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World Tunnel Congress and the 2018 NAT Conference

I've recently returned from the 2018 World Tunnel Congress and 44th ITA General Assembly in Dubai, U.A.E. It was my privilege and honor to represent all UCA of SME members at the General Assembly. This year's theme was “The Role of Underground Space in Building Future Sustainable Cities.” This was an appropriate theme, considering that Dubai is a bustling and majestic city rising out of the desert. And yes, they do tunnel under the desert.

The United States was well represented, with 38 delegates and seven exhibitors attending. Additionally, UCA members participated in 10 of the 14 active ITA Working Groups. One of the many important functions of these groups is the collection and dissemination of innovations and experiences from the global tunneling industry.

A highlight of the Congress is the annual Sir Alan Muir Wood Lecture. Ed Cording had previously been selected to present this year’s lecture, entitled, Monitoring and Controlling Ground Behavior at the Source. Ed’s lecture began by describing the development of ground control techniques using modern pressurized-face tunnel boring machines (TBM). This included several high-profile projects that many of our membership were involved with. He then explained how all of these past lessons and developments, good and bad, were brought to bear for the successful completion of Seattle’s SR-99 project.

While attending WTC, a few of us were invited to sit in on a meeting of the Nordic Forum. This group is comprised of the delegates from primarily Scandinavian countries. This is their opportunity to share interests and practices specific to their region. The Nordic Forum meets a few times per year, either in person or electronically. Following this meeting, those of us attending from the U.S. felt that such a forum could be beneficial to the United States tunneling industry. Accordingly, we reached out to delegates from Canada and South America, receiving warm reception to the concept. Over the next couple of months, members of the UCA will begin to explore what such an alliance of the Americas could accomplish to the mutual benefit of all member nations.

Please contact me if you would like to be a member of this exploratory committee.

Soon we will all be together in Washington, D.C. for the 2018 North American Tunneling (NAT) Conference. As always at NAT, the offerings include short courses, technical sessions, panel discussions, technical field trips and exhibits from the many suppliers and subcontractors that service our industry. Given the location of this year’s conference, we have been working to attract decision makers from Capital Hill. We all know of looming projects that could use some legislative support to move them closer to reality. I ask that you reach out to your representatives and ask them to attend. We may just aides and assistants, but they, too, are capable of carrying a torch.

Mike Roach,
UCA of SME Chairman
The North American Tunneling Conference is the premier biennial tunneling event for North America, bringing together the brightest, most resourceful, and innovative minds in the tunneling industry. It underscores the important role that the industry plays in the development of underground spaces, transportation and conveyance systems, and other forms of sustainable underground infrastructure.

With every conference, the number of attendees and breadth of topics grow. The authors—experts and leaders in the industry—share the latest case histories, expertise, lessons learned, and real-world applications from around the globe.

Crafted from a collection of 126 papers presented at the conference, this book takes you deep inside the projects. It includes challenging design issues, fresh approaches on performance, future projects, and industry trends as well as ground movement and support, structure analysis, risk and cost management, rock tunnels, caverns and shafts, TBM technology, and water and wastewater conveyance.

Your timely source for more cost-effective and less disruptive solutions to your underground infrastructure needs.
California WaterFix gets funding promise

The massive California WaterFix tunnel project might have gotten new life when the board of the Metropolitan Water District of Southern California, the largest water agency in the state, voted to bear most of the $11 billion cost to get the project started.

The project, which calls for two tunnels under the Sacramento-San Joaquin Delta to move water from the north to the southern part of the state, was in jeopardy after San Joaquin Valley agriculture districts that were supposed to pick up nearly half of the $17-billion tab backed out. The vote by the Metropolitan Water District of Southern California was seen as an 11th hour rescue of the project. However, it does not guarantee that the project will be built and was not without controversy.

“This vote was honestly quite divisive,” Los Angeles board member Mark Gold told the Los Angeles Times. “The Metropolitan Water District is basically subsidizing benefits for the entire state of California over and above the 19 million customers that Met has in Southern California. … To have local ratepayers incur that risk is inappropriate and potentially illegal.”

State constitutional provisions requiring local government fees to be proportional to the services provided could leave MWD vulnerable to court challenges, Gold and others warn.

According to MWD, financing the twin tunnels would add an average of $60 a year to household water rates across the Southland. But local purchases of agency supplies vary, meaning costs will vary too.

Backers are worried that a plan to downsize the project to one tunnel would drag out the permitting process beyond the end of the year, when Gov. Jerry Brown — WaterFix’s chief political cheerleader — would be out of office. His successor might not be so enthusiastic about the tunnels, which are opposed by delta interests and major environmental groups.

The Los Angeles Times reported that of the leading candidates for Brown’s office two are in favor of the one-tunnel option with an emphasis on finding other solutions to the water problem while others in the race are flatly opposed to the tunnels.

Moving ahead with just one tunnel would “risk serious delay … and jeopardize the entire project,” Brown wrote to the directors on the eve of the vote.

After the San Joaquin Valley agriculture backed out, the state was prompted to shrink the proposal to a cheaper, one-tunnel version that would be financed by MWD and the other, mostly urban districts that get State Water Project deliveries from the delta.

Under that scenario, WaterFix would move ahead in stages, with a second tunnel built when financing materialized. Not long after the downsizing proposal emerged, MWD started talking about picking up agriculture’s unfunded portion, with the assumption that the agency could recoup the extra cost by selling tunnel capacity to growers after the project is built.

But there is no guarantee agricultural districts will buy tunnel supplies — or if they do, that they will pay a price that reflects the water’s true cost.

New tunnel planned for Minneapolis

The tunnels that were built beneath the city of Minneapolis, MN to carry storm water from the city to the Mississippi River are about 80 years old and can no longer handle the job alone.

Like many large cities, Minneapolis has grown beyond its original infrastructure in recent years. The city is hoping to gain support of city council members and legislators to make the case for fixing an unseen problem. Minneapolis is seeking $19 million from the state legislature to defray the cost of its Washington Avenue project, which could begin construction in 2020.

“The tunnels were built to handle much less water, so even when it’s raining moderately it means they’re full,” said Katrina Kessler, the city’s director of surface water and sewers, on a tour of a tunnel in southeast Minneapolis.

The project wasn’t included in Gov. Mark Dayton’s bonding bill, and neither the House nor the Senate has released its bonding proposal. It

(Continued on page 10)
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When Elon Musk vowed to begin boring tunnels beneath the streets of Los Angeles, CA it seemed unlikely that much would come from the tweet. And when he began to raise money for the new venture by selling hats and flamethrowers it certainly raised some doubts. But when it was reported that he has raised more $110 million for the Boring Co., it looks as if this is more than a billionaire frustrated by traffic.

The Los Angeles Times and other outlets reported that Musk, the founder of Tesla and SpaceX, raised $112.5 million in a recent funding round, according to a document filed with the U.S. Securities and Exchange Commission.

Most of the money — more than 90 percent — came from Musk himself. The rest was from “early employees” of the company, according to the Boring Co.

The company said no venture capitalists or outside investors were involved in this round.

The funding round is a more conventional method of fundraising than Musk’s most recent money-maker — sales of flamethrowers. Musk said in January that the Boring Co. had pre-sold 10,000 flamethrowers branded with the company logo for $500 apiece. He also said at the time that he sold about 3,000 fire extinguishers for $30 each.

The flamethrower and fire extinguisher sales came after a similar, though less flashy, fundraiser by Musk to sell 50,000 Boring Co. branded hats for $20 each.

The Boring Co. has said its goal is to increase the speed and lower the price of digging tunnels to reduce traffic congestion.

The company has already dug a tunnel across from SpaceX’s headquarters with a boring machine it purchased. Musk said the company’s tunnels and Hyperloop plans would prioritize pedestrians and cyclists over cars. Passengers would load into a pod with large windows that’s lowered underground before it speeds on a track, according to a video Musk tweeted in March.

“Will still transport cars, but only after all personalized mass transit needs are met,” Musk tweeted March 9. “It’s a matter of courtesy & fairness. If someone can’t afford a car, they should go first.”

The company says tunnel-digging projects can cost as much as $1 billion per mile, but its goal is to lower these costs by a factor of 10 or more.

In October 2017, the Maryland Department of Transportation gave “conditional approval to the construction of a tunnel from Baltimore to Washington” for the project by issuing a utility permit.

In March, six Democratic members of Congress from Maryland and Washington wrote to Maryland Gov. Larry Hogan seeking information about the state’s support for the proposed Hyperloop Project, including the regulatory standards that will apply.

“While the Hyperloop is an exciting project that has the potential to transform transportation along the entire U.S. East Coast, it is also a project that would utilize a wholly new technology and could have significant impacts on our constituents,” the members wrote.
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Early-bird registration rates are available through Aug. 31, 2018.

Colorado School of Mines has a long-standing tradition of hosting world-class short courses in underground construction and tunneling. Learn more and register online at underground.mines.edu.
BART extension to San Jose approved

A long-awaited transit tunnel extension to San Jose, CA was approved by the Bay Area Rapid Transit (BART) Board of Directors in April.

In a 5-0 vote, the board approved a single-bore tunneling plan that the Santa Clara Valley Transportation Authority says will be faster and less disruptive to San Jose traffic.

Previously, BART planners had wanted to go with a more traditional dual-tunnel approach to the San Jose dig, and the disagreement put the $4.8-billion project into a holding pattern.

An editorial in the San Jose Mercury News supported the single bore plan, writing, “The technology allows the boring machine to dig deeper underground, without tearing up streets and disrupting traffic flow. It also should cut 10 months off the four-year tunneling phase and drop the total price tag by an estimated $50 million.

“The twin-tunnel approach originally supported by BART’s staff would have involved ripping up Santa Clara Street, from Market Street to Third Street, for a period of three years. The cut-and-cover process would have required relocating complex utility networks, frequently causing construction delays.”

The VTA board approved the tunnel plan earlier in May. The extension may qualify for federal grants that cover nearly a third of its costs.

Director Thomas Blalock recorded some reservations about the methods, predicting that a single tunnel would result in smaller stations and platforms that BART riders might regret down the line.

“Those platforms are going to limit capacity in Santa Clara County,” warned Blalock. But in the end, he was among those who voted yes on the proposal.

Writing in 2010, transit news site The Source noted that the single-bore method is the result of new technology and larger digging machines like those that could be used on this project.

Under the present timeline, construction to San Jose would begin toward the end of 2020, and the first passenger service would happen come 2026. The full 25-km (16-mile) plan involves six new stations, from Milpitas to Santa Clara.
The Rapid Excavation and Tunneling Conference (RETC) is the premier international forum for the exchange and dissemination of developments and advances in underground construction. RETC provides innovative solutions to the unique challenges associated with the tunneling industry.

Conference attendance exceeds 1,400 professionals from more than 30 countries. Industry sectors include: construction, mining, geotechnical engineering, exploration, environmental, economics, manufacturing, government, land, water/wastewater and transportation. The conference includes a comprehensive exhibit, short courses, field trips, and tours.

The 2019 RETC Organizing Committee has issued a call for papers. Prospective authors should submit the following by June 30, 2018: Abstract of 100 words to https://sme-retc.secure-platform.com/a

The ideal paper presents an interesting or unique challenge and the solution or outcome of that challenge.

For more information, contact:

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Deadline is June 30, 2018

Authors will be notified of acceptance by September 2018. Final manuscripts from accepted authors are due December 15, 2018. Manuscripts are mandatory for inclusion and must be received on time. All manuscripts will be included in the proceedings volume distributed on-site to all full registrants. If you cannot commit to completing a manuscript on time, please do not submit an abstract for consideration.
Tunneling to begin on LA Metro’s Purple Line

Tunneling for the first phase of Metro’s Purple Line Extension project will begin later this summer under the Miracle Mile. Two tunnel boring machines, named Elsie and Soyeon were unveiled on April 24, the local CBS affiliate in Los Angeles, CA reported.

The two boring machines will begin by digging parallel tunnels underneath Wilshire Boulevard between Koreatown and Beverly Hills to connect three new stations and 6.3 km (3.92) miles of new rail.

The full extension of the project that initially broke ground in late 2015 includes three phases, and will add about 14.5 km (9 miles) and seven new stations extending to the Westside, taking riders from downtown Los Angeles to Westwood in about 25 minutes.

The project, expected to cost $8.2 billion, is considered to be one of Metro’s priority projects.

“The Wilshire corridor has the highest population and employment density of any transportation corridor in Los Angeles,” said Mayor Eric Garcetti.

Boring each tunnel on the first phase will take about two years to complete.

It’s scheduled to be finished and ready for riders in 2023.

Sections 1 and 2 are funded primarily by Measure R, the sales tax Los Angeles County voters approved in 2008.

Minneapolis: Stormwater tunnel

is third on the city’s list of bonding priorities, behind an overhaul of the Upper Harbor Terminal property and an expansion of the city’s emergency operations and training facility.

The tunnels are significantly deeper than the other essential conduits beneath the sidewalks. Most gas, electric and communications lines on Nicollet Mall are 1 to 1.5 m (3 to 5 ft) below ground, just above water mains and sewer pipes.

Once stormwater drops to the tunnels, it flows by gravity toward Washington Avenue, where it follows the street’s path underground for several blocks before being spit out into the river beside the Stone Arch Bridge. The tentative plan is to build another tunnel beside the existing one to reduce pressure across the downtown system.

It’s not the only deep tunnel work happening in the city. The Minnesota Department of Transportation has spent nearly four years burrowing 36 m (120 ft) below Interstate 35W in south Minneapolis and repairing its stormwater tunnels there. And the Metropolitan Council is preparing to repair a wastewater tunnel near Minnehaha Park that’s as deep as 22 m (74 ft) underground.

Including tunnels outside downtown, the city’s system spans nearly 26 km (16 miles), ushering rainwater from about a fifth of the city to the river. St. Paul has 32 km (20 miles) of tunnels that perform a similar task.

Since 2009, Minneapolis has spent $2 million to $5 million a year largely on repairing breaks in the lining. Pressurized water over time fractures the concrete, creating voids in the surrounding sandstone that further compromise the tunnels’ strength.

St. Paul has spent about $3.5 million to $4 million per year since 2006 on rehab work, said Bruce Elder, the city’s sewer utility manager. It is now working on a Phalen Creek tunnel northeast of downtown.

“We’re more or less working within the existing tunnel and making repairs,” Elder said. “We don’t really have a great need for additional capacity.”

Epiroc introduces new hydraulic breakers

While incorporating the popular features of Epiroc’s market-leading Solid Body (SB) breaker range, the new SB 302 and SB 452 Tunnel versions provide application-specific modifications that extend equipment lifetime and reduce overall operating costs in underground applications.

Piston lifetime in the advanced Tunnel version is extended by a new piston in stainless steel, while bushing seat wear is minimized by a press-fit, one-piece bushing locked by an additional pin. An exchangeable wear plate protects the hammer body and durability is enhanced by heavy duty retainer bars and a locking pin.

The special tunneling tool with a collar supporting a robust front shield and dust cover minimizes the dust intake when working on overhead areas. Two restrictors are available that enable the performance of the hydraulic breaker to be adjusted for either traditional scaling operations or for more challenging rock breaking jobs.

Together, these new features add up to less wear, extended lifetime and lower overall operating costs in scaling, tunneling and underground mining applications.
Keller and Hayward Baker acquire Moretrench

Keller and Hayward Baker have acquired New Jersey-based Moretrench, a contractor operating predominantly along the east coast of the United States and with a strong heritage of complex geotechnical projects. Moretrench will operate as a division within Hayward Baker. The enlarged entity will be well-positioned for the expected long run renewal of infrastructure.

Eric Drooff, president of Hayward Baker, noted that, “Having worked closely with Moretrench on several key projects, we were impressed with the quality of the company and expertise of its people. We are excited to welcome Moretrench to Hayward Baker and look forward to developing new synergies.”

Hayward Baker and Moretrench both enjoy a strong and well-established presence in the tunneling and underground construction industry and each has worked extensively on major subway and other tunnel construction projects throughout North America. With each company contributing particular areas of expertise, and sharing others, together the company will bring to its clients the widest range of underground construction solutions available through any single geotechnical contractor.

Tom Tuozzolo, president of Moretrench, added, “As a division of Hayward Baker, we can now offer additional geotechnical solutions and resources to our established clients as well as extending our dewatering and ground freezing techniques to Hayward Baker’s clients. This translates to more comprehensive and even better customer service for both our companies. I am excited to lead the Moretrench team forward into this new venture.”

Czech railway project will link Prague to European transport network

With the expansion of the railway line between Rokycany and Pilsen as a high-speed rail link, the Czech railway network is being modernized. The line in the western part of the Czech Republic is part of the railway corridor linking Pilsen to Prague and, thus, to the European railway network. Over a distance of 4.1 km (2.5 miles) it consists of two single-track tunnel tubes. The tubes were built by the Czech contractor Metrostav. For the first time in Eastern Europe, a convertible multi-mode tunnel boring machine (TBM) (from earth pressure balance (EPB) mode to single-shield mode) specifically designed and manufactured by Herrenknecht at its Schwanaub plant, was used for the project.

The multi-mode TBM built two-thirds of the two tunnels through quartzite shale stone and clay soils in closed EPB mode with screw conveyor muck removal. On the last 1.1 km (0.7 miles) of each route, the machine S-799 had to penetrate hard spilite rock, for which it was converted to open single-shield mode with belt conveyor removal. Each of the conversions was realized inside the tunnel in just two weeks. “For variable ground conditions along the tunnel alignment, a convertible multi-mode TBM is the best and most flexible solution. It can be run in different tunneling modes and thus operate in changing geologies,” explained Korbinian Kröger, responsible project manager at Herrenknecht.

The cutting tools were also changed for the second section of each drive and 48 cm (19 in.) disc cutters were installed for the single-shield mode section instead of the previously used 46 cm (18 in.) disc cutters. The larger disc diameter allowed higher contact pressure in the solid hard rock and longer running times. With small overburdens in parts, the flexible allrounder among the tunnel boring machines achieved weekly top advance rates of up to 182 m (597 ft). After 12 months, in October 2017 the site crew was able to celebrate the final breakthrough for the second tunnel tube. In addition to the TBM, Herrenknecht provided additional equipment, such as multi-service vehicles from subsidiary TMS, a cooling tower and belt conveyor systems.

The new high-speed rail link reduces the average travel time between Rokycany and Pilsen by around 10 minutes, and the capital city of Prague can be reached from Pilsen in less than one hour. As a result the region around Pilsen – with about 170,000 inhabitants the fourth largest city in the Czech Republic – will be better connected to the trans-European transport network. The modernization project not only makes the railway line faster, but also brings it up to the state of the art. This includes, for example, special safety features such as fire protection solutions and escape routes in the new tunnels.

Herrenknecht is also involved in other infrastructure development projects in Eastern Europe. They include Poland's largest tunnel structure – the 10-km (6.1-mile) long Slowacki Route in Gdansk.
The future of transit tunneling in Washington, D.C.

By the time the latest expansion of the Washington Metropolitan Area Transit Authority (WMATA) system, known locally as Metro and which opened in 1976, is completed in 2020, the system will serve 97 stations and operate on 188 km (117 miles) of track on six interconnecting lines. Metro provides a critical transportation link to a population of approximately six million people within a 3,900-km² (1,500-sq-mile) Washington Metropolitan area and has allowed job growth to expand to all corners of the region. In the 1950s and 1960s, when the system was first conceived and construction began, most jobs were centered in downtown Washington, and most of the workforce commuted by bus or car. Today, transit-oriented development has increased residential, commercial and government facilities near most of the existing 91 stations increasing the importance of the Metro system as a critical transportation link for the region.

According to recent American Public Transportation Association (APTA) data, Metro is the second busiest transit system in the United States (after New York City’s transit system).

During the nearly 50 years of construction on the Washington Metro system, technology improvements and lessons learned from the global tunneling industry were implemented. Portions of this background and history have been adapted from other work by the authors Roach et al. (2017) and expanded for use herein. For soil tunnels, these improvements included the change from a “two-pass” tunnel lining with a typical initial lining of steel ribs with wood lagging or segmental precast lining erected within the tunnel shield followed by a final lining of cast-in-place concrete to a one-pass lining system of pre-cast concrete gasketed segmental lining. Soil tunnels were originally excavated using open-face tunnel shields, but changed over time. By the late 1980s, tunneling using closed, pressurized-face tunnel boring machines (TBMs) using a one-pass tunnel lining consisting of segmental precast concrete permitted tunneling in a wider range of soil conditions with much less risk of damaging overlying utilities or structures, greater safety for tunnel construction personnel and without the need to dewater the soils. However, due to concerns about conditioning clays with earth pressure balance (EPB) TBMs, open face machines were still favored by contractors for their better advance rates, lower cost and ability to deal with boulders that were occasionally encountered in the Coastal Plain Terrace Deposits.

Ground improvement techniques that made tunneling possible in weak or very wet soils at the start of Metro construction were largely limited to cement and chemical grouting and, to a lesser extent, ground freezing. Many early (pre-1978) WMATA tunneling contractors used chemical grout for use in fine-grained soils. This changed over time as technologies evolved for jet grouting (replacement of soil by grout), compaction grouting and compensation grouting where grouting is undertaken as tunneling takes place.

For tunnels in rock, the work started when tunneling technologies were transitioning from the traditional method of drill-and-blast excavation with rock support using structural steel (steel sets) to more modern methods. The first rock tunnel running north from Dupont Circle Station was a single double-track tunnel excavated by drill-and-blast methods. Later, tunnel contractors used hard-rock TBMs between and through the stations. WMATA personnel had concerns about the delays associated with gripper-type TBMs getting stuck for extended periods in weak rock formations (there was no reverse gear) and with replacing worn disc cutters. Consequently, they preferred conventional rock excavation techniques. Drill-and-blast excavation continued out of necessity to excavate station caverns in rock, as well as many smaller-size excavations such as for cross-passages between tunnels.

Design and construction of rock tunnel linings evolved to follow principles of rock reinforcement by using rock bolts and shotcrete, eliminating the use of steel sets. These practices progressed further where rock bolts were replaced by untensioned rock dowels fully encapsulated with cement or resin and shotcrete for initial support and, in some cases, shotcrete as the permanent lining. Ground water leaks were a major problem during early construction. Dry tunnels without leaks became possible when PVC membranes were placed between the initial and final linings of rock tunnels (Sauer et al., 1987). It was part of the early introduction and adaptation of European tunneling methods and initial use in the United States (Heflin 1985) of the New Austrian Tunneling Method (NATM), also known as the sequential excavation method (SEM). This was the first time in the United States where the owner fully accepted the method and used it for later projects. This approach to tunneling integrated the several techniques that had evolved globally...
over the years and was used to successfully excavate tunnels in rock and, for the first time in the United States soil (Heflin et al., 1991).

The contract for the Fort Totten Station and tunnels in 1988 was the only contract out of three offered by WMATA in which the contractor chose to utilize NATM. It was the first use of NATM in soft ground (sands and clays) for a transit tunnel in the United States. The project included 292 m (958 linear ft) of twin tunnels, in addition to a portion of the station excavation located west of the Fort Totten Station. Excavation and ground behavior were monitored during construction by an extensive geotechnical instrumentation program. Specified initial support included shotcrete applied in three stages, with welded wire fabric and lattice girders. Soil anchors were also required for initial support. Additional support was provided by forepoling bars, forepoling sheets and face shotcreting.

The tunnel research work that began on the first projects of the Washington Metro set the stage for geotechnical instrumentation and monitoring for tunneling that is undertaken throughout the world today. Metro engaged the University of Illinois at Urbana-Champaign Department of Civil Engineering to conduct field research on soil tunneling, rock tunneling and cut-and-cover excavations. The lessons learned for instrumentation and procedures for tunneling were published as Methods for Geotechnical Observations and Instrumentation in Tunneling (Cording et al., 1975).

Washington Metro engaged a board of experts to peer review and advise on all aspects of design and construction. The Washington Metro Tunnel Board of Consultants (including Ralph B. Peck, Don U. Deere and A. A. Mathews) became the forerunner for what is today a common practice within the underground industry (Roach et al., 2017).

Approximately half of the original 165-km (103-mile) system was constructed underground, including approximately 30 km (19 miles) of rock tunnels, 19 km (12 miles) of mined soft-ground tunnels and cut-and-cover construction. A total of 48 stations are underground, 11 of which were mined in rock, one was mined in soil, and the rest were constructed by cut-and-cover methods. The 30 km (19 miles) of rock tunnels were constructed for the Red Line extending from Dupont Circle Station north to the Rockville Station, approaches to and under the Potomac River between Foggy Bottom and Rosslyn Stations, and the north end of the Red Line between Wheaton and Glenmont Stations.

The local geology straddles the boundary between the Coastal Plain and the Piedmont Physiographic Provinces. From the boundary, also known as the Fall Line, which extends through the metropolitan area from SW to NE, there is an increasingly thickening wedge of Coastal Plain deposits to the southeast underlain by older Piedmont rocks. Coastal Plain soils include interbedded alluvial soils, ranging from clays, silts and sands to cobbles and boulders, deposited by rivers and tributary systems within channels, bars, floodplains, terraces and alluvial fans. The alluvial deposits are underlain by older Potomac Group soils, which were deposited in a marine environment and are generally denser and stiffer than the alluvial deposits. Northwest of the Fall Line, Piedmont residual soils, weathered and hard intact bedrock are evident near the ground surface. These geologic conditions had a significant influence on tunneling and underground construction methods. Also influencing construction were the presence of the Potomac and Anacostia Rivers, Rock Creek and other tributary streams and creeks.

Expansion of the system

In recent years, there have been several expansions of the original Metro system that have included tunneling and underground construction. These projects include the Dulles Corridor Metrorail, also known as the Silver Line, the Rosslyn Station Expansion and Access project, the Medical Center Station Metro Crossing project, and the Purple Line, a new light rail transit system overseen by the Maryland Transit Administration that will provide a circumferential connection between three suburban Metro Stations (Bethesda, Silver Spring and Greenbelt) in Maryland.

The Dulles Corridor Metrorail Project, estimated at more than $5 billion, extends Metro service from West Falls Church Station through Tysons Corner to Wiehle Avenue Station (Phase I) and to Dulles International Airport, terminating at a station beyond the airport in Loudoun County, VA (Phase II). SEM tunneling was employed for a 520 m (1,700 ft) section through Tysons Corner in Phase I of the project. SEM was used, including a single- and double-grouted steel pipe arch canopy pre-support due
to shallow cover and soft ground (Fig. 1). This design-build project, overseen by the Metropolitan Washington Airports Authority, is funded by various public and private entities, including the Dulles Toll Road, demonstrating how third parties can work together with WMATA to address regional transportation needs and expand the Metro system.

Rosslyn Station is an important underground hub station in Arlington, VA, that serves the Orange, Blue, and Silver lines. The station was constructed in the early 1970s and was opened in 1977. As part of a new residential and commercial development, an access improvement project was undertaken in 2009 and completed in 2013 to accommodate expanded station capacity associated with the new development. The work included a new station entrance and a new track-level mezzanine that expands the passenger capacity of the station. Construction included a new vertical elevator and stair shaft entrance from the ground surface, connected by a 11-m (35-ft)-wide by 12-m (40-ft) high mezzanine constructed using SEM techniques leading toward the existing station. Passengers walk through a 6-ft (19-ft) wide by 4.5-m (15-ft) high passageway between the new concourse and the existing escalator entranceway. The SEM approach to design and construction made the complex underground structures possible.

The Rosslyn Station expansion is an excellent example of transit-oriented development leading to privately-financed expansions of the system. In Maryland, the Purple Line will include a new underground entrance to Metro’s Bethesda Station to facilitate connectivity between Metro and the Purple Line.

Other recent and future tunneling in Washington, D.C.

The DC Water Clean Rivers Project is a $2.6-billion program to reduce the occurrence of combined sewer overflows into Washington’s local waterways. The project includes several large-diameter conveyance and storage tunnels in the soft ground of the Coastal Plain deep under the city. Some of these new tunnels pass below existing WMATA Metro lines.

The first major tunnel construction started in 2013 and included an 8-km (5-mile) long, 7-m (23-ft) inside diameter (ID) bored tunnel along the Potomac and Anacostia rivers from DC Water’s Blue Plains Advanced Waste water Treatment Plant to a pump station in the Navy Yard. Subsequent contracts included a 3.8-km (2.4-mile) long, 7-m (23-ft) ID tunnel from RFK Stadium under the WMATA Green Line and the Anacostia River to Poplar Point, and a half mile long 6-m (20-ft) ID tunnel in the Bloomingdale neighborhood along First Street (Fig. 2). All these tunnels have been successfully excavated in the Potomac Formation soils with state-of-the-art EPB TBMs. The most recent tunnel contract of the Clean Rivers Project was awarded in 2017 and will include an 8-km (5-mile) long tunnel connecting the previously constructed Anacostia River and First Street tunnels. This tunnel will also utilize an EPB TBM with pre-cast concrete gasketed segmental lining. The depth of this new tunnel system is between 21 and 49 m (70 to 160 ft) below the ground surface and includes multiple deep shafts and connection tunnels excavated by SEM. Unique to this project is the fact that DC Water used design-build procurement for all the tunnel contracts. To date, DC Water’s Clean Rivers project has been successful in terms of work quality and schedule adherence. Those projects with soft-ground tunneling and design-build procurement are solid precedents for any future transit tunneling in Washington, D.C.

A final DC Water tunnel scheduled to be procured in 2020 along the Potomac River will provide additional precedent for tunnel excavation by TBM in rock, mixed-face and soil. As with the other tunnels in DC Water’s Clean Rivers project, the Potomac River tunnel is expected to be procured as a design-build contract.

Current transit tunneling in other major U.S. cities

As urban areas grow in population, several major cities in the United States have been expanding their transit systems with tunneling and underground construction. These projects, which minimize impacts to surface streets and structures, are instructive in helping to envision the future of transit tunneling in Washington, D.C. As with the recent DC Water Clean Rivers tunneling program, owners in recent years have been favoring alternative delivery methods, such as design-build.

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**FIG.2**

DC Water’s First Street Tunnel EPB TBM “Lucy” as introduced by Mayor Muriel Bowser. Source: Brian Zelenko/WSP at TBM Naming Ceremony on April 14, 2015.
New York City

Similar to the Rosslyn Station expansion for WMATA, the New York City Metropolitan Transit Authority (NYC MTA) has added station access and increased the size of stations for a number of locations throughout their system, including Columbus Circle, Hudson Yards, Lexington Avenue/63rd Street Station, and South Ferry, just to name a few. The NYC MTA’s 2015-2019 Capital Program includes $7.1 billion to expand the network through major investments. The NYC MTA receives approximately 35 percent of its income from a regional sales tax, regional tax on mortgage receipts and a tax on businesses that refine or sell petroleum-based fuel. In recent years, underground transit improvements have included:

- NYC MTA 2nd Avenue Subway (Phase 1) — $4.4 billion project includes a 3.2-km (2-mile) long segment from 96th Street to 63rd Street and includes new stations at 96th, 86th and 72nd Streets. The 2nd Avenue Subway (Phase 2), which will extend the system north to 125th Street, has started preliminary design.
- NYC MTA No. 7 Subway Extension and Station — $2.1 billion project extended the subway line from Times Square Station to the Jacob K. Javits Convention Center at Tenth Avenue and West 34th Street.
- Long Island Railroad (LIRR) East Side Access Project — $10.8 billion project, still under construction, extends LIRR service from Queens and Long Island to Grand Central Terminal.

Los Angeles, CA

The Los Angeles County Metropolitan Transportation Authority has embarked on a major expansion through Measure R, a voter-approved ballot measure that resulted in a half-cent sales tax for Los Angeles County to finance new transportation projects and programs which has been in place since 2009.

Four segments that include tunneling and underground construction are underway as design-build contracts:

- Crenshaw to Los Angeles International Airport — $1.3 billion, 13.6-km (8.5-mile) long project includes 3.2 km (2 miles) of tunnels and three underground stations.
- Purple Line Extension Segment 1 — $1.6 billion, 6.2-km (3.9-mile) long tunnel project includes three underground stations and extends to Beverly Hills.
- Purple Line Extension Segment 2 — $2.4 billion, 4.1-km (2.6-mile) long tunnel project includes two underground stations and extends the Purple Line to Century City.
- Regional Connector — $1.8 billion, 3-km (1.9-mile) long project through downtown L.A. will connect two existing transit lines and will include three new underground stations.

In 2016, Los Angeles County voters approved Measure M, which will provide an additional $120 billion in transportation funding over the next 40 years. With the 2028 Olympics set to be in Los Angeles, further extension of the Purple Line (Segment 3) to UCLA, the location of several sports venues are anticipated.

San Francisco, CA

San Francisco is served by both the Bay Area Rapid Transit (BART) system and the San Francisco Municipal Transportation Agency (SFMTA). Several expansion projects are underway or have been proposed.

- SFMTA Central Subway Project — $1.6 billion, 2.7-km (1.7-mile) long tunnel project will extend the Muni Metro T-Third Street Light Rail Line from SOMA to Union Square and Chinatown. The project includes tunneling with two EPBs and three underground stations constructed by SEM and cut-and-cover methods.
- BART 2nd Transbay Tube — this proposed project would build a second tube between Oakland and San Francisco south of and parallel to the existing immersed tube tunnel. It would connect to the new Transbay Transit Center and provide connections to Caltrain and the new California High Speed Rail.

Seattle, WA

Over the past 20 years, Sound Transit has expanded Seattle’s transit system with a series of tunnel and underground projects. Since its creation in 1993, the agency has passed three major funding ballot measures. The most recent measure in 2016, Sound Transit 3, provides $53.8 billion in funding to support expansion of the transit system. The measure is partially funded by increases to sales, vehicle excise, property taxes as well as federal grants. Recent work has included:

- Northgate Link Extension — $1.9 billion project includes twin tunnels that will extend 5.8 km (3.6 miles) north from University of Washington Station at Husky Stadium.
- East Link Extension — $3.7 billion project, which includes a 610-m (2,000-ft) tunnel constructed by SEM, will extend light rail 22.5 km (14 miles) from downtown Seattle to downtown Bellevue and Redmond.

Future transit tunneling in Washington, D.C.

The future of Metro’s transit tunneling in Washington, D.C. is tied to future capital investments and improvements to the Metro system. This was discussed in WMATA’s Momentum Strategic Plan (2013-2025) and subsequently in planning and analyses conducted soon after the Momentum Plan for a 2040 Regional Transit System Plan. Although the 2040 Strategic Plan has not yet
been finalized and adopted by Metro’s Board, some of the planning associated with it has been posted on Metro’s planning blog website, PlanItMetro. As highlighted by a 2013 Washington Post article that included an interview with Shyam Kannan, Metro’s chief planner, Metro identified a need to expand capacity in the system’s core to meet future transit ridership demands. This could be accomplished by adding a new core loop that includes approximately 10 new stations and adding capacity and connections at four existing stations.

This investment faces several hurdles. One of the big hurdles that Metro has faced is the lack of a local dedicated funding source, unlike many of the other cities and transit agencies previously noted. Without a dedicated funding source, it will be difficult to achieve the goals of the Momentum Plan. Now, four years since the issuance of the Momentum Plan, a local dedicated funding source was finally established in 2018 with all three jurisdictions (Maryland, the District of Columbia and Virginia) committing funds. Secondly, future investment has been tied to ridership and recently transit ridership numbers have been declining across the country, especially for Metro. According to APTA, national transit ridership was down approximately 1.9 percent over the past two years. Metro’s ridership has been down by 14 percent during the same period. For Metro, this is partially due to recent repair work, such as the year-long SafeTrack program, and ongoing reliability challenges. It is also due to the increasing popularity of alternative works schedules, particularly by federal workers, reductions in late-night and weekend service, as well as the popularity of Uber and other ride share companies. However, in the larger, longer view, there will be a demand for safe, efficient and reliable service that can only be achieved by new tunnels.

Additionally, the future may also include an extension of planned high speed rail by Amtrak in the Northeast Corridor south to a redeveloped Union Station, possibly extending further south to Virginia and the Southeast Corridor. Recent news reports have noted that entrepreneur Elon Musk, chief executive officer of SpaceX and Tesla, is planning to privately finance and develop a new high-speed underground transit system, Hyperloop, between Baltimore, MD and Washington, D.C. Maryland has issued a conditional utility permit to his company, The Boring Company, allowing construction of a 16.5-km (10.3-mile) section of tunnel along the proposed route. These future projects are under consideration because long tunnels and complex underground works are more feasible and can be built with less risk than in the past.

Metro

In the last two years, Metro has focused its efforts on restoring its system to try to correct years of deferred maintenance on an aging system and improving safety and reliability for the travelling public. Programs such as Back2Good, designed to get the system in good repair, and SafeTrack, an accelerated track work plan to address safety recommendations by the Federal Transit Administration and the National Transportation Safety Board, have been implemented. Through SafeTrack, Metro completed approximately three years’ worth of maintenance and repair work in approximately one year. Much of the system’s maintenance work is related to leaking tunnels constructed in the 1970s and 1980s. Today’s tunneling industry has the ability and technology to construct nearly watertight tunnels, representing a huge improvement over past construction methods.

The Momentum Plan identified several key issues, which are common to other major cities in the United States that have invested in transit improvements:

- Improve regional mobility and connect communities.
- Enhance access.
- Add operational redundancy.
- Build for the future.
- Add new sources of predictable funding.

As noted in the Momentum Plan, the region is forecasted to increase 30 percent in population and 39 percent in employment over the next 30 years. And Washington, D.C. is one of the few metropolitan areas where growth is occurring in the city core, inner suburbs and outer suburbs. The Momentum Plan identified core station improvements, including pedestrian underground
connections, that Metro stated should be completed by 2025 to have maximum impact, increase system and core capacity, and improve the effectiveness of the rail network. These improvements are envisioned at stations such as Metro Center, Gallery Place, Union Station, L’Enfant Plaza, Farragut West, and Farragut North (Fig. 3). In 2012 dollars, they were estimated to have an order of magnitude cost of $1 billion.

Other conceptual improvements, included in the Momentum Plan, were further evaluated by Metro during the planning effort for a 2040 Regional Transit System Plan. These improvements would be required, in addition to the 2025 Plan Core Station Improvements, to serve the region’s transit needs with the projected growth. It noted that as transit patronage reaches full capacity on lines converging at Rosslyn and L’Enfant Plaza Stations, new east-west and north-south transit tunnels through Arlington and Washington, D.C. would be required to accommodate trips and improve capacity through the system core. Some of those improvements, with associated order of magnitude cost in 2012 dollars, related to future transit tunneling include:

- **New connection of existing lines at the Pentagon with a new Pentagon Station ($600 million).**
- **Silver/Orange Line Express Line from West Falls Church to a 2nd Rosslyn Station to a relocated Blue Line ($2.3 billion)** — this would allow passengers on the Silver and Orange Lines better access to the eastern side of downtown Washington. A second Pentagon station would allow passengers on the Orange and Silver lines to reach the Pentagon without having to switch to the Blue Line. The underground portion of this new line would begin in the Piedmont bedrock at the Rosslyn Station and then transition to Coastal Plain soil deposits at the second Pentagon Station. Tunneling could be completed by an EPB TBM or a Hybrid TBM (Fig. 4).
- **Relocated Yellow Line ($2.7 billion)** — this would improve north-south capacity and require a new tunnel south from the Pentagon under 10th Street SW and NW and then west to Thomas Circle allowing the Green and Yellow lines to operate in separate tunnels. As this alignment is generally in the Coastal Plain Deposits, tunneling could be accomplished using either a Slurry or EPB TBM.
- **Relocated Blue Line ($3.3 billion)** — this would improve east-west capacity by creating a new Blue Line alignment through Rosslyn to Georgetown and then along M Street NW to Thomas Circle. As this alignment is primarily in the Piedmont sections of Washington, D.C., tunneling could be accomplished using a hard rock TBM. Station construction could be completed fully by SEM or cut-and-cover methods. Construction of a station in Georgetown could be completed by SEM construction with significant attention made to protect existing
As indicated on the PlanItMetro website, one possible way to increase capacity in the downtown core would be the conceptual development of a Core Loop (Figs. 5 and 6) that extends north from a second Rosslyn Station in a deep tunnel to Georgetown, extends east toward Union Station to a second Metro station at Union Station. These are conceptual drawings and future planning could lead to alternatives such as a continuation of the new line from Union Station to the east, perhaps 3.2 km (2 miles) to RFK Stadium.

**Union Station redevelopment**

The Union Station Redevelopment Corporation (USRC), in coordination with Amtrak, is planning for a $7-billion phased expansion and modernization of Washington Union Station. The historic station, which opened in 1907, is proposed to handle triple the number of passengers and double the train service. Major improvements are being planned to add a 3-million SF air-rights development, named Burnham Place after Union Station architect Daniel Burnham, over the train shed. Additional improvements include increasing capacity along the Northeast Corridor to New York and Boston with the addition of new underground passenger concourses below the existing train shed, and plan for possible High Speed Rail, extension of Maryland Regional Rail Trains to Virginia, as well as possible extension of Virginia Railway Express trains to Maryland.

Constructed in the 1970s, Metro’s busiest station is at Union Station on the Red Line. The near-term station access improvements planned by Metro will be included in the Union Station redevelopment. According to the U.S. DOT Federal Railroad Administration (FRA) 2017 Concept Screening Report, a second Metro Line servicing Union Station is being considered in long-term planning (beyond 2040) in order to meet future travel demand. The proposed conceptual alignment is parallel and south of Massachusetts Avenue passing along the southern edge of Columbus Plaza, directly south of Union Station (Figs. 7 and 8). A second Metro Station would need to be constructed below the existing station at Union Station. This station would extend roughly between North Capitol Street and Louisiana Avenue, below existing surface parking lots just south of Massachusetts Avenue. Tunneling using a Slurry or EPB TBM would likely be required, combined with SEM for station construction within the Coastal Plain deposits. Alternatively, the second Metro Line could be located on the north side of Union Station to tie-in with the planned air-rights development. This would allow Union Station to be served by two Metro Lines. However,
the new Metro station would not be a transfer station due to the distance from the existing Metro Station on the Red Line.

**High speed rail**

High speed rail (HSR) connecting to the Northeast Corridor, which is only being considered in the fourth phase of Union Station Redevelopment, would likely enter the station at a new deep underground level below the existing station and platforms. High speed rail tunnels entering Union Station from the north would likely need to begin somewhere around the Anacostia River crossing, approximately five miles north of the station. As the tunnels enter the station, they would need to be aligned in coordination with the existing large footings which are supporting the existing historic station structure on Coastal Plain Terrace Deposits. For HSR to continue south to Virginia, it is possible that twin-bored tunnels would follow an arc route out of the station and below the National Mall before crossing the Potomac River into Virginia. The FRA, in cooperation with the Virginia Department of Rail and Public Transportation, is preparing a Tier II environmental impact statement for the 198-km (123-mile) portion of the Southeast High Speed Rail Corridor from Washington, D.C. to Richmond, VA. The study begins at the southern terminus of the Long Bridge across the Potomac River in Arlington, VA.

Due to the shallow connection at Union Station, it is anticipated that twin-bore tunnels would be a preferred approach, rather than a single large-bored tunnel with two tracks which would require more complex underpinning. Due to high groundwater levels and Coastal Plain deposits, a pressurized-face TBM, either slurry or EPB, would likely be used to build the HSR alignment south of Union Station. A superconducting maglev program to provide a high-speed connection in tunnels between Baltimore and Washington, DC is also being considered by planners.

**Conclusion**

Washington, D.C. expects an increase in population, employment and transit oriented development over the next 30 years that will put a strain on the existing Metro transit system. This led WMATA to develop the Momentum Strategic Plan 2013-2025 that identified core station improvements, new east-west and north-south transit lines that would improve access and effectiveness of the network in the system core. These proposed improvements, amounting to more than $10 billion (in 2012 dollars), would require tunneling and underground structures. In addition, Washington Union Station is about to begin a $7 billion phased expansion and modernization program that will include significant underground construction at the station and may include tunneling for High Speed Rail from the Northeast Corridor, through Union Station and south to Virginia across the Potomac River. These future projects are under consideration because long tunnels and complex underground works are more feasible and can be built with less risk than in the past.

Having a reliable funding source with dedicated funding from the region for the first time ever is a big step for the Washington Metro to meet its future needs. Other major cities such as New York, Los Angeles, Seattle and San Francisco have addressed the funding hurdle for transit capital programs, together with federal support, and are underway with major tunneling and underground construction works. A recent decline in transit ridership, particularly in Washington, D.C., would need to demonstrate signs of recovery before decision makers would be willing to make the substantial investments required to improve the transit system. However, planning and conceptual design work should continue given the clearly identified future demand in the system core. State-of-the-art tunneling and underground construction methods that have been used in other major cities for recent transit tunneling projects have been successfully used in Washington, D.C. for recent Metro expansion as well as the DC Water Clean Rivers Program. Therefore, Washington, D.C. is poised for significant transit tunneling work in the future. (References available from the authors.)

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Since ancient times, storing and conveying water via underground water systems and tunnels has been touted for its strategic advantages. Underground cisterns and tunnels assured protection of essential fresh water supplies from man made contamination and especially from enemies who would gain an advantage by disrupting an adversary’s water supply in a siege. Modern-day engineers do not usually specify tunnels for reasons of avoiding deliberate contamination or siege — however, they are just as enamored with the idea of building tunnels for water conveyances.

Such was the case for the San Francisco Public Utilities Commission (SFPUC). The SFPUC provides drinking water to 2.6 million residential, commercial and industrial customers in the San Francisco Bay Area. The SFPUC’s water system includes 257 km (160 miles) of transmission pipelines and tunnels from the SFPUC’s largest reservoir, the Hetch Hetchy Reservoir inside Yosemite National Park, to San Francisco. About 129 km (80 miles) of the system consist of tunnels. A 30-km (19-mile) section of the tunnel network, called the Mountain Tunnel, was thought to be at risk of a catastrophic failure in its concrete-lined section of 18 km (11 miles). For much of the project planning process, a new replacement tunnel was presumed to be required according to the tunnel planners.

Originally constructed between 1917 and 1925, the Mountain Tunnel has been in continuous service since 1925. The 30-km (19-mile) tunnel is located downstream of the Hetch Hetchy Reservoir water source in Yosemite National Park, between the Early Intake and Priest Reservoir (Fig. 1). Approximately 18 km (11 miles) of the tunnel is lined with unreinforced concrete. Though the condition of the tunnel was being monitored through water sampling and periodic inspections, there was growing concern that the tunnel lining was at risk of a partial collapse that could interrupt water delivery for up to nine months. The SFPUC was faced with a decision to construct a new bypass tunnel to replace the lined section of the Mountain Tunnel or to rehabilitate the existing tunnel.

In order to decide between constructing a new tunnel or rehabilitating the existing one, the SFPUC embarked on a detailed alternatives analysis study, developing a set of performance standards for the tunnel, and identifying different alternatives. The study included four alternatives for in-depth review (McMillen Jacobs, 2017):

- Rehabilitate the existing tunnel, focusing on repair and contact grouting of the 18 km (11 miles) of concrete lined section.
- Relining with smaller-diameter steel pipe in the 18 km (11 miles) of the concrete-lined section.
- Construct a new bypass tunnel within the tunnel right of way to replace the 18 km (11 miles) of concrete lined section.
- Construct a new bypass tunnel outside the tunnel right of way to replace the 18 km (11 miles) of concrete lined section.

A 60-day shutdown of the tunnel was scheduled in early 2017 to perform a visual inspection, gather detailed information regarding the location and type of defects in the lining and establish the current structural condition of the tunnel (Fig. 2). The inspection indicated the many defects in the existing tunnel lining and the feasibility of repair (McMillen Jacobs, 2017).

The study also performed geotechnical investigations to ascertain site conditions for the new tunnel alignments, a condition assessment of the existing tunnel and a detailed hydraulic analysis to assess the flow capacity of the existing tunnel and evaluate effects of various improvements. The overall assessment was that existing tunnel was found to be not beyond repair and many sections to be in relatively good condition (McMillen Jacobs, 2017). The hydraulic analysis indicated that relining the tunnel would significantly reduce hydraulic capacity (McMillen Jacobs and Black & Veatch, 2017). So, the selection of the preferred project came down to comparing the rehabilitation and the new bypass tunnels against the performance standards and the other considerations of construction, environmental, permitting, cost and schedule described in this article. After thoroughly reviewing all this information and data at hand, the SFPUC ultimately decided the best course of action was to rehabilitate the Mountain Tunnel.

Why rehab?

The purpose of this article is to explain why tunnel rehabilitation can sometimes meet the needs of water...
agency owners better, or just as well, as new tunnels or bypass tunnel projects. Many owners are resource limited. They have competing program priorities, limited capital resources and limited staff expertise to undertake and properly manage mega size new tunnel projects.

Water agency capital budgets typically include many improvement projects competing for the same capital. The project list can include improvements to treatment facilities, transmission pipelines, pump stations and other facilities besides tunnel projects. Not every project gets immediately funded and some are postponed for later funding in a 10-year plan. Owners want to stretch every dollar to cover as many priority projects as possible.

Water agency owners typically have to sell bonds to fund their capital projects. The sale of bonds is a long-term financial commitment that many water districts are more hesitant to undertake.
in fiscally conservative times. Smaller water districts, in particular, are not willing to mortgage the future operations of the district to significant long-term debt.

Some districts have to also contend with stakeholder and customer opposition to the raising of water rates to service the debt payback. After years of increased water rates to pay for improvements on other parts of the SFPUC water delivery system, ratepayers would be understandably wary of additional increases to their water bill to pay for a new Mountain Tunnel.

It's about less money and time

When choosing to upgrade major transmission facilities, most water districts would look seriously at cheaper alternatives rather than undertake a total replacement facility. Most owners would want to avoid a situation where the entire program budget is dominated by mega size projects, with outsized impacts on annual cash flows to service bond debt and unpopular customer rate increases to cover the bond repayments — as may be the case of large capital improvement programs, including new, expensive tunnel projects.

Given a choice between constructing a new tunnel, or bypass tunnel, or simply a rehabilitation of the existing tunnel, owners would naturally first look at the rehab option. Rehab projects are significantly cheaper than building from new. It is estimated that the upfront capital outlay of a rehab can be 30 percent to 50 percent of the cost of comparable size and length of a new or bypass tunnel. Cheaper upfront capital investment in initial construction can mean increased financial capacity to invest in periodic maintenance of a rehabilitated asset for the long term.

Because the scope of work for a rehab is significantly less, the rehab may be completed in approximately half the time or significantly less time for comparable size facilities. This also translates to significantly less expense for project management and other soft costs. A relatively simple rehab project will not require large consultant services contracts for highly skilled and expensive design consultants. Nor would just-as-expensive construction managers and inspectors need to be hired on large, multi-year contracts to do contract administration and in-tunnel inspections.

There is significantly less cost and schedule associated with property acquisition for a rehab project. No permanent tunnel easements or rights of ways are needed for new tunnel alignment. Permitting for temporary construction surface access and staging areas for non-agency owned property takes less effort because either the rehab project does not require them or require less of them. In the case of the new tunnel alignment proposed for Mountain Tunnel outside the tunnel right of way, there was the need to acquire tunnel easements and temporary surface rights for staging and access through private property and national forest lands. The property issues included concerns about noncooperative private owners, working with the U.S. Department of the Interior, and possibly with U.S. Congress for the final approval — a potentially long and daunting process.

Rehab projects can be done without the need for subsurface exploration. A new tunnel by comparison must conduct an extensive geotechnical investigation along any new alignment, at locations where tunnel portals, adit tunnels and vertical shafts are contemplated for the design. All this is dependent on gaining temporary access usually through private or other agency-owned property. The longer the new alignment, the more complicated and time-consuming will be the effort. All such considerations are essentially cost and time savings for owners who elect to go with the rehab option.

Construction considerations

With any new tunnel, there is also an increased risk of cost overruns due to technical challenges, unforeseen conditions, large upfront costs for tunnel boring machines...
and other support equipment, constraints on the electrical grid for construction power, and environmental unknowns. Each new day of new tunnel excavation can yield a new set of unknowns and the potential differing site condition change order.

By contrast, tunnel rehab projects are somewhat repetitive and have fewer unknowns that could promote a lot of cost overruns. The tunnel repairs are typically classified into about four types ranging from patching of small holes to routing, cleaning and backfilling of much larger cavities with welded wire mesh and shotcrete (Fig. 3). The design details and the construction for these repairs are fairly similar from rehab to rehab project. It is fairly easy for contractor labor crews to get proficient after the first few repairs of each type of repair, gain efficiencies from lessons learned, and possibly make remarkable reductions in the unit cost and unit time of the repairs. This would make subsequent repairs of the tunnel more efficient and less likely to overrun.

The scope of a rehab project also lends itself to flexibility during construction. Tunnel rehab construction focuses primarily on repair of the concrete lining. Such repairs are discrete as opposed to continuous construction along the tunnel alignment that must be completed in blocks or sections before any return to service can be contemplated. Discrete repairs can be done in prioritized batches, or as much as the owner’s shutdown window constraints and budget allows.

**Politics of new versus old**

Sometimes, project leadership has been known to advocate for new replacement projects for reasons other than the practicality of cost and time, or even beyond the performance standards. New projects promise improvements that can be considered as a panacea for problems ranging from the old facility as allegedly beyond repair, to local hiring for a massive number of construction jobs, to having the opportunity to associate one’s name with a legacy project.

By contrast, there is less glamor and notoriety associated with a repair or rehab project. Tunnel rehab projects tend to be very similar and familiar. The main work is the patching or repair of various defects ranging from small holes to larger sections big enough for an inspector to crawl into. The repair is usually performed by shotcreting followed by systematic contact grouting through injection holes drilled through the repaired sections and into the native rock surrounding the tunnel in order to fill the annular spaces between the rock and the lining. In the case of the current SFPUC Mountain Tunnel, the repair details are almost a carbon copy of similar repair details developed 15 years ago for the East Bay Municipal Utility District’s Claremont Tunnel.

**Environmental considerations**

New tunnel projects generally must undergo an extensive environmental review process before the project can be approved for construction. For projects in California, this involves the development, internal reviews and public review process of an environmental impact report (EIR) over several years. If a federal agency is involved as a project participant or for the approval of property for the tunnel easements and temporary construction staging areas, then an environmental impact statement (EIS) is also required. The EIS can be done concurrently with the EIR, but is typically completed with lag of an additional six months to more than one year after the EIR certification to allow the findings and related information in the EIR to be re-used in the EIS.

The environmental impacts of new tunnels are generally unavoidable and beyond simple mitigation offsets that are easily accepted by the communities that must host the construction of the tunnel facilities and staging areas. Neighborhoods must endure the visibility, dust and noise and share the streets and highways with the hundreds of truck traffic on a daily or weekly basis over many years of construction, and may want more mitigation for their endurance.

New tunnel construction projects of large diameter and long alignment have the additional issue of dealing with exceedingly large volumes of tunnel spoils. Such spoils must be transported often at long distances to commercial disposal fill sites, or shorter distances to agency owned fill sites. The longer haul to commercial sites often involves disclosure of the volume of regulated diesel emissions that have health effects on the public. The shorter haul to agency owned sites may involve less diesel emissions but requirements on the back end of the project for site restoration and native plant re-establishment.

Rehab projects generally have little to no significant environmental impacts that must be described, mitigated and publicly vetted before the project can be approved for implementation. Repairs, contact grouting and other work to rehab or improve an existing tunnel are completed underground and with relatively little surface visualization. The standard construction impacts of noise, traffic and environmental pollution can be avoided or mitigated by design to the point of insignificance. Rehab projects typically require smaller surface areas for temporary staging of construction trailers, equipment parking and storage of materials.

The environmental review process for a rehab project typically involves less documentation and less public review. Because the environmental impacts are so much less or can be avoided, it is often possible to publish a mitigated negative declaration for the rehab project. If federal agencies are involved, the comparable federal document is the environmental assessment. Both documents are easier and less time consuming to develop and may save about one year compared to the EIR/EIS process for the new tunnel (AECOM, 2017).

**Environmental permits**

Separate from the environmental documentation
process is the issue of obtaining the environmental permits to allow construction to proceed. For example, in California, a biological opinion must be evaluated and obtained, and then California Department of Fish & Wildlife permits must be obtained. If the project involves federal participation or obtaining of easements, then U.S. Fish & Wildlife Service permits must be obtained. Such permits typically require special expertise either in-house or hired as consultants to interact with the permitting officials in order to work out conditions of approvals and details of the final project descriptions before the permit can be approved. It is not uncommon for such permits to consume more than a year of critical schedule after the environmental review process is completed.

If the project requires new tunnel easements and temporary surface easements for staging areas in national park land or forest preserves, as was the case for the new Mountain Tunnel options, then the permitting process is more complicated. The federal agency may pre-condition the granting of property easements on the approvals of the environmental review process, and in the process add more conditions of approval to the environmental permits.

Meeting performance standards

It is generally assumed that new tunnel projects can be designed to satisfy any set of performance standards for the project. While this is basically true, it overshadows the fact that most performance standards are derived from the design and operations of the existing facility, with perhaps a few upgrades.

In the case of the SFPUC Mountain Tunnel Improvement project, some of the performance standards were based upon the performance of the existing tunnel back when the tunnel was relatively new. A few standards were derived from the current operations of the tunnel. There were eight performance standards used as criteria for the selection of the preferred project during the project alternatives analysis (McMillen Jacobs, 2017):

- Service life: This standard requires the typical tunnel design for 100 years of service life. Although the best way to meet this standard is to construct a new tunnel, the rehab option can also achieve a 100-year service life. The Mountain Tunnel design consultant’s solution was to fix all the defects in the concrete lining with welded wire reinforcement and shotcrete and perform contact grouting to fill all the annular spaces between the lining and the surrounding rock (Fig. 4). When completed, the lining should be as structurally sound as a new lining and the rehab tunnel should last another 100 years with normal, periodic maintenance.

- Water quality: This standard limits the overall turbidity from Mountain Tunnel to occurrences of more than 1 NTU to no more than twice per year, and occurrences of more than 100 NTU to no more than once every five years. During normal operations, ground water intrusion is the main culprit for degrading water quality. For both new and existing tunnels, a way has to be found to limit this intrusion. For concrete tunnels, the best way to cut off the intrusion seepage pathways is to do an adequate job of grout injection of the native ground surrounding the tunnel, or contact grouting. For the rehab project, the entire 18 km (11 miles) of concrete-lined section will be aggressively contact grouted, essentially sealing the rehab tunnel from seepage. As an improvement, Mountain Tunnel will also install new large control valves at the downstream portal to keep the tunnel full of water when the tunnel is not running. With the tunnel full and pressurized, there would be little to no hydraulic gradient for the initiation of ground water intrusion. In addition, a short section of very leaky tunnel, upstream of the South Fork Siphon crossing underneath the Tuolumne River, will be replaced by a new 137-m (450-ft) long bypass tunnel section. This will eliminate the one worst section where ground water intrusion occurs the most.
• Water conveyance capacity: This standard requires a hydraulic capacity of 740 cfs (478 MGD). Advantage goes here to a new tunnel, in that a new tunnel can be sized to accommodate any flow capacity. However, in the case of the Mountain Tunnel rehab, flow capacity will be enhanced by the complete repair of wall defects, and invert paving and possibly smoothing, to improve hydraulic efficiency. The rehab project should be able to recover 706 cfs of initial capacity, or more than 95 percent of this performance standard. The SFPUC found this sufficient and efficient when the consideration of budget cost and schedule savings over the new tunnel are factored in. Also, the addition of downstream control valves to keep the tunnel flow at full volume will eliminate the erosive effects of the current tunnel operations, with intermittent surges and turbulent transitions between full flow and open channel flow inside the tunnel on a daily basis.

• Minimum flow: This standard requires a minimum flow rate of 300 MGD be available at all times outside of planned and unplanned outages. This is actually a fairly easy criterion to satisfy for a new tunnel and a rehab tunnel. For an existing tunnel, the key is to do the repairs of lining defects competently so that lining fallout does not occur and block flow capacity. This is accomplished by routing the defects back to structurally sound concrete, and backfilling the cavity with welded steel reinforcement and high strength shotcrete. The resulting repair would be as structurally sound as new lining.

• Operational flexibility: This standard includes four key operations. Mountain Tunnel must accommodate reductions in demand such that the tunnel may operate in open channel flow for extended periods. The tunnel needs to operate at full portion to meet water supply needs. The tunnel needs to accommodate power generation and local recreational needs, such that the tunnel may operate with substantial fluctuations in daily and hourly flows to the extent possible. The tunnel needs to accommodate full dewatering every five years for 100-day shutdowns for needed inspections of the Hetch Hetchy Aqueduct. The new tunnel and rehab tunnel can both be designed to handle all of these operational needs. In the case of the Mountain Tunnel rehab, downstream control valves will be added to maintain full volume flows so the erosive effects between full flow and open channel flows can be significantly avoided. With the downstream control valves, keeping the tunnel full of water, flows can be ramped up and down relatively quickly without developing the vacuum or surge pressures that promote erosion of the lining.

A related operational consideration during construction is the owner’s requirement for emergency return to service. The implementation of tunnel repairs can be done in finite prioritized batches. Such repairs are discrete as opposed to continuous construction along the tunnel alignment that must be completed in large units before any return to service can be contemplated. This is a very important consideration for any owner that encounters an event that requires an emergency return to service. Such emergencies usually require the curtailing of construction and return to water services over a few days. The 2017 Mountain Tunnel inspection and interim repair contract had a three-day requirement for the contractor to return the tunnel back to the owner for emergency return to service.

• Planned outages: This standard requires the reliable operation of the tunnel with an inspection frequency of 20 years with outage durations limited to 30 days, and major repairs at no more than once every 20 years with outage durations limited to 100 days. This is fairly easy for a new tunnel or a rehab tunnel to satisfy. After completion of both types of projects, the key is to not ignore the periodic maintenance required to keep the tunnel lining in good physical condition, and eliminate the need for major maintenance that often results from neglect. In the case of the rehab tunnel, the repairs need to be done competently so that lining fallout does not occur and require major maintenance. For Mountain Tunnel, simple planned inspections would only require outage durations of less than 10 days. A 30-day outage would allow time for some patchwork repairs of the lining. These short duration outages should be conducted concurrently with the five-year periodic outages for the Hetch Hetchy Aqueduct inspection interval under the operational flexibility performance standard. Periodic inspections every 20 years with outage durations of 100 days for the Mountain Tunnel should only be planned if major repairs are needed. Again, the goal of the inspection outages should be to catch the incipient defects when such defects are still small in size and fairly easy to repair.

• Unplanned outages: This standard limits the interruption in water delivery from a catastrophic event to no more than 90 days. Although there is uncertainty with any catastrophic event, the new tunnel and rehab tunnel can both be designed to make the lining as robust as possible to withstand shakeout from the forces of remote earthquake faults, or inadvertent damage from man-made events. Such is the case with the Mountain Tunnel rehab. The 2017 inspection found the existing
tunnel lining to be an average of 35 cm (14 in.) thick. The rehab will structurally repair all the defects and the entire 18 km (11 miles) of lined section will be contact grouted to make sure the lining is in intimate contact with the surrounding granitic rock. By doing so, any need for repairs after a catastrophic event will be mitigated and the forecast interruption for repairs should be less than 90 days.

- Seismic reliability: This standard requires the reliable delivery of the minimum flow without interruption following a near tunnel seismic event. This is the easiest of the performance standards to satisfy in that the tunnel does not cross any active earthquake faults and the Sierra foothills location of the tunnel is in a region of low seismic activity.

Recommended inspections and maintenance
Comprehensive and competent repairs and contact grouting during the rehab construction should produce a tunnel whose lining is free from defects and with a renewed service life that compares with a new tunnel lining. It is important for owners to support the renewed tunnel with proper, periodic inspection monitoring, water quality testing and maintenance. The inspection should be conducted at reoccuring intervals of between five and 20 years, as required by tunnel condition. The inspections may have to be conducted at shorter intervals if it is noted during the initial inspection that the erosion is occurring more aggressively than anticipated. The key is to catch any new defects in the lining while they are still incipiently developing. Such defects should be small in scope and more easily addressed in subsequently scheduled tunnel shutdowns that are well planned and budgeted in advance. If the repairs can be scheduled periodically at intervals of no more than 20 years or concurrent with the inspections, then the scope of repairs will be less significant, cost less per shutdown, and be able to be accomplished in fewer shutdowns of shorter duration, with better control of the scheduling and costs of the work—all good considerations for budget and operation minded owners.

Conclusion
Done right, the rehab tunnel project can result in a renewed tunnel that can match the 100-year service life and other performance standards of a new tunnel but at a fraction of the cost and schedule. The new tunnel will typically require a less complicated and time-consuming environmental review process and fewer environmental permit conditions for completion. In the case of Mountain Tunnel, the rehab project can almost match the required flow capacity of the new tunnel with the same accommodations for operational flexibility, planned and unplanned outages, and seismic reliability. As with any new or renewed tunnel, the key to facility longevity, without major headaches, is the attention and commitment to performing periodic inspection and maintenance. A well-designed and executed periodic repair program with the newest engineering and construction methods can yield similar results in a fiscally responsible way. The rehab option will successfully preserve the SFPUC’s Mountain Tunnel and meet its needs for many years to come.

References
There’s no fast way to add more than four miles of track, most of it underground, to the Sound Transit Link Light Rail system in the Seattle area. But increasingly busy traffic through a number of neighborhoods made it necessary. That’s the challenge a joint venture of several tunneling contractors faced when starting its portion of the $1.9 billion Northgate Link Extension in 2013, and the project is still keeping them busy three years later. Completion will mean just a 14-minute ride from Northgate to downtown for an extra 60,000 passengers by 2030. The transit lines will join 58 km (36 miles) of new and under-construction light rail lines running north, east and south from Seattle.

Voters, tired of long commute times, approved the project, a key part of Seattle’s regional mass transit system, in 2008. The extension is part of a plan adopted by the Sound Transit board in 1996 to connect the region’s major activity centers. The Northgate project is meant to relieve one of the area’s most congested traffic areas by connecting the Northgate, Roosevelt and University District neighborhoods to existing routes including downtown Seattle and SeaTac airport.

Sound Transit dedicated more than a quarter of the project’s estimated expense — $440 million — to general contractor JCM Northlink LLC to handle the tunnel segment. JCM is a joint venture formed in 2013 between Jay Dee Contractors of Livonia, MI, Frank Coluccio Construction of Seattle, WA and Michels Corp. of Brownsville, WI. The contractors regularly collaborate on large-scale projects and brought experience working on a different section of the extension they completed in 2013.

Project leaders knew immediately that the schedule would be demanding. They had to work around the clock, six days a week to meet deadlines. The extension runs through highly populated areas, meaning contractors had to follow strict city noise restrictions between 10 p.m. and 7 a.m. Plus, supervisors needed to manage the scheduling of nearly 250 employees to keep work running smoothly.

“We had eight different operations and four different subcontractors trying to work in one tunnel,” said Chris Wood, JCM site project superintendent. “It’s important that we keep work linear. That’s the biggest challenge: keeping a path in and out so you can pour concrete, keep electricians and carpenters going, and accomplish everything else.”

Project planners also realized they wouldn’t be able to use the same equipment they had in the past for tunneling projects. The tunnels would run directly below the University of Washington, which has long-standing, ongoing sensitive science projects. The train and tracks JCM used for past projects to transport crews and supplies through tunnels are loud and produce significant vibrations, which would have disrupted the experiments. To lower noise levels throughout the tunnel and to avoid disturbing the university, project leaders incorporated new sound abatement methods. JCM brought in seven Metalliance rubber-tired vehicles that stretched 16 m (52 ft) long but were just 2 m (6 ft) wide and could handle 41 t (45 st). Crews could use them as an alternative to a locomotive on rail for transportation in and out of the tunnel. In addition, the vehicles work with a number of attachments, including high-car platforms and concrete distribution attachments, reducing the need for additional equipment.

Crews started the tunneling portion of the project by digging two large vertical shafts and a tunnel portal to initially be used as access points for tunnel boring machines (TBMs), service work, material removal and supplies. The shafts will be converted to light rail stations when the project is complete. JCM used a Kroll 15000 tower crane with 4,900 kg (108,000 lbs) of lifting capacity, the third largest capacity in North America, to lift stacks of tunnel liner segments, equipment and material in and out of the 31-m (100-ft) deep shafts.

Once shaft construction was well underway, JCM began digging the twin-bore tunnels from Northgate to the already-excavated University of Washington station and existing light rail track. Crews used Hitachi Zosen (Hitz) and Robbins TBMs to simultaneously dig two parallel 7-m (21-ft) diameter tunnels. The machines stretch about 122 m (400 ft) long and advanced an average of 9-15 m/d (30-50 ft/day).

The tough soil didn’t make the job easy. The TBMs hit harder ground than anticipated, slowing down the machines as cutters and scraper heads wore down or broke against...
As tunneling moved along, crews started digging 23 cross passages between the tunnels. The 5- to 6-m (16- to 20-ft) long openings house electrical rooms and serve as safe havens and escape routes for train passengers in case of an emergency.

Cross passages are typically constructed using pneumatic tools and mini-excavators, but about five years ago, on another section of the light rail expansion, JCM began using a different approach: Brokk remote-controlled demolition machines. They made the switch to limit worker exposure to harsh tunnel environments and reduce the inevitable fatigue and potential injuries that come with using handheld tools all day. The remote-controlled technology also allows workers to operate the units from a safe distance, minimizing exposure to falling debris. JCM owned a Brokk 260 from an earlier project but with the increased demands and tight deadlines of the Northgate project, they decided to invest in two larger Brokk 400Ds and rented another in order to maximize productivity. The equipment’s efficiency and precision sped up the excavation portion to less than three weeks, shaving off more than a week of work compared to handheld tools.

Staying true to its “Rain City” nickname, Seattle gave JCM much more ground water than expected, causing complications. The TBMs had earth pressure balance systems that pushed water away, allowing technicians to do inspections and service cutter heads, but the cross passages weren’t as easy. The water volumes that needed to be pumped at some of the cross passages was far greater than what the municipal system could handle. Project leaders knew freezing the soil was a solution that would prevent structural issues and ensure safety during excavation. They originally planned to freeze five of the cross passages but expanded that to 10 after encountering the excess water. Crews again used the Brokk 400D, this time to drill holes for freeze pipe they installed within the haunches of the cross passages. They then pumped the pipes with a brine solution, chilling the soil to a frozen -12 °C (10 °F) and making it an easy target for a Brokk machine’s hydraulic breaker.

“[The freezing technique is invaluable to keeping work going quickly and safely],” Wood said. “It is very effective. The frozen sand ends up being like concrete until it thaws. This makes it really easy to chip away at without worrying about stability issues.”

After three years of tunneling with the TBMs, JCM completed the final breakthrough on Sept. 1, 2016. In total, crews removed about 554,000 m³ (725,000 cu yd) of material — enough to fill about 242 Olympic-sized swimming pools. JCM was to continue follow-up work until February 2018. The next contractors will continue work on the stations, rail and electrical components in preparation for project completion in 2021.

The transit plan approved by voters in 2013 also included an 13.7-km (8.5-mile) above-ground light rail extension from Northgate to Lynnwood. Project construction is expected to begin in 2018 with a goal of service starting in 2023. Voters approved another expansion including 100 km (62 miles) of new light rail and other transit additions in November 2016. The project is just one of a series of planned improvements, all part of an overall goal to relieve commuter headaches.
New Book Chronicles 200 Years of Tunneling in the United States

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Klug, Lawrence, Roach, Fulcher
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8,800 | 28  
10 | 2020  
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| Amtrak B&P Tunnel                              | Amtrak                                     | Baltimore    | MD    | Rail           | 10,000        | 30           | 2018     | Under design              |
| Thimble Shoal Parallel Tunnel                  | Chesapeake Bay Bridge & Tunnel Dist.       | Chesapeake   | VA    | Highway        | 5,700         | 45           | 2016     | Dragados/ Schiavone awarded |
| Hampton Roads Bridge-Tunnel Project            | Virginia DOT                               | Hampton Roads | VA   | Highway        | 7,500         | 42           | 2018     | Shortlist announced       |
| Northeast Boundary Tunnel                     | DC Water and Sewer Authority               | Washington   | DC    | CSO            | 17,500        | 23           | 2017     | Impregilo/Healy JV awarded |
| Potomac River CSO Tunnel                       | DC Water and Sewer Authority               | Washington   | DC    | CSO            | 4,500         | 33           | 2022     | Under design              |
| Olentangy Relief Sewer Tunnel                  | City of Columbus                           | Columbus     | OH    | Sewer          | 58,000        | 14           | 2017     | Under design              |
| Alum Creek Relief Tunnel Phase 1 Phase 2       | City of Columbus                           | Columbus     | OH    | Sewer          | 30,000  
21,000 | 18  
14 | 2018  
2019 | Under design | Under design |
| Westerly Main Storage Tunnel                  | NEORSD                                     | Cleveland    | OH    | CSO            | 12,300        | 24           | 2020     | Jay Dee/ Obayashi awarded |
| Shoreline Storage Tunnel                       | NEORSD                                     | Cleveland    | OH    | CSO            | 16,100        | 21           | 2021     | Under design              |
| Shoreline Consolidation Tunnel                 | NEORSD                                     | Cleveland    | OH    | CSO            | 11,700        | 9.5          | 2022     | Under design              |
| ALCOSAN CSO Ohio River Allegheny River Monongahela River | Allegheny Co. Sanitary Authority           | Pittsburgh   | PA    | CSO            | 10,000  
41,700  
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30  
30 | 2019  
2020  
2021 | Under design | Under design | Under design |
<p>| I-75 modernization project                     | Michigan DOT                               | Detroit      | MI    | CSO            | 22,000        | 14           | 2018     | Bid date 8/21/2018        |
| KCMO Overflow Control Program                  | City of Kansas City                        | Kansas City  | MO    | CSO            | 62,000        | 14           | 2018     | Under design              |
| Ship Canal Water Quality Project               | Seattle Public Utilities                   | Seattle      | WA    | CSO            | 14,250        | 19           | 2018     | Under design              |</p>
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<td>Gov. of Newfoundland/Lab</td>
<td>Newfoundland</td>
<td>NL</td>
<td>Transit</td>
<td>56,000</td>
<td>40</td>
<td>2020</td>
<td>Under study</td>
</tr>
<tr>
<td>Green Line LRT</td>
<td>City of Calgary</td>
<td>Calgary</td>
<td>AB</td>
<td>Transit</td>
<td>26,250</td>
<td>20</td>
<td>2018</td>
<td>Under design</td>
</tr>
<tr>
<td>Second Narrows Tunnel</td>
<td>City of Vancouver</td>
<td>Vancouver</td>
<td>BC</td>
<td>CSO</td>
<td>3,600</td>
<td>14</td>
<td>2013</td>
<td>Shortlist announced</td>
</tr>
<tr>
<td>Annacis Island Outfall</td>
<td>City of Vancouver</td>
<td>Vancouver</td>
<td>BC</td>
<td>Water</td>
<td>8,000</td>
<td>10</td>
<td>2017</td>
<td>Shortlist announced</td>
</tr>
<tr>
<td>Burnaby Mountain</td>
<td>Kinder Morgan</td>
<td>Vancouver</td>
<td>BC</td>
<td>Oil</td>
<td>8,000</td>
<td>12</td>
<td>2017</td>
<td>Under design</td>
</tr>
<tr>
<td>Broadway Sky train extension</td>
<td>Trans Link</td>
<td>Vancouver</td>
<td>BC</td>
<td>Subway</td>
<td>25,000</td>
<td>18</td>
<td>18</td>
<td>Under design</td>
</tr>
<tr>
<td>Northern Gateway Hault Tunnel</td>
<td>Enbridge Northern</td>
<td>Kitimat</td>
<td>BC</td>
<td>Oil</td>
<td>23,000</td>
<td>20</td>
<td>2014</td>
<td>Under design</td>
</tr>
</tbody>
</table>

To have your major tunnel project added to the Tunnel Demand Forecast, or to update information on a listed project, please contact Jonathan Klug at jklug@drklug.com.
UCA presents four awards at NAT

Lifetime Achievement Award to Harvey W. Parker

The Lifetime Achievement Award recognizes outstanding achievements in the underground design and construction industry. The outstanding achievements recognized have been accomplished through design or construction of civil underground facilities. The winners have contributed significantly to the education, planning, design, construction or rehabilitation of tunnels and underground facilities. This includes seeking advances in new methods and materials, and advancing the public understanding and concurrence with the beneficial uses of underground space.

Harvey W. Parker received his B.S. in civil engineering from Auburn University in 1957, a masters degree from Harvard University in 1967, and his Ph.D. in civil engineering, with a minor in geology, from the University of Illinois in 1976. His specialties are tunnel and geotechnical engineering. He is a Fellow of the American Society of Civil Engineers (ASCE), a member of the Moles and is registered as a civil and a geotechnical engineer. He holds a Diplomate in geotechnical engineering from ASCE. Parker was involved in the pioneer development of steel-fiber reinforced shotcrete, improved geotechnical tunnel investigation methods and monitoring techniques, and innovative tunnel linings and tunnel support materials. He is the author or co-author of more than 60 publications. He has consulted on world-class projects, including transit systems and water, sewer, highway and hydroelectric tunnels.

Parker has served as chair of UTRC, USNC/IT and ACI underground shotcrete committees. He has also served on the executive council of the International Tunnelling and Underground Space Association (ITA), represented ITA at the United Nations and was ITA president for three years. He also served in senior management positions and helped develop engineering staff and new markets for several firms.

Outstanding Individual Award to David R. Klug

The Outstanding Individual Award recognizes those individuals, including contractors, engineers, owners and suppliers, who have made significant contributions to the field of tunneling and underground construction and to the Underground Construction Association (UCA).

David R. Klug is the president of David R. Klug and Associates Inc. and Klug Construction Systems LLC based near Pittsburgh, PA. The companies provide international and national manufacturer representative services to the underground heavy civil and mine construction industries. They also specialize in the market-

Outstanding Educator Award to Priscilla P. Nelson

The Outstanding Educator Award is presented by the UCA Executive Committee to professors and teachers who have had an exceptional career in academia and education in the areas of underground design and construction. These individuals have also made significant contributions to the industry through their academic interests, as well as through the introduction of many student graduates into the industry. They are nominated by their peers.

Priscilla P. Nelson is professor and head of the Department of Mining Engineering at the Colorado School of Mines. She previously was provost at the New Jersey Institute of Technology, program director and senior advisor at the U.S. National Science Foundation, and professor in civil
Awards

The Project of the Year Award recognizes an individual or a group that has shown insight and understanding of underground construction in a significant project, which may include a practice, developing concepts, theories or technologies to overcome unusual problems within a project.

The construction of the Northern Boulevard Crossing, characterized by complex soil geometry, a high water table and an active, triple-level transit corridor above the tunnel alignment, is recognized as the most technically challenging aspect of New York City MTA’s East Side Access project. The Crossing, approximately 12-m (40-ft) high by 18-m (60-ft) wide, 38-m (125-ft) long and 26 m (85 ft) below ground level, was constructed using the Sequential Excavation Method.

The pre-existing transit corridor consisted of an active five-track IND subway box just a few feet above the tunnel crown, the Northern Boulevard itself, and east/westbound elevated BMT tracks, all heavily traveled. Public safety during the work was critical, and protecting these structures from movement during the performance of the work was considered paramount. However, site restrictions that included groundwater drawdown limitations and a moratorium on vertical drilling from Northern Boulevard or from the overlying subway tunnel severely limited available options. A canopy of frozen ground installed above the tunnel alignment to provide the required ground water control, as well as a structural arch for the sequential tunneling operation, was considered the only technically viable option. This option was suggested by the project designer and adopted by the design-build contractor.

The project was the first sequentially excavated, soft-ground tunnel in New York City. The size of the excavated tunnel completed beneath a frozen arch is unprecedented. There were many complicating elements that had to be overcome in creating the frozen arch and constructing the tunnel, including underpinning the elevated rail line and penetrating the existing four clusters of 16 pipe piles, which were indicated without any detail on old structural drawings. There were unique and previously unattempted settlement and heave-control measures performed in conjunction with a frozen ground improvement to protect the pre-existing transit structures. Other challenges included waterproofing, which was installed in stages due to the underpinning piles, and the final lining, which was constructed using shotcrete and massive ring steel.

The complex and challenging project was marked by extensive preplanning, stringent controls, a sophisticated monitoring program and a cooperative project team effort, which resulted in problem-free tunnel excavation with no appreciable movement of the overhead structures.

International tunneling awards to Southland Holdings

Southland Holdings LLC received two international tunneling awards from New Civil Engineer. The company received the 2017 Tunneling Project of the Year Award (project of more than $150 million) for the Kaneoh/Kailua Sewer Tunnel Project and the 2017 Outstanding Contribution to a Project Award for the Jollyville Transmission Main Tunnel.

The Jollyville Transmission Main Tunnel, Austin, TX, was lauded for project innovations related to unique environmental conditions and endangered cave-dwelling invertebrates encountered in the project area within the Balcones Canyonlands Preserve.

Project of the Year Award to Northern Boulevard Crossing, Queens, NY to Schiavone/Kiewit, AJV, WSP/Parsons Brinckerhoff and NYCMTA Capital Construction

The award (project of more than $150 million) pays tribute to the American Rock Mechanics Association (ARMA), a group that has shown insight and understanding of underground construction in a significant project, which may include a practice, developing concepts, theories or technologies to overcome unusual problems within a project.

The company received the Tunneling Project of the Year Award to Northern Boulevard Crossing, Queens, NY, to Schiavone/Kiewit, AJV, WSP/Parsons Brinckerhoff and NYCMTA Capital Construction.
The $87-million, 3-m (10-ft) diameter tunnel transports water more than 107 m (350 ft) below ground from Austin’s Water Treatment Plant No. 4 to the Jollyville Reservoir. A public outreach program contributed to community support and positive client feedback regarding zero environmental impacts to groundwater and surface water.

The Kaneohe/Kailua Sewer Tunnel Project successfully implemented the first use of a tunnel boring machine in Hawaii and on the island of Oahu. The project conveys wastewater from the Kaneohe waste water pretreatment facility to the Kailua regional waste water treatment plant to prevent overflows and spills during heavy rain events.

Working within unique island conditions, the Southland/Mole Joint Venture coordinated closely with state, city and county environmental permitting and enforcement agencies to ensure minimal impact to the project’s surrounding areas. Ground water controls, community engagement, and equipment procurement and logistics were also significant factors for success.

The Kaneohe/Kailua Sewer Tunnel Project final tunnel liner consisted of 3-m (10-ft) Hobas glass fiber-reinforced thermosetting resin pipe grouted in place.

### STUDENT OUTREACH

**Growing the next generation of tunnelers**

*by Paul Schmall, UCA of SME Student Outreach Chair*

I had breakfast with Mesut Pervispour a couple of weeks ago. He teaches geotechnical engineering and construction at Lehigh University. Ted Dowey had just visited Pervispour to do a lecture on the Rondout Tunnel Project for his construction engineering class. Pervispour and the whole class were in awe. He recounted to me how Dowey used the site photos to bring the project to life for the students. I don’t think Dowey really knew how impactful his one hour lecture was. And most of us don’t know how jaw-dropping impressive underground construction work is to students who have never seen it.

The UCA of SME Student Outreach has one overriding mission — to attract students to careers in underground construction. The hard part is getting that across to the current (and future) crop of engineering students. Tunneling is not taught in the typical undergraduate civil engineering program. Only the Moles or the Beavers reach a significant number of undergraduate civil engineering students to expose them to the world of underground construction, and that is still a limited number of students. We are trying to change that. By polling university professors, we have learned that live, on-campus presentations, such as Ted Dowey’s at Lehigh, project site visits, and teaching the teachers are the things we can do to make a difference. And that is our focus now.

Two years ago, we forged a strategic alliance between the UCA and the ASCE Geo-Institute. ASCE has direct access to all of the civil engineers nationwide, and the UCA has the expertise. It is a complementary and mutually beneficial relationship. Since that time, we have coordinated several programs: university speakers, tunnel tours and a teach-the-teachers workshop.
University speakers

The number one thing that all professors want is industry people to come to their classes and show their students what the real world is like. University ASCE chapters are always looking for good speakers with interesting project case histories.

To date, we have dispatched Barry Doyle of MWH Global to the Milwaukee School of Engineering, Nick Maynard of Citizens Energy Group to Purdue, Amanda Elioff of Parsons Brinckerhoff to UCLA, Adam Curry and James Myers of Moretrench to Widener College, Allen Cadden and Joe O’Carroll of Parsons Brinckerhoff to the University of San Diego, Jeremy Kosegi of Citizens Energy Group to the University of Illinois, Gregory Raines of Stantec to the Polytechnic University at Pomona, Rozbeh Moghaddam of GRL Engineers to Texas Tech and, of course, Ted Dowey of NYC DEP to Lehigh University.

The response everywhere has been tremendous. “I cannot express how unique of an opportunity this was for our student chapter” is a typical response we hear. We have several more lectures scheduled for the fall.

Tunnel tours

The Tunnel Tours program exposes the students to life underground, so to speak. The program provides an opportunity for a small group to tour an active tunneling project, which most, if not all, of the students have never seen. With the participation of many industry professionals willing to give their time and expertise, the tours include an above-ground presentation as well as lunch with the members of the tunnel design and construction teams. This gives the students a chance to engage with experts in the field of underground construction who can give them a true picture of what will hopefully become their chosen career. While The Moles provide a similar, positive experience in the northeast with their very successful, annual Moles Students’ Day, the Tunnel Tours program aims to provide the experience to students nationwide.

So far, we have hosted tours for Columbia, the University of California Davis and Oregon Tech to the Central Subway Chinatown Station Project in San Francisco; the Rose-Hulman Institute of Technology, the University of Michigan and Purdue University to the White River Tunnel in Indianapolis; North Carolina State University to the MD355 (BRAC) Crossing in Bethesda, MD; and Drexel University to Randall’s Island in New York City. Special thanks goes to Liza Dwyre and Tom Pennington who have been our primary hosts and to Barnard Construction, Kiewit and Atkinson.

Teach the teachers

We are fortunate to have Mike Mooney from the Colorado School of Mines involved with the Student Outreach program. With one foot in academia and one in the industry, Mooney is uniquely capable of being a liaison between the students and the industry. He has been spearheading the first teach-the-professors workshop that will take place at NAT. The intent of this program is to collectively develop tunneling-focused content that can be woven into the undergraduate geotechnical, structures and construction courses, educate the professors in underground construction, and provide them with a suite of instructional tools. Our hope is to equip the people on the front lines every day (the professors) to promote Ted Dowey-like jaw dropping excitement in the classroom.

UCA Young Members

A lot of people have already been working hard behind the scenes or have committed to be a part of the future program. The UCA Young Members group is a great example under the leadership of Shannon Goff, Tony Bauer and Erin Clarke. Our young members section may be small, but it’s active. They are working toward developing close relationships with colleges and universities with strong programs, and they host monthly online webinars for younger engineers on a range of topics. One of their goals is to provide better networking and job-seeking opportunities for young professionals. They are on board and enthusiastic about college-based presentations, and they are our first line of communication in that respect. This goal is already paying dividends. The UCA scholarships, for example, have truly taken off in the last couple of years.

What can I do to get involved?

If you have felt that somebody in your past was instrumental in shaping your career, please consider passing that forward. We all have the duty to replicate ourselves at least once. We have a solid start but welcome more member participation.

There is an impressive roster of subject matter experts to do presentations, but we lack qualified young engineers who are seasoned enough to know their subject well yet young enough to relate directly to students. Energy and enthusiasm are especially needed, but we can use anybody (older members included) that has a strong connection with any civil engineering program. There is a need for people in the heartland of the country, too. It seems that most of the expertise is on the East Coast and the West Coast, but a lot of the schools are in the middle.

More tunneling projects need to open their doors to a handful of students at a time. If you have a project that could accommodate a couple of tours a year, please consider it. Nothing is more effective than seeing the real thing.

If you can be a part of this exciting and worthwhile initiative, or would just like more information, please contact me at pschmall@moretrench.com.
North American Tunneling 2018 Proceedings

The North American Tunneling Conference is the premier biennial tunneling event for North America, bringing together the brightest, most resourceful and innovative minds in the tunneling industry. It underscores the important role that the industry plays in the development of underground spaces, transportation and conveyance systems, and other forms of sustainable underground infrastructure.

With every conference, the number of attendees and breadth of topics grow. The authors — experts and leaders in the industry — share the latest case histories, expertise, lessons learned, and real-world applications from around the globe.

Crafted from a collection of 126 papers presented at the conference, this book takes you deep inside the projects. It includes challenging design issues, fresh approaches on performance, future projects, and industry trends as well as ground movement and support, structure analysis, risk and cost management, rock tunnels, caverns and shafts, TBM technology, and water and waste water conveyance.

CSM offers tunneling fundamentals short course

Colorado School of Mines (CSM) will offer its internationally acclaimed Tunneling Fundamentals, Applications and Innovation Short Course Oct. 15-18, 2018.

The three-and-a-half day course weaves presentations of emerging innovations in tunneling methods, materials and technology with instruction on key principles of design and construction in all ground types and across all excavation methods.

Taught by experts from industry and CSM faculty, this course blends classroom instruction and presentations in the morning and early afternoon with hands-on laboratories and demonstrations each afternoon in the school’s world-class tunneling laboratories. The labs cover a wide range of emerging advances including soil conditioning, slurries, grouts, rock cutting, abrasivity and wear, blasting, geotechnical investigation, TBM simulation, shotcrete, 3D modeling and BIM.

The course will be held on the CSM campus in Golden, CO and offers a one-of-a-kind learning experience and great networking opportunities with both industry and CSM students. For more information and to register, visit http://csmspace.com/events/tunneling.

The Colorado School of Mines Center for Underground is a collaborative, multidisciplinary group of faculty and students from civil engineering, geology and geological engineering, mining engineering and mechanical engineering, as well as geophysics and computer science, with a collective interest in education and research in underground engineering. For more information about the center, visit http://underground.mines.edu.

PERSONAL NEWS

DON PAINTER, a senior tunnel construction professional, has rejoined Brierley Associates and will head its new office in Honolulu, HI. Painter recently served as the project manager for Southland Mole JV during construction of the Kaneohe Kailua Sewer Tunnel. He has more than 43 years of experience, including almost 20 years working with Brierley Associates. He was senior tunnel consultant with Brierley from 2005-2008 and previously served as the general tunnel superintendent for the H3/Haiku Tunnels on Oahu.

He has extensive experience with conventional and tunnel boring machine (TBM) tunnel construction for wastewater, water and transportation projects utilizing open (main beam) shielded TBMs.
O
n March 27, 2018, the under
ground construction industry lost a leader and a gentleman with the passing of George D. Yoggy after an extended battle with cancer. Born in Morris, PA on Oct. 16, 1937, Yoggy grew up in Johnson City, NY, attended Wheaton College and was member of the U.S. Navy Reserves as a Seabee.

Yoggy always had a love for heavy construction and the satisfaction derived from seeing complex challenges being met, beginning with his career with a local contractor in 1956. He developed an early expertise in shotcrete design and material application systems to address specific project requirements. In 1968, he started his own company, Concrete Equipment Corp., and in 1978 he started Shotcrete Plus Inc. One of his first major projects was the shotcreting of the supportive excavation “bathtubs” for the original World Trade Center buildings in the early 1970s.

After the September 2001 terrorist attack on the World Trade Center buildings, I, and a group of other industry individuals, accompanied Yoggy on a visit of the 9/11 site to view the potential damage to the PATH Subway Tunnel lining and the condition of the 1970s shotcreted supportive excavation for the foundation bathtubs. Yoggy took great pleasure in seeing that the worked performed in the early 1970s was still preventing the Hudson River from entering the site, even after such a catastrophic event.

In 1986, his companies were acquired by Master Builders Inc. He and Anne moved to Cleveland, OH, where he created the Underground Construction Group (UCG) for Master Builders. As the leader of the UCG, he transformed the group into the domestic and international leader in the development of new concrete/shotcrete technologies and material placing systems. Yoggy was recognized internationally for the successes created by his group, but he always acknowledged that this could not have been accomplished without the high caliber people that were part of his UCG team. Many of these people now have leadership roles in the underground construction industry.

Yoggy was involved in many major underground infrastructure projects during his long career with the implementation of engineered high-performance shotcrete systems that accompanied the introduction of NATM/SEM construction practices to North America. These include the WMATA Program in Washington, DC; the Sound Transit Program in Seattle, WA; the Pennsylvania Turnpike Lehigh Tunnel and the Cumberland Gap Tunnel in Tennessee. Later in his life he was deeply involved in the expansion of the subway system in New York City by working with the major tunnel contractors in the implementation of quality shotcrete application programs for the East Side Access Program, the No. 7 Line Extension Project, and the Second Avenue Station and Tunnel Expansion Program.

Yoggy had the philosophy that one must give back to the industry and not just reap the rewards. And he did this in many ways. He was a mentor to many young people who showed an interest in the industry and a desire to learn. Having knowledgeable and dedicated people involved on industry technical committees and associations is most critical to their success, and Yoggy gave of his time freely to such endeavors.

As a member of the American Concrete Institute Committee 506, Yoggy was a leading advocate for proper shotcrete specifications. And as a founding member of the American Shotcrete Association (ASA), which was formed in 1998, he helped to make the organization the leading industry advocate for the use and proper application of shotcrete for a variety of structural concrete applications. His involvement with the development of the ASA/ACI Shotcrete Nozzleman Certification program in 1999 helped to assure that the program got off to a proper start. He was always willing to share his knowledge and experience and was a mentor to several of ASA members. His strong impact on the ASA was acknowledged, as several past presidents of the ASA, as well as the executive director, attended his memorial service in Allentown, PA.

From 1999 to 2005, Yoggy was involved in the management structure of the American Underground Association, the predecessor to the current Underground Construction Association (UCA) of SME. He was president from June 2001 through June 2003. In June 2009, he was awarded the UCA Lifetime Achievement Award for his many industry contributions. He was also active with the International Tunnel Association in conjunction with the home office of MBT that was based in Switzerland.

On April 21, 2018, a memorial service was held for Yoggy at his church in Allentown, PA, which (Continued on page 38)
3D Laser Mapping releases real-time, underground monitoring

A unique scanner and software package developed by 3D Laser Mapping will boost safety, efficiency and productivity for underground operations. Processmonitor Live provides real-time, automated measurements of underground surfaces and is designed to be deployed in underground mining, construction and tunneling. The package provides a visual representation of surface changes in processes, such as sprayed concrete applications, tunnel excavation and slope-stability monitoring. Processmonitor Live’s scanner and software interface was originally designed in response to a request from a specialist shotcrete operator based in Australia and has been used extensively by its underground mining team.

The system was developed in response to feedback from customers who need to place safety and productivity in equally high regard — clients who have identified that time-consuming tasks can now be automated while reducing cost and risk to onsite personnel.

www.3dlasermapping.com

Sandvik offers iSURE software for tunneling construction

Intelligent Sandvik underground rock excavation software (iSURE) is a computer program for tunneling construction and mining drill and blast process control. It produces all the data needed for an optimized drilling and blasting cycle. The full-featured iSURE software utilizes the drill rig’s data collection to improve the work cycle and the drill and blast excavation process. It also has an optional toolset for geological analysis, iSURE GEO, a tunnel profile 3D scanning system, iSURE 3D SCAN, and an interface to a third-party blasting vibration feedback system. iSURE software capitalizes the improved accuracy of iSeries rigs for drill and blast usage.

Together, the iSURE software and DT922i tunneling jumbo, the newest addition to Sandvik’s extensive tunneling offering, create a combination designed to change the future of tunneling. The fully automated DT922i tunneling jumbo brings quality, reliability and exceptional versatility. With a new articulated carrier, it features a next-generation cabin supplying 25 percent increased visibility and a noise level of less than 69 dB at all times. Sandvik DT922i is a computer-controlled, two-boom, electro-hydraulic drilling jumbo with an articulated carrier for tunneling excavation of 12-125 m² (129-1,345 sq ft) cross sections, including face drilling, bolt hole drilling and mechanized long-hole drilling.

www.rocktechnology.sandvik

OBITUARIES

YOGGY

(Continued from page 37)

I attended. Approximately 25-30 people from the underground construction industry were there to pay their respects to a man held in high esteem by the industry and all of the 250 people in attendance.

I knew George Yoggy for more than 30 years. He was always a gentleman and willing to lend a hand.

He will be missed by the many people who came to know him and benefited from his wisdom and guidance. Rest in peace George, it is well deserved.

George Yoggy is survived by Anne, his wife of 59 years; three children, Kimberly, Lynn and Kirk, and eight grandchildren. The Yoggy family has established a scholarship fund with the Moles organization to help the next generation of industry engineers.

Individual or company contributions can be made to the George Yoggy Moles Scholarship Fund, 50 Chestnut Ridge Rd., Ste. 102, Montvale, NJ 07645.
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- Ulrikentunnel: Skanska Strabag Ulriken ANS
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AJ McGinn; (315) 434-8885
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Sanja Zlatanic, PE, Chair
National Tunnel Practice
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Mobile 1-646-652-9440
szlatanic@hntb.com

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Forty three years ago, Timothy Barnard founded Barnard Construction Company, Inc. Since then, our privately held company has grown into a multimillion-dollar contractor, with a binding capacity exceeding $2 billion. Over these four decades, we have built our reputation on skill, innovation, reliability, safety, and our ability to complete projects on budget and ahead of schedule. Among our Barnard companies and affiliates, we have extensive experience in all aspects of construction, including tunnels and shafts, dams, reservoirs, hydroelectric power, utilities, pipelines, power transmission, oil and gas, and environmental efforts. Headquartered in Bozeman, Montana, we construct projects throughout North America.

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Through its Master Builders Solutions brand, BASF is a leading supplier of underground construction solutions that help tunneling customers to become more successful, even in highly challenging ground conditions. BASF has the largest range of products and services available to meet needs and solve problems in TBM and conventional tunneling, whether in soft ground or hard rock conditions. We offer a full range of Master-Roc® tunneling products such as soil conditioning foams and polymers, anti-clay agents, tail sealants, anti-abrasion agents, dust suppressants, bearing seal greases, EP2 greases and annulus grouts, plus product line for sprayed concrete and injection for ground consolidation.

**FKC-Lake Shore**
FKC-Lake Shore serves the underground heavy civil and mining industries throughout North and South America. We offer design-build-install services for innovative hoisting, elevator, and vertical conveyance systems used to transport personnel and material. Our Field Services Division provides routine maintenance, inspections, wire rope NDT, and 24/7 emergency repair of electrical and mechanical systems. FKC-Lake Shore products and services include: Vertical Belts, Skips, Hoists, Shaeves, Elevators, Cages, Headframes, Brake-man Cars, Controls, Field Services, and Wire Rope NDT.

**FJH Fletcher & Co.**
J.H. Fletcher & Co. is one of the top global producers of custom underground mining equipment. The company has engineered and manufactured solutions since 1937, creating a diverse product line. Fletcher roof bolters are world renowned and accompanied by an entire product line, including: drill jumbos, powder loaders, scalers, and specialty equipment. Fletcher equipment is manufactured in a state of the art facility in the United States. Products are supported through a highly skilled staff of field service technicians and stocked by a fully stocked warehouse. Visit our website at www.jhfletcher.com to learn more about our product line or call us today at 800-543-5431 to get your solution started.

**Jacobs**
Jacobs brings extensive design and construction management experience to all types of tunnels projects, including: highways, transit/railroad, water and wastewater systems. We have successfully delivered the design of some of the most challenging recent design-build/P3 tunnel projects in the U.S., such as the Port of Miami Tunnel project in Florida, the Blue Plains Tunnel in Washington D.C. and the Ohio River Bridge East End Crossing Tunnel in Louisville, Kentucky. With a talent force of more than 74,000, Jacobs provides a full spectrum of services including technical, professional and construction/program-management for business, industrial, commercial, government and infrastructure sectors. For more information, please visit www.jacobs.com.

**Kiewit**
For more than 50 years, Kiewit has built some of the most complex tunneling and underground projects in North America. We have the capabilities to self-perform soft ground and hard rock TBM tunneling, along with conventional tunneling techniques such as Drill and Blast, and SEM. At the heart of these projects is a workforce dedicated to industry-leading safety performance and unmatched quality excellence. From the unique, complex projects we build, to the committed professionals who design, engineer and construct them, Kiewit ensures the ordinary is always extraordinary.

Kiewit Infrastructure Co.
Underground District
1926 S 67th St., Suite 300
Omaha, NE 68106
(402) 342-2052

**Skanska**
Skanska USA Inc. is one of the largest, most financially sound construction and development companies in the U.S., serving a broad range of clients including those in transportation, power, industrial, water/wastewater, healthcare, education, sports, data centers, government, aviation, life sciences and commercial. Through the Skanska USA has extensive tunneling and complex underground experience and expertise in support of a variety of infrastructure sectors.

**Stantec**
Stantec is one of the world’s largest professional services firms, with expertise in design and engineering projects. Our expertise is wide-ranging, from underground infrastructure, to community revitalization, to environmental protection, to smart city solutions. We work across the globe with our clients to ensure that they have the tools they need to meet the needs of their communities and achieve their goals.

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www.fkc-lakeshore.com
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Babendererde Engineers

BabEng specializes in mechanized tunneling and underground storage construction. The world-wide services range from project development and design to construction management and practical work process optimization. Another successful service being offered is hands-on troubleshooting on-site for TBMs in difficult situations. For water and gas storage, BabEng joins forces with project developers and construction companies. TPC Tunnelsoft, the software branch, supports the tunneling industry with specialized software for technical data management and visualization on tunnel projects. Its unique flexibility, combined with powerful automatic reporting and notification tools, makes it one of the leading solutions in the market.

Lovsuns Tunnelling Canada Ltd.

Lovsuns is a LNSS company that acquired the entire assets of Caterpillar Tunneling Canada Corp. (formerly known as LOVAT) in 2014. Lovsuns continues to build on the 40+ years of TBM manufacturing legacy and is specialized in engineering and manufacturing full range of tunnel boring machines for both traffic and utility tunnel projects around the world, including EPB, single shaft, double shield and dual mode convertible TBMs. By leveraging our modern and high-capacity factory in China, Lovsuns is fully committed and capable of supplying new TBM and legacy LOVAT TBM refurbishment support solutions for our global customers.

Jay Dee Contractors, Inc.

Jay Dee Contractors, Inc. has been delivering quality and innovative underground construction since 1965. Our team is comprised of experienced and dedicated industry professionals, and our commitment to quality is evident in everything we do. We continue to build upon our reputation of excellence by delivering innovative, quality and reliable underground tunneling projects including: Soft Ground, Hard Rock and Pressurized Face Tunneling; Tunnel Rehabilitation – Shaft and Caisson Excavations - Concrete Structures

38777 Schoolcraft Road
Livonia, MI 48150
Telephone: (734) 591-3430
Email: estimating@jaydee.us

SAK Construction, LLC

SAK Construction, LLC (SAK), a national pipeline rehabilitation and tunneling services contractor is a leading provider of pipeline rehabilitation services. The company solves the challenge of maintaining and restoring aging water and sanitary infrastructure for the municipal, energy and industrial markets. Founded in 2006, SAK Construction has built a reputation as an industry leader and is recognized as one of the nation’s most respected pipeline rehabilitation contractors. Led by industry pioneers, Bob Affholder, Jerry Shaw and Tom Kalishman, SAK has become one of the fastest growing privately owned construction companies in the United States.

Traylor Bros

Traylor Bros., Inc. (TBI) is a family-owned corporation founded in 1946. For more than 72 years, TBI has provided single-source, comprehensive, cutting-edge construction and design-build services to public works agencies throughout North America. Headquartered in Evansville, Indiana, TBI has regional offices in Long Beach, California; Lakewood, Colorado; and Alexandria, Virginia. TBI capitalizes on state-of-the-art technology for its soft ground, hard rock, and drill and shot tunnel projects worldwide. We have successfully completed more than 110 tunneling projects, including two of the most technically demanding EPB tunnels in the United States and over 100 miles of tunnels utilizing tunnel boring machines. Our services also include drill and blast tunnels and precast tunnel segments.

Michael Roach
3050 E Airport Way
Long Beach, CA 90806
Telephone (562) 264-2500
NORTH AMERICAN TUNNELING CONFERENCE
June 24-27, 2018
Marriott Wardman Park - Hall B South & C - Washington, DC

Exhibit Hall Hours

Monday, June 25
5 PM – 7 PM
Tuesday, June 26
11 AM – 2 PM, 4 PM – 6 PM
Wednesday, June 27
9 AM – 12 PM
## NAT 2018 Exhibitors

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WSP | 208
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Zed Tunnel Guidance Ltd | 421
ABC Industries, Inc
Booth: 305
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For over 90 years, ABC Industries continues to be a leading supplier of high quality, customized ducting solutions in mine, tunnel and underground construction operations worldwide. As these operations continue to evolve, ABC proactively collaborates with industry professionals to engineer unique, premium ventilation products. A new innovative addition to ABC’s arsenal, RigiVent™ is a flexible, interlocking ducting solution for positive pressure applications requiring minimal storage and ease of handling. Similar to RigiDuct®, RigiVent™ is constructed from filament wound fiberglass rovings and reinforced with polyester fibers for added strength and resiliency. Visit our website to see more innovative solutions.

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Winona Lake, IN 46590 USA
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www.abc-industries.net

ABC Ventilation Systems
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ABC Ventilation Systems is one of the world’s leading companies in underground ventilation. ABC Ventilation Systems provides complete tunnel ventilation design along with a package of AMCA certified fans and MSHA approved ducting. ABC provides one of the most silent fan systems with its patented Sound Trap fans or optional exterior silencers. ABC now offers a highly efficient deduster as well as a new low resistance, high pressure, flat shipped hard line ducting for positive and negative pressure applications. ABC Ventilation Systems high pressure Zipper Coupling has one of the lowest resistance and leakage profiles available.

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Advanced Concrete Technologies
Booth: 225
See our ad on page 9
Advanced Concrete Technologies, Inc. is the North America division of German based Wiggert & Co manufacturer of turnkey concrete batching plants, mixers, control systems, batching equipment, concrete distribution systems. Amongst the well-known brands are the high shear HPGM planetary countercurrent mixer, High output DWM twin shaft mixer, MobilMat concrete plants, SmartMix concrete plants, HydroMat microwave moisture measuring technology and the WCS PC based control system. ACT delivers highly efficient, fully integrated equipment solutions to the concrete industries and fulfills the demands for today’s highest quality and environmental standards.

Products & Services
Concrete Mixing and Transportation Equipment

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AECOM
Booth: 500
AECOM is built to deliver a better world. We design, build, finance and operate infrastructure assets for governments, businesses and organizations in more than 150 countries. As a fully integrated firm, we connect knowledge and experience across our global network of experts to help clients solve their most complex problems.

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- Consulting Engineers
- Engineering Design and Services for Tunnels
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AECOM
1111 3rd Ave, Ste 1600
Seattle, WA 98101 USA
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Email: paul.nicholas2@aecom.com

Aerix Industries
Booth: 542
Aerix Industries (formerly Cellular Concrete Solutions), manufactures and supplies a dynamic product line of integrated engineered foam liquid concentrates, enabling its customers to produce and install high quality lightweight cellular concretes, ideal for annular grouting, tunnel arch backfill and flowable fill. The company’s foams also allow its customers to transport tailings, sand, or other construction materials using minimal amounts of water. Aerix Industries dedication to research and technical support has allowed it to provide advanced engineered foam solutions to the construction and mining industries for more than 70 years.

Products & Services
- Ground Improvement Equipment and Services
- Grouting Services, Equipment and Materials

Main Office
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Golden, CO 80403 USA
Telephone: (303) 271-1773
Fax: (303) 273-5411
www.aerixindustries.com
Agru America, Inc
Booth: 300
Since 1988, Georgetown, SC–based Agru America, Inc., has been the world’s leading manufacturer of flat die extrusion geomembranes, geonets, geocomposites, geotextiles, geo clay liners, concrete protective liners and fittings. Agru America also supplies vertical barrier systems and piping systems for the U.S. and international markets. The company’s state-of-the-art products include Sure-Grip® CPL, Hydroclick®, Agru Smooth Liner® / MicroSpike® (structured textured products), Super Gripnet®, and Drain Liner®. Agru America is part of the worldwide AGRU Group, an Austrian family-owned business since 1948 with production facilities in Austria, the U.S., Germany and China, and distribution in over 80 countries worldwide.

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Email: salesmg@agruamerica.com
www.agruamerica.com

AIL Mining
Booth: 510
AIL Mining designs and manufactures a 4 flange and 2 flange shaft or tunnel liner plate which is 10 times stiffer and 5 times stronger than traditional steel liner plate • Diameters in excess of 25 m/82 ft, • Custom sizes and shapes available, • Fabricated elbows • Easy to ship and install • Accelerated assembly, easier fitting of plates • Smaller crews needed, lower installed costs • Added safety, structures can be built from one side • Facilitates curved structures • Allows for leak-resistant structures • Structures can be dismantled and removed.

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111 Springstead Ave
Stoney Creek, ON L8E 6E7 Canada
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www.ailmining.com

Akkerman
Booth: 633
Established in 1973, Akkerman develops, manufactures and supports quality pipe jacking and tunneling equipment that accurately installs a variety of underground infrastructure. We partner with contractors to explore project solutions for a wide range of geology, pipe diameters and lengths. We are committed to making every effort to position our equipment on your next pipe jacking or tunneling project. Akkerman systems are available for purchase, lease-to-purchase, or rent from our rental fleet.

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Brownsdale, MN 55918 USA
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Fax: (507) 567-2605
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www.akkerman.com

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Babenderede Engineers, LLC specializes in mechanized tunneling and underground storage construction. BabEng joins forces with project developers and construction companies. TPC Tunnelsoft, the software branch, supports the tunneling industry with specialized software for technical data management and visualization on tunnel projects. BabEng’s unique flexibility, combined with powerful automatic reporting and notification tools, makes it one of the leading solutions in the market.
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Brokk is the world leader in electrically powered remote controlled demolition machines, which are used extensively in tunneling, cross-passages, shaft sinking, micro-tunneling, scaling, and other underground construction applications. BROKK machines can be equipped with a variety of attachments, such as hydraulic breakers, rock drills, rotary drum cutters, digging buckets, beam manipulators, and shotcrete nozzles. Boasting an impressive power-to-weight ratio, these compact machines can operate effectively in limited access, confined spaces, with zero-emissions. Operators can remain at a safe distance while they maneuver BROKK machines in challenging areas underground.

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Case Foundation - Bencor
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David R. Klug & Associates, Inc. provides manufacturers representative services to the underground civil and mine construction industries. The company specializes in products and services for soft ground, conventional, and NATM/SEM tunnels. Expertise is offered in the supply of componentry used in precast tunnel linings inclusive of EPDM gaskets, plastic and steel connectors, grout lifting assemblies and steel segment moulds plus final lining forming systems for C-I-P applications. Through their distribution company, Klug Construction Systems, LLC offers GFRP rock bolts and soft-eyes, steel and synthetic fiber reinforcement, prefabricated mesh and rebar reinforcement plus specialty grout systems for tunnel backfill requirements.

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Dr. Sauer & Partners has been in practice in the United States for over 30 years, and employs tunnel engineers at Main Offices located in Washington D.C., London and Salzburg. The firm provides cost effective and innovative tunneling solutions using conventional mining approaches to owners and contractors. Dr. Sauer & Partners is recognized worldwide as one of the leading consultants for design and construction supervision of tunnels and underground structures. The application of innovative design solutions and high quality field supervision has led to the successful completion of numerous transportation and utility tunnels.

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Epiroc
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Epiroc is responsible for the sales, aftersales service and rental of equipment for surface and underground rock excavation, civil works and infrastructure projects, exploration drilling, rock reinforcement, and ground engineering. The company is headquartered in the US near Denver, Colorado. Employing approximately 450 people, it extends its reach through a nationwide network of sales and service stores and specialist drilling distributors.

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Derrick’s separation technology offers unmatched solids removal performance. Using this equipment and innovative screen technology, customers continuously recycle and re-use drilling fluid, while also controlling drilled solids and impact on the environment. Our civil construction solutions are currently used worldwide by companies that require high efficiency separation and slurry dewatering in environmentally sensitive and urban environments.

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GCP Applied Technologies

Booth: 404

GCP is a leading global provider of construction products technologies that include DE NEEF® Injection Materials/Soil Stabilization, specialty systems including TYTRO™ solutions for tunnels, additives for cement and concrete, the VERIFI® in-transit concrete management system and high-performance waterproofing products. GCP products have been used to build some of the world’s most renowned structures. More information is available on our website.

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Grouting Services, Equipment and Materials
Precast Concrete Linings
Shotcrete Equipment, Supplies, and Services
Tunnel Lining and Support Materials

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www.gcpat.com

Geocomp Corp/GeoTesting Express, Inc

Booth: 312

Geocomp designs, installs, and manages real-time, web-based instrumentation and monitoring programs for tunnels around the world. We also help identify, assess, and mitigate risks associated with construction by providing quantitative identification of risks and the potential impact to project cost, schedule, and quality. Our laboratory division, GeoTesting Express, is a fully accredited, world-class laboratory providing high-quality results with fast turnaround time for mechanical and physical properties testing on soils, rocks, and geosynthetics. We perform a full suite of testing in support of tunnel projects, including rock strength, rock drillability, soil strength, and soil abrasion.

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Fax: (978) 635-0266
Email: info@geocomp.com
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Geo-Instruments, Inc

Booth: 327

Geo-Instruments provides geotechnical and structural monitoring services. We supply, install, and integrate geotechnical sensors and geomatic systems, and we automate the collection, processing, and delivery of data. Our systems monitor SOE, settlement, deformation, structures, vibration, dust, and noise.

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**Booth: 523**

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Tunnel Boring Equipment
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**Geokon, Inc**

**Booth: 552**

See our ad on page 26

Geokon, Inc is a specialist in the supply of instruments for the NATM method of tunnel support. In addition to almost all major cities in the USA, the company has instrumented subway systems in Seoul, Taipei, Guangzhou, Istanbul, Hong Kong, Singapore and London. Geokon also has instruments in the Channel Tunnel. Call Geokon for a quote or with questions on an application. The company is prompt and courteous in its replies.

**Products & Services**

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Grindex Pumps

Booth: 626

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Booth: 526

HAGER-RICHTER GEOSCIENCE, INC. is a well established small business that specializes in Surface and Borehole Geophysics for Engineering applications (NACS 541360). The firm has been in business since 1984, has earned a national reputation, and has a nationwide practice. Hager-Richter is headquartered in Salem, New Hampshire and has had a fully staffed and equipped New York/New Jersey Regional Office in New Jersey since 2001. Hager-Richter has extensive experience in providing high resolution geophysical services to support tunneling infrastructure projects in the Northeastern, Southeastern, and Midwestern sections of the U.S.

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Fax: (603) 893-8313
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Halfen

Booth: 620

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Hatch

Booth: 412

Hatch is an employee-owned, award winning, multi-disciplinary professional services firm that delivers a comprehensive array of technical and strategic services, including consulting, engineering and project and construction management to the Infrastructure, Energy and Mining sectors. Hatch has served clients for over six decades with project experience in more than 150 countries around the world. With over 9,000 staff in over 50 offices, the firm has more than $35 billion in projects currently under management. Hatch has participated in the delivery of most complex tunnels such as OPG Niagara tunnel, Seattle Beacon Hill project and Toronto-York Spadina Subway Extension Twin Tunnels.

Products & Services

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Hayward Baker Inc

Booth: 325

See our ad on Outside Back Cover

Hayward Baker is part of the connected companies of Keller and provides services to solve a variety of tunneling issues: the stabilization of soft soils for tunnel boring and break-ins and break-outs; groundwater control; tunnel liner stabilization; access shaft construction; re-leveling TBMs; and controlling settlement of overlying structures during tunnel boring. Hayward Baker has the experience and state-of-the-art technology to solve every subsurface problem, typical or unique.

Products & Services

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North American Tunneling Conference June 24-27
Booth #501
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Booth: 217

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Herrenknecht is a technology and market leader in the area of mechanized tunneling systems. As the only company worldwide, Herrenknecht delivers cutting-edge tunnel boring machines for all ground conditions and in all diameters — ranging from 0.10 to 19 meters. The Herrenknecht product range includes tailor-made machines for transport tunnels (Traffic Tunnelling) and supply and disposal tunnels (Utility Tunnelling). Furthermore, Herrenknecht supplies an entire range of innovative machines for the mechanized construction of underground mining infrastructures. The company also produces state-of-the-art deep drilling rigs that drill down to depths of 8,000m and plants for the exploration of shallow geothermal energy.

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www.herrenknecht.com

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Telephone: (253) 447-2300
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Email: brockway.jack@herrenknecht.com

HNTB Corp

Booth: 223

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With 3800 professionals, HNTB is a leader in providing solutions to infrastructure problems nationwide. The firm has a long history in design and engineering services for tunnels and underground construction. HNTB has completed award-winning projects on some of the country’s most complex projects, including highway, transit, rail, aviation and water resources. HNTB’s experts have the insight and knowledge to provide state of the art innovative solutions to tunneling challenges, from small diameter excavations to designing the largest bored tunnel in the world (Alaskan Way Tunnel)— utilizing both conventional tunneling methods (sequential excavation) or mechanized tunneling for variety of ground conditions.

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Booth: 647

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Booth: 643

Innovative Wireless Technologies, Inc. (IWT) is the leading supplier of wireless underground communications and tracking systems. IWT’s SENTINEL™ system is easy to install and maintain and provides crystal clear voice communications for maximum productivity and low cost of ownership. Continuous tracking is also supported – all in one system. IWT offers line-powered, battery-backed-up, mesh networking infrastructure for long term construction projects, or battery-powered infrastructure for shorter term inspections. IWT equipment is 100% recoverable and reusable once the project is completed. Listen to our presentation at the 2018 NAT Conference, stop by our booth or visit our website.

Products & Services
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JADCO Manufacturing Inc

Booth: 555

Founded in 1960, we are an industry leading and ISO 9001:2008 certified manufacturer of proprietary impact and abrasion resistant wear steel mainly focused on mining, tunneling, cement, dredging, pulp and paper, foundry, waste, recycling and general industry. Along with our wear steel offering we provide full line fabrication and service to compliment. JADCO delivers unmatched technical expertise, quality, and customer service - and offers an unparalleled array of wear-fighting products, particularly our QT-PLUS® and CHROMEWELD brands. Specific industry applications can be found on our website.

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Jennmar Civil

Booth: 607

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Jennmar Civil is dedicated to providing products and services to the Civil Construction and Tunneling industries. Products include various types of rock support bolts, anchoring systems and resins to support tunneling, geotechnical, foundation and earth retention projects. Jennmar Civil’s Specialist are experienced, knowledgeable and accessible. Jennmar’s primary product roster includes PYTHON expandable rock bolts, FRICTION-LOK stabilizer systems, steel sets, steel tunnel and shaft ribs, lattice girders, rail ties and resin. For more information, contact a specialist today or visit our products online.

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Kern Tunneltechnik SA

Booth: 457

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King Shotcrete Solutions

**Booth: 511**

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Lovsuns Tunneling Canada Ltd

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Lovsuns is a LNSS company that acquired the entire assets of Caterpillar Tunneling Canada Corp. (formerly known as LOVAT) in 2014. Lovsuns continues to build on the 40+ years of TBM manufacturing legacy and is specialized in engineering and manufacturing full range of tunnel boring machines for both traffic and utility tunnel projects around the world, including EPB, single shield, double shield and dual mode convertible TBMs. By leveraging our modern and high capacity factory in China, Lovsuns is fully committed and capable of supplying new TBM and legacy LOVAT TBM refurbishment support solutions for our global customers.

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- Rock TBM’s Tunnel Boring Equipment

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www.lovsuns.com

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**Booth: 619**

Malcolm Drilling Company, Inc. has for over 5 decades been an innovator and leader in the deep foundation industry. Malcolm’s list of core services as it relates to tunneling and geotechnical construction includes drilled shafts, support of excavation systems, cutoff, slurry and secant pile walls, grouting techniques, various soil mixing methods and dewatering. These combined services have routinely been applied on numerous complex tunneling projects throughout North America. The company’s engineering experience facilitates design/build efficiency and allows for timely collaboration with owners and contractors. This delivery system optimizes cost savings while offering inherent scheduling advantages.

**Products & Services**
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Mapei Corp

**Booth: 307**

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MAPEIs Underground Tunneling Technology (UTT) category offers a complete line of products and associated technologies for use in and on underground construction projects, including shotcrete accelerators and admixtures for concrete, as well as products for injection and consolidation, mechanized tunneling (TBM), engineering and soil stabilization, coating and protection, maintenance, repair and waterproofing.

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**Booth: 301**

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- Dust and Fume Control Technology
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- Safety Products
- Tunnel Communication Systems and Equipment

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We’ve been an innovative leader in ground control for the mining industry for more than forty years. Over the past decade, our growth has led us to make key acquisitions of resources to further enhance our deep commitment to serve the tunneling industry as well. Our rock bolts, anchoring systems, liner plates and resins are backed by experienced engineers and technicians who are with you every step of the way, from initial consultation to qualified instruction and on-going technical support. And, of course, our customer service is second-to-none. That’s something we’ve always demanded of ourselves.
McDowell Equipment Ltd

Booth: 405

McDowell can supply brand NEW and LATE model tunneling equipment for Rental or Sales. Our rental fleet consists of Underground Loaders(LHD) ½ yd to 10 yd, Underground Haul Trucks from 7 ton to 40 ton, low profile Motor Graders, Jumbo Drills with one, two or three booms, Underground Removers, Locomotives , Muck cars. We manufacture shotcrete machines, scissor lift , Arfo loaders, and personnel carriers. We can also offer fully re-manufactured or reconditioned equipment at significant savings from new with Fast delivery times.

Products & Services
- Microtunneling Equipment, Tools, and Supplies
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- Tunnel Haulage Systems
- Underground Excavation Services and Equipment
- Underground Locomotives and Rail Haulage Equipment

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Fax: (705) 566-6401
Email: sales@bmcdowell.com
www.bmc-dowell.com

McMillen Jacobs Associates

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McMillen Jacobs Associates offers a mid-sized multi-disciplined firm, with self-performing design-build capability. We are experts in tunneling and water resources and deploy that expertise to serve water, wastewater, transportation, hydropower, energy, aquaculture, and regulatory clients using a wide range of delivery methods. For over 60 years, we have worked closely with our clients at every stage of a project, assisting them with planning, design, project management, construction, and start-up services. McMillen Jacobs Associates maintains offices covering North America and Australasia.

Products & Services
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- Consulting Engineers
- Engineering Design and Services for Tunnels
- Geological, Geotechnical Services and Equipment
- Underground Excavation Services and Equipment

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Fax: (206) 388-6200
Email: info@mcmjac.com
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McMillen Jacobs CA

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Telephone: 925-945-0677
Email: spreng@mcmjac.com

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Messurand Inc

Booth: 538

Messurand designs and manufactures ShapeArray, a 3D shape-sensing automated instrument that measures deformation in slopes, tunnels, dams, and other civil structures. With over 96,000 m of ShapeArray installed worldwide, Messurand is the industry standard for real-time 3D geotechnical and structural deformation monitoring.

Products & Services
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- Instrumentation Equipment and Services

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www.messurand.com

Mighty Shield Industries Sdn Bhd

Booth: 603

Mighty Shield Industries incorporated in 2002, is located in Shah Alam, Malaysia. As part of our range of products, we manufacture Dunamis™ FRC macro polypropylene (PP) fibres to support reinforcement in mining and concrete construction. Our PP fibres bridge cracks, support and timely delivery to better support the tunnel market.

Products & Services
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Northwest Laborers-Employers Training Trust

Booth: 424

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**See our ad on page 48**

Schauenburg Flexadux Corp

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Shotcrete Technologies, Inc.

When You’re Six Miles Inside A Mountain, You’ll Really Appreciate Your Partnership With Shotcrete Technologies, Inc.

Whether it’s a quarry in Iowa, a subway tunnel in Washington D.C., or a mine in Australia, Shotcrete Technologies, Inc. has “been there, done that!” STI has the products, the know-how, and the service support to get your project done right, on time, and on budget.

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Everyone knows that ground freezing succeeds in extremely difficult soil conditions where other excavation support methods are not feasible. Everyone also knows that soil freezing is one of only a handful of shoring methods can eliminate groundwater infiltration. But did you also know advancements in freeze technology and refinements in our freeze equipment has made SoilFreeze more mobile, versatile, and more cost efficient than ever before? And that soil freezing is extremely eco-conscious?

So why wait for the worst soil conditions? Ground freezing can solve any ground support requirements and eliminate dewatering at the same time. SoilFreeze is a leading provider of efficient, environmentally friendly ground freezing solutions. Installations can be designed, installed, and maintained for projects lasting a few weeks, or for several years. We serve both the private and public sectors and have a substantial list of successful projects and clients.
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- Geological, Geotechnical Services and Equipment Instrumentation Equipment and Services

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Sika Corporation

Booth: 610

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Booth: 423

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Simem Underground Solutions, Inc
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SoilFreeze Inc
Booth: 116
See our ad on page 51
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Surecrete Inc
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Surecrete Inc. is a supplier focusing on packaged cementitious materials, admixtures, placing equip- ment and related accessories to the heavy civil tunnel, geotechnical and mining markets. Product lines in- clude Super Fine ultrafine cement and HNP nano-fine cement grouts as well as other specialized grouting materials. We also concentrate on supplying wet and dry shotcrete materials that are custom blended for specific applications by including fibers, accelerators, special cements, and additives. Our additives include rheology modifiers, waterproofing and repair materi- als. We also represent several major equipment manu- facturers specializing in the mixing and placing of shotcrete, concrete, and grout.

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Booth: 317
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Booth: 547

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TRE ALTAMIRA Inc

Booth: 543

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Tsurumi Pump

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Booth: 308
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Corp

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Worldsensing

Booth: 617

Make manual and cable readings an issue of the past: connect tunnels to the Internet of Things (IoT) and remotely monitor how the structure behaves. Load-sensing, the leading wireless monitoring system, is deployed in several sections of the Purple Line Metro Project in LA to enable the wireless monitoring of the stability of the tunnel and the surrounding buildings. Load-sensing is part of Worldsensing, a widely recognized global IoT pioneer. The technology provider delivers Operational Intelligence to traditional industries and cities. With offices in Barcelona, London and Los Angeles, Worldsensing is globally active with customers in over 50 countries.

Products & Services
Instrumentation Equipment and Services
Mining Equipment
Tunnel Communication Systems and Equipment

Main Office
C/ Viriat 47, 10th floor
Edificio Numancia 1
Barcelona, Barcelona 8014 Spain
Telephone: +34 93 418 05 85
www.worldsensing.com

WSP

Booth: 208

WSP is a leader in tunneling and underground construction, from San Francisco to Stockholm. The firm has participated in the design and construction of some of the longest, largest, deepest, and most complicated tunnels in the world, including tunnels built in hard rock, soft ground or mixed-face conditions, and using mining, boring, jacking, cut-and-cover, and immersed tunnel technology. Projects include the Second Avenue Subway in New York City; the Stockholm City Line; the Eurasia tunnel in Istanbul; and San Francisco’s Central Subway. WSP employs 42,000 professionals in 500 offices across 40 countries.

Products & Services
Consulting Engineers
Engineering Design and Services for Tunnels
Geological, Geotechnical Services and Equipment

Main Office
444 S Flower St, Ste 800
Los Angeles, CA 90071 USA
Telephone: (213) 465-5215
Email: Frank.Pepe@wsp.com
www.wsp.com

Zed Tunnel Guidance Ltd

Booth: 421

ZED manufactures and develops TBM guidance/navigation systems. More recently, ZED offers a redesigned system for long/curved pipejacks and a configuration that places the total station on the TBM backup rather than the tunnel wall, intended for smaller diameter TBM’s where space is at a premium, especially along the backup walkway. The company provides comprehensive R&D services for electro-optical instrumentation for a variety of uses, from applications in the railway industry to vertical shaft alignment. Based in the UK, ZED has an enthusiastic team who provide a seasoned and prompt reaction to customer requirements and technological advances applicable to their products.

Products & Services
Instrumentation Equipment and Services
Laser Guidance Systems
Microtunneling Equipment, Tools, and Supplies

Main Office
Unit 1 Russell House, Molesey Rd
Walton on Thames, Surrey KT12 3PJ United Kingdom
Telephone: +44 (0) 1932 251 440
Fax: +44 (0) 1932 244 971
Email: Sales@zedtg.com
www.zedtg.com

New Listings

Comtrol International

Booth: 459

Description: Comtrol has built a reputation for manufacturing and distributing the highest quality communication and control systems to work in harsh environments. Our communication and control systems include Cellular over leaky feeder, VHF, UHF, Tracking and Gas Monitoring. Comtrol has invested decades of research to produce the best in class products that will keep your operation safe when it matters the most.

Products & Services
Control Systems
Environmental Control Equipment and Supplies
Geological, Geotechnical Services and Equipment
Safety Products
Tunnel Communication Systems and Equipment
Underground Utility Materials and Operations

Main Office
500 Pennsylvania Ave
Irwin, PA 15642
Phone (724) 864-3800
www.comtrol-corp.com

Xylem

Booth: 556

Main Office
22 Floodgate Rd
Bridgeport, NJ 8014 USA
Telephone: (856) 467-3636
www.xyleminc.com
Abrasion and Impact Resistant Materials
JADCO Manufacturing Inc – Booth 555
KOSTEEL CO, LTD – Booth 336

Air Locks and Bulkheads
ASI Marine – Booth 522
Ballard Marine Construction – Booth 513
Tenbusch, Inc – Booth 516

Computer Hardware and Software
Amberg Technologies Ltd – Booth 653
BABENDERERDE ENGINEERS, LLC – Booth 216
GEOSLOPE International Ltd – Booth 553
Matrix Design Group – Booth 301
Plaxis Americas LLC – Booth 419
Roscience, Inc – Booth 310
SIXENSE – Booth 507

Concrete Mixing and Transportation Equipment
Advanced Concrete Technologies – Booth 225
Amix Systems Ltd – Booth 227
King Shotcrete Solutions – Booth 511
Mining Equipment Ltd – Booth 506
Normet Americas, Inc – Booth 611
Putzmeister – Booth 400
Techni-Metal Systems – Booth 402

Concrete Reinforcement
Bekaert Maccaferrì Underground Solutions – Booth 318
David R. Klug & Associates, Inc – Booth 418
Elasto Plastic Concrete – Booth 612
Fibermesh – Booth 509
GCP Applied Technologies – Booth 404
King Shotcrete Solutions – Booth 511
KOSTEEL CO, LTD – Booth 336
Mighty Shield Industries Sdn Bhd – Booth 603
Normet Americas, Inc – Booth 611
Sika Corporation – Booth 610
Williams Form Engineering Corp – Booth 657

Construction - Contracting Services
Ballard Marine Construction – Booth 513
Drill Tech Drilling & Shoring Inc – Booth 110
EC Applications - Tunnel Lining – Booth 302
Hayward Baker Inc – Booth 325
McMillen Jacobs Associates – Booth 316
Michels Corp – Booth 527
Moretrench – Booth 326
Mueser Rutledge Consulting Engineers – Booth 557
Promat International NV – Booth 600
Renesco Inc – Booth 102
Richard Goettle, Inc – Booth 601
Schnabel Foundation Co – Booth 541
Stantec – Booth 539
The Lane Construction Corporation – Booth 623
TREVICOS – Booth 545
Wisko America, Inc – Booth 332

Consulting Engineers
AECOM – Booth 500
ASI Marine – Booth 522
BABENDERERDE ENGINEERS, LLC – Booth 216
CDM Smith – Booth 429
COWI North America – Booth 329
Dr. Sauer & Partners Corp – Booth 410
Everest Equipment Co – Booth 428
Gall Zeidler Consultants – Booth 427
Gomez International, Inc – Booth 523
Hager-Richter Geoscience, Inc – Booth 526
Hatch – Booth 412
HNTB Corp – Booth 223
McMillen Jacobs Associates – Booth 316
Mott MacDonald – Booth 451
MSP Structures Inc – Booth 605
Mueser Rutledge Consulting Engineers – Booth 557
Nexans AmerCable – Booth 622
Schnabel – SWS – Booth 624
Shannon & Wilson, Inc – Booth 206
Stantec – Booth 539
WSP – Booth 208

Control Systems
Amberg Technologies Ltd – Booth 653
Amix Systems Ltd – Booth 227
Northern Light Technologies – Booth 518

Conveyor Equipment and Systems
Akkerman – Booth 633
Simem Underground Solutions, Inc – Booth 417
Tenbusch, Inc – Booth 516
Terratec – Booth 530
The Robbins Company – Booth 317

Drilling Services and Equipment
BAUER-Pileco Inc – Booth 546
Cascade Drilling L.P. – Booth 425
Crux Subsurface, Inc – Booth 406
Daigh Company, Inc – Booth 504
Derrick Equipment Co – Booth 608
Drill Tech Drilling & Shoring Inc – Booth 110
Malcolm Drilling Co Inc – Booth 619
Michels Corp – Booth 527
Palieri S.P.A. – Booth 112
Richard Goettle, Inc – Booth 601
ROBODRILL – Booth 222
Ruen Drilling, Inc – Booth 304
Sandvik Mining and Rock Technology – Booth 628
Schnabel Foundation Co – Booth 541
Tolsa Wyoming Bentonite Inc – Booth 547

Dust and Fume Control Technology
ABC Industries, Inc – Booth 305
BASF Corporation – Booth 401
Englo, Inc, DBA Engart, Inc – Booth 618
Matrix Design Group – Booth 301
Sandvik Mining and Rock Technology – Booth 628
Schauenburg Flexaduc Corp – Booth 636
Spendrups Fan Co – Booth 528

Earth Pressure Balance Machines
Akkerman – Booth 633
ASI Marine – Booth 522
Ballard Marine Construction – Booth 513
CDM Smith – Booth 429
Herrenknecht Tunnelling Systems USA, Inc – Booth 217
Lovsun Tunelling Canada Ltd – Booth 411
Terratec – Booth 530
The Robbins Company – Booth 317

Educational
Northwest Laborers-Employers Training Trust – Booth 424
Tunnel Business Magazine – Booth TBM – Booth 100
Tunnelling Journal/Tunnelling Journal – Booth 106
Tunnels & Tunnelling – Booth 114
TunnelTalk – Booth 108

Electrical - Generator-Motor, Wire-Cable
Line Power – Booth 616
Nexans AmerCable – Booth 622

Engineering Design and Services for Tunnels
AECOM – Booth 500
AIL Mining – Booth 510
BABENDERERDE ENGINEERS, LLC – Booth 216
CDM Smith – Booth 429
Dr. Sauer & Partners Corp – Booth 410
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Hager-Richter Geoscience, Inc – Booth 526
HNTB Corp – Booth 223
JENNIMAR Civil – Booth 607
KOSTEEL CO, LTD – Booth 336
McMillen Jacobs Associates – Booth 316
Mott MacDonald – Booth 451
MSP Structures Inc – Booth 605
Mueser Rutledge Consulting Engineers – Booth 557
Palieri S.P.A. – Booth 112
Parsons – Booth 529
Promat International NV – Booth 600
R.S.T. Instruments Ltd – Booth 561
Renesco Inc – Booth 102
Schnabel – SWS – Booth 624
Shannon & Wilson, Inc – Booth 206
SIXENSE – Booth 507
Stantec – Booth 539
WSP – Booth 208

SHOWGUIDE exhibitor listings as of April 17, 2018
**Environmental Control**
- Equipment and Supplies
  - Agri America, Inc – Booth 300
  - Matrix Design Group – Booth 301
  - Northern Light Technologies – Booth 518
  - The PBE Group – Booth 502

**Explosive Materials and Services**
- Daigh Company, Inc – Booth 504

**Fabrication Materials**
- AIL Mining – Booth 510
- Algaier S.A. – Booth 559
- Tenbusch, Inc – Booth 516

**Geological, Geotechnical Services and Equipment**
- AECOM – Booth 500
- Amberg Technologies Ltd – Booth 653
- Casey Foundation - Bencor – Booth 323
- CDM Smith – Booth 429
- Crux Subsurface, Inc – Booth 406
- Epiroc – Booth 501
- Gail Zeidler Consultants – Booth 427
- Geo-Instruments, Inc – Booth 327
- GeoCmp Corp/GeoTesting Express, Inc – Booth 312
- Geokon, Inc – Booth 552
- Hager-Richter Geoscience, Inc – Booth 526
- McLennan Jacobs Associates – Booth 316
- Measurand Inc – Booth 538
- Mueser Rutledge Consulting Engineers – Booth 557
- Nicholson Construction Co – Booth 505
- Plaxis Americas LLC – Booth 419
- R.S.T. Instruments Ltd – Booth 561
- Rocsience, Inc – Booth 310
- Schnabel - SWS – Booth 624
- Shannon & Wilson, Inc – Booth 206
- SIXENSE – Booth 507
- Stantec – Booth 539
- Tolsa Wyoming Bentonite Inc – Booth 547
- VMT USA – Booth 308
- Williams Form Engineering Corp – Booth 657

**Ground Freezing**
- CDM Smith – Booth 429
- Epiroc – Booth 326
- Mueser Rutledge Consulting Engineers – Booth 557
- SeaFreeze Inc – Booth 116
- Tioga Air Heaters - Mobile Air – Booth 560

**Ground Improvement Equipment and Services**
- AERIX Industries – Booth 542
- Amix Systems Ltd – Booth 227
- BAUER-Pileco Inc – Booth 546
- Crux Subsurface, Inc – Booth 406
- Hayward Baker Inc – Booth 325
- Malcolm Drilling Co Inc – Booth 619
- Moretrench – Booth 326
- Mueser Rutledge Consulting Engineers – Booth 557
- NKT Photonics Inc – Booth 512

**Grouting Services, Equipment and Materials**
- AERIX Industries – Booth 542
- Alchemy-Spetec – Booth 659
- Amix Systems Ltd – Booth 227
- Avanti International – Booth 455
- ChemGrout, Inc – Booth 224
- Crux Subsurface, Inc – Booth 406
- DSI Tunneling LLC – Booth 517
- Epiroc – Booth 501
- GCP Applied Technologies – Booth 404
- Gomez International, Inc – Booth 523
- Hayward Baker Inc – Booth 325
- JENNIRMAR Civil – Booth 607
- King Shotcrete Solutions – Booth 511
- Malcolm Drilling Co Inc – Booth 619
- Moretrench – Booth 326
- Nicholson Construction Co – Booth 505
- R.S.T. Instruments Ltd – Booth 561
- Richway Industries – Booth 416
- Schnabel Foundation Co – Booth 541
- Sika Corporation – Booth 610
- Simem Underground Solutions, Inc – Booth 417
- Surecrete Inc – Booth 226
- Techni-Metal Systems – Booth 402
- Technical Tunnelling Components LTD (TTC) – Booth 218
- Tolsa Wyoming Bentonite Inc – Booth 547
- TREVIICOS – Booth 545

**Hoists and Headframes**
- Mining Equipment Ltd – Booth 506

**Hydraulic Hammers and Drills**
- BAUER-Pileco Inc – Booth 546
- Brok Inc – Booth 407
- Daigh Company, Inc – Booth 504

**Instrumentation Equipment and Services**
- BARENBERGERIE ENGINEERS, LLC – Booth 216
- Geo-Instruments, Inc – Booth 327
- Geokon, Inc – Booth 552
- Hager-Richter Geoscience, Inc – Booth 526
- Measurand Inc – Booth 538
- Northern Light Technologies – Booth 518
- Pottinger Precision Systems GmbH – Booth 651
- R.S.T. Instruments Ltd – Booth 561
- Rite Geosystems – Booth 209
- Shannon & Wilson, Inc – Booth 206
- SIXENSE – Booth 507
- TRE ALTAMIRA Inc – Booth 543
- VMT USA – Booth 308
- WorldSensing – Booth 617
- Zed Tunnel Guidance Ltd – Booth 421

**Jet Grouting Equipment and Services**
- Amix Systems Ltd – Booth 227
- Drill Tech Drilling & Shoring Inc – Booth 110
- Hayward Baker Inc – Booth 325
- Malcolm Drilling Co Inc – Booth 619
- Moretrench – Booth 326
- Nicholson Construction Co – Booth 505
- Schnabel Foundation Co – Booth 541
- Simem Underground Solutions, Inc – Booth 417
- TREVIICOS – Booth 545

**Laser Guidance Systems**
- Amberg Technologies Ltd – Booth 653
- Pottinger Precision Systems GmbH – Booth 651
- VMT USA – Booth 308
- Zed Tunnel Guidance Ltd – Booth 421

**Lighting Systems**
- Matrix Design Group – Booth 301
- Nightstick – Booth 629
- Northern Light Technologies – Booth 518

**Lubricants for TBM**
- American Chemical Technologies, Inc – Booth 604
- BASF Corporation – Booth 401
- DSI Tunneling LLC – Booth 517
- Richway Industries – Booth 416
- Tolsa Wyoming Bentonite Inc – Booth 547

**Microtunneling Equipment, Tools, and Supplies**
- Akkerman – Booth 633
- Algaier S.A. – Booth 559
- ASI Marine – Booth 522
- Ballard Marine Construction – Booth 513
- BAUER-Pileco Inc – Booth 546
- Brok Inc – Booth 407
- Derrick Equipment Co – Booth 608
- Herrenknecht Tunnelling Systems USA, Inc – Booth 217
- Lovsuns Tunneling Canada Ltd – Booth 411
- McDowell Equipment Ltd – Booth 405
- Nightstick – Booth 629
- Palmieri S.p.A. – Booth 112
- Pottinger Precision Systems GmbH – Booth 651
- Techni-Metal Systems – Booth 402
- The Robbins Company – Booth 317
- Tsurumi Pump – Booth 563
- Zed Tunnel Guidance Ltd – Booth 421

**Mining Equipment**
- Antraquip Corp – Booth 311
- BASF Corporation – Booth 401
- Brookville Equipment Corp – Booth 430
- Engle, Inc, DBA Engart, Inc – Booth 618
- JENNIRMAR Civil – Booth 607
- King Shotcrete Solutions – Booth 511
- Line Power – Booth 616
- McDowell Equipment Ltd – Booth 405
- Messenger Bearings – Booth 606
- Mining Equipment Ltd – Booth 506
- Putzmeister – Booth 400
- R.S.T. Instruments Ltd – Booth 506
- Sandvik Mining and Rock Technology – Booth 628
## PRODUCTS & SERVICES

### Rock Drills
- Brokk Inc – Booth 407
- DSI Tunneling LLC – Booth 517
- Epiroc – Booth 501
- ROBODRILL – Booth 222
- Sandvik Mining and Rock Technology – Booth 628

### Rock TBM’s
- Akkerman – Booth 633
- CDM Smith – Booth 429
- Herrenknecht Tunneling Systems USA, Inc – Booth 217
- Lovsuns Tunneling Canada Ltd – Booth 411
- Messinger Bearings – Booth 606
- Terratec – Booth 530
- The Robbins Company – Booth 317

### Rotary Drum Cutters
- Alpine Equipment – Booth 211
- Antraquip Corp – Booth 311
- Brokk Inc – Booth 407

### Safety Products
- ABC Ventilation Systems – Booth 322
- Matrix Design Group – Booth 301
- Nightstick – Booth 629
- NKT Photonics Inc – Booth 512
- Ocean Advanced Research – Booth 338
- Promat International NV – Booth 600
- Schauenburg Flexadux Corp – Booth 636
- The PBE Group – Booth 502

### Scaling
- Alpine Equipment – Booth 211
- Antraquip Corp – Booth 311
- Brokk Inc – Booth 407
- Normet Americas, Inc – Booth 611

### Segment Accessories
- Algafer S.A. – Booth 559
- Datwyler Sealing Technologies – Booth 214
- Nightstick – Booth 629
- Technical Tunneling Components LTD (TTC) – Booth 218

### Shaft Drilling and Raiseboring Equipment
- Case Foundation - Bencor – Booth 323
- Epiroc – Booth 501
- Herrenknecht Tunneling Systems USA, Inc – Booth 217
- Malcolm Drilling Co Inc – Booth 619
- Michels Corp – Booth 527
- Nicholson Construction Co – Booth 505
- Palmieri S.P.A. – Booth 112
- Renesco Inc – Booth 102
- Richard Goettle, Inc – Booth 601
- ROBODRILL – Booth 222
- Terratec – Booth 530

### Pumps and Pumping Equipment
- Avanti International – Booth 455
- BAUER-Pileco Inc – Booth 546
- Gomez International, Inc – Booth 513
- Grindex Pumps – Booth 626
- King Shotcrete Solutions – Booth 311
- Putzmeister – Booth 400
- Schauenburg Flexadux Corp – Booth 636
- Technical Tunneling Components LTD (TTC) – Booth 218

### Soft Ground Shields
- Herrenknecht Tunneling Systems USA, Inc – Booth 217
- Tenbusch, Inc – Booth 516

### Slurry Services and Machines
- Amix Systems Ltd – Booth 227
- BAUER-Pileco Inc – Booth 546
- Case Foundation - Bencor – Booth 323
- Derrick Equipment Co – Booth 608
- Michels Corp – Booth 527
- The Robbins Company – Booth 317
- TREVICOS – Booth 545
- Tsurumi Pump – Booth 563

### Steel Pipe
- AIL Mining – Booth 510
- JADCO Manufacturing Inc – Booth 555
- Naylor Pipe Co – Booth 213
- TBM Supply – Booth 524
- Williams Form Engineering Corp – Booth 657

### Survey Equipment and Lasers
- Amberg Technologies Ltd – Booth 653
- NKT Photonics Inc – Booth 512
- Normet Americas, Inc – Booth 611
- Simem Underground Solutions, Inc – Booth 417

### Tunnel Boring Equipment
- Akkerman – Booth 633
- Ballard Marine Construction – Booth 513
- Gomez International, Inc – Booth 523
- Herrenknecht Tunneling Systems USA, Inc – Booth 217
- Lovsuns Tunneling Canada Ltd – Booth 411
- Messinger Bearings – Booth 606
- Palmieri S.P.A. – Booth 112
- Poltinger Precision Systems GmbH – Booth 651

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**Mucking Systems**
- Mining Equipment Ltd – Booth 506

**Non-Explosive Mechanical Excavation**
- Alpine Equipment – Booth 211
- Daigh Company, Inc – Booth 504
- Drill Tech Drilling & Shoring Inc – Booth 110
- Englo, Inc, DBA Engart, Inc – Booth 618
- Malcolm Drilling Co Inc – Booth 619

**Precast Concrete Linings**
- Agru America, Inc – Booth 300
- Algafer S.A. – Booth 559
- BASF Corporation – Booth 401
- Bekaiser Maccalferrer Underground Solutions – Booth 318
- Datwyler Sealing Technologies – Booth 214
- David R. Klug & Associates, Inc – Booth 418
- EC Applications – Tunnel Lining – Booth 302
- Everest Equipment Co – Booth 428
- GCP Applied Technologies – Booth 404
- KOSTEEL CO, LTD – Booth 336
- Mighty Shield Industries Sdn Bhd – Booth 603
- Schnabel - SWS – Booth 624
- Technical Tunneling Components LTD (TTC) – Booth 218
- VMT USA – Booth 308

**Publishers**
- Tunnel Business Magazine – Booth TBM – Booth 100
- Tunneling Journal/Tunnelling Journal – Booth 106
- Tunnels & Tunnelling – Booth 114
- TunnelTalk – Booth 108

**Rail Products**
- Algafer S.A. – Booth 559
- Brokkville Equipment Corp – Booth 430
- JENNMAR Civil – Booth 607

**Roadheaders**
- Alpine Equipment – Booth 211
- Antraquip Corp – Booth 311
- Poltinger Precision Systems GmbH – Booth 651
- Sandvik Mining and Rock Technology – Booth 628
- VMT USA – Booth 308

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**Shotcrete Technologies, Inc** – Booth 423
**Tenbusch, Inc** – Booth 516
**The PBE Group** – Booth 502
**Tsurumi Pump** – Booth 563
**Worldsensing** – Booth 617

**Shotcrete Equipment, Supplies, and Services**
- BASF Corporation – Booth 401
- GCP Applied Technologies – Booth 404
- JENNMAR Civil – Booth 607
- King Shotcrete Solutions – Booth 511
- KOSTEEL CO, LTD – Booth 336
- Mapei Corp – Booth 307
- McDowell Equipment Ltd – Booth 405
- Michels Corp – Booth 527
- Normet Americas, Inc – Booth 611
- Putzmeister – Booth 400
- Shotcrete Technologies, Inc – Booth 423
- Sika Corporation – Booth 610
- Surecrete Inc – Booth 226
- Techni-Metal Systems – Booth 402
- Tolsa Wyoming Bentonite Inc – Booth 547

**Slurry Systems**
- Haukes Slurry Equipment Ltd – Booth TBM – Booth 100
- Mott MacDonald Ltd – Booth 301
- Sewage Works Industry Association – Booth 302
- TLR Consulting – Booth 303
- Tsurumi Pump – Booth 563

**Soil Conditioning Equipment and Materials**
- Alpine Equipment – Booth 211
- Avanti International – Booth 455
- Mapei Corp – Booth 307
- NKT Photonics Inc – Booth 512
- Normet Americas, Inc – Booth 611
- Simem Underground Solutions, Inc – Booth 417

**Steel Pipe**
- AIL Mining – Booth 510
- JADCO Manufacturing Inc – Booth 555
- Naylor Pipe Co – Booth 213
- TBM Supply – Booth 524
- Williams Form Engineering Corp – Booth 657

**Survey Equipment and Lasers**
- Amberg Technologies Ltd – Booth 653
- NKT Photonics Inc – Booth 512
- Poltinger Precision Systems GmbH – Booth 651

**Tunnel Boring Equipment**
- Akkerman – Booth 633
- Ballard Marine Construction – Booth 513
- Gomez International, Inc – Booth 523
- Herrenknecht Tunneling Systems USA, Inc – Booth 217
- Lovsuns Tunneling Canada Ltd – Booth 411
- Messinger Bearings – Booth 606
- Palmieri S.P.A. – Booth 112
- Poltinger Precision Systems GmbH – Booth 651
Richway Industries – Booth 416
Sandvik Mining and Rock Technology – Booth 628
Spendrup Fan Co – Booth 528
Techni-Metal Systems – Booth 402
Tenbusch, Inc – Booth 516
Terratec – Booth 530
The Robbins Company – Booth 317

**Tunnel Communication Systems and Equipment**
DSI Tunneling LLC – Booth 517
Innovative Wireless Technologies – Booth 643
Matrix Design Group – Booth 301
NKT Photonics Inc – Booth 512
Northern Light Technologies – Booth 518
R.S.T. Instruments Ltd – Booth 561
The PBE Group – Booth 502
VMT USA – Booth 308
Worldsensing – Booth 617

**Tunnel Haulage Systems**
Akkerman – Booth 633
McDowell Equipment Ltd – Booth 405
Mining Equipment Ltd – Booth 506
Techni-Metal Systems – Booth 402

**Tunnel Lining and Support Materials**
Agru America, Inc – Booth 300
AIL Mining – Booth 510
Alghar S.A – Booth 559
Antraquip Corp – Booth 311
BASF Corporation – Booth 506
Bekaert Maccarelli Underground Solutions – Booth 318

**Underground Locomotives and Rail Haulage Equipment**
Brookville Equipment Corp – Booth 430
Gomez International, Inc – Booth 523
McDowell Equipment Ltd – Booth 405

**Underground Utility Materials and Operations**
Avanti International – Booth 455
Line Power – Booth 616
Nightstick – Booth 629
NKT Photonics Inc – Booth 512
Promat International NV – Booth 600
TBM Supply – Booth 524
Thompson Pipe Group - Flowtite – Booth 408

**Ventilation Systems, Materials and Equipment**
ABC Industries, Inc – Booth 305
ABC Ventilation Systems – Booth 322
AIL Mining – Booth 510
Englo, Inc, DBA Engart, Inc – Booth 618
Epiroc – Booth 501
Mining Equipment Ltd – Booth 506
Naylor Pipe Co – Booth 213
Promat International NV – Booth 600
Schauenburg Flexadux Corp – Booth 636
Spendrup Fan Co – Booth 528
The PBE Group – Booth 502
Tlgia Air Heaters - Mobile Air – Booth 560

**Wastewater Management Products**
Agru America, Inc – Booth 300
Avanti International – Booth 455
ConShield Technologies – Booth 118
Hobas Pipe USA – Booth 647

**Water Treatment Plant and Materials**
Agru America, Inc – Booth 300
Hobas Pipe USA – Booth 647
Moresonch – Booth 326
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