ITGAUM Geophysics Survey Summary

Investigation
What geophysics methods are used for underground mine investigation?

Alabama - None

Iowa **–** Mines: Resistivity and Ground Penetrating Radar.
Other Voids: Resistivity, GPR, MASW, and FWD.

Maryland - MdSHA rarely has to address abandoned underground coal mines. Geophysics used for karst , top of rock and environmental. GPR, microGravity, SP, Seismic.

Michigan - Very limited used of geophysics. Cross-well seismic imaging. FWD on pavement over top of mined areas. GPR, resistivity, and microgravity used once.

Minnesota - Electrical Resistivity Imaging/Induced Polarization, MASW (active and passive), Seismic Refraction, Falling Weight Deflectometer, CPT with resistivity and seismic cones

Ohio - Electrical resistivity, micro gravity, GPR, seismic reflection/refraction, FWD

Ontario - GPR, which is provided by third parties when requested.

Pennsylvania - GPR and Seismic has been used to detect voids.

Virginia - Mainly resistivity, but that's due to the fact that it's the most widely-known method.

Investigation
What methods are most useful for your purposes? (please explain)

Alabama – N/A

Iowa - Resistivity
In terms of mine investigation: coal seams are within a Pennsylvanian Sandstone or Shale, and most areas have thick overburden of glacial clay, making investigations with GPR (the next optimal technique, very useless.
For other void detections, under pavements and within fill: GPR and FWD have proven useful.

Maryland - for karst, most has been microgravity, sp and siesmic. gpr for environmental.

Michigan - None routinely used. Cross-well seismic worked well.

Minnesota - 1.) Electrical Resistivity Imaging/Induced Polarization
- Soils and underlying rock properties in Mesabi Iron Range are conducive to yielding excellent ERI data quality which translates to greater confidence in interpretations of soil/rock/void contrasts. Large IP chargeability contrasts also exist between iron formation and overlying drift.
2.) MASW (active)
- Utilized for subsurface characterization below pavement
3.) CPT with resistivity and seismic cones
- Allows for verification of ERI and MASW models and provides detail which is unresolvable in processed profiles
- limited to soils above bedrock and where boulders are not encountered
4.) Seismic Refraction
- Verification of bedrock surface in off-road setting; miscellaneous velocity contrasts are a bonus

Ohio - ER and micro gravity. ER is very versatile and relatively easy to process and interprete the data. Micro gravity has only recently been used to define the boundaries of unmapped underground mines. Very useful in measuring points along a line perpendicular to the roadway. One of the few geophysical methods that can be used without stopping traffic to generate data across highways and medians.

Ontario - Only used GPR with mixed results over the years. Always had test hole drilling as a follow up.

Pennsylvania - Any method useful in detecting voids would be helpful.

Virginia - Seismic refraction. Signal-stacking seems to give the best resolution in karst areas.

Investigation
What methods are least useful for your purposes? (please explain)

Alabama – N/A

Iowa - For mines related investigations: GPR (for reasons as stated above).
For other voids: MASW has not been shown to be useful, apparently pavement thicknesses can attenuate the signal, limiting usefulness.

Maryland - EM was being used for karst but now it is not.

Michigan - Limited success with methods other than Cross-well seismic

Minnesota -
1.) Falling Weight Deflectometer
- Used only in localized roadway lengths to add to existing seismic data sets
- Prone to mechanical and electrical failures, thus, dense sampling cannot be prescribed

Ohio - EM, GPR, Seismic reflection. EM is not used in this application. GPR is limited to the geologic setting. Ohio has limited applications (depth of penetration) due to high clay content and high seasonal water tables. Seismic reflection is costly and takes a significant amount of time for post processing.

Ontario - As above

Pennsylvania -

Virginia - Resistivity, due to the fact that it's susceptible to false-positives to a degree higher than other methods. We've seen about 50-50 accuracy.

Investigation
What methods were tried but were not successful? (please explain)

Alabama – N/A

Iowa - For mines: none, other than those discussed above.
For other voids: none, other than those discussed above.

Maryland - success of the methods has really depended on site conditions - high groundwater, concrete with rebar, etc.

Michigan - GPR

Minnesota - 1.) Ground Penetrating Radar
- Radar signal is quickly absorbed by moisture/iron content of iron range soils; reinforced concrete pavements are an obstacle to roadway surveys
2.) Microgravity
- Since drift-slice method (or various forms of it) was employed in the Mesabi Iron Range, it is difficult to interpret void presence in bedrock or soil since the remnants of caving of single or multiple sublevels also imparts a low density signature on the measurement.
3.) HRSW Reflection
- Transportation environment too noisy
- Corrections for near surface variations could not be determined and thus resulting static errors degraded data quality.

Ohio - All. Limited success with each method having its own limitations.

Ontario - Again, GPR is the only geophysical method used with only partial success. Limited use where there is clay and high moisture in the overburden overlying the bedrock

Pennsylvania -

Virginia - Resistivity has had many failures; see above. Some have caused substantial cost and schedule overruns, mainly due to poor planning and data interpretation.

Monitoring
What geophysics methods used for underground mine monitoring?

Alabama - None

Iowa - For mines: none.
For other voids (monitoring for sinkhole formation): Time Domain Reflectometry (TDR)

Maryland - MDSHA does not have any abandoned underground mine monitoring in place.

Michigan - None

Minnesota - ERI/IP (off-road)
Active MASW (roadway)

Ohio - FWD

Ontario - None

Pennsylvania - none

Virginia - We generally do not monitor active mines.

Monitoring
What methods are most useful for your purposes? (please explain)

Alabama – N/A

Iowa - For mines: none have been tried.
For other voids (monitoring for sinkhole formation): TDR is still a pilot project.

Maryland – N/A

Michigan - N/A

Minnesota - Potential failures within roadway area are of greatest concern. Geophysical monitoring surveys in roadway footprint are designed to focus on void presence in/propagation through glacial overburden (voids in underlying rock are related to known workings).

MASW
- Active MASW has provided useful information over pavement. MnDOT setup consists of 2 parallel landstreamers (12 foot separation) with 24 4.5Hz phones per streamer. Towed arrays are employed to give continuous profile of roadway through centers of both slow and passing lanes. Landstreamers are towed by a half ton pickup. A high-powered spring accuated seismic energy source is attached to the hitch of the truck and yields wider and clearer frequency bands than a conventional sledge hammer approach.

ERI/IP
- Best approach for monitoring subsurface off of roadway (ditches, medians, in-slopes, back-slopes).
- Surface-coupled electrical methods have been utilized on MnDOT pavements but require labor intensive setups and, depending on base conditions, do not always yield useful information.
- A buried system was considered under newly-constructed CRCP sections but was dismissed after cost and future maintenance was considered

Ohio - FWD-It is easily deployed, quick, repeatable.

Ontario - As we have only used GPR with limited success, we cannot really comment on this. We normally have some mine plans which give us a good idea of where near surface mine openings exist and we find test hole drilling the most effective followed by cavity surveys. GPR may be used where we have less information, to provide some indication of near surface openings.

Pennsylvania – N/A

Virginia -

Monitoring
What methods are least useful for your purposes? (please explain)

Alabama – N/A

Iowa - Not Applicable N/A

Maryland – N/A

Michigan - N/A

Minnesota - No other methods tried for monitoring. Although, FWD (in conjunction with focussed MASW surveys) may be an option for verification purposes if voids are suspected during MASW roadway monitoring. CPT would be used to verify void presence in off-road monitoring locales.

Ohio - n/a

Ontario - As above

Pennsylvania – N/A

Virginia -

Monitoring
What methods were tried but were not successful? (please explain)

Alabama – N/A

Iowa - N/A

Maryland – N/A

Michigan - N/A

Minnesota - No other methods tried for monitoring.

Ohio - n/a

Ontario -

Pennsylvania -

Virginia -

Equipment Ownership
What type of geophysics equipment is owned by your agency?

Alabama - None

Iowa - None within the Office of Design, Soils Design section.
Office of Materials (Inspection): GPR and FWD, for road rating.

Maryland - None. All geophysics are contracted out.

Michigan - GPR, FWD

Minnesota - 1.) Electrical (ERI/IP)
- 2 Supersting R8/56+ systems from Advanced Geosciences Inc. (AGI)
- accessories include: 2 sets of land cables (56 takeouts/set) and 3 sets of electrodes, 1 set of marine bottom/tow cables (56 takeouts), switch box (for using >56 electrodes), 2 infinity cable reels (for pole/pole and pole/dipole), soil test box, plethora of accessories and spares for marine and land surveying
2.) Seismic (refraction, surface wave, reflection)
- 2 Geodes from Geometrics
- 48 14Hz phones, 48 4.5Hz phones, spread cables for stationary/roll-along surveys (6m spacing), spread cables for land streaming (3m spacing), 2 land streaming systems, truck-mounted spring accuated seismic energy source (designed by Dr. Don Gendzwill and built by PMP in Saskatchewan), plethora of accessories and spares
3.) GPR
- SIR-20 from Geophysical Survey Systems Inc. (GSSI)
- Antennas: 100 MHz (X2), 400 MHz, 1.5 GHz, 2.6 GHz, 1 GHz (air-launched), 2 GHz (air-launched)
4.) CPT
- trucks and accessories manufactured by Vertek
- 30 ton truck, 13 ton truck, 14 ton track
- resistivity and seismic cones
5.) Geoprobe with CPT capability

Ohio - ER, CPT seismic, FWD

Ontario - None

Pennsylvania - Borehole camera only.

Virginia - VDOT owns resistivity equipment -- and old Bison -- 6-channel, I think.

Equipment Ownership
How often is it used for mine related investigation or monitoring?

Alabama – N/A

Iowa - N/A

Maryland – N/A

Michigan - Very rarely

Minnesota - For failures, probably about every 5 years or so. However, we put a lot of 'miles' on our systems when a UAM issue arises.
For monitoring, frequency is undecided at this point. First monitoring project was completed in spring of 2011.

Ohio - FWD is always used for mine studies. Recently purchased ER equipment. Estimated use for ER is 3 to 4 times per year.

Ontario - N/A

Pennsylvania -

Virginia - Less frequently than annually

Equipment Ownership
Please explain how useful that you find it.

Alabama – N.A.

Iowa - N/A

Maryland – N/A

Michigan - Not useful. GPR operators have limited antenna capability and limited skill in interpretation.

Minnesota - All systems are very useful for all sorts of applications, although GPR at MnDOT has been mostly relegated to pavement thickness monitoring. The impetus for geophysical ownership at MnDOT (particularly, ERI/IP) came from lingering uncertainties from drilling data that was acquired for subsurface investigations in MN karst terrain. Sites with void presence, including those related to UAM, require a level of characterization (source of void, mechanism, e.g.) that cannot be achieved with drilling methods alone, especially over large ROW lengths. Voids tend to contrast sharply with soil/rock making them readily identifiable in a geophysical data set. Incorporating data/profiles from geophysical methods allows for more intelligent investigation and design approaches.

Ohio - FWD is a shallow seismic method. But, we seem to detect slight subsurface deflections/subsidence with depth. It quick and easy to obtain and a good first run.

Ontario - N/A

Pennsylvania -

Virginia - Generally not too useful

Equipment Ownership
Please describe benefits to ownership.

Alabama – N.A.

Iowa - N/A

Maryland – N/A

Michigan - No contract's necessary to order use.

Minnesota - 1.) Instant Gratification
- no muddling through consultant contract process
- no wait for work to get done
- quick turn-around from data collection to interpretation to site recommendation
2.) Better Product
- we work intimately with our project engineers and drill crews and have other project data sets (past and present) at our immediate disposal which allows us to efficiently and effectively define a site and make a proper recommendation
- geophysical consultants often overlooked available supporting info and tended to not take proper ownership of our projects
- geophysical consultant field setups and processing schemes were often questionable in past surveys performed for MnDOT
3.) Build 'bridges' within and outside your agency
- we've built and rebuilt professional relationships with several different offices in MnDOT via geophysical assistance
- saved districts time and expense by providing useful info which they don't have the means or know-how to acquire (answered many questions in terrains which district auger crews could not forge through)
- built relationships at civil, municipal, county, state and federal level
4.) A great way to learn lots about soil and rock in one's state
5.) 'More data is more better' (Dr. Paul Mayne, GA Inst. of Tech.)
- there is always something that can be learned from a geophysical survey whether you 'need' the data or not; equipment that is owned is available and ready to use for 'the heck of it'
6.) One less consultant to baby-sit
7.) An argument can also be made that our in-house surveys cost less than using a consultant, particularly seismic work.

Ohio - Based on the cost to have a consultant conduct a single investigation, we will have paid for the equipment (ER) within the first year of use. We already own the FWD which is used for continuously for pavement evaluations.

Ontario - N/A

Pennsylvania - Quick response time in forensic studies of areas of mine collapse. Possibly less costly than consulting this work out to a specialized firm. May also enable us to be proactive in scanning areas of suspected voids and mitigate site before a collapse would occur.

Virginia - The only benefit is convenience

Equipment Ownership
Please describe drawbacks to ownership.

Alabama – N.A.

Iowa - N/A

Maryland – N/A

Michigan - Operators with limited skill as they have many other responsibilities.

Minnesota - 1.) Up-front geophysical equipment costs
2.) Miscellaneous costs for site preparation equipment, GPS, etc.
3.) Learning curve
- time expended while learning systems, setups, processing and soil/rock responses
- extra expense sometimes incurred for processing expertise when learning new codes, e.g.
4.) Dedicated expertise/staffing
5.) MN weather can restrict geophysical equipment usage

Ohio - Need to develop expertise in its use. Also, the equipment is useless without the personnel to deploy, run the test, interpret the results and generate a report.

Ontario - N/A

Pennsylvania - The Department currently lacks the equipment, manpower and specialized training to operate this type of equipment. It has been suggested by some to consider obtaining the necessary equipment and training to have these capabilities in-house.

Virginia - The unit requires constant maintenance and personnel capable to using both the hardware and software.

Software Ownership
What type of software is owned by your agency for geophysical data?

Alabama - None

Iowa - None

Maryland - MdSHA does not own geophysical processing software.

Michigan - None

Minnesota - 1.) ERI/IP
- EarthImager (Marine, 1D, 2D and 3D) (Advanced Geosciences Incorporated)
2.) MASW
- SurfSeis 3 (Kansas Geological Survey)
- SeisImager/SW (Geometrics)
- SeisOpt ReMi (Optim)
3.) Refraction
- SeisImager/2D (Geometrics)
- SeisOpt 2D (Optim)
- Rayfract (Intelligent Resources Inc.)
4.) GPR
- Radan (GSSI)
5.) CPT
- Prodat (Vertek)

Ohio - In most cases, the software is as important as the geophysical equipment. We have purchased the software and hardware from the same vendor.

Ontario - None

Pennsylvania - none

Virginia - None other than the software for the Bison resistivity meter

Software Ownership
Please explain how useful that you find it.

Alabama – N.A.

Iowa - N/A

Maryland – N/A

Michigan - N/A

Minnesota - They are all useful, although, the Geotechnical Engineering Section at MnDOT does not curate the GPR system and software mentioned above. Also, seismic software codes vary so several are utilized at MnDOT during an investigation for model comparison purposes.

Ohio –

Ontario - N/A

Pennsylvania -

Virginia - It's usefulness is limited by age.

Problems
Please describe investigation or monitoring problems that you need a method to resolve.

Alabama –

Iowa - "Possible" use of Resistivity or comparable method for subsurface profiles, slip plane detection, etc., of foreslope and backslope slides.

Maryland –

Michigan - Void detection

Minnesota –

Ohio - Running geophysical lines along highways is always problematic. Overhead and underground utilities pose some issues. Metal guardrail and posts are another issue. Metal culverts and heavily reinforced concrete can create their own limitations. Many times, we would prefer to run lines perpendicular to the face of the mine; however, this position would also require us to run the lines across the highway precluding many of the geophysical methods. We typically have at least two geophysical methods conducted at any site. Hopefully, the methods are chosen to compliment each other. When anomalies are identified, we fall back to conventional drilling to confirm the features. The identification of these anomalies seem to be hit and miss depending again of the target size, depth, geologic setting, and ground water regime.

Ontario -

Pennsylvania -

Virginia - We often have unknown subsurface conditions due to karst or abandoned underground mines -- due to infrastructure, we often have noisy conditions which make investigation difficult. Most of our jobs are adjacent to traffic.

Questions
Please provide any questions or discussion items that you would like to be discussed at the November 9, 2011 workshop.

Alabama -

Iowa - More topic papers on other geophysical methods:

Conductivity, Gravity/Magnetic, Seismic, etc.

Maryland - My question is more general in nature, How accurate is the interpreted geophysical surveys? Once you drill on the site, how well does the actual encountered materials meet the anticipated materials with the various geophysical methods?

Michigan -

Minnesota –

Ohio - What combination(s) of geophysical and non-geophysical methods are being employed to define subsurface mining conditions?

Ontario -

Pennsylvania - Provide a specific example of a DOT that has a staff of people (I'm thinking 2-3 employees) dedicated to operating geophysics equipment, such as GPR. Provide approximate annual costs, number and types of projects completed. This information may help other DOT's that are interested in pursuing this capability for themselves.

Virginia - -- New methods, particularly REMI
-- Lessons learned, and lessons that need to be unlearned