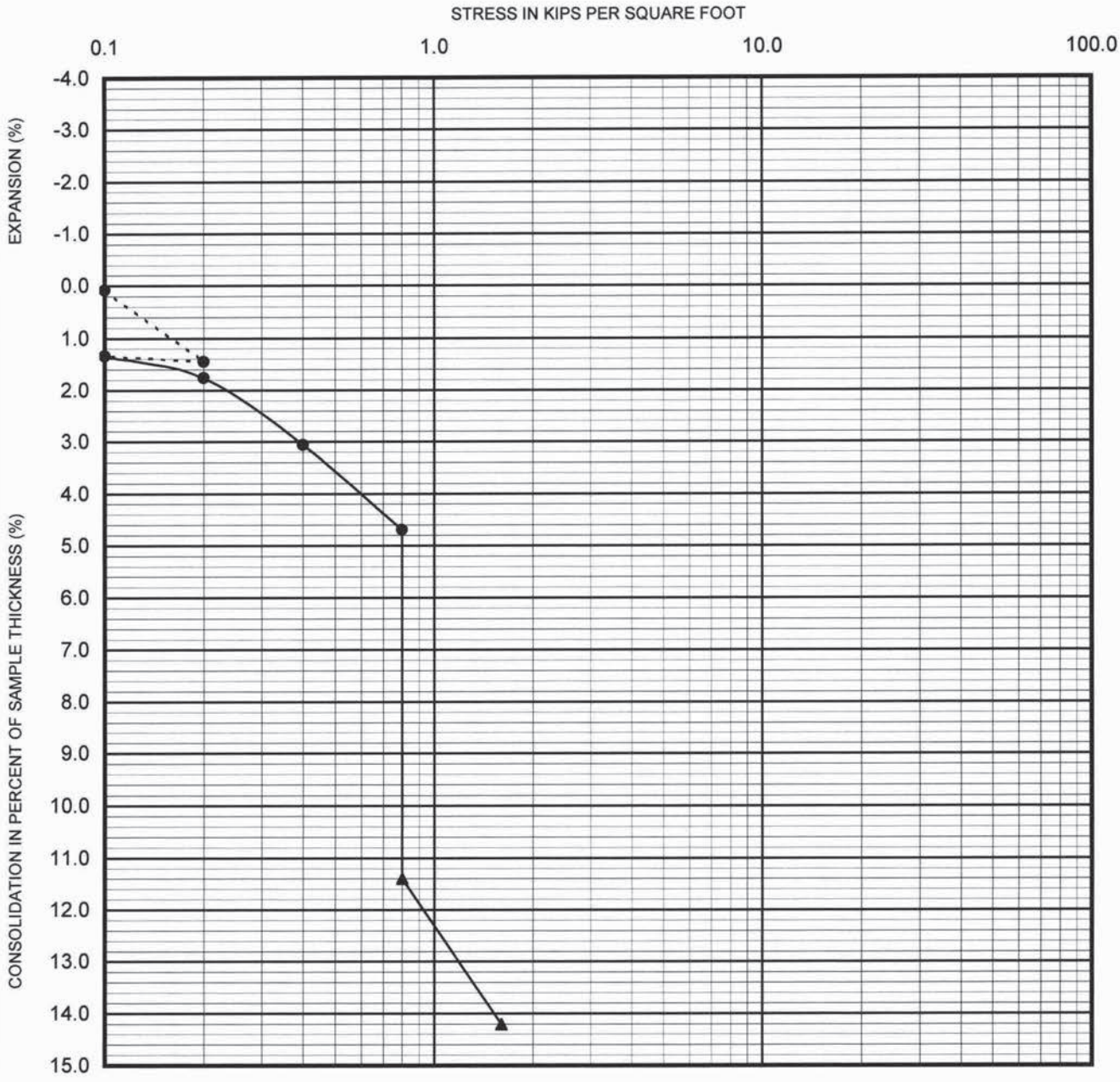
Ninyo & Moore	GRADATION TEST RESULTS	FIGURE
PROJECT NO. / DATE	MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS PINAL COUNTY, ARIZONA	B-4
604034001 / 12/13		

SYMBOL	LOCATION	DEPTH (FT)	LIQUID LIMIT, LL	PLASTIC LIMIT, PL	PLASTICITY INDEX, PI	USCS CLASSIFICATION (Fraction Finer Than No. 40 Sieve)	USCS (Entire Sample)
●	B-3	0.0-5.0	31	15	16	CL	SC
■	B-4	0.0-5.0	34	17	17	CL	CL
◆	B-5	0.0-5.0	28	15	13	CL	SC
○	B-8	0.0-5.0	27	15	12	CL	SC



PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 4318

Ninyo & Moore	ATTERBERG LIMITS TEST RESULTS	FIGURE
PROJECT NO. 604034001 / DATE 12/13	MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS PINAL COUNTY, ARIZONA	B-5



Seating Cycle		Sample Location	B-5
Loading Prior to Inundation		Depth (ft.)	6.0-7.5
Loading After Inundation		Soil Type	SM
Rebound Cycle			

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 2435

Ninyo & Moore		CONSOLIDATION TEST RESULTS	FIGURE
PROJECT NO.	DATE	MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS PINAL COUNTY, ARIZONA	B-6
604034001	12/13		

SAMPLE LOCATION	SAMPLE DEPTH (FT)	pH [1]	RESISTIVITY [1] (Ohm-cm)	SULFATE CONTENT [2]		CHLORIDE CONTENT [3] (ppm)
				(ppm)	(%)	
B-5	0.0-5.0	8.0	1,380	96	0.010	110

[1] PERFORMED IN GENERAL ACCORDANCE WITH ARIZONA TEST METHOD 236b
[2] PERFORMED IN GENERAL ACCORDANCE WITH ARIZONA TEST METHOD 733
[3] PERFORMED IN GENERAL ACCORDANCE WITH ARIZONA TEST METHOD 736

Ninyo & Moore	CORROSIVITY TEST RESULTS	FIGURE
PROJECT NO. / DATE	MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS PINAL COUNTY, ARIZONA	B-7
604034001 / 12/13		

PAVEMENT DESIGN SUMMARY
MARICOPA-CASA GRANDE HIGHWAY CROSSING IMPROVEMENTS
PINAL COUNTY, ARIZONA

PREPARED FOR:
Jacobs
101 North 1st Avenue, Suite 3100
Phoenix, Arizona 85003

PREPARED BY:
Ninyo & Moore
Geotechnical and Environmental Sciences Consultants
3202 East Harbour Drive
Phoenix, Arizona 85034

December 17, 2013
Project No. 604034001

December 17, 2013
Project No. 604034001

Mr. Berwyn Wilbrink, P.E.
Jacobs
101 North 1st Avenue, Suite 3100
Phoenix, Arizona 85003

Subject: Pavement Design Summary
Maricopa-Casa Grande Highway Crossing Improvements
Pinal County, Arizona

Dear Mr. Wilbrink:

In accordance with your authorization and our proposal dated November 15, 2012, we have performed a Pavement Design Summary for the Maricopa-Casa Grande Highway Crossing Improvements project in Pinal County, Arizona. This report presents our findings, conclusions, and pavement recommendations for the project. The Geotechnical Evaluation for this project is submitted separately.

We appreciate the opportunity to be of service to you during this phase of the project.

Sincerely,
NINYO & MOORE

Registered Professional Engineer (Civil)
CERTIFICATE NO. 41716
KEVIN L. PORTER
Date Signed 12-17-13
ARIZONA U.S.A.
EXPIRES 12/31/13

Kevin L. Porter, PE
Senior Engineer

Soumitra Guha, PhD, PE, GE
Principal Engineer

KLP/SG/clj

Distribution: (1) Addressee (Electronic Copy)

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Appendices

Appendix A – DARWin Analysis

1. INTRODUCTION

In accordance with our proposal dated November 15, 2012, we have performed geotechnical and pavement evaluations for the planned improvements for the Maricopa-Casa Grande Highway Crossing Improvements project in Pinal County, Arizona. The purpose of our pavement evaluation was to assess and document the subsurface conditions at the project site and provide engineering recommendations relative to pavement design.

This report includes our engineering analyses and the presentation of design parameters and recommendations for the proposed pavement sections. For brevity, it does not include explanations of field activities, discussion of laboratory tests performed, or an evaluation of the geological setting and hazards. These items are presented in our Geotechnical Evaluation Report dated October 31, 2013, for the project which is submitted separately.

2. SCOPE OF SERVICES

The scope of our services for this phase of the project generally included:

- Conducting a visual reconnaissance of the project area and reviewing available geologic literature and aerial photographs of the project site.
- Obtaining a right-of-way permit from Pinal County to perform the work, including arranging for traffic control.
- Drilling, logging, and sampling nine hollow-stem auger borings using a truck-mounted, two-wheel drive drill rig. Six borings extended approximately 15 feet deep (two at each box culvert crossing), and three borings extended approximately 5 feet deep (subgrade). The boring logs are provided in our Geotechnical Evaluation Report, submitted separately.
- Conducting laboratory testing of selected samples obtained from the borings to evaluate in-situ moisture and dry density, sieve analysis, Atterberg limits, consolidation, and corrosivity characteristics (including pH, minimum electrical resistivity, and sulfate and chloride contents). The results of our laboratory testing are provided in our Geotechnical Evaluation Report, submitted separately.
- Preparing this Pavement Design Summary to accompany the geotechnical report, which is submitted separately.

3. SITE/PROJECT DESCRIPTION

The project site is located on Maricopa-Casa Grande Highway, roughly between Murphy Road and 1,500 feet northwest of Murphy Road in Pinal County, Arizona. Presently, the existing roadway is a two-lane, asphalt concrete (AC) paved roadway trending in a northwest-southeast direction and is surrounded by undeveloped and agricultural lands. The roadway is generally at grade and crosses the Santa Cruz Channel. There is an existing railroad line located west of, and generally parallel to, the roadway near the project site. The railroad line is elevated above the surrounding grade in this area and has three box culverts that allow channel flows beneath the rail line. Scattered vegetation and rip rap, generally consisting of large cobbles and boulders, was observed adjacent to the roadway within the channel.

According to the *Stanfield, Arizona-Pinal County, 7.5-Minute United States Geological Survey (USGS) Topographic Quadrangle Map (2011),* the elevation at the project site is approximately 1,241 feet relative to mean sea level (MSL). The topography in the vicinity of the site generally slopes from the southeast down to the northwest. According to the plans obtained from your office, the roadway elevation ranges from approximately 1,240 to 1,245 feet MSL within the project limits.

Ten aerial photographs from Google Earth™ were reviewed for this project. The available aerial photographs from 1996, 2003, 2005, 2006, 2007, 2010, 2011, and 2012 depicted the site as being similar to its current condition. Several topographic maps and aerial photographs were reviewed for this project from the HistoricAerials.com website (NETR, 2013), including topographic maps from the period between 1924 and 1995. The topographic maps from 1924 to 1959 depict the railroad alignment crossing several washes. The topographic maps from 1967 to 1994 depict the roadway and the intersection with Murphy Road and also depicts the channelization of Santa Cruz Wash with levees.

We understand that the roadway will be reconstructed within the project limits and placed on up to approximately five feet of grade-raise engineered fill with three concrete box culverts allowing the flow of the Santa Cruz Channel beneath the elevated roadway. We understand the

planned improvements will be constructed following Maricopa Association of Governments (MAG) Specifications. In addition, a pipe culvert is planned beneath Murphy Road. We understand that the concrete box culverts will be on the order of 10 feet by 6 feet in dimension and will consist of 6 to 18 barrels.

4. PAVEMENT DESIGN RECOMMENDATIONS

The following sections present our design parameters and recommendations for new pavement within the project limits. For this project we utilized the pavement design method noted in the ADOT Preliminary Engineering and Design Manual (PEDM). We recommend that the pavement section provided in the table below be used for pavement improvements associated with this project.

Table 1 – Recommended Pavement Sections (in inches)

Roadway Segment	Aggregate Base	Asphalt Concrete	Total Thickness
Maricopa-Casa Grande Highway	10.0	6.0	16.0

5. CHECK OF PAVEMENT DESIGN SECTION

The pavement sections recommended above are based on the design R-value, traffic information provided by your office, and the pavement design procedures outlined in the ADOT PEDM. The sections, tables, or figures referenced by the procedure are included in the PEDM. Print-outs of the analysis performed using the DARwin software are presented in Appendix A.

5.1. Design R-value

The near-surface subsurface soils encountered in our borings consisted mainly of silty sand, clayey sand, and sandy clay, with varying amounts of gravel and cobbles. Boulders are possibly present; however, due to the diameter of our excavations, boulders could not be identified. Correlated R-values ranged from 23 to 42. We calculated an average R-value of

34, but for the sake of conservatism, we recommend a design R-value of 20. We recommend that soils placed within 3 feet of the finished roadway subgrade demonstrate a construction control R-value of 20 or more.

For areas that are to receive grade-raise fill or new pavement, we recommend the existing subgrade soils be improved by scarifying, moisture-conditioning and compacting to a depth of about 12 inches. Further evaluation should be made by the on-site geotechnical representative during this operation. Based on this evaluation, additional remediation may be needed. This additional remediation, if needed, should be addressed by the geotechnical consultant during the earthwork operations.

Engineered fill within improved zones should be placed in horizontal lifts not exceeding 8 inches in loose thickness and compacted to 95 percent relative compaction, as evaluated by ASTM D 698 at a moisture content generally slightly above the optimum.

5.2. Traffic Volumes and Truck Factor Growth Rates

Traffic loading information was provided by Jacobs and consisted of an Average Daily Traffic (ADT) value of 5,799 vehicles per day for the year 2011 and an ADT of about 15,000 for the year 2040. Using these values, a percent growth and design ADT for the year 2014 was calculated. Based on information you provided, we also used 10 percent trucks over a design life of 20 years. The table below presents the average daily traffic (ADT), percent growth, percent trucks, and calculated Equivalent Single Axle Loads (ESAL's) for the planned roadway:

Table 2 – Traffic Parameters

Roadway	ADT (2014)	% Growth	% Trucks	Calculated ESAL's
Maricopa-Casa Grande Highway	6,750	5.5	10	5,405,225

5.3. Resilient Modulus and Modulus of Subgrade Reaction

A design R-value of 20 was utilized in our analysis of new pavement sections. Based on an R-value of 20 and a seasonal variation factor of 1.0 taken from Figure 202.02-1 in the PEDM, a resilient modulus of 12,025 pounds per square inch (psi) was calculated.

5.4. Drainage Coefficient

A drainage coefficient of 1.0 was obtained from Table 202.02-7 in the PEDM, based on a seasonal variation factor of 1.0 and fair drainage conditions.

5.5. Serviceability

An initial serviceability of 4.1 and a terminal serviceability of 2.6 were used for the design of flexible pavements. The resulting serviceability index loss is 1.5.

5.6. Flexible Pavement - Standard Deviation and Level of Reliability

A standard deviation of 0.35 was used for the design of flexible pavements in accordance with current ADOT policy. Based on Table 202.02-01 for roadways with an ADT of 2,001 to 10,000, a level of reliability of 90 percent was utilized for the design. A standard normal deviation (Z_R) value of -1.282 was utilized.

5.7. Structural Number Summary

In accordance with the procedure for flexible pavement design noted in the PEDM, and using the above-mentioned parameters, we calculated the structural number (SN) for the AC roadway section, as presented below.

Table 3 – Structural Number Summary

Roadway Segment	Minimum Required Structural Number	Calculated Structural Number of New Pavement
Maricopa-Casa Grande Highway	3.74	4.04

6. LIMITATIONS

The field evaluation, laboratory testing, and geotechnical analyses presented in this geotechnical report have been conducted in general accordance with current practice and the standard of care exercised by geotechnical consultants performing similar tasks in the project area. No warranty, expressed or implied, is made regarding the conclusions, recommendations, and opinions presented in this report. There is no evaluation detailed enough to reveal every subsurface condition. Variations may exist and conditions not observed or described in this report may be encountered during construction. Uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration. Additional subsurface evaluation will be performed upon request. Please also note that our evaluation was limited to assessment of the geotechnical aspects of the project, and did not include evaluation of structural issues, environmental concerns, or the presence of hazardous materials.

This document is intended to be used only in its entirety. No portion of the document, by itself, is designed to completely represent any aspect of the project described herein. Ninyo & Moore should be contacted if the reader requires additional information or has questions regarding the content, interpretations presented, or completeness of this document.

This report is intended for design purposes only. It does not provide sufficient data to prepare an accurate bid by contractors. It is suggested that the bidders and their geotechnical consultant perform an independent evaluation of the subsurface conditions in the project areas. The independent evaluations may include, but not be limited to, review of other geotechnical reports prepared for the adjacent areas, site reconnaissance, and additional exploration and laboratory testing.

Our conclusions, recommendations, and opinions are based on an analysis of the observed site conditions. If geotechnical conditions different from those described in this report are encountered, our office should be notified and additional recommendations, if warranted, will be provided upon request. It should be understood that the conditions of a site could change with time as a result of natural processes or the activities of man at the subject site or nearby sites. In

addition, changes to the applicable laws, regulations, codes, and standards of practice may occur due to government action or the broadening of knowledge. The findings of this report may, therefore, be invalidated over time, in part or in whole, by changes over which Ninyo & Moore has no control.

This report is intended exclusively for use by the client. Any use or re-use of the findings, conclusions, and/or recommendations of this report by parties other than the client is undertaken at said parties' sole risk

7. REFERENCES

American Society for Testing and Materials (ASTM), Annual Book of ASTM Standards.

Arizona Department of Transportation (ADOT), 1989, Preliminary Engineering and Design Manual, Materials Section, ADOTM-XII-TWO-C, 3rd Edition: dated March.

DARWin Version 3.01, American Association of State Highway and Transportation Officials, 1997.

Maricopa Association of Governments, 2011, Uniform Standard Specifications and Details for Public Works Construction.

Ninyo & Moore, 2013, Geotechnical Evaluation Report, Maricopa-Casa Grande Highway: dated December 17.

APPENDIX A

DARWIN ANALYSIS

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product
I.S. Department

Flexible Structural Design Module

MCGH

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	5,405,225
Initial Serviceability	4.1
Terminal Serviceability	2.6
Reliability Level	90 %
Overall Standard Deviation	0.35
Roadbed Soil Resilient Modulus	12,125 psi
Stage Construction	1
Calculated Design Structural Number	3.74 in

Simple ESAL Calculation

Performance Period (years)	20
Two-Way Traffic (ADT)	6,750
Number of Lanes in Design Direction	1
Percent of All Trucks in Design Lane	100 %
Percent Trucks in Design Direction	60 %
Percent Heavy Trucks (of ADT) FHWA Class 5 or Greater	10 %
Average Initial Truck Factor (ESALs/truck)	1.2
Annual Truck Factor Growth Rate	0 %
Annual Truck Volume Growth Rate	5.5 %
Growth	Simple
Total Calculated Cumulative ESALs	5,405,225

Layered Thickness Design

Thickness precision: Nearest 0.5 in

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	AC	0.44	1	-	-	625,000	-	6.00	2.64
2	AB	0.14	1	-	-	34,000	-	9.50	1.33
Total	-	-	-	-	-	-	-	15.50	3.97