# SONIC CONE PENETROMETER TESTING

## TECHNOLOGY NEED

The U.S. Department of Defense (DoD) and U.S. Department of Energy (DOE) are currently pursuing efforts to identify and remediate thousands of contaminated sites. Attempts are being made to speed up, economize, and improve the quality of site characterization and remediation processes. Cone Penetrometer Testing (CPT) utilizes a truck that is equipped to hydraulically push a hollow rod into the subsurface and perform various sensing and sampling processes. CPT offers numerous advantages in that it is generally faster, less expensive, safer, and generates far less secondary waste than conventional drilling methods. As a result, DoD and DOE efforts have focused on developing advanced sensors and sampling devices to be delivered by the cone penetrometer. As probe sizes have increased (from 1.44-inch outside diameter (OD) to 1.75-inch OD and larger), the ability of the CPT to reach a desired depth for a given rig weight (reaction force) has been reduced. Integration of sonic drilling techniques with CPT will advance cone penetrometer sensor packages past the current depths of refusal and provide an efficient tool and technique for hazardous waste site characterization, remediation, and monitoring.

## TECHNOLOGY DESCRIPTION

Standard CPT has been around for decades and has been used to categorize the thickness and type of subsurface soil layers. In Sonic CPT the standard push system is modified by mounting a vibratory system above the push-frame allowing the option of vibrating the rod-string to enhance the effectiveness of advancing sensors into the ground. The drive head utilizes two counter-rotating eccentric weights to induce a sinusoidal driving force.

## BENEFITS

The benefits of Sonic-CPT were clearly demonstrated during an evaluation/ demonstration held at Camp Edwards located on the Massachusetts Military Reserve (MMR), Cape Cod, MA. Previous efforts by the Waterways Experimental Station using standard CPT yielded repeated refusal at approximately 20-feet below ground surface (bgs). The lithology of the site consists of gravels and cobbles with occasional boulder-sized fragments that made for difficult pushing. Using Sonic-CPT, six soundings were completed to various depths as deep as 100 feet bgs without meeting refusal.

The ability to reach these depths at similar sites can significantly reduce characterization and monitoring costs for responsible parties. For example, during this testing and evaluation program, one of the Installation Restoration Program (IRP) managers at Camp Edwards expressed an interest in retrieving groundwater samples from approximately 100 feet bgs at one of their sites currently in the remediation phase. They were considering placing a recovery well at this particular location and wanted to be sure that it was within the plume. Using the Sonic-CPT, several groundwater samples were retrieved for chemical analysis from the area of interest allowing the IRP to make a more informed decision regarding the location of the recovery well. The other option for them was to bring in a conventional auger drill-rig to conduct an exploratory boring at a cost of several thousand dollars.

## CAPABILITIES/LIMITATIONS

In general, the Sonic-CPT effectively increased the capability of standard CPT technology. Testing to date has demonstrated the effectiveness in silty-sands (e.g., U.S. Army Cold Regions Research and Engineering Laboratory), gravels and cobbles (e.g., MMR)), and in silty very fine to fine sands (e.g., Savannah River Site). Although the Sonic CPT showed marked improvements at all of the aforementioned sites, the most dramatic increase in penetration capabilities was noted in the gravel and cobble formations at the MMR. It is thought the larger grain sizes allow for a more complete reorientation

of the soil 'fabric' due to a reduction in effective intergranular stresses induced by the vibration than do finer-grained soils.

As with all CPT, a trained technician is required to run the Sonic-CPT equipment. Additional experience is required to become familiar with the additional controls and safety features of the Sonic -CPT system. The greater energy developed by the Sonic-CPT increases the potential to break equipment, therefore, additional hands-on experience is a must to allow the operator to develop a 'feel' for the equipment.

## COLLABORATION/TECHNOLOGY TRANSFER

Applied Research Associates, Inc. (ARA) collaborated with several federal agencies and commercial clients during the development of the Sonic-CPT. The U.S. Air Force Research Laboratory, Tyndall Air Force Base (AFB), the U.S. Army Environmental Center, Aberdeen Proving Grounds, and the DOE provided support for the project.

The DOE Savannah River Site (SRS) hosted a ten-day demonstration and testing event during FY 1997 with interest in using the Sonic CPT to reach the green-clay layer at a depth of approximately 160 feet below ground surface. The DOE Hanford site has scheduled a ten-day demonstration and testing event for FY 1998 as part of the Hanford Tank Initiative's (HTI) vadose zone characterization. ARA is currently discussing opportunities to use the Sonic-CPT to provide site characterization services at Kelly AFB. Soil conditions at this site have proven difficult for conventional CPT.

Within the commercial sector, ARA has provided Sonic-CPT services on Long Island, NY at a site where PCE contamination has reached a potable water source. ARA is actively marketing the use of the Sonic-CPT and has received many inquiries about its use. Research into the patentability of this technology is under way.

## ACCOMPLISHMENTS

To date, the Sonic-CPT has been field tested at several regional sites including the Cold Region Research and Engineering Laboratory (CRREL), located in Hanover, NH, followed by a one-week test and demonstration event at the US Army's Camp Edwards, located on the MMR, Cape Cod, MA. The sonic system was also tested and demonstrated at the DOE Savannah River Site (SRS), in Aiken, SC. At each and every location it was clear that the Sonic-CPT system improved the performance of standard CPT based on its ability to advance the rod-string beyond the depth achievable with standard CPT.

Preliminary testing of the Sonic-CPT was conducted at CRREL and consisted of seven soundings using the Sonic-CPT. The testing provided an opportunity to become familiar with the new system as well as a chance to experiment with different rod types and the use of an ARA-designed soil sampler. The results of the testing provided useful data and experience in using the Sonic-CPT system in silty-sand formations.

Testing at the MMR occurred during the week of August 18, 1997, and was conducted at two different sites exhibiting two distinct geologies. During the test program, ARA completed seven CPT soundings and collected four groundwater samples. The first area selected for testing was located along the northwest boundary of the LF-1 landfill. Drilling logs from previous investigations indicated a very dense region at a depth of approximately 20 feet below ground surface (bgs) followed by cobbles and boulders from 20 to 60 feet bgs. The MMR Installation Restoration Program (IRP) geologist described this site as a lateral moraine. Previous attempts by Waterways Experimental Station to use conventional CPT at this site were thwarted by repeated refusal at a depth of approximately 20 feet bgs. The Sonic-CPT was able to reach depths as deep as 100 feet without experiencing refusal.

The second area selected for testing was described as a "glacial outwash" and was located in the north-central portion of the MMR. Collecting groundwater samples using the sonic-CPT was the primary focus

at this location. The groundwater samples provided vital data for an ongoing remediation program currently underway at the site.

The primary goal of the SRS field testing program was to evaluate the effectiveness of Sonic-CPT in reaching the clay/sand soil strata characteristic of the M-Basin with particular emphasis on reaching the green-clay layer at a depth of approximately 160 feet bgs. SRS engineers are anxious to develop an economical method to reach this zone to both characterize the soils and begin clean up efforts of DNAPL contamination known to exist there. The use of the soil sampler with the vibratory system was emphasized during this testing program to demonstrate the utility and robustness of the ARA soil sampler and to provide SRS personnel with soil samples for logging purposes.

A secondary, but equally important, objective was to conduct a demonstration of the vibratory system for DOE and DoD personnel as well as representatives from the commercial sector. The goal was to educate the attendees on the utility of vibratory CPT and promote its use as a cost-effective technology for site characterization in difficult geologies.

During the ten-day testing program at the SRS hosted by Westinghouse Savannah River Company (WSRC), eight soundings were conducted. This site offered challenging conditions with a particularly dense, fine sand layer at approximately 120 feet bgs. The soils consisted of dense, fine-to-medium sands with little amounts of clay and were characteristic throughout the site. Sonic-CPT was only able to break through this dense layer once, reaching a maximum depth of 183 feet bgs.

During testing at the SRS, a prototype core barrel was developed and used to 'cut' through the dense layer. This provided the impetus for the next stage of development for the sonic system; i.e., incorporating coring and rotary capabilities to cut through particularly dense zones. This modification to the Sonic-CPT is currently under development.

## TECHNICAL TASK PLAN (TTP) INFORMATION

TTP No./Title: HQ07C222 - Sonic CPT Probing in Support of DNAPL Characterization

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**The truck pictured above is specially equipped to characterize subsurface contaminants using several sensors linked to instruments. A sonic device was developed by the CMST-CP to increase the penetration rate and depth into unconsolidated soils.**