Development of an Interactive Database for Soil for Design of New Pavements and Rehabilitation of Existing Pavements in Oklahoma

FINAL REPORT

ODOT TASK ORDER NUMBER 2160-21-03

Submitted to:
Office of Research and Implementation
Oklahoma Department of Transportation

Submitted by:
Syed Ashik Ali
Linda Nowlan
Musharraf Zaman
Kenneth R. Hobson

School of Civil Engineering and Environmental Science (CEES)
The University of Oklahoma

OKLAHOMA
Transportation

March 2022

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	Ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	Lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	Ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	Gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	Oz
kg	kilograms	2.202	pounds	Lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	Fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	Fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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EXECUTIVE SUMMARY

The Oklahoma Department of Transportation (ODOT) has been collecting geotechnical data for many years as a part of their construction projects. However, accessing this data for the purpose of design, analysis, visualization, and reporting is difficult as they are available in different formats (CDs, digital) and not included in an organized database. The objective of this Task Order was to develop a Geographic Information System (GIS)-based interactive database that can be readily used for estimating soil properties for pavement design/rehabilitation. For this purpose, geotechnical reports, in CDs and digital format, were collected from the ODOT Roadway Design Division and reviewed to understand report type and organization. The current digital geotechnical report folder was updated by matching with the reports in CDs. An Excel template was developed based on the review of the geotechnical reports and soil input requirements for AASHTO 1993 and AASHTOWare Pavement ME Design to extract necessary geotechnical data. An Excel-based soil database was developed using the template. During this Task Order, data from a total of 378 geotechnical reports involving 13 counties were extracted and incorporated into the soil database. The database was shared with the ODOT GIS team and incorporated into the ODOT GIS system. The ODOT GIS team will be responsible for developing necessary searching tools for the GIS-enabled database. Recommendations for data integration and searching tools are included in this report. It is recommended that ODOT continue this effort to enrich the database by incorporating soil properties from the remaining existing reports and future geotechnical investigations.

1. INTRODUCTION

Geotechnical data have been collected by Oklahoma Department of Transportation (ODOT) as part of construction projects involving pavements, bridges, and other structures. The data generally includes, but is not limited to, field test data, groundwater data, soil properties, and other laboratory test results. Most of these data are stored in different formats, such as hard copies, scanned images, and digital files (.pdf). Also, there is no single database or data management system for collecting, managing, archiving, and retrieving the geotechnical data that is being collected each year. Therefore, accessing this data and combining it with new data for the purpose of design, analysis, visualization, and reporting is time-consuming and difficult. Soil properties data in these reports can be a great resource for pavement design, if they are organized in an interactive and easy to use database.

Recently the use of Geographic Information System (GIS) has become popular and more prevalent in the engineering community. The GIS has the ability to store and retrieve data and represent that data spatially on a map. Therefore, coupling a soil database with GIS will allow pavement designers in retrieving the necessary data efficiently. Also, coupling with a GIS platform makes interpolation of soil properties data from nearby sites easier than currently possible. This GIS-based database is expected to be particularly helpful for short duration projects where geotechnical investigations are not feasible because of time and budgetary constraints. The Pavement Design Engineer of ODOT requested a Task Order (Development of an Interactive Database for Soil for Design of New Pavements and Rehabilitation of Existing Pavements in Oklahoma (2160-21-03)) to develop a GIS-based interactive database that can be readily used for estimating soil properties for pavement design/rehabilitation.

1.1 Scope of Work

This Task Order was divided into the following tasks: Task 1: collection of soil investigation reports, Task 2: extraction of necessary geotechnical properties of soil, Task 3: development of a GIS-based interactive soil database, Task 4: developemnt of interactive searching tool, Task 5: training ODOT staff on database use, and Task 6: submiting monthly progress reports and final report. A kickoff meeting was held on February 19, 2021 between ODOT and the OU team to discuss the workflow of the Task Order. Based on the discussions at the kickoff meeting, it was evident that the GIS group at ODOT would address Task 3 and Task 4 internally and the OU team would be responsible for providing data digitally. This arrangement allowed the OU team to review more geotechnical reports than previously expected for incorporation in the GIS-based interactive database. The OU team is working with ODOT staff to organize a trainging on the use of this GIS-based interactive soil database. The final version of this report will be updated by adding a section focusing on the training of using the GIS-based interactive soil database.

2. COLLECTION OF SOIL INVESTIGATION REPORTS

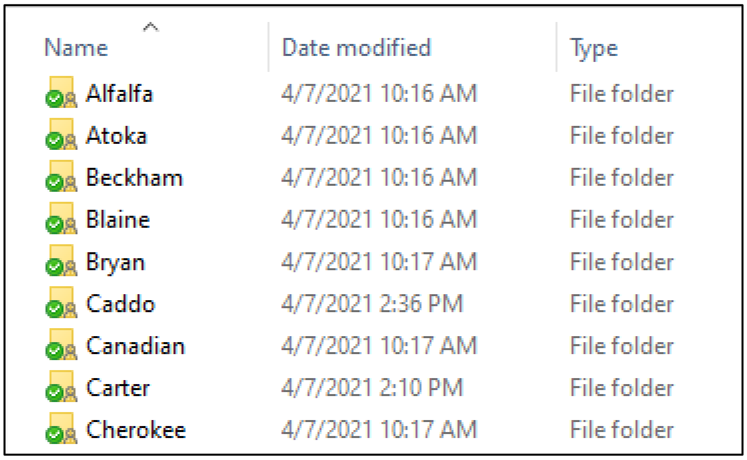
The OU team has collected geotechnical reports from the Pavement Design Engineer, Roadway Design Division at ODOT on March 15, 2021. This included transferring data to an external drive and collecting CDs containing geotechnical reports. A total of 3 Boxes of CDs containing geotechnical reports were collected (Figure 2.1). Also, the electronic version of the reports constituted approximately 14 gigabytes of hard-drive space. Approximately 1,500 reports were shared by ODOT Roadway Design Division for this Task Order. Considering the limited budget and timeline, it was not possible to include all soil investigation reports available at ODOT Roadway Design Division in this Task Order.

Figure 2.1 Geotechnical reports (in CDs) collected from ODOT

3. EXTRACTION OF NECESSARY GEOTECHNICAL PROPERTIES OF SOIL

3.1 Review of Geotechnical Reports

After collecting, the OU team has conducted an initial review by scanning through all the geotechnical investigation reports available in CDs and electronic format. ODOT’s existing report folder was updated by including the geotechnical reports that were not previously copied from the CDs. The electronic files were organized based on their location (county). Figure 3.1 shows a snippet of the organized electronic folders. Also, the CDs were arranged based on their county location (Figure 3.2). The OU team is in the process of sharing the updated electronic folder and CD boxes with ODOT.



Name	Date modified	Type
Alfalfa	4/7/2021 10:16 AM	File folder
Atoka	4/7/2021 10:16 AM	File folder
Beckham	4/7/2021 10:16 AM	File folder
Blaine	4/7/2021 10:16 AM	File folder
Bryan	4/7/2021 10:17 AM	File folder
Caddo	4/7/2021 2:36 PM	File folder
Canadian	4/7/2021 10:17 AM	File folder
Carter	4/7/2021 2:10 PM	File folder
Cherokee	4/7/2021 10:17 AM	File folder

Figure 3.1 Snippet of the geotechnical report folders arranged based on location (county)

Figure 3.2 Geotechnical reports in CDs arranged based on location (county)

During the initial review, it was observed that several different types of geotechnical investigation reports were available at ODOT. The types of the geotechnical reports included, but not limited to,

- Geological and pedological survey reports
- Pavement and subgrade survey
- Shoulder soil survey

- Cut section study
- Embankment Survey
- Geotechnical investigation for bridge

It was found that the organization of geotechnical reports varied significantly based on the type of investigation. For example, the pavement and subgrade soil surveys included information, such as site description, sub-surface conditions and engineering properties (generally up to 3 feet), Atterberg limit information (liquid and plastic limits), particle size distribution, gradation, moisture content, soil classification, groundwater level, core data and back-calculated layer moduli values. On the other hand, geological and pedological survey reports included site description, soil taxonomy, geologic soil formation, drainage and permeability, sub-surface conditions and engineering properties, liquid and plastic limits, gradation, moisture content, soil classification, optimum moisture content (OMC) and maximum dry density (MDD), resilient modulus (at OMC and OMC+2%) (bulk material), pH, resistivity, and soluble sulfate. Figures 3.3 and 3.4 show snippets of the soil information from a pedological survey and a pavement and subgrade soil survey, respectively.

Kleinfelder Project No. 20152395-5
North 129th East Ave Over Interstate 244
State J/P No. 25589(04)
Tulsa County, Oklahoma

Table D2: Pedological and Geological Survey

Surveyed by: Dr. James Nevels
Date of Survey: December 10, 2014

Approx. Location	Munsell Color	Sub-Horizon	Depth (inches)	LL	PI	Percent Passing				Classification			pH	Resistivity (Ω-cm)	Description
						#4	#10	#40	#200	AASHTO	USCS	OSI			
Along US 169 right of way North of Pine St. NW ¼ SW ¼ of Sec 30 542 Ft. N, 1043 Ft. W of SE corner of Section 30	**Dennis Series**														
	10YR3/2	A	0-12	39	18	99	98	94	84.6	A-6(15)	CL	15.0	7.4	3600	Lean Clay w/ Sand
	10YR4/3	AB	12-15	41	19	97	88	84	77.3	A-7-6(14)	CL	15.8	7.5	1200	Lean Clay w/ Sand
	10YR4/3	BA	15-18	43	19	96	90	84	76.7	A-7-6(15)	CL	16.2	7.0	3600	Lean Clay w/ Sand
	10YR5/4	Bt1	18-24	44	22	93	88	81	72.7	A-7-6(15)	CL	17.6	4.7	2900	Lean Clay w/ Sand
	10YR5/4	Bt2	24-30	47	24	95	91	83	73.6	A-7-6(17)	CL	19.0	5.2	2400	Lean Clay w/ Sand
	10YR5/6	Bt3	30-36	49	28	98	93	86	77.3	A-7-6(22)	CL	21.0	5.6	2100	Lean Clay w/ Sand
	10YR5/6	Bt4	36-50	58	35	89	83	76	69.4	A-7-6(24)	CH	25.1	6.3	1600	Sandy Fat Clay
	10YR6/6	Bt5	50-61	55	32	94	90	81	71.0	A-7-6(22)	CH	23.5	6.9	1500	Fat Clay w/ Sand
													Sulfate Content (ppm)		
	B Composite		15-61	48	25	100	97	94	87.4	A-7-6(23)	CL	19.6	N/A		Lean Clay

Figure 3.3 A snippet of a pedological soil survey report

gINT FILE: Klf_gint_master_2016
gINT TEMPLATE: E:KLF_STANDARD_GINT_LIBRARY_2016.GLB [LAB SUMMARY TABLE - OKLAHOMA (SHLR_IP)] PLOTTED: 10/04/2016 06:49 AM BY: swang

Field No.	Soil Group	Station	Description	Depth* (in)	LL	PI	Percent Passing						OSI	Water Content (%)	Soluble Sulfates (mg/kg)
							Passing 3 in.	Passing 3/4 in.	Passing #4	Passing #10	Passing #40	Passing #200			
1A	A-4(0)	1067+52 8.5' Lt.	SANDY SILT	9 - 21	NP	NP	100	100	98	96	90	65		12.8	
2A	A-1-a(0)	1080+04 8' Rt.	POORLY GRADED GRAVEL WITH SILT AND SAND	4 - 16	NP	NP	100	93	38	25	16	5.8		4.2	
3A	A-2-4(0)	1087+44 8' Lt.	SILTY SAND WITH GRAVEL	6 - 18	19	3	100	100	84	75	64	29		11.5	
4A	A-2-4(0)	1100+69 7' Rt.	SILTY SAND WITH GRAVEL	6 - 18	20	3	100	100	83	73	60	29		10.1	
5A	A-2-4(0)	1107+47 9' Lt.	SILTY, CLAYEY SAND	6 - 18	21	4	100	100	92	84	72	35		12.0	
6A	A-2-4(0)	1120+19 8' Rt.	SILTY SAND WITH GRAVEL	8 - 20	NP	NP	100	100	85	75	64	31		8.0	
7A	A-4(0)	1127+50 8.5' Lt.	SILTY SAND	11 - 23	NP	NP	100	100	95	84	69	36		8.3	
8A	A-4(1)	1141+11 7' Rt.	SILTY SAND	7 - 19	17	1	100	100	94	90	82	38		6.9	
9A	A-2-4(0)	1147+45 9' Lt.	SILTY SAND	7 - 19	NP	NP	100	100	86	74	54	25		8.8	
10A	A-4(0)	1160+47 7' Rt.	SILTY SAND	9 - 21	NP	NP	100	100	89	83	75	38		9.9	
11A	A-2-4(0)	1167+57 9' Lt.	SILTY SAND	9 - 21	18	1	100	100	88	76	59	28		10.1	
12A	A-2-4(0)	1180+59 8.5' Rt.	SILTY SAND WITH GRAVEL	8 - 20	19	3	100	100	79	67	52	21		9.6	
13A	A-2-4(0)	1187+57 9' Lt.	SILTY SAND	9 - 21	NP	NP	100	100	86	76	63	23		7.4	
14A	A-2-4(0)	1200+11 7.5' Rt.	SILTY SAND	5 - 17	18	1	100	100	88	80	72	34		9.9	
15A	A-4(0)	1201+99 9' Lt.	SILTY SAND	10 - 22	18	NP	100	100	95	89	83	40		13.3	
16A	A-6(10)	1220+21 8.5' Rt.	SANDY LEAN CLAY	9 - 21	33	19	100	100	95	93	91	68		17.3	
17A	A-4(3)	1222+60 8' Lt.	SANDY SILT	10 - 22	21	3	100	100	95	93	89	52		14.9	
18A	A-4(2)	1240+31 7.5' Rt.	CLAYEY SAND	10 - 19	25	10	100	100	94	92	91	46		12.7	
19A	A-4(1)	1242+65 8.5' Lt.	SILTY, CLAYEY SAND	9 - 21	23	7	100	100	95	93	89	42		11.2	
20A	A-6(3)	1260+26 8.5' Rt.	CLAYEY SAND WITH GRAVEL	9 - 21	31	17	100	91	85	82	78	42		15.3	
21A	A-6(8)	1262+48 8' Lt.	LEAN CLAY WITH SAND	9 - 21	27	12	100	100	99	99	97	70		21.4	
22A	A-4(3)	1280+18 8' Rt.	SANDY SILTY CLAY	11 - 23	24	6	100	100	95	92	88	52		14.7	
23A	A-4(0)	1282+48 8' Lt.	SILTY SAND	8 - 20	NP	NP	100	100	95	91	86	38		12.2	
24A	A-4(0)	1300+32 8' Rt.	SANDY SILT	8 - 20	NP	NP	100	100	100	99	98	55		15.7	
25A	A-4(1)	1312+61 9' Lt.	SILTY SAND	6 - 18	19	2	100	100	96	94	91	38		10.7	
26A	A-2-4(0)	1320+06 8' Rt.	SILTY SAND	8 - 20	19	2	100	100	93	90	88	35		9.4	
27A	A-2-4(0)	1332+58 7.5' Lt.	SILTY, CLAYEY SAND	8 - 20	20	4	100	100	92	88	85	34		9.9	

Refer to the Geotechnical Evaluation Report or the supplemental plates for the method used for the testing performed above.
NP = Nonplastic

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PROJECT NO.:20171966-4
DRAWN BY: MAP
CHECKED BY: SYW
DATE: 9/26/2016
REVISED: -

LABORATORY TEST RESULT SUMMARY

Pavement and Subgrade Soil Survey
SH 7 in Atoka County
State J/P No. 24006(04) & 24006(06)
Atoka County, Oklahoma

TABLE
B-1

KLEINFELDER - 10835 E. Independence, Suite 102 | Tulsa, OK 74116 | PH: 918.627.6161 | FAX: 918.627.6262 | www.kleinfelder.com

Figure 3.4 A snippet of a pavement and subgrade soil survey report

3.2 Development of an Excel Template for Soil Database

As the type and level of information available in the geotechnical reports varied significantly, it was necessary for the OU team to develop a soil database template that will incorporate necessary soil properties used as input parameters in designing new pavements and rehabilitation of existing pavements. For this purpose, the input requirements of the two most commonly used pavement design methods, namely AASHTO 1993 design [1] and AASHTOWare Pavement ME Design [2] were reviewed. The AASHTO 1993 design is based on the results obtained from the AASHO Road Test in the late 1950s and early 1960s [3]. The design guides were published by the AASHTO Committee on Design (1961 original, and then revised in 1972, 1981, 1986, and 1993). After several modifications to incorporate reliability and environmental effects, the current AASHTO 1993 design equation for flexible pavement took the form presented in Equation (1). Equation (1) is generally represented by a nomograph shown in

Figure 3.5. It was found that the only soil information needed for the flexible pavement design using the AASHTO 1993 method was resilient modulus (*M_R*).

$$logW_{18} = Z_R S_0 + 9.36\log(SN+1) - 0.20 + \frac{\log\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.4+1094/(SN+1)^{5.19}} + 2.32logM_R - 8.07 \quad (1)$$

where, W_{18} = No. of 18-kip single-axle load applications, *ΔPSI* = terminal serviceability index, Z_R = normal deviate for a given reliability R, and S_0 = standard deviation, *SN* = structural number, M_R = resilient modulus of soil.

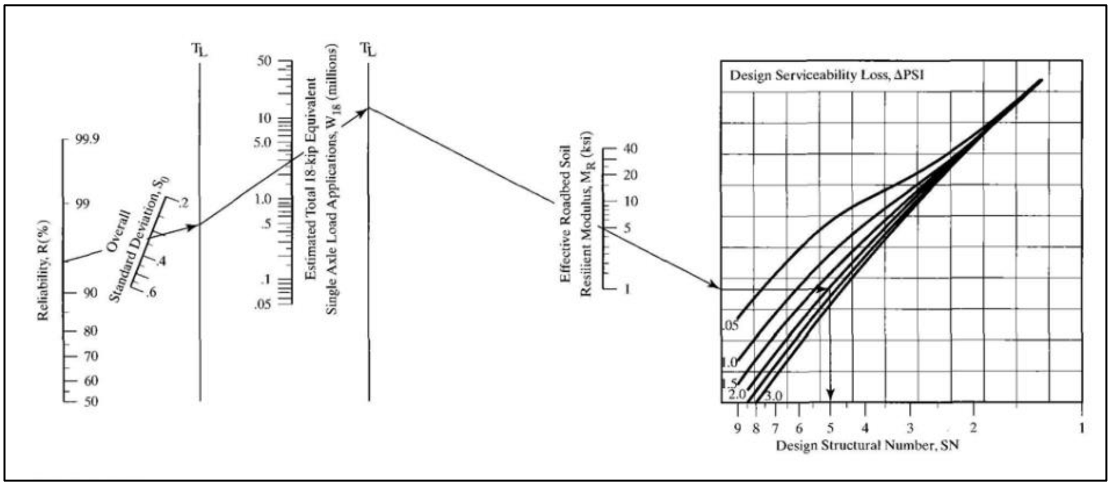


Figure 3.5 Nomograph for flexible pavement design using AASHTO 1993 Method

The design equation for rigid pavement using the AASHTO 1993 method is presented in Equation (2). The rigid pavement design uses modulus of subgrade reaction (k) as the input for soil. The k value can be determined in the field or estimated based on resilient modulus (*M_R*) of soil using Equation (3).

$$logW_{18} = Z_R S_o + 7.35\log(D+1) - 0.06 +$$

$$\frac{\log\left[\frac{\Delta PSI}{4.5-1.5}\right]}{1+1.624*10^7/(D+1)^{8.46}} + (4.22 - 0.32p_t)\log\left\{\frac{S_C C_d(D^{0.75}-1.132)}{215.63J\left[D^{0.75}-\frac{18.42}{(\frac{E_C}{k})^{0.25}}\right]}\right. \quad (2)$$

where, Z_R = Reliability level (%); S_o = standard deviation; ΔPSI = change in serviceability; S_C = modulus of rupture of concrete; C_d = Drainage coefficient; J = load transfer coefficient; *k* = modulus of subgrade reaction; E_c = modulus of elasticity of concrete.

$$k = \frac{M_R}{19.4} \quad (3)$$

where, k is in pci, and M_R in psi

The Pavement ME Design software uses a mechanistic-empirical design methodology to determine pavement performance at specific traffic and environmental conditions. Mechanistic principles are used to determine pavement responses due to traffic and environment, and transfer functions are used to convert the responses to different pavement distresses. The Pavement ME Design software requires detailed information about the engineering properties of soil for designing new pavement and rehabilitation of existing pavement. Figure 3.6 shows a snippet of the soil input window in Pavement ME Design. The input parameters for soil in Pavement ME Design generally include, resilient modulus, gradation, soil classification, Atterberg limits, hydraulic conductivity, maximum dry density, water content, compaction information, and parameters for soil-water characteristic curve (SWCC).

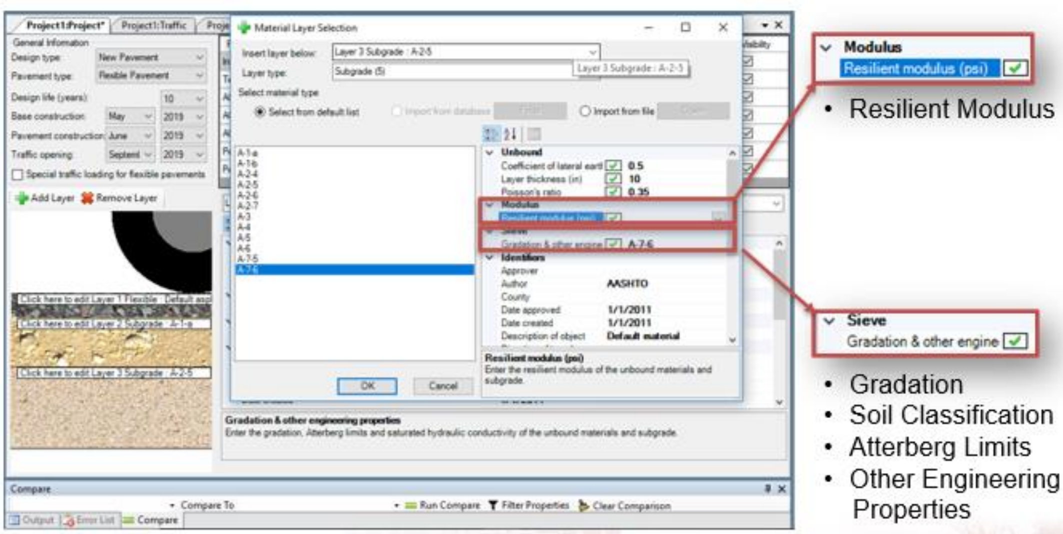
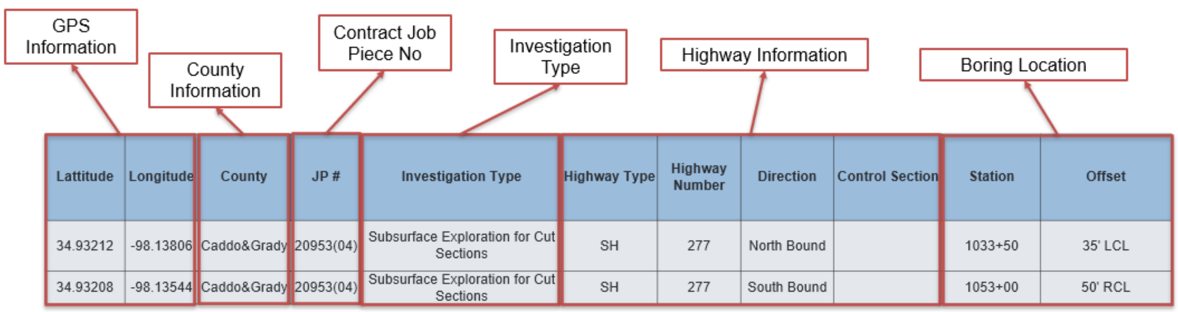


Figure 3.6 Snippet of the soil input window in AASHTOWare Pavement ME

Based on the review of the geotechnical reports and soil input requirements in AASHTO 1993 and Pavement ME Design, the OU team developed an Excel template that included the most necessary geotechnical parameters for pavement design. Also, the template was organized in an effective and logical way to ease incorporation of the database into ODOT GIS system. The template was presented to ODOT staff in a progress meeting held on June 10, 2021 and sought feedback. The database template was modified and finalized based on the inputs from ODOT staff.

The template included information related to project site, boring ID, location and depths, engineering and geologic properties of soil and reference information. In this template, soil data were recorded based on (Figure 3.7):

- GPS location (latitude and longitude of boring)
- JP# (contract Job Piece Number)
- Investigation type (pavement and subgrade soil survey, shoulder soil survey, pedological survey, embankment survey, cut section and investigation for bridge)
- County (county where the project took place)
- Highway information (highway type and number, direction, and control section number)
- Station and offset (boring location from construction plan)



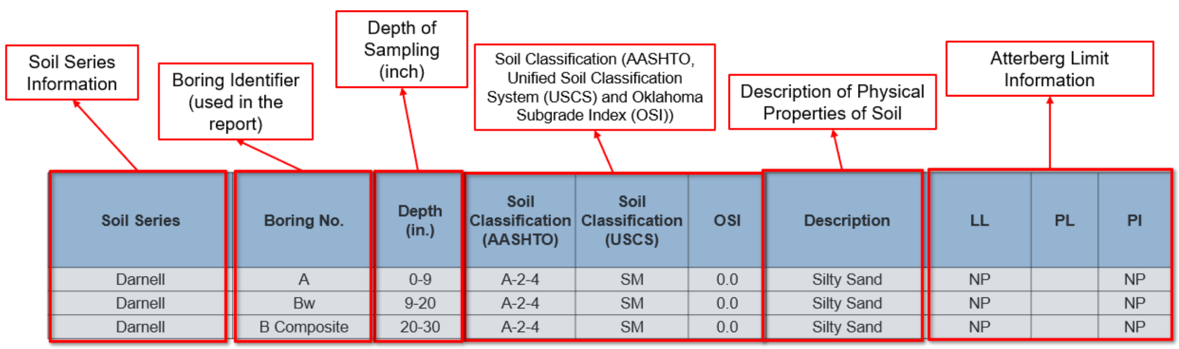
Lattitude	Longitude	County	JP #	Investigation Type	Highway Type	Highway Number	Direction	Control Section	Station	Offset
34.93212	-98.13806	Caddo&Grady	20953(04)	Subsurface Exploration for Cut Sections	SH	277	North Bound		1033+50	35' LCL
34.93208	-98.13544	Caddo&Grady	20953(04)	Subsurface Exploration for Cut Sections	SH	277	South Bound		1053+00	50' RCL

Figure 3.7 Snippet of the database template - location information

The engineering and geologic properties included in the database are presented in Figures 3.8 and 3.9 and mentioned in the following section:

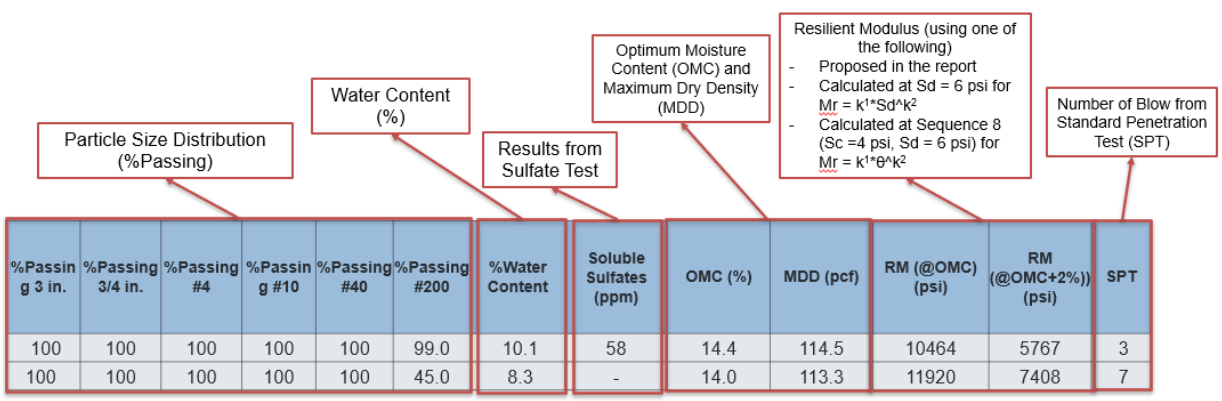
- Soil series (name of the series the soil was sampled from, mentioned separately from boring number in the database)
- Boring number and depth (boring identifier (used in the report) and depth of sampling)
- Soil classification (Soil Classification (AASHTO, Unified Soil Classification System (USCS) and Oklahoma Subgrade Index (OSI)). Group Index (GI) values were not included in the database, as suggested by the ODOT Materials Division, for the convenience of searching based on soil classification.
- Soil description (description of physical properties of soil, e.g., soil type, color, and hardness/stiffness)
- Atterberg limits (Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI))
- Particle size distribution (%Passing: 3-inch, ¾-inch, #4, #10, #40 and #200)
- Water content (amount of water in soil, in percent (%))
- Soluble sulfate (amount of sulfate in soil, parts per million (ppm))

- Optimum Moisture Content (OMC) (in percent (%)) and Maximum Dry Density (MDD) (in pcf)
- Resilient modulus: Resilient modulus value for both at OMC and OMC+2% were Included. Design resilient modulus was based on one of the following:
  - Proposed in the report
  - Calculated at Sd = 6 psi for Mr = k^1*Sd^k^2 [Sd = Deviatoric Stress]
  - Calculated at Sequence 8 (Sc =4 psi, Sd = 6 psi) for Mr = k^1*θ^k^2 [θ = Bulk Stress]
  - The estimated values are marked with an asterisk (*) in the database.
- Standard Penetration Test (SPT) (number of blows/foot)
- Information related to parent materials and depth to bedrock (inch)
- Drainage and Permeability (qualitative information)
- Shrink/swell factor (information related to earthwork volume calculation)



Soil Series	Boring No.	Depth (in.)	Soil Classification (AASHTO)	Soil Classification (USCS)	OSI	Description	LL	PL	PI
Darnell	A	0-9	A-2-4	SM	0.0	Silty Sand	NP		NP
Darnell	Bw	9-20	A-2-4	SM	0.0	Silty Sand	NP		NP
Darnell	B Composite	20-30	A-2-4	SM	0.0	Silty Sand	NP		NP

Figure 3.8 Snippet of the database template – soil series, boring information, soil classification and Atterberg limits

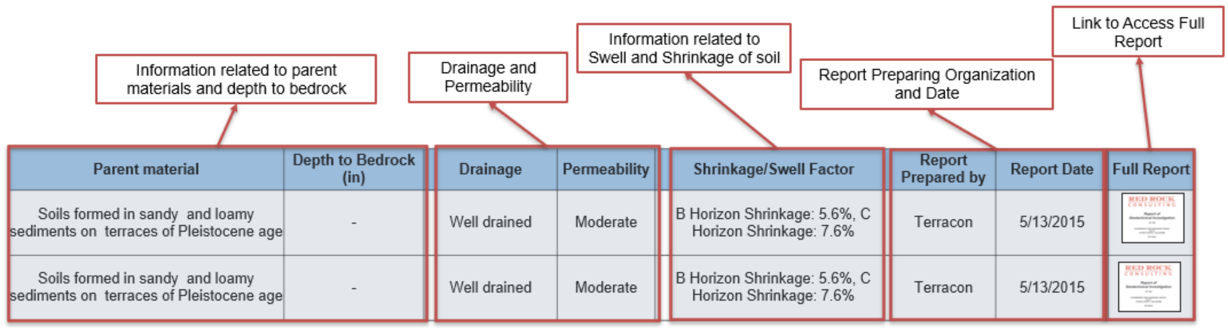


%Passing 3 in.	%Passing 3/4 in.	%Passing #4	%Passing #10	%Passing #40	%Passing #200	%Water Content	Soluble Sulfates (ppm)	OMC (%)	MDD (pcf)	RM (@OMC) (psi)	RM (@OMC+2%)) (psi)	SPT
100	100	100	100	100	99.0	10.1	58	14.4	114.5	10464	5767	3
100	100	100	100	100	45.0	8.3	-	14.0	113.3	11920	7408	7

Figure 3.9 Snippet of the database template – soil gradation, water content, soluble sulfate, OMC, MDD, resilient modulus and SPT

In addition, the database included some referencing information and link to access full report (Figure 3.10):

- Report preparing organization and date
- Link to access full report (a weblink to access the full report)



Parent material	Depth to Bedrock (in)	Drainage	Permeability	Shrinkage/Swell Factor	Report Prepared by	Report Date	Full Report
Soils formed in sandy and loamy sediments on terraces of Pleistocene age	-	Well drained	Moderate	B Horizon Shrinkage: 5.6%, C Horizon Shrinkage: 7.6%	Terracon	5/13/2015	
Soils formed in sandy and loamy sediments on terraces of Pleistocene age	-	Well drained	Moderate	B Horizon Shrinkage: 5.6%, C Horizon Shrinkage: 7.6%	Terracon	5/13/2015	

Figure 3.10 Snippet of the database template – soil taxonomy, drainage, permeability, shrink/swell, and reference information

3.3 Extraction of Necessary Data

After developing the template, the OU team started populating the database by extracting necessary geotechnical properties of soil from the collected reports. Depending on the type and organization of the geotechnical reports, the effort needed for the extraction of the necessary data varied significantly. Also, the OU team faced significant challenges extracting GPS locations of borings which were essential for integrating the database into ODOT GIS system. It was found that the GPS locations of borings were provided in only few geotechnical reports. Also, many of the reports were lacking construction plan or boring location map. For the reports contained boring location map, Google Earth and/or Google Map were used to obtain GPS locations by matching with the map. GPS locations for the reports with construction plan were obtained from Google Earth and/or Google Map using the station number and offset information. In absence of a project map or boring location map, the Beginning of a Project (BOP) was identified using the site description and all the data were referenced to that location. All the GPS locations were verified by checking the database with OU GIS system. Also, the OU team has added weblinks in the Excel database (to each data point) that provide access to the full geotechnical reports corresponding to the boring locations.

A total of 378 reports, out of approximately 1500 reports, were covered during this Task Order. These geotechnical reports involved thirteen (13) counties of Oklahoma. The counties were Adair, Alfalfa, Atoka, Beckham, Blaine, Bryan, Caddo, Canadian, Carter, Cleveland, Garvin, Oklahoma, and Tulsa (Figure 3.11). Initially, the OU team started extracting data following the alphabetic order of the counties. However, later the focus was changed to cover reports from counties that had significantly higher number of investigations. During this Task Order, approximately 10,000 data points were created. Table 3.1 presents the number and type of reports covered from each county. A sample of the extracted data is presented in Appendix A.

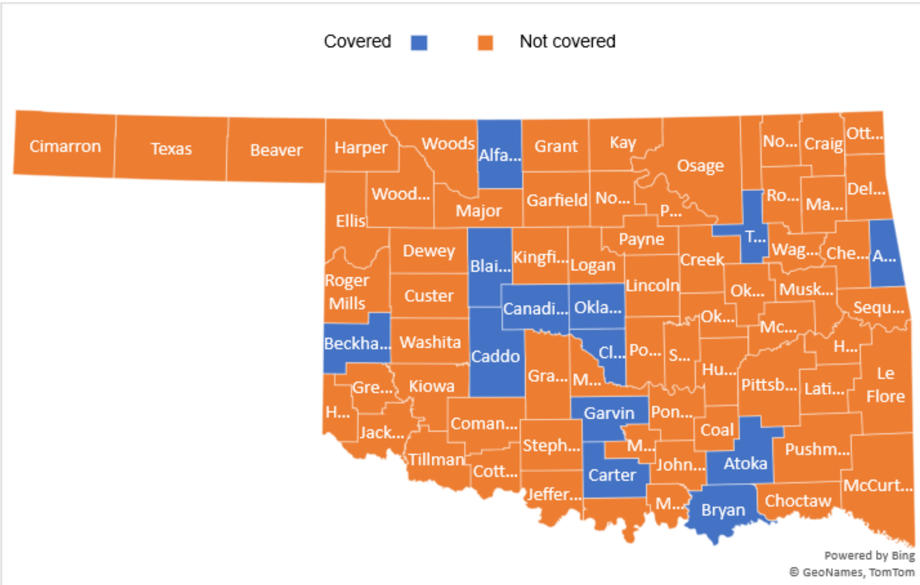


Figure 3.11 Map showing counties covered during the current Task Order

Table 3.1 Summary of reports covered during the current Task Order

Counties	Pavement and Subgrade	Pedological and Geological Survey	Shoulder	Embankment	Cut Section	Bridge	Total
Adair	1	5	2	2	4	0	14
Alfalfa	5	4	1	0	0	1	11
Atoka	5	5	3	0	1	1	15
Beckham	7	7	2	6	-	-	22
Blaine	6	4	3	4	0	1	18
Bryan	10	12	6	11	2	-	41
Caddo	10	10	8	7	2		37
Canadian	9	8	1	2	-	-	20
Carter	7	9	2	7	1		27
Cleveland	5	4	1	2	-	-	12
Garvin	17	8	4	5	-	-	34
Oklahoma	8	10	3	3	1	-	25
Tulsa	32	28	15	17	7	3	102
						Total	**378**

4. DEVELOPMENT OF A GIS-BASED INTERACTIVE DATABASE AND SEARCH TOOL

The Excel soil database was used to develop the GIS-based interactive database. As discussed in the project kick-off meeting, the ODOT GIS team agreed to develop the GIS database internally using the provided database. A meeting was held with the ODOT GIS team on July 1, 2021, to discuss the GIS integration of the soil database. The OU team has discussed different features and tools that will help searching and accessing the soil data from the GIS database. The searching tool developed in this Task Order is expected to assist in extracting the soil properties of interest from the database efficiently. The recommendations for integration and searching tool are as follows:

i. **Location marking:** In order to help the user with the search in the ODOT GIS system, it is recommended to mark the boring locations using corresponding Job Piece Number. Job Piece Number is a unique number assigned by ODOT to each project during letting. Location marking with Job Piece Number will help to separate data from different projects. Also, different colors can be used for different Job Piece Number. It will help to visually differentiate different projects. Figure 4.1 shows an example of marking boring locations with Job Piece Number. Alternatively, boring locations can be marked using 'Boring ID' mentioned in the corresponding report. Figure 4.2 shows an example of location marking using 'Boring ID'.

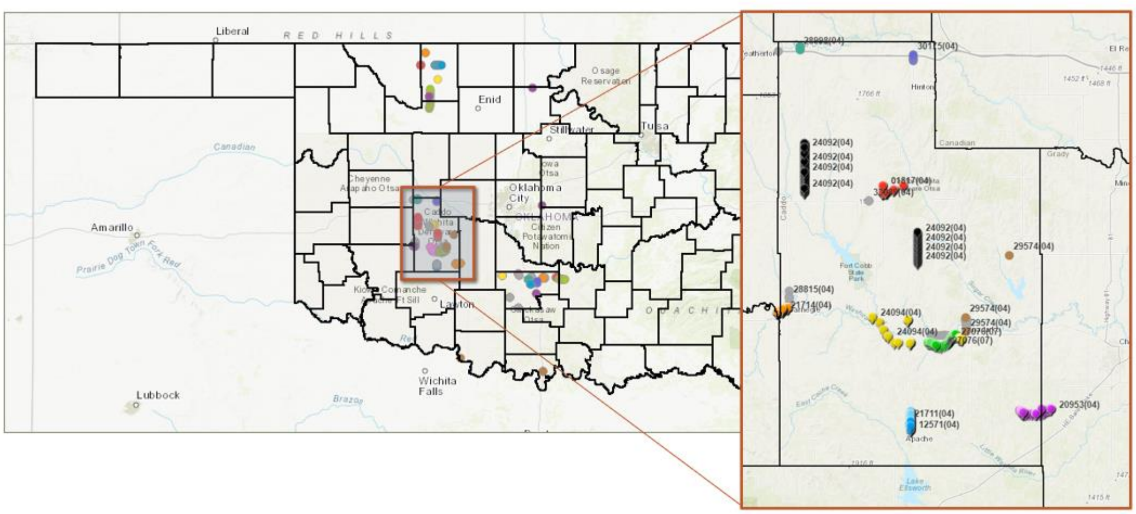


Figure 4.1 Marking boring locations with Job Piece Number (colors used to differentiate projects)

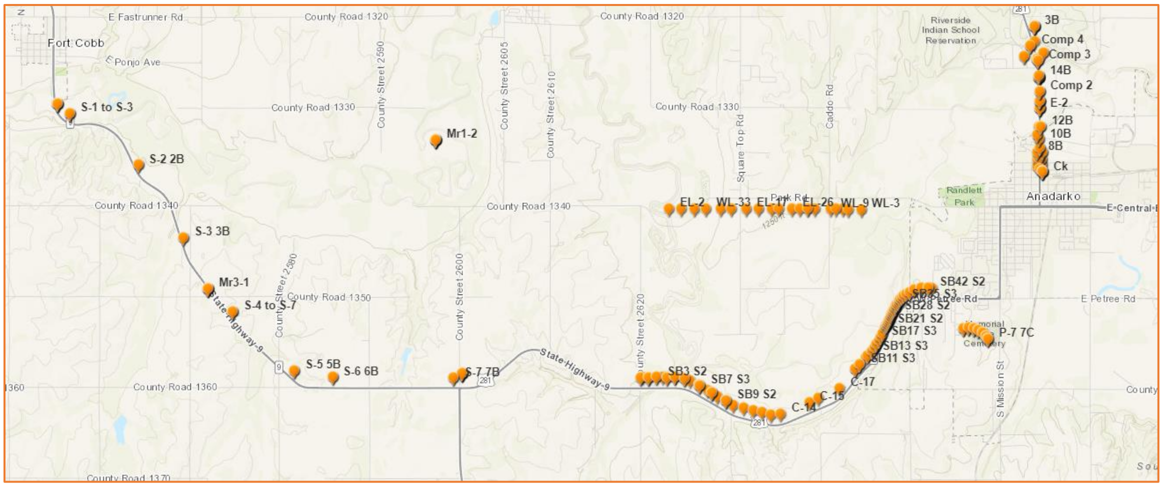


Figure 4.2 Marking boring locations with ‘Boring ID’

ii. **Clustering points to identify location with high intensity of data:** During Zoomed out state of the map, it is recommended to show points as clusters. Cluster will help to identify locations with more data points on a particular highway or county. Also, options can be included to open a pop-up window to show common attributes of the cluster while clicked on the clustered point. Figure 4.3 shows an example of clustering in the GIS system.

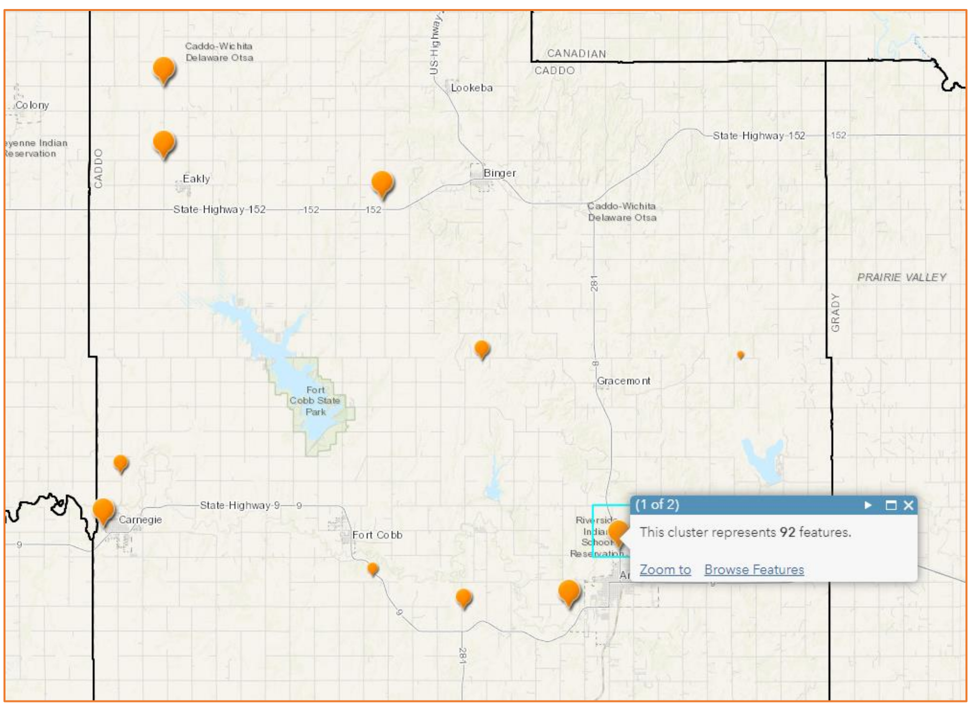


Figure 4.3 Use of cluster to identify locations with more data

iii. **Selection of a point or area of interest:** For the convenience of the user, options can be included to allow selection of a point or an area of interest on the GIS map. In case of a point selection, necessary geotechnical information related to that point (boring) can be viewed using a pop-up window. Figure 4.4 shows an example of point selection of a boring location. For borings with multiple depths entries, it is recommended that the selection of a point will show soil properties of different depths in a tabular format or using a pop-up window (Figure 4.5). In case of selecting an area of interest, soil information of the selected area can be viewed in a tabular format (Figure 4.6). Options can be added in the table to screen necessary geotechnical parameters based on user's interest.

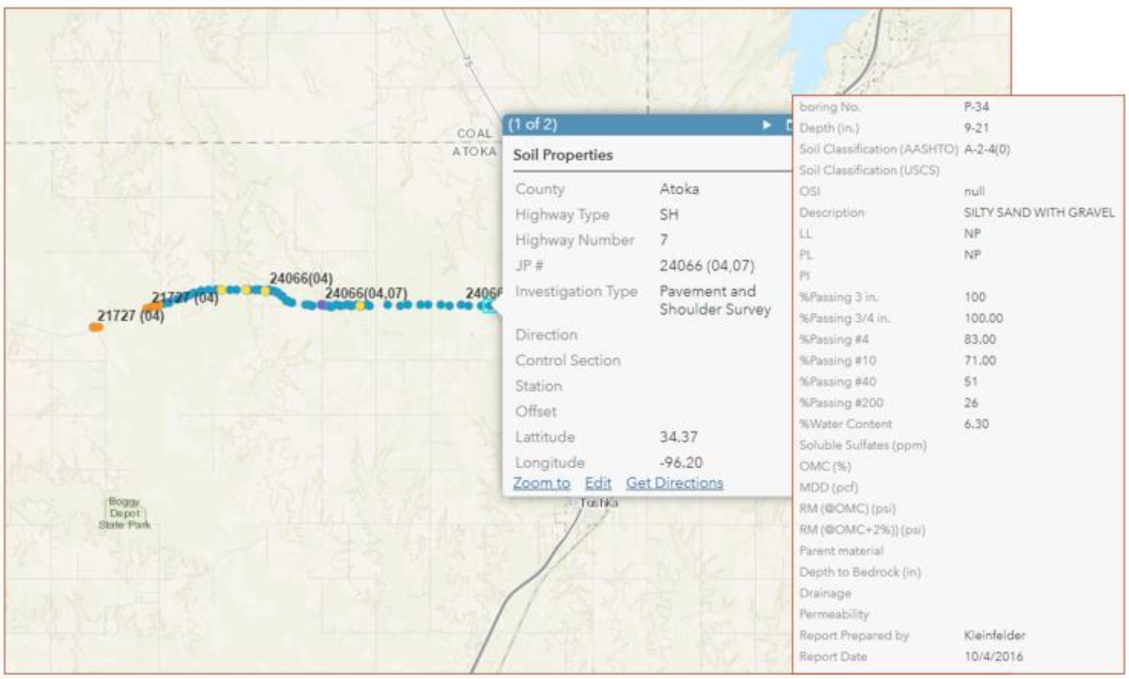
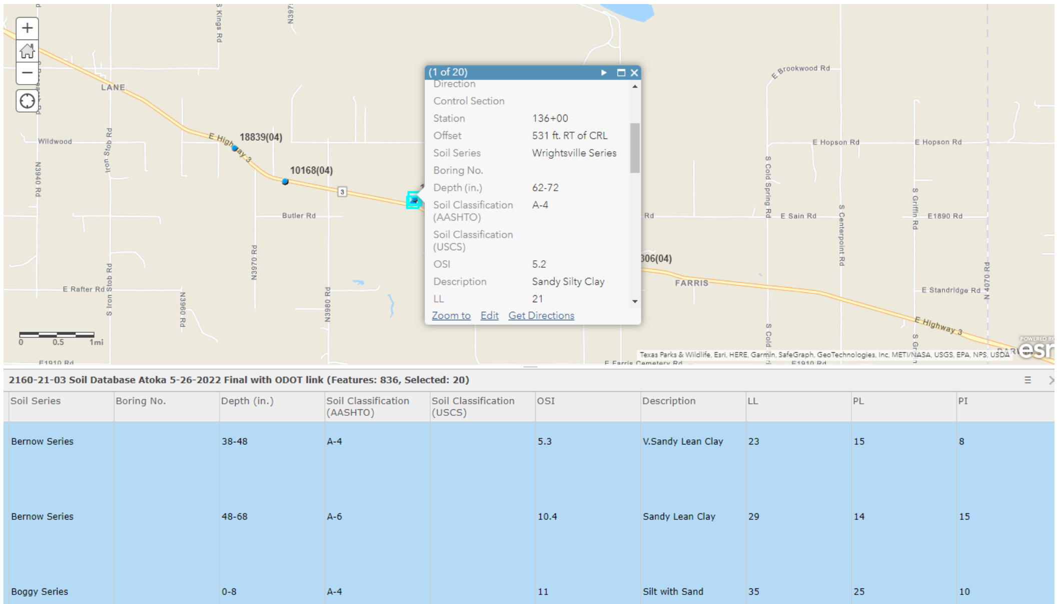
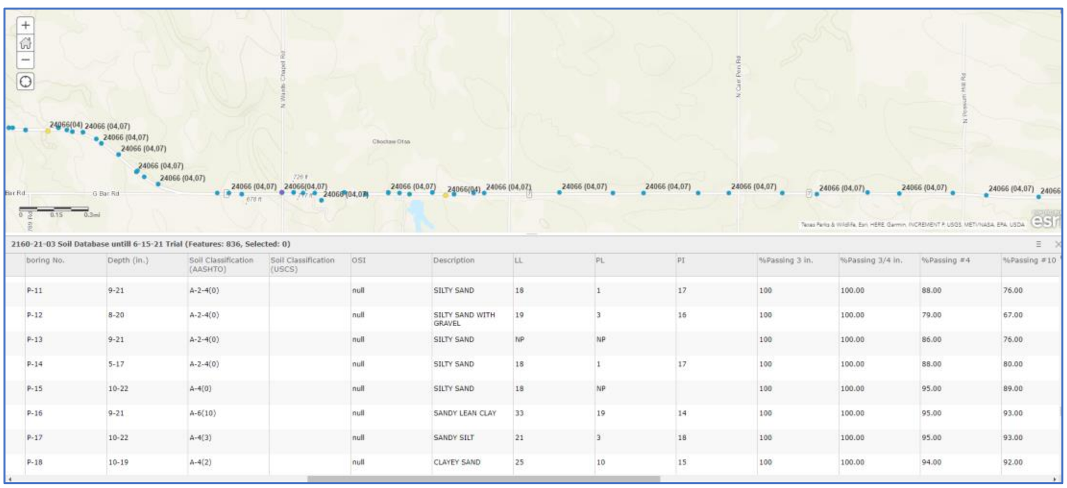


Figure 4.4 Example of point selection and viewing data in a of pop-up window



Soil Series	Boring No.	Depth (in.)	Soil Classification (AASHTO)	Soil Classification (USCS)	OSI	Description	LL	PL	PI
Bernow Series		38-48	A-4		5.3	V.Sandy Lean Clay	23	15	8
Bernow Series		48-68	A-6		10.4	Sandy Lean Clay	29	14	15
Boggy Series		0-8	A-4		11	Silt with Sand	35	25	10

Figure 4.5 Example of viewing data in tabular format for multi-depth entries for a single location



boring No.	Depth (in.)	Soil Classification (AASHTO)	Soil Classification (USCS)	OSI	Description	LL	PL	PI	%Passing 3 in.	%Passing 3/4 in.	%Passing #4	%Passing #10
P-11	9-21	A-2-4(0)		null	SILTY SAND	18	1	17	100	100.00	88.00	76.00
P-12	8-20	A-2-4(0)		null	SILTY SAND WITH GRAVEL	19	3	16	100	100.00	79.00	67.00
P-13	9-21	A-2-4(0)		null	SILTY SAND	NP	NP		100	100.00	86.00	76.00
P-14	5-17	A-2-4(0)		null	SILTY SAND	18	1	17	100	100.00	88.00	80.00
P-15	10-22	A-4(0)		null	SILTY SAND	18	NP		100	100.00	95.00	89.00
P-16	9-21	A-6(10)		null	SANDY LEAN CLAY	33	19	14	100	100.00	95.00	93.00
P-17	10-22	A-4(3)		null	SANDY SILT	21	3	18	100	100.00	95.00	93.00
P-18	10-19	A-4(2)		null	CLAYEY SAND	25	10	15	100	100.00	94.00	92.00

Figure 4.6 Example of viewing data in a tabular format for a selected area of interest

iv. **Access to view full report in GIS:** The OU team has worked with the ODOT GIS team to store the geotechnical reports covered during this Task Order into ODOT directory. Also, as mentioned earlier, the OU team has added weblinks in the Excel database (to each data point) that provide access to the full geotechnical reports corresponding to the boring locations. After incorporating the Excel database into ODOT GIS system, same links can be used to call the geotechnical reports from ODOT directory. It is recommended that the option to access and view full geotechnical report be included in the ODOT GIS system. The link can be included in the pop-up window which appear during the selection of a boring location. As shown in Figure 4.7, the full report can be viewed in a new window by selecting the link.

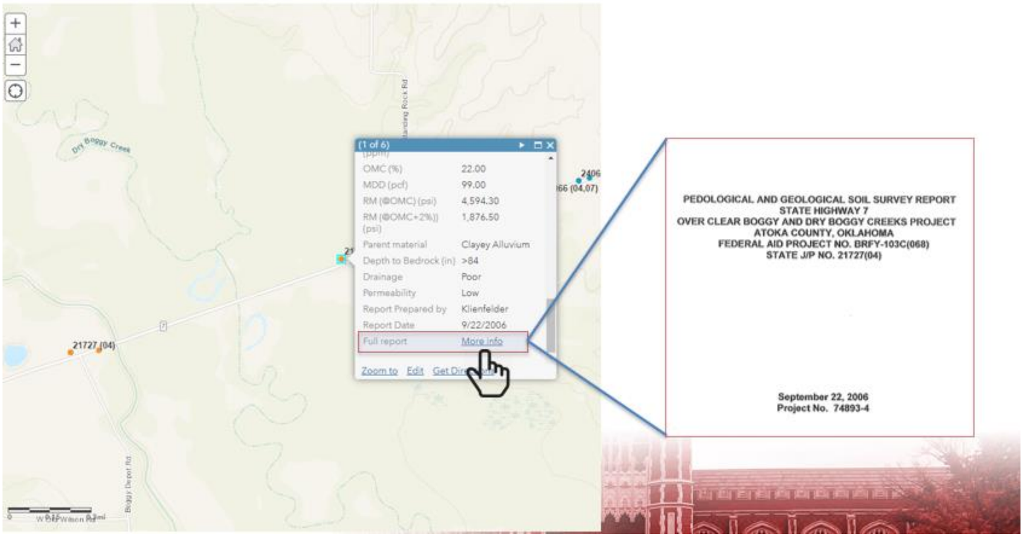


Figure 4.7 Example of accessing full report using weblink

v. **Option to customize map based on soil properties:** It is recommended to provide options to customize map using different soil properties (e.g., RM, LL, PI, Soil Classification etc.). This feature will help with the visualization and extraction of information necessary for pavement design. Figure 4.8 shows an example of map customization based on soil classification.

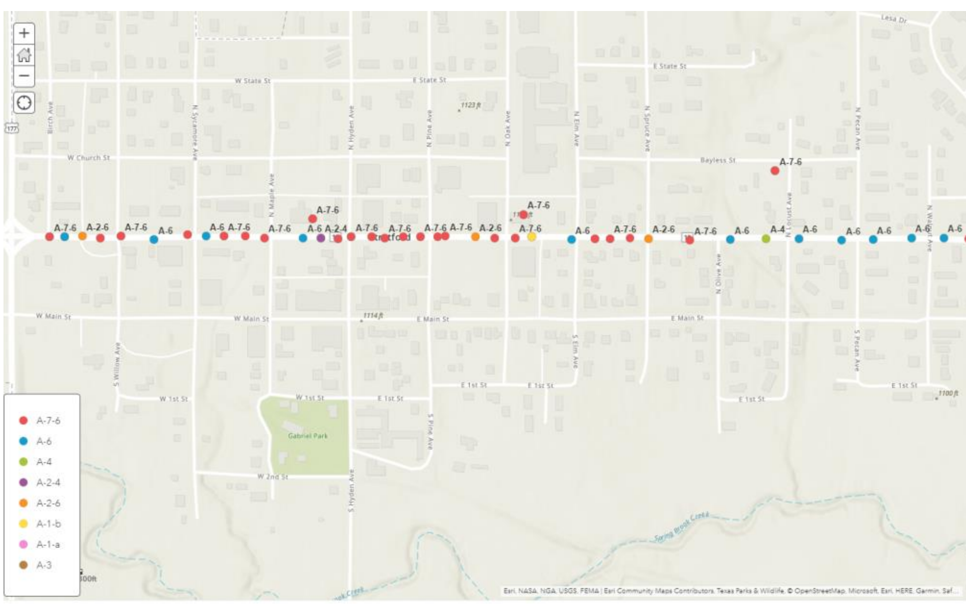


Figure 4.8 Example of customizing map based on soil type

5. CONCLUSIONS AND RECOMMENDATIONS

The main objective of this Task Order was to develop a GIS-based interactive database that can be readily used for estimating soil properties for pavement design/rehabilitation. For this purpose, the OU team has collected geotechnical reports from the ODOT Roadway Design Division in CDs and electronic format. An initial review was performed by scanning through all the geotechnical investigation reports to understand the report organization and update current report folders. Based on the review of the geotechnical reports and soil input requirements for AASHTO 1993 and Pavement ME Design, an Excel template was developed that included the most necessary geotechnical parameters for pavement design/rehabilitation. Using the template, an Excel database was developed by extracting data from the collected geotechnical reports. The database was shared with the ODOT GIS team and incorporated into ODOT GIS system. Recommendations for data integration and searching features for the GIS-based interactive database are included in this report. Following recommendations were proposed for the future development of the database:

i. Data from a total of 378 geotechnical reports out of approximately 1,500 reports were extracted in the database developed in this Task Order. Additional reports can be added to the database in a follow-up Task Order.
ii. The OU team faced significant challenges in extracting GPS information from the reports. ODOT may recommend geotechnical companies to include appropriate GPS information in future geotechnical reports.
iii. ODOT may want geotechnical companies to include raw data files (Excel, gNIT) with their reports. This will help with the incorporation of future data into the database.
iv. Auto incorporation of future geotechnical reports into the database regularly (weekly/monthly) may be pursued internally or through a Task Order.

REFERENCES

[1] American Association of State Highway and Transportation Officials (AASHTO) (1993). AASHTO Guide for Design of Pavement Structures, 1993 (Vol. 1). AASHTO.

[2] AASHTOWare Pavement ME Design (last access March 28, 2022), https://me-design.com/MEDesign/?AspxAutoDetectCookieSupport=1

[3] Huang, Y.H. (2004), “Pavement Analysis and Design (2nd Edition),” Pearson, ISBN 10: 0131424734, ISBN: 9780131424739.

APPENDIX A: SAMPLE OF EXCEL DATABASE

Table A.1 Sample extracted data from geotechnical reports

Lattitude	Longitude	County	JP #	Investigation Type	Highway Type	Highway Number	Direction	Control Section	Station	Offset
36.79728	-98.37729	Alfalfa	24064(04)	In-Place Soils	SH	64			1120+00	8' Rt
36.79728	-98.37729	Alfalfa	24064(04)	In-Place Soils	SH	64			1120+00	8' Rt
36.79728	-98.37729	Alfalfa	24064(04)	In-Place Soils	SH	64			1120+00	8' Rt
36.79734	-98.37445	Alfalfa	24064(04)	In-Place Soils	SH	64			1128+55	6' Lt
36.79734	-98.37445	Alfalfa	24064(04)	In-Place Soils	SH	64			1128+55	6' Lt
36.79734	-98.37445	Alfalfa	24064(04)	In-Place Soils	SH	64			1128+55	6' Lt
36.79729	-98.37098	Alfalfa	24064(04)	In-Place Soils	SH	64			1139+75	8' Rt
36.79729	-98.37098	Alfalfa	24064(04)	In-Place Soils	SH	64			1139+75	8' Rt
36.79733	-98.3678	Alfalfa	24064(04)	In-Place Soils	SH	64			1148+75	6' Lt
36.79733	-98.3678	Alfalfa	24064(04)	In-Place Soils	SH	64			1148+75	6' Lt
36.7973	-98.3638	Alfalfa	24064(04)	In-Place Soils	SH	64			1159+80	8' Rt
36.7973	-98.3638	Alfalfa	24064(04)	In-Place Soils	SH	64			1159+80	8' Rt
36.7973	-98.3638	Alfalfa	24064(04)	In-Place Soils	SH	64			1159+80	8' Rt
36.79731	-98.36024	Alfalfa	24064(04)	In-Place Soils	SH	64			1170+50	8' Lt
36.79731	-98.36024	Alfalfa	24064(04)	In-Place Soils	SH	64			1170+50	8' Lt
36.79727	-98.3573	Alfalfa	24064(04)	In-Place Soils	SH	64			1179+75	8' Rt
36.79722	-98.35422	Alfalfa	24064(04)	In-Place Soils	SH	64			1188+60	9' Lt
36.79722	-98.35422	Alfalfa	24064(04)	In-Place Soils	SH	64			1188+60	9' Lt
36.79724	-98.35067	Alfalfa	24064(04)	In-Place Soils	SH	64			1199+75	8' Rt
36.79724	-98.35067	Alfalfa	24064(04)	In-Place Soils	SH	64			1199+75	8' Rt
36.79726	-98.34759	Alfalfa	24064(04)	In-Place Soils	SH	64			1208+60	8' Lt
36.79726	-98.34759	Alfalfa	24064(04)	In-Place Soils	SH	64			1208+60	8' Lt
36.7972	-98.34328	Alfalfa	24064(04)	In-Place Soils	SH	64			1219+80	8' Rt
36.7972	-98.34328	Alfalfa	24064(04)	In-Place Soils	SH	64			1219+80	8' Rt
36.79722	-98.34077	Alfalfa	24064(04)	In-Place Soils	SH	64			1228+60	9' Lt
36.79717	-98.33668	Alfalfa	24064(04)	In-Place Soils	SH	64			1239+75	7' Rt
36.79717	-98.33668	Alfalfa	24064(04)	In-Place Soils	SH	64			1239+75	7' Rt
36.79717	-98.33668	Alfalfa	24064(04)	In-Place Soils	SH	64			1239+75	7' Rt
36.79718	-98.33367	Alfalfa	24064(04)	In-Place Soils	SH	64			1248+60	8' Lt
36.79718	-98.33367	Alfalfa	24064(04)	In-Place Soils	SH	64			1248+60	8' Lt
36.79714	-98.3305	Alfalfa	24064(04)	In-Place Soils	SH	64			1259+80	6' Rt
36.79714	-98.3305	Alfalfa	24064(04)	In-Place Soils	SH	64			1259+80	6' Rt
36.79715	-98.32767	Alfalfa	24064(04)	In-Place Soils	SH	64			1268+60	7' Lt
36.79715	-98.32767	Alfalfa	24064(04)	In-Place Soils	SH	64			1268+60	7' Lt
36.7971	-98.32318	Alfalfa	24064(04)	In-Place Soils	SH	64			1279+90	8' Rt
36.7971	-98.32318	Alfalfa	24064(04)	In-Place Soils	SH	64			1279+90	8' Rt
36.79713	-98.31995	Alfalfa	24064(04)	In-Place Soils	SH	64			1288+65	9' Lt
36.79713	-98.31995	Alfalfa	24064(04)	In-Place Soils	SH	64			1288+65	9' Lt
36.7971	-98.31621	Alfalfa	24064(04)	In-Place Soils	SH	64			1299+75	9' Rt
36.79707	-98.3129	Alfalfa	24064(04)	In-Place Soils	SH	64			1308+75	8' Lt
36.79707	-98.3129	Alfalfa	24064(04)	In-Place Soils	SH	64			1308+75	8' Lt
36.79728	-98.37788	Alfalfa	24064(04)	Shoulder Soils Survey	SH	64			1119+000	15' Right
36.79728	-98.37788	Alfalfa	24064(04)	Shoulder Soils Survey	SH	64			1119+000	15' Right
36.79736	-98.37647	Alfalfa	24064(04)	Shoulder Soils Survey	SH	64			1124+00	13' Left
36.79728	-98.37437	Alfalfa	24064(04)	Shoulder Soils Survey	SH	64			1129+00	14' Right
36.79728	-98.37437	Alfalfa	24064(04)	Shoulder Soils Survey	SH	64			1129+00	14' Right

Table A.1 Sample extracted data from geotechnical reports (cont.)

Soil Series	Boring No.	Depth (in.)	Soil Classification (AASHTO)	Soil Classification (USCS)	OSI	Description	LL	PL	PI
	C-1	3.8-11.8	A-1-b	SM	0	Silty Sand	NP		NP
	C-1	11.8-27.8	A-2-4	SC-SM	1	Silty Clayey Sand	20		5
	C-1	27.9-39.8	A-6	CL	14	Lean Clay with Sand	34		17
	C-2	4-16		SM		Silty Sand			
	C-2	16-28	A-2-4	SM	0	Silty Sand	19		3
	C-2	28-40	A-6	CL	11	Lean Clay	29		14
	C-3	4.5-16.5	A-2-4	SM	0	Silty Sand	NP		NP
	C-3	16.5-40.5	A-6	CL	11	Lean Clay with Sand	35		19
	C-4	5.8-17.8		SM		Silty Sand			
	C-4	17.8-41.8	A-6	CL	17	Lean Clay with Sand	39		23
	C-5	3.5-15.5	A-2-4	SM	0	Silty Sand	NP		NP
	C-5	15.5-27.5	A-6	CL	8	Sandy Lean Clay	26		14
	C-5	27.5-39.5	A-6	CL	13	Lean Clay	33		16
	C-6	6.5-30.5		SM		Silty Sand			
	C-6	30.5-42.5		CL		Lean Clay	32		17
	C-7	7.3-43.3	A-6	CL	13	Lean Clay	30		14
	C-8	4.5-22.5				Silty Sand			
	C-8	22.5-40.5	A-6	CL	15	Lean Clay	35		19
	C-9	3-27	A-6	CL	8	Sandy Lean Clay	26		11
	C-9	27-39	A-6	CL	14	Lean Clay	16		17
	C-10	4.5-28.5	A-4	SC	5	Clayey Sand	25		10
	C-10	28.5-40.5		CL		Lean Clay			
	C-11	3.5-15.5		SC		Clayey Sand			
	C-11	15.5-39.5	A-6	CL	10	Lean Clay	29		11
	C-12	4.3-22.3	A-4	CL-ML	5	Sandy Silty Clay	23		7
	C-13	22.3-40.3	A-46	CL	11	Lean Clay	30		13
	C-13	4.5-16.5		SC-SM		Silty Sandy Clay			
	C-13	16.5-40.5	A-6	CL	10	Lean Clay with Sand	28		12
	C-14	4.5-28.5		SC-SM		Silty Sandy Clay			
	C-14	28.5-40.5	A-4	CL-ML	7	Silty Clay with Sand	22		7
	C-15	4.5-28.5	A-4	SC-SM	4	Silty Clayey Sand	20		7
	C-15	28.5-40.5	A-6	CL	10	Lean Clay with Sand	26		12
	C-16	3.8-15.8		CL		Sandy lean Clay			
	C-16	15.8-39.8		CL		Sandy Lean Clay			
	C-17	2.8-14.8	A-4	CL	6	Sandy Lean Clay	24		8
	C-17	14.8-38.8	A-4	CL	7	Sandy Lean Clay	22		9
	C-18	3.5-15.5		SM		Silty Sand			
	C-18	15.5-39.5	A-4	CL	7	Lean Clay with Sand	21		8
	C-19	3.0-36.0	A-4	SM	0	Silty Sand	NP		NP
	C-20	4.5-12.5		SM		Silty Sand			
	C-20	12.5-40.5	A-4	CL	7	Sandy Lean Clay	22		9
	B-26	0-24		CL		Sandy Lean Clay			
	B-26	24-36	A-6	CL	8	Sandy Lean Clay	27		13
	B-27	0-36	A-6	CL	9	Sandy Lean Clay	32		13
	B-28	0-36		CL		Lean Clay with Sand			
	RM 1	0-36	A-6	CL	12	Lean Clay with Sand	34		15

Table A.1 Sample extracted data from geotechnical reports (cont.)

%Passing 3 in.	%Passing 3/4 in.	%Passing #4	%Passing #10	%Passing #40	%Passing #200	%Water Content	Soluble Sulfates (ppm)	OMC (%)	MDD (pcf)	RM (@OMC) (psi)	RM (@OMC +2%)) (psi)	SPT
		88	63	42	18.3	12	720					
		96	79	58	30	5	1993					
		99	98	91	78.5	18	2000					
						5	1240					
		95	79	57	28.3	7	2933					
		100	99	95	87	19	2680					
		94	84	59	27.1	10	440					
		98	96	84	71	15	>8000					
						6	1027					
		100	98	92	83.8	19	>8000					
		93	83	55	23.6	12	720					
		99	91	74	50.9	11	>8000					
		100	99	96	89.4	19	>8000					
						8	>8000					
		100	100	99	92.1	19	7960					
		100	97	93	82.5	16	>8000					
						14	>8000					
		100	98	95	84.3	16	>8000					
		99	96	91	63.6	11	4880					
		100	100	97	85.8	16	227					
		95	83	73	46	8	1133					
						17	3013					
						12	280					
		100	100	98	92.7	18	240					
		96	90	84	54.9	8	240					
		100	99	97	88.4	15	200					
						10	493					
		100	100	97	77.3	15	<200					
						10	240					
		100	100	97	72.1	16	200					
		100	99	93	47.7	6	267					
		100	100	97	73.8	18	200					
						10	640					
						12	213					
		100	98	92	54.4	9	240					
		100	99	94	69.7	9	427					
						8	440					
		100	99	95	70.2	11	<200					
		100	100	95	38.1	7	<200					
						10	213					
		100	99	96	65.4	11	<200					
						5	320					
		98	89	72	53.2	8	<200					
		95	89	75	57.4	8	200					
						7	200					
		97	93	84	72.1	11	240	15.6	108.8	5517	3908	
		97	94	82	66.1	13	<200					
		96.4	87.3	71	51.5	6	<200					

Table A.1 Sample extracted data from geotechnical reports (cont.)

Parent material	Depth to Bedrock (in)	Drainage	Permeability	Shrinkage/Swell Factor	Report Prepared by	Report Date	Full Report
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
					Burgess Engineering And Testing, Inc.	18-Feb-16	0Major%20SH8%2
		Well drained	Moderate		Red Rock Consulting	6-Oct-15	nical/Alfalfa/Alf
		Well drained	Moderate	1.0131	Red Rock Consulting	6-Oct-15	nical/Alfalfa/Alf
		Well drained	Moderate	1.0135	Red Rock Consulting	6-Oct-15	nical/Alfalfa/Alf
		Moderately well drained	Moderate to moderately slow		Red Rock Consulting	6-Oct-15	nical/Alfalfa/Alf
		Moderately well drained	Moderate to moderately slow	1.055	Red Rock Consulting	6-Oct-15	nical/Alfalfa/Alf
		Moderately well drained	Moderate to moderately slow	1.055	Red Rock Consulting	6-Oct-15	nical/Alfalfa/Alf
		Moderately well drained	Moderate to moderately slow	1.055	Red Rock Consulting	6-Oct-15	nical/Alfalfa/Alf
		Moderately well drained	Moderate to moderately slow		Red Rock Consulting	6-Oct-15	nical/Alfalfa/Alf
	336				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	336				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	336				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	336				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	336				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	240				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	240				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	240				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	264				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	264				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	354				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	354				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	354				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
	354				Red Rock Consulting	19-Jun-15	hnical/Alfalfa/Al
					Red Rock Consulting	23-Jul-15	l/Alfalfa/Alfalfa%
					Red Rock Consulting	23-Jul-15	l/Alfalfa/Alfalfa%
					Red Rock Consulting	23-Jul-15	l/Alfalfa/Alfalfa%
					Red Rock Consulting	23-Jul-15	l/Alfalfa/Alfalfa%
					Red Rock Consulting	23-Jul-15	l/Alfalfa/Alfalfa%
					Red Rock Consulting	23-Jul-15	l/Alfalfa/Alfalfa%
					Terracon	3-Nov-15	hnical/Alfalfa/Al
					Terracon	3-Nov-15	hnical/Alfalfa/Al