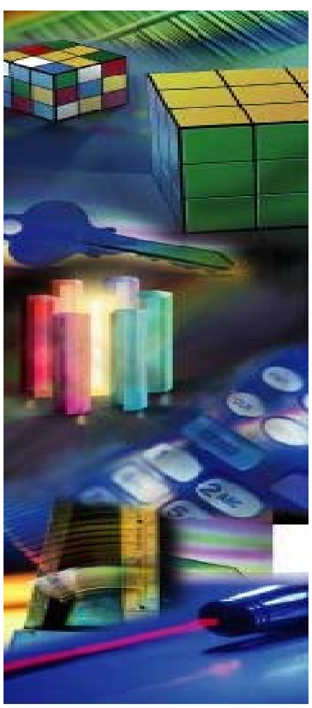
Current Environmental Solutions

Statement of Qualifications



LEADERS IN
ELECTRIC RESISTANCE HEATING
SINCE 1997

WE ARE CELEBRATING OUR 10TH YEAR
OF BEING THE WORLDWIDE LEADER IN THERMAL
TREATMENT OF SOIL AND GROUNDWATER.

Section 1: CES Company Overview

Current Environmental Solutions (CES) was formed as a Limited Liability Company (LLC) in 1997 under a license agreement with the Battelle Memorial Institute(BMI), the original developer of the Electric Resistance Heating (ERH) and Six Phase Heating (SPH) technology for the US Department of Energy. CES was the first licensee to all BMI polyphase subsurface heating patents in 1997. The only other licensee to the BMI patents has only had their license since January 2003, giving CES more than five (5) years experience than any other licensed competitor in applying the BMI patents. Since our formation, we have completed projects throughout the United States, and we have expanded our service internationally through a license agreement with Terravista bv in the Netherlands. Terravista now provides the SPH technology in the Benelux countries. After a vigorous due diligence, Terravista chose to sublicense through CES due to CES' vastly greater success and experience in applying subsurface electric resistive heating (ERH).

As the internationally recognized leader in the ERH technologies, our personnel include scientists, engineers, and technicians whose focus is to continue improving and adapting the ERH technology to meet difficult environmental challenges. Following are a selection of industry breakthroughs and successes achieved by CES over the past six years:

- **In 2003 the CES team (including prime contractor and subcontractors) who completed the Hunter Army Airfield SPH project were nominated by the US Army Corps of Engineers for the *Savannah District's Trainer's Award* for the "Project and Team of the Year" .**

- **CES ACHIEVED THE WORLDS FIRST DNAPL SITE CLOSURE in 1999 at a former manufacturing facility.**

- **CES ACHIEVED THE SECOND DNAPL SITE CLOSURE in 2000. The contamination extended under a building and under a public-access road. Methylene chloride was reduced to target concentrations by thermally accelerated hydrous-pyrolysis. These closures are unprecedented successes in the remediation industry.**

- **CES in 1999 ACHIEVED FIRST ERH CLEANUP OF PCE, TCE, and cis-1,2 DCE to EPA Maximum Contaminant Levels (MCLs). This was achieved under an operating strip mall where much of the remediation area was public access, and heating was in the presence of buried utilities. This achievement was another first for electrical resistance heating.**

- **CES DEMONSTRATED THE FIRST COMBINATION OF SIX-PHASE HEATING AND MULTI-PHASE EXTRACTION for LNAPL cleanup. The site contained as much as 10 ft of aviation fuel floating on the groundwater in a tight silty clay lithology, and the site treatment goal of less than 1/8 in. was achieved.**

- **CES' SIX-PHASE HEATING WAS SELECTED "BEST IN CLASS" for DNAPL remediation technologies in terms of cost, effectiveness, and speed by the Interagency DNAPL consortium (IDC) consisting of NASA, U.S. EPA, U.S. DOE, U.S. DOD, and the U.S. Air Force.**

- **CES SUCCESSFULLY DEPLOYED SIX-PHASE HEATING in a side by side technology demonstration of SPH, Steam Injection, and Permanganate Injection in 1999 at the Launch Complex 34, Cape Canaveral Florida. SPH was the fastest, most effective, and most cost-effective technology tested, and the only technology that met the 90% DNAPL removal goal.**

CES...."***FIRST*** in Electric Resistance Heating"
"WORLDWIDE LEADERS IN ERH SINCE 1997"

FIRST to license ERH patents from BMI. Greater then 5 years more experience over any other competitor.

FIRST to commercialize ERH.

FIRST to deploy ERH using both six phase and three phase configurations.

FIRST to design and deploy safety grounding methods for ERH.

FIRST to develop a comprehensive R&D laboratory for ERH bench tests.

FIRST to perform laboratory bench test for ERH & electrode corrosion tests.

FIRST to develop comprehensive site evaluation form.

FIRST to develop sophisticated numeric modeling for ERH cost & performance.

FIRST to close a DNAPL site using ERH.

FIRST to close an LNAPL site using ERH.

FIRST to meet drinking water MCLs from DNAPL using ERH.

FIRST to develop sophisticated numeric modeling for ERH cost & performance.

FIRST to license ERH in Europe.

FIRST to design and build a power supply to European Union Electric Code.

FIRST to remediate a site in Europe using ERH.

FIRST and ***ONLY*** ERH vendor personally invited by former **Secretary of State, General Alexander Haig,** to appear on ***WORLD BUSINESS REVIEW*** along with the U.S. Department of Energy.

FIRST and ***ONLY*** ERH vendor nominated by the U.S. Army Corps of Engineers for the *Savannah District's Trainer's Award* for the "Project and Team of the Year" .

Mission Statement

"Current Environmental Solutions is a growing environmental company improving the quality of life for our employees, clients, and communities by providing proven and innovative environmental restoration solutions. We are sought after and recognized worldwide for our technological and service leadership. We partner with our clients to provide creative and cost effective solutions using unique electrical techniques. Our employees thrive within an enjoyable atmosphere of opportunity, teamwork, and success."

Office Locations

CES maintains offices in the following locations:

Administration, Contracting, Legal :
909 NE 11th St
Grand Prairie, TX 75050
T: (972) 262-7855
F: (972) 262-6655
C: (267) 784-9234

Operations and Project Management:
35528 Fairview Heights Rd
Zephyrhills, FL 33541
T: (813) 782-0236
F: (813) 782-0493
C: (813) 786-5757

Equipment Design & Manufacture, R&D Laboratory:
P.O. Box 3848
Pasco, WA 99302
T: (509) 783-7174
F: (509) 783-6762
C: (509 727-2022

Field Supervision and Engineering
436 Beachwood Blvd.
Beachwood, NJ 08722
T: (203) 410-1741
F: (732) 240-9583

California

191 Baldwin Ave
Crockett, CA 94525
T: (510) 787-9934
F: (510) 77-9962
C: (925) 864-9628

316 Avocet Ave
Davis, CA 95616
T: (530) 758-6774
F: (530) 758-5353
C: (530) 848-6885

Services

At CES, we believe that our success will only follow the success of our clients and licensees. We partner with our clients to provide creative and cost effective environmental solutions using unique electrical techniques. Our services range from turnkey remediation projects, to technology licensing, training, and equipment manufacture.

Today, CES brings a wealth of experience and a track record of success to every site evaluation and remediation we perform. Our technical know-how and ability to enable clients to close difficult sites is unparalleled in the thermal remediation industry.

- **Site Evaluations -** CES has developed a proprietary site evaluation form that identifies the critical parameters required to quickly evaluate and predict the cost and performance of SPH for any particular site.

- **SETI™ Site Evaluation Testing -** A comprehensive on-site electrical resistance evaluation that identifies critical site electrical characteristics and design parameters for SPH remediation and safety sub-systems.

- **Numerical Modeling -** Some SPH applications benefit from numerical modeling to evaluate and optimize SPH, vapor extraction, or safety system designs. We offer several well-validated numeric codes capable of modeling vapor flows, vapor composition, electric power distribution, heat transfer, and other parameters.

- **Laboratory Testing –** We perform a wide range of testing services to evaluate treatability, soil dynamic electrical properties, and in-situ degradation rates. We also have strategic alliances with some of the nations' leading universities to offer world class laboratory and experimental capabilities associated with DNAPL fate and transport.

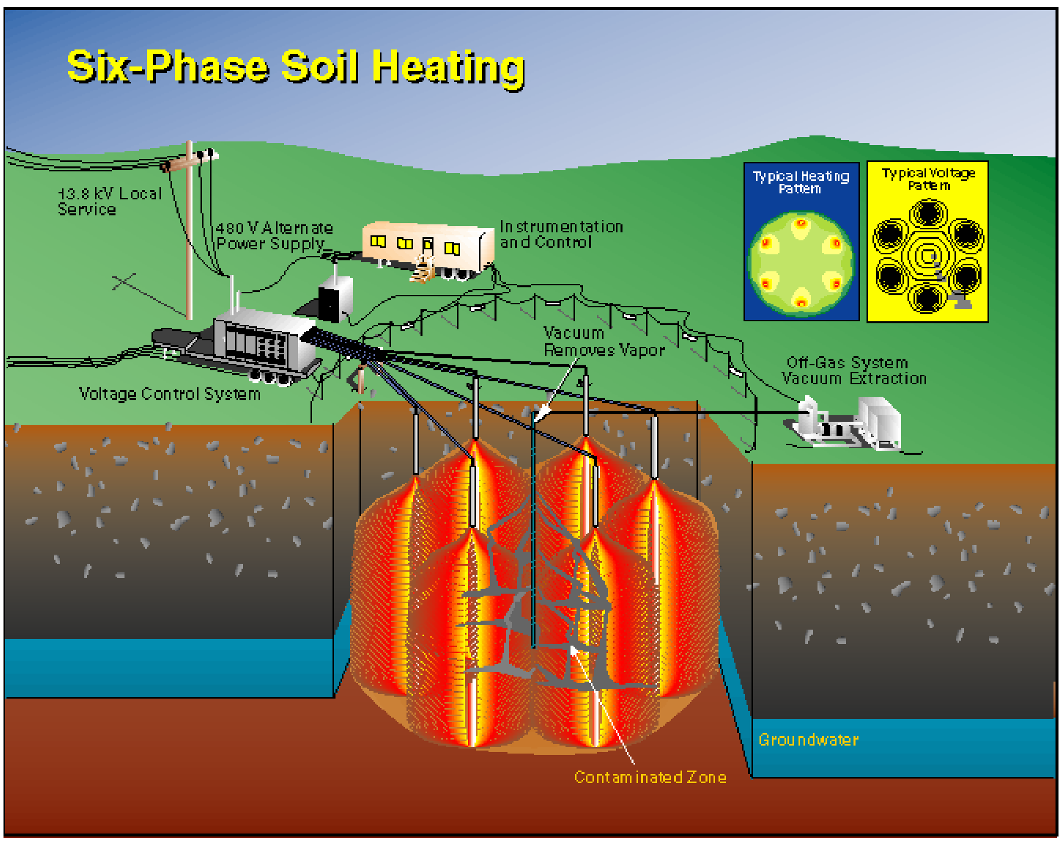
- **Equipment Manufacture -** CES designs, manufactures, and sells or leases the specialty poly-phase subsurface heating equipment including systems for power delivery, steam and vapor recovery, and air and water treatment. CES has successfully designed and manufactured power supply units to European electric code. These unit(s) have been independently tested and certified by KEMA, the Dutch equivalent of UL Laboratories.

- **Technology Partnerships -** Services range from turnkey remediation to licensing and overseeing the technology deployment. We can license the technology either on a site-by-site or permanent basis. CES also provides specialized equipment and technical support to help our licensees achieve success.

Six-Phase Heating (SPH) Technology and Electric Resistance Heating (ERH)

SPH and ERH use polyphase electricity in either a three or six phase configuration to resistively heat the soil and groundwater to the boiling point of water. Heating increases the volatility of contaminants. Steam is generated, and acts as a carrier gas that strips out contaminants as it rises. The steam is collected from the subsurface by a soil vapor extraction process, and treated above ground by conventional means, including air stripping, activated carbon, and catalytic or thermal oxidization.

SPH provides an efficient and rapid means of remediating soil and groundwater that are contaminated by volatile and semi-volatile organic contaminants. Other applications for SPH include accelerating degradation and reducing viscosity for pumping. Both degradation and viscosity are dramatically affected by heat. CES has successfully degraded contaminants as a primary treatment mechanism on two sites and performed reduced-viscosity LNAPL extraction on two other sites.



SPH and ERH Licensing Status

CES was the FIRST exclusive licensee of the BMI patents in 1997 and currently maintains a worldwide license and sublicensing rights to the BMI poly-phase subsurface heating patents listed below. In 2002, CES and BMI reached an agreement to convert the exclusive license to a non-exclusive license, whereby CES gained significant financial incentives on all subsequent licenses granted by BMI for an undisclosed period of time. Beyond the patents, CES has invested over $2 million in further refinement of the technology, which has resulted in a suite of intellectual property owned exclusively by CES. We have the ability to sublicense the BMI patents, and we offer licensing of the patents as well as our own intellectual property.

The only licensed competitor to CES has only been licensed by BMI since January 2003, whereas CES has been actively deploying ERH since 1997. Hence, CES' actual field experience in applying ERH exceeds that of any other company by more than 5 years. Most importantly, CES' VP of technology, William Heath, was the PRIMARY INVENTOR of ERH during his previous employment with BMI, and he is the only one in the industry actually named on the BMI patents.

BMI Patents	
In-Situ Heating to Detoxify Organic Contaminated Soils United States Patent, 4,957,393 Buelt et al. (Sept. 18, 1990)	Heating of Solid Earthen Material, Measuring Moisture and Resistivity United States Patent, 5,330,291 **Heath**, et al. (July 19, 1994)
Heating to Detoxify Solid Earthen Material Having Contaminants International Patent, WO 93/09888 Heath et al. (May 27,1993)	Treating of Solid Earthen Material and a Method for Measuring Moisture Content and Resistivity of Solid Earthen Material United States Patent, 5,347,070 **Heath** et al., September 13, 1994
	Heating of Solid Earthen Material, Measuring Moisture and Resistivity United States Patent, 5,545,803 **Heath** et al., August 13, 1996

We have licensed the SPH technology in Belgium, Netherlands, and Luxembourg exclusively to Terravista BV.io. Should you have interest regarding SPH in these areas, please contact Terravista at:

Terra Vista BV. io.
Kruisweg 835
2131 N.G. Hoofddorp
The Netherlands

Tel: +(31) (0)23 569 25 78
Fax: +(31) (0)23 569 25 88

Registrations and Licenses

Members of CES staff or affiliated companies hold Professional Engineering, Geologist or Electrician Licenses in the following states and US Territories

NY, NJ, CT, TX, NC, GA, CA, WA, FL, MI

Insurance

CES maintains the following standard insurance:

Comprehensive General Liability and Pollution Liability	**$5,000,000** per occurrence **$5,000,000** aggregate
Professional Liability	**$5,000,000** claims made **$5,000,000** aggregate
Automobile Liability	**$1,000,000**
Workman's Comp. & Employer's Liability	**$1,000,000**

OSHA Training & Medical Monitoring

CES employees maintain OSHA 40 hr. initial Health & Safety training and 8hr. annual training in compliance with OSHA 1910.120. Also, CES employees undergo annual medical monitoring which exceeds OSHA requirements.

Section 2: CES Experience

A History of Electric Resistance Heating

ERH and SPH were first conceived of in 1987 as a way of pre-drying soil for in-situ vitrification- an in-situ technology that converts soil into glass. Other in-situ thermal treatment technologies existed, such as steam injection, hot air injection, and radio frequency heating, but these technologies have difficulty in low permeability soils, and they do not transfer energy to the soil or groundwater as efficiently as SPH.

With potential applicability to decontamination of volatile organic contaminants (VOCs) from soil, the United States Department of Energy awarded funding to Battelle Memorial Institute (BMI) to develop SPH as a stand-alone technology. Several years of research and development led to the first field pilot study at a DOE site in Savannah River, GA. It took just 9 days to heat to 1000 cubic yards of soil to 100°C. An additional 17 days of boiling demonstrated the ability of SPH to remove VOCs from both clay and sand. This demonstration, along with further research and development led to three more BMI patents. These included an international patent (**Heath** et al., May 1993) for six-phases of electricity for heating (and hence, the name); A U.S. patent (**Heath** et al, Jul 1994) which specified six-phase electricity to achieve even heating patterns within the treatment region; and a U.S. patent (**Heath** et al, Sept 1994) which detailed variations of six–phase and three-phase heating schemes.

BMI performed a second field demonstration 1996 at a Niagara Falls Army Fire Training pit where BTEX and chlorinated VOCs were removed during the one-month remediation. A fifth BMI patent (**Heath** et al., Aug 1996) added a number variations of the poly-phase electrical heating scheme, including the now familiar ERH triangle pattern CES commonly uses for larger sites.

In February, 1997, a field study was conducted at Dover Air Force Base, Delaware, to determine whether or not SPH could heat an aquifer sufficiently to remove DNAPL contaminants. The 30-day test demonstrated the ability of SPH to heat rapidly heat a flowing aquifer and remove tracers mimicking DNAPLs.

Current Environmental Solutions (CES) was formed in April of 1997 by BMI to commercialize the poly-phase subsurface heating technology. In 2002, CES became an independent company.

From July through December 1997, CES performed a field verification study at Fort Richardson, Alaska that consisted of three sequential SPH arrays. In this study, CES succeeded in removing more than 99% of the DNAPL. Moreover, CES successfully demonstrated the effectiveness of larger electrode arrays (i.e. 40 ft spacing as opposed to the standard array of about 24-30 ft spacing). CES also began to develop new site surface grounding techniques for safety systems that led to the ability to heat in public-access areas such as roads, parking lots, and beneath occupied buildings. The demonstration was successful, and CES was contracted and completed the site remediation with three additional arrays during 1999.

Following the Fort Richardson success, the next SPH project was an experiment with heat-accelerated bioremedation followed by a test of steam stripping of benzene and diesel in a bake-off between SPH and radio-frequency (RF) heating at Ft. Wainwright, Alaska. The temperature was held at 35 °C for three months (April through June, 1998), then raised to 100 °C and held for another month. Microbial activity was significantly increased, and the diesel degradation rate was doubled. Then, continued subsurface heating up to 100°C resulted in much faster reduction of benzene and diesel concentrations. SPH was concluded to be more efficient and reliable than RF heating.

SPH was then deployed full-scale on a .86-acre commercial site in Skokie, IL. This project commenced in June 1998, and it was completed in April 1999. At this site, CES achieved the world's first regulatory site closure for a chlorinated DNAPL site with a letter of "No Further Action" (NFA) issued by the Illinois EPA on August 10, 1999.

Concurrently with the Skokie site, CES conducted a pilot study for a major oil company on a river island in Cincinnati, OH during October and November of 1998. Flood warnings resulted in a decision to shorten operating time, but the project goal of 98% reduction in benzene was accomplished as well as 80% removal of diesel components from the groundwater in silt and clay in just 31 days of heating.

From April through July of 1999, SPH was used to lower PCE levels to MCLs beneath an active shopping mall in Seattle, Washington. This was the first time subsurface electrical heating was safely performed in a public-access area and in the presence of buried utilities. The proprietary safety grounding techniques developed by CES to enable this were monumental developments for the technology.

Did You Know?

- CES' Six-Phase Heating couples energy to soil with 97% efficiency.
- CES' Six-Phase Heating uses fewer electrodes to heat to higher temperatures than any other electrical heating technology for minimum installation cost.
- In 1995, Six-Phase Heating won the international R&D 100 award (similar to the Oscars for the technology industry) for being the one of the top 100 technologically significant inventions in 1990.
- SPH has been covered in business week, popular mechanics as well as numerous trade publications.
- In 1999, CES' SPH was selected as BEST IN CLASS for DNAPL technologies by an Interagency DNAPL Consortium (IDC) consisting of NASA, US EPA, US DOE, US DOD, and the US Air Force.

Between May and December of 1999, CES deployed the SPH technology at a site where as much as 10 ft of kerosene and diesel were floating on the groundwater in a low permeability silty clay soil. The site to the treatment objective of <1/8-in. of NAPL was achieved.

The remediation of methylene chloride from tight silty clay began on a large industrial site from October of 1999 to November of 2000. This was the first in-situ degradation-based cleanup using SPH. The site received our second prized NFA letter from the Illinois EPA.

The famed "Cape Canaveral Demonstration" took place from August 1999 through July 2000. In side by side demonstrations, the three top-rated technologies for DNAPLs (i.e. SPH, Steam Injection, and Permanganate Injection) were compared for cost, effectiveness, and speed. SPH was the only technology to meet the DNAPL removal objectives within the specified treatment time. In fact, we achieved 99% removal of DNAPL while the treatment goal was set at 90%. SPH also proved to be half the cost of the other technologies tested.

In June and July of 2000, CES performed a pilot study at a site containing ethylene dibromide (EDB) in Newark, CA. Although complications existed because of the high conductivity of the brackish groundwater, and the site average temperature reached only 80 °C, the EDB was removed entirely from the groundwater due to heat-accelerated hydrolysis. This event of heat-accelerated degradation was another step forward in refining the applicability and cost effectiveness of SPH. A comprehensive R&D campaign including laboratory testing of modified electrodes and contaminant degradation research enabled CES to treat brackish sites and to better define thermally accelerated degradation reactions.

Heating began at a large TCE DNAPL site in Portland Oregon, in May of 2000 and continued through February of 2002. The treatment objective was to remove all DNAPL from fine silts with a high organic carbon content. At the beginning of this project, CES™ observed the lateral migration of steam due to a confining layer above the contaminated zone which prevented effective vapor capture. CES mitigated this situation with an innovative deep-submerged venting scheme. This was the first MULTIPHASE STEAM CAPTURE on a site where a confining layer prohibited vapor extraction above the water table. This system was able to contain lateral migration of contaminants and capture steam well below the water table, thereby significantly increasing the applicability of ERH to the remediation industry. In March 2002, the client received a letter from the Oregon Department of Environmental Quality indicating that the DNAPL was had been successfully removed and furthermore, that most areas were treated within **DRINKING WATER MAXIMUM CONTAMINANT LIMITS (MCLs).** **The letter stated *"We are very encouraged at the apparent success of this technology in addressing what is typically a highly intractable problem."***

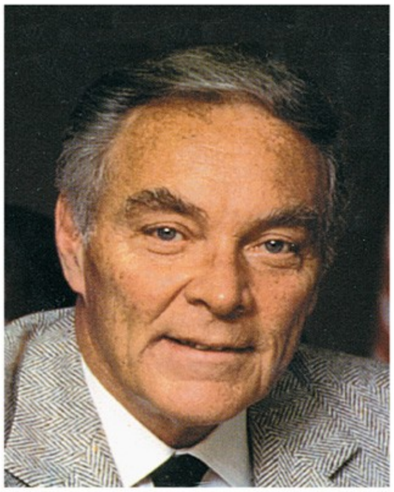
In August 2001, CES executed a license agreement in the Netherlands with Terra Vista, BV, io. Terra Vista is now licensed to perform SPH in Belgium, Netherlands, and Luxembourg, and they are currently progressing with specially modified equipment which CES helps to design and build to European specifications.

In March 2002, CES began operating on an LNAPL extraction site at a US Army Air Base in Georgia. There was up to two feet of weathered gasoline and diesel on the groundwater as well as dissolved benzene concentrations as high as 2700 μg/L. The goal of the remediation was to remove the LNAPL and reduce benzene concentrations to 469 μg/L. After three months operations, sampling indicated that the LNAPL was entirely removed and benzene concentrations were a maximum of 125 μg/L, surpassing the treatment objective. **Moreover, CES' ERH system successfully extracted more than 40,000 lbs of LNAPL in 8 weeks !**

Whereas the remediation of DNAPL sites was formerly considered very difficult, it now can be accomplished quickly and economically, even in tight soils using Six-Phase Heating. As we continue to refine and adapt SPH, new uses and broadening applicability are becoming available to the remediation industry. In-situ thermal degradation can now greatly reduce the energy and equipment costs on some sites. Reduced-viscosity pumping enables the removal of viscous NAPLs from soil, and this is quite attractive for remediation of **Manufactured Gas Plants (MGPs)**. Refinements in electrode and safety systems enable use of SPH in public areas. The development of deep venting techniques to capture steam underwater have broadened the applicability of SPH on very deep sites. Further refinements currently in progress are expanding the capabilities of SPH to handle more viscous DNAPLs such as coal tar, reductively dechlorinate PCBs in-situ, and to remediate larger sites more economically. Today, CES brings a wealth of practical field experience to each site.

As a result of CES' successes, superior technical expertise and experience, the CEO and COO of CES were personally invited by former Secretary of State, General Alexander Haig, to appear on his renowned *World Business Review* television program. The show aired in January 2003 to 150,000,000 potential viewers worldwide.

Alexander Haig's WORLD BUSINESS Review



Logo Courtesy of Multi Media Productions and WBR-TV

AFTER EXTENSIVE MEDIA RESEARCH INTO THE ELECTRIC RESISTANCE HEATING INDUSTRY, CES WAS THE ONLY ERH VENDOR SELECTED TO APPEAR ON ***WORLD BUSINESS REVIEW*** HOSTED BY FORMER SECRETARY OF STATE, **GENERAL ALEXANDER HAIG**. THE SHOW IS AVAILABLE VIA VIDEO LINK ON YAHOO BROADCAST AS WELL AS CES' WEB SITE. THE SHOW AIRED IN JANUARY 2003 ON PUBLIC TELEVISION AS WELL AS SYNDICATED BY MAJOR TELEVISION NETWORKS, INCLUDING ABC, CBS, FOX AND UNITED AIRLINES.

PLEASE CONTACT CES FOR INFORMATION REGARDING THE ABAILITY TO VIEW THE ON-LOCATION FOOTAGE AND PANEL DISCUSSIONS VIA WEB LINKS.

"**INNOVATION** at its finest.....

APPLICATION through science and technology.....

DEDICATION to excellence and closure....."

www.cesiweb.com

REGULATORY ACCEPTANCE

The following resources are available to research regulatory acceptance of Six Phase Heating (SPH).

The Interstate Technology Regulatory Council (ITRC) Website: http://www.itrc.org

ITRC is a state-led coalition working together with industry and stakeholders to achieve regulatory acceptance of environmental technologies. ITRC is a state and federal cooperation to break down barriers and reduce compliance costs, making it easier to use new technologies, and helping states maximize resources. ITRC accomplishes its mission in two ways: it develops guidance documents and training courses to meet the needs of both regulators and environmental consultants, and it works with state representatives to ensure that ITRC products and services have maximum impact among state environmental agencies and technology users.

The ITRC has published guidance documents for DNAPL source remediation that can be downloaded at http://www.itrcweb.org/user/DNAPL-2.pdf

Contact information is located at the following URL:
http://www.itrcweb.org/common/content.asp?en=NA33663&sea=Yes&set=Both&sca=Yes&sct=Long

The US Environmental Protection Agency Technology Innovation Office
Website: http://www.epa.gov/swertio1/

The Technology Innovation Office's Web Site provides information and resources related to the characterization and treatment technologies for the hazardous waste remediation community.

The following URL contains a PDF version of the EPA report:
"In Situ Thermal Treatment of Chlorinated Solvents: Fundamentals and Field Applications"
http://clu-in.org/products/thermal

Section 3: CES Management Team Resumes

CURRENT ENVIRONMENTAL SOLUTIONS

Joseph A. Pezzullo, P.E.

President/CEO

Education

B.S.E., 1978, Geological Engineering, Princeton University, Princeton, NJ

B.S.E., 1978, Civil Engineering, Princeton University, Princeton, NJ

Marine Geology, 1976, West Indies Laboratory, St. Croix, USVI

Schlumberger Geophysical Logging School, Bathgate, Scotland 1977

Certified Professional Diver in Marine Science, 1976 NAUI License SP-903

Registered Professional Engineer, Texas 59884

History

2000 – Present	Current Environmental Solutions President/CEO
1987 – 2000	Terra Vac Corporation, Vice President
1982 – 1987	Keplinger/Mccord-Lewis Energy Services, Sr. Petrophysicist/ Sr. Petroleum Engineer
1978-1982	Societe' de Prospection Electrique, Schlumberger Overseas Well Services, Senior Geophysical Engineer
1977	West Indies Laboratory, Professional Science Diving Team

CES Experience and Key Accomplishments

As the president/CEO of CES, Mr. Pezzullo is responsible for all corporate and fiduciary matters for the commercialization of the SPH soil and groundwater remediation technology. Mr. Pezzullo also pioneered CES's international expansion by negotiating and executing SPH licensing in Belgium, Luxembourg, and Netherlands (Benelux).

Related Experience and Key Accomplishments

Mr. Pezzullo was responsible for more than 400 remediation projects worldwide during his 13-year tenure with Terra Vac. Significant achievements were:

Successful implementation of Terra Vac's Superfund Innovative Technology Evaluation (SITE) demonstration (1987/88) for in-situ vacuum extraction at the Groveland Wells Superfund Site, Groveland Massachusetts under the auspices of EPA.

Mr. Pezzullo negotiated the export of environmental technology in the form of joint ventures and license agreements in Japan (1990), United Kingdom (1993), and France (1993). Other key exporting accomplishments involve agent representations in Singapore (1993), Sweden (1997) and obtaining the first ever funding from the Overseas Private Investment Corp. (OPIC) to perform environmental restoration work in Ukraine.

In 1997, pioneered Terra Vac's Ukraine Operations where Terra Vac conducted the first self-funding clean-up at a former Soviet airbase in Ukraine with jet fuel recovery and resale of more than 100 metric tons per month. As a result of this, Mr. Pezzullo was selected as the Keynote Speaker for the North Atlantic Treaty Organization's (NATO) annual science conference held in Vilnius Lithuania in October 1997. His speech concerned NATO and former Soviet base conversions in Europe, Eastern Europe and NIS focusing on the social and economic ramifications associated with environmental impairment and innovative methods to implement self-funding environmental solutions at bases under conversion for development and civilian use.

Pioneered ISO 9001 quality certification (1997) for Terra Vac (UK) Ltd. Currently maintained.

From 1990 to 1998 served as Managing Director of NST Entec Co. Ltd., Terra Vac's joint venture company in Japan. Implemented the fist in-situ clean up of chlorinated solvents in Japan, and also an in-situ remediation of the Kumamoto Prefecture well field, which was contaminated with trichloroethylene.

From 1992 to 1998 served as Director of GeoVac, SA, Terra Vac's joint venture company in France. Organized emergency response work for the train derailments at Chavanay and La Voulte utilizing in-situ recovery techniques for the removal of hydrocarbon products from derailed train tankers.

Prior Experience:

KEPLINGER/ MCCORD-LEWIS ENERGY SERVICES
Managed petroleum engineering projects and petrophysical evaluations for a multinational petroleum engineering consultant. Managed private and World Bank funded oil and gas exploration projects worldwide, including training of international groups on petrophysical evaluations in oil and gas E&P.

Instructor in Petroleum Engineering and Petrophysics at the Imperial College of London.

Worldwide experience including Africa, Middle East, Europe, and Asia

SOCIETE' de PROSPECTION ELECTRIQUE SCHLUMBERGER SCHLUMBERGER OVERSEAS WELL SERVICES, Paris, France and London, England:
Performed a wide range of oil field well services throughout Europe and the North Sea; including geophysical surveys, wireline logging, production and reservoir testing and petrophysical evaluations for major oil and geothermal clients. Responsible for the supervision, training, and management of rig service personnel in several remote locations. Corporate training for nuclear H&S, emergency response activities, and blow-out prevention.

WEST INDIES LABORATORY, St. Croix, U.S.V.I.
Member of a professional science diving team responsible for the geological mapping of a sub-sea canyon at Salt River Bay, St. Croix under funding from Exxon Research Foundation and U.S.G.S.

Obtained Professional Diving License in Marine Science form the National Association of Underwater Instructors (NAUI). License # SP-907.

Patents
Process for Soil Decontamination by Oxidation and Vacuum Extraction, US Patent No: 5,615,974 and European Patent No: EP 0741611

Board of Directors

President, Current Environmental Solutions

Director, Terra Vac Corp.

Director, Terra Vac, Inc.

Director, Terra Vac (UK), Ltd.

Former Managing Director, NST Entec Co. Ltd (Japan)   sold 1998

Former Director, GeoVac,sa   (France) sold 1997

Professional Affiliations

Registered Professional Engineer, Texas 59884

Society of Petroleum Engineers(SPE of AIME)

Society of Professional Well Log Analysts(SPWLA)

National Ground Water Association(NGWA)

Certified Professional Commercial Diver, National Association of Underwater Instructors

Honors

Nominated as honorary member of "Who's Who Worldwide"

Publications

On request

CES
CURRENT ENVIRONMENTAL SOLUTIONS

William O. Heath,

Chief Operating Officer

Education

B.S. Chemical Engineering, 1982. University of Washington, Seattle, WA

History

2001-Present	Current Environmental Solutions, Chief Operating officer
1998-2001	Current Environmental Solutions, Chief Technical Officer
1982-2000	Battelle Memorial Institute, Senior Research Engineer

Experience

Mr. Heath is the primary inventor of ERH and the Chief Operating Officer of CES. With over 20 years of experience as a research & development engineer, Mr. Heath is recognized internationally as an expert in the development and commercialization of technologies for detoxifying organic wastes based upon electrical fields. Mr. Heath manages the technical and operations staff at CES, provides oversight of Six-Phase Heating (SPH) remediation designs, client development, and sales and marketing.

As Chief Technology Officer for CES, Mr. Heath developed CES' laboratory capabilities used to evaluate treatability, electrical soil properties, and investigate thermally accelerated in situ contaminant degradation processes.. He developed the Site Evaluation Test Instrument (SETI) that CES uses to establish electrical characterization data for remediation design and electrical grounding. He continues to advance the state of the art and fundamental understanding of the SPH technology and thermal treatment systems. He represents CES in the ad hoc Thermal Remediation Industry Group, maintaining relationships and collaboration with major participants in this new and growing field.

At Battelle, Mr. Heath was the principal inventor and developer of the ERH and SPH technologies, which started as small research project in 1989. This grew into a multi-million dollar, multidisciplinary R&D program that Bill managed, called ERACE (Electrical Remediation At Contaminated Environments). The program successfully developed and demonstrated four new technologies including SPH for treating organic contaminants in air, water, and soil. All four technologies were patented and are in varying stages of commercial development and deployment. Two of the four, the Gas-Phase Corona Reactor (GPCR) and **SPH received the distinguished R&D Magazine Top 100 Award in 1993 and 1995, respectively as among “100 of the most technologically significant advances of the year”.**

Mr. Heath is an invited lecturer for the American Institute of Chemical Engineers and the American Nuclear Society, holds five U.S. patents, and has authored over 40 technical publications.

Honors

R&D 100 Award, naming the Gas Phase Corona Reactor as "one of the 100 most technologically significant advances" of 1993.

R&D 100 Award, naming Six-Phase Soil Heating as "one of the 100 most technologically significant advances" of 1995.

Selected Patents

Heath, W.O., P.A. Gauglitz, G. Pillay, T.M. Bergsman, E.A. Eschbach, S.C. Goheen, R.L. Richardson, J.S. Roberts, and R. Schalla. 1996. Heating of Solid Earthen Material, Measuring Moisture and Resistivity. United States Patent 5,545,803.

Heath, W.O., R.L. Richardson, and S.C. Goheen. 1994. Method and Apparatus for Solid Earthen Material. United States Patent 5,999,231.

Heath, W.O., R.L. Richardson, and S.C. Goheen. 1994. Heating of Solid Earthen Material and Measuring Moisture and Soil Resistivity. United States Patent 5,330,291.

Heath, W.O., R.L. Richardson, and S.C. Goheen. 1993. Decontamination of Soil by Electric Heating. Foreign Patent WO 9309888 A1.

Selected Publications

P.A. Gauglitz, J.S. Roberts, T.M. Bergsman, S.M. Caley, W.O. Heath, M.C.Miller, R.W. Moss, R. Schalla, M.H.Schlender, T.R. Jarosch, C.A. Eddy-Dilek, and B.B. Looney. 1994. Six-Phase Soil Heating for Enhanced Removal of Contaminants: Volatile Organic Compounds in Non-Arid Soils Integrated Demonstration, Savannah River Site. PNL-10184. Pacific Northwest Laboratory, Richland, Washington.

Gauglitz, P.A., J.S. Roberts, T.M. Bergsman, S.M. Caley, W.O. Heath, M.C. Miller, R.W. Moss, R. Schalla, T.R. Jarosch, and C.A. Eddy-Dilek. 1994. Six-Phase Soil Heating Accelerates VOC Extraction from Clay Soil. PNL SA-24002. Presented at International Nuclear and Hazardous Waste Management Conference, August 14-18, Atlanta, Georgia.

Heath, W.O. and M.J. Truex. 1994. Enhanced In Situ Bioremediation Using Six-Phase Electrical Heating. Presented at In Situ Remediation: Scientific Basis for Current and Future Technologies, November 7-11, 1994, Pasco, Washington.

Gauglitz, P.A., J.S. Roberts, T.M. Bergsman, W.O. Heath, M.C. Miller, R.W. Moss, R. Schalla, and M.H. Schlender. 1994. Field Test of Six-Phase Soil Heating at the Savannah River Site. PNL SA-24002. Presented at In Situ Remediation: Scientific Basis for Current and Future Technologies, November 7-11, 1994, Pasco, Washington.

Bergsman, T.M., J.S. Roberts, D.L. Lessor, and W.O. Heath. 1993. Field Test of Six-Phase Soil Heating and Evaluation of Engineering Design Code. PNL-SA-21537. Presented at Waste Management '93, February 28-March 4, Tucson, Arizona.

Heath, W.O. 1993. ERACE (Electrical Remediation at Contaminated Environments). Presented at Environmental Restoration Technical Interchange Symposium, March 16-19, Salt Lake City, Utah.

Heath, W.O. 1993. "In Situ Heating to Destroy and Remove Organics from Soils" in Smith, L.A. And R.E. Hinchee, In Situ Thermal Technologies for Site Remediation, CRC Press, Boca Raton, Florida.

Bergsman, T.M., J.S. Roberts, W.O. Heath, and D.L. Lessor. 1993. Six-Phase Heating to Enhance Removal of Contaminants. Presented at Second Semi-Annual OTD Information Meeting, Houston, TX.

Heath, W.O., S.C. Goheen, M.C. Miller, and R.L. Richardson. 1992. "Investigation of Electric Fields For Low-Temperature Treatment of Soils and Liquids", Proceedings of the 1992 U.S. EPA/A&WMA International Symposium on In Situ Treatment of Contaminated Soil and Water, VIP-24. Air & Waste Management Association, Pittsburgh, Pennsylvania.

J.S. Roberts, T.M. Bergsman, D.L. Lessor, W.O. Heath. 1992. Field Test of Six-Phase Soil Heating and Evaluation of Engineering Design Code. Presentation at Technology Information Exchange, Fall 1992.

Heath, W.O., J.S. Roberts, D.L. Lessor, and T.M. Bergsman. 1992. Engineering Scale up of Electrical Soil Heating for Soil Decontamination, DOE Spectrum'92.

Heath, W.O. 1990. In Situ Heating for Organic Waste Destruction. Presented at Department of Energy Thermal Treatment of Soil/In Situ Vitrification Workshop, August 8-9, Richland, Washington.

Heath, W.O. 1990. In Situ Heating to Destroy and Remove Organics from Soils. Presented at Department of Energy/Air Force Joint Technology Review Meeting, February 6-8, Atlanta, Georgia.

Heath, W.O. 1990. In Situ Heating Process for Destroying and Removing Organic Contaminants from Soils. PNL-SA-18154, Pacific Northwest Laboratory, Richland, Washington 99352.

Heath, W.O. 1990. Development of In Situ Heating for In Situ Soil Treatment. PNL-SA-185035, Pacific Northwest Laboratory, Richland, Washington 99352.

Brouns, T.M., S.S. Koegler, W.O. Heath, J.K. Fredrickson, H.D. Stensel, D.L. Johnstone, and T.L. Donaldson. 1989. Development of a Biological Treatment System for Hanford Groundwater Remediation. PNL-7290, Pacific Northwest Laboratory, Richland, Washington 99352.

Koegler, S.S., T.M. Brouns, W.O. Heath and R. J. Hicks. 1989. Biodenitrification of Hanford Groundwater and Process Effluents: FY 1988 Status Report. PNL-6917. Pacific Northwest Laboratory, Richland, Washington 99352.

Paul D. Armstrong
Operations Manager

EDUCATION

Cam Tech School of Construction – General Contractor (2005)
Hillsborough Community College- AABC 2004 (Building Construction)
Saint Mary's College 1983-1986: Majored in Business
Four Rivers Technical School 1982-1983: Majored in Process Technology
Lewis and Clark Technical School 1976: Majored in Process Technology

TRAINING

Loss Prevention System (LPS) Training Certification May 2004
30 Hr OSHA Outreach Program for Construction Industry 2003
Fernando Rodriguez & Associates, Puerto Rico, 1999: EPA/AHERA Certified Asbestos inspector.
University of North Florida, 1990: Hazardous Waste Site Supervisor- Certificate
OSHA 40 Hr Hazardous Trained, 1989

HISTORY

2007- Present	Current Environmental Solutions, Operations Manager
2002-2007	Handex Consulting & Remediation, Southeast, Construction Manager & General Contractor
1996-2002	Terra Vac Southeast Operation Group, Operations Manager
1990-1996	Terra Vac International Operations, Field Supervisor
1987-1990	Terra Vac Southeast, Remediation Specialist
1986-1987	Colds Pump & Machinery, Plant Manager
1975-1986	Nash Engineering, Sr Technical Representative

RELAVENT EXPERIENCE

Twenty years experience in remedial system construction, investigations, remedial design, operations, technician management, and client relationships. Currently, project manager for an ERH system installation located in the mid-west with over 400 electrodes and a $3 mil budget. Previous projects involve Florida State contracting for the Petroleum Cleanup Program. Managed over 50 construction projects with Florida state contracts with approximate value of $10 mil. Managed over 100 projects in environmental construction, source removals, assessments, remediation services, and auto lift removals. Previous projects have involved evaluation and application of traditional and innovative remediation technologies, including in-situ chemical oxidation treatment, air sparge, dual vacuum extraction and electrical resistive heating (ERH).

Previously, the Florida state qualifier (general contractor) for former company's construction business and responsible for all construction activities statewide and the senior project manager for the construction of remedial systems throughout the southeast and the largest remedial construction project for the Florida DEP Pre-Approval Program.

Project Manager for the largest ERH remediation system construction and operation in ERH history for a private industrial client with TCE as containment of concern. Responsible for the installation of 400 electrode system with muliti-year construction & operational phases. Planned the construction logistics, managed subcontractors, equipment purchases, and personnel for the project. Direct responsibilities for project planning, budget management, and client management.

Technical Operations for the large ERH system operation at Hunter Army Air Field base. Provided daily operational assistance to the project manager. Performed routine system performance adjustments and maintenance.

Project Manager for the largest remediation system construction in the FL Pre-Approval Programs. Responsible for the installation of 400 wells air sparge & vent system with a 1-year construction phase. Negotiated the contract with the State with a budget for construction of $2.7 million. Planned the budget, logistics, equipment purchase, and personnel for the project. Direct responsibilities for project planning, budget management, and client management.

Project Manager for a numerous remediation system installations in the FL Pre-Approval Programs. Remedial systems include air sparge & vent with 12 to 100 wells and source removals. Negotiated the contract with the State with a budget for construction. Planned the budget, logistics, equipment purchase, and personnel for the project. Direct responsibilities for project planning, budget management, and client management.

Project Manager for a large source removal project at St Mark Refinery, St Marks, FL. Supervised the excavation project to remove 4500 tons of petroleum impacted soil in 6 weeks. Planned the budget, logistics, equipment, and personnel for the project. Responsible for development of final report. Direct responsibility for project planning, budget management, and client management.

Project Manager for a direct chemical oxidation project at Prudhoe Bay, Alaska. Performed pilot test on diesel fuel soil pile with soil concentration greater than 1000 ppm. Supervised the onsite pilot test and achieved a 50% reduction in diesel impact in a 5 day test. Planned the logistics, equipment, and personnel for the project. Responsible for development of final report and developing second phase of remediation. Direct responsibility for projects planning, budget management, and onsite manager.

Project Manager for the subsurface remediation at an industrial facility in Puerto Rico. The site was impacted by #6 fuel oil with 2 feet of free product. The project included the installation of 20 dual soil vapor extraction (DVE) and 50 chemical oxidation injection points. The wells were connected to several manifolds that lead to three separate remedial systems, including recovered groundwater, vapor phase recovery, and recovered free product. The site was closed in February 2000 by approval of the local regulatory agency by a combination of risk-based and groundwater and soil clean up goals achieved. Responsible for projects planning, budget management and onsite operations.

Project Manager for the subsurface remediation at major oil service station. Managed the design, construction, and operation of the treatment system resulting in the cleanup of the site over a three-year period. The systems included over 19 dual-phase extraction wells. The following processes treated extracted groundwater: oil/water separation, filtration, and liquid phase carbon adsorption. Treated groundwater was discharged to onsite infiltration gallery. Extracted vapors were treated with by direct dispersion. Responsible for project planning, budget management and system operations.

Project Manager for numerous Phase I, II, and III site assessments in Puerto Rico. Supervised the general process, client relationship, and responsible for the local staff achieving client satisfaction. Responsible for project planning, budget management and process development.

Project Manager for automotive hydraulic lift removal project in various cities in Puerto Rico. Develop the closure plans, H & S plans and gain approval from local regulatory agency to proceed. Responsible for the final closure report and obtaining final regulatory agency closure with no further action required. Direct responsibility for project planning, budget management, client satisfaction, client relationship, client liaison with regulatory agency, and site manager.

Project Manager for the subsurface investigation at a major oil refinery in Puerto Rico. Accountable for the onsite crew installation of over 400 Geoprobe soil borings. Provide detailed reporting on soil conditions and summary of investigative procedures. Direct responsibilities for project planning, budget management, client satisfaction, client relationship, and site manager.

Project Manager for monthly ammonia monitoring program at a major pharmaceutical manufacture including monthly reporting and budgetary control.

Purchasing Manager and Construction Supervisor for a large-scale SVE system installed as an emergency response in France. Onsite construction supervisor for the installation of the system. Responsible for the training the French technicians for efficient operations. Provided onsite system technical advisor role. Accountable for achieving cleanup goal deadline, which was achieved ahead of schedule. Direct responsibilities for project planning, budget management, client satisfaction, client relationship, and onsite manager.

Construction and Operations Manager for 4 SVE projects at electronic manufacturing plants Japan. Remediation systems were designed to recover free phase TCE from impacted groundwater and soil. Supervised Japanese subcontractor construction firms during installations of systems. Responsible for training Japanese technicians and engineers to operate systems. Responsible for overseas inventory and purchasing. Produced O & M manuals for the projects. Daily coordination with Japanese clients during all phases of construction and operations to ensure client satisfaction. Direct responsibility for project planning, budget development and management, client satisfaction, client relationship, and onsite manager.

PROFESSIONAL AFFILIATIONS

Certified General Contractor- Florida License # CGC1511522

APPENDIX A

Selected CES Project Summaries

TECHNOLOGY COMPARISON

Of DNAPL Technologies

Client: US DOE

Launch Complex 34
Cape Canaveral, FL

August 1999-July 2000

"CES' SPH VOTED BEST IN CLASS FOR EFFECTIVENESS, SPEED AND COST"

The Six-Phase Heating (SPH) technology was demonstrated at Launch Complex 34 at Cape Canaveral, Florida, as part of a multiple technology demonstration for the in situ remediation of dense non-aqueous-phase liquids (DNAPL). Representatives of the US Department of Energy, US Environmental Protection Agency, National Risk Management Research Laboratory, National Aeronautics and Space Administration, and the US Air Force formalized the Interagency DNAPL Consortium (IDC) in April 1999 to evaluate remediation techniques for their application to DNAPL. A technical advisory group (TAG) evaluated promising DNAPL remediation by requesting detailed bids from selected technology vendors to demonstrate their commercially available technology at a federal DNAPL site. The TAG ranked the top five technologies in consideration of cost, schedule, and regulatory issues, with results published as shown in the table below. Rating range from one (best) to five (worst). The TAG's overall acceptance was also a consideration. The three technologies selected by the TAG for demonstration were SPH, potassium permanganate injection, and steam injection.

Technology and Ranking	Cost	Schedule	Regulatory	TAG	RANK
1. Six-Phase Heating	2	1	1	1	1
2. $KMnO_3$ injection	1	3	3	1	2
3. Steam injection	4	2	1	2	3
4. Fenton's reagent	3	1	2	5	4
5. Surfactant flushing	5	5	5	3	5

SITE

The site consisted of fine sands to about 23 feet above an irregular layer of clayey fine sands Below the clayey sands was another layer of silty fine sand from 30 to 45 feet below grade (bg). The TCE DNAPL plume primarily residing along the surface of a clay aquitard at a depth of 45 ft. Three areas were demarcated as test cells to enable side-by-side demonstration of the three technologies. Each test cell measured 75 ft × 50 ft. The SPH and potassium permanganate injection technologies were demonstrated over roughly the same time period within the two end cells, approximately 70 ft apart. The last technology, steam injection, was planned for demonstration at a later date in the center test cell.

APPLICATION

The SPH system consisted of 13 electrodes completed to a depth of 43 feet bg. Vapor treatment was accomplished using a 20,000-lb vessel of granular activated carbon (GAC),

with a final polish by potassium permanganate impregnated onto silica to remove any vinyl chloride. Construction of the SPH system was completed over a three-week period.
The system was operated intermittently over an 11-month period, from August 18, 1999 through July 12, 2000. Beginning six weeks after operations were initiated, Cape Canaveral experienced two hurricanes (Floyd and Irene) and a tropical storm, resulting in unusually heavy rainfall from mid-September 1999 through the end of October 1999. The weather impacted SPH operations by damaging equipment, causing significant delays, and necessitating the redesign of vapor capture systems.

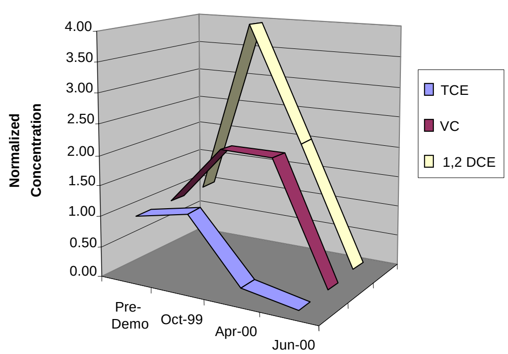
RESULTS

The demonstration was successful in that 97 % of the DNAPL mass was removed. However, the effect of SPH on dissolved-phase fractions of the contaminant could not be quantified because of large influxes of contaminated groundwater caused by tropical storms, and the nearby injection of nearly 2.7 pore volumes of an oxidant solution which created an artificial gradient adjacent to the SPH test area. Attempts to perform a total mass balance on the contaminants were similarly confounded.

Based on the production of elevated levels of chloride ion and other degradation byproducts throughout the demonstration, decontamination took place as follows:

- 44 % was removed via the primary route, an in situ degradation pathway
- 19 % was removed in the vapor phase by steam stripping
- Approximately 2 % was mobilized to the surrounding aquifer during a single flooding
- event caused by a tropical storm that occurred early in the demonstration
- The remaining 33 % could not be accounted for, but is likely to have been degraded in place
- Sampling wells and soil borings beyond the perimeter of the treatment area revealed a
- net decrease in contaminant levels, indicating that treatment extended beyond the boundaries of the test cell

The total cost of the SPH deployment was $569,000, including all costs for electricity, reporting, secondary waste treatment, equipment mobilization, and significant system modifications and repairs prompted by severe weather. This corresponds to a total unit cost of $\$91/yd^3$. Of this, the net cost for CES' SPH implementation (design, installation, operations, demobilization) was $\$65/yd^3$, and the cost of electricity was $\$12/yd^3$. For comparison, the total cost of the permanganate-injection demonstration was approximately $1,000,000, or 1.8 times the cost of the SPH technology. The DNAPL removal efficiency achieved by the permanganate treatment was 84 % compared with 97% achieved by SPH. The planned total cost for the steam injection demonstration was also around $1,000,000.



Typical monitoring well results

DNAPL REMEDIATION

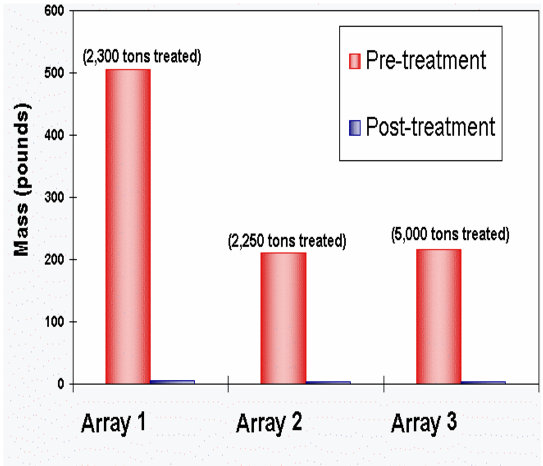
In Tight, Saturated Soil

Clients: URS-Woodward Clyde
US Army Corps of Engineers
United States Army

Fort Richardson,
Anchorage, Alaska

July – December 1997

The US Army Corps of Engineers conducted a design verification study of Six-Phase Heating (SPH) in Operable Unit B (OUB) at Fort Richardson in Anchorage, Alaska, to assess its potential to achieve OUB cleanup goals more rapidly than conventional soil vapor extraction methods.



AVERAGE SOIL CONTAMINANT MASS

The primary contaminants impacting the site were three chlorinated compounds, 1,1,2,2-tetrachloroethane, trichloroethylene (TCE) and perchloroethylene (PCE). Prior studies had indicated that, without heating, soil vapor extraction could take up to10 years to achieve OUB's cleanup goals. SPH was selected over steam injection and radio frequency heating because it had previously been shown to deliver energy to the subsurface more efficiently.

In three separate applications, each lasting six weeks, SPH successfully remediated dense non-aqueous phase liquids (DNAPL) from tight, saturated soil. Samples drawn after each six-week run (Figure 1) showed that more than 97 % of the primary contaminant had been removed at each array.

SITE

The lithology of the OUB site consisted of dense, low permeability, heterogeneous glacial tills. Three stacked aquifers existed between 8 and 40 ft below grade (bg).

The contamination by 1,1,2,2-tetrachloroethane, TCE and PCE extended to at least 35 ft bg. In the case of 1,1,2,2-tetrachloroethane, the soil concentration was up to 16,000 mg/kg, and the groundwater concentration was up to 1,900 mg/L.

TECHNOLOGY

SPH is emerging as a leading technology in difficult in-situ soil and groundwater remediation. It has proved an efficient, rapid means of remediating soil contaminated by volatile and semi-volatile organic contaminants.

The in situ cleanup of DNAPL remains one of the toughest challenges facing the remediation industry. Traditional remediation technologies require years of continued application to produce even marginal results at DNAPL sites.

The technology was developed for the US Department of Energy at Pacific Northwest National Laboratories. Current Environmental Solutions (CES) was the first licensee of this technology, as well as the proprietor of sundry improvements.

SPH uses polyphase electricity to resistively heat the soil and groundwater to the boiling point of water. This increases the volatility of contaminants, which improves the effects of vacuum extraction. Once steam is generated in situ, it acts as a carrier gas which strips out contaminants from the soil or groundwater. The steam is collected from the subsurface by a soil vapor extraction process, and treated aboveground by conventional means such as activated carbon, and catalytic oxidization.

APPLICATION

At Fort Richardson, three SPH arrays were used to treat DNAPL to a depth of 40 ft bg. Arrays 1 and 2 were 27 ft in diameter, while array 3 measured 40 ft. Combined, the arrays treated approximately 6,800 yd^3 of soil.

The SPH arrays consisted of six electrodes in a hexagonal pattern, with a neutral electrode in the center. These electrodes were inserted to a depth of 38.5 ft bg, and had the capacity to heat the soil from 10-40 ft bg. The three arrays were activated in sequence, and each operated for six weeks.

At each array, the temperature of the subsurface was increased to 100 °C during the first two weeks of heating. This caused the stacked aquifers to boil for the subsequent four weeks, producing steam which stripped contaminants from the soil matrix within the treatment area (Figure 2).

Contaminant-laden steam were collected at the electrodes by means of soil vapor extraction, was condensed to water and vapor, which was subsequently treated by air stripping and catalytic oxidization.

RESULTS

The contaminated soil was sampled before and after treatment. Sampling extended from inside each array to a distance of 40 % of the array diameter beyond each array.
Results for arrays 1 and 2 showed that, on average, 96-97 % of volatile organic compounds (VOCs) were removed, and 1,1,2,2 tetrachloroethane concentrations were reduced by 98-99 %.

Results for array 3 indicated an average VOC reduction of 44.5 %. However, seven of 12 soil samples removed from the interior of array 3 contained VOCs at concentrations below detection limits, and the average reduction of VOCs from the interior of array 3 was 96.7 %.

CONCLUSIONS

SPH successfully increased subsurface temperatures to the boiling point of water within days, and held that temperature throughout the design verification period.
Treatment at arrays 1 and 2 extended beyond the arrays by at least 40 % of the array diameters, but treatment was limited by the unusually large diameter of array 3.

NAPL REMEDIATION

From Low-Permeability Soil

Client: Fortune 500 Company

Former Consumer Product Manufacturing Facility, Georgia

May – December 1999

Current Environmental Solutions (CES) used Six-Phase Heating (SPH) and multi-phase extraction to remediate a free-floating hydrocarbon plume beneath a former manufacturing facility in Georgia. The hydrocarbon, a specialty fuel similar to kerosene or diesel fuel, covered an area of 4,900 ft^2 and up to l0 ft thick.

SITE

SPH was chosen for site remediation because conventional product recovery methods, such as pump and treat and multi-phase extraction, have a limited ability to remove light non-aqueous phase liquids (LNAPL) from low-permeability soils.
Most of the LNAPL was located beneath a 100,000-ft^2 building. The soil from the building floor to a depth of about 50 ft was composed of highly heterogeneous sandy clay saprolite, with moderately low permeability. Groundwater was encountered at 24 ft below grade (bg). Initially the LNAPL, which floated on the groundwater, covered an area 4,900 ft^2 and was up to 10 ft thick, with most wells containing 1-3 ft of LNAPL.

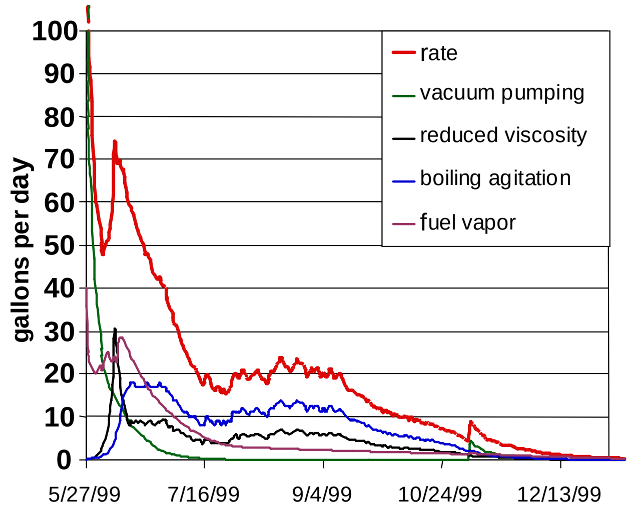
TECHNOLOGY

SPH is emerging as a leading technology in difficult in-situ soil and groundwater remediation. It has proved an efficient, rapid means of remediating soil contaminated by volatile and semi-volatile organic contaminants.

The technology was developed for the US Department of Energy at Pacific Northwest National Laboratories. CES has been applying the Battelle patents under a valid license since 1997. The only other licensee has experience in applying these patents just since January 2003, giving CES over five (5) years more experience than any other competitor.

SPH uses polyphase electricity to resistively heat the soil and groundwater to the boiling point of water. The heat increases the volatility and lowers the viscosity of the contaminants. Once steam is generated in situ, it acts as a carrier gas which strips out contaminants from the tight soil. The steam is collected from the subsurface by a soil vapor extraction process, and treated aboveground by conventional means, activated carbon, or catalytic oxidization.

APPLICATION



SITE MONITORING DATA DURING HEATING

Remediation work began on May 27, 1999. Altogether, 50 combination extraction and monitoring wells and SPH electrodes were installed. The electrodes were designed to heat the soil from 20 to 30 ft bg.

The remediation technology, as it was applied at this site, used several mechanisms to remove the hydrocarbon: Heating of the ground reduced the viscosity of the hydrocarbon, making it amenable to multiphase extraction; As the groundwater beneath the layer of LNAPL reached boiling point, rising bubbles of steam agitated the hydrocarbon and drove it towards the surface; Heating the ground also caused the LNAPL to boil, forming vapors which rose to the surface. Free product and vapors were extracted from the wells from 22 to 27 ft bg. The vapor was cooled in a condenser, and the steam was released to the atmosphere after a thermal oxidizer had destroyed the hydrocarbon vapors. An oil-water separator was used to remove separate-phase hydrocarbon from the condensed steam and extracted groundwater. Most of the liquid hydrocarbon was pumped to the oxidizer for destruction.

RESULTS

By December 10, 1999, after 6.5 months of SPH and multiphase extraction operations, the hydrocarbon plume had been reduced from a thickness of up to 10 ft to the remediation goal of less than 0.125 inches.

CONCLUSIONS

SPH achieved the site remediation goals by both increasing vapor pressure for enhanced vapor recovery and reducing product viscosity for pumping.

DNAPL REMEDIATION

In the Saturated Zone

Client: Fortune 500 Company

**Commercial site,
Skokie, Illinois**

June 1998 – October 1999

Current Environmental Solutions (CES) successfully used Six-Phase Heating (SPH) to remediate soil containing dense non-aqueous phase liquid (DNAPL) at a former manufacturing facility near Skokie, Illinois.

Others had been working at removing solvents from the subsurface of the site since 1991. These chemicals, used in various manufacturing processes, were released when underground storage tanks leaked between 1958 and 1988.

After seven years, technologies including steam injection combined with various extraction technologies and bioremediation had reduced the level of soil pollution on the site. The remaining DNAPL was present as pools of trichloroethylene (TCE) and 1,1,1-trichloroethane (TCA) to 21 ft below grade (bg). The remaining pollutants were removed within less than a year using SPH.

SITE

The lithology of the site consisted of a shallow groundwater table at 7 ft bg, heterogeneous sandy silts to 18 ft bg, and a dense clay till aquitard from 18-25 ft bg. Hydraulic conductivity through the remediation zone ranged from10^{-4} to 10^{-8} cm/s.

As DNAPL migrated downward, it was trapped in silt-rich stringers or on top of the clay aquitard. Over time, pockets of elevated chloride ions were created from the biological dechlorination of the solvents.

TECHNOLOGY

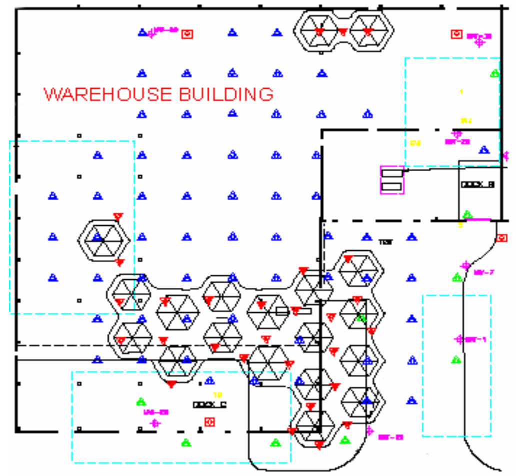
SPH is emerging as a leading technology in difficult in-situ soil and groundwater remediation. It has proved an efficient, rapid means of remediating soil contaminated by volatile and semi-volatile organic contaminants. The in situ cleanup of DNAPL remains one of the toughest challenges facing the remediation industry. Traditional remediation technologies require years of continued application to produce even marginal results at DNAPL sites.

SPH uses polyphase electricity to resistively heat the soil and groundwater to the boiling point of water. This increases the volatility of contaminants, which improves the effects of vacuum extraction. Once steam is generated in situ, it acts as a carrier gas which strips out contaminants from the soil or groundwater. The steam is collected from the subsurface by a soil vapor extraction process, and treated aboveground by conventional means such as activated carbon and catalytic oxidization.

APPLICATION

To ensure complete treatment of the DNAPL pools, 107 electrodes were placed across two-thirds of an acre, covering the site (see Figure 1). Of these, 85 were located beneath a warehouse, having been constructed directly through the floor of the building.

These electrodes were electrically conductive from 11-21 ft bg, and were designed to increase subsurface temperatures from 5-24 ft bg to the boiling point of groundwater. Within 60 days, temperatures throughout the entire 23,100 yd^3 treatment volume had reached the boiling point of water. At this stage, steam laden with chlorinated solvents rose to the surface and was collected by a network of 37 soil vapor extraction wells, screened to 5 ft bg.



SPH ELECTRODE LAYOUT

Subsurface regions displaying higher electrical conductivity, such as clay-rich soil lenses and pockets where the concentration of chloride ion was elevated, were preferentially heated. As a result, SPH specifically targeted those subsurface locations, which held most of the remaining DNAPL mass.

RESULTS

For 70 days, temperatures throughout the treatment volume were maintained at 100 ºC. All the separate phase DNAPL was removed from the area, and overall groundwater concentrations of TCE and TCA was reduced to below the standards specific to the site.

TYPICAL GROUNDWATER CLEANUP RESULTS

Well	*Compound*	*March 1998 (μg/l)*	*November 1998 (μg/l)*	*Reduction (%)*
B-3	TCE	34,000	120	99.6
	TCA	82,000	31	99.9
Fa2	TCE	22,000	70	99.7
	TCA	24,000	24	99.9
C4	TCE	76,000	280	99.9
	TCA	11,000	15	99.9

The cleanup goal for the site was based on the State of Illinois RBCA Tier III standards, but in fact most of the area was cleaned to the more stringent Tier I standards.

CONCLUSIONS

SPH successfully remediated this site within 130 days. After four quarters of post-remediation monitoring, no rebound was detected. The Illinois Environmental Protection Agency issued a letter of **"No Further Action"** for the site on 10 Aug 1999.

PCE REMEDIATION

Under Former Dry Cleaners Facility

Clients: Fortune 500 Company
Retail Facility
Western Washington
April-August 1999

In February 1999, Current Environmental Solutions (CES) was retained to remediate tetrachloroethylene (PCE) from beneath a former dry cleaners facility. The dry cleaner was in the corner storefront of a busy retail facility in Western Washington. The storefront shared common walls with other active retail businesses (see site map on next page).
Just prior to initiating remediation, additional site characterization disclosed that the PCE plume extended beyond the footprint of the dry cleaners and into the adjacent alley. Remediation efforts were immediately expanded to simultaneously treat both the interior and the exterior segments of the plume.

SITE

Site lithology consisted of sands to sandy-silts. An extremely shallow groundwater table was encountered at 2-4 feet below grade (bg) that rose to above the ground during part of the remediation. Initial PCE concentrations were 2,000 ug/kg in soil and 3,600 ug/l in groundwater. PCE Cleanup goals were 500 ug/kg in soil (75.0% removal) and 5 ug/l in groundwater (99.9% removal).

TECHNOLOGY

SPH is emerging as a leading technology in difficult in-situ soil and groundwater remediation. It has proved an efficient, rapid means of remediating soil contaminated by volatile and semi-volatile organic contaminants.

The *in situ* cleanup of DNAPL remains one of the toughest challenges facing the remediation industry. Traditional remediation technologies require years of continued application to produce even marginal results at DNAPL sites.

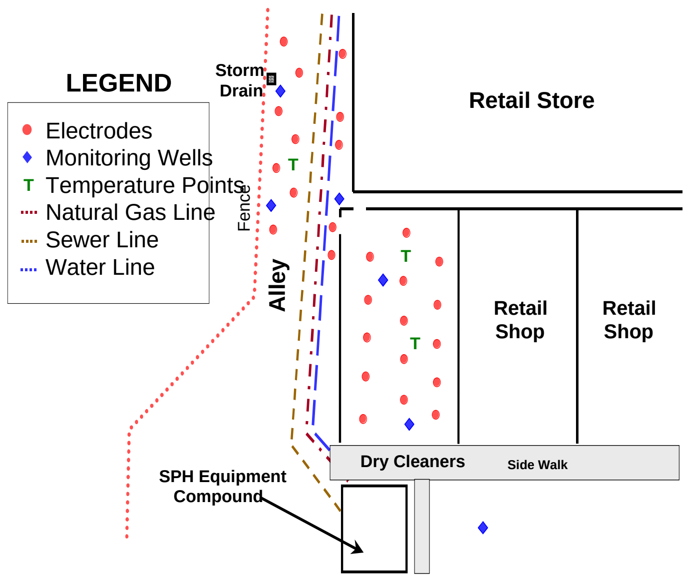
The technology was developed for the US Department of Energy at Pacific Northwest National Laboratories. CES was the first licensee of this technology, and we are the proprietor of sundry improvements. CES has been a licensee of this technology since 1997. The only other licensee has only had experience in applying these patents since January 2003, giving CES over five (5) years more experience than any other competitor.

SPH uses polyphase electricity to resistively heat the soil and groundwater to the boiling point of water. This increases the volatility of contaminants, which improves the effects of vacuum extraction. Once steam is generated in situ, it acts as a carrier gas which strips out contaminants from the soil or groundwater. The steam is collected from the subsurface by a soil vapor extraction process, and treated aboveground by conventional means such as activated carbon, and catalytic oxidization.

APPLICATION

Fifteen SPH electrodes were constructed inside the former dry cleaning store and 12 electrodes were installed in the alley. Electrodes extended to a depth of 20 feet bg and were electrically conductive from 12-20 feet bg. The groundwater was cleaned from 2-22 ft bg.

Inside the building the SPH system was installed through the concrete floor slab. Performing SPH in the alley however, represented a challenge. The alley contained buried utilities for sewer, electrical, water and natural gas. Additionally, it was a fire lane and could not be closed. CES developed a unique electrode design and installation process that allowed the alley to remain open to delivery truck and pedestrian traffic throughout the SPH operation.



Site Layout

The subsurface was heated using a 500kW-power supply. The steam created was collected in 4 horizontal Soil Vapor Extraction (SVE) wells, 2 in the building and 2 in the alley. The condensed steam was clean and could be discharged directly to a sanitary sewer while vapors were treated by activated carbon.

RESULTS

After 75 days of SPH operations, PCE, TCE, and cis-1-2 DCE levels had been lowered below the MCLs in groundwater, both beneath the building and in the alley. The specialized grounding methods and electrode design enabled electrical resistance heating to operate in a public access road and directly adjacent to an operating retail facility.

The electrical heating did not cause danger to the public. The alleyway remained open to the public for the duration of the remediation and the adjacent retail shop was unaffected. There was no damage to the existing utilities.

AQUIFER TREATING

And DNAPL Treatment

Client: US Air Force
Dover AFB, Dover, Delaware
February 1997

In August 1995, Armstrong Laboratory's Environics Directorate selected Six-Phase Heating (SPH) as part of their program to identify technologies for treating Dense Non-Aqueous Phase Liquids (DNAPL). An expert panel reviewed various technologies and SPH was identified as a promising technology deserving further evaluation.

In February 1997, a field demonstration was performed at the Dover Air Force Base, Groundwater Remediation Field Laboratory (GRFL) to determine if SPH could heat an aquifer sufficiently to remove DNAPL contaminants. Field testing was conducted in an uncontaminated aquifer using tracer compounds to mimic DNAPL.

TECHNOLOGY

SPH is emerging as the leading technology in difficult in-situ soil and groundwater remediation. It has proved an efficient, rapid means of remediating soil contaminated by volatile and semi-volatile organic contaminants. The in situ cleanup of DNAPL remains one of the toughest challenges facing the remediation industry. Traditional remediation technologies require years of continued application to produce even marginal results at DNAPL sites.

SPH uses polyphase electricity to resistively heat the soil and groundwater to the boiling point of water. This increases the volatility of contaminants. Steam is generated, and acts as a carrier gas that strips out contaminants as it rises. The steam is collected from the subsurface by a soil vapor extraction process, and treated aboveground by conventional means, including air stripping, activated carbon, or catalytic oxidization.

APPLICATION

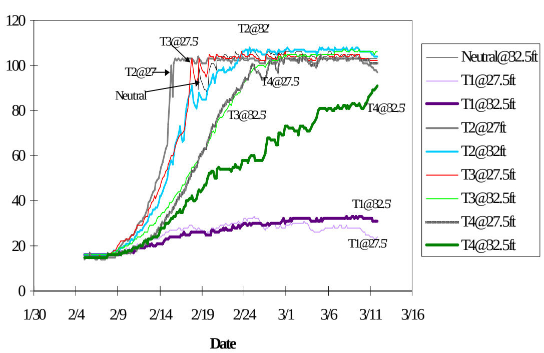
A 30-foot diameter, six-electrode heating array was installed into the upper aquifer at the GRFL site. Stratigraphy at the GRFL consists of sand, gravel, thin clay layers, and silt to a depth of 33.5-34 ft below grade (bg). A dense clay aquitard containing thin laminations of silt and fine sand is located at 34 feet bg. Groundwater was encountered at 25 ft bg.
Electrodes were installed in a hexagonal pattern to a depth of 35 feet bg and were electrically conductive from 20-35 ft bg. Because a 30-ft diameter SPH array heats an area measuring roughly 42-ft in diameter, the electrodes directly heated about 800 cubic yards of subsurface. Soil and groundwater above the electrically conductive interval of the electrodes were heated by rising steam, making the total volume of subsurface treated during the demonstration equal to approximately 1,800 cubic yards.

Steam generated by SPH was collected by a Soil Vapor Extraction (SVE) system that used the electrodes and a central vent as extraction wells. Non-hazardous organic tracers were used as surrogates for DNAPL compounds commonly found at Department of Defense sites, and were injected in the center and along the edges of the heated region.

RESULTS

Power was applied to the array beginning on February 7, 1997. Over the first 12-17 days, temperatures in the treatment volume rose to the boiling point of water. Aquifer boiling continued for another 13 days while the extracted soil vapors were sampled for the tracers. During the 30-day demonstration, 200,000 kW-hr of energy were used and 50,000 gallons of condensate were removed from the site as steam. The volume of condensate recovered roughly equaled the initial subsurface moisture present in the treatment volume.

Tracer sampling results showed some migration of tracers in the unsaturated zone but no significant migration of tracers in the groundwater. The tracer perfluoromethylcyclohexane (PMCH) was recovered fully in the extracted soil vapors, while only 35% of the tracer perfluorotrimethylcyclohexane (PTMCH) was recovered.



Saturated Zone Temperatures

Sampling results also showed that tracer recovery was complete after only 21 days of heating. Energy consumption to that time was 136,000 kW-hr and condensate production was 29,000 gallons.

CONCLUSIONS

The fate of the unrecovered PTMCH is uncertain. Its appearance in the soil vapors may have been missed during a failure of the sampling system. Moreover, soil vapor and groundwater sampling at the end of the demonstration clearly indicated that a negligible amount of PTMCH remained in the subsurface after heating.

The removal of a significant portion of the injected tracers indicates that SPH was capable of heating the aquifer to the temperatures necessary for DNAPL remediation. It also indicates that SPH has the potential to successfully treat DNAPLs in the saturated zone.

At 20% of the total demonstration budget, energy is an important part, but not a majority, of the overall costs for applying SPH. For the 30-day test, 200,000 kW-hrs of electrical energy was used. However, most of the tracers were removed during the first 21 days of heating when only 136,000 kW-hr were used. At $0.07/kW-hr, 21 days of SPH operations required an energy expenditure of $9,500 or approximately $5.3/cu. yd of subsurface heated.

PCE/TCE REMEDIATION

From Impermeable Clay

Client: Department of Energy
Savannah River Site,
Aiken, South Carolina
November 1983

Early in the development of Six-Phase Heating (SPH), it underwent a full-scale demonstration by its developers at Pacific Northwest National Laboratory and the Department of Energy (DOE), at the DOE Savannah River site. This demonstration was conducted to show that SPH could enhance the performance of conventional soil-venting techniques in removing volatile organic compounds (VOCs) from tight lithologies.
It was also intended to gather cost and engineering data for the further development of SPH technology.

SITE

The soil in the vadose zone of the SPH demonstration site had been contaminated with perchloroethylene (PCE) and trichloroethylene (TCE). The greatest contamination occurred within a 10-ft thick clay lens, which was sandwiched between two highly permeable sand layers at about 30 ft below grade (bg). Within this layer, the level of contamination was 100-200 parts per million of both PCE and TCE.

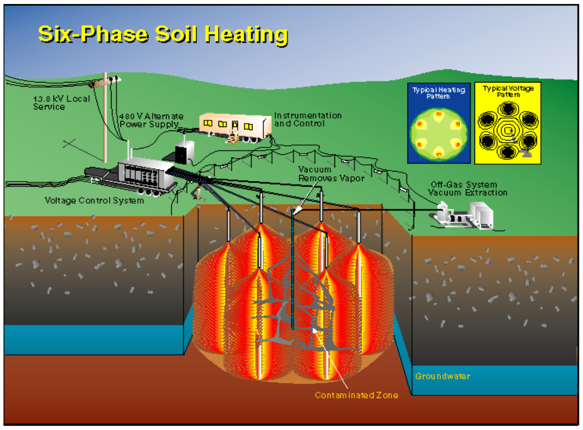


ILLUSTRATION OF THE SPH SYSTEM

TECHNOLOGY

SPH is emerging as a leading technology in difficult in-situ soil and groundwater remediation. It has proved an efficient, rapid means of remediating soil contaminated by volatile and semi-volatile organic contaminants.

SPH uses polyphase electricity to resistively heat the soil and groundwater to the boiling point of water. This increases the volatility of contaminants, which improves the effects of vacuum extraction. Once steam is generated in situ, it acts as a carrier gas which strips out contaminants from the soil or groundwater. The steam is collected from the subsurface by a soil vapor extraction process, and treated aboveground by conventional means such as activated carbon, and catalytic oxidization.

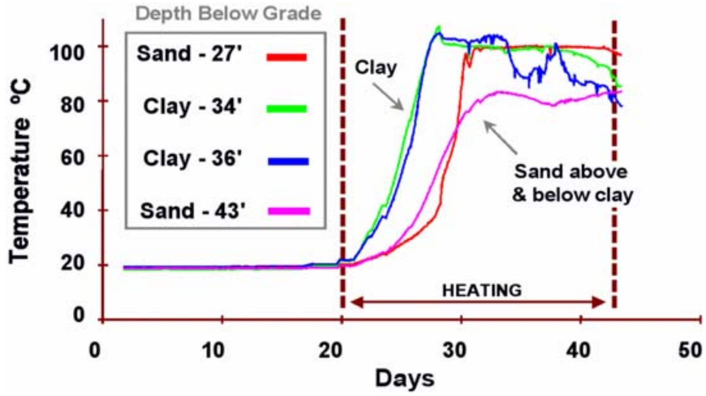
APPLICATION

The SPH electrodes were constructed in a 30-ft diameter hexagon pattern, to a depth of 45 ft bg. During the course of 25 days, approximately 100,000 kWh of electrical energy was applied to the subsurface at, on average, 200 kW. At least 1,430 yd^3 of soil was heated to above 70 °C.

In the first eight days of heating, the subsurface temperature within the diameter of the electrode pattern was raised to 100 °C. This temperature was maintained for about 17 days while data was collected on soil moisture removal rates, subsurface heating patterns, steam collection and offgas VOC concentrations.

RESULTS

Analysis of almost 200 soil samples indicated that SPH had removed 97 % of the VOCs in the clay layer and 100 % from the sand layers. The demonstration results indicated that SPH rapidly heated and remediated low-permeability soil lenses containing VOCs. Approximately 1,430 yd^3 of soil was treated, including soil beyond the diameter of the electrode pattern. Heating was uniform within each soil layer, but the clay layer became heated sooner than the sand layers and reached a higher final temperature.



VERTICAL TEMPERATURE PROFILES

Within the electrode field, the median contaminant removal rate from the clay zone was 99.7 % after only 25 days of heating. Vertical soil temperature profiles (see Figure 1) showed that the tight clay lens, which contained most of the contamination, was heated faster and to higher temperatures as compared to the surrounding soils. This was expected, as the clay lenses represented a more electrically conductive pathway than the sand layers above and below it. Horizontal soil temperature profiles showed that effective heating extended beyond the electrode field by a distance of approximately 40 % of the diameter of the hexagon.

During the SPH process, subsurface steaming resulted in the generation of 19,000 gal of water at the SPH condenser. The peak removal rate was 1,500 gal of condensed steam per day. The production of steam enabled SPH to strip contaminants from the soil matrix and achieve remediation efficiencies exceeding 99 %.

The energy use was 70 kWh/yd^3 of treated soil, which amounted to \$5/yd^3 of treated soil (assuming an electricity rate of \$0.07 per kWh).

CONCLUSIONS

The field demonstration proved that SPH could preferentially heat and rapidly remediate lenses of low-permeability soil containing relatively high concentrations of VOCs.

DNAPL REMEDIATION

IN A RESIDENTIAL NEIGHBORHOOD

Client: Dutch Environment AgencyUS ACE

Zwijndrecht, The NetherlandsLowell, Massachusetts

February 2003October, 2002

Current Environmental Solutions (CES) and their affiliated licensee, Terravista bv were contracted to perform a full-scale Six-Phase Heating (SPH) remediation electrical resistance heating (ERH) pilot study using Six Phase Heating (SPH) in a residential neighborhood in the Netherlands.at the Silresim Superfund (site) in Lowell, MA. The EPA oversight contractor is the US Army Corps of Engineers (USACE). The SPH system as deployed in an area of attached homes, and a portion of the SPH system was installed directly beneath a single family home.

SITE

The site is located in Prinssenpark Zwijndrecht, an attached single family residential area that was built upon contaminated soil. The residences were about 80% occupied. It was not until one of the homeowner's complained that the Dutch government discovered that one particular area of the neighborhood was contaminated with tetrachloroethylene (PCE), trichloroethylene (TCE), and Cis 1,2-dichloroethylene (DCE). The homeowners living directly above the soil hot spot were temporarily relocated, but the surrounding neighbors remained.

CES's SPH technology was chosen after a vigorous due diligence on behalf of the Dutch regulators. This time critical project required a safe, efficient, and cost effective technology that could reduce the soil and groundwater contamination to below the residential Dutch "C" contaminant levels. CES was chosen for the work based upon our reputation as the leader in applying SPH, and being the most experienced licensee of the Battelle patents for ERH. Clean-up was mandatory within (2) months.

APPLICATION

The volume of impacted soil was roughly 2,000m^3. As much of the Netherlands is below sea level, the soils were nearly saturated from surface, although the technical groundwater level was approximately 1.5m bg. Soils were marine sands and peat. Soil contamination ranged from 300 – 700 mg/kg and groundwater contaminant levels ranged from 100 – 3,800 u/l.

CES mobilized in August 2002 by first constructing a Power Supply Unit to European Union standards. Authorities from the Dutch Government KEMA (European equivalent of the USA UL Laboratories) Branch oversaw the construction and testing of the PSU at CES's Applied Process Engineering Laboratory in Richland, WA. After vigorous field testing, the unit was shipped to Rotterdam and then transferred to the site.

While constructing the PSU, the site was prepared for SPH. A series of 20 electrodes were installed to 7m bg. Two of the electrodes were directly beneath the living room of the home. A horizontal SVE system was used beneath the house as a safety venting system. Operations began in November 2002.

RESULTS

Groundwater was boiling within two weeks of start-up. By the end of December 2002, preliminary sampling showed that the clean-up criteria had been achieved, but the system was kept running for one extra month. By February 2003, soil sampling showed that the Dutch "C" levels had been exceeded. Groundwater samples showed PCE < 40u/l, TCE < 500 u/l, and DCE < 20 u /l. Power was discontinued in February 2003 and the site restored. There was no adverse impact to the home, its foundation, the surrounding residences, nor any reports of fugitive emissions throughout the project.

Six-Phase Heating Beneath Residential Home.

Six-Phase Heating Power Supply Unit (PSU)

Six-Phase Heating in Residential Neighborhood.
Experience only by CES

THERMALLY ENHANCED VAPOR EXTRACTION REMEDIATES DNAPL IN LOW PERMEABILITY CLAYS AT AN EPA SUPERFUND SITE IN NORTH DAKOTA

Joseph A. Pezzullo, PE and Christopher J. Thomas
Current Environmental Solutions

Abstract

Thermally Enhanced Vapor Extraction using Electric Resistance Heating (ERH) was selected by the U.S. Environmental Protection Agency to remediate chlorinated volatile organic compounds that existed as dense non-aqueous phase liquids (DNAPL) at the Camelot Cleaners Superfund Site in West Fargo, North Dakota. The primary compounds of concern were Tetrachloroethylene (PCE) and its daughter degradation products. Investigations revealed that DNAPL had migrated dangerously close to the drinking water aquifer of West Fargo situated at approximately 60 to 70 ft below grade (bg). The performance objectives were 3 mg/kg PCE in soil and 1 mg/L total VOCs in groundwater.

The site covered a footprint of about 10,300 square feet with five specific treatment depths ranging from surface to 56 ft bg, resulting in a treatment volume of approximately 13,800 cubic yards. More importantly, the site bordered both residential and commercial areas, and a portion of the treatment area was, in fact, in the side and front yard of an occupied residence.

The subsurface geology presented particularly difficult conditions for in-situ remediation, as the site consisted of extremely low permeability clays. Goethite infilling of joints and fractures posed unique challenges to the design and operation of the ERH system. Groundwater levels ranged from 3 to 7 ft bg. The groundwater conductivity was greater than 5,000 µS/cm.

The ERH thermal remedy included 56 multi-zone electrode/vent assemblies and an array of horizontal vapor extraction wells. Additional dual vacuum extraction (DVE) wells were added to augment contaminant extraction in the low permeability clays. Subsurface temperatures were monitored with 10 Temperature Monitoring Piezometers (TMPs), and nine multi-level Perimeter Monitoring Wells (PMWs) were installed around the perimeter of the site to assess pre-existing site conditions and also to monitor any subsurface contaminant migration. Extracted vapors and condensate were treated with activated carbon.

Site construction began in June 2004, and active subsurface heating commenced in February 2005. Subsurface steaming temperatures were achieved in May 2005. Power was terminated in November 2005 with a total of 2.8 mW-hrs of energy input to the subsurface. The DVE system continued to operate for a cool-down period until January 2006. The total mass of contaminants extracted was 5,188 lbs. EPA conducted confirmatory sampling of soil and groundwater in January 2006 whereupon all soil and groundwater samples were below the target levels save one soil sample near the northeast perimeter of the site in a location where previous site characterizations indicated that contamination extended beyond the boundary of the designated treatment area.

The official final soil and groundwater sampling by EPA indicated that CES' ERH remedy had reduced soil concentrations from 99.96% to 100% and groundwater concentrations by 99.98%. EPA authorized demobilization of the site in February 2006. CES completed demobilization in April 2006, and EPA independently removed the electrode and vent assemblies in July 2006.

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