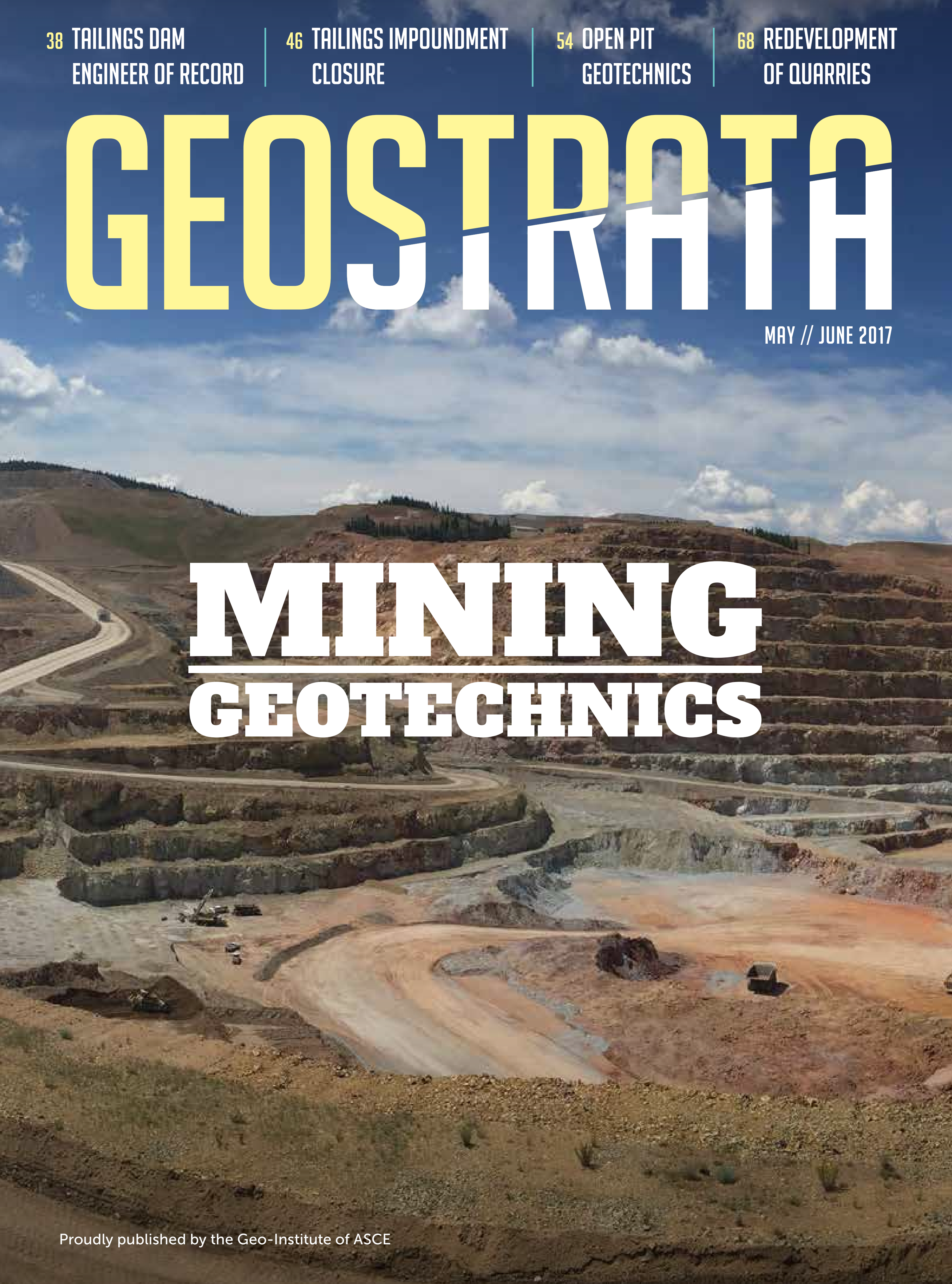
GEOSTRATA

MAY // JUNE 2017



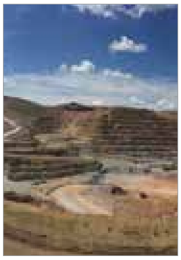
MINING GEOTECHNICS

Proudly published by the Geo-Institute of ASCE


GROUND
IMPROVEMENT
STARTS HERE.
menard
US WICK DRAIN
150 East Main Street, Suite 500
Carnegie, PA 15106
412.620.6000
www.menardgroupusa.com

GEOSTRATA May // June 2017

Features



ON THE COVER
View from the Grassy Valley Overlook of WHEX Pit at Newmont's Cripple Creek & Victor Gold Mine in Victor, CO (October 2016). (Photo courtesy of Kimberly Finke Morrison.)

CONNECT WITH US

www.asce.org/geo twitter.com/GeoInstitute facebook.com/GeoInstitute LinkedInGeo GeoInstituteASCE

GEOPIER IS GROUND IMPROVEMENT®

Geotechnical Engineer: McPhail Associates, Inc.
Structural Engineer: McNamara/Salvia, Inc.
General Contractor: John Moriarty & Associates, LLC.

SAVE TIME AND MONEY WITH GEOPIER RIGID INCLUSIONS

CUSTOMIZED SOIL SOLUTIONS

Our geotechnical engineers want to provide the right solution for you. Save time and money with Geopier solutions - Submit project details at geopier.com/feasibilityrequest.

For more information call 800-371-7470, e-mail info@geopier.com or visit geopier.com.

Geopier's goal is to bring you advanced, innovative ground improvement technology in a way that is easy to use every day. Geopier rigid inclusion systems enable you to:

- Support heavy loads in poor soil
- Improve variable fill soils in place
- Replace deep foundations
- Control settlement

GEOPIER®
Tensar

GEOSTRATA

May // June 2017

Departments

GEOSTRATA is published by the Geo-Institute and the American Society of Civil Engineers.

GEOSTRATA is a forum for the free expression and interchange of ideas. The opinions and positions stated within are those of the authors, and not necessarily those of *GEOSTRATA*, the Geo-Institute, or the American Society of Civil Engineers (ASCE). *GEOSTRATA*—ISSN 1529-2975—is published bi-monthly by ASCE, 1801 Alexander Bell Drive, Reston, VA 20191-4400 and is a free ASCE/Geo-Institute membership benefit, not available by subscription. ADDRESS CHANGES: ASCE/G-I members should e-mail *memrec@asce.org*, or click on "My Profile" at *asce.org*. Periodicals postage paid at Herndon, VA, and at additional mailing offices. POSTMASTER: Send address changes to *GEOSTRATA*, 1801 Alexander Bell Drive, Reston, VA 20191-4400.

ISSUE NO. 3 • VOLUME 21

Geotechnical and Structural Instrumentation

- Bridges
- Dams
- Embankments
- Excavations
- Foundations
- Geogrids
- Groundwater
- Landfills
- Mines
- Piles
- Pipelines
- Slope Stability
- Tunnels
- Waste Repositories
- Wind Turbines

- Strain Gages
- Crackmeters
- Jointmeters
- Strandmeters
- Convergence Meters
- Extensometers

- Piezometers
- Pressure Transducers
- Weir Monitors
- Settlement Sensors
- Pressure Cells
- DeAerators
- Temperature Gages
- Cables

- Load Cells
- Concrete Stress Cells
- B/H Deformation Gages
- Stressmeters
- Inclinometers
- Tiltmeters
- Pendulum Readouts

- Readouts
- Terminal Boxes
- Dataloggers
- Multiplexers
- Wireless Networks
- Software
- Custom Designs

GEOKON The World Leader in Vibrating Wire Technology®

www.geokon.com/projects

From the President

In Pursuit of Excellence in the Geoprofession

GARRY H. GREGORY

The American Heritage Dictionary defines excellence as "the state, quality, or condition of excelling." But what does this mean in terms of the geoprofession? Do we truly strive to excel and achieve excellence — or do we often strive for mediocrity? Perhaps in many situations we may not know the difference. As used here, the term "achieving excellence" does not mean holding ourselves to a standard that exceeds the legal standard of care. Indeed, we can perform within the legal standard of care while achieving either excellence or mediocrity. Mediocrity is consistently achieving barely adequate quality, while excellence means consistently achieving high quality in our professional services, but not the "highest" possible quality.

Unfortunately, it seems like far too many geotechnical engineers strive for mediocrity. You may think that as engineers, we always strive for excellence, right? As a child, I remember hearing my grandfather (a farmer) often say, "We've done this the right way for so long that we've forgotten how to do it any other way." That's an admirable and desirable place to be, but in our profession, we may often find ourselves in the opposite position of having done it with mediocrity for so long that we also have forgotten how to do it any other way!

If we take a hard look at our services, are we achieving excellence or mediocrity? Are we accepting budgets and/or schedules that we know are grossly insufficient to pay for the required services? Are we producing geotechnical engineering reports that are virtually identical for many projects, with just the names and places changed (and in some cases if we're not careful, nothing gets changed!). Are most of our recommendations based on SPT values and rules of thumb? Are we recommending 2,000 psf allowable bearing capacity for shallow foundations, no matter what the soil conditions? Are we recommending only one type of foundation in virtually all cases just because that's what is usually done in the area? Do we not recognize the looming slope failure at the site

because the drill crew was sent out without an engineer or geologist? These are all signs of mediocrity.

In today's economic climate, we are typically under enormous budget and schedule constraints, and it would at first appear that these constraints are contrary to achieving excellence in our work. It may appear that much more generous budgets and schedules would be required to "allow" us to achieve excellence, thus the trend toward mediocrity. I once heard a CEO of a large geotechnical engineering firm say that due to tight budgets and schedules, "B-level" services are what his company should strive for rather than "A" or "A+" services! In my opinion, this situation shouts mediocrity. On the other hand, we cannot routinely blow the budget and schedule trying to achieve excellence in the final product. This would also be striving for mediocrity. We must have the discipline to refuse assignments with grossly insufficient budgets or schedules. The alternative is to convince the Client that a budget sufficient to provide more complete geotechnical services can result in construction cost savings far greater than the engineering budget increases. We must also be able to consistently produce high-quality services within reasonable, albeit tight, budgets and schedules.

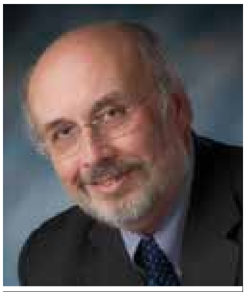
In my early years, my father was a construction superintendent on large projects. He virtually always met budgets and schedules, often finishing projects well below both, while maintaining high quality in the finished product. This trait placed him in high demand in the construction industry in those days. I believe this trait of achieving high quality in the finished product — while consistently meeting or beating budgets and schedules — is the true measure of excellence. How did my father do it? In one word: "innovation." Calling on his vast experience and often after consulting with other experts, he would come up with better, quicker, and more economical ways of getting the job done. The innovation often involved combining numerous proven methods or technologies in a unique way.

The fear of claims and lawsuits in our extremely litigious society has caused many to almost completely shy away from innovation… but I suggest that many more claims have been paid due to mediocrity than due to innovation! Innovative ideas for our projects must come from experience, consultation with recognized experts, and unique combinations of proven methods from past experience. Significant caution must be exercised to avoid innovations based on inexperience, no matter how colorful the elaborate models on which they are based, since this can be more disastrous than mediocrity! People are often reluctant to seek recognized experts for consultation on innovative approaches. We must strive to overcome this reluctance. Expert advice in a timely manner can save many hours of wasted time and budget.

If we realistically evaluate our individual practices, I believe it will become obvious whether we are striving for excellence or for mediocrity. If we push ever-closer toward striving for excellence, we can significantly elevate our profession. GS

Garry H. Gregory, PhD, PE, D.GE, M.ASCE
Geo-Institute President
ggregory@gregeo.com

From the Editorial Board



JAMES L. WITHIAM

In school, aspiring geotechnical engineers are taught principles about soil and rock mechanics and how they relate to facility design and performance. When I learned and first applied these concepts, they were usually linked to building foundations. But during my career, I've found that application of these principles has broadened beyond their traditional role, as new research and technologies have found their way into virtually all business sectors. Recent issues of *GEOSTRATA* have delved into many of these sectors by introducing geotechnical applications and advancements in areas such as railway, highway transport, military, ports and harbors, urban, and offshore environments. Now, with this issue on "Mining Geotechnics," we explore the application of geotechnical and geomorphic principles to the unique structures and features associated with the extraction and processing of minerals from the earth, and their sustainable closure.

What's Inside?

Engineer of Record (EoR) is a simple, resolute concept whereby a single person is assigned sole responsibility for engineering design. But how can the EoR concept be applied to a transient design like a tailings dam that may be constructed over decades and often exceeds the design engineer's career or lifetime? In "Tailings Dam Engineer of Record," Kim Morrison and Chris Hatton describe efforts by regulatory agencies and professional associations to better define EoR for these facilities in the shadow of two recent and disastrous tailings impoundment failures.

Closure of a dam involves eliminating the water impounding capability of the structure… but not when it comes to tailings dams. In this case, the impounded tailings will likely remain flowable even after any pooled water is eliminated. There are many definitions of "closure," as authors Aaron Antell and Robert Shusko discuss in "Tailings Impoundment Closure: It's All in the Eye of the Beholder." They also introduce the concept of transitioning these impoundments into a landform to address the types of risk that tailings impoundments pose to the public beyond the topographic definition — risks that include structural, chemical, ecologic, and social stability.

For most hard rock surface mining operations, an open pit must be developed to extract the ore resource. In designing an open pit, the challenge is to develop the most cost-effective pit slopes that can be mined safely, and geotechnics is a critical element of the design process. In "Open Pit Geotechnics," Tom Byers and John Lupo describe the process used to design slopes for pits that can be 300-m deep.

Advancements in geosynthetic materials over the last several years have improved the performance and reliability of engineered facilities at operating mines. In his article "Where Geosynthetics Meet Mining Geotechnics," John Lupo describes how geosynthetic materials play an important role in mining projects to enhance stability, control drainage, and provide environmental containment.

As urban and suburban developments encroach into rural areas, redevelopment of former quarries is becoming increasingly attractive. The identification and control of residual waste products, surface and groundwater, subsurface conditions, and the slope stability concerns in them is described in "Redevelopment of Aggregate and Rock Quarries – No Longer Just a Hole in the Ground," by Haze Rodgers.

Geomorphology is the study of landforms, and like nature's landforms, a reclaimed mine site will change in accordance with the principles of geomorphology. So for this issue's commentary, "Geomorphology for the Engineer of Record," Jack Caldwell makes the case that knowledge of the principles of geomorphology is needed for sustainable mine closure.

In the latest installment of "Lessons Learned from GeoLegends," Joel Conzelmann, Aliena Debelak, Mohammad Gorakhki, and Cameron Fritz introduce us to geoenvironmental engineering educator, researcher, and visionary David E. Daniel.

Using an important tale from the past, our curmudgeonly GeoCurmudgeon John Bachner tells us why it's important to "Do It Right, or Don't Do It at All." And in "Buried," the curiosity of our GeoPoet, Mary Nodine, is focused not on what's above ground, but rather by what's below.

Transition

Since *GEOSTRATA*'s beginning in 2000, it has been blessed with many volunteers who have contributed mightily to the magazine's success and popularity. In 2010, we began the GeoLegend series, in which graduate students interview and write articles about the lives and careers of prominent geoprofessionals. For the past year, Gizem Bozkurt has coordinated these articles with the student authors. But now that she has completed her PhD studies at Wisconsin-Madison and begun her professional career, Rehab ElZeiny from Lehigh University has assumed these responsibilities. We thank Gizem for her hard work for *GEOSTRATA*, and wish her all the best in the future.

We hope you enjoy this issue of *GEOSTRATA*. We encourage you to send us feedback at *geostrata@asce.org*.

This message was prepared by **JAMES L. WITHIAM, PhD, PE, D.GE, M.ASCE.** He can be reached at *jlwithiam@dappolonia.com*.

Board of Governors Update

Summary of February 2017 Board Meeting

The G-I Board meets periodically by conference call and in person at least twice per year, with one of the meetings at the annual GeoCongress. Key items discussed during our February 2017 meeting at Geotechnical Frontiers 2017 included:

- The results of a survey of our members
- Approval of the G-I's collaboration with FHWA on the new and self-sustaining Innovations Developments, Enhancements, and Advancements (IDEA) program, which evaluates new and modified earth-retention systems (ERS) and ERS components
- The G-I and Structural Engineering Institute's joint response to the Georgia State Board of Registration for Professional Engineers and Land Surveyors' proposed amendment to Rule 180-2-.04, which would require Structural Engineering licensure for "Designated Structures," including tunnels
- Our short-term strategy for improving the G-I website

Greetings from the Outreach and Engagement Committee

It was wonderful to see many G-I members at Geotechnical Frontiers 2017 in Orlando, FL. The G-I's Outreach and Engagement Committee (OEC) worked closely with the conference organizing committee and our partnering organizations to provide a welcoming environment to our diverse group of attendees. We developed several activities for the event, following our committee's mission of providing a collaborative environment for all G-I members and venues of interactions between members. We also performed outreach activities to promote the geo-profession to the next generation of engineers.

This year we initiated the GI-OEC Photo Contest for Geotechnical Frontiers 2017. Geoprofessionals from around the world participated. The contest winners were announced onsite, and winning photos were featured in the Conference program. The first place winner, Alberto Jose Perez Zarco, general manager of INGNOVA in Guatemala City, Guatemala, won free registration for Geotechnical Frontiers 2017 and joined us in Orlando. The second place winner, Rodrigues Dos Santos, a project manager with Intermas Group in Barcelona, Spain, and the third place winners, Mohammad Joshaghani, graduate fellow at the University of Louisville, and Frank Amend, director at GeoStabilization International in Grand Junction, CO, won gift cards. The Photo Contest for IFCEE 2018 is now open: post your geo-themed photos or pictures of geoprofessionals using #geopics18 on social media, or send them to *ascegioec@gmail.com* for a chance to win free registration to IFCEE 2018 and be featured in the Conference program.

The OEC organized the Geo-Women Networking Happy Hour (participants shown above), which provided a venue for over 50 women engineers who attended Geotechnical Frontiers 2017 to meet, interact, and network with each other. Our G-I Board members also participated in the event, showing their support of successful women professionals in our organization. Next year, as a part of IFCEE 2018, the OEC will be collaborating with the DFI to organize a workshop for women engineers in our industry.

Also at Geotechnical Frontiers 2017, the OEC and the G-I hosted a special screening of the IMAX movie *Dream Big: Engineering Our World*. The film is a one-of-a-kind engineering film designed to inspire the next generation to follow STEM careers and to increase society's awareness of the importance of engineering in sustainable development. Attendees enjoyed the movie night, which began with a reception and was followed by a Q&A session after the film.

The OEC aims to engage and collaborate with local high schools and undergraduate college programs to promote geotechnical engineering and bring more interest into our profession. While in Orlando, OEC members visited Edgewater High School, an engineering, science, and technology magnet school. We talked to approximately 100 first-year students about the geotechnical engineering profession. The OEC also provided students with tickets to the *Dream Big* special screening and the opportunity to interact with geoprofessionals during the event. We look forward to collaborating with Edgewater High School next year during IFCEE 2018 to attract the interest of the next generation of engineers while exposing them to the rich, diverse, and welcoming environment of geoprofessionals through the G-I.

Menzer Pehlivan, Chair, Outreach and Engagement Committee

G-I Board of Governors

Garry H. Gregory
PhD, PE, D.GE, M.ASCE
President
ggregory@gregeo.com

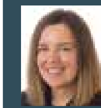
Committees: Codes & Standards, Geo-Congress Organizing

Other Activities: AGP Collaboration, Strategic Planning

Youssef M.A. Hashash,
PhD, PE, D.GE, F.ASCE
Vice-President
hashash@illinois.edu

Committees: International Activities, Nominations & Elections

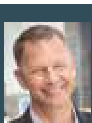
Other Activities: ASCE Publication Access, SEI Licensure for Designated Structures, Digital Media/Website



Beth A. Gross
PhD, PE, D.GE, F.ASCE
Treasurer
bgross@geosyntec.com

Committees: Awards, *GEOSTRATA*, ISSMGE Fund, Technical Coordination

Other Activities: ASTM Collaboration, Specialty Conferences



Kord Wissmann
PhD, PE, D.GE, M.ASCE
Past President
kwissmann@geopier.com

Committees: Organizational Member, Past Presidents, Regional Conferences

Other Activities: Committee Summit Meeting, GBA Collaboration

James G. Collin
PhD, PE, D.GE, F.ASCE
jim@thecollingroup.com

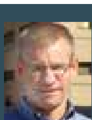
Committees: Local Involvement

Other Activities: DFI and FHWA Collaboration

Patrick J. Fox
PhD, PE, D.GE, F.ASCE
pjfox@engr.psu.edu

Committees: Continuing Education, Outreach & Engagement, Student Participation, Technical Publications

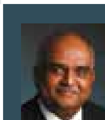
Other Activities: Member Survey, USUCGER Collaboration



Robert B. Gilbert
PhD, PE, D.GE, M.ASCE
bob_gilbert@mail.utexas.edu

Committees: Regional Conferences

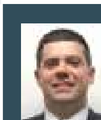
Other Activities: Geo-Institute Risk Design Standards (GI-RDS)



Kancheepuram N. Gunalan
(a.k.a. "Guna")
PhD, PE, D.GE, F.ASCE
k.n.gunalan@aecom.com

Committees: Geo-Legislative

Other Activities: Digital Media/Website



Brad Keelor
Secretary and G-I Director
bkeelor@asce.org

Manages the day-to-day activities of the G-I

Technical Activities Update

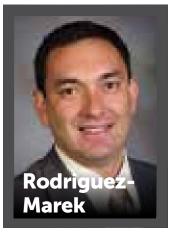
The *Grouting Committee*, chaired by **Paulo Gazzarrini, PE, M.ASCE**, continues its effort to organize the Grouting 2017 specialty conference to be held this year in Honolulu, HI, July 9-12. See the ad on page 36. Of the 180 initial submissions, 120 papers were accepted after thorough peer review following the ASCE-GI GSP (Geotechnical Special Publications) recommended procedures.

The Grouting Committee continues its regular quarterly meetings and has recently established an Awards Subcommittee (chaired by **Britt Babcock, PE, M.ASCE**) and an Educational Outreach Subcommittee (chaired by **Chadi El Mohtar, PhD, A.M.ASCE**). The Awards Subcommittee has submitted its first round of award nominations this past summer, and the Educational Outreach Subcommittee is working on presentations that will be readily available for delivery at local G-I and ASCE Chapters.

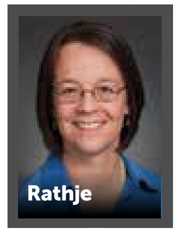
Finally, the newly updated jet-grouting guideline specification has been completed, thanks to the great effort put forth by the task force, led by **Thomas D. Richards, Jr., PE, D.GE, M.ASCE**. The new version is available on the Grouting Committee webpage, *committees.geoinstitute.org/people/grouting.*

Technical Committees

COMMITTEE	COMMITTEE CHAIR	EMAIL ADDRESS
Computational Geotechnics	José E. Andrade, PhD, M.ASCE	*jandrade@caltech.edu*
Deep Foundations	Luis O. Garcia, A.M.ASCE	*logarcia@geocim.com*
Earth Retaining Structures	Anne Lemnitzer, PE, M.ASCE	*alemnitz@uci.edu*
Earthquake Engineering and Soil Dynamics	Adrian Rodriguez-Marek, PhD, M.ASCE	*adrianrm@vt.edu*
Embankments, Dams, and Slopes	J. Erik Loehr, PhD, PE, M.ASCE	*eloehr@missouri.edu*
Engineering Geology and Site Characterization	Xiong “Bill” Yu, PhD, PE, M.ASCE	*xxy21@case.edu*
Geoenvironmental Engineering	Dimitrios Zekkos, PhD, PE, M.ASCE	*zekkos@umich.edu*
Geophysical Engineering	Brent L. Rosenblad, A.M.ASCE	*rosenbladb@missouri.edu*
Geosynthetics	Jorge G. Zornberg, PhD, PE, M.ASCE	*zornberg@mail.utexas.edu*
Geotechnics of Soil Erosion	Ming Xiao, PhD, PE, M.ASCE	*mxiao@engr.psu.edu*
Grouting	Paolo Gazzarrini, P.Eng, M.ASCE	*paolo@paologaz.com*
Pavements	Charles W. Schwartz, PhD, M.ASCE	*schwartz@umd.edu*
Risk Assessment and Management	D. Vaughan Griffiths, PhD, PE, D.GE, F.ASCE	*d.v.griffiths@mines.edu*
Rock Mechanics	M. Ronald Yeung, PhD, PE, M.ASCE	*mryeung@cpp.edu*
Shallow Foundations	Derrick D. Dasenbrock, PE, F.ASCE	*derrick.dasenbrock@state.mn.us*
Soil Improvement	Kord J. Wissmann, PhD, PE, D.GE, M.ASCE	*kwissmann@geopier.com*
Soil Properties and Modeling	T. Matthew Evans, PhD, A.M.ASCE	*matt.evans@oregonstate.edu*
Sustainability in Geotechnical Engineering	Jeffrey R. Keaton, PhD, PE, D.GE, PG, ENV SP, F.ASCE	*jeff.keaton@amecfw.com*
Underground Engineering and Construction	Elizabeth Dwyre, PE, D.GE, M.ASCE	*dwyre@pbworld.com*
Unsaturated Soils	Laureano R. Hoyos, PhD, PE, M.ASCE	*hoyos@uta.edu*



The *Earthquake Engineering & Soil Dynamics (EESD) Committee*, chaired by **Adrian Rodriguez-Marek, PhD, A.M.ASCE**, continues its popular Speakers Program. The EESD has national experts in earthquake engineering presenting state-of-the-art knowledge to local and regional practitioners on earthquake engineering and seismic hazards, including areas where awareness of seismic hazards is not in the forefront. **Ellen Rathje, PhD, F.ASCE**, professor at UT Austin, was supported by the EESD Speakers Program to present at the Earthquake Engineering Research Institute (EERI), Geotechnical Extreme Events Reconnaissance (GEER) Mini Symposium on February 2, 2017, in New York City (NYC). The focus was recent earthquakes in New Zealand and their relevance to NYC and U.S. critical infrastructure. Dr. Rathje was among several international and NYC code seismic experts who discussed key aspects of the NZ practice modifications and implementations as they relate to protection and resiliency of the critical infrastructure of the NYC metropolis and the nation at large.



"We are bringing together our expertise in engineering and information technology to develop the best tools to help engineers better understand the impact of natural hazards on our cities and infrastructure. There is tremendous potential to save lives and property through better engineering, design, and planning," she said.

Howard Schirmer (r) with Dr. Robert Harley, chairman of the UC-Berkeley Civil and Environmental Engineering Department.

Schirmer Honored by UC Berkeley

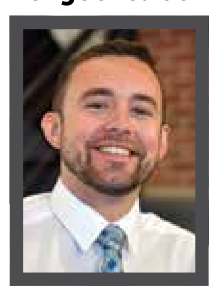
Howard Schirmer, Jr., PE, ENV SP, F.ASCE, was recently elected to the Academy of Distinguished Engineering Alumni at the University of California at Berkeley. He was honored at a banquet at the University Club atop Memorial Stadium in Berkeley.

Schirmer was recognized for "his global efforts to build sustainable infrastructure, promote U.S. environmental technology exports, build global engineering practices, and strengthen the civil and environmental engineering professions through extensive professional society activities." He joins 47 other living civil and environmental engineers in the Academy at the time of his election.

Schirmer, an ASCE Life Member, has served ASCE in a variety of roles, including international director and president of the Hawaii Section. He has also served on various committees and has been active locally in the Los Angeles and Colorado sections. He is a member of the Geo-Institute and has served on the G-I's International Activities Council.

Professionally, Schirmer is the founder and past president of CH2M HILL International Ltd., a former COO at Dames & Moore, and now serves as president of his own firm, Transnational Associates Inc.

Bengochea Joins GeoStructures



Pedro O. Bengochea, EIT, recently joined GeoStructures as a design engineer. He is responsible for supporting GeoStructures' customers by preparing engineering designs for the construction of ground improvement technology. Bengochea received his B.S. in civil and environmental engineering in 2012 from the University of Puerto Rico, and an M.S. in geotechnical engineering in 2016 from Virginia Tech. Before attending graduate school, he worked for three years as an estimator and design engineer with Southern Company in Atlanta, GA. While

attending Virginia Tech, he acquired experience in lab testing, such as performing CD triaxial tests on quartz sands, compaction tests, and hydraulic conductivity tests on clays. In the summer of 2016, Bengochea was awarded an NSF grant to conduct research in South Korea to study how high temperatures affect the consolidation of kaolin clay.

In Memoriam: James H. Kleinfelder

James H. Kleinfelder, founder of the engineering, construction management, design, and environmental professional services firm that bears his name (Kleinfelder), passed away March 5, 2017.

"Jim was truly a pioneer," said Kleinfelder President and CEO George J. Pierson. "He established this company from scratch, which speaks highly of his skills as an engineer as well as his character, leadership, and business acumen."

Kleinfelder received a B.S. in 1956 and an M.S. in 1964, both from UC Berkeley in the field of civil engineering. In 1961, while working as a resident engineer for the City of Stockton, he recognized a need for a local materials testing firm. With little more than $1,500 to his name, he founded a small testing firm that came to be known as Stockton Testing and Controls, Inc. By 1966, the company had grown significantly and was renamed to J.H. Kleinfelder and Associates (Kleinfelder).

Throughout the late 1960s, 70s, and 80s, Kleinfelder pursued acquisitions and global ventures throughout North America and the Middle East while expanding the company's capabilities into a diverse set of engineering services. By the end of the 1980s, the firm had grown to more than 600 employees and $37 million in annual revenue. Kleinfelder retired as president and CEO in 1993.

Throughout his career, he remained very active in the industry. He was a member of the American Council of Engineering Companies (ACEC), a lifetime member of the American Society of Civil Engineers (ASCE), and served terms as president of both the Hazardous Waste National Coalition and the Associated Soil and Foundation Engineers (now known as the Geoprofessional Business Association).

In 2010, Kleinfelder developed the James H. Kleinfelder Fellowship in Geotechnical Engineering—a monetary award that is given annually to a graduate student in the civil engineering master's program at UC Berkeley. Faculty at the University select one student to receive the award each year based on a number of academic and financial factors.

// As I See It

Geomorphology for the Engineer of Record

Sustainable Mine Closure

By Jack A. Caldwell, PE

Geomorphology is the study of landforms. Or as Wikipedia says:

> *Geomorphologists seek to understand why landscapes look the way they do, to understand landform history and dynamics, and to predict changes through a combination of field observations, physical experiments, and numerical modeling.*

The geoprofessional designing and closing a mine *must* be a sensitive geomorphologist. This is important because all mines change the landscape: the deep open pit, the extensive tailings facility, and the steep waste rock piles are new landforms unlike anything Mother Nature sculpts in a mature topography.

We may conclude that a proposed mine is sustainable and will have an acceptable impact on the environment. But we can never conclude that the mining landscape will be the same after mining as it was before mining. There will inevitably be: a new pit-lake; new surface water channels; mountains of tailings, waste rock, and spent heap leach pads; and sources of geochemical impact beyond our ability to fully comprehend.

After mine closure, this new mining-sculptured landscape will proceed to change in accordance with the principles

The tailings embankment after closure of the Cannon Mine in Wenatchee, WA, is visible in the background. (Photo courtesy of Frank Cone.)

of geomorphology, essentially as long as geology itself. The challenge for the geoprofessional is to close the mine by landscaping the site so that the long-term geomorphological changes and impacts are acceptable to future generations. We are tasked with creating a new landscape that does not burden society, but benefits society — ultimately until the end of conceivable time.

I have just returned from a visit to Cádiz, an ancient port in southwest Spain built on a strip of land that's surrounded by the sea. In the basement of a theater is a museum that is simply a glass-covered archaeological dig. The lowest layer bears the house foundations and kilns of 600 BC — all that remains of a fire that swept through the suburb. The upper layer, built on the remains of the old, is a 1 AD Roman fish factory — they pickled tuna in large clay pits and packed the mixture into amphora jugs to be shipped to Rome.

But to me, the most fascinating exhibit was the panorama of Cádiz some 3,000 years ago: a series of islands separated from the mainland by a swamp.

> Most closed mines will not have pirates, privateers, adventurers, and merchants fighting over them or looking after them. Instead, the pit walls will fail and ravel back to flat angles; the pit-lake will expand, dry up, or overflow as the climate changes; the waste piles will flatten to soft contours or be carried away as floods and fires dictate.

The swamp is still there, now criss-crossed with bike paths, which I rode. But the waterways are filled in and built over; the whole area is surrounded by large seawalls and fortifications built piecemeal over centuries to defend against every invader from Africa, France, and England — in 1587 Sir Frances Drake burnt the city to the ground.

Most closed mines are not as favorably located as Cádiz. Most closed mines will not have pirates, privateers, adventurers, and merchants fighting over them or looking after them. Instead, the pit walls will fail and ravel back to flat angles; the pit-lake will expand, dry up, or overflow as the climate changes; the waste piles will flatten to soft contours or be carried away as floods and fires dictate. The forest will return, or maybe tourists will come to see memories of hardship and wealth creation.

Some closed mines are favorably located and maybe will endure, becoming a community asset someday in the future — like Cádiz. The mine that best fits this mould is the Cannon Mine in Wenatchee, WA. The mine is now a riding stable; the tailings embankment is a route to high ground and beautiful views, and the surrounding countryside is a state nature reserve. As long as there is a livable Wenatchee, a viable Washington State, and a respected Constitution, I suspect there will be a riding stable at this former mine site. As any trip to Europe rapidly impresses, societies change, fail, and revive, but not always with their former glory. Cádiz is no exception, an outpost of Phoenician trade, a Roman colony and distribution point for seafood, a center of Moorish learning, the starting point of Spain's American trade routes, a city feared by the Elizabethans, and even for a short time the capital of Spain when Napoleon ruled in Madrid. Maybe the Cannon Mine will survive regime changes, inept politicians, and climate fluctuations.

And if geoprofessionals cannot close the mine so it can be another Cádiz or Cannon Mine, then at least they should study and apply the principles of geomorphology. For only the principles of geomorphology enable us to predict how rain, floods, erosion, deposition, landslides, vegetation, and fires will shape the site and impact the environment in the future. And hence the Engineer of Record for closing the mine may decide how much to spend to construct the engineering works required to leave a site that is sustainable in the broadest sense.

Anything less is simply not good professional practice. It may not yet be standard practice, but now that an Engineer of Record has to sign off on the closure works, maybe big changes lie ahead.

Which leaves us with the ultimate question: can the Engineer of Record be the geomorphologist that he/she needs to be?

JACK A. CALDWELL, PE, is a civil engineer located in Vancouver, BC, Canada. With over 45 years of engineering experience on mining, civil, geotechnical, and site remediation projects, he has worked throughout southern Africa, Europe, Canada, and the U.S., and can be reached at *jcaldwell@infomine.com*.

David E. Daniel, PhD, PE, NAE, Dist.M.ASCE

By Joel Conzelmann, EIT, S.M.ASCE, Aliena Debelak, EIT, S.M.ASCE, Mohammad Gorakhki, S.M.ASCE, and Cameron Fritz, EIT, S.M.ASCE


Dr. David E. Daniel

Professor David E. Daniel has played a legendary role in the development of geoenvironmental engineering through his leadership and research on waste disposal containment systems and cleanup of contaminated sites. He was editor-in-chief for the ASCE *Journal of Geotechnical Engineering* from 1992 to 1995 (changed to *Journal of Geotechnical and Geoenvironmental Engineering* during his tenure) and a member of the Board of Editors for the *Geotextile and Geomembranes Journal* from 1997 to 2005.

Daniel earned his bachelor's and master's degrees from the University of Texas at Austin (UT Austin). He then spent three years working for Woodward-Clyde Consultants (WCC) as a staff engineer in San Francisco, CA. He returned to UT Austin to earn a doctoral degree under Professor Roy Olson, and then served as faculty there from 1980 to 1996. Daniel left to serve as civil and environmental engineering department head at the University of Illinois at Urbana-Champaign (UIUC) from 1996 to 2001, and as dean of engineering from 2001 to 2005. In 2005, he returned to Texas as president of the University of Texas at Dallas from 2005 to 2015. He was appointed deputy chancellor of the University of Texas system in 2015 and is currently serving in that position.

Daniel has received numerous awards throughout his career. In 1975, ASCE presented him with the Norman Medal, the highest honor for a research paper published in an ASCE journal, for his paper "Finite Difference Analyses of Sand Drain Problems." ASCE also honored him with the Croes Medal (1984, 2000), the President's Award (2007), and the Hero's Award (2008). In 2000, he was elected to the

National Academy of Engineering, widely viewed as the most prestigious honor an engineer can receive.

The authors caught up with Dr. Daniel at Geo-Chicago 2016 prior to a mini-symposium honoring his contributions to geoenvironmental engineering.

Q: What inspired you to study civil engineering and continue on to geotechnical engineering?

As an undergraduate, I changed majors multiple times and discovered civil engineering somewhat accidentally. Originally an aerospace engineering major, I was required to take a materials engineering course, which was taught by a civil engineering professor. It seemed interesting, so I thought I'd give civil engineering a try. I was not particularly motivated or inspired until I took an introductory geotechnical engineering course from Lymon Reese. I'm a golfer, and one goal in the game is to keep your golf ball out of the water. I remember one day Reese brought in a glass beaker and some golf balls. He put the golf balls in the water and then began explaining about effective stress using golf balls as soil particles. I thought that was pretty cool. Then I took a second geotechnical engineering course on foundation engineering from Roy Olson. I was fascinated and was hooked on geotechnical engineering for a lifetime!

Q: What is your definition of geoenvironmental engineering?

I've never tried to define that. I was the editor-in-chief of the *Journal* when we added the word "Geoenvironmental" to the title. It was a big deal to change the name. We spent a lot of time arguing about what's geoenvironmental engineering? How is geotechnics applied to the geoenvironment? After much discussion, we gave up on that. To me, it's like trying to define a duck. If it looks like a duck, walks like a duck, quacks like a duck, it's a duck — but that's not a definition. Well, if it involves any environmental matter, whether it is groundwater quality, trees growing in the earth, or carbon sequestration in the earth, and it's subsurface, and related to engineering somehow, its fair game for geoenvironmental engineering.

When we were considering changing the *Journal*'s name, we noticed a tendency for some engineers to stay true to traditional geotechnical engineering and not drift into the geoenvironmental area, where there was much work already being done. My feeling then was that geotechnical engineers were at risk of being left behind. If we didn't claim the geoenvironmental field, we could have been out of the game altogether.

Conducting a laboratory permeability test (1997).

Q: What led you to tackling environmental problems with a geotechnical engineering focus?

When I got out of graduate school with a master's degree, I moved to San Francisco to work for WCC. I noticed that successful geotechnical engineers there fell into two categories. One group did great work for their clients. They were quiet, highly competent, and highly capable engineers who did super work and earned their clients' trust. There was a second group of "high-rollers," who seemed to be out there in a newly emerging field where there was not much leadership. Impatiently, I decided the second route was a better path for me.

In the 1960s and 1970s, when nuclear power plant siting and construction was flourishing, we didn't have a clue about what to do with spent fuel or radioactive waste. I thought, here's an important national problem that's not going to go away, and nobody knows anything about it! After my doctorate studies on radioactive waste disposal at UT Austin, I became a faculty member there. I soon learned that it wasn't radioactive waste disposal that had research money, but *chemical* waste disposal. I focused my interest on that area and started receiving funding from the U.S. EPA. I was in the right place at the right time. So if there's a lesson from my experience, it's for young, aspiring engineers to pick an

Daniel (l) on site of an EPA research project with Bob Koerner, Rudy Bonaparte, and David Carson (1989).

area where the field is not crowded with existing experts, and position themselves to make a difference. Truly, I got lucky!

Q: What do you consider to be your most outstanding career achievement or professional contribution?

I believe that would be sorting out how to compact clay liners with the correct water contents and densities, and how to think about desiccation cracking. People had always thought about clay liners as structural fills, but that doesn't deliver the performance results that you need. Craig Benson and I worked on that problem and sorted it out. We extended what had been done several decades earlier to a much better place. I'm really proud of that.

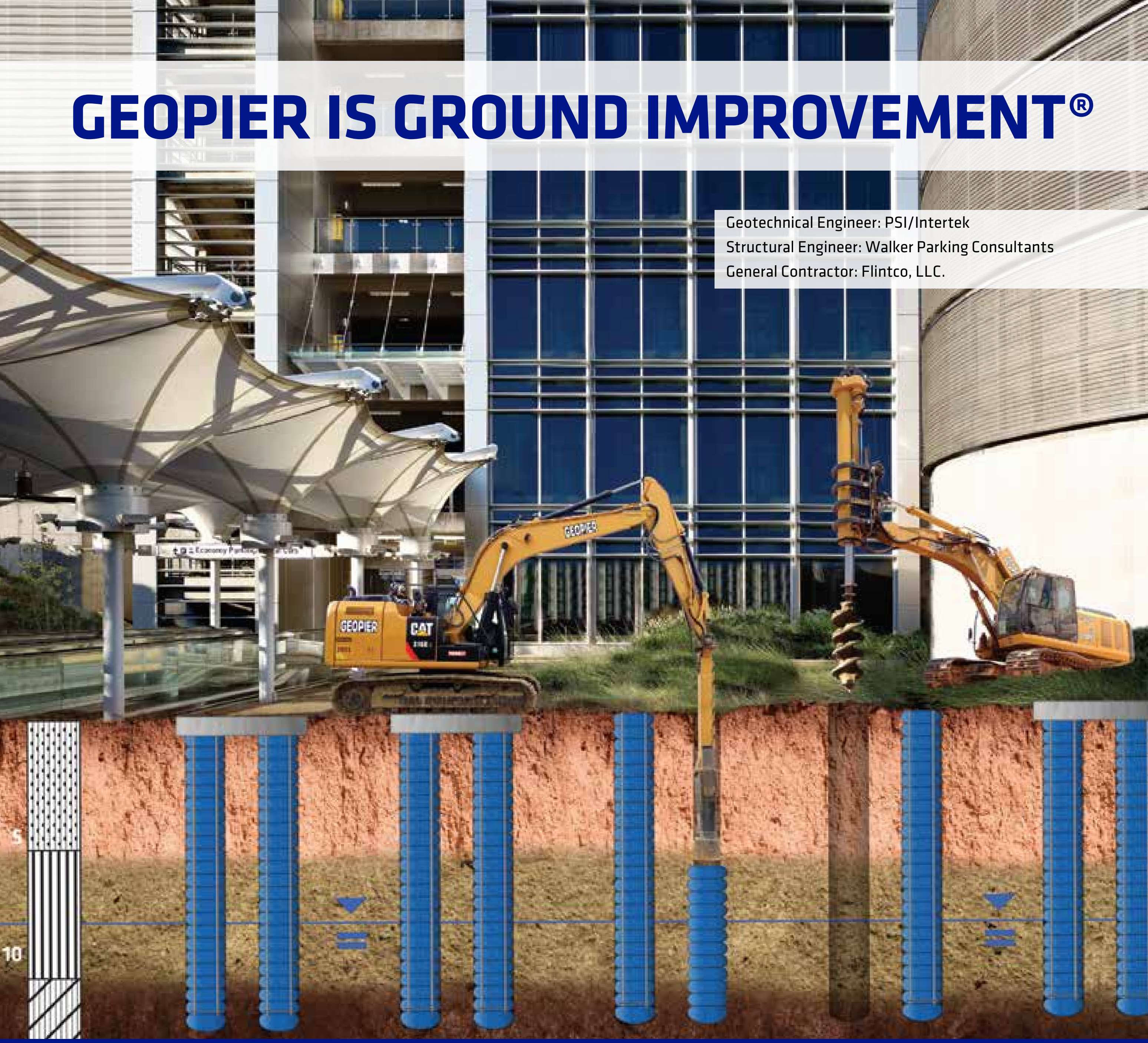
Q: A common criterion is that hydraulic conductivity of compacted clay liners must not exceed 10^{-7} cm/s. Where did that come from?

10^{-7} cm/s was a number pulled from thin air! I was involved as an expert in some lawsuits where the hydraulic conductivity issue came up, and I did a lot of studying of it by reviewing state regulations. Suddenly, 1×10^{-7} cm/s popped up in one state regulation — I don't remember which one — and implementation of it happened without much clarity of thought. Paul Schroder, who developed the HELP computer code for water balance in landfill covers, claimed that as he was running the numbers with different permeabilities in the cover, he found that 1×10^{-7} cm/s was low enough to minimize infiltration through a cap. That's the only rational explanation anyone has ever offered that I know of. I've always noted that 1×10^{-7} cm/s is equal to one inch per year. It turns out that when the hydraulic conductivity is near that value, flow switches from an advection-dominated situation to a diffusion-dominated situation. Many like to think that this was the rationale, but that just wasn't on people's minds at the time.

Q: How has working as a consultant influenced your career?

Working for three years at WCC between my master's and PhD degrees was one of the best decisions I ever made. It had an enormous and positive impact on me, mostly in terms of being sensitive to a client's perspective and developing respect for what an issue looks like from the other person's

GEOPIER IS GROUND IMPROVEMENT®



PROVIDING CUSTOMIZED SOLUTIONS FOR ALL SOIL TYPES

REQUEST FEASIBILITY ASSESSMENT

We will help you develop a customized engineering solution to meet your project needs. geopier.com/feasibilityrequest

For more information call 800-371-7470,
e-mail info@geopier.com or visit geopier.com.

Geopier's goal is to bring you advanced, innovative ground improvement technology in a way that is easy to use every day. Geopier Rammed Aggregate Pier® and rigid inclusion products enable you to:

- Improve variable fill soils in place
- Replace deep foundations
- Control settlement
- Increase soil bearing capacities

GEOPIER®
Tensar.

point of view. I remember working a very difficult foundation engineering problem involving footings on a slope. I drafted a four-page memo for our client. I thought it was absolutely brilliant in technical insight and clarity! I gave it to my boss, Ed Margasson, to review. He cut it down to one sentence that basically recommended allowable foundation pressures to our client. Ed said, "David, our client doesn't care *why*; they just want to know *what* to do." This taught me to view my work from the other person's perspective. I must say that only about 20 percent of my work really interested me, which taught me another life lesson: when you're a student, not every single class or every single professor is fascinating. The successful student somehow slogs their way through the less-than-fascinating professor and less-than-interesting class. The same things can be true for a professor or a consultant: some of it is routine, so you just sort of live for the fun things.

Q: What advice do you have for new engineers entering consulting or industry?

Follow your passions, and do not let others program you. You only have one life, and your career is part of your life. There's almost nothing worse than going to work and not enjoying it. The other thing that worked out well for me was trying not to take the easy road. After getting my master's degree, I went to work in San Francisco because I thought that area was the most geotechnically complex place to work. When projects came along, I tended to avoid the ones where I knew what I was doing and volunteered for the ones where I did not. I learned a lot, and I learned a lot fast. Sometimes just raising your hand and saying, "I'm interested in that," can be helpful. Follow your heart, and try to program yourself for projects and work where you are going to learn. That approach will serve any engineer well.

Q: Did you ever experience failure on a research project, and how did you deal with that?

I got interested in expert systems about 25 years ago, when artificial intelligence was first bubbling up, and the idea was to capture and codify a person's expertise. Clay liners, and some of our other lines of work, are procedurally driven. It's not exactly cookbook, but there is some structure. I thought developing an expert system for liners would be interesting, and I had a student also interested in it. We never got the project through the PhD committee because no new ground was being broken in understanding either clay liners or expert systems. That experience taught me a harsh lesson about the dangers of interdisciplinary work. When I worked in interdisciplinary technical areas afterward, I was far more cautious in asking, "What's really new, and is it really important?" It's true that you learn from your failures and not your successes. If you never fail, I would argue you've never stretched yourself far enough.

Daniel (center) upon election to the National Academy of Engineering (2000).

Q: What personal traits or characteristics contributed most to your success?

The ability to listen and to understand someone else's point of view and respect other people played a big role. People are not going to follow your lead unless they feel engaged and appreciated. Some people let their ego drive the way they behave and essentially make themselves unlikeable. As an example, I'll tell a story about Roy Olson. The very first paper he and I wrote together was published in the *Journal of Geotechnical Engineering*, and I was very proud. Fred Kulhawy, a professor at Cornell at the time, wrote a scathing discussion of the paper. I composed what I thought was

The authors with Dr. Daniel at Geo-Chicago 2016. From l to r: Cameron Fritz, Joel Conzelmann, Dr. Daniel, Aliena Debelak, and Mohammad Gorakhki.

an equally scathing closure. Roy wisely put a red line through most of it. We shortened and simplified the closure and responded to a couple of key points. The closure got published, and after I got my PhD, Fred offered me a job to join the faculty at Cornell. Over the years I got to know, respect, and really enjoy Fred's company. I was always grateful I took Roy's advice and didn't pick a fight with Fred over a simple paper. I think the ability to maintain relationships with people, even if we disagree with them about something, has served me well.

Q: Who most influenced your career?
Unquestionably, it was Roy Olson. He was my master's and PhD mentor, and he taught me so much. He inspired me, taught me to think critically, showed me what it means to be a professional, taught me more about how to write than anyone else, and had an enormous positive impact on my life. He gave me the best gift a teacher can give: life-changing guidance. It's hard to guess what my life would have been like if I had not bumped into him in that second course in geotechnical engineering.

Q: If you could interview any geoprofessional, past or present, as your GeoLegend, who would you pick?
I would like to talk to John Burland (Editor's Note: See Burland's GeoLegend interview in the November/December 2012 issue of *GEOSTRATA*). I'd ask him about how he developed and executed the concept for straightening the Pisa Tower and how he dealt with such a public and even emotional issue. The Pisa Tower is such a visible and political project, and I thought it was gutsy of him to excavate from the other side instead of shoring up the leaning side. I would like to talk to him not so much about what engineering he did, but about what he was thinking at the time and what the pressures were.

Q: How do you see the future of civil engineering education evolving?
For decades, engineers have talked about bridging academic education with training in the practice of civil engineering. This remains a big challenge. I think the single best thing we could do is find more ways to engage students in summer internships and co-op programs. I think the academic

approach of "educating for a lifetime," coupled with exposure to practice, is ideal.

Q: What geoenvironmental topic do you find the most challenging?

In the past, the biggest challenge was getting people to think about compacted clay liners in a different way than they thought about structural fills. To get really low permeability, the clay must be wetter and softer than might be appropriate for a structural fill. I would say it was not really a technical problem so much as a challenge in the way people traditionally thought about compaction. Toward that end, we had to develop the data to prove how the clay should be compacted and offer simple "how to" procedures to accomplish goals. That's essentially what we did, and it worked!

Today, I think carbon sequestration has my interest. If I could reposition myself as an aspiring PhD or master's student, I think I'd tackle carbon sequestration. It's a high risk area because it's not clear to me that anybody is ever going to spend any money sequestering carbon, but on the other hand, we've got a problem. There's no question that carbon is building up in the atmosphere. You can argue about the impacts, but if the carbon build-up keeps going in perpetuity, the challenge is going to be to take the carbon out of the atmosphere and put it back on earth. I'm convinced it can be done — and led by geoenvironmental engineers!

Q: What geotechnical engineering topics outside geoenvironmental do you find the most interesting?

I love foundation engineering and slope stability; they are fascinating. I had such a wonderful experience taking classes from Lymon Reese, Roy Olson, and Steve Wright. Those courses inspired me to a lifetime of curiosity. I remember once there was a retaining wall by my house in Austin, and I could tell that it was going to fail because there was no drainage in the wall. I drove my kids by that wall, and I'd say, "That wall is going to fall down one day." And one day after a very heavy rain, it fell right down. Were my kids ever impressed with me! Slopes are interesting because they are visible. You can look at them and know there is going to be a problem. It was interesting for me when I became an engineering dean at UIUC to see how there's some disrespect for civil engineering because it's not viewed as high tech. There's all this interest in nanotechnology and all sorts of high-tech things, but I can tell you that high-tech people, like those nanotechnologists, are blown away by some of the work that we civil engineers do. The big, complex projects are mind blowing, which is especially visible with slopes and foundations. I think we, as civil engineers, are too involved to see how challenging they are, but

Dedication of the Bioengineering and Sciences Building at the University of Texas – Dallas (2016); guests were served punch in a flask.

other scientists and engineers recognize it. I think we probably ought to do a better job communicating it.

Q: What do you do in your spare time?

I wish there was more spare time, but if I could be reincarnated, I would be one of two people. I would be Paul Simon of Simon and Garfunkel, because of his ability to write songs and play guitar. I would be a guitarist and songwriter if I had any talent. There is an acoustic guitar next to my home office computer that I like to pick up and play to relax. The other thing I would have done would have been to try to golf professionally. I love golf, but it's a terribly time-consuming sport. I also love

Daniel (l) and Steve Trautwein travel to a remote site for a field permeability test.

great wine and visiting wineries, and binge-watching TV series. I enjoy everything from Downton Abbey to the Sopranos.

Q: What do you miss most about being a professor and being directly involved in research/teaching?

Students! The best thing about being a professor is interacting with students. They uplift us, challenge us, and remind us of the purpose of our work. As I've moved up the academic administration ladder, I find I cherish more and more those occasional lunches and other encounters with students.

JOEL CONZELMANN, EIT, S.M.ASCE, is a master's candidate at Colorado State University. His research focuses on the hydraulic and chemical properties of geosynthetic clay liners (GCLs) in mine waste containment applications. He can be contacted at *jtconzy@colostate.edu*.

ALIENA DEBELAK, EIT, S.M.ASCE, is a master's candidate at Colorado State University. Her research focuses on the numerical simulation of debris flow-structure interactions for flexible barrier mitigation systems. She can be contacted at *adebelak@colostate.edu*.

MOHAMMAD GORAKHKI, S.M.ASCE, is a PhD candidate at Colorado State University. His research focuses on the re-use of tailings and waste rock in water balance covers for mine waste storage facilities. He can be contacted at *mrhg@colostate.edu*.

CAMERON FRITZ, EIT, S.M.ASCE, is a master's candidate at Colorado State University. His research focuses on semi-permeable membrane behavior of clays for waste containment applications, and investigating the persistence of membrane behavior in compacted sand-bentonite mixtures at high permeant solution concentrations. He can be contacted at *cfritz@colostate.edu*.

Do It Right, or Don't Do It at All

By John P. Bachner

The Geoprofessional Business Association's (GBA's) more than 100 case histories are a treasure trove of important experiences, almost all related to professional-liability losses. The following story is one to learn from, documented far more extensively in *GBA Case History 76*. It took place about 25 years ago, but that has no impact on its relevance to today's practice, because it's not about technology; it's about people.

In essence, Downs was practicing his profession and, accordingly, he had a responsibility to do so professionally. As a result, Downs was not only negligent; he was willfully negligent.

The location involved was Boston's historic Back Bay, created through a 30-year filling operation begun shortly after the Civil War. Once the filling was complete, development followed, with the construction of three- to five-story rowhouses supported on wooden piles. In order to last, the piles had to be submerged below groundwater to prevent exposure to air and the resulting activation of fungi that can reduce a 10-in.-diameter wooden pile to peat moss in just five years.

The rowhouses began to experience severe settlement problems starting in the 1920s. Groundwater had begun to leak into interceptor sewers, lowering the groundwater table and exposing the tops of many wooden piles to air, causing them to rot. Underpinning was performed to correct the problem: the tops of the piles were cut off 4-6 ft below the original level, steel posts were inserted to hold up the granite block, and a concrete mass was placed to fill from the top of the pile to the granite block.

One block of 19 rowhouses was spared the problems until the mid-1980s. Then, within five years, all had to be underpinned. The GBA-Member Firm – we'll call it Blue Clay Associates – was retained to design repairs and observe their implementation. Because litigation was expected, the firm gave each homeowner client a brief summary report, based on daily field reports, indicating the degree of rot in each wooden pile, and describing the repairs. The summary report was to be used solely to document the need for remediation; other information was omitted.

About three years later, Doug Downs, one of Blue Clay's Downs, took a call from Ben Arnold, an acquaintance who was buying one of the 19 rowhouses whose repairs Blue Clay had designed. Its owner had furnished a copy of the summary report, prepared by a junior engineer and signed by Downs. "Can you answer some questions?" Arnold asked. It was Friday afternoon, and even though he was extremely busy, Downs agreed to meet Arnold at the rowhouse at 9:00 a.m. Monday morning. However, because of the short notice, Downs was unable to retrieve the project file because it was stored in a remote facility. Fortunately, Arnold brought his copy of the summary report. It indicated that underpinning began in 1984, with repair of one of the party walls. The front and rear walls were underpinned in 1986, and the remaining party wall was completed in 1988.

Arnold asked questions about the underpinning. Downs was unable to answer most of them and suggested that Arnold obtain the daily field reports from the rowhouse owner. Then the two walked through the house. On the first floor, several odd cracks in a transverse wall suggested sagging in the middle. Downs told Arnold to retain a structural engineer.

The visit was over in about 40 minutes, with Downs saying he would review the files. "There's no need for that," Arnold said. "Just send me a bill." Downs responded that his service was a favor, and that evening he prepared notes about the meeting.

Six weeks later, Arnold called Downs to let him know he had purchased the rowhouse, and that his renovation constructor found something odd in the crawlspace. Downs visited the home the next day, and what he saw was distressing: a relatively short central girder designed to support the floor joists had settled and left gaps. The girder was supported on granite blocks, indicating the piles had not been repaired. Becoming somewhat panicked, Downs drove to the storage facility and retrieved the project file. It revealed a note stating that the girder had been found during repairs, but the homeowner, who was in the construction business, did not want the wooden piles repaired. The homeowner said that a structural engineer had told him the girder was not needed to support the building's interior load.

Feeling guilty about not having researched the project earlier, Downs called his acquaintance to apologize for forgetting about the girder and its support. Arnold became agitated: "I retained you to give me a professional opinion. If this thing isn't fixed, the structure might not be able to handle the renovations upstairs. We're moving in in two months. What's your firm going to do about this?"

Downs agreed to prepare specifications and provide construction observation services at no charge. The specialty constructor who had underpinned the house originally agreed to do the work at its cost, about $30,000. The constructor completed its work without incident and sent Arnold the bill. A few weeks later, Arnold sent Downs a letter demanding that Blue Clay pay for the repairs, given that the additional costs and delays were Downs' fault. Blue Clay principals met with the firm's attorney. They decided they had done nothing particularly wrong, especially so because Arnold could have avoided the problem if he had followed Downs's advice and retained a structural engineer before purchasing the house. Nonetheless, they offered to pay $10,000 to make the problem go away. It didn't.

Arnold filed suit in 1989, claiming that Blue Clay Associates and Downs were liable for professional negligence, negligent misrepresentation, and breach of contract, and that the firm and Downs were guilty of deceptive trade practices (Massachusetts General Law 93A), making them liable for treble damages. The firm's principals and attorney were not overly concerned. They believed the court would see things their way; i.e., that all Downs did was provide friendly advice and, accordingly, no contract existed. And the advice was basically sound. In fact, in their opinion, the plaintiff committed contributory negligence by not following that advice.

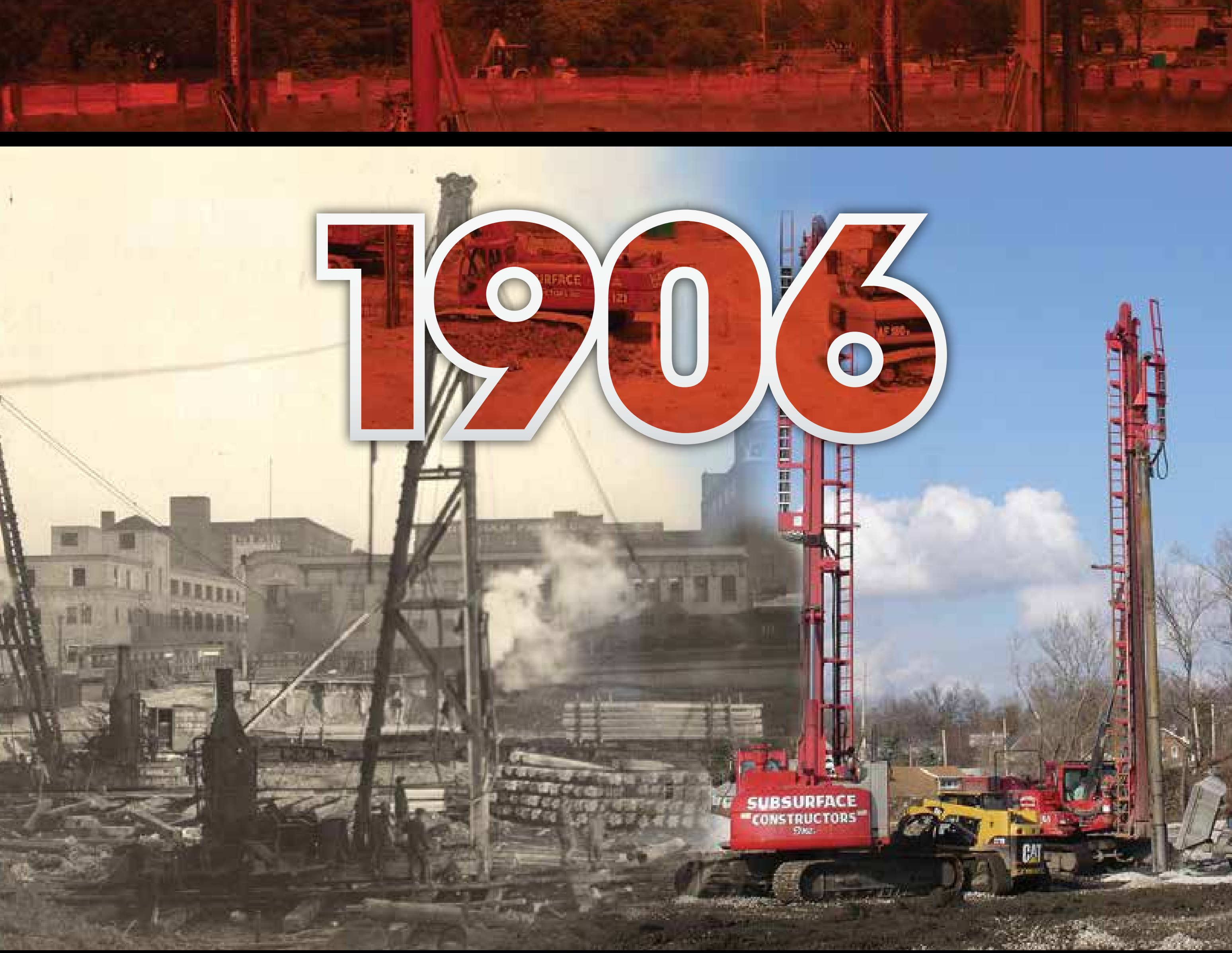
As part of litigation's discovery process, Blue Clay produced all relevant files for the plaintiff's review. One of the documents was a hand-written note memo about a telephone conversation between Downs and the rowhouse's prior owner: "Wants completion report – OK – but should wait until [other party] wall is completed. Wants brief & concise report that says pile problem corrected." Plaintiff's counsel asked, "Did [the prior owner's] desire for a report that states the pile problem was corrected have an impact on the completion letter?" Downs could not recall the conversation, but he answered, "No." After all, although he signed the summary report, a junior engineer had prepared it, based on daily field reports describing the repairs.

The trial took place five years after Downs agreed to look at the rowhouse, a time lapse that is not at all unusual for litigation. Also not unusual, it took 14 more months for the judge to render his decision. He ruled that, because there was no "meeting of the minds" about the contract, no contract was ever formed. But that did not matter, because, the judge said, professionals owe a duty of care to any party that could foreseeably be damaged or injured by their negligent professional acts. The judge noted that Downs had failed to "exercise the reasonable skill and knowledge normally possessed by members of his profession in good standing in the community.... Regardless of whether he remembered the problems with the center girder [at the time of the site meeting, Downs] had a duty to check notes and advise [Arnold] correctly as to the condition of the foundation." Furthermore, the judge said, Downs should have made it clear that he was at the meeting only to speak in generalities; that he was giving casual advice and not an opinion; and that Arnold should not rely on the advice. In essence, Downs was practicing his profession and, accordingly, he had a responsibility to do so professionally. As a result, Downs was not only negligent; he was willfully negligent.

The judge also ruled that the summary report comprised negligent misrepresentation. Because it contained no information about its purpose and limitations, and because it failed to mention the center girder and its unrepaired wood piles, it communicated "a false representation of a material fact and [Downs] should have known it would be relied on" to show that the foundation problems had been corrected. Further, Downs "should have known that the previous owner might use the letter as an accurate representation of the conditions of the foundation." In addition, the judge said, Downs made the misrepresentation knowingly, because he had written earlier about the lack of repairs. Whether or not Downs remembered doing so at the time he made the letter his own, by signing it, did not matter. Accordingly, Massachusetts General Law 93A was invoked, and the firm wound up spending more than $150,000 for the award it had to pay, plus defense costs and internal costs.

Here are the take-aways, in brief:

- Society expects professionals to act professionally whenever they provide a professional service, no matter how small.
- Haste makes waste.
- Be wary of doing favors, even for friends and relatives, because lack of payment or lack of formality can lull you into thinking that an inadequate professional service is adequate.
- Understand your duty of care.
- As documented in GBA case histories, project risk is inversely proportional to the project's size and complexity; i.e., the smaller and simpler the project, the bigger the risk.
- Do not apologize for what you think may be errors, because they may not be errors after all, or they might not be solely *your* error. Think how different the outcome might have been if Downs, instead of apologizing, had said, "What did the structural engineer say before you bought the house?… What? You didn't call the structural engineer like I told you to? Why not?"
- The purpose and limitations of any instrument of professional service should be made clear. Professionals do not know how something they prepare will be used in the future, or by whom.
- Documentation is always important, if only because the human memory is so notoriously unreliable. After giving Arnold his recommendations orally, Downs should have issued a memo that put those recommendations into writing, and which indicated that, per Arnold's instructions, he did not check the project file.
- Homeowners are almost a protected class in the eyes of the court, making a legal defense difficult, a situation that can actually encourage some homeowners — with their attorneys' guidance — to file suit. That being the case, geoprofessionals who accept residential commissions need to dot every "i," cross every "t," and prepare all the documentation needed to affirm that such dotting and crossing occurred. That did not occur in this case; the result was predictable, as Blue Clay's principals and attorney should have known.
- Having an effective document-retention policy in place as part of an up-to-date file-management policy is critically important. Files that go into storage still containing every scrap germane to the project can be disasters waiting to happen. In this case, the memo documenting a telephone call contributed mightily


1906
SUBSURFACE
CONSTRUCTORS

to an additional expense of $60,000 or more. Imagine the outcome that would have occurred had the memo been discarded before the file went into storage, and if the file contained a memo from Downs to Arnold indicating that, per Arnold's instructions, Downs had not checked the project file and that, in any event, Arnold needed to retain a structural engineer before purchasing the home.

- Litigation is a fact of business life and so needs to be looked at in a matter-of-fact, unemotional manner. For that reason, when a claim is filed against them, geoprofessionals need to examine the cost of one's "day in court" vs. the cost of settling early on, to avoid the day in court altogether. In this case, Blue Clay wasted $120,000 because of its stubborn refusal to settle the claim for $30,000 when it had the chance. Was it a cavalier attitude? Hubris? No matter. Whatever it was, it was expensive.

Bottom line: Providing a flawless professional service does not mean providing a flawless deliverable. That's only part of it. You also need to know what society expects of you, then deliver it and document that you did so. If you're not willing to learn what's involved, or if you're not willing to take the time to provide it, you've chosen the wrong profession, an outcome that will probably become painfully clear sooner rather than later.

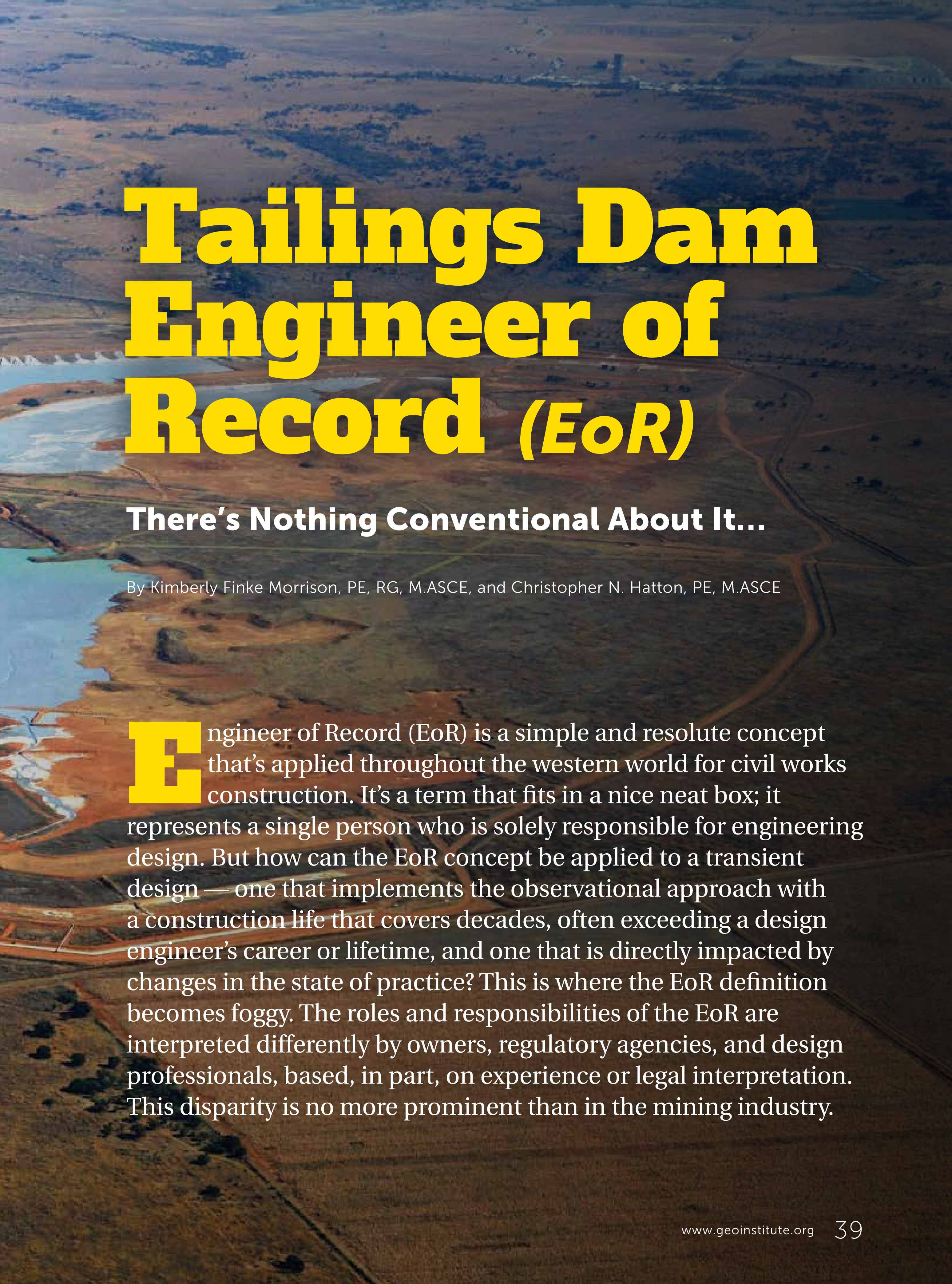
Do it right, or don't do it at all. GS

JOHN PHILIP BACHNER has been an independent consultant since 1971. Through Bachner Communications' association-/foundation-management division, he served as the Geoprofessional Business Association's (GBA's) executive vice president from 1973 through 2015.

GBA is a not-for-profit association that develops programs, services, and materials to help its member firms and their clients confront risk and optimize performance. GBA-Member Firms provide geotechnical, geologic, environmental, construction-materials engineering and testing (CoMET), and related professional services (*en.wikipedia.org/wiki/geoprofessions*). GBA invites geoprofessional constructors, educators, and government officials to become involved. Contact GBA at *info@geoprofessional.org*.

MAY/JUNE 2017 | MINING GEOTECHNICS

Aerial view of Gold Fields' South Deep TSF near Doornpoort, South Africa. (Photo courtesy of SLF Consulting.)



Tailings Dam Engineer of Record *(EoR)*

There's Nothing Conventional About It...

By Kimberly Finke Morrison, PE, RG, M.ASCE, and Christopher N. Hatton, PE, M.ASCE

Engineer of Record (EoR) is a simple and resolute concept that's applied throughout the western world for civil works construction. It's a term that fits in a nice neat box; it represents a single person who is solely responsible for engineering design. But how can the EoR concept be applied to a transient design — one that implements the observational approach with a construction life that covers decades, often exceeding a design engineer's career or lifetime, and one that is directly impacted by changes in the state of practice? This is where the EoR definition becomes foggy. The roles and responsibilities of the EoR are interpreted differently by owners, regulatory agencies, and design professionals, based, in part, on experience or legal interpretation. This disparity is no more prominent than in the mining industry.

Tailings slurry discharge into TSF.
(Photo courtesy of Christopher Hatton.)

Tailings storage facilities (TSFs) are the necessary result of successful mining. However, unlike conventional water storage dams that are viewed as an asset by their owners, TSFs and the dams that retain them are an ever-expanding and undesirable, yet necessary and ongoing, liability throughout the life of mining operations and into perpetuity. These structures can have service lives that transcend generations as they pass between owners through acquisition and divestment, and are subject to the inherently-transient support of engineering firms responsible for design of tailings management systems.

In the wake of the Mount Polley (Canada) tailings dam failure in August 2014 and the Samarco (Brazil) tailings dam failure in November 2015, the efficacy of the EoR for TSFs has been brought into question worldwide. Industry is looking for guidance on how to approach management of these constantly changing and perpetual facilities.

Tailings – What Are They, and How Are They Managed?

Tailings are a waste product of the mining process. From the mine (open pit or underground mine), mineralized rock (i.e., ore) is processed and reduced in size to recover the economic mineral. The remnant material from the process, known as tailings, is composed primarily of sand-, silt-, and clay-sized material with chemicals and process water. Moreover, because mine tailings are not a natural earthen material, they do not behave like soil and rock, which makes their management challenging from a geotechnical and environmental standpoint.

The volume of tailings produced from mining and processing is significant. For example, the extractable mineral for base metals (e.g., copper, molybdenum, lead, and nickel) is only a few percent of the total volume of ore mined. This disparity is even greater for precious metals (e.g., gold, silver, platinum, and palladium), which, in many cases, results in only a few ounces per tonne of ore converted to a salable commodity. The residual tailings are typically discharged to and stored in an engineered surface facility (i.e., a TSF) which often incorporates dams that have complex configurations.

To design and operate a TSF requires a unique set of engineering skills. The requisite technical training is borne of civil-geotechnical engineering principles, tempered by the disciplines developed and applied to water-retention structures, and modified by experience to account for a geochemically harsh environment that provides safe containment of processed waste products. Construction of the TSF is typically an ongoing process, with the facility continually expanding during the life of the mining operation through vertical raises and/or lateral expansions until the economic ore reserves are depleted. The construction process can span many years, decades, or even generations. Supporting these systems as the EoR is complicated by the fact that mine owners and tailings operators change from time to time due to acquisition and divestment. But moreover, engineering firms responsible for design/construction/operations/closure support of TSFs can experience similar, if not more dramatic, change.

Ore reserves are not characterized by the quantity of extractable mineral, but rather by the economics of mining and beneficiation. The sustainability of an ore reserve thus fluctuates with global market conditions and is influenced by the economics of improving extraction methods. Accordingly, a once-small TSF designed for a limited capacity expands as the mineralized limits are further defined, market conditions cycle, and technological advances improve mineral recovery and reduce costs. In many cases, the ultimate mine and associated TSF differs significantly from the original design, and, of equal importance, reflects the continually evolving engineering practice.

Industry Trends and Recent Failures

Our collective understanding of the behavior of tailings under dynamic and static loading conditions has changed over the decades. At the same time, mineral production worldwide has increased every decade. Mines in the late 1800s produced up to 100 tonnes per day of ore, while today, mines are producing in excess of one million tonnes per day. With this clear trend in ever-increasing mineral production, TSFs are getting larger in volume and area, and the associated tailings dams are getting higher.

In the wake of the Mount Polley (Canada) tailings dam failure in August 2014 and the Samarco (Brazil) tailings dam failure in November 2015, the efficacy of the EoR for TSFs has been brought into question worldwide.

Remarkably, the industry record on tailings dam performance, as measured by number of failures, has been generally unchanged over the last 50 years, with an average of about two failures per year. However, there is a disturbing trend of increased severity of the failures, with 63 percent of all incidents and failures since 1990 classifying as Serious (i.e., large enough to cause significant impacts or loss of life) or Very Serious (i.e., catastrophic dam failures that released more than one million m^3 of tailings and, in some instances, resulted in multiple loss of life). Two recent catastrophic tailings dam failures — the Mount Polley tailings dam failure in 2014 and the Samarco tailings dam failure in 2015 — have caught significant attention, necessitating a change in how these facilities are managed.

Mount Polley TSF Failure - Canada

On August 4, 2014, the perimeter embankment breached at Imperial Metals' Mount Polley gold and copper mine, located in British Columbia. The breach released an estimated 10 billion liters of water and 4.5 million m^3 of tailings into the environment. One publication coined the breach the "largest environmental disaster in modern Canadian history."

Shortly afterward, British Columbia's Ministry of Energy and Mines (BCMEM) announced that it had commissioned an independent, expert engineering review panel to study the breach. After a large and complex investigation, the panel found that a design flaw was the dominant contribution to the failure. Specifically, the report states that the "design did not take into account the complexity of the sub-glacial and pre-glacial geological environment," and that the tailings engineers "failed to identify a continuous [Glaciolacustrine] layer in the vicinity of the breach and to recognize that it was susceptible to undrained failure."

The panel report also discusses the roles and responsibilities of the EoR and the regulatory agencies, stating that "the EoR is responsible for the overall performance of the structure as well as the interpretation of site conditions," while the "regulator has to rely on the expertise and the professionalism

Mount Polley TSF viewing downstream. Photo was taken shortly after the August 4, 2014, failure in British Columbia that was the catalyst for review of the EoR concept. Note embankment breach on left. (Photo: Reuters.)

Configuration of Samarco's Fundão TSF on July 20, 2015. (Photo: GoogleEarth.)

of the EoR, as the regulator is not the designer"; however, the panel report provides little discussion of the roles and responsibilities of the owner. Several consulting firms were involved at various points in the design and operation of the facility up to the point of the breach, and litigation is currently underway with uncertainty surrounding the EoR.

Samarco TSF Failure – Brazil

The ink on the Mount Polley failure studies was barely dry when another catastrophic tailings dam failure occurred, this time at the Samarco iron ore mine in the state of Minas Gerais, Brazil. Samarco's Fundão tailings dam failed on November 5, 2015, releasing mine tailings into the town of Bento Rodrigues, killing 19 people.

The TSF owners commissioned their own review panel to evaluate the cause of the failure. The review panel's August 2016 report found that three small, seismic shocks provided the increment of loading required to trigger collapse of the dam, which resulted in a liquefaction flowslide. However, it also stated that a series of unplanned occurrences during the dam's construction established the conditions that allowed the failure to take place in the first place. These conditions included damage to the original starter dam that resulted in increased saturation, deposition of slimes in unintended areas, and structural problems with a concrete conduit that caused the dam to be raised over the slimes.

In addition to an active EoR, this facility had an independent technical review board in place prior to the failure. With design and construction flaws blamed, the social, environmental, and economic impacts triggered by this incident led to court action against the owners.

What Happens Now?

Both Mount Polley and Samarco had active EoRs in place, which begs the question, "What happens now?" To chart the course, it's important to first understand the mistakes that were made, learn from them, and apply lessons learned from these experiences. It's well known that TSFs are continuously expanding in size, both vertically and laterally, which continually raises the engineering and operational bars to a whole new level. The industry must come together as a group to safeguard these important structures. In doing so, we must retool the basic principle of EoR.

Canadian associations and agencies, such as the Canadian Dam Association (CDA), have taken the lead in addressing issues surrounding the EoR for TSFs (e.g., EoR succession,

Samarco's Fundão TSF following the November 5, 2015, failure in Brazil. (Photo: Reuters.)

roles and responsibilities, implementation of EoR recommendations, owner's responsibilities with respect to the EoR). However, other organizations and agencies are following suit.

Canadian Dam Association (CDA)

After BCMEM released its panel report, the CDA board of directors established a Mount Polley Task Group, composed of members of its Dam Safety and Mining Dams committees. The task group's mandate was to coordinate follow-up to the panel report recommendations, which included the need to improve the definition of the EoR. Following the task group's recommendations, the CDA proposed a revised definition for the Dam Safety EoR, whose overarching professional responsibility is to determine if the dam aligns with and meets applicable regulations, guidelines, codes, and standards by applying professional engineering judgment based on available data.

CDA states that the EoR should be a qualified professional engineer with experience in the design and/or construction of mining dams commensurate with the consequence classification or complexity of the dam. The EoR can be a consultant (i.e., an individual supported by a firm) or an employee of the mine owner. The EoR is not necessarily the designer of the TSF. Instead, a separate (or multiple) "Design Engineer" or "Designer of Record" may take responsibility for the design(s) that they prepare. CDA acknowledges that, for other disciplines (e.g., transportation and structural), the Design Engineer is referred to as the EoR, so confusion may arise. As such, CDA differentiates between the Designer of Record, whose job is complete when the initial or expansion design and requisite construction is complete, and the Dam Safety EoR, who provides ongoing support. This concept for the EoR does not exist in other engineering disciplines.

British Columbia Ministry of Energy and Mines (BCMEM)

In July 2016, the BCMEM revised its Health Safety and Reclamation Code for Mines (i.e., Mining Code) to contain new requirements for tailings management. The accompanying guidance document for application of the revised Mining Code states that "the Mine Manager is ultimately responsible for the safety of all TSFs on the site," and is required "to designate a person to fulfill the role of a TSF-Qualified Person, ensure each TSF has an Engineer of Record, ensure an Independent Tailings Review Board has been convened and fulfills its mandate, and answers to the Chief Inspector on all issues of compliance with the Code on the mine site."

It's well known that TSFs are continuously expanding in size, both vertically and laterally, which continually raises the engineering and operational bars to a whole new level.

Under the revised Code, key legislated requirements surrounding the EoR include:

- The mine manager retains a Professional Engineer as the EoR for each TSF under his/her management.
- The EoR has professional responsibility for ensuring that a TSF has been designed and constructed in accordance with the applicable guidelines, standards, and regulations.
- The mine manager shall notify the chief inspector of the retained EoR and of changes to the EoR. The notification needs to include acknowledgement by the EoR.
- The EoR has a duty to report safety issues at TSFs.

Regarding reporting of safety issues, the EoR is required to provide immediate written notification to the mine manager of any unresolved safety issues that compromise the integrity of the TSF. If the EoR and mine manager are unable to resolve the safety issue together, the mine manager must report the issue to the chief inspector with a copy of the report to the EoR. However, if the mine manager fails to report the issue in a timely manner, the EoR must report the issue directly to the chief inspector.

Geoprofessional Business Association (GBA)

In 1993, GBA (formerly ASFE) first published the National Practice Guideline for the *Geotechnical Engineer of Record*, which was updated in 2008. The document was intended to clarify the role of the Geotechnical Engineer of Record (GER) in "conventional" design/bid/build construction projects performed in the U.S. GBA defines the GER as a licensed professional engineer who signs and seals a project's geotechnical-engineering documents, verifying that the GER has performed or supervised the geotechnical-engineering analyses involved, and has prepared or supervised preparation of the design (drawings and specifications) and other documents associated with the geotechnical elements of a project. Of note, the GBA guideline states that "the geotechnical engineer must provide certain basic services to be considered the GER," including observing construction and conducting testing to evaluate actual site conditions and the contractor's compliance with the plans and specifications. Continuity of service of the GER from design through construction completion has been shown to assist in project success; this point has not been addressed by the other organizations looking at the roles and responsibilities of the EoR.

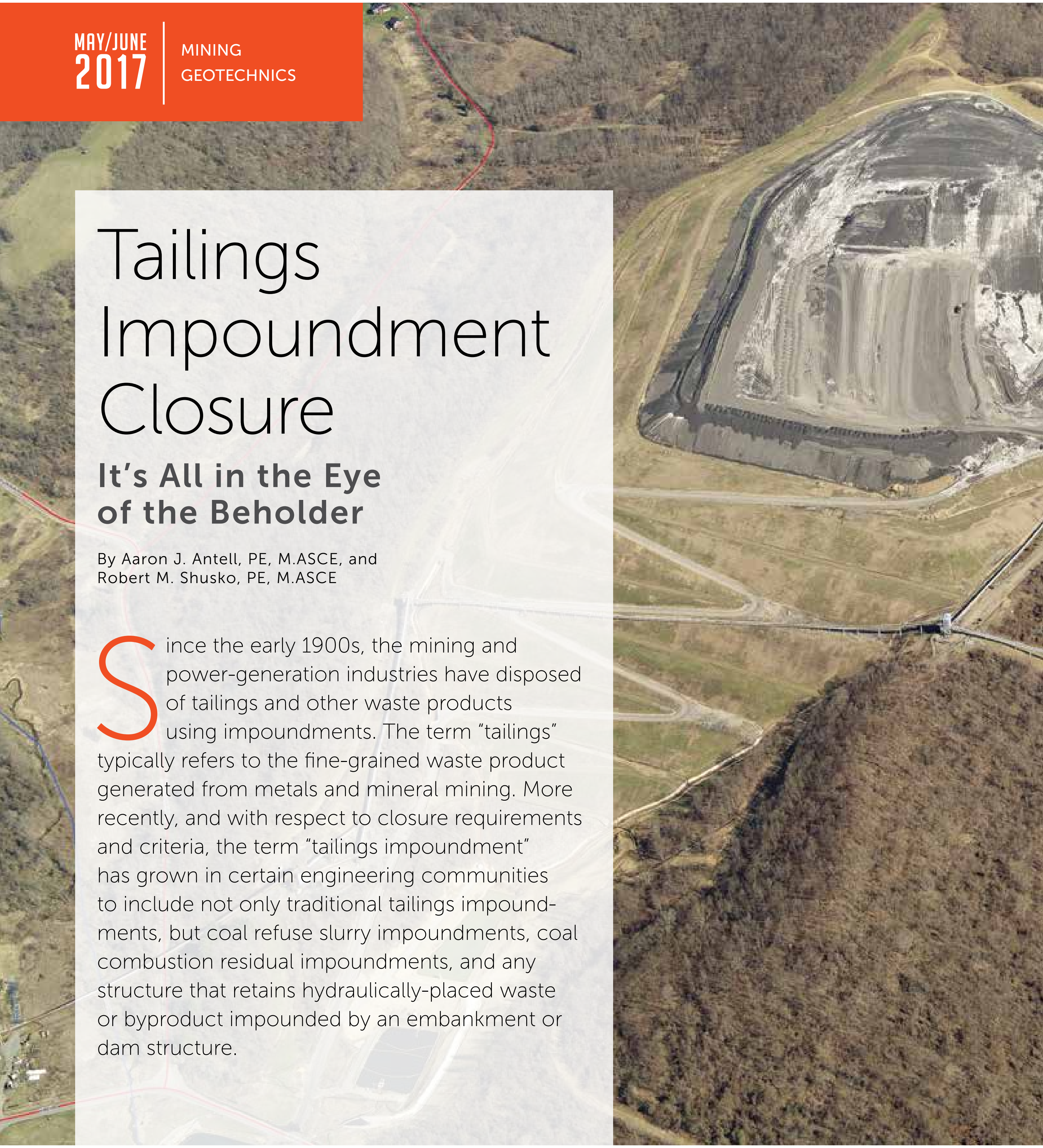
Signaling its recognition that TSFs, by their nature, do not represent "conventional" construction, GBA established a Tailings EoR Task Force in January 2016 to look more closely at the EoR issue for these facilities. The mission of the Task Force is to raise awareness among firms that perform TSF design services of the concerns and issues related to the EoR. It also performs outreach via a workshop with industry to, in part, define the roles, responsibilities, and transfer process (or succession plan) for the EoR during the life of a TSF.

Coming Together for the Benefit of All

Though widely applied, the term EoR is interpreted differently by owners, regulatory agencies, and professionals working within the mining industry. The recent catastrophic tailings dam failures have challenged the EoR concept, particularly with regard to roles and responsibilities, and EoR succession. Now, the industry is working to develop improved guidance on how to approach management of TSFs. GS

KIMBERLY FINKE MORRISON, PE, RG, M.ASCE, is president and principal geotechnical engineer at Morrison Geotechnical Solutions, Inc. in Lakewood, CO. With 20 years of experience specializing in the geotechnical and environmental design, construction, and operation of mine waste facilities, she also performs third-party review of tailings management strategies and environmental due diligence. She serves on GBA's board of directors and chairs GBA's Tailings EoR Task Force. She can be reached at *kimberly@morrisongeo.com*.

CHRISTOPHER N. HATTON, PE, M.ASCE, is a principal geotechnical engineer with Haley & Aldrich in Denver, CO. He has 29 years of experience in the evaluation, design, construction, and operation of tailings storage facilities worldwide. A leader in tailings stewardship execution and tailings operator training, he is a vice-chair of GBA's Tailings EoR Task Force and an active member of the USSD Tailing Committee. He can be reached at *chatton@haleyaldrich.com*.



Tailings Impoundment Closure

It's All in the Eye of the Beholder

By Aaron J. Antell, PE, M.ASCE, and Robert M. Shusko, PE, M.ASCE

Since the early 1900s, the mining and power-generation industries have disposed of tailings and other waste products using impoundments. The term "tailings" typically refers to the fine-grained waste product generated from metals and mineral mining. More recently, and with respect to closure requirements and criteria, the term "tailings impoundment" has grown in certain engineering communities to include not only traditional tailings impoundments, but coal refuse slurry impoundments, coal combustion residual impoundments, and any structure that retains hydraulically-placed waste or byproduct impounded by an embankment or dam structure.

A coal waste disposal facility in the Appalachian coal region comprised of two impoundments: one in the closure process and one actively being constructed and impounding free water. (Photo copyright © 2015, Pictometry International Corp. All rights reserved.)

This is the first of a series of photos showing various stages during the construction and closure of a coal waste impoundment located in the Appalachian coal region. This photo from April 2008 shows active embankment construction. The impoundment possesses the capacity to impound slurry and free water. (Photo copyright © 2008, Pictometry International Corp. All rights reserved.)

These impoundments typically consist of an embankment constructed of soil or waste product that forms a containment system for disposal of hydraulically placed waste. Modern mining, extraction, and processing techniques commonly use water and other reagents to separate the desired mineral or rock from uneconomic in-situ rock, thus generating waste in a slurry form. Because the slurry can be easily transported with pipelines, distributing waste materials to surface impoundments has become an economically attractive solution for disposal. Similarly, coal combustion residuals were commonly disposed of as slurry within impoundments due to the economics; therefore, many of the same issues associated with closure of tailings dams are applicable to coal combustion residuals impoundments. The photos in this article show aerial views of a tailings impoundment as it is transitioned from active storage to closure over the course of seven years.

Historically, tailings impoundments and similar waste disposal impoundments have had a higher failure rate than conventional dams. In most cases, there are greater environmental consequences upon failure due to the composition of the impounded waste materials. The reasons for the greater failure rate of tailings impoundments can be debated, but it's generally accepted that closure of inactive tailings impoundments is prudent and reduces the risk of failure. Considering these factors and others, the engineering community is now challenged with closuring impoundments and deciding just what closure ultimately means.

Perspectives Can Differ

The term "closure," when used relative to tailings impoundments, has different meanings depending upon the viewpoint of the facility's stakeholders. It's not as simple as defining closure as a point in time when the structure's geometric configuration can no longer impound a mixture of solids and fluids. So when addressing the process of closing an impoundment, one must be aware of the different meanings as they relate to the specific stakeholders — typically the owner or operator, the design engineer or engineer of record, regulatory entities, and the public. The point of view or perspective of the stakeholders can substantially influence decisions about what is required for closure and the criteria used to consider when an impoundment is closed.

Mine Operator

From a mine operator's perspective, tailings impoundments are generally only considered an asset when they can be actively used for tailings disposal. Even so, they are often viewed as an expensive necessity of the mining operation; any sustained costs or risks beyond the functional life of the impoundment are highly unattractive. This is not to say that operators of tailings impoundments don't care about potential dam safety and environmental risks in operating their impoundments. It's a reality that mine operators are in the business of extracting money from the earth and are not in the business of building dams. As such, when a tailings impoundment has reached the end of its functional disposal capacity, some mine operators often consider the impoundment to be closed because it's not an integral part of their active operations.

Regulatory Agency

Regulatory entities have an obligation to ensure that the closure process meets applicable policies, regulations, and laws, but once the structure is deemed closed by the controlling agency, it no longer requires regulation. The process of deregulating or delisting an impoundment involves documenting that the structure meets a set of requirements dictated by policies, regulations, and laws, but does not necessarily consider whether the structure still exhibits the characteristics of a dam. In some cases, multiple regulatory agencies oversee the same impoundment; thus, varying policies, regulations, and laws may apply. The overlapping agency requirements sometimes complicate the issue further due to differing criteria for deregulation and closure of impoundments. Although the inspection and reporting requirements may be reduced or eliminated when an impoundment is no longer regulated, the structure may still present dam safety and environmental risks.

The Public

The public's perspective on the closure of a tailings impoundment most certainly varies, but it's reasonable for people to expect that the former impoundment will be left in a condition that affords no unnatural risks to public safety, minimizes potential for future environmental degradation, and requires no public obligation for maintenance costs. The public's perspective is one of perpetuity. After the structure is considered to be closed, the mine operator and design engineer move on. Once the structure is no longer regulated, the public is left with any long-term consequences or benefits of the closed impoundment. Although in theory there are mechanisms and laws to hold responsible parties liable for post-closure situations, in reality the public lives with any and all long-term consequences.

Design Engineer

The design engineer's viewpoint of tailings impoundment closure is to develop and guide a technically sound approach that responsibly balances the needs and perspectives of the other stakeholders. The design engineer must understand the perspective of all stakeholders because he or she generally works for — and is a representative of — a mine operator. The design engineer also works with representatives of regulatory entities to meet agency requirements, and has an ethical obligation to the public welfare. The task of developing a solution to a complex problem while balancing the concerns of a client, regulations, and the public is nothing new for the engineering community. In the case of tailings impoundment closure, the stakes are particularly high because the rate of failure is higher than conventional dams. Also, there is greater potential for environmental impacts due to the continued presence of the waste material and the flowability of the waste if the impoundment fails. The focus on establishing criteria for closure of tailings impoundments is relatively new.

When Is a Tailings Dam No Longer a Dam?

The International Commission on Large Dams (ICOLD) has determined that a tailings dam is no longer a dam when it is considered to be physically, chemically, ecologically, and socially stable, and no longer poses a risk to life or the environment. This definition addresses public risks posed by a tailings dam, but part of meeting this definition of closure is eliminating dam safety risks that are associated with all dams. Because tailings impoundments include dams built from earth and waste materials, part of responsible ownership and operation of a tailings impoundment involves managing the dam safety concerns, which may include complying with applicable dam safety programs. From a dam safety perspective, closure of a tailings impoundment includes progressively eliminating or reducing the operational features and attributes of a dam that present safety risks. This is an important consideration because an impoundment can still pose dam safety risks even when the structure is no longer operated as a dam. One unique component of closing tailings impoundments is determining when a structure has a configuration and condition that no longer poses dam safety risks.

From an operational standpoint, closing an impoundment can mean that the impoundment is no longer operated for its primary purpose of disposal of waste materials. Under this definition, the structure could remain idle with no substantive geometric changes, but could be used for a secondary or a new purpose, such as water storage or storm water detention and treatment. Although disposal of tailings is discontinued, the structure clearly is still a dam because it impounds water

The second photo in the series, from November 2010, shows early stages of impoundment elimination, when slurry deposition has ceased and free water has been nearly eliminated. (Photo copyright © 2010, Pictometry International Corp. All rights reserved.)

and tailings that, if perimeter containment fails, could flow. So from a dam safety perspective, the act of discontinuing tailings disposal, and even removing ponded water from the impoundment, does not constitute closure of an impoundment.

In almost all cases, a tailings impoundment will exhibit attributes of a dam immediately after tailings disposal is discontinued. Because tailings impoundments are continually built and raised in height until disposal capacity is exhausted, changes to embankment and pool conditions are the norm. In fact, discontinuing tailings disposal may represent the instance when true steady-state conditions are established. Under this definition or stage of impoundment closure, potential dam safety and environmental risks remain unmitigated, and the structure should continue to be operated and managed as an active impoundment. From a dam safety perspective, when the tailings disposal is discontinued, construction of the dam is finally complete. From that same viewpoint, closure involves transforming the recently completed impoundment into an engineered structure that no longer possesses the attributes of a dam, such as the capacity to impound water and discharge seepage through the structure. So from a broader perspective, an obvious but key step in the closure process is the discontinuation of tailings disposal in the impoundment. However, ensuring that the structure no longer presents the hazards of a dam is the next and more important step to complete.

There are many guidelines, regulatory or otherwise, that determine whether a structure is a conventional dam that impounds water, but the primary function of a tailings dam is to contain flowable waste material. The requirement for closure of a conventional dam involves eliminating the potential for the dam to impound water and restoring the associated waterway. But in the case of tailings dams, the impounded tailings will likely remain flowable for a time period after any pooled water is eliminated and during the process of dewatering the tailings. When the tailings are sufficiently dewatered and in a condition where the potential to flow is reduced to a level similar to nearby, natural, non-impounding earthen structures, it's reasonable to conclude that the structure no longer functions as a dam. In this scenario, public safety risks related to releasing flowable materials are similar to those of a non-impounding structure, so it's reasonable to consider the impoundment closed from a dam safety perspective. Addressing the potential for release of flowable materials is a key step in the impoundment exhibiting structural stability characteristics of a structure that is not a dam, but does not fully address the chemical, ecological, and social stability.

When Is a Tailings Dam a Landform?

The concept of landform design and terminology has been applied and, based on the 2016 workshop about the concept sponsored by the Tailing Dams Committee of the United States Society on Dams, is gaining acceptance as the ultimate goal for closure of impoundments. A topographic definition of a landform is a naturally formed feature having characteristics and shapes similar to large geomorphic features like plains, plateaus, mountains, and valleys, and smaller features like hills, eskers, and canyons. The idea of transitioning a tailings impoundment into a landform extends the landform concept beyond the topographic definition to include structural, chemical, ecologic, and social stability.

A tailings dam that has been transitioned into a landform exhibits features and characteristics similar to natural structures in the environment or region surrounding the tailings dam. The elimination of dam safety concerns and risks is only an incremental step in closure. While closure may discontinue some regulatory requirements, it may not return the structure

The third photo in the series, from November 2012, shows an interim stage of impoundment elimination, when free water has been eliminated, but the capacity to impound slurry or free water still exists. (Photo copyright © 2012, Pictometry International Corp. All rights reserved.)

Develop G-I WEBINARS

HTTP://WWW.ASCE.ORG/BECOME_AN_INSTRUCTOR/

Webinars Provide You With a Means to:

Build
recognition, prestige, and clients

Educate & network
with many geoprofessionals

Develop
a gateway to short courses/workshops, conferences, and articles

Give back
to the profession

Attend G-I WEBINARS

HTTP://WWW.ASCE.ORG/CONTINUING-EDUCATION/LIVE-WEBINARS/

Webinars are convenient, low-cost, and an efficient training option.

Login anywhere and interact with the instructor and other participants. Our webinars cover practical, targeted topics taught by experts in their field. Gain knowledge and earn PDHs.

Please direct questions regarding development of webinars to programproposals@asce.org.
For questions regarding attending webinars, please contact continuingeducation@asce.org.

The fourth and last photo in the series, from April 2015, shows the impoundment has been completely eliminated. The capacity to impound slurry or free water is gone, and the site has been graded with positive drainage away from the former impoundment. (Photo copyright © 2015, Pictometry International Corp. All rights reserved.)

to the public in a reasonable condition when considering its surroundings. It's important therefore, to identify what represents a reasonable condition. And it's this condition where the concept of creating a landform with structural, chemical, ecologic, and social stability can be applied. In most cases, the structural, chemical, and ecologic stability can be numerically measured and compared to surrounding natural features, but social stability is a criterion that cannot be easily measured. Social stability is based on the public's opinion of the structure's final configuration and will vary based on regional and generational preferences, which may include aesthetics or repurposing potential or natural habitat potential. When a tailings impoundment can be demonstrated to be similar to a natural structure, the tailings dam can be considered a landform and no longer an impoundment.

A successful landform concept will address structural, chemical, ecologic, and social stability. The impoundment will be geometrically reconfigured to eliminate the capacity to impound fluids and to continue discharging seepage. Reconfiguration will also include outlet structures or control structures as needed to address structural stability. Safeguards, such as liners, and passive systems, such as reagents that offset detrimental effect of the tailings, could be installed as part of closure to minimize chemical reactions and ecological effects. To address social stability, the impoundment is left in a configuration that is aesthetically acceptable to the public. This might entail things like regrading and revegetating in a manner that makes the impoundment appear natural or be suitable for repurposing.

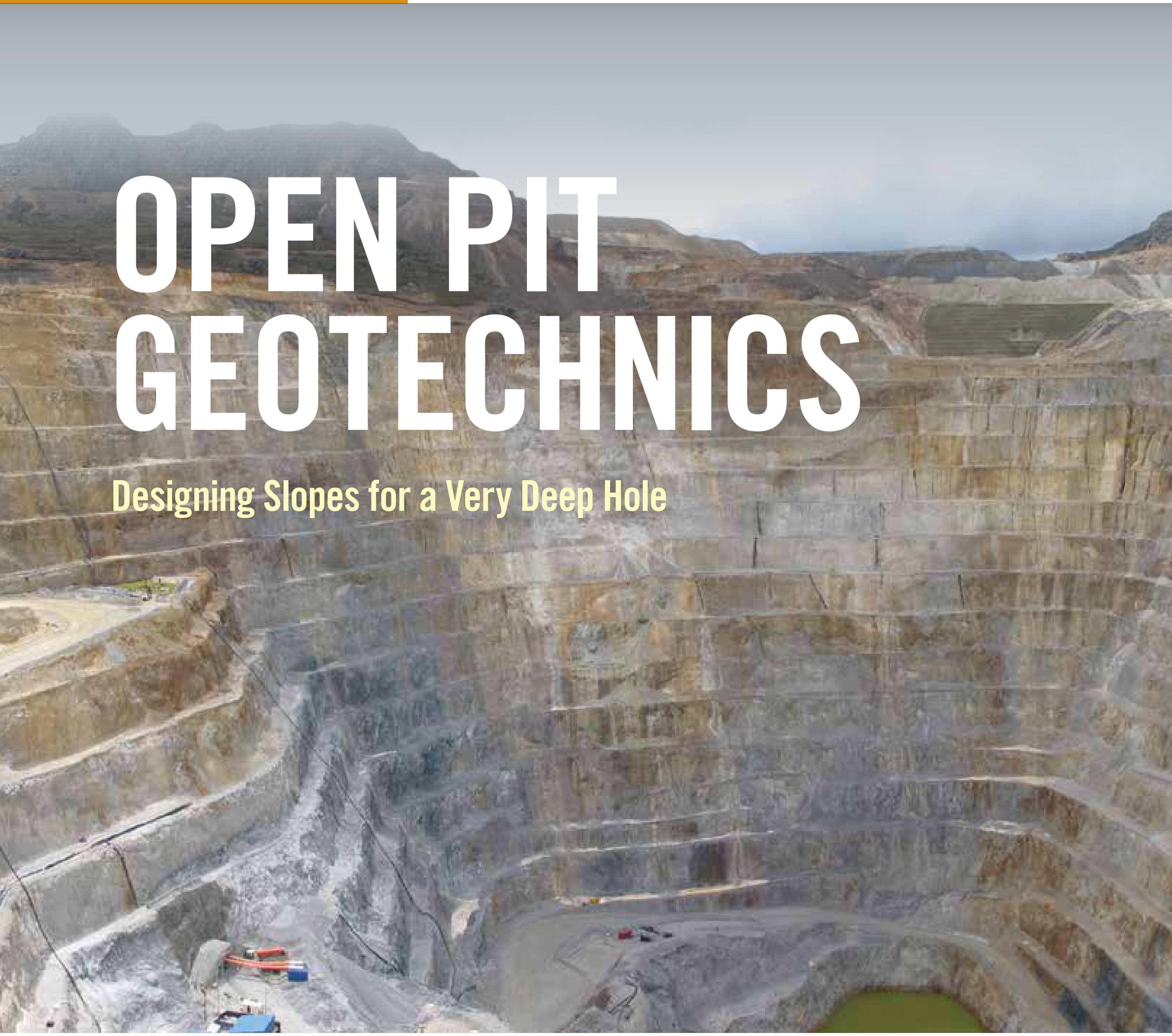
Applying the landform concept as a closure goal is a way to address the types of risk that tailings impoundments pose to the public. It's very possible, and in many cases likely, that the structural, chemical, ecologic, and social risks of tailings impoundments cannot be reduced to a level similar to surrounding natural landforms. In these cases, the tailings impoundment cannot be truly closed, and the operator is responsible for continuing management of the unmitigated risks. Although transitioning some existing impoundments into a landform as a closure criterion may be impractical, it should be considered the target criteria for closure when new tailings facilities are being planned.

Closure?

It's important for all stakeholders to remember that although there are many varying views of closure, it's perhaps the public that may be impacted in perpetuity by the presence of the structure after closure. Is it reasonable for the public to expect closure criteria that results in no unnatural safety risk, no unnatural environmental concerns, and no maintenance? Can mine operators be expected to meet closure criteria that are more strict than regulatory requirements — or should they be responsible for post-closure in perpetuity? Can designers be expected to retrofit a landform concept to closure of all existing impoundment without the benefit of integrating landform design into the structure's life? At this time, questions like these need to be considered by all stakeholders so that closure is not only in the eye of the beholder. GS

AARON J. ANTELL, PE, is a principal engineer at D'Appolonia Engineering in Pittsburgh, PA, where he is responsible for management of, and technical guidance on, complex geotechnical and dam projects. He can be contacted at *ajantell@dappolonia.com*.

ROBERT M. SHUSKO, PE, is senior principal engineer and president at D'Appolonia Engineering in Pittsburgh, PA, where he is responsible for overseeing operations, developing new client relationships, and providing technical expertise on multidiscipline projects. He can be contacted at *rmshusko@dappolonia.com*.



OPEN PIT GEOTECHNICS

Designing Slopes for a Very Deep Hole

By Tom Byers, PE, and John Lupo, PhD, PE, M.ASCE

For most hard rock surface mining operations, the development of an open pit is required to extract the ore resource. In designing an open pit, the challenge is to develop the most cost-effective pit slopes that can be mined safely. Pit slope designs can be fairly complex, particularly with many open pit depths exceeding 300 m and the deepest open pits exceeding 1,000 m. The process of developing a safe but optimized pit slope angle is the same regardless of the pit scale; however, the greater stress changes and increased highwall exposures associated with deeper pits tend to correlate with an increased risk of instability.

The development of an open pit project is advanced through a series of planning studies. Evaluated on parallel tracks, these studies ultimately lead to the decision to proceed with mining of a resource. The geotechnical aspect is one of the factors considered; others include resource estimation, mining engineering, ore processing, waste materials storage, environmental considerations, and reclamation. Incorporating these inputs is a complex business task that is further complicated by changing economic conditions and mining-related factors. Considering that some open pits operate for well over 20 years, the challenges and uncertainties involved can be very large.

The Geotechnical Design Process

Beginning with the initial planning phase and continuing through active mining, pit slope design involves an iterative process of rock mass characterization, engineering geologic analysis, and slope performance evaluation. As the understanding of rock mass structure is refined during each phase of

Figure 1. Controls of pit slope designs.

a mine planning study, slope stability analyses are completed, and pit slope designs (i.e., highwall orientation and slope) are optimized. After mining starts, a pit slope design can change in large or small ways, depending on performance of the highwalls. The need for redesign is a function of the completeness/accuracy of the initial characterization work, unanticipated geotechnical conditions, and the mining methods employed.

The goals of the pit slope geotechnical design process are to identify factors that will control slope performance in the rock mass, and to develop appropriate design parameters. As illustrated in Figure 1, the controls are geotechnical in some cases (e.g., structure, rock mass strength), but operational in others.

The Geotechnical Model

The geotechnical model forms the basis of the pit slope design process. As indicated in Figure 2, the geotechnical model does not rely on a single type of input. Rather, the model is a collection of information that describes the conditions in which an open pit will be mined. Of course the components and detail of the model will vary depending on site conditions.

Some of these components are data or work products generated by other functions. For example, three-dimensional geological shapes for material types and large-scale structural features are typically generated during geological modeling of a potential resource. In addition, geotechnical core logging data may be available from geological drilling programs. However, even with these types of information, targeted characterization is often required to address specific pit slope design issues. In most cases, these needs are met through a combination of core drilling with associated data collection, structure mapping, and laboratory testing.

Characterization Priorities in Hard Rock Open Pits

The behavior of a fractured rock mass exposed in an open pit is a function of rock mass shear strength and rock structure. Therefore, much of the characterization effort to support pit slope design involves soil and rock mass properties, and rock structure.

Rock characterization work to support pit slope designs is often conducted in phases, with each phase of data acquisition designed to address risks or data gaps considered to be "significant" to that phase of the pit design. For example, test drilling and coring is performed to identify rock structure and strata. If potentially adverse jointing or faulting is identified, such features would become geotechnical characterization priorities. This outcome would lead to further drilling and additional testing and analysis to understand location, orientation, and shear strength properties of the potentially adverse structural features.

Characterization work consumes time and capital, and uncertainties are inevitable. Therefore, a question that must be asked continually during the design process is, "When is there enough detail in the geotechnical model to support the design?" Stakeholders responsible for answering this question must be in agreement on potential slope stability issues, uncertainties and data gaps in the geotechnical model, risk exposure, and slope-design acceptance criteria.

The conversation of risk with regard to the uncertainties in the geotechnical model is one of the most important steps in pit slope design process. As with the process overall, risk-based discussions do not end with pre-mining studies, but extend through the period of active mining, and even into closure.

Rock Structure Characterization

Pit slope designs call for a broad view of the structural geology that includes the surrounding waste rock, as well as the structural controls of mineralization. Structure characterizations start with structural domains, which are subdivisions of the pit-area rock mass in which unique rock structure conditions exist. Within each domain, the characterization is typically developed at two levels:

- Large-scale structures (faults, folds, contacts)
- Structural fabric (bedding planes, joints)

Larger-scale rock structures may impact the stability of larger-scale slopes, but the influence of smaller-scale rock structures is more likely to be limited to bench- and multiple bench-scale slopes. Characterizations for both include discontinuity orientation, persistence, spacing, and shear strength parameters. Within sets of parallel structures, these parameters are random variables, so characterizations may also include probability distribution types and associated statistical parameters. From an engineering perspective, distinctions between "larger-scale" and "smaller-scale" structures relate to continuity, spacing, and shear strength. For example, compared to smaller-scale structures, faults are usually more continuous, widely-spaced, and lower-strength.

The characterization approach is left to the discretion of the pit slope designer and depends on the type and amount of available data, the type of analyses that will be completed, and the relative experience of the designer. Approaches may include some or all of the following examples:

- Discrete structures with orientations and locations defined in 3D can be used for limit equilibrium or numerical analyses that assess the potential for these structures to affect stability at specific locations within a pit.
- A data set that is representative of smaller-scale structure in a rock mass can be used for kinematic analyses without necessarily knowing the exact locations of these structures in 3D. In the most basic approach with this method, the data set is reduced to a series of orientations based on well-defined concentrations of structures within the data set. These orientations can be used as input into a basic deterministic kinematic analysis. As an extension of this approach, concentrations of structures can be described statistically to define the variability of characterization parameters. This type of characterization could be used for deterministic or probabilistic kinematic analyses.
- Unfiltered data can be used for certain types of probabilistic kinematic analyses. With this approach, stability is analyzed for each individual structure; results are compiled to express probability of failure that a data set presents for a given slope design.

Material and Rock Mass Properties

A fractured rock mass consists of intact blocks bounded by fractures. The shear strength and deformation characteristics of the rock mass are affected by the nature of the rock structure. Intact rock properties can be measured directly through standard laboratory tests. However, compared to these tests, direct measurement of the shear strength of fractured rock masses is difficult and costly. In part, this relates to technical

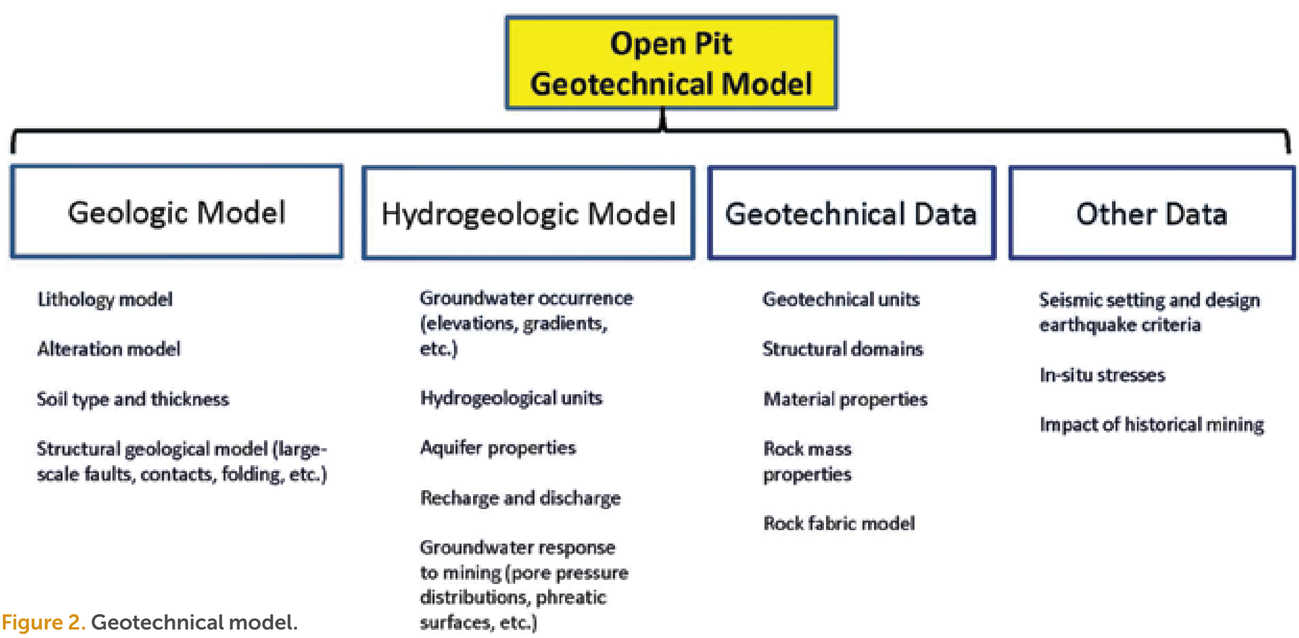


Figure 2. Geotechnical model.

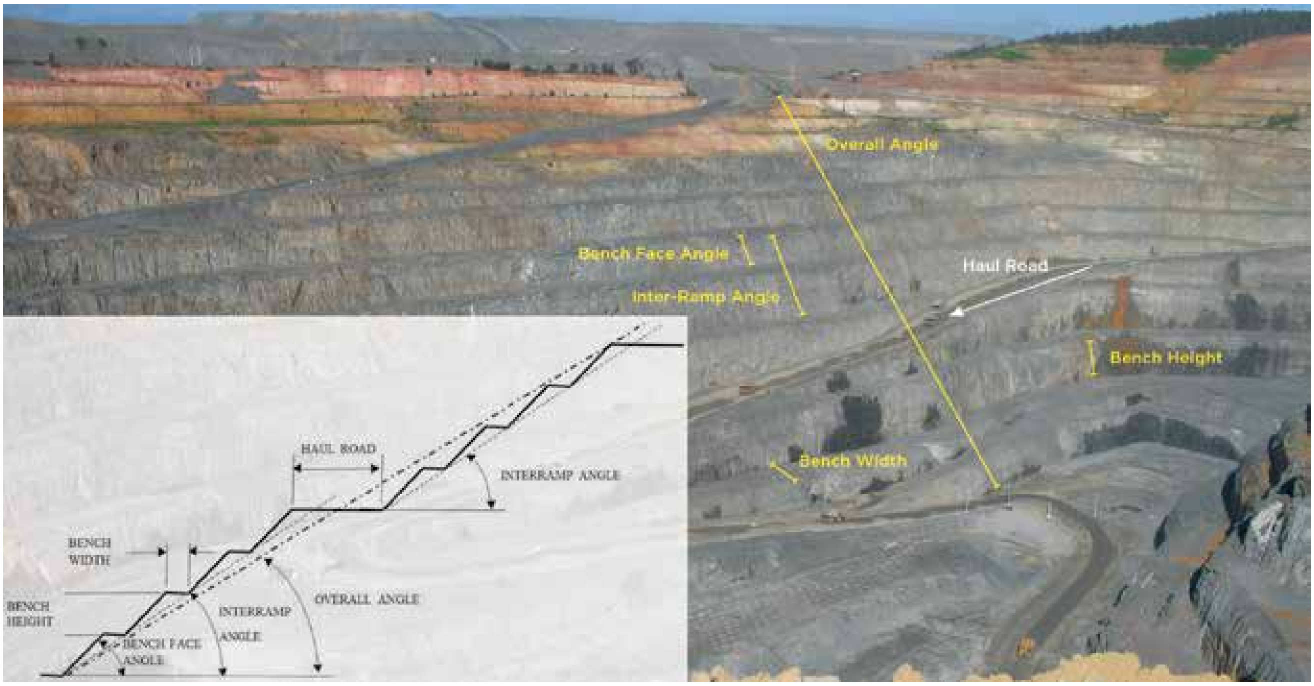


Figure 3. Pit slope design parameters.

challenges involved in obtaining representative, "undisturbed" samples for laboratory testing. However, there are few laboratories that are capable of testing such samples, and safety and technical challenges often complicate or preclude in-situ testing.

As an alternative to direct measurement of rock mass strength and deformation properties, empirical methods have been developed for obtaining estimates of jointed rock mass strength (e.g., Hoek-Brown criterion). These methods require both material property and rock mass property inputs. Material properties that are needed to define rock mass shear strength typically include the following, all of which can be measured directly through standard laboratory tests:

- Unconfined compressive strength (UCS)
- Unconfined tensile strength (UTS)
- Discontinuity shear strength
- Elastic properties (modulus of elasticity, Poisson's ratio)
- Triaxial compressive strength properties

Other information may be required to address specific conditions or deformation mechanisms. Examples include shear modulus, joint stiffness, and shear strength of intact ("healed") discontinuities.

Rock mass property data are usually based on geotechnical core logging parameters, or equivalent parameters assigned through mapping. Perhaps the most commonly used parameters are:

- Rock Quality Designation (RQD)
- Rock Mass Rating (RMR) or Geological Strength Index (GSI)

RQD is a standard geotechnical core logging parameter that has also been adapted to surface mapping via scan lines. The original definition of RQD reflects a modified measurement of recovery, which considers only lengths of "sound rock" 4 in. or greater, measured along the core axis.

RMR accounts for a greater range of conditions than RQD. It is calculated from a group of geotechnical core logging parameters that includes RQD, intact strength, fracture spacing, and joint condition rating. These parameters can be assigned during geotechnical core logging, or mapping of exposures. GSI was designed to be equivalent to RMR, but with fewer quantitative inputs so that ratings can be assigned directly during core logging or mapping.

Material properties and rock mass quality parameters are random variables. Therefore, it is important for characterizations to include probability density functions and associated basic statistical parameters.

Putting it All Together

The nature of developing the geotechnical model ensures the collection and characterization of rock mass conditions that lead to the optimization of pit slope design. In particular, a well-conceived model should provide for:

- Identification of potential controls of pit slope performance and stability
- Input values and/or data sets for use in stability analyses
- Framework for engineering analyses (e.g., distributions of material types in slope stability models)

Slope stability analyses are used to develop pit slope design inputs from the conditions represented in the geotechnical model. Mine planners usually require a framework of design sectors and geometric parameters for each sector. However, pit slope design inputs can also include such details as limiting slope heights, depressurization requirements, surface-water controls, ramp routing, requirements for geotechnical benches, and restrictions on highwall geometry (e.g., elimination of convex geometry). Figure 3 shows typical geometric parameters; and Figure 4 shows an example of design sectors that account for changes in geotechnical conditions across a pit area.

Given some basic design information such as the height of bench slopes and the overall shape of the excavation, pit slope design analyses can proceed. These analyses can be divided into three categories based on scale.

Bench configurations — Bench geometries are defined in terms of achievable bench face angle, vertical separation between catch benches, and bench widths sized to provide sufficient rockfall catchment. Design bench face angles are derived based on bench-scale structural controls, which are evaluated with kinematic analyses of planar, wedge, and toppling failure modes. If strong structural controls are not indicated in the data for a particular area of the pit, bench face angles must be estimated, given the blasting and excavation practices that are expected.

The definition of design bench widths and vertical separation between catch benches requires both interpretation of the rock mass performance (e.g., geotechnical model) and experience. Before mining, defining vertical separation usually involves a decision between single- and double-bench configurations (i.e., two production bench heights between catch benches). Stacking more than two production benches between catch benches is often possible, but requires an optimistic assumption prior to mining. Realistically, developing these more aggressive bench configurations is better left as an optimization

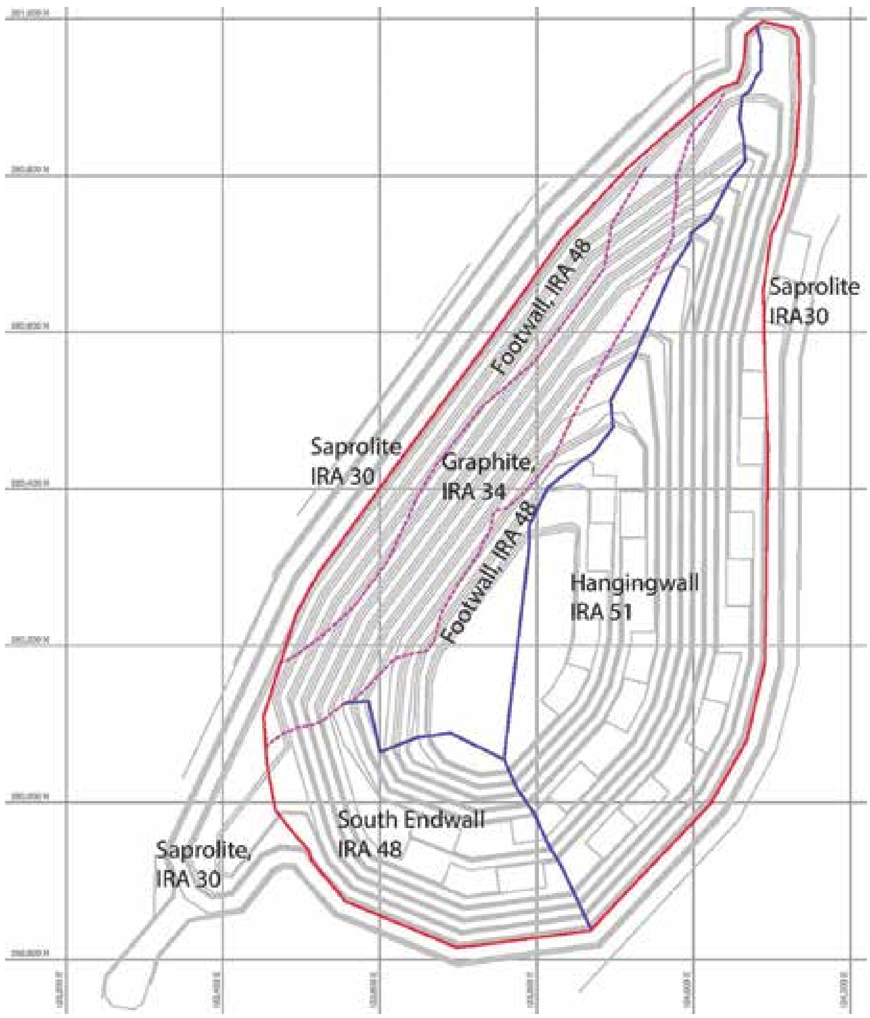


Figure 4. Pit slope design example.

exercise after the start of mining. Methods that are applied to determine bench widths include:

- An empirical relationship between vertical separation and bench width, known as the Modified Ritchie criterion
- Kinematic methods that estimate backbreak and debris volume generation from rock fabric populations; bench widths are predicated on providing adequate catchment to retain a debris volume generated with a specified probability of failure
- Rockfall modeling
- Benchmarking
- After the start of mining, observations/rockfall experience

Inter-ramp and overall slope stability — Compared to bench-scale slopes, higher slopes involve considerations of higher stresses, more continuous structures, potential groundwater impacts, and greater variability of material types. Analysis methods used to evaluate stability of these slopes depend on geological/structural complexities, but often involve a combination of kinematic analyses, limit-equilibrium methods, and numerical models to evaluate potential structural and rock mass controls.

Analysis of larger-scale slopes — |These analyses can lead to design details that go beyond the basic relationship between bench configuration and inter-ramp angle. Whether to address a specific condition (e.g., non-daylighting fault just behind a slope), or basic risk reduction, "geotechnical benches" can be used to effectively break up a long, continuous slope exposure, as well as provide a stabilizing effect. Haulage ramps are sized by mine planners according to equipment size, and located based on mining sequence. However, ramps can also be strategically located to function as geotechnical benches. Design details such as this require close work with mine planners to optimize the design while enhancing slope stability.

Does This Really Work?

The pit slope design process is applied in a unique way for each project, but it is widely accepted as an essential part of planning and developing open pit mines. The fundamentals of the process are fixed, meaning that there will always be a need for a geotechnical model, and analyses to translate that model into design inputs. However, some aspects of the process continually evolve, such as characterization and analysis methods, and risk tolerance when it comes to uncertainties in a geotechnical model.

The process is a forum for geology, geotechnics, and mining engineering to intersect. It *does* work because pit slopes designed to conditions that exist in the field generally perform to expectations. Still, slope instabilities occur, and some require modifications to provide for safe working conditions, and designs that can actually be achieved. Common reasons instabilities occur include:

- Actual conditions encountered in the field differ locally from the model. Examples include unexpected faults, groundwater pressures, or material type distributions. It is important to identify deviations, and make decisions about whether they justify slope design changes. This can keep a design consistent with actual conditions, and reduce the potential for small problems to turn into larger problems.

- Poor operational execution, such as excessive blast damage, poor surface water control, or over-digging bench faces. This gets to the "match" between mining methods and geotechnical conditions. For a given set of conditions, possible slope performance results can range from, "This is a disaster!" to "Slopes could actually be steeper!" The range can be narrow or wide, but mining methods determine where in this range the slope performance lies.
- The design process is not strictly followed, as can occur if a pit design is changed without reviewing pit slope design inputs.
- Some instabilities are a reflection of a risk-based business decision. A "scram" pit is a good example. In a slope that has performed acceptably, the lower benches are sometimes steepened to recover "bonus" mineralization that would otherwise remain in the walls. This involves an intentional deviation from an established design.
- Another risk-based decision involves the cost or time effects of characterization on projects or production. In these cases, it is usually up to the geotechnical professionals to clearly communicate the risks to stakeholders.
- Preconceived ideas, such that potential stability controls that are indicated in a geotechnical model are not recognized as such.

Open pit geotechnical professionals are usually not sound sleepers. Now maybe you understand why!

TOM BYERS, PE, LEG, is a director of geotechnical engineering for Newmont Mining Corporation in Denver, CO, and has 28 years of experience in mining geotechnics. He can be reached at *thomas.byers@newmont.com*.

JOHN F. LUPO, PhD, PE, M.ASCE, is senior director of geotechnical engineering for Newmont Mining Corporation in Denver, CO. He has over 30 years of experience in mining geotechnics. He can be reached at *john.lupo@newmont.com.*

MAY/JUNE 2017 | MINING GEOTECHNICS

Figure 1. Typical field leach pad.

WHERE GEOSYNTHETICS MEET MINING GEOTECHNICS

Part of the Mining Engineer's Toolbox

By John F. Lupo, PhD, PE, M.ASCE

From enhancing stability to providing environmental containment, geosynthetic materials play an important role in mining projects and geotechnics in general. While often overlooked, advancements in geosynthetic materials over the last several years have improved the performance and reliability of engineered facilities at operating mines. These improvements have been focused mostly on heap leach pads (HLPs), tailings storage facilities (TSFs), overburden storage facilities (OSFs), and water management structures.

What Are Heap Leach Pads?

Heap leach pads (Figure 1) are lined facilities where ore is placed and then leached with a solution. The leach solution liberates precious metals, base metals, and other compounds from the ore. The leach solution is then collected and sent to a process plant for further processing.

While the basic concept of an HLP is relatively simple, their actual design and operation is a complex balance of leach solution hydraulics, ore heap geochemistry, geotechnical stability, and ore production scheduling. As illustrated in the Figure 2 schematic, a number of geosynthetic materials may be used within a heap leach pad, each of which must be carefully selected to achieve a desired outcome.

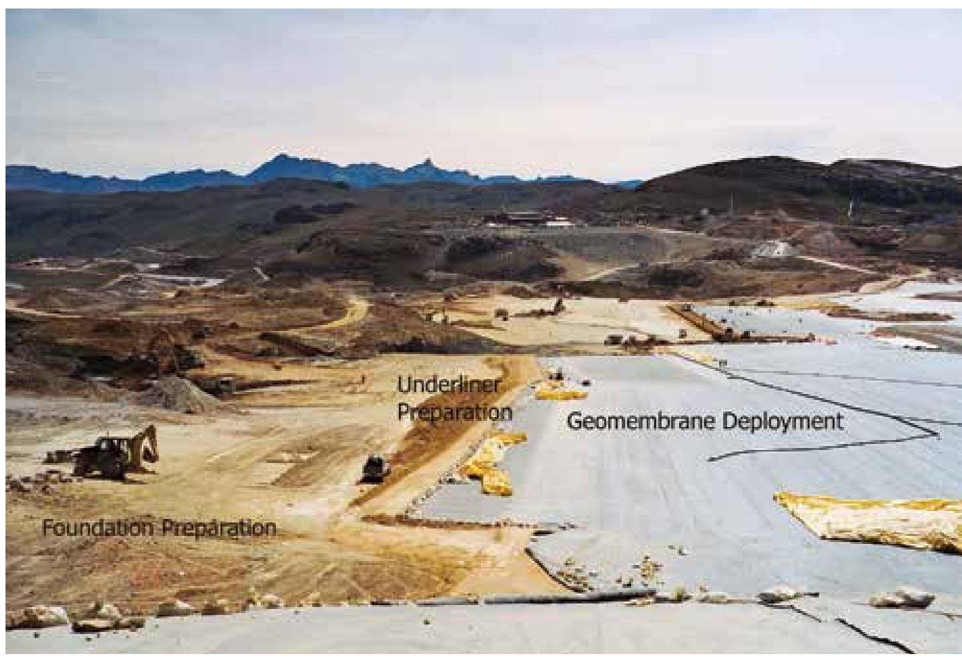


Figure 2. **Geosynthetics placed at the base of an FLP.**

Starting at the base of the facility, a geomembrane (GM) composed of high-density polyethylene (HDPE), linear low-density polyethylene (LLDPE), polyvinyl chloride (PVC), or reinforced polyethylene (RPE) is placed to provide a physical barrier for containment of leach solutions. Typically, the GM thickness for a leach pad ranges from 1.5 to 2.0 mm thick, depending on the ultimate ore stack height and foundation conditions. In some instances, a geosynthetic clay liner (GCL) may be incorporated beneath the GM to augment solution containment. Geogrids may also be placed beneath the GM to mitigate differential settlements.

Within the leach pad, the GM is overlain by a drainage layer that often consists of perforated polyethylene (PE) collection pipes embedded in a drainage gravel or sand. As the name implies, the function of the drainage layer is to intercept and route leach solution for collection. The design of this layer is not a trivial manner.

Figure 3. **Typical tailings storage facility.**

The drainage layer must not only collect leach solution, but it governs the hydraulic head that may develop in the ore heap, which, in turn, influences stability of the ore on the pad. In some heaps, a geotextile may be added over the GM to protect the liner from the potentially high ore loads. Modern heap leach pads can have ultimate ore stacks in excess of 200 m, exerting a normal load in excess of 4 MPa onto the GM liner and drainage layer. For this part of the HLP design, specialized high-load compression tests are conducted on the liner system and drainage layer components to assess strain and yielding under the anticipated loading conditions.

Physical stability and solution containment/recovery are key design issues for a heap leach facility. While the GM provides a physical barrier for solution containment, the stability of the ore heap is closely tied to the interface shear strength between the GM and the materials below and above the GM (which may or may not include other geosynthetics). As part of the design process, numerous interface shear tests are conducted between various interfaces that comprise the liner system and drainage layer (Figure 2). The results of these tests affect the leach pad design and serve as input for the stability analyses.

What Are Tailings Storage Facilities?

A typical TSF (Figure 3) contains the byproducts generated from mechanical and chemical processing of ore. Once ore is processed, the unrecoverable and uneconomic metals, minerals, chemicals, organics, and process water are discharged, normally as slurry into the TSF.

Similar to a water storage dam, TSFs are typically formed by constructing one or more embankments to form a storage basin for containment of tailings slurry. Depending on the site conditions and characteristics of the tailings, the TSF design may include the use of geosynthetic materials, such as GMs and geotextiles. To meet design and performance requirements, GMs may be used to partially or fully line the facility. Both GMs and geotextiles may also be placed on slopes within and outside of the TSF to mitigate erosion in areas with high rainfall and erosive soils. In some instances, wick drains may be installed in the contained slurry as part of the TSF closure plan to accelerate consolidation of the tailings.

There are five main TSF configurations that are commonly used:

- Cross-valley: A cross-valley TSF is formed by constructing containment embankments across a natural valley or drainage. The natural topography, combined with the containment embankments, forms the primary tailings storage basin.

- Paddock: A paddock TSF (often referred to as a Cell TSF, a Ring Dike TSF, or a Turkey's Nest TSF) is one where containment embankments are constructed around the entire facility. A paddock TSF is generally used in areas that are very flat and have little topographical relief.
- In-Pit Disposal: As the name implies, an in-pit TSF is one where tailings are deposited into an inactive open pit.
- Dry Stacking: Dry stacking refers to placement of dry cake (filtered) tailings in an engineered facility. The tailings are typically filtered to a moisture content that allows them to be stacked, using either a conveyor or a truck/dozer operation.
- Co-mingling: Co-mingled or co-disposal of tailings consists of mixing other materials, such as waste rock, in a single storage area. This approach allows the tailings to be "stacked" by filling in the void spaces within the waste rock or other media.

TSFs are seldom constructed for the life of mine (LOM) tailings upfront. Rather, they are periodically raised over time to provide additional tailings storage. This allows capital expenditures to be deferred until additional storage is needed. The first dam or embankment that is constructed in a TSF is often called the "starter dam."

There are three primary methods to raise TSF embankments (Figure 4):

- Upstream Raise: In an upstream raise, the embankment is constructed over deposited tailings, upstream of the starter dam.
- Centerline Raise: In a centerline raise, the embankment is constructed so that the centerline remains more or less the same as the starter dam. In a modification of a centerline raise, the embankment can be constructed so that the centerline moves upstream or downstream of the starter dam.
- Downstream Raise: In a downstream raise, the embankment is progressively constructed on the downstream end of the starter dam and TSF.

Table 1 summarizes the advantages and disadvantages associated with each of these TSF raise methods.

Given the consequence of failure, the design, construction, and operation of TSFs undergo a high degree of scrutiny, with frequent technical reviews and performance auditing.

Overburden Storage Facilities and Geosynthetics

Overburden storage facilities contain materials (soil and rock) that have been generated as part of mine development, but do not contain ore. The use of geosynthetics in OSFs is generally limited to underdrains that are excavated into the foundation to collect meteoric water infiltrating through the overburden. These drains generally consist of geotextile-lined trenches with perforated PE pipe embedded in a gravel drain. In some cases,

TYPE OF RAISE	ADVANTAGE	DISADVANTAGE
Upstream Raise	• Requires the least amount of earthworks. • Has the smallest footprint compared to the other methods.	• Least seismically stable configuration. • Not designed to have water against the embankment face. • Generally limited to less than 3 m per year rate of rise. • Geometry not conducive for using geosynthetics. • Very sensitive to deposition planning and water management.
Centerline Raise	• Has a smaller footprint than a downstream raise. • Can be designed to have water against the embankment face. • Better seismic stability than upstream method.	• Challenging geometry for implementation of geosynthetics. • Can be susceptible to upstream slope failure, particularly in seismic events.
Downstream Raise	• Provides the greatest amount of seismic stability. • Can be designed as a water-retention structure. • Easily accommodates use of geosynthetics.	• Requires the most amount of earthworks. • Generally requires a greater footprint in comparison to other methods.

Table 1. Advantages and Disadvantages of TSF Raise Methods (adapted from *Planning, Design, and Analysis of Tailings Dams* [Vick, 1990])

a GM (typically a bituminous GM) may be placed on the OSF base to contain seepage from the overburden that may require treatment.

Geosynthetics and Process Water Ponds and Other Water Management Structures

Mining operations often require the creation of several structures that are used for sitewide water management. These structures can include ponds, channels, and spillways. In these applications, geosynthetic materials are commonly included in the design for containment and for erosion control.

Process water ponds are very common in mining operations and may be single- or double-lined, depending on the quality of water to be stored. Single-lined ponds simply have a GM placed over a prepared subgrade, while a double-lined pond will have GMs separated by a leachate collection and removal system (LCRS). Typically, the LCRS is installed by placing a geocomposite, geonet, or drainage gravel layer between the two GMs.

In locations with high rainfall and erodible soils, GMs are incorporated into the construction of surface water channels and spillways for erosion mitigation. GM-lined channels are even used within open pits (Figure 5) to not only control erosion, but to limit infiltration of surface water into the open-pit benches. The use of lined channels within open pits is particularly important where pit slope stability is sensitive to surface water infiltration.

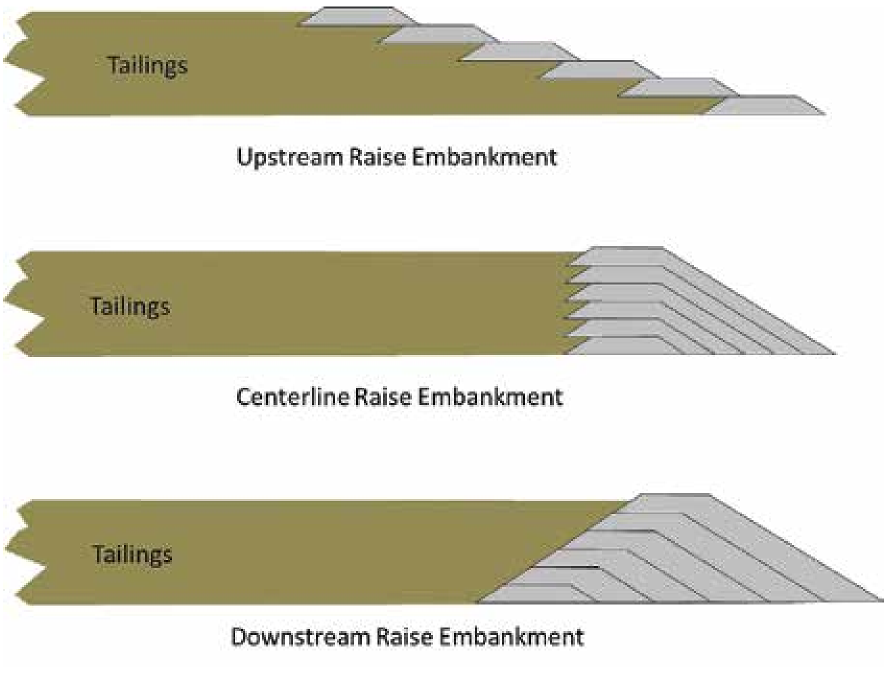


Figure 4. **Primary methods to raise a TSF embankment. (Adapted from Vick, 1990).**

Ground Improvement with Geosynthetics

Geosynthetics are commonly used for ground improvement in civil applications, the requirements of which are essentially the same for the mining environment. Geogrids and geotextiles are generally used to improve load distribution and settlement in haul roads and platforms (for ore stockpiles and HLPs).

Many surface mines are developed in areas that have been previously mined using underground methods. As a result, underground workings or voids may be encountered within the footprint of proposed surface workings. The presence of these voids obviously poses a risk to the operation and related infrastructure. Where possible, infrastructure can be moved to avoid interfering with the underground workings, but at many mine sites this may not be possible. When infrastructure and facilities cannot be moved, the mine voids are remediated using a variety of geosynthetics or a combination of geosynthetics with a structural backfill (cement, cemented rockfill, rockfill, etc.). Figure 6 shows construction of a typical geogrid cap over a backfilled void.

Geosynthetics Underground – The Backfill Barricade

Geosynthetic applications are generally used for surface mining operations, but there are also a few underground applications for geosynthetics. In a specialized application, geotextiles are being used in underground mines as part of the backfilling operation. In operating underground mines, mined voids (e.g., stopes) are often backfilled to provide ground support for the adjacent stope. In some operations, the backfill is "paste" that consists of a mix of silts, sands, fly ash, cement, and other binders. The concept of paste backfill is to provide a material that can fill the mine void with very little "bleed" water. Once the paste backfill cures, it provides structural support for the mine. However, before placement of the paste backfill, a barricade must be constructed to confine the backfill to the stope, otherwise the paste would flow out of the mined void.

The paste backfill barricade is a unique structure that contains the backfill until it has reached an acceptable strength. These barricades typically consist of a wire mesh that is bolted in place to the wall rock of the mine. A geofabric is then attached to the wire mesh, and shotcrete is sprayed over the fabric and mesh

Figure 5. **Geomembrane-lined channels along the benches of an open-pit mine.**

Figure 6. **Construction of a geogrid cap over a backfilled void.**

to form a barricade. The geofabric provides the substrate for bonding the shotcrete that forms the barricade. After the shotcrete has cured, the barricade and stope are ready for backfill placement.

Geosynthetics in Reclamation and Closure Covers

During and at the end of a mine's service life, a number of the facilities, such as TSFs, HLPs, and OSFs, must be reclaimed. A cover is constructed as part of the reclamation requirements for these facilities to:

- Limit oxygen ingress that may result in the oxidation of sulfidic minerals and generation of acid rock drainage
- Limit the infiltration of meteoric water and the generation of acid rock drainage
- Promote revegetation and mitigate erosion

While many reclamation and closure covers are designed and constructed using native soil and rock materials, geosynthetics are often used when limited, suitable, on-site cover materials are available. Geosynthetic materials provide reliability in the performance of the cover because the properties of these manufactured products are well controlled.

For reclamation and closure covers, GMs, geotextiles, geonets, GCLs, and geocells may be used to achieve a desired cover performance. For example, GMs and GCLs may be employed to mitigate seepage, while geotextiles and geonets may be used in the cover design to intercept and route seepage for collection. In steep sections of a cover, geocells may be used to mitigate cover erosion and promote revegetation.

Cover designs that incorporate geosynthetics need to consider stability, particularly planar failures along the geosynthetic interfaces. Covers tend to be relatively thin (a few meters), so the effective stress along the interfaces with the geosynthetics can be quite low, which results in a low shear strength. The low shear strength can be compounded if the cover has poor drainage. Therefore, the focus should be on shaping the cover to promote drainage (surface water and cover seepage) and stability.

What's Next?

For the foreseeable future, geosynthetic materials will continue to play an important role in the mining industry. Geosynthetic materials provide a distinct advantage over natural materials by providing uniform and reliable drainage, permeability, and ground support, which are key design and performance attributes for engineered facilities at mining operations.

While geosynthetic materials can provide desirable benefits, the materials must be installed correctly with sufficient Quality Control (QC) and Quality Assurance (QA) oversight, recognizing that the vast majority of defects in geosynthetic materials are introduced during construction. A well-planned and executed QC and QA program is a critical component to ensuring that the anticipated geosynthetic material properties are being achieved in the constructed facility. GS

JOHN F. LUPO, PhD, PE, M.ASCE, is senior director of geotechnical engineering for Newmont Mining Corporation in Denver, CO. He has over 30 years of experience in mining geotechnics. Contact him at *john.lupo@newmont.com*.

MAY/JUNE 2017 | MINING GEOTECHNICS

Redevelopment of Aggregate and Rock Quarries

No Longer Just a Hole in the Ground

By Haze M. Rodgers, PE, GE, M.ASCE

Figure 1. Vertical rock cut in a marble quarry.

Redevelopment of former sand and gravel (aggregate) and rock quarries can be challenging, often requiring developers, quarry operators, planners, and engineers to work in tandem. As urban and suburban developments encroach into rural and agricultural areas, redevelopment of former quarries is becoming increasingly attractive. Driven by the price of land, former quarries can be much less costly than non-quarried sites; however, a significant amount of engineering evaluation and potentially costly remedial mitigation is typically needed to successfully redevelop these sites and manage construction development risks.

Geological and geotechnical studies of former and existing quarries typically include historical research, field mapping, subsurface exploration, and laboratory testing. These studies are generally focused on identifying, locating, and characterizing problematic conditions, which are often the result of previous mining and reclamation activities. Various soil improvements and mitigation of the problematic conditions are required in order to successfully redevelop former quarries.

Making the Hole

Most sand and gravel quarries are excavated vertically (Figure 1), and rock quarries are generally excavated into the sides of hills or mountains. Activities associated with both types of quarries generally result in conditions that can be challenging for redevelopment, including:

- Waste products (overburden soil, spoils, and processing waste sludge or slurry)
- Surface and groundwater control
- Subsurface conditions
- Slope stability (internal and side slopes)

In addition, many quarries are located in areas that were previously undeveloped or used

Figure 2. Water-filled quarry.

Figure 3. An internal mine slope with tension cracks and surficial raveling of the slope face.

primarily for agricultural purposes. Typically, the permitted reclamation plans require quarries to be returned to their former land use prior to mining (agricultural or open space). The level of construction care (compaction, fill quality, etc.) and engineering required to reconstruct conditions suitable for agricultural or open space is generally much less than required for construction of roads and buildings. Agricultural and open space land uses and the improvements associated with them are generally more tolerable of long-term settlement, effects of expansive soil, and low bearing capacities.

Waste Products

Removing and processing aggregates and rock generates waste products. Typical types of waste include overburden soil (including top soil), fine-grained sediments and byproducts like clays, silts, fine sand, and rock flower, and water. Water is specifically generated as a waste product, as it is used in the processing and removal of the targeted materials, resulting in a slurry or sludge. Controlling waste can be a significant undertaking, and a large portion of a quarry can be dedicated to the processing and/or storage of the waste. It's common for the locations and sizes of the waste control features to be modified and/or relocated.

Overburden soil is generally stripped and stockpiled for later reuse to construct roadways, waste control pond embankments, etc. Unless required, the engineering properties of the overburden soil are seldom evaluated, and the placement and compaction of the material is often not well documented.

Most liquid waste products are stored and processed in ponds. These ponds serve the functions of storm water retention, waste sludge/slurry storage, wash water retention and processing, and drying beds. In some larger quarries, drying beds and evaporation ponds are created in previously mined areas for processing waste slurries/sludge and sediments. The engineering criteria and level of design varies depending upon the permit requirements, size, and location of the ponds. Ponds located completely within a mine are typically not designed using the same criteria or level of design as those where embankment failure can impact public safety, natural resources (streams, rivers, habitat), or adjacent properties. In general, the earthen embankments of most large ponds are well designed, engineered, and evaluated.

The materials left behind in the ponds can pose significant challenges for mine redevelopment down the road. Typically, the ponds contain saturated, under-consolidated sediments, slurries, and sludge, and many are partially or completely filled with water. Depending on the type of mining being performed,

Understanding the subsurface conditions and the potential variation of subsurface conditions in former quarries is often the most challenging task for redevelopment.

the engineering characteristics of these sediments can be unusual and the materials modified from their natural states. In many aggregate mines, these sediments are generally fine-grained clays and silts, and very-fine sands. In hard rock mines, the sediments may be saturated rock flower or pulverized/crushed rock. When evaluating the behavior and feasible mitigation methods for these materials, additional field and laboratory testing may be appropriate to properly predict the long-term performance of the material.

In other types of mines, such as those that unearth limestone, precious stone and metals, or tar sand, the waste products are significantly altered from their natural states by processing (superheating, washing, emulsifying, grinding, etc.). The engineering characteristics of these altered waste products can be significantly different from the original natural material. There are also significant environmental concerns (toxicity, solubility, chemical reactivity, etc.) that must be considered when working with these special waste products. Redevelopment of these types of mines would be unusual and therefore is not discussed further.

Surface and Groundwater Control

The presence of groundwater (or storm water run-off into lower elevations) can be a significant factor in any activity involving excavation or construction. With respect to aggregate and rock quarries, groundwater can be depressed significantly during mining, and then allowed to rise upon completion of mining. In quarries with shallow groundwater tables, drag line methods are often used so that dewatering is not required. Many sand and gravel mines are located near existing waterways, and in some instances, can be hydraulically connected; therefore, seepage through the side slopes or up from the mine bottom can become an issue. Once mining is completed, the low areas of many former quarries are allowed to fill with water (Figure 2) and are reclaimed as reservoirs for water storage or recreational uses.

The presence of water and depth of the quarry can create practical challenges for documenting and evaluating submerged areas. Access to the water and depth of the submerged portions can prevent the use of routine exploration and surveying methods that might ordinarily be used to evaluate or document the quarries conditions.

Subsurface Conditions

As mining progresses, the features of the quarries change. It's common to construct temporary cuts and fills, ponds (retention, water, waste, etc.), and other features. Compounding this issue, construction of these temporary features is seldom observed, tested, designed, or surveyed. Further, some features may not be fully removed, filled, or reworked. Ponds and low spots are generally filled in an uncontrolled manner using excess material like soil, rock, or debris. The material and quality of the fill can vary and may contain debris (organic and inorganic), with little consideration for long-term performance of the filled areas.

Slope Stability

Aggregate and rock mining creates slopes. Because the primary goal of mining is to remove as much material as quickly and efficiently as possible, mine slopes are generally cut as steep as possible. A steep slope along the quarry's boundaries or a large, pond embankment slope is usually engineered when excavated in locations that expose the public or adjacent improvements to risks. Internal slopes, however, are generally not engineered since they are considered temporary, and many are vertical to near vertical (Figure 3). Depending upon the permit requirements, embankments for internal ponds may or may not be engineered at all. The level of engineering and construction practices for mine slopes is usually based on the tolerance for minor slope instability, such as rock falls, deformations, and erosion.

Exploring and Finding the Holes

Understanding the subsurface conditions and the potential variation of subsurface conditions in former quarries is often the most challenging task for redevelopment. As already discussed, mining tends to cause changes in temporary features like access ramps, fills, and ponds, which are built and then removed in short periods of time. The interim configurations and conditions of a quarry are often much different than the final results. The actual locations of temporary structures may not be documented by surveys or photographs.

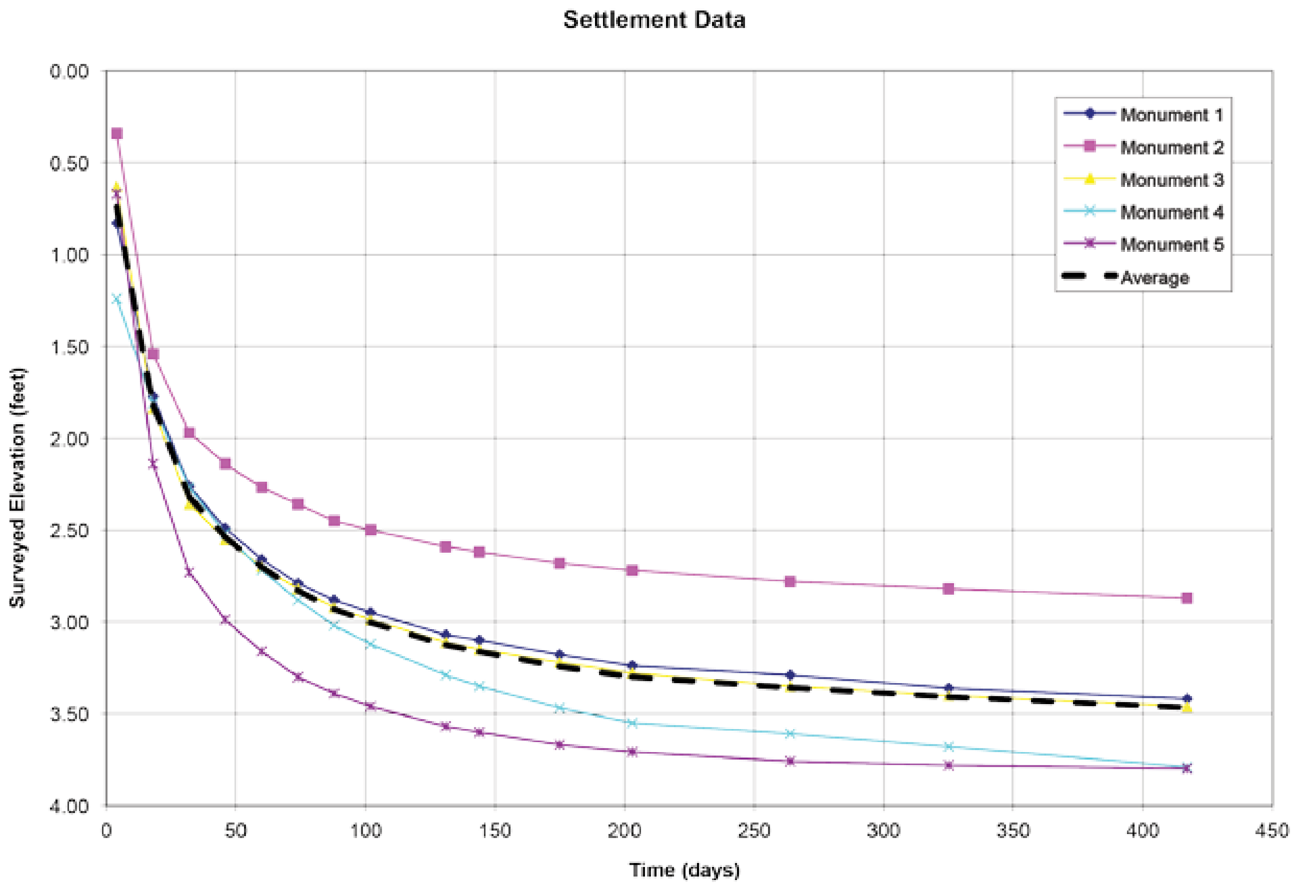


Figure 4. Measured settlement of a former sedimentation pond due to 10 ft of soil surcharge.

Geotechnical and geological studies are often performed in multiple phases. The initial phase typically focuses on locating areas of concern, such as former ponds and undocumented fills. This begins by reviewing historical documents, including aerial photographs and mine operation documentation (interim condition surveys, photographs, etc.). Another valuable resource can be interviews with mine employees. Remote surveying technologies such as drone and Lidar are becoming more common to track and document interim mine conditions that can be compared to identify locations that may be of interest.

Following review of existing information, field mapping is often performed to correlate and map the actual conditions of the mines. The team may conduct preliminary subsurface exploration to supplement visual observations and mapping. Once the location and sizes of features of interest (ponds, undocumented fills, over-steepened slopes) have been determined, subsurface explorations involving test pits and borings should be performed. Samples of the materials encountered are collected and tested to evaluate their engineering properties. It's important to remember that, regardless of the number of borings drilled or test pits excavated, these are relatively small exploration points, and variations in the conditions can change over short distances.

In addition to traditional borings and test pits, geophysical survey methods can be used to supplement the information that is collected. Geophysical methods can be helpful in evaluating the horizontal limits of mined areas, depths of filled ponds, presence of subsurface voids, and other challenging features that are difficult and expensive to evaluate with intrusive methods. Geophysical methods can be performed over large areas relatively quickly, and for relatively low cost.

Engineering Solutions and Mitigation

Multiple approaches and techniques may be required on a single site, and in some cases, a combination of various mitigation techniques may be required. The most appropriate solution will depend upon many factors, including the subsurface conditions, engineering properties of the material to be mitigated, type, weight, and desired performance of the proposed improvements, project schedule, and of course, cost.

Soft Pond Sediments, Slurries, and Sludge

Mitigating soft pond sediments depends upon factors like sediment thickness, engineering properties, desired long-term performance, amount of material, cost, schedule, and available space. Often, the material can be over-excavated, moisture conditioned, and recompacted; alternatively, pre-fabricated vertical drains (wick drains) can be installed. Wick drains have been used to pre-consolidate compressible soil deposits throughout the world, and many quarries use wick drains to increase volume and extend the life of their sedimentation ponds. To create space in existing sedimentation ponds, a surcharge is generally not necessary; however, a surcharge is required to induce the necessary amount of pre-construction settlement to allow for permanent surface construction.

Many sedimentation ponds have a thin crust of desiccated material formed during dry periods. This crust is generally too thin to support the construction equipment used to install wick drains and/or place the surcharge. The maximum height of a surcharge is usually limited by the strength of the sediments, often requiring phased surcharge applications. Settlement of pond sediments can occur quickly and may be significant (30 percent or more of the sediment thickness). Such large settlements may damage or kink the wick drains, which reduces or prevents drainage through the drains.

The inclination of internal pond slopes needs careful consideration for improvements located near or crossing pond edges, such as roadways and utilities. Steep pond slopes can cause significant differential settlement over short horizontal distances, as can be seen in settlement data collected from monitoring points spread across a slope/pond interface (Figure 4). Even with effective pre-consolidation, long-term secondary compression settlements may be large, variable, and difficult to predict. For these and other reasons, structures over pre-consolidated sediments are generally limited to relatively light, single story structures or parking and storage lots.

Undocumented Fill

Undocumented fill can be removed and recompacted, densified, or chemically treated to improve the soil to support new improvements. If fills are generally shallow, removal and replacement is usually the most economical technique; however, most fills placed in aggregate mines are thicker than a few feet, making removal and recompaction expensive and undesirable.

If the undocumented fill is composed of granular material, it may be possible to densify the material using techniques like dynamic compaction and vibroflotation, or by using chemical or permeation grouting. The presence of debris and groundwater, material characteristics, and proximity to adjacent vibration-sensitive structures must be considered when evaluating densification techniques.

Improvement of Slope-Related Issues

Generally, the most efficient means of improving the stability of mine slopes is to re-grade them to more stable inclinations or construct a stabilization buttress or retaining wall at the toes. For sites with limited space, stabilization systems such as piles, soil nails, or tiebacks may be more appropriate. In hard rock mines, rock bolts and catchment fences are often used to increase stability of the slopes.

Storm Water Control

Typically, the soil remaining in mines and used for development and reclamation generally consists of waste materials or highly overconsolidated, fine-grained soil. These materials tend to have a low permeability and infiltration rate. The implementation of low-impact design features such as bioswales, permeable pavements, and storm water infiltration ponds can be challenging. Storm water infiltration features may require under-drainage, gravel layers, or dry wells of sufficient size for temporary storage of storm water during storm events.

Foundation Support and Systems

Conventional shallow foundations sometimes can be used for new structures; however, in many cases, due to the presence of compressible materials, undocumented fill, or to manage risk, stiffened shallow foundations (grade beams, waffles slabs, mats, and post-tensioned slabs) or deep foundations are necessary. Deep foundations include driven drilled piles, drilled piers, displacement columns, auger cast piles, or other specialty systems. The evaluation criteria and process used to select appropriate foundation system at non-mine sites are typically used in the selection of the appropriate foundation for redeveloped mines. These include desired settlement performance, anticipated foundation bearing pressures, seismic hazards, development configuration (improvement locations), economics, and tolerable risk. Many times, it's appropriate to use multiple solutions in combination, such as pre-consolidation, reinforced earth pads, and stiffened shallow foundation systems or deep foundations.

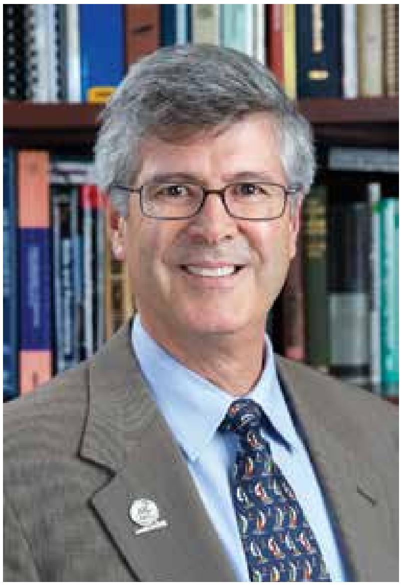
Filling the Holes

As urban and suburban development continues to encroach on former and existing aggregate and rock mines, the redevelopment and re-use of these properties will only increase. An understanding of the history of a quarry, and early coordination between redevelopment planning with the quarry operations, can help reduce the cost of redevelopment. The challenges of these projects provide opportunities for creative use of traditional and emerging exploratory, mitigation, and construction techniques. GS

HAZE M. RODGERS, PE, GE, M.ASCE, is an associate engineer with Langan Engineering & Environmental Services in Rancho Cordova, CA. His projects involve dynamic and static soil-structure interaction, ground improvement, slope stability, foundation, and settlement evaluations. He can be contacted at *hrodgers@langan.com*.

Look Who's a D.GE

Jose N. Gómez S., MSc, PE, D.GE, F.ASCE



JOSE N. GÓMEZ S.

Jose N. Gómez, S. is vice president/senior principal geotechnical engineer and director of geotechnical services for ECS Florida, LLC. After graduating in 1980 from Javeriana University in Bogotá D.C., Colombia, with a civil engineering degree, he came to the U.S. to learn English and pursue higher education in the field of civil engineering. Gómez earned a master of science degree with emphasis in geotechnical engineering from the Georgia Institute of Technology in 1983. Returning to his native country, he worked for Ingetec S.A. until 1992 and then for C.I.C. Consultores S.A.S. until 2008. During this time, he combined professional activities with educational practice as an adjunct professor in the geotechnical field for undergraduate and graduate courses in his alma mater university for almost 20 years.

In September 2008, Gómez returned to the U.S. to run the Virginia Beach, VA branch office of ECS Mid-Atlantic, LLC. While in the Hampton Roads area, he served as an adjunct lecturer at Old Dominion University. In 2013, he transferred to ECS Florida, LLC as the senior principal geotechnical engineer for special projects before becoming the director of geotechnical services within the Florida region and overseas. Although based at the West Palm Beach, FL, branch office of ECS, Gómez is focused on providing consulting to large and complex projects in the marine ports, heavy industrial, commercial and transportation sectors.

What class did you enjoy the most while in school?

I am a geotechnical person; I realized that during the last two semesters out of ten at the university. I enjoyed statics and structural undergraduate courses, and also project management. I really enjoyed a design of bracing systems graduate course, partially because you can combine the interaction of soils and structures, and deal with excavation plans and dewatering systems, lateral earth pressures, instrumentation, and the list continues. There are so many things that you need to know related to behavioral concepts of soils and structures, like sheet pile walls, cutoff walls, and bracing and shoring.

What was your favorite project?

One project that I really enjoyed during my early years as an engineer was the La Palma irrigation project located in Buenos Aires, Tolima, Colombia. Designed and built in 1987 and 1988, the dirty gravel dam had a silty core and transition and filter zones, a concrete spillway, and a pressure conduit outlet. The dam length was 590 ft, and its height was 95 ft, for a total dam volume of 146,600 CY. It took almost a year to build. I really enjoyed the project because I participated in the design of the dam, and then I was in charge of project supervision and QC/QA onsite during construction. The interesting issue about this project was the fact that dam construction began during the rainy season rather than the dry season, and, as a result, the conduit box-culvert capacity was insufficient to handle creek rainy flood. The project couldn't be stopped; therefore, the only option was to build the dam by stages so high creek flows could be freely drained while half of the dam fill was placed, including the silty core. Once the dry season started, the creek was diverted through the pressure conduit, and the other half of the dam was built. A special "key" was excavated to connect the core portion within the previous one. There were concerns about infiltrations through the transversal joint across the silty core; at the end, infiltrations through the dam were low and within estimates.

Where did you spend most of your childhood, and what was it like for you to grow up there?
My hometown is Cartagena. I grew up in the Colombian Navy Academy housing complex known as Manzanillo. It was one of the best times of my life; we lived technically on an island just separated from the main land by a small bridge. We were in a safe place surrounded by Cartagena Bay, full of fish and with plenty of nice breezes all year long. We learned how to fish from the shore and in small, native canoes made of trunks (called "cayucos"), and also how to sail in those native canoes.

How do you feel about the state of civil engineering and the profession as it is today?
We are not the same industry that used to exist when our words were always listened to. We are often forced to adjust our geotechnical scope to project budget, even though the geotechnical budget is a slim portion of project budget. Creativity and alternative analysis are not as common as they used to be. Computer software does everything, so engineers don't see the steps that are required to properly design a project. Please don't think I don't like computers — I do — but the point is that engineering problems need to be understood first, and a plan must be drawn, rather than start from the beginning using software. One young engineer asked me the other day when discussing a solution: "So, what computer program should we use now?"

What do you feel are the biggest challenges on the horizon for the profession?
The biggest challenge would be to keep teaching students and professionals the engineering concepts of how things work rather than jump in and provide solutions using software and other computer tools. We need to keep teaching how to fish rather than just giving the fish. The lack of this commitment is what is converting our profession into a commodity, which is not right.

Do you have a message about specialty certification that you'd like professional engineers to be aware of?
I think it is important to spread the word out more about D.GE certification. Many colleagues ask me about the meaning of D.GE. A campaign must be conducted nationwide throughout ASCE and G-I events.

Was the effort to get the D.GE worth it?
It was. I am proud of my geotechnical experience and the opportunity I have had to be a practitioner and academic in this field. Being a D.GE positioned me within a knowledgeable peer group that recognizes my professional abilities.

What are some of your personal hobbies and interests?
I have several hobbies. I would say they go with the seasons and my mood. But the most important one is probably blue water sailing. I also enjoy teaching/mentoring, woodworking, cooking, and now that I live in Florida, fishing. I considered myself to be a self-learner, so I love reading whatever I want to learn or review from the past. My personal interests are to live a nice and uncomplicated life with my wife and family, and enjoy every moment of my life by keeping myself busy, either by working or by doing any of my hobbies. GS

> Creativity and alternative analysis are not as common as they used to be. Computer software does everything, so engineers don't see the steps that are required to properly design a project.

For the complete interview, please visit *geoprofessionals.org*.

G-I ORGANIZATIONAL **MEMBER NEWS**

Densification, Inc. Announces New Hire


Drumheller

Densification, Inc. has hired Samuel J. Drumheller, EIT, as a project manager. He will also assist in project bidding, drafting, equipment management, and business development. Drumheller started with Densification in January after three years in the consulting field. He holds a bachelor's degree from Shepherd University in West Virginia and a master's degree in civil (geotechnical) engineering from Virginia Tech.

New President at Terracon

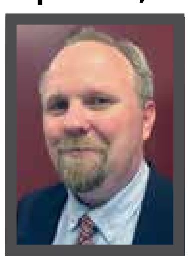

Srinivasan

Terracon Consultants, Inc. has announced that its new president is Swaminathan (Vasan) Srinivasan, PE. Srinivasan assumes leadership of Terracon's operating company, including the firm's geographical operating groups, service lines, business sectors, and quality group, which provide professional services across the country. He succeeds David Gaboury, PE, who has served as president since 1997. Gaboury continues as Terracon's chairman and CEO. Gaboury and Srinivasan will continue the executive transition throughout the year.

After joining the firm in 2007 as part of Terracon's acquisition of H.C. Nutting in Cincinnati, Srinivasan advanced from senior engineer to geotechnical engineering manager to division manager. His progression continued while serving as Western Operating Group manager and executive vice president. He has held a seat on the company's board of directors since 2013, and recently served as Terracon's chief operating officer.

Srinivasan is a licensed professional engineer with a master's degree in business administration from the Haas School of Business, University of California, Berkeley, a master's degree in geotechnical engineering from the University of Cincinnati, and a bachelor's degree in civil engineering from the Indian Institute of Technology Delhi. He has served as an adjunct faculty member at Cincinnati State College, authored several technical papers, and delivered presentations on numerous geotechnical engineering topics.

Shannon & Wilson Announces Expansion, Promotions

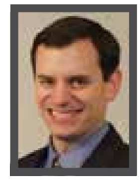


Shannon & Wilson continues to expand its geographic reach with a new hire, **Corbett Hansen, PE, M.ASCE**. Hansen recently joined Shannon & Wilson as a geotechnical engineer and senior associate. Based in Salt Lake City, he will be leveraging his transportation experience and knowledge of the local market and geographic conditions to develop a branch office for Shannon & Wilson in Utah.

Hansen has more than 18 years of experience with geotechnical and geological projects, ranging from small pavement designs to billion dollar design-build highway projects. He has worked extensively on design-build proposal and project efforts for the Utah Department of Transportation.

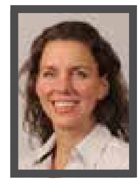
Shannon & Wilson also recently announced several promotions for 2017. Christopher Darrah, a geologist and environmental scientist who leads the firm's office in Fairbanks, AK, has been promoted to vice president. Andy Caneday, a licensed engineering geologist, and geotechnical engineers **Jeremy Butkovich, PE, M.ASCE**; **Matt Gibson, PE, M.ASCE**; **Kathryn Petek, PE, M.ASCE**; and **Tyler Stephens, PE, M.ASCE**, have been promoted to associate.


Darrah


Caneday


Butkovich


Gibson


Petek


Stephens

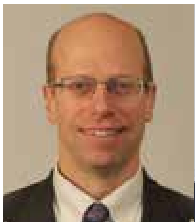
Menard Names Three New Vice-Presidents

Pittsburgh-based geotechnical firm Menard Group USA recently promoted three directors to vice-president positions.

Jason Griffin, PG, was promoted to vice-president of sales after three years as the director of sales. **Chris Parinella, PE, M.ASCE**, is now the vice-president of operations, with new responsibilities related to an increasing number of projects, project managers, and equipment. Formerly the director of operations, he has been with Menard for nine years. **Aaron Goldberg, PE, D.GE, M.ASCE**, has been named vice-president of sales and engineering of US Wick Drain. He has been with the company since Menard Group USA acquired US Wick Drain in 2012, most recently as the director of engineering.

Moretrench Promotes Fjotland

Moretrench has promoted Wayne Fjotland to the position of vice president. Fjotland has more than 36 years of focused geotechnical construction management experience. He joined Moretrench as manager of field operations in 2001 and became Northeast geotech regional manager in 2015. Fjotland will continue to oversee Moretrench's geotechnical operations in the greater New York City area, NJ, and Eastern PA. GS


Stan Boyle (Chair)

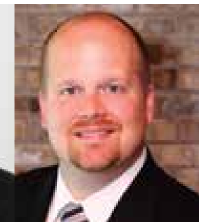

Tim Abrams


Curtis R. Basnett


Ronald Boyer


Donald E. Gerken


Ara G. Mouradian


Robert M. Saunders

"We're Looking Out for You!"

The Geo-Institute Organizational Member Council (OMC) invites your organization to join us. Enjoy the numerous benefits that G-I organizational membership offers, including the following:

- Up to a 50 percent discount on the G-I annual Geo-Congress for one person.
- A 5 percent discount for advertising in *GEOSTRATA* magazine.
- Forty percent ($400) of your annual G-I OM dues goes directly to fund G-I student activities. A portion of that money finances student travel to the annual Geo-Congress and the OM/Student Career Fair.
- Each year during the annual Geo-Congress, the OMC hosts an OM Career Fair/Reception. Two OM members from each OM firm are invited to participate, along with 45-50 students carefully chosen by the OMC.
- Opportunity to publish news about your company, including awards, new staff and promotions, company projects, etc.
- Your company logo posted on the G-I website at *geoinstitute.org/membership/organizational-membership*.
- Your company name listed in Organizational Member News in each issue of *GEOSTRATA* magazine.
- Opportunity to display the G-I logo on your website and on printed materials.
- Opportunity to display a G-I Organizational Member placard at your exhibit booth.

For more information, visit the G-I website at *geoinstitute.org/membership/organizational-membership*, where you can download the Organizational Membership application.

GEO-INSTITUTE ORGANIZATIONAL MEMBERS

Visit us at *geoinstitute.org/membership/organizational-membership*

- AECOM
- Advanced Construction Techniques, Inc.
- AMEC
- American Engineering Testing, Inc.
- Ardaman & Associates, Inc.
- Arup
- Atlas EPS
- Bechtel
- Bentley Systems
- Berkel and Company Contractors, Inc.
- Braun Intertec Corporation
- CH2M
- ConeTec, Inc.
- DBM Contractors, Inc.
- Dan Brown and Associates, Inc.
- D'Appolonia
- Densification, Inc.
- ECS Corporate Services
- FECON JSC
- Fudo Construction, Inc.
- Fugro Consultants LP
- GRL Engineers, Inc.
- GZA
- GeoEnvironmental, Inc.
- Gannett Fleming, Inc.
- GeoEngineers, Inc.
- Geo-Instruments, Inc.
- Geokon, Inc.
- Geopier Foundation Company
- Geo-Solutions, Inc.
- GeoStabilization International®
- Geosyntec Consultants
- Golder Associates, Inc.
- HNTB Corporation
- Haley & Aldrich, Inc.
- Hart Crowser
- Hayward Baker, Inc.
- HUESKER, Inc.
- Insulfoam
- Jafec USA, Inc.
- Kelchner
- Kleinfelder, Inc
- Langan Engineering & Environmental Services, Inc.
- Layne GeoConstruction
- Loadtest, Inc.
- Logic Technologies — Global Sensing Solutions Division
- Magnus Pacific Corporation
- Malcolm Drilling Company, Inc.
- McKinney Drilling Company
- Menard, Inc.
- Moretrench
- NTH Consultants, Ltd.
- Nicholson Construction Company
- Pagani Geotechnical Equipment®
- PB Americas, Inc.
- The Reinforced Earth Company
- Rembco Geotechnical Contractors, Inc.
- Richard Goettle, Inc.
- RocScience
- S&ME, Inc.
- Sanborn, Head & Associates, Inc.
- Schnabel Engineering
- Schnabel Foundation Company
- Sentez Insaat Ltd. Sti.
- Shannon & Wilson
- Soil and Materials Engineers, Inc.
- Specrete-IP Incorporated
- Stantec
- Strata Systems, Inc.
- Subsurface Constructors, Inc.
- TenCate Geosynthetics
- Tensar International
- Terracon, Inc.
- Terra Insurance Company
- Tolunay-Wong Engineers, Inc.
- ZETAS Zemin Teknolojisi A.S.

// COREBITS **CHAPTERS**

Los Angeles Chapter

(Front) Lisa Star, Vice Chair. (Back row, l to r) Anne Lemnitzer, Chair; Sharid Amiri, Treasurer; Derek Deutscher, Second Director; Ahmadreza (Reza) Mortezaie, Secretary; David E. Albus, First Director.

In February of this year, the Los Angeles (LA) Chapter was awarded the Geo-Institute's 2017 Best Chapter Award, established to recognize a Chapter's outstanding commitment in advancing the geoprofession at the local level. The LA Chapter regularly hosts technically-current presentations and seminars, with recognized experts from industry and award-level researchers from academia. The proactive outreach and collaborative efforts of this Chapter have marked it as a leading geotechnical, regional organization. Membership goals continue to grow a diverse group of members, consisting of academics, industry, and governmental agencies.

One of the LA Chapter's annual events is the Geotechnical Spring Seminar at the Queen Mary Ship in Long Beach. This has become the regional meeting highlight for geoprofessionals in Southern California, with approximately 300 professionals, academics, and students attending. This is coupled with the annual GeoExpo, which attracts a variety of exhibitors and provides an ideal opportunity for networking, student/professional interaction, Chapter support, and member exposure. The LA Chapter offered travel scholarships for ASCE student Chapter teams who competed in the 2017 National G-I Geo-Wall Competition that was held at Geotechnical Frontiers in March.

The LA Chapter has established strong relationships with sister chapters in the local and broader regional area. As a result of travel challenges (i.e., traffic in the LA region), two smaller Chapters formed over the last several years: the ASCE Inland Empire Chapter and the ASCE Orange County Chapter. The LA Chapter has consistently collaborated with and supported these Chapters by co-hosting, shouldering some financial expenses, and providing them with speakers. Outside of the ASCE framework, the LA Chapter interacts and collaborates with CalGeo, the International Association of Chinese Geotechnical Engineers, the Deep Foundations Institute (DFI), and the Earthquake Engineering Research Institute (Los Southern CA Chapter). Joint dinner meetings are held twice annually with the Association of Engineering Geologists (AEG). Currently, it is supporting and helping the EERI San Diego Chapter by recruiting attendees for the 2017 Symposium in Honor of Prof. Ishihara, and by supporting the Deep Foundations Institute with the SuperPile 2017 Conference as a regional supporting organization. As the winning Chapter, the Los Angeles G-I Chapter was recognized at Geotechnical Frontiers in Orlando, is highlighted here in *GEOSTRATA*, and will have the honor of hosting the Cross-USA Lecturer, Dr. George Filz, who will present "Deep-Mixing Method for Support of Embankments" during a Chapter event.

Susquehanna Valley Chapter

Dr. George Filz, 2016-17 Geo-Institute Cross-USA Lecturer, at the Susquehanna Valley Chapter lunch.

The Susquehanna Valley Chapter hosted Dr. George Filz's presentation, entitled "Column-Supported Embankments," as part of the 2016-17 Geo-Institute Cross-USA Lecture on Friday, February 17, 2017. Dr. George Filz, PhD, PE, is the Charles E. Via Professor of Civil Engineering at Virginia Tech, where he has been teaching and conducting research in geotechnical engineering for 27 years. Professor Filz's teaching, research, and practice interests include foundation engineering, soil-structure interaction, ground improvement, and seepage barriers. He has been recognized with several awards from ASCE, including the Middlebrooks Award, the Croes Medal, the Florida Project-of-the-Year Award, and the Wallace Hayward Baker Award.

Over 40 members and guests attended the presentation. These free "lunch and learn" presentations are a way for the ASCE Central Pennsylvania Section to provide value to its membership. Given the large geographic area covered by the Central PA Section, the presentation was made available by webex so that those who could not attend in person would still have the opportunity to attain professional development hours. A Professional Development Hour was earned by all attendees to help with their professional continuing education requirements.

Pittsburgh Chapter

Dr. Suresh Gutta presents to more than 80 attending the G-I Pittsburgh Chapter meeting.

On February 23, 2017, the Pittsburgh Chapter hosted Dr. Suresh Gutta, PhD, PE, from American Geotechnical and Environmental Services, Inc. (A.G.E.S.). Dr. Gutta presented "New Baltimore Landslide Remediation – Design Perspective," a project that was completed last year, significantly ahead of time and below the original cost estimate. He covered the history of the slide, how it reactivated during initial construction of the Pennsylvania Turnpike in the 1940s, and the maintenance problem it has created since then. The presentation focused on the last 17 years of subsurface investigations, instrumentation programs, monitoring, and how this information was used in the final remediation design. The construction of the remediation was also discussed. The event was attended by more than 80 geotechnical professionals.

The February meeting also served as a reunion of eight past chairs of the local Pittsburgh G-I Chapter, as seen here.

From l to r: William R. Adams, Jr., PhD, PE, PG; Andrew T. Rose, PhD, PE; Don Splitstone, PE; Craig W. Steigerwald, PE; Suresh Gutta, PhD, PE; Brian F. Heinzl, PE; Sebastian Lobo-Guerrero, PhD, PE; James V. Hamel, PhD, PE, PG.

▸ **PLEASE SUBMIT** G-I chapter and company news and career achievements to *GEOSTRATA* via *geostrata@asce.org*.

▸ ***GEOSTRATA* PRINT ARCHIVE** Electronic copies of full issues of *GEOSTRATA* Magazine dating from the current issue to January/February 2010 are available in the *GEOSTRATA* Print Archive at *geostrata.geoinstitute.org/print-archive.* The archive is only available to current members of ASCE and the Geo-Institute.

COREBITS **EDUCATION and CAREERS**

ASCE/G-I Co-sponsored Online Live Webinars

All posted webinars offer professional development hours (PDHs) as indicated.

- **Bridge Deep Foundation Design for Liquefaction and Lateral Spreading: Lessons Learned** - **NEW** (PDH: 1.0)
  May 1, 2017, 12:00 p.m. – 1:00 p.m. (ET)
- **Installation, Verification, and Application of Driven Piles** (PDHs: 1.5)
  May 3, 2017, 11:30 a.m. – 1:00 p.m. (ET)
- **Considerations of Induced Ground Deformations on Deep Foundation Designs** (PDHs: 1.5)
  May 8, 2017, 11:30 a.m. – 1:00 p.m. (ET)
- **Design of Geomembranes for Surface Impoundments (Ponds, Reservoirs, Etc.)** (PDHs: 1.5)
  May 19, 2017, 11:30 a.m. – 1:00 p.m. (ET)
- **Geotechnical Engineering Features - Earth-Retaining Structures: Fill Walls** (PDHs: 1.5)
  May 22, 2017, 11:30 a.m. – 1:00 p.m. (ET)
- **Design of Slab on Grade for Light Buildings on Shrink Swell Soils** (PDHs: 1.5)
  May 31, 2017, 11:30 a.m. – 1:00 p.m. (ET)
- **Understanding the Properties of Fills for Mechanically Stabilized Earth (MSE) Walls** (PDHs: 1.5)
  June 5, 2017, 11:30 a.m. – 1:00 p.m. (ET)
- **Mechanically Stabilized Earth (MSE) and Gravity-Retaining Wall Design Software Parameters** - **NEW** (PDHs: 1.5)
  June 14, 2017, 12:00 p.m. – 1:30 p.m. (ET)
- **Capillary Barrier Principles and Design** (PDH: 1.0)
  June 16, 2017, 12:00 p.m. – 1:00 p.m. (ET)
- **Introduction to Grouting in Rock** (PDHs: 1.5)
  June 21, 2017, 11:30 a.m. – 1:00 p.m. (ET)
- **The Seismic Coefficient Method for Slope and Retaining Wall Design** (PDHs: 1.5)
  June 28, 2017, 11:30 a.m. – 1:00 p.m. (ET)
- **Geotechnical Engineering Features: Earth-Retaining Structures: Cut Walls** (PDHs: 1.5)
  July 10, 2017, 11:30 a.m. – 1:00 p.m. (ET)
- **Geotechnical Engineering Features: Earth-Retaining Structures: MSE Walls** (PDHs: 1.5)
  July 17, 2017, 11:30 a.m. – 1:00 p.m. (ET)
- **Lessons Learned from the Design, Construction, and Maintenance of Permeable Pavements for Stormwater Management** (PDH: 1.0)
  July 17, 2017, 12:00 p.m. – 1:00 p.m. (ET)
- **Dynamically Loaded Machine and Equipment Foundations: A Design Primer** (PDHs: 1.5)
  July 18, 2017, 11:30 a.m. – 1:00 p.m. (ET)

ASCE/G-I Seminars

All posted seminars offer continuing education units (CEUs).

- **Earth-Retaining Structures: Selection, Design, Construction, and Inspection - Now in an LRFD Design Platform** (CEUs: 1.4)
  May 18-19, 2017, Denver, CO
- **Earthquake-Induced Ground Motions** (CEUs: 1.6)
  May 25-26, 2017, Anchorage, AK
- **Seismic Hazard Evaluation and Mitigation Using Simple Methods** (CEUs: 1.6)
  May 25-26, 2017, Kansas City, MO
- **Design and Installation of Buried Pipes** (CEUs: 1.4)
  June 1-2, 2017, Chicago Metro Area, IL
- **Deep Foundations: Design, Construction, and Quality Control** (CEUs: 1.4)
  June 8-9, 2017, Scottsdale, AZ
- **Instrumentation and Monitoring Bootcamp: Planning, Execution, and Measurement Uncertainty for Structural and Geotechnical Construction Projects** (CEUs: 1.4)
  June 8-9, 2017, Boston, MA
- **Ground-Improvement Methods** - **NEW** (CEUs: 1.4)
  June 15-16, 2017, Baltimore, MD
- **Application of Soil-Structure Interaction to Buildings and Bridges** - **NEW** (CEUs: 1.4)
  June 26-27, 2017, Philadelphia, PA
  July 20-21, 2017, San Francisco Metro Area, CA
- **Dam Breach Analysis Using HEC-RAS** (CEUs: 2.4)
  June 28-30, 2017, Boston, MA
- **Soil and Rock Slope Stability** (CEUs: 1.4)
  July 13-14, 2017, New York City Metro Area, NJ

On-Demand Learning

On-demand learning opportunities offer continuing education units (CEUs). Recorded from ASCE's most popular live webinars or in-person seminars, these courses allow you to hear the instructor's lecture, see the presentation, and listen in on questions from the audience.

For more information about webinars, seminars, and on-demand learning, visit the ASCE Continuing Education website: *asce.org/continuing_education*.

Guided Online Courses - NEW

ASCE announces asynchronous online instructor-led programs in which you move through a 6- or 12-week learning experience with your peers. The Guided Online Course content includes video lectures, interactive exercises, case studies, live webinars, and weekly discussion topics to help you master the course material. Unlimited, 24/7 accessibility to weekly modules. Complete coursework at the time and pace that is most convenient for you, using your own devices.

For more information about guided online courses, visit the ASCE Continuing Education website: *asce.org/guided-online-courses*.

Internships Available

Are you looking for an internship? Explore the positions listed on the ASCE website to help you obtain the experience you need to further your career path. New opportunities are added all the time, so start your search today: *careers.asce.org/jobs?keywords=internship.*

GEOSTRATA

COMING IN JULY/AUGUST 2017

Ground Vibrations

As I See It: Remember the DEW Line?
By Richard D. Woods

Guidelines for Construction Vibrations
By Sandy Figuers

Automated Vibration Monitoring for Construction Applications
By Pierre W. Gouvin

Seismic Data from Smartphones
By Qingkai Kong, Richard M. Allen, and Louis Schreier

What's New in Geo: Claims against Geotechnical Engineers
By Patrick C. Lucia, Lisa Yabusaki, Jason T. DeJong, and David L. J. Coduto

Lessons Learned from GeoLegends: Tien Wu
By Tugce Baser, Yewei Zheng, and Mohammed Zayed

Did You Know? The Uselessness of Elephants in Compacting Fill
By Richard L. Meehan

INDUSTRY CALENDAR

Geo-Risk 2017
June 4-7, 2017
Denver, CO

3rd North American Symposium on Landslides (NASL) 2017
June 4-8, 2017
Roanoke, VA

Grouting, Deep Mixing, and Diaphragm Walls 2017
July 9-12, 2017
Honolulu, Oahu, HI

GeoMEast 2017
July 15-19, 2017
Sharm El-Sheik, Egypt
geomeast2017.org

3rd International Conference on Performance-based Design in Earthquake Geotechnical Engineering (PBD-III)
July 16-19, 2017
Vancouver, BC, Canada

ASCE Pipelines Conference
August 6-9, 2017
Phoenix, AZ

International Conference on Highway Pavements & Airfield Technology
August 27-30, 2017
Philadelphia, PA

19th International Conference on Soil Mechanics and Geotechnical Engineering
September 17-22, 2017
Seoul, Korea
icsmge2017.org

PanAm-UNSAT 2017: Second Pan American Conference on Unsaturated Soils
November 12-15, 2017
Dallas, TX

2018

IFCEE 2018
March 5-10, 2018
Orlando, FL

Geotechnical Earthquake Engineering and Soil Dynamics V 2018
June 10-13, 2018
Austin, TX

5th GeoChina International Conference Civil Infrastructures Confronting Severe Weathers and Climate Changes
July 23-25, 2018
HangZhou, China

2019

2019 Geo-Congress
March 24-27, 2019
Philadelphia, PA

For more seminar information:
asce.org/continuing-education/face-to-face-seminars

// GeoPoem

By Mary C. Nodine, PE, M.ASCE

Buried

When most folks see a building, their gazes will rise
As they count all the stories straight up to the sky,
Marveling at the great trusses and walls
That make the steel structure stand so very tall.

But as for me… my gaze wanders down
To invisible marvels well below ground.
For I know that this great engineering feat
Could never go high if it didn't go deep.

I envision those massive and stout concrete shafts,
The load-bearing kings of all drilling craft.
In dogged pursuit of stiff soils they go,
Gathering skin friction, downward they grow.

When I see a bridge, with arches so grand,
And seven impressively long, sweeping spans,
I pause to imagine components concealed:
Spindly H-sections, A36 steel,

Driven deep down to bedrock. They counted the blows,
Ensuring advancement sufficiently slowed
So those piles would have the capacity
To stay put as the bridge swayed in traffic and breeze.

The marvelous structures that get so much glory
Only tell half of the engineering story…
Our foundations, too, would be world renowned
If we only could see what was built underground.

MARY C. NODINE, PE, M.ASCE, is a geotechnical poet, a member of *GEOSTRATA*'s Editorial Board, and a project engineer with GEI Consultants, Inc. in Woburn, MA. She can be reached at *mnodine@geiconsultants.com*.

Your True Project Partner

You have partnered with us on your piling needs, now you can count on Skyline Steel for the most comprehensive line of geostructural products.

New State-of-the-Art, Highly Efficient, Hot-Melt Extrusion Process Now Available from Skyline Steel.

- Provides lowest coefficient of friction
- Meets all specifications set forth in the “PTI Recommendations for Prestressed Rock & Soil Anchors”
- Additional applications include: Barrier Cable, Monostrand, Post-tensioned Concrete Reinforcement
- Polypropylene available upon request
- Now available for both 0.5” and 0.6” diameter steel strand

Skyline Steel is a premier steel foundation supplier with a worldwide network of manufacturing and stocking locations.

See how Skyline Steel can help with your next geostructural project.
Visit **www.skylinesteel.com** or call **888.450.4330**.

Exclusive Distributors of Anker Schroeder within NAFTA and Caribbean Countries ASDO