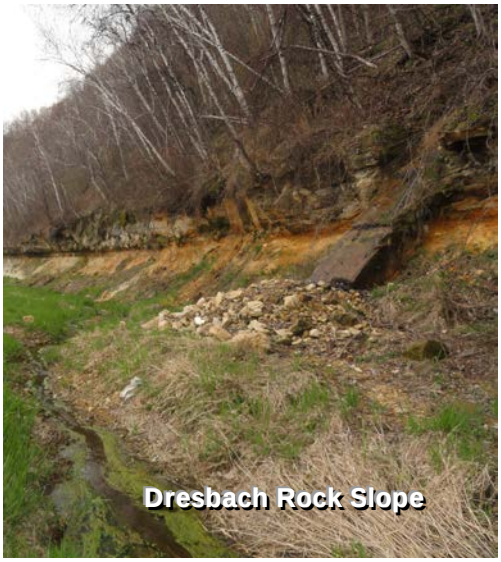
Geotechnical Section
2011 Annual Report
MnDOT Office of Materials and Road Research


Chisholm MASW


New Drill Rig

SPT Hammer Calibration


Dresbach Rock Slope

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Executive Summary

The Geotechnical Section experienced a significant change during 2011 with Grading and Base moving to the Pavement Section of Materials and Road Research and the Aggregate Unit becoming part of the Geology Unit. The three week shutdown of government had a profound effect on investigations, especially since it occurred during what is normally a very productive time of year. CPT production also suffered due to the CPT track being out of service for the year. However, the Geotechnical Section continued to utilize new technology to provide services to customers. The following paragraphs give a brief description of what each unit accomplished in 2011.

Foundations

Innovative contracting was a major part of operations in the Foundations Unit. Several major design/build contracts requiring geotechnical oversight and assistance occurred during the year. Load and Resistance factor design also played a major role in foundation operations during 2011. Two load frames for pile load testing are being constructed as part of a major effort to calibrate dynamic formulas and provide data for optimizing pile design. Several projects have been selected for pile load testing which are expected to result in immediate cost savings due to fewer and/or shorter piles. Valuable information will also be obtained for future considerations. Several piles on select bridges have also been instrumented to monitor their long term performance resulting in valuable information for future pile design.

Geology

The year in Geology can be characterized as quality rather than quantity as we worked on several large projects and rolled out a new, innovative geophysical method. The major projects included performing a MASW monitoring project over 2 miles of newly-constructed CRCP on TH169 in Chisholm; providing analysis, recommendations and testimony related to sulfide content of the bedrock in a new alignment to TH169 near Ely; and providing an evaluation and recommendations for the rock slope design and rock fall mitigation on the I-90 Dresbach reconstruction project. The new geophysical method, known as Multichannel Analysis of Surface Waves (MASW), uses a towed array of seismic geophones, a mechanical vibration source, and a multichannel seismograph to record surface waves. A multistep processing of the collected data produces a 2-D map of subsurface shear-wave velocity. This technique was used successfully on several projects, including TH169 in Chisholm (mentioned above). The use of this unique method (MASW) is innovative in itself, but adding to the innovation was the purchasing and assembling of the various components that make up the array, the towing device and the seismic source – in this case, a hitch-mounted hydraulic hammer.

Grading, Base and Aggregate

The Grading, Base and Aggregate Unit was an integral part of the Geotechnical Section for a portion of 2011. The Unit declined an invitation to supply information to be included in this report. Contributions from the Aggregate specialist are included under the Geology Unit.

2011 Geotechnical Annual Report

Report Purpose

The purpose of this report is to describe the accomplishments and future direction of the Geotechnical Engineering Section of Mn/DOT's Office of Materials and Road Research. It is also intended to help our customers gain a better understanding of what technical services are available for their use. Other benefits include:

1. Aiding in effectively managing the section.
2. A tool to report to upper management.
3. Supporting strategic planning efforts.
4. Measuring past accomplishments and set goals for the future.

Section Mission

Support the Office of Materials and Road Research, Mn/DOT Districts, Policy, Safety and Strategic Initiatives Division and other agencies by providing geotechnical and geological engineering expertise.

Section Overview

The Geotechnical Section provides geotechnical and geological services for:

- Structural foundations
- Engineered soil and rock slopes
- Aggregate durability, quality and availability
- Roadway subgrade and base construction
- Geosynthetics
- Vibrations

These services are provided in the form of, surface and subsurface investigations, design recommendations, field assistance, laboratory testing, resource databases, specifications, design standards, and technical training. The section is comprised of two units, Foundations and Geology.

The Foundations Unit duties include:

- Subsurface investigations, sampling and testing of soil, rock, and groundwater and measurement of in-situ engineering properties for foundations for bridges, retaining walls, high embankments and other structures.
- Design and review recommendations for bearing capacity, settlement, slope stability, and other foundation related problems.
- Design and review for engineered embankments and excavations of soil and rock, retaining walls and reinforced earth systems of all kinds on stable and unstable ground.
- Construction assistance and monitoring of geotechnical related functions such as pile driving (using the Pile Driving Analyzer), slope stability (using slope indicators), and pore water pressure (using piezometers).
- Expertise and training in geosynthetics, lightweight materials, alternate retaining walls/systems, geotechnical instrumentation, steepened slopes, swamp crossings, and failure investigations.
- Technical research liaison for geotechnical issues at local, regional, and national levels.

The Geology Unit duties include:

- Complete subsurface geophysical investigations using electrical resistivity and/or seismic surveys for a variety of transportation infrastructure facilities.
- Lithological identification, rock mass classification and analysis of rock competence for recommendations including; rock slope and excavation design, foundation bearing capacities, blasting, vibrations, and rock fall management.
- Evaluation of groundwater problems and design of groundwater control systems; mitigation of dewatering impacts and prevention of moisture damage to pavement structures.
- Guidance in the search for sound, durable aggregates for construction by identification of deleterious properties and recommendations for screening test procedures, and assessment of properties of native materials produced by the aggregate industry.

- Technical recommendations and guidance in the areas of engineering geology, vibrations, water wells, and aggregate quality by: providing training for technical certification; preparing manuals, standards, specifications and special provisions.
- Provide aggregate source information to district soils, materials, design engineers, and Office of Technical Support personnel.
- Maintain the Aggregate Source Information System (ASIS) computer database for aggregate sources and provide updates for district users, and others as requested.

Technical Classes

As a specialty office one of our major functions is technical assistance. One way this is accomplished is through formal training. The Geotechnical Section was involved in teaching the following courses:

- Aggregate Production
- Grading and Base I and 2
- Grading & Base Recertification
- Construction Engineers Workshop
- Materials Engineers Organization
- Construction Inspectors Workshop
- MSPE Inspector Workshop
- Lab Chiefs Workshop
- IAI Workshop
- Soils Engineers Workshop
- AGC Grading and Base Workshop
- Midwest Geotechnical Conference

Web site

The Geotechnical Engineering Section has a comprehensive web site on the Office of Materials web site at http://www.dot.state.mn.us/materials. The site is divided into four sections, Aggregate, Foundations, Geology, and Grading and Base. Each section contains information for our customers such as manuals, approved products, borings and CPT's, pit maps, specifications, standard forms and staff contacts. Our intent is to eventually move all of our shared information to the site including all of our Mn/DOT manuals.

Geotechnical Section Activities

This section of the report details the various activities completed by each unit during 2011. This is the fourth time that most of this information was collected

and comparisons with data from 2004 to 2011 are made. Variations in the type and amount of investigation are primarily due to the projects that occur during the year. The tools used depend on what information is needed to characterize the site to the level necessary and in the most efficient manner. With the track CPT rig unavailable, options were limited and adjustments had to be made to less efficient methods.

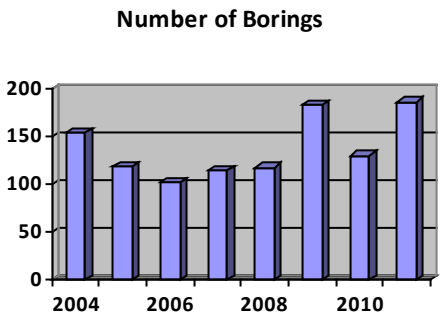
Foundation Unit Activities

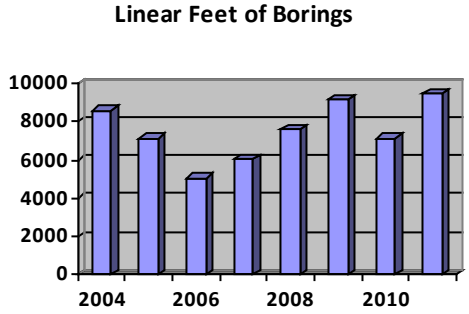
The following are a summation of the 2011 Foundations Unit activities.

Standard Penetration Test Borings

The SPT is a major part of our geotechnical exploration program. Mn/DOT has three full-time crews assigned to the program. A fleet of three drill-rigs, each with its own unique capabilities, is used to complete drilling operations. The fleet size also allows for continuous operation in cases where mechanical breakdowns occur. The following borings were completed in 2011.

- 186 standard borings
- 9465 lf of borings

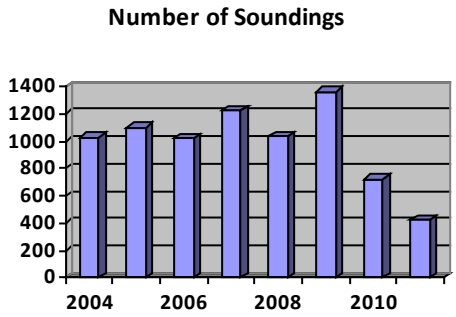


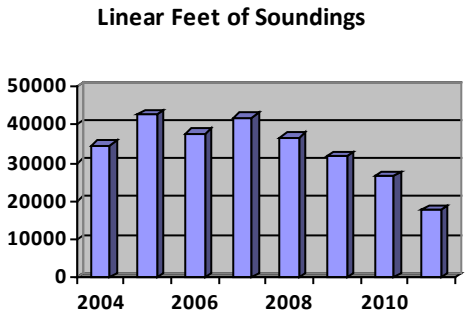


Cone Penetration Test

The CPT forms the other major part of our geotechnical investigation program. With the CPT track down, Mn/DOT had two full-time crews assigned to two rigs in 2011. The following work was completed in 2011. Fewer CPT soundings and correspondingly less footage was taken in 2011 primarily due to the availability of only two rigs for the season, but also due to a three week shutdown of government services. The Geoprobe was also used to fill in for the CPT track, but is much less efficient than a dedicated CPT rig.

- 424 CPT soundings
- 17786 lf of soundings





The following specialty tests are conducted when needed for specific design recommendations and with the exception of the DMT are included with the total CPT statistics above.

Test	2007	2008	2009	2010	2011
Seismic	58	33	18	6	111
SMR	45	22	21	11	11
PWP dissipation	9	1	13	1	4
Video	21	0	0	1	1
DMT	20	4	3	0	10

Geoprobe

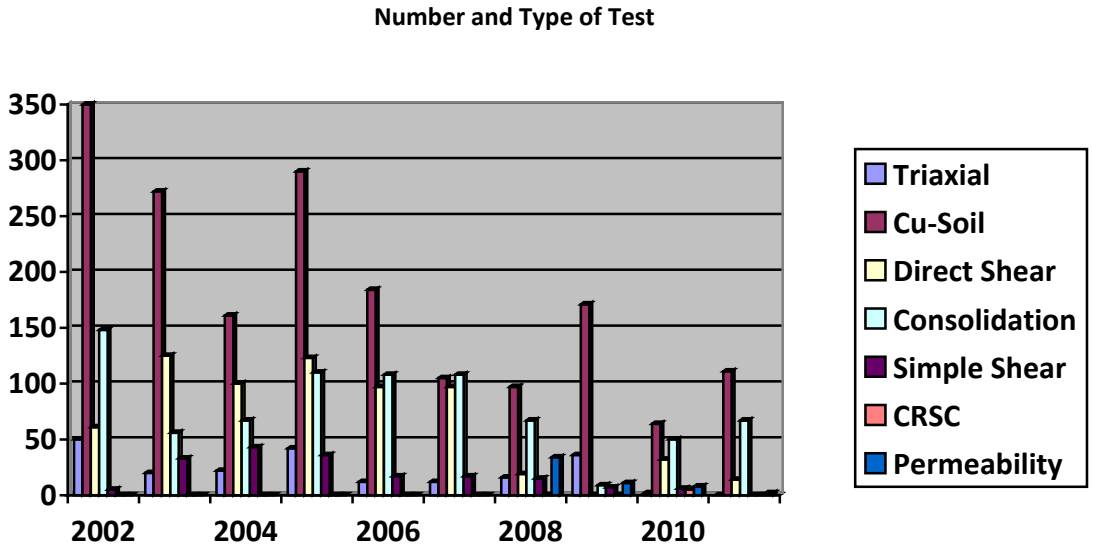
The Geoprobe was in its third full year of production work in 2011. It can do a variety of work including SPT, CPT, coring, electrical conductivity, and continuous sampling. The statistics for the Geoprobe are included in the numbers above. The Geoprobe has proven to be a useful addition to our investigation fleet, but is significantly less efficient than our dedicated CPT rigs for CPT investigations.

Laboratory Testing Program

The Foundations Unit has a very well equipped testing lab capable of performing tests on a variety of soils and rock to measure their engineering properties. Testing is performed on a project basis as directed by the assigned geotechnical engineer. Each test result is used to aid in the design of a specific design feature. The following tests were performed in 2011.

111 Unconfined Compression - Soil
67 Consolidation
0 Direct Simple Shear
0 Triaxial Tests (3 or 4 to a test series)
14 Direct Shear Tests (3 or 4 to a test series)
0 Flexible Walled Permeability
2 Constant rate of strain consolidation

The following chart compares the number of tests completed since 2002. The chart generally reflects the overall construction program seen over the past seven years.



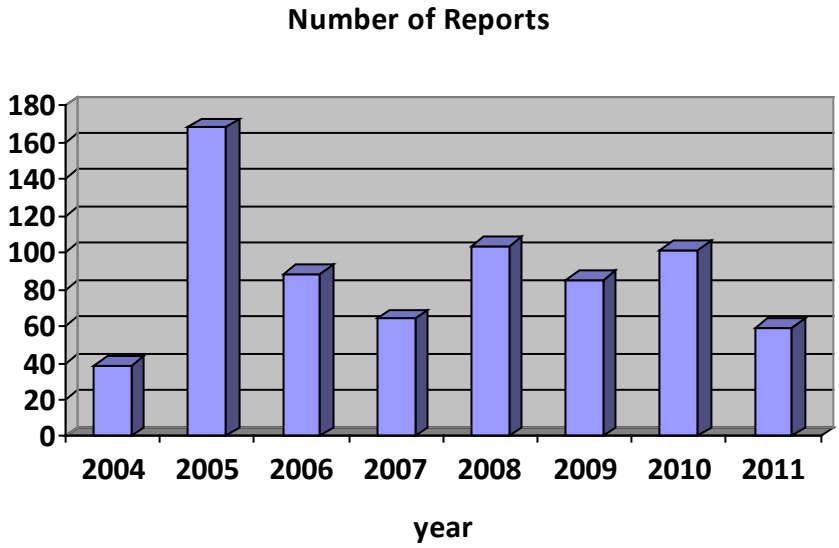
Foundation Reports

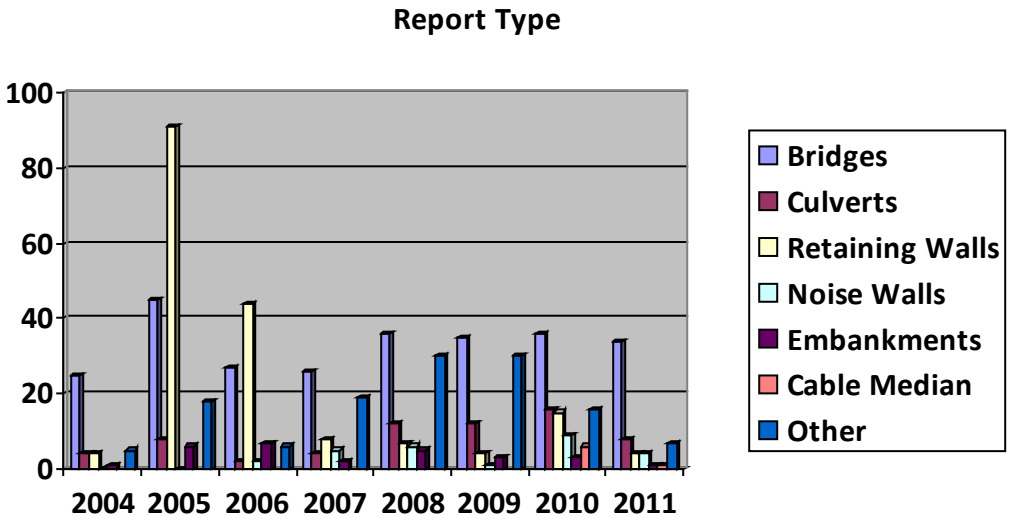
Foundation Reports are the primary product produced by the Foundations Unit. The reports are used as a guide to complete final designs for bridges, walls, culverts, embankments, and other features. Scheduling is driven by the current PPMS output.

Fifty-nine Foundation Reports were completed in CY 2011 in the following categories:

34 Bridges
8 Culverts
4 Retaining walls
4 Noise walls
1 Embankment
1 Cable median barriers
7 Other

The following two charts show the total number and type of reports completed over the past seven years.





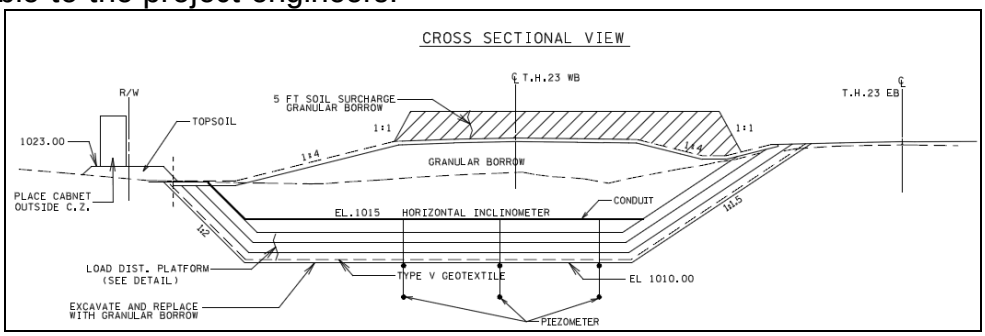
Consultant Contracts

The Foundation Unit prepares and administers consultant contracts for the Office of Materials and Road Research. Contracts for consultant drilling and reporting are currently being handled by the district or often through state-aid by local entities.

Projects Summary

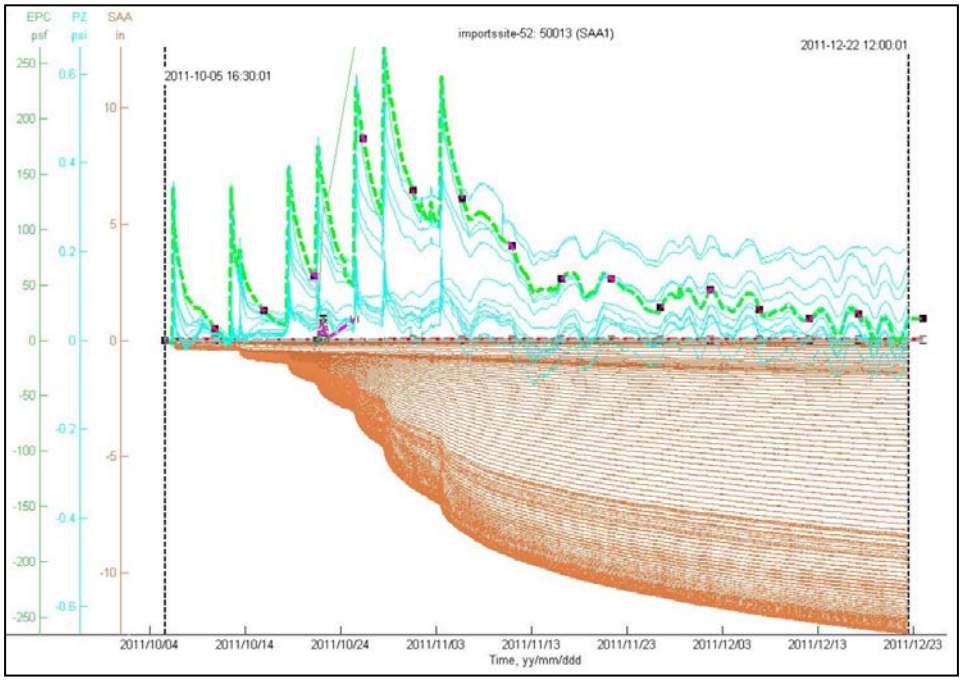
TH23 - Foley Embankment Settlement Monitoring

In summer of 2011, construction began for the TH 23 widening project in the vicinity of the Elk River crossing between St. Cloud and Foley. This project involves the construction of a very large embankment in order to widen TH 23 from two to four lanes. This new embankment passes through a low, swampy area and field investigations indicated the presence of deep organic material. After an initial design considered a very long bridge spanning this area, the Foundations Unit recommended limited surface soil removal and a reinforced embankment in conjunction with an additional five foot temporary surcharge. It was primarily due to the fact that considerable construction and future maintenance costs could be saved that the reinforced embankment option was chosen as the preferred design over a bridge. Some of the cost savings were utilized to provide the means for a fairly robust monitoring program, which would be used to control construction sequencing of the embankment. The monitoring program gave the engineer the ability to accurately determine the progress of the settlement below the future westbound lanes and with that the potential to accelerate certain work. In late summer of 2011, the instrumentation was installed. Included in the project were 31 vibrating wire piezometers, six earth pressure cells (provided and installed by the project geotech engineers, American Engineering Testing) and six ShapeAccelArrays (provided and installed by the MnDOT Foundations Unit). The various gages and sensors were distributed along six full width cross sections of the embankment, shown below. The monitoring system is fully automated, gathering sensor data several times per day during active settlement periods and placing that data on an FTP site available to the project engineers.



Cross Sectional View of Instrumentation Plan

Thus far, the system is performing exceptionally well as only once sensor has become inoperable. The data clearly shows each individual lift placed over the load distribution platform, see the figure below. Additionally, it is clear that settlement across the new embankment area is still occurring. Currently between 8 and 15 inches of settlement has been observed at the different centerlines of the new embankment. It is expected that in 2012 primary settlement will slow and construction can advance along the embankment. With this information, the engineer will be able to accurately predict when future settlement has been reduced to an acceptable level and the work can advance. This is a big benefit both in regards to quality construction, but also in terms of assisting the contractor in scheduling work.



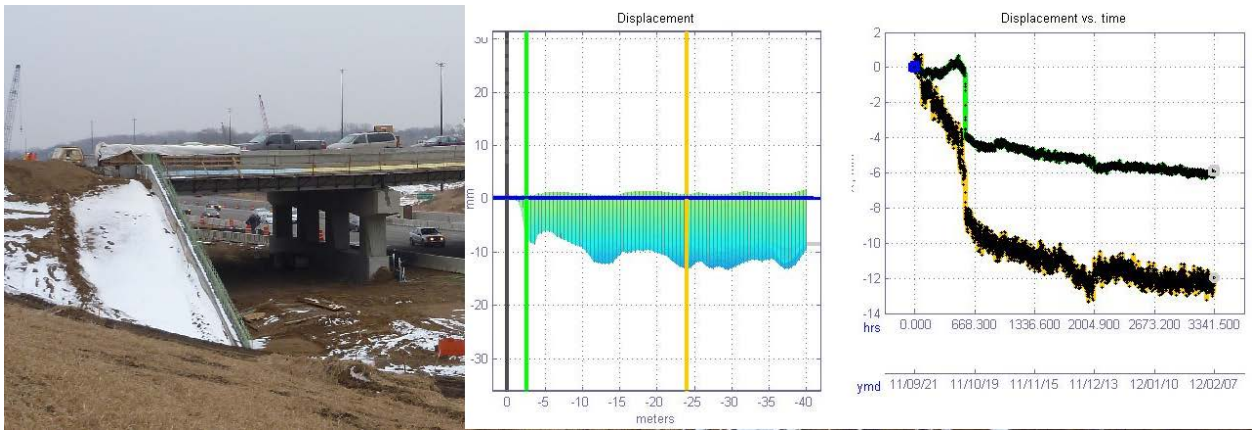
Data shown through Dec. 2011. Notice the various spikes in the blue and green lines, representing the increasing earth pressure and water pressure on the sensors from construction activities. The brown line shows settlement, and in turn is responding to the increase of earth/water pressure due to loading and global settlement over time. Note that each jog in the brown settlement curves corresponds to additional loading – indicated also by the blue and green spikes.

Shallow Foundation Settlement Monitoring QA Project

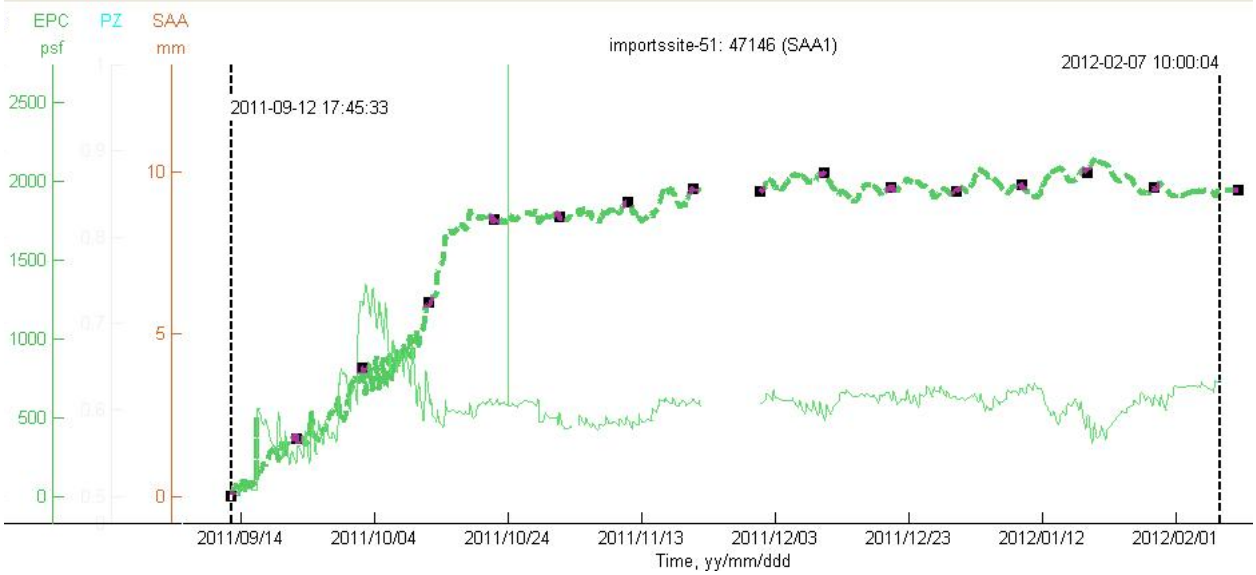
As part of quality assurance monitoring on the 494/169 design-build project, sensors were installed at the north abutment of bridge 27R29 which, along with all the other substructures for this bridge, was constructed on spread footings. Originally, settlement of 2.0 to 2.5 inches was predicted at the north abutment; a pre-load was specified to reduce settlement to below the 1.0 inch tolerance. The contractor preloaded the north abutment with a temporary embankment fill and monitored the embankment area with traditional settlement plates. The bridge foundation and abutment wall were monitored with survey target reflectors.

The base of the spread footing foundation for the North Abutment of the Washington Avenue Bridge crossing I-494 just west of the US 169 interchange was instrumented with a ShapeAccelArray deformation sensor and two earth pressure cells to assess footing pressure and deflection. The array can be seen mostly in the middle of the foundation, exiting in the lower right out the front face.

The Foundations Unit installed a ShapeAccelArray (SAA) and two earth pressure cells (EPC) below the future foundation in mid-September 2011. Within days, the rebar was installed and the footing cast, followed fairly quickly by the construction of the abutment wall. The backfill behind the wall was placed to help facilitate access to the north end of the bridge for setting the beams and pouring the deck. The deck was poured the night of October 17, 2011. Some of the backfill was later removed to construct the foundations for the adjacent east and west retaining walls. Interestingly, as the northern span was relatively short, the settlement observed from the loading from the embankment backfill was the most significant and the load from the beams and the deck was largest loading. The earth pressure cell readings correlated well with the SAA data, showing the largest increase in pressure as the backfill was being added. One EPC was placed below the wall stem (in the center of the footing), the other EPC was placed near where the SAA exited the front of the footing to the reference point between the abutment and the adjacent pier. The maximum observed earth pressure was about 2000 psf [note that EPC values can have substantial error if they are not rigorously calibrated, as in this case]. The maximum observed deformation- following the preload- was about 12 mm (1/2 inch). Of interest is that the settlement is not yet complete, although it does appear to be slowing, and is expected to be well within the tolerance of 1.0 inch.



At left is the north abutment after the wall was constructed and the backfill was placed. The center diagram shows the deformation distribution across the base of the foundation. As is expected, the deformation is relatively uniform below the center of the foundation and somewhat less at the free edges (near and far ends). The right graph shows the deformation at the edge of the front of the footing (green) where the array exits to the reference location and the point of maximum deformation (yellow) near the middle of the footing.



The EPC data shows a trend that has been observed previously: the pressure below the center of the footing (or heel) is greater than that at the toe, and the toe pressure reduces as backfill is placed.

SPT Hammer Calibration and Training

On December 5th and 6th of 2011, Pat Hannigan (with Pile Dynamics Inc.) visited MnDOT for a 2-day Standard Penetration Test (SPT) hammer calibration and training visit. Each of MnDOTs four drill rigs is equipped with a hammer system which should be regularly calibrated. This was the first calibration for the hammer on our new CME 750 rig. Consistent with outdoor test scheduling, the field portion occurred on one of the colder days of the 2011/2012 winter season. A goal of the course was to help instruct members of the foundations unit how to

use the Pile Driving Analyzer (PDA) to assess hammer performance and the amount of transferred energy. MnDOT calibrates its SPT hammers to run close to 60% efficiency in the field so that values do not need to be corrected for the 'standard' energy that is given as part of the ASTM standard for conducting SPT tests.

A day-long training session covering the topics of high-strain dynamic foundation testing, the wave equation approach to pile capacity prediction, and the use of signal matching software (CAPWAP), was conducted for staff from the Bridge Office and the Office of Materials, geotechnical section. Discussions regarding data quality, specifications, equipment, and related topics were highly productive.

Granite Falls Inclinometer Installation

After successfully stabilizing a landslide that impacted MN 67 just SE of Granite Falls in the winter of 2010, two additional inclinometers were installed in December of 2011 to monitor upslope movements. Two private structures were showing signs of some subsidence and a determination was made that monitoring potential upslope movement would be important to determining if this upper slope was unstable, and if so, where the failure was occurring and at what rate.

Presently the site data is showing that the deep soils are stable. There is some settlement and movement in un-improved soils near the river channel (which was expected due to ROW restrictions and other construction constraints). There appears to be some slow movement in the up-slope area, but the movements are small and variable and inconclusive due to the relatively short 3 month monitoring period. The embankment behavior will probably become clearer after a longer duration or if there are any large snowfall or rainfall events this spring.

Traditional inclinometers were installed as part of the column supported reinforced embankment construction as part of a QA program. Little or no movement was anticipated, and this has been shown to be true in the deeper soil layers (of greatest interest and concern).

Automated near-real-time monitoring was recommended for the new upslope installations as the slope stability here is somewhat more questionable in the native soils above the roadway. Automated daily readings help build a high-quality picture of how the slope movements vary with time and any seasonal changes or rainfall events. District 8 personnel continue to read and report the manual inclinometers on a regular basis.

Two traditional traversing-probe inclinometers were installed in December of 2010 to monitor the stability of the new reinforced slope roadway embankment. The new, automated, inclinometers were installed near the two buildings seen in the upper left of the photo to monitor potential upslope movement.

MnPILE Static Load Testing Project

As part of the implementation of LRFD design at MnDOT, several research projects and construction modifications are being undertaken and implemented. A study related to the calibration of the resistance factors for MnDOT's pile driving formula is continuing. An offshoot of that calibration effort is a static load testing (SLT) program to accrue a body of knowledge, based on local practice, that will provide necessary statistical information needed to adapt the code for more efficient or safe designs.

Two re-usable load frames have been designed (one by American Engineering and Testing) and one by MnDOT and are currently being fabricated by LeJeune Steel of Minneapolis. One will have a 500 ton capacity and the other a 1000 ton capacity. The intent will be to deploy the load frames for use on projects where construction practice, materials, or site soils are of interest to help further the LRFD local calibration process.

A set of standardized plans and special provisions is in development to help make incorporating the testing into construction practice as easy as possible. As MnDOT will be providing the major frame components, it is anticipated that the testing will be much cheaper and faster than seen on previous projects where the contractor was responsible for the design and fabrication of the load testing system.

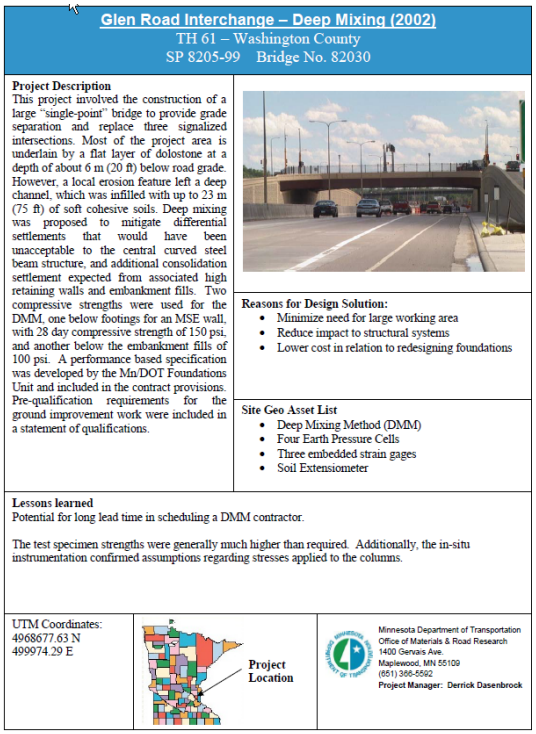
Construction savings or improved safety are outcomes expected on each project where the load tests are conducted. The static load tests are expected to add value in a number of potential ways: 1) a less conservative resistance factor can be employed where a SLT is performed due to the increased reliability associated with having performed the test. 2) The outcome of the test can be used to adjust the number of deep foundation elements, or their length on a given project 3) if the site geology is not excessively variable; the test could be used to adapt the pile lengths on nearby bridges or structures. 4) if the test shows longer pile lengths are needed although this will add cost it will either improve performance or safety. 5) The results of each test will be added to the body of knowledge necessary to statistically calibrate the MnDOT dynamic pile driving formula. The larger the number of tests, the more confidence the Department can establish in the values obtained in the calibration effort (from both a qualitative and quantitative standpoint).

Three tests are planned for the 2012 inaugural year: BR 62717, SP 6285-135 on I-694 at the junction with US 10; BR 10003, SP 1002-89 on MN 5 near Victoria; and BR 62057/62058, SP 6284-159 at the junction of I-35W and US 10 in Arden Hills near the potential future Minnesota Vikings stadium site.

The 500 ton main jacking beam is awaiting delivery to MnDOT

Project Update

2011 saw the beginning of a long term project aimed at providing a resource for anyone who might be interested in the various work that the Foundations Office provides. This project, known as the Geotechnical Asset Project Portfolio, or GeoAPP, will be an online GIS map application accessible by both MnDOT personnel as well as the general public. The map will provide an easy way to view, search and sort through the various *Geo-Assets* that the Foundations Unit has worked with, so that others might be able to better understand the work that the Foundations Unit provides. Examples of unique *Geo-Assets* might be lightweight fills (shredded tires, geofoam, etc...), reinforced embankments, MSE walls, spread footings, field instrumentation and many more.



Glen Road Interchange – Deep Mixing (2002)
TH 61 – Washington County
SP 8205-99 Bridge No. 82030

Project Description
This project involved the construction of a large "single-point" bridge to provide grade separation and replace three signalized intersections. Most of the project area is underlain by a flat layer of dolostone at a depth of about 6 m (20 ft) below road grade. However, a local erosion feature left a deep channel, which was infilled with up to 23 m (75 ft) of soft cohesive soils. Deep mixing was proposed to mitigate differential settlements that would have been unacceptable to the central curved steel beam structure, and additional consolidation settlement expected from associated high retaining walls and embankment fills. Two compressive strengths were used for the DMM, one below footings for an MSE wall, with 28 day compressive strength of 150 psi, and another below the embankment fills of 100 psi. A performance based specification was developed by the Mn/DOT Foundations Unit and included in the contract provisions. Pre-qualification requirements for the ground improvement work were included in a statement of qualifications.

Reasons for Design Solution:
- Minimize need for large working area
- Reduce impact to structural systems
- Lower cost in relation to redesigning foundations

Site Geo Asset List
- Deep Mixing Method (DMM)
- Four Earth Pressure Cells
- Three embedded strain gages
- Soil Extensiometer

Lessons learned
Potential for long lead time in scheduling a DMM contractor.

The test specimen strengths were generally much higher than required. Additionally, the in-situ instrumentation confirmed assumptions regarding stresses applied to the columns.

UTM Coordinates:
4968677.63 N
499974.29 E

Project Location

Minnesota Department of Transportation
Office of Materials & Road Research
1400 Gervais Ave.
Maplewood, MN 55109
(651) 366-5592
Project Manager: Derrick Dasenbrock

Example of a typical project one-pager

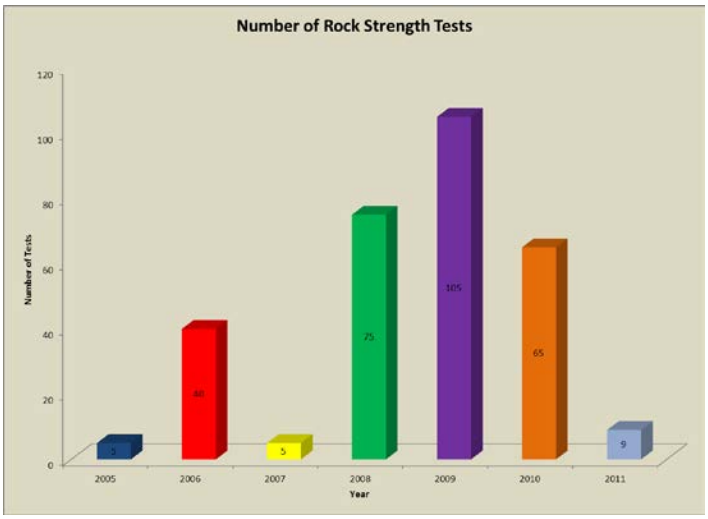
Development on GeoAPP in 2011 was limited to the preliminary planning and development of the behind the scenes database format as well as gathering the first test projects that will be entered into the database. A one-pager format was developed that will carry through the rest of the projects entered into GeoAPP, see Figure XX. The one-pager will function as a project summary sheet, and about 10 were written for various test projects in 2011. In addition to a project one-pager, the website will serve as a data warehouse; many projects will have additional supporting information which may include design information, foundations reports, and cost estimates. Universities, designers, contractors, construction inspectors, etc. will be able to use GeoAPP as a resource to learn more about geo-assets that they may not have much experience with. Currently, the office gets several requests per year from research institutes for data we have. Typically these requests can be resource intensive to fulfill, however with GeoAPP these requests will make the work much more routine, as ideally the bulk of important information will already be located on our website. It is expected that in 2012, further development will occur on GeoAPP and it is hoped that by the site will be live with as many as twenty projects by the end of the year.

Geology Unit Activities

The Geology Unit consists of 4 geologists who provide statewide assistance and expertise with needs related to geophysics, groundwater, rock classification and strength testing, aggregate quality, rock slope recommendations, vibration monitoring, environmental assessments and other specialized geologic issues. The following is a summary of some of the tasks that the Geology Unit has worked on throughout 2011.

Rock Core Description and Rock Strength Testing

Bedrock retrieved from core drilling is subjected to qualitative and quantitative characterization. Information acquired from rock core descriptions is used to make recommendations on projects related to bridge foundations, slope stability, aggregate quality, to name a few.



After rock core is classified, the Geology Unit prepares and tests rock core for unconfined compressive strength (UCS). The need for UCS tests in 2011 was greatly decreased due to the number and type of foundations projects. The amount of rock core classified also decreased this year. However, the rock core is not the only way rock is classified. Much of the rock classification in 2011 came from rock samples obtained by SPT or wash samples.

Aggregate Production Class

Aggregate Production is a prerequisite for several courses in the Tech Certification Program. The Geology Unit teaches a half-day session on Minnesota geology and how it relates to aggregate quality. The 2011-2012 season is underway with 12 classes already taught.

EAW's, Water Well Recs, Aggregate Source Recs, Vibration Monitoring

EAW, water well and new quarry source recommendations as well as vibration monitoring were all down in 2011. Vibrations were monitored during construction of the Hastings Bridge. Traffic vibrations were also monitored in response to a resident homeowner request along from vibrations generated on TH62. Three EAW's were written in 2011 for projects on I-35E in St. Paul, TH169 in Brooklyn Park and TH100 in St. Louis Park. Although no requests for aggregate source recommendations were made in 2011, the Geology Unit routinely addresses aggregate quality inquiries which arise during testing in the Aggregate Lab.

Rock Slopes/Rock Fall

TH95-Stillwater

As in previous years, 2011 saw a number of rock fall events along TH95, both north and south of Stillwater. These events began in the spring and continued into the fall. The rock slopes along this stretch of highway experience frequent rockfall, which is likely to continue in the future. After each rockfall event, the Geology Unit is called upon to make recommendations to Metro Maintenance crews. Several slope and ditch improvements were carried out this year.

In 2011 the Geology Unit installed crack monitoring instrumentation on a dolostone block above the roadway. Monitoring of this crack is continuing.

TH90-Dresbach

The Geology Unit was also called upon this year to provide rock slope recommendations for the new bridge and highway construction along I-90 near Dresbach. Utilizing updated LIDAR topography information, GIS technology, and site visits, the unit was able to provide recommendations for rock slope design and rock fall hazard mitigation.

Other Projects

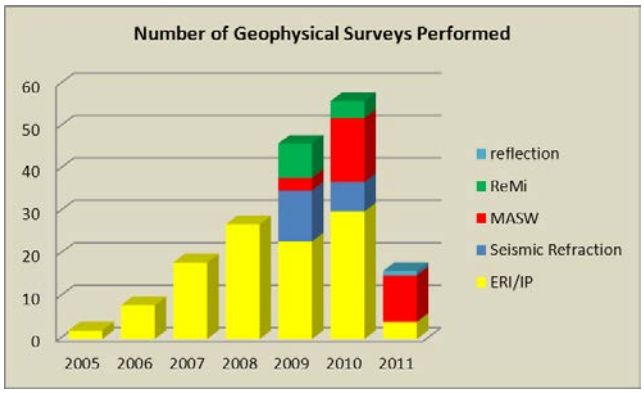
The Geology Unit is often called upon to provide geological expertise in projects relating to groundwater and groundwater issues. One such project this year occurred along TH12, where groundwater was seeping onto the roadway. The Geology Unit made recommendations for the monitoring and investigation of the source of the seepage. Another project included the TH169 Eagles Nest Lake Area Improvement project, described below.

TH169 Eagles Nest Lake Area Improvement Project (Ely, MN)
Geologic investigations and guidance continued in 2011 for the proposed Highway 1/169 Eagles Nest Lake Area Improvement Project located in rural St. Louis County, west of Ely, Minnesota. Portions of the existing highway are located adjacent to a ridge line that causes permanent shading to occur on the roadway during winter months. The shading along the corridor results in the buildup of ice and snow for extended periods causing safety and maintenance concerns. Additionally, several deficient design conditions and poor pavement conditions characterize the study area. Consequently, the western portion of the highway that experiences shading issues is proposed to be reconstructed on a new alignment so the shading issues can be minimized; the eastern portion will also be reconstructed in order to bring the entire 5.6 mile segment up to current design conditions.

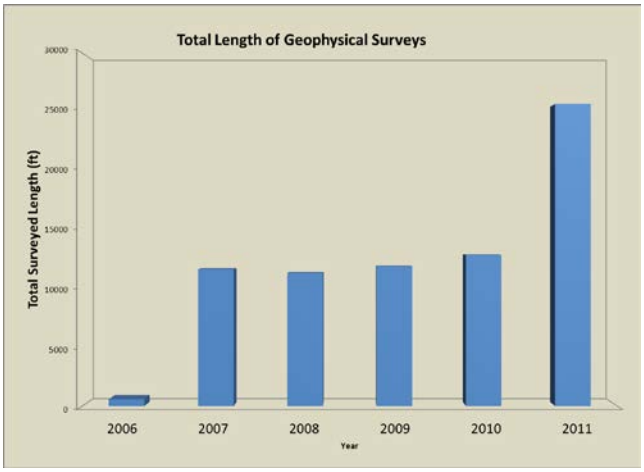
The project is situated within bedrock formations that have been identified as sulfide bearing. In June 2009, during the early planning and design phase of the highway project development process, concerns were raised by area property owners and resource agencies that the presence of sulfide minerals, such as pyrite, in bedrock and overburden present in the project area should be considered since exposing sulfides could potentially generate acid which could harm area water resources. Several locations within the improvement area will require extensive rock excavation. Soil excavations could also expose sulfide-laden boulders. Much of 2011 was spent in discussions with regulating agencies (DNR, PCA, USCOE, EPA) reviewing information acquired from MnDOT-initiated geologic investigations and establishing future investigation/testing needs and parameters.

Sulfide burns/oxidation on Soudan Iron Formation Member outcrop

Geophysics

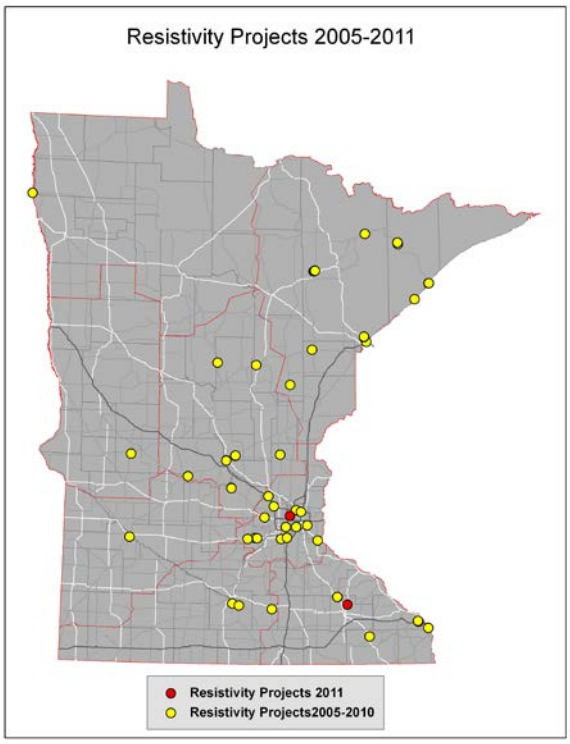


Geophysical information supplements other subsurface data sets created by conventional drilling techniques and cone penetration testing performed within the Geotechnical Engineering Section. In some cases, geophysical surveying provides the only information acquirable from a project site. The Geology Unit has instrumentation which allows for subsurface interpretations to be made based on electrical and seismic properties of soil, rock, and other targets within the subsurface. Electrical Resistivity Imaging/Induced Polarization (ERI/IP) has been the most common method used by the Geology Unit in the past 5 years. However, with the recent addition of software and other accessories, Multi-Channel Analysis of Surface Waves (MASW) has been increasingly utilized where electrical methods are not feasible, particularly on the roadway. Using multiple methods on a single site is always desired to help bolster the subsurface data set. The number of geophysical surveys for each year since 2005 is shown in the chart above. The number of surveys for each category was down this year.



This was in part due to the state government shutdown in July, usually one of the busiest months for geophysical investigations. The total length of geophysical surveys conducted each year is shown in the chart to the left. It should be noted that though only 16 geophysical investigations were performed the total length of ground investigated doubled from 2010 to 2011.

Electrical Resistivity/Induced Polarization Imaging (ERI/IP)



The map to the right shows the locations where the Geology Unit has performed ERI/IP since 2005. Most usage continues to be conducted in the eastern half of the state, particularly in Districts 1, 3 and Metro. This year saw projects in District 6 and Metro.

A few of the projects where the Geology Unit used ERI/IP are described below.

TH63 Dresser Drive

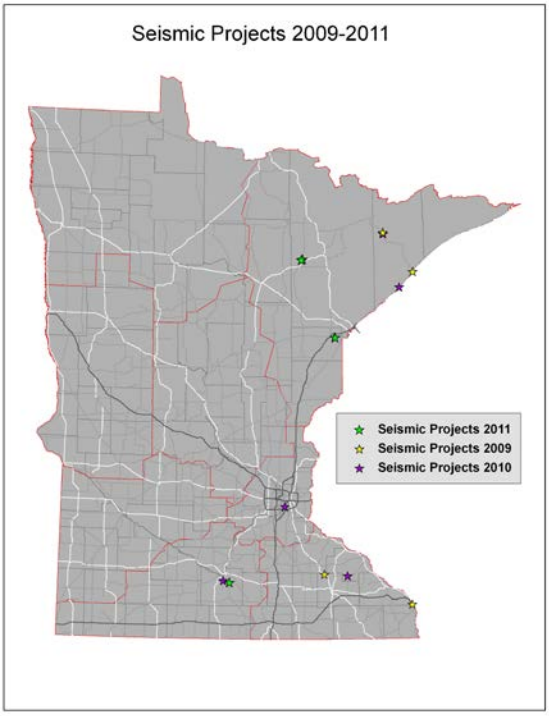
At the request of District 6, ERI surveys were conducted in the vicinity of a roadway failure which took place on TH63 at Dresser Drive north of Rochester, MN. Sinkholes had developed during heavy rains on the investigated stretch of roadway as a result of ponded runoff from poor surface drainage in the NB ditch which facilitated water and soil infiltration into shallow bedrock. ERI coupled with CPT borings identified a narrow zone of fractured and weathered dolostone transverse to the roadway and likely allowed siphoning of overlying embankment materials during. A concrete 'plug' will be constructed in 2012 to span over the fractured/weathered zone and prevent future settlement.

TH65 Central Ave

The Geology Unit was contacted by Rich Lamb to conduct a resistivity survey for a proposed temporary rail road bypass along the south embankment of BR90446 in Minneapolis, Minnesota. The main concern was the potential for shallow bedrock in the project area causing difficulty in driving piles. The inverted resistivity section revealed a potentially shallow bedrock surface. The field site investigation showed buried rail road ties and other rail road debris in the area which may create obstacles for sheet piling.

Seismic Surveys

The Geology Unit continued to conduct seismic geophysical surveys in 2011. This was an innovative year for utilizing MASW around the state on large projects. A trial seismic reflection survey was also performed and is described below.



TH210 Jay Cook Slide MASW Survey (Carlton, MN)

A towed multichannel analysis of surface waves survey (MASW) was performed on SB TH210 near Jay Cooke State Park where roadway and in-slope failure occurred on a roughly 50 foot stretch of SB roadway. A 2D profile of shear wave velocity was constructed and showed: 1.) Increasing bedrock depths in the uphill direction, 2.) Variation in embankment thickness, particularly within the failure area, possibly caused by settlement and/or past remediation and, 3.) Pockets of low shear wave velocity below embankment depths and above bedrock which are indicative of soils with low stiffness properties.

TH13 Bedrock Analysis (Lilydale/Mendota Heights, MN)

The Geology Unit was asked to assist in assessing factors which may be contributing to slope stability issues on TH13 in Lilydale/Mendota Heights. Depth to bedrock variation within the roadway was considered as one possible contributor and was analyzed via towed multichannel analysis of surface waves (MASW). Individual surveys were performed along centerline (CL) and west bound fogline (FL) over a 1,600-foot stretch of TH13. 2D subsurface models of shear velocity were created for both lengths and suggest that bedrock depth does not vary markedly through most of the investigated area. However, as much as 12 feet of variation was seen between CL and FL in the final 300 feet of the survey where an old drainage valley is present at the base of a hill. Some localized variation in bedrock depth can be seen throughout the survey,

particularly near the shotcrete wall where some bedrock depths may be higher on the downhill side of the road along the FL.

TH169 Seismic Monitoring Project (Chisholm, MN)
Towed MASW was conducted over continuously reinforced concrete pavement (CRCP), which was constructed by District 1 to prevent potential roadway failures related to early 1900's vintage underground abandoned mines present in and around the Chisholm area. Goals of monitoring project were: 1.) Identify potential voids below roadway and above the iron formation which hosts the mine workings, 2.) Create a subsurface baseline for future investigations and, 3.) Establish a monitoring frequency. Surveys were performed during evening to pre-dawn hours over 4 consecutive nights to ensure traffic safety and optimize data quality. Two geophone streamers were towed simultaneously allowing surveying of both lanes at once. This approach is a first for MASW. 2D shear wave, backscatter and common offset profiles of the subsurface were generated. Ultimately, 3 potential void sites were identified which will be verified in 2012 using a refined MASW approach. Annual monitoring of the 3 potential void sites may be undertaken and will depend on the outcome of the verification surveys. Based on historical subsidence rates, a 5 year survey frequency was recommended for all CRCP sections.

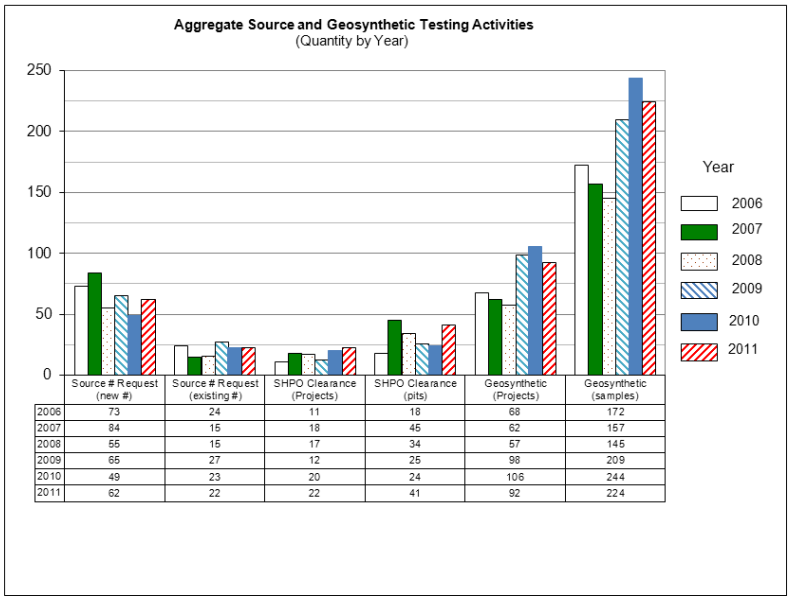
TH22 Reflection Feasibility Study (Mankato, MN)

Given current geophysical hardware, the possibility of performing reflection seismic surveys for future subsurface investigations seemed plausible. Since reflection planning, processing and interpretation requires expertise beyond the capabilities of the Geology Unit, a consultant contract was requested and acquired. A site for the study was sought which could be described as a 'typical' transportation environment (moderate to high seismic noise) with adequate amount of known subsurface information (for corroboration purposes) and is currently the subject of a geotechnical investigation. A portion of TH22 south of Mankato where a recent slope failure occurred was chosen. Depth to bedrock and identification of large boulders was of primary importance for purposes related to a potential sheet pile remedy. Ultimately, the study showed that the reflection seismic method is a viable option in the Geology Unit's geophysical toolbox. Despite some unfortunate and avoidable complications

during data acquisition, reflectors indicative of bedrock presence were observed at known depths. Smaller scale features within the till, such as a possible buried fluvial channel, were also identifiable. Reflections as deep as 300' were recorded for the given field geometry. The study also suggested that deep refraction geometries (for profile depths >100 feet) could also be employed on future seismic projects.

Aggregate Activities

The chart below shows items that were completed in the past year in the aggregate unit. The management of geosynthetic testing consumes the greatest quantity of time. Nearly all of the functions showed a slight decline in work except for coordinating SHPO clearance on construction projects and aggregate sources.



	Source # Request (new #)	Source # Request (existing #)	SHPO Clearance (Projects)	SHPO Clearance (pits)	Geosynthetic (Projects)	Geosynthetic (samples)
2006	73	24	11	18	68	172
2007	84	15	18	45	62	157
2008	55	15	17	34	57	145
2009	65	27	12	25	98	209
2010	49	23	20	24	106	244
2011	62	22	22	41	92	224