MISSISSIPPI DEPARTMENT OF TRANSPORTATION

GEOTECHNICAL MANUAL

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Chapter 1

PURPOSE

1-1 Purpose and Scope

The purpose of this manual is to serve as a guidance document for the performance of geotechnical work by consulting firms, and to provide Mississippi Department of Transportation (MDOT) employees in the Roadway Design Division, Bridge Design Division, and the District offices pertinent geotechnical considerations prior to or during development of construction project plans. These engineering considerations should be coordinated with MDOT Materials Division/Geotechnical Branch. Information and guidance presented in this manual is intended to aid the Engineer in adequately scoping geotechnical explorations, selecting appropriate field and laboratory testing methods, and to direct the Engineer to suitable references for geotechnical analysis methods. Except where specified, the information is presented as guidance and is not exhaustive of the available exploration or analysis methods. Use of this manual does not relieve the user of the responsibility for the results of geotechnical explorations, design of foundation or roadway components, or geotechnical activities represented herein.

For the purposes of this manual, the term Engineer refers to the Engineer of Record responsible for the various investigations and reporting referenced in this manual. Primarily, it refers to either the State Geotechnical Engineer, the Consultant hired to perform the work for the State, or the District Materials Engineer. The Engineer has primary responsibility for the scoping and execution of the geotechnical exploration, evaluating alternatives, performing analyses, developing recommendations, issuing reports, and providing other support as requested by the various design divisions of MDOT.

The Consultant will act as the Engineer when contracted by the state for a project. Information/requests from the Consultant to other MDOT offices as noted in this manual (such as the District Offices or the Roadway Design, Bridge, or the Right-of-Way [ROW] Divisions) shall be through the Geotechnical Branch.

1-2 Standards and References

1-2.1 MDOT Specifications, Drawings, and Procedures

- MDOT standard specifications for road and bridges, drawings, and procedures:
  https://mdot.ms.gov/portal/engineering_standards_guides_manuals
- TMD-20-14-00-000 Soil Profiles
  https://mdot.ms.gov/documents/Materials/Manuals/GeoTech/TMD-20-14-00-000(CURRENT).pdf
- TMD-20-14-01-000 Standard Design Procedures for Construction of Roadways Through High Volume Change Soils

https://mdot.ms.gov/documents/Materials/Manuals/GeoTech/TMD-20-14-01-000(CURRENT).pdf

- MDOT Pavement Design Policy
  https://mdot.ms.gov/documents/Materials/Manuals/GeoTech/Approved%20MDOT%20Pavement%20Design%20Procedures%202024.pdf

1-2.2 AASHTO

- AASHTO LRFD Bridge Design Specifications
- AASHTO Guide Specifications for LRFD Seismic Bridge Design
- AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals
- AASHTO LRFD Bridge Construction Specifications
- AASHTO Standard Specifications for Highway Bridges
- AASHTO Manual on Subsurface Investigations
- AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing (particularly AASHTO R 13 – Standard Practice for Conducting Geotechnical Subsurface Investigations and AASHTO R 27-01 – Standard Practice for Assessment of Corrosion of Steel Piling for Non-Marine Applications)

1-2.3 FHWA

- Geotechnical Guidance Manual - https://highways.dot.gov/federal-lands/pddm/geotechnical-technical-guidance-manual
- FHWA Geotechnical Engineering Circulars
- Manual on Uniform Traffic Control Devices for Streets and Highways https://mutcd.fhwa.dot.gov/

1-3 Example Forms, Tables, and Other Documents

Example forms and tables for the documents listed below are provided in Appendices.

- Right of Entry Example Letter
- TMD-683
  https://mdot.ms.gov/documents/Materials/Manuals/GeoTech/TMD-683-Form.pdf
- Mississippi Geologic Map
  https://mrdata.usgs.gov/geology/state/kml/msgeol.kmz
- Geotechnical Branch Policy Statement *Geologic Descriptions of Soils and Stratigraphic Nomenclature*

1-4 Software Used/Accepted by MDOT

Software for various Geotechnical tasks is listed in the table below. MDOT may consider alternative software for specialized use or if outputs are compatible with the below:

Table 1: MDOT Preferred Software

Software Name	Use
OpenGround	Boring Logs
OpenRoads	CADD Drawings
SLIDE, SLOPE/W	Slope Stability
APILE/Shaft	Axial Pile Capacities
LPILE	Lateral Pile Capacities
CAPWAP/GRLWEAP	Pile Dynamic Load Testing
Group	Pile Group Analysis

Chapter 2

GEOLOGY OF MISSISSIPPI

2-1 General Overview

Mississippi is generally divided into ten physiographic provinces. These are more fully described at https://pubs.usgs.gov/ha/739/plate-1.pdf

Mississippi Alluvial Plain (“Delta”): a very broad, flat, gently sloping plain formed by the Mississippi River and its tributaries.

Loess bluffs: The loess bluffs occur along the eastern side of the Delta. These are wind-blown deposits of silt that rest upon the underlying sands, clays, and gravels comprising the hills that adjoin the Delta, forming an abrupt escarpment 150 to 250 feet above the flat bottom lands. The deposits thin gradually to the east.

Coastal Meadows (Lower Plain): This is a low-lying area between 7 and 20 miles wide along the Gulf of Mexico. There are considerable areas of marsh and swamp.

Pine Hills: This region covers most of the lower third of the state. The predominant geological formations are the Vicksburg Group, Catahoula, Hattiesburg/Pascagoula, and Citronelle formations. Much of the area is quite hilly.

Jackson Prairie: This is a relatively narrow strip of land which is defined by outcrops of the Jackson Group. It appears on the eastern side of the state near Shubuta and extends west-north westerly becoming gradually wider until it outcrops at the bluffs near Yazoo City.

North Central Hills: This large area is a hilly upland shaped by stream erosion and consists of formations of the Wilcox and Claiborne Groups. The Tallahatta formation has many ledges of weathered rock which may be encountered in a road cut. Along the eastern side of this region within soils of the Wilcox Group, seams of lignite can be encountered.

Flatwoods: Extending from Kemper County northward to Tippah County, this narrow band lowland consists almost exclusively of the Porters Creek Formation. It is characterized by gently undulating to rolling wooded plains from the south to tall hills in the north.

Pontotoc Ridge: This is another narrow band which starts near Macon in Noxubee County extending north to Alcorn County. Soils of the Prairie Bluff Chalk and Owl Creek formations, and the Ripley and Clayton formations make up this region of gently sloped and rounded hills.

Black Prairie: This region consists primarily of Demopolis (Selma) Chalk and is also defined by level plains and gently sloped small hills.

Tombigbee Hills: In the northeastern part of the state, this area is made up of tall hills with mostly narrow valleys, except along the valley plain of the Tombigbee River. Most of this region is characterized by the dense sands and stiff clays of the Eutaw formation and the sands and gravels of the Tuscaloosa formation in lower lying areas. In Tishomingo County, one may encounter limestone and shale along the state border.

2-2 Expansive Clays of Mississippi

The Geologic Map of Mississippi lists several geological formations which are known to locals to exhibit shrinking and swelling tendencies. Clays from these formations routinely show volume change test results greater than 60% when tested from the liquid limit. MDOT nomenclature refers to the soils as "high volume change", or HVC. In no particular order, the major formations with these tendencies include:

- Black Prairie Residuum from Soils of the Selma Group (Prairie Bluff, Ripley, Demopolis, and Mooreville chalks)
- Owl Creek Formation
- Porters Creek Formation
- Zilpha Formation
- Yazoo Clay of the Jackson Group
- Pascagoula and Hattiesburg Formations
- "Gumbo" clays of the Mississippi River Delta Alluvium

2-3 Problematic Soils of Mississippi

2-3.1 Low CBR, High Volume Change, and Highly Plastic Soils

Mississippi has an abundance of low CBR soils, which either directly or indirectly can have an impact upon the subgrade resilient modulus used in a pavement design. These soils are typically fine-grained materials with an AASHTO classification of A-7-6 or sometimes A-7-5. Some, but not all, of these fine-grained soils become problematic due to sensitivity to moisture content. These sensitivities manifest themselves in the form of subgrade instability which inhibit proper construction of subsequent pavement layers, shrinking and swelling which destroy the smoothness of the finished pavement, or simply the difficulty of processing the materials during earthmoving operations.

Each MDOT District has areas of HVC soils. In particular, the eastern ½ of the state, in Districts 1, 5, and 6, has an *abundance* of HVC soils. As noted, there are many locations around the state where problematic soils are encountered, and most are related to highly plastic or HVC soils. HVC soils will usually have an AASHTO classification of A-7-6.

"Highly plastic" is a term loosely used on some clay soils, and there are various opinions as to what constitutes a "highly plastic" designation. As a general rule, any clay material with a plasticity index of 23 or higher will present issues during earthwork construction, regardless of the volume change measured in the laboratory, and must be dealt with accordingly. These materials typically classify as AASHTO A-7-5 or A-6.

From strictly a pavement design perspective, subgrades consisting of “highly plastic” soils should be presumed to have basically the same material characteristics as any HVC soil – i.e., CBR values are too low to be suitable as a subgrade material.

2-3.2 AASHTO A-4 Soils

There are certain soils in Mississippi with an AASHTO classification of A-4 which are also identified as being problematic.

On the western side of the state, along the bluffs leading to the Mississippi Delta and the Mississippi River, massive wind-blown deposits of silt known as loess exist. This material consists of 90% or more silt size particles and has little to no plasticity. As Districts 2, 3, and 7 can affirm, it is highly erodible. As long as the moisture content is at approximately 3% below the optimum moisture at maximum dry density, the material can typically be excavated, shaped and compacted. Based upon resilient modulus testing of samples of this material, an A-4 material would be expected to provide a substantially good subgrade. However, when this loess material gets wet and saturated, stability loss occurs. This can limit earthwork operations to occur only when the prevailing weather pattern is dry. As a subgrade material, it must be quickly chemically treated with cement and primed with bituminous material to avoid excessive moisture intrusion and loss of stability.

Other similar A-4 materials, not associated with the loess bluffs, are prevalent within the southern 1/3 of the state. These are usually found in a natural condition as very wet and soft, and are sometimes mis-categorized as muck even though the organic content of the material does not indicate such. These materials can often be excavated (undercut), stockpiled in a place where they can naturally drain and dry, and then used as an unclassified excavation material in embankment construction below the design soil prism.

There are areas in the Delta which have natural A-4 materials. If properly processed, placed, and kept above standing water situations, this material has been successfully used as suitable embankment and subgrade material. Again, proper moisture content during placement is critical for success. When excessive moisture is present, or the material gets blended with underlying clay materials, it is expected to exhibit low CBR values.

Class B9-6 Borrow Excavation is a material which historically has worked well in the design soil prism. It has been used extensively statewide to backfill undercut subgrades in HVC areas. MDOT’s standard specifications allow up to 100% of the B9-6 material to pass the No. 200 sieve, but the liquid limit cannot exceed 40 and the plasticity index must be between 6 and 20. This insures that “lean clay” is being placed over the HVC undercut subgrade in an attempt to keep the moisture content of the HVC subgrade at a constant level. Quality B9-6 borrow excavation should classify as an AASHTO A-6 material.

There are several areas within the state where quality B9-6 borrow excavation material is difficult to locate within a reasonable haul distance, and some of these materials are so silty or sandy that they are at the lower limit of the plasticity index requirement. In addition, some B9-6 borrow excavation materials do not always respond well to the usual chemical treatment methods. In most cases these types of B9-6 borrow excavation materials are trending towards an AASHTO A-4 classification.

Class 9 granular material has traditionally been used with great success in roadway construction projects statewide. It is used extensively across the state as a sub-base beneath pavements (“topping”) and is chemically treated for a cement treated base before placement of hot mix asphalt or concrete pavements.

MDOT’s standard specifications define a Class 9 granular material as a material with 30 - 100% passing the No. 10 sieve. Of the material passing the No. 10 sieve, the following gradation limitations apply:

Sieve Size	% Passing
No. 10	100
No. 40	20 – 100
No. 60	15 – 85
No. 200	6 - 40

Historically most pit sources of Class 9 granular material have fallen into the median range of the percent passing specified. This material would classify as an AASHTO A-2-4 material.

For many years, when available, Class 9 granular material with a Group C designation (limiting the PI of the material to a maximum of 10) has been preferred for subbase material. This ensures a good sandy material with just enough clay fines to hold the sand sized particles together is utilized. As sources of this preferred material within the state have been depleted, Class 9 granular material must now often be specified with a Group E designation, *requiring* it to have a plasticity index between 6 and 15. The sources which do meet the specification limits (regardless of Group designation) are trending at the upper end of the gradation bands for the No. 60 and No. 200 sieves, and there is also very little plasticity – i.e., the material is fine and silty. Here again, the material is trending towards an AASHTO A-4 classification.

2-4 Unstable Soils

These have been previously defined as “low CBR, saturated soils having an organic content less than 6 percent as defined by AASHTO T 267. Several soils which classify as A-4 or A-5 can fall into this type.” There are many definitions for unstable soil, including:

- Soil that will not stay in place on its own and therefore requires extra support
- A portion of land surface which is prone to slipping, sloughing, or landslides
- Soil which is subject to movement or unsafe because of soil or geotechnical conditions
- Soil that is prone to shifting, moving or shrinking due to its composition
- Soil that is too soft to provide a sufficient foundation for pavement installation

For the purposes of this manual, Unstable Soils shall be designated by the Engineer for the type of construction being proposed.

For the structural or geotechnical engineer, any soft soil prone to settlement, liquefaction, or contributing to slope instability would be considered unstable. These soils are usually determined through field testing (standard penetration test blow counts $\leq$ 6), or through lab testing with consolidation tests indicating "normally consolidated" soils with high void ratios. They can also be determined through unconfined compression testing in conjunction with unconsolidated-undrained triaxial testing, resulting in undrained shear strengths of 500 psf or less. There are some expansive clays with high plasticity index (>23) or high volume change characteristics that would not meet these criteria but will be unstable in an embankment or backslope.

For the materials or construction engineer, an unstable soil is a soft, low CBR, saturated soil having an organic content less than 6 percent. These soils should be verified by additional lab testing. If the in-situ moisture content is greater than 3% of optimum as determined by standard proctor tests and/or if the CBR of the material is less than 5 as determined by laboratory CBR tests, the material will likely be designated as an unstable soil.

Chapter 3

GEOTECHNICAL EXPLORATION AND DATA COLLECTION

3-1 Geotechnical Exploration and Data Collection Overview

Proper planning is integral to a successful geotechnical investigation. The Engineer must have a detailed knowledge and understanding of the project requirements (project type, project stage, construction/contracting method, etc), anticipated site and subsurface conditions, risk factors, and probable field and laboratory test methods to develop an appropriate Geotechnical Report.

The guidance provided in the sections below is not intended to be prescriptive or exhaustive. The Engineer is responsible for planning field investigations based on their knowledge of site conditions, local geology, risk factors, project requirements, etc. Adjustments to the minimum requirements of an exploration scope may be prudent based on the factors above. The Engineer should be prepared to adjust the field exploration and laboratory testing scopes, and communication between the Engineer and field personnel (Field Superintendent, Chief Driller, logger, etc.) is imperative to ensuring the intent of the investigation is carried out.

3-1.1 Risk Based Approach to Geotechnical Investigations

MDOT will take a risk-based approach to Geotechnical investigations. Engineers should evaluate projects based on type, geologic region, construction/contracting method, and project cost during scoping of Geotechnical Investigations.

3-1.1.1 Procedure for Evaluating Risk

Upon initiation of a project, the designated District Engineer (for Soil Profiles) or State Geotechnical Engineer (for all other projects) will evaluate the risk in accordance with Section 3-1.1.2 to 3-1.1.7. Once the evaluation is complete and risks have been identified, the Engineer will assign a Category in accordance with Section 3-1.1.5. Low-risk projects proceed through the normal Planning Geotechnical Explorations process.

Medium risk projects must go through the Planning Geotechnical Explorations process and risk considerations and mitigations detailed in Table 2: Guidelines for Field Investigation should be considered when planning the Geotechnical Exploration.

High risk projects must go through the Planning Geotechnical Explorations process and must also go to the Geotechnical/Site Investigation Committee (Section 3-1.1.7) process for approval. Risk considerations and mitigations detailed in Table 2: Guidelines for Field Investigation should be considered when planning the Geotechnical Exploration. The Final Report should be provided to the Geotechnical/Site Investigation Committee for review.

3-1.1.2 Project Types and Associated Risks

As part of the Planning Geotechnical Explorations process, the project type should be evaluated for specific risks. The list below details some of the specific geologic risks that should be considered:

- Roadway – high volume change soils, unstable soils, muck, landslide potential
- Bridge – scour, seismic potential, liquefaction, embankment settlement/pile downdrag
- Retaining Wall – compressible soils, backfill material type, high groundwater
- Slope Studies and Landslides – high volume change soils, soil saturation source
- Culverts – electrochemical, soluble sulfates

3-1.1.3 Risks Related to Construction Method

Geotechnical risk will vary by Construction Method, from the least risk of a Design – Bid – Build (DBB) project to the most risk of a Design-Build project.

Design-Build is typically the most challenging case for Geotechnical Risk and requires a balance of pre-bid MDOT Geotechnical Investigation and post-award contractor investigation. MDOT, pre-bid, shall conduct an investigation that provides the contractor with a baseline, identifies potential areas that may require more detailed investigation, and the minimum required follow-on investigation.

3-1.1.4 Risks related to Physiographic Regions

Mississippi has diverse physiographic regions and stratigraphy, and each region presents unique Geotechnical Risks. The oldest geological formations in the state occur in the extreme northeastern corner of the state, which are the result of erosion of the Appalachian Mountains. The near-surface geology for much of the rest of the state was established by the withdrawal of waters of the Mississippi Embayment, which had filled in with sediments from the Appalachian and Ouachita Mountains. The Delta region on the state's northwestern side consists of more recent alluvial deposits from the Mississippi River and Yazoo Basin. Along the eastern bluff side of the Delta, the hills are covered with wind-blown silt known as Loess. Thus, most of the state is characterized by fine grained soils of varying consistency, strength, and natural moisture content. In addition, narrow valleys and flood plains usually exhibit very recent, somewhat unconsolidated, deposits of varying thickness overlying more competent formational soils.

The following is a generalized list of risks per region of the state:

- **Delta:** An abundance of very low CBR materials in the form of wet silts (AASHTO A-4 soils) and plastic high volume change “gumbo” clays can make construction of roadway embankments and subgrades very difficult or expensive. Additionally, compressible soils abound throughout the Delta, especially near old river runs. Bridge and box culvert approach embankments are much more prone to settlement due to consolidation of the underlying soils. In some locations, the bearing stratum for driven piles can be quite deep.

- **Loess bluffs:** These true silts are very prone to erosion and sensitive to moisture content. Both surface and subsurface drainage must be addressed in the roadway design. Embankment foreslopes and cut backslopes generally must be 3H:1V or flatter, depending on height of slope and the type of soils underlying the loess, which necessitates a detailed look at slope stability at critical cross sections. As a subgrade material, it must be kept on the dry side of optimum moisture content as much as possible during construction.
- **Coastal Meadows (Lower Plain):** There are considerable areas of marsh and swamp, and even just outside those areas there are low-density sands and soft fine-grained soils near the surface which must be identified in investigations and considered with design activities.
- **Pine Hills:** Sands, gravels, indurated clay or rock ledges, occasional high volume change clays, and Artesian groundwater conditions can be expected. The formational soils are generally easy to work with, but lower lying flat areas (stream bottoms, narrow valleys, etc.) are very prone to having soft wet alluvium at the surface. This material is often mischaracterized as “muck” yet is lacking in organic content. Consideration for handling these materials must be given depending on the type of construction being affected by it.
- **Jackson Prairie:** Noted as the most troublesome soil in the state, detailed consideration must be given to any design to mitigate the shrink-swell characteristics of the high volume change Yazoo clay and its affinity for free water. This can affect structure foundations, ditch grades, embankment subgrades, and slopes.
- **North Central Hills:** The Zilpha formation contains some particularly troublesome high volume change clays. Although not as active for shrink-swell as the Yazoo clay, it does present risks for slope stability and performs terribly in embankments. The abundance of sand on clay ledges in this region produces many perched water tables. Properly defined limits of these perched water tables in roadcuts are needed for underdrain design. The Tallahatta formation has many ledges of weathered rock which may be encountered in a road cut. Along the eastern side of this region within soils of the Wilcox Group, seams of lignite can be encountered. Soils in this region are known to exhibit electro-chemical properties which affect selection of the type of cement to be used in concrete, and topsoil for grass growth on slopes.
- **Flatwoods:** The Porters Creek Formation is another high volume change troublesome soil, notoriously known for landslides and poor subgrade material.

- **Pontotoc Ridge:** The chalk-like materials typically lie beneath upper weathered chalk (residuum) in these formations, which can have some high volume change characteristics that make it a poor subgrade material, and shallow slough landslides are common. Penetration with driven pile foundations for bridges over hydraulic crossings can also be an issue if trying to circumvent scour.
- **Black Prairie:** Since this region consists primarily of Demopolis (Selma) Chalk, the upper layer of weathered chalk can have some high volume change characteristics that make it a poor subgrade material, and shallow slough landslides can occur. Penetration with driven pile foundations for bridges over hydraulic crossings can also be an issue if trying to circumvent scour. North of US Hwy 82, the eastern edge of this region consists of Mooreville Chalk up to Tupelo, and with the dense to very dense Coffee Sand formation from there up to Corinth. The unweathered chalk and the Coffee Sand provide excellent load bearing characteristics for structural foundations.
- **Tombigbee Hills:** Some of the gravels of the Tuscaloosa are difficult to drill through and sample, and some of its clays are highly plastic. In Tishomingo County, one may encounter limestone and shale along the state border. The stratification of these layers should be well identified.
- **Northwest Corner (Tunica, Desoto, Marshall, and Tate):** Four counties in the northwestern corner of the state (Tunica, Desoto, Marshall, and Tate) are in a seismically active zone. Any projects in these four counties MUST consider the implications of a seismic event in the design of any structures or high embankments.

3-1.1.5 Risk Categories

High-Risk: High-risk projects are associated with either the project type and/or geologic conditions.

High-Risk Project Types:

- Major Investment Projects, including pavement rehabilitation and capacity projects
- Roadway Widenings and grade/drain projects on new alignments
- Complex projects involving structures, such as bridges crossing rivers and retaining walls
- Environmentally sensitive projects
- Alternate Delivery Projects (Design-Build, CMGC, etc.)

High-Risk Project types, if containing geologic risk

- Overlay projects

Medium-Risk: Projects types that are not included in the High-Risk category, but that contain geologic risks.

Low-Risk: Projects types not included in the medium or high risk categories and/or have no readily identifiable geologic risks.

Examples of Low, Medium, and High Risk Projects:

Low-Risk: Cable safety barrier installation, pavement milling/overlays of roads absent of visible or known subgrade issues, bridge preventive maintenance

Medium-Risk: Roadway lighting or ITS projects, bridge repair projects involving routine foundation repairs or upgrades, intersection improvements or roundabouts

High-Risk: Bridge replacements or major foundation repairs, pavement rehabilitation (widening or replacement of existing pavement structure), capacity projects, retaining walls, grade or drain projects on new alignment, landslide repairs or slope reestablishment,

3-1.1.6 Risk Mitigation

Projects that have elevated risks should be mitigated as appropriate. Risk mitigation tools include:

- Additional borings to better define limits of materials of concern
- Additional lab testing
- Third-party review of investigation plans and reports
- Alerting appropriate agency or personnel of potential risks (roadway design, bridge design, construction, district engineer, etc.)
- Geotechnical/Site Investigation Committee

3-1.1.7 Geotechnical/Site Investigation Committee

Prior to the subsurface investigation on high-risk projects, an on-site meeting/investigation should be conducted to formally document field conditions and issues that may require changes to the geotechnical investigation, drainage plan, or testing requirements. The Geotechnical/Site Investigation Committee shall be comprised of representatives from Geotechnical, Materials, the project District, Construction Division, design divisions, and other departments relevant to the project. A detailed report will be generated by the Geotechnical Branch or District that outlines the meeting discussions and any additional needs regarding the geotechnical and testing scope or drainage considerations. The members of the committee should remain engaged with the project until the completion of construction. The committee will be responsible for selecting and recommending engineering solutions during the design phase, as well as justifying items such as Supplemental Agreements related to drainage and soils.

At a minimum, the site meeting should include the following:

- Overview of the project

- Site walk to look for areas of wet or soft soils, utilities, structures and condition, access, etc.
- Latent conditions at the time of the site meeting (frequent rainfall, drought)
- Review Site Investigation details, Laboratory Testing, and Engineering Plan

After the report is finalized, it should be forwarded to the Geotechnical/Site Investigation Committee. The committee will review the report to ensure that risks have been appropriately considered or addressed.

The Geotechnical Branch or District shall ensure the report is provided to consultants performing work on the project.

3-2 Planning Geotechnical Explorations

The Engineer should review the current project plan/profile sheets, with design flood elevations, if applicable. The Engineer should use standard geotechnical engineering practices to investigate the site. The Engineer should:

1. Conduct a desktop review of available data for the site.
2. Conduct a Site Reconnaissance whenever possible.
3. Develop the Geotechnical Exploration Plan.
4. Obtain appropriate level of approval.
5. Execute the plan.

Below are guidelines for investigations per project types.

Table 2: Guidelines for Field Investigation

Exploration Type		Boring Frequency Guidance	Boring Depth Guidance	Risk Considerations and Mitigation
Bridge Foundations	General	At least one boring per substructure (abutment/bent) At least two borings per substructure/footing for footing widths >60 feet Piezometers shall be necessary only at locations in which footings (pile-supported or spread) or drilled shafts will be utilized or for the determination of liquefaction potential. One boring completed to a minimum depth of 100 feet below existing ground shall be required for determination of site classification and seismic design as the Work Assignment dictates	Through unsuitable material and into competent material for foundation support, with competent material to be defined by the Engineer for the project For hydraulic crossings, borings should extend a minimum of 30 feet below anticipated scour elevation. For all projects, if a review of the available nearby geotechnical information or published geology suggests that compressible layers may be present underlying upper harder/denser layers, sufficient borings drilled deeper than outlined below should be advanced to characterize that possibility.	Bridge projects, regardless of foundation type, will go through the Geotechnical/Site Investigation Committee process

Exploration Type		Boring Frequency Guidance	Boring Depth Guidance	Risk Considerations and Mitigation
Bridge Foundations, continued	Driven Piles	At least one boring within 20 feet of planned pile bents supporting a span length of greater than 60 feet. For span lengths of less than 60 feet, one boring for every other pile bent.	Friction/soil bearing piles: 1) Minimum of 30 feet below anticipated scour, or 80 feet, whichever is greater. 2) Generally, borings at least 30 feet into competent material (SPT N-values of ≥50 blows per foot [bpf] will meet the above criteria); 3) Consider advancing at least one boring per substructure (abutment) or pile group to the shallower of: A depth of two times the maximum expected pile group width below the anticipated pile tip elevation, or to SPT refusal (50 blows to advance <6 inches). Rock bearing piles: At least 10 below top of the rock. 4) For span lengths greater than 60 feet, at least one substructure boring shall be drilled to a depth of 150 feet.	
	Drilled Shafts/Micro Piles	At least one boring as close as practicable to shaft location, but no further than 20 feet of redundant shafts where bearing materials are variable At least one boring at the shaft location per non-redundant shaft Piezometers shall be placed adjacent to each boring	Soil bearing: A minimum of 30 feet below anticipated scour or as determined by the Engineer based on expected/provided loads Rock bearing: To at least 10 feet into bedrock for each boring, or 3x shaft diameter for isolated shafts, or 2x for group shafts. Interior bent locations shall be drilled to a depth no less than 150 feet for main spans <220 feet, and no less than 200 feet for main spans >220 feet.	Drilled shafts greater than 48" in diameter shall include non-destructive testing as outlined in Section 4.
	Spread Footings	Boring at two opposite corners (diagonal)	Soil bearing: Extending below the bearing elevation to depths of 2B for L ≤ 2B 3B for 2B ≤ L ≤ 5B 4B for L≥ 5B Rock bearing: Extend the	Additional investigation locations should be included if uncertain or highly variable subsurface conditions are encountered, or in an

Exploration Type		Boring Frequency Guidance	Boring Depth Guidance	Risk Considerations and Mitigation
			boring 10 feet below top of rock.	area of known poor soil conditions.
Soil Profile Investigations	New Roadway Alignment	Fill sections: Auger borings every 200 feet along centerline Cut sections: Auger borings every 100 feet along centerline	Fill sections: 5 feet below existing ground, sampled at 1 foot intervals Cut sections: 3 feet below proposed ditch line, sampled at 1-foot intervals	Geotechnical/Site Investigation Committee Geological High-Risk: Consider up to 25% increase in boring frequency Extend investigation laterally within ROW, increase boring frequency up to 50% along roadway, and extend depths
	Overlays* *If needed	At least one set of cores per ½ mile. If considerable faulting and maintenance leveling is present, core spacing at a maximum of 200 feet through the problem area.	Usually core the top two layers. If considerable faulting and leveling is present, or stripping of the intermediate lifts is apparent, full depth cores through the problem area.	*Perform DCP on underlying base/subgrade every 6 inches through the core hole down to competent material. Additional research with FWD or GPR may be needed
	Widening	Maximum of 200 feet.	3 feet, sampled at 1-foot intervals. If coring through existing paved shoulder, perform DCP every 6 inches below core.	If soils are saturated, boring should be extended until suitable material is encountered
	Roadway Reconstruction	Maximum of 200 feet.	5 feet below existing subgrade or proposed subgrade, whichever is deeper, sampled at 1 foot intervals Full depth cores, DCP every 6 inches of underlying materials through the core hole.	If soils are saturated, boring should be extended until suitable material is encountered
Bridge Culverts		One boring at the downstream end and at the middle of the culvert Additional borings between the ends of the culvert spaced at 100-300 feet depending on the variability of the subsurface conditions.	Minimum of 10 feet below anticipated invert elevation or SPT refusal, whichever is shallower.	If local geology has the potential for compressible material in the upper 30 feet, extend borings to a depth determined by the Engineer.

Exploration Type	Boring Frequency Guidance	Boring Depth Guidance	Risk Considerations and Mitigation
	For culvert extensions, one boring every 50-100 feet with a minimum of one boring.		
Retaining Structures	A minimum of one location for each wall. If wall length is greater than 100 ft, spacing should be at intervals of 100 ft alternating in front and back of the wall. Anchored walls: Additional locations in the anchorage zone spaced at intervals of 100 ft. Soil nail walls: Additional locations behind the wall at a distance of 1-1.5x the wall height. Spacing should be at intervals of 100 ft. Temporary structures: The same recommendation apply.	Extend below bottom of the wall 2x the wall height or to refusal. Extend borings through soft or compressible soils (N value ≤ 6. One boring completed to a minimum depth of 100 feet below existing ground shall be required for determination of site classification and seismic design as the Work Assignment dictates.	Geotechnical/Site Investigation Committee process
Roadway Cuts	Spacing of 100 ft in uncertain or highly variable conditions to 200 ft in uniform condition along the centerline of the cut. At critical locations (maximum cut depth or maximum depth of soft strata): a minimum of three locations along the transverse direction. For cut slopes in rock, perform geologic mapping along the length of the cut slope.	Depth of 10 ft below anticipated ditch grade.	Geotechnical/Site Investigation Committee process
Roadway/Bridge Approach Embankment Foundation	Spacing of 200 ft in uncertain or highly variable conditions to 400 ft in uniform condition along the centerline of the cut. At critical locations (maximum height > 30 ft) or soft strata in the upper 5 ft: a minimum of three locations along the cross section in the transverse direction. Bridge approach embankment: a minimum of one location per abutment.	Depth of 2x the embankment height unless a hard stratum is encountered above this depth. If soft strata are encountered extending to a depth greater than 2x embankment height, extend below the soft strata into competent material.	For soft/compressible soils, additional borings laterally along the embankment should be performed, as agreed to in the exploration plan.

Exploration Type	Boring Frequency Guidance	Boring Depth Guidance	Risk Considerations and Mitigation
Landslide	Refer to Section 4.5 for details.	Refer to Section 4.5 for details.	Geotechnical/Site Investigation Committee process
Traffic signal poles, high mast towers, overhead sign structures	One boring at each foundation location.	Minimum 50 ft below the anticipated top of foundation in soil or 10 ft of rock coring, whichever is shallower.	Medium-risk: Consider additional lab testing
Borrow Pit Source	One boring per acre, plus borings at the corners.	Depth of anticipated bottom of borrow material, plus 10 feet.	See Section 4.9 QA testing may be necessary
Sound Barrier Walls	A minimum of one location for each wall. If wall length is greater than 200 ft, spacing should be at intervals of 200 ft.	Through unsuitable material and into competent material for foundation support, with competent material to be defined by the Engineer for the project.	Geotechnical/Site Investigation Committee process

3-2.1 Desktop Review

The desktop review should be performed by the Engineer (State Geotechnical Engineer or District Materials Engineer, per project) and consultant (if used on the project) and will consist of obtaining and reviewing the following.

- A review of plans and available project information, including alignment and structure locations. The Engineer should check the plans' completeness and note that the correct FMS Project Number is written on the plans and that appropriate reference markings are included on the plans so field locations can be found and referenced appropriately.
- A search of the *Geotechnical Branch* Database for old Geotechnical Borings or Reports.
- Topographical maps and aerial photographs – USGS 7.5 Quadrangles and Digital Aerial photographs area available for download from MARIS or USGS at:

  https://www.usgs.gov/programs/national-geospatial-program/topographic-maps.
- Existing Bridge Data may be obtained from MDOT Bridge Divisions' Intranet site
- Geologic information can be obtained from geologic maps (Miss. Dept. Of Environmental Quality – Geological Survey) or adjacent Geotechnical Reports.

After the desktop review is complete, a conceptual Geotechnical Exploration Plan should be developed, in accordance with Table 2 - Guidelines for Field Exploration.

3-2.2 Site Reconnaissance

After the Desktop review is complete and a conceptual boring layout is developed, site reconnaissance should be performed by the Engineer or Consultant, as appropriate. Observations and notes from the site reconnaissance should be included in the final Geotechnical Exploration plan. The people performing the site reconnaissance should observe and note:

- Site access for fieldwork, including rig drop-off locations, ingress/egress for drilling equipment, general site conditions that would dictate rig type (Truck, ATV, track), clearing, water availability, existing utilities, and overhead obstructions
- Property ownership and need for Right-of-Entry
- Site hazards (sinkholes, landslides, flooding, wetlands, etc)
- Rock outcrops or rock cut slopes
- Existing structures
  - Bridge Replacements note type, size, and condition of foundations
  - Stream crossings note scour around foundations and abutment walls
- Any other unusual features that may impact the project

After the site reconnaissance is complete, the conceptual Geotechnical Exploration Plan should be reviewed and modified as necessary to develop the final Geotechnical Exploration Plan.

3-3 Field Testing Methods

The Engineer is responsible for selecting the most appropriate field exploration and laboratory testing methods to adequately characterize the subsurface conditions and provide appropriate design information to the designer. The following sections are not exhaustive and are intended to provide an overview of methods. Methods should generally follow approved methods such as AASHTO, ASTM, or FHWA.

3-3.1 Field Sampling and Testing Methods

3-3.1.1 Soil Borings

A wide variety of equipment and methods are available to advance soil borings; therefore, consideration should be taken to ensure an appropriate method is used for the relevant soil and groundwater conditions. Continuous flight augers or rotary wash boring methods are typically used to advance soil borings. An alternative to traditional drilling methods is the direct-push method (“Geoprobe”). For locations that are inaccessible to drilling equipment, hand auger methods can also be used for sites with limited access.

Borings shall be performed in accordance with the AASHTO *Manual on Subsurface Investigations.* Samples should be obtained via either Standard Penetration Test (SPT) in accordance with AASHTO T-206 *Penetration Tests and Split Barrel Sampling of Soils*, typically for non-cohesive soils, or by thin-walled tubes in accordance with AASHTO T-207 *Thin-Walled Tube Sampling Soils.*

Where advantageous, Measurement While Drilling (MWD) should be utilized for site investigations and subsurface characterization. This method is used to obtain continuous, real-time data on drilling parameters such as fluid pressure, torque, rotation speed, thrust-on-bit, penetration depth, and drilling speed. MWD is particularly useful in identifying variations in soil and rock properties, detecting voids or cavities, and mapping the depth to bedrock. MWD enhances the reliability of geotechnical assessments by correlating drilling performance with collected samples and integrating with other methods like CPT and SPT, ensuring safe and stable construction projects.

3-3.1.2 Rock Coring

Rock coring shall be performed with size NQ tooling, unless another size is approved by the State Geotechnical Engineer, in accordance with AASHTO T-225 *Diamond Core Drilling for Site Investigation.*. Recovery and RQD should be noted on boring logs and all cores should be placed in sturdy cardboard or wooden boxes with the project name, number, boring number, depths, runs, and date. The top and bottom of the cores should be labeled.

3-3.1.3 In-Situ Testing

The goal of in-situ-testing is to obtain or determine engineering properties. During in-situ testing, samples are not obtained. Commonly used in-situ testing methods in Mississippi are cone penetrometer testing (CPT) and dynamic cone penetrometer testing (DCP).

3-3.1.3.1 Cone Penetrometer Testing (CPT)

CPT soundings shall be performed in accordance with ASTM D5778 *Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils*. The CPT records tip resistance, sleeve friction resistance, and pore pressures, which can be correlated to behavioral soil type, undrained shear strength and pre-consolidation stress (cohesive soils), or friction angle, relative density, and effective horizontal stress (cohesionless soils). When performed as a seismic CPT, shear wave velocity can be obtained.

Soil samples are not obtained with the CPT. For this reason, CPT soundings will be augmented with conventional borings in close proximity for correlation purposes. Thought must be given to CPT penetration refusal depths, which can occur in very dense soils and rock. As CPT soundings can be performed at higher per foot rate than borings, there may be schedule advantages to substituting borings with CPT, when enough borings are performed for sufficient correlation purposes.

3-3.1.3.2 Dynamic Cone Penetrometer (DCP)

DCP is frequently used along existing alignments, primarily through core holes in existing pavement, and is performed in accordance with ASTM D6951 *Standard Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications*. The DCP should be performed every 6 inches of depth through the core hole to determine the relative CBR and consistency.

3-3.2 Geophysical Testing

Geophysical methods are relatively economical, quick, and non-intrusive methods that can be used to supplement traditional intrusive means to investigate and characterize a site. They can assist in determining soil stratigraphy, top of bedrock, or existing features such as utilities and obstructions.

Typical geophysical methods are electrical resistivity (ERI), seismic methods (MASW), and ground penetrating radar (GPR), which are discussed below.

3-3.2.1 Electrical Resistivity

Electrical Resistivity, usually measured in ohm-meters, is an electrical property of geomaterials and is the measurement of electrical resistance (difference in electrical potential) of the material. Procedures and guidelines for the field electrical resistivity test can be found in ASTM G57. The test should be limited to shallow depths and homogenous deposits as test resolution quality can be negatively affected with increasing test depth or in highly heterogenous deposits.

Electrical resistivity test can be used to:

- Determine depth to bedrock, groundwater table, and anomalies in the subsurface;
- Evaluate subsurface stratigraphy, particularly interfaces where hard material lies over soft material; and
- Locate prospective borrow material sources, contamination plumes, and buried features.

3-3.2.2 Shear Wave Velocity Profiling

Shear wave velocity profiling is accomplished by either Downhole Seismic Testing in accordance with ASTM D7400 or Crosshole Seismic Testing in accordance with ASTM D2248.

The Downhole Seismic Test makes direct measurements of compression (P-) or shear (S-) wave velocities, or both, in a borehole advanced through soil or rock or in a cone penetration test sounding. A seismic source is used to generate a seismic wave train at the ground surface offset horizontally from the top of a cased borehole. Downhole receivers are used to detect the arrival of the seismic wave train. The downhole receiver(s) may be positioned at selected test depths in a borehole or advanced as part of the instrumentation package on an electronic cone penetrometer (Test Method D5778).

The seismic source is connected to and triggers a data recording system that records the response of the downhole receiver(s), thus measuring the travel time of the wave train between the source and receiver(s). Measurements of the arrival times (travel time from source to sensor) of the generated P- and S- waves are then made so that the low strain (<10–4 %) in-situ P-wave and S-wave velocities can be determined. The calculated seismic velocities are used to characterize the natural or man-made (or both) properties of the stratigraphic profile.

The Crosshole Seismic Test is similar in many respects to the Downhole Seismic Test, except that the Crosshole uses a seismic source generated in a borehole and downhole receivers placed in cased borings that are spaced 10 to 20 ft apart. The distance between boreholes at the test depths is measured using a borehole deviation survey.

3-3.2.3 Ground Penetrating Radar

GPR is a quick and easy to perform procedure that utilizes a pair of transmitting and receiving antennas in a GPR track cart to detect changes in permittivity, or dielectric properties, in the subsurface environment to locate shallow soil and rock strata boundaries, groundwater table, underground manmade structures (utilities or tanks), and voids. The procedure can also determine the thickness of pavements and map steel reinforcements in concrete floors, decks, and walls. Data collected is viewed in real-time and requires an experienced operator. The procedure is less effective in the presence of water and clayey soils.

3-3.2.4 Seismic Methods

Seismic methods measure the seismic waves travelling through the subsurface to determine the physical properties of rock and soil, such as small-strain shear modulus, and map soil stratigraphy, water tables, top of bedrock profiles, and shear wave profiles.

Seismic surveys can be performed in a variety of soils and types of terrain. If the survey is performed in an urban or industrial setting, surrounding seismic noise can influence the survey results. Seismic refraction, seismic reflection, surface wave analysis, and seismic piezocone test (SCPTu) are the most commonly used seismic surveys.

Soil refraction methods are generally used to determine depth to very hard and dense layers and rippability of rock. Guidelines and procedures for the method should be performed in accordance with ASTM D 5777. Soil reflection methods are generally used to determine geological delineations at depths below 10 feet as the method is not constrained by layers of low seismic velocity.

Surface wave methods include spectral analysis of surface waves (SASW) and multichannel analysis of surface waves (MASW). The SASW method utilizes a two-receiver approach while the MASW method utilizes a multichannel approach. Compared to the SASW method, the MASW method is more effective and is more commonly used, especially for pavement explorations as the method can be conducted on roadway surfaces. The MASW method evaluates the thickness and stiffness of various subsurface soils and pavement layers; investigates underground mine voids, map voids, and sinkholes; and can produce a top of bedrock profile. The test can be conducted quickly and survey data from the multichannels at multiple locations produce a 2D shear wave velocity versus depth profile at a single point that can be used to determine elastic soil properties of the subsurface strata.

The SCPTu is a type of downhole seismic survey that collects penetration and seismic wave data as a function of depth in clays, sands, silts, and peats during a sounding. The seismic survey is performed as an addition to the CPT to collect shear wave velocity data at an interval of 3.28 feet (see Section 3-3.1.3.1).

3-3.3 Instrumentation

The need for and type of instrumentation will be determined by the Engineer based on project type and data needed for evaluation or design.

Instrumentation potentially used during field exploration are piezometers to determine groundwater levels or piezometric head in a specific soil or zone, and inclinometers to measure deflections within slopes and embankments.

3-3.3.1 Piezometers

A piezometer is a device that is installed and sealed within an aquifer at the depth of interest to measure and monitor groundwater pressure, porewater pressure, or piezometric head of a specific zone of soil or rock mass. Piezometers can also be used to monitor water flow patterns and estimate effective stress. Water pressure measurements can be used to:

- Determine and control a safe rate of fill placement, especially over soft soils;
- Monitor soil consolidation;
- Aid in slope stability analysis;
- Design and build for lateral earth and uplift pressures; and
- Monitor the effectiveness of drainage systems.

Measurements of pore pressures in soils should be conducted in accordance with AASHTO T252. The two standard piezometer types are open standpipe and diaphragm. It should be noted that a piezometer is different from an observation well and monitoring well. An observation well does not have a subsurface seal and creates a vertical connection between strata. A monitoring well is used to monitor groundwater levels and water quality by sampling water that is removed from the well.

3-3.3.2 Inclinometers

An inclinometer is a device used to measure and monitor subsurface deformation both laterally and vertically. Measurements of lateral deformation can be used to evaluate slope and embankment stability and verify the performance and safety of structures. Measurements of vertical deformation can be used to evaluate settlement in soft grounds. The device typically consists of a sensing probe housed within an inclinometer casing oriented vertically (in a borehole) or horizontally (in a trench). The inclinometer casing extends through the zone of suspected movement and is anchored or secured in-place to allow for minimal movement, thus providing a surface from which to measure deflection. Standard guidelines and practice for inclinometers is described in AASHTO R45.

3.4 Field Exploration Procedures

The following sections describe best practices and guidelines for the execution of a field exploration.

3-4.1 Access to Private Property and Right of Entry

Fieldwork requiring access to private property requires obtaining right of entry before entering the site. Initial property owner contact occurs either during the initial site assessment or during the site visit. During the initial contact with the owner/operator of a site, the consultant, designated representative to the State Geotechnical Engineer, or ROW Agent shall explain the general site investigation process.

During the initial contact with the owner/operator of a site, the Consultant, designated representative for the State Geotechnical Engineer, or ROW Agent, requests permission for MDOT representative and/or the consultant to access the property. The designated representative for the State Geotechnical Engineer staff provides property owner contact information to the consultant to enable scheduling of field assessment activities.

Mississippi Code § 65-1-335 allows MDOT access to any lands and structures to make surveys, borings, environmental assessments, or examinations as necessary to perform its duties and responsibilities. If the property owner denies access to the property for environmental assessment, the State Geotechnical Engineer shall request assistance from MDOT's Legal Division in obtaining access to the property to conduct the site investigation. An example Right of Entry letter can be found in Appendix A.

3-4.2 Permitting

The Consultant or State Geotechnical Engineer shall be responsible for obtaining permits, licenses, and/or authority from public agencies required for the conduct of its operations including payment of any charges for the same and shall not work or use public property without such authority, licenses, or permits. This also applies to permits required to transport their equipment over or across public thoroughfares.

Permits may include but are not limited to USACE permits (water and levees), FAA (drone services), and MDEQ stormwater permits (land disturbance).

3-4.3 Boring and Test Location Layout

Proposed boring and test locations should be surveyed and staked with wooden stakes and white flagging by MDOT survey crews. Survey requests can be made by the Engineer to the District Survey Office. If a boring offset is required, the field logger should measure the offset from the staked locations and note on the field logs. For over the water borings, the boring should be staked at the closest practical point and distances from existing structures should be noted. Handheld GPS can be used at the time of drilling to confirm the boring location.

3-4.4 Utility Locate and Clearance

Prior to any excavation activities, utilities will be located and marked in and around all test locations. At a minimum, a Mississippi 811 locate request will be submitted and obtained for the test locations. A private utility locate should be performed if the Engineer feels the risk of hitting an unmarked utility is high (working outside the ROW, non-response from utility, uncertainty regarding utility presence, etc).

3-4.5 Traffic Control

Traffic control is required when field work will be performed in the roadway, shoulders or if crossing roadways. The Engineer or Consultant (whichever is drilling the project) will develop the Traffic Control Plan in accordance with the *Manual on Uniform Traffic Control Devices for Streets and Highways* and submit to the District Permit Office for approval.

3-4.6 Field Logging Procedures

The field logger is responsible for maintaining a field log during field work. The log will record field test procedures, SPT or pocket penetrometer test data, percent recovery of Shelby tube samples, description of subsurface material and depths, groundwater, and other pertinent information.

The Geotechnical Site Investigation field boring logs should include:

- Project number – FMS Number
- Boring number – unique identifier for each test location
- County – Written name of the county. When drilling a for bridge which crosses a county line, list both counties, with the county containing the largest section last (e.g. County: Hinds/Warren)
- MDOT District
- Driller – Company and Person
- Ground Elevation
- Hole Depth
- Landowner (if not on MDOT ROW)
- Station Number and Offset
- Latitude/Longitude
- Drilling Method – e.g. Auger, Rotary Wash, etc.
- Date Began/Completed
- Groundwater Depth

- Remarks
- Drilling and Sampling Information
  - Sample number and depth
  - SPT blow counts for each interval
  - Inches of recovery of Shelby Tube Samples
  - Field Testing results (e.g. pocket penetrometer or hand Torvane)
  - Casing depth, if used
  - Visual-Manual Identification of soils for each sample
  - Lost circulation
  - Rock core run lengths and recovery lengths
  - Unexpected conditions

For Soil Profile boring logs, sampling and classification requirements, please refer to TMD-20-14-00-000 and Section 4.6 of this manual.

3-4.6.1 Field Visual-Manual Classification of Soil

The field logger will classify soils as samples are obtained in accordance with ASTM D2488 Standard Practice for Description and Identification of Soils (Visual-Manual Method). At a minimum, the field logs should include, in the following order:

- Consistency (Cohesive Strength or Density)
- Color
- Supplementary Constituents
- Grainsize Modifiers for cohesionless soils
- Basic Constituents
- Modifying Phrases

Example 1: Hard, Greenish Gray Silty Clay

Example 2: Dense, Gray, Silty, Fine Sand with some Ironstone Layers

3-4.6.2 Soil Description and Classification Soil

After drilling is completed, samples should be described by a Professional Geologist or Engineer in accordance with the Geotechnical Branch Policy Statement *Geologic Descriptions of Soils and Stratigraphic Nomenclature.*

For Soil Profile Investigation and Reports, after lab testing is complete, the AASHTO Soil Classification System M145 will be used for soil classification.

3-4.6.3 Classification of Rock

The field logger will classify rock as samples are obtained. Rock Quality Designation (RQD) should be determined on all cores in accordance with ASTM D6032. At a minimum, the field logs should include, in the following order:

- Hardness
- Color
- Degree of Weathering
- Bedding Characteristics
- Supplementary Constituents
- Rock Types

Example 1: Hard, gray, highly weathered, thick bedded, ferruginous, Ironstone.

After drilling is completed, samples should be described by a Professional Geologist or Engineer in accordance with the Geotechnical Branch Policy Statement *Geologic Descriptions of Soils and Stratigraphic Nomenclature.*

3-4.7 Transporting, Storing, and Handling Samples

Samples shall be stored and transported in accordance with AASHTO Manual on Subsurface Investigation Section 8.2.2.

3-4.8 Water Table Readings

Depth to water table information is a key element of geotechnical explorations and reports. Water table readings should be taken as follows:

- At time of drilling: When auger boring, note possible groundwater (increase soil moisture content, cave-in, etc.).
- After drilling: Where possible, measure each boring 24 hours later. Note depth of hole collapse, if occurred.

3-4.9 Borehole Closure

Boreholes will be closed by grouting, except those less than twenty-five (25) feet in depth that do not penetrate water bearing strata and boreholes drilled in planned roadbed construction areas where the natural overburden will be removed to within twenty-five (25) feet of the bottom of the hole.

Grout for all holes shall consist of neat cement, cement grout, cement bentonite mixture (5-8% bentonite), or bentonite. Bentonite pellets may be added under free-fall conditions for depths not exceeding twenty-five (25) feet, providing pellets are placed in layers not more than five (5) feet deep and tamped into place after addition of each layer. Granulated or pelletized bentonite may be placed to greater depths if introduced through a tremie pipe. Free-fall addition of other types of grout from the surface is prohibited;

3-5 Laboratory Test Methods

Laboratory testing of soil or rock samples obtained during field exploration must be conducted to determine essential classification and design parameters. These parameters include Atterberg and shrinkage limits, in-situ moisture content, unit weight, grain size, shear strength, angle of internal friction, rock quality designation (RQD), and compressibility. Adequate testing on representative samples from each designated strata is necessary to determine shear strength, settlement potential, grain size distribution, seismic design properties, and bearing capacity. All testing and sampling should comply with MDOT, AASHTO, ASTM, and industry standards.

3-5.1 Classification Testing

A robust laboratory testing program typically includes tests for moisture content, Atterberg limits (AASHTO T89 and T90), shrinkage limits (if necessary) (MT-92) and grain size distribution (AASHTO T88, T27, and T11) to classify soils accurately in accordance with AASHTO M 145 and the Unified Soil Classification System. Organic content tests are also essential to determine the presence of decomposable material that could affect soil behavior.

3-5.2 Strength Testing

To assess soil strength, triaxial compression tests (both consolidated-undrained and unconsolidated-undrained) and unconfined compression tests are crucial. These tests help determine the shear strength parameters, which are vital for stability analyses and foundation design.

To determine the shear strength characteristics of cohesive soils, undisturbed samples should be tested using unconfined compression (UC) (AASHTO T208) and unconsolidated undrained (UU) (AASHTO T296) triaxial compression methods. A range of confining pressures should be applied to samples from each soil zone to develop a Mohr’s failure envelope. Additionally, consolidated-undrained (CU) (AASHTO T297) triaxial compression tests and 3-point direct shear tests (AASHTO T236) will be performed if specified in the Work Assignment.

3-5.3 Permeability Testing

Permeability tests (AASHTO T215), such as constant head and falling head tests, are necessary to evaluate the hydraulic conductivity of soils. These tests provide insights into the soil’s ability to transmit water, which is critical for drainage and seepage analysis.

3-5.4 Consolidation Testing

Consolidation tests (AASHTO T216), including one-dimensional oedometer tests, are performed to understand the compressibility and settlement characteristics of soils. These tests help predict the magnitude and rate of settlement under load, which is essential for designing foundations and embankments.

Consolidation tests shall be conducted on representative samples of all potentially compressible soil strata to determine in-situ void ratio, saturation percentage, specific gravity, over-consolidation ratio, and coefficients of compression and vertical drainage.

3-5.5 Corrosion Testing

Assessing the corrosion potential of soils involves testing for pH (MT-30), resistivity (MT-47), sulfate content (AASHTO T290), and chloride content (AASHTO T260). These tests are particularly important for projects involving buried metal structures, such as pipes and foundations. Soluble sulfate testing is very important for projects involving concrete culverts, spread footings, drilled shafts, or driven concrete piles. At least one soluble sulfate test per clay zone per structure shall be conducted for any structure utilizing driven concrete pile or drilled shaft foundations.

3-5.6 High Volume Change Testing

For soils with a liquid limit greater than 40 and a plasticity index greater than 23, the volume change characteristics will need to be assessed by performing an HVC laboratory test as per MT-92. MT-92 also provides calculations concerning volume change.

3-5.7 Rock Testing

When dealing with rock, tests such as uniaxial compressive strength (AASHTO T208), point load tests, and rock quality designation (RQD) are performed. These tests provide critical information on the strength and quality of rock, which is essential for designing rock foundations and slopes.

3-5.8 California Bearing Ratio (CBR)

The California Bearing Ratio (CBR) test (AASHTO T193) is a crucial method for evaluating the strength and load-bearing capacity of soil subgrades, which helps in designing durable roadways and pavements. The results from the CBR test can be correlated to Resilient Modulus values and are used to determine the necessary thickness of pavement layers, ensuring they can withstand anticipated traffic loads.

Chapter 4

Project Types and Scope of Work Guidance

4-1 Current Practice and Overview of Load and Resistance Factor Design

4-1.1 Current MDOT Practice

Foundation bearing resistances and settlement calculations should adhere to LRFD methods as outlined in the AASHTO LRFD Bridge Design Specifications and relevant FHWA manuals. This encompasses foundations for bridges, bridge culverts, retaining walls, ground anchors for soil nail walls and tiebacks, and ground improvement techniques.

The procedures for determining foundation nominal bearing resistance (previously known as “ultimate bearing capacity” under ASD methods), settlement, and global slope stability (or “overall stability” of foundations) remain consistent with recent practices. In line with LRFD principles, engineers should use average material properties in their design calculations and account for uncertainties and variability when selecting resistance factors.

Engineers should continue to report factors of safety for global slope stability, with the minimum required factor of safety being the inverse of the resistance factor specified in the AASHTO LRFD Bridge Design Specifications, unless otherwise noted.

The field investigation of project types listed in this section should follow the guidelines provided in Table 2 of Section 3-2 of this manual.

4-1.2 Load and Resistance Factor Design

Load and resistance factor design (LRFD) is a civil engineering methodology that incorporates safety factors to account for uncertainties in loads and material strengths. It aims to ensure that structures can withstand loads with a high degree of reliability, considering the variability and unpredictability of real-world conditions. By applying different factors to loads and resistances, LRFD explicitly addresses the risk of failure, aiming for a consistent level of safety across different types of structures and materials.

Unlike Allowable Stress Design (ASD), which uses a single factor of safety applied to the material’s yield strength to determine allowable stresses, LRFD uses separate load and resistance factors based on probabilistic methods. ASD is simpler but less precise, while LRFD provides a more accurate and reliable design by considering the variability in both loads and material strengths.

In LRFD, load factors and resistance factors are determined based on statistical analysis of loads, material properties, and verification methods. These factors account for the uncertainties in load effects (e.g., dead loads, live loads, wind loads) and material resistances (e.g., concrete strength, steel yield strength). The variability in these factors reflects the inherent uncertainties in the design parameters, ensuring that the probability of failure remains within acceptable limits.

LRFD considers different limit states to ensure the safety and serviceability of structures. Strength limit states ensure that the structure can support the maximum expected loads without failure. Serviceability limit states ensure that the structure performs adequately under normal usage conditions, without excessive deflections or vibrations. Fatigue limit states ensure that the structure can withstand repeated loading without experiencing fatigue failure. Extreme event limit states ensure that the structure can survive rare but severe events, such as earthquakes or hurricanes.

LRFD methodology is detailed in AASHTO LRFD Bridge Design Specifications and applicable FHWA publications.

4-2 Bridges

4-2.1 Overview of Bridge Foundation Evaluation

Bridge foundation projects require evaluating the feasibility of shallow and deep foundation alternatives based on structural loading and soil data from subsurface exploration and laboratory testing. This comprehensive process ensures the stability, safety, and longevity of the bridge by analyzing subsurface conditions to determine the most suitable foundation type. It involves a detailed assessment of soil and rock properties, groundwater conditions, and potential geotechnical hazards, aiming to identify challenges and develop solutions to mitigate risks. The assessment should include preliminary data collection, subsurface exploration, laboratory testing, and geotechnical analysis.

4-2.2 Required Preliminary Information

4-2.2.1 Bridge Plan

The bridge plan will consist of a detailed set of drawings and specifications that outline the design and layout of the bridge. It includes information on the bridge's dimensions, type, span lengths, and structural components. This plan is essential for understanding the load distribution and structural requirements of the bridge. It also provides information on the location of piers and abutments, which are critical for foundation design. The bridge plan should be reviewed in conjunction with site plans and topographic maps to ensure a comprehensive understanding of the project.

4-2.2.2 Loads

Accurate load data is crucial for designing a foundation that can safely support the bridge. The loads considered in the design include:

- <u>Strength Limit States</u>: Ensure local and global strength and stability against significant load combinations, considering factors like axial compression, uplift, lateral resistance, bearing failure, structural resistance, and drivability.

- Service Limit States: Provide limits on stress, deformation, and cracking under regular service conditions, including vertical deformation, horizontal movements, rotation, overall stability, and deformations due to scour.
- Extreme Event Limit States: Ensure structural survival under major occurrences such as earthquakes, floods, collisions, blasts, and other site-specific situations, with a required liquefaction assessment for certain seismic zones.

4-2.3 Typical Subsurface Exploration Approach and Considerations

4-2.3.1 Subsurface Exploration

Subsurface exploration is a critical step in the geotechnical evaluation of a bridge foundation. It involves drilling boreholes, conducting soil and rock sampling, and performing in-situ tests to gather detailed information about the subsurface conditions. The primary objectives of subsurface exploration are to:

- Determine the soil stratigraphy and identify the different soil and rock layers.
- Assess the engineering properties of the soil and rock, such as strength, compressibility, and permeability.
- Identify any potential geotechnical hazards, such as weak or compressible layers, high groundwater levels, or the presence of contaminants.

4-2.3.2 Exploration Considerations

Several key considerations must be taken into account during subsurface exploration:

- Depth of Exploration: The depth of boreholes should extend to a sufficient depth to capture all relevant soil and rock layers that may affect the foundation. This typically includes extending the boreholes to a depth where the soil or rock is competent enough to support the foundation loads.
- Sampling Methods: The choice of sampling methods (e.g., disturbed vs. undisturbed samples) depends on the type of soil and the required testing. Undisturbed samples are preferred for laboratory testing of soil properties, while disturbed samples may be sufficient for certain types of tests.
- In-Situ Testing: In-situ tests, such as the Standard Penetration Test (SPT) and Cone Penetration Test (CPT), provide valuable information about the soil's strength and density. These tests are often conducted at regular intervals within the boreholes.

Groundwater Conditions: Groundwater levels should be monitored during and after drilling to assess their potential impact on the foundation. High groundwater levels can affect the stability and bearing capacity of the soil

4-2.4 Scour Analysis

Scour analysis is essential for evaluating the potential for erosion around bridge foundations caused by flowing water. Scour can undermine the foundation, leading to structural instability and potential failure. The analysis involves assessing the velocity and flow characteristics of the water, as well as the erodibility of the soil. Scour analysis helps in designing foundations that can withstand the effects of scour and prevent structural failure. It also informs the design of scour protection measures, such as riprap or concrete aprons, to protect the foundation from erosion.

The D50 grain size, which represents the median particle size of the soil, is a critical parameter in scour analysis. It helps in assessing the erodibility of the soil and determining appropriate scour protection measures. Soils with larger D50 values are generally less susceptible to scour, while finer soils with smaller D50 values are more prone to erosion. The D50 grain size is used in empirical equations and models to estimate the depth and extent of scour around the foundation. Accurate determination of the D50 grain size is essential for reliable scour analysis and the design of effective scour protection measures.

The MDOT Bridge Division or their consultant typically conducts the scour analysis.

4-2.5. Approach for Evaluating Foundation Alternatives

4-2.5.1 Foundation Alternatives

Evaluating foundation alternatives involves comparing different foundation types based on factors such as load-bearing capacity, settlement characteristics, constructability, and cost. The primary foundation types considered in bridge design include shallow foundations, deep foundations, and hybrid foundations. Each type has its advantages and limitations, and the choice depends on the specific site conditions and project requirements.

4-2.5.2 Evaluation Criteria

The evaluation criteria for selecting the most suitable foundation type include:

- Geotechnical Conditions: The soil and rock properties, groundwater conditions, and potential geotechnical hazards must be thoroughly assessed to determine the feasibility of different foundation types.
- Load-Bearing Capacity: The foundation must be capable of supporting the imposed loads without excessive settlement or failure. This requires a detailed analysis of the soil's bearing capacity and the foundation's load distribution.
- Settlement Characteristics: The foundation should minimize differential settlement to prevent damage to the bridge structure. This involves evaluating the compressibility and consolidation characteristics of the soil.
- Constructability: The ease and feasibility of constructing the foundation are important considerations. This includes assessing the availability of

construction materials, equipment, and skilled labor, as well as the potential impact on the surrounding environment.

- Cost: The overall cost of the foundation, including construction, maintenance, and potential mitigation measures, should be considered. A cost-benefit analysis can help in selecting the most economical foundation option.

4-2.6 Bridge Foundation Types and Feasibility

4-2.6.1 Shallow Foundations

When spread footings are indicated on plans or considered a viable alternative, the Engineer will evaluate their use. Shallow footings should not be used in soils with insufficient bearing resistance, where potential settlement or differential settlement exceeds structural tolerance, or where excessive scour or erosion could compromise foundation integrity. Spread footings are generally not economical at depths greater than 10 feet.

If feasible, the Engineer will assess bearing resistance and settlement for spread footings, providing footing bearing elevation, bearing resistance, estimated potential settlement, and recommendations on load testing, construction, and inspection. Calculation methods for nominal bearing resistance and settlement are detailed in AASHTO LRFD Bridge Design Specifications and GEC 6 – Shallow Foundations. The Engineer will select footing size and bearing elevation to ensure factored bearing resistance meets or exceeds factored loads, considering resistance factors from relevant tables. For rock-bearing footings, the presence, orientation, and condition of discontinuities will be considered.

Settlement will be estimated using the service limit state, typically governing for soil-bearing footings. If settlement criteria are not provided, the Engineer will estimate total and differential settlement based on bearing resistance calculations. Additionally, the Engineer will provide recommendations on founding material, inspection requirements, dewatering, sheeting, shoring, and other construction considerations.

4-2.6.2 Driven Piles

The Engineer will assess driven pile geotechnical resistance and settlement, providing estimated tip elevations, resistance vs. depth curves, potential pile group settlement, and recommendations on load testing, construction, and inspection. The general LRFD analysis methodology involves calculating nominal axial bearing resistance, evaluating factored resistance, selecting pile tip elevations, and estimating potential settlement for each Geotechnical Site. Calculation methods are detailed in AASHTO LRFD Bridge Design Specifications and GEC 12. The Engineer will develop resistance curves considering various scour and drag load scenarios, apply resistance factors, and ensure factored resistance meets or exceeds factored load requirements. Additionally, the Engineer will address pile drivability, recommend pile types, consider pile relaxation, and evaluate pile driving resistance for scour conditions. Dynamic testing and monitoring of at least one pile per site condition are recommended to estimate side resistance within potential scour layers.

4-2.6.3 Drilled Shafts

The Engineer will assess drilled shaft bearing resistance and settlement, providing minimum or target shaft tip elevations, estimated potential shaft settlement, and recommendations on load testing, construction, and inspection.

To determine shaft tip elevations and potential settlement estimates, the Engineer will follow a general process using methods from AASHTO LRFD Bridge Design Specifications and GEC 10. This involves calculating axial nominal bearing resistance, applying resistance factors, selecting shaft tip elevations, and estimating potential settlement. Specifically, resistance curves are developed considering various scour and drag load scenarios, and resistance factors are applied as per relevant tables. Tip elevations are chosen to ensure factored resistance meets or exceeds factored load requirements, and settlement is estimated for both no scour and design flood scour profiles.

For rock-bearing shafts, resistance curves may not be necessary if base resistance alone is considered, with tip elevations governed by bedrock conditions. If load testing is planned, higher resistance factors may be used, with considerations from AASHTO LRFD specifications. The Engineer will also provide recommendations on construction methods, non-destructive testing, evaluation of non-destructive testing data, coring requirements, permanent casing needs, and verification of subsurface conditions through probe/boring/core holes. *Drilled shafts that are 48" or larger and/or 60 feet or greater in depth are required to have non-destructive testing consisting of Thermal Integrity Profiling (TIP), cross-hole sonic logging (CSL), or Gamma-Gamma Logging (GGL). Section 7-1.3 contains additional information on testing requirements.*

For rock-bearing shafts, a minimum socket of one shaft diameter into competent bedrock is required.

4-2.6.4 Micropiles

Micropiles are a viable alternative to rock-bearing drilled shafts, particularly when bedrock conditions are unfavorable (e.g., karst bedrock or bedrock with joints/seams of weathered or compressible material), when boulders or debris fill are present, or when construction must occur in low-headroom conditions or near vibration-sensitive structures. Typically, a group of micropiles replaces a single shaft. These guidelines apply to micropiles installed into bedrock, though soil-bearing micropiles can be considered if deemed viable by the Engineer.

Micropiles are usually designed by a specialty contractor, with resistances verified through load testing and tip elevations determined in the field based on minimum penetration through continuous rock. The Engineer will evaluate the need for micropiles and provide justification, preliminary bond zone strength based on historical data or presumptive values, estimated tip elevations or micropile lengths for quantity estimation, and potential group settlement estimates. Recommendations will also cover load testing, construction, and inspection. Load testing should follow the Micropile Design and Construction Reference Manual and project specifications. At least one performance load test should be conducted per Geotechnical Site before production installation to verify bond zone strength and installation methods. Proof load testing should be performed on at least one micropile per footing/group and on at least five percent of production micropiles.

4-2.6.5 Feasibility Considerations

The feasibility of different foundation types depends on several factors:

- Soil Conditions: The type and strength of the soil, as well as the presence of any weak or compressible layers, influence the choice of foundation. Shallow foundations are feasible in strong, stable soils, while deep foundations are required for weak or variable soils.
- Groundwater Levels: High groundwater levels can affect the stability and constructability of the foundation. Dewatering or other mitigation measures may be required for shallow foundations, while deep foundations may be less affected by groundwater.
- Construction Constraints: The availability of construction materials, equipment, and skilled labor, as well as site access and environmental regulations, can impact the feasibility of different foundation types. Deep foundations may require specialized equipment and techniques, while shallow foundations are generally simpler to construct.
- Environmental Impact: The potential impact on the surrounding environment, including soil erosion, water quality, and habitat disruption, should be considered. Mitigation measures may be required to minimize environmental impacts.

The Engineer must conduct a thorough analysis of subsurface conditions, including soil and rock properties, groundwater conditions, and potential geotechnical hazards, to determine the most suitable foundation type

4-3 Box Bridges

4-3.1 Overview of Box Bridges Evaluation

Box bridges (defined as a box culvert spanning 20 feet or more along the centerline of roadway), require a specific foundation study. The Engineer will first review project and site information, then develop a Geotechnical Exploration Plan tailored to evaluate the proposed bridge culvert foundation. Upon approval of this plan by the Geotechnical Division, the geotechnical exploration will be conducted. Following this, the Engineer will perform analyses and develop recommendations as part of the Geotechnical Investigation and Substructure Reports.

NOTE: Some projects may require a box culvert supporting a considerable embankment height (>20 feet). These culverts should be investigated in the same manner as box bridges, as described below.

4-3.2 Required Preliminary Information

The Engineer will receive the box bridge location along with the available plan, profile, and cross-section drawings.

4-3.3 Subsurface Exploration

The Geotechnical Exploration Plan should be scoped to evaluate bearing resistance and potential settlement, providing necessary recommendations. The Engineer must understand the data needs for the specific site and project, selecting appropriate field exploration and laboratory testing methods to gather the required geotechnical data. The Engineer should also include intact sampling, in-situ testing, and laboratory testing to develop necessary geotechnical parameters, such as verifying field soil classifications with laboratory tests and characterizing material parameters for bearing resistance and settlement evaluation. If electro-chemical results indicate bearing soils prone to potential sulfate attack on concrete, provide recommended cement types (with or without pozzolans) to mitigate the potential.

4-3.4 Bearing and Settlement Considerations

After completing the geotechnical field exploration and laboratory testing, the Engineer will interpret the data, analyze bearing resistance and potential settlement, and develop recommendations. This includes creating subsurface stratigraphy and determining material parameters such as unit weight, undrained shear strength for cohesive soils, effective stress friction angle for all soil types, and consolidation/compressibility properties. The Engineer will analyze bearing resistance and settlement following AASHTO LRFD Bridge Design Specifications or relevant FHWA manuals, reporting both nominal and factored bearing resistance. If bearing resistance is insufficient or settlement is excessive, recommendations for subgrade improvement (e.g., undercutting, aggregate piers, lightweight fill) will be provided. For thicker embankments, the Engineer will advise structural engineers on expected pressure magnitudes. Settlement is deemed excessive if total settlement exceeds 2.5 inches or differential settlement exceeds 2 inches over 100 feet.

4-4 Retaining Walls

4-4.1 Overview of Retaining Wall Evaluation

Retaining Wall Foundation Studies typically involve several key steps. The Engineer should review the project and site information and develop a Geotechnical Exploration Plan to gather data for evaluating the proposed wall and any viable alternatives. Once the Geotechnical Branch approves the plan, the geotechnical exploration is conducted. The Engineer will analyze the findings and provide recommendations in the Geotechnical Investigation and Substructure Reports.

The Engineer is tasked with designing mechanically stabilized earth (MSE) and similar gravity walls to ensure internal, external, and global stability along the wall’s length. Conventional cantilever walls must be designed to resist sliding, overturning, and bearing capacity failure. While structural details are not required, the Engineer must provide geometric details necessary for MDOT to develop construction plans, as well as recommended backfill material specifications.

4-4.2 Required Preliminary Information

The Engineer will receive the retaining wall location along with the available plan, profile, and cross-section drawings. Project drawings may or may not include the type of retaining wall to be used.

4-4.3 Subsurface Exploration

When evaluating retaining walls, the Engineer should consider various wall types, regardless of those indicated on the plans. Often, a more suitable wall type can be selected or others eliminated based on project requirements, site review, and experience. Common wall types for state projects include cast-in-place (CIP) cantilever walls, pile supported cantilever walls, mechanically stabilized earth (MSE) walls, soil nail walls, and soldier pile walls. MSE walls are generally more economical and settlement-tolerant for fill applications, while soil nail walls are ideal for cut sections using a top-down construction method. Soldier pile walls are suitable alternatives in cut sections where soil nails may be subject to creep or global stability requirements cannot be met.

For potentially viable wall types, the Geotechnical Exploration Plan should be scoped to evaluate alternatives and provide recommendations. The Engineer must understand the data needs for the specific site, project requirements, and wall types under consideration, selecting appropriate field and laboratory testing methods. The Engineer should also scope intact sampling, in-situ testing, and laboratory testing to develop necessary geotechnical parameters, such as verifying field soil classifications, evaluating global slope stability, external wall stability, potential settlement, and preliminary soil nail/tieback resistance. Representative samples from near-surface soils, potential wall retained/reinforced zone soil, groundwater, and surface water should be tested for corrosion potential indicators. If expansive or soft soils are known or encountered, additional testing should be scoped to evaluate shrink/swell potential and determine the vertical and lateral extents of such soils along the wall alignment.

4-4.4 Global Stability and Settlement

For walls in cut slopes, the Engineer should first evaluate the recommended type (soldier pile or soil nailed). Once MDOT selects the type, the Engineer will provide a generic wall design along with construction recommendations and considerations.

While the Wall Designer is responsible for the actual wall design, the Engineer must evaluate the wall's feasibility and establish minimum design requirements. This involves performing calculations and analyses according to AASHTO LRFD Bridge Design Specifications and relevant FHWA publications.

Key considerations include global slope stability (both short-term and long-term), wall sliding, and wall eccentricity. For global stability, a minimum factor of safety of 1.5 is required, though a factor of 1.3 may be acceptable if geotechnical parameters are well-defined and the slope does not support critical structures. For temporary excavation stability, a minimum factor of safety of 1.2 is required.

Settlement analyses should be conducted for retaining walls supporting new embankment, considering total settlement, time-rate of settlement, and differential settlement. If settlement is excessive, the Engineer will recommend mitigation measures such as ground improvement, preloading, lightweight fill, or temporary wall facing for MSE walls. For anchors like soil nails or tiebacks, the Engineer will estimate preliminary bond zone stress and recommend verification methods during construction.

If the project involves retaining structures not covered by standard specifications, the Engineer will draft or review special provisions, paying attention to the location of ROW lines for elements like rock bolts and soil nails. References for wall analysis include AASHTO LRFD Bridge Design Specifications, GEC 4, GEC 7, and GEC 11. The Engineer will also evaluate bearing resistance and provide recommendations for ground improvement or structural support if necessary.

4-5 Landslides

4-5.1 Overview of Landslide Evaluation

Landslide studies encompass both naturally occurring landslides and slope failures in cut or fill slopes, collectively referred to as “landslides.” These studies are conducted when such movements affect or pose a threat to roadways or related structures. The process typically involves several key steps: initially, the Engineer reviews project and site details. Following this, a Geotechnical Exploration Plan is crafted to gather necessary data for landslide evaluation. Once the Geotechnical Branch approves this plan, the geotechnical exploration is carried out. The Engineer should analyze the findings and formulate remediation recommendations.

4-5.2 Required Preliminary Information

Prior to conducting the subsurface investigation and landslide evaluation, the Engineer will be provided with a location and vicinity map, and if available, a cross-section of the landslide. The Engineer will then reach out to the District Maintenance Engineer and/or County Engineer to gather information on the maintenance history of the slide area, including any previous corrective actions taken.

4-5.3 Subsurface Exploration

The Geotechnical Exploration Plan should be designed to gather data that allows the Engineer to assess and recommend stabilization methods for the landslide. Given the diverse nature of landslides in terms of size and complexity, the scope of geotechnical explorations can vary significantly. Specific guidelines for the scope of exploration will be dependent on the data requirements for the specific site.

Key considerations for scoping a landslide study include positioning borings to create geologic cross-sections near the landslide, advancing borings through the failure plane if accessible and safe, and potentially installing inclinometers in the boreholes.

Inclinometers will help identify the depth of the failure plane if slope movement is ongoing. Determining the depth of the failure plane as well as evaluating the strength of soils along the failure plane is crucial. For laboratory strength testing, the Engineer should either plan for intact sampling of potential failure plane materials or arrange for follow-up sampling after identifying the failure plane depth from inclinometer data. Additionally, considering water table conditions, which often contribute to landslides, is essential. If thin, continuous layers of water-bearing or water-restrictive soils are expected or encountered, the Engineer should use CPT to detect these layers and should consider installing nested piezometers to identify perched water tables.

4-5.4 Landslide Evaluation

After completing the geotechnical field exploration and laboratory testing, the Engineer will interpret the data, perform slope stability analyses, and develop recommendations for remediation or stabilization. Initially, the Engineer will establish the subsurface stratigraphy and relevant geotechnical parameters, such as unit weight, soil strength (undrained shear strength for cohesive soils and effective stress friction angle for both cohesive and cohesionless soils), and water table conditions (including groundwater table, perched water table, and water-bearing seams).

The Engineer should also investigate the conditions that may have caused the landslide. This involves creating a slope stability model based on the ground surface and water table conditions that likely existed just before the landslide, calibrated to a factor of safety of approximately 0.95 - 1.0. By understanding the depth of the failure plane (through inclinometer monitoring), the strength of materials along the failure plane (via laboratory or in-situ testing), and potential perched water table conditions, the Engineer can develop a reasonable model of the landslide’s causative factors.

Using this calibrated slope stability model, the Engineer will then evaluate various remediation, or stabilization approaches to ensure the slope’s stability, ensuring a factor of safety of 1.3 exists against slope failure (1.4 in critical applications). Potential solutions include rock buttresses, regrading to a stable slope possibly utilizing berms, surface and subsurface drainage systems (such as interceptors, drain trenches, and horizontal drains), and mechanically stabilized retaining structures, typically constructed using top-down methods like tied-back walls or soil nail reinforced slopes. Additionally, the construction sequence and slope stability during construction must be addressed.

Landslide remediation design will require recommendations for subsurface drainage, surface drainage, retaining walls, ground anchors, soil nails, buttresses, driven or bored piling, or other stabilization features. Design drawings will be provided to the MDOT Project Manager or designee in CADD drawing sets generated using software approved by MDOT.

The Engineer will be required to develop landslide repair designs and produce plan drawings in CADD format for inclusion in the final construction bid plans. Plan drawings shall indicate additional Right of Way required, where necessary. These drawings may include geotechnical design sheets (structure design or earthwork design), estimated bid quantities with pay items, typical sections, hydraulic design sheets, surface and subsurface drainage details, roadway plan/profile sheets, traffic control sheets, erosion control sheets, and/or cross sections.

4-6 Soil Profile Investigation

Soil profile investigations, commonly known as centerline soil profiles, shall follow the requirements of MDOT S.O.P. TMD-20-14-00-000. These investigations are performed to determine the various types of materials that will be encountered along a project alignment.

4-6.1 Overview

Traditionally, these types of investigations have been conducted primarily for grade and drain projects. The need for a soil profile investigation is now extended to include roadway widening projects, roadway rehabilitation projects, and even some overlay projects. The MDOT Pavement Design Policy directs the various inputs needed to design pavements, including soil material characterization, Falling Weight Deflectometer (FWD) analysis when warranted, California Bearing Ratio (CBR), and projected traffic data.

The District Materials Laboratories are responsible for providing the necessary geotechnical inputs for pavement design. These inputs include:

- Soil type (AASHTO Designation and Unified Soils Classification)
- Plasticity Index
- Volume change
- Estimated CBR for pavement design

Soil Profile Investigations are essential for identifying the types of materials along a project alignment, ensuring that roadway designers, project offices, and potential bidders are well-informed about the earthwork requirements. The goal of a successful Soil Profile Investigation is to preclude any required design changes after construction bid award due to unforeseen soil conditions, necessitating a change order/supplemental agreement. The process typically begins with the Geotechnical/Site Investigation Committee as outlined in Section 3-1.1.7.

Before starting field work on the project, the Engineer will obtain the Findings of No Significant Impact (FONSI) and/or Environmental Assessment (EA) documents from the Environmental Division to determine if there are any hindrances or “gold sheets” limiting the field investigation. These documents shall be reviewed to check for delineated wetlands. If wetlands are present, the Geotechnical Exploration Plan should include probing and hand auger boring in these areas to determine the depth of soft soils or unsuitable materials, which will be part of the fieldwork.

Finally, the Engineer formulates recommendations and compiles them into a Soil Profile Report. The Soil Profile Report should be disseminated to the appropriate District office, Roadway Design Division, Bridge Division (if any structures are involved in the project), Construction Division, Materials Division, and the Geotechnical Branch. If the Soil Profile report is for a project with a Risk Category of **High**, the Materials Division will coordinate a meeting to be attended by the affected Divisions and District Construction with the Engineer that prepared the report to discuss findings and develop any mitigation plans necessary to address geotechnical issues which could affect final cost of the project.

4-6.1.1 Laboratory Testing

As a minimum, the following tests and calculations shall be completed:

- AASHTO R 58 – Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test
- AASHTO T 11 – Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
- AASHTO T 27 – Sieve Analysis of Fine and Coarse Aggregates
- AASHTO T 88 – Particle Size Analysis of Soils (with MT-23 Methods for Testing Soils)
- AASHTO T 89 – Determination of the Liquid Limit of Soils
- AASHTO T 90 – Determining the Plastic Limit and Plasticity Index of Soils
- AASHTO T 193 – The California Bearing Ratio (for any soils which could potentially be used in the design soil subgrade)
- AASHTO T 265 – Laboratory Determination of Moisture Content of Soils
- MT-92 – Determining the Shrinkage Factors of Soils
- MT-30 – pH Determination
- MT-47 – Soil Resistivity (if alternate pipe culverts are proposed)

4-6.2 New Location (Grade and Drain Projects)

The Engineer will include a written description of any soft soil areas identified in the Soil Profile. Soft soils, which are usually saturated silts and clays, can cause long-term settlement of embankments, slope failures, and instability of structures. The extent of soft soil areas will be delineated based on site observations and probing/drilling, with rainfall conditions at the time of the survey noted. A table listing soft soil areas will be included in the Soil Profile Report, detailing station numbers, lateral extent, anticipated depth of excavation or other remediation methods, and estimated quantities of soil to be removed if necessary. If no soft soils are found, the Engineer will provide a written statement outlining the efforts made to locate them.

The limits of any other unsuitable soils such as muck or highly plastic materials shall be appropriately described in the Soil Profile report, with recommendations on disposition or treatment.

4-6.2.1 Subsurface Exploration

The spacing and depth of the soil borings could vary due to field constraints or if unusual conditions such as rock layers or weak deposits (muck or very soft soil) are encountered.

The auger method of drilling for disturbed samples is generally suitable for identification and testing; however, Geoprobe sampling is more accurate for delineation of changes in soil strata. If it becomes apparent that adequate samples are not being obtained from the auger method, the Geotechnical Branch should be contacted for guidance in obtaining the samples needed.

The borings, as nearly as possible, shall be sampled on one (1) foot intervals. From these samples the Engineer shall obtain a representative sample for each type of soil encountered. Auger cuttings or Geoprobe tube samples are used to create a bulk sample for each soil zone identified by the driller or logger. The Engineer should use extreme caution when obtaining representative soil samples from cuttings to ensure that the samples are not contaminated. This is especially true when sand or silt overlies a clay soil. It is permissible, if it becomes obvious that the same soil type is occurring on consecutive borings, to combine samples from the individual borings to make one bulk sample, but caution should be exercised when doing this. A bulk sample made up of auger cuttings should not represent more than five consecutive borings along the alignment.

The Engineer shall prepare a boring log that describes and classifies the soil and lists the depth where soil zone changes occur. The boring log should denote the depth at which any groundwater was encountered.

4-7 Sign, Lighting, and Signal Pole Foundations

4-7.1 Overview

When designing traffic control devices, highway lighting, and overhead sign structures, specific guidelines according to the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* shall be followed. Typically, foundation investigation requests for these structures are made at the end of the PS&E plan review by the design teams.

4-7.2 Required Preliminary Information

Prior to conducting the subsurface investigation and foundation evaluation, the Engineer will receive project plans that depict the sign, lighting or signal pole placement on the project. These plans should include the details of the sign, lighting or signal pole. If the foundation type has already been chosen, this information must also be included. Moreover, the loading requirements for each foundation should be specified to enable the Engineer to provide accurate foundation recommendations, including construction requirements.

4-7.3 Subsurface Exploration

Drilling and lab testing is conducted to provide boring logs and appropriate parameters to contractors and designers which aids in the selection of appropriate foundation types and sizes. Borings should be drilled as close to the structure locations as possible.

Water table data should be collected if possible. For structures placed in fill sections over 3 feet deep, a plan note should indicate that the required soils data will be collected after fill placement.

4-7.4 Foundation Evaluation

For drilled shaft foundations, the Engineer will provide boring logs and an LPILE parameters table for each boring. The investigation report should include foundation recommendations, subsurface stratigraphy, and relevant properties (water table conditions, material type, unit weight, strength, and recommended LPILE parameters). Foundations with similar subsurface conditions can be grouped into a Geotechnical Site, with a generalized subsurface profile presented for those foundations.

For spread footing foundations, the Engineer will provide allowable bearing capacity and soil description of the bearing layer, water table information, and any other properties pertinent to the design. If the spread footing is to be pile supported, the investigation report should list allowable pile types, design curves for both ultimate capacity and uplift capacity (with depth) and describe any construction considerations that should be taken into account.

4-8 Sound Barrier Walls

4-8.1 Overview

Sound barrier wall foundation studies start with a detailed review of project specifics and site conditions. Upon approval of the Geotechnical Exploration Plan, geotechnical investigations focus on subsurface conditions affecting foundation performance, using appropriate drilling and sampling techniques to obtain comprehensive soil profiles and identify any weak or problematic layers. The Engineer shall then analyze the data to recommend foundation types (if not determined) and depths based on subsurface stratigraphy, soil strength, and groundwater conditions, compiling these recommendations into a detailed report that outlines foundation requirements and potential construction challenges.

4-8.2 Required Preliminary Information

Prior to conducting the subsurface investigation and foundation evaluation, the Engineer will receive project plans that depict the sound wall placement on the project. These plans should include the wall envelope that details the location and total length of the sound barrier wall. Additionally, if the foundation type has already been chosen, this information must also be included. Moreover, the loading requirements for each foundation should be specified to enable the Engineer to provide accurate foundation recommendations, including construction and load testing requirements.

4-8.3 Subsurface Exploration

The Geotechnical Exploration Plan should be scoped to evaluate bearing resistance and lateral resistance, providing necessary recommendations. The Engineer must understand the data needs for the specific site and project, selecting appropriate field exploration and laboratory testing methods to gather the required geotechnical data.

Additionally, soil borings can be supplemented with in-situ methods such as CPT soundings in between borings for long sound barrier walls.

4-8.4 Foundation Evaluation

See Section 4-2.6.2 and 4-2.6.3 for guidance on foundation evaluation for applicable foundation types.

4-9 Borrow Pit Source Approval

For projects requiring over 5,000 cubic yards of borrow excavation, the Contractor shall conduct a Borrow Pit Source Approval Investigation. All proposed borrow pit source locations will comply with MDOT *Standard Specifications for Road and Bridge Construction* Section 106 – Control of Materials and 107.23 - Material Pits.

4-9.1 Subsurface Exploration

Bulk samples of materials are to be obtained by traditional soil borings, test pits made by an excavator, or for existing borrow pits a shovel may be used. It is important to get samples of material from each stratigraphic layer in the pit area. Care should be taken not to cross-contaminate the sample from each layer. One sampling location per acre is required, as well as one at each corner of the proposed pit area. To perform the required lab testing, a minimum of 75 pounds of material from each stratigraphic layer shall be obtained from each sampling location.

4-9.2 Laboratory Testing

As a minimum, the following tests and calculations shall be completed:

- AASHTO R 58 – Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test
- AASHTO T 11 – Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
- AASHTO T 27 – Sieve Analysis of Fine and Coarse Aggregates
- AASHTO T 88 – Particle Size Analysis of Soils (with MT-23 Methods for Testing Soils)
- AASHTO T 89 – Determination of the Liquid Limit of Soils
- AASHTO T 90 – Determining the Plastic Limit and Plasticity Index of Soils
- AASHTO T 265 – Laboratory Determination of Moisture Content of Soils
- MT-92 – Determining the Shrinkage Factors of Soils

4-9.3 Approval Process

Once the subsurface exploration and laboratory testing is complete, the Contractor shall submit a Quality Control Plan (QCP) to the District Materials Engineer for approval. The QCP plan shall include test results and any blending methods to be used by the Contractor to make the material meet the specifications for the designated borrow excavation.

The Contractor shall install a physical mark to identify the approved area of the pit, including location, GPS coordinates, and depth/elevation. For final approval of the pit, the MDOT District Materials lab will perform verification testing on pit samples provided by the contractor.

QA verification of the borrow excavation will be performed when a visual change in the material is observed, questionable density results are observed, or as directed by the Engineer.

During construction, if the material being excavated changes from the QCP approved material, the Contractor shall conduct additional laboratory and present recommended updates, as appropriate, to the QCP for approval by the Engineer.

Chapter 5

Information and Report Management

5-1 Site Investigation and Substructure Reports - Preparation of Plan Sheets and Special Provisions Requirements

All plan sheets, including additions and revisions, shall be developed with OpenRoads (Version 22, Release 3, or later), unless instructed otherwise in writing by the MDOT Project Manager. Additionally, all soil boring data, including, but not limited to, lab test data, lithology, groundwater elevation, and boring logs, shall be developed in OpenGround or in a software approved by MDOT, capable of exporting data formats acceptable by OpenGround, unless instructed otherwise in writing by the MDOT Project Manager. Final digital submittal of these services will be required in MDOT standard acceptable formats.

The Generalized Soil Profile, any Special Provisions, and any special design sheets shall be submitted with the Final Report. The level/element symbology, color, and level schemes shall be in accordance with the format provided by MDOT. Generalized soil profiles and boring logs shall contain standard notes and disclaimers. These notes will be furnished by MDOT. In addition, the generalized soil profiles shall contain a table of soil strengths and unit weights used for design calculations as well as a geologic description of the individual soil zones and USCS classification.

a. **Scale of Drawings:**
   Unless otherwise indicated, drawings submitted for final plans shall be the following scales:

   Standard Units: 1-inch= 20 ft., or 1-inch= 40 ft.

b. **Size of Lettering:**
   MDOT's standard plans policy requires the contract plans to be a 50% reduction of the original plans; therefore, the Engineer shall provide a minimum letter size of 1/8 inch in order to be legible when reduced to 50% of the original size.

5-2 Geotechnical Report Requirements

5-2.1 Soil Profile Report Requirements

The results of a soil profile investigation shall be reported by the Engineer in the form of a report. The report shall be in accordance with TMD 21-14-00-000 and shall contain the following:

- Soil Profile - The soil profile shall be prepared on grid sheets with a logical horizontal and vertical scale to show the necessary detail. These grid sheets should depict a profile of the plan grade of the subgrade by station number, as well as the existing ground line. The soil profile shall clearly delineate differing soil types. Each soil type shall have an identification number to reference it to the laboratory test results, the AASHTO Classification, Unified Soils Classification, estimated or laboratory CBR value, Plasticity Index, and Percent Volume Change (if applicable).

- Laboratory Test Results - All test results shall be reported on Form TMD-683 clearly identifying the sample number, location, depth, Station Number(s), and test completion date. If the DCP was used in an investigation, the results shall be tabularized separately and shall indicate the corresponding in-situ moisture content at each DCP reading.
- Conclusions and Recommendations - Areas along the roadway requiring special consideration during construction shall be delineated by Station and offset. As a minimum, the recommendations shall include areas that require undercut (or other construction considerations) due to the presence of high plasticity index material, high volume change clay, muck, or unstable material. Recommendations regarding cut and fill slopes in potentially unstable areas should be addressed. Additionally, recommendations as to type of chemical treatment of subgrades (soil-lime-water, lime-fly ash, or soil cement) should be delineated by Station limits.

5-2.2 Geotechnical Investigation Report Requirements

For Work Assignments involving a subsurface field investigation, engineering analyses, and/or geotechnical designs, the Engineer shall prepare a draft report of all findings and designs pertinent to the assigned scope of work. At that point, a meeting shall be held between the Engineer and the MDOT Project Manager or designee to discuss the findings of the investigation and to review the draft report. After this meeting, the Geotechnical Site Investigation Report shall be prepared and signed by an engineer licensed in the State of Mississippi with a minimum of 10 years' experience in the practice of geotechnical engineering. The report shall also contain the following as a minimum, unless specifically stated otherwise by the MDOT Project Manager or designee:

- A cover letter containing Project Number, County, and a general description of the project.
- A Project Layout Sheet containing the project termini and a map encompassing the entire project area.
- Final boring logs.
- Laboratory test results.
- Generalized soil profiles.
- Seismic site classification.
- Liquefaction potential assessment.
- Recommended seismic response spectra.

- Preliminary foundation recommendations for bridges and/or retaining walls; and
- Draft design sheets and/or draft special provisions required for the preparation of final construction bid plans.

5-2.3 Geotechnical Substructure Report Requirements

In addition to the items listed in the Geotechnical Site Investigation Report, the Geotechnical Substructure Report, when required, shall contain the following and shall be organized according to the following outline:

I. Cover Letter
II. Layout Sheet
III. General
IV. Geology
V. Conclusions and Recommendations
    a. Settlement Analysis of Bridge Approach or Roadway Embankments
    b. Slope Stability Analysis – Static (End of Construction & Long-Term) and Seismic
    c. Foundation Analysis
        i. Soluble-Sulfates Test Results
        ii. Spread Footings
        iii. Driven Piles
            1. Design
                - Ultimate Capacity Curves (Compression and Tension, if required)
                - Recommended LPILE Parameters
            2. Construction
                - Test Pile Recommendations
                - Driving Recommendations
        iv. Drilled Shafts
            1. Design
                - Ultimate Capacity Curves (Compression and Tension, if required)
                - Recommended LPILE Parameters
            2. Construction
                - Static Load Test Recommendations
                - Construction Recommendations
        v. Geotechnical Seismic Design
            1. Recommended Response Spectra
            2. Site Classification
            3. Foundation Stiffness Matrices (if required)
            4. Liquefaction Potential Assessment
                - Settlement (if liquefiable)
                - Lateral Spread (if liquefiable)
                - Drag Loads (if liquefiable)

VI. Reference Section
   a. Generalized Soil Profile(s)
   b. Spread Footing/Driven Pile/Drilled Shaft Design Curves
   c. Laboratory Test Results
   d. Final Boring Logs
   e. Seismic Design Information

5-3 Submission of Deliverables

Deliverable files will be submitted utilizing the MDOT File Exchange System. The MDOT Project Manager will provide a file upload link.

Chapter 6

Geotechnical Consultant Information

6-1 Overview of the Consultant Selection and Work Assignment Process

MDOT typically issues a Request for Proposal (RFP) for Statewide IDIQ Master (On-Call) Contracts for Geotechnical Engineering Services on a not to exceed 5 year timeframe. Under the IDIQ contract, selected consultants receive requests from the Materials Division/Geotechnical Branch to perform Work Assignments as needed to fulfill their mission during periods of high workload, or projects that additional expertise is required. The MDOT Geotechnical Branch is responsible for issuing Work Assignments based on MDOT's standard operating procedures.

Guidance on MDOT procurement, contract awards, proposal preparation for Work Assignments under the IDIQ, invoicing procedures, and other project/contract management can be obtained through the Consultant Services Unit and their issued Manuals, Guides and Forms found on the Consultant Services Unit Documents page, located here:

https://mdot.ms.gov/portal/consultant_services_unit_documents

Chapter 7

Construction Submittals

7-1 Overview

After the design phase, the Engineer plays a crucial role in ensuring the project's success. This includes reviewing construction submittals to ensure they meet specifications and plans, confirming compliance with geotechnical designs and recommendations, and developing an instrumentation program to monitor ground and structure movements, water table elevations, and vibrations. The Engineer also verifies foundation resistance and integrity; reviews conditions encountered during construction to revise recommendations as needed and provides clarification on geotechnical recommendations and specifications.

7-1.1 Constructability

The Engineer may be involved during pile installation if piles do not meet design requirements, are driven deeper than anticipated (overdrive), encounter early refusal, or have pile driving resistances that differ from expectations. Additionally, the Engineer may provide guidance and recommendations regarding predrilling of shallow rock and the use of protective pile tips. For drilled shafts, the Engineer will review the Drilled Shaft Installation Plan (DSIP) and assess shaft constructability, including the choice between dry and wet construction methods. The Engineer may also evaluate rock socket length at the request of the State Geotechnical Engineer.

7-1.2 Bearing Determination of Piling

Load testing may be required depending on the resistance factor (φ) selected during design. This can include high-strain (Pile Driving Analyzer [PDA]) or static/rapid (Statnamic®) load tests.

7-1.2.1 PDA Monitoring of Piling

For Work Assignments involving PDA Monitoring of Piling, the Engineer will be responsible for supplying the labor and equipment necessary to complete the required task.

The Engineer will be required to supply MDOT PDA data and bearing values determined by CAPWAP analysis (if required) for the number of test piles or production piles specified in the individual Work Assignment. In addition, the Engineer will be required in the Work Assignment to formulate driving criteria for the production piles that are specific to the pile hammer(s) used for installation of the piles. These driving criteria shall take into account the soil damping and quake values determined from CAPWAP analysis and any pile setup/freeze measured during pile restrikes.

The Engineer shall use the collected data and analyses to determine production pile lengths and shall prepare a PDA test pile report following the initial drive and restrikes of each PDA test pile. Each PDA test pile report shall be provided to the MDOT Project Manager or their designee within three working days of completion of all restrikes to be performed on the specific PDA test pile. Each PDA test pile report shall include complete results of all dynamic pile testing with recommended pile lengths, driving criteria, and driving system requirements for the installation of production piles at bents covered by the PDA test pile.

The driving criteria will include a table of hammer blows as a function of hammer stroke which are required to achieve the minimum bearing capacity required in the construction plans. Also required as part of the driving criteria are any requirements to be placed on the Contractor related to the driving system and method. These could include requirements related to pile cushion thickness, frequency of changing pile cushions, or hammer fuel setting adjustments. The Engineer shall submit two copies of each driving log, the PDIPLOT output in graphical and tabular format, all the CAPWAP results, all GRLWEAP wave equation analysis results, and a PDA testing report to the MDOT Project Manager or their designee within three working days following the completion of all PDA testing related to the specific test pile. MDOT will review the report and provide any questions, comments, or modifications to the Engineer. The Engineer shall address all questions, comments, or modifications and within one working day resubmit the PDA Test Pile Report to the MDOT Project Manager or their designee. All electronic data files including raw data (.W01), PDIPLOT (.PIL), CAPWAP (.CWW), and GRLWEAP (.GWW) shall be provided to MDOT by the Engineer.

The Engineer performing the test must supply MDOT with a copy of a certificate showing that they have achieved an Advanced, Master, or Expert Level Certification in High Strain Dynamic Pile Testing from the Pile Driving Contractors Association Dynamic Measurement and Analysis Proficiency Test.

7-1.2.2 Load Testing

If specified in the individual Work Assignment, the Engineer will be required to assist the Contractor in the setup of static load tests, administer the load test in accordance with ASTM Designation D1143 using the Quick Test Method, and analyze the load test data to determine the ultimate capacity of the pile. The static load test data shall be compiled into a final report containing all of the data collected from the load test and a plot of load vs. top of pile deflection. The Engineer will be required to perform additional analysis to compare the ultimate capacity determined from the static load test to the measured PDA capacity. The Engineer shall submit the load test data file(s) in raw format to the State Geotechnical Engineer, as well as all data files from analysis software.

7-1.3 Drilled Shaft Construction Inspection and Bearing Determination

For Work Assignments involving Crosshole Sonic Logging (CSL), Thermal Integrity Profiling (TIP), Gamma-Gamma Logging (GGL), or Bi-Directional Load Testing, the Engineer is responsible for providing the necessary labor and equipment. The Engineer must set up instrumentation for CSL (ASTM D6760), TIP (ASTM D7949), and/or GGL (CALTRANS CT-233) and analyze the data to assess the integrity and quality of drilled shafts. They will compile the test data into a final report, including all collected data and individual plots. Additionally, the Engineer must submit the raw data files for CSL, TIP, and GGL, along with any analysis software data files.

For bi-directional load testing (ASTM D8169), the Contractor will be required to furnish all materials, equipment, labor and incidentals necessary for conducting the load test and reporting the results. The Contractor shall subcontract the instrumenting, conducting and reporting of the load test to the company supplying the instrumentation with the const included in the contract unit price for test shaft.

The Engineer will observe the test shaft installation, observe the load test, and review the test results and determine the production shaft lengths from the load test data.

7-1.4 Submittal Review

At the request of the State Geotechnical Engineer, the Engineer may review Contractors' design and installation submittals to ensure they comply with the plans and specifications during the initial construction stages. For consultant-reviewed projects, the Engineer will provide a response to the State Geotechnical Engineer, including a cover letter with relevant comments. The State Geotechnical Engineer will accept or reject submittals, regardless of who reviewed the project, and forward them to the Construction Division for distribution to the Contractor. Rejected submittals must be resubmitted for review. In addition to the submittals previously discussed, typical submittals reviewed include:

- Retaining wall designs, details, and installation plan;
- Wick drain submittal;
- Temporary shoring;
- Micropile design, details, and installation.

APPENDIX A

Appendix A: Example Forms

TMD-683
REV. 7-96

MISSISSIPPI DEPARTMENT OF TRANSPORTATION
MATERIALS DIVISION
JACKSON, MS

Lab. Nos.	Project Nos.
Material	County
Submitted by	Sampled by
Reported to	Date Sampled
Producer	Date Received
Class Group	Date Reported

TEST RESULTS

Hole No.								
Sample No.								
Depth								
Quantity Rep.								

SIEVE ANALYSIS - TOTAL % PASSING BY WEIGHT (SQUARE OPENINGS)

No. 3" Sieve								
No. 1 3/4" Sieve								
No. 1 1/2" Sieve								
No. 1" Sieve								
No. 1/2" Sieve								
No. 4 Sieve								
No. 10 Sieve								

MECHANICAL ANALYSIS MATERIAL PASSING NO. 10 SIEVE

% Pass No. 10 Sieve								
% Pass No. 40 Sieve								
% Pass No. 60 Sieve								
% Pass No. 200 Sieve								
% Pass No. 270 Sieve								
% Silt								
% Clay								
Est. CBR								
GROUP								
U. S. C.								

PHYSICAL CHARACTERISTICS MATERIAL PASSING THE NO. 40 SIEVE

Liquid Limit								
Plastic Limit								
Plasticity Index								
Shrinkage Limit								
Shrinkage Ratio								
Volume Change								
Abrasion								

This material ______ the requirements of ______
for ______ on the above tests.

Remarks:

Reported By ______
District Materials Engineer

MDOT GEOTECHNICAL EXPLORATION NOTIFICATION
Right of Entry & Release for Testing Services

DATE: ________________________________

TIME: _________________________________

PLACE: ________________________________

I, We, the below undersigned owner or designated caretaker, do hereby acknowledge receipt of the Mississippi Department of Transportation's intent to enter upon or across the below described property for the purpose of performing geotechnical exploration work.

____
____
____

________________ County, Mississippi

It is understood that the purpose of this entry is to perform geotechnical exploration work including drilling holes. This could require the cutting of vegetation including small trees, limbs, and/or bushes to the minimum extent needed to obtain the required geotechnical data.

Furthermore, it is understood that the information to be obtained by this geotechnical exploration work is to be used to produce preliminary plans for the improvement of the subject project, subject to change as might be indicated necessary from this preliminary work.

The employees of MDOT and its consultants pledge cooperation in the preservation of fences, timber, shrubbery, etc maintained as assets to the above described property and its undersigned owner(s). Any holes drilled during geotechnical exploration will be backfilled and tamped with soil.

____
Signature of Property Owner of Property Owner's Authorized Agent

____
Print Name

____
Day, Date, Time

____
Witnessed by

Address: ____

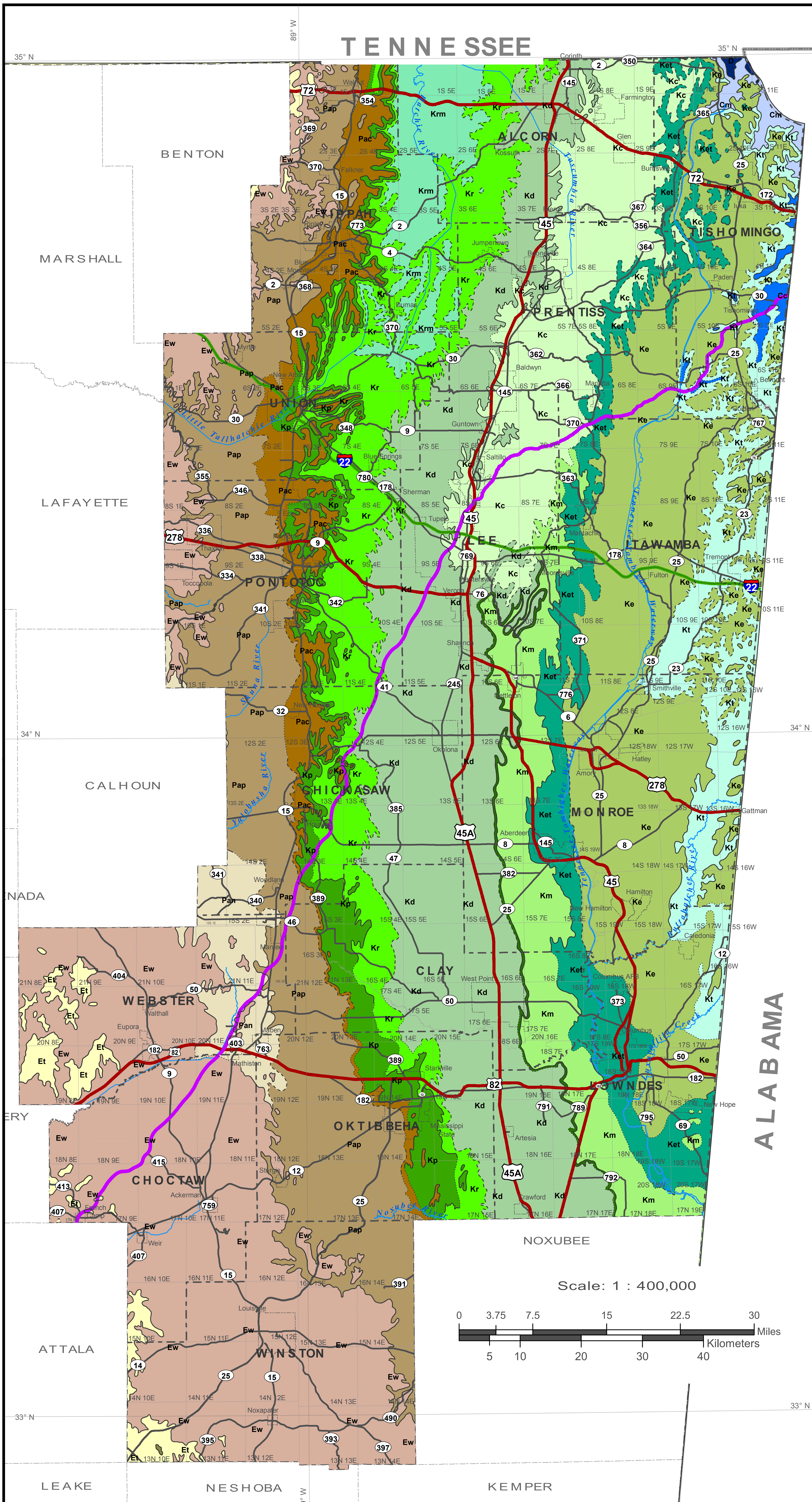
____

Telephone: ____

EXAMPLE FORMS

APPENDIX B

DISTRICT GEOLOGIC MAPS



LEGEND

TERTIARY

Eocene

Claiborne group

Ezw

Zilpha formation and Winona formation

Zilpha clay, chocolate-colored clay containing some glauconitic sand, not recognized north of Yalobusha River, Winona sand, highly glauconitic sand, more or less clayey

Et

Tallahatta formation and Neshoba sand

Southeast of Pearl River predominantly more or less glauconitic claystone and clay with lenses of sand and some sandstone; highly cross-bedded sand at base; northwest of Pearl River predominantly sand, locally glauconitic, containing claystone and clay lenses and abundant clay stringers, Neshoba sand, sparingly glauconitic fairly coarse sand not recognized southeast of Newton County or north of Yalobusha River

UNCONFORMITY

Ew / **Ewb** / **Ewn** / **Ew**

Wilcox formation

Ewb **Ewn** Map Symbols

Wilcox (Bashi and Mid Nanafilia)

Irregularly bedded fine to coarse sand, more ot less lignitic clay, and lignite; includes bauxite bearing Fearn Springs sand member at base; Ewb Bashi marl member, glauconitic fossiliferous sand containing large calcareous fossiliferous concretions; Ewn, fossiliferous marl bed which in Alabama occurs near middle of Nanafilia formation of Alabama

UNCONFORMITY

Paleocene

Midway group

Pan

Naheola formation

Fine to coarse micaceous sand, kaolin, and bauxitic clay

Pap

Porters Creek formation

Dark-gray clay, north of Clay County contains slightly glauconitic, micaceous sand lenses

Pac

Clayton formation

Upper part, greenish-gray coarsely glauconitic sandy clay and marl; lower part,crystalline sandy limestone and loose sand, represented south of Houston by a discontinuous bed of indurated calcareous sandstone

UNCONFORMITY

CRETACIOUS

Upper Cretaceous

Kp

Prairie Bluff chalk and Owl Creek formation

Prairie Bluff chalk, compact brittle chalk, sandy chalk, and calcareous clay; at base contains many phosphatic molds of fossils; in Pontotoc and Union Counties merges northward into Owl Creek formation, tough blue glauconitic sandy clay

UNCONFORMITY

Kr **Krm**

Ripley formation

Gray to greenish-gray fine glauconitic sand, clay, and sandy limestone; south of Oktibbeha County is very sandy micaceous chalk; Krm McNairy sand member, red and white cross-bedded micaceous sand and white sandy clay

Kd

Demopolis chalk

Chalk and marly chalk containing fewer impurities than underlying formations

Kma / **Km**

Mooreville chalk

Marly chalk and calcareous clay;Kma, Arcola limestone member on top, hard buff-colored limestone

UNCONFORMITY

Kc

Coffee sand

Light-gray cross-bedded to massive glauconitic sand and sandy clay and calcareous sandstone

UNCONFORMITY

Ket / **Ke**

Eutaw formation

More or less cross-bedded and thinly laminated glauconitic sand and clay; basal part includes the McShan formation, greenish-gray, micaceous, locally very glauconitic, very fine-grained sand and thin-bedded light-gray clay, small chert gravels may be present in basal beds, not recognized in northern Tishomingo County; Ket Tombigbee sand member, massive fine glauconitic sand

UNCONFORMITY

Kt

Tuscaloosa formation

Light and vari-colored irregularly bedded sand, clay, and gravel; gravel is mostly in lower portion

UNCONFORMITY

DEVONIAN CARBONIFEROUS

Mississippian

Cc

Chester group

Sandstone, shale and limestone

Cm

Limestones, chert and shale of Meramec, Osage and Kinderhook age

Devonian

D

Chatanooga shale (Carboniferous or Devonian) and underlying lime-stones of Early Devonian age

ROADS

- Interstate
- US Route
- MS Route
- Natchez Trace

Roads provided by MDOT Planning Division.

CLASSIFICATION OF CONTACTS

- Abrupt change of lithology or disconformity
- Gradual change of lithology
- Contact concealed by surficial formation
- Lateral transition from one stratigraphic unit into another
- FAULT (Many known faults, such as the Pickens Fault in Madison County, are not shown)

NOTE: This map does not show alluvium, except in the Mississipp River Alluvial Plain, nor terrace deposits which are extensively developed along the larger streams.

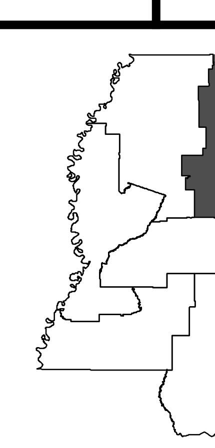
MDEQ

Geologic Map of Mississippi created from ESRI® vector data shapefiles provided by the Surface Geology Division of the Mississippi Department of Environmental Quality (MDEQ Feb. 2017).
Lithology feature styles and colors based on MDEQ Surface Geology Division map by Director David E.Thompson, RPG (Sept. 2011).
Other map line styles and legend elements based on the 1969 Geologic Map of Mississippi compiled by geologist Alvin R. Bicker Jr. for William Halsell Moore Dir. MS Geological Survey / State Geologist. The 1969 Geologic Map of Mississippi was a revision of the 1945 geologic map published by the Mississippi Geological Society in cooperation with the United States Geological Survey using data submitted by Dr. E.E. Russell of Mississippi State University from published reports of the Mississippi Geological Survey and from field revisions.

Map Projection: MS Transverse Mercator

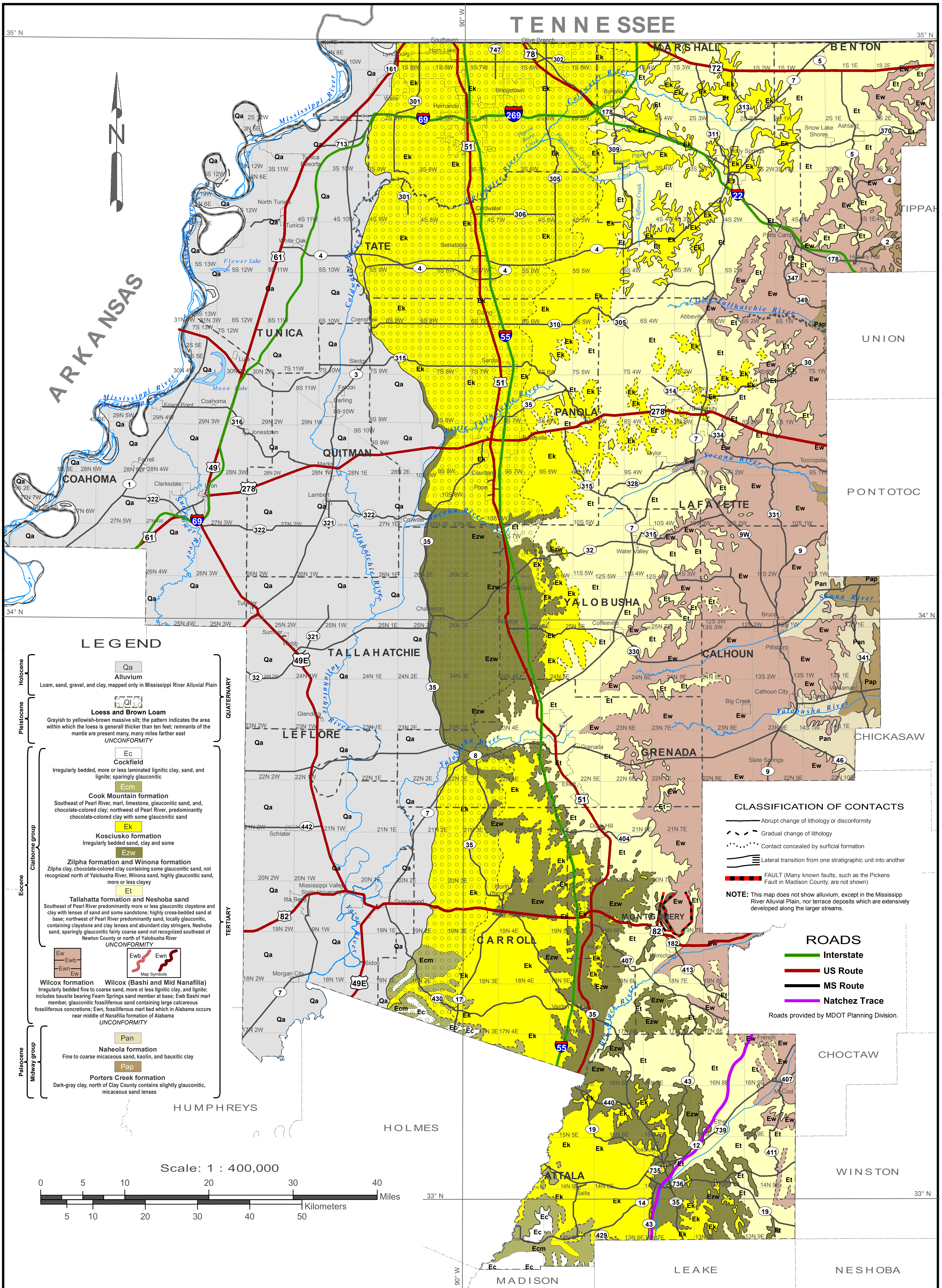
Prepared for MDOT Geotechnical Division use by Transportation Information - September 2017.

Map created using ArcMap® software by ESRI.
ArcMap™ Copyright © ESRI.



GEOLOGIC MAP
DISTRICT 1

MDOT
MISSISSIPPI DEPARTMENT OF TRANSPORTATION



DISCLAIMER: This map is provided by the Mississppi Department of Transportation (MDOT) on an "as is" basis.
MDOT will not be liable for any damages of any kind arising from the use of this map, including, but not limited to direct, indirect, punitive, and consequential. MDOT makes no warranties on this map, express, implied, statutory, or in any other provision of any agreement or communication, and specifically disclaims any implied warranties of merchantablility or fitness for a particular purpose.

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MDEQ

Map Projection: MS Transverse Mercator

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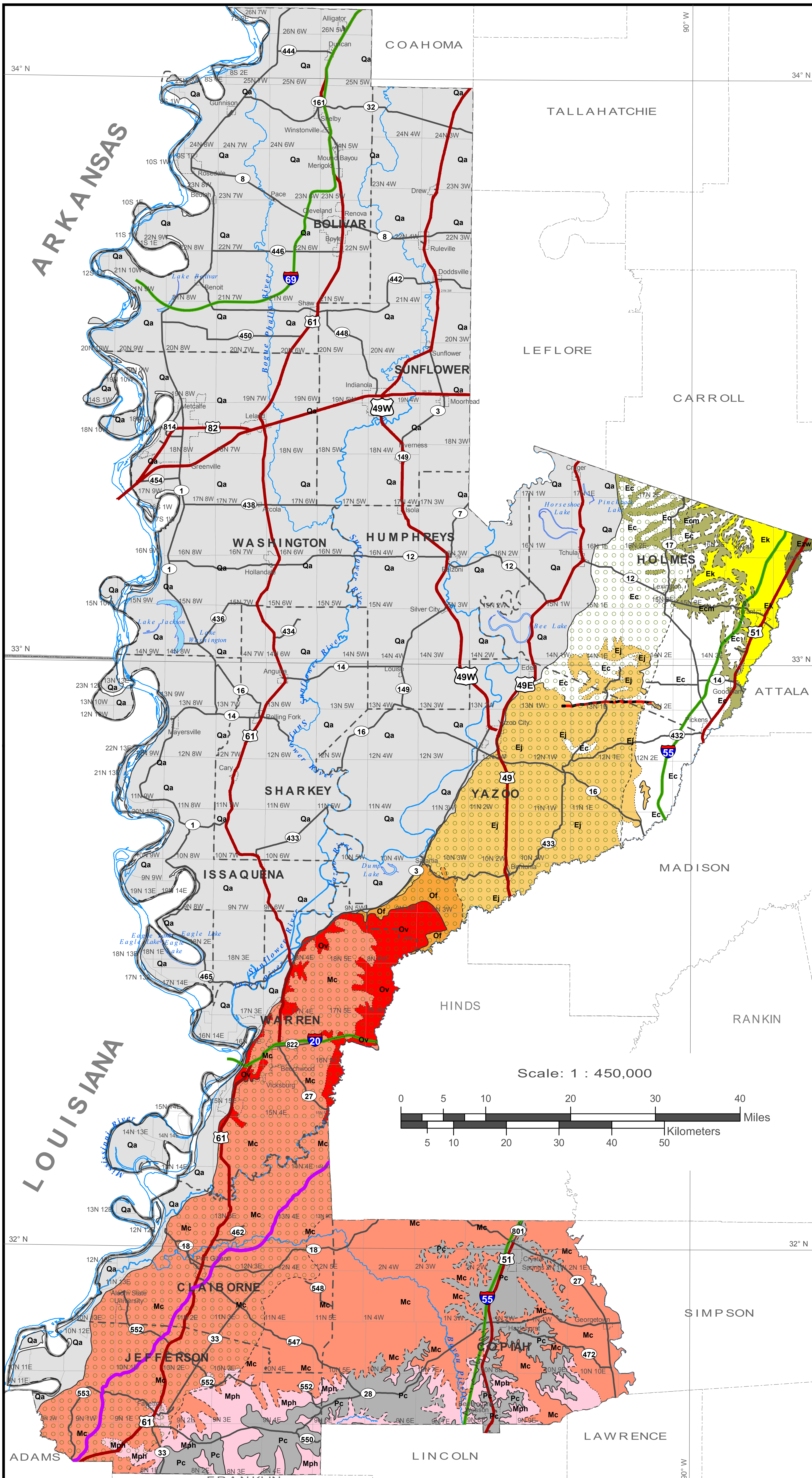
Map created using ArcMap® software by ESRI.
ArcMap™ Copyright © ESRI.

2

GEOLOGIC MAP
DISTRICT 2

MDOT
MISSISSIPPI DEPARTMENT OF TRANSPORTATION



LEGEND

QUATERNARY

Holocene

Qa
Alluvium
Loam, sand, gravel, and clay, mapped only in Mississippi River Alluvial Plain

Pleistocene

Ql
Loess and Brown Loam
Grayish to yellowish-brown massive silt; the pattern indicates the area within which the loess is generall thicker than ten feet; remnants of the mantle are present many, many miles farther east
UNCONFORMITY

Pc
Citronelle formation
Red sand and gravel and white clay; may be of Pliocene age; the formation mapped is equivalent to the Willis sand and does not include the terrace deposits, colluvium, and residuum commonly considered "Citronelle"
UNCONFORMITY

TERTIARY

Miocene

Mph
Pascagoula and Hattiesburg formation
Green and bluish-green clay, sandy clay, and sand; gray siltstone and sand; locally fossiliferous

Mc
Catahoula formation
Irregularly bedded gray sand and sandstone; mottled red and gray, green and chocolate-colored clay; some quartzite; and some gravel; the Paynes Hammock sand, sandy limestone cross-bedded fine green sand, and thin-bedded sand and clay, is mapped with the underlying Chickasawhay limestone in eastern MS
UNCONFORMITY

Oligocene

Ov
Vicksburg group and Chickasawhay limestone
Chickasawhay limestone, sandy limestone and sand, present only in eastern Mississippi (mapped with it is the overlying Paynes Hammock sand of Miocene age); Vicksburg group, predominantly limestone and marl, but contains some bentonite and near the top chocolate-colored clay and some sand
UNCONFORMITY

Of
Forest Hill formation and Red Bluff clay
Forest Hill sand, cross-bedded fine gray sand, laminated fine sand and clay, and a little lignite; in Wayne and Clarke Counties lower part merges eastward into Red Bluff clay, blue-green glauconitic, gypsiferous, fossiliferous clay and thin limestone beds
UNCONFORMITY

Eocene

Ej
Jackson group
Yazoo clay, green and gray calcareous clay containing some sand and marl; Moody's Branch formation at base, shells embedded in glauconitic clayey quartz sand
UNCONFORMITY

Claiborne group

Ec
Cockfield
Irregularly bedded, more or less laminated lignitic clay, sand, and lignite; sparingly glauconitic

Ecm
Cook Mountain formation
Southeast of Pearl River, marl, limestone, glauconitic sand, and, chocolate-colored clay; northwest of Pearl River, predominantly chocolate-colored clay with some glauconitic sand

Ek
Kosciusko formation
Irregularly bedded sand, clay and some quartzite

Ezw
Zilpha formation and Winona formation
Zilpha clay, chocolate-colored clay containing some glauconitic sand, not recognized north of Yalobusha River, Winona sand, highly glauconitic sand, more or less clayey

CLASSIFICATION OF CONTACTS

- Abrupt change of lithology or disconformity
- Gradual change of lithology
- Contact concealed by surficial formation
- Lateral transition from one stratigraphic unit into another
- FAULT (Many known faults, such as the Pickens Fault in Madison County, are not shown)

NOTE: This map does not show alluvium, except in the Mississipp River Alluvial Plain, nor terrace deposits which are extensively developed along the larger streams.

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MDEQ

Map Projection: MS Transverse Mercator

Prepared for MDOT Geotechnical Division use by Transportation Information - September 2017.

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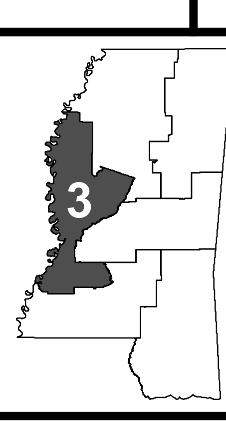
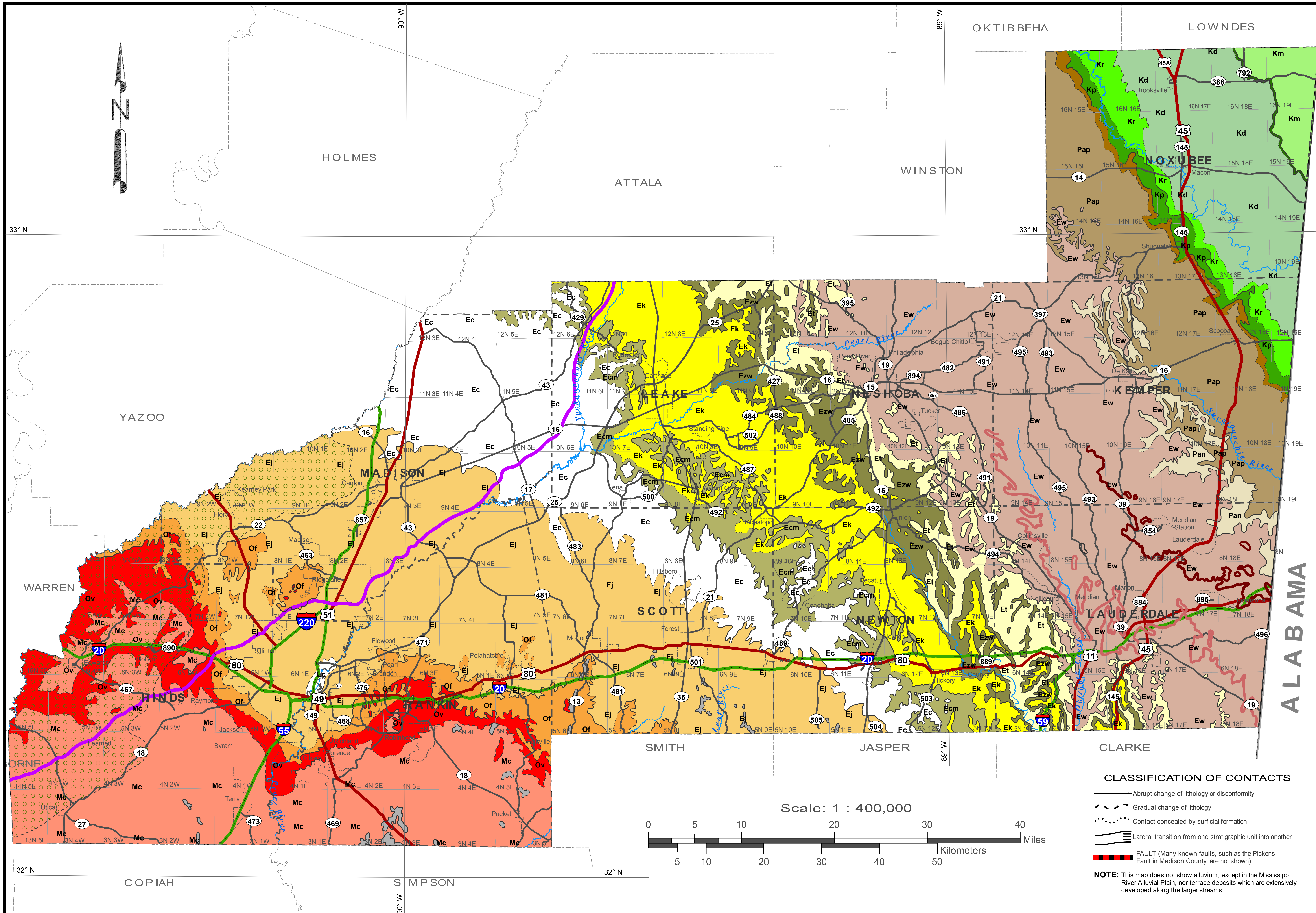


GEOLOGIC MAP
DISTRICT 3

MDOT
MISSISSIPPI DEPARTMENT OF TRANSPORTATION



LEGEND

QUATERNARY

Pleistocene

Ql — **Loess and Brown Loam**
Grayish to yellowish-brown massive silt; the pattern indicates the area within which the loess is generall thicker than ten feet; remnants of the mantle are present many, many miles farther east
UNCONFORMITY

Pc — **Citronelle formation**
Red sand and gravel and white clay; may be of Pliocene age; the formation mapped is equivalent to the Willis sand and does not include the terrace deposits, colluvium, and residuum commonly considered "Citronelle"
UNCONFORMITY

TERTIARY

Miocene

Mph — **Pascagoula and Hattiesburg formation**
Green and bluish-green clay, sandy clay, and sand; gray siltstone and sand; locally fossiliferous

Mc — **Catahoula formation**
Irregularly bedded gray sand and sandstone; mottled red and gray, green and chocolate-colored clay; some quartzite; and some gravel; the Paynes Hammock sand, sandy limestone cross-bedded fine green sand, and thin-bedded sand and clay, is mapped with the underlying Chickasawhay limestone in eastern MS
UNCONFORMITY

Oligocene

Ov — **Vicksburg group and Chickasawhay limestone**
Chickasawhay limestone, sandy limestone and sand, present only in eastern Mississippi (mapped with it is the overlying Paynes Hammock sand of Miocene age); Vicksburg group, predominantly limestone and marl, but contains some bentonite and near the top chocolate-colored clay and some sand
UNCONFORMITY

Of — **Forest Hill formation and Red Bluff clay**
Forest Hill sand, cross-bedded fine gray sand, laminated fine sand and clay, and a little lignite; in Wayne and Clarke Counties lower part merges eastward into Red Bluff clay, blue-green glauconitic, gypsiferous, fossiliferous clay and thin limestone beds
UNCONFORMITY

Eocene

Ej — **Jackson group**
Yazoo clay, green and gray calcareous clay containing some sand and marl; Moody's Branch formation at base, shells embedded in glauconitic clayey quartz sand
UNCONFORMITY

Claiborne group

Ec — **Cockfield**
Irregularly bedded, more or less laminated lignitic clay, sand, and lignite; sparingly glauconitic

Ecm — **Cook Mountain formation**
Southeast of Pearl River, marl, limestone, glauconitic sand, and, chocolate-colored clay; northwest of Pearl River, predominantly chocolate-colored clay with some glauconitic sand

Ek — **Kosciusko formation**
Irregularly bedded sand, clay and some quartzite

Ezw — **Zilpha formation and Winona formation**
Zilpha clay, chocolate-colored clay containing some glauconitic sand, not recognized north of Yalobusha River, Winona sand, highly glauconitic sand, more or less clayey

Et — **Tallahatta formation and Neshoba sand**
Southeast of Pearl River predominantly more or less glauconitic claystone and clay with lenses of sand and some sandstone; highly cross-bedded sand at base; northwest of Pearl River predominantly sand, locally glauconitic, containing claystone and clay lenses and abundant clay stringers, Neshoba sand, sparingly glauconitic fairly coarse sand not recognized southeast of Newton County or north of Yalobusha River
UNCONFORMITY

Ew / Ewb / Ewn / Ew — **Wilcox formation**

Ewb / Ewn (Map Symbols) — **Wilcox (Bashi and Mid Nanafilia)**

Irregularly bedded fine to coarse sand, more ot less lignitic clay, and lignite; includes bauxite bearing Fearn Springs sand member at base; Ewb Bashi marl member, glauconitic fossiliferous sand containing large calcareous fossiliferous concretions; Ewn, fossiliferous marl bed which in Alabama occurs near middle of Nanafilia formation of Alabama
UNCONFORMITY

Paleocene

Midway group

Pan — **Naheola formation**
Fine to coarse micaceous sand, kaolin, and bauxitic clay

Pap — **Porters Creek formation**
Dark-gray clay, north of Clay County contains slightly glauconitic, micaceous sand lenses

Pac — **Clayton formation**
Upper part, greenish-gray coarsely glauconitic sandy clay and marl; lower part,crystalline sandy limestone and loose sand, represented south of Houston by a discontinuous bed of indurated calcareous sandstone
UNCONFORMITY

CRETACIOUS

Upper Cretaceous

Selma group

Kp — **Prairie Bluff chalk and Owl Creek formation**
Prairie Bluff chalk, compact brittle chalk, sandy chalk, and calcareous clay; at base contains many phosphatic molds of fossils; in Pontotoc and Union Counties merges northward into Owl Creek formation, tough blue glauconitic sandy clay
UNCONFORMITY

Kr / Krm — **Ripley formation**
Gray to greenish-gray fine glauconitic sand, clay, and sandy limestone; south of Oktibbeha County is very sandy micaceous chalk; Krm McNairy sand member, red and white cross-bedded micaceous sand and white sandy clay

Kd — **Demopolis chalk**
Chalk and marly chalk containing fewer impurities than underlying formations

Kma / Km — **Mooreville chalk**
Marly chalk and calcareous clay;Kma, Arcola limestone member on top, hard buff-colored limestone
UNCONFORMITY

MDEQ

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Map Projection: MS Transverse Mercator

Prepared for MDOT Geotechnical Division use by Transportation Information - September 2017.

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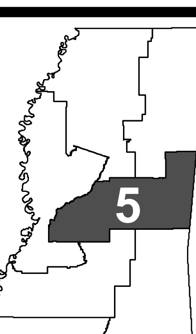
ROADS

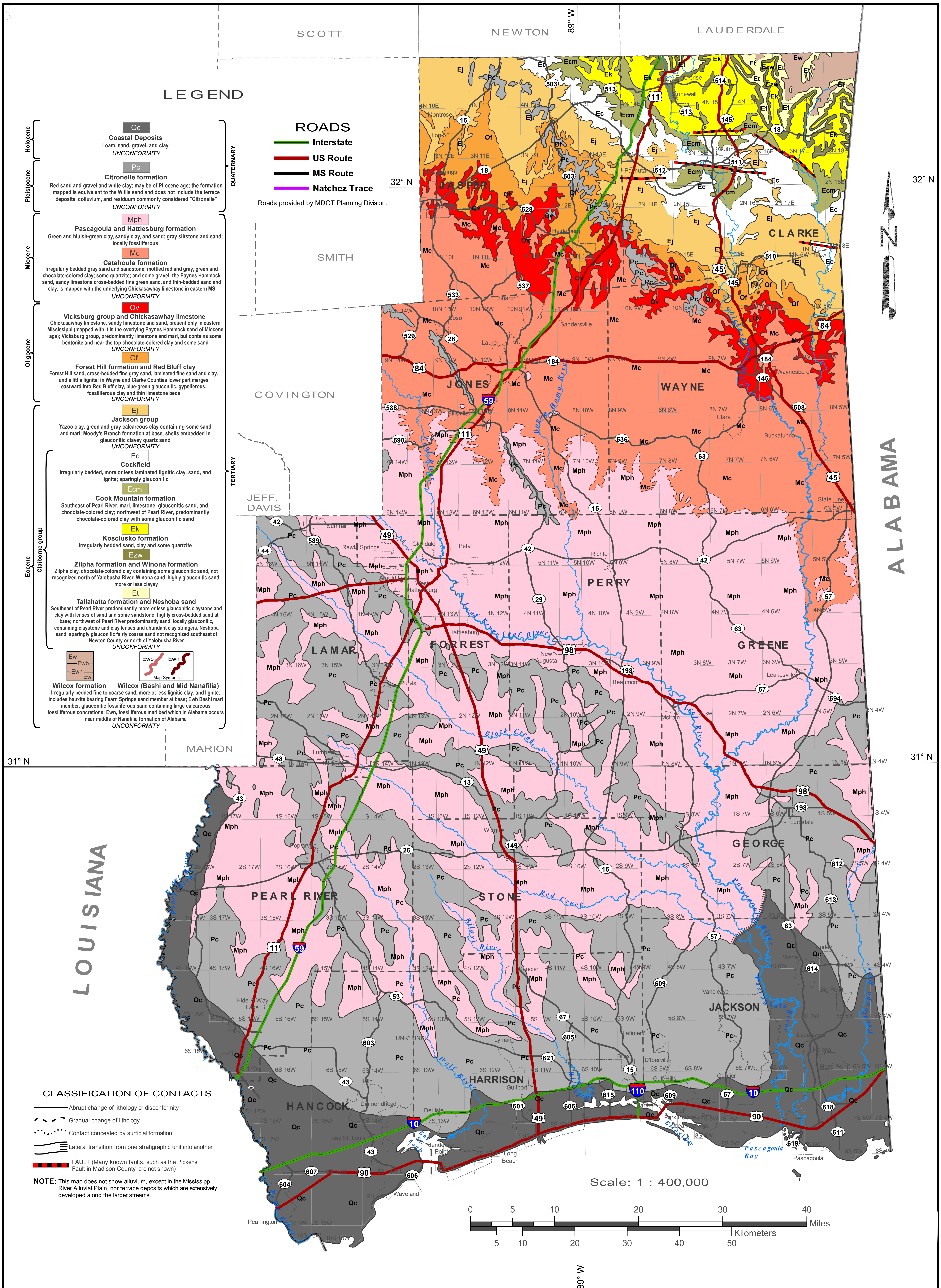
- Interstate
- US Route
- MS Route
- Natchez Trace

Roads provided by MDOT Planning Division.



GEOLOGIC MAP
DISTRICT 5

MDOT
MISSISSIPPI DEPARTMENT OF TRANSPORTATION



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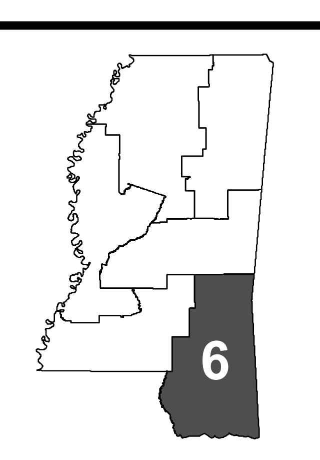
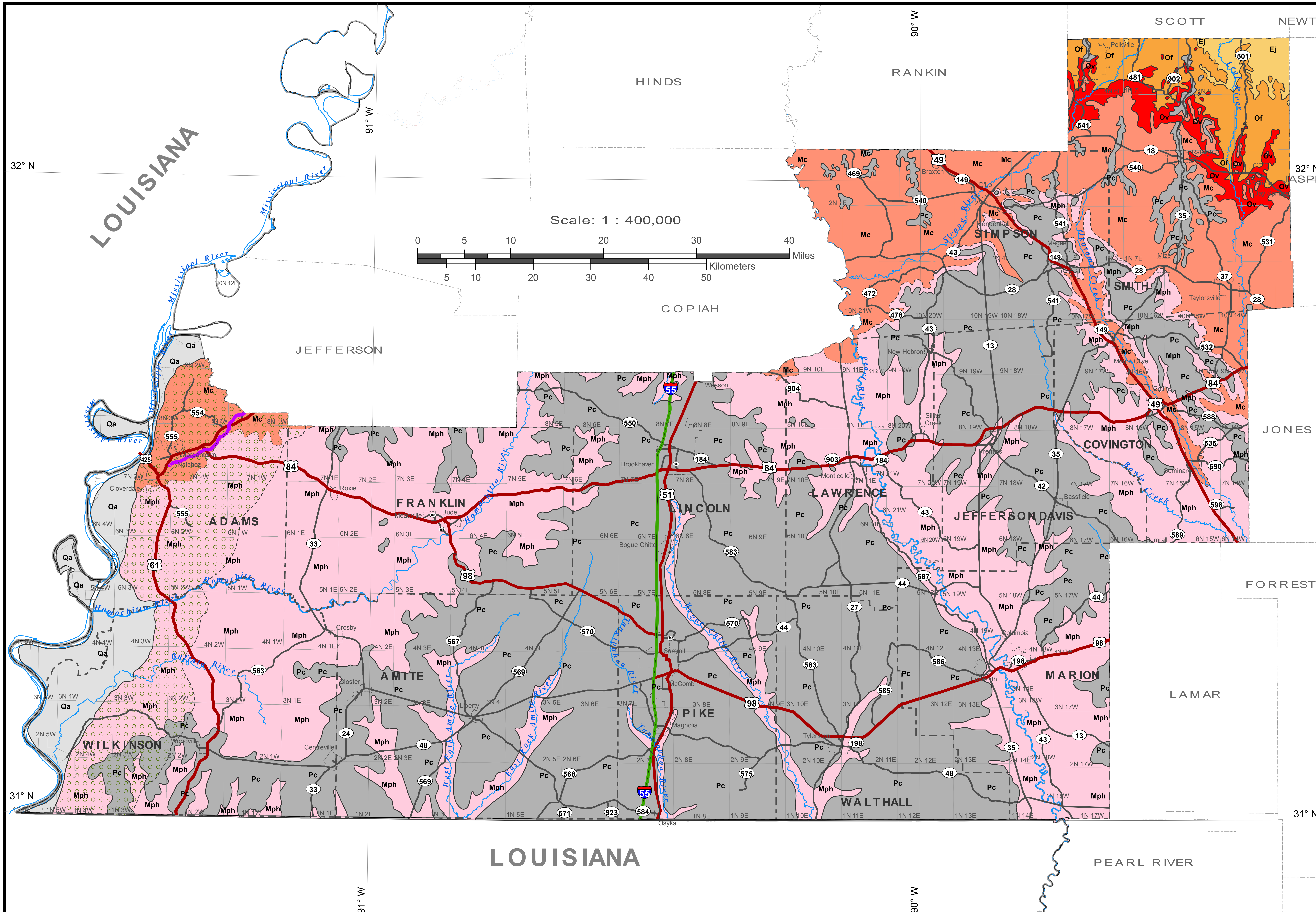


GEOLOGIC MAP
DISTRICT 6

MDOT
MISSISSIPPI DEPARTMENT OF TRANSPORTATION



LEGEND

QUATERNARY

Holocene

Qa — Alluvium
Loam, sand, gravel, and clay, mapped only in Mississippi River Alluvial Plain

Pleistocene

Ql — Loess and Brown Loam
Grayish to yellowish-brown massive silt; the pattern indicates the area within which the loess is generall thicker than ten feet; remnants of the mantle are present many, many miles farther east
UNCONFORMITY

Pc — Citronelle formation
Red sand and gravel and white clay; may be of Pliocene age; the formation mapped is equivalent to the Willis sand and does not include the terrace deposits, colluvium, and residuum commonly considered "Citronelle"
UNCONFORMITY

TERTIARY

Miocene

Mph — Pascagoula and Hattiesburg formation
Green and bluish-green clay, sandy clay, and sand; gray siltstone and sand; locally fossiliferous

Mc — Catahoula formation
Irregularly bedded gray sand and sandstone; mottled red and gray, green and chocolate-colored clay; some quartzite; and some gravel; the Paynes Hammock sand, sandy limestone cross-bedded fine green sand, and thin-bedded sand and clay, is mapped with the underlying Chickasawhay limestone in eastern MS
UNCONFORMITY

Oligocene

Ov — Vicksburg group and Chickasawhay limestone
Chickasawhay limestone, sandy limestone and sand, present only in eastern Mississippi (mapped with it is the overlying Paynes Hammock sand of Miocene age); Vicksburg group, predominantly limestone and marl, but contains some bentonite and near the top chocolate-colored clay and some sand
UNCONFORMITY

Of — Forest Hill formation and Red Bluff clay
Forest Hill sand, cross-bedded fine gray sand, laminated fine sand and clay, and a little lignite; in Wayne and Clarke Counties lower part merges eastward into Red Bluff clay, blue-green glauconitic, gypsiferous, fossiliferous clay and thin limestone beds
UNCONFORMITY

Eocene

Ej — Jackson group
Yazoo clay, green and gray calcareous clay containing some sand and marl; Moody's Branch formation at base, shells embedded in glauconitic clayey quartz sand
UNCONFORMITY

CLASSIFICATION OF CONTACTS

- Abrupt change of lithology or disconformity
- Gradual change of lithology
- Contact concealed by surficial formation
- Lateral transition from one stratigraphic unit into another
- FAULT (Many known faults, such as the Pickens Fault in Madison County, are not shown)

NOTE: This map does not show alluvium, except in the Mississippi River Alluvial Plain, nor terrace deposits which are extensively developed along the larger streams.

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MDEQ

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ROADS

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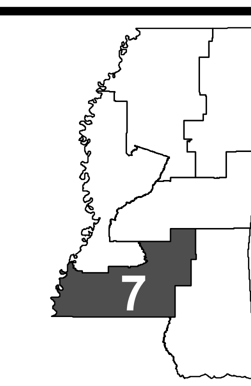


GEOLOGIC MAP
DISTRICT 7

MDOT
MISSISSIPPI DEPARTMENT OF TRANSPORTATION

APPENDIX C

GEOTECHNICAL BRANCH POLICY STATEMENT GEOLOGIC DESCRIPTIONS OF SOILS AND STRATIGRAPHIC NOMENCLATURE

Mississippi Department of Transportation
Geotechnical Branch

Policy Statement: Geological Descriptions of Soils and Stratigraphic Nomenclature

Purpose: To provide a guideline for the description of soils and rocks encountered in geotechnical borings completed for the expressed purpose of generating a soil profile.

Application: This guideline applies to boring logs completed in the field by trained personnel and to generalized soil profiles generated for inclusion in MDOT plans.

Objective: To provide a uniform classification system for soil types encountered in geotechnical borings for use by MDOT employees and MDOT Consultants.

STRATIGRAPHIC NOMENCLATURE

A Professional Geologist should zone the soils encountered in the borings using the following criteria:

Alluvial soils must be separated from formational soils. The alluvial soils must then be zoned based on different soil types **and** on geological origin (depositional environment). For example a single zone may transition into another soil type; however, the zone description must be representative and inclusive of both soil types. (E.g., Firm, Dark Gray, Micaceous, Clayey Silt grading downward into a Basal Silty Sand. Typically, these secondary soil types in a zone are typically less than a few feet thick.)

Alluvial soils should be labeled as a group as Zone 1. Each different soil type within the alluvium should be labeled as Zone 1A, 1B, 1C, ... etc.

Formational soils must be correctly identified and properly named according to the **Stratigraphic Column of Mississippi.** If any formational member can be identified, it should also be utilized. Formational Group names by themselves are not acceptable. The formational soils must then be zoned based on different soil types **and** on geological origin (depositional environment).

Formational soils should be labeled as a group as Zone 2. Each different soil type within the formation should be labeled as Zone 2A, 2B, 2C, ... etc. Underlying formations encountered in the borings should be labeled as a group as Zone 3 with each different soil type within the formational labeled as Zone 3A, 3B, 3C, ... etc.

SOIL CLASSIFICATION AND DESCRIPTIONS

Borings logs and generalized soil profiles are to use the following method to describe a soil samples and generalized soil profiles:

(Cohesive Strength or Density), + (Color), + (Supplementary Constituents), + (Grain Size Modifiers for Sand), + (Basic Constituents) + (Modifying Phrases) --USE PUNCTUATION!

The above terminology is to be utilized as follows:

Cohesive Strength - for use with clays and silts only

Very soft	0.00 – 0.25 ksf
Soft	0.25 – 0.50 ksf
Firm	0.50 – 1.00 ksf
Stiff	1.00 – 2.00 ksf
Very Stiff	2.00 – 4.00 ksf
Hard	> 4.00 ksf

Density – for use with sands only

Very loose	0-4 B/F
Loose	4-10 B/F
Medium dense	10-30 B/F
Dense	30-50 B/F
Very Dense	> 50 B/F

Color - Color should represent the color(s) of a fresh surface of the sample. It should include all colors or ranges of colors present and it can include terminology such as mottled and variegated. (E.g., Light to Dark Gray, Maroon and Gray Mottled; Variegated Red, Orange, Gray, and Green)

Supplementary Constituents -

If the sample contains:	Then it is:
Mica	Micaceous
Fossils	Fossiliferous
Glauconite	Glauconitic
Organics (including wood)	Organic
Silt sized organics	Carbonaceous
Iron nodules	Limonitic
Calcite (cement)	Calcareous (it reacts with hydrochloric acid)
Silica (cement)	Siliceous
Bentonite (clay)	Bentonitic
Slickensides	Slickensided

If it is:	Then it is:
Very over consolidated	Indurated
Thinly bedded or has thin layers	Laminated

Grain Size Modifiers – It includes any range of grain sizes from very fine to very coarse. It does not typically exclude a single grain size. (E.g., Very Fine to Medium, or Fine to Coarse). It includes: Very Fine, Fine, Medium, Coarse, and Very Coarse.

Basic Constituents - These are listed from least abundant to most abundant and includes

*Sand	Silt	Clay
Silty *Sand	Clayey Silt	Silty Clay
Clayey *Sand	Sandy Silt	Sandy Clay
Clayey, Silty *Sand	Sandy, Clayey Silt	Sandy Silty Clay
Silty, Clayey *Sand	Clayey, Sandy Silt	Silty, Sandy Clay
*Gravel		

*Grain Size Modifiers belong here.

These constituents may include descriptive terms such as slightly or very (e.g., Slightly Silty Clay)

Modifying Phrases -		**To be used with** -	
		Sand Seams	Roots
With Some	- a noticeable quantity	Clay Layers	Gravel
With	- with a moderate quantity	Silt Layers	Ironstone
And	- with equal quantities	Sand, Silt, or Clay Stringers	Siltstone
		Wood Fragments	Sandstone

ROCK CORES

Cuttings should be obtained and described from all rock layers less than 4 inches thick. Cores should be obtained and described from all rock layers thicker than 4inches. A Rock Quality Designation (RQD) should be determined on all cores by dividing the total length of all core pieces over 4 inches in length by the total length of the core. The cored interval and the RQD should be recorded on the boring log. The generalized soil profile and the boring log should clearly delineate rock layers. Rocks should be described by as follows: .

(Hardness), + (Color), + (Degree of Weathering), + (Bedding Characteristics), + (Supplementary Constituents) + (Rock Type) – USE PUNCTUATION!

The descriptions include, but are not limited to the following:

Hardness	Weathering	Bedding Characteristics	Supplementary Constituents	Rock Type
Very Soft	Fresh	Laminated	Calcareous	Sandstone
Soft	Slightly	Thin Bedded	Siliceous	Siltstone
Medium Hard	Moderately	Medium Bedded	Ferruginous	Limestone
Hard	Predominantly	Thick Bedded	Micaceous, Fossiliferous	Chalk, Marl
	Decomposed	Massively Bedded	Sandy, Silty, Clayey	Conglomerate
	Decomposed			Ironstone

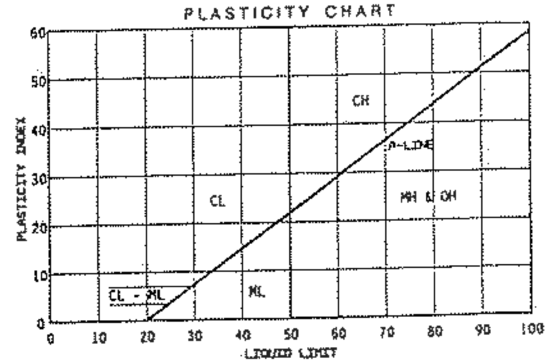
UNIFIED SOIL CLASSIFICATION SYSTEM (ASTM D 2487)

	MAJOR DIVISIONS		SYMBOL & LETTER	DESCRIPTION
COARSE-GRAINED SOILS More than half of material Passing No. 200 sieve	GRAVELS More than half of coarse fraction larger than No. 4 sieve size	Clean Gravels (Little or no fines)	GW	WELL GRADED GRAVEL, GRAVEL-SAND MIXTURE
			GP	POORLY GRADED GRAVEL, GRAVEL-SAND MIXTURE
		Gravels with fines (Appreciable amount of fines)	GM	SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURE
			GC	CLAYEY GRAVEL, GRAVEL-SAND-CLAY MIXTURE
	SANDS More than half of coarse fraction smaller than No. 4 sieve size	Clean Sands (Little or no fines)	SW	WELL GRADED SAND, GRAVELLY SAND
			SP	POORLY GRADED SAND, GRAVELLY SAND
		Sands with fines (Appreciable amount of fines)	SM	SILTY SAND, SAND-SILT MIXTURE
			SC	CLAYEY SAND, SAND-CLAY MIXTURE
FINE-GRAINED SOILS More than half of material smaller than No. 200 sieve	SILTS AND CLAYS	Liquid limit less than 50	ML	SILT WITH LITTLE OR NO PLASTICITY
			ML	CLAYEY SILT, SILT WITH SLIGHT TO MEDIUM PLASTICITY
			CL	SILTY CLAY, LOW TO MEDIUM PLASTICITY
			CL	SANDY CLAY, LOW TO MEDIUM PLASTICITY (30% TO 50% SAND)
	SILTS AND CLAYS	Liquid limit greater than 50	MH	SILT, FINE SANDY OR SILTY SOIL WITH HIGH PLASTICITY
			CH	CLAY, HIGH PLASTICITY
			OH	ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY
	HIGHLY ORGANIC SOILS		PT	PEAT, HUMUS, SWAMP SOIL

TERMS CHARACTERIZING SOIL STRUCTURE

Slickensided	- Clays with polished and striated planes created as a result of movements within the geologic history.
Fissured	- Clays with a blocky or jointed structure, generally created by seasonal shrinking and swelling.
Laminated	- Composed of thin alternating layers of varying color and texture.
Calcareous	- Containing appreciable quantities of calcium carbonate.
Parting	- Paper thin (less than 1/8 inch).
Seam	- 1/8 inch to 3 inch thickness
Layer	- Greater than 3 inches in thickness

PLASTICITY CHART

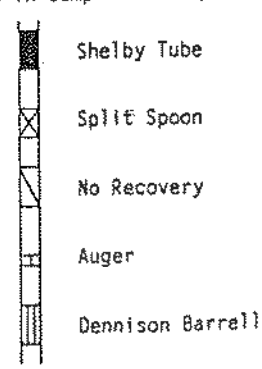


FOR CLASSIFICATION OF FINE GRAINED SOILS

DENSITY AND CONSISTENCY

COARSE-GRAINED SOILS		FINE-GRAINED SOILS		
DENSITY	PENETRATION RESISTANCE, N Blows per Foot	CONSISTENCY	COHESION Kips/Sq.Ft	PENETRATION RESISTANCE, N Blows per Foot
Very Loose	0 - 4	Very Soft	<0.25	0 - 1
Loose	5 - 10	Soft	0.25 - 0.50	2 - 4
Medium Dense	11 - 30	Medium Stiff	0.50 - 1.00	5 - 8
Dense	31 - 50	Stiff	1.00 - 2.00	9 - 15
Very Dense	>50	Very Stiff	2.00 - 4.00	16 - 30
		Hard	>4.00	>30

SAMPLE TYPES
(Shown in Sample Column)



PARTICLE SIZE IDENTIFICATION

Cobbles	- Greater than 3 inches
Gravel	- Coarse - 3/4 inch to 3 inches Fine - 4.76 mm to 3/4 inch
Sand	- Coarse - 2 mm to 4.76 mm Medium - 0.42 mm to 2 mm Fine - 0.074 mm to 0.42 mm
Silt or Clay	- Less than 0.074 mm

RELATIVE COMPOSITION

Slightly	5 -15%
With	16 - 29%
Sandy (or Gravelly)	30 - 50%

CLASSIFICATION, SYMBOLS AND TERMS USED ON GRAPHICAL BORING LOGS

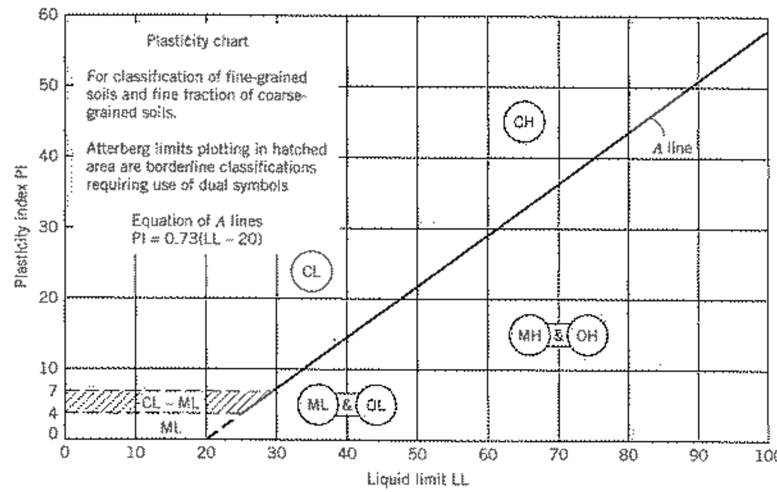
FIGURE 8

Major Divisions			Group Symbols	Typical Names	Classification Criteria	
Coarse-Grained Soils More than 50% retained on No. 200 sieve*	Gravels 50% or more of coarse fraction retained on No. 4 sieve	Clean gravels −200 <5%	GW	Well-graded gravels and gravel–sand mixtures, little or no fines	$C_u = D_{60}/D_{10} > 4$ $C_z = \frac{D_{30}^2}{D_{10}D_{60}}$ between 1 and 3	
			GP	Poorly graded gravels and gravel–sand mixtures, little or no fines	Not meeting both criteria for GW	
		Gravels with fines −200 >12%	GM	Silty gravels, gravel–sand–silt mixtures	Atterberg limits plot below *A* line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC	Clayey gravels, gravel–sand–clay mixtures	Atterberg limits plot above *A* line and plasticity index greater than 7	
	Sands More than 50% of coarse fraction passes No. 4 sieve	Clean sands −200 <5%	SW	Well-graded sands and gravelly sands, little or no fines	$C_u = D_{60}/D_{10} > 6$ $C_z = \frac{D_{30}^2}{D_{10}D_{60}}$ between 1 and 3	
			SP	Poorly graded sands and gravelly sands, little or no fines	Not meeting both criteria for SW	
		Sands with fines −200 >12%	SM	Silty sands, sand–silt mixtures	Atterberg limits plot below *A* line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			SC	Clayey sands, sand–clay mixtures	Atterberg limits plot above *A* line and plasticity index greater than 7	
Fine-Grained Soils 50% or more passes No. 200 sieve*	Silts and Clays Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands		
			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 and Clays Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts		
			CH	Inorganic clays of high plasticity, fat clays		
			OH	Organic clays of medium to high plasticity		
Highly Organic Soils			PT	Peat, muck, and other highly organic soils	Visual-manual identification, see ASTM D-2488.	

More than 12%: GM, GC
5–12% Borderline

Classification on Basis of Percentage of Fines

Less than 5% pass No. 200 sieve	GW, GP, SW, SP
More than 12% pass No. 200 sieve	GM, GC, SM, SC
5–12% pass No. 200 sieve	Borderline classification requiring use of dual symbols



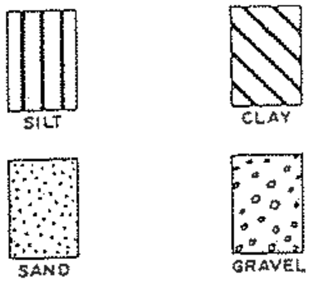
* 0.075-mm sieve.

Figure 4.9 Unified Classification System, ASTM D-2487-69.

SYMBOLS AND TERMS USED ON BORING LOGS

SYMBOL DESCRIPTIONS

SOIL TYPES
(SHOWN IN SYMBOL COLUMN)



(PREDOMINANT TYPE SHOWN HEAVY)

GROUNDWATER INFORMATION
(SHOWN IN SYMBOL COLUMN)

Depth where groundwater was initially encountered

Water level in boring approximately 15 minutes after initial encounter

Water level in boring at least 10 hours after rotary washing

SAMPLER TYPES
(SHOWN IN SAMPLES COLUMN)

AUGER

SHELBY TUBE

SPLIT SPOON

PISTON

NO RECOVERY

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (more than 50% retained on No. 200 sieve): Includes clean gravels and sands, and silty or clayey gravels and sands. Condition is rated according to Standard Penetration Resistance. (ASTM D1586)

DESCRIPTIVE TERM	STANDARD PENETRATION RESISTANCE (BLOWS / FT)
Very Loose	0 to 4
Loose	5 to 9
Medium Dense	10 to 29
Dense	30 to 50
Very Dense	Above 50

FINE GRAINED SOILS (50% or more passes the No. 200 sieve): Includes (1) inorganic and organic silts and clays, (2) gravely, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength as indicated by field or laboratory tests.

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (KIPS/SQ FT)
Very Soft	Below 0.25
Soft	0.25 to 0.50
Firm	0.50 to 1.00
Stiff	1.00 to 2.00
Very Stiff	2.00 to 4.00
Hard	Above 4.00

TERMS DESCRIBING SOIL STRUCTURE

SLICKENSIDED – having fracture planes that appear polished and glossy
FISSURED – having definite planes of fracture with little resistance to fracturing
LAMINATED – composed of thin seams of varying color and texture
STRATIFIED – composed of alternating layers of varying material or color
CALCAREOUS – containing appreciable quantities of calcium carbonate
INDURATED – hardened by pressure or cementation
GLAUCONITIC – containing a green mineral commonly occuring in soils of marine origin
FRIABLE – easily crumbled

HOMOGENEOUS – having the same color and appearance throughout
WELL GRADED – having wide range in grain sizes and substantial amounts of all intermediate particle sizes
POORLY GRADED – predominantly of one grain size, or having a range of sizes with some intermediate size missing
BLOCKY – having a structure that can be broken down into small angular lumps which resist further breakdown
ORGANIC – containing remains of living organisms
LAYER – a soil deposit with a thickness of about six inches
SEAM – a bed of soil less than six inches thick deposited within another soil mass
PARTING – a very small thickness of soil within another soil
VARVED –

NOTES

(1) Soil classification methods are in general agreement with ASTM Standard Test Methods D2487 and D2488. Wherever possible, classifications are based on laboratory test results. Where laboratory testing is insufficient to completely describe soil conditions, visual identifications are provided.

(2) Groundwater information is presented when available. The presence of initial free water is masked in borings advanced by rotary wash methods. Drilling fluid levels indicated might not reflect static groundwater conditions. Groundwater level fluctuations with rainfall and other seasonal factors will occur.

LEGEND AND NOTES FOR LOG OF BORING AND TEST RESULTS

PP — Pocket penetrometer resistance in tons per square foot

TV — Torvane shear strength in tons per square foot

SPT — Standard Penetration Test. Number of blows of a 140-lb. hammer dropped 30 inches required to drive 2-in O.D., 1.4-in. I.D. sampler a distance of one foot into the soil, after first seating it 6 inches

SPLR — Type of Sampling: Shelby, SPT, Auger, No Sample

SYMBOL — Clay · Silt, Sand, Humus. Predominant type shown heavy; Modifying type shown light

DENSITY — Unit weight in pounds per cubic foot

USC — Unified Soil Classification

TYPE

TYPE	UC	Unconfined compression shear
	OB	Unconsolidated undrained triaxial compression shear on one specimen confined at the approximate overburden pressure
	UU	Unconsolidated undrained triaxial compression shear
	CU	Consolidated undrained triaxial compression shear
	DS	Direct shear
	CON	Consolidation
	PD	Particle size distribution
	k	Coefficient of permeability in centimeters per second
	SP	Swelling pressure in pounds per square foot

ϕ — Angle of internal friction in degrees

c — Cohesion in pounds per square foot

Other laboratory test results reported on separate figure

Ground Water Measurements — Initial — Final

GENERAL NOTES

(1) At the time the borings were made, ground water levels were measured below existing ground surface. These observations are shown on the boring logs. However, ground water levels may vary due to seasonal and other factors. If important to construction, the depth to ground water should be determined by those persons responsible for construction, immediately prior to beginning work.

(2) While the individual logs of borings are considered to be representative of subsurface conditions at their respective locations on the dates shown, it is not warranted that they are representative of subsurface conditions at other locations and times.

SOIL CLASSIFICATION AND DESCRIPTIONS

Borings logs and generalized soil profiles are to use the following method to describe a soil samples and generalized soil profiles:

(Cohesive Strength or Density), + (Color), + (Supplementary Constituents), + (Grain Size Modifiers for Sand), + (Basic Constituents) + (Modifying Phrases) --USE PUNCTUATION!

The above terminology is to be utilized as follows:

Cohesive Strength - for use with clays and silts only		Density - for use with sands only	
Very soft	0.00 – 0.25 ksf	Very loose	0-4 B/F
Soft	0.25 – 0.50 ksf	Loose	4-10 B/F
Firm	0.50 – 1.00 ksf	Medium dense	10-30 B/F
Stiff	1.00 – 2.00 ksf	Dense	30-50 B/F
Very Stiff	2.00 – 4.00 ksf	Very Dense	> 50 B/F
Hard	> 4.00 ksf		

Color - Color should represent the color(s) of a fresh surface of the sample. It should include all colors or ranges of colors present and it can include terminology such as mottled and variegated. (E.g., Light to Dark Gray, Maroon and Gray Mottled; Variegated Red, Orange, Gray, and Green)

Supplementary Constituents -

If the sample contains:	Then it is:
Mica	Micaceous
Fossils	Fossiliferous
Glauconite	Glauconitic
Organics (including wood)	Organic
Silt sized organics	Carbonaceous
Iron nodules	Limonitic
Calcite (cement)	Calcareous (it reacts with hydrochloric acid)
Silica (cement)	Siliceous
Bentonite (clay)	Bentonitic
Slickensides	Slickensided

If it is:	Then it is:
Very over consolidated	Indurated
Thinly bedded or has thin layers	Laminated

Grain Size Modifiers – It includes any range of grain sizes from very fine to very coarse. It does not typically exclude a single grain size. (E.g., Very Fine to Medium, or Fine to Coarse). It includes: Very Fine, Fine, Medium, Coarse, and Very Coarse.

Basic Constituents - These are listed from least abundant to most abundant and includes

*Sand	Silt	Clay
Silty *Sand	Clayey Silt	Silty Clay
Clayey *Sand	Sandy Silt	Sandy Clay
Clayey, Silty *Sand	Sandy, Clayey Silt	Sandy Silty Clay
Silty, Clayey *Sand	Clayey, Sandy Silt	Silty, Sandy Clay
*Gravel		

*Grain Size Modifiers belong here.

These constituents may include descriptive terms such as slightly or very (e.g., Slightly Silty Clay)

Modifying Phrases -

		To be used with -	
		Sand Seams	Roots
With Some	- a noticeable quantity	Clay Layers	Gravel
With	- with a moderate quantity	Silt Layers	Ironstone
And	- with equal quantities	Sand, Silt, or Clay Stringers	Siltstone
		Wood Fragments	Sandstone

ROCK CORES

Cuttings should be obtained and described from all rock layers less than 4 inches thick. Cores should be obtained and described from all rock layers thicker than 4inches. A Rock Quality Designation (RQD) should be determined on all cores by dividing the total length of all core pieces over 4 inches in length by the total length of the core. The cored interval and the RQD should be recorded on the boring log. The generalized soil profile and the boring log should clearly delineate rock layers. Rocks should be described by as follows: .

(Hardness), + (Color), + (Degree of Weathering), + (Bedding Characteristics), + (Supplementary Constituents) + (Rock Type) – USE PUNCTUATION!

The descriptions include, but are not limited to the following:

Hardness	Weathering	Bedding Characteristics	Supplementary Constituents	Rock Type
Very Soft	Fresh	Laminated	Calcareous	Sandstone
Soft	Slightly	Thin Bedded	Siliceous	Siltstone
Medium Hard	Moderately	Medium Bedded	Ferruginous	Limestone
Hard	Predominantly	Thick Bedded	Micaceous, Fossiliferous	Chalk, Marl
	Decomposed	Massively Bedded	Sandy, Silty, Clayey	Conglomerate
	Decomposed			Ironstone

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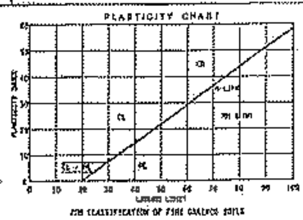
UNIFIED SOIL CLASSIFICATION SYSTEM (ASTM D 2487)

	MAJOR DIVISIONS		SYMBOL & LETTER		DESCRIPTION
COARSE-GRAINED SOILS More than half of material Passing No. 200 sieve	GRAVELS More than half of coarse fraction larger than No. 4 sieve size	Clean Gravels (Little or no fines)		GW	WELL GRADED GRAVEL, GRAVEL-SAND MIXTURE
				GP	POORLY GRADED GRAVEL, GRAVEL-SAND MIXTURE
		Gravels with fines (Appreciable amount of fines)		GM	SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURE
				GC	CLAYEY GRAVEL, GRAVEL-SAND-CLAY MIXTURE
	SANDS More than half of coarse fraction smaller than No. 4 sieve size	Clean Sands (Little or no fines)		SW	WELL GRADED SAND, GRAVELLY SAND
				SP	POORLY GRADED SAND, GRAVELLY SAND
		Sands with fines (Appreciable amount of fines)		SM	SILTY SAND, SAND-SILT MIXTURE
				SC	CLAYEY SAND, SAND-CLAY MIXTURE
FINE-GRAINED SOILS More than half of material smaller than No. 200 sieve	SILTS AND CLAYS	Liquid limit less than 50		ML	SILT WITH LITTLE OR NO PLASTICITY
				ML	CLAYEY SILT, SILT WITH SLIGHT TO MEDIUM PLASTICITY
				CL	SILTY CLAY, LOW TO MEDIUM PLASTICITY
				CL	SANDY CLAY, LOW TO MEDIUM PLASTICITY (20% TO 50% SAND)
	SILTS AND CLAYS	Liquid limit greater than 50		MH	SILT, FINE SANDY OR SILTY SOIL WITH HIGH PLASTICITY
				CH	CLAY, HIGH PLASTICITY,
				OH	ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOIL

TERMS CHARACTERIZING SOIL STRUCTURE

Slickensided	- Clays with polished and striated planes created as a result of movements within the geologic history.
Fissured	- Clays with a blocky or jointed structure, generally created by seasonal shrinking and swelling.
Laminated	- Composed of thin alternating layers of varying color and texture.
Calcareous	- Containing appreciable quantities of calcium carbonate.
Parting	- Paper thin (less than 1/8 inch).
Seam	- 1/8 inch to 3 inch thickness
Layer	- Greater than 3 inches in thickness

PLASTICITY CHART



FOR CLASSIFICATION OF FINE GRAINED SOILS

DENSITY AND CONSISTENCY

COARSE-GRAINED SOILS		FINE-GRAINED SOILS		
DENSITY	PENETRATION RESISTANCE, N Blows per Foot	CONSISTENCY	COHESION Kips/Sq.Ft.	PENETRATION RESISTANCE, N Blows per Foot
Very Loose	0 - 4	Very Soft	<0.25	0 - 1
Loose	5 - 10	Soft	0.25 - 0.50	2 - 4
Medium Dense	11 - 30	Medium Stiff	0.50 - 1.00	5 - 8
Dense	31 - 50	Stiff	1.00 - 2.00	9 - 15
Very Dense	>50	Very Stiff	2.00 - 4.00	16 - 30
		Hard	>4.00	>30

PARTICLE SIZE IDENTIFICATION

Cobbles	- Greater than 3 inches
Gravel	- Coarse - 3/4 inch to 3 inches Fine - 4.76 mm to 3/4 inch
Sand	- Coarse - 2 mm to 4.76 mm Medium - 0.42 mm to 2 mm Fine - 0.074 mm to 0.42 mm
Silt or Clay	- Less than 0.074 mm

RELATIVE COMPOSITION

Slightly	5 - 15%
With	16 - 29%
Sandy (or Gravelly)	30 - 50%

SAMPLE TYPES
(Shown in Sample Column)

Shelby Tube
Split Spoon
No Recovery
Auger
Dennison Barrell

CLASSIFICATION, SYMBOLS AND TERMS USED ON GRAPHICAL BORING LOGS

SYMBOLS AND TERMS USED ON BORING LOGS

SYMBOL DESCRIPTIONS

SOIL TYPES (SHOWN IN SYMBOL COLUMN)

SILT · CLAY · SAND · GRAVEL

(PREDOMINANT TYPE SHOWN HEAVY)

GROUNDWATER INFORMATION (SHOWN IN SYMBOL COLUMN)

- Depth where groundwater was initially encountered
- Water level in boring approximately 15 minutes after initial encounter
- Water level in boring at least 10 hours after rotary washing

SAMPLER TYPES (SHOWN IN SAMPLES COLUMN)

- AUGER
- SHELBY TUBE
- SPLIT SPOON
- PISTON
- NO RECOVERY

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (more than 50% retained on No. 200 sieve): Includes clean gravels and sands, and silty or clayey gravels and sands. Condition is rated according to Standard Penetration Resistance. (ASTM D1586)

DESCRIPTIVE TERM	STANDARD PENETRATION RESISTANCE (BLOWS / FT)
Very Loose	0 to 4
Loose	5 to 9
Medium Dense	10 to 29
Dense	30 to 50
Very Dense	Above 50

FINE GRAINED SOILS (50% or more passes the No. 200 sieve): Includes (1) inorganic and organic silts and clays, (2) gravely, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength as indicated by field or laboratory tests.

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (KIPS/SQ FT)
Very Soft	Below 0.25
Soft	0.25 to 0.50
Firm	0.50 to 1.00
Stiff	1.00 to 2.00
Very Stiff	2.00 to 4.00
Hard	Above 4.00

TERMS DESCRIBING SOIL STRUCTURE

SLICKENSIDED – having fracture planes that appear polished and glossy.
FISSURED – having definite planes of fracture with little resistance to fracturing
LAMINATED – composed of thin seams of varying color and texture
STRATIFIED – composed of alternating layers of varying material or color
CALCAREOUS – containing appreciable quantities of calcium carbonate
INDURATED – hardened by pressure or cementation
GLAUCONITIC – containing a green mineral commonly occuring in soils of marine origin
FRIABLE – easily crumbled

HOMOGENEOUS – having the same color and appearance throughout
WELL GRADED – having wide range in grain sizes and substantial amounts of all intermediate particle sizes
POORLY GRADED – predominantly of one grain size, or having a range of sizes with some intermediate size missing
BLOCKY – having a structure that can be broken down into small angular lumps which resist further breakdown
ORGANIC – containing remains of living organisms
LAYER – a soil deposit with a thickness of about six inches
SEAM – a bed of soil less than six inches thick deposited within another soil mass
PARTING – a very small thickness of soil within another soil
VARVED –

NOTES

(1) Soil classification methods are in general agreement with ASTM Standard Test Methods D2487 and D2488. Wherever possible, classifications are based on laboratory test results. Where laboratory testing is insufficient to completely describe soil conditions, visual identifications are provided.

(2) Groundwater information is presented when available. The presence of initial free water is masked in borings advanced by rotary wash methods. Drilling fluid levels indicated might not reflect static groundwater conditions. Groundwater level fluctuations with rainfall and other seasonal factors will occur.

LEGEND AND NOTES FOR LOG OF BORING AND TEST RESULTS

PP	Pocket penetrometer resistance in tons per square foot	
TV	Torvane shear strength in tons per square foot	
SPT	Standard Penetration Test. Number of blows of a 140-lb. hammer dropped 30 inches required to drive 2-in O.D., 1.4-in. I.D. sampler a distance of one foot into the soil, after first seating it 6 inches	
SPLR	Type of Sampling	Shelby · SPT · Auger · No Sample
SYMBOL	Clay · Silt · Sand · Humus	Predominant type shown heavy; Modifying type shown light
DENSITY	Unit weight in pounds per cubic foot	
USC	Unified Soil Classification	

TYPE

UC	Unconfined compression shear
OB	Unconsolidated undrained triaxial compression shear on one specimen confined at the approximate overburden pressure
UU	Unconsolidated undrained triaxial compression shear
CU	Consolidated undrained triaxial compression shear
DS	Direct shear
CON	Consolidation
PD	Particle size distribution
k	Coefficient of permeability in centimeters per second
SP	Swelling pressure in pounds per square foot

ϕ Angle of internal friction in degrees

c Cohesion in pounds per square foot

Other laboratory test results reported on separate figure

Ground Water Measurements Initial Final

GENERAL NOTES

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