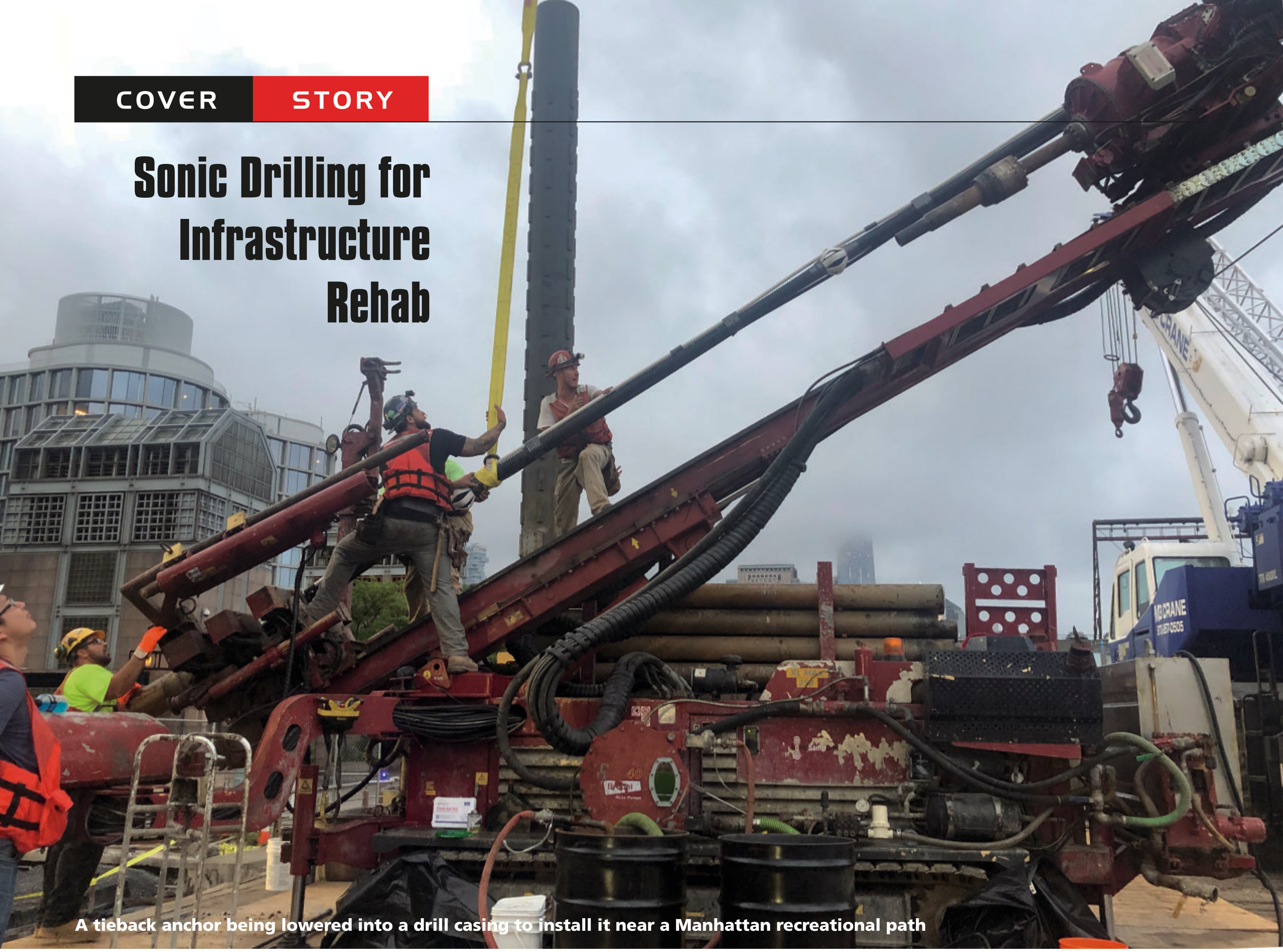
COVER STORY

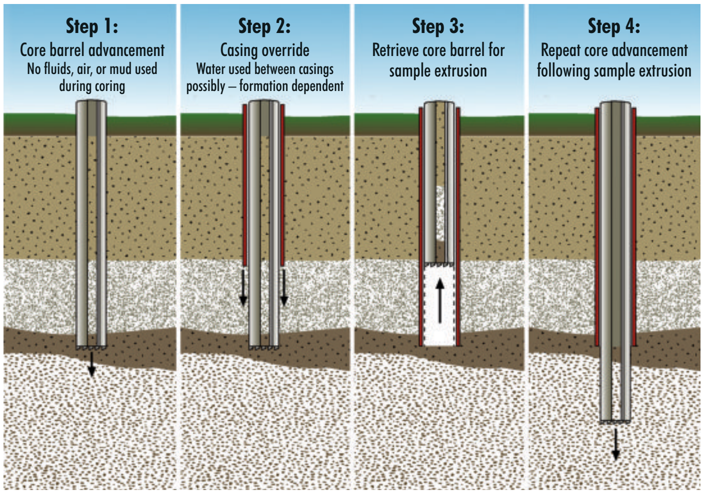
Sonic Drilling for Infrastructure Rehab



A tieback anchor being lowered into a drill casing to install it near a Manhattan recreational path

Sonic drilling was initially developed primarily as an exploration tool for core sampling of unconsolidated materials. However, it has evolved quite a lot over the past few decades, and has gained considerable popularity in the infrastructure/geoconstruction market as a multifaceted drilling platform capable of providing a wide range of drilling solutions.

In the 1940s and 1950s, sonic technology gained the interest of the U.S. oil industry as an exploration tool. Then in the 1970s, the British aircraft manufacturer, Hawker Siddeley, with its facilities in Canada, began advancing the sonic drilling design further. The technology gained real market traction during the 1980s and 1990s as an excellent tool to efficiently and quickly collect continuous core samples of the most challenging unconsolidated materials. By allowing geologists and engineers to obtain 100% continuous 4 in (10.1 cm) to 8 in (20.3 cm) diameter core samples that could be laid out on the ground, sonic drilling enabled them to see first-hand the true nature and characteristics of subsurface materials. For once, they were not limited by the soil sampling constraints of the standard 2 in (5.1 cm) diameter split-spoon sample. This was true especially with cobble and boulder formations that contain a fine-grained interstitial matrix.



Sonic drilling process

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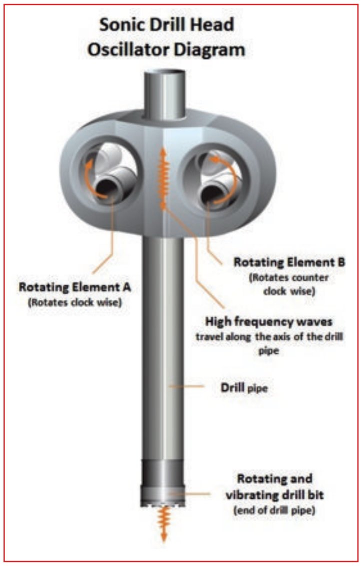
It became clear that sonic had the technological capabilities of collecting virtually everything, as it existed in situ, for laying out on the ground to be read like a book. With sonic providing higher-resolution samples and subsurface information, engineers around the world have therefore saved millions on project budgets by avoiding the need to overdesign and overconstruct. Today, sonic has advanced from providing high-quality core samples to serving as a platform capable of installing instrumentation, foundation relief wells and tiebacks in challenging formations, as well as providing foundation grout borings for seepage control in dams, micropiles in contamination-impacted soils, angled wells and drains, freeze piles, and much, much more.



In summary, sonic drilling is a very flexible and very versatile drilling platform in the hands of a skilled and experienced driller. In this article, Cascade Environmental presents three case studies to show a few of the many novel ways sonic drilling is currently being implemented. However, let's first touch briefly on what sonic drilling is and its inherent drilling benefits.

Sonic drilling works on the principle of advancing a boring by resonating the entire tool string (core barrel, casing or rods) at a frequency ranging from 50 Hz to 150 Hz (cycles per second) to overcome borehole friction. The frequency is generated by an oscillator that is contained in the drill head. With the help of hydraulically powered motors, two small counterweights spin extremely fast, thereby transmitting a resonating frequency directly down the tool string. At the pulsating bit face, subsurface materials are either sheared and collected inside a core barrel during the drilling process, or become assimilated into the adjacent borehole wall. Depending on the type of material being drilled, sonic drilling can be done without the use of drilling fluids. This unique approach to tool string advancement allows sonic to drill very quickly and efficiently into some of the most challenging subsurface materials, such as urban fill containing thick steel and other mixed materials. In addition, other formations that pose a challenge to conventional rotary and auger drilling techniques, such as boulders and cobbles, are quickly and easily overcome by sonic drilling.

The simplest sequence in which the drill tooling is advanced is as follows: first, a core barrel (of sizes ranging from 4.75 in [120 mm] to 10.5 in [266 mm]) is advanced into the subsurface. Then, a slightly larger casing is advanced directly over the core barrel in the over-drilling process to stabilize the borehole so the core barrel can be retrieved without collapse. These casings range in size from 6 in (152 mm) to 12 in (305 mm), with multiple increments possible in between. Also, for special applications, larger tooling can be fabricated. As a result of this telescopic drilling process, borehole deviation and verticality can be greatly constrained to less than 0.5% in many cases. In addition, this tooling can be advanced on angles ranging from vertical to as low as 20 degrees above horizontal.

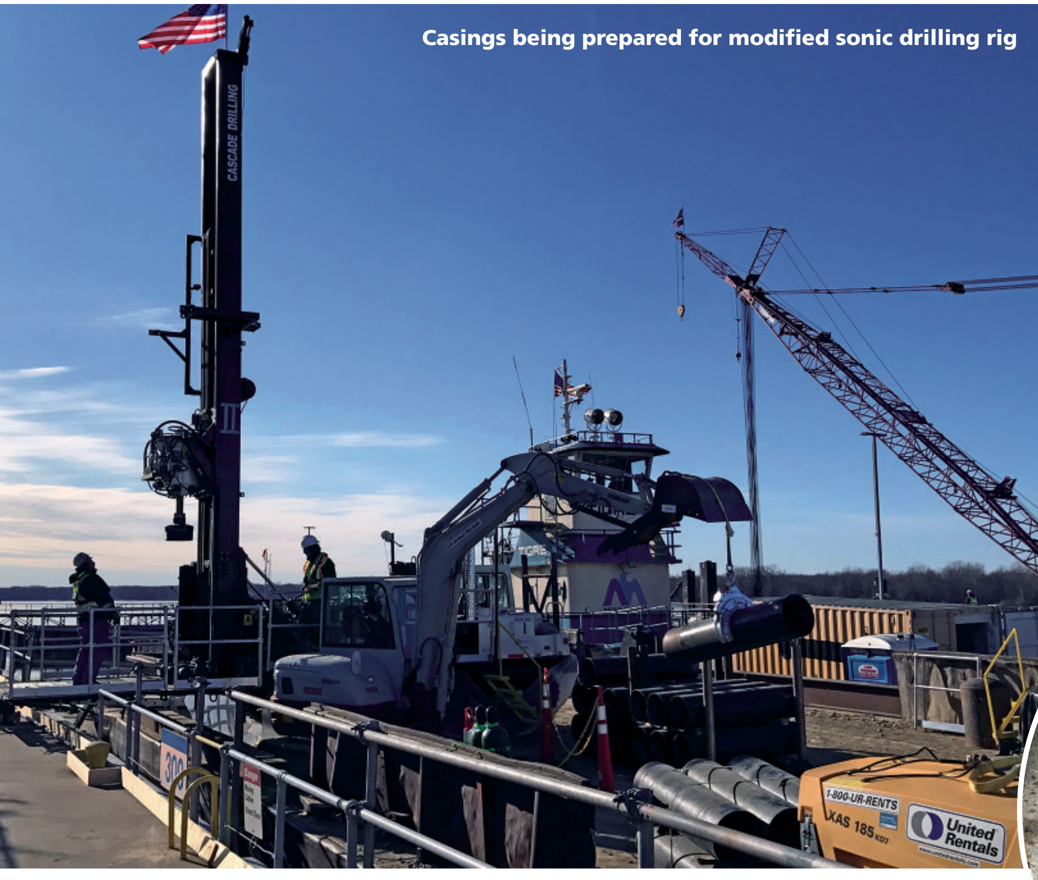
Here are some project applications where sonic drilling was adapted to deliver successful results. These applications demonstrate sonic use with dam foundations, sea wall bulkhead tieback installations, and retrofitting deep angled leachate drains that extend through a landfill's mixed waste.

Dam Foundations

When a dam needs to be drilled despite the risks, sonic drilling provides a method that complies with best safety practices. Such projects require taking into consideration that no damage be imposed during the drilling process, whether it's into an embankment dam or a lock chamber for river operations. Damage could result from elevated pore pressures while using drilling fluids or from drilling that involves an unsupported or uncased borehole. This is why the use is discouraged of water, mud — and particularly air rotary — methods on these types of projects as those technologies can exacerbate voids and embankment fracturing, which could cause dam structure failure.

Floating platforms for river lock chamber drilling

In December 2017, Cascade Environmental served as a subcontractor that developed a safe and effective method to install a series of foundation relief wells around the perimeter of a river lock



Casings being prepared for modified sonic drilling rig

chamber on the Mississippi River in between Iowa and Illinois. These wells are important for allowing hydraulic pressure in the lock chamber to be reduced when the chamber is fully dewatered for maintenance. When a lock chamber is isolated from adjacent river water and dewatered, water in the relief wells is allowed to flow freely from the gravel foundation below the concrete lock chamber floor in an effort to prevent damage from excessive hydraulic pressures.

The key challenges solved on this project for the U.S. Army Corps of Engineers included:

- Developing a drilling approach that avoided fluids or excessive fluid pressures below the floor
- Maintaining a continually cased borehole with depths of approximately 40 ft (12 m), and with a diameter of 16 in (406 mm)
- Drilling through a thick concrete slab to install 8 in (203 mm) wells
- Working from multiple floating plants in 30 ft (9.1 m) of water at all times
- Maintaining an accelerated schedule to minimize lock closure

Due to the speed of sonic drilling, its ability to cut though both the concrete floor (without a separate core drill) and to drill into the underlying formation with the same tools, sonic was selected over pile-driving or rotary methods to drill 37 relief wells.

Previously, the largest sonic tooling available in the industry was 12 in (305 mm). Therefore, the subcontractor had to develop a means of drilling with 16 in (406 mm) sonic tooling. For the test and development phase, Cascade Environmental considered three key items: the need for larger tooling, the drill modifications needed to use this larger tooling and the tooling handling process.

Due to the quick turnaround nature of the project, an outside vendor manufactured the tools with input from the subcontractor's senior sonic drillers. The senior drillers helped develop a thread design that could retain the vibrational frequency for multiple uses, as well as helping with all the smaller components integral to the tooling system.

Cascade Environmental adapted the rig design from its current fleet of sonic drills. Using its senior sonic drill fabricators on staff, the subcontractor was also able to scale up and build the larger make-up and break-out wrenches required to work the larger casing size. Lastly, since the work would occur on a limited space, floating platform, it was important to consider how to safely handle this tooling. Due to weight and space constraints, 5 ft (1.5 m) tooling lengths that could be handled by a compact excavator and pipe grapple were selected.

Concrete core from lock floor

After a few months of rig modifications at the subcontractor's Marietta, Ohio, and Flint, Michigan, locations and test drilling at its Little Falls, Minnesota, facility, the sonic method was applied at the dam. The rig and tooling were able to both core the lock chamber floor that was approximately 18 in (0.46 m) in thickness, as well as advance casing and core the river sands and gravels with 10 in (0.25 m) and 12 in (0.3 m) core barrels. Once the casing reached the total designed depth, the well materials were installed as the drill casing was retracted to the surface. All told, 37 relief wells were installed in just a few weeks using three separate drilling crews working around the clock.

Sea Wall Tiebacks

Tieback anchor installation involves many unique challenges, particularly the complexity (and potential pitfalls) of shorelines. The technology selected can have a big impact, whether it reduces time spent and waste created or adds new logistical issues to factor into an overall project plan and management.

Drill casing being advanced for a tieback anchor at the Manhattan waterfront bulkhead

When planning a tieback project, project managers and engineers may lean on technologies that have worked for them in the past. However, every site has different requirements, and it is important to review all options — even less traditional ones. Using factors that the subcontractor took into account for installing tiebacks along a waterfront bulkhead near a roadside recreational path in downtown Manhattan in 2018, here are four things to consider:

Space Requirements: On tieback installation sites, space might be at a premium. It's wise to check what size rig the site can truly accommodate, as well as if there will be issues moving from one location to another. Additionally, if part of the job site is restricted, you will want to determine if the other section will be open to accept a truck rig. One of the benefits of a sonic rig is that it can be half to one third the size of conventional (air rotary) rigs.

Subsurface Conditions: What is the geology of the site? Before selecting the drill technology, it is best to ascertain if the formation is homogeneous or interbedded, and whether urban fill will be an issue. Although every drilling technology has its sweet spot, when it comes to subsurface formations, sonic drilling's strength is its versatility.

Drill Cuttings/Waste Management: Although it may seem like a minor detail, drilling fluid and solid management should inform your technology decisions on tieback projects. When a borehole is advanced, how are the cuttings and fluids managed? In over-water drilling situations, this is an especially important consideration. Sonic drilling produces significantly less investigation-derived waste (IDW) than conventional drilling technologies, which saves on project time, money and hassle.

One of the 37 tieback anchors being installed down a drill casing

Safety Concerns: The fewer processes required around the drilling program, the safer the job site. Ask if additional labor is required to handle tooling, waste management and overall operation of the drilling program under consideration, and then determine if the value those add outweighs the risks. Key safety challenges to review are:

- Based on the nature of a tieback project, there may be limited space for the drill rig and any accompanying equipment.
- Obstructions or urban fill to contend with.
- Cuttings and/or fluids must be managed — and if a shoreline is involved, it is especially important to minimize any risk of these ending up in the water.

While sonic drilling has not been the traditional technology for tieback projects, it can be a great alternative to air rotary, auger and mud approaches. Sonic is compact, rarely experiences refusal, and produces little IDW. It does well with angled drilling, and drills quickly. Sonic thus addresses many common challenges with tieback installations, saving time, space and potential material disposal issues.

Angled Landfill Drains

Landfills by their very nature require drilling in a host of materials, including soils, solid waste and other mixed manufactured materials. Pipes that allow access to fluids in the foundation of the landfill are critical to manage these fluids.

During the summer of 2017 at a landfill near Philadelphia, the subcontractor drilled and installed several angled 6 in (152 mm) diameter perforated leachate drainpipes on a 20 degree angle. The high-density polyethylene (HDPE) pipes of approximately 75 lft (22.8 m) were to help enhance the leachate collection system in the foundation of the landfill. Each drain in the system was designed to be drilled and installed on a linear trajectory just above the landfill's critical basal liner (which seals the landfill away from mixing with groundwater and underlying native formations).

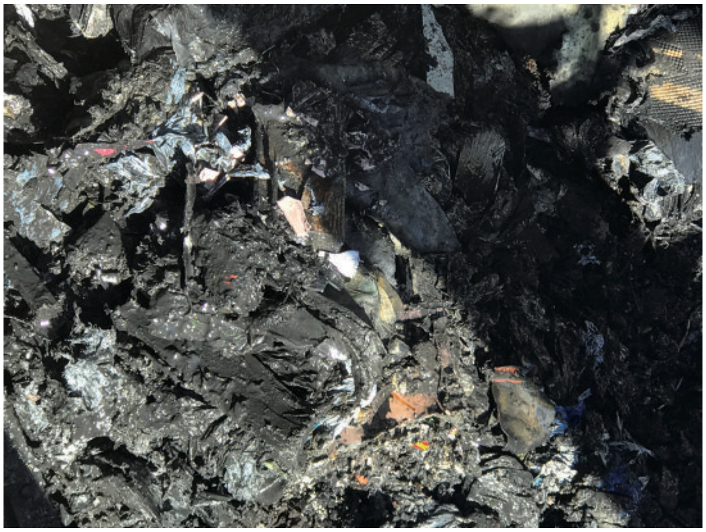
Drilling through mixed waste is challenging for most drilling technologies. Traditional small-diameter rotary methods can become tangled up in a web of debris. However, sonic drilling can tackle this task not only for vertical alignments, but also on a very steep battered angle. Also, nearly all other drilling technologies, such as auger, rotary, horizontal directional drilling (HDD), air and down-the-hole (DTH) air hammer, would have failed at the drilling or failed in the amount of borehole deviation.

The process of installing the drainpipe involved drilling at a very low angle just above the basal geofabric liner. Because sonic drilling utilizes a smooth-wall casing and core barrel advancement system, there is nothing for the waste to get hung up on in the tooling. Additionally, since the core barrel guides the casing, and the casing guides the core barrel concentrically during the drilling process, a very straight boring can be achieved. This allows for optimal placement of a pipe that's being installed.

In this case, a 9.25 in (245 mm) sonic drill casing and an 8 in (20 mm) core barrel system were used to advance the fully cased boring at 5 ft (1.5 m) intervals. First, the core barrel was advanced into the subsurface; then, larger casing was used to override or over-drill the core barrel. The core barrel was used to bring to the surface a core of waste and cuttings so that the process could be

A 75 ft (22.8 m) drill casing ready for HDPE pipe insertion

Adding a section of steel drill casing for landfill pipe drainage prep



Sample of the landfill's mixed trash, debris being drilled through

quickly repeated until total depth was achieved. After nearly every 10 ft to 15 ft (3.0 m to 4.6 m) of drilling, a gyroscopic borehole deviation survey was taken to plot the actual boring azimuth and dip against the planned drain installation specifications. The average deviation on this project was less than 1% to 2%, and in some cases, much tighter.

Once the borehole was cased with the larger sonic override casing, a 6 in (15.2 cm) perforated HDPE pipe was installed inside to total depth. Then the sonic drill casing was extracted, leaving the HDPE pipe in place.

Conclusion

As demonstrated in a small cross section of unique applications, sonic drilling technology can be a "Swiss Army knife" in foundation developers' toolbox for challenging projects. It is able to have minimal site impact while drilling very tight tolerance, fully cased boreholes, at various angles. Sonic equipment has a tight footprint and can drill through a wide range of formations and fill, with no depth refusal. These characteristics make sonic drilling an extremely valuable tool to consider.

Acknowledgements: The 'Sea Wall Tiebacks' section of this article was provided by Bill Poupis and Shawn Miller from Aquifer Drilling & Testing, a Cascade Environmental company.

Jim McCombs is a key accounts manager at Cascade Environmental. He has spent most of his career solving difficult project objectives using sonic drilling technology and an integrated approach throughout project stages, whether they are multimillion-dollar federal projects or small projects with specific, narrow objectives. McCombs works on projects for large infrastructure such as dams, tunnels and ground improvement, and with key clients that have drilling demands throughout the environmental and infrastructure market.