INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0522

Ribbon NAPL Sampler

Subsurface Contaminants Focus Area and Characterization, Monitoring, and Sensor Technology Crosscutting Program

Prepared for
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Office of Science and Technology

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INNOVATIVE TECHNOLOGY
Summary Report

Ribbon NAPL Sampler

OST/TMS ID 2238

Subsurface Contaminants Focus Area and Characterization Monitoring, and Sensor Technology Crosscutting Program

Demonstrated at
Savannah River Site
Aiken, South Carolina

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under "Publications."

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SECTION 1

SUMMARY

Technology Summary

Problem: Dense Non-Aqueous Phase Liquid (DNAPL) contamination is a high priority problem at many DOE sites. Remediation of DNAPL-contaminated sites is especially critical because DNAPLs in the subsurface represent a long-term source for groundwater contamination. Robust characterization is essential to the design of effective and efficient remediation solutions. Unfortunately DNAPLs are very difficult to characterize because they are denser than water and migrate as a result of gravity rather than moving with groundwater flow as is typical of most contaminants. Standard characterization strategies based on collection of groundwater samples are not effective at delineating the nature and extent of DNAPL contamination.

How It Works: The Ribbon NAPL Sampler is a sampling device that can provide detailed delineation of DNAPL in a borehole. A dye-impregnated ribbon is installed in a borehole with an inflatable liner. The system is inflated against the walls of the borehole and the ribbon absorbs the DNAPL that is in contact with the membrane. The dye in the ribbon reacts with the DNAPL causing a significant color change. The membrane is retrieved with a tether connected to the bottom of the membrane that turns the liner inside out. At the surface, the liner is everted and ribbon is removed and examined. The presence of DNAPL is indicated by brilliant red marks on the ribbon. The membrane can be installed with a cone penetrometer truck or with traditional thin-walled drilling methods.

Figure 1. Section of Ribbon NAPL Sampler from 321-M

Potential Markets: The Ribbon NAPL sampler was specifically designed for site screening at hazardous waste sites where NAPL contamination is suspected. The best application of the technology is to use it during early stages of site characterization to focus and optimize subsequent characterization and remediation activities.

Advantages over baseline: *In situ* verification of the presence of NAPL at contaminated sites is critical for design and optimization of remedial systems. A robust conceptual model of the nature and extent of contamination can significantly reduce the costs of characterization and remediation of these source areas. Currently sediment or soil samples are collected, taken to the laboratory, and analyzed. Specific advantages include:

- Provides a continuous record of the distribution of zones contaminated with separate phase contaminants.

  -- At many sites, it is difficult to validate the presence of NAPL using groundwater and sometimes sediment sampling

- Significant cost savings

  --For a demonstration of the technology at the 321-M Solvent Storage Tank site at SRS, the total cost for site characterization with the Ribbon NAPL Sampler would be approximately $15,213 compared to $34,199 for the baseline

  -- In this example, the estimated cost savings over the baseline technology of sediment sampling and analysis is more than 55%.

- Significant reduction in the amount of secondary waste generated during sample collection, analysis, and disposal.

- Reduction in the risk of human exposure during sample collection and analysis.

Demonstration Summary

The Ribbon NAPL Sampler has been used successfully for site characterization at the Savannah River Site, South Carolina, the Cape Canaveral Air Station, Florida, the Paducah Gaseous Diffusion Plant, Kentucky, and the McCormick and Baxter Creosoting Co. Superfund Site, California. These three DOE sites and one EPA Superfund site have documented DNAPL contamination. The evaluations at SRS focused on vadose zone deployment, while the evaluations at Paducah, Cape Canaveral, and McCormick and Baxter implemented trials below the water table.

- The technology evaluation at the Savannah River Site was conducted at 321-M in June of 1998. In 1985 unused solvent (tetrachloroethylene) was spilled and formed a plume in heterogeneous unsaturated sand and clay sediments. The goal of this demonstration was to evaluate the Ribbon NAPL Sampler's ability to identify NAPL in the heterogeneous, vadose zone sediments. These liners were installed in open CPT boreholes by manually holding the SEAMIST canister and inverting the liner into the borehole. Retrieval and examination of the ribbon showed clear delineation of depth discrete NAPL presence evidenced by brilliant red marks on the ribbon.

- A second evaluation was conducted in December of 1998 at Cape Canaveral Air Station in Florida. This demonstration was the first implementation of the Ribbon NAPL Sampler (RNS) in saturated sediments. Installing the RNS below the water table was accomplished by feeding the ribbon down into the CPT rods before retracting them. Some complications were encountered upon retrieval of the liner using the tether, but the ribbon was successfully extracted and indicated presence of NAPL where free phase contaminant existed.

- The third evaluation completed in June of 1999 was at DOE's Paducah Gaseous Diffusion Plant (PGDP), Kentucky. The demonstration included both depths above and below the water table; therefore installation was achieved using the CPT system. Indicative red marks were found both above and below the water table when the ribbon was retrieved.

- The fourth evaluation completed in August of 1999 was at an EPA Superfund site in Stockton, California. The DNAPL at this site was creosote. The demonstration included both depths above and below the water table; therefore installation was achieved using the CPT system. Indicative marks were found both above and below the water table when the ribbon was retrieved.

Contacts

Technical

Carl Keller, Flexible Liner Underground Technologies, Ltd., 505-455-1300, www.flut.com, ckmist@aol.com
Brian Riha, Westinghouse Savannah River Company, 803-557-7807, brian.riha@srs.gov

Management

Joe Ginanni, U.S. Department of Energy, 702-295-0209, ginanni@nv.doe.gov
Charles Nalezny, U.S. Department of Energy, 301-903-1742, charles.nalezny@em.doe.gov

All published Innovative Technology Summary Reports are available on the OST Web site at http://em-50.em.doe.gov under "Publications." The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST Reference number for the Ribbon NAPL Sampler is #2238.

SECTION 2

TECHNOLOGY DESCRIPTION

Overall Process Definition

The Ribbon NAPL Sampler consists of a membrane system that is installed into a borehole to detect the presence of NAPL. Inflation of the membrane in the borehole pushes a reactive ribbon against the walls of the borehole. If NAPL is present in the subsurface along the borehole, it will be absorbed or "wicked" into the ribbon where it interacts with the dye and stains the ribbon a brilliant red color. The liner system is brought to the surface and spots on the ribbon provide immediate information about the location of NAPL.

The Ribbon NAPL Sampler is composed of a liner and a reactive ribbon.

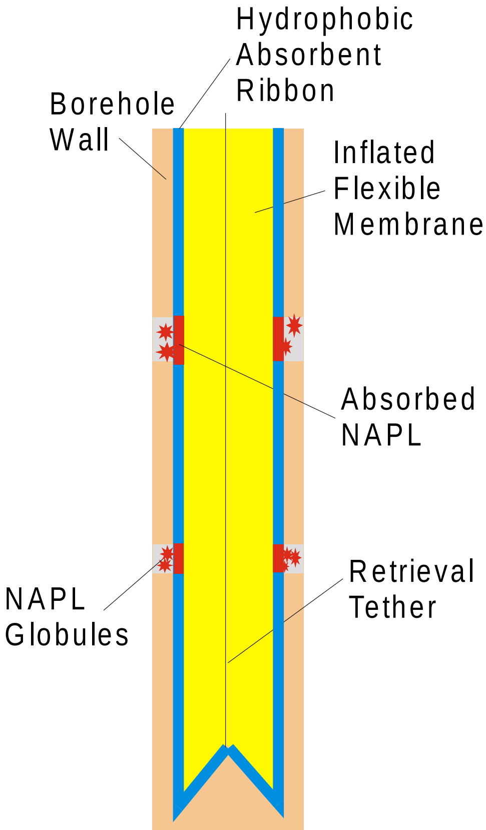


Figure 2. Schematic Diagram and Photograph of the Ribbon NAPL Sampler

–The liner is a flexible tubular membrane that is pressurized and inverted by unrolling against the walls of a borehole. In an open borehole, the liner is pressurized using a SEAMIST ™ portable canister system. When the system is installed through CPT or drill rods, a bundled system is inserted through the rods to depth and then individual sections of liner are incrementally inflated by adding water (saturated zone) or air (unsaturated zone) to the inside of the liner system.

– A reactive ribbon is attached to the inside of the membrane. The ribbon is hydrophobic and is impregnated with Sudan IV dye in powdered oil form. Contact between NAPL and the ribbon solubilizes the dye and produces a brilliant red stain on the ribbon. The ribbon is inverted during installation resulting in direct contact of the ribbon with the borehole walls. The reaction of the dye occurs quickly (within 5-10 minutes) but leaving the ribbon in place for longer (approximately an hour) results in clearer, larger red NAPL indications.

System Operation

The Ribbon NAPL Sampler was designed to be installed with a cone penetrometer truck but may be adapted for use with other types of drilling systems. Installation into an open borehole is relatively simple. Installation is possible through CPT and drill rod casing. A detailed description of the installation process follows:

Installation of the Ribbon NAPL Sampler below the Water Table and in Collapsing Sediments

(1) The Ribbon NAPL Sampler is purchased from the vendor and consists of a dye-impregnated hydrophobic ribbon that is attached to the membrane. The membrane system is packed into a smaller diameter bundle.

(2) A CPT is used to open a borehole to the desired depth. The bundled Ribbon NAPL Sampler is lowered through the CPT rods to depth.

(3) The CPT rods are pulled up a few feet. This releases the sacrificial CPT tip and allows the sediments to collapse around the end of the membrane to anchor the membrane in place. The Ribbon NAPL Sampler is pressurized with water inside the rods to break the seams of the bundle.

Figure 3. The bundled system is lowered into the CPT rods, the membrane is pressurized to break the seams, and the rods are pulled up.

(4) Water is measured into the inside of the Ribbon NAPL Sampler through an interior tube. The addition of water pushes the membrane against the borehole walls as the rods are retrieved. Water is also added between the Ribbon NAPL Sampler and the CPT rods to balance the fluid pressure and reduce friction. This process continues until all the rods are retrieved and the Ribbon NAPL Sampler is expanding in the borehole.

Figure 4. Water is added to the membrane system.

(5) The Ribbon NAPL Sampler is left in place in the subsurface for 30 minutes to 1 hour. The actual length of exposure is determined by knowledge of suspected DNAPL residual and contaminant distribution.

(6) The Ribbon NAPL Sampler is retrieved by pulling the tether anchored at the bottom of the membrane. The membrane turns inside out and is removed from the hole. The inversion brings the ribbon up on the inside away from the sediments and contaminants.

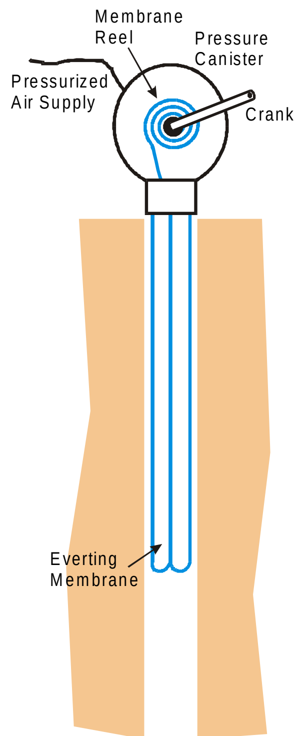
Figure 5. The membrane is retrieved by inversion.

(7) At the ground surface, the Ribbon NAPL Sampler is turned right side out. The location of NAPL is indicated by the presence of colored spots on the membrane. The distribution of contamination is described and photographed. If desired, small portions of the ribbon can be removed from the liner and analyzed to identify specific compounds present in the NAPL.

Figure 6. The membrane is turned inside out and examined for dyed spots.

Installation of the Ribbon NAPL Sampler in the Open Boreholes

1. A CPT or drill rig is used to open a borehole to the desired depth.



2. The Ribbon NAPL Sampler is inflated into the borehole using an air blower. The hydrophobic ribbon is attached to the inside of the flexible liner, both of which are coiled on a reel inside a canister. Using air pressure, the liner is turned inside out as it extends down into the open borehole, thus exposing the membrane. Air pressure drives the downward movement and forces the liner and hydrophobic ribbon against the walls of the borehole.

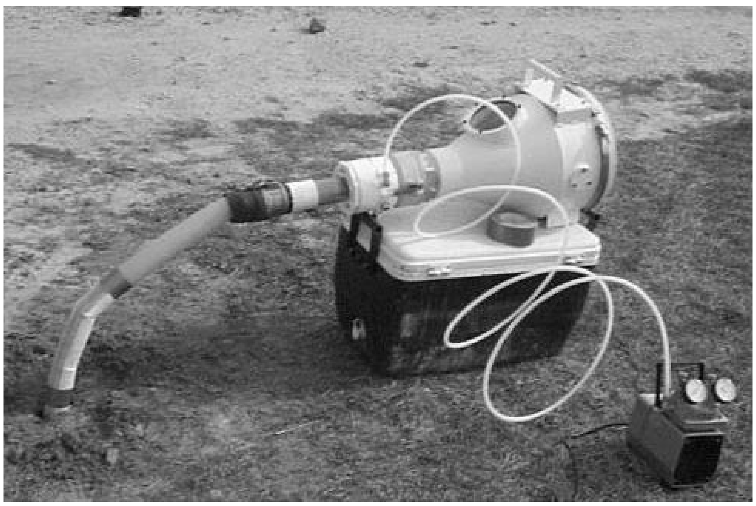


Figure 7. Canister system and schematic for installation into open boreholes.

(3) The membrane system is left in place in the subsurface for 30 minutes to 1 hour. The actual length of exposure is determined by knowledge of suspected DNAPL residuals and contaminant distribution.

(4) The ribbon is recovered by winding the canister. The tether everts the membrane through the borehole, which protects it from additional contact with the hole.

(5) Once the membrane is retrieved back into the canister, it can be inflated and inverted above ground for examination. Sections of the ribbon with red dye indicating the presence of NAPL can be cut and analyzed in the laboratory for specific identification of the NAPL compound.

Other Operational Issues

–The liner can be reused but the vendor must replace the ribbon. Reusing the liner will significantly reduce the cost of materials for the subsequent deployment.

–In most applications, a three man CPT crew can install the ribbon. In the case of installation below the water table or in collapsing sediments, installation through the rods can be time consuming. A typical 60-ft deployment takes 3-4 hours.

–The use of Ribbon NAPL Sampler significantly reduces the amount of secondary waste relative to the baseline method of sediment sampling. The use of CPT virtually eliminates drilling waste. The only potential waste disposal issue would be disposal of the membrane, which can be rolled into a small bundle.

PERFORMANCE

Demonstration Plan

The Ribbon NAPL Sampler has undergone a series of evaluations and deployments, mostly at the Savannah River Site. After each evaluation, modifications were made to improve the overall system design and to simplify the installation process. The test sites were chosen to provide progressively more challenging conditions for use and installation of the system.

Evaluations and Deployments

321-M Solvent Storage Tank Area, Savannah River Site

The first evaluation of Ribbon NAPL Sampler for detection of DNAPL was completed at 321-M Solvent Storage Tank area in July 1998. This site was chosen because residual NAPL is present in the vadose zone due primarily to a spill of unused tetrachloroethylene (TCE) solvent in 1985. The geology at 321-M is extremely heterogeneous and is characterized by interbedded clays and sands.

Two Ribbon NAPL Samplers were successfully installed from the surface to a depth of 50 feet below the location of the former solvent storage tank and were successfully retrieved. Both membranes indicated the presence of DNAPL in multiple locations. Sediment sampling and analysis was used to confirm the presence of NAPL. Figure 8 shows compares the results from Ribbon NAPL Sampler (Location 3) to two adjacent boreholes (Locations 1 and 2) where sediment samples were collected and analyzed. NAPL should be present at concentrations exceeding ~400 micrograms/gram.

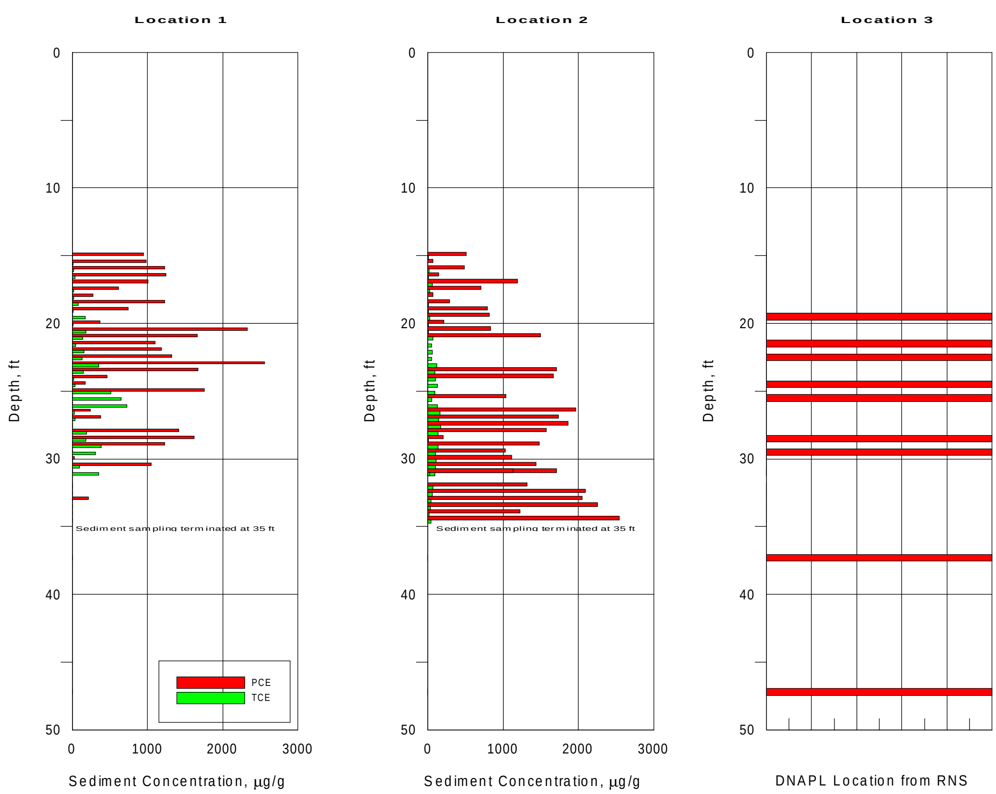


Figure 8. Comparison of concentration determined by the traditional analysis of sediments (Locations 1 and 2) and location of DNAPL indicated by the RNS (Location 3) at the 321-M site.

Interagency DNAPL Consortium Site, Launch Complex 34, Cape Canaveral Air Station, Florida

The first installation of the Ribbon NAPL Sampler below the water table was done at the Interagency DNAPL Consortium Site at the Cape Canaveral Air Station. The geology of the site is characterized by interbedded sand and clay with occasional layers of shell fragments. The water table is close to ground surface.

Ribbon NAPL Samplers were deployed and retrieved in two locations (LC34B-45, 46) near borehole (LC34B-26) where sediment samples were collected at two foot intervals and analyzed for DNAPL compounds in the laboratory. These measurements provided the basis for comparison for an assessment of the ability of the Ribbon NAPL Sampler to detect DNAPL in the subsurface. In these sediments, separate phase DNAPL will be present at concentrations exceeding 250 to 450 μg/g depending on the carbon content and porosity of the sediments (Eddy-Dilek et al, 1998).

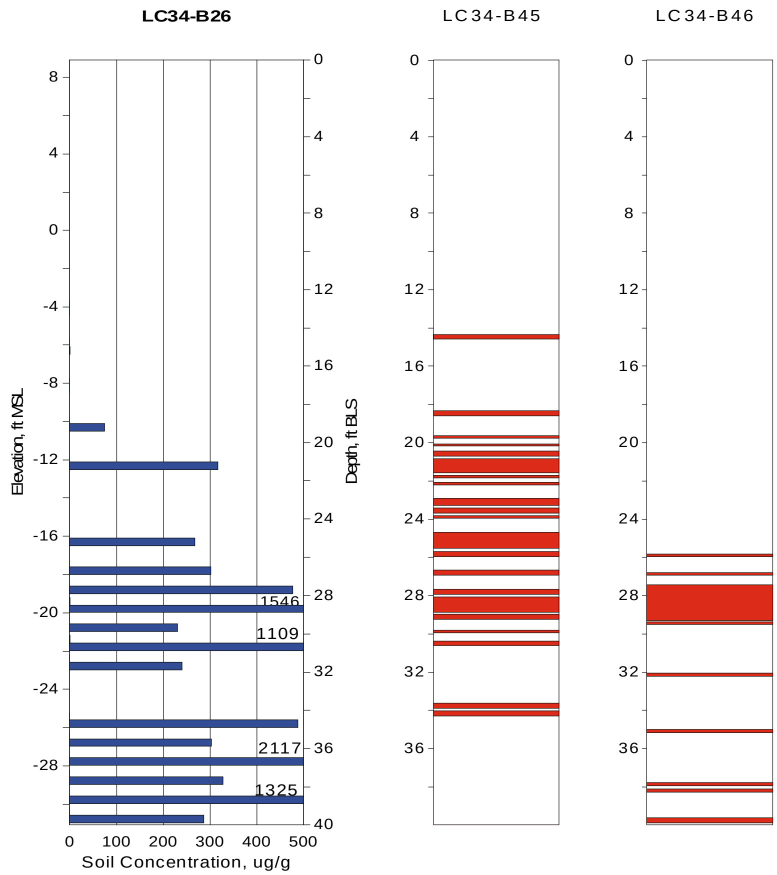


Figure 9. Comparison of sediment concentration and location of DNAPL indicated by the RNS at the IDC site.

The DNAPL depth profiles from the Ribbon NAPL Sampler ribbons shown in Figure 9 show good agreement with the soil concentrations measured in the adjacent borehole. This figure shows that even with sediment sampling at intervals of 2 feet that the membrane provides more detailed information on the depth discrete nature of the contamination. Depths with high concentration such as the 28-32 feet depth correlate well with the locations of DNAPL detected marks on the membrane.

A-14 Outfall, Savannah River Site

The next installation of the Ribbon NAPL Sampler was completed at the A-014 Outfall at SRS where high concentrations of solvent had been identified in the shallow subsurface in soil gas measurements. Four liners were installed by SRS Environmental Restoration in order to delineate shallow vadose zone contamination to support location and optimization of new vapor extraction wells near the outfall. These liners were installed to a depth of 30 feet in the vadose zone in February and April 1999. New vapor extraction wells were installed at this location in May 1999; the location of screened intervals was based on information on the nature and extent of contamination identified with the Ribbon NAPL Samplers

Paducah Gaseous Diffusion Plant

A team of environmental researchers from Bechtel Jacobs, Applied Research Associates, and the Savannah River Technology Center (SRTC) successfully deployed a Ribbon NAPL Sampler at the C 400 area of the Paducah Gaseous Diffusion Plant during June 1999. The Ribbon NAPL Sampler was used to provide a depth profile of DNAPL following a cone penetrometer push.

The Ribbon NAPL Sampler was deployed to a depth of approximately 60 feet below surface (water table at approximately 45 feet) through 1.75" diameter cone penetrometer rods. Red spots from contact with subsurface TCE at the site were noted at multiple depths through the vadose zone and below the water table. This information was used to supplement previous characterization studies that were hampered by difficulties in recovering core material for sampling from the subsurface.

McCormick and Baxter Creosoting Co. Superfund Site

A team of environmental researchers from the U.S. Army Corps of Engineers and the Savannah River Technology Center (SRTC) successfully deployed two Ribbon NAPL Samplers at a former wood preserving facility in Stockton, CA. The Ribbon NAPL Samplers were deployed to approximately 45 feet below the surface (water table is at approximately 12 feet) through 1.75" diameter cone penetrometer rods. Dark spots from contact with subsurface creosote were noted at multiple depths through the vadose zone and below the water table. The information was used to determine the location of pure phase product, to determine if DNAPL was present in pools or as dispersed ganglia, and to corroborate previous CPT laser induced fluorescence (LIF, OST 2237) data. The information gained from the Ribbon NAPL Sampler indicated the DNAPL in the areas characterized were in the form of dispersed ganglia and that pools do not exist.

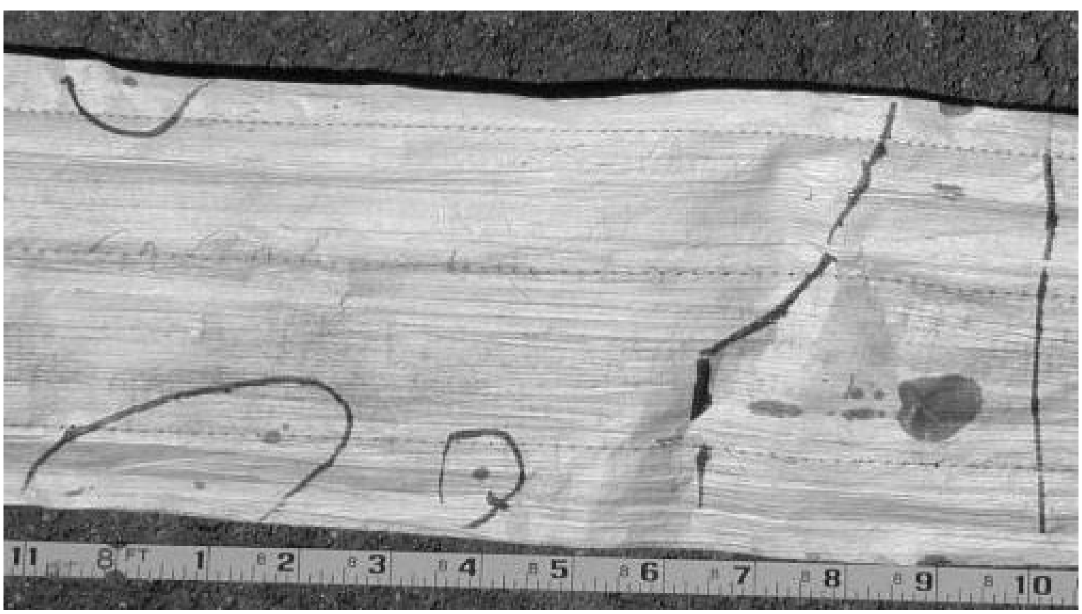


Figure 10. Creosote DNAPL spots on the Ribbon NAPL Sampler

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

Currently, a baseline method is not available for *in situ* characterization of DNAPL contaminated sites. The approach typically used for characterization of DNAPL-contaminated sites requires collection of sediment samples with a drilling rig followed by laboratory analysis of the samples. The results from these two methods are not directly analogous and each results in a unique data set. In most situations where the DNAPL Ribbon Sampler is used, it will be used to complement a smaller number of baseline measurements.

Baseline Sediment Sampling and Analysis

- Yields quantitative analysis of contaminant distribution in a discrete number of locations, typically 1 sample every 5 to 10 feet.
- Yields information on the distribution of dissolved phase contamination.
- In many cases, the unequivocal identification of the presence of NAPL cannot be determined without knowledge the porosity and organic carbon content of the sediments.

Advantages of Ribbon NAPL Sampler

- Only available *in situ* technique that unequivocally detects the presence of separate phase NAPL.
- Provides detailed information on the depth discrete distribution of DNAPL.
- Can be used in applications where cores are difficult to retrieve.
- Use of Ribbon NAPL Sampler is fifty percent less expensive than the baseline.

Several other innovative technologies are being evaluated for *in situ* screening of DNAPL. One of the most promising approaches uses spectroscopic methods deployed with a cone penetrometer. Cone penetrometer-based Raman spectroscopy has been used successfully in the unsaturated zone to identify DNAPL at several waste sites at SRS. The technique has been less successful below the water table. Laser-induced fluorescence can also be used as a screening tool at DNAPL contaminated sites where the DNAPL has incorporated fluorescent compounds such as naturally organic carbon present in the subsurface or co-disposed components such as machine oils. These methods have not worked at all waste sites. At sites where they are effective, they can be used in a dynamic sampling strategy to effectively characterize relatively large areas.

Technology Applicability

This technology is appropriate only for *in situ* detection of separate phase material because it will not detect high dissolved phase concentrations. It is most appropriate in a situation where detailed information on the depth discrete distribution of DNAPL is required to support conceptual model development or optimization of remedial design. In most applications, it will be used in conjunction with other techniques including baseline sampling and analysis.

Scale-up requirements

Testing and deployment of the Ribbon NAPL Sampler has been successful in unconsolidated sediments at shallow to intermediate depths. Installation at greater depths in the saturated zone may require modification of the installation procedure. The system may also be applicable with other drilling techniques such as air rotary or sonic drilling and in fractured rock environments

Patents/Commercialization/Sponsor

The Ribbon NAPL Sampler was developed jointly by Flexible Liner Underground Technologies, Inc. and the Savannah River Technology Center and is commercially available from FLUTe™. Cone penetrometer services are widely available from vendors including Applied Research Associates Inc., Fugro Geosciences Inc., and Gregg In-Situ, Inc.

SECTION 5

COST

Methodology

This cost analysis was prepared in 1999 by MSE Technology Applications, Inc. at the request of the DOE's Subsurface Contaminants Focus Area. The cost scenario was developed for a specific application at the DOE Savannah River Site (SRS) where the technology was evaluated. The cost data were obtained from a variety of sources including the SRS and from commercial vendors who perform this type of work. Because this is a highly competitive industry, an attempt was made to keep from identifying specific companies that contributed to this analysis and their respective costs. In most cases, the cost data are in the form of unit costs, which are averages of expenses obtained from two or more vendors.

The objective of this cost analysis is to compare the expenses associated with DNAPL characterization using the RNS to the expenses for using the baseline sampling and analysis by GC/MS. At SRS, hollow-stem augers are typically used for collection of sediment samples. In many geologic environments, more robust sampling techniques such as sonic drilling or air rotary techniques are required and will significantly increase the cost of sample collection. To complete this cost analysis for the Ribbon NAPL Sampler, certain assumptions regarding where it was completed, the area and depth of the suspected contamination plume, and the frequency of sampling were made. These assumptions were obtained from the principal investigators deploying this technology in the field.

It should be noted that the baseline system provides fundamentally different information. The baseline method can both identify and quantify the organic compounds contained in the sediment sample. The baseline technique is limited by the number of samples that can be recovered and analyzed.

Cost Analysis

For this analysis, it was assumed that the Ribbon NAPL Sampler would be used for DNAPL characterization in the vadose zone of a site with geologic characteristics similar to the 321-M solvent storage site at SRS. This site was selected for this analysis, as it is fairly typical example of a DNAPL source adjacent to a long-term solvent storage facility. At this site, a tank was located adjacent to a railroad car transfer facility and was used to store chlorinated solvents including trichloroethylene (TCE), perchloroethylene (PCE), and trichloroethane (1,1,1-TCA) from 1957 until 1984. Numerous spills and leaks occurred in the vicinity of the solvent storage tank releasing solvent to the subsurface. Characterization data collected at this site revealed high levels of chlorinated solvents (0.2% to 0.3% by weight) in shallow clayey and silty sediments. The extent of the plume comprises a cylinder with a radius of approximately 29 feet down to a depth of 130 feet.

For this scenario, it was assumed three membranes would be emplaced from ground surface to a depth of 130 feet below surface using the CPT and a two-person crew. Unit costs used in this analysis are typically averages of cost data obtained from vendors that commercially perform this type of work. Unit costs are summarized in Table 2-1.

Assumptions:

- These unit costs were used to calculate the total costs for pushing, mobilization and demobilization, materials, standby, decontamination, grouting, and per diem.
- The equipment expense for the reusable pressurized canister is the depreciated value using the straight-line method for an estimated useful life of 3 years.
- Although the absorbent ribbon can be sampled and sent to a laboratory for analysis, this cost analysis assumes this will only be an evaluation to determine the location of NAPL zones.
- Because the Ribbon NAPL Sampler is removed and visually inspected for color changes that indicate the presence of DNAPLs, there is no cost for laboratory analysis for this innovative technology.

The assumed time at the site to complete the characterization using the Ribbon NAPL Sampler was assumed to be 4 days including mobilization and demobilization. It was also assumed there would be 1-1/2 hours of standby each day, one-half hour to decontaminate the equipment used, and a typical workday would consist of 10 hours.

Table 2-1. Unit costs for the installation of a Ribbon NAPL Sampler.

Description	Cost, $	Unit
CPT	7.25	Per foot
Ribbon NAPL Sampler	10.00	""
Color reactive material ribbon	5.00	""
Grouting CPT hole	2.50	""
Mobilization and demobilization	1,250.00	Per day
Per diem for two-person crew	165.00	""
Standby labor rate	231.00	Per hour
Decontamination labor rate	175.00	""

Baseline Scenario

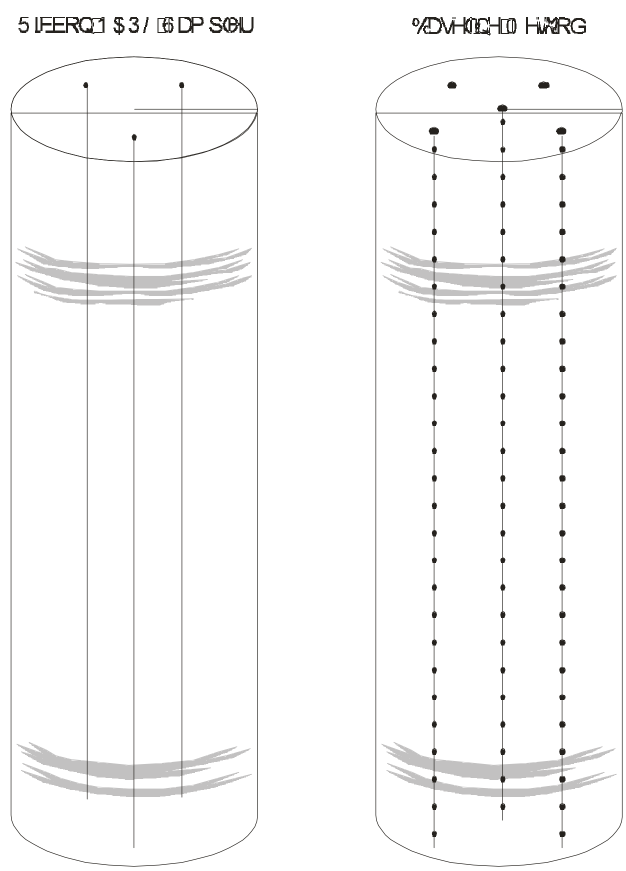


Figure 10. Schematic Diagram comparing baseline and innovative technology characterization scenarios at a vadose zone site with depth discrete contamination in two zones. The left cylinder shows three RNS which provide a continuous depth-discrete record of the distribution of contamination. The right cylinder shows the baseline example where sample locations are shown by the squares. At certain depths, baseline sampling at a 5-foot interval would miss some of the contaminated zones (see lower zone).

The baseline characterization was assumed to consist of five boreholes drilled using a hollow-stem auger with sediment samples taken every 5 feet. . Figure 9 schematically compares the baseline to the innovative sample density. This represents a somewhat high level of effort for a site like this with relatively high concentrations of solvent and a known documented source. In this analysis, the sediment samples are packaged and sent to an off-site laboratory for chemical analysis. This fieldwork was assumed to require a three-person crew, a driller and a helper to collect the core, and a sampler to collect the samples for analysis. These costs were used to calculate total costs for drilling, mobilization and demobilization, sampling, standby, decontamination, grouting, laboratory analysis, waste disposal, and per diem expenses. These unit costs are summarized in Table 2-2.

Table 2-2. Unit costs for the baseline sediment sampling and laboratory analysis.

Description	Cost, $	Unit
Hollow-stem auger	10.00	Per foot
Split-spoon sampling	20.00	Per sample
Grouting borehole	3.00	Per foot
Mobilization and demobilization	1,000.00	Per day
Per diem for three-person crew	150.00	""
Standby labor rate	170.00	Per hour
Decontamination labor rate	100.00	""
Drilling waste disposal	36.50	Per cubic foot
Laboratory analysis	144.00	Per sample

A total necessary time at the site to complete the characterization using the baseline technology was assumed to be 4 days including mobilization and demobilization. It was also assumed there would be 1-1/2 hours of standby each day, one-half hour to decontaminate the equipment used, and a typical workday would consist of 10 hours. This cost analysis does not take into account the turnaround time for the samples being sent to the laboratory.

Cost Conclusions

In this scenario, the use of Ribbon NAPL Sampler to detect DNAPLs would be considerably more cost-effective than the baseline. In this particular case, the total cost for the Ribbon NAPL Sampler would be approximately $15,213 compared to $34,199 for the baseline, resulting in a cost savings over the baseline technology of more than 55%. A large part of the total baseline expense can be attributed to the sediment sampling and laboratory analysis, which contributes to more than half of the total cost. The membrane does not require laboratory analysis when used as a qualitative test for detecting DNAPLs. Drilling the boreholes and disposing of the drilling waste also contributes significantly to the baseline technology cost. The installation of a Ribbon NAPL Sampler is completed using a CPT, which is not as costly as hollow-stem auger drilling and results in little waste. Major cost components of the Ribbon NAPL Sampler technology are the membrane and ribbon, and the cost to install these materials.

In a well-planned characterization strategy at a NAPL-contaminated site, the RNS could be used in conjunction with baseline sampling and analysis to optimize the selection of borehole and sampling locations.

SECTION 6

REGULATORY AND POLICY ISSUES

Regulatory Considerations

Special permits are not required for the operation of a cone penetrometer. The permit process should be similar or less stringent to that required for the baseline collection of sample with drilling rigs.

Safety, Risks, Benefits, and Community Reaction

Worker Safety

Occupational Safety and Health Administration (OSHA) requirements should be similar or less stringent than those required by baseline drilling and sampling because direct push methods are used.

- The hazards associated with the collection and analysis of samples are significantly reduced.
- The hazards associated with the containment, disposal, and treatment of secondary waste are significantly reduced or eliminated.
- Crew exposure is minimized because rods are cleaned before they are drawn into the truck.
- Data are collected in a more rapid manner thereby reducing the length of worker exposure to hazardous materials.

Community Safety

The use of this technology eliminates risk of exposure associated with shipping and analysis of potentially hazardous samples.

Environmental Impact

The use of the Ribbon NAPL Sampler should reduce the environmental impact of characterization activities.

- Drill cuttings or secondary waste is virtually eliminated.
- The penetrometer holes are smaller diameter and can be sealed during retraction of the rods.
- The penetrometer can be easily decontaminated with only a small volume of fluid.

Socioeconomic Impacts and Community Reaction

The use of the Ribbon NAPL Sampler should not have any socioeconomic impacts. Community reaction should be positive due to the use of an environmentally friendly technology.

SECTION 7

LESSONS LEARNED

Implementation Considerations

Th use of the Ribbon NAPL Sampler is restricted to sites where the contaminated zones are relatively shallow (<50 m) and the sediments are accessible using standard investigation techniques that are compatible with the installation of the RNS.

The program manager must work with regulators to assure acceptance of the data collected. The technology should be used to guide and optimize selection of sample locations for chemical analysis.

Technology Limitations and Needs for Future Development

Deployment of the Ribbon NAPL Sampler is currently limited to locations in the vadose zone where open boreholes are stable or where cone penetrometer techniques are capable of penetrating to the desired depth. Work is ongoing to extend the options for technology deployment to sonic drilling and other type of drilling systems such as cryogenic or other non-rotary systems. Advances might allow installation to deeper depths and other geologic materials such as fractured rock.

APPENDIX A

ACRONYMS

CPT	Cone Penetrometer Truck
DOE	U. S. Department of Energy
RNS	Ribbon NAPL Sampler
SRS	Savannah River Site
SCAPS	Site Characterization and Analysis Penetrometer System