Innovative Direct Push Technologies for Characterization of the 216-Z-9 Trench at DOE's Hanford Site - 8235

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ABSTRACT

Because of the significant radiological and chemical hazards present at the 216-Z-9 Trench at the US Department of Energy Hanford Site, the only practical subsurface characterization methods are those that minimize or control airborne vapors and particles. This study evaluates and compares the performance of two Direct Push Technologies (Hydraulic Hammer Rig (HHR) and Cone Penetrometer Testing (CPT)) with traditional cable tool drilling in similar difficult geologic conditions. The performance was based on the depth of penetration, the ability to collect representative vadose zone soil samples, the penetration rate, and the relative cost. The HHR achieved deeper penetration depths and faster penetration rates than CPT techniques, while still maintaining the waste minimization benefits of direct push technologies. Although cable tool drilling achieved the deepest penetration, the safety and disposal concerns due to the soil cuttings that were generated made this drilling approach both slow and costly compared to the direct push techniques.

INTRODUCTION

Remedial investigation of the 200-PW-1 Operable Unit mixed-waste disposal sites in the 200 West Area of the U.S. Department of Energy's (DOE) Hanford Site, near Richland, WA, utilized a graded approach to characterize the nature and extent of radioactive (plutonium and americium) and organic (carbon tetrachloride) contaminants in the vadose zone. Initial passive soil vapor surveys provided broad coverage to identify areas for a more focused and intensive investigation. One of the waste sites intensively investigated was the 216-Z-9 Trench. From 1955 to 1962, 132 000 to 477 000 kg of carbon tetrachloride (CCl_4) was estimated to have been disposed to the 216-Z-9 Trench along with high-salt, acidic aqueous and organics wastes, which included tributyl phosphate, dibutyl butyl phosphonate, lard oil, nitrate, americium, and an estimated 106 kg of plutonium.

Because of the significant radiological and chemical hazards present at the 216-Z-9 Trench, the only practical subsurface characterization methods are those that minimize or control airborne vapors and particles. Previous investigations have included cable tool drilling of boreholes and cone penetrometer (CPT) push holes [1, 2]. In 2005, a new direct-push technology was developed to provide improved vadose zone characterization at the Hanford Site Tank Farms (a collection of subsurface tanks that stored liquid waste from the historic processing of uranium and plutonium) that was called the Hydraulic Hammer Rig (HHR). The HHR combines a percussion hammer for a penetrating force with a rotating head and fluted tip to increase penetration capabilities. The HHR rotates slowly, 10 to 50 revolutions per minute, and pounds with the percussion hammer to move materials aside; this allows room for the HHR rod and tools to penetrate the subsurface soils. The HHR is mounted on the front end of a backhoe for easy mobility. After several modifications, an additional HHR was built to conduct vadose zone characterization at nine unique locations adjacent to the 216-Z-9 Trench [3].

This study evaluates and compares the performance of two Direct Push Technologies (HHR and CPT) with traditional cable tool drilling in similar difficult geologic conditions. The performance was based on the depth of penetration, the ability to collect representative vadose zone soil samples, the penetration rate, and the relative cost. The evaluation was made by comparing the performance based upon nine HHR penetrations, five CPT boreholes, and one cable tool drilled borehole. The investigation was adjacent to the 216-Z-9 Trench, where all of the penetrations were conducted, as shown in Figure 1. The hypothesis for this study was that the HHR is an innovative and rapid vadose zone technology capable of penetrating, characterizing, and sampling sediments from the ground surface down to the Cold Creek unit (CCU) calcic layer (caliche) in the 200 West Area at the Hanford Site, WA.

OVERVIEW OF SITE

The vadose zone in the 200 West Area adjacent to the 216-Z-9 Trench is approximately 67 m thick and is comprised of three main geologic units. The Hanford formation is the uppermost unit extending from the ground surface to about 33 m depth. This cataclysmic glacial flood deposit is composed of a heterogeneous mix of unconsolidated sediments that range from boulder- to silt-size particles. The CCU is present from about 33 to 36 m depth and is comprised of two distinct layers. The upper silt layer is about 2.5 m thick and the lower “caliche” layer is about 0.5 m thick and varies from gravel, sand, and silt with a calcium carbonate cemented matrix. The lowermost vadose zone unit in the study area is the Ringold Formation which consists of a semi-consolidated silty-sandy gravel with lenses of gravelly to muddy sand [1].

Over the years, the more mobile wastes disposed to the 216-Z-9 Trench have migrated from the original disposal site into the Hanford formation and subsequently passed through the Cold Creek unit to the groundwater. The conceptual site model indicates that presently the remaining CCl_4 in the vadose zone is retained in thin, fine-grained (i.e., silt) layers of the Hanford formation and the Cold Creek unit. Significant concentrations of CCl_4 have been observed in a 61 cm thick silt lense at an average depth of 19.8 m below ground surface (bgs) in the vicinity of well 299-W15-46, on the south side of the 216-Z-9 Trench [1].

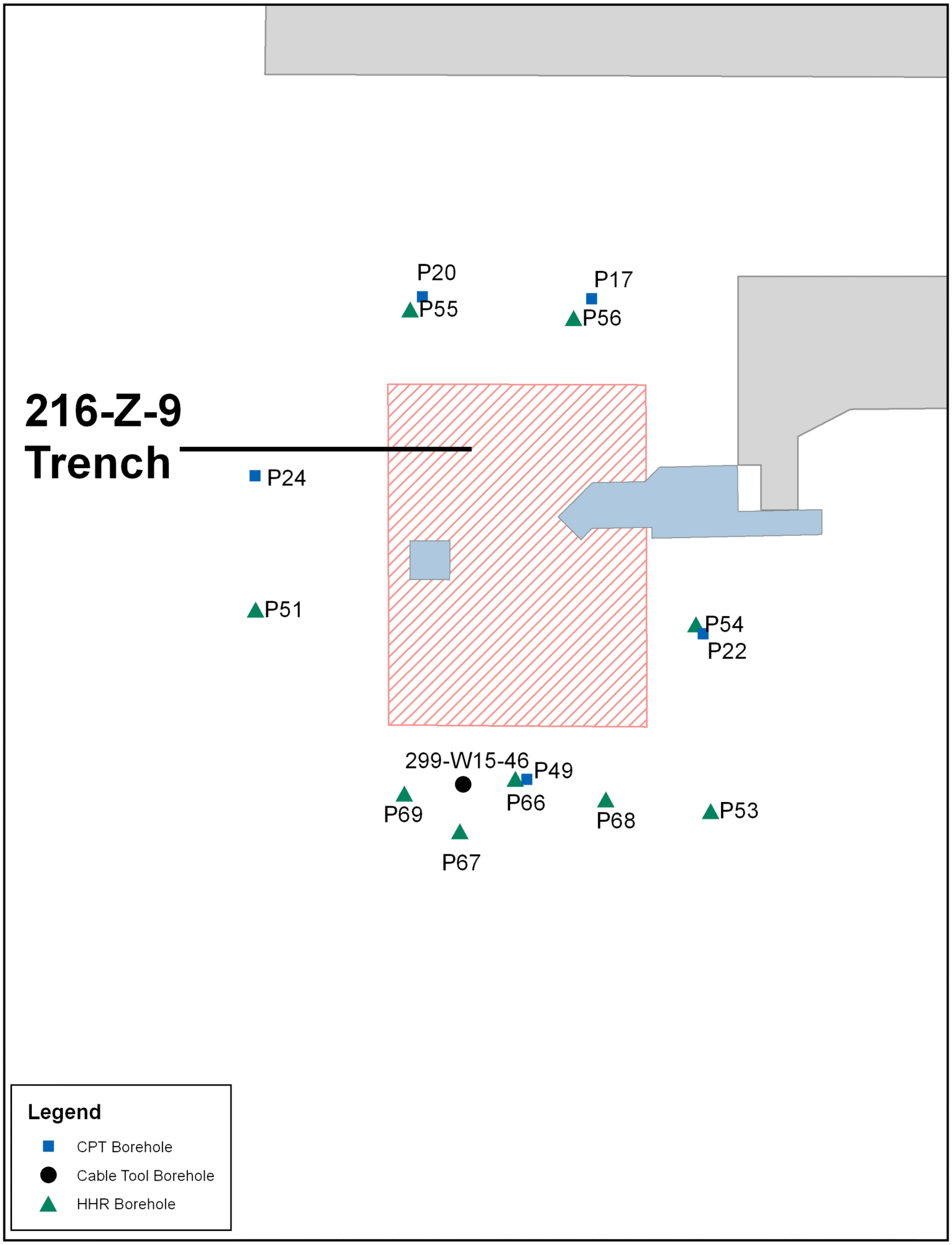

Fig. 1. Hydraulic Hammer Rig (HHR), Cable Tool and Cone Penetrometer (CPT) Borehole Location Map, 200 West Area, Hanford Site, WA.

HYDRAULIC HAMMER RIG

The HHR is comprised of a EuroDrill®, HD5012 percussion drilling system with a hydraulically powered mast and hammer mounted on a rubber tire backhoe (Figure 2). The EuroDrill® HD5012 is typically used for driving anchors and micropiles in civil construction projects[1], but was adapted by Energy*Solutions*, L.L.C., Richland, WA, for subsurface soil sampling on the Hanford Site. The HHR pushes steel rods, 6.7 cm outside diameter by 1.2 m long, into the vadose zone. The impact force from the hammer is approximately 450 ft/lbs. The HHR rotating head operated at a rate of less than 10 revolutions per minute (rpm) during this study, although it is capable of rotating up to 68 rpm. The rate was optimized to allow for maximum depth of penetration by moving the soil away from the rods using a fluted cone tip. The slower rotational rate minimizes heat and sample disturbance while the cone tip is being advanced, allowing representative soil samples to be collected for volatile organic analysis.[2] However, the HHR can only be used in unconsolidated sediments and the maximum depth of penetration was limited by the presence of gravel, cobbles, or highly-consolidated or cemented geologic units (e.g. the CCU calcic layer in this study).

The HHR, as with most direct push technology approaches such as CPT, does not bring soil cuttings to the surface. This is important at mixed-waste and radiologically contaminated sites where waste minimization is a high priority. The only soil brought to the surface using the HHR are depth-discrete soil samples obtained specifically for analytical purposes [3].

Since July 2005, the original HHR has pushed vertical and angled boreholes adjacent to Hanford Site Tank Farms to successfully collect characterization data to a depth of 19.8 m bgs [3]. An early soil sampling test with the Tank Farm HHR tooling at the 216-Z-9 Trench failed due to the difficult geologic conditions dominated by sand, gravel, and cobbles present in the Hanford formation. As a consequence, sturdier tooling capable of penetrating and sampling to the CCU calcic layer (36.6 m bgs) was designed and employed at the 216-Z-9 Trench. The objective of the testing was to collect sediment samples at multiple depths to evaluate CCl_4 and radionuclide (plutonium and americium) contamination levels as deep as the top of the CCU calcic layer.

The HHR pushed steel rods with a solid tip cone, solid tip soil sampler, or dual-wall retractable soil sampler. Initial sampling of the vadose zone sediments using the HHR was performed with a soil sampling system which required a separate borehole for each soil sample collected. Later, a Mavrik Environmental dual-wall soil sampling approach was implemented to allow multiple soil samples to be collected from a single borehole. The maximum gravel size collected was limited to 1.7 cm with the dual-wall soil sampling approach. During application of the dual-wall system, the HHR outer rod was advanced in conjunction with a locked internal split-spoon soil sampler to the desired sampling depth. To collect a depth-discrete sample, the tip located inside the split-spoon sampler was unlocked from the sampling unit. The rods and soil sampler were then advanced the length of the sampler to allow material to move into the sampler, pushing the tip up inside the sampler. The sampler was then unlocked from the outer rods and the sampling unit retrieved to the ground surface leaving the outer rod in place. A new sampler was then placed in the borehole outer rods, lowered to the corresponding depth, and locked into place. The borehole was then advanced until the next depth-discrete sampling

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[1] Personal communication with Mr. Joe Patterson, TEI Rock Drills, January 2, 2007.

[2] Personal communication with Mr. John Auten, Senior Drilling Engineer, Mavrik Environmental, January 28, 2007.

interval was reached. The dual-wall sampling system significantly enhanced sample collection, although minor design modifications were required to the tooling to initially optimize the system. The HHR dual-wall system was used to collect depth-discrete vadose zone soil samples for volatile organic analysis (e.g., CCl_4) and radionuclide analysis from up to 10 intervals in a single borehole. All boreholes were decommissioned in accordance with state regulations, which consisted of placing bentonite clay crumbles down the outer rods from the ground surface as the rods were withdrawn [3].

In addition to obtaining depth-discrete soil samples, the HHR provided additional capabilities. For example, during the investigation near the 216-Z-9 Trench, slim-hole borehole geophysical instruments (less than 5.7 cm in diameter) were raised and lowered down the HHR rod for collection of geophysical logging data. These spectral gamma and neutron moisture logging surveys were performed inside the HHR rod to guide the selection of depth-discrete vadose zone soil samples, assess radiological hazards, prepare for extraction of borehole rods, and support sample management controls. One active soil gas sample was also collected and field measured for carbon dioxide, CCl_4, chloroform and water vapor. In addition, the HHR was used to install three, 1.9-cm diameter, GeoInsight® soil vapor monitoring wells with a screen depth at approximately 19.0 to 19.5 m bgs. It took less than 6 hours for the HHR to penetrate to 19.5 m bgs and complete installation of each soil vapor monitoring well [3].

Fig. 2. Hydraulic Hammer Rig Direct Push Technology.

CONE PENETROMETER

Cone Penetrometer Testing (CPT) is another standard direct push technology that has been extensively used in the US for the past couple of decades. Typically, CPT has been deployed in unconsolidated sediments such as the costal areas of the US. With limited success CPT has been applied in glacial till formations and in valley fill deposits typical of the southwestern US [4]. To increase the penetration capabilities in these difficult geologies, the standard 20 ton CPT rig has been upgraded to both 30 and 40 ton units. Previous CPT investigations in the 200 West Area of the Hanford Site had shown that 30-ton CPT rigs had marginal success in achieving penetration depths ranging from 15.2 to 24.4 ft. To increase the probability of reaching the CCU at 36.6 m, a 40 ton unit was utilized in 2006 prior to the development of the HHR. The 40 ton CPT was utilized to collect soil samples and soil gas samples at 49 locations within the 200 West Area of the Hanford site [3]. Five of these penetrations were immediately surrounding the 216-Z-9 Trench and were selected for comparison in this paper (see Figure 1).

The 40 ton CPT unit utilized for this investigation is shown in Figure 3. Initial penetrations were made with a 15-cm^2 standard CPT probe to obtain soil stratigraphy and soil resistivity measurements. Soil-gas samples were collected during the penetrations through a dry pore pressure filter. Sediment samples were collected on subsequent penetrations near the initial penetration and utilized a wireline soil sampler that collected samples through a 2.1 cm opening. The CPT rig was also used to measure gamma radiation levels during selected penetrations and to deploy five dense non-aqueous phase liquid (DNAPL) ribbon samplers.

Fig. 3. 40 Ton Cone Penetrometer Direct Push Rig.

CABLE TOOL DRILLING AT WELL 299-W15-46

Well 299-W15-46 was drilled by cable tool drilling technology immediately south of the 216-Z-9 Trench (Figure 1). Using this method, a cable tool drive barrel continuously removed soil from inside and ahead of the casing; then, the drive barrel was brought to the surface and the soil cuttings were removed for disposal. Cable tool drilling can penetrate through the vadose zone, unconfined aquifer, and the underlying semi-confined aquifer and into the basalt bedrock at the Hanford Site. Cable tool drilling is commonly used to drill groundwater monitoring wells and waste site characterization boreholes at highly radioactively contaminated sites because only minimal amounts of drilling fluids are used and the contaminated soil cuttings can be contained for subsequent waste characterization. Soil samples and characterization data may be collected with the cable tool drilling method throughout the entire vadose zone and deeper. However, the drilling method is relatively slow and it has the disadvantage that soil cuttings must be contained, sampled for waste characterization, and disposed at appropriate facilities.

At well 299-W15-46 the drill cuttings from 14.0 to 36.6 m bgs were classified as transuranic waste, which was expensive to dispose of and required workers to wear high levels of personnel protective equipment. During drilling, a temporary 34.3 cm outside diameter casing was used from ground surface to 36.3 m bgs, then a 29.8 cm outside diameter casing was used to 61.2 m bgs. From 61.2 to 160.0 m bgs, the borehole diameter was decreased in stages to 10.2 cm. Depth-discrete vadose zone soil samples were collected and analyzed for CCl_4 and other contaminants of concern. Drilling was intermittently delayed due to CCl_4 and radiological contamination levels encountered that exceeded established control levels. The daily drilling rate was impacted by sample handling and packaging, the use of personnel protective equipment and waste management concerns [5].

MATERIALS AND METHODS

Three drilling technologies were evaluated based on their penetration capability to reach the CCU calcic layer. Furthermore, the capability to collect representative vadose zone samples was compared. Although the Hanford formation is heterogeneous, by comparing the three drilling technologies within a small part of the 200 West Area, minimal variations of the formation were expected due to the close proximity of the boreholes. Therefore, the constraint of the drilling conditions would be similar so the characteristics of the drilling approach could be compared.

Table 1 presents a summary of the drilling comparisons for the various boreholes adjacent to the 216-Z-9 Trench. The HHR depth data were obtained with a downhole tape measure which provided a bottom depth measurement to the nearest 0.3 m [3]. At the five CPT boreholes considered in this study, depth was measured in real time as the head clamp was raised and lowered during the penetration, and was reported to the nearest 0.3 m [2]. Depth data from well 299-W15-46, drilled using cable tool technology, was reported to the nearest 0.2 m [5].

Table 1. Time for the Hydraulic Hammer Rig, Cable Tool and Cone Penetrometer Technologies to Reach the Cold Creek unit (CCU) Calcic Layer at Boreholes Investigated.

Drilling Method	Borehole Identification Number	Total Depth (m bgs)	Penetrated to CCU Calcic Layer	Time to CCU Calcic Layer
HHR	P55	25.6	No	NA
HHR	P56	34.4	Yes	10 h
HHR	P54	33.8	No	NA
HHR	P53	33.2	No	NA
HHR	P51	36.9	Yes	5 h
HHR	P67	35.7	Yes	8 h
HHR	P66	36.0	Yes	3 h
HHR	P69	35.9	Yes	6 h
HHR	P68	34.9	Yes	6 h
Cable Tool	299-W15-46	160.0	Yes	91 d
CPT	P17	32.2	No	NA
CPT	P20	13.7	No	NA
CPT	P22	21.4	No	NA
CPT	P24	17.0	No	NA
CPT	P49	16.20	No	NA

HHR = Hydraulic Hammer Rig bgs = below ground surface
CPT = Cone Penetrometer NA = not applicable
CCU = Cold Creek unit
bgs = below ground surface

The drilling time required to characterize the vadose zone by each technology to the CCU calcic layer, including collection of vadose zone soil samples and other characterization data, was evaluated. The geologic units observed during the installation of well 299-W15-46 were representative of the geologic units encountered by the three drilling technologies in the study area. The CCU layer was identified based on color, texture, and particle size from soil samples. The HHR and CPT drilling time was reported to the nearest minute, and included sampling and/or logging of the vadose zone and addressing radiological hazards. The penetration time to reach the CCU calcic layer at well 299-W15-46, installed using cable tool drilling technology, included sampling and on-site support services for radiological concerns. The borehole log from this well provided the actual time to reach the CCU calcic layer, excluding delays encountered in drilling to upgrade personnel protective equipment, and was reported to the nearest day [5].

To determine if a drilling technology was able to collect representative soil samples from the formation, a thin silt lens at 19.8 m bgs was selected as a known and unique benchmark. Utilizing HHR and cable tool drilling technologies, depth-discrete vadose zone soil samples were collected. The visual analysis of vadose zone material obtained using either HHR or cable tool drilling allowed a qualitative comparison of the representative nature of the material collected at this depth interval. Slough, soil that has fallen back into the borehole during drilling, is not representative of in-situ conditions.

RESULTS AND DISCUSSION

Depth of Penetration

The average HHR penetration was 34.0 m bgs, and the maximum penetration depth was 36.9 m bgs at P51. The standard deviation of the depth of penetration was ± 3.4 m. Borehole P55 was the first and shallowest borehole of the investigation with a penetration depth of 25.6 m bgs. During penetration at P55, engineering modifications were made to refine the sampling equipment. Excluding P55, the standard deviation of the maximum depth of penetration of the remaining boreholes was ± 1.2 m.

The HHR penetrated 0.3 m into the CCU calcic layer at P51 and P56. In addition, the HHR was able to penetrate into the CCU and collect representative vadose zone soil samples at locations P66, P67, and P69, each less than 6.1 m from well 299-W15-46. At P66, P67, and P69, the CCU calcic layer was encountered at approximately 35.5 m bgs, with approximately 0.3 m of this stratum collected at each location. The CCU calcic layer was also reached at P68 at 35.1 m bgs. The HHR succeeded in reaching the CCU calcic layer at 100% of the locations south of the 216-Z-9 Trench with the dual-wall sampling system [3]. However, the HHR was not capable of penetrating beyond this layer, due to its dense and cemented nature. The maximum depth of penetration for the HHR in its current configuration was the CCU calcic layer for these geologic conditions.

The average CPT penetration was 20.1 m bgs, and the maximum penetration depth was 32.2 m bgs at P17 for the five locations selected for this study. The standard deviation of the CPT depth of penetration was ± 7.3 m. None of the five selected CPT penetrations or the 49 total CPT penetrations, reached the target depth of approximately 36 m for the CCU calcic layer. The average depth for all 49 penetrations was 21.4 m and the maximum depth was 35.3 m.

Well 299-W15-46 was drilled using cable tool methods to penetrate through the CCU calcic layer. The CCU calcic layer was observed from 35.5 to 36.0 m bgs [5]. Cable tool drilling was capable of penetrating through this layer and into the bedrock at this borehole, but the safety and regulatory controls associated with management of soil samples and drill cuttings was extensive. The large diameter casing used at well 299-W15-46 in the vadose zone was a factor that increased time and volume of drill cuttings, but was necessary in order to reach the underlying basalt layer at 160.0 m bgs.

The depth of penetration using HHR is limited by the degree of consolidation of the formation sediments. The CCU calcic layer is a variably dense layer that the HHR was able to penetrate to, but not completely through. The shallow depth of penetration at the initial borehole, P55, can likely be attributed to inadequate design of the sampler, which was subsequently modified. Following design modifications, the HHR was able to penetrate, sample, and collect soil samples into the top of the CCU calcic layer. The HHR penetrated to the engineered limits of the equipment. The HHR and the CPT moved vadose zone sediments with the probe using force to reach the desired depth, resulting in no soil cuttings. If the formation material cannot be moved, or if there is no porosity, there is no penetration of the formation. The cable tool drilling technology removes soil for the drill to penetrate, which takes longer and creates soil cuttings.

Time to Drill to the CCU Calcic Layer

The HHR was able to successfully penetrate into the calcic layer and collect a representative soil sample of the CCU calcic layer at six of nine locations in an average of 6.3 h.

The time to reach this stratum for each HHR borehole is presented in Table 1. At P56, the HHR time to the CCU calcic layer was 10 h, but this included neutron moisture logging throughout the borehole and vadose zone soil sample collection from 33.8 to 34.4 m bgs. Although this borehole took the longest time to reach the CCU calcic layer, it was also the first HHR borehole produced after initial engineering modifications. At borehole location P51, the HHR time to the CCU calcic layer was 5 h, and this included collecting a vadose zone soil sample between 36.3 to 36.9 m bgs. At P66, the HHR time to the CCU calcic layer was less than 3 h, with no attempt to collect a vadose zone soil sample. At P67, the HHR penetration time to the CCU calcic layer was 8 h, with an unsuccessful attempt to obtain a vadose zone soil sample, from 32.6 to 33.2 m bgs, due to a tooling malfunction. At P68, the HHR penetration time to the CCU calcic layer was 6 h, with no soil sample attempted. At P69, the HHR penetration time to the CCU calcic layer was 6 h, with no attempt to collect a vadose zone soil sample.

The CPT was not able to reach the CCU calcic layer for each of the five boreholes considered, as presented in Table 1 [2]. The average penetration rate for the CPT rig was approximately 24 to 36 m per day, but none of the penetrations were able to reach the CCU calcic layer.

The time to the CCU calcic layer by cable tool drilling at well 299-W15-46 is also presented in Table 1. Cable tool drilling started on 7 Oct. 2003, and stopped 12 Nov. 2003 through 9 Mar. 2004 to allow an evaluation for safety and exposure concerns due to radioactive material and volatile CCl_4 associated with the vadose zone soil. Total drilling time to reach the CCU calcic layer was 91 days. The increased total time to this layer compared to the HHR boreholes was a result of the drilling technology utilized, the necessary use of personnel protective equipment for the management of soil cuttings and for soil sample collection and management [5]. Cable tool drilling achieved sampling objectives in the vadose zone, but at a slower rate.

The HHR can be used to permit rapid geologic and contamination characterization, and sampling of the vadose zone. The HHR was able to reach the CCU calcic layer in substantially less time than cable tool drilling. In addition to engineering differences as described previously, a significant factor impacting the penetration rate was the relative need to address personnel safety and waste management issues. If drill cuttings were not generated, then radiological controls during drilling and the effort related to waste management of soil cuttings could be significantly reduced. The duration of drilling well 299-W15-46 using cable tool methods can be tied to the volume of radiologically contaminated soil cuttings. The primary benefit of the HHR is the successful accomplishment of characterization objectives at radioactive and mixed-waste sites in the least amount of project time. An additional benefit is the elimination of soil cuttings that may need to be managed and disposed of due to radiological contamination. This can result in a significant reduction in operational costs associated with health and safety concerns.

Representative Vadose Zone Soil Samples

The vadose zone soil samples collected using the HHR were determined to be representative based on visual observation of color, texture, and particle size compared to the lithology from well 299-W15-46 [5]. A potential limitation of sampling during cable tool drilling is that the top few centimeters of material collected may be slough. No slough was observed in any of the HHR soil samples collected using the dual-wall system, based on the lithology reported for well 299-W15-46. This is particularly important when collecting vadose zone soil for determining the presence and amount of potential contaminants.

A thin silt lens was found from 19.8 to 20.4 m bgs in well 299-W15-46 [5]. The samples from HHR locations P66, P67, P68, and P69 were geographically close enough to well 299-W15-46 to permit a comparison to the soil samples south of the 216-Z-9 Trench from 19.8 to 20.4 m bgs (Figure 1). At P66, a silt lens was observed from 19.7 to 19.8 m bgs. At P67 the silt lens was observed from 19.8 to 20.0 m bgs. At P68, a silt lens was observed shallower at 19.2 to 19.4 m bgs. At P69, the silt lens was observed from 19.7 to 19.8 m bgs, approximately consistent with P66. The HHR collected representative vadose zone soils from a thin, laterally discrete, interval (19.8 to 20.4 m bgs) south of the 216-Z-9 Trench, which correlated with the lithology of well 299-W15-46. The visual analysis of vadose zone samples obtained using either HHR or cable tool drilling qualitatively indicated the samples were similar.

FURTHER STUDIES

The capabilities of the HHR warrant further studies in a range of environments. While the HHR is designed to be used in unconsolidated sediments, its use in this study of a geologic formation with a wide range of grain sizes, from boulder- to silt-size particles, provided an especially challenging environment to evaluate this drilling method. A geologic formation lacking a highly-consolidated cemented layer, such as a calcic layer, could have a greater maximum depth of penetration than found in this study.

Due to the relative newness of the HHR technology, there is a need to evaluate its capabilities and limitations. In particular, studies are needed to evaluate its utility at non-hazardous waste sites where the absence of radiological and on-site support should increase productivity. The HHR also has the capability to drill angled boreholes, but further studies are needed to determine the penetration rate and depth capabilities of angled boreholes in comparison to vertical boreholes. The HHR also could be used for the collection of water samples.

Although the HHR may allow a relatively rapid penetration of unconsolidated vadose zone soil, a study of drilling technologies based on the cost of operation would be useful. These data would allow the comparison of costs associated with the drilling technologies presented in this study and other readily available technologies, such as GeoProbe®, in hazardous and non-hazardous environments. Application of the HHR technology does not create soil cuttings, which significantly reduces the costs associated with the cuttings management and disposal, and the use of personnel protective equipment. Consequently, utilizing HHR for drilling projects, specifically at hazardous waste sites, should provide significant cost benefits.

The drawback of the HHR is that no information on the soil stratigraphy is obtained. As a result of the lack of soil cuttings, selecting specific lithologic layers to sample can be difficult. The use of borehole geophysics such as gamma and neutron moisture logs greatly aided the ability to select fine-grained lenses for sampling around the 216-Z-9 Trench.

CONCLUSIONS

This study presents a comparison of the time to reach the CCU calcic layer at about 36 m bgs using HHR, CPT technologies, and cable tool drilling in similar geologic conditions. The relative ability to obtain representative vadose zone soil samples was also evaluated. Compared to cable tool drilling, the HHR allowed a more rapid penetration, including collection of vadose zone soil samples. The HHR technology took several hours to reach the CCU calcic layer versus weeks to months for cable tool drilling. The CPT was not able to reach the CCU calcic layer. An additional advantage of the HHR over cable tool drilling was the elimination of soil cuttings, which are a significant project expense at a mixed-waste site. The latter characteristic significantly reduces both health and safety issues associated with waste management and soil sample handling controls. However, a disadvantage of the HHR, compared to cable tool drilling, was the apparent limited capabilities to penetrate beyond the highly-consolidated cemented CCU calcic layer. Vadose zone soil samples collected using the HHR were representative of the formation, as the technology prevents slough during sample collection.

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REFERENCES

1. USDOE, "Remedial Investigation Report for the Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Unit." DOE/RL-2006-51, Draft A., 2006, USDOE, Richland, WA.

2. USDOE, "Carbon Tetrachloride Dense Non-Aqueous Phase Liquid (DNAPL) Source Term Interim Characterization Report." DOE/RL-2006-58, Rev. 0., 2006, USDOE, Richland, WA.

3. USDOE, "Carbon Tetrachloride Dense Non-Aqueous Phase Liquid (DNAPL) Source Term Characterization Report Addendum." DOE/RL-2007-22, Rev. 0., 2007, USDOE, Richland, WA.

4. LOONEY, B.B. AND R.W. FALTA, Vadose Zone – Science and Technology Solutions, Volume I, 2007, Battelle Press, Columbus, OH.

5. CARON, M.E., "Borehole Summary Report for Well 299-W15-46 (C3426) Drilled at the 216-Z-9 Trench." WMP-26264, Rev. 0., 2005, Fluor Hanford Inc., Richland, WA.