7th Annual Technical Forum

GEOHAZARDS IN TRANSPORTATION IN THE APPALACHIAN REGION

Haywood Park Hotel, Asheville, August 1-2, 2007

TECHNICAL PROGRAM

DAY 1

7:00 a.m. Registration

8:00 a.m. Haywood Ballroom Welcome: Tony Szwilski (CEGAS)

Opening Session: Gotechnical Case Studies of North Carolina. Chair: Jody Kuhne (NCGS)

1. **Big Slow Movers: A Look At Weathered-Rock Slides in Western North Carolina**
Rebecca S. Latham, Richard M. Wooten, Anne C. Witt, Kenneth A. Gillon, Thomas J. Douglas, Stephen J. Fuemmeler, Jennifer B. Bauer, North Carolina Geological Survey
2. **Geohazard and Transportation Aspects of Sulfidic Rock (Acid Rock) in North Carolina**
Thomas J. Douglas[1], Richard M. Wooten[1], Kenneth A. Gillon[1], Jennifer B. Bauer[1], Jody C. Kuhne[2], Rebecca S. Latham[1], Anne C. Witt[1], Stephen J. Fuemmeler[1]: [1]North Carolina Geological Survey; [2]North Carolina Department of Transportation.
3. **A Brief History of Horizontal Drains in Western North Carolina**
Michael Hager, North Carolina Department of Transportation.
4. **2D MASW Surveys To Evaluate Subsurface Stiffness: Investigations of the 2004 I-40 Landslide and Other Projects**
Ned Billington, Jeremy Strohmeyer, Alex Rutledge, Schnabel Engineering, Greensboro, NC.

10:00 a.m. COFFEE BREAK

10:30 a.m. Session 2: Landslides: Past, Present & Future. Chair: Kirk Beach (ODOT)

1. **An Integrated Landslide Management System for Highway Applications**
Kirk Beach and Gene Geiger, ODOT; Robert Liang, University of Akron, Akron Ohio
2. **A Remediation Cost Database and Web-Based Application for Geologic Hazards**
Kirk Beach, ODOT; Patrick Fox and Paul Sivilotti, Ohio State University, Columbus, Ohio.
3. **Drilled Shafts for Bridge Foundation Stability Improvement Ohio 833 Bridge over the Ohio River Pomeroy, Meigs County, Ohio: An Update**
Stan A. Harris, P.E., Geotechnical Program Manager and Eric M. Kistner, P.E., Senior Project Engineer; Fuller, Mossbarger, Scott and May Engineers, Inc. Cincinnati, Ohio
4. **Geoenvironmental and Geotechnical Data Exchange: Setting the Standard**
Scot D. Weaver, EarthSoft, Inc.; Thomas Lefchik, FHWA

12:15 n Lunch Speaker: Chester Watts, Radford University.

1:30 p.m. **Starnes Room** (CONCURRENT SESSION)

Session 3: Cost Benefits of Geoscience Information. **Chair: Hugh Bevans (USGS)**

1. **Valuation of Services from Natural Systems in Estimating the Benefits and Costs of Changes in the Appalachian Development Highway System: The Role of USGS Data**

Gregory A. Bischak, Senior Economist, Appalachian Regional Commission, Washington DC

2. **The Value of Geologic Maps for Transportation Planning in Kentucky**

James C. Cobb, Kentucky Geological Survey, University of Kentucky, Lexington, KY

3. **Integrating Geoscience and Socioeconomic Information Reduces Uncertainty in Societal Decision Making**

Carl Shapiro, USGS, Geography Discipline, Reston, VA and Richard Bernknopf, USGS, Western Geographic Science Center, Menlo Park, CA.

1:30 p.m. **Haywood Ballroom** (CONCURRENT SESSION)

Session 4: Economic Impact of Geological Hazards. **Chair: Jody Stanton (USACE)**

1. **Perceived Risk Versus Cost In Karst Remediation – A Case History.**

Sam Vance, AMEC, 3800 Ezel Road, Suite 100, Nashville, TN 37211

2. **West Virginia Route 2 Rock Fall Hazards at "The Narrows" Using a Rock Fence Catchment System for Remediation**

Aaron L. Wentz, West Virginia DOT

3. **Wolf Creek Dam, Balancing Extreme Consequences of Failure and Extreme Economic Impacts in the Uncertain World of Karst.**

Jody Stanton, U.S. Army Corps of Engineers, 801 Broadway, Nashville, TN 37202.

4. **Current Results of Landslides Hazard Mapping in Western Carolina**

Kenneth Gillion, Richard Wooten; Rebecca Latham, Anne Witt, Thomas Douglas, Stephen Fuemmeler, Jennifer Bauer; John Nickerson, North Carolina Geological Survey .

3:30 p.m. COFFEE BREAK

4:00 p.m. **Starnes Room** (CONCURRENT SESSION)

Session 5: Geological Mapping **Chair: John Kiefer (KGS)**

1. **Geohazards in the Kope Formation, Northern Kentucky**

John Kiefer, Warren Anderson, Kentucky Geological Survey

2. **Geological Maps for Land-Use Planning**

Daniel I. Carey, Kentucky Geological Survey, University of Kentucky, Lexington..

3. **New Geologic mapping for Landslide Mitigation in Eastern Kentucky**

William M. Andrews Jr., John D. Kiefer, Matthew M. Crawford, Kentucky Geological Survey, UK.

4. **Foundation Problems and Pyrite Oxidation in the Chattanooga (Ohio) Shale Estill County, Kentucky**

John Kiefer, Warren H. Anderson, Kentucky Geological Survey

4:00 p.m. **Haywood Ballroom** (CONCURRENT SESSION)

Session 6: Innovations in Real-Time Monitoring **Chair: Silas Nichols (FHWA)**

1. **Design of Instrumentation Systems for Monitoring Geo-Hazards in Transportation**

Barry R. Christopher, Ph.D., P.E., Christopher Consultants, Roswell, GA

2. **Advancements and Innovations in Instrumentation Systems for Real-Time Monitoring of Geo-Hazards in Transportation**

W. Allen Marr, Ph.D., P.E., Geocomp Corporation, Boxborough, MA; Thomas A Tye, P.E., Geocomp Corporation, Atlanta, GA

3. **Value of Instrumentation Systems and Real-Time Monitoring: An Owner's Perspective**

Silas C. Nichols, P.E., Federal Highway Administration, Atlanta, GA

Adjourn 5:45 p.m.

DAY 2

7:30 am Registration

8:00 a.m. Haywood Ballroom

Session 7: Rock Slope Problems and Stabilization **Chair: Jane McColloch (WVGS)**

1. **Slope Stabilization at the Canon Del Pato Hydroelectric Project, Peru. Part 1: Background and Site Studies.**

Malcolm Schaefer, Devine Tarbell & Associates, Inc., Charlotte, NC

2. **Slope Stabilization at the Canon Del Pato Hydroelectric Project, Peru. Part 2: Design and Construction**

Malcolm Schaefer, Devine Tarbell & Associates, Inc., Charlotte, NC

3. **Emergency Project Maui DOT**

Renee Reccord, Janod of Companies, Vaudreuil-Dorion, QC

4. **Slope Stabilization with High Tensile Wire Mesh**

Frank Ahmend, Geobrugg

10:00 am COFFEE BREAK

10:30 am. Haywood Ballroom

Session 8: Karst and Mine subsidence Hazards in Transportation
Chair: Steve Brewster (USACE)

1. **On the Time-Frame of Cover Collapse Sinkhole Development**

Barry F. Beck and Wanfang Zhou, P.E. LaMoreaux & Associates, Inc., Oak Ridge, TN.

2. **The Nelsonville Bypass: A Hitchhiker's Journey through the Galaxy of Mine Hazards**

Stan A. Harris, Eric M. Kistner, Fuller, Mossbarger, Scott and May Engineers, Inc., Cincinnati, Ohio; Alan Craig, P.E., Ohio Department of Transportation, District 10, Marietta, Ohio

3. **Ohio's Underground Mine Hazards—Getting Out of the Pits**

Christopher P. Gordon, ODNR, Division of Geological Survey; Tim Jackson, ODNR, Division of Mineral Resources Management

12:30 pm Closing Remarks

Forum Presentations: The Powerpoint presentations, in pdf format, of this and previous forums can be found on the Marshall University-CEGAS website:
http://www.marshall.edu/cegas/geohazards/

Note: PDH's (Professional Development Hours) will be granted for this conference. However you must register both (2) days in order to receive the credit.

GEOHAZARDS IN TRANSPORTATION IN THE APPALACHIAN REGION

ABSTRACTS

DAY 1:
OPENING SESSION: Gotechnical Case studies of North Carolina. Chair: Jody Kuhne

Big Slow Movers: A Look At Weathered-Rock Slides in Western North Carolina

Rebecca S. Latham, Richard M. Wooten, Anne C. Witt, Kenneth A. Gillon, Thomas J. Douglas, Stephen J. Fuemmeler, Jennifer B. Bauer, North Carolina Geological Survey, 2090 U.S. Highway 70, Swannanoa, NC 28778. Telephone: 828-296-4633; Fax: 828-299-7043

The North Carolina Geological Survey implemented a landslide hazard-mapping program with legislatively appropriated funding from the Hurricane Recovery Act of 2005. Part of this work involves classifying the slope movements (landslides) and gathering geologic and geomorphic data on the failures. Slow to very slow moving, weathered rock slides are a type of slope movement encountered in western North Carolina.

The Toxaway River Slide is a composite, translational, weathered-rock slide in Gorges State Park in Transylvania County, North Carolina. This four-acre slope movement most likely began moving in 1916 when the Lake Toxaway dam failed, sending a torrent of water and debris down the Toxaway River that scoured material from the toe of the slope. Recent movement of the landslide at the Lake Logan Center southeast of Waynesville in Haywood County was triggered in September 2004 by heavy rainfall from the remnants of Hurricane Ivan. High antecedent moisture conditions caused by rainfall from Hurricane Frances, as well as undercutting at the toe by the West Fork of the Pigeon River, were likely precursors that reactivated movement of an earlier inactive weathered-rock slide. The Hunters Crossing landslide is also located in Haywood County near the town of Waynesville. Residents first noted movement of this 1.5-acre rotational failure in mid-September 2005 approximately three weeks after very intense rainfall caused localized flooding in the area, and around the time a leak was detected in the community water line. These failures have similar geomorphic settings and fail within the transition zone from weathered to unweathered bedrock, or along manganese/iron oxide-coated discontinuities in the bedrock. Predictive models are being investigated to aid in determining the locations of thick zones of completely decomposed bedrock prone to slope failure in western North Carolina.

Geohazard and Transportation Aspects of Sulfidic Rock (Acid Rock) in North Carolina

Thomas J. Douglas[1], Richard M. Wooten[1], Kenneth A. Gillon[1], Jennifer B. Bauer[1], Jody C. Kuhne[2], Rebecca S. Latham[1], Anne C. Witt[1], Stephen J. Fuemmeler[1]

[1]North Carolina Geological Survey, 2090 U.S. Highway 70, Swannanoa, NC 28778, Telephone: 828-296-4633; Fax: 828-299-7043

[2]North Carolina Department of Transportation, PO Box 3279, US Highway 74, Asheville, NC 28802, Telephone 828-298-3874, Fax 828-299-1273

Western North Carolina has a history of natural and man-induced environmental issues caused by the presence of acid producing rock. Ground disturbing activities, such as road construction, in sulfidic rock units can lead to the introduction of acid leachate into the surface water. Sulfidic rock units are also susceptible to landslide activity. Pyrite and pyrrhotite are two sulfide minerals commonly found primarily in metasedimentary rocks in western North Carolina. Excavations of sulfide-rich rock greatly increase the exposed surface area of the rock and constituent minerals. Oxidation and hydrolysis of the freshly exposed sulfide mineral produces sulfuric acid runoff that can cause a sudden decrease in pH in nearby streams, harming aquatic life.

Landslides, specifically debris flows and rock slides, have initiated in several western North Carolina counties where slopes underlain by acid producing rock have been modified by embankments and excavations. These recent slides have mostly occurred in sulfidic schist and metagraywacke bedrock units within the Great Smoky Group, and in several cases, have resulted in property damage. The North Carolina Geological Survey's landslide hazard mapping program continues to discover landslides related to sulfidic rock. Several case studies of hazards induced by sulfidic rock and remediation techniques will be discussed, including problems encountered by the North Carolina Department of Transportation and the Great Smoky Mountain National Park.

A Brief History of Horizontal Drains in Western North Carolina

Hager, Michael M., LG., North Carolina Department of Transportation, PO Box 3279, Old Charlotte Highway, Asheville, NC 28805

Since the mid 1970's there have been several transportation projects in western North Carolina that have employed horizontal drains to reduce high groundwater pore pressure in landslide prone engineered slopes. Horizontal drains actively draw down groundwater table levels, dewatering a project area and reducing the associated groundwater pore pressures, effectively stabilizing the treated area. The North Carolina Department of Transportation has implemented horizontal drains in two projects of note since the 1970's, both along the existing I-26 corridor.

During the construction of 1-26 in Polk County in the vicinity of Howard Gap Rd, large scale sliding and mass wasting triggered by high groundwater and construction techniques in unsuitable, colluvial material delayed the completion of the project by nearly 3 years. Horizontal drains were designed and installed to reduce groundwater pore pressures in the largest horizontal drain project of it's time (401 drains were designed for a combined total length of 117,000' of drainpipe). Since completion of construction there have been minimal ground movements in the treated area (there have been numerous small scale slumps and slope movements that have effectively destroyed the drainage system but have yet to affect the highway grade).

Construction of the 1-26 corridor north of Asheville, NC began in the 1990's and consisted of large areas of colluvium underlying new highway alignment in places. Horizontal drains were implemented by the NCDOT in order to actively drain areas underlain by large viscous colluvial tongues, avoiding the alternate option of undercutting, transporting, and wasting large quantities of unsuitable material. Many of these drains continue to produce today, stressing the need for long term monitoring and maintenance of horizontal drain systems.

2D MASW Surveys To Evaluate Subsurface Stiffness: Investigations of the 2004 I-40 Landslide and Other Projects

Ned Billington, L.G., Jeremy Strohmeyer, L.G., and Alex Rutledge, E.I.T., Schnabel Engineering, 11-A Oak Branch Drive, Greensboro, NC 27407

The Multi-channel Analysis of Surface Waves (MASW) method has become an established method for evaluating the stiffness of subsurface materials. It is particularly suited for roadway studies, since data acquisition is possible in areas with high traffic counts, in locations with overhead and buried utilities, and on concrete and asphalt surfaces – conditions that can impair the results of other geophysical methods. The relatively smooth surface of roadways allows the surface wave data to be collected quickly using a seismic land streamer towed behind a vehicle.

The basis of surface wave studies lies in the fact that the surface waves are dispersive and that their velocity is highly dependent on the shear wave velocity of the subsurface. The term "dispersive" means that different frequency components of the surface wave energy travel at different velocities and to different depths, depending on the wavelength of each component and the shear wave velocities of the subsurface. By determining the velocity of each frequency component, we can develop a layered shear

wave velocity model that matches the observed surface wave dispersion. The shear wave velocity model is a direct indication of the stiffness of the subsurface materials.

Surface wave data can be collected at multiple locations along a survey line and processed to obtain 2D cross-sections of subsurface shear wave velocity – a method referred to as 2D MASW. The 2D MASW method has been used successfully to image abandoned underground mines, locate incipient sinkholes, map weak zones in soil and rock, and map depth to bedrock, such as in the following example.

In September 2004, part of I-40 in Haywood County, NC collapsed when the embankment was eroded by floodwaters in the Pigeon River, caused by heavy rain from Hurricane Ivan. Information on the depth to bedrock was needed quickly by the NCDOT to supplement boring data. Noise from traffic in the west-bound lanes precluded the use of seismic refraction, a common method for depth-to-bedrock studies. The 2D MASW method was selected since data could be collected on the asphalt roadway and the traffic noise would not significantly affect the surface wave data. Seismic data were collected along the closed east-bound lanes using a land streamer and an accelerated weight drop source. The 2D MASW results indicated a variable depth to bedrock and provided valuable information for the contractor to design the tieback system for the new retaining wall.

SESSION 2: Landslides: Past, Present & Future. Chair: Kirk Beach (ODOT)

An Integrated Landslide Management System for Highway Applications

Kirk Beach, Geology Program Supervisor, and Gene Geiger Administrator, Office of Geotechnical Engineering, Ohio Department of Transportation; and Robert Liang, Professor, Department of Civil Engineering, University of Akron, Akron Ohio 44325-3905

Managing the landslide and/or slope failure induced hazards on the highway system is an important and challenging task for the state transportation agency, particularly form the perspective of protecting the traveling motorists from these potential hazards. With a finite financial resource available to mitigate these potential landslide hazards, the state transportation agency needs to develop an efficient landslide management system, not only to compile an inventory of landslides and slope failures but also to assess the level of hazards of each of these landslide sites. The Ohio DOT has developed an integrated landslide management system, which utilizes a suit of information technology platforms to maximize the system's connectivity and functionality. This paper will present the pertinent innovations and novel features embedded in the ODOT Landslide Management System. Specifically, the GIS based database structure, the secured database access via. Internet connectivity, and the ODOT specific landslide hazards rating matrix will be presented. Experiences and challenges of full implementation of the system will be discussed in the presentation as well.

A Remediation Cost Database and Web-Based Application for Geologic Hazards

Kirk Beach, Geology Program Supervisor, Office of Geotechnical Engineering, Ohio Department of Transportation; Patrick Fox, Professor, Department of Civil and Environmental Engineering and Geodetic Science, Ohio State University, Columbus, Ohio; and Paul Sivilotti, Associate Professor, Department of Computer Science and Engineering, Ohio State University, Columbus, Ohio.

Ohio roadways contain a large number and wide variety of geologic hazards; however funds to remediate such hazards are limited. To effectively handle this problem, the Ohio Department of Transportation (ODOT) Office of Geotechnical Engineering has created the Geological Site Management Program (GSMP). This systematic approach to minimize risk on Ohio roadways begins with the inventory of all recognized hazards. The GSMP committee distributes remediation funds to the ODOT districts based on the hazard rating, expected remediation cost, and the benefit-to-cost ratio. The Remediation Cost Database and Application (RCDA) is a web-based estimation tool that will be used to provide preliminary cost estimates for the remediation of geologic hazards around the state. Remediation costs are currently

calculated by engineers or geologists based on best professional judgement and line item costs. Without the RCDA, unit costs for the same line items vary from district to district. To avoid this source of variability in cost estimation, the RCDA draws upon unit costs for all the various remediation strategies that have been compiled into one centrally-controlled database. Uniform unit costs will help decision makers better evaluate the benefit-to-cost ratio and priority of each remediation project. District engineers will also be able to quickly compare costs of different remediation methods by entering the appropriate site data into the RCDA.

The RCDA provides general cost estimates for underground mine, landslide, and rockfall hazards. The RCDA currently considers three methods to remediate underground abandoned mines: excavate and fill, drill and grout, and land bridge. More landslide sites exist in Ohio than for abandoned mines or rockfalls, and many methods are considered in the RCDA for landslide remediation. These methods are divided into five categories: slope modification, drainage, soil modification, retaining structures, and retaining walls for road relocation. The most direct hazards to motorists often come from rockfalls. The RCDA methods to remediate rockfalls include: slope modification, barrier and catchment systems, rock bolts and retaining structures, and drainage. The RCDA also allows an open-ended "User-Defined" method for the development of new remediation methods that are not currently included in the application.

Drilled Shafts for Bridge Foundation Stability Improvement Ohio 833 Bridge over the Ohio River Pomeroy, Meigs County, Ohio: An Update

Stan A. Harris, P.E., Geotechnical Program Manager and Eric M. Kistner, P.E., Senior Project Engineer; Fuller, Mossbarger, Scott and May Engineers, Inc. Cincinnati, Ohio

The Ohio Department of Transportation (ODOT), the West Virginia Department of Transportation (WVDOT) and the Federal Highway Administration (FHWA) are working together to construct a replacement structure for the existing U.S. Route 33 Bridge over the Ohio River between Pomeroy, Ohio and Mason, West Virginia. The proposed structure will be a cable-stayed structure with an abutment to abutment length of 1,910 feet. Relocation of Main Street on the Ohio side of the river was to require new roadway embankment ranging up to 30 feet in height

Embankment construction began in October of 2003. Slope inclinometer data obtained in November of 2003 indicated the presence of deep slope movement. Subsequent explorations and monitoring confirmed the presence of what appeared to be a remnant landslide. Although the proposed bridge foundations were not within the area of slope movement, it was decided that proactive steps should be taken to protect the new foundations in the event that the movement expanded. Working with URS, the bridge designer, and the ODOT Office of Geotechnical Engineering, a foundation protection scheme was developed consisting of the construction of nine, eight-foot diameter heavily-reinforced drilled shafts on the Ohio river bank, just uphill of the tower pier. The shafts were instrumented with slope inclinometer casing, strain gauges and tiltmeters. This presentation will focus on results from the last two years of data monitoring as well as lessons learned.

Geoenvironmental and Geotechnical Data Exchange: Setting the Standard

Scot D. Weaver, EarthSoft, Inc.; Thomas Lefchik, Federal Highway Administration
Marc Hoit, University of Florida; Kirk Beach, Ohio Department of Transportation

Data Interchange for Geotechnical and Geoenvironmental Specialists (DIGGS) is a data exchange standard developed through the cooperation of a multinational group of agencies, organizations, academics, and industry. To the extent feasible, current data standards are being incorporated, with modifications, into DIGGS. DIGGS will provide a standardized means of data exchange between disparate geotechnical and geoenvironmental databases and software. The several significant advantages to the user of DIGGS include the ability to: • exchange data between databases within an agency or organization.

- receive data from consultants in a standard format
- exchange information with other agencies
- perform data quality checks
- exchange data between software packages and providers
- produce software products that are more standardized and more compatible with other products
- utilize and analyze data from various sources in an integrated geoenvironmental/ geotechnical data management system.

The development of DIGGS is proceeding in a staged process. However, DIGGS will ultimately cover the entire gamut of geotechnical and geoenvironmental data including boreholes, tests, assets, and hazards. DIGGS version 1, released in the Fall of 2007, will include a data dictionary and data standard for boreholes, tests, and deep foundations. Several DIGGS compatible tools will be available at the time of the release of DIGGS version 1. These tools include: the EQuIS Data Processor (EDP) from EarthSoft, gINT, Holebase, COSMOS Virtual Geotechnical Data Center (VGDC), United Kingdom Highway Agency geotechnical management system, an AGS to DIGGS translator, and a public-domain database with GIS interface for state DOTs. Several other software vendors are also making their software compatible with DIGGS. This paper discusses the current and future development of DIGGS and its practical and technical advantages.

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SESSION 3: Cost Benefits of Geoscience Information. Chair: Hugh Bevans (USGS)

Valuation of Services from Natural Systems in Estimating the Benefits and Costs of Changes in the Appalachian Development Highway System: The Role of USGS Data

Gregory A. Bischak, Senior Economist, Appalachian Regional Commission, 1666 Connecticut Ave. NW Washington DC 20009-1068; 202-884-7790; gbischak@arc.gov

This presentation will focus on the role of key geological data in valuing services from natural systems that may be affected by proposed changes in the alignment of corridors of the Appalachian Development Highway System. Given the need for well-engineered transportation infrastructure and better natural resource management, the valuation of the services provided by natural systems is a key step in benefit-cost analyses for planning land-use changes and natural resource management and infrastructure associated with expanding transportation corridors. In addition, these analyses are required to meet increased public expectations for prevention, warning, and protection during weather-related and other natural disasters. This panel will discuss economic models capable of valuing ecological services and natural resources and the contribution of USGS data to accomplish this task. Ecological services include a complex array of provisioning, regulatory and other services that are provided by natural systems to many species, including humans. Services that humans normally recognize and value through market prices include the provisioning of food, fiber, water, fuel, genetic and medicinal resources and materials. Natural regulatory services, which ensure water quality, flood and erosion control, biological propagation and control, climate and gas regulation, soil formation and retention, nutrient cycles, and disturbance mitigation and resilience of ecosystems, etc. are not usually valued through markets but can be valued economically. Other services such as habitat formation and stability, and cultural services such as recreation, aesthetic, spiritual, scientific, and educational uses of natural systems are not always valued economically or through the market.

The Value of Geologic Maps for Transportation Planning in Kentucky

James C. Cobb, Kentucky Geological Survey, University of Kentucky, Lexington, KY

Geologic maps have been one of the most valuable tools for transportation planning, design, and construction. To illustrate this fact, the Kentucky Transportation Cabinet has accounted for a large share of the 200,000 Kentucky geologic maps sold since they became available in the 1960's. A question that often comes up is, *What is the value of a geologic map and how can a cost-benefit analysis of these maps be done?*

Geologic mapping in Kentucky was completed in 1978 at a cost of $90 million in 1999 dollars. The benefit to society from the initial investment is between 25 and 39 times its cost, an outstanding return on the investment of public funds.

A joint investigation of geologic maps by the Kentucky and Illinois Geological Surveys in 2000 was based upon responses to a questionnaire sent to 2,200 registered professional geologists in Kentucky. Results showed that having detailed geologic maps available, which made new data collection unnecessary, accounted for an average savings of $43,527 per quadrangle and a minimum savings of $27, 776.. Since this economic analysis was done, geologic maps have gone digital and moved to the Internet. Digital map services disseminate geologic map information 24 hours a day, 7 days a week. Although no economic analysis has been done to assess the new cost to benefit ratio of digital maps, it is clear that the ratio has been greatly enhanced.

The KGS interactive Geologic Map Service at kgsweb.uky.edu/main.asp offers all the usual detailed geologic map information along with point data for a large variety of resource, mineral, and environmental applications. Users can customize a geologic map for any area in Kentucky, and overlay the map with sites that pertain to the problem at hand; a number of derivative classifications are also possible. They can then download a high-resolution, geo-referenced image of the map along with the attributed site data for use in their own GIS or CAD system. Hundreds of these maps are downloaded each day.

To continue meeting the needs of highway planners, the Kentucky Geological Survey is working with the Kentucky Transportation Cabinet to create new and useful methods to store geologic information and disseminate geologic map information.

Integrating Geoscience and Socioeconomic Information Reduces Uncertainty in Societal Decision Making

Carl Shapiro, USGS, Geography Discipline, Reston, VA, and Richard Bernknopf, USGS, Western Geographic Science Center, Menlo Park, CA

Decisions to reduce natural hazards risk and to manage natural resources are routinely made with information that is imperfect and uncertain. Information uncertainty can cause wide variation in the expected outcomes and in the predicted societal consequences of policy and regulatory decisions. These variations can result in decisions that are costly in terms of life and property.

It is important to estimate and document the benefits of additional scientific information and its potential for reducing the costs of decision risk. The emerging multidisciplinary research area of the science of science policy illustrates the growing importance in understanding the benefits of using scientific information to inform decisions. The increased use of adaptive management principles recognizes the need to reduce the uncertainty associated with scientific information, even after initial decisions have been made.

USGS studies evaluating the use of scientific information in reducing the uncertainty in societal decisions have demonstrated the importance of integrated multidisciplinary efforts to combine natural and socioeconomic science information. "After the fact" economic evaluations of existing scientific information provide limited perspectives on the benefits from using scientific information in decision making. To fully understand and maximize the value of geoscience information to inform future policy choices, it is necessary to take a forward-looking perspective. USGS has conducted integrated natural

and social science assessments combining scientific information and process models to inform future policy and regulatory choices. These studies demonstrate the value in use of geoscience information in addressing issues that include:

- The effectiveness of alternative mitigation strategies for New Madrid seismic zone earthquakes in Memphis , TN;
- The benefits of alternative risk reduction strategies for liquefaction in Watsonville, CA;
- The benefits of updated, more detailed geoscience information for mineral exploration in central Canada (in cooperation with the Geological Survey of Canada); and
- The effectiveness of alternative mitigation strategies for flood hazards in Squamish, BC (in cooperation with the Geological Survey of Canada).

Session 4: Economic Impact of Geological Hazards. Chair: Jody Stanton (USACE)

Perceived Risk Versus Cost In Karst Remediation – A Case History
Sam Vance, AMEC Engineers, Nashville

This case history discusses issues associated with a section of Norfolk Southern Corporation (NSC) track located about 30 miles northeast of Knoxville, Tennessee. At this location, the alignment includes a fill embankment that supports a single, curved track crossing the low point of a broad topographic depression. The local geology includes bedrock of the Knox Limestone Formation that is highly susceptible to solution weathering and the development of karst landforms. Beginning in the mid-to-late 1990's, rail traffic was frequently halted or placed on slow order due to periodic development of sinkholes that threatened the track structure and trains. After several dropouts exceeding 30 feet in depth occurred adjacent to the track, a study was completed to assess the general subsurface conditions, to develop alternative repair schemes, to provide cost estimates for constructing each option, and to assess the level of long-term risk for the alternatives.

Four alternatives were considered including, in general order of decreasing cost and increasing risk of future problems: 1) replacement of the embankment fill with a multi-span, at-grade bridge; 2) permanent track shift; 3) temporary track relocation, excavation followed by bedrock repairs and track replacement; and, 4) a compaction grout program. Ultimately, because of the Owner's lack of experience with the lower cost options, and their perceived risk, liability, and exposure arising from incident associated with a catastrophic collapse, NSC selected and constructed the at-grade bridge. Although more costly than the other alternatives, this option provided a low risk, "walk away" fix to the problem. NSC determined that the value of the selected alternative was worth the additional cost in order to help ensure safe and timely movement of rail traffic.

West Virginia Route 2 Rock Fall Hazards at " The Narrows" Using a Rock Fence Catchment System for Remediation
Aaron L. Wentz, West Virginia DOT

The hazards of rockfalls and debris flows plague transportation departments throughout the country, and West Virginia is no exception. One section of West Virginia State Route 2 in Marshall County has a history of rockfalls dating back nearly to the inception of this stretch of road.

This area of roadway, termed "The Narrows" by DOT officials and the media, is wedged between rock-cut slopes and a steeply-wooded hillside along the northbound lanes, and an aging series of retaining walls and a railroad along the southbound lanes. This section of roadway is located just north of Moundsville in West Virginia's northern panhandle. The geologic units comprising the cuts consist of

weak shales and freshwater limestone interbedded with layered sandstone. Debris from the highly weatherable rock often cascades onto the travel lanes of the road, which has led to numerous court claims for vehicle damages as well as at least one fatality.

Remediation measures have been studied throughout the troubled history of this road. However, due to the topographic constraints and continual funding shortfalls affecting the Transportation Department, no viable solutions were pursued for years. In the winter of 2004, finances became available to begin a design to help mitigate the rock fall problem at this location. Several changes in the scope of the work slowed progress but came to fruition in the spring of 2006 with the letting of a project to install 6050 lineal feet of a Geobrugg rock net catchment system in combination with a concrete barrier. Shortly after the completion of the project, the WVDOT saw the results of its efforts when the ring net system stopped a large rock fall and prevented the boulders and debris from reaching the travel lanes of Route 2.

Wolf Creek Dam, Balancing Extreme Consequences of Failure and Extreme Economic Impacts in the Uncertain World of Karst.

Jody Stanton, U.S. Army Corps of Engineers, 801 Broadway, Nashville

While not a transportation focused topic there is significant public interest in the fate of Wolf Creek Dam and Lake Cumberland. Wolf Creek Dam, located in south central Kentucky impounds one of the largest reservoirs in the Eastern United States. Lake Cumberland at full storage contains slightly over 6,000,000 acre feet of water. In the event of a failure a significant population is at risk and damage to downstream communities, which include Nashville, Tennessee is estimated to exceed $3 Billion.

Since its completion in 1951 Wolf Creek Dam has experienced episodes of distress caused by seepage through a well developed network of karst features in the limestone foundation. A near catastrophe was averted in 1968 through a program of intensive emergency grouting followed by construction of a composite cut-off wall. The cut-off wall, completed in 1975 effectively slowed the progress of seepage damage but did not stop it completely as evidenced by various observations and instrumentally recorded distress indicators. The difficult task of quantifying the risk presented by this situation has evolved over the past 3 years using various methods. This presentation will provide an overview of this evolution and how it has been used to manage risk both in terms of interim measures and long term performance of the project. The complexity involved in balancing a tolerable level of risk with the certainty of significant impacts caused by interim risk reduction measures is described.

Current Results of Landslides Hazard Mapping in Western Carolina

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In September 2004, heavy rainfall from the remnants of Hurricanes Frances and Ivan triggered at least 155 slope movements that caused five deaths, destroyed 27 homes, and disrupted transportation corridors throughout western North Carolina (WNC). In response to the damage and fatalities from these storms, the N.C. General Assembly passed the Hurricane Recovery Act of 2005 that provided funding for the NCGS to begin a landslide hazard-mapping program in nineteen WNC counties.

After completing the Macon County pilot study in 2006, the NCGS undertook an aggressive schedule to complete landslide hazard maps for 2 to 3 WNC counties a year. Watauga County, in northern WNC, and Buncombe County in central WNC were selected for mapping in 2006-07 because of their population growth and increase in development on steep slopes. Our mapping program utilizes GIS (geographic information system), GPS (global positioning system), and Microsoft Access™ platforms to develop an extensive slope movement-slope movement deposit database, and debris flow susceptibility modeling to produce county-based maps that delineate areas of high, moderate, and low debris flow-slide hazards. We employ an iterative mapping concept whereby preliminary maps are made using GIS-based models to target areas for field verification of initial model results and input parameters. High-resolution

LiDAR (Light Detection and Ranging) digital elevation data and multiple vintages of remote imagery are also used to locate areas of possible slope movements and slope movement deposits. Over 2,500 landslides were identified from remote imagery and field studies in these three counties. Representative locations of these landslide locations were then field verified including collection of geologic, geomorphic, hydrologic, sites. These data will then be used to refine the computer models and expand the database.

Digital products include: the slope movement – slope movement deposit map, stability index map for debris flow-slide hazards, a downslope hazards map, and a geologic hazards map. Information on this landslide hazard assessment program is available on the NCGS website (http://www.geology.enr.state.nc.us/); and locations of slope movements and slope movement deposits are available at http://www.nconemap.com/.

Session 5: Geological Mapping — Chair: John Kiefer (KGS)

Geohazards in the Kope Formation, Northern Kentucky

John Kiefer, Warren Anderson, Kentucky Geological Survey

Slope instability in the Kope, Point Pleasant and Clays Ferry Formations of Ordovician age in northern Kentucky affects residential and commercial construction and engineering projects. Landslides, soil creep and rock falls occur in embankments, hillsides and colluvial wedges at the base of slopes or valleys. Sometimes this process may take many years before embankments or slopes in these formations begin to fail. Water saturation is the primary cause of failure because the clay minerals in these shales shrink and swell, which causes heaving and movement of sediments. Roads, homes, and other structures built on these sediments should have adequate drainage to channel water away from the sediments and colluvium. The clay content of the soils consists of illlite and montmorillonite and readily expand when wet. Glacial lacustrine deposits also have a high shrink-swell potential and can be unstable.

Several examples of homes and roadways built on these rocks that have failed are examined to identify the causes of failure. Water saturation and steep slopes are a dominant cause of failures. Most of these shales are relatively impermeable and percolation rates are to low for adequate septic tank drainage. Several new homes inspected had both lawn sprinklers and septic tank effluent discharged into the slope in front of their homes providing a natural lubrication for slope, foundation and home failure.

Roadways built on these formations have repetitive maintenance issues. The maintenance costs for roadway repair in this part of the state are expensive are the highway maintenance episodes are 5 times other parts of the state. Usually the Department of Transportation will solve the problem by milling and adding new asphalt to the heaving highway, when a more porous subbase might also help the problem.

Education about these issues is a major concern. KGS has conducted several workshops to educate highway engineers, realtors, builders and homeowners about prevention, and remediation of affected structures. KGS has also provided a series of county land use maps to assist local planning and zoning agencies in preparation for development of northern Kentucky. The problem arises when these agencies or professions do not listen or adhere to recommendations given by geotechnical professionals.

Geological Maps for Land-Use Planning

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The Kentucky Geological Survey has completed the digitization of 7.5-minute, 1:24,000-scale geologic maps for the entire state. The digital geologic data, coupled with a geographic information system, provide for the efficient and cost-effective development of maps to support land-use planning in Kentucky. Generalized geologic maps for land-use planning at scales of 1:48,000 or 1:63,360 are being prepared for each of Kentucky's 120 counties. Eighty-six maps have been completed, and the goal is to

complete the remaining 34 maps by the end of 2007. The maps can be used by homeowners, developers, policy-makers, and planners. The maps provide information, in nontechnical language, on how underlying rocks affect excavation and foundations; suitability for on-site wastewater treatment systems; underground utilities; residential, commercial, industrial, and recreational developments; highway and street development; and pond and reservoir construction. Photos of sites in the county are used to illustrate local issues: landslide hazards and slope stability, radon, drainage and flooding problems, karst hazardsI thin, natural resources, and development pressures. Photos are used to illustrate underlying lithology and its relationship to the terrain, land use, and economy. Links to additional information for each county are given. The maps are available in pdf format at kgsweb.uky.edu/download/geology/landuse/lumaps.htm.

New Geologic mapping for Landslide Mitigation in Eastern Kentucky

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Eastern Kentucky has a high incidence and susceptibility to landslides. Debris flows, debris avalanches, and slumps are significant hazards to property and transportation infrastructure in this steep, high-relief landscape. The Kentucky Geological Survey is working with multiple partners, including the Kentucky Transportation Cabinet, to make improved geologic maps and new derivative maps to better delineate and communicate the scope and setting of landslide hazards in the eastern part of Kentucky.

During the cooperative USGS-KGS Geologic Mapping Program from 1960 to 1978, the lithologic complexity of Pennsylvanian coal-bearing strata in eastern Kentucky prevented field mappers from producing lithostratigraphic maps of the highly variable sandstone and shale bodies in the coal field. The resulting geologic maps did not adequately differentiate bedrock lithology for slope stability analyses. In the late 1970's other workers produced landslide inventories for much of eastern Kentucky and reconnaissance surficial geologic maps for three 7.5-minute quadrangles. The concepts behind these reconnaissance maps provide the foundation for a new surficial geologic mapping effort.

In 2006, KGS resumed surficial geologic mapping and GIS analysis to develop landslide susceptibility maps for eastern Kentucky. The proposed maps display areas of varying slope stability and highlight key environmental features that may increase the chances of slope failure. Collar information describes the geologic materials, processes, and potential geotechnical behaviors to be expected within the map area. Derivative maps from the project are intended to allow geotechnical professionals, planners, and landowners to plan projects supported by accurate geologic information

Foundation Problems and Pyrite Oxidation in the Chattanooga (Ohio) Shale Estill County, Kentucky

John Kiefer, Warren H. Anderson, Kentucky Geological Survey

Significant foundation and structural problems have developed in several large buildings constructed in the Devonian Chattanooga (Ohio) Shale in Estill County which is located in east central Kentucky**.** The Estill County Middle School, Carhartt Factory and Marcum and Wallace Hospital Auxiliary buildings have all had foundation problems such as cracked and heaving floors, cracked walls, ceilings and sidewalks. The Irvine Bypass, (Kentucky Route 499), has had pavement and heaving problems in segments of the roadway near the schools.

The Middle School was built in 1996 and has had extensive foundation problems and numerous stages of remediation to correct the problems. The Carhartt Factory was built in 1994 and had severe foundation problems since it was constructed. It is currently evaluating remediation possibilities. The Hospital was built in 1959, and although the history of previous repairs are not known, the hospital has had minor repairs to correct foundation related problems at the time of this report was completed. The Bypass was constructed in 2000 and had swelling problems since the initial construction. The highway

required extensive milling and repair work. All of these problems appear to be related to their foundations being developed in the Devonian Chattanooga (Ohio) Shale with the exception of State Route 499, whose foundation is in the Crab Orchard Shale, a unit that underlies the Chattanooga Shale.

The Chattanooga Shale is black, organic, containing primarily illite, but also some montmorillonite clay, and is exposed on the ground surface over a wide area in east-central Kentucky. Some sections of the shale contain various clay and iron sulfide minerals (pyrite) that react with water to form sulfates and a mild sulfuric acid. This formation of sulfates creates "pyrite swelling" which causes significant heaving of foundations. Pyrite swelling is actually a chemical reaction between the iron sulfide of pyrite, and water to create various secondary sulfates such as jarosite, melanterite, and copiapite, all of which are iron sulfates. The reaction of the pyrite and water also creates a mild sulfuric acid that accelerates further sulfate growth and expansion of foundations. This mild acid also acts upon the shale to cause it to weather very rapidly and degrade into unstable clay and sulfate minerals.

This study inspected various buildings and their foundations, State Highway 499, and examined the Chattanooga (Ohio) Shale in cores and outcrops. Analysis of the chemistry and mineralogy was performed to determine the source(s) of the foundation problems associated with the shale. This study suggests limiting water infiltration of the shale to prevent oxidation of the pyrite. If this is not possible special construction techniques are needed to prevent foundation failures. Prevention is less expensive than remediation of existing problems within the Chattanooga (Ohio) Shale.

Session 6: Innovations in Real-Time Monitoring Chair: Silas Nichols (FHWA)

Design of Instrumentation Systems for Monitoring Geo-Hazards in Transportation

Barry R. Christopher, Ph.D., P.E., Christopher Consultants, Roswell, GA

The design and installation of efficient, cost effective instrumentation programs for the monitoring of landslides or other geohazards has long been a difficult problem for engineers. The challenge comes in the magnitude and lack of definition of such large scale problems. With any geohazard, the ability to accurately measure movement (magnitude, rate and location), water pressure, and the impact on transportation facilities is critical to mitigation of these problems. The design of instrumentation systems for monitoring of geohazards and for the evaluation geotechnical feature construction is not simply the selection and installation of instruments for measurement. The engineering process for planning and execution of an instrumentation program is comprehensive and detailed, and requires the engineer to have a complete understanding of the geotechnical questions that must be answered, and the parameters that must be measured in support of those questions. This presentation will address the importance of a comprehensive engineering process for the planning and execution of instrumentation program for monitoring and evaluating geotechnical parameters, and the benefits and limitations of real-time data collection and reduction in assessing the condition and safety of geohazards. A recent case history from the Woodrow Wilson Bridge project will be presented to illustrate the engineering process and benefits of instrumentation programs.

Advancements and Innovations in Instrumentation Systems for Real-Time Monitoring of Geo-Hazards in Transportation

W. Allen Marr, Ph.D., P.E., Geocomp Corporation, Boxborough, MA; Thomas A Tye, P.E., Geocomp Corporation, Atlanta, GA

The benefits of real-time monitoring of instrumentation systems are realized in the ability to collect data for large, complex and/or inaccessible geohazards in a cost effective manner. Monitoring of landslides, or subsidence due to Karst terrains or mining activity has traditionally posed challenging problems for engineers attempting to define the problem (purpose of instrumentation and questions to be answered),

select instrumentation, and collect and process data. In recent years, exciting new advancements and innovations have been made in the types and capabilities of instruments used for measuring a wide range of geotechnical parameters. In addition, rapid advancements in technology are allowing instrumentation systems to provide real-time, web accessible data acquisition, processing, and wireless communication from remote locations. This presentation will discuss some of the innovations and advancements in instrumentation systems that are currently available for monitoring typical geohazards in the Appalachian Region. Preliminary information on a case history from the I-20 bridge in Vicksburg, MS will be presented to illustrate the benefits of real-time monitoring on an active landslide affecting a transportation facility.

Value of Instrumentation Systems and Real-Time Monitoring: An Owner's Perspective
Silas C. Nichols, P.E., Federal Highway Administration, Atlanta, GA

The Federal Highway Administration's (FHWA) National Geotechnical Team has identified several areas where the use sophisticated instrumentation systems and real-time monitoring will be required for use. For years the FHWA has encouraged the use of properly designed instrumentation systems during construction to monitor performance of geotechnical construction and verify predicted behavior. As the transportation industry continues to look for ways to extend the life of its existing infrastructure, economically repair or replace assets, and lesson the environmental impacts of facilities on the public, geotechnical instrumentation is relied upon for providing feedback in such areas as health monitoring, quality control and quality assurance, innovative contracting, and geohazard monitoring. This presentation will summarize case histories from several transportation projects where instrumentation systems were installed to either monitor the performance of geotechnical features during and after construction, or to monitor the condition of a geohazard and the effect on an adjacent transportation facility. The case histories will be used to illustrate the value of instrumentation systems to provide critical feedback to engineers as well as the benefits of real-time monitoring.

DAY 2

SESSION 7: Rock Slope Problems and Stabilization **Chair: Jane McColloch (WVGS)**

Slope Stabilization at the Canon Del Pato Hydroelectric Project, Peru. Part 1: Background and Site Studies.
Schafer, Malcolm F., Devine Tarbell & Associates, Inc., 400 South Tryon Street, Suite 2401, Charlotte, NC 28285

The Canon del Pato Hydroelectric Project is located in the Cordillera Blanca region of Peru, approximately 250 km north of Lima. A complementary intake structure was built from September 1998 to March 2000 as part of a 100 MW expansion project. More than 50 m (depth) of the rock slope along the Rio Santa was excavated for the construction of the concrete structure. Rock support measures were taken to stabilize the excavation and geotechnical instrumentation was installed to monitor the slope. Movement was noted (~1 mm/month) during the construction phase in an inclinometer and extensometer and load increases in rock anchors were noted during lift-off tests. Movement did not decrease after all the design rock support was installed (rock anchors, rock bolts, pressure relief holes, and shotcrete with wire mesh). A second phase of work was initiated in April 2000 including the installation of cable anchors and additional instrumentation. This additional work did not slow the movement of the slope. The author was hired in May 2000 to review all the work completed to date and to make additional recommendations for stabilization of the slope. The client decided to implement a geotechnical-geologic investigation program to develop a geologic model of the slope to understand the nature of the slope movement so that appropriate measures to mitigate the movement. The additional work included: 1) the

review of all previous geologic/geotechnical work, 2) aerial photo interpretation, 3) additional borehole exploration and instrumentation installation, 4) geophysical exploration (seismic refraction lines), and 5) geologic mapping and structural analysis. These studies identified five modes or mechanisms of slope movement in the vicinity of the intake structure: 1) movement of colluvium above rock, 2) rock falls related to movement along foliation planes joints in hornfels, 3) translational sliding of rock blocks on foliation joints in hornfels, 4) sliding of rock blocks along relict bedding planes in the hornfels, and 5) sliding along zones of shearing and brecciation (sheared mica schist/hornfels/pegmatites) related to batholith intrusion. The movement affecting the stability of the intake structure and excavation was determined to be Mode 5 sliding. The failure plane was modeled using geologic and geophysical data and this model was used in analyzing the stability of the slope and designing a rock stabilization program.

Slope Stabilization at the Canon Del Pato Hydroelectric Project, Peru. Part 2: Design and Construction

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The Mode 5 sliding along the zone of shearing and brecciation affects the intake excavation, daylighting in the east and south walls. To the north, the failure plane daylights in the slope above the dam and the old intake structure. To the south of the new intake structure, a high angle feature, a series of northeast-striking joints, truncates the failure zone. The geologic/geotechnical studies indicated that this boundary of the deep-seated movement potentially limited the size of the sliding area affecting the intake structure. The rock stabilization design for the Canon del Pato complementary intake excavation was therefore intended to stop the movement affecting the concrete of the intake structure, but was not designed to stop the movement of the entire sliding area above the structure. Additional rock anchors installed south of the intake structure were designed to stabilize that area with the potential that the stabilized rock mass developed by the new anchors will act like a wedge, deflecting movement away from the intake structure concrete. The main assumptions in calculating the stability of the slope and the number of anchors required for stabilization were: 1) the slope can be modeled using a 2-dimensional analysis where it is assumed that the strike of the face slope, upper slope, failure plane, and a tension crack are parallel or nearly parallel, 2) the failure plane daylights into the slope face, 3) the analysis is performed on a unit width of slope, 4) all forces in the analysis (wedge weight, external and internal forces) are assumed to act through the centroid of the wedge, moments are not considered, 5) the assumed failure mode is therefore translational slip, rotational movements and toppling are not taken into account, and 6) release surfaces are present, parallel to the cross-section of the analysis and provide negligible resistance to sliding at the lateral boundaries of the failure. The calculation showed that 134 rock anchors of 225 Tonnes GUTS were required for stabilization for a total working load of 18,090 Tonnes at 60% GUTS. The 134 anchors were laid out in plan and section in the area to be stabilized and anchor lengths estimated to develop cost estimates. The specifications were written such that the contractor would be responsible for the final anchor design and could propose any type or size of anchoring system as long as the total installed ultimate capacity (100% GUTS) was equal to or greater than 30.0150 Tonnes. The contractor installed 134 rock anchors with ultimate capacity of 32,026 Tonnes. Additional inclinometers and extensometers were installed during construction as well as hydraulic load cells on selected rock anchors.

Emergency Project Maui DOT

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Initial Response**:** Following an earthquake off of the Big Island in Hawaii in October 2006 Janod was called in to evaluate the extent of the damage along Route 30 (the Pali Highway). Janod's Hawaiian manager Pierre Rousseau contacted the DOT following the earthquake to offer our services to deal with the emergency situation. The consulting firm hired by the DOT had already come up with a report and cost estimate which was sent to allow us to prepare for the site visit. Relying on the professional recommendations of the consulting engineer we concentrated on the areas in the consultants report. We were allowed 2 days, following the arrival of Daniel Journeaux in Hawaii to put our recommendations together.

Site Visit and Report**:** Pierre Rousseau and Daniel Journeaux walked the site and put together an initial evaluation which included using ring net drapes suspended by cranes or excavators to allow the scaling operation to proceed without putting the putting the general public in danger, ring net drapes on the slopes to contain the material close to the base of the slope and within the Jersey Barriers, synthetic fibre reinforced shotcrete for shoring up transmission line posts that had lost support and dental shotcrete for some unstable slopes. Once the alternate report and proposal was submitted a site meeting was set up with the representatives from the different groups involved in the project. The state was represented by Ferdinand Cajigal, the FHWA was represented by Pat Phung, Earth Tech was represented by Pan Yucheng (the states chosen consultant for this project), and Janod were represented by Pierre Rousseau (Hawaii General Manager) and Daniel Journeaux (President of Janod)

Janod had included in their evaluation a ring net installation to scale out the slope. The reasoning behind using the ring nets was that due to the heavy traffic on that roadway (up to 60,000 vehicles a day) and due to the lack of room to perform the work safely. This had been proposed on only one location and the remaining locations the work was to be performed using ring nets suspended by two excavators. Pan from Earth Tech insisted that this type of procedure be used on all of the sites that were to require remediation which was approved on site by State and the FHWA

Schedules and Final Procedures**:** Because the State wanted to limit the impact on the general public as much as possible the work was broken down into 2 shifts, dayshift and nightshift. Dayshift started at 7:00 and the men worked till 16:00. Due to the shear volume of traffic during the day it was not possible to have any traffic stoppages or slow downs and with that in mind the dayshift performed all of the tasks that could be performed without impacting traffic. These tasks included drilling and installing the anchors on top for the net drape, preparing all of the ring nets for installation, preparing the top cable so the ring nets could be attached at night. Nightshift started at 21:00 and the men worked until 5:00. Since we could intermittently stop traffic and reduce traffic to one lane all of the ring net installation and the scaling were performed at night. The procedure of scaling through the ring nets proved to be a complete success allowing Janod to scale out and remove on the average 1,000 tons of rock a night.

Short and Long Term Benefits of the Ring Net Scaling Operation**:** The short term benefits of the procedure were that the work could be performed safely and in a controlled manner. Another short term benefit was that the ring nets were installed as the first procedure on all of the rock slopes. Once the ring nets were installed the slope was contained so that even if a block were to fall out during the day it would be contained within the ring net drape and not pose a threat to the traveling public. It would have been impossible to scale out some of the slopes in one night shift and we were under strict orders to work only within the allotted times, so we could leave a jobsite unfinished and have the confidence that if a block slipped out during the day it would stay contained within the netting system. The amount of material scaled out from the slope is an indication on how much damage the earthquake caused to the slopes and how dangerous the slopes were.

The long term benefits of the ring net scaling system is the fact that it was cheaper to leave the ring nets in place after the emergency work was completed than to remove them, therefore there was the added benefit to the State DOT that they ended up with a long term solution to a short term problem.

Once the scaling was completed mesh was installed to the ring nets to stop any of the smaller material from getting out into the roadway.

Final Product**:** As with any emergency project of this magnitude there were many changes as the work proceeded, although the basic system of ring net scaling remained. The work proceeded without any major interruptions in the flow of traffic, there were no injuries to anyone working on site or to the general public. The slopes were scaled of all the loose material. The state ended up with a long term solution. The project was finished well below the last estimate submitted by Janod even though there was extra work added to the original scope.

Slope Stabilization with High Tensile Wire Mesh

Frank Ahmend, Geobrugg

One popular approach to achieving slope stabilization is covering the slope with flexible steel mesh facing. In North America these systems are typically anchored only at the top, allowing the mesh material to drape freely down the slope. The weight and friction of the mesh material provides stability, and allows controlled downward movement of material. More advanced installations provide deeper stabilization by holding the mesh to the surface with anchors or soil nails throughout. These designs are largely dependent on the ability of the system to transfer forces from the facing material to the anchor points. The low tensile strength of conventional wire mesh has led to the use of steel wire rope nets, but these nets tend to be relatively expensive.

These limitations have been overcome by the development of a cost-effective diagonal wire mesh manufactured from high tensile strength, highly corrosion-resistant wire. In extensive testing this mesh has demonstrated a strength approaching that of wire rope nets. Additional development has produced an anchor plate that optimizes force transfer from mesh to anchors. These factors allow the mesh to be pre-tensioned against the slope, which restricts deformations in critical surface sections and prevents movement along planes of weakness. Newly developed dimensioning models yield an engineered design of these systems, including anchor design. Numerous such systems have been installed throughout Europe and the U.S. A review of material properties and system performance will be presented in addition to a temporary shoring application.

SESSION 8: Karst and Mine subsidence Hazards in Transportation
Chair: Steve Brewster (USACE)

On the Time-Frame of Cover Collapse Sinkhole Development

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Cover collapse sinkholes develop as unconsolidated cover sediment is eroded downward into karstic drainage features in the underlying soluble rock, usually limestone or dolostone. The final collapse is often rapid, but the upward migration of the void may occur at widely different rates. Beneath a thin (<10 feet) sand cover, collapse may develop within hours following heavy rainfall, such as more than 100 sinkholes that collapsed in Chiefland, Florida, in 1992, damaging stormwater basins, drainageways, parking lots, roads and other infrastructure. Under rapid groundwater lowering, sinkhole collapse may occur overnight through much greater thicknesses of sandy sediment. During agricultural freeze protection pumping in Florida, sinkholes have damaged roads, homes and other infrastructure.

Durable strata may impede the upward collapse process, allowing erosion to widen the void until a large collapse occurs, such as in the gold mining area of South Africa where roads were closed to avoid collapse and then were redesigned with special reinforcement. Or, the bridging clay stratum may gradually sag, producing a cover subsidence sinkhole, such as was originally documented on the runway apron at McDill Air Force Base. The roof of an upward stoping void may “fail” as an intact plug and drop

only a few feet, until further erosion occurs. In thick plastic clay it appears that a stable soil arch may propagate upward over many years, until the apex finally breaches the surface. Such a sinkhole recently disrupted the main Oak Ridge—Knoxville highway in Tennessee. In such instances geophysical data may be able to delineate or even monitor the voids as they develop.

The Nelsonville Bypass: A Hitchhiker's Journey through the Galaxy of Mine Hazards

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US 33 is an important route between Columbus, Ohio and Charleston, West Virginia. It is also an integral part of local and regional transportation networks. The last remaining section of US 33 in Southeast Ohio to be upgraded to a modern limited access highway is the portion through Nelsonville. The project begins in Hocking County just east of the community of Haydenville and extends to the southeast for approximately 9 miles, ending in Athens County, just south of Nelsonville.

Extensive underground and surface mining, dating to the late 1800's and the early 1900's, has occurred along the project alignment. The minerals mined were coal and clay. The presence of abandoned mines presents many challenges for design and construction. Issues of concern include possible mine subsidence under the roadway, settlement of structure foundations due to subsidence, discharges of acid mine drainage (AMD), and stability of cut and embankment slopes. The methodology and results of the geotechnical exploration will be presented along with plans for mine mitigation during construction.

Ohio's Underground Mine Hazards—Getting Out of the Pits

Christopher P. Gordon, ODNR, Division of Geological Survey; Tim Jackson, ODNR, Division of Mineral Resources Management

Mining of the Appalachian Region's abundant coal deposits began more than 200 years ago. Initially, coal extraction involved crude underground methods that developed into room-and-pillar mining. With the advent of more advanced mechanization technologies, longwall mining replaced room-and-pillar mining as the primary method of underground mining. Both methods of extraction can lead to surface damage that affects Ohio's transportation infrastructure. The Ohio Division of Mineral Resources Management (MRM), through federal Abandoned Mine Land funding, works to mitigate public emergencies caused by mine hazards such as pit subsidence and landslides, which can adversely affect road and railway systems.

In 2006, MRM mitigated 56 abandoned-mine-related incidents. Five of these incidents directly affected people using Ohio's transportation infrastructure. When a transportation emergency occurs that could be mine-related, or there is risk of a mine hazard, underground mine maps need to be available as references. The Ohio Division of Geological Survey provides approximately 4,000 mine locations to transportation authorities and the public through an abandoned underground mine locator website. This website is integral in facilitating a swift response to mine-related emergencies, and provides a tool to help mitigate existing and potential geohazards.

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GOALS

The Appalachian states are tied by common geographical and geological challenges. Multi-Model transportation in the Appalachian region is essential for economic development. The coalition includes members from West Virginia, Virginia, Kentucky, Pennsylvania, Tennessee, North Carolina, Ohio Departments of Transport, and Geological Surveys, FHWA, USGS, CSX, Norfolk Southern and USACE. This grass root organization of federal, state and private entities confront similar geological hazard prevention and remediation issues in the Appalachian region.

OVERALL GOALS:

- Address geologic hazards in the Appalachian states related to transportation, highway, river, rail and air.
- Promote the sharing of technical resources and information.
- Provide and electronic medium for the exchange of ideas, experiences, and methodologies.
- Facilitate the development of geologic hazard inventories and to assemble remediation costs.
- Identify new and innovative technologies/research applicable to transportation projects involving remediation of geologic hazards.
- Identify resources to address geohazards.

SHORT-TERM GOALS

- Initiate appropriate communication channels that will benefit the Appalachian Coalition members and other interested parties.
- Develop a regional database/Geohazard Management System that will store geohazard inventories, remediation methods and costs.
- Develop a methodology and testing protocol for site characterization over karst and abandoned mine working for transportation infrastructure planning.
- Identify and characterize geohazards through the resources required (information, equipment, collaboration, funding) to assess and address geohazards.