Development of a DIGGS-Compatible Geotechnical Database from Existing Geotechnical Reports – Phase I

INTERIM FINAL REPORT

ODOT TASK ORDER NUMBER 2160-21-09

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

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OKLAHOMA Transportation

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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)		
^{o}F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^{o}C
		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)		
^{o}C	Celsius	1.8C+32	Fahrenheit	^{o}F
		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

There are 50 or more years' worth of geotechnical data available to the ODOT Geotechnical Engineering Branch, Bridge Division, and Roadway Design Division. Currently, these data are stored in different formats, such as hard copies, scanned images and digital files (.pdf) with limited accessibility. An organized easy-to-use database will help accessing, viewing and retrieving geotechnical information from these reports. The purpose of this task order was to develop a *Data Interchange for Geotechnical and Geoenvironmental Specialists* (DIGGS)-compatible geotechnical database using existing geotechnical reports available at ODOT. For this purpose, the OU team collected geotechnical reports from ODOT Materials Division. A standard excel template was developed to help extract necessary geotechnical information from various types of reports. Using the template, an excel database was developed by extracting data from the collected geotechnical reports. The excel files were then converted to DIGGS XML format. During Phase I, a total of 92 geotechnical reports in pdf format were converted into excel and DIGGS XML. Also, gNIT files collected from ODOT were converted as well. In addition, a preliminary excel template to integrate these databases (excel and DIGGS XML) into ODOT GIS system was developed. The DIGGS-compatible GIS database is expected to benefit ODOT by reducing or eliminating the need and time necessary to conduct new soil borings and test samples. Also, the database can be used as a valuable reference resource to the design and other divisions. An enrich database will help geotechnical engineers at OODT to perform advanced analysis using artificial intelligence/machine learning.

Originally, this project was conceived as a single phase project. Subsequently, it was divided into two phases, based on the discussions with the agency. Phase I was funded by the FFY21 funds ($46,350), while Phase II was funded by the FFY22 funds ($28,650). Allocation of Phase I and Phase II funds was not compatible with the duration (six months for each phase). A no-cost extension was submitted to Office of Research and Implementation (ORI), but it was denied. This will likely impact pursuit of the remaining tasks and the project deliverables. The OU research team is committed to making as much effort as possible to minimize the agency's decision (not approve the NCE).

1. INTRODUCTION

Knowledge of existing soil conditions prior to construction of pavement, bridge or other structures is essential to make informed design decisions and reduce uncertainty during construction. The Oklahoma Department of Transportation (ODOT) has been collecting geotechnical data for many years as part of the construction projects undertaken by the agency. There is 50 or more years' worth of geotechnical data available to the ODOT Geotechnical Engineering Branch, Bridge Division, and Roadway Design Division. Currently, these data are stored in different formats, such as hard copies, scanned images and digital files (.pdf). Geotechnical information in these reports can be a great resource for ODOT Materials and other divisions, if they are organized in an easy-to-use database. Several state DOTs are converting their geotechnical reports into *Data Interchange for Geotechnical and Geoenvironmental Specialists* (DIGGS) format, which utilizes an Extensible Markup Language (XML) structure and labeling convention with elements of Geography Markup Language (GML). Conversion of existing reports to DIGGS format will help access, analyze, filter, and report geotechnical information efficiently both time and effort wise. Also, integrating this database with Geographic Information System (GIS) will help with viewing and retrieving the necessary data efficiently. To address this issue, the Geotchnical Branch Manager at ODOT requested two Task Orders (Development of a DIGGS-Compatible Geotechnical Database from Existing Geotechnical Reports – Phase I and II (2160-21-09 and 2160-22-03)). The goal of this task order was to develop a DIGGS-compatible geotechnical database using existing geotechnical reports available at ODOT. The proposed database will become a part of a knowledge base available for use in other future projects undertaken by ODOT which will eventually reduce the need for new geotechnical investigation and help save taxpayers' money.

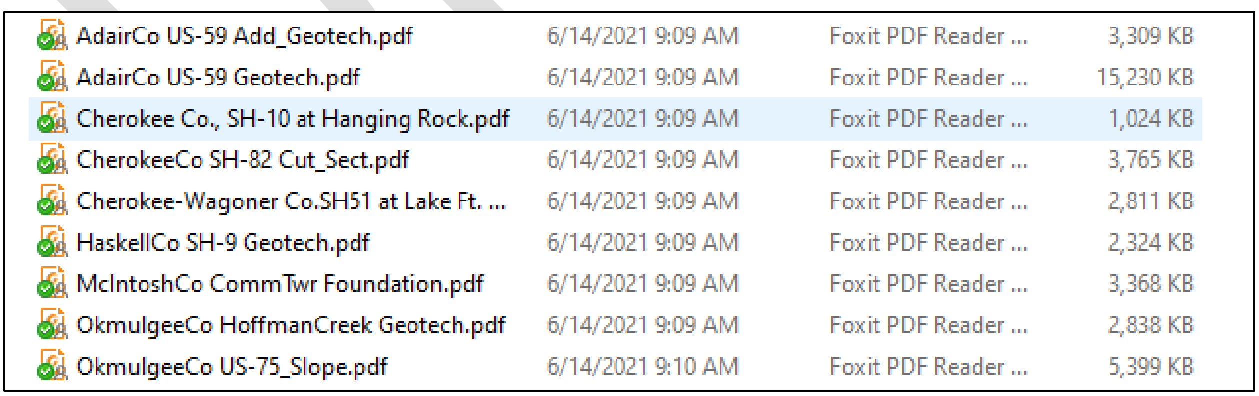
1.1 Scope of Work

Originally, this Task Order was proposed as a 12-month $75,000 study. Because of available funds in the FFY21 program and not enough funds in the FFY22 program, it was divided into two phases. Phase I ($46,350) was funded by the FFY21 program and Phase II ($28,650) was funded by the FFY22 program. The overall tasks remain unchanged. The following tasks were identified for this Task Order: (1) collect geotechnical reports from ODOT; (2) develop a standard excel template for geotechnical properties of soil that can be converted to DIGGS; (3) extract geotechnical information from the collected reports in excel format and develop a geotechnical information database; (4) convert excel database into XML database;

(5) verify the compatibility of the XML database for DIGGS; (6) integrate DIGGS XML database with ODOT GIS system; (7) train ODOT staff to use the DIGGS XML database, and (8) prepare monthly progress reports and a final report. Task 1 and part of Tasks 2 through 5 were pursued in Phase I. The remaining tasks will be pursued in Phase II. This interim final report summarizes the activities undertaken in Phase I. The overall activities and findings will be included in the final report of Phase II. A kickoff meeting was held among the OU team and the sponsor of this Task Order on September 10, 2021. The scope of the Task Order was discussed. Also, the OU team presented the workflow of tasks that will be pursued to accomplish the goal of this task order.

2. COLLECTION OF GEOTECHNICAL INVESTIGATION REPORTS

The Geotechnical Branch Manager at ODOT Materials Division has shared several geotechnical reports with the research team. These reports are in digital format, such as PDF and scanned images. These reports occupied more than 100 gigabytes of hard drive space. Figure 2.1 shows a snippet of the reports collected for this Task Order. During the kickoff meeting, sharing of geotechnical reports in the form of gINT file and other formats (e.g., Microsoft Access or Excel) was discussed. As a follow-up, ODOT Material Division shared gNIT, Falling Weight Deflectometer (FWD) and Cone Penetration (CPT) files from 2017, 2018 and 2019 with OU team. The OU team worked on these files to convert to DIGGS format and to integrate with GIS. Approximately 75% of the reports was collected during Phase I of this Task Order. Additional geotechnical reports will be collected in consultation with the Geotechnical Branch Manager and other personnel at ODOT. Considering limited budget and timeline, it may not be possible to include all geotechnical reports available at ODOT in this study.



AdairCo US-59 Add_Geotech.pdf	6/14/2021 9:09 AM	Foxit PDF Reader ...	3,309 KB
AdairCo US-59 Geotech.pdf	6/14/2021 9:09 AM	Foxit PDF Reader ...	15,230 KB
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McIntoshCo CommTwr Foundation.pdf	6/14/2021 9:09 AM	Foxit PDF Reader ...	3,368 KB
OkmulgeeCo HoffmanCreek Geotech.pdf	6/14/2021 9:09 AM	Foxit PDF Reader ...	2,838 KB
OkmulgeeCo US-75_Slope.pdf	6/14/2021 9:10 AM	Foxit PDF Reader ...	5,399 KB

Figure 2.1 Geotechnical reports collected from ODOT

3. DEVELOPMENT OF A STANDARD EXCEL TEMPLATE FOR GEOTECHNICAL PROPERTIES OF SOIL

An initial review of the reports, shared by ODOT, revealed significant differences in available information depending upon the scope and size of projects. The types of reports shared with the OU team included, but not limited to

- Preliminary Geological Investigations
- Pedological Soil Survey
- In-Place Soil Survey
- Shoulder Soil Survey
- Cut Section Investigation
- Settlement Investigation
- Investigation for Bridge Foundation
- Seepage Investigation
- Landslide Investigation

Therefore, during Phase I, the OU team focused develop a standard excel template to help extract necessary geotechnical information from various types of reports. During the development, it was kept in mind that the template has to be compatible with the DIGGS format. For this purpose, the OU team carefully reviewed several selected geotechnical reports and document information, such as types of tests, analysis process and geotechnical properties that are necessary inputs for geotechnical designs. Also, the information shared in the DIGGS website (https://www.geoinstitute.org/special-projects/diggs) and templates available in their Github repository (https://github.com/DIGGSml) were reviewed. After gathering all the necessary information, the excel template to extract geotechnical information was developed. The template was shared with ODOT personnel during monthly progress meetings and their inputs were sought. The template may need further modification to include additional geotechnical tests and properties. Figure 3.1 shows a snippet of the current form of the excel template. As shown in Figure 3.2, the template contained a number of ‘Tab’ to include different geotechnical test results. The information in the template included, but not limited to

- Project Information
- Boring Point Information
- Properties of Laboratory Samples
- Lithology

- Atterberg limits
- Standard Penetration Test
- Sieve Readings
- Water Level
- Water Content and Density

START	PointID	Depth	Bottom	Graphic	AASHTO	Description
IGNORE	PointID	Depth	Bottom	Graphic	AASHT	Description
1	4309	0	0.5		A-4(0)	Silty Sand
2	4310	0.5	3		A-6(8)	Lean Clay with Sand
3	4311	0	0.5		A-4(1)	Clayey Sand
4	4312	0.5	3		A-6(10)	Sandy Lean Clay
5	4313	0	0.5		A-7-6(9)	Clayey gravel with Sand
6	4314	0.5	3		A-7-6(23)	Lean Clay with Sand
7	4315	0	0.5		A-6(16)	Lean Clay with Sand
8	4316	0.5	3		A-6(20)	Lean Clay
9	4317	0	0.5		A-6(8)	Sandy Lean Clay
10	4318	0.5	3		A-6(12)	Lean Clay with Sand
11	4319	0	0.5		A-6(4)	Clayey gravel with Sand
12	4320	0.5	3		A-6(16)	Lean Clay
13	4321	0	0.5		A-6(7)	Sandy Lean Clay
14	4322	0.5	3		A-6(15)	Lean Clay with Sand
15	4323	0	0.5		A-6(5)	Gravelly Lean Clay with Sand
16	4324	0.5	3		A-7-6(20)	Lean Clay with Sand
17	4325	0	0.5		A-6(9)	Gravelly Lean Clay with Sand

Figure 3.1 Snippet of the excel template for extracting soil properties

IGNORI	PointID	HoleDept	Date Started	Date Completed	Elevation	Hole Size	Contractor	Method	Logged By
1	Boring No 1	15	1/13/2009	1/13/2009	1118		ODOT		L. Taylor
2	Boring No 2	7	1/6/2009	1/6/2009	1115		ODOT		R. Kenneda
3	Boring No 2A	4.9	1/7/2009	1/7/2009	1119		ODOT		R. Kenneda

... | ATTERBERG | LAB SPECIMEN | LITHOLOGY | POINT | PROJECT | SAMPLE | SIEVE | SV READINGS | WATER LEVELS | WC DEI ...

Figure 3.2 Snippet showing different tabs for different soil properties

4. EXTRACTION OF GEOTECHNICAL DATA IN EXCEL AND DIGGS XML DATABASE

Upon developing the excel template, the OU team started reviewing the collected geotechnical reports and extracting necessary geotechnical information that will be helpful for Materials (particularly Geotechnical Engineering Branch) and other divisions such as Bridge and Roadway Design. Depending on the type and organization of the geotechnical reports, the effort needed for the extraction of the necessary data varied significantly. It was expected that 350 reports will be covered in this Task Order (Phase I and II combined). A total of 92 reports, were covered during the Phase I of this Task Order. These geotechnical reports involved thirty-four (34) counties of Oklahoma. Table 3.1 shows a list of the counties covered during Phase I. Table 3.2 presents the number of reports covered by investigation type. It is expected that the efficiency of the team to extract data and covert to DIGGS will increase with time. In addition to pdf reports, gNIT report files from 2017, 2018 and 2019 were converted into excel database. The OU team faced significant challenges in extracting GPS locations of boreholes which were essential for integrating the database into ODOT GIS system. It was found that the GPS locations of borings were not included in many geotechnical reports.

Table 4.1 Summary of reports covered during Phase I

County	**Number of Reports**	**County**	**Number of Reports**
Alfalfa	2	Latimer	5
Atoka	1	Le Flore	2
Blaine	1	Lincoln	2
Canadian	2	McCurtain	1
Carter	6	Murray	1
Cherokee	2	Okfuskee	1
Cleveland	3	Oklahoma	2
Comanche	25	Okmulgee	1
Craig	1	Osage	5
Custer	2	Pawnee	2
Ellis	2	Pushmataha	1
Garfield	1	Rogers	5
Grady	2	Seminole	2
Harper	4	Tulsa	1
Johnston	1	Wagoner	1
Kay	2	Woods	1
Kingfisher	1	Woodward	1

Table 4.2 Summary of reports covered by investigation type

Type	**Number of Reports**
Bridge Foundation	10
Back Slope	1
Cut Section	4
Landslide Investigation	4
Pedological and Geological	22
Preliminary	39
Radio Tower Foundation	1
Seepage	9
Shoulder	2
Total	**92**

As mentioned in the previous section, the DIGGS format uses an XML structure and labeling convention with elements of GML. Therefore, it requires converting the excel database into an XML database. For this purpose, a free conversion tool, available in the DIGGS website (https://www.geoinstitute.org/special-projects/diggs/schema-tools) was used to convert the excel files into XML files. Figure 4.1 shows a snippet of the converted files from excel to DIGGS XML format. All the excel files developed during Phase I were converted to DIGGS XML files. Figure 4.2 presents a snapshot of the different soil properties in DIGGS XML file. After completion of Phase II, the completed excel and XML database will be shared with ODOT.

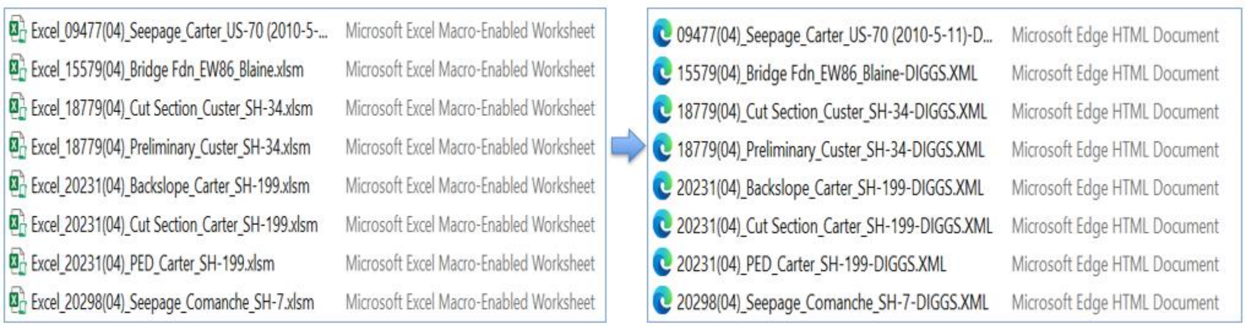

Figure 4.1 Snippet showing conversion of files from excel to DIGGS XML

Figure 4.2 Soil properties shown in a DIGGS XML file

5. VERIFING THE COMPATIBILITY OF THE XML DATABASE FOR DIGGS

A validator tool is available in DIGGS website (https://github.com/DIGGSml) to verify the compatibility of the XML database to DIGGS format. The tool will be used to verify the compatibility of the converted DIGGS XML files. During Phase I, only a portion of the files checked for their compatibility. This task will be completed in Phase II. Any XML file with an incompatibility issue will be closely looked at and fixed for error.

6. INTEGRATION OF DIGGS XML DATABASE WITH ODOT GIS SYSTEM

The excel and DIGGS XML database will be integrated with the ODOT GIS system to develop a GIS-based interactive database. The structure of the database and the GIS interface will be decided upon consultation with ODOT Material Division and the GIS team. Features, such as advanced searching tool, interpolated soil property maps and integration with web soil survey map will be used which will assist the user in extracting the geotechnical properties of interest from the database efficiently. During Phase I, the OU team has developed a preliminary excel template to incorporate Excel and DIGGS files into GIS system with respect to their GPS coordinates. The excel template for GIS will be finalized after consultation with the ODOT Material Division and the GIS team. Figure 6.1 shows the GIS interface for geotechnical database. In addition, the OU team has explored the possibility of adding FWD test results into GIS database. Figure 6.2 shows a snippet of GIS interface for FWD database. The excel template for FWD database will be finalized after consulting with ODOT staff.

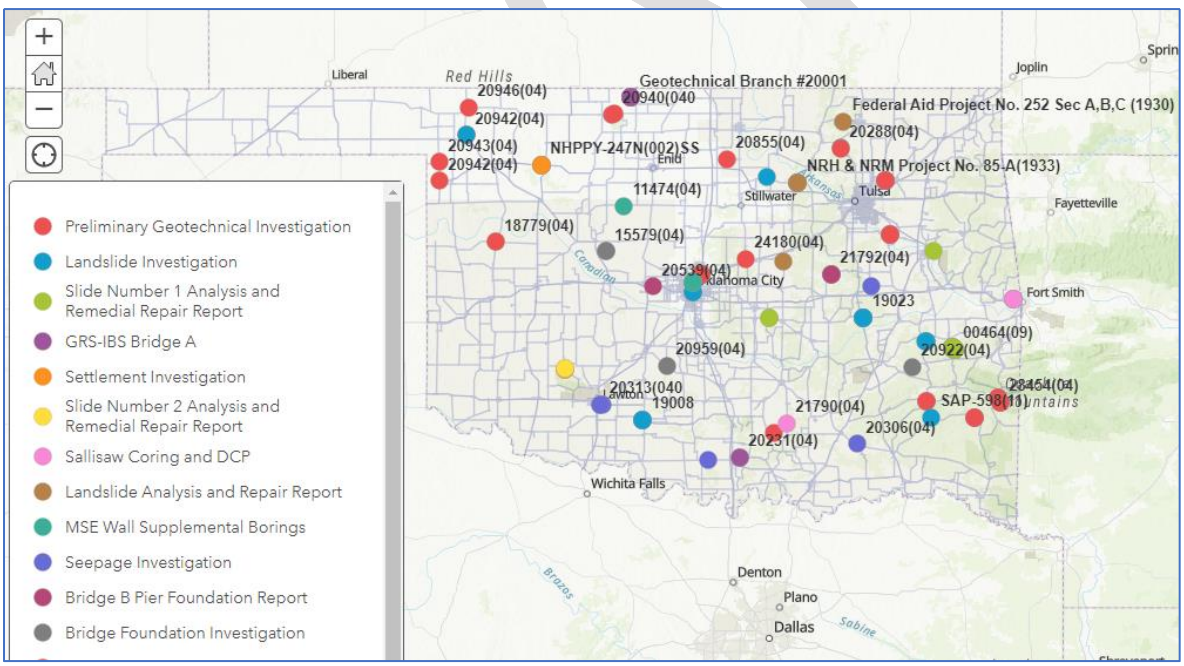

Figure 6.1 Incorporation of geotechnical data into GIS

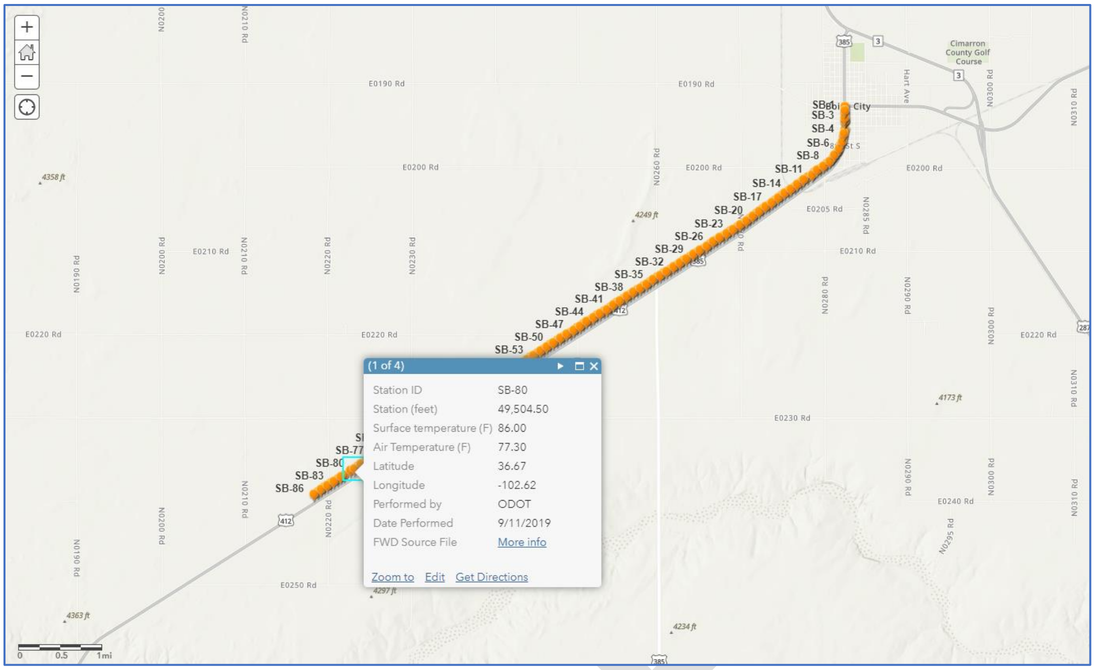

Figure 6.2 Incorporation of FWD data into GIS

7. TRAINING ODOT STAFF TO USE THE DIGGS XML AND GIS DATABASE

A training workshop will be organized to introduce the developed DIGGS XML and GIS databases to potential users at ODOT. Additional workshops may be organized depending upon the need, the budget, and the timeline. This task will be performed in Phase II.

8. CONCLUSIONS

The purpose of this task order is to develop a DIGGS-compatible geotechnical database using existing geotechnical reports available at ODOT. For this purpose, the OU team collected geotechnical reports from ODOT and reviewed to develop an excel template that will be compatible with DIGGS format. Using the template, an excel database was developed by extracting data from the collected geotechnical reports. The excel files were then converted to DIGGS format. A total of 92 pdf reports and gNIT files from 2017, 2018 and 2019 were converted into excel and DIGGS XML format. Also, a preliminary excel template to integrate these databases (excel and DIGGS XML) into ODOT GIS system was developed. The OU team will continue working on the Phase II of this Task Order. At the end of Phase II, a final report documenting all the data and instructions to use the database will be submitted. Also, the excel, DIGGS XML-based geotechnical database and the GIS database to be used by ODOT Materials and other divisions will be shared during Phase II.

Originally, this project was conceived as a single phase project. Subsequently, it was divided into two phases, based on the discussions with the agency. Phase I was funded by the FFY21 funds ($46,350), while Phase II was funded by the FFY22 funds ($28,650). Allocation of Phase I and Phase II funds was not compatible with the duration (six months for each phase). A no-cost extension was submitted to Office of Research and Implementation (ORI), but it was denied. This will likely impact pursuit of the remaining tasks and the project deliverables. The OU research team is committed to making as much effort as possible to minimize the agency's decision (not approve the NCE).