Development of a MnDOT Foundation Boring Mobile Application Gateway, GeoApp

Minnesota Department of Transportation

RESEARCH SERVICES & LIBRARY

Office of Transportation System Management

Allan M. Hart, Principal Investigator
Department of Computer Information Science
Minnesota State University

August 2016

Research Project
Final Report 2016-26

To request this document in an alternative format call 651-366-4718 or 1-800-657-3774 (Greater Minnesota) or email your request to ADArequest.dot@state.mn.us. Please request at least one week in advance.

Technical Report Documentation Page

1. Report No.	2.	3. Recipients Accession No.
MN/RC 2016-26		

4. Title and Subtitle	5. Report Date
Development of a MnDOT Foundation Boring Mobile Application Gateway, GeoApp	August 2016
	6.
7. Author(s) Allan M. Hart, Ph.D., Derrick Dasenbrock, P.E., Aaron S. Budge, Ph.D., P.E.	8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Computer Information Science 273 Wissink Hall Minnesota State University, Mankato Mankato, MN 56001 Derrick Dasenbrock Minnesota Department of Transportation Geotechnical Section, Office of Materials and Road Research 1400 Gervais Ave Maplewood, MN 55109	10. Project/Task/Work Unit No. 11. Contract (C) or Grant (G) No. (c) 04439
12. Sponsoring Organization Name and Address Minnesota Department of Transportation Research Services & Library 395 John Ireland Boulevard, MS 330 St. Paul, Minnesota 55155-1899	13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code

15. Supplementary Notes
http://www.lrrb.org/PDF/201626.pdf

16. Abstract (Limit: 250 words)
A custom application "app" has been created for use on "smart devices" (phones and tablets on iOS and Android platforms) that will allow users to easily access MnDOT geotechnical asset information in the field. Through the app, users can access MnDOT foundation boring metadata and download PDF files of boring logs of interest. In addition to the development of a mobile-friendly tool [supplementing an existing website], this research effort is partly to determine a proof-of-concept related to development time, effort, documentation, and interdisciplinary coordination for development of similar systems.

Through this tool, an interactive map, using boring GPS locations, or search queries, will allow improved access to subsurface information in the field in real time. This will provide a broader benefit to consultants, contractors, local units of government, researchers, and other groups especially when making decisions on-site and in the field (i.e., project scoping, site review, construction inspection, forensic analysis, etc.) This effort builds on efforts to create a data warehouse of geotechnical information and make it more easily sharable and useful to the engineering community.

17. Document Analysis/Descriptors	18. Availability Statement
asset management, soil penetration test, boring, soil mapping, mobile applications, geotechnical engineering	No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312

19. Security Class (this report)	20. Security Class (this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	41	$0

Development of a MnDOT Foundation Boring Mobile Application Gateway, GeoApp

Final Report

Prepared by:

Allan M. Hart, Ph.D.
Department of Computer Information Science
Minnesota State University, Mankato

Derrick Dasenbrock, P.E.*
Minnesota Department of Transportation

Aaron S. Budge, Ph.D., P.E.*
Department of Mechanical and Civil Engineering
Minnesota State University, Mankato

August 2016

Published by:

Minnesota Department of Transportation
Research Services & Library
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

*Additional report authoring, preparation, and editing were performed by members of the TAP panel due a health concern experienced by the Principal Investigator during preparation of the final project report.

ACKNOWLEDGMENTS

The authors wish to thank Thomas Carstens for his efforts in assisting Professor Hart with the mobile app development work. Salvatore Caronna (Caronna 2006) developed a script that allowed MnDOT's individual project-based gINT files to be searched and the point level information aggregated for use with the application.

TABLE OF CONTENTS

LIST OF FIGURES

EXECUTIVE SUMMARY

A custom mobile phone and tablet application ("app") has been created for use on smart-devices (phones and tablets running iOS and Android operating systems) that will allow users to easily access MnDOT geotechnical boring asset information in the field. Through the app, users can easily access MnDOT foundation boring point-level metadata and download PDF files of boring logs of interest.

This mobile-friendly tool supplements an existing website, which is being reconstructed, and was off-line, during this research project. In addition to the development of the app itself, the research implementation effort explored the development time, effort, documentation, and interdisciplinary coordination for development of similar systems. It was found that technical terminology and industry jargon presented an unusual level of complication through the development process. In addition, there were challenges coordinating the development of the app using both iOS and Android platforms and accessing MnDOT data.

The GeoApp is currently available for Android devices on the Google Play store. It can be found by searching for "GeoApp" (one word) by Allan M. Hart. Through this tool, MnDOT foundation borings can be accessed using queries, with available filtering, or by using map navigation. The app link to the MnDOT webserver and allows users to access electronic PDF files of soil borings in real time. The app provides an interface more directly tailored to use on mobile devices than the MnDOT ArcIMS application, which was developed for desktop web browsing.

The app development showed that a mobile application was possible using a variety of development tools, tools which were unfamiliar to geotechnical engineers who developed the initial specifications for the study. The work underscored the need for collaboration and clarity in interdisciplinary communications. The app is expected to provide a broader benefit to consultants, contractors, local units of government, researchers, students, and others when access to MnDOT borings in the field would be helpful.

A copy of the app, modified for use on desktop computers was also provided as an outcome of the research effort. The app development project has already provided useful background for the redevelopment of the MnDOT Foundations web interface. The new interface is somewhat faster than the legacy application and possesses similar features, developed for the GeoApp. The app introduced features not included in earlier desktop interface tools, including waypoint navigation, pick lists for queries, boring clustering, metadata pop-up windows, and other interface tools, which were not part of the legacy applications. Some of these features are being included in the Gi5 desktop webpage redevelopment effort.

A comprehensive discussion of the desktop web-based ArcIMS application, which served as the foundation for this mobile application, is included in the report.

CHAPTER 1: INTRODUCTION

1.1 MnDOT Geotechnical Information

The Minnesota Department of Transportation (MnDOT) has advanced over 35,000 geotechnical exploration borings (often called "SPT" borings, as they frequently use the standard penetration test during the boring advance) and cone penetration test (CPT) soundings for state transportation projects; there is increasing interest in using this information for private projects, studies, and new construction. Boring and sounding information is stored electronically in separate project databases, created for each highway project. The databases may contain a single boring, or sounding, or several hundred borings and soundings depending on the nature of the project. These discrete project databases are used to populate a composite database for a web-based GIS application. This aggregated database does not contain subsurface information, but contains point-level metadata. It has been developed to make the metadata, including boring locations, more accessible to MnDOT personnel and the general public. Interfaces and query tools have been developed to create a 'self-service' environment for users to find, select, and download information. Static PDF files of historic scans or more current electronically formatted data are available for many borings; logs not currently in the system are being slowly scanned or added as time and funding permits. Usually, new information is added when projects provide a current need to update legacy information or if specific logs are requested by external users.

Building on this initial framework, a custom mobile phone and tablet application (app) has been created for use on smart-devices (phones and tablets running iOS and Android operating systems). The app is a software application which uses a web browser as the user interface. It was intended to provide similar functionality to the existing desktop software web-based application, but with the interface and features retooled for the smaller screens and touch-screen capabilities of phones and tablets. This revised user configuration would allow phone and tablet users to more easily access MnDOT geotechnical boring asset information in the field, on increasingly common hand held devices, as compared to using the standard web page on a notebook computer. Through the mobile app, users can easily access MnDOT foundation boring point-level metadata and download PDF files of boring logs of interest.

In a related effort for improved data exchange, MnDOT is participating in the development of the DIGGS (Data Interchange for Geotechnical and Geoenvironmental Specialists) data exchange standard. This effort is described further in the reference Dasenbrock (2008) and later in this chapter. Development aspects of the MnDOT geotechnical database and the applications associated with the data storage and exchange are described.

1.2 MnDOT Foundation Borings Database

The Minnesota Department of Transportation (MnDOT) has been performing geotechnical site investigations, since 1959. To date, MnDOT personnel and consultants under contract to MnDOT have advanced more than 35,000 SPT soil borings and CPT soundings. Although regional District soils crews routinely advance shallow soil borings for roadways, these borings are not included in the dataset, and generally of less interest to internal and external users due to their shallow nature and limited descriptions.

From 1959 to 1992, boring logs were recorded on paper and later entered into electronic systems that would print formatted type-written copies of the logs, but not store the information in a useful format. Electronic database storage of completed boring log data began in 1992 using gINT, a MS-DOS® database system with a graphical user interface; this system was upgraded to a MS-Windows® environment in 1997. Today, roughly 30% of logs have complete information stored in a database format; another 50% have been scanned and are electronically available in an Adobe PDF® format. Location and general point-level (and not depth-related) attribute information is available for about 98% of all borings. At present, boring information is entered based on time and project need. In the interim, older logs are being scanned and stored as electronic documents.

1.3 Web-based Application Development

Recognizing the increasing importance of accessing historic geotechnical data, which often represents a cost savings or data quality improvement to new projects, MnDOT began developing specifications for the development of a GIS application to access geotechnical data in 2003. The intent was to allow internal and external users to search for borings and soundings using interactive maps and query tools.

A group of MnDOT personnel familiar with the development of web-based applications and geospatial data, held a series of meetings beginning in the spring of 2003 to define the scope of work for developing a geotechnical ArcIMS application. Boring information and existing database content was reviewed. Specifications for functionality and user interface organization were developed. Concepts for queries, reports, map navigation, selection tools, links, and other issues of the user interface were discussed. Different mapping layers, entities, boundaries, labels, colors, and other aspects were also explored. In addition to the interface and overall application development, a method to populate a new geotechnical database, referenced by this application, was included as part of the application scope.

A web-based ESRI (Environmental System Research Institute) ArcIMS® application was developed by a consultant to MnDOT in the summer of 2003 to allow point attribute data to be queried by a variety of properties including project number, structure number, and boring number. The boring location information would display on background maps including United States Geological Survey (USGS) topographic maps, aerial photos, or a MnDOT base map.

A basic querying tool was developed, as was a simple output report. The output report contained links to a PDF file of the associated logs. This PDF file was either a scanned copy of the original log or a PDF output log generated by the gINT® software. In many cases PDF files did not yet exist; a separate project to scan old paper logs was initiated. Several thousand logs were scanned, but funding did not allow all existing logs to be scanned. There were also some gaps in the paper log archive, as such, not all legacy borings are available.

After using the 2003 application, it was recognized as a powerful tool for searching MnDOT geotechnical data; it also quickly showed that a substantial portion of the older data contained erroneous information, including the coordinate location, highway number or asset number or type. The work to correct the erroneous data has been ongoing since the application roll-out. In the summer of 2005, the functionality for referencing and presenting map backgrounds was substantially improved. Entering historic data, creating electronic images of old borings, and exporting current logs to Adobe PDF files is ongoing.

Following the initial development, in 2006, the Office of Materials, of which the geotechnical section is a part, began an effort to update the user interface and other functional components. This second-generation version was created by in-house computer software developers. It possessed enhanced functionality, adopting a new [at the time] MnDOT GIS base map. The MnDOT interactive base map and application had been resident on the web on MnDOT's external web site at: http://www.dot.state.mn.us/maps/gisweb/. A screen shot of the web application is shown in Figure 1.1.

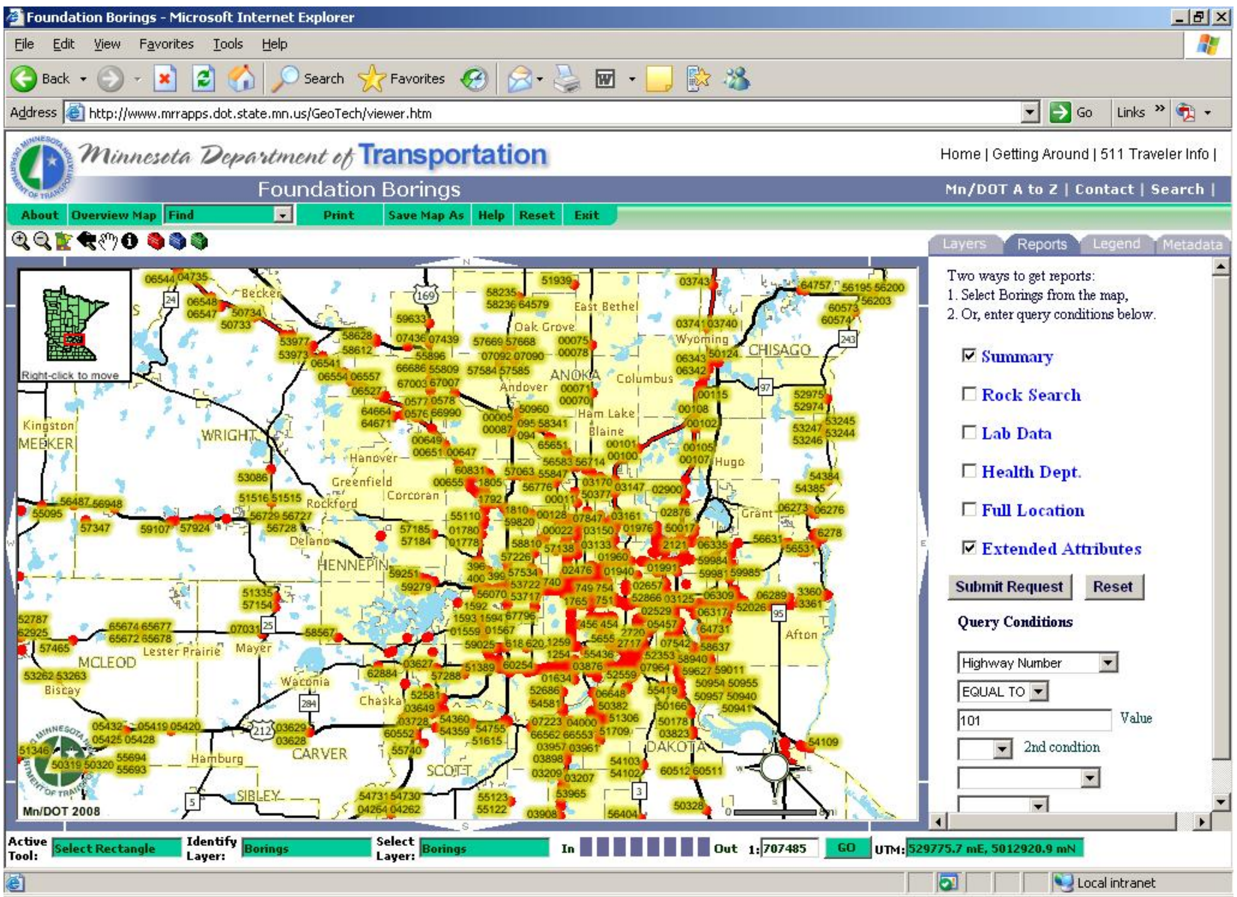

Figure 1.1 The second generation Foundations Boring website. Users could navigate to locations of interest using pan and zoom commands, as well as execute queries to generate reports listing borehole attributes in 5 predesignated formats.

In this second generation application, users could obtain Adobe PDF files of complete boring and sounding logs and could query results (point-based metadata information) to the screen in an HTML file or select to create a MS Excel file. The user could select one of 6 predefined report queries to best suit their information needs with respect to the asset point information.

Improvements were made in the background mapping and data presentation formats. Additional map 'layers' were also in development for the presentation of other geotechnical information, assets, and features, although this (despite years of potential development opportunity) has not been actively pursued, mainly due to limited resources.

With the newer web-based system, individuals could easily search for geotechnical data relevant to their project, research, or other needs. Boring and sounding asset data could be easily queried in a 'self-service' fashion by keying in search parameters or by navigating on a state map. Several background imagery layers were available (Figure 1.2). Users were able to print logs or download information without traveling to the MnDOT geotechnical offices.

Figure 1.2 The second generation Foundations Boring website had several imagery types available, including state and county CAD maps, FSA images, DOQ images, and DRG images. Depending on the boring locations, the quality of the background images could vary. Many background images were also dependent on the zoom scale.

Lingering problems with the application were data files where the geospatial coordinates of assets were inaccurate, for a variety of reasons, and a very cumbersome data loading technique which used a 17-step process, described further in Section 1.6, to take the individual project database (gINT software) files and manipulate the data to generate records in an Oracle data format for use with the ArcIMS application. The cumbersome loader system was only understood by a few members of the computer staff, one of whom retired during the development process. Consequently, new boring and sounding information was only loaded into the system in an initial 2006 effort. Geotechnical borings after this date were not loaded into the system. Additional history about MnDOT's geotechnical database development is described by Dasenbrock (2006).

1.4 The MnDOT Base Map

The base map includes information about transportation features, as well as boundary information, stream and lake locations. The MnDOT web based GIS base map was a recent development during the GIS project (circa 2006), although components of it were created over the past 40 years. In 1979, MnDOT began using computer aided drafting to convert hand drafted MnDOT cartography into electronic files. Minnesota's 1,745 USGS 1:24,000 scale quadrangles were digitized to obtain seamless digital map coverage. By 1985, the seven-county St. Paul-Minneapolis Metropolitan Area was completed and a set of 50 edge matched CAD files containing all public road centerlines, railroads, political/administrative boundaries, the Public Land Survey System and surface water was produced. In the late 1980's, MnDOT began to research the potential offered by the exploding use of Geographic Information System (GIS) technology for its own needs and services. A series of internal task forces and consultation with the [Minnesota] state Land Management Information Center (LMIC) resulted in a 1992 decision to incorporate the CAD digitizing into a statewide seamless basic core of geography providing a means for relating MnDOT spatial data to other spatial data. The GIS software chosen was ESRI's Arc/Info®. Digitizing continued, to complete statewide 1:24,000 scale coverage within 18 months. MnDOT also switched from using State Plane Coordinates, zone specific, NAD83, to Universal Transverse Mercator (UTM) Minnesota extended Zone 15, NAD83 coordinates. In 1996, MnDOT produced its first State of Minnesota GIS base map on a CD-ROM. In 2003, Federal Geographic Data Committee (FGDC) compliant metadata was also provided for each individual feature data set. The metadata presents the basic characteristics of the data resource and information on data sources, and information related to geographic and database elements (MnDOT 2007).

1.5 The MnDOT Project Database Architecture

Originally, only point level attribute information was stored in an electronic format within a mainframe-based computer application. In the 1980's information was entered into electronic systems that created dot-matrix log printouts; it is unclear if this information was stored in a useful electronic fashion, other than purely for improved printing and presentation formatting. Some 'floppy disks' survive with data from that era; these disks are not readable by any known current software programs. In 1992, information was entered into an early DOS version of the gINT software package; a MS Windows version (by Bentley systems) is in current use today. Depth based boring information from 1992 forward has been entered into project databases; point-based attribute information was entered both there and in the replacement for the original mainframe application, which by this time had been migrated to a Borland Paradox database. This database was later migrated again to a MS Access structure and then to a MS Excel table, where it resided for several years. The newest version has returned to a MS Access structure.

Approximately 670 projects were entered into gINT MS-DOS databases from 1992 to 1997 when a MS Windows version of gINT (version 4) was purchased. When a new file structure was implemented, the legacy MS-DOS files (several per project) needed to be converted to the new format. In an unusual effort, engineers came into the office over a weekend to data migrate several hundred "good" files. There were however, a number of MS-DOS files that were unusual, corrupt, or somehow compromised. These files took longer to evaluate and correct. This process was combined with a larger error checking and validation program and took several years of intermittent work, as time permitted, to update all of the old project files to the same file structure. It is believed that there was some data loss- but much of the lost electronic data was recoverable by re-entering the data from the original log files which have been kept in office records or in boxes in an off-site storage archive.

Boring and sounding data is principally grouped by either State Project Number or by Minnesota State Highway Control Section. Within these contexts a number of discrete projects may have been created. Boring and sounding information for each of these project types is usually entered and stored in an independent database. There are roughly 3500 project databases, organized by County and State Project Number. The smaller databases are useful from an organizational standpoint as well as maintaining a small enough file size that manipulating the information in each database can be done with little or no perceptible delay. Larger databases are generally more difficult to search without sorting and filtering and there becomes a noticeable lag in computer operations when the number of individual records is large.

Until 2003, point attribute information was entered separately into both the MS Access database and the gINT databases, where depth-based boring information was also entered and stored. This allowed for easy searching and querying among all borings in the MS Access database. After 2003, the MS Access database was only periodically updated with exports from the gINT project databases. The ArcGIS system has replaced the legacy MS Access system in general function.

In November of 2006, all borings and soundings were loaded into gINT project database files. Placeholder gINT databases for all borings in the MS Access database, based on the mainframe data. All the current exploration borings and soundings, as well as the historic investigation point level metadata now reside in gINT project databases. The placeholder databases have no depth-type data, but this data is entered as these projects are updated. The gINT databases were subsequently used to populate the ArcGIS database. The legacy MS Excel table is still available as an archived record of the borings during that period of data structures and information. During his effort, legacy and current files were all updated to a new database structure; this structure included some substantial revisions to better organize similar data and create new tables and fields for in-situ testing information.

Several scripts and utilities were incorporated, including coordinate and CPT data importing routines, a coordinate conversion system to populate county coordinate, latitude/longitude, and UTM fields. A system to provide automated ‘public lands’ survey legal descriptions, based on coordinate locations, was also coded and implemented.

1.6 GIS Application Architecture

The GIS application system consists of a web server, an ArcIMS web application server, and an ArcSDE® server application [used to access multi-user geographic databases stored in relational database management systems (RDBMSs)], an Oracle® database with the boring and sounding data, the data loader system to take the gINT data and populate the Oracle database, and the related databases with base maps, background maps, and other feature class information. Figure 1.3 shows the system of databases and applications used to provide content to the user.

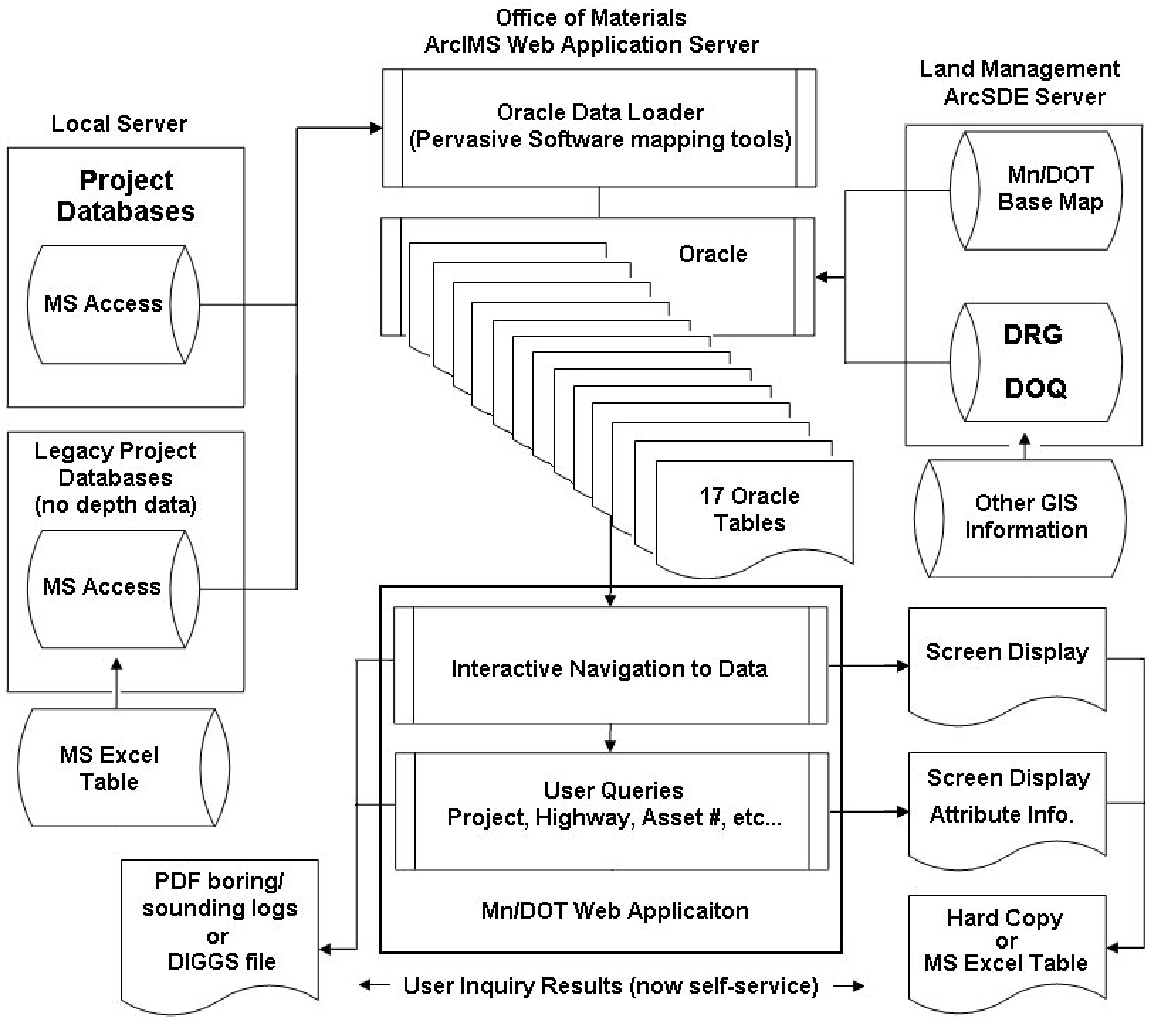

Figure 1.3 Diagram of the new MnDOT Foundation Boring ArcGIS application.

For a time, two different systems were needed to load data into the ArcGIS system. Data was loaded from the single legacy point attribute MS Access database and the multiple individual gINT project databases. With the successful migration of all of the legacy point-based information to individual, project-based, gINT database files, the legacy database was no longer needed to independently import older project information into the ArcGIS system. The current process involves loading the data into 17 Oracle database tables by executing Pervasive Software® mapping tools. A reporting table is created to contain data for reporting through SQL procedures.

A new universally unique identifier (UUID) field was added at the project and point level tables to relate project table data to all points within that project (as the point table did not inherently contain a reference to the parent project table). Target plans were to purge the data in the ArcGIS application every two months and upload new data from the project databases. During the life of the second generation application, this never occurred. It is more likely in the 3rd generation, now that the loading process has been dramatically simplified using a flat table generated through gINT software scripts.

1.7 Digital Interchange for Geotechnical and Geoenvironmental Specialists, DIGGS

In 2005, a Federal Highway Administration (FHWA) Transportation Pooled Fund (TPF) Study was created, with the intent to collect input and establish collaboration among a number of interested groups, for the purpose of establishing a data transfer protocol for sharing of geotechnical data. The effort would come to be known as DIGGS. The study, TPF-5(111), was initially championed by the Ohio DOT and had several member DOT states, in addition to partners including AGS, COSMOS, EarthSoft, EPA, FHWA, gINT, KeyNetix, the UK highway Administration, University of Florida, and USGS.

The intent was that a specialized Extensible Markup Language (XML) would be created, based in part on the Geography Markup Language (GML), which is the XML grammar defined by the Open Geospatial Consortium (OGC). A markup language defines a set of rules for encoding documents. DIGGS would be a format [language] that computers could use to exchange geotechnical information. It was conceived as a merger of existing XML standards, including the

AGS standard (UK), COSMOS standard (CA, Earthquake group), and FDOT/UF pile standard, with new additions and features.

The original DIGGS Project deliverables consisted of a final data dictionary (imbedded in the XML schema), and the XML schema including: boreholes, soil layers, tests & measurements, samples, wells, logging, and code lists. Additionally, a set of guidelines for using and adding to the schema and a set of tools supporting the schema were to be created and provided to aid in further use and development. The tools were to include a MS Excel extractor and a Google KML converter tool.

The complexity of the effort, while anticipated, was perhaps not fully appreciated. The first fully working version (version 2) was provided in 2012, after nearly 10 years of development. Much of the time was spent working on issues related to the dictionary and schema associated with the system. The structure was revised several times to make it logical and usable to as wide an audience as was practical.

The effort passed from the Ohio DOT to Caltrans for a time and now DIGGS is managed by the GeoInstitute of American Society of Civil Engineers (ASCE). A timeline of the development is provided in Figure 1.4 (Ohio Department of Transportation 2012). The current project website can be found at: http://diggsml.org/. Several presentations related to the format are available at http://diggsml.org/presentations.

It was envisioned that the MnDOT GIS web application would eventually provide a web link, not only for static PDF files, but also DIGGS-compliant files which users would be able to download as an option. In this way, external users would have access to the boring data in a format compatible with the free tools being developed for the DIGGS XML architecture. One of the limitations with providing the MnDOT project database files is that there are multiple tables populated with information, and users would likely need a reasonable understanding of MnDOT practice to understand the organization and meaning of the raw data for it to be useful. The DIGGS system offered greater promise for external customers.

Anticipating the development of the DIGGS standard in the middle 2000's, the MnDOT web application was given the name "Geotechnical Investigation Information Interchange Internet Interface (GI^5)." While it would be now possible to develop an export tool to create current DIGGS v2.0.B (released in May 2016), this is not anticipated to occur in the near future.

Meeting	Purpose	Date	Outcomes
Pre-planning	Develop consensus on basic structure of schema	May 16-17, 2005, Atlanta, GA	Draft schema structure and plans for proposal
First Workshop	Schema outline & Data dictionary for data in existing systems. Dates, Deadlines and Deliverables	August 10-13, 2005, San Francisco, CA	Schema team and dictionary team, refined schema structure, data dictionary,
Second Workshop	Continue development of schema and dictionary	November 18, 2006, Orlando, FL	Draft schema, dictionary and users guide for presentation to GMS
GMS Meeting	Update governing body on progress and get approval for directions	January 18-19, 2006, Atlanta, GA	Approved
AGS Meeting	Develop plan to improve progress	March 2007, UK	Move to UML version with now tool to automate schema creation for consistency
Workshop V1.0 review	Review release candidate for V1.0 and plan final corrections – using new UML tool system	September, 2007, Boston, MA	Set actions, assignments and tasks to finalize V1.0 – set release for spring 2008
Invitational Workshop	Present and approve new directions for DIGGS	Orlando Florida, March 25-26, 2009	Approved new timeline, consultant for final stages, plan for permanent governance/ownership
Consultant hired	Send RFP and hire consultant	August 2009	Galdos Hired to complete Schema
Update Schema to v1.1	Consultant completes v1.1 – working with GDC members and Loren Turner – weekly calls	May 19, 2010	V1.1 released
Completion of v2.0a	Consultant delivers v2.0a schema, dictionary and report	June 30, 2012	V2.0a released
Final Transfer Workshop	Transfer DIGGS to ASCE-GeoInstitute, develop implantation proposal to ODOT	June 22-23, 2012, SF, CA	Developed proposal to ODOT for new funding to transfer schema to ASCE-GeoInstitue and make available to community.

Figure 1.4 A Timeline of the Development of the DIGGS Project by the GeoInstitute of the American Society of Civil Engineers (ASCE).

1.8 GI^5 and Web-based Data Viewing

As an increasing number of MnDOT projects now involve facility reconstruction, the usefulness of legacy data is steadily becoming more important, as is the need to be able to search for this information effectively. There is also increased interest in making geotechnical information more available to MnDOT staff, other units of government, researchers, geotechnical practitioners, project contractors, and the public. Even without the depth-based electronic data, the MnDOT Geotechnical Investigation Information Interchange Internet Interface (GI5) is proving to be very useful to both internal and external geotechnical users.

The system is regularly to find borings either using the interactive map or by searching for records by their unique boring number, structure number, or a combinations of these and/or other parameters. Figure 2 shows an example of several borings found using the MnDOT ArcGIS application; a DOQ map is selected as the background.

1.9 Recent Updates to the MnDOT Desktop Web Application

In the summer of 2015, the MnDOT web application had to be taken offline. The second generation system resided on a server running MS Windows Server 2003, which was becoming obsolete and would not be supported by Microsoft for security patches and updates. While important, the boring application was not deemed mission critical infrastructure and was given a lower priority for replacement than other systems. The system did however remain on-line behind the MnDOT firewall and was still able to be used internally. Users could forward inquiries to DOT staff and the self-service application became full-service for a time. The temporary project webpage is at: http://www.dot.state.mn.us/materials/gi5splash.html

Rather than use resources to simply adapt the application to a new server and newer software (the architecture and code of the system had become outdated) a decision was made to improve the entire web application. This update (generation 3) became concurrent with the later stages of the GeoApp mobile app development process. While not by original design intent, the two systems (the desktop 3rd generation system and the app) are similar in functionality and general appearance.

At present the system uses Google Maps and Google satellite imagery. Some functions available in the second generation system such as using the MnDOT state base-map, USGS digital raster graphic (DRG) topographic quadrangle maps, and digital orthophoto quadrangle (DOQ) maps (aerial photos), as backgrounds are not currently supported.

One of the primary challenges for the web application continues to be the need for collaboration between the geotechnical staff and software developers; both groups have challenging schedules and limited resources. The system does save time and money by allowing users to seek out and select boring information themselves. If the PDF files of the logs have been previously generated, no additional time is needed on the part of DOT staff to fulfill information requests. In addition to reducing workload, this also allows external customers immediate service and feedback, as opposed to submitting an information request and waiting until it can be processed. The GeoApp builds on this theme, allowing easier access for users who may be in the field and would like access with a more mobile-friendly user interface.

CHAPTER 2: GEOAPP SOFTWARE DEVELOPMENT

The GeoApp is a smartphone app inspired by MnDOT's Gi5 web site and is primarily of interest to MnDOT geotechnical engineers, and external users who have a project need for soil boring information related to highway bridges and structures in Minnesota. Inquiries are often received from researchers, geologists, consulting engineers, developers, planners, and private individuals.

Because MnDOT is responsible for creating and maintaining transportation infrastructure (roads and bridges) in the state of Minnesota and because doing so requires knowing the soil conditions at those sites located throughout the state, there is a wealth of assembled information from nearly 60 years of site investigation. Usually, one or more boreholes are advanced at a site; in situ testing is conducted and in most cases soil samples are obtained and later tested in a laboratory for such properties as strength, compressibility, and permeability. The tests are used to ensure proposed transportation asset locations are suitable for constructing a road, bridge, or other facility. In some cases a typical foundation can be used, and in other cases unusual means and methods may be required to improve the site prior to, or during, construction. The original soil boring information and in-situ tests, as well as laboratory tests are entered on a boring log. These logs are then printed electronically into PDF files which are organized by their unique number. The unique number is a sequential number provided to each boring. Often a project identifying number may also be assigned.

2.1 App Development Background

Mobile app development began in the 1990s with the release of the Psion Epoc, a palmtop computer. Refer to the URL: https://manifesto.co.uk/history-mobile-application-development/ for a discussion of the history of mobile app development. Subsequently a large variety of mobile devices were released using a variety of different operating systems. These included Apple iOS, Bada, BlackBerry, Firefox OS, Google Android, LG webOS, Microsoft Windows Phone (7 and 8), Nokia Symbian OS, Tizen (SDK 2.x), and Ubuntu Touch as a representative selection (https://en.wikipedia.org/wiki/Apache_Cordova). This variety presented app developers with a serious problem since developing for each of these platforms usually required the installation of a software development kit (SDK) for each platform and the use of a different programing language for each supported platform. Additionally, a developer usually had to use a machine running the operating system being programmed, as in the case of Apple devices, as an example. It wasn't possible for an app developer couldn't use a MS Windows machine to develop an app for an Apple device.

2.2 App Categories

Apps for smart phones/tablets can be roughly divided into one of three categories.

1. Web applications (web apps) which consist of web sites in the traditional sense and that are accessed by web browser(s) installed on the users' device. Such apps have no access to many of the features frequently included on a particular mobile device. These added features often include: an Accelerometer, Camera, Compass, [user] Contacts, File, Geolocation, Media, Network, Notification (Alert, Sound, Vibration) and local or cloud Storage.

2. Native apps that are developed using a particular programming language such as Java for Android devices or Objective C or Swift for Apple devices. These apps usually have access to all of the features included on a particular mobile device.

3. Hybrid apps that are developed using a framework such as Cordova/Phonegap. Such apps are developed using traditional web tools such as HTML5, Cascading Style Sheets (CSS) and Javascript. However, the framework allows such apps to have access to most of the features available on a smartphone or tablet. This approach allows the user to maintain a single code base that can be deployed to a variety of different devices. See https://en.wikipedia.org/wiki/Apache_Cordova for a discussion of the different platforms and features supported by Cordova.

2.3 Using the Google Maps API

Each bore hole is displayed on a map using the Google Maps JavaScript application programming interface (API). This API is available for free for a wide variety of use cases; refer to: https://developers.google.com/maps/documentation/javascript/. Fortunately, the MnDOT GeoApp's use case fits the STANDARD plan (https://developers.google.com/maps/pricing-and-plans/#details) and is therefore free for use. When the GeoApp is first started by a user, Google Maps is downloaded from Google and the app display is centered on the state of Minnesota.

2.4 Developing Webpages for Mobile Users

Single-page web applications are more mobile (app) friendly as they are organized differently than the more common organization or moving among distinct pages with different URLs. Single-page frameworks such as Sencha Touch and AngularJS could be used to develop a web application for a mobile platform.

There are several ways of targeting mobile devices. Context sensitive web design can often be used to make a web application viewable on small screens and work well with touch-screens. There may be difficulties in doing this if there are guidelines or formatting templates which dictate how web pages are to be organized and displayed for consistency and conformity with other use requirements. Native apps or "mobile apps" are designed to run directly on mobile devices, just as a conventional software applications run directly on desktop systems without a web browser (and potentially without the need for Internet connectivity); these are typically written in Java (for Android devices) or Objective C or Swift (for iOS devices). React Native and Flutter are new programming tools, allowing the creation of native apps for Android iOS platforms using languages other than the standard native languages. Hybrid apps embed a mobile web site inside a native app, often using hybrid frameworks like Apache Cordova and Ionic or Appcelerator Titanium. These tools allow development using web technologies (and possibly directly applying code from existing mobile web sites) while retaining advantages of native apps (direct access to device hardware, offline operation, app store visibility).

2.5 Developing the Prototype GeoApp (Phase I)

The GeoApp development was separated into two phases to allow development to begin in the spring of 2013 in an earlier fiscal cycle than the rest of the project. Phase 2 would begin following the July 1, 2013 beginning of the new budget year.

Development work on GeoApp began with approval in mid-April of 2013 and authorization to proceed on May 7, 2013. A prototype of GeoApp was completed by late May with some of the core functionality already in place. The prototype was, however, only based on information available at that time from approximately 1800+ bore holes in a test database.

A new database structure was being created to simplify data importing to the new MnDOT web application and the GeoApp. Although the prototype structure existed, there was a significant delay in executing a separate contract to code the script that would aggregate the data from the thousands of individual project databases to populate the new database. Unfortunately, due to unfavorable contract timing, a master contract lapsed and it took several months to proceed with the independent development of the gINT file export script.

During the contracting delay, a correspondence file was created and several large project files were exported independently, one at a time, into the test database. This was the 1800 borehole database used for preliminary development of the GeoApp.

Also during this period, the researchers were working on using clustering to represent the bore hole sites within the app. The idea being, since there are a very large number of borings and soundings, representing them individually on a map at large scales (until zoomed in to a more localized area) is likely to provide a very poor user experience. With clustering, a collection of bore holes is, at a certain “altitude” [map scale], represented by a single marker. The marker has a number on it that corresponds to the number of bore holes in that cluster. As you zoom in the cluster marker eventually disappears in favor of markers that represent individual bore holes. Refer to Figure 2.1 for a map of the borings available in the greater Minneapolis/St.Paul area using the cluster markers. This can be compared to Figure 1.1 for what the available borings in the same general area looked like in the generation 2 desktop web application.

As the development intent was for multiple platforms, the researchers began experimenting with PhoneGap (http://phonegap.com/). PhoneGap is a cross platform development framework that allows developers to create apps using standardized web APIs for a variety of platforms. PhoneGap’s primary advantage over native app development is that an app developed for a single platform can, with little modification, be adapted for another. PhoneGap currently supports development for iOS (Apple), Android, Blackberry, WebOS, Windows Phone 7 + 8, Symbian and Bada. The support provided is, in some cases, limited but that provided for iOS and Android (the primary platforms required by the agreement) is complete. PhoneGap is an open source framework and thus has little or no cost to the developer. In addition to PhoneGap, it was the intent to incorporate the Google Maps JavaScript API for rendering the map view and JQuery Mobile to facilitate development. Both are available to developers at no cost.

Additional information on GIS efforts in Minnesota was provided through a link to the MN Geospatial Information Office at http://www.mngeo.state.mn.us/

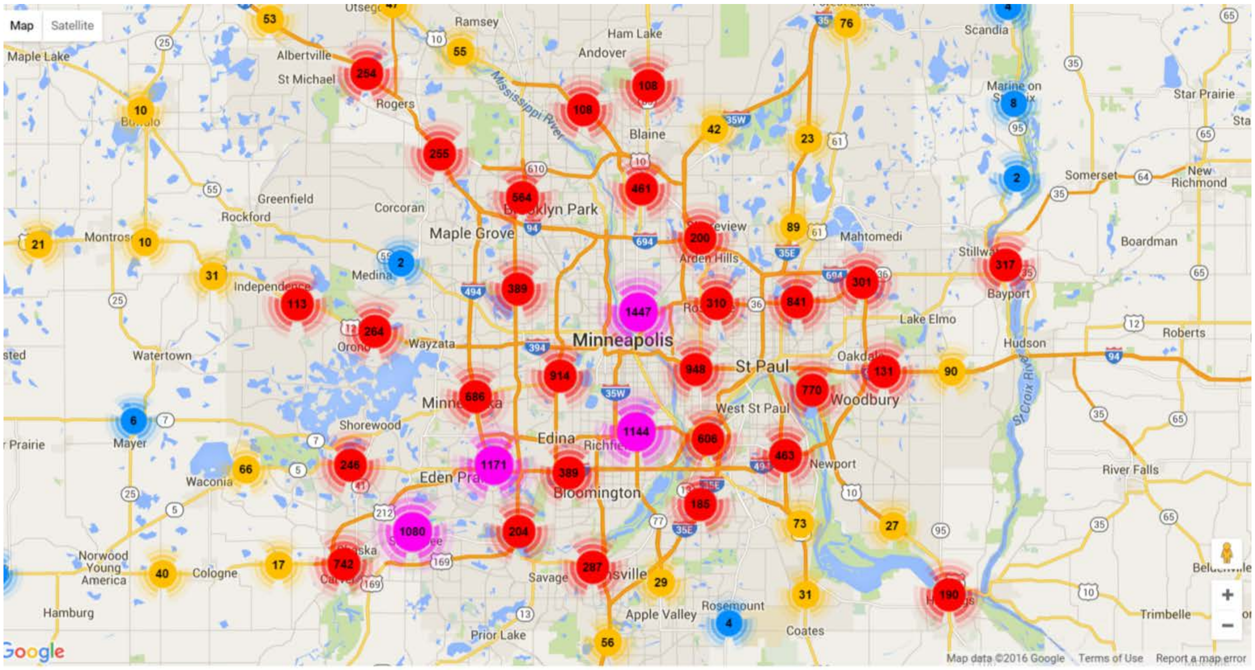

Figure 2.1 Sample of the clustering markers employed by the GeoApp.

2.6 Developing the Full GeoApp (Phase II)

In the summer of 2013 the second phase of the GeoApp development contract was executed. It was intended that this application would be based on the full 34,000+ bore holes. Unfortunately that information didn't become available until March 2014. In late 2013 a contract extension was executed to adjust the development period to reflect the delay in the development of the full boring database.

The GeoApp has undergone numerous development revisions in an effort to incorporate improvements and make it more usable. Most notably, changes were made to how the data is loaded into the app to make it somewhat faster, so the user doesn't experience a disconcerting lag when navigating in the map interface. Time was spent attempting to minimize the amount of time it would take the app to respond to the user and improve the user environment (such as the appearance of the dialog boxes and the amount of content provided).

In some cases features common to mobile apps could be incorporated to help improve the user experience, where others were determined to actually provide a worse interface. A sample of a development challenge was in the form of the use of scrolling and pick-lists to help select parameters- rather than typing information in. There are 87 counties in Minnesota, and it would be easier for a mobile user to select from a list county names such as Clay, Hennepin, and Mower than to have to type them in- certainly so for Kandiyohi, Koochiching, and Lac qui Parle. However, the list of 87 counties is a bit long to scroll among, and more importantly for the app, the counties are arranged in the MnDOT database by their number only. This would make a pick-list difficult to interpret for a casual user who, more than likely, is unfamiliar with the alphabetic sequence of the counties in Minnesota.

2.7 Development Hurdles

During the course of the development process, it became apparent that there were numerous technical terms related to both the content of the app and the development framework. Things which were obvious to the geotechnical engineering team (the owner) were not always well understood by the app development team. The app functionality was not particularly detailed, however, so this was not a major hurdle.

More often the programmers were using terms that were not well understood by the geotechnical team. As an example- there were frequent references to ".json" files. Not being involved in programming, this file extension was unfamiliar and even when the files were further described as JavaScript Object Notation files, it was still unclear as to their role or what their content contributed to the functionality of the app. Not possessing the development tools, the programming process appeared very "black box' in nature. Having people involved in a project that can act as liaisons or interpreters can be very valuable to help convey meaning and context that might otherwise be lost due to the very different backgrounds of the project team members.

Although a goal of the project was to determine the level of difficulty associated with the development hurdles, the team struggled with a way to quantify communication difficulty.

An unanticipated difficulty was that the development was being carried out by a small team consisting of a university professor and an undergraduate student worker. The development process would have likely been different if an IT contractor more familiar with client interaction had been selected for the work. Given the significant external delays associated with developing the primary loading databases this development path was certainly less expensive and more forgiving to the fits and spurts of companion efforts.

A second example of an unanticipated difficulty was related to hardware and transferring the app onto mobile devices for demonstration and testing. There were different processes for loading the app onto Android and iOS devices and often a variety of cables were necessary for connections with iPad, iPhone, Samsung Galaxy phones and Panasonic Toughpad tablets. Figure 2.2 shows the GeoApp after it was loaded on a Panasonic Toughpad tablet. Where a fully developed app would normally be downloaded from the iTunes or Google Play electronic "stores," during development, direct loading was necessary through a physical connection with the development mobile computer. This meant a physical trip to Mankato State University for periodic updates. In one instance, the app refused to load onto a Panasonic Toughbook, despite repeated attempts.

There were also difficulties associated with the nature of some of the input data. Some MnDOT boring locations with poor legacy location information were "snapped" to coordinates associated with legal descriptions of land parcels (section, township, range). This resulted in multiple assets being located at a single spatial coordinate. This created data presentation difficulties- How could a user select among multiple features all displaying "one top of one another?" This and the other difficulties were eventually overcome.

Figure 2.2 The GeoApp was loaded onto a Panasonic Toughpad using the USB connection port, connection cable, and the development computer.

CHAPTER 3: USING THE GEOAPP

3.1 Getting the App

The app is currently available on the Google Play store. The app is scheduled to also be available on the Apple iTunes store, but further development is required to meet their somewhat more stringent development guidelines. Figure 3.1 shows a search to find the GeoApp in the Google Play store. The easiest way to find it is to do a search for “geoapp allan hart.” Figure 3.2 shows the app (highlighted in the red circle) in the Google Play store for android OS mobile devices. The logo is small and unassuming, and looks like a small robotic computer screen; it may be revised or enlarged in the future.

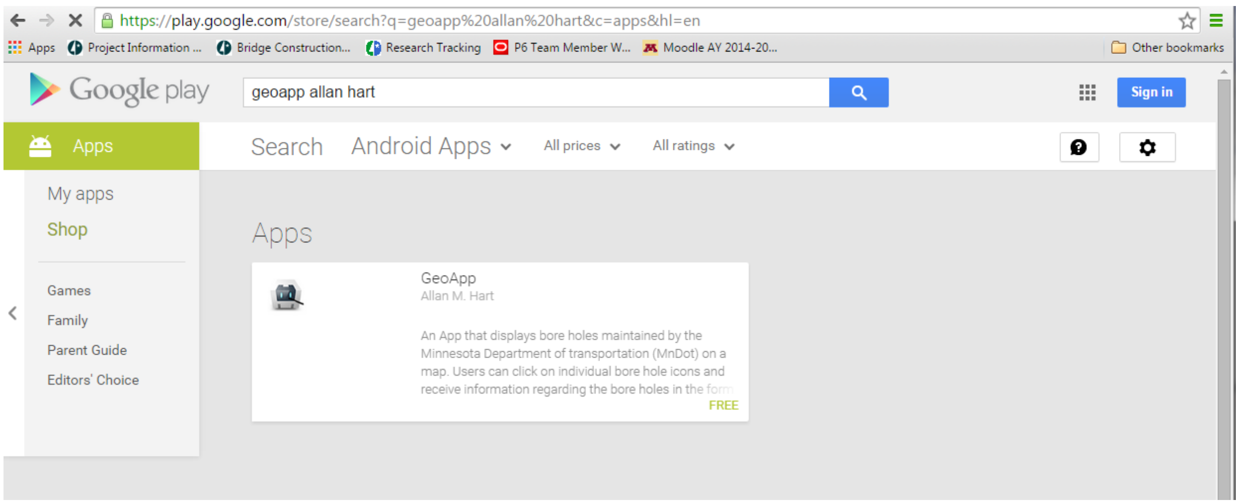

Figure 3.1 Searching for the GeoApp in the Google Play Store

3.2 Launching the App

The GeoApp has an icon associated with it. A user launches the mobile app in the same way other apps are launched, by tapping on the touch-screen of the device. When GeoApp is first started, an disclaimer text box is displayed explaining some of the “legalese” associated with GeoApp- basically, stating that the user acknowledges there may be errors in the information and that the app and the information are not guaranteed to be true and correct in all cases.

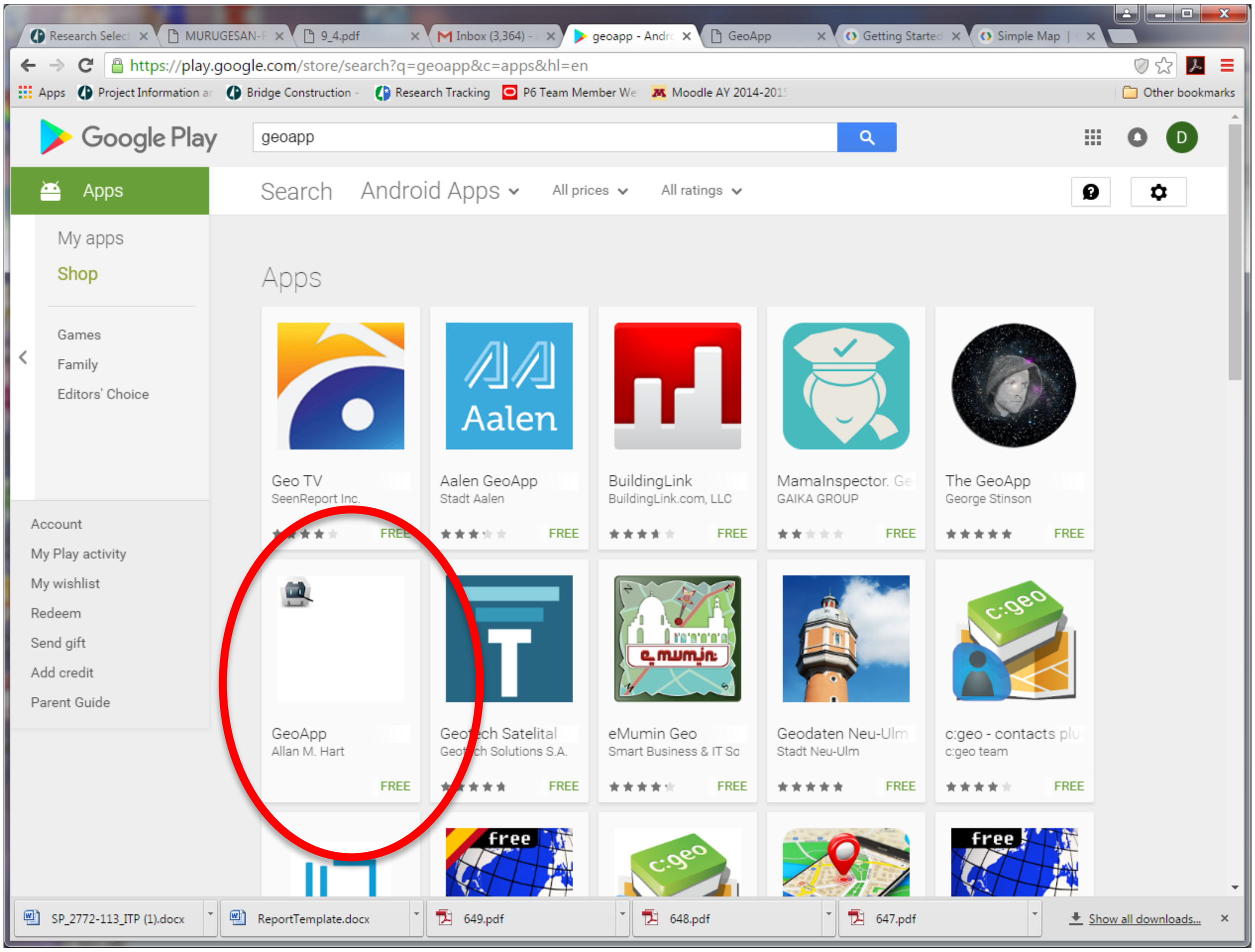

Figure 3.2 The GeoApp in the Google Play Store for Android OS mobile devices.

3.3 The Opening Dialogue

After clicking on OK to dismiss the introduction alert and acknowledge the limitations associated with the app, the “Bore hole Filters” page is displayed. The page is shown as a screen shot in Figure 3.3. In the development version of the app where the screen capture was taken, the County list was by county number, rather than by county name.

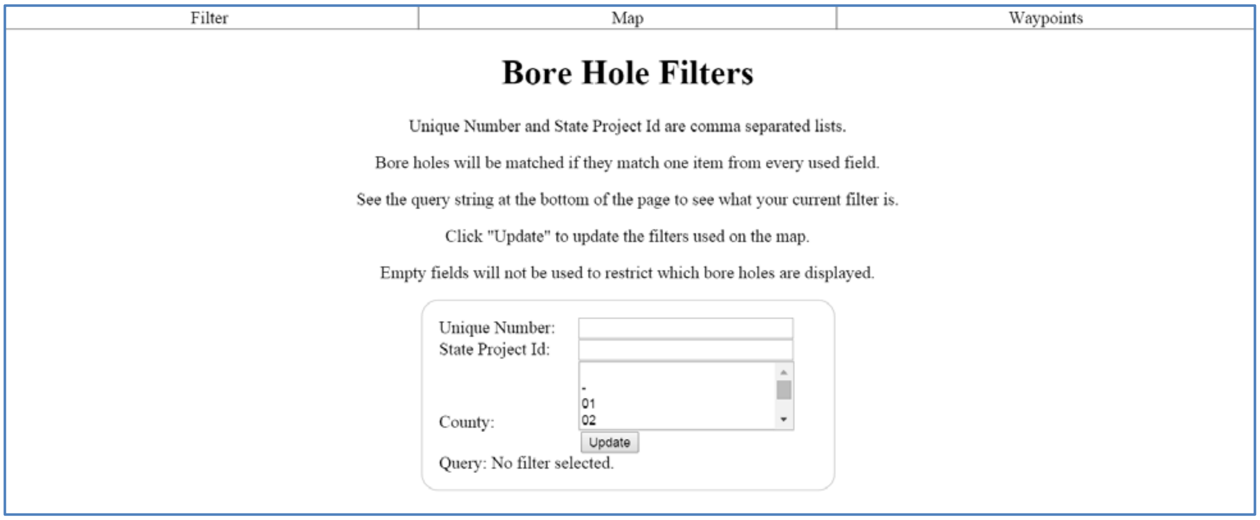

Figure 3.3 Opening filter dialogue.

Because some devices have very limited memory, this page allows the user to filter the bore holes that are displayed. The user can immediately select bore holes of interest by supplying criteria including: a boring Unique Number, State Project ID, or by selecting one of more Minnesota counties.

After making the appropriate selections, the user can click on the gray Update button to see the map with the selected bore holes. Alternatively if the user does not have filtering information available, the user can, if desired, click on Map (center top) to see all 35000+ bore holes.

Figure 3.4 shows the GeoApp running on a tablet device. The user has selected the Map function and zoomed in the map to an area just east of the Minneapolis-St. Paul Airport at the junction of I-494 an I-35E. Several boring marker clusters, of two types (blue and yellow) are shown.

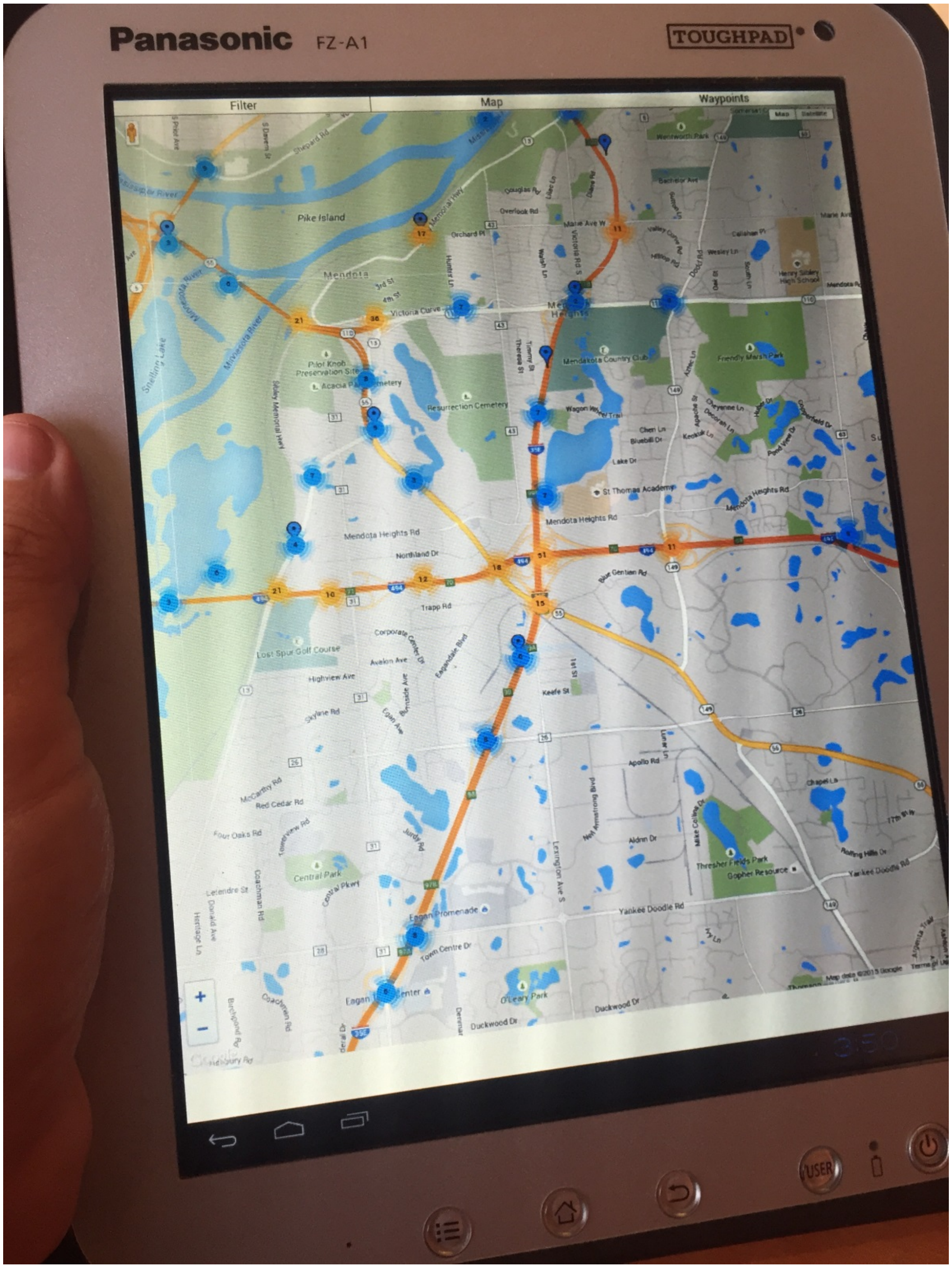

Figure 3.4 Navigating in the GeoApp using the Map selection on a tablet device.

3.4 Markerclusters

The colored circles in Figures 3.4 and 3.5 are examples of markerclusters. Each markercluster represents a collection of bore hole markers near the location of the markercluster. The number of bore holes in the cluster is given by the number in the circle. The markerclusters are also color coded. Blue is the color for a collection of 1-9 bore holes. Yellow is the color if there are between 10 and 99 bore holes. Red is the color if there are between 100 and 999 bore holes. Pink is the color if there are between 1000 and 9999 bore holes. Purple is the color for a cluster of more than 10000 bore holes. As the user zooms out, the clusters are combined into fewer and fewer clusters. The left image in Figure 3.5 shows a screen capture after zooming all the way out; the result is a map with a single cluster. Alternately, when a user zooms in sufficiently, individual borings appear with blue location markers (as seen at center in Figure 3.5). When a single boring is selected, a metadata dialogue opens, showing point-level attribute information.

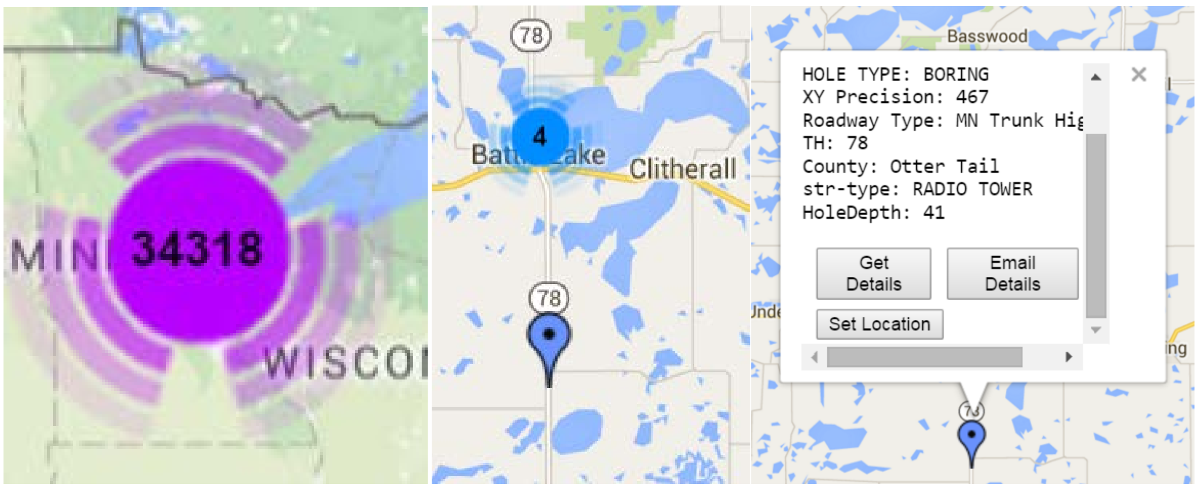

Figure 3.5 Samples of markerclusters when zoomed out (left) and when zoomed in to a specific location.

The purpose of the markerclusters is to make it possible to more easily see the map and not be overwhelmed by the individual borings. More importantly, it would take more time and processing resources to plot the thousands of individual boring locations. Without clusters the markers would need to be rendered to cover the entire map and the user experience would be quite poor due to the delay, especially if the user was attempting to resize or shift the map as the borings were rendering.

As the user zooms in the clusters are broken down into smaller and smaller clusters and individual markers begin to appear. The user can zoom in by using the map controls located in the lower right corner of the map or by clicking on a given cluster. The image in Figure 3.5 (at center) shows an individual marker as well as a nearby blue cluster with 4 borings associated with it. Clicking on an individual marker causes an info window to appear as shown in the rightmost image in Figure 3.5. The metadata box includes information on the hole type, hole depth, the approximate largest error in the asset location, the highway type, highway number, county, and the type of structure the asset was advanced to characterize. Three buttons are also included in the dialogue- “Get Details, “Email Details” and “Set Location.”

Clicking on the Get Details button will usually result in the display of a .pdf file containing the information associated with that particular bore hole. Figure 3.6 includes two examples. Most newer borings and cone penetration test soundings advanced from about 1992 forward were entered into an electronic database with graphics capabilities. Most of this information is in a crisp original electronic PDF file format. Older boring log information can appear on one or multiple pages and was often scanned in from paper records. The image quality is not always good for these records and not all legacy data has been scanned. Some historic information was lost or misfiled.

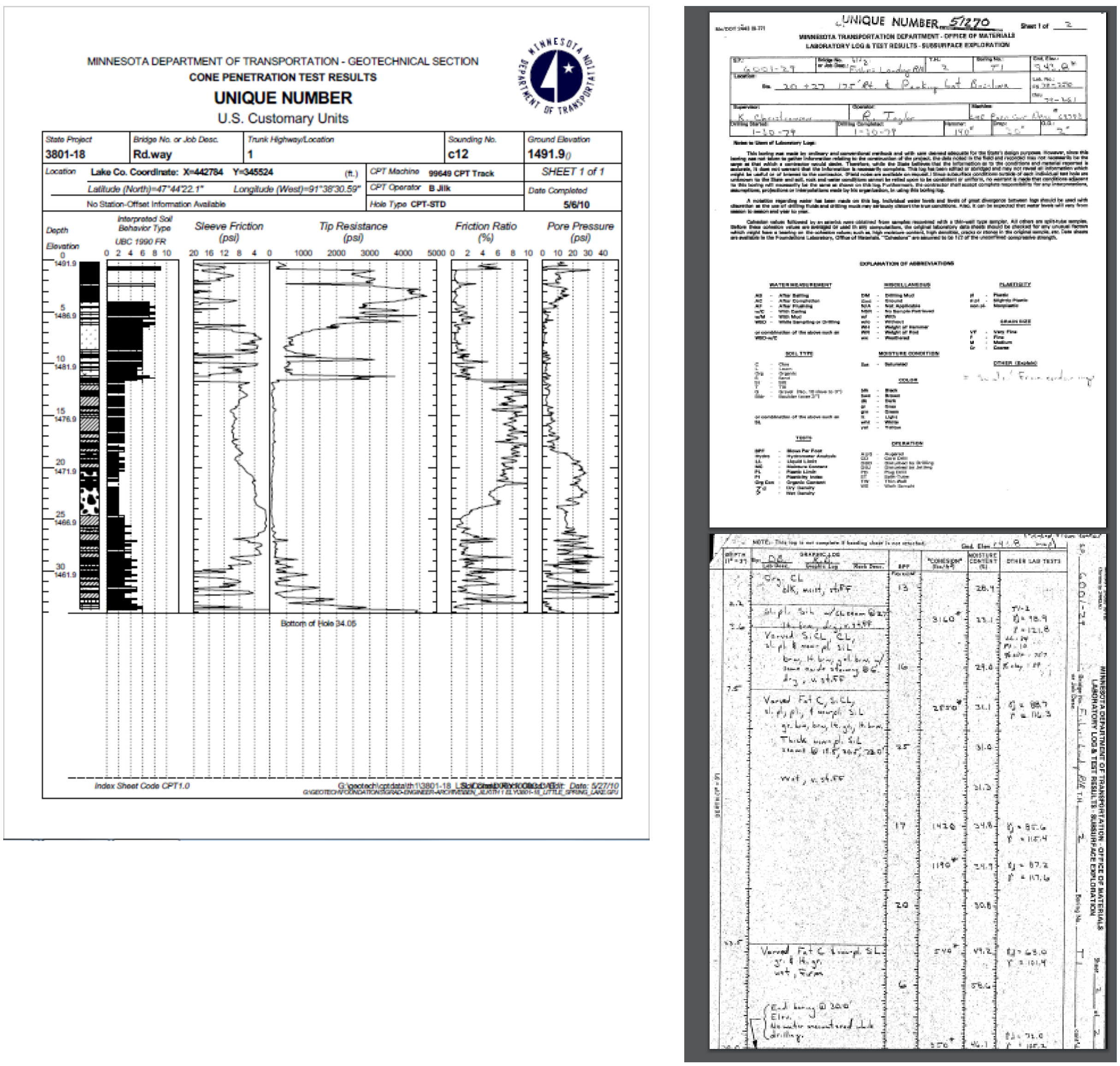

Figure 3.6 Samples of a computer generated cone penetration test advance log (at left) and an older, scanned, log of a handwritten SPT boring log (2 pages, at right).

Not all bore holes and soundings have an associated .pdf file. If that is the case for a particular bore hole, then the text in Figure 3.7 will be displayed. Most assets have either scanned or electronically generated PDF files. Often MnDOT receives inquiries from self-service web users with respect to borings which are shown in the GI5 web-based desktop system when PDF files are not available. In many cases the borings have not yet been scanned or electronically printed. In most circumstances, the borings can be made into PDF files on demand. It likely about 3% to 10% of the borings shown in the system do not yet have electronic files associated with them. 1% to 2% likely have “lost data” where the depth dependent data is unrecoverable and only the point-level metadata survives. In some rare cases, boring data exists, but location data does not, so the asset can’t be properly located for any future use.

Figure 3.7 Error 404, File not found.

3.5 Using Mobile Device Capabilities/Functionality

If the device being used to run the GeoApp has GPS capability then a marker will be displayed using a different color than those used for designating bore hole markers and the map will initially be centered around that marker. The purpose of that marker is to have it be the first in a series of markers known as waypoints.

Figure 3.8 shows the marker displayed for a device having GPS capability. Note that the color of this marker is red whereas the color of a marker for an individual borehole or sounding asset is blue. Unlike the blue asset markers, clicking on the red user-location marker does nothing (there is no database information associated with the user’s current location). The marker’s sole purpose is to represent the user’s current location.

Waypoints will be explained in the following section. If the device being used does not have GPS capability, then the Set Location button is displayed. This button allows the user to set a particular marker as the first marker in a set of waypoints. Note that this button allows the user to reset the beginning location even if a beginning location has already been set either by GPS or if the user has previously used the Set Location button. The Email Details button allows the user to send the .pdf file (if it exists) with the details of the soil analysis to themselves or to others.

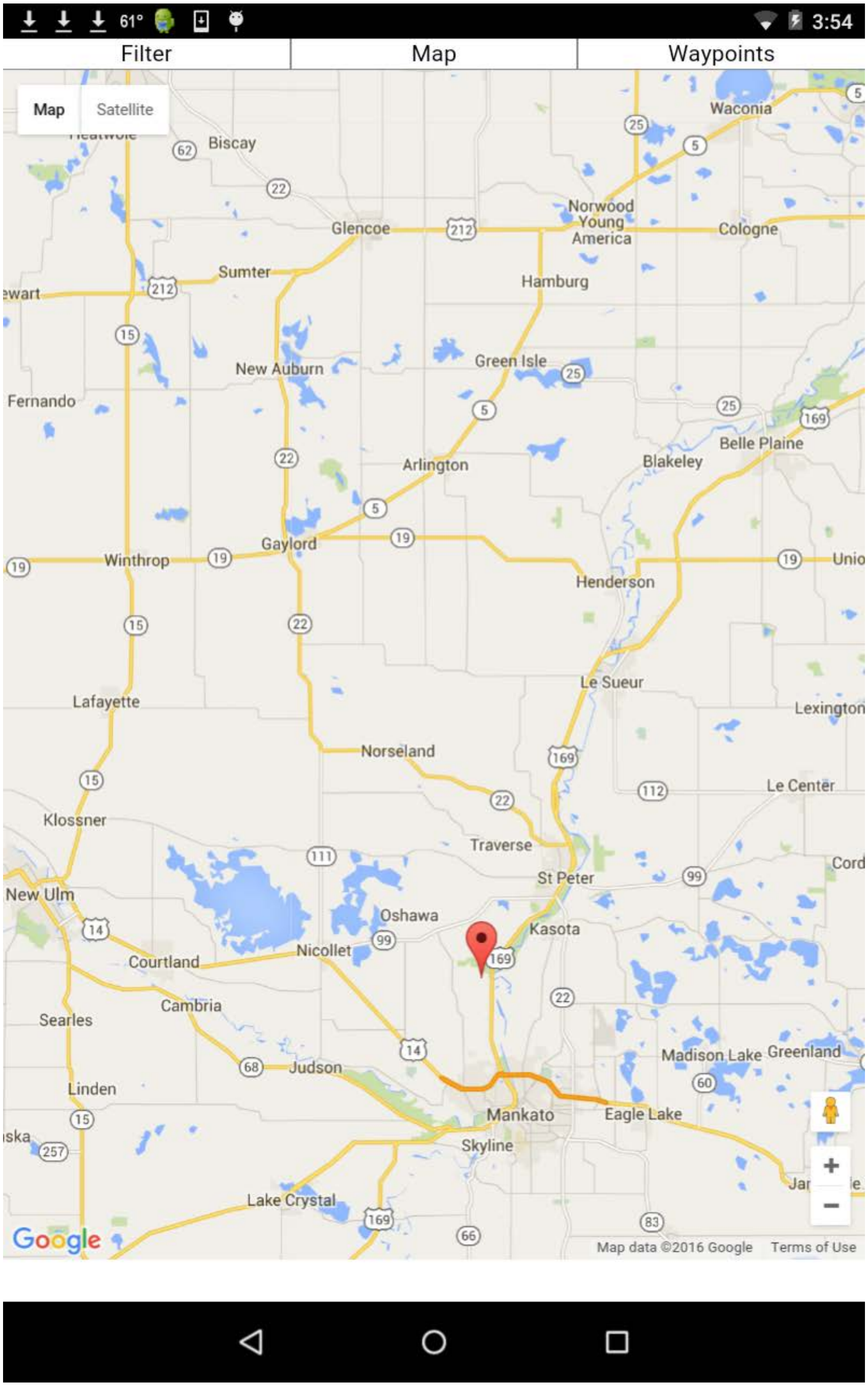

Figure 3.8 A red marker displays the user's location.

CHAPTER 4: WAYPOINT FEATURE

4.1 Waypoints

Since mobile devices have GPS functionality and GeoApp users may be in the field looking for geotechnical assets, these users may also be interested in site visits or determining where the borings were physically taken with respect to current site features.

The GeoApp allows users to specify boring locations as navigational features and then allow users to navigate from one feature to another using the GPS and mapping functionality.

4.2 Using the Waypoint Functionality

If the device supports GPS functionality, the GeoApp allows the user to designate up to 8 bore holes as members of a set of waypoints. Waypoints allow the user to display a route through a set of waypoints. Figure 4.1, below, shows an infowindow with an Add to waypoints button.

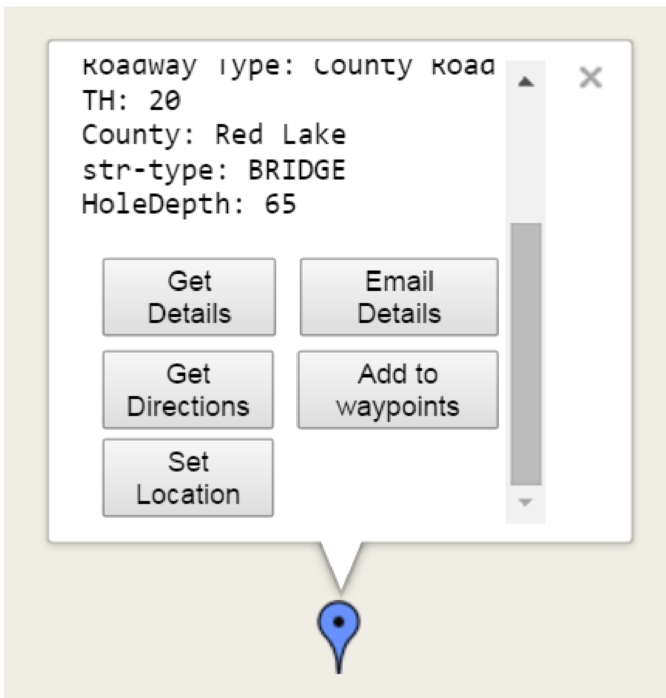

Figure 4.1 Information window in the waypoint feature.

If the user clicks on the Add to waypoints button then that particular bore hole will become part of the route. If a set of waypoints has been established, then a Get Directions button appears and if the user clicks on that button, then a route will be shown from the starting location to the last marker in the set of waypoints. Figure 4.2 shows an example.

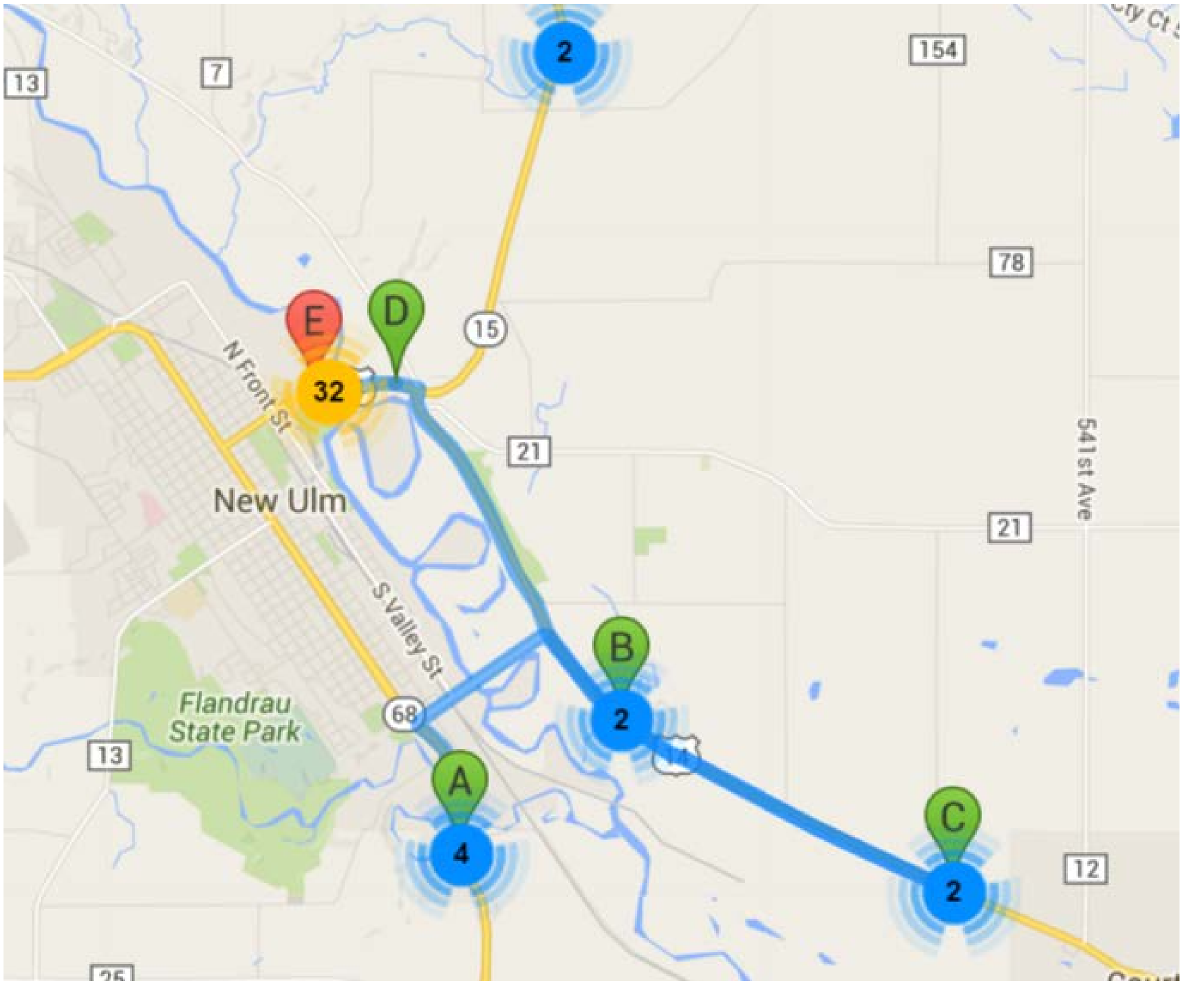

Figure 4.2 Using waypoints to navigate to borehole features.

Waypoints can also be controlled by the Remove Route and Waypoints buttons. Clicking on the Remove Route button removes the route displayed and clicking on the Waypoints button gives something like the following list as shown in Figure 4.3.

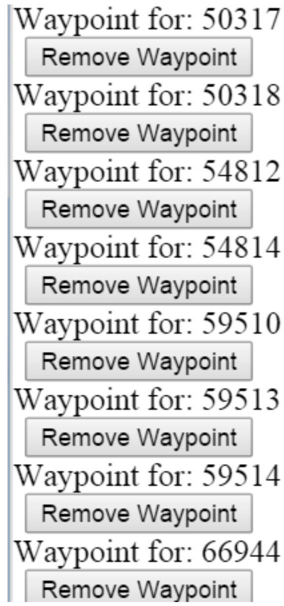

Figure 4.3 Sample waypoint list.

The Remove Waypoint button allows the user to remove particular waypoints from the route if so desired.

CHAPTER 5: GEOAPP DEPENDENCIES

5.1 Using Mobile Device Capabilities/Functionality

The GeoApp utilizes Google Map services. Refer to the website at the URL below for a description of Google Map services and how a developer can incorporate Google Maps into a web site. The URL page is shown in Figure 5.1.

https://developers.google.com/maps/documentation/javascript/tutorial

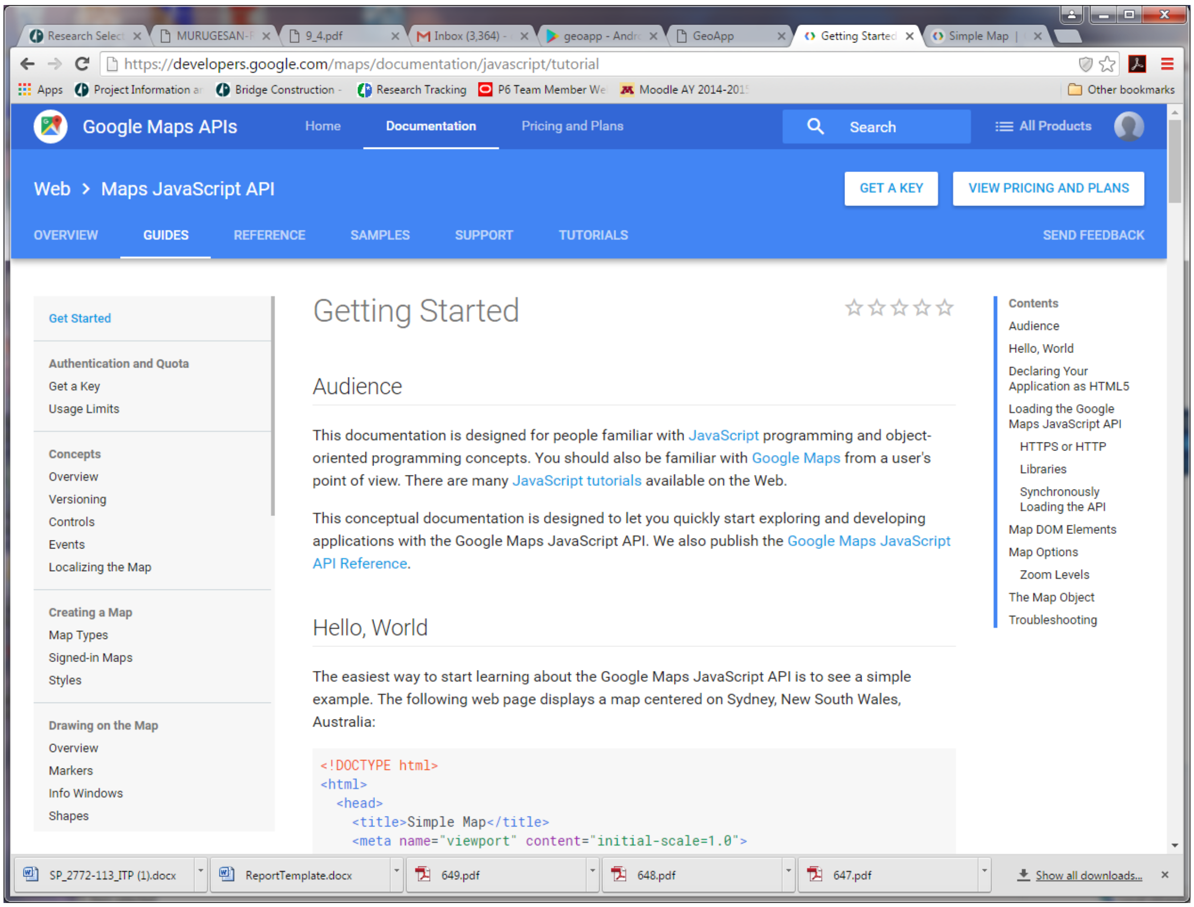

Figure 5.1 Google Maps APIs web page.

GeoApp also utilizes the Marker Clusterer utility as described earlier. Refer to the website at the URL below for a description of Marker Clusterer and how a developer can incorporate Marker Clusterer into an app that utilizes Google Maps.

https://code.google.com/p/google-maps-utility-library-v3/wiki/Libraries

GeoApp uses the popular jQuery framework. As noted at its web site (https://jquery.com/), jQuery is a fast, small, and feature-rich JavaScript library. It makes things like HTML document traversal and manipulation, event handling, animation, and Ajax much simpler with an easy-to-use API that works across a multitude of browsers. With a combination of versatility and extensibility, jQuery has benefited many coders who use JavaScript.

CHAPTER 6: THE GEOAPP AS PART OF A SUITE OF TOOLS

6.1 Desktop and Mobile Device Functionality

With the GeoApp the MnDOT Geotechnical Section will haves developed two web-based applications which make most agency geotechnical borings web-searchable and printable. Additional areas for development include the addition of 2-D geophysical data, lab data, and monitoring/instrumentation data, although there are no current efforts underway to include this information.

The overall effort to develop the self-service data sharing and exchange systems has resulted in an increase in data quality, an improvement in overall process automation, and a significant reduction in MnDOT staff time running queries and looking up project information on request. Using the mobile and desktop applications records can now be obtained in real-time by both internal and external customers through the user-intuitive mapping interfaces. Figure 6.1 shows a sample of the GeoApp interface with the marker clusters at left and a PDF of a boring log associated with one of the borings at right. The system is similar to the desktop application shown in Figure 6.2 for a harmonized user experience between the two systems (compare the similarity of the dialogue boxes in Figure 3.4 and 6.2).

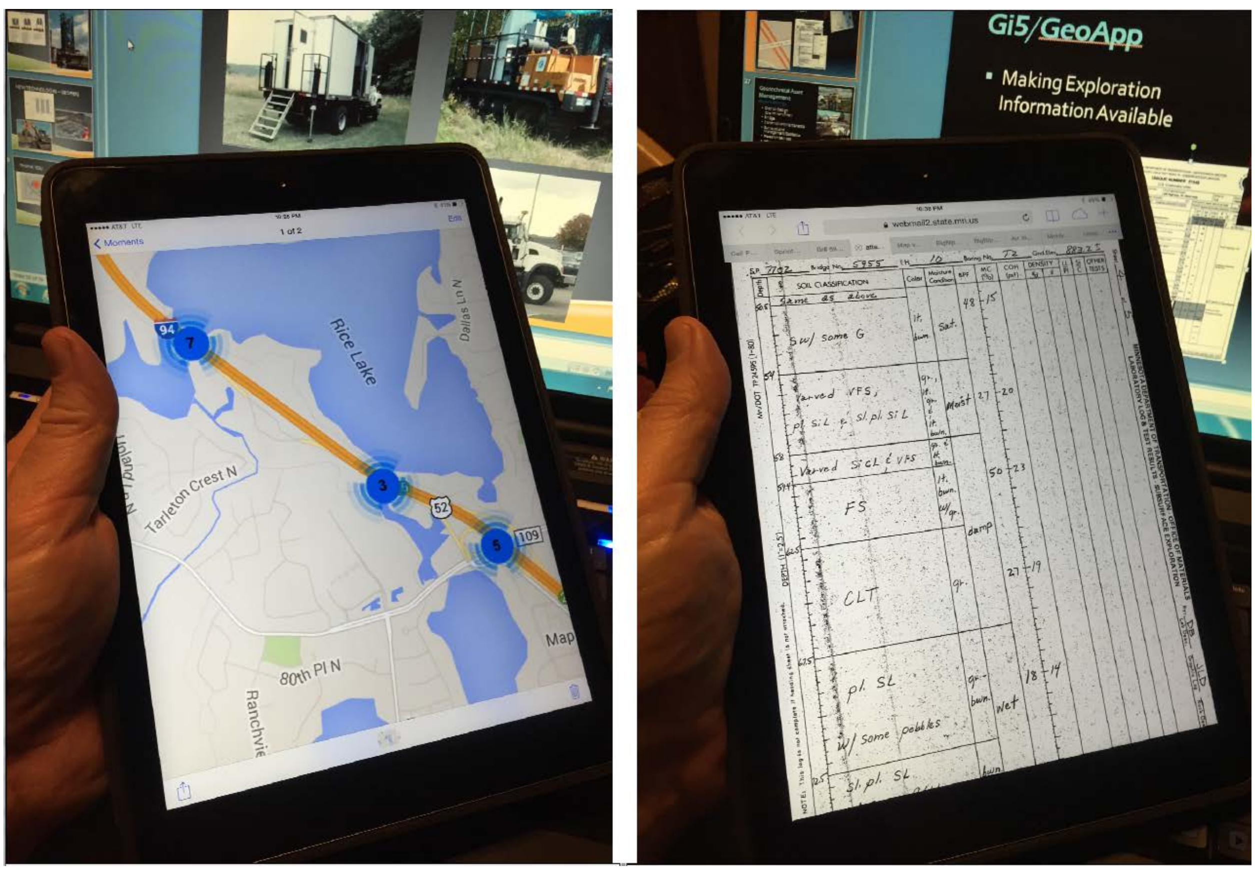

Figure 6.1 The GeoApp allows the functionality of the desktop GI5 application tailored to mobile devices to make use of the touch-screen and GPS functionality.

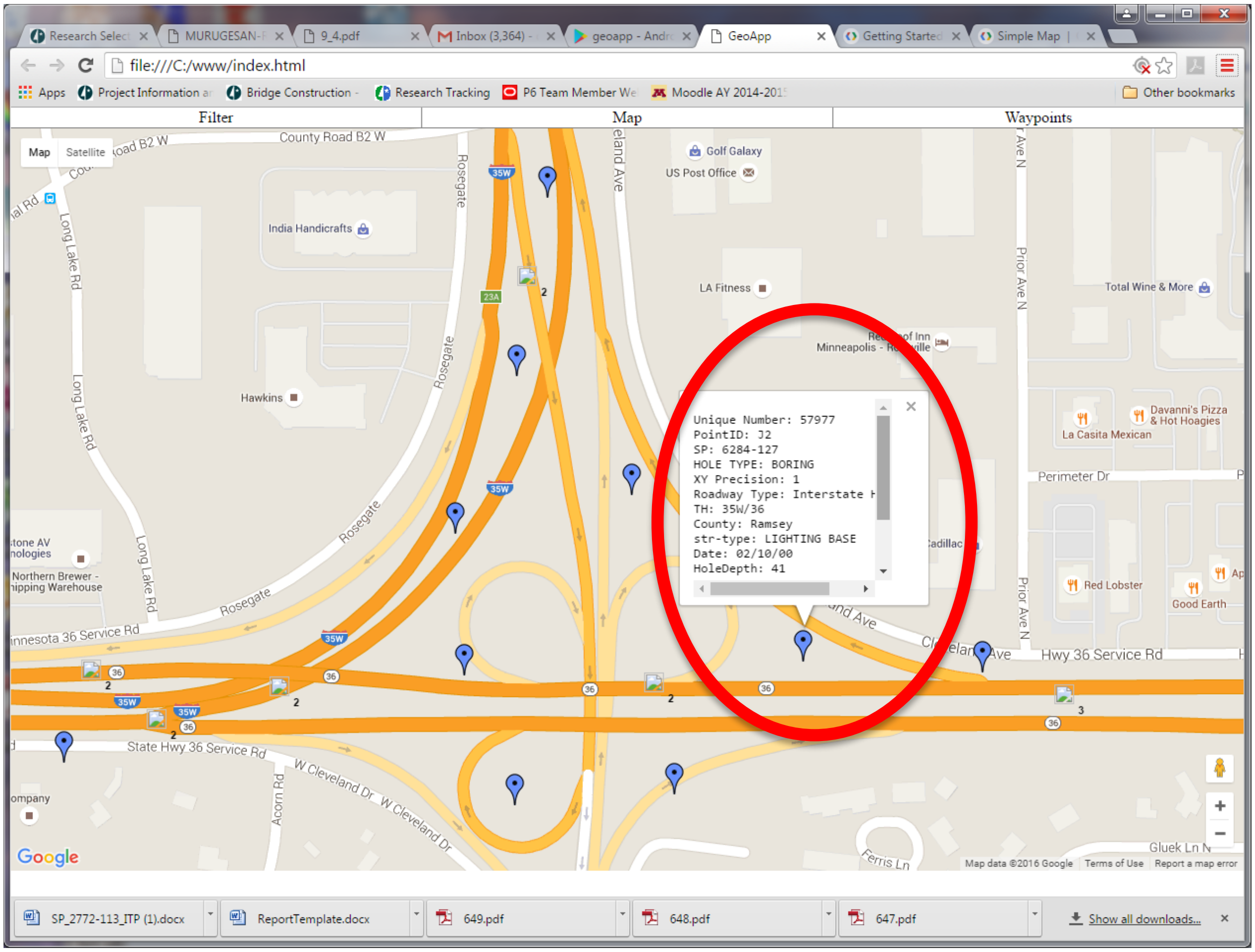

Figure 6.2 Screen shot of the desktop boring locations and the small dialogue box (red circle) showing the additional boring information, including the unique number. In the desktop interface, if a PDF of the boring exists, the Unique Number will display in blue and be underlined. Clicking on it will link to the boring (compare to the "Get Details" button in the GeoApp for mobile devices.)

CHAPTER 7: CONCLUSIONS

7.1 Conclusions from the GeoApp Project

A custom mobile phone and tablet application ("app") has been created for use on smart-devices (phones and tablets running iOS and Android operating systems) that will allow users to easily access MnDOT geotechnical boring asset information in the field. Through the app, users can easily access MnDOT foundation boring point-level metadata and download PDF files of boring logs of interest.

This mobile-friendly tool supplements an existing website, which is being reconstructed, and was off-line, during this research project. In addition to the development of the app itself, the research implementation effort explored the development time, effort, documentation, and interdisciplinary coordination for development of similar systems. It was found that technical terminology and industry jargon presented an unusual level of complication through the development process. In addition, there were challenges coordinating the development of the app using both iOS and Android platforms and accessing MnDOT data.

The GeoApp is currently available for Android devices on the Google Play store. It can be found by searching for "GeoApp" (one word) by Allan M. Hart. Through this tool, MnDOT foundation borings can be accessed using queries, with available filtering, or by using map navigation. The app link to the MnDOT webserver and allows users to access electronic PDF files of soil borings in real time. The app provides an interface more directly tailored to use on mobile devices than the MnDOT ArcIMS application, which was developed for desktop web browsing.

The app development showed that a mobile application was possible using a variety of development tools, tools which were unfamiliar to geotechnical engineers who developed the initial specifications for the study. The work underscored the need for collaboration and clarity in interdisciplinary communications. The app is expected to provide a broader benefit to consultants, contractors, local units of government, researchers, students, and others when access to MnDOT borings in the field would be helpful.

A copy of the app, modified for use on desktop computers was also provided as an outcome of the research effort. The app development project has already provided useful background for the redevelopment of the MnDOT Foundations web interface. The new interface is somewhat faster than the legacy application and possesses similar features, developed for the GeoApp. The app introduced features not included in earlier desktop interface tools, including waypoint navigation, pick lists for queries, boring clustering, metadata pop-up windows, and other interface tools, which were not part of the legacy applications. Some of these features are being included in the Gi5 desktop webpage redevelopment effort.

A comprehensive discussion of the desktop web-based ArcIMS application, which served as the foundation for this mobile application, has been discussed in this report.

REFERENCES

Caronna, S., (2006) "Implementing XML for Geotechnical Databases," JTC2 Workshop on Geo-Engineering Data: Representation and Standardisation, IAEG Congress, September 9, 2006, University of Nottingham, United Kingdom, url: http://www.dur.ac.uk/geo-engineering/jtc2/.

Dasenbrock, D. D., (2006) "MnDOT's 'On-Line' Geo-Spatial Borehole/Sounding Database Development." *GeoCongress 2008: Characterization, Monitoring, and Modeling of Geosystems, Proc.*, Geo-Congress 2008, Feb 26-March 1, 2006, Atlanta, GA, Edited by DeGroot, DeJong, Frost, and Baise, ASCE, Reston, VA.

Dasenbrock, D. D., (2008) "Geotechnical Data Sharing and Electronic Data Exchange at Minnesota DOT." *Geotechnical Engineering In the Information Technology Age, Proc.*, Geo-Congress 2008, March 9-12, 2008, Atlanta, GA, Edited by Reddy, Khire and Alshawabkeh, ASCE, Reston, VA.

MnDOT (2007), "MnDOT BaseMap History," Minnesota Department of Transportation, url: http://www.dot.state.mn.us/maps/gisbase/html/history.html.

Ohio Department of Transportation (2012), "Development of Geotechnical Data Schema in Transportation," Ohio Department of Transportation, url: https://www.dot.state.oh.us/Divisions/Planning/SPR/Research/Training/Documents/Presentations/134254DIGGS2012June22.pdf.