# In Situ Thermal Remediation
# Remedial Action
# Work Plan and Project Operations Plan

## Solvents Recovery Service of New England, Inc.
## Superfund Site
## Southington, Connecticut

**Prepared for:**

**SRSNE Site Group**

**Revised, May 2014**

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"Covered by one or more of the following: U.S. Patent Nos.5,553,189; 5,656,239; 5,660,500; 5,997,214; 6,102,622; 6,419,423; 6,485,232; 6,543,539; 6,632,047; 6,824,328; 6,854,929; 6,881,009; 6,945,734; 6,951,436; 6,962,466; 7,004,678; 7,121,341; 7,481,274; 7,490,665; 7,534,926; 7,559,367; 8,200,072; 8,224,163; 8,224,164; 8,224,165; 8,238,730; 8,348,551 and 8,355,623; and Pending; Australia Patent Nos. 720947, 774595, 2002336664, 2002359299, 2002365145, 2003286673, 2005238948, 2006239963, 2006306404 and Pending; Austria Patent No. E222147; Belgium Patent Nos. EP1011882, EP1272290 and 1446239; Brazil Patent No. PI9809922-1, PI01100505, PI02135116, PI02135124, PI02135132 and Pending; Canada Patent Nos. 2289080, 2405612, 2462215, 2463053, 2463108, 2503394, 2565594 and Pending; China Patent Nos. 98805738.7, 01809975.0, 200380104391.1, 200580016609.7 and Pending; Czech Republic Patent No. 294883; Denmark Patent Nos. EP1011882, EP1272290, EP1446239, EP1467826, and Pending; Eurasian Patent Convention 009586, 014215, 014258, 200601956 and Pending; European Patent Office Patent Nos. 1272290, 1446239, 1467826, 1738056 and Pending; France Patent Nos. EP1011882, EP1272290, EP1446239, EP1467826, EP1738056, EP1871982, and Pending; Germany Patent Nos. P60110056.5-08, P602005016096.5-08, P602006013437.1-08, P6020503803-08, P60215378.6-08, P69807238.3-08, EP1871982, and Pending; Gulf Cooperation Council Patents Pending; Hungary Patent No. 224761; India Patents Pending; Indonesia Patent Nos. ID0008181, IDP0026666 and Pending; Ireland Patent No. EP1011882; Israel Patent No. 168125, 178468, 190658 and Pending; Italy Patent Nos. EP1011882, EP1446239, EP1467826, EP1738056, EP1871982 and Pending; Japan Patent Nos. 4344795, 4344803, 4399033, 4509558, 4,806,398 and Pending; Kazakhstan Patent Nos. 009586, 014215 and 014258; Kyrgyzstan Patent No. 011007; Madagascar Patent No. 004600, 00460 and Pending; Mexico Patent Nos. 216411, 241679, 247287, 249734, 256799, 270586 and Pending; Morocco Patent Nos. 29719 and 29960; Netherlands Patent Nos. EP1011882, EP1272290, EP1446239, EP1467826, EP1738056, EP1871982 and Pending; New Zealand Patent Nos. 500724, 522078, 550505, 562242, 567255 and Pending; PCT Patents Pending; Poland Patent No. 191230; Russia Patent Nos. 001706, 009586, 011007, 014215, 014258 and EP1871982; Singapore Patent No. 68767; Slovakia Patent No. 283577; South Africa Patent Nos. 2006/08260, 2007/08023 and 2008/02758; South Korea Patent Nos. 499762, 771407, 900892, 925129, 925130, and Pending; Spain Patent Nos. 1011882 and ES2182337; Sweden Patent Nos. 98932146.8, EP1011882, EP1446239, EP1467826, and Pending; Taiwan Patent No. I192090; United Kingdom Patent Nos. EP1011882, EP1272290, EP1446239, EP1467826, EP1738056, EP1871982 and Pending; and Venezuela Patents Pending."

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AOC | Administrative Order on Consent |
| AQC | Air Quality Control |
| ATS | automatic transfer switch |
| BACT | Best Available Control Technology |
| bgs | below ground surface |
| Btu | British Thermal Units |
| $^{o}C$ | degrees Celsius |
| $CaCl_2$ | calcium chloride |
| CCC | Catalytic Combustion Corporation |
| CD | Consent Decree |
| CD/WP | Conceptual Design Remedial Action Work Plan |
| CF | cubic feet |
| COCs | Contaminants of Concern |
| CTDEEP | Connecticut Department of Energy and Environmental Protection |
| CVOCs | chlorinated volatile organic compounds |
| CY | cubic yards |
| DNAPL | Dense Non-Aqueous Phase Liquid |
| DPT | Direct Push Technology |
| DRE | Destruction Removal Efficiency |
| $^{o}F$ | degrees Fahrenheit |
| FS | Feasibility Study |
| FSP | Field Sampling Plan |
| ft | foot or feet |
| GAC | granular activated carbon |
| gpd | gallons per day |
| gpm | gallons per minute |
| HAP | Hazardous Air Pollutant |
| HASP | Health and Safety Plan |
| HAZOP | Hazard and Operability Review |
| HCl | hydrochloric acid |
| HCTS | Hydraulic Containment and Treatment System |
| HLVs | Hazard Limiting Values |
| hr | hour |
| in. wc | inches of water column |
| IQAT | Independent Quality Assurance Team |
| ISTR | In-Situ Thermal Remediation |
| $^{o}K$ | degrees Kelvin |
| KCl | potassium chloride |
| kWh | kilowatt hours |
| LEL | lower explosive limit |
| LNAPL | Light Non-Aqueous Phase Liquid |
| M | meter |
| M&E | Mass and Energy |
| MASC | Maximum Allowable Stack Concentrations |

| | |
|---|---|
| mg/Kg | milligrams per kilogram |
| $mg/m^3$ | milligrams per cubic meter |
| NaCl | sodium chloride |
| NaOH | sodium hydroxide |
| NAPL | Non-Aqueous Phase Liquid |
| NEC | National Electrical Code |
| NFPA | National Fire Protection Association |
| NPL | National Priorities List |
| O&M | Operations and Maintenance |
| P&ID | piping & instrumentation diagram |
| PCE | tetrachloroethene |
| PFD | Process Flow Diagram |
| PID | photoionization detector |
| PIPP | Pre-ISTR Preparation Plan |
| PLC | Programmable Logic Controller |
| PM | Project Manager |
| POP | Project Operations Plan |
| POTW | Publicly Owned Treatment Works |
| PPE | personal protective equipment |
| ppm | parts per minute |
| ppmv | parts per minute by volume |
| psig | pounds per square inch gauge |
| QAPP | Quality Assurance Project Plan |
| RAOs | Remedial Action Objectives |
| RAWP | Remedial Action Work Plan |
| RCRA | Resource Conservation and Recovery Act |
| RD | Remedial Design |
| RD/RA | Remedial Design/Remedial Action |
| RDWP | Remedial Design Work Plan |
| RI | Remedial Investigation |
| ROD | Record of Decision |
| RTOs | Regenerative Thermal Oxidizers |
| SAP | Sampling and Analysis Plan |
| scfm | standard cubic feet per minute |
| SCRs | Silicon Controlled Rectifiers |
| SOPs | Standard Operating Procedures |
| SOW | Statement of Work |
| SPCC | spill prevention control and countermeasures |
| SRSNE | Solvents Recovery Service of New England, Inc. |
| SSO | Site Safety Officer |
| SVOCs | semi-volatile organic compounds |
| TCE | trichloroethene |
| TCH | thermal conduction heating |
| TO | thermal oxidizer |
| TTZ | thermal treatment zone |
| TWISP | Thermal Wellfield Installation Support Plan |
| USEPA | United States Environmental Protection Agency |

| | |
|---|---|
| VEW | vapor extraction well |
| VOCs | volatile organic compounds |
| W | Watts |

# EXECUTIVE SUMMARY

This combined Remedial Action Work Plan (RAWP) and Project Operations Plan (POP) has been prepared on behalf of the SRSNE Site Group, an unincorporated association of the Settling Defendants to a Consent Decree (CD) and Statement of Work (SOW) for the Remedial Design/Remedial Action (RD/RA) at the Solvents Recovery Service of New England, Inc. (SRSNE) Superfund Site in Southington, Connecticut (Site). The CD was lodged on October 30, 2008 with the United States District Court for the District of Connecticut in connection with Civil Actions No. 3:08cv1509 (SRU) and No. 3:08cv1504 (WWE). The CD was entered by the Court on March 26, 2009. As identified in the CD and SOW, the selected remedy for the overburden soil at the Site that contains Non-Aqueous Phase Liquid (NAPL) is In-Situ Thermal Remediation (ISTR).

An ISTR Remedial Design Work Plan (RDWP) was prepared on behalf of the SRSNE Site Group and submitted to the United States Environmental Protection Agency (USEPA) for review on April 20, 2009. One component of the RDWP was the Overburden NAPL Delineation Plan, which provided additional information on the extent of NAPL in the overburden in the vicinity of the former Operations Area. These data provided the basis for delineating the full extent of the area to be treated by ISTR. Other components of the RDWP included:

- Development of the thermal treatment monitoring program and performance assessment criteria;

- Preparation of a Vapor Treatment Needs Evaluation Work Plan to evaluate and select the approach and equipment for treatment of vapors and liquids generated during ISTR; and

- Preparation of a System Design Evaluation Work Plan that included thermal modeling to assess the rate of heat-up and mass removal of the Site and assessment of the corrosion potential for subsurface and aboveground piping.

The RDWP also included the *Pre-ISTR Preparation Plan* (PIPP), which provided concept-level design for certain activities to be conducted to prepare the Site for implementation of the ISTR component of the remedial approach. USEPA approval of the PIPP was received on September 17, 2010. The associated site preparation activities were initiated in f fall 2010 and were completed in fall 2012 once an easement was finalized between AT&T and the State of Connecticut that allowed for the relocation of an existing fiber optic line within an area of state-owned land. The design information presented herein reflects the planned post-PIPP-implementation site conditions, which were documented in the Pre-ISTR Site Preparation Completion Report (ARCADIS, April 2013).

This report presents a combined RAWP/POP for the ISTR system. As such, this report presents the design basis for the ISTR system and describes implementation of the various activities necessary to address the remedial objectives. Several pre-design studies were performed to support the design of the ISTR system. Results from the studies, discussed in Section 5.0, were used to design the thermal treatment system.

As of the date of this revised RAWP/POP, the thermal wellfield installation has been completed. Based on actual field conditions, the treatment depth, number of wells installed, number of monitoring wells installed, equipment layout and energy demand has changed relative to the initial design. In addition, the target TTZ was modified slightly at certain perimeter locations based on field observations. Note that this document still reflects the original (i.e., pre-wellfield-installation) design. While interim modifications have been presented and discussed with the regulatory agencies over the course of the work, deviations from the original design will be presented in the completion report rather than in this revised design report. However, actual design conditions, as of December 2013, are represented in the O&M Manual (Appendix D of this design document).
The overall objective of this document is to facilitate the successful and cost-effective design, construction, operation, monitoring, demobilization, and reporting for an ISTR system that achieves the Remedial Action Objectives (RAOs) for the Site established in the Record of Decision (ROD) and that meets the performance standards (cleanup levels) for the Overburden NAPL Area.

The RAOs are intended to protect human health and the environment. As stated in the RD/RA SOW, the Interim NAPL Cleanup Levels have been defined as concentrations in soils that are not indicative of the presence of pooled or residual NAPL, and are as follows:

Trichloroethene (TCE) – 222 milligrams per kilogram (mg/Kg)
Tetrachloroethene (PCE) – 46 mg/Kg
1,1,1-Trichloroethane – 221 mg/Kg
Ethylbenzene – 59 mg/Kg
Toluene – 48 mg/Kg
p/m-Xylene – 70 mg/Kg
o-Xylene – 42 mg/Kg

The RD/RA SOW further states:

*At the time all the Interim NAPL Cleanup Levels are attained in the Overburden NAPL Area, USEPA will evaluate whether to continue to operate the in-situ thermal treatment system in areas within the Overburden NAPL Area where USEPA determines that appreciable amounts of NAPL contamination continue to be recovered. For this purpose, EPA will only require continued operation of the portions of the in-situ thermal treatment where "appreciable recovery of NAPL contamination" continues to occur.*

*Regardless of the level of recovery, the maximum amount of time that USEPA shall require continued operation of the in-situ thermal treatment system in portions of the Overburden NAPL Area where appreciable recovery of NAPL* *contamination continues to occur, after all the Interim NAPL Cleanup Standards are achieved, shall not exceed the initial heating time required to achieve Interim NAPL Cleanup Levels (e.g., if it takes 180 days of heating to achieve all the Interim NAPL Cleanup Levels, the maximum amount of time that USEPA will require that any or all wells be operated will be an additional 180 days). The start date for measuring the duration of such period of additional operation, if any, will be the first day of operation after the collection of the last sample within the data set used to successfully demonstration that all Interim NAPL Cleanup Levels have been attained at every location.*

The conceptual thermal treatment zone (TTZ) covers an approximate area of 74,195 square feet with a target treatment depth ranging between 12 and 24 feet below ground surface (ft bgs), with some deeper locations extending to depths between 26 and 32 ft bgs, depending on the depth to bedrock in the wellfield. The weighted average treatment depth is 17.1 ft. Based on this, the volume of soil to be treated in the thermal remediation project is approximately 47,298 cubic yards (CY).

In general, the ISTR system will heat the western portion of the TTZ from 0-15 ft bgs, the middle/main portion of the Site will be heated from 0-18 ft bgs, and the eastern portion will be heated from 0-24 ft bgs. A small portion of the middle zone will be heated to depths between 20 and 22 ft, corresponding to a thicker overburden where re-grading was necessary as part of the site preparation activities. A small portion of the eastern zone will be heated to depths between 26 and 32 ft where available top-of-bedrock interpretations suggest a possible local bedrock depression. To ensure adequate heating of the bottom of the TTZ and to address potential heat losses due to groundwater flux, power output of the lower 5 to 6 ft of the heaters will be boosted.

The design of the thermal wellfield includes the following components:

- Electrically powered heater wells to supply heat by thermal conduction from the ground surface to depths ranging from 15 ft bgs to 32 ft bgs, dependent on the specific location within the wellfield.
- Vapor extraction wells (VEWs) to extract vapors from the vadose zone. VEWs will be installed approximately 3 ft from each heater well.
- Horizontal VEWs to extract vapors in the shallowest easternmost part of the TTZ to extract vapors from the vadose zone.
- Pressure and water level monitoring points will be installed throughout the wellfield to monitor and document pneumatic and hydraulic control.
- Groundwater monitoring wells, installed in locations of historically observed NAPL to generally monitor changes in concentrations of volatile organic compounds (VOCs) in groundwater during ISTR. It is important to reiterate that the performance standards for the thermal treatment remedy do not include any metrics based on dissolved concentrations in groundwater.
- Temperature sensors will be installed throughout the wellfield to monitor heating.
- A low-permeability, waterproof concrete vapor cap to limit precipitation infiltration, assist in the capture of the vapors, and minimize heat losses.

Vapors will be extracted from the subsurface under vacuum and pass through a moisture separator to remove entrained liquid and condensate prior to vapor treatment through a thermal oxidizer and a wet scrubber.

The liquid condensate that accumulates in the wellfield piping manifold and moisture separator will be transferred to a phase separator designed to separate Light Non-Aqueous Phase Liquid (LNAPL) and Dense Non-Aqueous Phase Liquid (DNAPL) from water, if present. LNAPL and DNAPL, if present, will be collected in drums. The effluent water from the phase separator will be conveyed to an air stripper for treatment followed by liquid phase carbon for final polish prior to discharge to the Publicly Owned Treatment Works (POTW).

Thermal design modeling indicates that the optimal approach to heat and treat the Site is to divide the Site into two segments or phases with each phase lasting approximately 135 days, and with the second phase starting 60 days after the first. This approach significantly reduces the peak mass loading rate (fuel and Contaminants of Concern [COCs] loads) and provides a means to heat the TTZ in a controlled fashion and to regulate the mass loading rate to the off gas treatment system.

A mass and energy balance performed based on site data showed that the chosen ISTR wellfield design will be capable of heating the Site to 100 degrees Celsius ($^{o}$C) within an overall operational period of approximately 195 days (i.e., two phases each lasting 135 days with the second phase starting 60 days after the start of the first). During the 195-day operating period, approximately 13.8 million kilowatt hours (kWh) of electrical power will be delivered to the heater wells. These operational objectives were based on conservative design parameters provided by the group which were numerically modeled by TerraTherm. Results of the model are used to assist with equipment sizing, cooling requirements, estimated power usage, and the overall level of effort needed to meet the RAOs.

Monitoring and sampling will be conducted to assess the treatment progress. Monitoring includes measurement of subsurface wellfield temperatures; measurements of temperature, pressure, flow rates, and liquid levels throughout the process treatment system; as well as power delivery from the ISTR system. Screening level measurements will be taken and grab samples will be collected to assess the VOC removal rate during operations and to assess remedial progress. These data will also be used to document compliance with applicable vapor and liquid discharge limits.

Additional screening level groundwater samples will be collected before and periodically during thermal treatment operations. These data results will not be used as a compliance metric, but rather to evaluate general changes in the dissolved phase VOC concentrations.

Progress soil sampling events will be conducted to determine the progress of the remedy toward achieving the cleanup levels. Based on evaluation of the results of the progress soil sampling events, the VOC removal rates, the distribution of subsurface temperatures, and the observed trends in groundwater concentrations, the decision will be made to conduct the final confirmatory soil sampling event to verify compliance with the project cleanup levels. Confirmatory soil sampling will be performed separately for each phase.

# 1.0 UPDATED BASIS OF CONCEPTUAL DESIGN

This section identifies the key components of the design that have been revised, modified, or added since the conceptual design was submitted to the USEPA in 2010.

Additional modeling and analysis, including a combined Hazard and Operability Review (HAZOP) and Constructability Review, were performed by TerraTherm's design team for the proposed ISTR system. The combined HAZOP and Constructability Review is included as Appendix A.

The HAZOP review was a structured and systematic examination of the wellfield and electrical design, and the vapor/liquid treatment system piping & instrumentation diagram (P&IDs). The ISTR system was broken down piece-by-piece to identify, evaluate, and rank potential problems that may represent risks to personnel, public, equipment, or the environment. The Constructability Review focused on reviewing the proposed ISTR system design with known site conditions and evaluating the functionality of the current design. Modifications to the ISTR Conceptual Design Remedial Action Work Plan (CD/WP) were made as a result of the HAZOP review. These modifications and corresponding sections are summarized below.

Comments from the USEPA and Connecticut Department of Energy and Environmental Protection (CTDEEP) on the CD/WP have been addressed in multiple memoranda since the conceptual design report was initially submitted in April 2010. Modifications resulting from additional modeling and analysis and the comment/response process have been incorporated within this final RAWP/POP submittal.

Treatment depths within the TTZ have been refined based on an additional review of the surface grading elevations reflecting the prepared site conditions. In general, the ISTR system will heat the western portion of the TTZ from 0-15 ft bgs, the middle/main portion of the TTZ will be heated from 0-18 ft bgs, and the eastern portion of the TTZ will be heated from 0-24 ft bgs. A small portion of the middle zone will be heated to depths between 20 and 22 ft, corresponding to a thicker overburden due to re-grading of the Site. A small portion of the eastern zone will be heated to depths between 26 and 32 ft bgs, corresponding to an interpreted local bedrock depression. Additional details on the modified treatment depths are provided in Section 9.0.

Seven groundwater monitoring wells were added within the TTZ at the request of USEPA to assist with evaluating general changes in the dissolved phase VOC concentrations during thermal operations. Additional details on the groundwater monitoring wells are provided in Section 9.0.

Forty-four additional temperature and pressure monitoring points were added within the TTZ to provide a more robust network for confirming the heat distribution and effectiveness of the vapor collection system throughout the targeted soil volume. The majority of locations were added at centroids between heater wells, which are locations farthest from the heat sources and therefore most difficult to heat to target temperatures. Others targeted locations nearer to heaters (to monitor the heat propagation), or other specific locations of potential interest during the thermal process (e.g., near the ends of the barrier wall extensions to assess the potential cooling effects in the event of groundwater inflow near the end of the wall).

The general approach of the ISTR system has not changed since preparation of the ISTR CD/WP with the exception that one full-sized oxidizer has been selected for use during thermal operations rather than two smaller oxidizers. This decision was made at the recommendation of the selected thermal oxidizer vendor, Catalytic Combustion Corporation (CCC), in consultation with TerraTherm's design team. There are a number of technical considerations that enter into the use of dual oxidizers in a parallel treatment train, including flow and load balancing, control system interactions, and additional high-temperature-resistant interconnecting components at the oxidizer outlets. CCC expressed some concerns regarding the use of two separate oxidizers during operations, and, while possible, it is more complicated than operating and maintaining a single oxidizer.

TerraTherm worked closely with CCC to specify a highly reliable single thermal oxidizer/scrubber package guaranteed for a minimum 99% uptime operation. The high-reliability single oxidizer/scrubber system includes multiple installed redundant components (i.e., dual flame scanners, dual combustion air blowers, dual scrubber liquid circulating pumps, dual pH probes, etc.), along with a set of manufacturer-recommended redundant and spare parts that will be provided as part of the high-reliability package (i.e., gas control valve, high/low pressure switches, Hastelloy quench spray nozzles, caustic metering pump, makeup water solenoid, air flow switches, etc.) to allow for rapid on-site repair/replacement enabling maximum uptime for the system. CCC has confidence in this high-reliability design and has provided such systems on previous projects and TerraTherm's operation technicians are familiar with operation, maintenance, troubleshooting and repair of thermal oxidizer and scrubber systems. We believe this change will result in a robust, yet simpler system compared with a dual parallel oxidizer system. Additional details on the oxidizer/scrubber package are provided in Section 9.3.

Sections 10.5, 11.4, 12.0, and 13.11 have been added and discuss the spill prevention control and countermeasures (SPCC) plan, meeting frequency, emergency response plan, and thermal operation adjustments, respectively.

As of the date of this revised RAWP/POP, the thermal wellfield installation has been completed. Based on actual field conditions, the treatment depth, number of wells installed, number of monitoring wells installed, equipment layout and energy demand changed relative to the initial design. In addition, the target TTZ was modified slightly at certain perimeter locations based on field observations. Note that this document still reflects the original (i.e., pre-wellfield-installation) design. While interim modifications have been presented and discussed with the regulatory agencies over the course of the work, deviations from the original design will be presented in the completion report rather than in this revised design report.

# 2.0 INTRODUCTION

TerraTherm, Inc. has been contracted by the SRSNE Site Group to design, install, and operate a thermal conduction heating-based ISTR system within the Overburden NAPL Area at the SRSNE Site in Southington, Connecticut. The work will be performed pursuant to an RD/RA CD and SOW that has been negotiated with USEPA Region I and CTDEEP by the SRSNE Site Group, an unincorporated association of Settling Defendants to the CD and SOW for the RD/RA activities at the Site.

## 2.1 Project Delivery Status

This document, known as the RAWP and POP, combines the design for the TTZ and the RAWP as required in Sections V.E and VI.A of the RD/RA SOW. Comments from USEPA and CTDEEP on the Conceptual Design/RAWP have been addressed in multiple memoranda since the conceptual design report was initially submitted in April 2010. Modifications resulting from the comment/response process have been incorporated within this final RAWP/POP submittal.

This RAWP/POP addresses the SOW requirements listed below and outlines the steps required to implement the planned remediation project at the Site. The primary objective of this document is to present the basis for design of the ISTR system and to describe implementation of the activities required to construct, operate, and monitor the system. Accordingly, this document includes the following:

- Definition of the treatment goals including RAOs and Performance Standards;
- Site Background;
- Refinement of the TTZ based on the July 2009 DNAPL data results;
- Description of ISTR layout and operations;
- Definition of the ISTR system utility/infrastructure support needs;
- Identification of site constraints and design objectives; and
- Description of the monitoring program and evaluation criteria.

## 2.2 Requirements of the SOW

The SOW requires that the RAWP address the following:

- Results of pre-design activities;
- Basis of design/assumptions;
- Changes to any design/assumptions;
- Plans, drawings, sketches, calculations, and technical specifications, as needed;
- Project delivery status;
- Statement of regulatory compliance;
- Construction environmental monitoring plan;
- Independent Quality Assurance Team (IQAT) Work Plan (submitted by ***de maximis, inc***. *(de maximis),* under separate cover);
- Sampling program to determine if Overburden NAPL Cleanup Levels have been met;
- Award of project contracts, including off-site treatment and/or disposal facilities;
- Contractor mobilization/site preparation, including utility hookups;

- Construction, shake-down, and start-up; and
- Demobilization.

Part of the design initiation phase, as outlined in the SOW, included preparation and implementation of the following RDWP components to evaluate and further define site conditions:

- Materials Compatibility Test(s);
- Analysis of NAPL samples collected from the thermal treatment area;
- Thermal Simulation Model; and
- System Design Evaluation.

The information concluded from these studies was used to design the thermal treatment system. Results of these studies are presented in Section 5.0.

In addition to the above studies, the RDWP included development of the thermal treatment monitoring plan and performance criteria. These RDWP work products have been incorporated into this document.

The SOW also required the preparation of an ISTR POP specific to the construction and operation of the thermal treatment system. The ISTR POP and supporting sections are addenda to the site-wide Remedial Design (RD) POP. The ISTR POP can be found in Section 6.0 and includes the following:

- ISTR-Specific Site Management Plan;
- Schedule for implementation and reporting;
- Sampling and Analysis Plan (SAP) including the Quality Assurance Project Plan (QAPP) and Field Sampling Plan (FSP) prepared by ARCADIS as an RDWP. Additional standard operation procedures specific to the thermal remedy are included herewith as Appendix E; and
- Site-Specific Health and Safety Plan (Appendix F).

A POP was also prepared by ARCADIS as part of the RD phase, which pertains to the overall fieldwork including but not limited to site grading, relocation of utilities, abandonment of downgradient monitoring wells, etc. Where applicable, the ISTR POP builds on and references the RD POP.

## 2.3 Document Format

This RAWP/POP is divided into the following sections:

1. **Updated Basis of Design** – Includes changes to the design that was submitted under the Conceptual Design Work Plan.
2. **Introduction -** Includes a discussion on the project delivery strategy.
3. **Project Objectives** - Defines the cleanup goals for the overburden NAPL zone.
4. **Thermal Technology Background** - Provides an overview of thermal conduction heating.
5. **Design Basis and Results of Pre-Design Studies -** Discusses the results of the pre-design studies and development of the basis for the design of the ISTR system.

6. **Project Operations Plan** - Presents the Site Management Plan and discusses subcontracts; project schedule and reporting; mobilization, construction, start-up, and demobilization of the ISTR system; and modifications to the site-wide QAPP (including the SAP and FSP).
7. **Health & Safety Plan** – Describes the health and safety procedures to be followed during thermal implementation and operation.
8. **Construction Environmental Monitoring Plan –** Describes the monitoring that will be conducted during drilling, construction, and operation of the ISTR system.
9. **ISTR System Design and Construction** - Provides a detailed discussion of the design and implementation of the thermal remedy.
10. **Regulatory Compliance** – Summarizes how the design of the ISTR system addresses the applicable or relevant and appropriate requirements (ARARs) relevant to the overburden NAPL zone.
11. **Thermal Remediation Operations** - Discusses the sequence for construction, operation, shutdown, and demobilization.
12. **Emergency Response Plan –** Establishes procedures to be employed in the event of an emergency.
13. **Treatment Performance Evaluation** - Provides a sampling program to evaluate the overburden NAPL cleanup goals.

The following appendices provide supporting information necessary for the design and implementation of the ISTR system. As indicated below, some of these appendices are currently placeholders or only include outlines of the attachments.

- Appendix A includes the conclusion of the HAZOP and constructability reviews.
- Appendix B includes the results of the pre-design studies (materials compatibility test, NAPL analysis, thermal modeling, and off-gas treatment design evaluation).
- Appendix C contains the design drawings.
- Appendix D includes the Operations and Maintenance (O&M) Manual.
- Appendix E includes the Standard Operating Procedures that are specific to the ISTR activities.
- Appendix F is the Site-Specific Health and Safety Plan specific to the ISTR system.
- Appendix G is the Thermal Wellfield Installation Support Plan (TWISP) (ARCADIS, revised November 2013).
- Appendix H provides the equipment manuals.
- Appendix I contains copies of permit equivalency applications and approvals.
- Appendix J contains the SPCC Plan.
- Appendix K contains the Emergency Response Plan for the Site.

## 3.0 PROJECT OBJECTIVES

The overall objective of this document is to facilitate the successful and cost-effective design, construction, operation, monitoring, demobilization, and reporting for an ISTR system that achieves the RAOs for the Site established in the ROD as well as to meet the performance standards (cleanup levels) for the Overburden NAPL Area as described below.

### 3.1 Remedial Action Objectives

**Human Health**

Reduce or stabilize the NAPL mass that would otherwise result in groundwater concentrations that may pose an excess carcinogenic risk of $1 \times 10^{-4}$ to $1 \times 10^{-6}$, non-carcinogenic Hazard Index greater than 1, a cumulative risk from multiple contaminants exceeding a lifetime cancer risk of $1 \times 10^{-5}$, or that exceed ARARs.

**Protection of the Environment**

1. Shorten the time frame that groundwater standards are exceeded;
2. Shrink the size of the groundwater contaminant plume;
3. Reduce groundwater contaminant concentrations; and
4. Prevent the migration of NAPL.

### 3.2 Performance Standards

Section IV.1 of the SOW establishes Interim Cleanup Levels for groundwater. Because waste will be left in place after the completion of ISTR, the point of compliance for groundwater is to the edge of the waste management unit. Groundwater Cleanup Levels shall be met throughout the contaminated plume, except for under the cap that will be installed subsequent to ISTR. The TTZ will be completely within the footprint of the planned future cap.

As established in Section IV.4 of the SOW, the Interim NAPL Cleanup Levels for soils are as follows:

| | |
|---|---|
| TCE | 222 mg/Kg |
| PCE | 46 mg/Kg |
| 1,1,1-Trichloroethane | 221 mg/Kg |
| Ethylbenzene | 59 mg/Kg |
| Toluene | 48 mg/Kg |
| p/m Xylene | 70 mg/Kg |
| o Xylene | 42 mg/Kg |

These levels shall be met from the ground surface to the top of bedrock throughout the TTZ. At the time that all the Interim NAPL Cleanup Levels are attained, USEPA will evaluate whether to continue to operate the ISTR system in areas where USEPA determines that appreciable recovery of NAPL continues to occur. The maximum amount of time that USEPA may require continued operation in any area is limited to the same length of time that was required to meet the Interim Cleanup standards.

### 3.3 Site Background

The SRSNE Site is located in the Town of Southington, Connecticut, in Hartford County, approximately 15 miles southwest of the City of Hartford. It is located on Lazy Lane, just off Route 10 (Queen Street), and adjacent to the Quinnipiac River. The Site generally consists of the SRSNE Operations Area (4 acres), the Cianci Property (10 acres), a railroad right-of-way, and those areas where the SRSNE-related plume in groundwater has come to be located, including Southington's Curtiss Street Well Field (the Town Well Field Property). The Town Well Field Property is a 28-acre parcel of undeveloped land containing two municipal drinking water wells (Production Wells No. 4 and No. 6). The wells were closed in 1979 when they were found to contain VOCs.

The SRSNE facility began operations in Southington in 1955. From approximately 1955 until the facility closed in 1991, spent solvents were received from customers and distilled to remove impurities. Solvents and other wastes were handled and processed by several methods over the operational period, including distillation columns, lagoons, drums, and open pit incineration. Such operations were a source of historical releases of processed materials solvents and spent fuels, which resulted in the presence of NAPL in the subsurface.

The Site was listed on the National Priorities List (NPL) in September 1983 and the USEPA initiated the Remedial Investigation (RI) for the Site in 1990. SRSNE operations ceased in 1991, and USEPA conducted a Time-Critical Removal Action to remove contaminated soils from the railroad grade drainage ditch and to remove some chemicals stored at the property to an off-site location in 1992. In 1994, USEPA and the SRSNE Site Group entered into an Administrative Order on Consent (AOC) to, among other things, construct and operate a pump and treat system to contain the principally contaminated overburden groundwater (the NTCRA 1 work). USEPA subsequently issued an Action Memorandum for a second NTCRA (NTCRA 2) in 1995 to hydraulically contain VOC-impacted bedrock groundwater downgradient from the NTCRA 1 system. USEPA and the SRSNE Site Group entered into a second AOC in 1996 to implement NTCRA 2 and to complete the RI and prepare a Feasibility Study (FS). NTCRA 2 started operation in 1998. The RI and FS were completed between 1996 and 2004, and USEPA issued the ROD in 2005. The ROD described the selected remedy for the Site, which is the basis for the RD/RA activities being undertaken.
Additional information regarding the site background is provided in the RDWP (ARCADIS, November 2010).

### 3.4 Site Geology/Hydrogeology

The Site is located within the Connecticut Valley Lowland section of the New England physiographic province. The Connecticut Valley Lowland occupies a regional, structural rift basin, which is characterized by block-faulted and tilted bedrock strata. The geology of the region, in general, consists of glacially derived, unconsolidated deposits overlying the Upper Triassic New Haven Arkose bedrock (Rogers 1985). Bedrock fractures in the region dip moderately eastward, parallel to the eastward-dipping bedding (Hubert et al. 1978; Rogers 1985; BBL 1998). Steeply dipping fractures, however, have also been observed in outcrops near the Site, and in core samples and down-hole fracture-logging results obtained within the Site. While normal faults have been mapped approximately 2.5 miles west and 2.0 miles east of the Site (Rogers 1985), no bedrock faults have been reported within the Study Area (i.e., the targeted investigation area during the RI, including the Site and surrounding areas). The published bedrock geologic maps do not provide a sufficient basis to evaluate the presence or locations of faults, if any, beneath the thick sequence of unconsolidated materials within the Quinnipiac River Valley in the vicinity of the Site (Rogers 1997).

Additional information regarding the site Geology and Hydrogeologic settings are provided in the RDWP (ARCADIS, November 2010).

### 3.5 Target Treatment Zone

The *Overburden NAPL Delineation Plan* [Attachment A to the RDWP (ARCADIS, 2010)] was prepared to address the requirements of Section V.C.1.a of the SOW, which required an investigation to complete the delineation of NAPL in and near the northwestern portion of the Overburden NAPL Area. During activities completed in support of the FS for the Site, a preliminary NAPL delineation was established for the Overburden NAPL Area. That delineation was based on the results of prior site investigation activities, including a NAPL Delineation Pilot Study performed in 2003, and resulted in a nearly complete delineation of NAPL in the overburden in the general vicinity of the former Operations Area. The resulting delineation of the Overburden NAPL Area was identified in the 2005 ROD as the target area for in-situ thermal treatment of soil. The ROD also indicated, however, that further NAPL delineation was required in the vicinity of prior boring location PTB-30 in the northwestern portion of the former Operations Area Visible NAPL was noted at this location as part of the NAPL Delineation Pilot Study, but steep upward slopes and adjacent property access limitations precluded additional investigation at that time. The Overburden NAPL investigation was performed in two phases. The first phase was performed in July 2009; following negotiation of access to the adjacent property, the second phase was performed in October 2009.

The revised interpretation of the extent of NAPL in the overburden is shown on Figure 3.1. This delineation served as the basis for the TTZ and design of the ISTR component of the remedial approach for the Site. The TTZ covers an approximate area of 74,195 square feet with a target treatment depth ranging between 12 and 30 ft bgs, depending on the depth to bedrock in the wellfield. The weighted average treatment depth is 17.1 ft. Based on this, the volume of soil to be treated in the thermal remediation project is approximately 47,298 CY. The TTZ is shown below on Figure 3.1.

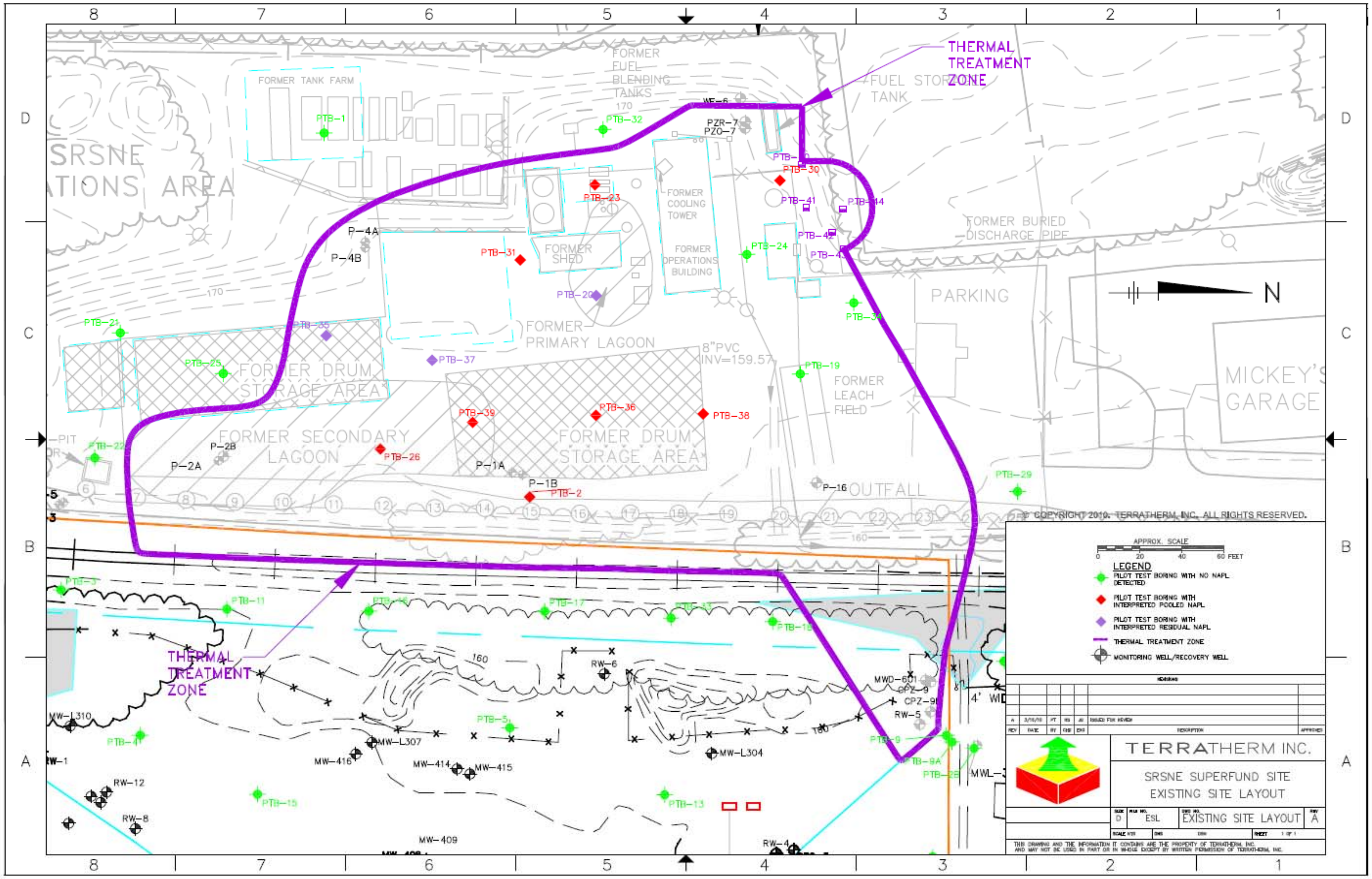


**Figure 3.1. Thermal Treatment Zone**

# 4.0 THERMAL TECHNOLOGY BACKGROUND

For this Site, thermal conduction heating (TCH) was chosen as the thermal technology. This is a heating technique where electric heaters are placed inside steel wells to generate heat by thermal conduction to the soil, driven by temperature gradients.

Figure 4.1 below shows a generic sketch of an ISTR remediation process. The following sections present a background to the thermal technology proposed for this Site.

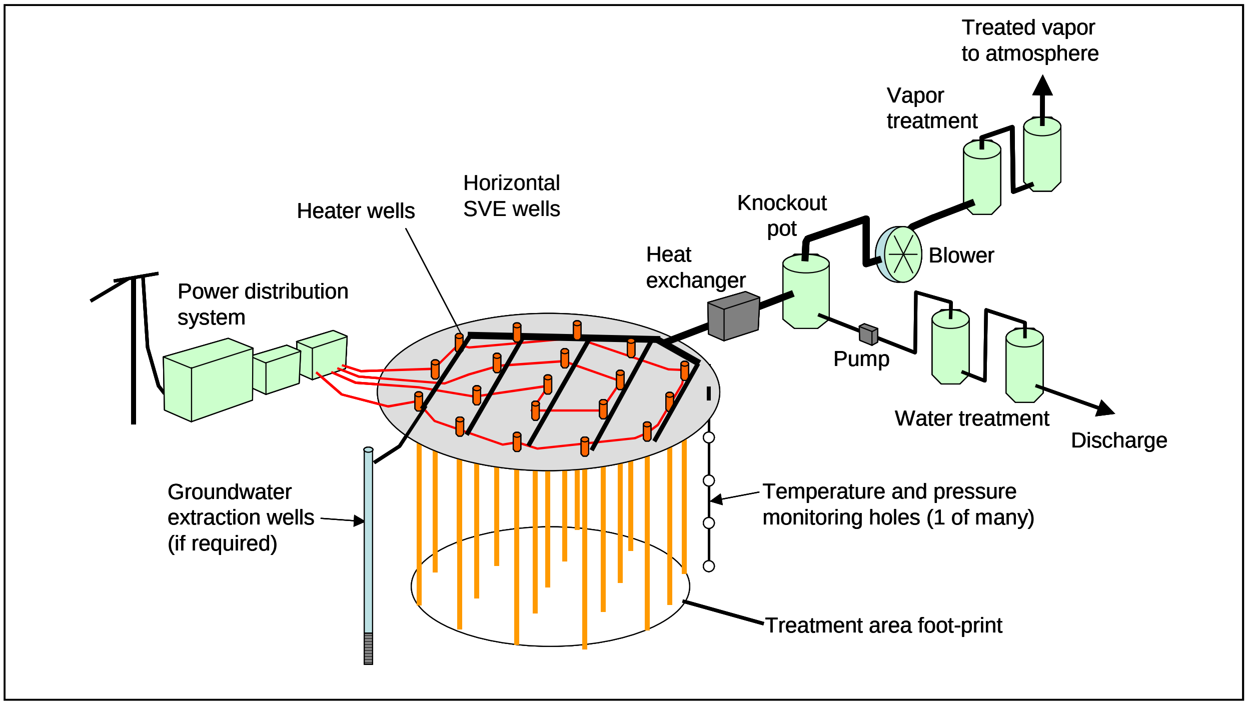


**Figure 4.1. Sketch of Thermal Remediation Process** (not specific to the actual site)

The major equipment used includes:

- A transformer delivering power for the electrical circuits;
- A power distribution system with switches, meters, and controllers;
- The wells and borings: heater borings, vapor and liquid recovery wells, temperature monitoring borings, and groundwater monitoring wells;
- Cables and wiring for the ISTR heaters, which are located in vertical borings (heater borings);
- Manifold and conveyance piping for extracted fluids; and
- Treatment system for extracted fluids (vapor and liquids, as required).

An office trailer is used to house data management computers and other monitoring equipment. The process is automated, with operators overseeing the system and collecting data and samples during the daytime. As the Site is heated, vapors are extracted, cooled, separated, and treated. The subsurface process is monitored using temperature and pressure sensors and detailed sampling and analysis of subsurface fluids.

### 4.1 In Situ Thermal Desorption Background

TCH, one method of ISTR, is a field-proven remediation technology licensed by TerraTherm that has been successfully used to remediate the full range of VOCs and semi-volatile organic compounds (SVOCs)[1] at over 40 sites across the U.S. and world-wide. TCH is a viable treatment technology for nearly all VOCs including the COCs present at the SRSNE Site. TCH is particularly well suited for application in low permeability soils because heat distribution is not affected by the low hydraulic conductivity of the soil matrix. TerraTherm is currently implementing TCH at multiple similar sites, and has successfully completed many TCH projects for VOC constituents similar to those present at the SRSNE site. Combined with a good vapor and liquid extraction strategy, the confidence in reaching remedial goals is extremely high, as evidenced by the successful completion of several time-critical Brownfield development projects using TCH[2].

1. Thermal energy provided by vertical heater borings will heat the soil, water, and contaminants. The heating progresses by thermal conduction, as the heater wells are heated to temperatures around 1,000 to 1,500 degrees Fahrenheit (°F) (500 to 800°C), creating significant temperature gradients in the formation around each heater. Thermal conductivity of soil materials varies over a very narrow range – only by a factor of 3; therefore, thermal conduction heating (ISTR) is very precise and predictable regardless of the permeability of the soil or its degree of heterogeneity.

   Temperature profiles were calculated for several scenarios, including different groundwater flows in the saturated zone, different R values of the vapor cover, etc. The saturated zone has a higher heat capacity than the vadose zone, and the modeling indicated that it would be beneficial to inject more power in the lower, saturated zone, than in the vadose zone. This is accomplished by the boosted heaters.
2. The heat front moves away from the heaters through the soil by thermal conduction and convection, and the superposition of heat from the many heaters results in a temperature rise throughout the TTZ.
3. As soil temperatures increase, contaminants and water contained in the soil matrix are vaporized. While locations close to heaters (i.e., 1 ft) may achieve temperatures well above the boiling point of water (212°F or 100°C), locations in between heaters need only achieve 212°F (100°C) to accomplish steam distillation for effective removal of VOCs. Boiling off all the soil water is not necessary. Very high (>99%) removal results have been repeatedly measured for ISTR of VOCs.
4. The vacuum applied to the VEWs from the process system will draw the vapors through the soils and into the off-gas piping network for subsequent treatment.

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[1] Stegemeier, G.L., and H.J. Vinegar. 2001. "Thermal Conduction Heating for In-Situ Thermal Desorption of Soils." Ch. 4.6, pp. 1-37. In: Chang H. Oh (ed.), *Hazardous and Radioactive Waste Treatment Technologies Handbook*, CRC Press, Boca Raton, FL.

[2] LaChance, J., G. Heron, and R. Baker. 2006. "Verification of an Improved Approach for Implementing In-Situ Thermal Desorption for the Remediation of Chlorinated Solvents." *Remediation of Chlorinated and Recalcitrant Compounds: Proceedings of the Fifth International Conference* (May 22-25, 2006). Battelle, Columbus, OH.

The heater wells are 3.5-inch-diameter steel cased wells housing thermal conduction heaters. Each of these contains a stainless steel heater as shown on Figure 4.2.

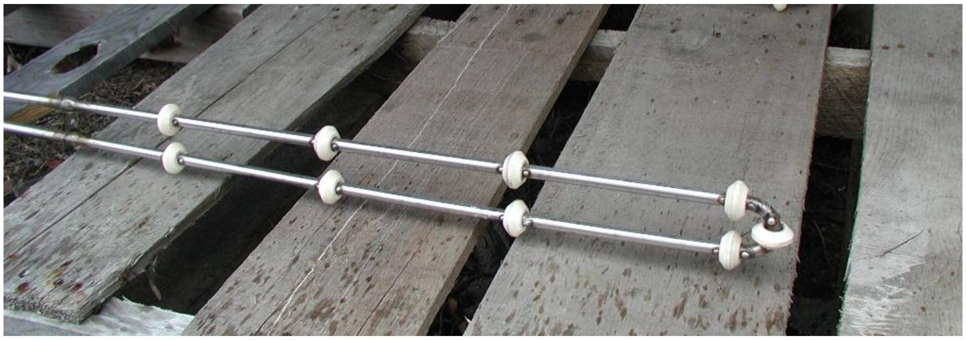

**Figure 4.2. Proprietary TerraTherm Heater Element used inside each Thermal Conduction Heater Boring.** *The metal rod has a diameter of approximately 0.5 inch (1.2 cm). The white beads are ceramic isolators. Electric power flows through the steel rod, causing it to heat resistively. The design is covered by one or more of the following: U.S. Patent Nos. 5,190,405, 5,318,116, 6,485,232 and 6,632,047.*

Figure 4.3 shows an example of a full-scale ISTR wellfield. Each heater is connected with a heavy-duty portable power cord through an electrical junction box. A surface cover is placed over the treatment area to serve several purposes:

- Provide a thermal barrier and reduce heat losses;
- Prevent rainwater infiltration such that cold water is not added to the treatment volume; and
- Provide a surface seal such that vapor extraction can lead to effective capture of vaporized contaminants.

**Figure 4.3. Example ISTR Wellfield** *(not specific to actual site)*

### 4.2 Remediation Mechanisms

Heating the subsurface to temperatures around the boiling point of water can lead to significant changes in the thermodynamic conditions in the subsurface and can create conditions that make it impossible for the NAPL to remain in the liquid state, driving it to the vapor phase where it can be readily extracted from the subsurface as vapor. For chlorinated solvents such as PCE and TCE, vaporization is the most important physical removal/remediation mechanism. Other remediation mechanisms may include thermal destruction by oxidation and pyrolysis near ISTR heating elements[3], microbial mineralization, and hydrolysis at elevated temperature.

The major effects of heating are:

- The vapor pressure of the NAPL increases markedly with temperature. As the subsurface is heated from ambient temperature to temperatures in the range of 212°F (100°C), the vapor pressure of the NAPL constituents will typically increase between 10- and 30-fold.[4]
- Adsorption coefficients are reduced moderately during heating, leading to an increased rate of desorption of COCs from the soil.[5]
- Boiling of NAPL (if present) occurs at temperatures below the boiling point of water.[6] For this Site, the estimated boiling point for the NAPL is 75°C based on the components present and their molar fractions. Heating the subsurface to above this temperature will make DNAPL (if present) thermodynamically unstable, causing it to boil and convert to a vapor. Other mechanisms, as discussed below, will work to remove the remaining contamination.

Due to the presence of a significant mass of chlorinated volatiles at this Site, the thermal treatment will target steam temperatures (i.e., 212°F, 100°C). This ensures that the VOC contaminants will be removed by vaporization.

In summary, application of thermal energy (heat) will lead to removal of the contaminants primarily as a vapor phase.

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[3] Baker, R.S., and M. Kuhlman. 2002. "A Description of the Mechanisms of In-Situ Thermal Destruction (ISTD) Reactions." In: H. Al-Ekabi (Ed.), *Current Practices in Oxidation and Reduction Technologies for Soil and Groundwater*. Presented at the 2nd International Conf. on Oxidation and Reduction Technologies for Soil and Groundwater, ORTs-2, Toronto, Ontario, Canada, Nov. 17-21.

[4] Udell, K.S. 1996. Heat and mass transfer in clean-up of underground toxic wastes. In *Annual Reviews of Heat Transfer*, Vol. 7, Chang-Lin Tien, Ed.; Begell House, Inc.: New York, Wallingford, UK: 333-405.

[5] Heron, G., M. Van Zutphen, T.H. Christensen, and C.G. Enfield. 1998. Soil heating for enhanced remediation of chlorinated solvents: A laboratory study on resistive heating and vapor extraction in a silty, low-permeable soil contaminated with trichloroethylene. *Environmental Science and Technology*, 32 (10): 1474-1481.

[6] DeVoe, C., and K.S. Udell. 1998. Thermodynamic and Hydrodynamic behavior of water and DNAPLs during heating, In *Proceedings from the First Conference on Remediation of Chlorinated and Recalcitrant Compounds*, May 18-21, Monterey CA, Battelle Press 1 (2): 61-66.

# 5.0 DESIGN BASIS AND RESULTS OF PRE-DESIGN STUDIES

## 5.1 Introduction

In accordance with the SOW, an RDWP was prepared and submitted to USEPA. The RDWP included, among other things, several pre-design studies in support of the design of the ISTR system. The following sections summarize the results of the pre-design studies that provide the design basis for the ISTR system. The results of the pre-design studies are presented in order of the design development process.

## 5.2 System Design Evaluation

The System Design Evaluation Work Plan included a pre-design study for thermal modeling to assess the rate of heat-up and mass removal of the Site and assessment of the corrosion potential for subsurface and aboveground piping. The following summarizes the results.

### 5.2.1 Numerical Simulation Model (Pre-Design Study)

A numerical simulation model was prepared to provide the design basis for the thermal system. The model is based on simplified mass and energy balance principles and uses nine distinct layers, each with different model inputs. A detailed description of the thermal model simulations is included in Appendix B.

This section summarizes the model setup, equations, and principles. To represent the site conditions, the model included a series of layers as shown on Figure 5.1. For each layer, a water and energy balance is kept in incremental time-steps, allowing for exchange of fluids and energy by convection and conduction. Heat losses through the vapor cap, through the bottom of the TTZ (to deeper bedrock), and to the sides are included. Injected energy is simulated based on a ramp-up and heating strategy, which is derived by iteration.

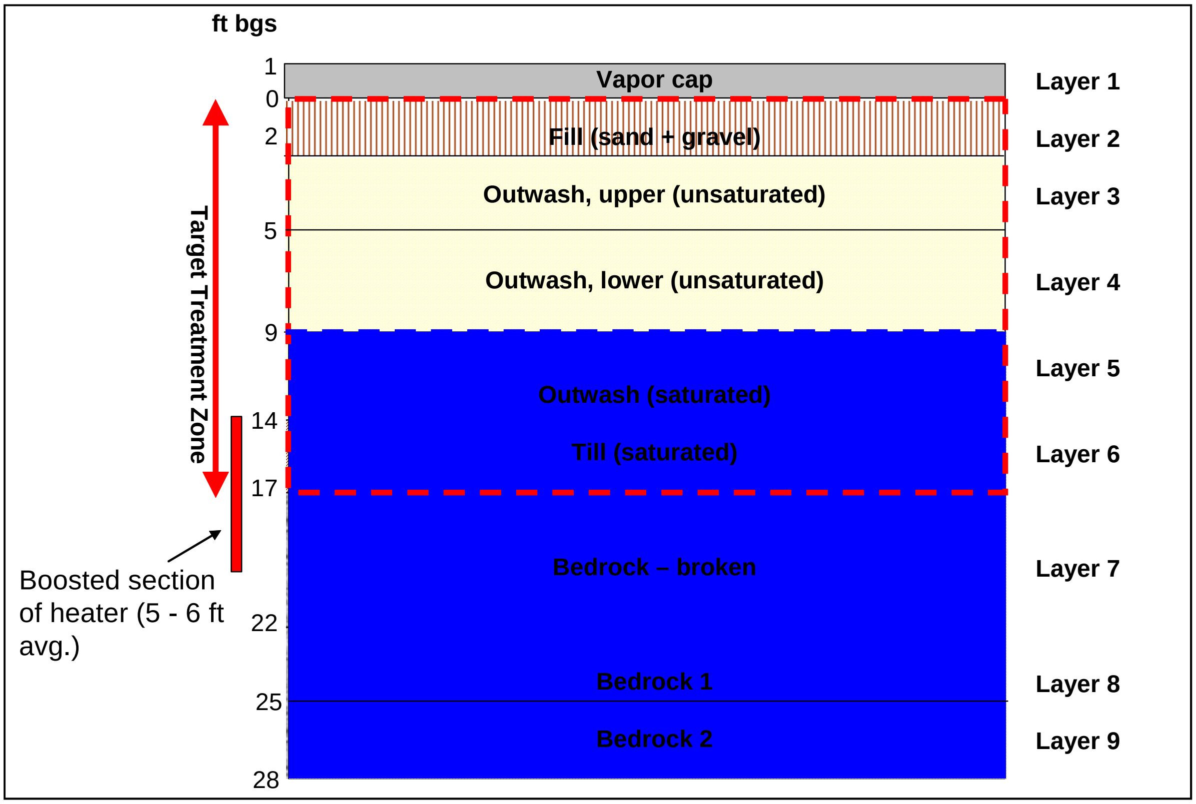



**Figure 5.1. Model Setup with Individual Layers.** *Note that the average treatment depths are used.*

Table 5.1 below shows the parameters used for each of the model layers.

**Table 5.1. Input Parameters for the Numerical Model**

| Layer | Geology | Top [ft] | Bottom [ft] | Thickness [ft] | Porosity [-] | Initial saturation [-] | Ambient temperature [F] |
|---|---|---|---|---|---|---|---|
| Layer 1 | Vapor cap | +1.0 | 0.0 | 1.0 | 0.01 | 0.1 | 59 |
| Layer 2 | Fill, sand, gravel | 0.0 | 2.0 | 2.0 | 0.275 | 0.5 | 59 |
| Layer 3 | Outwash, upper (unsaturated) | 2.0 | 5.0 | 3.0 | 0.275 | 0.7 | 59 |
| Layer 4 | Outwash, lower (unsaturated) | 5.0 | 9.0 | 4.0 | 0.275 | 0.8 | 59 |
| Layer 5 | Outwash (saturated) | 9.0 | 14.0 | 5.0 | 0.275 | 1.0 | 59 |
| Layer 6 | Till (saturated) | 14.0 | 17.0 | 3.0 | 0.275 | 1.0 | 59 |
| Layer 7 | Bedrock, weathered | 17.0 | 22.0 | 5.0 | 0.077 | 1.0 | 59 |
| Layer 8 | Bedrock 1 | 22.0 | 25.0 | 3.0 | 0.077 | 1.0 | 59 |
| Layer 9 | Bedrock 2 | 25.0 | 26.0 | 3.0 | 0.077 | 1.0 | 59 |

A phased heating approach will be used to spread out the VOC loading on the vapor treatment system. Specifically, approximately 50% of the wellfield will be operated for the first 60 days; the other 50% of the wellfield will be turned on at day 60. This approximate sequence is shown on Figure 5.2.

The actual operation sequence may differ from the model if VOC mass/concentrations within the wellfield differ than the model (e.g., if higher VOC concentrations are observed in Phase 1, Phase 2 operations may not be turned on until Day 70 or 90, etc., and vice versa. If lower VOC mass/concentrations are observed in Phase 1, Phase 2 operations may be turned on at Day 30 or 50, etc.).

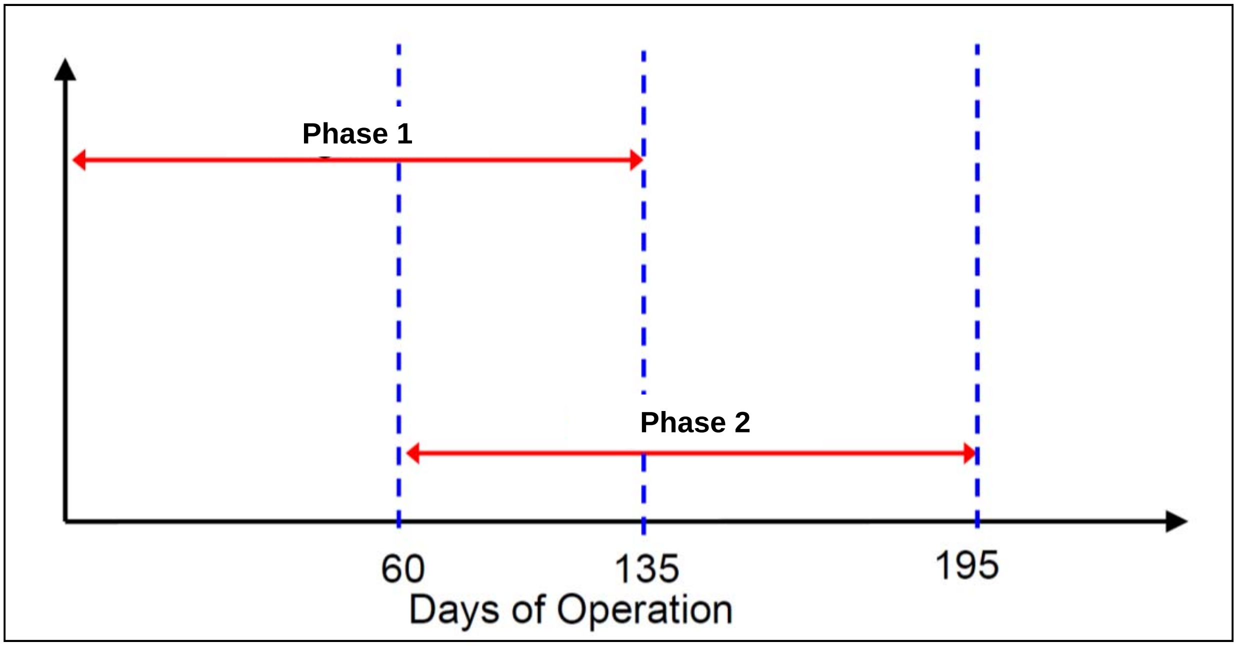



**Figure 5.2. Phased Operation.** *Each phase represents 50% of the wellfield and heater borings.*

Under this approach, each phase is anticipated to be operated for 135 days, with a total operating period of 195 days. Actual durations and lag between phases may be adjusted based on field observations regarding the VOC mass removal rate.

The wellfield will be constructed in a manner to support this phased operational approach. Vapor extraction along the Phase 1/Phase 2 boundary will remain online when Phase 1 is turned off and Phase 2 is turned on to capture vapors and minimize potential releases.

#### 5.2.2 Discussion of Simulation Results for the Base Case Scenario

The following sections present the results of the base case scenario. The base case scenario model reflects what is believed to be the most likely input parameters for each geological layer at the site. Because some of the parameters are expected to vary across the Site and may be difficult to estimate, the model sensitivity to selected input parameters are further evaluated in the sensitivity model by changing one of the input parameters in the base case at a time and subsequently evaluating the corresponding changes in the calculations. In the base case model scenario, a geological cross-section and matching initial input parameters as shown on Figure 5.1 and Table 5.1 were used to define the subsurface parameters.

Furthermore, in the base case model scenario, the following input parameters are applied to the numerical calculations:

- Heater spacing 14 ft, corresponding to a total of 593 heaters
- Heaters extend 3 ft into the bedrock
- Vapor cap thickness is 1 ft. Thermal conductivity for the cap is 0.15 W/m* $^{o}$K.
- 10 gallons per minute (gpm) horizontal influx of groundwater into the treatment area. No vertical influx.

- Heaters are boosted at the bottom. Boosted output is 435 W/ft compared to the regular heater output at 300 W/ft.

The base case scenario is described in detail in the Numerical Calculations of Heating pre-design study results included in Appendix B. Note that the actual design parameters may vary slightly from these base case scenario modeling parameters.

#### 5.2.2.1 Area, Volume and Energy Demand Calculations

The energy demand required to heat the subsurface and provide mass removal is calculated based on the heating requirements for the porous media and contained fluids, heat losses to surrounding zones, and heat losses to water flowing into the treatment zone. Table 4.2 shows the estimated treatment zone volume and basic parameters used for the design calculations.

**Table 5.2. Sizes and Properties of the Thermal Treatment Zone**

| | Value | Unit |
|---|---:|---|
| Treatment zone footprint | 74,195 | $ft^2$ |
| Depth of heating | 15 to 32 (varies) | ft bgs |
| Treatment zone volume | 47,298 | CY |

Notes:
$ft^2$ – square feet
ft bgs – feet below ground surface
CY – cubic yards

Table 5.3 contains an overview of the calculated heat capacity and energy demand for the TTZ using average values for the operations phase. These calculations incorporate heating needs caused by the soil and water in the treatment zone, heating needs caused by water flowing into the treatment zone, and heat losses provided by fluids extracted from the treatment zone.

Based on the calculations provided below, an average heat input of 2,325 kilowatts (kW) per day of electrical energy would be used for the 195-day operational period. In each phase, the heating rate will be larger than the average during the heat-up period, with a peak delivery of approximately 2,000 kW per phase, and a total peak around 3,627 kW when both segments are heated simultaneously and are in different stages of heating (between days 60 and 135). Once each phase is heated to desired temperatures, the power input rate is adjusted to optimize energy efficiency.

**Table 5.3. Heat Capacity and Energy Calculations**

| Volume and Heat Capacity | Value | Unit |
|---|---|---|
| Volume, Thermal Treatment Zone | 47,298 | CY |
| Solids volume | 34,200 | CY |
| Pore volume | 12,900 | CY |
| Soil weight | 152,786,000 | lb soil |
| Water weight | 18,396,000 | lb water |
| Water heat capacity | 18,396,000 | BTU/°F |
| Total heat capacity, whole treatment zone | 56,593,000 | BTU/°F |
| | | |
| **Energy Balance, Average Numbers** | | |
| TCH power input rate | 2,325 | kW |
| Energy lost in water migrating toward NTCRA | 175 | kW |
| Energy extracted as steam | 980 | kW |
| Heat loss through vapor cap | 86 | kW |
| Heat loss to bottom | 299 | kW |
| Heat loss along perimeter | 197 | kW |
| Net energy addition | 588 | kW |

Notes:
CY – cubic yards
lb – pounds
BTU – British thermal unit
°F – degree Fahrenheit
kW – kilowatt

Due to the unknown COC mass present at the Site, the wellfield will be divided into phases (Figure C105 – Appendix C). Based on the calculated energy inputs and energy removal and heat losses, a minimum of 135 days was estimated for the operating duration of each phase. (With the planned 60-day lag in start-up between the two phases, the total operating duration is estimated at 195 days.) This will allow for a phased start-up of the heaters and treatment of a mass of up to 1 million pounds of COCs within the 135-day schedule using the designed off-gas treatment system. Additionally, phasing of the wellfield for operations allows for a gradual ramp-up of the wellfield temperature, which offers greater control of the COC mass removal rate from the wellfield. The flexibility of the thermal treatment system and operational approach will allow for treatment of a larger COC mass by extending the operating duration to flatten out the peak mass load input to the Air Quality Control (AQC) system. Table 5.4 contains the estimated power usage for the ISTR heating system.

**Table 5.4. Power Usage for Subsurface Heating during Operations**

| | Duration Days | Power Usage TCH kWh | Power Usage Treatment kWh |
|---|---|---|---|
| Period 1 | 30 | 1,016,000 | 389,520 |
| Period 2 | 30 | 1,306,000 | 444,960 |
| Period 3 | 30 | 2,321,000 | 501,120 |
| Period 4 | 30 | 2,612,000 | 501,120 |
| Period 5 | 30 | 1,814,000 | 473,040 |
| Period 6 | 45 | 1,814,000 | 612,000 |
| Total | 195 | 10,883,000 | 2,922,000 |
| Total Project Power Usage | | | 13,805,000 |

Note:
kWh - kilowatt hour

A total of 13.8 million kWh is estimated to be needed to achieve RAOs in soil at the SRSNE Site.

#### 5.2.2.2 Subsurface Temperature Progression

Figure 5.3 shows the predicted vertical temperature distribution in the TTZ as a function of time, using average values for the Site. The heat-up and the boiling of pore water occur simultaneously as the heat moves away from the heater wells. The last regions to boil and achieve sufficient steam stripping are the coolest locations within the TTZ, which typically correspond to the midpoints between the heater wells, also called “centroid locations.”

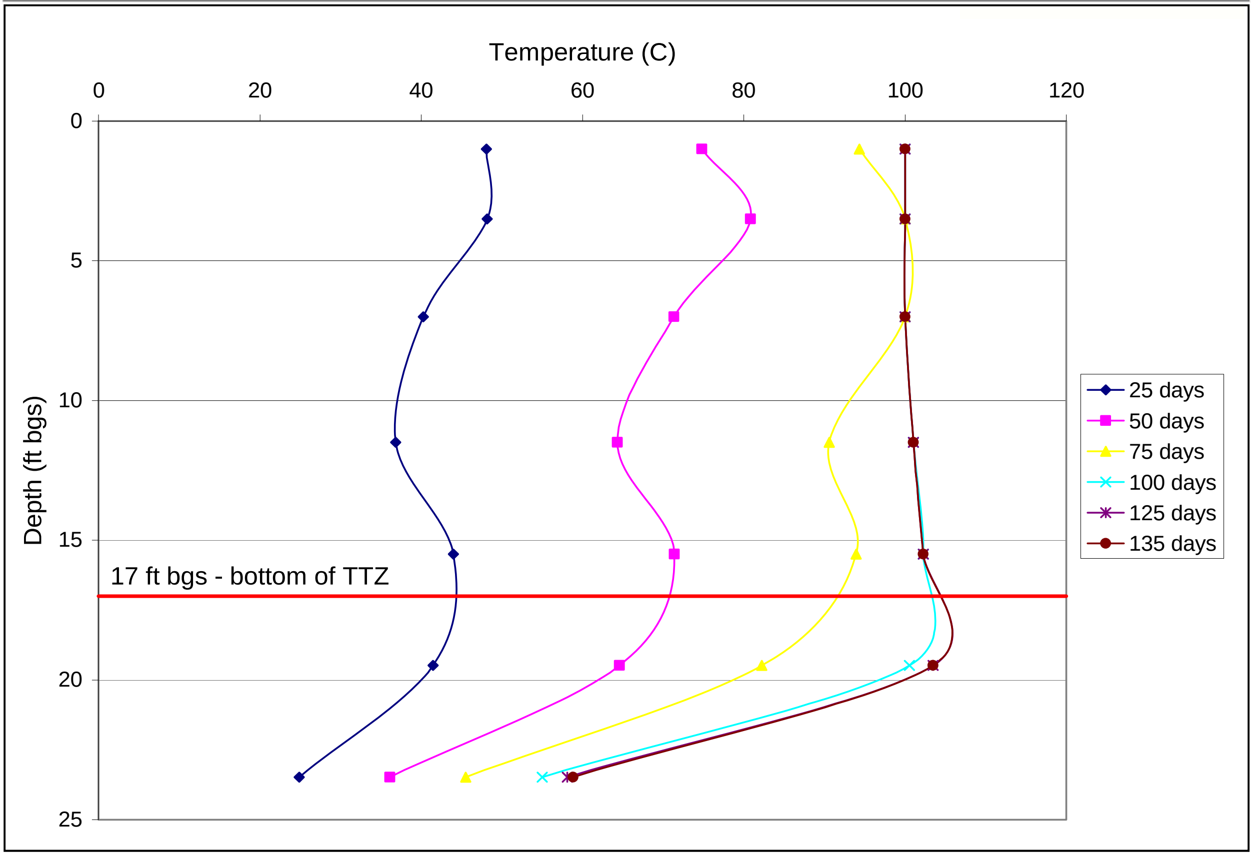



**Figure 5.3. Temperature Profiles during Thermal Remediation, Heat up of Each Phase. The red line represents the average top of bedrock.**

After approximately 100 days of heating in each phase, the average temperatures are near the boiling point of water at all depths within the TTZ. Note that the heating is near complete after 100 days in both phases, allowing 35 days of additional treatment and polishing after reaching the boiling point.

Figure 5.3 also indicates that the modeled vapor cover has sufficient insulation capacity to allow for heating to the boiling point all the way to the surface.

#### 5.2.2.3 Heating Strategy

The primary thermal strategy is to optimize mass removal by first reaching the in-situ boiling point of DNAPL constituents, then continuing heating to reach the boiling point of the groundwater and steam stripping COCs for additional mass removal benefits. In each phase, the strategy is as follows:

Days 0-55: Ramp-up of the ISTR energy input from 10 to 70% of the maximum rate.
Days 55-125: Heating at or near maximum capacity, averaging 80 to 90% of the maximum rate (approximately 255 W/ft for non-boosted section and 370 W/ft for boosted sections, assuming 85% power output).
Days 125-135: Extraction and maintenance of pneumatic control, with some initial cool-down.

The strategy is flexible, and will be adjusted based on measured performance.

#### 5.2.2.4 Estimated Treatment System Design Parameters

The energy balance calculations in the numerical model are used to calculate values for vapor and liquid extraction rates necessary to maintain capture and optimize the treatment. From these values, Tables 5.5 and 5.6 present design parameters and treatment rate estimates resulting from the numerical model calculations.

**Table 5.5. Process Parameters**

| Process Parameters | Estimate Based on Model | Units |
|---|---|---|
| ISTR power supply, max | 4,052 | kW |
| Condensable vapor flow | 5,386 | lb/hr |
| Non-condensable vapor flow | 9,030 | lb/hr |
| Condensable liquid rate* | 11 | gpm |

Notes:
kW – kilowatt
gpm – gallons per minute
(*) – Based on 100% condensation of water vapor

Based on the calculated values, the vapor treatment system is designed to manage approximately 4,000 scfm of condensable and non-condensable vapor from the wellfield. In addition, the air stripper discharge will be treated. More detail is provided in Section 9.3.

**Table 5.6. Condensate and Non-Condensable Vapor Treatment Rates and Totals**

| | | Condensed Water* | | Non-Condensable Wellfield Vapor | |
|---|---|---|---|---|---|
| | Days | Average Rate (gpm) | Total Volume (gallons) | Rate (scfm) | Total Volume (million CF) |
| Period 1 | 30 | 4.2 | 181,000 | 1,005 | 43 |
| Period 2 | 30 | 5.4 | 233,000 | 1,005 | 43 |
| Period 3 | 30 | 9.6 | 414,000 | 2,010 | 87 |
| Period 4 | 30 | 10.9 | 471,000 | 2,010 | 87 |
| Period 5 | 30 | 7.5 | 324,000 | 2,010 | 87 |
| Period 6 | 45 | 5.0 | 324,000 | 2,010 | 130 |
| Total | 195 | | 1,950,000 | | 477 |

Notes:
gpm – gallons per minute
scfm – standard cubic feet per minute
CF – cubic feet
(*) – Based on 100% condensation of water vapor

According to Table 5.6 above, over the course of the thermal treatment, an estimated 1.95 million gallons of condensed water and approximately 477 million CF of non-condensable wellfield vapor will be treated.

#### 5.2.2.5 Sensitivity Analysis

Appendix B contains the pre-design study results of the sensitivity analysis performed, using the described scenario as the base case. The *Numerical Simulation Model* results are summarized below:

- Horizontal heater spacing (varied between 14 and 16 ft): the results indicated that 14-ft spacing is adequate for reaching the target temperatures.
- Depth of heating into bedrock (varied between 2 and 5 ft): the results indicate that a minimum of 3 ft is necessary for obtaining satisfactory heating in the bottom of the TTZ.
- Boosting of bottom section of heaters: it was shown that boosting power is necessary in the bottom 5 to 6 ft of the heaters to achieve target temperatures at the top of bedrock.
- Horizontal groundwater influx (varied between 0 and 10 gpm): results indicate that up to 10 gpm of groundwater influx is acceptable.
- Vertical (upward) groundwater influx (varied between 0 and 6 gpm): results indicate that up to 6 gpm of groundwater influx is acceptable.
- Vapor cap thickness and insulating value: the results indicate that a vapor cap with thermal conductivity of 0.12 to 0.15 W/(mK) (1.04 BTU-in/hr ft$^2$-F) and a thickness of at least 12 inches is satisfactory. Different vapor cap designs with the same insulating capacity are acceptable.

Both the horizontal and vertical influx used in the numerical model was based on data from the site-specific groundwater model performed by others. However, groundwater models are no better than the input parameters, and it is not unusual that actual flows are different than the modeled numbers, due to inaccuracies in model numbers or a local variability in gradients and hydraulic conductivities. Thus, a sensitivity analysis was conducted to quantify how robust the thermal system design is for changes in groundwater influx rates. The base model setup used a horizontal influx of 10 gpm and a vertical influx of 0 gpm. In the sensitivity analysis, the horizontal and vertical influx varied between 0 to 20 gpm and 0 to 6 gpm, respectively.

These results have been incorporated into the design.

### 5.2.3 Materials Compatibility Test(s) (Pre-Design Study)

Six different alloys (Alloy 20, 304 SS, AL6XN, Hastelloy B3, carbon steel, and Hastelloy C-276) and two sets of coupons were selected for corrosion testing at Intertek Aptek, of Houston, Texas. The results of these *Material Compatibility Test(s)* are included in Appendix B. The first set of coupons was exposed to an environment to simulate the conditions near the heater well. The second set was exposed to conditions similar to proposed process piping material.

Results of these tests indicate that carbon steel has the highest corrosion rate near the well at 160 mils/year (thousandths of an inch per year). This is an acceptable level of corrosion given that the system will operate for less than 1 year and the material thickness of the 3-inch-diameter Schedule 40 C.S. pipe used for the heaters will be 0.22 inch. For process piping, data suggest using carbon steel for low temperature piping and AL6XN (a high nickel stainless steel alloy) for high temperature connections and major pieces of equipment.

### 5.2.4 Analysis of Non-Aqueous Phase Liquid (NAPL) (Pre-Design Study)

A sample of the NAPL was collected from the Site for the Materials Compatibility Test. Laboratory analytical results (Appendix B) on the NAPL collected from the source area indicate that the heat of combustion was 13,012 BTU/lb, which is substantially higher than the calculated BTU value of previous NAPL samples. This is consistent with the chloride content being lower than earlier estimates at 319,957 parts per million (ppm) (32% by mass) and the presence of large quantities of non-chlorinated petroleum hydrocarbons including 1,2-dimethylcyclopentane (11 Vol %), methylcyclohexane (1.1 Vol %), n-nonane (1.2 Vol %), 1,3 ethylmethylbenzene (1.4 Vol %), and 1,3,5-trimethylbenzene (0.9 Vol %). These petroleum hydrocarbons were not reported in the previous VOC analysis. These data results suggest a higher heat load to the oxidizer and a lower salt production due to the lower chlorine content.

### 5.2.5 NAPL Delineation (Pre-Design Study)

The results of the overburden NAPL delineation activities were provided for Agency review in the Overburden NAPL Investigation Delineation Summary Memorandum (ARCADIS, November 2009) (Appendix B), and approved by USEPA on December 16, 2009. The revised interpretation of the extent of NAPL in the overburden was shown on Figure 3.1. This delineation served as the basis for the TTZ and design of the ISTR component of the remedial approach for the Site. Additional discussion on the TTZ is provided in Section 9.0.

### 5.2.6 Vapor Treatment Needs Evaluation (Pre-Design Study)

The Vapor Treatment Needs Evaluation described the approach used to evaluate and select an off-gas treatment system. The results of this evaluation were presented in a memo titled Treatment Process Options Memorandum (included in Appendix B) and are summarized below.

The design basis for the off-gas treatment system is an estimated 1,000,000 lb of COC mass in the TTZ, but the system has the flexibility to treat the COC mass range estimated in the FS (i.e., 500,000 to 2,000,000 lb) as efficiently as possible. The RDWP original concept for the Site intended to utilize Regenerative Thermal Oxidizers (RTOs) to treat extracted vapors. Instead, a non-regenerative thermal oxidizer will be used to allow higher fuel loadings to be processed at higher rates. The processing time of 195 days will cover two process phases. These phases will overlap to spread out and reduce the peak loading. This reduced peak allows for more cost-effective equipment sizing.

The wellfield is segregated into two segments corresponding to the two treatment phases. The process system has the ability to cool the wellfield vapors with the goal of knocking out steam and removing water from the influent vapor stream. Short-term COC mass load variability is controlled by variable frequency drives (if speed is decreased, flow [vacuum] is decreased) on the vacuum blowers, which regulate the vacuum level in the wellfield. Longer term variations are controlled by varying the heating rate in the wellfield. Further flexibility is built into the scrubber where quench and caustic addition rates can be varied to match variations in COC loadings to the process.

### 5.2.7 NAPL Mobilization and Mitigation Plan

The NAPL Mobilization and Mitigation Plan describes the potential for downward mobilization of DNAPL, how potential vapor releases would be minimized, and the safety measures that would be instituted during the implementation of the ISTR system. Safety measures, such as a surface vapor cover, well installation, and the process equipment and wellfield maintained under vacuum, were presented as Remedial Design/Remedial Action Work Plans under separate submittal.

### 5.2.8 Thermal Treatment Monitoring

The Thermal Treatment Monitoring Plan was prepared to describe the scope and approach for monitoring air quality within and around the perimeter of the ISTR treatment area during implementation of the thermal treatment system to minimize potential impacts to on-site workers and the community.

### 5.2.9 Thermal Treatment Performance Criteria

The Thermal Treatment Performance Criteria Work Plan [Attachment C to the RDWP (ARCADIS 2010)] was prepared to describe the scope and approach for performance monitoring of the ISTR system, to determine the progress of the ISTR system, to demonstrate compliance with the applicable permit equivalency requirements, and to monitor the quality of any air or water discharged from the system. The results of this work plan are described in Section 13.0.

Success of the thermal remedy is defined by the interim NAPL cleanup levels for soils presented in Section 3.0. These levels shall be met from the ground surface to the top of bedrock throughout the TTZ. Temperature criteria, in conjunction with soil data results, will be used to evaluate whether or not the treatment goals have been met; however, 100% of the thermocouples do not need to reach 100ºC in order to achieve the cleanup levels.

# 6.0 PROJECT OPERATIONS PLAN

## 6.1 Site Management Plan

A number of factors specific to the existing conditions at the Site were considered in the design of the thermal remediation system, and may require some variation during field installation. These factors included site grading, potential to encounter NAPL during drilling, and underground utilities that fall within, or near, the TTZ that may require adjustments to well locations or other design features. Additional changes will be noted in as-built drawings and will not affect the overall design and expected performance.

### 6.1.1 Access

Access to the thermal treatment area and aboveground treatment equipment will be restricted through the use of temporary fencing or other protective barrier(s), as appropriate. Access to the Site is restricted by a permanent fence installed during PIPP activities. Signage will be posted to identify the work area(s) and specify access only for authorized personnel. Signage may include yellow construction site tape and signs stating “Authorized Personnel Only”, “High Voltage”, or similar. Personnel looking to gain access to the Site shall sign in and out at the *de maximis* office trailer prior to entering the Site.

### 6.1.2 Roadways

A portion of the treatment zone extends into the existing roadway on the north side of the wellfield, as indicated on the existing site plan (Drawing C101 in Appendix C). The road was relocated around the wellfield during PIPP activities and is shown in Drawing C101 (Appendix C) to allow for vehicle access to the wellfield during construction and operation.

### 6.1.3 Utilities

Existing underground utilities that may interfere with the system installation or operation will be relocated prior to wellfield installation and construction in accordance with the pre-ISTR site preparation activities (refer to the separately submitted PIPP Design Report).

### 6.1.4 Laydown Area, Staging, and Storage Facilities

Heavy equipment, process equipment, and/or piping will be stored either in the process equipment area just east of the wellfield as indicated on Drawing M102 (Appendix C) or in the wellfield itself. Tools, safety equipment, and office equipment will be kept either in the job trailer, tool trailer, or conex box that will be located east of the wellfield.

### 6.1.5 Field Oversight/Construction Management

TerraTherm staff will be on site, providing management and/or oversight, during all phases of the thermal effort. Drilling and construction efforts will most likely occur in shifts of 10 days on/4 days off, with weekend work, as needed.

During all phases of operation, the system will run continuously 24 hours per day, 7 days per week from the start of heating until final system shutdown. TerraTherm operators will either be on site or on call. The operators will be onsite at least one shift per day, 5 to 6 days per week. Additionally, the operators will be within 30 minutes of the Site, in the event it is necessary to respond after hours.

Additional details on staffing and schedule can be found in the Operations and Maintenance Manual provided as Appendix D.

#### 6.1.6 Independent Quality Assurance Team (IQAT)

Drilling, construction, and system operation will be monitored by the IQAT, whose function and responsibility, in summary, is to verify that the remedy is constructed and operated in compliance with the approved design criteria, plans, and specifications. IQAT for this Site will be performed by *de maximis.* The IQAT will report results of all inspections independently to USEPA and CTDEEP*.* *de maximis* will not be responsible for quality control of the construction. The *de maximis* representative will check quantities and general compliance with the design drawings. TerraTherm is solely responsible for the successful construction of the remedy.

### 6.2 Subcontracts

It is anticipated that three subcontractors will perform work at the Site: 1) driller(s) for well installations, 2) contractor for cover installation, and 3) an electrician. Contracts will be issued to each of these subcontractors prior to the start of work referencing the Terms and Conditions, including insurance requirements, specified in the Prime Contract between TerraTherm and the SRSNE Site Group.

### 6.3 Schedule and Reporting

The general construction, operation, and reporting schedule is listed below.

| | |
|---|---|
| Mobilization | April 2013 |
| Field Construction | April – January 2014 |
| Thermal Treatment Operations | January 2014 – July 2014 |
| Decommissioning/Demobilization | July – September 2014 |
| Final Reporting | September – December 2014 |

Data reporting schedules are discussed in Sections 11.0 and 13.0.

### 6.4 Site Preparation and Utility Hook-Ups

Site preparation and utility hook-ups including electric, gas, water, sanitary sewer, and telecommunications were provided for the thermal treatment equipment in accordance with the Pre-ISTR Design Report (ARCADIS, 2010).

### 6.5 Construction, Shake-Down, Start-up, and Demobilization of ISTR System

Construction details on drilling, wellfield installation, heater and liner installation, and surface cover installation are discussed in Section 9.0. Operations of the thermal treatment system are described in Section 11.0.

### 6.6 Modifications to Quality Assurance Project Plan (QAPP)

A SAP, including a QAPP and an FSP, was prepared to ensure that fieldwork and laboratory analyses are performed in a manner that is consistent with the data objectives for the Site. An addendum to the site-wide SAP has been prepared to include the following SOPs specific to sampling during thermal operations. The SOPs included are:

- Air Monitoring
- Calibration of the Nephelometric (Turbidity) Meter
- Water Quality Meter Calibration (YSI Model)
- Emissions Sampling
- Hot Groundwater Sampling
- Hot Soil Sampling for Chlorinated Volatile Organic Compounds

These SOPs are provided in Appendix E.

Other applicable components described in the site-wide FSP (e.g., sample designation system, quality assurance/quality control [QA/QC] procedures, decontamination, etc.) will also be followed for this sampling effort.

### 6.7 Construction Standard Operating Procedures

The following SOPs, which describe the procedures to be followed during construction and decommissioning of the thermal treatment system, are also included in Appendix E:

- Equipment Decontamination at the SRSNE Superfund Site
- Monitoring Well Development with Possible NAPL at the SRSNE Superfund Site
- Waste Stream Management
- Well Decommissioning at the SRSNE Superfund Site
- Well Installations within the Thermal Treatment Zone

# 7.0 HEALTH AND SAFETY PLAN

A site-wide Health and Safety Plan (HASP) has been developed to ensure that on-site workers and nearby workers or visitors are protected. TerraTherm has developed a site-specific HASP (Appendix F) for the thermal treatment project that will, at a minimum, meet the requirements of the site-wide HASP and will also address specific hazard mitigation and control measures related to implementation of thermal treatment at the Site. Activity Hazard Analyses (AHAs) have been developed to address potential health and safety hazards and control measures for the various work tasks associated with construction, operation, and demobilization phases of the project. An AHA will be developed for any unanticipated task or activity or if a significant change in means or methods is required in response to field conditions.

The implementation of health and safety during this ISTR program will be the shared responsibility of the TerraTherm Project Manager (PM), the TerraTherm Construction Manager, the TerraTherm Site Safety Officer (SSO), and all other onsite TerraTherm and contractor personnel.

# 8.0 CONSTRUCTION ENVIRONMENTAL MONITORING PLAN

During drilling and installation of the heater wells, VEWs, and monitoring points, real-time VOC and particulate air monitoring will be performed by others at representative perimeter locations. The program to be implemented during wellfield installation, including equipment and action levels, was described in the Thermal Wellfield Implementation Support Plan (TWISP, Appendix G). The program will also be performed during the thermal treatment operations, with the exception that particulate monitoring will be discontinued after the thermal cap is constructed. This is based on the fact that affected site soils will no longer be available to generate dust/particulates once the cover is placed. Further, personal monitoring as described in the site-specific HASP (Appendix F) will be performed during wellfield installation and thermal operations to minimize any potential risk to TerraTherm and TerraTherm's subcontractor involved with the thermal remedy.

# 9.0 ISTR SYSTEM DESIGN AND CONSTRUCTION

This section describes the design and construction associated with the various ISTR components, including the wellfield, insulating cover application,and vapor treatment system. The design of the vapor treatment system also discusses ancillary processes, including liquid treatment, backup power, and control systems.

## 9.1 Wellfield

Details on the design and construction of the thermal wellfield are described below. Installation of the thermal wellfield commenced in April 2013.

### 9.1.1 Wellfield Layout

The TCH heater wells are laid out on a triangular grid pattern with a spacing of approximately 14 ft. In portions of the Site with sufficient vadose zone thickness, the VEWs are located approximately 3 ft from each heater well. In the portion of the Site to the east of the railroad right-of-way, where the vadose zone is thin (i.e., <3 ft thick), permeable fill was placed over the ground surface as part of the site preparation activities and horizontal VEWs will be installed in this area. Temperature/pressure and groundwater level monitoring wells are distributed evenly throughout the wellfield. The proposed layout of the operational wells is presented on Drawing C104 in Appendix C.

The total number of wells for the TTZ is as follows:

- 593 heater wells (based on a spacing of 14 feet);
- 534 vertical vapor extraction wells across the unsaturated zone;
- 260 linear feet of horizontal vapor extraction wells;
- 98 boreholes for temperature monitoring;
- 64 temperature/pressure and groundwater level; and
- Seven groundwater monitoring wells.

### 9.1.2 Sheetpile Barrier Extensions Installation

Based on observations of geologic conditions at the Site, an area of permeable sand was found that extends along the northern boundary of the TTZ. Based on these observations, it was determined that sheetpile extensions would be installed to connect to the north and south ends of the existing NTCRA 1 sheetpile wall located east of the Former Operations Area (Figure C101 Sheet 2 of 2 – Appendix C). The purpose of the sheetpile barrier extensions is to minimize the potential for migration of groundwater through subsurface high-permeability zones and into the area subject to ISTR. The northern barrier wall extension is approximately 182 ft in length, and the southern barrier wall extension is approximately 173 ft in length. Additional detail on the installation and construction of the sheetpile wall can be found in the SRSNE Site PIPP Construction – Sheetpile Barrier Wall Extensions memorandum (ARCADIS, 2011) submitted to USEPA on 21 March 2011, and in the Pre-ISTR Site Preparation Completion Report (ARCADIS, April 2013).

### 9.1.3 Wellfield Design

Figure 9.1 shows a conceptual cross-section with operational wells, including the heater and VEWs. The different types of wells and their function that will be installed include:

- Heater wells to supply heat by thermal conduction from the ground surface to a depth of 15 to 32 ft bgs, dependent on their location.
- Vertical VEWs to extract vapors from the vadose zone in portions of the Site where the vadose zone is sufficiently thick. Vertical VEWs will be installed approximately 3 ft from each heater well.
- Horizontal VEWs to extract vapors from the permeable fill material placed over portions of the treatment zone where the water table is close to the ground surface (<3 ft bgs). Horizontal VEWs will be installed in between rows of heater wells.
- Ninety-eight temperature sensors within the TTZ will be installed per the following:
    - 72% (71) will be at centroids
    - 20% (19) will be approximately 3 ft from a heater well
    - 8% (8) will be located along the eastern perimeter of the TTZ (the hydraulically downgradient side and the area closest to the HCTS extraction wells)
- Sixty-four temperature/pressure and groundwater level monitoring points that monitor temperature to confirm heating effectiveness, and pressure and water levels to ensure pneumatic and hydraulic control installed evenly throughout the wellfield.

Seven groundwater wells will be installed within Zone C. Screening level groundwater samples will be collected before, and periodically during thermal treatment to evaluate general changes in the dissolved phase VOC concentrations. It is important to reiterate that the performance standards for the thermal treatment remedy do not include any metrics based on dissolved concentrations in groundwater. Additional discussion on performance standards can be found in Section 13.0.

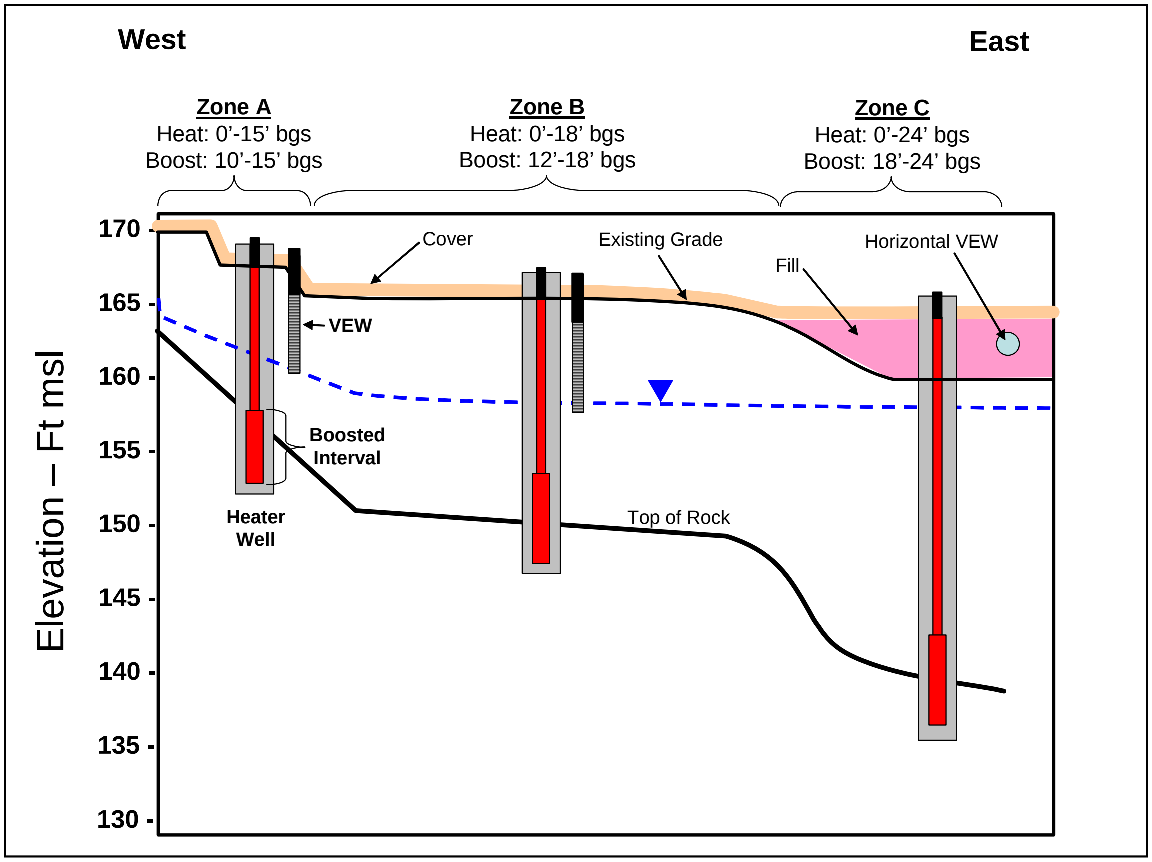



**Figure 9.1. Conceptual Cross Section Showing Typical Depths of Heating**

The treatment zone area has been divided into three zones of similar overburden thickness and "typical" drilling depth, and the heater interval has been estimated for the wells within each zone. Table 9.1 summarizes the typical drilling and heating depths for each zone.

**Table 9.1. Summary of Drilling and Heated Depths**

| | Drilling Depth ft bgs | Heated Interval ft bgs | Boosted Interval ft bgs | Approximate Treatment Depth ft bgs |
|---|---|---|---|---|
| **Zone A** | 16 | 0 – 15 | 10 – 15 | 12 |
| **Zone B** | 19 | 0 – 18 | 12 – 18 | 15 |
| **Zone C** | 25 | 0 - 24 | 18 - 24 | 21 |

A small portion of Zone B will be heated to depths between 20 and 22 feet, corresponding to a thicker overburden due to re-grading of the site. A small portion of Zone C will be heated to depths between 26 and 32 feet, corresponding to a local bedrock depression interpreted based on existing depth-to-bedrock information from prior borings. Actual installation depths of heater cans may vary based on the actual depths of bedrock. Boring logs of actual heater can installation depths will be reviewed after wellfield installation and adjustments to heater depths will be made accordingly.

These depths will, on average, result in the bottom of the heater casing extending approximately 3 to 4 ft into the top of bedrock. The vapor extraction wells will be installed approximately 3 ft from the heater wells and will consist of 2-inch stainless steel screen and carbon steel riser pipe. The total depth and screen interval of VEWs in zone A is 7 ft and 2 to 7 ft, respectively. The total depth and screen interval of VEWs in zones B and C is 8 ft and 2 to 8 ft, respectively.

As indicated in Table 9.1, thermal remediation will extend from ground surface to a depth between 12 and 30 ft bgs (varies across the site). Heating will extend to depths of between 15 and 32 ft bgs across the site. The bottom of each thermal conduction heater will be boosted from 5 to 6 ft to provide additional energy input into the lower portion of the heated zone.[7] This will offset heat losses due to conduction and groundwater flux and ensure that the bottom of the treatment zone reaches the target treatment temperature. This will also ensure that the top of the bedrock heats up faster than the overlying soil, thereby creating a hot floor and further reducing the potential for vertical mobilization of DNAPL.

### 9.1.4 Construction Details

Drawings C106 through C110, included with the Design Drawings in Appendix C, provide construction details for TCH and VEWs; and temperature and pressure monitoring points. Additionally, Drawing C111 provides construction details for groundwater monitoring wells. Figures 9.2 and 9.3 below provide construction schematics for the TCH heaters and combined vapor extraction points, temperature monitoring points, and pressure/water level monitoring wells.

[7] Heaters, including boosted heaters, are proprietary to TerraTherm.

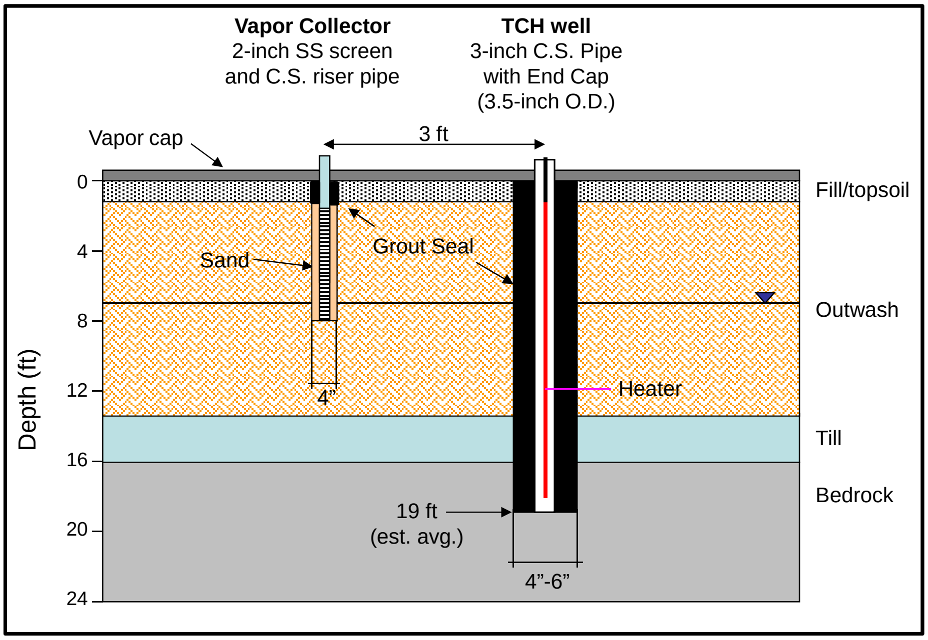



**Figure 9.2. Well Construction Detail for TCH Well and Vapor Extraction Well for Average Site Conditions**

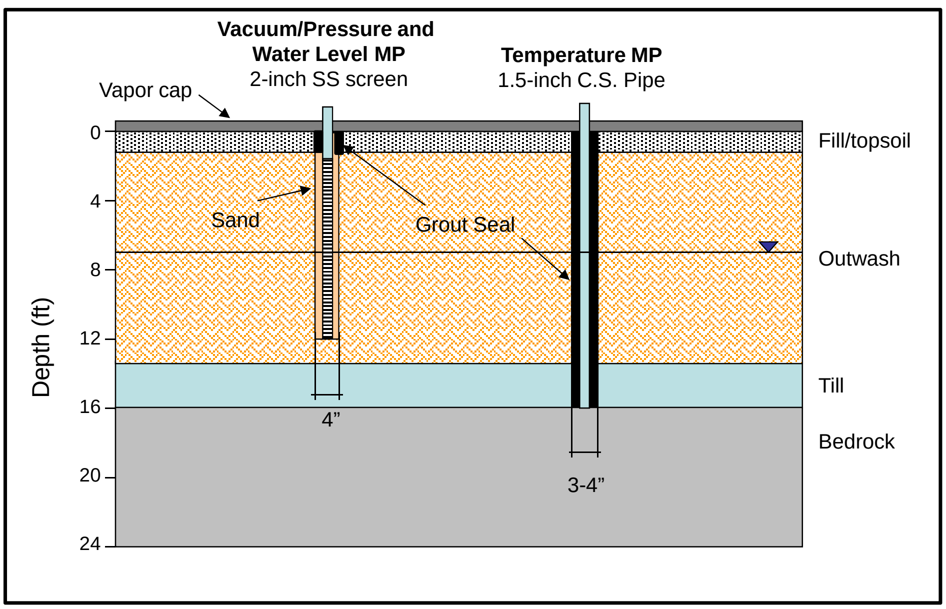



**Figure 9.3. Well Construction Detail for Temperature and Pressure Monitoring Points**

The temperature monitoring points will consist of 1.5-inch threaded carbon steel pipe with an end cap, extending 2 ft into bedrock to an average depth of 18 ft bgs. Efforts will be made during drilling and temperature monitoring point installation to determine the depth of bedrock below the ground surface.

The vacuum/pressure and water level monitoring points will consist of 2-inch stainless steel screen and carbon steel riser pipe. The total depth and screen interval of each of these wells is approximately 7 or 12 ft and 2 to 7 or 2 to 12 ft, respectively, depending on their location within the wellfield. These wells will be installed using the same methods used for installing the VEWs described below.

The heater wells will consist of a 3-inch carbon steel outer casing with a thin-walled, stainless steel liner on the inside. The heater well can and liner will have welded joints to prevent water and/or steam from entering the well and potentially contacting the energized heater elements. Assuming an average depth to the top of bedrock of 18 ft, the average borehole or drilling depth is 21 ft while the average length of the heater cans are 23 ft long, which provides for a 2-ft stickup above grade following installation. On average, each heater will be installed 3 to 4 ft into the bedrock. During drilling and well installation, efforts will be made to determine the depth of bedrock below ground surface at each heater well to minimize the penetration of bedrock to approximately 3 to 4 ft.

Each heater well located in areas of sufficient vadose zone thickness will have a corresponding VEW. The VEWs will be installed approximately 3 ft from the heater wells and consist of 2-inch stainless steel screen and carbon steel riser pipe. The total depth and screen interval in Zone A is 7 ft and 2 to 7 ft, respectively. Zones B and C will be 8 ft deep and screened between 2 and 8 ft. These wells will be installed using the same sonic drilling methods described below, but, instead of adding grout to the annular space, sand will be placed in the annular space corresponding with the screened section of the well. The sand will extend approximately 1 foot above the top of the well screen. Grout will be placed in the remaining annular space (0 to 1 ft bgs) to provide a surface seal.

In addition to the vertical VEWs, the easternmost section of Zone C will have horizontal VEWs, rather than vertical VEWs. Because of the shallow depth to water of approximately 3 to 4 ft bgs, horizontal vapor wells will be installed within the fill and covered with 1 to 2 ft of clean fill.

Groundwater monitoring wells will be installed near locations that historically contained visible NAPL. Groundwater monitoring points will be installed with 2-inch stainless steel screen and carbon steel riser, with a 2-foot-long sump at the bottom. The bottom of the sump will be installed 2 ft into bedrock, and the annular space around the sump will be tremied with high temperature grout. The screen for each groundwater monitoring point will extend from the top of the sump to the approximate water table, such that each groundwater monitoring point will be essentially fully screened across the saturated overburden, while equipped with a grouted sump and avoiding penetrating the top of bedrock. After grouting in the sump, an appropriate gradation of silica sand will be placed in the annulus to approximately 2 ft above the top of the screen. A 1-ft-thick layer of finer-grained sand will be placed above the main sand pack, and the remainder of the annulus will be filled with high temperature grout to the final well completion at ground surface.

Table 9.2 provides well construction details including depth, number of locations, materials of construction, and borehole and sand pack specifications for the various types of wells that will be installed at the Site.

**Table 9.2. Well Construction Details**

| Well Type | Depth (ft bgs) | Number of Locations | Well Casing/ Pipe Specifications | Screen Interval (if present) | Borehole & Sandpack Specs |
|---|---|---|---|---|---|
| Heater-Only Wells | 15 to 32 | 593 | 3" Sch. 80 carbon steel (CS) Pipe (welded joints) | N/A | Min. 6" Bore; High Temp Grout |
| Vapor Extraction Wells | 7, 8 | 534 | 2" Sch. 80 CS w/ 2" stainless steel (SS) screen | 2-7 ft bgs (zone A) and 2-8 ft bgs (zones B & C) | Min. 6" bore; sand #0 from bottom up to 2 ft bgs; sand #00 1-2 ft bgs; high temp grout 0-1 ft bgs |
| Horizontal Vapor Extraction Wells | 1 to 2 ft bgs. | Approximately 260 linear ft | 3" SS 3" screen | Fully screened | Pipe will be installed in granular fill placed as part of the pre-ISTR site preparation activities |
| Temperature Monitoring Points | 13, 16, 22 | 98 | 1.5" Sch 40 CS pipe | N/A | Min. 3" bore; Grout full length |
| Pressure/Water Level Monitoring Points | 7, 12 | 64 | 2" Sch 40 CS pipe w/ 2" SS screen 10 slot | N/A | Min. 4" Bore; 20-40 Sand at Screen; High Temp Grout 0-1 ft bgs |
| Groundwater Monitoring Wells | 14, 17 | 7 | 2" Sch. 40 CS pipe w/ 2" SS screen 10 slot and 2' sump | Screen 2-12' bgs (Zone A) and 2-15 ft bgs (Zones B & C) | Min. 6" bore; high temp grout from bottom of borehole to top of sump (2 ft). Sand #0 top of sump to 2 ft bgs. Sand #00 1-2 ft bgs. High temp grout 0-1 ft bgs. |

Drill cuttings generated during the installation of the wells will be transferred to a spoils pit located within the thermal wellfield for later treatment during operations.

### 9.1.5 Drilling Method

For the SRSNE Site, the geology, DNAPL presence, health and safety concerns, and cuttings disposal have been carefully evaluated and, based on this evaluation, rotosonic ("sonic") drilling has been selected as the most advantageous approach for installation of the ISTR wellfield.

Sonic drilling methods will be used to install the drill casing and to core a hole in the bedrock to the desired depth for installation of the ISTR wellfield. Sonic drilling can be used to penetrate the concrete (up to 8 inches thick) that exists in places under the asphalt cover and at foundations of the former buildings. Details pertaining to the proposed drilling and installation methods for the heater and vapor recovery wells and the temperature and pressure monitoring points are provided further below. Additional discussion on the approach that will be used for well installations can be found in the TerraTherm SOP titled "Well Installations with Possible NAPL" (Appendix E).

Sonic drilling will provide significant protection against unintended NAPL migration and minimize water production during drilling and well installation. The minimum amount of water necessary to advance the casing will be used.

The sonic method results in a relatively tight seal between the outside of the drill casing and the borehole wall, unlike Hollow-Stem Augers, which actively mix soil along the entire length of the borehole and do not provide a tight seal.

The sonic method has flexibility in advancing two concentric, smooth-wall casings. It is proposed that, if possible, the outer casing will be advanced only to the top-of-rock surface to isolate the overburden while the inner casing drills the required socket in the top of rock to facilitate heater-well installation into the upper portion of the bedrock.

The sonic method will result in minimal production of cuttings and the cuttings can be efficiently and safely handled since they will be removed from the subsurface in a core barrel and directly deposited into a bin, thereby minimizing handling, odors, and volatilization of COCs. Drill cuttings generated during the installation of the wells will be transferred to a spoils consolidation area, located within the wellfield, for subsequent treatment during thermal operations.

### 9.1.6 Installation of Borings/Wells

Figures 9.4a through 9.4c below provide a summary of the drilling and well installation methods for the heater wells. The wellfield installation SOP (Appendix E) provides detailed descriptions of the drilling approach that will be used to install the wellfield.

A standard 4 x 6 sonic drilling system will be used for advancing the borehole and installation of the heater wells. The 4 x 6 system consists of a 4-inch core barrel (4.5” OD, 3.75” ID) and a 6-inch outer casing (5.5” OD with 0.5” OD bit, 4.75” ID). The core barrel fits snugly within the outer casing with ~1/8-inch clearance between the outside of the core barrel and the inside wall of the casing. Both the core barrel and outer casing are equipped with cutting shoes.

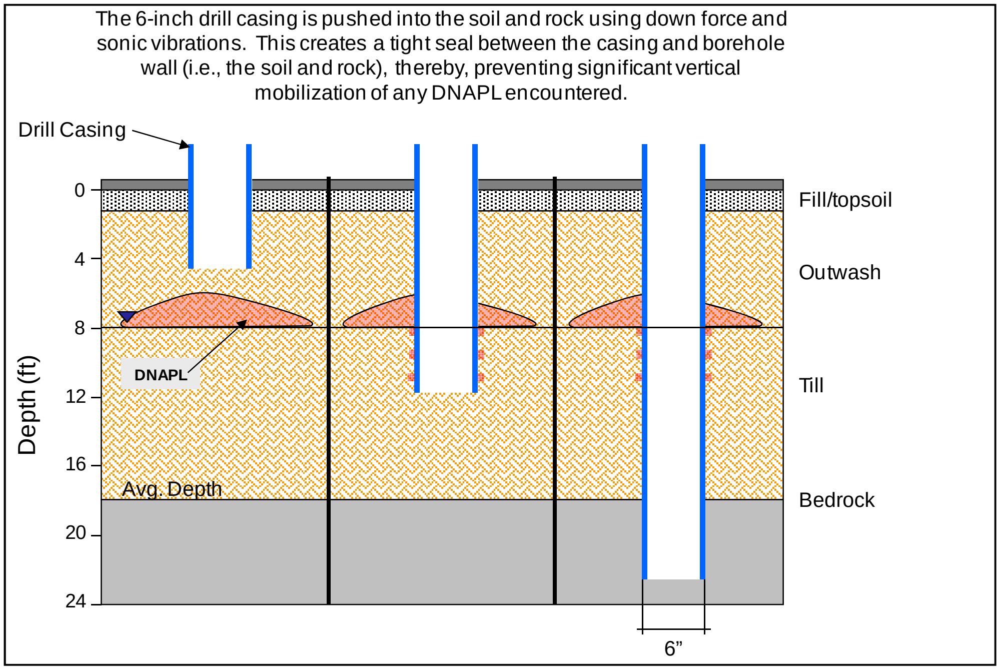



**Figure 9.4a. Drilling Approach**

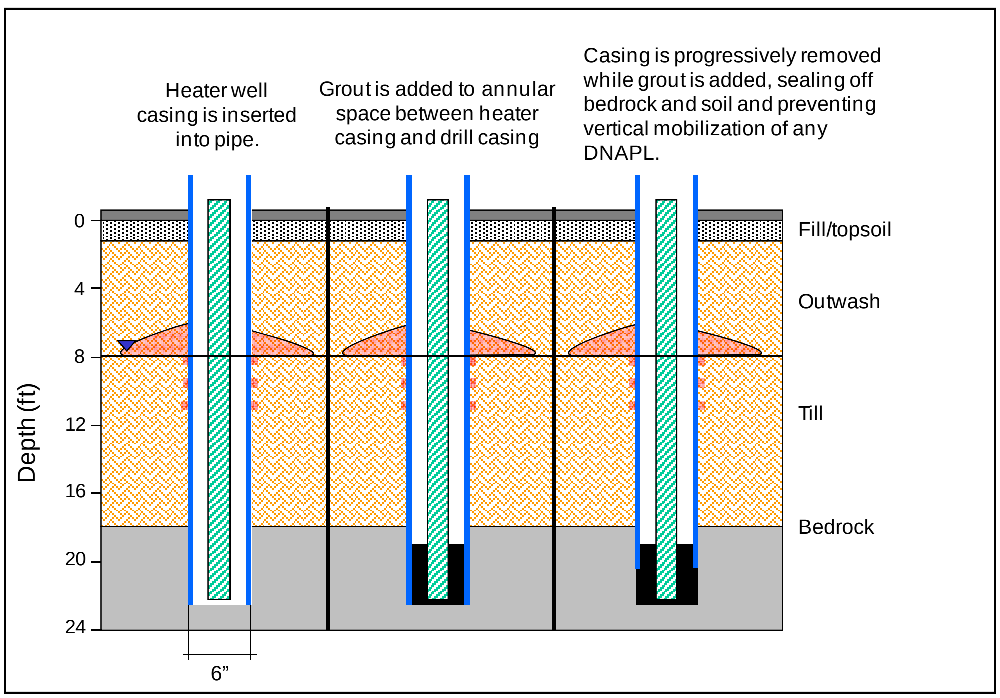



**Figure 9.4b. Setting of Thermal Well and Initial Grouting Process**

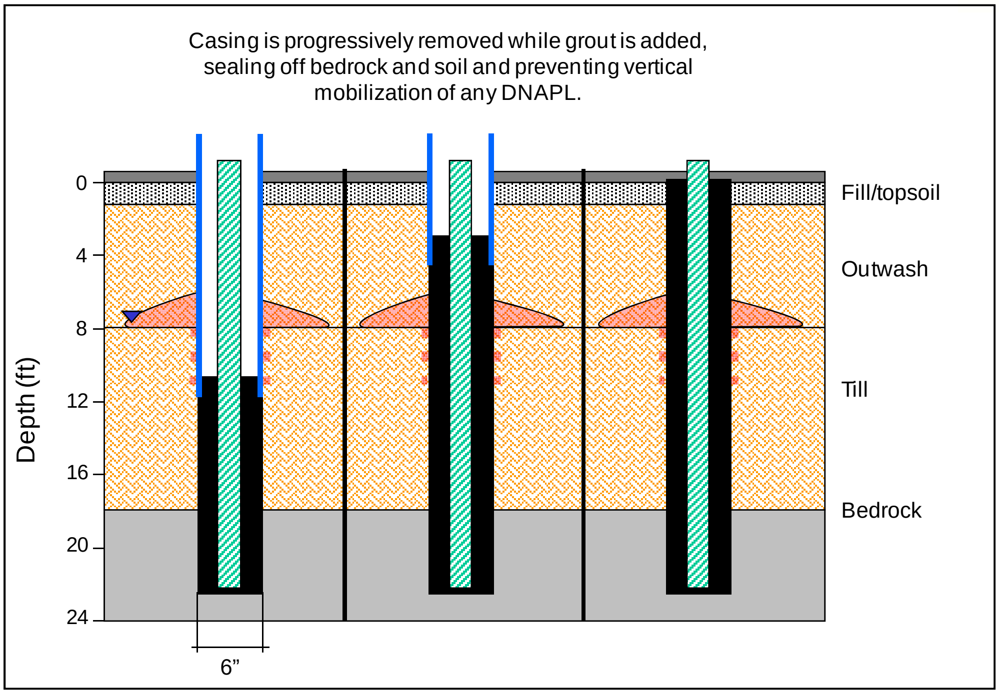



**Figure 9.4c. Thermal Well Grouting and Completion**

The temperature, vacuum/pressure monitoring points, and water level monitoring points will be installed using the sonic drilling methods described above for the heater wells; however, the diameter of the cased hole for the temperature monitoring points will be smaller (3 to 4 inches).

The VEWs will also be installed using sonic drilling methods to a total depth of approximately 7 to 8 ft. Sand will be placed in the annular space corresponding with the screened section of the well. The sand will extend approximately 1 ft above the top of the well screen. Grout will be placed in the remaining annular space (0 to 1 ft bgs) to provide a surface seal.

Groundwater monitoring wells will be installed using sonic drilling methods to the top of bedrock. The groundwater monitoring wells will have 2-foot-long blank sumps that are installed to the top of bedrock and grouted in place at the bottom. The screen of each groundwater monitoring well will extend from the top of the sump to a depth of approximately 2 ft below grade. Sand will be placed in the annular space from the bottom of the screen to approximately 1 ft above the top of the well screen. Grout will be placed in the remaining annular space (0 to 1 ft bgs) to provide a surface seal.

In summary, with the exception of the groundwater monitoring wells, none of the heater wells or borings used during the thermal remediation at the SRSNE Site will have a screen or a sand-pack that extends across the water table and into the bedrock. The TCH heater wells are comprised of solid steel casings that are grouted in place within a few minutes of drilling. The SVE screens, vacuum/pressure and water level monitoring screens, and the groundwater monitoring well screens will not penetrate the bedrock. Thermocouple monitoring borings will be metal pipes, grouted immediately upon installation.

These installation procedures and designs have been carefully developed to minimize the potential for NAPL to migrate during installation and construction, to the extent practicable. This approach is consistent with the NAPL Mobilization Assessment and Mitigation Plan. There is no way to quantify vertical migration; it is assumed that the installation minimizes DNAPL vertical migration.

#### 9.1.7 Liner and Heater Installation

Stainless steel liners will be installed inside the carbon steel heater casings, also called the heater cans, to protect the TCH heaters. As with the heater can, the TCH heaters and liners will be prepared and partially fabricated off site, and final assembly welding will take place on site.

### 9.2 Insulating Surface Cover

After the installation of the wellfield, an insulating surface cover will be installed over the treatment area, extending approximately 8 to 10 ft beyond the boundaries of the well array. The limits of the surface cover are provided in Drawing C104 (Appendix C). An insulating surface cover will be used to minimize surface heat losses, prevent precipitation infiltration into the TTZ, and minimize uncontrolled vapor/steam emissions from the treatment zone.

The surface cover will slope from west to east across the Site to shed surface water to the downgradient swale. The insulating surface cover will consist of approximately 12 inches of lightweight, air-entrained insulating concrete (minimum R = 0.12 W/m$^{o}$K) to minimize water infiltration, provide a vapor seal, and minimize heat loss. The cover will be poured in multiple layers, with each layer stronger than the previous layer. Two to three layers will be poured in total with the top layer containing a minimum of 1 lb/CY of polypropylene Fibermesh fibers, or similar, to minimize cracking. In addition, the surface of the cover will have a water repellant admixture applied to its surface to minimize water infiltration.

The R-value of the cover will be confirmed by the subcontractor by collecting discrete samples from each batch and determining both wet and dry densities. Wet densities will be available immediately and used to confirm the mix. Dry densities will be available approximately one month later and will be used to confirm the R-value. Calculated values will be compared to a library of R-values provided by the vendor.

If cracking is observed during operations, the cracking will be evaluated and possibly repaired. With the wellfield under vacuum, minor cracks do not need to be repaired. Larger cracks that may lead to potential contaminant releases if the system is down for prolonged periods of time will be repaired with cement and sealant. We have successfully used this method at other sites. PID readings will be collected within the wellfield after repairs have been made to confirm that the crack(s) has been properly sealed.

It is expected that the surface cover will be left in place until construction of the Resource Conservation and Recovery Act (RCRA) cap commences. At that time, the cover will be broken up and/or crushed by others and used for fill under the cap.

## 9.3 Vapor Treatment System

### 9.3.1 Process Design

A Process Flow Diagram (PFD, Drawing P101 in Appendix C), including a Mass and Energy (M&E) balance, has been developed based on the system design. The vapor M&E balances can be found on Sheet 3 of Drawing P101.

### 9.3.2 Piping, Mechanical, and Electrical Installations

A P&ID has been developed and is included as Drawing P102 (seven sheets). The P&ID depicts the major system components, valves, instruments and controls, alarms, and sample ports as well as the basic component sizing information for the effluent treatment system designed for the Site.

In general, the major process components will be skid-mounted, with local control panels on the individual skids. Local Programmable Logic Controller- (PLC-) based control panels will monitor and control the system components based on flow, temperature, pressure, and level inputs from instruments and sensors on the process equipment skids. The local control panels will report to a main PLC via a Modbus network, or similar, where the main PLC will log the system data.

In the event of an alarm or upset condition, the PLC on the local skid where the alarm occurs will take immediate action and report the alarm to the main PLC, which will then initiate any other required actions on the other local control panels. The main PLC is equipped with dial-out alarm capability to notify the system operator in the event of an alarm or upset condition.

A discussion of the various control system components is included sequentially below as the components occur in the process treatment system.

### 9.3.3 Vapor Collection Piping

The wellfield vapor collection piping will consist of fiberglass pipe, fitted on site, to connect extraction wells to the vapor treatment equipment. The conveyance piping will consist of several main header trunk lines with branches extending to the individual extraction wells. Because the vapor conveyance piping between the wellfield and the vacuum blowers operates under vacuum, any leakage should be inward into the pipe, minimizing the potential for fugitive emissions.

The conveyance piping will be sloped to a condensate tank to prevent condensate from accumulating in the lines. If necessary, condensate collection drains will be located at low points along the manifold as well. Collected condensate will be pumped to an oil/water separator for subsequent treatment prior to discharge.

### 9.3.4 Electrical Installation

The electrical installation consists of three major components: 1. the service drop and transformer/distribution equipment feeds; 2. the wellfield electrical installation; and 3. the process equipment and instrumentation wiring. All of these activities will be performed in accordance with the site-specific HASP and NFPA 70 (National Electrical Code [NEC]) and NFPA 70E (Standard for Electrical Safety in the Workplace). A Connecticut-licensed electrician will complete the wiring connections in the electrical panelboards.

TerraTherm will coordinate with the client to select appropriately sized transformers for the power distribution system. Two services from the utility will be required to power TerraTherm's equipment at 480V, 3-phase, 60Hz, four-wire system.

TerraTherm's electrical contractor will be responsible for wiring from the secondary side of the 480V transformers to the electrical distribution panels and all downstream equipment for the in-situ thermal systems. The main circuit breaker will be equipped with adjustable ground fault protection as required by the NEC. In addition, the main circuit breaker will be provided with a shunt trip mechanism, which will interrupt power from the main switchboard if any of the Emergency Shut-Down buttons are activated.

Power distribution switchboards will be located along the perimeter or in the interior of the thermal wellfield. TerraTherm and our subcontracted electricians will run secondary conductors from the branch breakers in the electrical switchboards to the heater power controllers, as well as the effluent treatment system components as shown on the Electrical One-Line Drawing (Drawing E101). The majority of the electrical panel boards and effluent treatment equipment proposed for use on this project are skid-mounted portable equipment, designed to be deployed at multiple sites. Due to the temporary nature of the project, the majority of the wellfield and equipment connections will be made using extra hard duty-rated portable power cords (e.g., Type W cord, Type G cord, "mining cable") and other cords (e.g., Type SOW) suited for outdoor use in wet environments. All electrical installations will be in full compliance with Article 590 (Temporary Installation) of the NEC Code and other National Fire Protection Association (NFPA) guidelines.

Silicon Controlled Rectifiers (SCRs) will regulate the power delivered to the TCH heaters. The SCR control systems are equipped with automated alarms and are controlled by our operation team to achieve optimal heating of the TTZ.

A backup generator working in concert with an automatic transfer switch (ATS) will be provided to ensure continued operation of the effluent treatment systems in the event of a power failure. Drawing E101 Sheet 1 provides a basic electrical schematic for the process equipment that will be backed up by the generator. Emergency Shut-Down switches will be provided at several locations around the wellfield to immediately shut down power to all of the ISTR components, including the treatment system and heater wells, in the event of a system emergency. Please note that the Emergency Shut-Down should ONLY be used in the event of a fire or if an individual is in imminent danger.

### 9.3.5 Process Components

The vapor treatment system depicted on the PFD consists of the following major components:

- Moisture separator #1
- Heat exchanger(s)
- Cooling tower
- Moisture separator #2
- Vacuum blower(s)
- Moisture separator #23
- Duct heater

- Dilution blower
- Thermal oxidizer
- Scrubber

A summary description of each major component is presented in the following paragraphs. Calculations used to size major equipment are provided on Sheet 3 of the PFD. Typical equipment specification sheets are included as Appendix H. Specification sheets specific to the vapor treatment system will be included in the final O&M manual once the process equipment has been procured.

#### 9.3.5.1 Moisture Separator #1

Any condensate generated in the wellfield manifold will drain to moisture separator #1. Water collected in the moisture separator will be pumped to the oil/water separator component of the liquid treatment system.

The moisture separator is a skid-mounted horizontal fiberglass vessel. A pair of parallel discharge pumps are connected to the liquid effluent port. The moisture separator has nozzles for vapor inlet/outlet connections. The moisture separator has end-mounted level sensors and a sight glass for level monitoring. A manway is located on top of the moisture separator for inspection and cleaning of the vessel.

Level sensors installed through the ports on the moisture separator provide discrete input signals to the local skid-mounted control panel for operation of the two moisture separator condensate transfer pumps and provide a high-high level interlock alarm. Additionally, a low level switch connected to the transfer pumps provides an interlock in the event of no flow.

#### 9.3.5.2 Heat Exchangers

The vapors from the wellfield are initially processed in heat exchangers to cool and condense the incoming steam and reduce the moisture content of the vapor stream for the remaining steps in the process. The vapors entering the heat exchangers are cooled using a recirculating loop of water supplied by a cooling tower. The cooling tower releases the heat removed from the vapor stream into the ambient air through evaporation of recirculated water. The heat exchangers and cooling tower system are designed to sufficiently reduce the temperature of the vapor stream to the point where the bulk of the moisture is removed from the wellfield vapors, and minimal COCs are removed via condensation. Both the vapor stream and cooling water side of the heat exchangers are instrumented with temperature indicators to allow adjustment of the recirculation loop flow to maintain proper moisture removal.

The process design requirement and the capacity of the equipment selected are summarized in the table below:

| E-101A/B | Process Design | Equipment Capacity (Modeling) |
|---|---|---|
| Incoming air flow | 9,030 lb/hr | 9,030 lb/hr |
| Incoming steam flow | 5,386 lb/hr | 5,386 lb/hr |
| Condensate rate | 4,692 lb/hr | 4,836 lb/hr |
| Cooling rate | 4.80 MM Btu/hr | 5.03 MM Btu/hr |
| Material of construction | Graphite | Graphite |

The heat exchangers selected are designed to operate with cooling water supply at the worst case summer cooling water temperatures. Spare capacity is included in the heat exchanger design. The units were sized based on heat transfer coefficients that represent fouled conditions just before the units need to be serviced/cleaned. Clean unit heat transfer rates are approximately 48% greater than the modeled fouled value.

#### 9.3.5.3 Cooling Tower

The cooling tower supplies a cooled water stream to the heat exchangers. Based on the actual heat transferred in the heat exchangers, the temperature of the recirculated water will increase as it passes through the exchangers. The returning warmed liquid is delivered to the top of the cooling tower where it is cooled by evaporation via contact with ambient air. The cooled water is collected at the bottom of the tower and returned to the heat exchanger. Design specifications for the cooling tower are summarized as follows:

| W-101 | Process Design | Equipment Capacity |
|---|---|---|
| Nominal capacity | 320 tons normal / 336 tons max | 500 tons (rental unit) |
| Cooling water discharge temperature | 82°F normal / 83°F max | - |
| Cooling water return temperature | 92°F normal / 93°F max | - |
| Water supply rate | 960 gpm normal / 1,011 gpm max | 1,200 gpm |

A potable water supply to the cooling tower is required to replace water lost via evaporation in the system. To prevent equipment fouling, a steady blowdown stream of approximately 1 gpm will be bled from the system and will be directed to the POTW discharge. The blowdown will limit the concentration of dissolved minerals that build up in the cooling loop due to evaporation. A biocide may be added to the recirculated water to control bacterial growth in this warm aerobic environment. The biocide used will be a standard 3-inch chlorine tablet designed for domestic pool use, purchased locally as needed.

#### 9.3.5.4 Moisture Separator #2

After exiting the heat exchanger, the cooled vapor stream and generated condensate will be drawn through a moisture separator to remove free liquids and entrained liquid droplets. Water collected in the moisture separator will be pumped to the oil/water separator component of the liquid treatment system.

The moisture separator is a skid-mounted, Teflon®-lined carbon steel vessel. A pair of parallel discharge pumps are connected to the liquid effluent port. The moisture separator has nozzles for vapor inlet/outlet connections. The moisture separator has side-mounted level sensors and a sight glass for level monitoring. A manway is located on top of the moisture separator for inspection and cleaning of the vessel.

Level sensors installed through the ports on the moisture separator provide discrete input signals to the local skid-mounted control panel for operation of the two moisture separator condensate transfer pumps and provide a high-high level interlock alarm. Additionally, a low level switch connected to the transfer pumps provides an interlock in the event of no flow. The design of the moisture separator system includes accommodations to amend accumulated condensate with a caustic solution to neutralize any acidic materials recovered from the wellfield.

Design specifications for the moisture separator are summarized as follows:

| S-101 | Process Design | Equipment Capacity |
|---|---|---|
| Vapor flow | 2,310 scfm stream total | 2,610 scfm |
| Liquid flow, outlet | 9.2 gpm normal / 9.7 gpm max | 20 gpm |
| Material of construction | - | Carbon Steel Teflon Lined |
| Pressure rating | 24" WC vacuum | 54" WC vacuum relief |
| Inlet/exhaust port | - | 12" diameter |

#### 9.3.5.5 Vacuum Blowers

Rotary lobe blowers are planned for use to create an adequate vacuum in the wellfield, draw vapors through the heat exchangers and moisture separator, and create a sufficient positive pressure to direct conditioned vapors through the remaining process steps. The vacuum blowers will tend to raise the temperature of the vapor stream through heat of compression. The blowers are designed such that a single unit will be capable of managing the full vapor flow expected during thermal treatment operations. A second unit will be included as an installed spare. The blowers will include variable speed motors, and variable frequency drives (VFDs) will control the output of these units based on desired pressure and flow conditions in the wellfield and vapor ducting.

The process design conditions for the vacuum blowers are summarized below. The actual blower design will include additional sizing contingency to ensure proper performance for a range of operating conditions.

| B-101A/B | Process Design |
|---|---|
| Inlet temperature | 120°F |
| Inlet pressure | -24 in. wc (vac) |
| Inlet flow | 2,310 scfm |
| Outlet temperature | 140°F |
| Outlet pressure | +19 in. wc (pos) |

Notes: in. wc = inches of water column

The selected blowers have the capacity to meet the process design conditions highlighted above at less than 50% of the motor/blower's maximum operating speed.

#### 9.3.5.6 Moisture Separator #3

The vapors leaving the vacuum blowers are combined with the vapors from the liquid air stripper (Section 9.3.6.4). This combined vapor stream will pass through an additional moisture separator to remove any residual water. Water collected in the moisture separator will be pumped to the oil/water separator component of the liquid treatment system. The moisture separator is constructed and instrumented in a similar manner to the previously described moisture separator vessel.

| S-102 | Process Design | Equipment Capacity |
|---|---|---|
| Vapor flow | 2,861 scfm stream total | 3,000 scfm |
| Liquid flow, outlet | <<0.5 gpm | 20 gpm |
| Material of construction | - | 36" dia. Vertical Vessel Carbon Steel Teflon Lined |
| Pressure rating | 19 in. wc | 50 in. wc pressure relief |
| Inlet/exhaust port | - | 10" diameter |

#### 9.3.5.7 Duct Heater

Exiting the second moisture separator, the combined vapor stream will be heated approximately 6°F to raise the temperature of the combined vapors above the dew point of the stream and prevent entrained moisture from entering the thermal oxidizer. The duct heater operates automatically based on a thermostat and SCR power controller, utilizing input from a downstream temperature sensor. When the blower is operating at higher differential pressure, the blower itself may generate sufficient heat such that the duct heater may not be required to operate. Design specifications for the duct heater are summarized as follows:

| H-101 | Process Design | Equipment Capacity |
|---|---|---|
| Vapor flow | 2,861 scfm | 3000 scfm |
| Pressure rating | 15 in. wc | 15 psig |
| Heating rate | 6 kW | 15 kW |
| Material of construction | N/A | Inconel 600 |

Notes: psig = pounds per square inch gauge

#### 9.3.5.8 Dilution Blower

Due to potentially high concentrations of vapor phase COCs and related heat of combustion, supplemental dilution air may be needed in the thermal oxidizer to prevent overheating in the unit. The dilution air helps to maintain inlet vapor concentrations to the thermal oxidizer at safe levels (below 50% lower explosive limit [LEL]) and provides enough total air flow so that the temperature of the oxidizer exhaust vapors does not exceed the operational limits of the quench system. The dilution blower is designed to produce a discharge pressure equal to or greater than the vacuum and air stripper blowers to ensure that the combustion/dilution air can overcome the oxidizer system operating pressure.

The dilution air blower is an integral part of the thermal oxidizer package. It is equipped with a variable speed motor. The oxidizer control system will employ a flammability analyzer to determine the combustion heat value of the inlet vapors. The oxidizer controls will bring the dilution air blower on-line if necessary, and will control the speed of the blower motor to maintain appropriate operating conditions in the unit when the fuel value of inlet vapors are elevated. The dilution air blower is sized for 750 scfm of ambient air flow but is expected to operate at a fraction of its maximum design rate when engaged for high heat of combustion conditions.

#### 9.3.5.9 Thermal Oxidizer (TO)

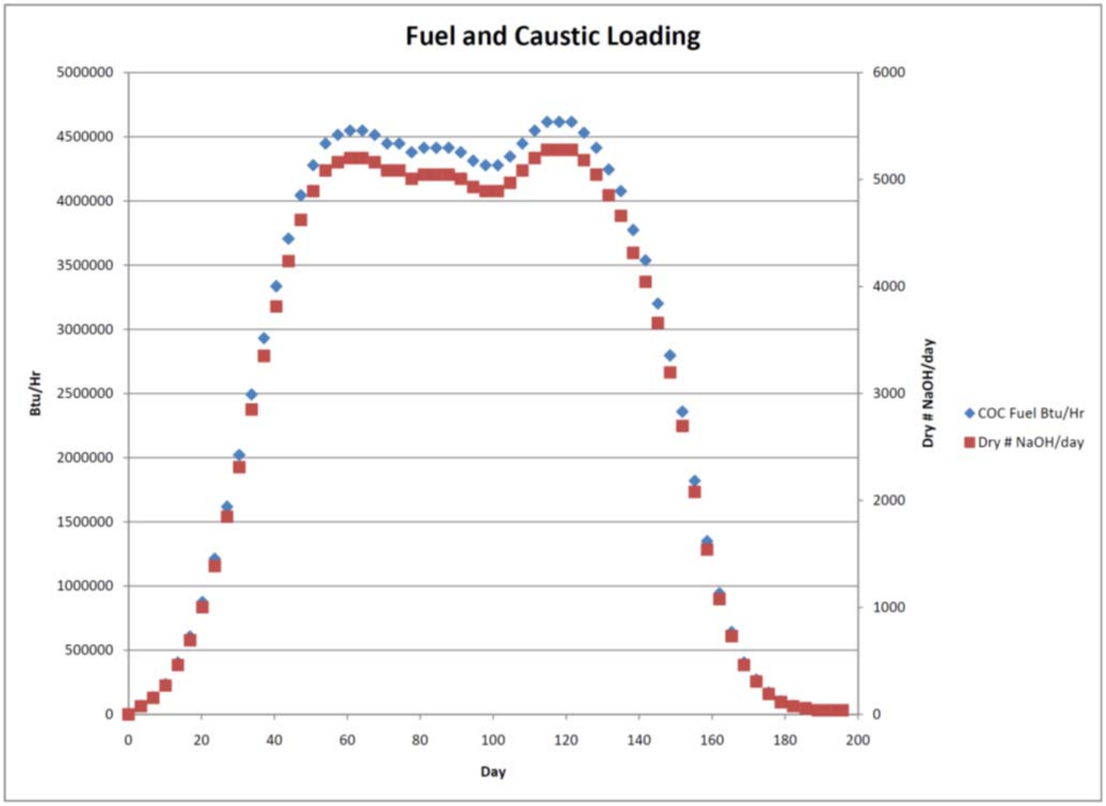
The thermal oxidizer is the primary component of the vapor treatment system. The thermal oxidizer is an HGTO 3000 HD manufactured by CCC, in Bloomer, Wisconsin. The unit is nominally designed to manage 3,000 scfm of ISTR vapors, heated to 1,600°F at 1-second residence time, producing a 99% Destruction Removal Efficiency (DRE) for VOCs and chlorinated volatile organic compounds (CVOCs). The unit is designed for a 99% up-time and includes a heat exchanger to preheat inlet vapors with hot exhaust gases to limit fuel consumption.

The oxidizer unit can be operated at an elevated temperature setpoint of up to 1,750°F. This increased temperature allowance coincides with a reduction in the dilution air feed to the system via the dilution blower. This operating scenario will maintain an adequate residence time in the unit (> 1 second) while accommodating a higher incoming combustion energy. The increased operating temperature will provide additional destruction efficiency for when the system is operated near its capacity. Thus, the system may be operated at the lower 1,600°F setpoint during periods of lower contaminant loading to conserve fuel and then increased to the 1,750°F setpoint as contaminant loading increases to maximize the system's loading capacity and increase DRE.

The oxidizer automatically maintains the temperature profile through a proportioning valve that adjusts the mixture of extracted vapors, combustion air, and supplemental fuel (natural gas) to maintain the reaction zone temperature profile. Within the reaction zone, the oxidizer destroys COC vapors, yielding carbon dioxide, water vapor, and hydrochloric acid (HCl). The concentration of the HCl produced depends on the concentration of the chlorinated COCs in the vapors entering the unit.

The thermal oxidizer is equipped with a non-contact shell and tube heat exchanger, which uses thermal energy in the oxidizer exhaust to pre-heat the incoming process vapors. Hot oxidizer exhaust vapors pass through the shell of the exchanger and flow counter-current to the cool inlet vapor passing through the exchanger tubes. This arrangement preheats the oxidizer vapor influent stream and results in a significant decrease in required fuel consumption. A bypass line is provided around the shell side of the heat exchanger in case the oxidizer generates more heat than is needed to pre-heat the incoming process vapors.

Thermal remediation treatment operations will be conducted in two phases, with the start of the second phase of operations delayed by approximately 60 days (as discussed in Section 5.2.1). This two segment approach spreads the COC generation across a longer period, reducing the peak thermal requirement of the oxidizer. Figure 9.5 below provides an estimate of the combustion heat energy expected to impact the thermal oxidizer during the two-phase thermal operation described above. The figure also includes an estimate of the caustic material to be used in neutralizing acid gas vapors exiting the oxidizer.




Design specifications for the thermal oxidizer are summarized below.

| F-101 | Process Design |
|---|---|
| Total process vapor flow, inlet | 3,000 scfm at 50% LEL |
| Operating Pressure | 16 in.wc |
| Required DRE | 99% |
| Material of construction | AL6XN |
| Burner Rating | 4.0 MM Btu/hr |
| Chamber temperature | 1,600°F – 1,750°F |

#### 9.3.5.10 Scrubber

Oxidation of chlorinated compounds produces HCl. The acid-laden gases will enter the scrubber through a vertical quench section mounted directly to the scrubber gas inlet. As the hot gases enter the quench section, a water/caustic solution spray will rapidly cool them, resulting in a cooler, reduced-volume saturated vapor stream. Some portion of the cooling spray will be evaporated as a result of the flash cooling. Liquid condensate, if present, will drain by gravity into the scrubber sump. The cooled vapors will continue to a counter-current packed tower scrubber section.

The vapors in the scrubber will flow upward through Kynar® packing media while a caustic solution is introduced through a series of spray nozzles at the top of the scrubber tower. The caustic solution will flow downward through the tower packing media, countercurrent to the acidic vapors. The packing media provides a large contact surface area for the caustic solution to neutralize the acid gases. The scrubbing solution will continue to fall through the packing media and return to the scrubber sump, typically at a lower pH and containing mineral salts [sodium chloride (NaCl), calcium chloride ($CaCl_2$), potassium chloride (KCl), etc.] that form as products of the neutralization reaction.

The pH of the scrubbing water will be automatically adjusted using a sodium hydroxide (NaOH) solution to maintain the pH of the scrubbing liquid within the range necessary for effective neutralization of the acid gases. The scrubber pH controller will automatically maintain an appropriate pH in the scrubber sump. If it is necessary to operate in cool weather (below approximately 55°F), a 25% NaOH solution or a blended sodium/potassium hydroxide solution will be used to avoid the freezing point issues associated with higher strength NaOH. Caustic will be stored in a tank and delivered to the scrubber recirculation lines by a local chemical feed pump.

A portion of the scrubber sump solution recirculated to the top of the tower and excess solution will be bled off via level controls in the sump and discharged to the POTW. Makeup water and resulting blowdown discharge rates will be controlled to maintain acceptable levels of dissolved solid levels to prevent mineral fouling in the scrubber and to limit salinity levels in the effluent between 3% and 5%. Additionally, makeup water will be pre-treated in a water softener to further address scaling and fouling concerns. At peak extraction and COC production, it is estimated that up to 7,300 lb/day of salt could be generated as a result of the neutralization reaction in the scrubber. Lower makeup flow rates would be required during periods of lower COC loading.

Expected operating conditions for the scrubber are summarized as follows:

| A-101 | Process Design |
|---|---|
| Total process vapor flow, inlet | 2,990 scfm |
| Inlet temperature | 1,600$^{o}$F |
| Material of construction | AL6XN |
| Quench water rate | 5 gpm |
| Water circulation rate | 216 gpm |
| Caustic usage, peak rate | 13,207 lb/day |

### 9.3.6 Liquid Treatment

Water from vapor condensation operations will be subject to treatment prior to discharge to the POTW sewer. Average effluent flow rates to the discharge will be approximately 15 gpm, and peak flow rates are estimated to be as high as 60 gpm (maximum scrubber blowdown, collected rainwater, etc.). The liquid treatment system depicted on the PFD consists of the following major components:

- Moisture separator(s)
- Oil/Water separator
- Bag filter(s)
- Air stripper
- Granular activated carbon vessel(s)

#### 9.3.6.1 Moisture Separator(s)

The moisture separators collect condensate generated in the vapor heat exchangers as described in the previous sections. This condensate is expected to be primarily water with very low mineral content, but may contain trace amounts of COC. The accumulated condensate will be sent to the oil/water separator periodically as determined by the level sensors in each moisture separator.

#### 9.3.6.2 Oil/Water Separator

The oil/water separator is a HydroQuip model AGM-3CS-150V-HP-1H (or similar), parallel-corrugated plate coalescing oil/water separator rated for a 20 gpm flow rate. The separator is designed to remove oil droplets larger than 20 microns with specific gravity ranging from 0.9 or less to greater than 1.1. The separator body is constructed of epoxy-coated carbon steel for improved corrosion resistance, with polypropylene coalescing plates. The unit is equipped with separate LNAPL and DNAPL accumulation areas, by virtue of an underflow baffle and overflow weir. The separator has a vapor-tight cover, with appropriate vents that are connected to the vapor treatment system to capture emission from the separator.

Accumulated LNAPL (if present) will drain by gravity to the LNAPL accumulation tank. Accumulated DNAPL (if present) will be transferred from the separator to the DNAPL accumulation tank by pneumatic diaphragm pumps. Effluent water from the clear-well of the oil/water separator flows via gravity to a discharge tank, which is fitted with level switches for automated pumpdown control operations. Accumulated clarified water is pumped through bag filters and conveyed to an air stripper for further treatment.

#### 9.3.6.3 Bag Filter(s)

A Rosedale Model 6 (or similar) duplex bag filter will be installed downstream from the oil/water separator to remove emulsion globules or particulates prior to entering the air stripper. The units are equipped with pressure gauges to determine if the filter elements are becoming fouled and need to be changed. The units are configured in parallel so that one unit can be taken off-line for service while the other unit remains in service, providing operational redundancy.

#### 9.3.6.4 Air Stripper

The air stripper for this project is a shallow-tray style air stripper, rated for 1 to 50 gpm, QED E-Z Tray, Model 12.4, or comparable. Water exiting the bag filters is introduced at the top of a stack of perforated air stripper trays, and is forced to follow a convoluted path through the stripper housing while a countercurrent air steam is passed upward through the flowing water. This creates a turbulent flow condition within the air stripper housing, inducing the VOCs in the liquid to partition to the vapor phase. The air stripper is capable of 99.9% or greater removal of VOCs from the liquid phase. The elevated temperature of the water entering the air stripper during the high COC mass removal periods, estimated to be approximately 120˚F, will further enhance the vapor phase partitioning within the air stripper.

The air stripper will operate continuously and is equipped with appropriate flow, temperature, pressure and level controls, and alarm interlocks, and is also provided with duplex pumps and blowers to serve as an installed spare in the event of a problem with the primary pump/blower.

#### 9.3.6.5 Liquid Granular Activated Carbon Vessel(s)

Two liquid-phase activated carbon absorbers will be installed downstream from the air stripper to provide final effluent polishing prior to discharging to the POTW. The carbon absorbers will be Tigg Model CP-500, or comparable, containing 800 lb of carbon and rated for a flow rate greater than 78 gpm. The carbon beds provide additional effluent polishing downstream from the air stripper and an added measure of protection in the event that an emulsion occurs that the oil/water separator is not capable of managing. The carbon bed is equipped with isolation valves, pressure gauges, and sample ports.

#### 9.3.6.6 Vapor Granular Activated Carbon Vessel(s)

A backup vapor-phase granular activated carbon (GAC) system is included in the design. The GAC system will consist of two vessels configured and piped to operate in a lead/lag scenario. In the event that the thermal oxidizer and/or the scrubber require maintenance for an extended length of time (e.g., >12 hours), the backup GAC system will provide temporary treatment at reduced vapor extraction rates so that the wellfield can be maintained under net vacuum conditions and vapors will continue to receive adequate treatment. These vessels will not be sized to operate as a primary contaminant treatment, but rather as temporary until the primary vapor treatment equipment is operating properly.

### 9.3.7 Backup Power

A backup generator working in concert with an ATS will provide backup power to the vapor treatment system to maintain pneumatic control in the event of a power loss or failure. The generator will power the vacuum blowers, cooling tower, transfer pumps, and air stripper to maintain operational continuity. However, the generator will not be sized to meet the considerable power demands of the TCH heaters during a power outage. Heating operations will resume when primary power is back in service.

### 9.3.8 Control Systems

The control systems are described below sequentially through the process.

Vapor flows managed by the treatment system are collected through a network of vapor extraction wells. The vapor flow rate extracted from the wellfield is controlled by monitoring and controlling the pressure as measured in the wellfield and vapor collection manifold. The vacuum level is controlled by adjusting the (VFD powering the vacuum blowers.

The heat exchangers are used to remove moisture to reduce potential for condensation in downstream process equipment. The inlet temperature of the heat exchanger is expected to vary during the project. The exit temperature of the heat exchanger is controlled by the temperature and flow rate of the cooled fluid provided by the cooling tower. The exit temperature of the cooling tower will be dependent on ambient temperature and humidity. In general, the cooling water recirculation rate is kept constant during the process. The heat exchangers and cooling loops are equipped with inlet/outlet pressure and temperature gauges to enable the operator to monitor the system and make adjustments if necessary. High temperature alarms are provided at the inlet and outlet of the heat exchangers. A water softener will control the hardness of the cooling tower makeup water, and accumulated minerals will be controlled via a steady blowdown stream. Biocide will be used as necessary to control biological growth.

Condensed liquid generated in the heat exchangers accumulates in the sump of the moisture separators. Level sensors are used to monitor the liquid level in the moisture knockout sump. A high level switch starts the transfer pumps. The transfer pumps are shut off when the level reaches the low level switch. A high-high level alarm is used to alert the operator if the pumps do not reduce the liquid level in the knockout sump. A high temperature alarm is provided between the moisture knockout and the blower inlet to prevent hot (inadequately cooled) incoming vapors from entering the vacuum blower.

The discharge stream from the vacuum blowers is combined with the discharge of the air stripper and fed to a moisture separator prior to going to a duct heater. The heat is used to raise the temperature of the vapor stream above dew point if there is not a sufficient temperature rise across the vacuum blowers. Operation of the duct heater is controlled by an on-board thermostat. A high-temperature limit switch and flow alarm prevent the duct heater from operating or overheating in the event of a no- or low-flow condition.

The conditioned vapor then enters the thermal oxidizer. The oxidizer oxidizes, or burns, the COCs carried in the vapor stream. The temperature of the combustion chamber is automatically maintained at temperatures from 1,600˚F to 1,750°F. Natural gas is used to provide supplemental fuel for combustion to maintain the combustion chamber in the desired temperature range. Operation of the oxidizer is controlled by a PLC. Permissive and shutdown signals based on the oxidizer’s on-board flow, pressure, and temperature sensors, along with input from the scrubber, are managed by the oxidizer PLC to maintain or safely shut down operation of the oxidizer.

The oxidizer is followed by a quench and wet scrubber. The quench is supplied with potable city water that has been treated in a water softener. Softened water is collected in a water supply tank and pumped to the quench/scrubber via water supply pumps. In the event of a loss of pumped water supply pressure, a pressure switch sends a signal to the oxidizer PLC to engage a backup municipal water supply and shut down the oxidizer in a controlled manner so that the scrubber section does not overheat. A thermal relief valve located on the discharge of the oxidizer vents the vapors in the oxidizer to prevent sending high temperatures to the scrubber.

The scrubber section includes a recirculation loop in which a caustic solution is added based on pH of the liquid in the scrubber sump. Salt is formed by the neutralization reaction of the caustic solution with HCl generated in the combustion process. Conductivity of the liquid in the sump is monitored to signal the operator that additional makeup water flow is required to prevent buildup of excessive solids in the sump and circulating loop and to remain within effluent discharge limits. The scrubber circulating loop is fitted with a discharge control valve that will automatically discharge wastewater from the scrubber sump when the sump fills up. The valve closes when the liquid level returns to the low level set-point.

Condensate generated in the vapor treatment system is sent to the oil/water separator system for separation of any NAPL. Overflow from the oil/water separator is pumped through bag filters before being processed in the air stripper. The air stripper has a flow switch to signal the operator in case of loss of air flow. Additionally, there are high and low level alarms to monitor the sump level.

### 9.3.9 Expected Water Discharge Rates to the POTW System

Average effluent flow rates to the POTW discharge will be approximately 25 gpm, and short-term peak flow rates are estimated to be as high as 60 gpm (scrubber blowdown, collected rainwater, etc.). The maximum daily allowable discharge to the POTW is 53,000 gallons per day (gpd). Aqueous discharge monitoring requirements are summarized in Section 13.7 below.

# 10.0 STATEMENT OF REGULATORY COMPLIANCE

## 10.1 Permit Equivalency

The appropriate local and state agencies have been contacted to obtain the permit equivalencies required to operate the thermal remediation system. The remaining anticipated permits specifically for the in-situ thermal program include:

- Building permits from the City of Southington for the mechanical, electrical, and plumbing components of the system.

## 10.2 Air Permit Equivalency

Because the remediation is being performed as part of a Superfund remedial action, a CTDEEP air permit is not required; however, the vapor-phase control system was designed to meet or exceed Best Available Control Technology (BACT) criteria, thus meeting the substantive permit requirements. BACT measures incorporated into the design include but are not limited to the following:

- Emissions calculations, including Hazardous Air Pollutant (HAP) Maximum Allowable Stack Concentrations (MASC) compliance analysis;
- BACT analysis using USEPA/NESCAUM “top-down” procedures; and
- Program for compliance demonstration including performance of a destruction efficiency test conducted during operations.

A copy of the permit equivalency application and approval is included as Appendix I. Vapor samples will be collected from the discharge of the oxidizer stack to confirm COC destruction as per the permit equivalency. Additional system performance monitoring is discussed in Section 13.0.

## 10.3 Water Permit Equivalency

Since the remediation is being performed as part of a Superfund remedial action, a wastewater discharge permit is not required; however, the ISTR system was designed to meet current discharge criteria as defined by the Southington sanitary sewer system, thus meeting the substantive permit requirements.

Copies of the permit equivalency application, the approval letter dated January 14, 2011, and the general permit issued on January 7, 2011 are included as Appendix I. Discharge is limited to 53,000 gpd, maximum, at no more than 60 gpm. Water samples will be collected within 30 days of operation and submitted to the analytical laboratory for the analyses listed in the permit approval. Results will be submitted to the Town of Southington and CTDEEP to confirm compliance with the provisions of the General Permit.

### 10.4 Compliance with Project Specific ARARs

The following table summarizes the ARARs for the project and describes how they will be met during implementation of the ISTR.

| Regulatory Level | Requirement | Citation | Compliance with ARAR | Comply with ARAR |
|---|---|---|---|---|
| Federal | RCRA Air Emission Standards for Equipment Leaks | 40 CFR 264 Subpart BB | Air discharges are expected to be limited to the effluent stack from the thermal oxidizer/scrubber package. Effluent vapors from the air stripper will be directed to the thermal oxidizer(s) for treatment. The thermal oxidizers are expected to maintain a minimum of 99% DRE for VOCs and CVOCs. Acid gases exiting the oxidizer will be treated and neutralized in a caustic scrubber, which is expected to maintain a minimum 99% DRE for neutralization of HCl vapors.<br><br>Emission standards for VOC and HCl emissions will be determined by CTDEEP. At this time, it is expected that the air discharge will be limited to not more than 1 ton/year for the TCE and 2.8 tons/year for HCl, as both are considered to be HAPs under the Clean Air Act. An emission limit of 2.8 tons/year (5,600 lb/yr) equates to a daily emission rate of ~15 lb/day. The TCE input to the thermal oxidizer is expected to be up to 1,500 lb/day or ~63 lb/hr. With a minimum 99% DRE in the oxidizer and 99% HCl neutralization in the scrubber, expected VOC emissions should be below 3.5 lb/hr at peak and the expected HCl emissions should be below 2 lb/hr, which is well below the anticipated emission standards. | Y |
| | RCRA Air Emission Standards for Process Vents | 40 CFR 264 Subpart AA | Same as above. | Y |

| Regulatory Level | Requirement | Citation | Compliance with ARAR | Comply with ARAR |
|---|---|---|---|---|
| State of Connecticut | Hazardous Waste Management Regulations | CGS 22a ch 445 RCSA §22a-449(c) | Wastes generated during the thermal remediation process may include:<br>• Recovered NAPL;<br>• Liquid condensate;<br>• Spent media (e.g., activated carbon, etc.);<br>• Decontamination fluids;<br>• Used PPE; and<br>• Normal construction debris.<br>Hazardous and potentially hazardous wastes including, NAPL, decontamination fluids, and spent media will be sampled, profiled, and disposed of at a properly licensed disposal facility. Liquid condensate is expected to be treated on site by the liquid treatment train. Used personal protective equipment (PPE) and construction debris will be managed and disposed of at appropriately licensed facilities. All manifests, shipping documents, weight tickets, etc., will be maintained in the project file and included with the completion documentation. | Y |
| | Air Pollution Control | CGS 22a ch 446c RCSA §22a-174-1 to 33 | Real-time VOC air monitoring will be performed at representative perimeter locations consistent with the plan established in the TWISP (Appendix G). The purpose of this monitoring is to assess the potential for VOC concentrations to exceed action levels protective of surrounding populations, and to trigger control measures if action levels are exceeded.<br><br>The approach uses four perimeter stations located along the property boundary in the four corners of the treatment area. VOC monitoring is performed with a MiniRAE 3000 equipped with a 10.6 eV lamp, capable of readings from 0 to 15,000 ppm. Readings will be taken every second and a 15-second time-weighted average is sent wirelessly from the instruments and stored in an online database. All available data are instantly accessible through an established website. This system is capable of sending out alerts, via text and email, to notify responsible personnel to take responsive actions before established thresholds are breached. Perimeter air monitoring for VOCs will be performed at all times (24 hours a day, 7 days a week) during operations. | Y |

| Regulatory Level | Requirement | Citation | Compliance with ARAR | Comply with ARAR |
|---|---|---|---|---|
| | Control of Noise | RCSA §22a-69-1 to 7.4 | To minimize noise in and around the thermal treatment area, drilling efforts will occur in 10-day shifts starting on Tuesday. Work is expected to occur between the hours of 7 am to 5 pm; however, because of the hazards associated with the wellfield installation, hours may be extended to finish (seal) a borehole. Construction efforts will occur Monday through Friday from 7 am 5 pm with weekends, as necessary. Operations will be Monday through Sunday 24 hr/day. Equipment, such as the vacuum blower, is predicted to have a noise level less than 90 dBA (free-field at 1m distance) at maximum performance. Once the blowers have been procured, predicted blower noise levels will be evaluated at the fenceline to determine what, if any, additional soundproofing is necessary. | Y |
| | Discharge of Remediation Wastewater to a Sanitary Sewer | CGS 22a-430b RCSA §22a-430-1 to 7 | Water generated during thermal remediation will be treated and sent off site to a local POTW. Water is expected to be generated from vapors produced during operation, scrubber blowdown, and collected rainwater. Prior to discharge, liquids generated in the vapor treatment process will be sent to any oil/water separator. The liquids will go through an air stripper and finally GAC. Scrubber blowdown will be neutralized prior to discharge. Rainwater collected during operations will be directly discharged to the sewer. | Y |

| Regulatory Level | Requirement | Citation | Compliance with ARAR | Comply with ARAR |
|---|---|---|---|---|
| Other | Liquid | | Several items will contribute to the liquid effluent from the thermal treatment system. The primary liquid discharge will be from the effluent of the air stripper and carbon treatment system, which are used to remove VOCs from the vapor extraction system condensate. Expected air stripper effluent flows are on the order of 10 to 15 gpm.<br><br>Neutralization of hydrogen chloride gas and HCl condensate in the wet scrubber will produce chloride salts in the scrubber sump that must be discharged to control the level of suspended solids in the scrubber recirculation loop. This may initially begin as a batch process, but as the mass load of extracted VOCs increases, the rate of salt generation will increase and the process will likely convert to a continuous discharge. The scrubber blowdown discharge rate will depend on the quantity of VOCs destroyed in the thermal oxidizer. A conductivity sensor will be utilized to automatically maintain an acceptable level of suspended solids in the scrubber. It is anticipated that the scrubber blowdown will contain 3% to 5% salt by volume, with an average discharge flow rate of approximately 30 to 40 gpm. | N/A |
| | Storage of Caustic | | Caustic solution (NaOH or KOH/NaOH blend) will be stored in a plastic tank within a secondary containment berm. Storage tank volume will depend on the estimated peak usage rate and the selected caustic vendor's available delivery schedule. At this time, it is expected that the caustic tank will be a 5,000-gallon tank to allow for up to two days storage volume at the peak calculated caustic demand. | N/A |

### 10.5 Spill Prevention Control and Countermeasure (SPCC) Plan

An SPCC Plan was prepared in accordance with the USEPA Oil Pollution Prevention Regulations (40 CFR Part 112) and Chemical Accident Prevention Provisions (40 CFR Part 68), to address the potential for spills from vehicle and equipment fuel tanks, and process equipment holding tanks that will be utilized during the ISTR process. The SPCC Plan is provided as Appendix J.

# 11.0 THERMAL REMEDIATION OPERATIONS

## 11.1 Operational Sequence

Based on the model calculations, operational durations have been estimated. A numerical model (Appendix B) was used to calculate energy fluxes and subsurface temperatures. The model accounts for

- Energy input by conduction heating.
- Energy extracted with groundwater.
- Energy extracted with vapors (steam and air).
- Heat losses to surrounding areas (top, bottom, and sides).

This model has been calibrated and verified for several large thermal projects conducted in the United States. Results are presented in Section 5.0. The Site is divided into two segments of nearly identical size. The segments are heated as follows:

Phase 1: From day 0 to 135
Phase 2: From day 60 to 195

In summary, the operational sequence is as follows:

Days 0-55: Ramp-up of the ISTR energy input in Phase 1 from 10 to 70% of the maximum rate.
Days 55-125: Heating at or near maximum capacity in Phase 1, averaging 80 to 90% of the maximum rate.
Days 125-135: Extraction and maintenance of pneumatic control in Phase 1, during cool-down.
Days 60-115: Ramp-up of the ISTR energy input in Phase 2 from 10 to 70% of the maximum rate.
Days 115-185: Heating at or near maximum capacity in Phase 2, averaging 80 to 90% of the maximum rate.
Days 185-195: Extraction and maintenance of pneumatic control in Phase 2, during cool-down.

The strategy is flexible and will be adjusted based on measured performance. In particular, the 60-day lag in start-up between the two phases is based on the estimated peak loading from the initial phase reflecting the modeled assumptions. The actual point at which the second phase is initiated may be adjusted based on field monitoring to ensure that the peak VOC loading is maintained below the capacity of the oxidizer.

Performance must also include up-time for the TO, and reaching and maintaining an extraction rate close to the maximum capacity of the TO, and mass removal close to 8,000 lb/day.

## 11.2 Thermal System Start-up

The following sections summarize procedures for the ISTR system start-up. A more detailed discussion can be found in the O&M Manual.

### 11.2.1 Meeting and Readiness Review

Before operations begin, a readiness review meeting and inspection will be held at the Site. The following will be performed as part of this meeting:

- Review of the entire facility;
- Review of effluent treatment system;
- Review of operations plan;
- Review of HASP, job-hazard analyses, and completion of safety checklist;
- Review of detailed data collection schedule and forms;
- Review of sampling and analysis schedule;
- Review of staffing plan; and
- Discussion about uncertainties and contingencies.

It is anticipated that this will facilitate start-up of the thermal remediation system a few days following the meeting.

### 11.2.2 Commissioning/Shakedown Period

Once all of the heating and effluent treatment equipment is installed, the operations staff will test all of the equipment and verify proper operation prior to start-up. The activities will include, but are not limited to, the following. A system start-up checklist is included in the O&M Manual as Appendix D.

- Test all major pipelines;
- Leak-check vapor and liquid transfer lines;
- Physically inspect all heater connections;
- Test heater circuits for circuit and ground resistance (to confirm proper circuit connections and verify no shorts to ground) prior to energizing the circuits;
- Test effluent treatment system with clean water and vapor;
- Check all motors for proper rotation;
- Verify and calibrate all instrument signals;
- Verify all analog and discrete signals to/from the PLC;
- Set all valves to the proper pre-start positions;
- Collect background temperature, pressure, and water level data; and
- Engage all safety locks.

The commissioning period is expected to take approximately 5 to 10 days.

## 11.3 Operation

Thermal remediation operations are expected to last approximately 195 days (or longer if USEPA invokes provision for additional operational duration). In general, the effluent treatment system operation will be controlled and monitored by the PLC. ISTR heater operation will be controlled by the individual heater circuit SCRs and their individual temperature controllers. The Operators will monitor the system throughout the operation and make adjustments to the ISTR heater circuits, balance extraction flows and pressures, and monitor/adjust the operation of the aboveground treatment equipment to maintain optimum performance. Adjustments to the system operation will be made in consultation with the TerraTherm project manager and project engineer.

During the operational period, vapor and liquid samples will be collected from the treatment system to monitor and track the mass loading and treatment system performance. In general, these samples will be collected at the inlet and outlet of the treatment system, selected manifold legs, and selected vacuum extraction wells based on field observations.

Operators will be on site Monday through Friday for approximately 8 to 10 hours per day and possibly partial days on the weekends, based on the operating status of the system. During off hours, operators can be at the Site within approximately one-half hour after being notified by the PLC. Equipment will be visually inspected using a Process Equipment checklist developed specifically for this Site. At a minimum, daily inspections will include checking the vapor and liquid manifold piping, connections, pressures, and temperatures throughout the wellfield, secondary containment systems, and the operational status and performance of all heating and treatment equipment.

The following describes possible conditions when the heaters and/or off-gas treatment system would be shut down and what measures will be taken to ensure protection of human health and the environment:

| Conditions | Actions | Potential Impacts |
|---|---|---|
| Loss of line power | • Heaters and off-gas treatment systems automatically shutdown.<br>• Wellfield block valve automatically closes.<br>• Operator automatically notified.<br>• Emergency generator automatically starts within 30 seconds of power loss.<br>• Operator reports to site within 30 minutes (if not already on site).<br>• Operator re-starts oxidizers and off-gas treatment system on dilution air.<br>• Operator notifies Project Coordinator.<br>• Wellfield block valve is opened and vapors are extracted and treated from subsurface.<br>• Heaters remain off until line power is restored. | • None.<br>• Extraction and treatment typically restored within 1 to 2 hours. If loss of power exceeds 1 to 2 hours, heating may need to be extended. |
| Failure of thermal oxidizer, scrubber, and/or other major equipment | • TO, blowers, pumps, and other equipment with meters and alarms to monitor operating parameters.<br>• If TO, scrubber, and/or other major components go off-line, off-gas treatment system automatically shuts down.<br>• Wellfield block valve automatically closes.<br>• Operator automatically notified.<br>• Operator reports to site within 30 minutes (if not already on site).<br>• Operator collects photoionization detector (PID) readings within wellfield.<br>• If the operator, in conjunction with the project engineer, determine that the repairs will take longer than 2 to 4 hours, the | • None.<br>• Extraction and treatment typically restored within 2 to 6 hours.<br>• If ambient VOC concentrations are observed or loss of containment occurs, or if the required repairs will take longer than originally estimated, a backup vapor phase GAC system will be manually brought on-line. If ambient VOCs persist, the heater power will be reduced until the system is repaired. |

| Conditions | Actions | Potential Impacts |
|---|---|---|
| | heaters will be shut down.<br>• Operator makes repairs and re-starts oxidizers and off-gas treatment system on dilution air.<br>• Wellfield block valve is opened and vapors are extracted and treated from subsurface. | • Significant deviation from specified operating ranges and/or prolonged repairs would cause shutdown of the heating system. Based on our experience (empirical observations at our 30+ sites), the treatment zone could remain bottled up with the heaters off for up to 12 hours with little to no pressure buildup in the subsurface or releases to the atmosphere, regardless of the amount of energy already in the subsurface. This assumes that the treatment zone is up to target temperature. During shutdown conditions, vacuums within the wellfield are observed. |

### 11.4 Project Meetings

Project meetings between the immediate project team (*de maximis*, TerraTherm, and ARCADIS) will be held weekly during construction and operations; USEPA and CTDEEP will be invited to participate on these calls. Conference calls, including the immediate project team, USEPA, and CTDEEP, will be held monthly during operations to discuss the progress of the thermal remedy. Weekly construction reports and monthly progress reports will be submitted detailing the progress of the construction or thermal remedy, as appropriate. Additionally, real-time data will be posted and available to the project website.

### 11.5 Community Outreach and Relations

On 6 June 2013, USEPA prepared a brief community update and mailed it to residents in the vicinity of the Site. In this letter, the local residents were invited to attend an open house, scheduled for 7 September 2013. The open house was intended to allow the public to see the progress of thermal treatment system installation and notify them on the expected system operations that will follow once installation is complete. The site periodically hosts meetings that include community members, local officials, and members of regulatory agencies in an effort to maintain a favorable and informative relationship with the public. Additional information that describes the activities the SRSNE Site Group has proposed to undertake to support USEPA's community involvement and outreach work required under CERCLA can be found in the Community Relations Support Plan (ARCADIS 2010) located in the RD POP.

In the event of an emergency that could expand from the Site and impact the surrounding community, the Town of Southington's reverse 911 call system would be implemented. *de maximis* would be responsible to notify the Town to commence the alerts. The notification telephone calls will alert people in the vicinity of the Site to evacuate and avoid the area. *de* *maximis* would request the Southington Police Department to follow up with neighbors to ensure they have safely evacuated and ensure the area is secure from the public.

### 11.6 Project Website

Data are of paramount concern on a thermal remediation project. The Team uses only state-of-the-art electronics in the equipment for accurate and reliable reporting of relevant temperature and process data. This information will be stored in a database and then compiled and presented via a secure project website in a manner that allows for rapid response to project issues as they arise.

Operational information about the status and progress of the thermal treatment will be posted to the project website. The website will have multiple screens that provide general project information, specific data such as power or temperature, project documents, and contact information. Current and historical information will be available on the website. The website will be secured via a username and password.

### 11.7 Shutdown

Once it is determined that the thermal remediation objectives have been achieved (see Section 13.0) and approval is granted by USEPA, the TCH heaters will be turned off. The extraction and treatment systems will continue to extract and treat vapors and liquids during the initial decommissioning activities to allow for partial cool-down and to ensure capture of steam and vapors in the subsurface. During this phase, both vapor and water treatment systems will operate, and the subsurface temperature and pressure monitoring will continue for approximately two weeks. Throughout this period, influent vapors will continue to be monitored; if PID readings continue to be detected, the cool-down phase may be continued. Following the cooling period, once subsurface temperatures drop below that of steam, the system will be shut down and decommissioning will continue.

### 11.8 Decommissioning and Demobilization

Once the vapor treatment system is shut down, the vapor conveyance piping and treatment equipment will be broken down and decontaminated prior to demobilization. Heaters and stainless steel liners will be removed from the well casings. Electrical equipment will be disconnected and demobilized from the Site for return to TerraTherm.

All wells will be decommissioned according to TerraTherm's SOP titled "Well Decommissioning at the SRSNE Superfund Site" (Appendix E) and summarized as follows. Where possible, thermal wells and monitoring points will be pulled out using a forklift. The remaining open portion of the borehole will be backfilled with a bentonite-cement grout installed using a tremie tube or other suitable pressurized placement method. Once the grout sets, a minimum 2,000 pounds per square inch (psi) concrete plug will be installed from the top of the grout to the ground surface.

In the event that a well or portion of a well cannot be removed from the ground, the casing will be cut off at a depth of approximately 2 ft bgs. The remaining portion of the casing will be backfilled as described in the previous paragraph.

## 11.9 Waste Streams

Wastes generated during the thermal remediation process may include the following and are anticipated to be handled and disposed of as indicated:

- Drill cuttings – containerized in the spoils containment area located within the thermal wellfield for later treatment during operations.
- NAPL and NAPL–saturated cuttings (if any) will be containerized and temporarily stored on site, pending characterization, then properly disposed of offsite.
- Liquid condensate –Sent off-site to POTW.
- Spent media (e.g., activated carbon, filter bags) – regenerated or off-site incineration; filter bags will be drummed and properly disposed of offsite.
- Decontamination fluids – processed through the groundwater treatment plant.
- Normal construction debris including used PPE – off-site disposal as general refuse.
- Well development and purge water – processed through the groundwater treatment plant.

Hazardous and potentially hazardous wastes including NAPL will be sampled, profiled, and disposed of at a properly licensed disposal facility. Spent media will also be sampled, profiled, and disposed of at a properly licensed disposal facility. Used PPE and construction debris will be managed and disposed of at appropriately licensed facilities.

## 11.10 Site Restoration

Prior to demobilizing from the Site, excess material, construction and demolition debris, and trash will be removed from the Site within 60 days and properly managed. The Site will be left in a condition substantially similar to its condition prior to construction. The surface cover will remain in place until construction of the RCRA cap. At such time, the cap will be broken up by others, as needed, and graded/reused as fill prior to cap construction.

## 11.11 Re-Equilibration of Subsurface Temperatures - Heat Dissipation Model

A numerical model was built to answer the following questions:

- How long will it take before the Site returns to an equilibrium state, near ambient temperatures?
- What temperatures will be observed downgradient from the treated zone, particularly at locations of existing monitoring wells in the NTCRA containment area?
- How will the temperature of the water extracted by the NTCRA wells vary over time?

The model results are included in Appendix B. Based on the results, select NTCRA wells were determined to be too close to the heated zones, and were decommissioned as part of the pre-ISTR site preparation activities. It was also shown that minimal temperature impacts (less than 10$^{o}$C) are expected for the NTCRA water treatment system. Finally, the model indicated that the Site will cool to within 10$^{o}$C of ambient temperature approximately 1 to 1.5 years after the thermal treatment.

# 12.0 EMERGENCY RESPONSE PLAN

During thermal operations, VOC levels will be continuously monitored to identify, verify, and alert site workers and the community to the presence/existence of any air quality impacts due to the operation of the ISTR remediation system, and to monitor perimeter air concentrations to assess whether VOC levels are within CTDEEP Hazard Limiting Values (HLVs). Should VOC levels exceed CTDEEP HLVs, the Project Coordinator will immediately be notified and the Emergency Response Plan will be activated. Perimeter air monitoring will be performed in accordance with the procedures outlined in the table in Section 10.4, Compliance with Project Specific ARARs, Air Pollution Control and as specified in the TWISP (Appendix G).

The Emergency Response Plan (Appendix K) addresses actions personnel will take in response to emergencies or unplanned releases at the Site, arrangements with local, state, and federal emergency responders to coordinate emergency services, identification of the roles and responsibilities of the emergency coordinator and alternates, supply and maintenance of on-site emergency equipment, and stop work and emergency evacuation planning. The objective of the plan is to minimize hazards to human health or the environment from fires, releases of hazardous constituents, and other emergency conditions.

# 13.0 TREATMENT PERFORMANCE EVALUATION

This section describes the scope and approach for performance monitoring of the ISTR remedy, to determine the progress of the ISTR system, to demonstrate compliance with the applicable permit equivalency requirements, and to monitor the quality of any air or water discharges from the system. The following sections describe the performance monitoring (samples, locations and frequency) that will be collected during operations based on the final design of the ISTR system.

Specific objectives of the performance monitoring during thermal treatment are:

- Evaluate the performance of the ISTR system.
- Provide data to document that cleanup levels are attained.
- Provide data to evaluate the rate of mass removal.
- Provide data to determine when the appreciable recovery of NAPL ceases.
- Demonstrate that the process discharge criteria are being maintained.
- Adhere to the HASP; monitor personal breathing space during tasks that may potentially expose personnel to hazardous concentrations such as vapor sampling, repair/modifications to wellfield, groundwater sampling, etc.

## 13.1 Principles of Monitoring and Sampling

During operation, operating data will be collected and reviewed to track the progress and compare it to the predicted performance, so proper operational adjustments can be made in a timely manner. Data are recorded and displayed on a project-specific web-based database accessible by the project manager, engineering team, and operations staff. These data include:

- Energy consumption, power delivery, and other utility usages;
- Mass and energy balances for the subsurface volume;
- Subsurface temperatures;
- Groundwater samples from the TTZ;
- Analytical data;
- Data documenting pneumatic and hydraulic control (water levels and in-situ pressure measurements);
- Mass removal rates and cumulative totals for COCs; and
- Other key data displayed in the weekly progress report, including wellfield temperatures, vapor extraction rates, removal efficiency, total mass removed, water levels, wellfield vacuum, water balance, and power usage.

These data will also be made available to the project team through a web address and password. Weekly and monthly progress reports (as discussed below) will summarize the data collected.

During operation, a monthly report will be submitted to *de maximis* that includes energy balance and energy input plots, snapshots of subsurface temperatures collected from installed thermocouples, temperature versus time plots collected from thermocouple strings, average site temperature versus time plot, and mass removed versus time plot.

Using these data, the progress can be monitored and evaluated. TerraTherm will review data and modify operating parameters, as needed, to optimize the heating pattern and enhance mass removal.

Operational modifications may include:

- Increase or decrease of the TCH heater temperatures and power input;
- Increase or decrease of the vacuum extraction rate (total and individual well); and/or
- Install additional TCH heater wells.

### 13.2 Daily Operations Staffing Plan

Experienced TerraTherm Operators, with engineering staff as needed, will be on site during the testing and commissioning phase. As the system transitions into full operation mode, TerraTherm will have a lead Operator and support Operator at the Site every weekday and for partial days, as needed, on the weekends, or as required for data collection, maintenance, and troubleshooting. TerraTherm's Operators will be available to respond to the Site within approximately 30 minutes should the monitoring system detect any issues with the ISTR system. Additional details on alarm response can be found in the site-specific HASP.

### 13.3 Remote Monitoring

The PLC will log selected system operating data including relevant temperatures, pressures, and flows through the aboveground vapor treatment equipment, as well as the position of safety sensors and controls (e.g., pressure switches, level switches, motor operated valves, etc.), including POTW operation (e.g., the water level in the pump vault). Wellfield temperature data from the field thermocouples will be collected and logged by the PLC, or similar. The PLC and temperature logging system will be accessible remotely through a dial-up modem or high-speed internet connection, allowing TerraTherm engineering and project management staff in the office to access the PLC and observe the same operating information available to the field staff. Alarms and shutdown conditions will result in automatic notification of TerraTherm's Operators by cell phone.

### 13.4 Manual Process Data Collection

The manually collected data include:

- Power usage - reading of totalizing meters;
- Cumulative liquid flows - reading of totalizing flow-meters inserted in the treatment system transfer lines for condensate and total flow through the air stripper, as well as city water supply to the boiler and scrubber;
- Temperature and pressure readings - gauge readings for the treatment system; and
- Wellfield pressure readings - gauges placed throughout the wellfield.

### 13.5 Wellfield and Subsurface Monitoring

Separate temperature monitoring points and combined vacuum/pressure and water level monitoring points will be installed within the thermal wellfield to monitor the effects of the heater and vacuum extraction wells on subsurface conditions, including:

- Temperature,
- Vacuum/Pressure, and
- Potentiometric Surface (i.e., depth to the water table).

In situ temperature monitoring will be focused on locations within the TTZ that are expected to heat-up the slowest. These locations are the centroids of the triangles formed by the heater well array, which represent locations farthest from any heater. Approximately 60% of thermocouples will be in this location representing an intense focus on these areas that comprise a small fraction of the overall wellfield. The remaining temperature points will be distributed as described below. Vacuum/pressures and water levels will be monitored to document pneumatic control and drawdown for hydraulic control.

In addition, some temperature and pressure monitoring points will be located outside the TTZ, documenting control of heat and fluids on the outer boundary of the TTZ.

### 13.5.1 Subsurface Temperature Monitoring

Data from the temperature sensors will be used to evaluate heating progress. A total of 98 temperature monitoring points will be installed. Each temperature monitoring point will include a string of between four and seven thermocouples that will provide temperature data from the ground surface to the top of bedrock, with varying depths and number of sensors depending on the overburden thickness. These monitoring points will be distributed evenly throughout the entire wellfield on the following basis:

- 72% (71) at centroid locations (i.e., center of triangle formed by three heater wells);
- 21% (19) located 3 ft from heater wells; and
- 8% (8) located along the perimeter of the wellfield.

The centroid temperature monitoring points will provide information on the progress of heating the regions of the TTZ that are located farthest from the heaters. The monitoring points located 3 ft from the heater wells will provide important information on the temperature gradients adjacent to the heaters, and the perimeter monitoring points will be used to evaluate any impacts outside of the thermal treatment zone.

This distribution of temperature monitoring points will provide the data necessary to monitor:

- The progress of the ISTR system in heating the subsurface;
- The uniformity of the heating; and
- The impact, if any, of groundwater flow through the TTZ.

### 13.5.2 Subsurface Vacuum/Pressure and Water Level Monitoring

A total of 64 combined vacuum/pressure and water level monitoring points will be distributed evenly throughout the thermal wellfield to provide information on the vacuum/pressure of the vadose zone and the potentiometric surface within the TTZ. These wells will be screened across the water table from 2 to 8 ft bgs and 2 to 12 ft bgs, depending on their location within the wellfield, and be equipped with dual-port well heads that will allow measurement of both the vacuum/pressure and water level at each location.

Vacuum/pressure measurements will be collected using a handheld manometer. This is a manual reading within the wellfield that will be collected at least once a week by the operators;

more frequent measurements will be collected if positive pressures are observed within the wellfield (until such time that negative pressures are achieved). If pressures are observed in the wellfield, water levels may be collected to ensure that the water is at a sufficient level to capture vapors. Because of the elevated temperatures within the wellfield, traditional procedures cannot be used. To minimize potential health and safety hazards, water levels, when needed, will be collected using a manometer and Teflon tube inserted into the well. Once the manometer reaches the water, a value will be displayed on the manometer. The Teflon tube will be marked at the top of the well. Using a tape measure, or similar, the total distance from the mark to the manometer will be recorded.

The vacuum/pressure measurements will be used to assess and adjust the vapor extraction system to maintain capture of steam and contaminant vapors. The water level measurements will be combined with data from existing overburden and bedrock monitoring wells around the TTZ to assess horizontal and vertical groundwater gradients within and around the treatment area. This assessment will be used to evaluate the degree of hydraulic capture of the ISTR system.

#### 13.5.3 Wellhead Monitoring

Select wellheads will be periodically monitored during operation of the thermal remediation system for pressure, temperature, and VOC concentrations (by PID-screening of a vapor sample), at the discretion of TerraTherm, to determine the variability of mass removal rates from different portions of the treatment zone. It will be of special interest to monitor conditions at selected well heads during later phases of the remediation to identify areas that may not have been sufficiently remediated and to determine when to proceed with progress and performance soil sampling. Wellhead monitoring will also be used to evaluate if and where appreciable NAPL is being recovered following attainment of the Interim NAPL Cleanup Levels. As the wellfield begins to meet criteria, specific locations that have lagging temperatures, known NAPL, or high VOC concentrations may be selected for additional discrete sampling. This frequency is at the discretion of TerraTherm.

### 13.6 Screening Level Sampling

A handheld PID (MiniRae 3000, or similar) will be used to screen the vapor concentrations at locations along the ISTR system on a daily basis:

- At the combined influent to the treatment system and inlet to the oxidizer; and
- At the discharge location (effluent stack).

Vapor samples for screening will be collected in Tedlar™ bags using a dedicated sample pump. Since moisture is known to interfere with the PIDs, a humidity filter will be used with the PID.

In addition, weekly vapor samples will be collected from each operational manifold leg at the points where they enter the main manifold line. These samples will be collected in evacuated stainless steel canisters (Summa or equivalent) and analyzed at the laboratory for a list of VOCs via USEPA Method TO-15 (GC/MS). The laboratory data will provide estimates of the concentrations and composition of VOCs present in the samples. Similar samples will also be collected from the inlet and outlet of the off-gas treatment system. The screening samples will be collected once per week and will be used to estimate:

- The mass removed from the TTZ;
- The mass and fuel loading rates;
- The relative concentrations or rates of contribution of VOCs from portions of the TTZ; and
- Changes in composition of VOCs from the entire TTZ and portions thereof.

These data will be used to track the progress of remediation in portions of the TTZ and to make decisions about when to initiate progress sampling and, in conjunction with the soil data results, whether to shut down portions of the TTZ. The screening data will be compared with the grab samples collected for full laboratory analysis described below (Section 13.7).

TerraTherm may also choose to collect additional vapor samples from individual wells or manifold sections in order to obtain information about the VOC levels in vapors extracted across the Site. Sampling vapor concentrations from individual manifold sections can indicate performance of each of the two treatment phases. These data can be used to calculate a mass removal estimate for that area/phase.

### 13.7 Grab Samples for Laboratory Analysis

Because all the extracted COCs flow through the vapor extraction manifold pipes to the treatment system, and the COCs are recovered as a vapor and to a lesser degree, liquid, tracking the mass removed from the remediation area is straightforward. Samples and process data from numerous locations will be used by TerraTherm to optimize the operation of the system, and to provide estimates for the following:

- Mass removed in the vapor state (measured at the inlet to the thermal oxidizer);
- Mass removed in dissolved state (measured downstream from the air stripper); and
- DRE of the vapor treatment system (determined by comparing vapor influent samples described above, with discharged vapor sample concentrations).

Grab samples will be collected for verification and determination of the COC load in the extracted and discharged water and vapor streams. At a minimum, vapor effluent and water discharge samples will be collected weekly throughout operations. Additional sampling may be performed, at the discretion of TerraTherm or *de maximis*, as appropriate to facilitate optimization of the system and evaluation of system performance. At a minimum, the following grab samples will be collected:

- Vapors conveyed to the oxidizer: one grab sample per month initially, and then one per week during peak removal (> 6,000 pounds per day VOCs treated), assumed to be from days 40 – 150 of operation These samples will be collected in Summa canisters and will be analyzed for VOCs using USEPA method TO-15.
- Liquid condensate samples: collected monthly. These samples will be collected in pre-preserved (HCl) 40 milliliter (mL) vials and be analyzed for VOCs using USEPA Method 8260B (GC/MS).
- Samples discharged to the POTW: one grab sample within 30 days of system start-up to be analyzed for VOCs (Method 624), SVOCs (Method 625), PAHs (Method 625), PCBs (Method 608), pesticides (Method 608), total metals (method furnace), and other

inorganics such as cyanide; subsequent samples will be collected monthly for VOCs. In addition, samples will be collected for total suspended solids and pH.

- Groundwater samples will be collected prior to, and periodically during, thermal operations (every 2 weeks once the peak VOC removal rate has been observed). These samples will be screened by the laboratory using a gas chromatograph for VOC concentrations.

Additional samples may be collected at the discretion of TerraTherm. These laboratory VOC data will be used in conjunction with the oxidizer influent flow rate and condensate flow rate as discussed below in Section 13.8.

## 13.8 Mass Removal Calculations

We have designed the wellfield such that Phase I can be isolated from Phase II. During periods of overlap, Phase I and Phase II can be differentiated from one another by subtraction. TerraTherm plans to collect PID readings from each manifold leg on a weekly basis (Section 13.6). From these data, we intend to create a ratio of Phase I / Phase II vapor concentrations, and apply that ratio to the combined flow at the oxidizer influent to estimate how much mass was removed from each phase.

Mass removal estimate calculations are normally performed via a few different techniques, such that the mass removed estimate is ultimately a range of values. One technique uses the laboratory data (alone) to estimate mass removed. A second technique uses the daily PID readings in conjunction with the laboratory data to estimate mass removed.

The oxidizer influent flow (scfm) is read off of the oxidizer control screen, and recorded daily by the site operator as part of the manual data. The scfm is converted to $m^3$/day. The oxidizer influent vapor is monitored on site daily using a handheld PID. This value (parts per million by volume [ppmv], calibrated to isobutylene) is recorded daily by the site operator as part of the manual data. In addition, periodically (weekly/monthly, per Section 13.7), oxidizer influent vapors will be sampled and submitted for laboratory analysis via USEPA TO-15.

### 13.8.1 Mass Removed (PID) Estimate Calculations

Using the periodic laboratory data from the oxidizer influent and the corresponding PID reading taken at the same location on the same day (generally within a few hours of each other, maximum), a sample specific response factor and representative COC molecular weight are calculated. The representative COC molecular weight multiplies the mass fraction of each VOC detected in the TO-15 analysis by the molecular weight of that VOC. Those fractions are then summed to obtain the representative COC molecular weight for that sample. A simple example is shown in the following table.

**Example of Representative COC Molecular Weight Calculation using TO-15 Data**

| Compound | MW | Concentration from TO-15 Analysis, mg/m$^3$ | % of Total Mass | Adjusted MW |
|---|---|---|---|---|
| Acetone | 58.08 | 1.2 | 72.86% | 42.3169 |
| Benzene | 78.11 | 0.172 | 10.44% | 8.1572 |
| Tetrachloroethene | 165.80 | 0.250 | 15.18% | 25.1670 |
| Toluene | 92.14 | 0.025 | 1.52% | 1.3986 |
| | TOTAL | 1.647 | TOTAL | 77.04 |

Next, to calculate the sample specific response factor, the daily PID reading (ppmV) is converted to mg/m$^3$ using the representative COC molecular weight. This field PID reading (mg/m$^3$) is compared with the actual mg/m$^3$ total VOC concentration from the TO-15 data (1.647 mg/m$^3$ in the example shown in Table 1). The calculation is as follows:

*Sample specific response factor = [Field PID reading, adjusted mg/m$^3$] / [Laboratory total VOC, mg/m$^3$]*

*Note: adjusted mg/m$^3$ value converts field ppmV to mg/m$^3$ using representative COC molecular weight*

For mass removal estimate calculations, the daily PID reading from the oxidizer influent (ppmV) is multiplied by the sample specific response factor, and then converted to mg/m$^3$ using the representative COC molecular weight. From there, the concentration is multiplied by the oxidizer influent flow to yield the daily flux (mg/day, then converted to kg/day or lb/day). Those daily flux values are totalized and graphed as a cumulative function over time. It should be noted that for the days following a laboratory confirmation sample, the previous sample-specific response factor and representative COC molecular weights are used for each day's calculations until a new set of lab data is available. An example of the mass removal based on PID graph is shown on Figure 1 below.

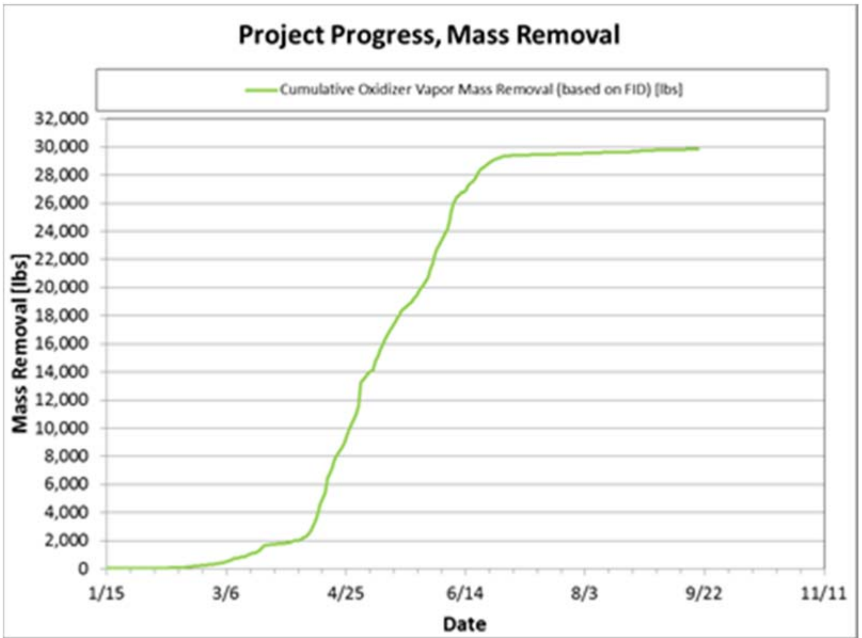



**Figure 1. Example of Cumulative Mass Removal Estimate, based on PID**

### 13.8.2 Mass Removed (lab) Estimate Calculations

Using the periodic laboratory data from the oxidizer influent and the oxidizer influent flow, the daily flux is calculated and those daily flux values are totalized and graphed, similar to the PID mass removal estimate. Figure 2 is an example graph showing cumulative mass removal estimate, based on lab data.

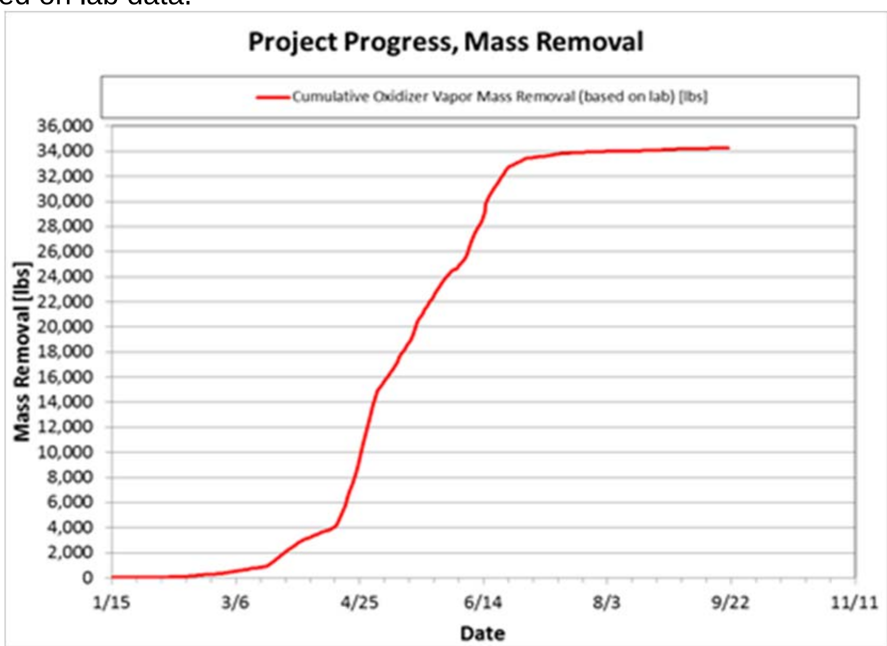



**Figure 2. Example of Cumulative Mass Removal Estimate, based on Lab Data**

## 13.9 Energy Balance Calculations

For the treatment zone, an energy balance will be maintained using the following data:

- Energy delivered to the heaters - meter readings and power loads on the heater circuits;
- Energy removed in the form of entrained liquid - estimated based on liquid rates and temperature;
- Energy removed in the form of steam - estimated based on the condensate flow rate by a flow-meter at the discharge line of the first knock-out vessel;
- Energy removed in non-condensable air - estimated from total treatment system vapor flow rate and temperature; and
- Estimated heat losses.

A condensate sump is located at the influent to the vapor treatment system, prior to cooling the vapors. The water collected in the sump will either be steam condensed in the main manifold or entrained water. In the first phase of the project, while the Site is still cold, any water collected in the sump will be entrained water. Data collected in the initial part of the project will indicate to what extent entrained water should be expected during operation, and the energy balance will be adjusted accordingly based on these results. In addition, it will be assumed that any water collected at the moisture separator originated from steam extracted from the wellfield. The moisture separator is located immediately after the heat exchangers, and, since any entrained water is expected to drop out at the sump skid, all remaining water is assumed to be condensate from steam.

The energy balance returns an average heating rate (in degrees per day) and an average remediation zone temperature. These numbers are compared to the design numbers (energy delivery, average temperature) and the observed subsurface temperatures (from thermocouple measurements). An energy balance will be periodically calculated for the Site to verify that the thermocouples are providing accurate representation of conditions throughout the thermal treatment zone and to assess the progress of heating.

### 13.9.1 Energy Injected

The total energy delivered to the Site using the TCH heater wells will be derived from readings from a totalizing electric meter. Power used for the process equipment (blowers, pumps, etc.), will either be subtracted from the total or measured separately.

### 13.9.2 Energy Stored

The thermocouple data will be evaluated to provide detailed information on the heat-up of the subsurface. These data will be used to determine the amount of energy stored in the subsurface (e.g., energy stored in soil is equal to the soil temperature times the specific capacity of soil times the mass of soil).

### 13.9.3 Energy Removed

Energy will be removed from the Site in the form of hot water and vapors. The water will be entrained with the extracted vapors from the VEWs. The hot vapors from the VEWs will consist of steam and air. For air and water, the energy fluxes are determined by multiplying the flow rate times a heat capacity times the fluid temperature. For steam, it is determined as a flow rate times the specific enthalpy of the steam (heat of condensation).

## 13.10 Soil Sampling Events

To determine the effectiveness of the ISTR treatment within the footprint of the treatment area, soil sampling will be performed. Soil samples will be collected during operation of the ISTR system to evaluate the progress of the soil treatment, and following completion of the treatment, to verify attainment of the Interim NAPL Cleanup Levels.

Soil samples will be collected using a track-mounted Geoprobe® Direct Push Technology (DPT), or equivalent, to the treatment depth. Samples will be collected using a steel macro-core sampler with dedicated inner stainless steel sleeves. Some areas within the wellfield may not have access for soil sampling due to the thermal system infrastructure (manifold lines, wells, monitoring points, cable). The wellfield will be constructed in a manner to minimize potential obstructions and allow access.

### 13.10.1 Progress Soil Sampling

Progress sampling events will be used to document remedial progress and to identify potential areas that may require additional treatment or modifications to the heater well network. Progress sampling is not intended for compliance purposes or to verify that treatment has achieved the target cleanup goals. Hot sampling techniques as described in the SOP titled “Hot Soil Sampling” (Appendix E) will be used to sample zones that have achieved target temperatures and are expected to have been depleted of DNAPL, and zones that resist heating and may need additional focus.

Two progress sampling events will be conducted in each segment to evaluate VOC concentrations in soil when concentrations in the inlet vapor stream to the off-gas treatment system have decreased and temperatures within the TTZ have reached or exceeded the eutectic boiling point of NAPL. In addition, the screening results of the groundwater samples will be evaluated to determine if zones or regions within the TTZ still contain NAPL.

In general, the sampling procedures will involve the following:

- Soil borings will be advanced at the selected locations, and soil sample(s) will be collected from the predetermined depths. Soil sample coring devices will be chilled to ambient temperature prior to opening by placing the sample core devices in ice trays.

- Soil samples will be obtained in approximately 6-inch lengths (sufficient for obtaining three Encore™, or similar, samplers for VOC analysis) centered at the predetermined sample depths. The use of pre-calculated sample depths will minimize sample collection time and VOC loss. However, if visible staining, sheen, or NAPL is readily observed in the sampler, such visibly impacted material will be targeted for sampling in lieu of the predetermined sample.

Progress soil sampling locations will be determined at TerraTherm’s discretion based on the ISTR system monitoring data and operational observations (e.g., soil temperatures, vapor concentrations, etc.). The purpose of the progress sampling is to identify potential areas that may need additional treatment (e.g., particular depths or areas with lagging temperatures). Additionally, TerraTherm will use a discretionary but biased approach to select progress sample locations and depths. Specifically, the samples will target areas believed to contain the highest pre-treatment soil concentrations, areas where heating may have progressed at a slower rate, variable locations within the grid (i.e., nearer heater wells and centroids), and/or other biasing factors based on the status of the heating process as of the time of the progress sampling.

Approximately 15 soil samples will be collected in each segment (30 total) after approximately 60 to 70 days of operation of each segment. Approximately 35 soil samples will be collected from each segment (70 total) after approximately 90 to 110 days of operation of each segment. Estimates of mass removal will be based on the screening-level sampling at several locations in the conveyance pipe system (as described in Section 9.5), at the treatment system, and to some degree by sampling individual extraction wells in critical areas of the TTZ. Because these interim samples are only to be used for assessing the heating progress, they will not be subject to quality assurance and quality control requirements otherwise used for compliance data (e.g., blind duplicates, trip blanks, etc.).

#### 13.10.2 Confirmation Soil Sampling

As described in the preceding sections, various operational parameters will be monitored in the course of ISTR operations to assess the progression of the treatment. Once a determination is made that the treatment goals have very likely been met based on monitoring of these parameters, (e.g., temperature and mass removal) including the results of the progress sampling events, a confirmation soil sampling program will be performed to verify that the thermal treatment has resulted in achievement of the applicable Performance Standards. This section identifies a preliminary approach for soil sampling to confirm that the ISTR activities have achieved the Interim NAPL Cleanup Levels specified in Section IV.A.4 of the SOW. These levels were calculated using site-specific data, where available, and conservative literature values, and apply from the ground surface to the top of bedrock throughout the TTZ. These levels represent the point at which soil concentrations are not indicative of the presence of pooled or residual NAPL. Accordingly, the goal of the ISTR is to achieve soil concentrations within the overburden NAPL area that are equal to or lower than the following:

- TCE – 222 ppm
- PCE – 46 ppm
- 1,1,1-Trichloroethane – 221 ppm
- Ethylbenzene – 59 ppm
- Toluene – 48 ppm
- p/m-Xylene – 70 ppm
- o-Xylene – 42 ppm

The planned approach for verifying that ISTR has achieved the Interim NAPL Cleanup Levels involves collection of 100 soil samples from approximately 50 locations within the thermal treatment area or approximately 50 samples from 25 locations in each segment (phase).

The final confirmatory soil sample locations will be collected from randomly selected grid blocks as shown on Figure 13.1. USEPA, at its discretion, may modify up to 20% of the randomly selected 100 soil sampling points to ensure sampling “interrogation” of zones where the thermal treatment effectiveness may be slower to progress. To the extent possible, the main manifold pipe runs have been configured to allow sampling equipment to access the wellfield. However, given the amount of infrastructure that will be in place in the wellfield and the need to continue to maintain hydraulic and pneumatic control in the subsurface during the sampling events, it may be necessary to modify or adjust proposed sampling locations slightly to accommodate the thermal wellfield infrastructure.

The target number of samples to be obtained from each boring will be determined based on the estimated overburden thickness as follows:

| Overburden Thickness | # of Samples per Boring |
|---|---|
| <10 ft | 1 sample |
| >10 to 20 ft | 2 samples |
| >20 ft | 3 samples |

The average number of samples to be collected per boring is expected to be approximately two, producing a total of approximately 100 compliance soil samples. For each boring, the total estimated boring depth (depth to rock) will be divided into equal length increments, one per required soil sample, and a random depth for sampling within each depth increment will be calculated. For example, if the bedrock is expected to be 13 ft deep at a given boring, the two equal increments will be from ground surface to 6.5 ft deep, and from 6.5 to 13 ft deep. Within each 6.5-ft-long increment, random depths for sampling will be calculated using a random number generator in a spreadsheet (e.g., Microsoft Excel). The random number generator will return a value from 0 to 1, where 0 and 1 equate to the top and bottom, respectively, of the depth increment to be sampled. In the example above, if the random numbers returned for the top and bottom increments are 0.895 and 0.598, the target sample depths will be 5.8 ft and 10.4 ft, respectively.

This process produces an unbiased, even distribution of samples covering the entire thickness of the thermal treatment zone. However, to help ensure that the randomly selected samples do not end up at redundant locations, it is proposed that a minimum of 3 ft of vertical separation be maintained between subjacent soil sampling depths at any given soil boring. Within each 6-ft-long increment, random depths for sampling will be calculated, and adjustments will be made as necessary to maintain at least 3 ft of vertical separation between samples within a given boring.

At least two weeks prior to the planned confirmation sampling activity, de maximis will provide the USEPA a sampling plan indicating the planned sample locations based on the grid locations shown on Figure 13.1 below, and the specific depths calculated based on the procedure above. The USEPA may then modify up to 20% of the locations to ensure targeting of specific areas of interest. The sampling plan would then be revised accordingly and soil sample(s) will be collected from the specific locations and depth depth intervals.

Soil sample coring devices will be chilled to room temperature prior to opening the core by placing the sample core devices in ice trays. Soil samples will be obtained in approximately 6-inch lengths (sufficient for obtaining three Encore™ samplers, or similar, for VOC analysis) centered at the predetermined sample depths, within each of the 50 borings. The samples will be analyzed on a rush-turnaround basis. Pending confirmation that NAPL Cleanup Goals have been achieved, de maximis will report the data as soon as possible to USEPA with a request to initiate cool down procedures for that phase. The USEPA may approve the request, or require additional operation in accordance with Section IV.A.4 of the SOW. If the soil sampling indicates that NAPL Cleanup Goals have not been met in one or more areas, TerraTherm will continue treatment operations and resample when operational data suggest remaining areas have been adequately treated. If warranted in such cases, de maximis may request USEPA approval to continue treating only in specific areas where NAPL Cleanup Goals have not been met, and to limit re-sampling only to those areas. Such request would be made in conjunction with submittal of the initial sampling data.

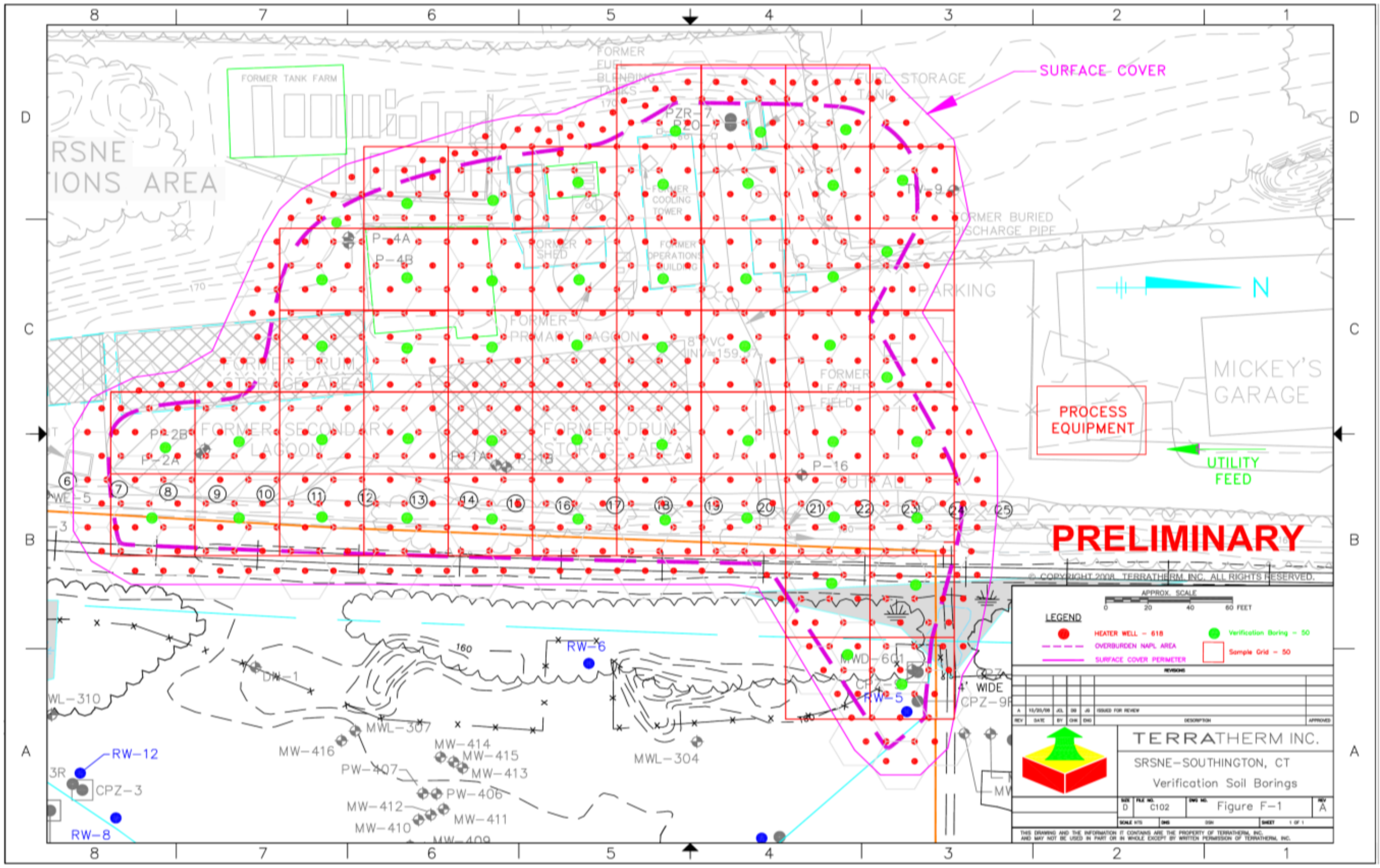



**Figure 13.1 Proposed Sampling Grid for Final Soil Samples**

### 13.11 Performance Criteria

The performance of the thermal remediation project will be determined by collection and analysis of soil samples and comparison of the analytical results with the soil performance objectives. The performance soil sampling will be triggered as soon as the operational parameters indicate that sufficient mass has been removed such that DNAPL no longer exists within the treatment zone. The critical data for this evaluation are:

- Achievement of temperatures above the eutectic point for DNAPL at most of the temperature monitoring locations within the treatment volume (i.e., at thermocouple locations that are properly calibrated and properly operating) as summarized below.

**Table 13.1. Summary of Temperature Monitoring Program for Entire Treatment Zone.**

| Total TTZ | Treatment Sub Area | | | |
|---|---|---|---|---|
| | A | B | C | Total |
| # of TMP Locations | 6 | 42 | 25 | 73 |
| Bottom of Treatment - ft BGS | 12 | 15 | 21 | |
| Bottom of TC Well - ft BGS | 13 | 16 | 22 | |
| Depth Intervals - ft BGS | 2,5,8,12 | 2,5,8,11,15 | 2,5,8,11,14,17,21 | 409 |

- A trend in the mass removal indicating diminishing returns. For instance, for a treatment area the size of that contemplated for the SRSNE Site, our experience is that a mass removal of less than 100 lb/day of COCs will be seen as an indication that very little, if any, DNAPL exists in the treatment volume. This is very subjective, and should not be an indicator for SRSNE and that the performance standards likely are met. While this removal rate is not proposed as a performance criterion, it is an experience-based rule of thumb that TerraTherm will consider, among other indicators, when determining the time at which soil samples will be collected for assessing achievement of the performance criteria.

- Soil sampling results from progress soil sampling events, when some areas are expected to have met the remediation goals.

- Wellfield samples measured in the conveyance pipe system, at the treatment system and to some degree by sampling individual critical extraction wells in critical areas of the TTZ verify that individual site segments are depleted in extractable COCs.

- Miscellaneous operational observations such as mass and energy balance interpretations, caustic usage, etc.

The actual vapor-phase concentrations and mass-flux that trigger the performance sampling will be discussed among USEPA, CTDEEP, and the Project Coordinator (Mr. Bruce Thompson of *de maximis*, as named on 7 November 2008 in the Consent Decree), and based on all available data collected during treatment to fulfill the Settling Defendants responsibility to meet the thermal treatment performance standards.

Screening level groundwater samples will also be collected before and periodically during thermal operations to evaluate general changes in dissolved phase VOC concentrations. These data results will not be used as a performance metric. Performance standards, as stated in the ROD, for the thermal treatment remedy do not include any metrics based on dissolved concentrations in groundwater. As specified in the SOW, this metric will be evaluated by comparing VOC concentrations in *soil* to the Interim NAPL Cleanup Levels. The absence or decline of dissolved concentrations in groundwater is indicative of concentrations that will be found in soils or that the thermal remedy has not succeeded at reducing VOCs. To illustrate the relationship between the soil cleanup levels and pore water concentrations, an example calculation was performed.[8] Using the average bulk density and TOC, the results are as follows:

| VOC | Progress Cleanup Level (soil) mg/kg | Calculated Pore Water Concentration (mg/L) |
|---|---|---|
| TCE | 222 | 340.86 |
| PCE | 46 | 41.36 |
| 1,1,1-Trichloroethane | 221 | 470.90 |
| Ethylbenzene | 59 | 73.29 |
| Toluene | 48 | 6.84 |
| p/m and o-Xylene (summed for this example) | p/m – 70<br>o - 42 | 100.69 |

The ultimate determination of whether the NAPL Cleanup Levels have been achieved will be the progress and final soil data.

## 13.12 Data Usage, System Adjustments and ISTR Completion

The following sections describe how the operations team will use the collected data to make operational decisions, determine the progress toward successful site remediation, and determine when to proceed with progress and confirmation sampling.

### 13.12.1 ISTR Energy Delivery

The ISTR power distribution system is equipped with automatic controls and data acquisition, which allow the operators to evaluate the load and energy delivery to each circuit or group of heater borings. If the delivery of energy to certain circuits lags behind the design numbers, an investigation into the cause will be made. Adjustments may include:

8 Feenstra, S., D.M. Mackay, and J.A. Cherry. 1991. A method for assessing the presence of residual NAPL based on organic chemical concentrations in soil samples. Ground Water Monitoring Review, Vol. 11, no. 2, pp. 128-136.

- Raising the set-point of the heaters to create larger temperature gradients;
- Modifying the extraction approach to reduce influx of water; and/or
- Addition of heater borings to the problematic areas.

#### 13.12.2 Hydraulic Control Issues

The extraction strategy may be modified if the groundwater level monitoring or the temperature monitoring indicates that inward gradients and flow are not maintained in one or more locations, and the groundwater flow is deemed unacceptable. Unacceptable groundwater flow has the potential to prevent or reduce subsurface heating and consequently affect treatment performance. Options for modifications include:

- Application of higher vacuum at select locations to increase the rate of liquid entrainment and steam extraction;
- Changes to the heating strategy if it is believed that steam may be pushing water away; and/or
- Addition of groundwater extraction either to existing wells or by installation of new wells by contractors retained by Settling Defendants. These locations would be determined based on monitoring temperature and groundwater elevations in areas where heating is lagging and around the perimeter of the thermal treatment zone.

#### 13.12.3 Areas Lagging behind in Heating

If the heat-up of certain areas lags behind the design numbers, an investigation into the cause will be made. The most probable cause will be movement of cold or cool water into the treatment zone, either from perimeter locations or upward from the bedrock. Adjustments may include:

- Raising the set-point of the heaters in those areas to create larger temperature gradients and increase the energy input;
- Modifying the extraction approach to reduce influx of water; and/or
- Addition of heater borings to the problematic areas.

With the installation of the sheetpile wall around the northern and southern perimeter of the thermal wellfield, cool water is not expected to impact temperatures.

#### 13.12.4 Areas with Extreme CVOC Concentrations

If the PID screening from a manifold leg indicates that some areas release extreme concentrations (PID response larger than the instrument range) of VOCs in the vapor stream, it may be an indication that large amounts of NAPL mass are present. Additional PID screenings will be collected from individual extraction wells to identify the area of high concentrations. Samples will be collected in a Tedlar™ bag and allowed to cool to ambient temperature before readings are collected. The remediation of such areas may be stimulated by:

- Increasing the energy input to speed up the vaporization process;
- Increasing the extraction vacuum and rate to pull the COCs out more rapidly; and/or
- Extracting liquids from existing wells or from new wells installed for the purpose of extracting DNAPL.

#### 13.12.5 Effluent Treatment System Capacity Exceeded

If the system is overloaded with contaminant mass (3,000 scfm at 50% LEL), two options are:

- Add treatment capacity to the system by cooling more aggressively, compressing the cooled vapors, or by decreasing the flow and diverting through carbon; and/or
- Slowing the heating and ISTR process to spread out the mass loading over a longer treatment time.

#### 13.12.6 CVOC Load not Declining as Expected

If the mass removal remains high (indicated by a PID response near or above the instrument range, or laboratory data for the joint vapor stream indicating removal of more than 500 lb/day), even after the TTZ has been heated to the target temperatures and treated as designed, the most plausible explanation will be that contaminant mass is entering from outside the TTZ at a substantial rate. Such mass flux would have to be in the form of NAPL, in order to make a substantial contribution. NAPL could hypothetically enter either horizontally around the perimeter of the treated area, or upward from the bedrock.

NAPL present in close proximity to the TTZ would be partially vaporized and extracted with the system. It would move in the vapor phase, delivering COC mass to the extraction system. This is an inherent feature of how the TTZ boundaries were selected. Particularly near the bottom of the TTZ, in the upper part of the bedrock, DNAPL mass is likely to be present in some locations. This is a function of the established treatment system boundaries that cannot be eliminated.

If this problem exists, the first step is to investigate the source. A wellfield survey would be used to identify the areas where the mass is coming from. Select boreholes would then be advanced to determine if NAPL is present in substantial quantities, and whether this is the case in locations outside the perimeter, or below the treatment zone.

Such initiatives would be proposed to USEPA by TerraTherm, in consultation with the Project Coordinator, and the SRSNE Site Group after a careful review of all available data.

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# Appendix A

# HAZOP and Constructability Review

# Appendix B

# Pre-Design Studies and Modeling Reports

# Appendix C

# Design Drawings

# Appendix D

# Operations and Maintenance Manual

# Appendix E

# Standard Operating Procedures

# Appendix F

## Site-Specific Health and Safety Plan

# Appendix G

# Thermal Wellfield Implementation Support Plan (TWISP)

# Appendix H

# Typical Equipment Specifications

# Appendix I

# Permit Equivalencies and Approvals

# Appendix J

## Spill Prevention Control and Countermeasure Plan

# Appendix K

# Emergency Response Plan