The Council of State Governments
Sharing capitol ideas.

ID: 10-MW-19MN

2010 Innovations Awards Application

Program Category

Infrastructure and Economic Development

Transportation

Integrated Geotechnical Investigations

Minnesota Department of Transportation

1. Program Name

Integrated Geotechnical Investigations

2. Administering Agency

Minnesota Department of Transportation

3. Contact Person (Name and Title)

Glenn M Engstrom

Chief, Geotechnical Engineer

4. Address

Office of Materials and Road Research

1400 Gervais Avenue

Maplewood, Minnesota 55109

5. Telephone Number

651- 366-5531

6. FAX Number

651-366-5461

7. E-mail Address

glenn.engstrom@state.mn.us

8. Web site Address

http://www.dot.state.mn.us/materials/geoteng.html

9. Please provide a two-sentence description of the program.

MnDOT's geotechnical investigation program uses a combination of the latest technology to accurately and cost-effectively determine soil and rock stratigraphy. Accurate sub-surface profiles improve foundation designs, reduce construction costs and improve the overall design of the final product.

10. How long has this program been operational (month and year)? Note: the program must be between 9 months and 5 years old on March 1, 2010 to be considered.

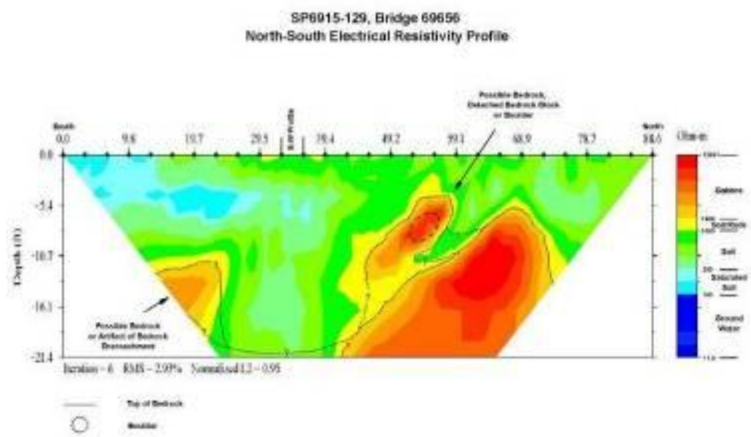
About 3 years of full implementation.

11. Why was the program created? What problem[s] or issue[s] was it designed to address?

A recent Federal Highway Administration (FHWA) study showed that 50% of all construction claims nationally are related to geotechnical issues. These claims cost MnDOT millions of dollars each year. Furthermore, meetings with each of the MnDOT Districts have highlighted the need for more complete geotechnical investigations, especially during the scoping stage of projects. This need was especially apparent during a recent meeting with the Metro District on the Cost Estimating Improvement Initiative. At this meeting, it was agreed that better

geotechnical investigations early in the process would result in significant cost savings and improved overall design.

An accurate and comprehensive geotechnical investigation is vital to the success of any transportation construction project. Traditional methods are limited to the use of soil borings to determine the stratigraphy of the subsurface layers. Soil borings require a team of three people to operate the drill rig and can take several days to complete a single boring. In addition, the data is only valid for the size of the hole, generally 3-inch diameter and samples are only taken about every 5 feet vertically. The area between the exploratory holes and samples is assumed to vary linearly. This approach limits the overall subsurface "picture" of a site and gaps in the data can lead to problems in the field during construction.



The use of new technology fills-in the gaps left from traditional soil boring methods. First, Electrical Resititivity Imaging (ERI) is used to give an image of the subsurface layers much like an MRI is used in the medical field. Depths up to 60 feet can be accurately defined for future more precise examination. ERI can be used to generate 2-dimensional and 3-dimensional subsurface resistivity distribution and by correlation with CPT and soil borings provide valuable information about soil stratigraphy.

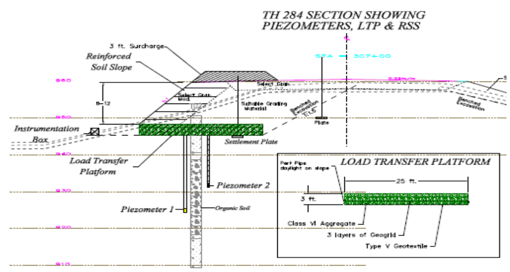
Second, the Cone Penetrometer Test (CPT) uses an instrumented probe to measure mechanical soil properties as it pushed through the soil. The CPT instantly gives engineers a continuous measurement of in-situ soil properties that can be used directly for design purposes. The device is also up to 12 times

faster than conventional soil boring and only requires a two person crew vs. three on a traditional drill rig.

12. Describe the specific activities and operations of the program in chronological order.

Project Selection

Each project is unique. Projects are reviewed by the Geology and Foundations Units with District personnel to determine what geotechnical features need to be examined and what data will be collected for design. During this review it is determined which investigation tools are used to perform the subsurface exploration. Each piece of equipment has its own attributes and must be fit into the investigation program to optimize its use. Items considered include, existing geology, structure type, environmental issues, equipment capability, past history, and data required.



Geotechnical Investigation

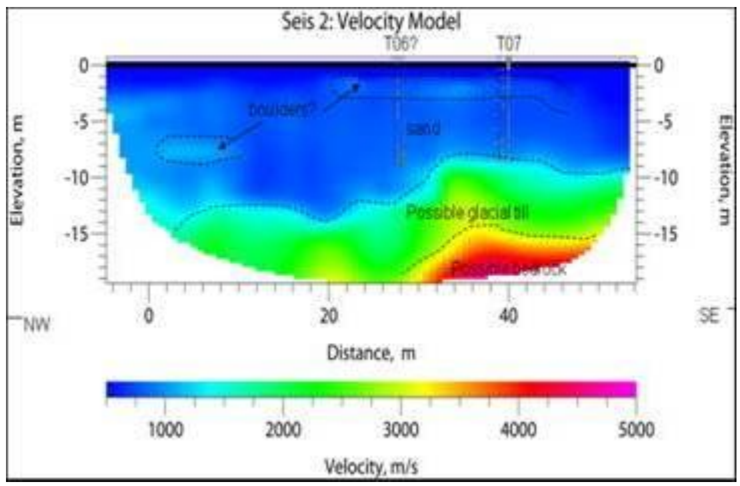
Phase 1

The field investigation generally starts with an ERI survey. The location is selected by reviewing the plans, reviewing existing maps and surveys and conducting an on-site field visit. The ERI survey is completed by 2 to 3 people and can be completed in one day for small projects to several days for large projects. The survey is very non-intrusive, 14-inch long, 3/8 inch diameter steel rods are driven into the ground at 10 foot intervals. The rods are connected by cable to a power supply and data collection device.

Survey lengths of up to 1100 ft can be completed at one time and take about 90 minutes. All data is precisely located using GPS coordinates to ensure that the data can be directly compared in the future.

Phase 2

Back at the office, the data collected from the field is analyzed using software developed by the manufacturer. Data collected in the morning in the field is often analyzed and reviewed the same afternoon. The ERI gives some really neat colored pictures and results in an excellent "big picture" view of the subsurface. However, without additional investigation and testing you don't necessarily know what the big blue blob is, how strong it is, or how it is going to perform if a large embankment is placed on top of it. Is the red area really hard rock or is it a large void? This is where the real power of the process begins. We can now target our remaining tools to further define the questionable areas. The result is less drilling and more useful information.



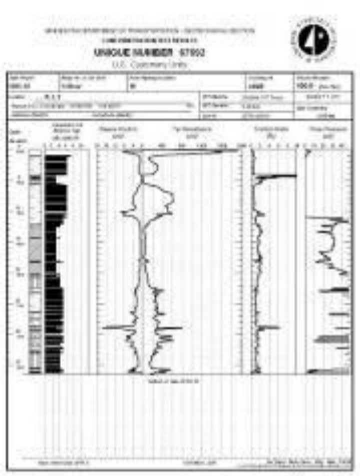
Phase 3

Engineers and geologists review the data collected and layout a plan to direct the continuing investigation. The CPT gives a good indication of how the soils behave, especially in-situ, but adds little information to a rock investigation beyond where penetration gets hard. It also leaves you wanting more if you are accustomed to seeing, feeling, smelling, or tasting soil. The Standard

Penetration Test (SPT) is the slowpoke of the bunch, but provides samples that can be seen, tasted, felt, and smelled. They can also be tested in the laboratory. Each tool has its value and when taken together in the right combination gives an exceptional picture of what Mother Nature left us to use when we build. Deciding which to use when and how is not a trivial decision that is probably best made by the people that do the work. It is also a dynamic process that gets adjusted as the investigation progresses. Sometimes what we thought would work well turns out to be the wrong piece of equipment for the conditions encountered. For the Geotechnical Section, this has required a joint effort of Foundations and Geology to coordinate what is done, when it is done, and who does it.

Phase 4

During the final exploration phase MnDOT drill crews use the CPT and SPT to target areas of interest and collect samples. The CPT is often the tool of choice for this operation because of its speed, in-situ data collected and cost. Data collected with the CPT is continuous, eliminating the gaps with created with other methods. We also use a team approach with constant feedback from the field. Drill crews are briefed on what is expected to be encountered in the field and report on what is actually found. The plan is routinely modified to better define areas of interest. Additional borings and deeper borings are required on a case-by-case basis. All data collected in the field is placed in a database for easy access to the design team and also acts as an historical archive. All the geotechnical investigation data is



included in the final report and available for review by contractors during the bid process and through construction. The final geotechnical investigation gives the designer all the inputs necessary to complete an efficient and cost effective design.

13. Why is the program a new and creative approach or method?

MnDOT's Geotechnical Section is always looking to improve the way we deliver our products to our customers. MnDOT was one of the first DOT's to purchase and use a CPT for production work in 1999. We also are leaders in using GPS technology for locating borings and have been storing the information in our gINT boring log template with an ArcIMS application for the last 6years. ERI surveys were first completed on a experimental basis in 2005.

MnDOT's approach to geotechnical investigations integrates a variety of tools and technology to produce a complete picture of the subsurface regime. This method optimizes the use of equipment and personnel to give designers the information they need to make sound design decisions. Communication between geologists, engineers and field technicians is key to making the system work. Each must know their role and how they fit into the final goal. MnDOT presented our method at the Transportation Research Board Annual meeting in Washington DC. We received several positive comments but maybe the best was from Asger Eriksen, CEO, Zetica Ltd, Long Hanborough, UK,

"I attended the geophysics session on January 10 at the TRB conference and very much enjoyed your talk on integrating geophysics in your SI strategy. I found this a refreshingly practical approach which I think other organizations would benefit a lot from."

14. What were the program's start-up costs? (Provide details about specific purchases for this program, staffing needs and other financial expenditures, as well as existing materials, technology and staff already in place.)

ERI Only (The CPT was already in-place.)

Dedicated Truck - $35,000

Hardware - $46,500

Software - $3,500

Training - $5,000

Staff - In-place staff is used to collect and analyze data.

15. What are the program's annual operational costs?

Staff - $70,000

Travel - $4,000

16. How is the program funded?

Annual Scientific Equipment Budget

Annual Materials Office Operating Budget

17. Did this program require the passage of legislation, executive order or regulations? If YES, please indicate the citation number.

NO!

18. What equipment, technology and software are used to operate and administer this program?

Cone Penetration Test – Uses an instrumented cone to measure in-situ soil properties as it is pushed into the ground.

Electrical Resistivity Imaging - A geophysical method that measures variations in the electrical resistivity of the ground, by applying small electric currents across arrays of ground electrodes. The survey data is processed to produce graphic depth sections of the thickness and resistivity of subsurface electrical layers. The resistivity sections are correlated with ground interfaces such as soil and fill layers or soil-bedrock interfaces, to provide engineers with detailed information on subsurface ground conditions.

GPS Surveying - Global Positioning System surveting equipment that is used to establish the location of ERI surveys, soil borings and CPT soundings.

gINT/ArcIMS Soil Boring Application – A data base that archives soil boring and CPT data in a map-based format.

19. To the best of your knowledge, did this program originate in your state? If YES, please indicate the innovator's name, present address, telephone number and e-mail address.

Yes.

Jason Richter, 1400 Gervais Avenue, Maplewood, MN 55109

651-366-5453 jason.richter@state.mn.us

Rich Lamb, 1400 Gervais Avenue, Maplewood, MN 55109

651-366-5595 rich.lamb@state.mn.us

Derrick Dassenbrock, 1400 Gervais Avenue, Maplewood, MN 55109

651-366-5597 derrick.dassenbrock@state.mn.us

20. Are you aware of similar programs in other states? If YES, which ones and how does this program differ?

No.

21. Has the program been fully implemented? If NO, what actions remain to be taken?

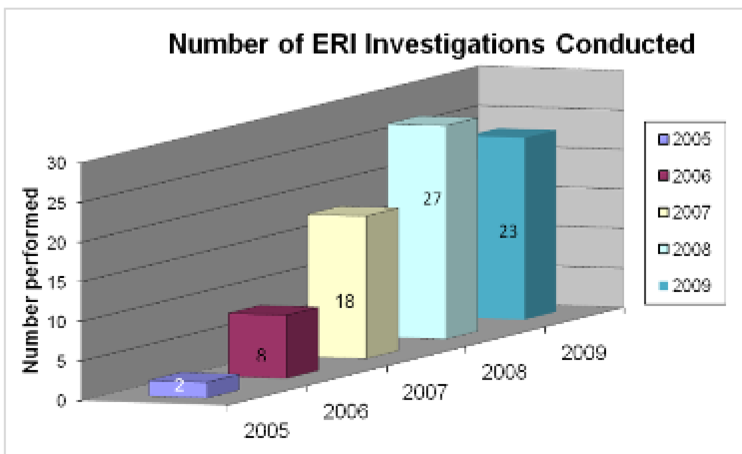
Yes.

22. Briefly evaluate (pro and con) the program's effectiveness in addressing the defined problem[s] or issue[s]. Provide tangible examples.

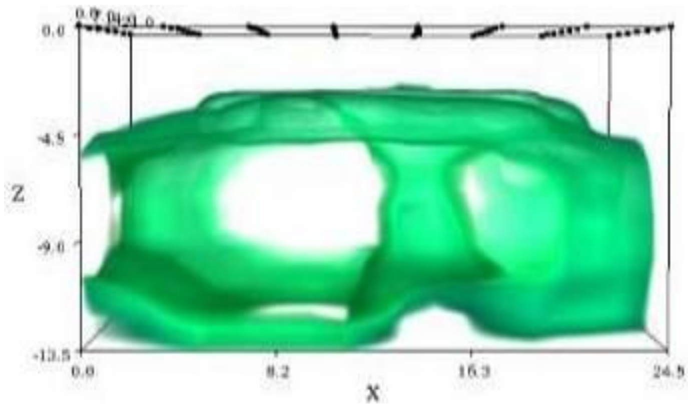
The geophysical capabilities employed by the MnDOT Geotechnical Engineering Section have been an effective supplement to the subsurface investigation process. Seismic refraction, surface wave and electrical methods have been employed on a variety of projects related to scoping, preliminary design and post-construction failures. On most projects, geophysical methods are used in conjunction with drilling methods and, therefore, provide information that reduces uncertainty between boreholes and allows more intelligent locating of soil and rock sampling sites. However, in some cases, geophysical methods are the only source of subsurface information utilized in the design of a structure. One such application was the Kohl's Bridge Project in Duluth, MN. In this instance, conventional methods of acquiring soil and rock data (such as standard

penetration testing, cone penetration testing and rock coring) could not be performed due to the sensitive nature of the project site. Electrical resistivity imaging was performed and revealed shallow bedrock thereby completely modifying the original plan which called for deep foundations for both the bridge and 400 feet of associated retaining walls. In another case, depth to bedrock estimates were needed in select areas of a proposed realignment of a 4-mile stretch of TH1 near Ely, MN to constrain locations of and acquire cost estimates for potential rock slope construction. Since drill rig access was restricted by steep topography, dense woods and large boulders seismic refraction and surface wave methods were utilized and located bedrock at depths sufficient for soil slope construction.

23. How has the program grown and/or changed since its inception?



Electrical resistivity imaging has become an effective supplement to the subsurface investigation process for the Mn/DOT Geotechnical Engineering Section. Since acquiring the system, the Geology Unit has performed approximately 36 ERI surveys (30 two-dimensional surveys, 6 three-dimensional surveys) and 4 induced polarization surveys on 12 different projects. ERI surveying has provided seamless 2D and 3D subsurface views when used, preferably, in conjunction with CPT and traditional drilling methods or in areas where drilling was not possible or restricted. The Geology Unit has employed electrical resistivity imaging in a variety of terrains (roadways, ditches, rivers, thick woods, frozen marsh, farm fields, to name a few) and on a variety of projects encompassing the scoping, pre-construction and post-construction phases. ERI



has specifically been used to ascertain general soil-rock stratigraphy, constrain thicknesses and/or locations of organic deposits, acquire bedrock profiles and groundwater elevations, investigate sinkhole-related cavities/voids as well as void space related to underground abandoned mine workings. In one instance, ERI was used to assess the failure mechanism in an embankment constructed with Geofoam. Future applications are also planned and will involve underwater profiling of swamps and other bodies of water, contaminant detection via the induced polarization method and assessment of aggregate availability in Mn/DOT gravel pits. The usefulness of ERI has prompted plans to incorporate the method into the new Mn/DOT Scoping Initiative to help curb unwanted, construction phase cost overruns from, for example, unplanned muck excavations.

24. What limitations or obstacles might other states expect to encounter if they attempt to adopt this program?

Despite significant use of ERI and the cone penetration test (CPT) in geotechnical engineering practice, there is still limited use of the technology by State Department's of Transportation (DOTs) in the United States. Reasons for slow adoption of the technology range from:

- ground conditions too hard;
- staffing requirements
- cost
- data analysis requires too much expertise
- existing practice is "good enough"
- training
- equipment too expensive / not available in the area.