In Situ Alcohol Flushing for the Remediation of NAPL Source Zones

IN THE PAST TWO DECADES, SEVERAL NEW APPROACHES HAVE BEEN DEVELOPED TO CHARACTERIZE CONTAMINATED SITES AND THEN REMEDIATE THEM.
THESE NEW CLEANUP TECHNOLOGIES MAY BE CLASSIFIED INTO FOUR BROAD GROUPS: CONTAINMENT, STABILIZATION, EXTRACTION, AND TRANSFORMATION.

THESE GROUPS OF TECHNOLOGIES ARE ALSO CALLED EX-SITU, WHEN CLEANUP INVOLVES EXCAVATION FOLLOWED BY ABOVE-GROUND TREATMENT OR DISPOSAL. IN-SITU TECHNOLOGIES ACHIEVE CLEANUP IN PLACE WITHIN THE SUBSURFACE SETTING BY PUMPING EITHER WATER OR WATER WITH ADDITIVES, SUCH AS ALCOHOL, STEAM, OR SURFACTANTS, TO ENHANCE THE EXTRACTION RATE. BUT ADOPTION OF THESE REMEDIATION STRATEGIES HAS BEEN LIMITED, SO A COMMITTEE APPOINTED BY THE NATIONAL RESEARCH COUNCIL EXAMINED BARRIERS TO COMMERCIALIZATION OF NEW CLEANUP TECHNOLOGIES IN THE UNITED STATES.

Dr. Suresh Rao: The committee found that the record of adoption of these new technologies was quite discouraging. And we found that traditional technologies, such as pump and treat are still the most popular method of choice at most sites. And we identified a series of interlinked factors, economic, regulatory, social and financial factors that contribute to this pattern of failure to adopt these new technologies that hold a lot of promise.
Carl Enfield - EPA: The reason it is so important to look at innovative techniques is that the current techniques won't solve the problem. They will leave the problem for not only our generation but the next generations to come.

ONE OF THE MAJOR FACTORS LIMITING COMMERCIALIZATION OF INNOVATIVE SITE CLEAN-UP TECHNOLOGIES IS THE LACK OF RELIABLE DATA ON FIELD-SCALE PERFORMANCE AND COST EFFECTIVENESS.

Rao: These new clean-up technologies hold considerable promise, but these practitioners, regulators and site owners are unwilling to adopt these new technologies., because they're concerned that if they fail they would have to start over...start over with additional technologies and pay more for that. And of course this adds to clean-up costs at the site.. So our goal, basically is to make this technology more credible. And credibility is achieved by conducting field scale tests at a number of sites under diverse conditions and have these data available for peer review... and to have a campaign desiminating this information to interested people including stakeholders and the public.

THIS VIDEO WILL SHARE RESULTS FROM THREE RECENT FIELD-SCALE TESTS OF IN SITU ALCOHOL FLUSHING TECHNOLOGY. THIS RESEARCH WAS CONDUCTED BY A TEAM OF SCIENTISTS FROM THE UNIVERSITY OF FLORIDA AND THE US EPA IN COLLABORATION WITH OTHER PARTNERS TO EVALUATE THE PERFORMANCE OF USING ALCOHOLS FOR ENHANCED REMEDIATION OF NON-AQUEOUS PHASE LIQUIDS, KNOWN AS NAPLS. NAPLS ARE CLASSIFIED INTO TWO BROAD GROUPS: THOSE THAT ARE LIGHTER THAN WATER, CALLED LIGHT NAPLS OR LNAPLS, WHICH INCLUDE GASOLINE, DIESEL, OTHER FUELS, AND MINERAL OILS. AND THEN THERE ARE DENSE NAPLS OR DNAPLS, ONES THAT ARE DENSER THAN WATER, INCLUDING COAL TAR, CREOSOTE AND CHLORINATED SOLVENTS. LNAPLS TEND TO BE LOCATED IN A SMEAR ZONE JUST ABOVE THE WATER TABLE, BUT DNAPLS SINK DEEPER AND CAUSE MORE EXTENSIVE CONTAMINATION.

20:24 Lynn Wood: We've learned that the dense non-aqueous phase liquid such as chlorinated solvents are very, first of all very difficult to locate and sub-surface but even small sources of these can generate and create very large

contaminated ground water plumes which are, can continue for many, many years, decades if not longer, and it's very difficult to clean up the sub-surface once it's contaminated. We feel like a major effort should be focused, or at least a significant effort should be focused on addressing these small source areas where perhaps we may get a return on our investment, if these are removed and other processes may be available to address the dissolved lower concentration plumes that result from the source areas.

WHEN A SITE IS CONTAMINATED WITH NAPL WASTES, THE LOCATION AND DELINEATION OF THE SOURCE ZONES IS AN ESSENTIAL ELEMENT IN SITE CHARACTERIZATION, RISK ASSESSMENT, AND DESIGNING REMEDIATION ACTION PLANS. SOLUBILIZATION OF THE NAPL CONSTITUENTS WITHIN THESE SOURCE ZONES CAN PROVIDE A CONTINUOUS SUPPLY OF CONTAMINANT MASS THAT CONTRIBUTES TO THE GRADUAL EXTENSION OF THE DISSOLVED PLUME. FOR THIS REASON, SITE MANAGEMENT MUST INCLUDE PLANS TO CONTAIN OR ELIMINATE THE CONTAMINATION SOURCE AS A PART OF THE OVERALL CLEANUP STRATEGY. WITHOUT THE SOURCE REMOVAL - A GROUND WATER CLEAN-UP TECHNOLOGY WOULD HAVE TO BE APPLIED FOR SEVERAL DECADES.

UNIVERSITY OF FLORIDA AND EPA RESEARCHERS, IN COLLABORATION WITH U.S. AIR FORCE CONSULTANTS, AND STATE AGENCIES, HAVE EVALUATED THE PERFORMANCE OF IN-SITU ALCOHOL FLUSHING THROUGH A SERIES FIELD TESTS - TWO WITH DNAPL CONTAMINATION FROM PCE AND ONE CONTAMINATED BY AN AGED, COMPLEX, MULTI-COMPONENT LNAPL. ALL OF THESE EXPERIMENTS INVOLVED THE FOLLOWING SEQUENCE OF EVENTS.

SOIL CORING AND GROUND WATER SAMPLING IS THE FIRST STEP FOR QUANTIFYING THE AMOUNT AND DISTRUBUTION OF CONTAMINANT IN THE SOURCE ZONE. PARTITIONING TRACER TESTS ARE USED TO ESTIMATE NAPL VOLUME AND SPATIAL DISTRIBUTION WITHIN THE TEST ZONE. ENVIRONMENTAL APPLICATIONS FOR TRACER TESTS WERE DEVELOPED AT THE UNIVERSITY OF TEXAS AND FIELD TESTED BY THE UNIVERSITY OF FLORIDA DURING THE LAST FIVE YEARS AS A PART OF THE REMEDIATION TECHNOLOGY PERFORMANCE EVALUATIONS.

Rao: Partitioning tracers have the tendency to selectively dissolve into the NAPL source, so they can be used to identify areas where the NAPL is present in the subsurface. There is a list of several organic compounds, primarily methylated alcohols, that can be used as partitioning tracers. And a mixture of these tracers disssolved in water along with some non-reactive tracers are injected into the test zone, and as they migrate through the NAPL source zone, the partititioning tracers selectively partition into the NAPL, and as a result their rate of migration is slower compared to the non-reactive tracers. And this retardation then is measured in the rate of transport through the zone and allows us to estimate the mass of the NAPL present in the source zone.

THE NEXT PHASE OF THE STUDY IS THE IN SITU FLUSHING, USING ALCOHOL-WATER MIXTURES TO ACHIEVE ENHANCED SOLUBILIZATION.

Rao: In situ flushing with alcohol is one of many aggressive, innovative technologies that are available for cleaning up NAPL source zones. The NAPL source can either be extracted or can be destroyed in-situ, and the in-situ flushing is based on extraction. In this method, either alcohols or surfactants or other agents can be flushing through injection wells into the source zone, through the NAPL, dissolve it, or mobilize it and remedial fluids are then extracted through extraction wells. And this whole process is preferred because it achieved the goal of removing the source in the shortest possible time, compared to traditional technologies...and removal of source is

important issue as we've discovered that small sources can contribute to large contaminant plumes. And alcohol flushing in particular that we are developing at the University of Florida is a technology that the petroleum industry had used many years ago and had discontinued for various reasons. But we've found a new use for this old technology in the environmental field for cleaning up NAPL sites.

AFTER THE FLUSHING IS COMPLETE, A SECOND TRACER TEST IS RUN TO HELP DETERMINE THE DISTRIBUTION AND TOTAL MASS OF NAPL REMAINING IN THE TEST SITE. ANOTHER SERIES OF SOIL CORES AND GROUND WATER SAMPLES ARE ALSO TAKEN TO PROVIDE ADDITIONAL DATA FOR DETERMINING HOW MUCH NAPL MASS WAS REMOVED FROM THE SOURCE ZONE. IN EACH FIELD TEST, COLLECTIONS FROM THE MULTI-SAMPLERS WERE ANALYZED ON SITE TO PROVIDE A PRELIMINARY ASSESMENT OF HOW THE TEST WAS PROGRESSING AND TO MAKE MODIFICATIONS AS NEEDED. SAMPLES WERE ALSO SENT TO UNIVERSITY OF FLORIDA LABORATORIES FOR ANALYSIS USING GAS AND LIQUID CHROMATOGRAPHY.
THE COST OF DISPOSING FLUIDS PRODUCED IN THE TREATMENT PROCESS HAS ALSO LIMITED FIELD SCALE IMPLEMENTATION OF IN-SITU FLUSHING. OVERALL COSTS CAN BE GREATLY REDUCED BY TREATING THE WASTE FLUIDS AND LOWERING THE VOLUME DISPOSED OR BY REUSING THE ALCOHOL DURING TREAMENT. RESEARCHERS EVALUATED THREE TREATMENT TECHNOLOGIES AT THE FIELD SITES.

THE FIRST OF THREE PILOT-SCALE ALCOHOL-FLUSHING TESTS WAS CONDUCTED IN 1995, AT HILL AIR FORCE BASE, IN UTAH. TESTING TOOK PLACE AT A SUPERFUND SITE FORMERLY USED FOR EQUIPMENT MAINTENANCE AND TO TRAIN.FIREFIGHTERS.

BOB ELLIOTT, HILL AFB ENVIRONMENTAL RESTORATION DIV: This has been a maintenance depot since the 1940s and, as a result, has significant quantities of wastes that were generated associated with those maintenance activities. So although our problems are very similar to other problems at other Air Force Bases, the magnitude of the waste at these sites at Hill Air Force Base is significant in nature.

HILL AIR FORCE BASE WAS ALSO THE SITE FOR THE FIRST FIELD-SCALE EXPERIMENT USING PARTITIONING TRACER TESTS, WHICH ALLOWED UF AND EPA RESEARCHERS TO COMPARE DATA FROM TRADITIONAL SOIL CORING WITH LABORATORY ANALYSIS OF THE TRACERS.

Rao: Soil coring is a traditional method and allows us to get point estimates of NAPL concentrations because we extract a small sample and analyze it above ground. But the data is found to be highly variable, because they represent point estimates...and to get reliable data, we have to get a large number of tests which is costly. Partitioning tracers, in contrast provides data averaged over much larger volumes...and so they tend to be generally less variable and more reliable.

THE SAND AND GRAVEL AQUIFER AT THE SITE IS CONTAMINATED WITH A COMPLEX LNAPL, A MIXTURE OF JET FUEL AND ORGANIC WASTE. THIS NAPL IS DISTRIBUTED IN A TWO-METER DEEP SMEAR ZONE, JUST ABOVE THE THICK CONFINING CLAY UNIT AT THE SITE. RESEARCHERS CONDUCTED THEIR FLUSHING EXPERIMENT IN A TEST CELL INSTALLED WITHIN A LARGE SOURCE ZONE OF LNAPL. THE FLUSHING SOLUTION WAS A MIXTURE OF 78% ETHANOL, 12% PENTANOL, AND 10% WATER. PENTANOL WAS ADDED TO EXTRACT MORE OF THE COMPLEX LNAPL AT THIS SITE. A TOTAL OF 10 PORE VOLUMES WERE INJECTED.

DR. MICHAEL ANNABLE: The co-solvent flushing study at Hill Air Force Base was conducted inside of a test cell that was keyed down into a confining unit

twenty feet deep and we characterized the contaminants inside the test cell using both partitioning tracers and soil cores. The NAPL was an LNAPL. It was a complex mixed waste of solids and fuels that was very hydrophobic and very difficult to remove. And the soil cores and partitioning tracers both showed that the NAPL distribution was highest near the confining unit and lower about 3 or 4 feet above the clay unit. So we had a non-uniform distrubution of oil that we needed to target with the co-solvent flushing technique. Graphics Start Here Flushing with an alcohol water mixture was efficient in extracting a significant fraction of the NAPL mass from the test cell. As the alcohol flood proceeded, the solubilization caused a rapid increase in the NAPL constituents. As the NAPL mass was completed, concentrations gradually dropped. Towards the end of the alcohol flood, concentrations in much of the test cell were low, and only a small amount of NAPL remained near the bottom. This result was due to inefficient hydrodyamic content in this low permeability zone. Data from soil cores taken after the alcohol flood , and tracer test results confirmed that NAPL constituents had been extracted in the upper zone, and a small amount of NAPL remained near the bottom.

Annable: We flushed about 40,000 liters of a ten day period and removed about 200 liters of NAPL. This gives us an efficiency of about 5 liters of NAPL for every 1000 liters of alcohol flushed. We succeeded in getting about 80 to 90 percent effectiveness overall.

SAGES, Jacksonville , FL
FIELD TESTING CONTINUED WITH A PILOT-SCALE DEMONSTRATION AT SAGES, A FORMER DRY CLEANER FACILITY IN JACKSONVILLE, FLORIDA, WHERE THE OWNERS VOLUNTEERED TO PARTICIPATE IN A CLEANUP PROGRAM OFFERED BY THE FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION.
DOUGLAS FITTON -– Environmental Specialist, FL DEP: The Dry Cleaning Solvent Cleanup Program was established at the request of the industry to try and address some issues regarding liability for contamination at contaminated dry cleaner sites, particularly with an eye toward the Mom and Pop type facilities where they wouldn't have the resources to address the contamination issues at those sites.

LEGISLATION WAS PASSED TO FUND THIS VOLUNTARY CLEANUP PROGRAM THROUGH TAXES AND FEES ON THE DRY CLEANING INDUSTRY. NEARLY HALF OF FLORIDA'S 2800 CURRENT AND FORMER DRY CLEANER SITES QUALIFY TO PARTICIPATE, BUT THEY HAVE TO PROVIDE EVIDENCE OF CONTAMINATION.

FITTON: Part of the program is to go out and assess and quantify how much contamination is there and then address that appropriately. So, there's a significant number to be addressed, and we've found that significant numbers of the ones that we've looked at to date seem to have a significant environmental impact at them.

THIS SITE CONTAINED THE DRY CLEANING SOLVENT, PCE IN THIN LAYERS OF THE SHALLOW UNCONFINED SAND AQUIFER. ETHANOL FLUSHING WAS INITIATED TO SOLUBILIZE THE PCE. HOWEVER, THE FLUSHING STRATEGY HAD TO MINIMIZE THE POTENTIAL TO MOBILIZE THIS DNAPL.

ANNABLE: We started the alcohol injection about twenty four hours ago and we started out by injecting alcohol just into the lower zone of the aquifer. So, rather than inject the alcohol uniformly everywhere, our goal was to get it

into the lowest parts of the aquifers first and we're now in the process of bringing the alcohol up into shallower and shallower parts of the aquifer.

THE CONTAINMENT OF FLUIDS WITHIN THE TEST ZONE WAS ACHIEVED WITH HYDRAULIC CONTROL BY MANAGING FLOW INTO A SET OF INJECTION AND EXTRACTION WELLS.

Annable: We're using consumable grade alcohol that's injected into the ground, but we make every effort to make sure it's hydraulically controlled. So we inject it we're injecting it into three wells that are surrounded by six wells that are pumping at a greater rate than the rate that we're injecting. We also confirm that we have hydraulic control by conducting the tracer test a week or so ago. We use that to make sure that whatever we inject in the ground, which was tracers the first time around, that we can hydraulically control that and pull it back out. Once we confirm that, then we move into the alcohol phase and inject that and we'll confirm that we've pulled the alcohol back out of the ground and we'll continue to pump ground water until we get it all out.

THE SAGES SITE WAS ALSO USED TO TEST A COMMERCIAL MICRO-POROUS POLYMER PACKING SYSTEM, FOR REMOVING PCE FROM THE EXTRACTED FLUIDS. HOWEVER,THE DILUTED ALCOHOL WAS NOT RECYCLED, DUE TO PERMITTING ISSUES.

Rao: The study that we conducted at the Sages site had three important features. It was the first field-scale demonstration of a DNAPL site with alcohol flushing. It was done in collaboration with a commercial partner, and it was done not in test cell, like the other two sites, but was hydraulic contained. And at this site, with the DNAPL being distributed in a sparse fashion, meaning in thin layers within the test zone, it was important to achieve high efficiency by flushing with alcohols. We had two primary goals at this site... One was to achieve significant solubalization of the DNAPL and not cause mobilization, which is a concern. Second was to achieve increased solubility in a very short period of time, less than two weeks. We flushed about 40,000 liters of ethanol, and recovered by solubalization approximately 40 liters of PCE. During the alcohol flood the concentrations of the extracted fluids rose rapidly and reached a maximum of 1600 parts per million. And this is considerably higher than the aqueous solubility limit we would have achieved with water flushing. And these concentrations declined gradually during the flood as the rapidly as the PCE mass was depleted. The efficiency of the extraction to be achieved a function of how the PCE is distributed. At this site, sparse distribution meant that we would probably get low efficiency. Based on partitioning tracer tests we conducted before and after the alcohol flushing, we determined that effectiveness achieved was about 60 to 70%. The efficiency of alcohol flushing turned out to be about one liter of PCE extracted per one thousand liter of alcohol flushed. This number is considerably lower than what we found at the Hill Air Force Base site, and this is attributed to the sparse distribution of PCE at this site.

THE FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION IS CURRENTLY EVALUATING THE TEST RESULTS FROM SAGES, TO DETERMINE IF ALCOHOL FLUSHING CAN BE USED AT OTHER DRY CLEANER SITES WITHIN THE STATE.

Dan Didominico - Fla DEP - The co-solvent flushing test at Sages Dry Cleaners site enabled us to get some very useful information that's necessary to enable us to scale the project up to full-scale applications. We went out there and actually applied it in an actual situation, real-life situation, not a

laboratory situtation, that enabled us to get a lot of performance characteristics, cost data and efficiency type data.

SUCCESSFUL TESTING AT SAGES MAY LEAD TO APPLICATION AT OTHER SITES AS WELL.

Kevin Warner-Levine, Fricke, Recon Environmental Consulting: We're also going to apply this at other facilities in the state of Florida. And basically those are moving through the regulatory process and part of that movement is due to the pilot test at the Sages facility.

DOVER AFB - Dover, Delaware

THE THIRD FIELD-SCALE EXPERIMENT TOOK PLACE AT DOVER AIRFORCE BASE IN DELWARE -- HOME TO A FLEET OF C-5 PLANES AND THE NATIONAL TEST SITE. TESTING AT DOVER WAS DONE IN COLLABORATION WITH USEPA AND THE US AIR FORCE BROUGHT A NEW SET OF CHALLENGES.

Annable: The study at Dover Air Force Base had two primary objectives. The first was to evaluate the reliability and accuracy of the partitioning tracersfor defining and distribution and volume of PCE inside the test cell. This was a blind test where the EPA researchers released an undisclosed amount of PCE at various location within the test cell. And it was our job to try to locate and quantify that. We did that by conducting a partitioning tracer test using both extraction wells and multi-level samplers to try to find and quantify the amount within the test cell. The second objective was to conduct a co-solvent flushing study to try to remove the PCE that was there. This was conducted using ethanol as a consolvent flood and was conducted over about a forty day period to remove the PCE released by EPA researchers.

THE INJECTION OF FLUIDS INTO THE TEST CELL IS FOCUSED INTO TWO ZONES - WATER IN THE UPPER ZONE AND ETHANOL IN THE LOWER ZONE.

Annable: Those two zones are separated by a packer system that keeps the fluids from coming in contact with each other within the well. So within the well vertically there is a packer that's down at the bottom. The alcohol comes in through a line that passes through the packer and flows into the lower part of the zone, and the water just flows in above this.

Flushing Animation: DURING THE FLUSHING PROCESS, ETHANOL IS INTRODUCED INTO THE LOWER ZONE OF THE TEST AREA, AND WATER IS PUMPED INTO THE UPPER ZONE. THIS HELPS MINIMIZE GRAVITY AND DESEGREGATION OF OF THE ETHANOL. THE PACKERS ARE RAISED IN STEPS UNTIL THE ENTIRE TEST ZONE IS FLUSHED WITH ETHANOL DISSOLVING THE PCE. THEN THIS PROCESS IS REVERSED. THE PACKERS ARE LOWERED IN STEPS AND THE ETHANOL IS GRADUALLY REPLACED WITH WATER.

THROUGH OUT THE FLUSHING PROCESS, SAMPLES ARE TAKEN FROM A NETWORK OF MULTI-LEVEL SAMPLERS AT OVER A HUNDRED LOCATIONS AND VARIOUS DEPTHS WITHIN THE SYSTEM.
(Revise this)

Annable: What you're seeing and hearing here are celanoid valves that turn on and off. What they do is apply pressure and vacuum to in affect pump the water or push the water up from about 35 to 40 feet down, push the water up through stainless steel lines into a sampling vial so we can collect the samples. These continually run during the entire test so we get continued flow through these

multi-level samplers and we take samples on the two or three or four hour intervals to get basically snapshot pictures of the concentration distribution everywhere within the test cell so we can analyze again for ethanol or PCE so we can see how effective the ethanol is moving through the aquifer and how much PCE it's solubalizing as it moves through the aquifer.

THE DOVER SITE DEMONSTRATED A GOOD WAY TO REDUCE CLEANUP COSTS BY USING A GRANULATED ACTIVATED CARBON SYSTEM TO REMOVE PCE FROM THE EXTRACTION FLUIDS, ALLOWING THEM TO BE REUSED.

Annable: So we're not generating any new waste. We've got a closed system for the upper water zone. Right now in the lower zone the waste... ethanol concentrations are just starting to come up. That waste is going out to a holding tank and when the ethanol concentration reaches about 70% we're going to start treating that waste by the same method. We'll bring that ethanol waste, send it through activated carbon canisters, and our goal there is to take the PCE out so that we can reuse that ethanol send it back in and it has a very low PCE concentration so we can solubilize more the next time we pass it through the cell.

THE DOVER SITE RESEARCH WAS FUNDED BY THE STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM WHICH IS A COOPERATIVE EFFORT BETWEEN THE DEPARTMENT OF DEFENSE, THE DEPARTMENT OF ENERGY AND THE EPA, TO COMBINE KNOWLEDGE AND RESOURCES FOR DEVELOPING NEW TECHNOLOGIES.

Paul Devane - Air Force Bio-Environmental Engineer: Not all DNAPL sites are not going to be the same. One that may work here in Dover may not work in a different situation where we have fractured bedrock. So it's important to try the different technologies to find one that's robust enough to take throughout the nation and work in different hydra-geological conditions.

IN-SITU ALCOHOL FLUSHING IS JUST ONE OF SEVERAL TECHNOLOGIES BEING EVALUATED AT THE NATIONAL TEST SITE.

Devane: As recently as 2 or 3 years ago there was no way to clean up DNAPL source zones and people were spending millions and millions of dollars per year and it would take years and years of pumping and treat methods to be able to contain DNAPLs and still not solve the problem. The work with the University of Florida, they are on the forefront of this surfactant and cosolvent flushing technology and along with the thermal technology it looks very promising.

Annable: Based on the tracer test, we estimate that about 81 liters of PCE was released into the test cell. EPA scientists later revealed that they release 92 liters of PCE. The total mass of PCErecoved in this test was estimated to be about 53 liters, and about half of this was extracted during the alcohol recycling phase. Our preliminary estimates are that we achieved about 65% effectiveness and an efficiency of about one liter of PCEremoved per 1000 liters of ethanol flushed. Without alcohol recycling the efficiency would have been about half a litre PCE per 1000 liters of alcohol flushed.

THESE THREE PILOT TESTS FOCUSED ON CONDUCTING RESERACH TO EVALUATE FIELD-SCALE PERFORMNACE OF IN-SITU ALCOHOL FLUSHING FOR ENHANCED SOURCE-ZONE REMEDIATION. IMPROVEMENTS IN DESIGN AND IMPLEMENTATION WERE MADE IN EACH SUCCESSIVE TEST.

Didominico: Some technologies will be useful given a certain set of parameters, certain set of conditions out on a site, and some won't be applicable. What we need to do is increase the arsenal we have available to us. In other words, we need to improve the number of tools we have in our tool belt. This co-solvent flushing techniques has proven to be a promising tool that we can add to our tool belt.
THE FIELD TESTS ALSO ALLOWED RESEARCHERS TO COLLECT ADDITIONAL DATA TO EVALUATE DESIGN AND SITE FACTORS THAT CAN LIMIT PERFORMANCE.

Enfield: Using some of these newer techniques, we can probably finish the job in the matter of a few years rather than centuries. So, it dramatically reduces the time and therefore the liability that's sitting out there for the long term. Now it's true that the cost of doing the short-term cleanup is expensive, even at the present time, and what we have to do is figure out ways to make that more cost effective. We've demonstrated that we can do it; what we haven't done is optimized the performance such that it's very cost effective and cheap.

SUCCESSFUL COMMERCIALIZATION OF INNOVATIVE CLEANUP TECHNOLOGY REQUIRES CREDIBLE FIELD-SCALE PERFORMANCE IN TESTS WHERE SITE OWNERS, GOVERNMENT AGENCIES, CONSULTING COMPANIES, AND ACADEMIA WORK TOGETHER TO BUILD CONFIDENCE IN NEW CLEANUP METHODS. THE NEXT LOGICAL STAGES IN THE DEVELOPMENT OF THIS TECHNOLOGY ARE: (1) FULL-SCALE DEMONSTRATION, AND (2) ENGINEERING IMPROVEMENTS TO MAKE THE TECHNOLOGY MORE COST-EFFECTIVE.