DEVELOPMENT OF A WIRELINE CPT SYSTEM FOR MULTIPLE TOOL USAGE

BASE CONTRACT

VOLUME I

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ABSTRACT

The first phase of development of a wireline cone penetrometer system for multiple tool usage was completed under DOE award number DE-AR26-98FT40366. Cone penetrometer technology (CPT) has received widespread interest and is becoming more commonplace as a tool for environmental site characterization activities at several Department of Energy (DOE) facilities. Although CPT already offers many benefits for site characterization, the wireline system can improve CPT technology by offering greater utility and increased cost savings. Currently the use of multiple CPT tools during a site characterization (i.e. piezometric cone, chemical sensors, core sampler, grouting tool) must be accomplished by withdrawing the entire penetrometer rod string to change tools. This results in multiple penetrations being required to collect the data and samples that may be required during characterization of a site, and to subsequently seal the resulting holes with grout. The wireline CPT system allows multiple CPT tools to be interchanged during a single penetration, without withdrawing the CPT rod string from the ground. The goal of the project is to develop and demonstrate a system by which various tools can be placed at the tip of the rod string depending on the type of information or sample desired. Under the base contract, an interchangeable piezocone and grouting tool was designed, fabricated, and evaluated. The results of the evaluation indicate that success criteria for the base contract were achieved. In addition, the wireline piezocone tool was validated against ASTM standard cones, the depth capability of the system was found to compare favorably with that of conventional CPT, and the reliability and survivability of the system were demonstrated.

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EXECUTIVE SUMMARY

This topical report is prepared in accordance with the reporting requirement's checklist of DOE award number DE-AR26-98FT40366: "Development of a Wireline Cone Penetrometer System for Multiple Tool Usage." The contract is divided into three portions; a base and two options. This report describes the work completed under the base contract.

Cone penetrometer technology (CPT) has received widespread interest and is becoming more commonplace as a tool for environmental site characterization activities at several Department of Energy (DOE) facilities. There are three major reasons for this increased interest: (a) CPT is typically faster and less expensive than drilling techniques, (b) it provides significantly more detailed information about subsurface conditions, and (c) it generates very little drilling waste. Although CPT already offers many benefits for site characterization, the technology can be improved to offer greater utility and increased cost savings with the development of an innovative wireline CPT system.

The goal of the project is to develop and demonstrate a system by which various tools can be placed at the tip of the rod string depending on the type of information or sample desired. Specifically, under the base contract, an interchangeable piezocone and grouting tool was designed, fabricated, and evaluated. The results of the evaluation indicate that success criteria for the base contract were achieved. In addition, the wireline piezocone tool was validated against ASTM standard cones, the depth capability of the system was found to compare favorably with that of conventional CPT, and the reliability and survivability of the system were demonstrated. An accurate comparison of refusal depth of the wireline system to that of conventional CPT was not possible because the wireline system exceeded expectations and we ran out of rods before refusal was encountered.

In one instance of field testing, minor difficulty was encountered in re-deployment of the wireline tools through an embedded CPT rod string. The cause of the interference was positively identified as binding of the tools due to deflection of the rods (rod deflection sometimes occurs while penetrating particularly hard to penetrate layers). We will reduce future potential for this phenomenon to occur will be reduced by shortening the length of the tools by six inches (a relative reduction of 21 to 33%).

In comparisons of geotechnical measurements produced using the wireline piezocone (1.125" diameter) to those produced using ASTM standard piezocones (1.44" and 1.75" diameter), we found that no statistically significant variation exists in tip stress and sleeve stress measurements. In fact, no variation can be distinguished as separate from natural geologic variation at the test sites. Pore pressure measurements vary among cone sizes in both theory and practice, and will be further analyzed under the remainder of the contract.

Under options to the contract an additional sampler/cutting shoe tool will be developed and integrated with a depth-increasing sonic (vibratory) CPT system developed under a separate project. Additionally, the utility of the system for performing vadose zone site characterization during simultaneous emplacement of tank leak detection infrastructure will be demonstrated.

1. BACKGROUND

Over the past five years, the Department of Energy (DOE) has invested in the development of Cone Penetrometer Technology (CPT) to reduce both time and costs associated with site characterization efforts. To date CPT has been effectively demonstrated at nearly all DOE facilities and is a technology that is being routinely used at all of the larger DOE sites (i.e. SRS, Hanford, Fernald, etc.). As the DOE moves from characterization activities at these facilities to site remediation and monitoring activities, CPT technologies need to be adapted in order to maintain the advantages of providing the most cost effective and rapid means for remediation and monitoring. It is held that the single biggest technical and cost advance in adapting CPT technology to site remediation and monitoring will be the development of a wireline CPT system which permits deployment of interchangeable sensors, samplers, remediation and grouting equipment during a single CPT push. This will help ensure that all cleanup goals are met under both the limited budget directed from Congress and the aggressive time scales outlined in each site's "Accelerated Clean-Up: Paths to Closure" plan.

2. SIGNIFICANCE

Prior to development of the wireline system, the use of multiple CPT tools during a site characterization (i.e. piezometric cone, chemical sensors, core sampler, grouting tool) was accomplished by withdrawing the entire penetrometer rod string to change tools. This results in multiple penetrations being required to collect the data and samples that may be required during characterization of a site, and to subsequently seal the resulting holes with grout. The wireline CPT system being developed allows multiple CPT tools to be interchanged during a single penetration, without withdrawing the CPT rod string from the ground. This innovation will allow more work to be accomplished, and reduce overall costs as time is not wasted pulling rods back into the truck to change tools.

By reducing the number of penetrations and thus the time required to perform typical site characterization tasks by up to 75 percent, the development of the wireline CPT system is expected to reduce the costs of standard CPT operations by a quarter to one half. Current CPT costs are roughly half of drilling techniques. Thus, the wireline approach is expected to cut CPT site characterization costs to roughly a quarter of drilling costs. Additionally the utility of CPT will be increased by allowing appropriate tools to be employed as they are needed. Overall, the wireline CPT system is expected to significantly enhance site characterization and monitoring activities at most DOE facilities, as well as having significant potential for enabling the injection of remedial treatment fluids and other materials into precisely targeted subsurface zones.

3. TECHNICAL OBJECTIVES

The objective of the project is to design, fabricate and test a wireline system for Cone Penetration Testing (CPT) that will allow the deployment of several tools during a single penetration. This approach will save time and cost by decreasing the number of penetrations required to perform the analyses and collect multiple media samples that may be required from a single sounding location during site characterization. Additionally, significant potential exists for using the wireline system to enable injection of remedial fluids or materials to specific subsurface target zones based on concurrent sensor deployment or sample collection and analysis.

The project is divided into a base contract and two options. Under the base contract, the wireline rod string, tool exchange mechanism, and two interchangeable tools -- a piezocone module and a grouting module -- were developed and evaluated. This report documents completion of the base contract.

3.1 Success Criteria

The approved management plan for the project states the success criteria for the Wireline CPT development project. They are:

- to demonstrate the ability to advance a piezocone to refusal depth at Savannah River Site using the DOE SCAPS rig,
- with the rod string in place, to replace the piezocone with a grouting tool, and
- to subsequently grout the hole upon withdrawal of the rod string.

During execution of the base contract statement of work, these criteria were not only satisfied, but exceeded. Additional accomplishments achieved include:

- validation of the wireline piezocone performance against ASTM standard geometry cones (1.44-inch and 1.75-inch diameter),
- demonstration of the reliability of retrieval and re-deployment of the developed wireline tools at multiple depths and in multiple geologies,
- comparison of production time with that of conventional CPT for geotechnical characterization, and
- identification of and correspondence with several potential end-users of the wireline system within the DOE complex.

4. DESCRIPTION OF EQUIPMENT

A patent is being pursued by the developers of the wireline CPT system. Therefore, detailed discussions, proprietary photographs, and design drawings of the system components are submitted separately as Appendices A and B. However, in summary, the wireline CPT system consists of five major components:

- segmented rod string,
- tool and lock housing (including cutting mouth),
- tool locking and retrieval mechanism,
- piezocone module, and
- grout module.

5. SCOPE OF WORK

The scope of work (SOW) under the base contract was divided into four tasks to be performed. Several subtasks were completed under these tasks. This following sections of the report are organized by logical order of subtasks completed. The NEPA questionnaire and project planning were completed under Task 1 (*Information Required for the National Environmental Policy Act*) of the SOW. All system design, engineering, fabrication, and preliminary field testing were conducted under, and distributed across Tasks 2 and 3 (*Piezocone Wireline Development* and *Wireline Grouting*

Module). The field evaluation and demonstration of the system at Savannah River Site (SRS) was conducted under Task 4 of the SOW (*Prototype Evaluation*). Finally, all reports, including the Field Operations Plan (FOP), monthly status reports, cost management reports, milestone status reports, and this topical report were completed under Task 5 (*Field Operations Plan and Topical Report*). A photograph of the prototype system appears in Figure 1. Depicted are the rod string and cutting mouth with piezocone tool installed.

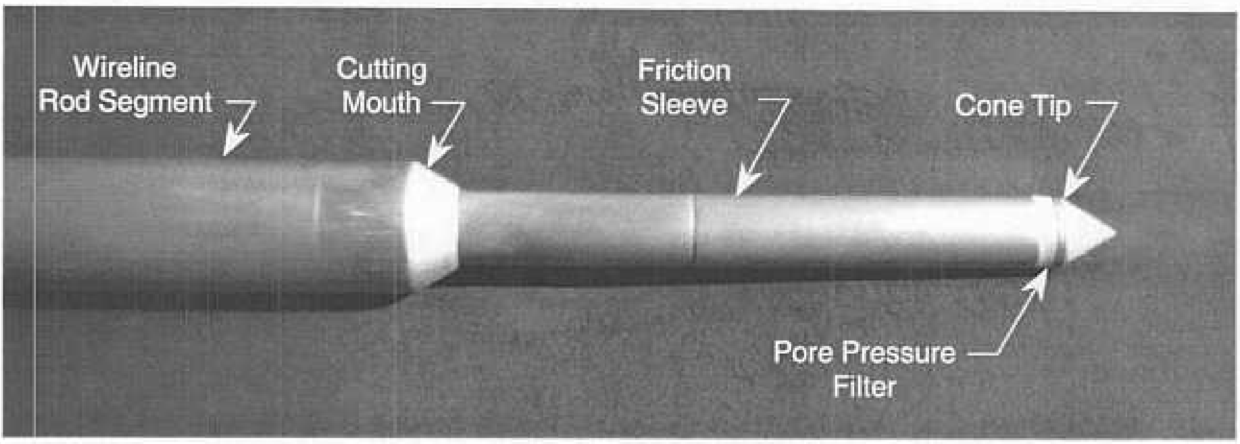

Figure 1. Photograph of Prototype Wireline CPT System with Piezocone Tool Installed.

5.1 NEPA Questionnaire and Project Planning

Under Task 1 of the contract scope of work, ARA completed an Environmental Questionnaire, which was used by the DOE to prepare the appropriate level of National Environmental Policy Act (NEPA) documentation of the project. No action was taken that would have an adverse impact on the environment or limit the choice of reasonable alternatives to the proposed action until the NEPA review and approval process was completed. Also under this task, a project management plan was prepared, which describes the approach, organizational structure, and technical, schedule, and cost control systems to complete the effort, achieve the project goals, and provide contract deliverables. Significant components of this plan include:

- Milestone Log
- Work Breakdown Structure (WBS): Index, Diagrams, and Dictionary
- Project Organization
- Technical and Managerial Approach
- Synopses of Safety and Health, Environmental Protection, and Quality Assurance/Quality Control plans
- Success Criteria
- Approach to Interact with Potential Users
- Test Plans

Additionally, a project kick-off meeting was held at FETC in Morgantown, VW.

5.2 Wireline System Design

The wireline system designed under Tasks 2 and 3 of the SOW consists of several major and minor components. The major functional components include the wireline rod string, tool locking mechanism, piezocone tool, and grouting module. A discussion of the system design is included in Appendix A.

5.3 Fabrication

All components were fabricated and assembled in New England by ARA's manufacturing group. The finished parts conformed to specifications for materials and hardening, machining tolerances, and surface finishes. Components produced include 35 one-meter rod segments (six with expanders), two lock housings with associated parts, one piezocone, two cable jigs, two sets of spare dogs and pins, two cutting mouths, one grout module, and two disposable grout tips.

5.4 Preliminary Testing

Preliminary testing was conducted in Vermont prior to field evaluation at a DOE facility to assure the smoothest possible system operation and ultimate project success.

5.4.1 Bench Test

The first tests were conducted immediately followed fabrication of the major components and consisted of above ground testing of the locking mechanism and it's ability to sustain free-fall re-deployment through the rod string. These tests elucidated areas in which design improvements could be made to improve component durability and assure smoother field operation and ultimate project success. The improvements were implemented and two preliminary field testing events followed. In addition, a deflection tolerance study was undertaken to ensure that geometry of individual wireline tools would allow them to pass reliably through an embedded rod string that may be deflected due to encounters with boulders, hard layers, or other obstructions during penetration.

5.4.2 Preliminary Field Tests

The field testing events were conducted at two test sites in Vermont and occurred in March and April of 1999. Findings from these tests guided further, minor modifications to the system design and operating procedures.

The first field tests of the locking mechanism used a dummy piezocone module in place of an actual tool. The dummy module was fabricated to match the outside geometry of the functional piezocone module. During this testing, the module was deployed repeatedly at several depths between 0 and 40 feet in sands, gravels and silty sands. In the first 5 of 8 trials, the tool was removed from the rod string, pulled up-hole, and re-deployed uneventfully. On the last three attempts, the tool did not drop fully into the locking position. Determining whether or not the lock was engaged was difficult because the tension induced in the retrieval wire by the locking wedge spring was very nearly equivalent to the weight of the tool. This resulted in ambiguity as to whether vertical displacement of the wire was due to movement of the locking wedge or of the entire tool when manually gauging the tension. The problem was resolved by marking the retrieval cable at periodic intervals which end up coincident with rod joints when the lock is properly engaged. This allowed the operator to gauge the position of the tool down-hole by observing the position of marks on the retrieval wire. Additionally, a washer was added between the locking wedge retaining ring and the compression spring. This increased spring force, allowing displacement of the locking wedge by tugging on the retrieval wire to be readily discernable from displacement of the entire tool. Thus the lock condition can be easily determined from up-hole.

During April and May 1999, preliminary field testing continued at SRS, using the modified locking component, the fully instrumented piezocone module, and the grouting module. During this testing, the piezocone module was deployed and retrieved repeatedly at every one-meter increment of depth between 0 and 40 feet. In all trials, the tool was removed from the rod string, pulled up-hole, and re-deployed successfully without event. Groundwater was encountered consistently below about 9.1 meters (30 feet), but did not impact the performance of the system.

In addition to evaluating the reliability of the mechanical components, the Vermont field testing compared the results of piezocone characterization between three configurations:

- 1.44-in ASTM standard cone on 1.44-inch rod string,
- 1.125-in wireline piezocone on 1.44-inch rod string, and
- 1.125-in wireline piezocone on 2-inch wireline rod string.

This comparison was made to (1) validate the wireline piezocone data against the ASTM standard geometry cone, and (2) determine whether the increase in diameter of the wireline system from 1.125 inches at the cone to 2 inches at the cutting mouth had any impact on cone measurements.

5.4.3 Deflection Tolerance Study

Tip deflections up to several degrees have been observed in CPT inclinometer data due to encounters with boulders and other obstructions during penetration. When these deflections occur, the rod often deforms slightly, resulting in possible obstruction to the free passage of wireline tools by binding against the interior of the deflected rod string. A deflection tolerance study was undertaken to determine if the geometry of the piezocone module will allow it to pass through the full length of a potentially deflected rod string embedded in a difficult geology. In operation, the piezocone module must protrude several inches out the end of the rod string. It is therefore the longest of the wireline tool modules, creating the greatest potential for binding against the interior of a deflected rod string.

A theoretical evaluation of rod deflection was conducted using data obtained from a two-axis inclinometer mounted in the tip of a 2-inch diameter rod string at ARA's Hanford facility. However, confidence was low that the inclinometer data represented the continued deflection of the rod string once the cone tip had passed the subsurface obstruction which caused the deflection. The extrapolated path of the tip is not necessarily that of the rod which follows, because the tip inclinometer data does not account for lateral displacement of the trailing rod, allowed by compression or displacement of material in the of the sidewall of the hole. Thus, a component was added to the test matrix of the field evaluation phase to evaluate this phenomenon under actual in-field conditions at the DOE site.

5.5 Field Evaluation

Under Task 4 of the SOW, the prototype wireline designs developed under Tasks 2 and 3 were demonstrated and evaluated during a one-week testing period conducted from 10 to 14 May, 1999 at the DOE's Savannah River Site (SRS). Cost estimates, penetration depths, and geotechnical characterization data were gathered for comparison to conventional techniques.

5.5.1 Test Objective

The objective of the field evaluation was to test a wireline system that will allow the deployment of several CPT tools during a single penetration. The field effort was carefully designed to gather the information necessary for evaluating the following functional concerns:

- performance of the tool locking mechanism,
- adequacy of operational procedures developed,
- system survivability,
- refusal depth versus conventional CPT,
- piezocone performance versus ASTM standard piezocone, and
- production rate versus conventional CPT.

The test series was completed successfully, providing ample data to fully evaluate all the issues identified.

5.5.2 Site Description

The field evaluation was conducted at the M-basin of DOE's Savannah River Site (SRS), located in the northwest corner of the site, just south of the SRS administrative area. The M-basin was selected as the field evaluation location due to the diversity of geologic strata available at M-basin's Integrated Demonstration Area, the extensive history of prior site use for CPT evaluations, and the experience and familiarity of the on-site personnel with CPT operations and concepts. The prior experience of the site itself provides a plethora of data on soil conditions and the effectiveness of diverse types of CPT operations and innovations previously tested.

This site offers challenging conditions for CPT and is actively serving as a site for pilot characterization/remediation studies conducted by the DOE. Previous studies of the site have identified four clay layers and other significant stratigraphic variability in the upper reaches of the formation at the M-basin. Specific locations of penetrations conducted during the field evaluation are shown in Figure 2.

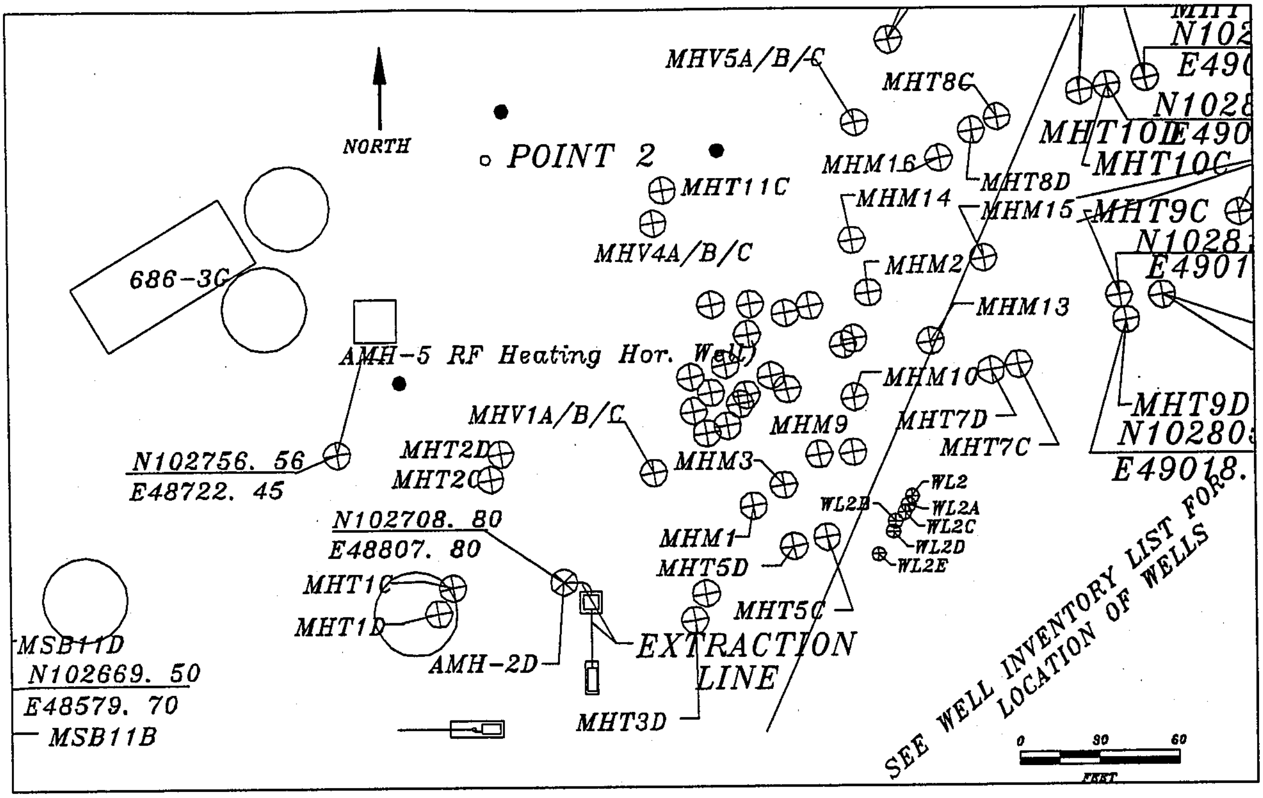

Figure 2. Map of M-Basin Showing Penetration Locations for Field Evaluation

Support provided by SRS on-site personnel included obtaining necessary permits and dig clearances, securing site access, and providing requisite safety and security training for project personnel. In addition, the familiarity of the SRS on-site personnel with CPT operations enriched the evaluation process by enabling efficient support to be rendered and by bringing valid technical feedback into the process from outside the immediate development team. The feedback obtained from observers of the field evaluation is discussed in the section on attendance, below.

5.5.3 Field Evaluation Schedule

The five-day field effort was performed from 10 to 14 May, 1999. During this period, the first day was consumed with site-specific training and orientation, badging, and equipment preparation. The remaining four days were devoted to field operations, allowing a completion of the test matrix as planned.

The field operations began by hand-augering the locations of six planned penetrations to approximately 4.5-feet below grade, as required by SRS to insure that no utilities would be inadvertently struck during penetration. The locations were approximately one meter apart and oriented in-line with each other (see Figure 4).

5.5.4 Test Procedures

Testing operations adhered to generally accepted principles of sound CPT operation and to the provisions of the ARA and SRS health and safety plans. For comparison to conventional CPT, the test matrix included a pair of conventional CPT soundings using an ASTM standard 1.75-inch piezocone. These soundings were conducted in close proximity to, and interspersed with, the wireline piezocone soundings. The time required to conduct a complete wireline piezocone sounding including pressure grouting upon rod retraction was recorded, as well as the time to complete a standard 1.75-piezocone sounding and grouting by re-penetration for comparison. The full test matrix and the objective of each action performed is summarized in Table 1 below.

Table 1. Test Matrix for Base Contract Field Evaluation

Action	Objective(s) for Data Obtained
Penetrate to 15 meters bgs using wireline rod string and dummy piezocone module stopping every 1 meter to retrieve, inspect, and re-deploy module; grout out using wireline grout module	1. Evaluate reliability of tool retrieval and re-deployment afforded by design 2. Evaluate tool susceptibility to contaminant (soil) entry into rod string in vadose zone[1] 3. Develop operator intuition for local push stresses and tool survivability
Penetrate to 15 meters bgs at ASTM quasi-static rate using wireline rod string and functional piezocone module while collecting tip, sleeve, and pore pressure data; replace piezocone module with grouting module and grout out.	1. Collect data for comparison of cone performance to ASTM-conformant geometry 2. Collect timing data on operation to compare with conventional tool usage for basis of cost analysis 3. Assure survivability of wireline piezocone module under conditions encountered
Repeat previous action two meters from previous location	1. Provide confirmation data in support of objectives above
At location between previous two penetrations, penetrate to 15 meters bgs at ASTM quasi-static rate using 1.75" diameter cone (ASTM-conformant geometry) on same diameter rod string while collecting tip, sleeve, and pore pressure data; withdraw rods and re-penetrate with 1.75" grout-out tip replace piezocone module with grouting module and grout out.	1. Collect data to compare to wireline cone for performance 2. Collect timing data on conventional approach operation to compare with wireline approach for basis of cost analysis
Repeat previous action two meters from previous location, leap-frogging wireline piezocone push location by one meter	1. Provide confirmation data in support of objectives above
Penetrate to refusal (or until out of rods) using 1.75" diameter piezocone and rods	1. Determine refusal depth of standard tools for basis of comparison to wireline tools 2. Collect geotechnical data to assure comparable *in situ* conditions in comparison

1 If contamination of the rod interior with soil is the suspected cause of any inability to re-deploy a wireline tool, the rod interior should be flushed by pouring clean tap water through it prior to abandoning any effort at re-deployment (provided the practice does not violate any permit requirement).

One meter from previous location, penetrate to refusal (or until out of rods) using wireline rod string **without rod expanders** and functional piezocone module	1. Determine refusal depth of wireline rod string for comparison to standard tools 2. Collect geotechnical data to assure comparable *in situ* conditions for comparison 3. Assure survivability of wireline piezocone module under conditions encountered
If refusal met on previous action, move rig one meter from previous location, penetrate to refusal (or until out of rods) using wireline rod string **with rod expanders** and functional piezocone module	1. Determine refusal depth of wireline rod string for comparison to standard tools 2. Collect geotechnical data to assure comparable *in situ* conditions for comparison 3. Assure survivability of wireline piezocone module under conditions encountered

Should failure of equipment or unanticipated environmental conditions have impacted the ability of the field crew to complete any action within the test matrix, the on-site engineer was charged with determining the feasibility and priority of completing the remaining actions so as to best support the overall test objectives.

5.5.4.1. Retrieval and Re-deployment Reliability

The purpose of the first field testing task was to evaluate the reliability of the locking and release mechanism at multiple depths and in multiple geologies, and to determine the depth of refusal without using rod expanders, for comparison to conventional 1.75-inch diameter CPT rods under identical conditions. Additionally, the potential for binding of the individual wireline tools within the embedded rod string due to deflection was evaluated. These tests were accomplished by advancing a dummy cone tip to refusal using the wireline system, while repeatedly pausing (approximately every 2-meters) to release the locking mechanism, retrieve the dummy tool for inspection, and re-deploy it before continuing with the penetration. The removable tool was successfully retrieved and re-deployed with little or no difficulty at eleven depth intervals between 2.1 m (7.1 ft) and 16.2 m (53.1 ft) at location WL-2 (see Figure 2 above). Refusal was encountered at a depth of 16.2 m (53.1 ft).

5.5.4.2. Piezocone Validation and Refusal Depth

This test series allowed direct comparison, in nearly identical geologic conditions, of data obtained using the wireline piezocone with data obtained using an ASTM standard 4.4-cm (1.75-in) diameter cone. The calibrated 2.9-cm (1.125-in) diameter wireline piezocone was advanced to refusal without rod expanders twice, at locations WL-2A and WL-2B. Refusal was encountered at depths of 15.8 m (51.8 ft) and 15.7 m (51.6 ft) below ground surface (bgs), respectively, at these locations. The locations were horizontally separated by two meters. During each penetration, a hard layer was encountered at an approximate depth of 6.1 m (20 feet), which required liberal cycling to penetrate. Cycling is achieved by repeated retraction and re-advancement of the CPT rod string over a short depth interval (2 to 5 cm). This action results in cyclic unloading and loading of the force on the rods and underlying soil.

The ability to cycle the wireline tool is an advantage over the use of a grout-through 4.4-cm (1.75-in) diameter piezocone, whose design does not support cycling. Upon retrieval of the piezocone tool at both locations, slight binding of the tool within the rod string was observed at the 6.1-m (20-ft) depth, where a rod deflection due to the hard layer was apparent. At location WL-2A this deflection prevented re-deployment of the grout module within the rod string until the rod string was withdrawn to a depth of 6.7 m (22 ft) bgs. Pressure grouting was, however, successfully completed through the wireline grout tool at each of these locations. Production time data from the wireline piezocone penetration and subsequent pressure grouting at WL-2B was obtained for later comparison to the use of conventional CPT at an adjacent location.

To obtain both production time data and ASTM standard piezocone characterization data for comparison to the 2.9-cm (1.125-in) diameter wireline piezocone system, a conventional 4.4-cm (1.75-in) diameter piezocone penetration was completed at location WL-2C. WL-2C was located halfway between the two wireline piezocone penetrations (WL-2A and WL-2B). The sounding was completed uneventfully, without cycling, and provided the data necessary for the evaluation. The time and cost savings afforded by the wireline system are discussed in section 6.5 below. Results of validation of the wireline piezocone data are discussed in section 6.4.

At location WL-2D, another 4.4-cm (1.75-in) piezocone penetration was conducted, to provide confirmation of the previous conventional piezocone sounding and to determine refusal depth of a 4.4-cm (1.75-in) diameter rod string. WL-2D was located approximately one meter from WL-2B, and in line with WL-2A, WL-2B, and WL-2C. Refusal of this penetration was encountered at a depth of 44.5 m (146 ft) below ground surface (bgs). For this sounding a grout-through cone was used to avert the need to withdraw the rod string prior to grouting.

5.5.4.3. Refusal Depth with Expanders

The final penetration was conducted at location 2E, using the wireline CPT system with rod expanders. Expanders are usually employed with CPT to decrease the friction along the side of the embedded rod by widening the hole, thereby improving the maximum depth of penetration. An expander is fabricated by welding a section of steel pipe to the outside of a rod segment. An expander is shown in Figure 3. A total of six one-meter, 2-in rods with 2.25-in diameter expanders were interspersed among the 35 one-meter rods in the wireline system rod string. Beginning directly behind the wireline lock housing, the rods with expanders were staggered so that the expanders were located in the 1st, 3rd, 5th, 7th, 11th, and 15th positions. Using this configuration, all rods were used without encountering refusal. Total penetration depth was 33.2 m (109 ft) bgs. The locking mechanism released on the first tug and the piezocone was retrieved.

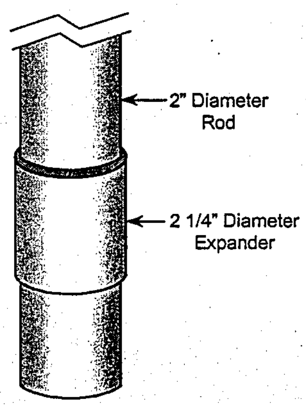

Figure 3. Depiction of a CPT Rod Expander.

Subsequently, the grout module was lowered down the embedded rod string. However, at a depth of approximately 16.2 m (20 ft), it would not pass a bend in the rod string. The difficulty was circumvented by unthreading the grout head from the locking mechanism, resulting in a shorter tool which easily passed the bend. With the high-pressure grout tube still attached, the locking mechanism was lowered to the bottom, where it engaged, and the hole was successfully pressure grouted to the surface using a total of 95 liters (25 gal) of grout. No problems were observed in grouting without the grouting head. It was determined that the locking mechanism with the attached grout hose was sufficient for grouting operations.

5.5.5 Attendance

The evaluation also provided SRS employees (both DOE and WSRC) an opportunity to observe the new wireline tools in operation and to provide input for further development to meet their specific needs.

6. RESULTS

6.1 Reliability and Survivability

While initial bench testing of the wireline system components raised concerns regarding their ability to withstand repeated free-fall deployment, design changes were promptly implemented to harden shock-bearing elements of the tool locking mechanism. Subsequent bench and field testing resulted in no discernable damage, even with multiple free-falls to depths exceeding 16 meters (53 feet). Since the wireline rod string is more robust than that of conventional CPT equipment, its survivability as a component was not of concern.

The wireline piezocone tool, whose diameter is smaller than that of conventional cones, withstood repeated deployments through an extremely difficult-to-penetrate layer at the SRS M-Basin field testing site. In fact, the survival and continued performance of this component in an environment which required extensive cycling to penetrate and caused profound deflection of the robust 2-inch diameter wireline rod string, allays any concern regarding it's survivability.

Additionally, the tools developed under the base contract were successfully retrieved from the tip of the rod string and deployed multiple times at several depths and in several different geologic materials. During this testing, a single impairment to flawless reliability was recognized. That was the binding of the long tools within the rod string upon retrieval and re-deployment under conditions of a deflected rod string due to difficult geology. The recommendations below suggest how recurrence of this phenomenon may be further guarded against by shortening the tool length.

6.2 Rod deflection interference.

Conditions encountered in each penetration during the field evaluation were not likely to induce the most extreme deflection of the rod string that may ultimately be encountered in practice. However, four such penetrations were performed successively in an extremely difficult geology with only one notable interference to passage of the wireline tools. Thus confidence in the system's ability to perform successfully in practice is high. In addition, Joe Rossabi (SCAPS program, WSRC) noted that 12 inches of core material for a wireline soil sampler would be sufficient for most needs. Thus the length of each tool package, designed to be compatible with a planned 18-inch core barrel, can be shortened by six inches, likely eliminating the potential for binding during all conceivable operations.

6.3 Piezocone validation

Data obtained from the field evaluation at SRS were used to validate the wireline piezocone against the ASTM standard 1.75-in diameter cone. For this interim report, the data collected at the SRS site using the wireline 1.125-in cone and the 1.75-in cone will be statistically analyzed using the "Student t" test statistical method. Additional analysis on all sets of data will be presented in the final report.

The paired Student t test computes the differences of paired data sets, to test the null hypothesis that the expected value (mean) of the differences is zero. The 'T' test statistic is then used to estimate a probability for rejecting this hypothesis that is based on an assumed Gaussian distribution and the number of degrees of freedom of the data set. In this case, the T-statistic as calculated for all paired combinations of the wireline 1.125-in cone and the ASTM 1.75-in cone. The data sets were truncated at a depth of 15.8 meters (51.7 feet), the depth of the shallowest penetration. Then, the tip stress, sleeve stress and pore pressure were transformed into log(base 10) space, and all possible pairings were matched so that the mean and standard deviation of each population of differences could be determined to calculate the t test statistic. The matched data sets included two 1.75-in cones, two 1.125-in cones or one 1.125-in cone and a 1.75-in cone.

Figure 4 presents the tip, sleeve, and pore pressure data obtained from four adjacent penetrations conducted at SRS M-basin during the field evaluation. The locations of the penetrations are shown in Figure 2 above. Two penetrations represented in the figure were conducted using a calibrated 1.75-in ASTM standard piezocone. The other two used the calibrated 1.125-in wireline piezocone.

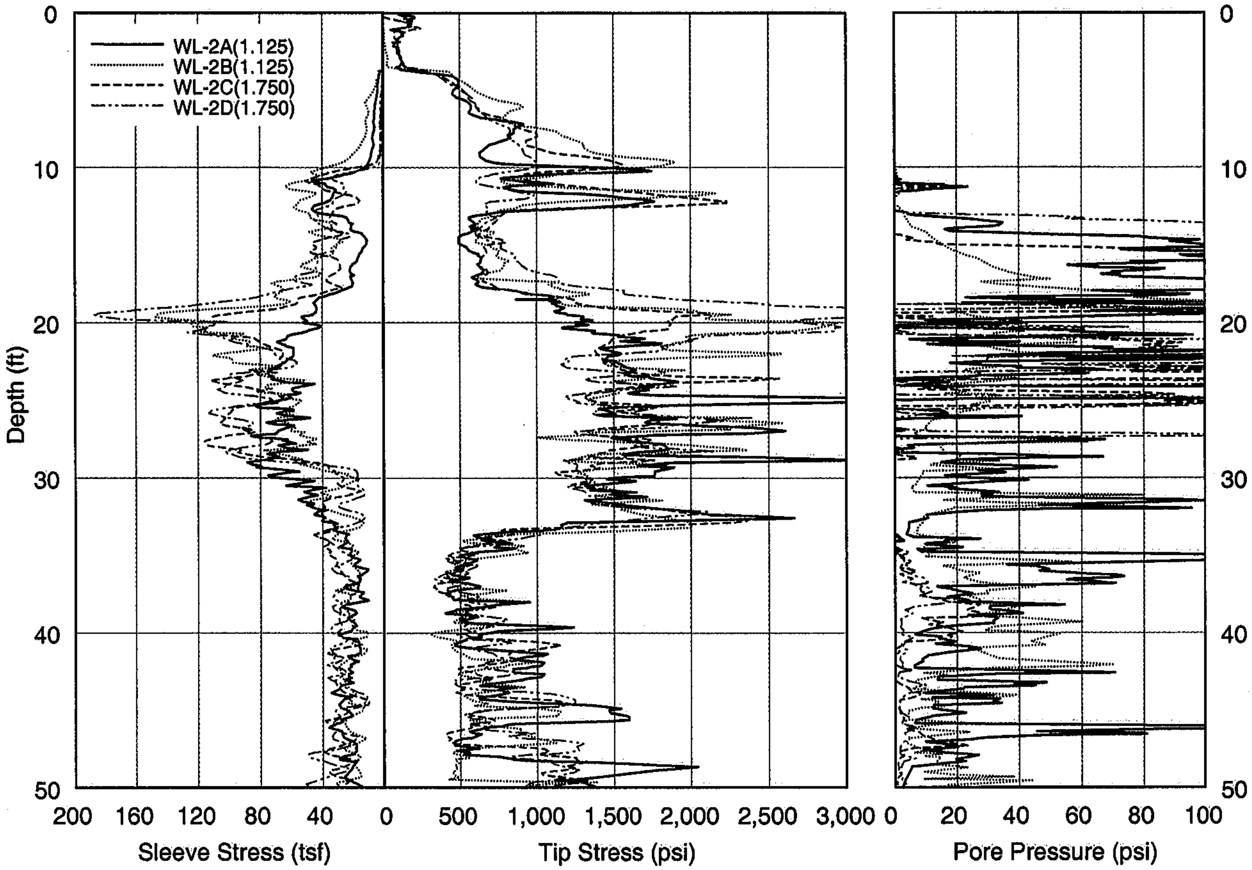

Figure 4. Tip stress, sleeve stress, and pore pressure data from a set of adjacent penetrations at SRS using two different piezocone geometries

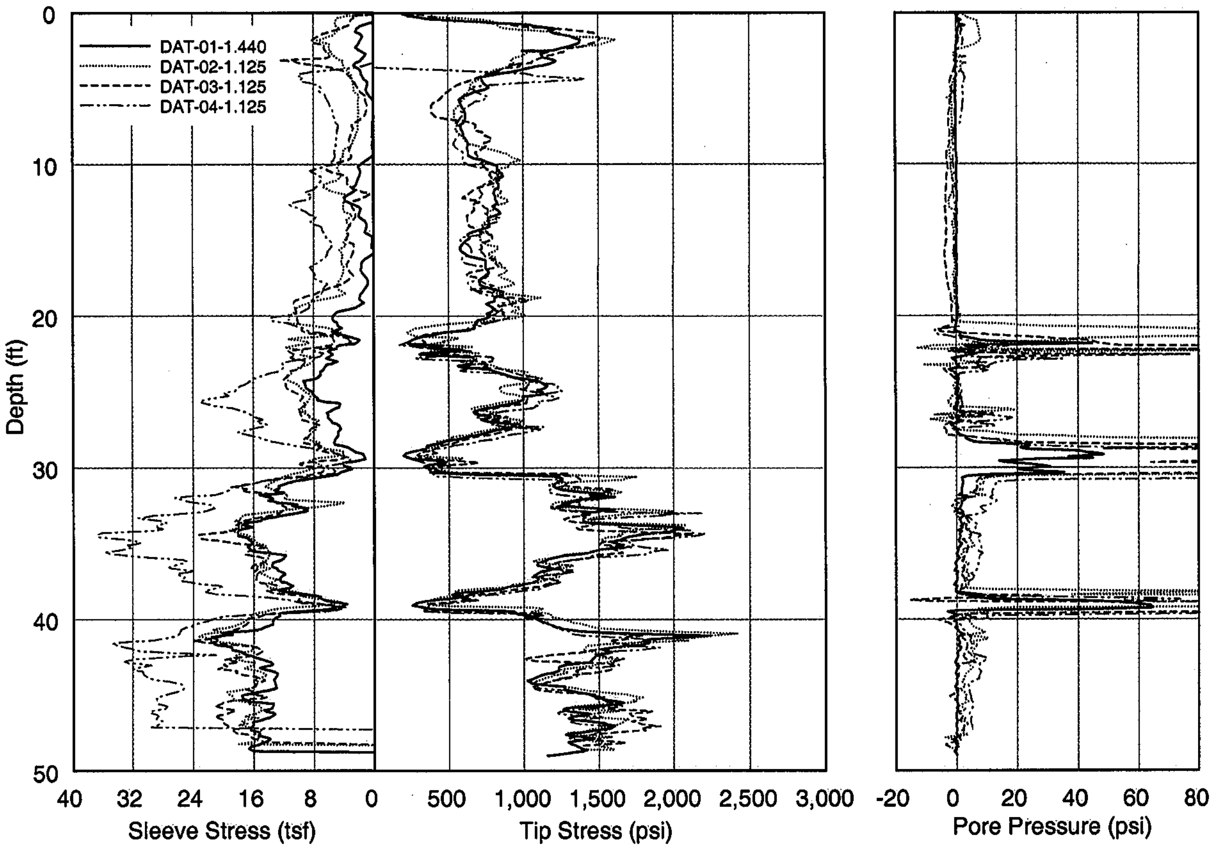

Figure 5. Tip stress, sleeve stress, and pore pressure data from a set of adjacent penetrations at New England test site using two different piezocone geometries.

Similarly, Figure 5 shows the same type data for four adjacent penetrations conducted in Vermont, comparing the wireline piezocone to the 1.44-in ASTM standard cone. Table 3 summarizes the results of comparing the paired data sets between the various combinations of piezocone probe geometries at the SRS site.

The cumulative frequency distributions of the differences of log data from the four cone pairings are overlain in Figure 6, Figure 8 , and Figure 9 below for each type of piezocone data collected. Results from the first 3 feet of all penetrations were omitted from the study due to the known influence of free-surface effects in relation to probe diameter (Rohani 1989).

Table 2, Table 3, and Table 4 list the statistical parameters calculated from the differences between the logs of tip stress, sleeve stress and pore pressure for adjacent pushes. Since the t test assumes the data set follows a Gaussian distribution, the log of these parameters were used to transform the data closer to a normal distribution. The mean of the differences, the standard deviation and the number of measurements are used to calculate the t test statistic listed in Table 2, Table 3, and Table 4. Each push consisted of approximately 400 to 500 points. The t statistic tests the hypothesis that the expected value of the differences is zero and reveals information about the central tendency of the two data sets, but not about the variation, or distribution of the data. Since an inference on the variance of the differences in the data set is just as important as an inference on the mean, we will examine the variances both in independent pushes and the variance in the differences between paired data sets for the final report.

Table 2. **Statistics of paired Tip Stress data from adjacent penetrations at SRS using Wireline Piezocone (WL-2A and WL-2B) and ASTM standard 1.75-in cone (WL-2C and WL-2D).**

Pair	Note	Distance (m)	n	Mean μ_d	Standard Deviation S_d	T-Statistic 95% Confidence Interval ($t_{.025}$ = ±1.96)	Result
WL-2A,WL-2C	WL & ASTM	0.9	550	-0.00916	0.13800	-1.55645	
WL-2A,WL-2D	WL & ASTM	3.5	550	-0.02214	0.17901	-2.90094	Reject
WL-2B,WL-2C	WL & ASTM	1.4	419	0.00680	0.16466	0.84563	
WL-2B,WL-2D	WL & ASTM	1.2	420	0.00461	0.17469	0.54090	
WL-2C,WL-2D	ASTM & ASTM	2.5	599	-0.01257	0.13931	-2.20780	Reject
WL-2A,WL-2B	WL & WL	2.4	550	-0.02638	0.18397	-3.36234	Reject

Note: WL = Wireline 1.125" Cone

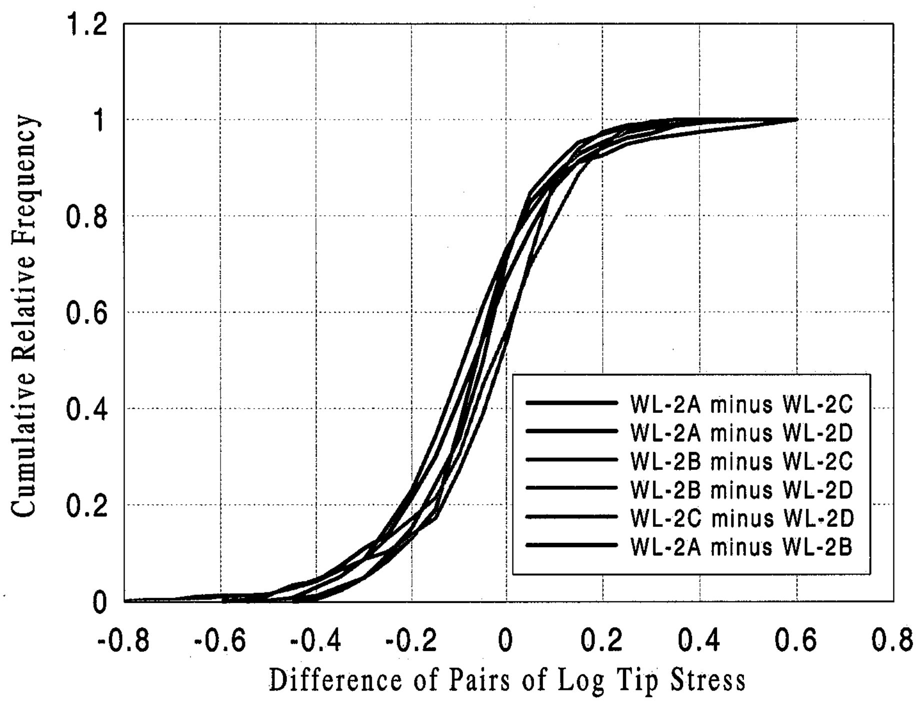

Figure 6. **Cumulative relative frequency distributions of paired Tip Stress data adjacent penetrations at SRS using Wireline Piezocone (WL-2A and WL-2B) and ASTM standard 1.75-in cone (WL-2C and WL-2D).**

The t test statistic would indicate that at the 95% confidence interval there is a statistically discernable mean difference between the paired observations. In the comparisons of tip stress, this null hypothesis was rejected for three of the six paired distributions at the 95% confidence interval These three pairing represent combinations of both the same and different types of cones (ASTM 1.75-in and Wireline 1.125-in). The result indicates that, more often than not, the differences between two penetrations with different sized cones were less than the differences between two penetrations with identical cones. The t statistic for two pushes using the same cone (i.e. ASTM 1.75-in listed in

Table 2, WL-2C, WL-2D, as –2.2078) is rejected at the 95% confidence interval. Looking at the distance between the pushes reveals that the paired data sets rejected at the 95% confidence interval were those for which the penetrations were separated by the greatest distance. This analysis shows that variations due to site heterogeneity are greater than any variation attributable to differences in cone geometry.

The variation between pushes is affirmed visually when comparing the frequency diagrams of tip stress, sleeve stress and pore pressure. Since the t distribution assumes that the individual data sets each have the same variance, it is possible that the statistical result from geologic variation between the pushes is greater than that produced by simply using the different cones. To demonstrate this point Figure 7 shows the results from two different cones. The plot on the right is the ASTM 1.75-in cone pushed in two different locations. The plot on the left is the result of pushing the wireline in two different locations. It appears that the outcome of the t statistic test may be in part due to geologic variation rather than a function of the cone type.

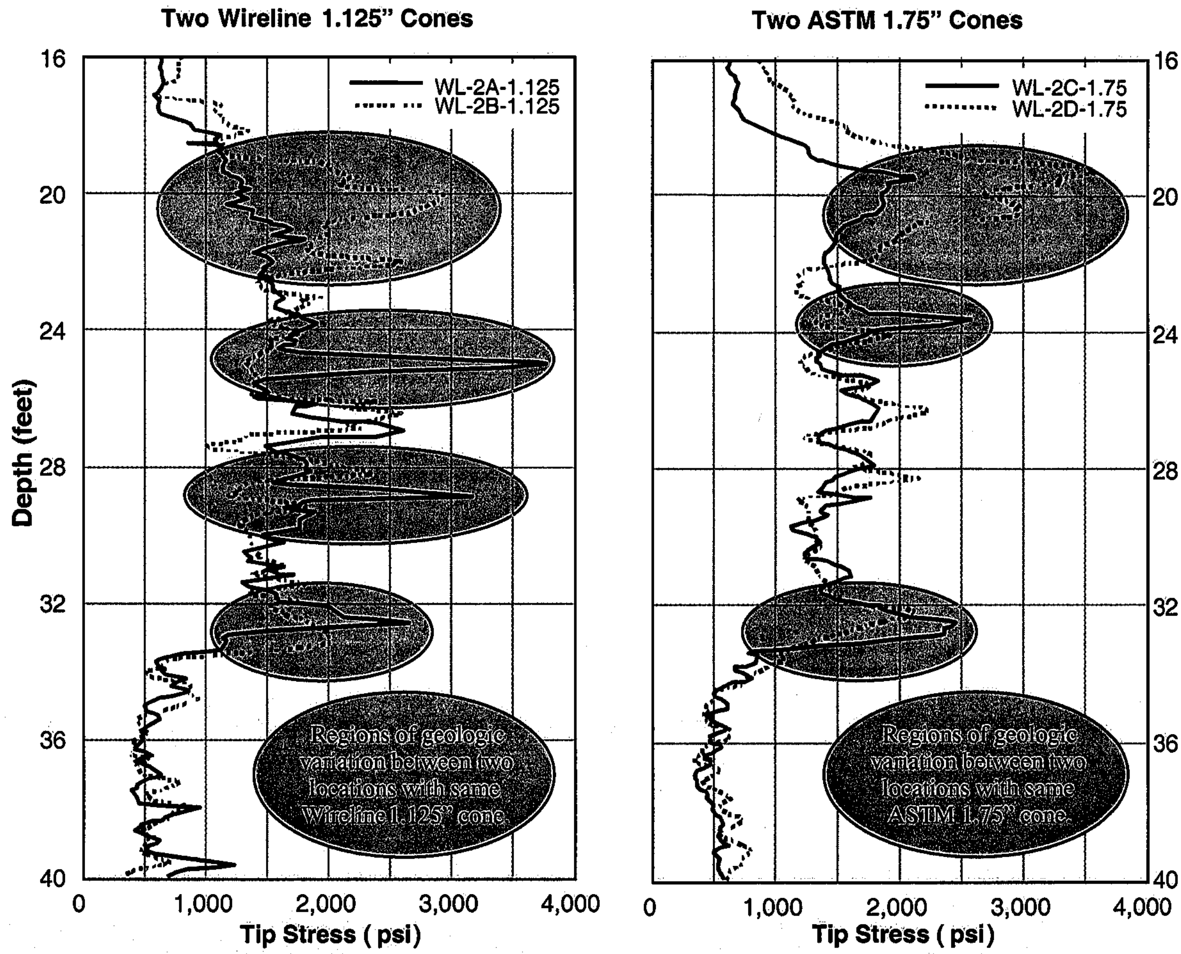

Figure 7. Comparison of Tip Stress data from similar cones. The distance between the two wireline 1.125" cone locations was 7.8 feet and the distance between the two ASTM 1.75" cone locations was 8.3 feet.

Table 3. **Statistics of paired Sleeve Stress data from adjacent penetrations at SRS using Wireline Piezocone (WL-2A and WL-2B) and ASTM standard 1.75-in cone (WL-2C and WL-2D).**

Pair	Note	Distance (m)	n	Mean μ_d	Standard Deviation S_d	T-Statistic 95% Confidence Interval ($t_{.025} = \pm 1.96$)	Result
WL-2A, WL-2C	WL & ASTM	0.9	561	0.026	0.350	1.776	
WL-2A, WL-2D	WL & ASTM	3.5	550	-0.005	0.331	-0.325	
WL-2B, WL-2C	WL & ASTM	1.4	417	0.173	0.396	8.943	Reject
WL-2B, WL-2D	WL & ASTM	1.2	420	0.130	0.370	7.187	Reject
WL-2C, WL-2D	ASTM & ASTM	2.5	595	-0.022	0.171	-3.094	Reject
WL-2A, WL-2B	WL & WL	2.4	550	-0.101	0.221	-10.766	Reject

Note: WL = Wireline 1.125" Cone

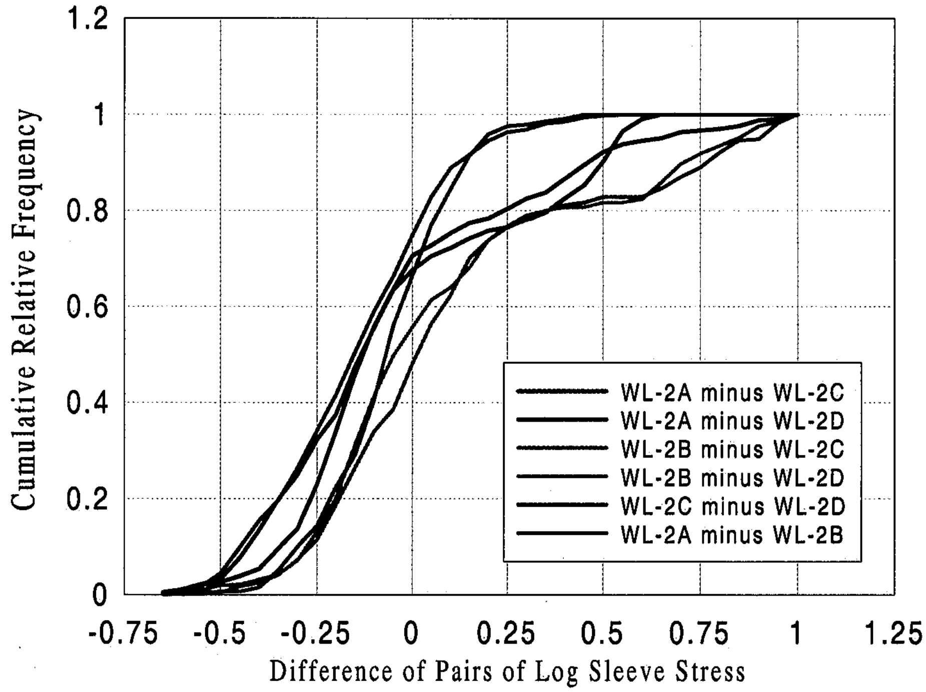

Figure 8. **Cumulative relative frequency distributions of paired Sleeve Stress data adjacent penetrations at SRS using Wireline Piezocone (WL-2A and WL-2B) and ASTM standard 1.75-in cone (WL-2C and WL-2D).**

Table 4. **Statistics of paired Pore Pressure data from adjacent penetrations at SRS using Wireline Piezocone (WL-2A and WL-2B) and ASTM standard 1.75-in cone (WL-2C and WL-2D).**

Pair	Note	Distance (m)	n	Mean μ_d	Standard Deviation S_d	T-Statistic 95% Confidence Interval ($t_{.025}=\pm1.96$)	Result
WL-2A, WL-2C	WL & ASTM	0.9	454	0.645	1.072	12.827	Reject
WL-2A, WL-2D	WL & ASTM	3.5	454	0.544	0.975	11.883	Reject
WL-2B, WL-2C	WL & ASTM	1.4	336	0.475	0.923	9.436	Reject
WL-2B, WL-2D	WL & ASTM	1.2	337	0.327	0.990	6.069	Reject
WL-2C, WL-2D	ASTM & ASTM	2.5	515	-0.074	0.771	-2.172	Reject
WL-2A, WL-2B	WL & WL	2.4	454	0.108	0.592	3.891	Reject

Note: WL = Wireline 1.125" Cone

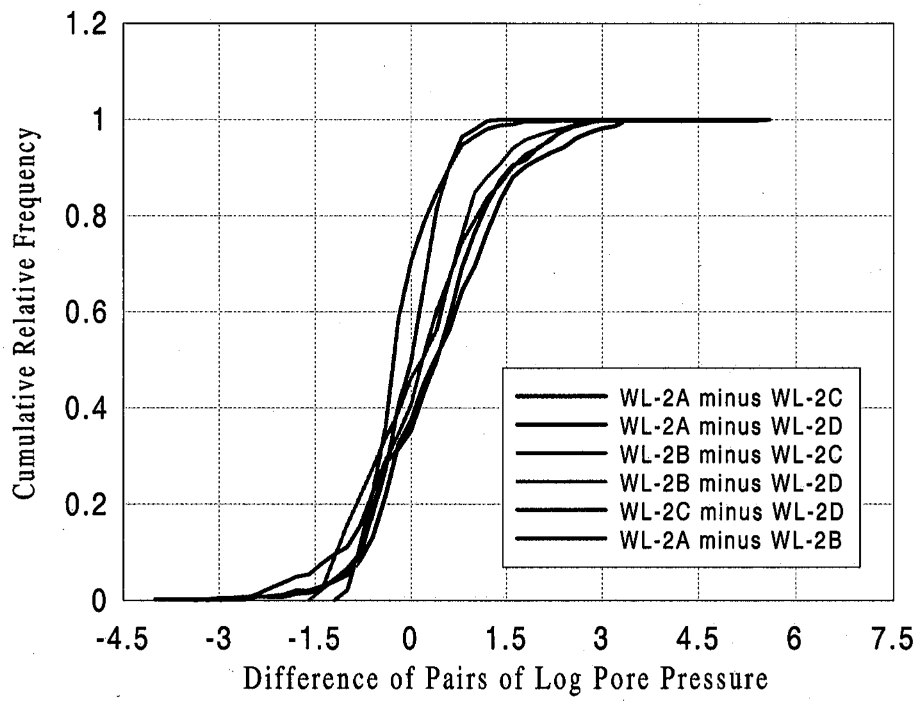

Figure 9. **Cumulative relative frequency distributions of paired Pore Pressure data adjacent penetrations at SRS using Wireline Piezocone (WL-2A and WL-2B) and ASTM standard 1.75-in cone (WL-2C and WL-2D).**

The statistical comparison of the pore pressure data indicates that cone geometry has an effect on the excess pore pressure measured. This is not an unexpected result, since excess pore pressure is created by cavity expansion which is a result of displacing the volume of soil occupied by the cone. Past experience has shown that these differences may be predicted based on a physical interpretation. Further study is planned to explore this issue.

6.4 Refusal Depth

Refusal depth of the wireline system was compared to that of conventional CPT under identical conditions during the field evaluation at M-basin, SRS. The table below shows refusal depth with and without rod expanders to the refusal depth of conventional CPT using a 1.75-inch diameter rod string.

Table 5. Comparison of refusal depths for wireline system, with and without rod expanders, versus conventional CPT.

Penetration ID	System	Rod Diameter	Depth to Refusal
WL-2	Wireline without expanders	5.1 cm (2.0 in)	16.2 m (53.1 ft)
WL-2A	Wireline without expanders	5.1 cm (2.0 in)	15.8 m (51.8 ft)
WL-2B	Wireline without expanders	5.1 cm (2.0 in)	15.7 m (51.6 ft)
WL-2D	Conventional with expanders	4.4 cm (1.75 in) (2.00-in expanders)	44.5 m (146 ft)
WL-2E	Wireline with Expanders	5.1 cm (2.0 in) (2.25-in expanders)	> 33.2 m (109 ft)[2]

With expanders, performance of the wireline system far exceeded expectations, and refusal was not encountered before running out of rods. Therefore, the 33.2-meter (109-foot) depth reported does not reflect refusal. Based on these data, we anticipate little compromise, if any, in the maximum penetration depth achievable with the 2-inch diameter wireline system versus the 1.75-inch diameter conventional CPT system.

6.5 Time Trials and Cost Comparison

In practice, CPT services are sometimes contracted at daily rates, and sometimes per foot penetrated. The cost savings herein are predicted based on a per day contract structure, and the time savings afforded by the wireline system for a paricular task (i.e. for conducting piezocone characterization only, where sealing the hole created is also required).

Data obtained in the field evaluation indicate the wireline system offers a 24% savings in time and thus cost. For this particular activity, these data compare the process of (a) conducting a single penetration to a depth of 51.8 meters using the wireline piezocone tool, exchanging tools with the rod string embedded, and grouting out with the wireline grouting module, to the process of (b) penetrating to the same depth using a conventional 1.75-in CPT piezocone, withdrawing the rod string, re-penetrating the same location using a conventional grout tip, and grouting out. The table below summarizes these findings.

2 Ran out of rods, refusal not encountered.

Table 6. Summary of Time/Cost Comparison

Description	Time to Complete Task
Conventional CPT Process	1 hour, 32 minutes
Wireline CPT Process	1 hour, 10 minutes
Time Savings	22 minutes
Time/Cost Reduction	24%

It is important to note that in the conventional process, is that to avoid the time required to unthread the piezocone umbilical from the rod string with and re-thread the string with the grout tube, a second full set of rods is maintained on the CPT rig pre-threaded with a grout tube.

7. CONCLUSIONS

Development of the wireline CPT for multiple tool usage has been a success. Under the base contract, all project success criteria were met, additional technical performance measures were documented, and substantial interest was generated among potential end-users.

The success criteria for the project were to:

- demonstrate the ability to advance a piezocone to refusal depth at SRS;
- with the rod string in place, replace the piezocone with a grouting tool; and
- subsequently grout the hole upon withdrawal of the rod string.

In addition to meeting these success criteria, the performers:

- validated the performance of the 1.125-in diameter wireline piezocone against 1.44-in and 1.75-in diameter ASTM standard geometry piezocones;
- demonstrated the reliability of retrieving and re-deploying the wireline tools at multiple depths and in multiple geologies;
- compared the production time using the wireline system with that of conventional CPT for geotechnical characterization; and
- identified and contacted several potential end-users of the wireline system within the DOE complex.

7.1 Technical Performance

The reliability and survivability of the wireline CPT system components were demonstrated in a heterogeneous, difficult-to-penetrate geologic setting at SRS M-Basin. In addition, the ability of the tools to work under conditions of free-fall deployment (e.g. being dropped to the bottom of the embedded rod string rather than lowered) was demonstrated, and the influence of rod deflection due to hard layers was evaluated, resulting in recommendation of a minor design change.

The performance of the wireline piezocone was validated against that of ASTM standard geometries. In two field tests, the variability in differences between measurements taken with the same ASTM standard cone geometry was compared to the variability between measurements taken with a standard cone and the wireline tool. Statistical analyses were performed which rejected, with 95% confidence, the hypothesis that the results differed with respect to central tendency. In other words, we can be 95% certain that the tip and sleeve stress measurements produced by the wireline cone do not differ from ASTM standard cone measurements. Additional statistical analysis will be performed as a part of the final report.

Additionally, during field evaluation, it was recognized that the ability to cycle during penetration with the wireline piezocone system provides a major advantage over the standard sized grout-through piezocone. A standard grout-though cone can not be cycled because cycling will result in premature release of the sacrificial tip, before the penetration has been completed. The wireline piezocone remains locked in place until final refusal is encountered, subsequent to which it is removed and replaced by the grouting module.

7.2 Cost Savings

Although a cost reduction of only 24% relative to conventional CPT was demonstrated for the process of piezocone characterization and grouting of the hole created, this application requires the least amount of re-penetration of all conventional applications. In other applications, such as multiple depth soil sampling, greater savings of time and cost are anticipated. The greatest cost savings will be realized in mixed applications, such as a combination of characterization and sampling, where, in addition to reducing re-penetration, the wireline approach will eliminate the need to move the CPT rig to a new location each time a new process of initiated.

7.3 Potential End-Users

Potential end-users for the wireline system were also identified both prior to and during execution of the base contract statement of work. Prior to award of the contract, end-users at Savannah River Site had already been contacted by ARA and indicated a need for the technology, as well as a willingness to participate in its evaluation. Specific site needs for this technology were also pre-established and are incorporated into the work plan for Options I and II of the contract. In addition, during the field evaluation at Savannah River Site, several observers from within the DOE complex had expressed interest in using the wireline system for various applications. Visitors to the field evaluation and their areas of application interest are listed in Table 7 below.

Table 7. Potential End Users of Wireline CPT System

Name	DOE Program	Organization	Application
Frank Syms	ER	Bechtel Savannah River, Inc.	Soil/Water Sampling
Mark Amidon	ER	Bechtel Savannah River, Inc.	Soil/Water Sampling
Michelle Ewart		DoE Savannah River	Soil/Water Sampling
Brian Riha	SRTC	Westinghouse Savannah River Company	Soil/Water Sampling
Joe Rossabi	SRTC	Westinghouse Savannah River Company	Soil/Water Sampling
Doug Wyatt	ER	Westinghouse Savannah River Company	Soil/Water Sampling
Shirley Burdick	SRTC	Westinghouse Savannah River Company	Soil/Water Sampling
Randy Raymond	SRTC	Westinghouse Savannah River Company	Soil/Water Sampling

Mike Serrato	SRTC	Westinghouse Savannah River Company	Remediation Applications - Injection of Treatment Media
Johnny Simmons	SRTC	Westinghouse Savannah River Company	Soil/Water Sampling

In addition to the initial field evaluation conducted at Savannah River Site under the base contract, the additional field evaluations to be held at DOE sites under the contract options will be the principal means of transferring technology to the end-users.

8. RECOMMENDATIONS

8.1 Tool Shortening

The 18-inch core barrel length planned for development under Option 1 of the contract, should be shortened to 12 inches to enable completely reliable retrieval and re-deployment of wireline tools. Because the core barrel length defines the distance between the locking mechanism and cutting mouth for all wireline tools, shortening the core barrel will shorten all tools, thus alleviating the tendency to bind within the rods under difficult, rod-deflecting geologic conditions. Joe Rossabi (WSRC) of the DoE Site Characterization and Penetration System (SCAPS) program witnessed the field evaluation, expressed intense interest in the development of a wireline soil sampler, and noted that a 12-inch soil core is sufficient for virtually all sampling applications.

8.2 Contract Options

The resounding success of the wireline development to date, as well as the level of interest expressed by the end-user community justifies award of the contract options to complete the development and demonstration of the system.

A Field Operations Plan (FOP) was developed under Task 4 of the SOW that identifies potential locations of the Option 1 and 2 demonstrations, the type of measurements to be made, data quality objectives, safety and health requirements, and permitting requirements. The FOP includes letters of commitment from the host sites. It is contained in Attachment 1 of this report.

8.3 Additional Tool Development

In addition to the wireline soil sampler planned for development under Option 1, strong interest was expressed by the potential end-user community in the potential for the wireline system to enable reliable collection of multiple depth water samples. Currently, reliable application of the multiple-depth water samplers requires them to be continuously purged with inert gas or de-ionized water to keep the screen from clogging with fine-grained particles during a penetration. The possibility of developing a tool which shields the inlet screen during penetration to avert clogging has been discussed. The wireline system configuration affords the ideal opportunity for shielding the inlet screen of a multiple depth water sampler during probe advancement by partial withdrawal within the rod string. Additionally, other sensors could be used for characterization, and a water sample collected wherever desired by simply replacing the real-time characterization tool with the water sampler tool. These advantages strongly support the development of a wireline water sampling tool.

ATTACHMENT 1

FIELD OPERATIONS PLAN
DEVELOPMENT OF A WIRELINE CPT SYSTEM
FOR MULTIPLE TOOL USAGE

FIELD OPERATIONS PLAN
DEVELOPMENT OF A WIRELINE CPT SYSTEM FOR MULTIPLE TOOL USAGE

Prepared for
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ARA 4840

October, 1999

DISCLAIMER

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1. INTRODUCTION

1.1 Background

Over the past five years, the Department of Energy (DOE) has invested in the development of Cone Penetrometer Technology (CPT) to reduce both time and costs associated with site characterization efforts. To date CPT has been effectively demonstrated at nearly all DOE facilities and is a technology that is being routinely used at all of the larger DOE sites (i.e. SRS, Hanford, Fernald, etc.). As the DOE moves from characterization activities at these facilities to site remediation and monitoring activities, CPT technologies need to be adapted in order to maintain the advantages of providing the most cost effective and rapid means for remediation and monitoring. It is held that the single biggest technical and cost advance in adapting CPT technology to site remediation and monitoring will be the development of a wireline CPT system which permits deployment of interchangeable sensors, samplers, remediation and grouting equipment during a single CPT push. This will help ensure that all cleanup goals are met under both the limited budget directed from Congress and the aggressive time scales outlined in each site's 10-year plan.

1.2 Project Objectives

The objective of the project is to design, fabricate and test a wireline system for Cone Penetration Testing (CPT) that will allow the deployment of several tools during a single penetration. This approach will save time and cost by decreasing the number of penetrations required to perform the analyses and collect multiple media samples that may be required from a single sounding location during site characterization.

1.3 Project Scope

This project is composed of a base contract and two options, which may be exercised at the discretion of the DoE. The base contract involved the design, fabrication, and testing of a wireline piezocone and grouting module. The piezocone is used to profile soil type, stratigraphy, and soil strength characteristics, *in situ* and in real-time. The wireline piezocone design is based on ASTM standard 1.44-inch and 1.75-inch diameter cone designs. It measures 1.00 inches in diameter and is designed to protrude a distance 10.5 inches at its tip from the mouth of the 2-inch diameter wireline rod string. The wireline piezocone incorporates sensors for tip stress, sleeve stress, and pore pressure and attaches rigidly to a locking and release mechanisms which allows it to be retrieved and re-deployed while the rod string remains embedded in the ground. The wireline grouting tool permits grouting the penetration hole during retraction. This tool utilizes the same locking and release design as the piezocone. When locked into position at the end of the rod string, it allows grout to be pumped through a high-pressure hose connected to the tool, and into the void created by withdrawal of the rod string. Testing of the system was conducted locally at various ARA test sites then, more formally, during a one-week field evaluation at SRS M-Basin.

Under Option 1 of the contract, a wireline soil-sampler will be developed to allow the collection of soil samples from multiple depths during a single penetration. The wireline soil sampler will also facilitate cutting through and removing hard-to-penetrate materials, such as dense cemented soils, without withdrawing the rod string to change tips and remove samples.

This tool will be designed to operate with the sonic CPT system that ARA has developed under joint DoE and DoD funding. The soil sampler, as well as the previously developed piezocone and grouting module will be evaluated at SRS during a 10-day testing and evaluation program.

Option 2 of the contract will consist of a 12-day evaluation at DoE's Hanford, Washington site. The objective of this demonstration will be to utilize the wireline CPT tools to perform baseline probing and monitoring point installations for the detection of radiation leaks around a high-level waste tank. Radiation leakage from the tanks will be evaluated and compared using both electrical resistance tomography (ERT) and hydrogen gas concentration monitoring *in situ.*

1.4 Significance

Currently, each time a different CPT tool is deployed, all of the CPT rods must be extracted from the hole, the new tool attached, and either the rods advanced back into the hole or a new push is started at an adjacent location. By adapting the wireline technology to CPT, multiple tools can be deployed during a single push, greatly reducing the time and expense required.

The wireline concept will also allow development of new methods for installing monitoring points and sensors as well as for installing various barrier types. Specific applications of the wireline technology at various DOE sites include:

- the use of the sonic approach with CPT sensors at SRS for very deep penetrations;
- installation of vadose monitoring points around the Hanford tanks for leak detection purposes; and
- eventual deployment into the tank waste materials using the Hanford tank farm CPT unit to obtain both *in* situ waste information and confirmation samples in a single riser deployment without disturbing the materials under two risers.

1.5 Document Organization

This Field Operations Plan presents the process and procedures to be followed during the development and testing of the wireline CPT tools during the two contract options. Section 2 presents the data quality objectives that serve as a guide to ensure that the proper data is collected in sufficient quantities to allow for a successful design and testing program. Section 3 covers the specific methodologies that will be employed over the course of the project to design and test the wireline tools. Health and Safety issues will be covered in Section 5 and permitting requirements in Section 6. The project schedule is discussed in Section 7.

2. WIRELINE CPT SYSTEM DESIGN AND OPERATION

The wireline CPT system developed under the base contract currently consists of the following four main components:

- wireline rod string,
- locking mechanism,
- replaceable piezocone module, and
- replaceable grouting module.

A fifth component, to be developed under Option 1, will be the wireline soils sampler. This portion of the Field Operation Plan (FOP) describes the design and operation of each major hardware component in the wireline system developed under the base contract and the interactions between them.

2.1 Rod String

The rods segments, which compose the wireline system rod string, measure one meter in length from joint-to-joint. Their outer diameter is 2.00 inches, and their inner diameter is 1.25 inches. The rods allow the passage of 1.125-inch diameter wireline tools through their interior. A nominal stock rod diameter was used to bound the cost of manufacturing to within reasonable limit of commercial feasibility. The 2-inch diameter of the rods allows them to be used with most commercial CPT rigs in operation at DOE sites. A photograph of the wireline CPT rods is shown in Figure 2.1.

Figure 2.1 Photograph of wireline CPT rods.

2.2 Locking Mechanism

The locking mechanism is identical for each individual wireline tool. It utilizes two horizontally opposed, horizontally rotating *locking dogs* which, when engaged, occupy a slot formed in the interior of a rod segment. A circular cross-section *locking wedge* slides vertically between the dogs to push them radially outward and into the slot. The locking wedge is spring loaded, so outward pressure is applied to the dogs, centering the tool as it slides down the interior of the rod string during deployment. The shape of the locking dogs allows them to skate smoothly over rod joints and other potential obstructions to vertical travel. The slot into which the locking dogs engage is formed by a cylindrical *brake nut* inserted into the expanded bore at the end of a wireline rod segment. This approach allows easy replacement of the lock bearing surface (i.e. the inexpensive brake nut) to compensate for ordinary wear. The *lock housing* contains the locking wedge, compression spring, and locking dogs and constrains their paths of travel. Photographs of the assembled locking mechanism and its individual components appear in Figure 2.2. Figure 2.3 shows the assembled mechanism with the locking dogs retracted (a) and extended (b) for illustration.

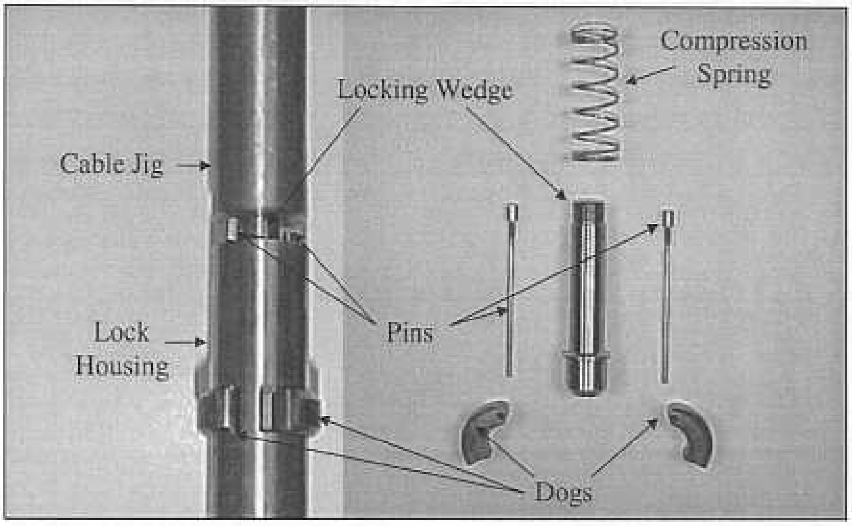

Figure 2.2 Photographs of assembled locking mechanism and individual components.

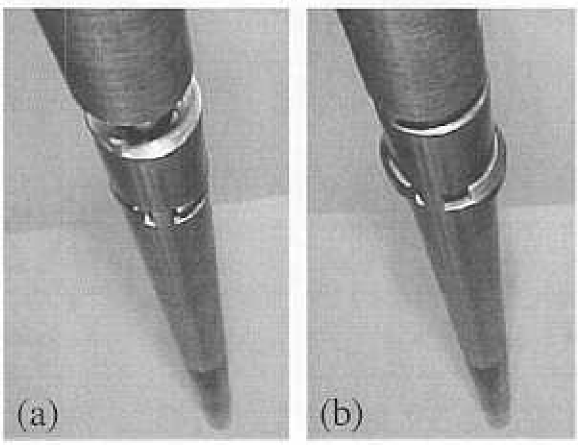

Figure 2.3 Photographs showing the locking dogs retracted (a) and extended (b) for illustration.

A *cable jig* is employed at the top of the locking mechanism, threaded to the up-hole end of the locking wedge, to allow the *retrieval wire* to exert its force through the radial axis (i.e. center) of the locking wedge while also threading the piezocone instrument cable or high pressure grout tube through the hollow center of the locking wedge, depending on which tool is deployed. When upward force is applied to the locking wedge via tension on the retrieval wire, the wedge slides upward allowing the dogs to move freely inward. The dogs retract into the lock housing under the force transferred to them through their 45-degree inclined upper bearing surface in contact with a matching surface on the receiving groove.

2.3 Soil Sampler

A wireline soil sampler is planned for development under Option 1 of the wireline CPT development contract. It will be fully compatible with the wireline system developed under the base contract. The soil sampler will be interchangeable with the piezo-cone to obtain soil samples from any depth during a penetration without the removal of any of the CPT rods.

The wireline soil sampler/cutter and locking mechanism design will build on the proven design of the commercially available ARA soil sampler, as well as on previously proven petroleum and soil drilling technologies.

2.4 Piezocone Module

The piezocone module threads to the base of the lock housing and provides the standard three geotechnical CPT measurements: tip stress, sleeve stress, and pore pressure. It employs analog electronic circuitry, which provides four-channel operation, including the excitation sensing circuit. Power is supplied to the piezocone and analog signals are transmitted up-hole via a 10-conductor instrument cable, which interfaces with standard analog CPT data acquisition systems. The measures 1.125 inches in diameter as does the lock housing, and protrudes 10.5 inches from the end of the wireline rod string when locked in deployment position. A photograph of the piezocone module with major features labeled is shown in Figure 2.4.

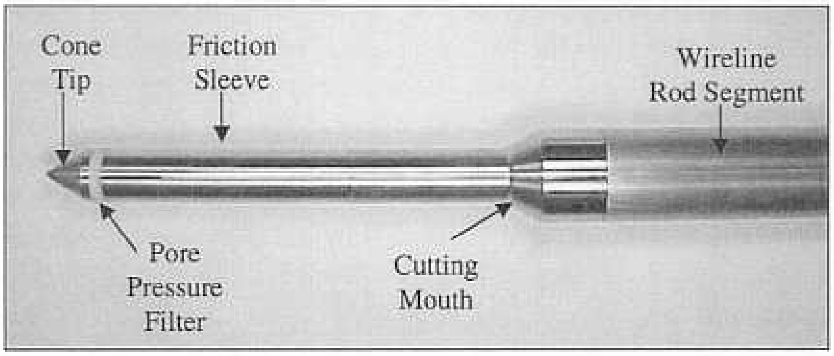

Figure 2.4 Photograph of wireline piezocone tool protruding from rod string

2.5 Grouting Module

The wireline grouting tool module utilizes the same locking mechanism and is the same diameter as the piezocone tool. Its design was intentionally kept simple and composed of only three parts: the grout-through body, sacrificial tip, and hose nipple. A photograph is shown in Figure 2.5.

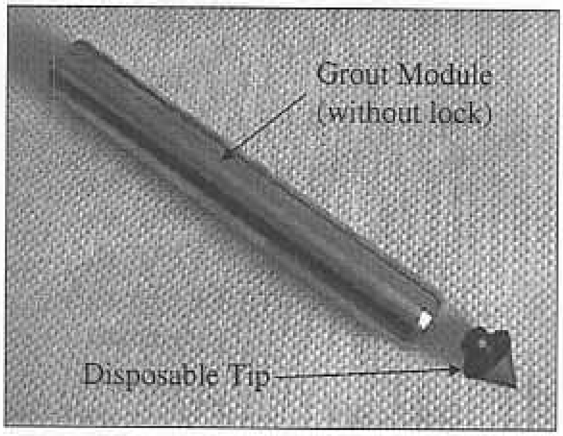

Figure 2.5 Photograph of wireline grouting tool showing simplicity of design.

The high-pressure grout tube connects from an up-hole grout pump to a brass barbed nipple fitting in the rear of the module. Use of the sacrificial tip is optional and may only be required to avoid plugging of the module when advancing the penetration through undisturbed or collapsed soil with the grouting module deployed.

3. SOIL SAMPLER FIELD DEMONSTRATION

Option 1 of the wireline CPT development contract includes the design and fabrication of a wireline soil sampling/cutter tool, as well as demonstration and evaluation of the soil sampling tool using the Sonic CPT system. The wireline soil sampler will be designed to be fully compatible with the equipment developed under the base contract. The soil sampler will be interchangeable with the piezo-cone to obtain soil samples from any depth during a penetration without the removal of any of the CPT rods.

The wireline soil sampler/cutter tool will be field demonstrated at the Savannah River Site (SRS). The sampler tool will be interchanged with the piezo-cone and grouting tools. The goal of the evaluation is to demonstrate the functionality of each of the tools (particularly the ability to penetrate hard layers using the sampler/cutter in combination with sonic technology) and to document the time and cost savings of the wireline approach compared to conventional drilling or cone penetrometer techniques.

3.1 Technology Need: Multiple Depth Soil Sampling

Using current technology for soil sampling at multiple depths, several trips down the hole must be made by the entire CPT rod string. Not only does this accumulate footage at a per foot cost for sampling, but it requires much time. The South Carolina Department of Health and Environmental Control (SCDHEC) currently does not allow penetration of a confining layer without grouting during removal. This prohibits the retrieval of soil samples from beneath a confining layers using current technology because the rod string must be withdrawn once prior to grouting. The wireline approach to sample collection using CPT holds potential for overcoming these problems.

In addition, attempts at penetrating overconsolidated and cemented layers using conventional and sonic (vibratory) CPT have sometimes failed because there is nowhere to displace the hard material. The wireline soil sampler is seen as a potential means for removing difficult material, thus allowing penetration of, and continued characterization below these layers.

The need for this technology is clearly expressed in the letter of support from Bruce Triplett of Westinghouse Savannah River Corporation (WSRC), a photocopy of which appear in Attachment 1.

3.2 Test Site Selection

SRS was selected at the location of the wireline soil sampler demonstration because the tools to be demonstrated pose a great potential to reduce the time and costs of multiple depth soil sampling currently conducted at SRS using the conventional CPT approach (i.e. separate penetration and withdrawal for each sample).

Field verification of the wireline soil sampler will be conducted at the M-basin, located in the northwest corner of the DoE's Savannah River Site (SRS), just south of the SRS administrative area. The M-basin was selected as the field evaluation location due to the diversity of geologic strata available at M-basin's Integrated Demonstration Area, the extensive history of prior site use for CPT evaluations, and the experience and familiarity of the on-site personnel with CPT operations and concepts. The prior experience of the site itself provides a plethora of data on soil conditions and the effectiveness of diverse types of CPT operations and innovations previously tested. The familiarity of the site personnel with CPT operations enriches the evaluation process by enabling efficient support to be rendered and bringing valid technical feedback into the process from outside the immediate development team.

This site offers challenging conditions for CPT and is actively serving as a site for pilot characterization/remediation studies conducted by the DoE. Previous studies of the site have identified four clay layers and other significant stratigraphic variability in the upper reaches of the formation at the M-basin.

3.3 Test Site Description

The field evaluation will be conducted at the M-basin of DoE's Savannah River Site (SRS), located in the northwest corner of the site, just south of the SRS administrative area. The M-basin was selected as the field evaluation location due to the diversity of geologic strata available at M-basin's Integrated Demonstration Area, the extensive history of prior site use for CPT evaluations, and the experience and familiarity of the on-site personnel with CPT operations and concepts. The prior experience of the site itself provides a plethora of data on soil conditions and the effectiveness of diverse types of CPT operations and innovations previously tested.

This site offers challenging conditions for CPT and is actively serving as a site for pilot characterization/remediation studies conducted by the DOE. Previous studies of the site have identified four clay layers and other significant stratigraphic variability in the upper reaches of the formation at the M-basin.

3.3.1 Site Access Point of Contact

The table below provides site contact information for conducting technology demonstrations at SRS M-Basin.

Table 3.1. Contact Information for Demonstrations

Name	Organization	Telephone
Michelle Ewart	DOE	(803) 725-1115
Keith Hyde	WSRC	(803) 725-5220

3.4 Test Methodology

3.4.1 Objective

The general objective of the test plan is to determine the feasibility of using the wireline system to perform multiple CPT functions in a single penetration, and to provide data necessary to quantify the potential benefits of meeting this objective in an operational context. The functions to be performed will include multiple depth soil sampling and a combination of geotechnical site characterization with soil sampling in the same penetration. In addition, the feasibility of using the soil sampler to enhance the penetration capability of Sonic CPT will be determined.

3.4.2 Technical Approach

The technical approach to meeting the test objectives will be to complete the execution of a well-defined matrix of CPT field operations using the wireline tools and conventional CPT tools. The purpose of the test matrix is to provide data and experience necessary to provide answers to the following specific questions:

- How reliably can a soil sample be retrieved using the wireline soil sampler in comparison to a conventional CPT soil sampler?
- How reliably does the system allow interchanging the soil sampler with other wireline tools, such as the piezocone and grouting module at multiple depths and in a variety of soil types?
- Is the tool locking system reliable for all tools under conditions of vibratory excitation using the Sonic CPT head?
- Does soil (or water) enter into the rods when the tools are retracted, and does this impede reliability?
- Is the weight of the empty core barrel sufficient to allow re-deployment in an embedded rod string without applying additional downward force?
- How does refusal depth of the wireline rod string compare to that of a standard 1.75-inch diameter rod string under identical soil and push capacity (i.e. rig) conditions?
- How does refusal depth of the wireline system when using the Sonic CPT vibratory head compare to refusal depth when using static force?
- How much time is saved using the wireline soil sampler at multiple depths during one penetration versus several penetrations as required using a conventional sampler?
- How much cost savings does the time savings, if any translate into?

3.4.3 Procedures

Testing operations will adhere to generally accepted principles of sound CPT operation and to the provisions of the ARA and SRS health and safety plans. While adhering to these principles, the test matrix detailed in the table below will be executed. Four days of field operation are planned to allow completion of the matrix.

Table 3.2. Test Matrix for Base Contract Field Evaluation

Action	Objective(s) for Data Obtained
Penetrate to a depth of 30 meters, using a wireline piezocone and soil sampler, and obtaining a soil sample at four discrete depths (10, 15, 20, 25 meters). Grout hole upon retraction using wireline grouting module. Time the entire action.	1. Evaluate reliability of tool retrieval and re-deployment afforded by design 2. Assure survivability of wireline piezocone module under conditions encountered 3. Assess ability to retain soil samples during retrieval 4. Demonstrate interchangeability of components and ability to perform multiple actions in a single penetration
Penetrate again to a depth of 30 meters (about one meter from previous location),	1. Collect data for basis of comparing time and wireline to conventional tools

using conventional CPT piezocone. Re-penetrate to grout hole. Then, move truck to obtain soil samples at the same intervals using conventional tools. Time the entire action.	
Penetrate to refusal under static push force using wireline rod (with expanders) and piezocone tool. Note refusal depth, then continue to penetrate again to refusal using Sonic CPT. Note Sonic CPT refusal depth, then obtain soil samples to 'cut through' hard layer, and continue to penetrate using Sonic CPT. Note final refusal depth, and grout out of hole.	1. Determine wireline system refusal depth without sonic vibration. 2. Determine wireline system refusal depth with Sonic CPT. 3. Determine wireline system refusal depth with Sonic CPT and cuttings removal. 4. Collect geotechnical data to assist in interpretation of results.
Penetrate to refusal using 1.75-inch conventional CPT rod string and piezocone, using static push force. Note refusal depth, then resume penetration again to refusal using Sonic CPT. Note 2nd refusal depth and grout out.	1. Determine refusal depth of conventional CPT with and without Sonic head. 2. Collect geotechnical data to assist in interpretation of results.
If time allows, repeat entire sequence.	1. Provide confirmation data in support of objectives above

3.4.4 Contingencies

Should failure of equipment or unanticipated environmental conditions impact the ability of the field crew to complete any action within the test matrix, the on-site engineer will make a determination as to the feasibility and priority of completing the remaining actions to best support the overall test objectives.

3.4.5 Equipment, Supplies, and Materials

The following equipment and materials are required and/or recommended for performing the tests in the field evaluation matrix. All required equipment and materials should be assembled and inventoried on the first day of field operations, prior to beginning execution of the test matrix.

Major Equipment

CPT rig and support vehicle
CPT data acquisition system
Sonic CPT vibratory head
Grout mixer, sieve, and high-pressure grout pump
Steam cleaning attachment

Standard Tools

1.75" rod string (70 meters)
Vertek or Mostap Soil Sampler
Standard instrument cable, at least 135 feet

Wireline Components

Wireline rod string (70 meters)
Wireline soil sampler with attached locking mechanism
Wireline piezocone module with attached locking mechanism
Wireline grouting module with attached locking mechanism and spare sacrificial tips
Retrieval wire and spare
Spare core barrels, piezocone tips, pore pressure filters, friction sleeve, cutting mouth, locking dogs, locking dog pivot pins, and brake nuts (2 sets)
Wireline instrument cable (10-pin Lemo), at least 135 feet

Miscellaneous Materials and Supplies

Dry powdered sodium bentonite grout
Additional high pressure grout tubing
Water bucket and tap water supply (for grout mixing and cleaning rod interior)
Cable adapters
Cone calibration jigs, adapters, and load cells
CPT (*Mechanic's*) tool kit

3.5 Health and Safety

Health and Safety issues are of utmost concern at ARA. Throughout the course of the project, ARA's corporate Health and Safety Plan will provide guidance on all aspects of health and safety to ensure that all tasks are completed safely and in compliance with State and Federal OSHA requirements. A copy of ARA's Health and Safety Manual is included as Appendix A.

During the field evaluations at Savannah River Site, ARA will comply with the site-specific health and safety plans provided by the SRS coordinating staff. Required training for conducting CPT operations at SRS's M-Basin includes:

- OSHA 40 hour hazardous worker training.
- SRS Site Indoctrination (video).

All field personnel will be hazardous waste operations (40 CFR 1910.120) and hazard communications (40 CFR 1910.1200) training certified.

3.6 Permitting Requirements

The staff of the Savannah River Technology Center (SRTC) who are coordinating the field evaluation will identify all permitting requirements applicable to the base contract field evaluation activities. ARA field personnel will bear responsibility for inquiring with the SRTC staff to assure they are familiar with all applicable permit requirements and for complying therewith.

3.7 Field Demonstration Schedule

Execution of the Option 1 field demonstration will be conducted during a ten-day field effort. The first day will be dedicated to review of applicable health and safety plans and applicable permit requirements, site orientation, review of and familiarization with the test matrix, and assembly of the required equipment, materials, and supplies. Beginning the second day, calibration of piezocones will be conducted and the Sonic CPT head will be installed on the rig. By the fourth day, execution of the test matrix will begin. It is anticipated the test matrix will require six full days to complete. The last day is reserved as a buffer to assure any unanticipated delays or equipment failures will not jeopardize completion of the required testing.

4. TANK LEAK MONITORING DEMONSTRATION

Option 2 of the wireline CPT development contract includes a field demonstration at the Hanford, Washington High Level Waste Tank Farm. Under this option, the wireline system will be used to perform baseline probing and monitoring point installation for the detection of leaks around a High Level Waste (HLW) tank at DoE's Hanford site. The goal of the evaluation is to demonstrate the functionality of each of the tools and to document the time and cost savings of the wireline approach compared to conventional drilling or cone penetrometer techniques.

4.1 Technology Need: High Level Waste Tank Monitoring and Leak Detection

As a part of the Tank Waste Remediation System program, high-level, radioactive mixed waste is to be removed from the tanks and immobilized. After this waste has been removed, the tanks are to be closed in an environmentally safe and cost-effective manner. To evaluate waste removal processes and to assess the available technologies for characterizing vadose zone contamination in the soils adjacent to the tanks, demonstration programs are being conducted in a variety of tank farms. This information is prepared assuming the vadose zone surrounding tank 241-AX-104 is to be investigated for the wireline CPT demonstration. The same activities could easily occur at another tank farm, with only minor modifications to the existing plans. The demonstration program is in support of the Retrieval Performance Evaluation Criteria Assessment (RPECA), which has the goal of evaluating the engineering and scientific analyses necessary to establish retrieval performance criteria and to provide the basis for future *National Environmental Policy Act* safety and regulatory actions affecting waste retrieval and tank closure alternatives.

The RPECA includes a study of vadose zone contaminant transport mechanisms including the analysis of absorption characteristics, hydrogeologic and groundwater characteristics, and the observed distribution of contaminants in the vadose zone at the AX Tank Farm. Vadose zone transport models, which will be used to evaluate contaminant transport, require additional characterization data. The impacts of retrieval losses and the end-state of the tank farms must be analyzed to determine the type, amount, and location of vadose zone characterization activities. Information from these two programs (i.e., tank closure and vadose zone characterization) supports one another as well as the long-term monitoring needs. Without an understanding of the end-state of the tank farms, definitive requirements for vadose zone characterization can not be established, and the end-state of the tank farms cannot be determined without better knowledge of contaminant transport and distribution in the vadose zone. The U.S. Department of Energy (DOE) has decided on a phased approach to these issues.

Phase 1 of the RPECA includes screening assessments to identify key vadose zone uncertainties that are important in calculating human health risks. Phase 2 will use characterization data from Phase 1 to develop greater certainty in human health risk calculations, which will in turn contribute to decisions regarding viable methods for waste retrieval and tank farm closure. Phase 2 also will identify additional field characterization needs, to be collected during Phase 3. Transport models and risk calculations will be revised, and appropriate retrieval techniques will be established. It is anticipated that the characterization and retrieval/closure programs will progress iteratively towards an understanding of the end-state of the tank farms.

The need for this technology is expressed in a letter of support from Lloyd Piper, Deputy Manager of DoE Richland Operations, to P. Steve Cooke, the project COR, dated 27 May, 1999 and reproduced in Attachment 1.

4.2 Test Site Selection

A High Level Waste (HLW) Tank located in one of several tank farms at DoE's Hanford, WA site will be selected as the location for the integrated tank leak monitoring demonstration. Most likely a tank in the AX farm will be selected although other options are possible, depending on the objectives of Hanford Vadose Zone Program. The Hanford tank farms were selected due to the difficult geology as well as an opportunity to assist in achieving required site activities. The diverse requirements of the Hanford site provide an opportunity to demonstrate the versatility of the wireline approach for achieving multiple CPT functional objectives while minimizing the number of penetrations. In this effort, vadose zone characterization activities will occur as the CPT rod is advanced. Characterization consisting of soil classification and stratigraphy as well as soil moisture and resistivity profiling will be conducted. A series of Electrical Resistivity Tomography (ERT) array will be installed for leak detection and moisture movement monitoring. The ERT arrays may also include some soil vapor sampling ports that can also be used to track movement of chemical vapors near the tank perimeter. Soil samples will also be collected based upon on real-time findings of the vadose zone characterization component.

Additionally, use of the Sonic CPT vibratory driver and the soil cutting retrieval capabilities of the wireline approach may be necessary to penetrate difficult geologic strata present at the Hanford site to enable the tank monitoring objectives to be met.

4.3 Test Site Description

The AX tank farm is a small tank farm consisting of four tanks in the western half of the 200-East area of the Hanford site. Figure 4.1 presents an overview of the Hanford site showing the various waste management areas. Figure 4.2 shows a map of the A tank farms located in the western half of the 200-East area. The A tank farms consist of the AX tanks, the AY tanks and the AZ tanks. Figure 4.3 shows additional information on the AX tanks as well as the associated dry wells around these tanks. The tanks, which are known to have leaked in the past, are cross-hatched in Figure 4.3

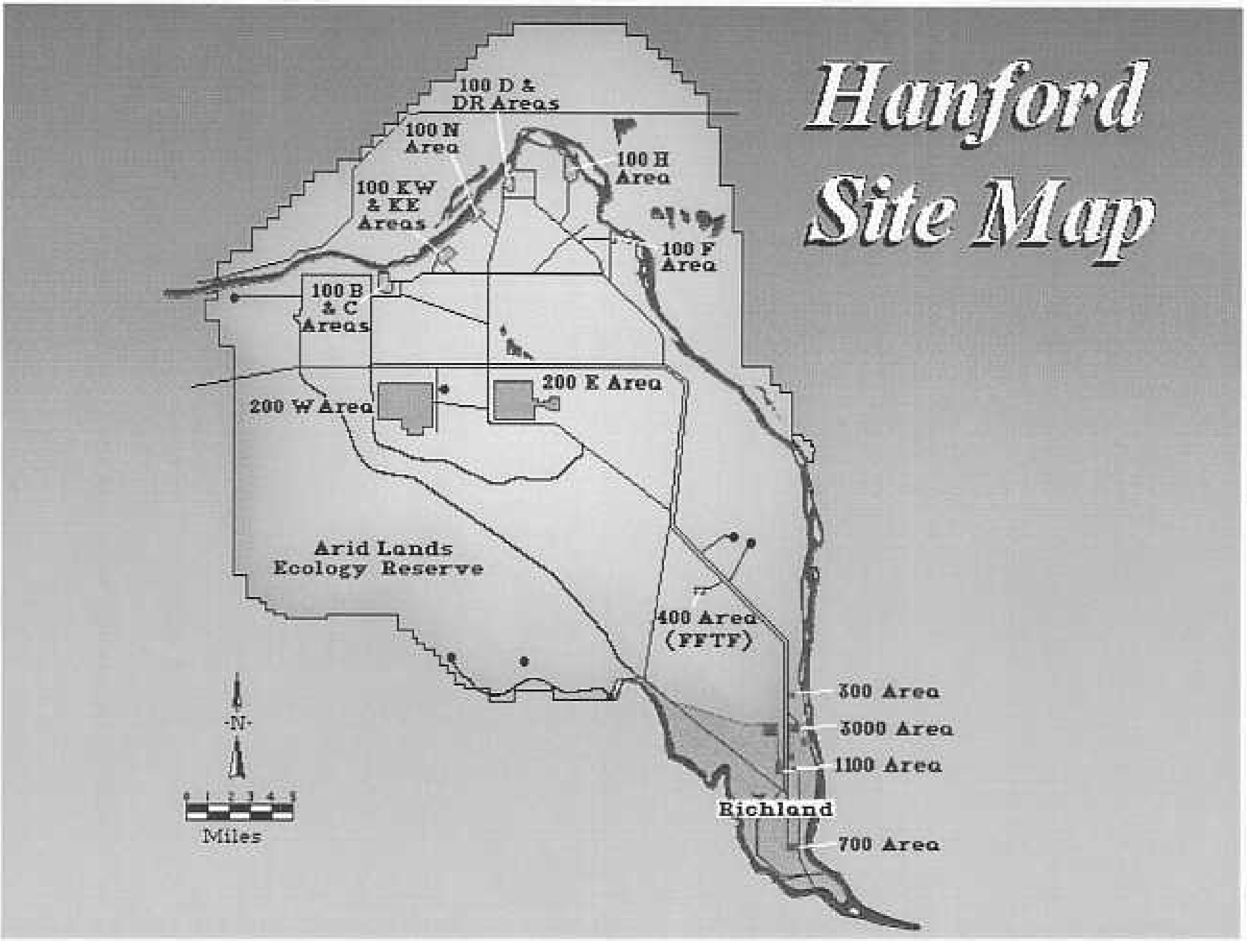

Figure 4.1 Map of the Hanford site showing the various waste management areas.

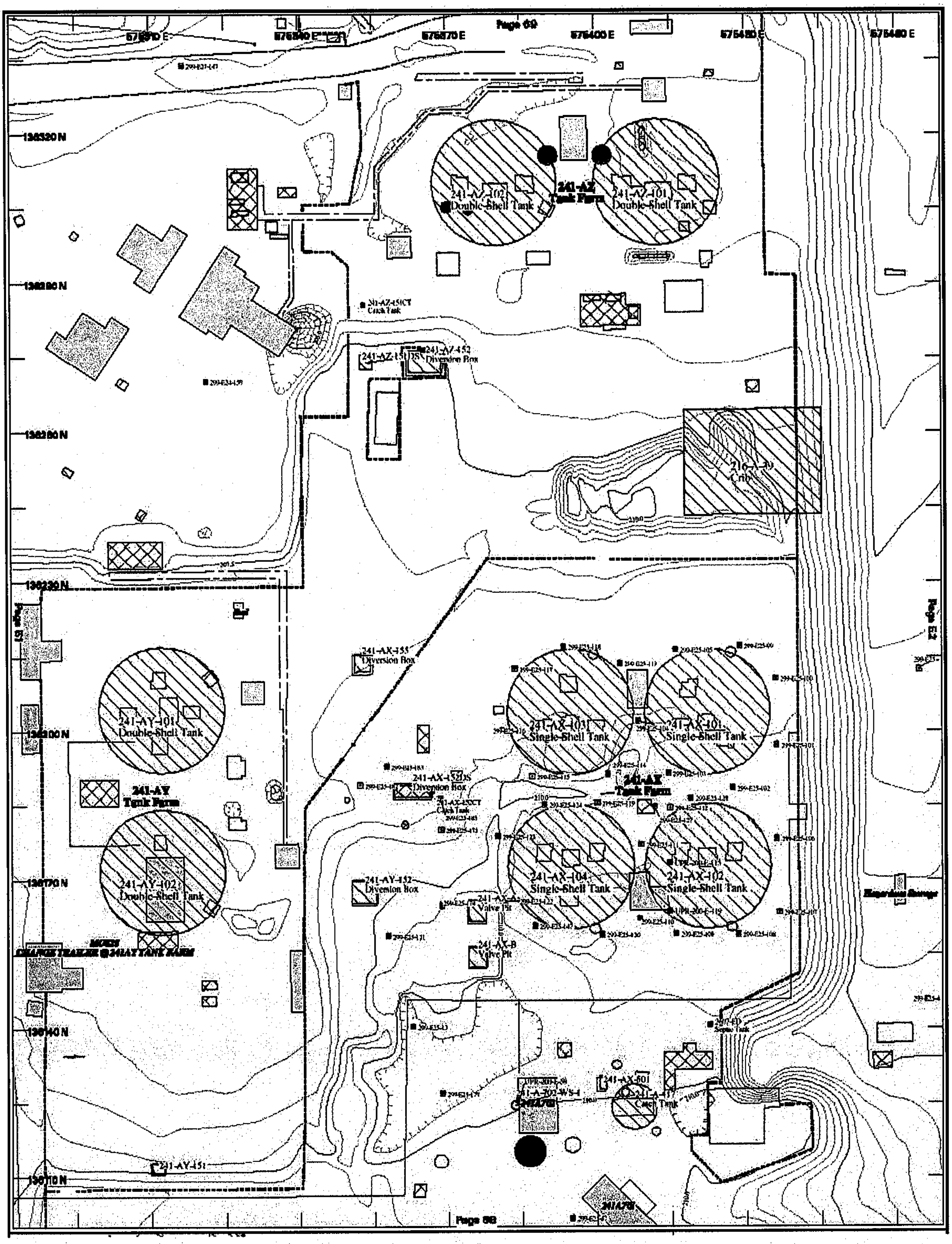

Figure 4.2 Map of the 'A' tank farms located in the western half of the 200-East area of the Hanford Site.

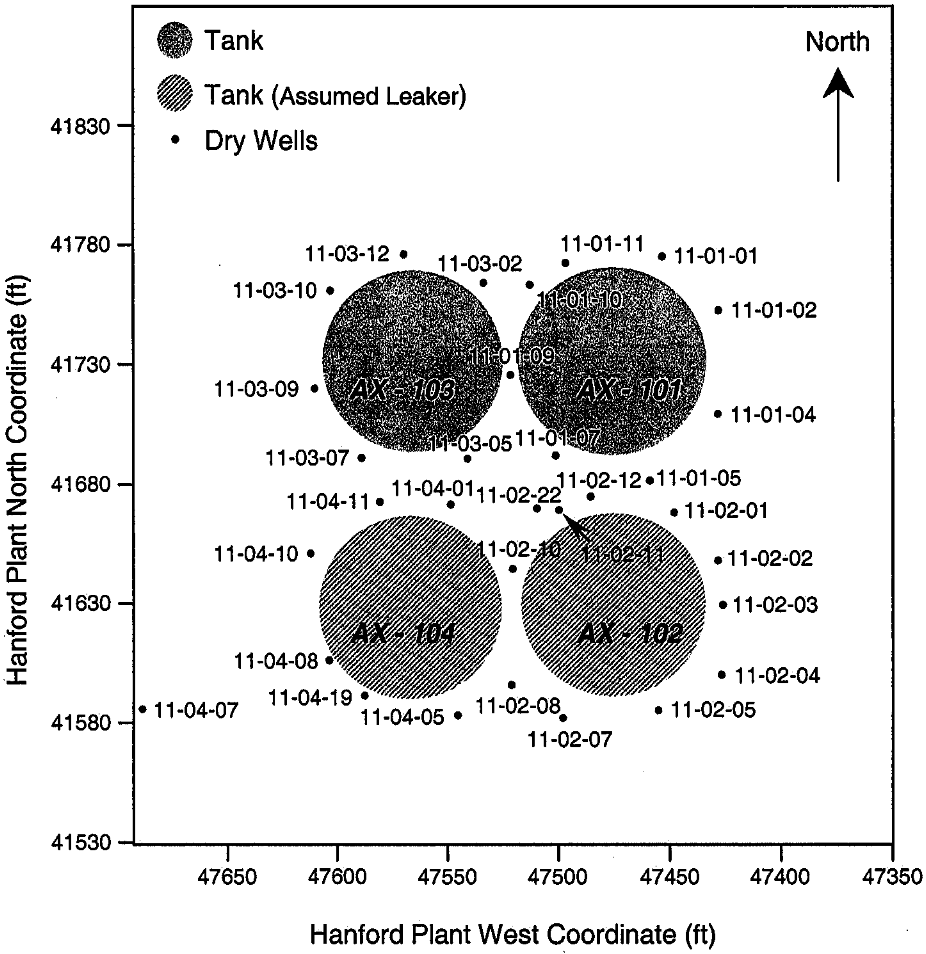

Figure 4.3 Map showing AX tanks and associated dry wells. Cross-hatched tanks are those which are known to have leaked in the past.

The AX Tank Farm is underlain by three major stratigraphic units:

1. The unconsolidated sand, silt, and gravel of the Hanford formation (collectively termed glaciofluvial sediments),
2. The semi-consolidated sediments of the Ringold Formation, and
3. The basalt of the Columbia River Group that forms the bedrock beneath the AX Tank Farm area (DOE-Grand Junction 1997).

The Hanford Formation sediments consist of coarse to very coarse gravel, fine- to coarse-grained sand, and silt. Three distinct facies have been recognized: gravel dominant, sand dominant, and silt dominant (ordered from top to bottom of the formation).

The AX Tank Farm appears to be located above a transitional zone between the Hanford Formation sandy and lower gravel facies. The sands and gravels of the Hanford Formation extend to a depth of approximately 79.25 m (260 ft) below ground surface (BGS) (Lindsey 1993).

The AX Tank Farm was constructed during 1963 and 1964 to store high-level radioactive mixed waste generated by chemical processing of irradiated uranium fuel from the Plutonium-Uranium Extraction (PUREX) Plant. The four SSTs in the AX Tank Farm are 22.86 m (75 ft) in diameter, approximately 9.91 m (32.5 ft) tall, and are covered with a 4.04 m

(13.25 ft) high concrete dome, for a total height of approximately 14.02 m (46 ft). The tanks are constructed of steel-reinforced concrete with a .375 mm (3/8 in.) steel liner that covers the bottom and side walls up to 9.91 m (32.5 ft). They were constructed in a 16.7 m (55 ft) deep excavation, backfilled, and covered with approximately 1.8 m (6 ft) of soil at the apex of the dome. The tanks are not equipped with the cascade overflow lines characteristic of other SSTs at the Hanford Site. A grid of drain slots in the concrete below the steel liner allows fluids that penetrate the liner to flow into a leak detection pit.

Waste streams sent to the AX Tank Farm were essentially nitric acid solutions of metals from irradiated fuel rods; before delivery to the tanks the solutions were made basic through the addition of sodium hydroxide.

The AX tanks were taken out of service by 1980. Tank 241-AX-104 was sluiced to recover ^{90}Sr and ^{137}Cs in 1977. Because of increased radionuclide activity in surrounding boreholes, tank 241-AX-104 was declared to have questionable integrity later in 1977. No basis was ever formally provided for the designation. The volume of material that may have leaked from the tank is estimated at 30.28 kL (8,000 gal) (Hanlon 1997). Possible sources of a leak that have been considered include a dresser coupling on an exhaust vapor header or a tank breach. The supernatant in the tank was pumped in August 1981 and the present waste inventory in tank 241-AX-104 is estimated as between 18.9 and 26.4 kL (5,000 and 7,500 gal) +/- 15 to 20 percent (Reich 1997).

Single-shell tank 241-AX-104 has been selected as the site for demonstration of technologies that are being evaluated for their potential to characterize vadose zone contamination. Previous studies indicate that contaminants are present in the soils (DOE-Grand Junction 1997), but the extent of the contaminant plume has not been defined. Figure 3 shows a plan view of the tanks and the dry wells at the AX Tank Farm. Measurable ^{137}Cs was detected near the ground surface in all dry wells near tank 241-AX-104. This contamination is likely caused by surface spills. Cesium-137 also has been detected below 6.1 m (20 ft) in dry wells 11-04-01, 11-04-05, 11-04-19, 11-04-08, 11-04-10, and 11-04-11. The source of this contamination has not been definitively established. It could originate from surface spills migrating down dry well casings, or it could have been dragged down during casing installation or dry well drilling. Minor amounts of ^{137}Cs also were found at or near the bottom of three drywells: 11-04-01, 11-04-05, and 11-04-08. The source of this contamination also is uncertain.

Cobalt-60 and ^{154}Eu were detected in dry well 11-04-10. Spectral gamma logging system (SGLS) profiles from dry wells 11-04-05, 11-04-19, and 11-04-08; and historical gamma log data for 11-04-08 suggest that tank 241-AX-104 is the likely source of the contamination found below 16.76 m (55 ft) in this area (DOE-Grand Junction 1997). Plots from these logs are included in Figure 4.4.

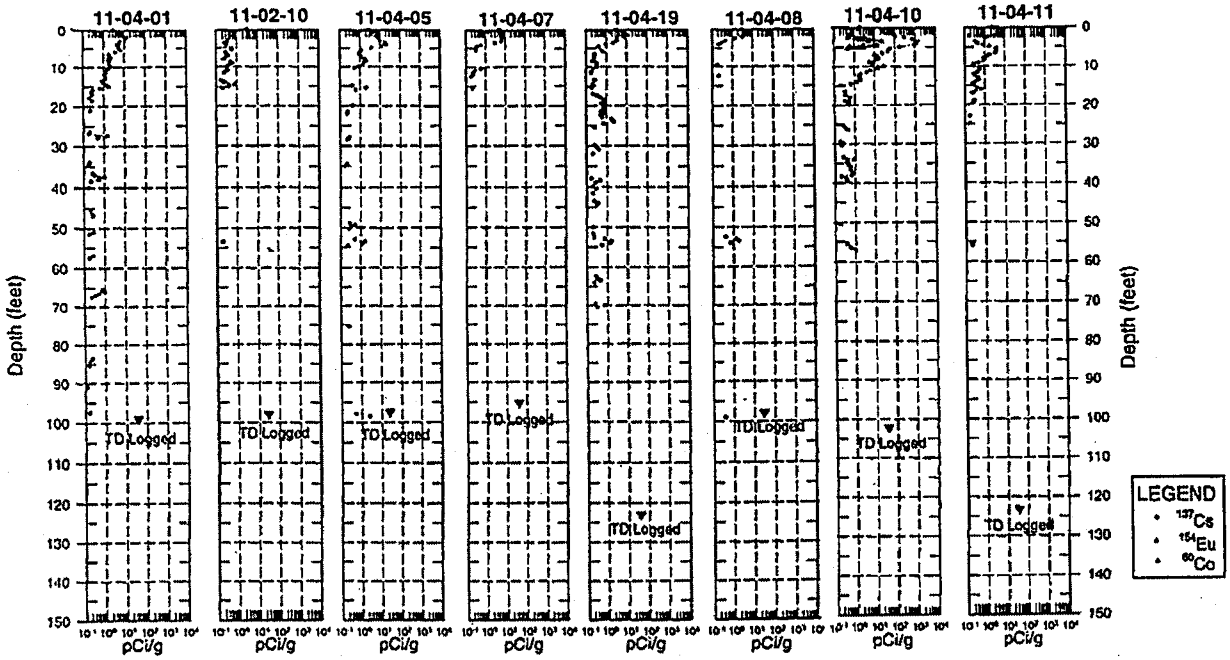

Figure 4.4 Correlation Plot of Man-Made Radionuclide Concentrations in Dry Wells Surrounding Tank 241-AX-104.

To support risk assessment and environmental impact analyses associated with tank closure, the Vadose Zone Demonstration must be able to evaluate residual contamination in the soils adjacent to the tanks and provide an estimate of the volume of the contaminate plume under theAX-104 tank. The wireline ERT demonstration deployment at tank 241-AX-104 will evaluate technology that may help reduce uncertainties in the upper vadose zone characterization and provide this information.

4.3.1 Site Access Point of Contact

The table below provides site contact information for the AX Tank Area at the Hanford Site.

Table 4.1 Contact Information for AX Tank Farm

Name	Organization	Telephone
Scott Peterson	CH2M Hill Hanford, Inc.	(509) 372-9126
Dave Myers	International Technology	(509) 372-9393

4.3.2 Required Training

The training requirements for operations in the tank farm environment are quite extensive. Each person entering the tank farm must have the following training requirements.

- OSHA 40 Hr hazardous worker training
- OSHA 8 hr Supervisor training

- DOE Radiological Worker II
- Hanford General Employee Training
- Tank Farm orientation

The ARA crew for this option is based out of Richland, Washington and routinely works on the Hanford site. The crew is fully badged and has all of the above listed training requirements.

4.4 Test Methodology

4.4.1 Objective

The objective of option 2 is to demonstrate installation of an ERT array in a tank farm environment using the wireline system to both characterize the soils during the initial penetrations and install the ERT array during withdrawal of the CPT rods.

4.4.2 Technical Approach

The technical approach to meeting the test objectives will be to complete the execution of a well-defined matrix of CPT field operations using the previously developed wireline tools and a new ERT emplacement technique. The purpose of the test matrix is to provide data and experience necessary to provide answers to the following specific questions:

- Is radiological contamination within the rods an issue in the vadose zone?
- Can the ERT array be lowered down the rods?
- Does the soil collapse back around the electrodes or is backfilling required?
- Can the electrodes be integrated for vapor sampling ports?
- Can both sampling and non-sampling electrodes be mixed in a single electrode string?

4.4.3 Procedures

Testing operations will adhere to generally accepted principles of sound CPT operation and to the provisions of the ARA and Hanford health and safety plans. While adhering to these principles, the test matrix detailed in the table below will be executed. Twelve days of field operation are planned to allow completion of the matrix.

Table 4.2 Test Matrix for Contract Option 2 Field Activities

Action	Objective(s) for Data Obtained
Penetrate to 30 to 36 meters bgs using wireline rod string and piezocone module with soil moisture and resistivity module.	5. Evaluate ability of tools to obtain characterization data. 6. Develop operator intuition for local push stresses and tool survivability 7. Collect data for comparison of cone

	performance to ASTM-conformant geometry
Unlock and remove the piezcone and soil moisture/resistivity module to the ground surface.	2. Confirm unlocking ability.
Assemble and ERT array and lower down the interior of the CPT rods. Remove the rods placing the electrode array. Test array for connectivity.	3. Evaluate the utility of ERT installation using a wireline approach. 4. Confirm that the ERT array is embedded in the soil matrix and making solid contact.
Repeat actions 1 to 3 at 7 more locations around the tank. All eight arrays should be equally spaced. Use array electrodes with gas sampling ports on even number penetrations. Collect soil vapor from appropriate arrays	5. Confirm integration of sampling ports with ERT arrays. 6. Confirm ability to install vapor sampling monitoring array string using Wireline approach. 7. Confirm ability to collect soil vapor samples.
At desired soil sampling locations, penetrate to the soil sample depth using a dummy tip and then removed the tip.	
Lower a Sodium Iodine (NaI) gamma spectroscopy crystal down the CPT rods and monitor total gamma counts during both lowering and retrieval.	8. Collect data to assess if the interior of the wireline rods is susceptible to radiological contamination.
Lower sampling tool and lock in. Advance sampler to fill chamber. Remove sampler equipment from the CPT rods.	1. Demonstrate ability to collect soil samples using equipment developed under option 1. 2. Evaluate sampler capabilities in a gravely geology. 3. Assure survivability of wireline sampler module under conditions encountered
Lower a Sodium Iodine (NaI) gamma spectroscopy crystal down the CPT rods and monitor total gamma counts both during lowering and retrieval	1. Collect data to assess if the interiors of the wireline rods are susceptible to radiological contamination due to sample leakage during retrieval.
Advance Sampler to next depth	1. Demonstrate multiple depth soil sampling in Hanford geology.
Repeat activities 5-9 at three additional soil sampling locations.	1. Complete the demonstration and provide additional data.

4.4.4 Contingencies

Should failure of equipment or unanticipated environmental or work conditions impact the ability of the field crew to complete any action within the test matrix, the on-site engineer will make a determination as to the feasibility and priority of completing the remaining actions so as to best support the overall test objectives.

4.4.5 Equipment, Supplies, and Materials

The following equipment and materials are required and/or recommended for performing the tests in the field evaluation matrix. All required equipment and materials should be assembled and inventoried on the first day of field operations, prior to beginning execution of the test matrix.

Major Equipment

DOE 35-ton Cone Penetrometer Platform located at Hanford
CPT data acquisition system
Crane & Rigging support for platform movement.

Wireline Components

Wireline rod string (40 meters)
Wireline piezocone and soil moisture/resistivity module with attached locking mechanism
Wireline dummy piezocone module and spare
Wireline grouting module with attached locking mechanism and spare sacrificial tips
Retrieval wire and spare
Spare piezocone tips, pore pressure filters, friction sleeve, cutting mouth, locking dogs, locking dog pivot pins, and internal brake nut
Wireline instrument cable (10-pin Lemo), at least 200 feet
4 -ERT Array strings (36 meters with electrodes every meter below 50 feet) utilizing standard electrode configurations.
4 -ERT Array strings (36 meters with electrodes every meter below 50 feet) utilizing vapor sampling electrode configurations.
Wireline Soil sampling equipment
20 soil sample chambers.

Miscellaneous Materials and Supplies

Cable adapters
Cone calibration jigs, adapters, and load cells
CPT (*Mechanic's*) tool kit
NaI crystal with rate meter for logging sampling penetrations

4.5 Health and Safety

Health and Safety issues are of utmost concern at ARA. Throughout the course of the project, ARA's corporate Health and Safety Plan will provide guidance on all aspects of health and safety to ensure that all tasks are completed safely and in compliance with State and Federal OSHA requirements. A copy of ARA's Health and Safety Manual is included as Appendix A.

During the field evaluations at both the Savannah River Site and at the Hanford Site, ARA will comply with the site specific health and safety plans provided by the coordinating staff of the respective sites. All field personnel will be hazardous waste operations (40 CFR 1910.120) and hazard communications (40 CFR 1910.1200) training certified.

A detailed tank farm specific health and safety plan will be prepared once the option is authorized and a coordination meeting with the Vadose Zone Program has been conducted to identify the particular tank that the ERT will be installed around.

4.6 Permitting Requirements

ARA will work closely with the Hanford site personnel from the Hanford Vadose Zone Project who will be providing oversight for this project. It is anticipated that point of contact will be either Scott Peterson or Dave Meyers. Working with the Hanford POC, ARA will obtain the permits required to conduct penetrations in a tank farm. The bullet list below presents the required permits that will be necessary to perform the planned activities.

- Prepare a Notice of construction (NOC) document and have reviewed by Flour Daniel Hanford (FDH), DOE-RL, and Washington Department of Health (WDOH)
- Prepare siting Plan for planned penetrations
- Obtain Dome Loading approval
- Prepare an Excavation Permit
- Obtain USQ safety screening approval
- Obtain Start cards from Washington Department of Ecology

Once all permits are in place, then the field activities can begin.

4.7 Schedule

The demonstration work at the DOE Hanford facility will occur once option 1 has been completed and will occur over a duration of 3 months. Nearly 2 full months will be required to get the appropriate documentation and permitting in place such that the field activities can occur in the Tank Farm environment.

Once the fieldwork is initiated, it is estimated to last approximately 12 days. The first day will be used to orientated to the tank farm environment, establish relations with the tank farm operations staffs and the radiological control technicians. It is estimated that the eight ERT installations will be conducted at one per day, taking the first eight days of the demonstration. Following the ERT array installation, four days of soil sampling will be conducted. The soil sampling is scheduled after the ERT installation to permit time for review of the characterization data obtained during the array installation. This information will be used to guide the soil sampling efforts. The soil sampling effort will conclude the Hanford demonstration.

A draft report will be submitted to FETC approximately one month after the fielding effort for Option 2 is completed.

ATTACHMENT 2

LETTERS OF SUPPORT

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

Mr. Steve Cooke
ROA Project Manager
Federal Energy Technology Center
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26505

Dear Mr. Cooke:

SUPPORT FOR WIRELINE CONE PENETROMETER (CPT) WORK AT THE HANFORD SITE

The U.S. Department of Energy, Richland Operations Office (RL), Site Technology Coordination Group (STCG) Subsurface Contamination Subgroup has endorsed the demonstration of CPT work that uses wireline-retrievable sensors and sampling devices. We encourage the funding of this work, partially described in option II, contract number DE-AR26-98FT40366, entitled "Development of a Wireline Cone Penetrometer System for Multiple Tool Usage." The current scope of work under this contract calls for 12 penetrations surrounding a high-level waste tank. The STCG proposes that several of these penetrations be made outside the tank farm around the carbon tetrachloride plume in the 200 West Area of the Hanford Site.

This technology, if successful in the proposed location, would allow rapid and cost-effective sampling and in-situ measurements of the carbon tetrachloride plume to better characterize its extent and quantify the concentrations and mass of carbon tetrachloride in the vadose zone. The ability to grout the hole on retraction without pulling the entire rod string, which this wireline system would do, will also increase the cost-effectiveness of this technique. The success of this effort and the data obtained will assist the Innovative Treatment Remediation Demonstration project currently being conducted to assess remediation and characteriztion technologies to address carbon tetrachloride contamination in the 200 West Area.

The demonstration of the CPT in the 200 West Area is supported by RL's Environmental Restoration (ER) Project and the U.S. Environmental Protection Agency, the lead regulatory agency for this site.

If you have any questions regarding this letter or require additional information, please contact Mr. Fred Serier or Ms. Arlene Tortoso of the ER Project, on (509) 376-8517 and (509) 372-9631, respectively.

Sincerely,

Lloyd Piper
Deputy Manager

RPS:FRS

cc: J. D. White, BHI

Letter of Support For Wireline CPT Solution From Savannah River Site End User

Return-Path: <Bruce.Triplett@srs.gov
From: Bruce.Triplett@srs.gov
Date: Tue, 19 Jan 1999 11:22 -0400 (EDT)
Subject: Re: wireline testing at SRS
To: bfisk@ara.com

We have had several requests for CPT soil sampling at multiple depths here at SRS. I see the benefits of a "wireline" CPT sampler as three fold.

1. COST: Using the current methodology for multiple soil samples we must trip up and down the same hole several times. Not only does this accumulate footage charges it takes a lot of time.

2. REGULATORY ISSUES: For our environmental investigations, the South Carolina Department of Health and Environmental Control(SCDHEC) currently will not allow penetration of a confining layer unless you grout as you pull up the rods. Wireline sampling would allow us to continue to greater depths within the same hole.

3. SAMPLE DISTURBANCE: Recently we sampled "soft zone" material at a depth of 104' to 112', from an area at SRS. We were using two traditional Vertek samplers(stacked) and a 4' clear 1.44" tube. We obtained two 4' continuous samples. Traditional shelby tube sampling with mud-rotary drilling has been ineffective in obtaining samples from this section. A large amount of water accumulated in the top portion of the sample tube indicating a very saturated material(almost in suspension). We have speculated why the material settles out and my thought is, during retrieval of the sampler, the CPT rods vibrate severely as they are withdrawn. This is due to the tight formation conditions above the soft zone. This vibration extremely disturbs the sample. A wireline sampler would bring the sample up through the CPT rod with very little disturbance and would be very useful in studying the in situ conditions.

I see a wireline sampler as a very useful tool, which would be utilized in our investigations here at SRS. Please keep me advised as to the development schedule. If you need help in obtaining locations here at SRS for testing, I stand ready to assist.

Regards,

Bruce Triplett