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1. TerraTherm Company Overview

1.1 About TerraTherm

TerraTherm is a worldwide leader in the development and implementation of in situ thermal remediation of hazardous waste. We advise on, design, build, and operate thermal remediation projects from concept to closure.

We offer the broadest array of thermal remediation technologies in the industry, allowing us to tailor project designs to specific site conditions, using the optimal combination of methods, without bias towards any single technology or approach.

TerraTherm partners with leading engineering firms, government agencies, corporations, and property owners in flexible, cooperative relationships to achieve cleanup goals. Our expertise, broad set of proven technologies, and seasoned staff combine to provide the most effective cleanup available for a broad array of contaminants within all soils and site conditions.

We deliver high return on investment, dramatically increase property value, and reduce liability. Our projects are neighborhood-friendly, producing minimal noise, dust, and disruption. They achieve complete results within predictable time-frames, enable final site closure, optimize property value, and eliminate the risks of liability and long-term threats from contaminants.

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<td><strong>Krüger, A/S</strong></td>
</tr>
<tr>
<td>151 Suffolk Lane</td>
<td>Gladsaxevej 363</td>
</tr>
<tr>
<td>Gardner, MA 01440</td>
<td>DK-2860 Søborg</td>
</tr>
<tr>
<td>TEL: (978) 730-1200</td>
<td>Denmark</td>
</tr>
<tr>
<td>FAX: (978) 632-3422</td>
<td><a href="http://www.kruger.dk">www.kruger.dk</a></td>
</tr>
<tr>
<td>E-mail: <a href="mailto:info@terratherm.com">info@terratherm.com</a></td>
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<tr>
<td><strong>TerraTherm, Inc.</strong></td>
<td>Shibaura SEC Building 2nd Floor,</td>
</tr>
<tr>
<td>28900 Indian Point</td>
<td>Shibaura 3-13-1, Minato-ku</td>
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<tr>
<td>Keene, CA 93531</td>
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<td></td>
<td><a href="http://www.shegotec.com">www.shegotec.com</a></td>
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| **Beijing Enviro-Chem**             |                                     |
| Room No. 7 Guanghua Road, Chaoyang |                                     |
| District, Hanwei Plaza West, Room  |
| 5B16                                |                                     |
| Beijing, China 100004               |                                     |
| TEL: +86 010 89230845               |                                     |
1.2 History

TerraTherm was formed by a team of seasoned industry veterans with a passion for innovation and a dedication to making breakthroughs in the effectiveness of remediation technologies and processes. In 2000, a division of Royal Dutch Shell donated a cutting edge technology to the University of Texas at Austin, which in turn licensed it to TerraTherm’s co-founders, making the formation of TerraTherm possible. Since that time, TerraTherm has broadened its capabilities, developed and patented new methods, added numerous partners, proven the applicability of thermal remediation, and completed numerous successful projects worldwide.

Milestones:

Late 1980s/early 1990s
- Shell Exploration and Production (Shell E&P), a division of Royal Dutch Shell (Shell) develops the TerraTherm In Situ Thermal Desorption (ISTD) technology as part of its effort to enhance oil recovery.

1994 to 1998
- Shell E&P recognizes the technology’s potential to clean up contaminated soil.
- Shell Technology Ventures, Inc. (STVI), a wholly owned subsidiary of Shell E&P that held the ISTD patents, and TerraTherm Environmental Services Inc., an STVI spin-off, conduct seven ISTD demonstrations and projects.

1999-2000
- Shell exits the remediation business and donates the ISTD rights to the University of Texas at Austin (UT).

2000 - 2001
- Ralph Baker, Ph.D. and John Bierschenk, P.G. secure the exclusive license to commercialize ISTD within the United States from UT.
- They co-founded TerraTherm, LLC, assuming the roles of CEO and President, respectively.
- Jim Galligan, P.E. joins the company as lead engineer. TerraTherm opens offices in Fitchburg, MA and equipment facilities in Houston, TX.
- TerraTherm, LLC completes first round of funding and becomes TerraTherm, Inc.

2002
- Secures the exclusive worldwide rights to commercialize ISTD
- Partnership with SheGoTec Japan, Inc. is established.

2004
- Successful completion of the first ISTD Chlorinated Volatile Organic Compounds (CVOCs) project.
- Industry leader Dr. Gorm Heron joins TerraTherm.

2005
- Achieves ISTD milestone with the successful completion of its first Manufactured Gas Plant (MGP) project.
- Successful completion of a fast turnaround Brownfield cleanup of CVOCs for the City of Richmond, CA.

2006
- Successful completion of the pioneering Southern California Edison Alhambra ISTD project, achieving a No Further Action letter from the State of California.
- Partnerships forged with Krüger A/S in Denmark and Sweden.

2007
- Secures a license to practice Steam Enhanced Extraction (SEE) from the University of California Berkeley, and begins first SEE project.
- Successful completion of the first ISTD project remediating Dense Nonaqueous Phase Liquid (DNAPL) in fractured rock.

2008
- Utilizes ISTD to successfully treat 48,000 cubic yards of CVOC-contaminated soil for the U.S. Air Force at Memphis Depot, TN.
- Successful completion of first ISTD-SEE combination at an active dry cleaning facility in Odense, Denmark.
2009
• Awarded the Gold Medal award for Business and Achievement in the Remediation Contracting category by the Environmental Business Journal.

2010
• Celebrates its 10th anniversary.
• Receives a gold medal from EBI for outstanding achievement in environmental remediation.

2011
• Reports that 60 sites worldwide have been treated with ISTD.
• Zweig Letter names TerraTherm to its 2011 Hot Firm List of fastest growing firms in the A/E/P and design-build industry sector.

2012
• Steve McInerney joins the company as Remediation Department Manager.
• David Allworth joins the company as Chief Financial Officer.

2013
• Awarded a $37M project by USAID in Vietnam.
• The Zweig Letter names TerraTherm to its 2013 Hot Firms List.
• Completed largest-ever ISTD project, in Teterboro, NJ.

2014
• Began heating at SRSNE Superfund Site and at Danang Airport In Pile Thermal Desorption® (IPTD®) site in Danang, Vietnam.
• Constructs SEE project at former Williams Air Force Base in Mesa, AZ. The largest thermal remediation project in the world (409,000 yd³ [313,000 m³], 250 ft [76 m] deep), for treatment of jet fuel (LNAPL).

2015
• Acquired by Cascade Drilling, now Cascade Technical Services. Adds characterization and additional in situ remediation technologies.
• Performs pilot tests for new modular IPTD® technology, the Heated-Box.

2016
• Acquires Current Environmental Services (CES), the original Battelle company and inventor of ERH technology. Now offers ERH services in-house.

Technology Commercialization Timeline

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1.3 TerraTherm Leadership Team

For more information on the leadership team visit www.terratherm.com/about/leadership.htm

John M. Bierschenk, P.G. is one of TerraTherm’s co-founder and President. Mr. Bierschenk has overall responsibility for general management of the company. In addition, he directs TerraTherm’s Operations, serves as Contracting Manager, and oversees TerraTherm’s Strategic Programs. Mr. Bierschenk is a registered Professional Geologist in Pennsylvania (USA), and holds a BS in Geology as well as an MBA. He has over 30 years of technical and management experience in the environmental and energy business; working as an environmental consultant and as an exploration geophysicist.

Gorm Heron, Ph.D. is TerraTherm’s Vice President and Chief Technology Officer. Dr. Heron has over 20 years of experience in assessment, design, and management of In Situ Thermal Remediation (ISTR) projects, focusing on the treatment of CVOC and DNAPL sites in soil and fractured rock. Dr. Heron provides technical leadership and oversight in the design and application of ISTD, SEE and combined ISTD/SEE/ERH systems. From 1997-2004, Dr. Heron served as Principal Environmental Engineer with SteamTech Environmental Services, Inc.

James P. Galligan, P.E. is TerraTherm’s Principal of Projects. Mr. Galligan oversees all of TerraTherm’s Project Execution and serves as Project Manager for TerraTherm’s largest project. Mr Galligan has over 20 years of experience with in situ and ex situ remediation system design, installation, operation and troubleshooting, including over 10 years experience with ISTR projects. Mr. Galligan has conducted numerous remedial technology pilot tests, feasibility studies and life-cycle cost evaluations. He has extensive experience in cost estimating and health and safety management.

David B. Allworth is TerraTherm’s Chief Financial Officer. He has more than 30 years of experience in corporate financial management & accounting. Prior to joining TerraTherm in 2012, Mr. Allworth was the CFO for InEnTec Inc., a waste-to-energy technology company where he led efforts to raise more than $100 million through the issuance of equity, convertible debt and joint venture partnership interests. He has extensive experience in strategic planning, financial analysis, international tax & finance, and financial systems implementation.
1.4 Leadership Team Publication Examples

Members of TerraTherm’s leadership team are frequently invited to serve on research advisory committees and have published dozens of papers, handbooks, and presentations. A sample of those includes:


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1.5 TerraTherm R&D

TerraTherm’s R&D efforts are focused on making our proven thermal technologies even better; advancing the efficiency, applicability and cost-effectiveness of our solutions, and sharing our findings to advance the state of the art. Our internal R&D group works with leading research institutions to develop, test, and deploy new methodologies and materials. We have frequently been selected as a key contractor in important research projects to prove the reliability of thermal methods for various contaminants, soils, and site types such as fractured rock. Our principals are frequent contributors to the remediation community; providing papers, presentations, and insight in a wide variety of forums and publications, examples include:

- Having been selected as a key contractor in important research projects to prove the thermal methods.
- Partnerships and joint projects with leading institutions for advanced research in thermal remediation, including; the University of Texas, the University of Stuttgart, and Queens University.
- Frequent presentations and panel appearances at important industry events and government sponsored conferences worldwide.
- In-house R&D and innovation to improve the reliability and cost-effectiveness of thermal solutions.
- Respected and recognized leadership staff with a history of leading publications and innovations in thermal technologies.

1.6 Research Partnerships and Joint Projects

We work closely with leading institutions such as the University of Texas, Queens University and the University of Stuttgart to improve processes and tools. Shell Technology Ventures donated patents to The University of Texas, which in turn licensed them exclusively to TerraTherm. We fund and collaborate with The University of Texas at Austin’s faculty and students in their research. This close relationship has led to many papers, graduate theses, and numerous research publications and papers.

Another example of research collaboration was a three-year SERDP-funded project featuring controlled release of DNAPL into a lower-permeability layer beneath the water table. This research was conducted at the facilities of VEGAS - the Research Facility for Subsurface Remediation at the University of Stuttgart, Germany.
1.7 Intellectual Property Examples

Patented and Proprietary Materials and Methods

TerraTherm, its licensor’s, and its leadership team have over 28 patents, and 127 International Patents on a wide range of topics. They include U.S. patents on:

- Remediation of soil in containers or piles
- Remediation of soil piles using central equipment
- Vacuum methods for removing soil contamination
- Thermal well designs
- Enhanced deep soil vapor extraction processes for removing contaminants trapped in or below the water table
- Methods for treating DNAPL by applying heat
- Electrical Resistance Heating (ERH)
1.8 Patent Examples


[28 U.S. Patents + Pending; 127 International Patents + Pending]
1.9 Commitment to Health and Safety

TerraTherm gives the utmost attention and priority to health and safety issues. We are driven to ensure that all of our procedures, processes, attitudes, and plans are highly safety-centric. This attention to detail is at the core of our company's culture, and has resulted in an impeccable safety record to date. Visit http://terratherm.com/services/build/commitment.htm for more information.

All of our field engineers, project managers, construction managers, craftsmen, and equipment operators are OSHA 40 Hour HAZWOPER trained. They also participate in training programs including:

- Electrical Safety
- Hazardous Energy Control
- Hazard Communication
- Respiratory Protection
- Powered Industrial Truck

TerraTherm’s Experience Modification Rating (EMR) is 0.70.

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2. In Situ Thermal Remediation Technologies

2.1 Introduction: In Situ Thermal Remediation

In Situ Thermal Remediation (ISTR) has become a “hot topic” for environmental consultants, regulators, developers, utilities, and other companies. Thermal remediation technologies have proven both capable and highly consistent in remediating essentially all hazardous organic compounds to levels at or below regulatory cleanup standards. As a result, the number of thermal projects has skyrocketed.

Why are so many people “thinking thermal?” The many advantages of thermal remediation include:

- Delivers robust, highly predictable results.
- Provides clean, quiet, dust free, and neighborhood friendly operations.
- Increases property values and reduces liability on the books.
- Treats inside buildings and near infrastructure.
- Eliminates contaminants in soil to non-detect levels, even to drinking water standards.
- Meets the needs of a broad range of project sites and contaminants.
- Achieves closure in short time-frames.
- Captures vapors and prevents unwanted contaminant mobilization.
- Provides cost effective remedies — often Thermal is the obvious choice.

In close cooperation with you, we design, build, and operate remediation projects from concept to closure. Our broad set of technologies and applications allow us to tailor an optimal design to your site’s soil, permeability, contaminants, location and cleanup goals. We apply each technology to its best purpose, alone or in combinations, ensuring that no method is stretched or force-fit to purposes for which another might be more cost effective or efficient. No other thermal remediation company offers this full range of options.
2.2 Thermal Remediation Technologies

TerraTherm performs screening and technology selection for all sites to determine and propose the optimal and most cost-effective heating technique or combinations. Visit http://terratherm.com/thermal/index.htm for more information.

**Thermal Conduction Heating**

TerraTherm offers low, moderate, and high temperature applications of Thermal Conduction Heating (TCH), as incorporated within TerraTherm’s proprietary In Situ Thermal Desorption (ISTD) technology.

Thermal Conduction is the process of heat flowing from the hot end of a solid object (like an iron rod) to the cold end. In soil or rock, heat flows from TerraTherm’s heater wells out into the formation by grain-to-grain contact (in soil) and across solid objects (rocks).

The TCH technology can be utilized to heat in situ soils and stockpiled soils and sediments. The design of the treatment system of in situ soils typically includes vertically installed heaters, whereas the design of the treatment system for the stockpiled soils (In-Pile Thermal Desorption®, or IPTD®) can incorporate vertical or horizontal heater wells.

**Steam Enhanced Extraction**

Steam Enhanced Extraction (SEE) is a highly effective technology used in the recovery of free product and the remediation of volatile organic compounds (VOCs) since the mid-1990s.

SEE achieves on-site separation and treatment through steam injection into wells and extractions of hot fluids. Steam propagation is a stable and predictable process, governed by heat transfer to the formation and has been studied intensively and utilized for oil recovery and remediation of a wide-range of contaminants.

**Electrical Resistance Heating**

TerraTherm now offers Electrical Resistance Heating (ERH) in-house, though our acquisition of Current Environmental Solutions (CES). CES is the original Battelle company and inventor of the ERH technology. ERH has been widely applied and proven effective for free product recovery and enhanced vapor extraction at sites with volatile contaminants such as VOCs, CVOCs, and NAPLs, and is applied at low and moderate temperatures.

**Combinations**

SEE may be combined with either ERH, or with ISTD. Together these combinations comprise a glove-fit design for sites with complex geologies (e.g., silty clay aquitards, and sandy or gravelly aquifers).

A combination approach often addresses the entire target treatment zone (TTZ). At each well location, either a single full-length TCH heating element or one or more ERH electrodes is used along the depth interval of the low-permeability material, while steam is injected into wells screened in the permeable zones. Extraction wells exert hydraulic and pneumatic control.
2.3 Thermal Conduction Heating

TerraTherm offers low, moderate, and high temperature applications of Thermal Conduction Heating (TCH). TCH has been applied as a remedial technology to sites worldwide since 1995.

2.3.1 TCH Installation

TerraTherm uses the TCH technology by installing a series of patented electrically-powered heaters and vapor extraction points installed in situ, and operated to heat contaminated soil to target treatment temperatures. Target treatment temperatures are typically the boiling point of the contaminant of concern at the site.

What is Thermal Conduction?

Thermal conduction is the process of heat flow from the hot end of a solid object (like an iron rod) to the cold end. In soil or rock, heat flows from TerraTherm’s heater wells out into the formation by grain-to-grain contact (in soil) and across solid objects (rocks). The fluids (water, air, NAPL) in contact with the solids also heat up at the same time. The heat moves out radially from each thermal well until the heat fronts overlap. Due to the invariance of thermal conductivity, sands, silts, and clays conduct heat at nearly the same rate, leading to highly predictable in situ heating, even in challenging and heterogeneous subsurface settings.
2.3.2 Benefits of TCH

Thermal conductivity values for the entire range of known soils vary by a factor of less than plus or minus three, while fluid conductivity of soils may vary by a factor of a million or more. Compared to fluid injection processes, the conductive heating process is uniform in its vertical and horizontal sweep. Transport of the vaporized contaminants is further improved by the creation of permeability, which results from drying (and, if clay is present, shrinking) of the soil close to the heaters. Preferential flow paths are created even in tight silt and clay layers, allowing escape and capture of the vaporized contaminants. TCH produces uniform heat transfer through thermal conduction and convection in the bulk of the soil volume. This allows the achievement of very high contaminant removal efficiency with a nearly 100% sweep efficiency, leaving no area untreated.

TCH can be applied at low (<100°C), moderate (~100°C), and higher (>100°C) temperature levels to accomplish the remediation of a wide variety of contaminants, both above and below the water table.

We most often apply TCH to achieve 100°C for treatment of VOC sites. We are often being placed in a box for the more difficult sites - while we actually can be competitive on all thermal sites.

TCH is the only ISTR technology capable of achieving target treatment temperatures above the boiling point of water.

TCH is effective at virtually any depth in almost any media.

TCH works in tight soils, clay layers, and soils with wide heterogeneity in permeability or moisture content that are impacted by a broad range of volatile and semi-volatile contaminants such as:

- DNAPL
- LNAPL
- Tar
- PCBs
- Pesticides
- PAHs
- Dioxins
- Chlorinated Solvents
- Explosives Residue
- Heavy Hydrocarbons
- Mercury

**In Situ Thermal Remediation**

Lower, Moderate and Higher Temperature Applications

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<td>Lower below 100°C</td>
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<td>Higher above 100°C</td>
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2.3.3 TCH Applicability

TCH technology can be utilized both for \textit{in situ soils} and \textit{ex situ stockpiled soils} and treats both \textit{Volatile Organic Compounds (VOCs)} and \textit{Semi-Volatile Organic Compounds (SVOCs)}. TerraTherm calls the in situ application of TCH, In Situ Thermal Desorption (ISTD), and the ex situ application, In Pile Thermal Desorption\textsuperscript{®} (IPTD\textsuperscript{®}). The design of the treatment system for in situ soils typically includes vertically installed heaters whereas the design of the treatment system for the stockpiled soils typically incorporates horizontally installed heaters in a modular container. If the volume of the soil requiring treatment is large enough, a pile structure can be constructed and heaters installed vertically, just as they are for ISTR applications. Examples of each system are shown below:
Works Inside Buildings and Near Structures

The TCH technology can operate inside and near buildings and infrastructure. This capability has been field proven in several projects. The photo below shows installation inside a working dry cleaning plant in Denmark.

Applicable Above and Below the Water Table

The TCH technology can be applied to contaminants in soils both above and below the water table where the soils can be heated up to target treatment temperatures. Contaminants such as TCE, PCE, and other VOCs that do not require treatment temperatures higher than the boiling point of water, can be treated simply by steam distillation. Contaminants such as PAHs, dioxins, PCBs, and other SVOCs that require higher temperatures are treated by boiling off the water within the treatment zone, and then by heating the soil to the designated treatment temperatures. Where significant groundwater flow is present, additional measures such as groundwater management or a hydraulic barrier may be required.
2.4 Steam Enhanced Extraction

What is Steam Enhanced Extraction?

Steam Enhanced Extraction (SEE) achieves on-site separation and treatment through steam injection into wells and extraction of hot fluids. Steam propagation is a stable and predictable process, governed by heat transfer to the formation, and has been studied intensively for oil recovery and remediation of a wide range of contaminants.

TerraTherm offers Steam Enhanced Extraction, a technology that has proven highly effective for the recovery of free product and the remediation of volatile organic compounds (VOCs).

TerraTherm uses SEE at low and moderate temperatures. It is applied through the installation of steam injection and extraction wells that are used to inject steam into the subsurface while simultaneously extracting steam, vapors, mobile non-aqueous phase liquid (NAPL), and groundwater. The injected steam is used to heat the subsurface to target treatment temperatures, typically the boiling point of the contaminant of concern at the site.
SEE Contaminant Removal and Destruction Mechanisms:

- Displacement as a NAPL phase and extracted with the pumped groundwater.
- Vaporization in the steam zone.
- Accelerated vaporization and extraction is achieved in the vapor phase through pulsed pressurization and depressurization cycles.
- Dissolution, destruction, and removal with the extracted water.

SEE is a Good Fit for Sites with Significant Groundwater Flow

SEE is a logical choice for large and deep sites with significant groundwater flow. The process allows for high net extraction of fluids and displaces large amounts of groundwater towards the extraction wells. As a result, less water has to be heated to allow the formation to reach target temperatures. In addition, this displacement facilitates hydraulic control of NAPL mobility. The steam sweeps through the formation and the accompanying pressure gradient displaces the mobile NAPL and vaporized components as an oil front, which is recovered when it reaches the extraction wells.

Pressure Cycling for Improved Contaminant Removal Rates

Another significant benefit of SEE is the ability to conduct pressure cycling to improve contaminant removal rates dramatically. After the target zone has been heated and the majority of the NAPL extracted as a liquid, pressure cycling is induced by varying the injection pressure and the applied vacuum. This has been demonstrated to achieve very low concentrations in the original source zone.
2.5 Electrical Resistance Heating

**What is Electrical Resistance Heating?**

When electrical current is passed through the soil, the resistance it encounters causes the soil and fluids to heat up, due to Ohmic (or Joule) heating. The current flows from one electrode to another, primarily through the soil water. Once the water boils off, electrical conductivity becomes negligible and heating ceases; thus, water is added at each electrode to keep them from drying out. Heat-up with Electrical Resistance Heating (ERH) is limited to the boiling point of water.

**Electrical Resistance Heating** has been widely applied and proven effective for free product recovery and enhanced vapor extraction at sites with volatile contaminants such as VOCs, CVOCs, and NAPLs, and is applied at low and moderate temperatures.

**2.5.1 ERH Process**

Electrodes are installed in wells throughout the contaminated soil and groundwater volume. The electrode array is connected to a Power Delivery System unit that uses standard, readily available three-phase power from the grid. The process begins by passing current between electrodes causing the soil temperature to rise. This increased temperature results in the volatilization of contaminant compounds into the vapor phase for removal with vapor extraction techniques.

Comprehensive computer controls are used to regulate and optimize the thermal response of the target formation.
2.6 Technology Combinations

Combining Thermal Conduction Technologies provides an optimal solution for many sites. TerraTherm has demonstrated that SEE may be combined with either ERH or TCH methods for a glove-fit design for sites that include complex geology and layers with highly permeable materials (e.g., sandy or gravelly aquifers).

A combination of TCH or ERH and SEE often addresses the entire target treatment zone (TTZ). At each well location, TCH or ERH is used along the entire depth interval, and steam is injected into the permeable zones.

Each of the heating technologies is applied where it is most effective.

TCH or ERH:

• Heats at all depths, including the bottom of the treatment zone, where it can form a “hot floor” that prevents downward migration of condensate and/or DNAPL.
• Heats the near-surface soils such that shallow NAPL condensation is prevented; and heats thick clay layers.
• ERH is applied at temperatures at or near the boiling point of water.
• TCH may be chosen across a wide range of temperatures, and is the logical choice for higher temperature applications where high boiling contaminants are targeted for removal.

Combined with SEE:

Heats the permeable zones and builds a high pressure steam filled zone that reduces the water flow into the TTZ by reducing or negating the inward hydraulic gradient, and by reducing the relative permeability of water within the steam saturated porous media.

The combined technologies approach optimizes overall heating and treatment efficiency, often reducing both the operational period and the overall project cost.
3. Services

TerraTherm advises on, designs, builds, and operates In Situ Thermal Remediation (ISTR) projects from concept to closure.

Our breadth of technologies and field experience combine to maximize our ability to tailor solutions and provide creative problem solving. TerraTherm provides the people, equipment, project management, safety process, logistics, and regulatory understanding required for smooth and successful projects with positive, predictable outcomes.

At each phase of a project, we listen carefully and work as partners with our clients to create and execute the most cost-effective and timely path to your cleanup goals.

For more information about TerraTherm services visit: [http://terratherm.com/services/index.htm](http://terratherm.com/services/index.htm)
4 Site Types, Applications and Projects

Get it right the first time

When it comes to remediation projects, getting it right the first time is the key to cost-effectiveness and value. To design the optimal solution and deliver on promised cleanup goals and time-frames, we work with you to gain a profound understanding of all aspects of the site including contaminants, geology, location, and potential complexities.

Permeability and Geology

Permeability and geology are key factors that guide the selection of the optimal Thermal Remediation Technology(ies) and remediation design for a given site. Our technologies have been proven effective across a wide range of site conditions.

TCH, SEE, and ERH, offer flexibility that can be matched to almost any site, both above and below the water table. Using each of these technologies alone or in combination, we are able to treat a wide variety of geologies including:

- Tight soils
- Clay layers
- Fractured rock
- Unconsolidated soils
- Complex stratigraphies
- Soils with wide heterogeneity in permeability or moisture content
- Above and below the water table
- Unsaturated zone
- Saturated zone
- Smear zone

Example Site Types and Applications

- Manufactured Gas Plants (MGP)
- Brownfields
- Railroad and Wood Treatment sites
- Fractured rock sites
- Inside and near buildings and infrastructure
- Rapid site cleanup, for closure and resale

For more information about site types and applications, visit: [http://terratherm.com/projects/applications/index.htm](http://terratherm.com/projects/applications/index.htm)
4.1 Contaminants of Concern

In Situ Thermal Remediation (ISTR) techniques will treat just about any organic compound, including:

- Trichloroethene (TCE), tetrachloroethene (PCE), 1,2-dichloroethene (1,2-DCE), trichloroethanes (TCA), and other halogenated hydrocarbons, often referred to as chlorinated solvents
- Dense and light non-aqueous phase liquids (DNAPLs and LNAPLs)
- Polychlorinated biphenyls (PCBs), Polychlorinated dibenzodioxins and furans (PCDD/Fs), better known as simply Dioxins
- Polycyclic aromatic hydrocarbons (PAHs), often present in creosote at wood treatment sites, and coal tar at former Manufactured Gas Plant sites
- Pesticides and herbicides
- Petroleum, petroleum products and their volatile constituents including benzene, toluene, ethylbenzene, xylenes (BTEX), and methyl tertiary butyl ether (MTBE)
- Any other volatile or semi-volatile hydrocarbon
- Nearly any other organic compounds or combination of organic compounds

Mercury, a volatile metal whose boiling point is within the PCB range, can also be treated by appropriate use of ISTR techniques.

Visit our website www.terratherm.com/projects/contaminant/index.htm for more information on CVOCs, SVOCs, and DNAPL as well as descriptions of selected projects and examples of applications for certain site types by industry, location, or contaminant. You may also wish to use the site search tool to locate the information you need on specific keywords, such as a contaminant or site geology; see the resources section for FAQs, white papers, and more. Also, please feel free to contact us with any questions about your site or about ISTR. Email us at info@terratherm.com.
Appendix A: Project Case Study Examples

TerraTherm has completed numerous full-scale and pilot remediation projects at contaminated sites on five continents. Our technologies offer flexibility not only in the variety of contaminants that they can treat, but also in the applicability of the technologies to various site types.

TerraTherm’s projects represent a wide variety of site applications including:

- Manufactured Gas Plants sites
- Brownfield redevelopment
- Fractured rock sites
- Inside & near buildings & infrastructure
- Rapid site cleanup, for closure and Resale

If you are interested in a site or project type not listed above, please contact us to discuss your site.

On the following pages, we provide some brief case study examples. For more case study examples, please visit http://terratherm.com/projects/index.htm
Remediation of Coal Tar in a Manufactured Gas Plant (MGP) Gasholder:
North Adams, Massachusetts

Site Information:
Manufactured Gas Plant (MGP) operations began in the 1860s and continued until 1952. On Site, an abandoned gasholder contained approximately 2,010 cubic yards (cy) (1,537 m³) of soil and debris contaminated with coal tar. The 62 ft (19 m) diameter by 18 ft (5.5 m) deep gasholder had brick walls and a bottom believed to be constructed of concrete.

Contract Type and Project Goals: Guaranteed performance contract to achieve a permanent solution in accordance with the Massachusetts Contingency Plan (MCP), by eliminating Dense Non-Aqueous Phase Liquid (DNAPL) within the holder and reducing concentrations of Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs) and Total Petroleum Hydrocarbons (TPH) below MCP Upper Concentration Limits (UCLs) so that residual risk is minimized.

Contaminants of Concern (COCs) were as follows: Coal tar containing concentrations as high as benzo(a)pyrene [B(a)P] 650 mg/kg; naphthalene 14,000 mg/kg; benzene 6,200 mg/kg; and TPH 230,000 mg/kg.

Soil Characteristics: Mixture of sand, gravel, cobbles, bricks, concrete fragments, ash, and clincker.

Groundwater: Perched water table was encountered within the gasholder at 5.5 ft (1.7 m) below ground surface (bgs). The regional groundwater table is beneath the holder.

Results:
• Achieved all remedial goals
• Approximately 101,000 gallons (382 m³) of water were treated
• Approximately 16,700 gallons (63 m³) of coal tar were recovered and disposed of
• At least 300,000 lbs (136,000 kg) of contaminants (expressed as naphthalene) removed in total

Approach:
• In Situ Thermal Desorption (ISTD)
• Target temperature: 325°C (617°F)
• Thermal wells: 25
• Spacing between thermal wells: 12 ft (3.7 m)
• Thermal well depth: 18 ft (5.5 m)
• Water treatment by oil-water separator, clay-carbon media, liquid-phase Granular Activated Carbon (GAC)
• Vapor treatment by regenerative thermal oxidizer with backup vapor-phase GAC

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Close-Up of Stabilized Coal Tar from just above the Bottom of the Gasholder
**Project Summary:** TerraTherm used its In Situ Thermal Desorption (ISTD) technology at full scale as follows: Prior to the site being heated, coal tar DNAPL had resisted recovery. After dewatering, TerraTherm applied ISTD in a step-wise fashion, without excavation. To our knowledge, this is the first site where a multi-level in-situ heating approach has been applied. We utilized three levels of heating (Levels 1, 2 and 3) sequentially, achieving low (80°C), moderate (100°C) and higher (325°C) soil temperatures, respectively. During Level 1, >16,000 gal (60,000 l) of coal tar/emulsion was recovered, while during Levels 2 and 3, >166,000 lb (75,000 kg) expressed as naphthalene were extracted and treated in the vapor phase. ISTD resulted in the following reductions in soil concentrations (mg/kg): Level 2, benzene from 3400 to 0.95, naphthalene from 14000 to 70, and benzo(a)pyrene from 650 to 100; Level 3, benzene from 2068 to 0.35, naphthalene from 679 to 5.7, and benzo(a)pyrene from 20 to 0.33. No DNAPL remained within the gasholder, and all constituents were below the remedial goals. National Grid judged the turn-key cost ($850,000 for ISTD) to be less than the excavation alternative.

TerraTherm mobilized to the site in November 2003, with site construction beginning the same month. Dewatering/tar recovery began in February 2004. Full power heating began in July 2004 and was completed in March 2005, with demobilization completed June 2005.

**Results:**

**Pre- and Post-Treatment Soil Concentrations Within the Construction Worker Exposure Depth**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Pre-Treatment mg/kg</th>
<th>Post-Treatment mg/kg</th>
<th>Reduction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>2068</td>
<td>0.35</td>
<td>99.98%</td>
</tr>
<tr>
<td>Anthracene</td>
<td>19</td>
<td>0.48</td>
<td>97.47%</td>
</tr>
<tr>
<td>Benzo(a)anthracene</td>
<td>20</td>
<td>0.51</td>
<td>97.45%</td>
</tr>
<tr>
<td>Benzo(a)pyrene</td>
<td>20</td>
<td>0.33</td>
<td>98.35%</td>
</tr>
<tr>
<td>Chryrsene</td>
<td>20</td>
<td>0.71</td>
<td>96.45%</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>43</td>
<td>1.02</td>
<td>97.63%</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>679</td>
<td>5.7</td>
<td>99.16%</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>107</td>
<td>3.82</td>
<td>96.43%</td>
</tr>
<tr>
<td>Pyrene</td>
<td>65</td>
<td>1.12</td>
<td>98.28%</td>
</tr>
<tr>
<td>C11-C22 Aromatics, unadj.</td>
<td>4000</td>
<td>43.15</td>
<td>98.92%</td>
</tr>
</tbody>
</table>

*All below UCLs*
Results:
• Met remedial goals
• Estimated 48,000 lbs (22,000 kgs) of volatile organic compound (VOC) contamination was removed in recovered volatile vapors and 428 lbs (194 kgs) of chlorinated compounds were recovered from the groundwater

Approach:
• Electrical Resistance Heating
• Target Treatment Zone (TTZ):
  ◊ Area = 15,900 ft² (10,500 m²)
  ◊ Volume = 130,000 cy (10,000 m³)
  ◊ Depth = 5-26 ft (1.5-8 m) bgs
• 91 Electrodes
  ◊ 43 deep heating electrodes installed to a depth of 26 ft bgs (8 m)
  ◊ 48 shallow electrodes installed to a depth of 19 ft (6 m) bgs.
• 15 monitoring wells
• 17 horizontal vapor extraction wells

Site Information: Site 89 at the Camp Geiger portion of Marine Corps Base Camp Lejeune was used primarily as a storage yard for the Defense Re-Utilization Marketing Office until June 2000. 1,1,2,2 Tetrachloroethane (TECA) and Trichloroethene (TCE) were detected in monitoring wells and investigations concluded that a separate-phase DNAPL was encountered between 5 and 19 ft (1.5 and 6 m) bgs. The upper vadose zone was immediately treated with a separate technology; however a more sophisticated approach was required to address the DNAPL problem.

To meet the project objectives, CES deployed ERH to an array of vented electrodes. Of specific interest was that isolated deep electrode segments were installed approximately 8 ft below the treatment zone to first create a “hot floor” which prevented downward and lateral migration of DNAPL. Once the floor was hot, the core was heated to create what we called the “chimney or tepee effect.” This chimney effect functioned in the subsurface much the same as a fireplace which draws cooler air into and beneath the fire where it is heated and expelled up the chimney. The same effect was used to heat the floor of the site, draw-in lateral cooler water from the perimeter to control lateral migration, and force the heat inward and upward to heat the shallower formations where it was finally collected by the venting system.

A vacuum extraction system was used to capture steam and vapors. The contaminated steam was condensed in a heat exchanger and the condensate stored in a Baker tank for sampling and appropriate treatment or disposal. The non-condensed vapor, containing most of the contaminant mass, was then be treated by catalytic oxidation (CATOX) with an acid scrubber before discharge to the atmosphere.

Objectives: Remove DNAPL from subsurface.

Geology: Site 89 was characterized by three hydro-stratigraphic units within the treatment interval of 5 to 26 ft (1.5 to 8 m) bgs.

1. An undifferentiated formation from grade to around 8-15 ft (2.4-4.5 m) bgs consisting of fine to medium sand with interbedded silt and clay layers.
2. The Belgrade formation, a discontinuous clay layer (perching layer) that was presumed to have retarded much of the downward migration of DNAPL. The discontinuous Belgrade formation occurs at depths from 8 to 18 ft (2.4 to 5.4 m) bgs, and consists of clays, fine silty sand, or silt and was presumed to have retarded downward contaminant migration.
3. The River Bend formation begins at a depth of approximately 18 ft (5.4 m) bgs and is distinguished by the presence of calcareous sands, shell fragments, and fossil fragments. The overall hydraulic conductivity of the Castle Hayne aquifer and Belgrade formation are 10-3 cm/sec and 10-6 cm/sec, respectively. Groundwater is typically found at 3 ft (1 m) bgs.
**Project Summary:** Operations began in Mid October, 2003 with targeted energy to the floor of the site. Approximately two months later, active heating began at the core of the site. Energy was balanced to keep the floor at a slightly higher temperature than the core until the bulk of the site reached active steaming temperatures in early February. Project performance data showed that the ERH Technology was able to increase subsurface temperatures in both the soil and groundwater to 100°C or greater and hold the temperatures to these levels until the desired remediation levels were reached. Active heating continued until April 30, 2004 at which time a review of operational data concluded that the objectives of the test had been achieved.

Heating served to dramatically increase the removal rate of VOCs. The contaminant extraction rate increased from an average of 2 lbs/day (1 kg/day) at the beginning to averages of 200-440 lbs/day (90-180 kg/day) in December and January. As heating continued, the concentrations gradually tailed off to a rate of about 10 lbs/day (4.5 kg/day). It was concluded that DNAPL was no longer present and groundwater concentrations exceeded the treatment goals.

Groundwater monitoring throughout the project showed that the average total dissolved VOCs increased from about 1,500 mg/L to over 4,700 mg/L during heating. DNAPL was actually recovered from monitoring wells during sampling events during this period. Following the first 30 days of steaming, the dissolved total VOC concentrations were reduced to 24 mg/L, and at the conclusion of heating, the average total VOC concentrations were 4 mg/L throughout the site. TECA concentrations decreased by 99.99% after 6 months of operations; from an average of 992 mg/L to 0.9 mg/L.

The results of the technology exceeded the clients’ expectations and were completed safely without a single health and safety incident.
Site Information:
The Danville facility was originally constructed in the 1880’s to manufacture rolled steel and steel parts. A total of 26 on-site tanks and pits were reportedly used for storage of raw materials and wastes, including gasoline, Varso®, kerosene, fuel oil, cutting oil, hydraulic oil and waste oil.

Numerous remediation activities have been completed on the site since 1972. A brief summary of these activities is provided below:

• 1972 - Removed/abandoned Former Pits 17 and 18.
• 1986 - Leak tested and removed underground storage tanks (USTs). Closed Pits 10 and 11.
• 1987 - Installed groundwater monitoring wells and initiated routine groundwater monitoring.
• 1989 - Constructed a slurry wall and asphalt cap containment system.
  » Constructed and activated a groundwater extraction and treatment system.
  » Constructed and activated a light non-aqueous-phase liquid (LNAPL) recovery system.
  » Constructed and activated a soil vapor extraction (SVE) system.
• 2007 - Implemented a Steam Enhanced Extraction (SEE) interim remedial measure (IRM) in the Former Pit 17/18 Area.

The IRM was designed to reduce residual CVOC source mass and LNAPL within the former Pit 17/18 area.

Contaminants of Concern (COCs): were chlorinated volatile organic compounds (CVOCs); 1,1,1-TCA, TCE, 1,1-and cis-1,2-DCE, 1,1-DCA, VC and PCBs. A significant quantity of LNAPL was present and targeted for removal as well.

Geology/Hydrogeology: Three layer unconsolidated aquifer system comprised of:

• A fill layer 0-15 ft (0-4.5 m) below ground surface (bgs),
• Semi Confining Intermediate Silty Clay Layer 15 - 25 ft (4.5-8 m) bgs
• Sand/gravel layer 25-50 ft (8-15 m) bgs

Shallow bedrock was encountered at 40 ft (12 m) bgs, and the water levels were influenced by the nearby Susquehanna River.

Project Goals: The remedial objectives for the site were to

1. Remove NAPL within the shallow fill and deep sand/gravel unit;
2. Remove the sorbed phase CVOC mass;
3. Eliminate CVOC mass flux to groundwater;
4. Enable shut down of the existing pump and treat system; and,
5. Expedite site closure.

Results:

• All remedial goals met
• 19,500 lbs (8,850 kgs) of sorbed phase CVOCs along with 12,700 gallons (48,000 liters) CVOC entrained LNAPL, which was not recoverable through the previously existing treatment systems, were recovered

Approach:

• Steam Enhanced Extraction (SEE)
• Target temperature: 90°C
• Target treatment zone
  ○ Area: 44,500 square ft. (4,130 m²)
  ○ Volume: 71,800 cubic yards (55,000 m³)
• Steam injection wells: 89 (injecting steam into two different permeable zones)
• Temperature monitoring points: 25
• Multi-phase extraction wells: 31
• Monitoring wells: 10

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Steam Enhanced Extraction (SEE) for DNAPL Source Removal:
Confidential Client, Danville, PA

SEE Welfield
Steam Enhanced Extraction (SEE) for DNAPL Source Removal: Confidential Client, Danville, PA

**Results:**

- Approximately 127,361 million British thermal units (MM BTUs) were injected into the subsurface and 23,379 MM BTUs were extracted, resulting in a net energy gain of 103,982 MM BTUs. As a result, the IRM treatment volume was successfully heated and maintained within a target temperature range (+/- 90 degrees Celsius) during the IRM O&M period.

- Approximately 26,000,000 gallons (100,000,000 liters) of groundwater was extracted from perched groundwater table within the fill unit and regional unconsolidated aquifer within the sand/gravel unit, which equates to an average total extraction rate of 34 gallons per minute (130 liters per minute) during IRM O&M.

- Approximately 19,500 lbs (8,850 kgs) of CVOCs were removed from the subsurface as a result of IRM implementation. Mass removal rates up to 160 pounds per day (73 kgs per day) were observed during the initial four months of O&M. The mass removal rate was observed to stabilize after May 2008 and decrease significantly by IRM system shutdown.

- Approximately 12,700 gallons (45,000 liters) of LNAPL were extracted from the subsurface, recovered by separation, and then disposed offsite by incineration. A decreasing trend in LNAPL recovery was also observed though completion of IRM O&M.

- May 2009 influent concentrations for 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethene (1,1-DCE), cis-1,2-DCE, and 1,1,1-trichloroethane (1,1,1-TCA) were reduced by more than 90 percent relative to their respective maximum sustained value. Trichloroethene (TCE) reduction was reported to be 85 percent; however, its maximum sustained is likely biased low due to elevated detection limits in November 2007.

- The offgas treatment system consistently achieved greater than 99 percent destruction and removal efficiency (DRE) for VOCs, excluding two minor exceptions (both greater than 97 percent DRE).
Site Information:
For 70 years, the 63-acre (25 hectare) Teterboro Landing site in New Jersey operated as Bendix Aviation Corporation. Activities at the site included manufacturing aircraft technology to supply both World Wars, guiding the Jet Age and pioneering the Space Age. In its heyday, the site employed 15,000 people. In March 2007, a developer purchased the property with plans to redevelop the site into a transit-oriented development with connections throughout the Meadowlands Region.

TerraTherm was contracted to remediate source area contamination. Remediation at the Teterboro Landing site was completed in 2013. This site is noteworthy because it is the largest In Situ Thermal Desorption (ISTD) project to ever be completed, covering an area of 3.2 acres (1.3 hectares).

Remediation Goals and Results:

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TerraTherm worked closely with O’Brien & Gere, who developed the Conceptual Site Model for the treatment area, specified the remedial objectives, and provided multi-media permitting and regulatory / operations support throughout the program. The team executed a hot soil sampling protocol to demonstrate compliance attainment.

The ISTD system operated for 8 months, at which time interim soil sampling showed that all but one sampling location had met the remedial goal of 1 mg/kg. A small area with high starting concentrations proved to be recalcitrant, with soil concentrations plateauing at levels between 5 and 20 mg/kg. Four additional heater wells were installed, and 10 days later the remedial goals were achieved in this location. The energy used for heating was 23 million kWh, equal to 225 kWh/cubic yard treated. An estimated contaminant mass of 34,000 lbs (15,000 kg) was recovered and destroyed on-site through the thermal oxidizer treatment system.

Client Remarks:

I wanted to write to thank you and the rest of the TerraTherm team for your work on this important project. Your company was a pleasure to deal with. You clearly understand your business and the application of the thermal technology to the remediation of chlorinated organic compounds. I found your company to be thoughtful, responsive and capable. The objectives for the project were clearly defined at the outset, and contractually structured so everyone was clear on what was going to take place. The treatment objectives were successfully met within the time frame that was established at the beginning of the project. I found Ken Parker to be a pleasure to work with, as was the rest of your staff that I had the opportunity to interact with.

Sincerely,
Prologis

Steven E. Campbell, Senior Vice President
Head of Global Environmental, Engineering, and Sustainability
Results:

- Composite soil sample results show treated soil is suitable for unrestricted use
- 28 to 32 day treatment durations
- 60 cubic yards (cy) or 90 tons of contaminated soils treated in pilot test (larger volumes planned for field-scale units)
- Up to 368°C average temperature achieved

Approach:

- COR-TEN steel box, insulated to minimize heat loss, and covered, such that any vapors generated are collected and treated in the off-gas treatment system.
- Heat from steel box transferred to contaminated soil via thermal conduction heating

Background: The IPTD® HB1100 is a cost-effective, indirect thermal desorption technology for on-site treatment of contaminated soils, sediments and debris.

Two pilot tests were designed and implemented, under the auspices and with the permission of NYSDEC, to demonstrate the applicability of this technology. Test One treated VOC- and light-end SVOC-contaminated soils, while Test Two treated heavy-end, SVOC (in this case MGP)-contaminated soil.

Both pilot tests took place at the ESMI of NY, fixed thermal treatment facility, located in Fort Edward, New York.

Objectives:

- Demonstrate technology's ability to treat organic contaminants on-site for small/moderately sized projects (<10,000 cy), in a cost-effective way.
- Achieve soil cleanup levels meeting the 6 NYCRR Part 375-6.3 unrestricted use soil cleanup objectives.
- Verify model of predictions of in-box relationships between boiling points of contaminants, effects of vapor pressure, treatment duration and post treatment soil characteristics.
- Implement design enhancements for full-scale HB1100 deployment.

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<table>
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<th>Select Contaminants</th>
<th>Pre-Treatment Concentrations (PPM)</th>
<th>Unrestricted Land-Use Cleanup Goals* (PPM)</th>
<th>Met/Exceeded Cleanup Goals?</th>
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<tr>
<td>Benzene</td>
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<td>Benz[a]anthracene</td>
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<td>1</td>
<td>Yes</td>
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</tr>
<tr>
<td>Naphthalene</td>
<td>270</td>
<td>12</td>
<td>Yes</td>
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</table>

*From soil cleanup objective tables. Table 375-68(a): Unrestricted use Soil Cleanup Objectives
Appendix B: Applicable Systems and Contracting Qualifications

Corporate Project Management and Financial Data Management Systems

TerraTherm maintains an integrated project management system and protocols designed to ensure consistency of project planning, execution, oversight, and accountability. Each TerraTherm Project Manager has many years of experience in project management. Weekly project review meetings with Senior Management facilitate timely communications and ensure each project stays on track. TerraTherm utilizes several up to date project management tools and accounting systems to enable the successful scheduling, implementation, and tracking of projects. Our accounting system has undergone a Defense Contract Auditing Agency (DCAA) assist audit and a USAID survey audit.

Representations and Certificates (for Government Contracting)

TerraTherm, Inc. meets the definition of a Small Business for nearly all government procurements. Our Representations and Certifications are available online at www.bpn.gov (our D&B number is 00-266-6522).

Corporate Quality Assurance/Quality Control (QA/QC) Program

TerraTherm is typically responsible for developing and implementing a Quality Assurance/Quality Control (QA/QC) program for each major project. As a component of such project-specific programs, a Quality Assurance Project Plan (QAPP) is developed, as well as a Sampling and Analysis Plan (SAP). It is the ultimate responsibility of the Corporate Officers to ensure that the plans meet both corporate and client requirements prior to their submittal and that they are adhered to in all respects.

Major Elements of TerraTherm’s Corporate QA/QC Program Include:

Maintenance of a Lessons Learned Process and Database: TerraTherm regularly convenes a Lessons Learned Committee, comprised of engineering and field staff, which scrutinizes all significant design features, construction methods, and operational procedures. Decisions are made concerning needed changes and a database is maintained and distributed to ensure that the resulting improvements are promulgated to all staff.

Standard Operating Procedures: TerraTherm has developed a series of Standard Operating Procedures (SOPs), including Engineering Review; Constructibility Review; Hot Soil Sampling; Accident Reporting & Investigation; and Operations Data Management/Reporting.

Project Technical Reviews: Project Technical Reviews are carried out biweekly for most major projects. Such reviews include senior staff not involved in the day-to-day project or technical management of the projects. The purposes of such reviews are to review project progress against planned milestones; ensure that QA/QC requirements are being adhered to; and enable timely response to issues that may arise.
Appendix C: TerraTherm Sustainability Policy

TerraTherm is a Contributor to the Sustainable Remediation Forum (SuRF)

TerraTherm endorses and contributes to the efforts of the Sustainable Remediation Forum (SuRF) in working to define sustainability and social responsibility as they relate to site cleanup. TerraTherm strives to establish and maintain a leadership role in the evolution of sustainable remediation through improvement in all operational aspects.

Ancillary Environmental Impacts from Cleanups

Our ISTR technologies prevent migration of contaminants from the site. In addition, since there is no excavation or transportation of materials, airborne contaminants, dust, and noise are virtually non-existent. Treatment of collected gases is thorough with odorless and clean vapor emissions. As a result, ISTR is a leading method in preventing ancillary environmental impacts.

Energy Consumption and Greenhouse Gas Emissions

TerraTherm’s ISTR technologies employ electrical power. Since our project cycles are short and predictable, total energy use is well defined and the need for repeated applications or long-term operations and maintenance is eliminated; therefore, remediation is rapid and is inherently more sustainable than potential trial-and-error approaches that may use more resources, delay redevelopment, put Greenfields at risk of development, and create more emissions in the long run. TerraTherm has participated in cutting edge Life Cycle Assessments to evaluate the sustainability of our projects and find ways to make them more sustainable. TerraTherm offers verifiable Carbon Offsets to our clients for TerraTherm field projects. Offsetting the carbon footprint of a typical ISTR project adds less than 1% to the project cost. Such initiatives have been successful in steadily increasing the energy efficiency of our technologies through R&D and innovation. The rapid and final site cleanup advantages, extremely high level of safety, cleanliness of our operations, and low community impact combine to make ISTR a logical and leading choice for sustainability. These factors greatly outweigh the slight carbon impact incurred in the use of electrical power.

Preservation of Natural Resources and Maximization of Land Reuse to Preserve Underdeveloped Areas

Undeveloped lands play an important role in mitigating the effects of greenhouse gas emissions. In the effort to preserve such lands, time is of the essence. Among the most efficient ways to prevent undeveloped lands from being committed to industrial use is to revitalize and clean Brownfields for reuse in a timely and predictable manner. The rapid and predictable results of ISTR ensure the redevelopment of Brownfields on a fixed timeline, thereby preserving Greenfields. No other technology achieves this sustainability goal as quickly, or completely, as ISTR.

Permanent Elimination of Contamination

ISTR is proven uniquely effective in the elimination and stabilization of contaminants. Results consistently demonstrate the achievement of site cleanup goals, even to drinking water standards (where applicable). Through carefully engineered and controlled processes, permanent remediation is measurable and ensured through in situ destruction, desorption, stabilization, and/or extraction of offending materials. In addition, these processes prevent mobilization of contaminants ensuring the safety of adjacent water supplies. No other remediation technology has proven more effective in the permanent elimination of contaminants.
Public Contractor Safety and Health During and After the Project

TerraTherm has maintained an impeccable safety record throughout its history. Further, it can be said that in situ thermal remediation is inherently safer than other methods because of little or no dust, heavy vehicle movement, chemical use, harmful emissions, or noise are consequential to the process. In this way, threats to public and contractor health that are common to excavation, chemical treatment, and some other purportedly “green” methods are eliminated or greatly reduced.

Recycling of Materials

TerraTherm endeavors to reuse, refurbish, and recycle materials to the fullest extent possible. We have found that refurbishing process equipment to fully restore it to useful life is both economical and safe. It also provides reductions in ancillary life cycle costs (resource extraction, manufacturing, shipping, etc.). Our aim is to exemplify the principal of “waste not, want not.”
Appendix D: TerraTherm’s Online Presence

You can now keep up-to-date with all things thermal and follow TerraTherm through various social media networks. View, Follow, and “Like” us on LinkedIn, Facebook and Twitter, as well as our very own blog titled “Think Thermal-The Blog.”

Our goal is to provide our audience with value-added posts to educate about what we do, and explain why TerraTherm, continues to be the “Thought Leader” in our industry.

If you have any questions about our process, we would be happy to organize an educational webinar on the topic of your choice. Email marketing@terratherm.com.

Also make sure that you sign up for our Quarterly Newsletter through the button below, for project updates and other important news from TerraTherm.