In Situ Thermal Remediation Conceptual Design/Remedial Action Work Plan

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

Prepared for: SRSNE Site Group

April 2010

Prepared by:



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TABLE OF CONTENTS

Executi	ve Summary	5
1.0 Intro	oduction	8
1.1	Project Delivery Status	8
1.2	Requirements of the SOW	8
1.3	Document Format	9
2.0 Pro	ject Objectives	11
2.1	Remedial Action Objectives	11
2.2	Performance Standards	11
2.3	Site Background	12
2.4	Site Geology/Hydrogeology	12
2.5	Target Treatment Zone	13
3.0 The	rmal Technology Background	15
3.1	In Situ Thermal Desorption Background	16
3.2	Remediation Mechanisms	18
4.0 Des	ign Basis and Results of Pre-Design Studies	19
4.1	Introduction	19
4.2	System Design Evaluation	19
4.2	.1 Numerical Simulation Model	19
4.2	.2 Discussion of Simulation Results for the Base Case Scenario	22
4.2	.3 Materials Compatibility Test(s)	27
4.2	.4 Analysis of Non Aqueous Phase Liquid (NAPL)	27
4.3	Vapor Treatment Needs Evaluation	28
4.4	Thermal Treatment Monitoring	28
4.5	Thermal Treatment Performance Criteria	28
4.6	NAPL Delineation	29
5.0 Pro	ect Operations Plan	30
5.1	Site Management Plan	30
5.1	.1 Access	30
5.1	.2 Roadways	30
5.1	.3 Utilities	30
5.1	.4 Laydown Area, Staging and Storage Facilities	30
5.1	.5 Field Oversight/Construction Management	30
5.1	.6 Independent Quality Assurance Team (IQAT)	30
5.2	Subcontracts	31
5.3	Schedule and Reporting	31
5.4	Mobilization, Site Preparation and Utility Hook-Ups	31
5.5	Construction, Shake-Down, Start-up, and Demobilization of ISTR System	31



5.6	Mod	lifications to Proiect Sampling and Analysis Plan	31
5.7	Hea	Ith and Safety Plan	32
6.0 Con	struct	tion Environmental Monitoring Plan	33
7.0 ISTF	R Sys	tem Design and Construction	34
7.1	Well	lfield	34
7.1.	.1	Wellfield Layout	34
7.1.	.2	Wellfield Design	34
7.1.	.3	Construction Details	36
7.1.	.4	Drilling Method	39
7.1.	.5	Installation of Borings/Wells	40
7.1.	.6	Liner and Heater Installation	44
7.2	Surf	ace Cover	44
7.3	Vap	or Treatment System	45
7.3.	.1	Process Design	45
7.3.	.2	Piping, Mechanical and Electrical Installations	45
7.3.	.3	Vapor Collection Piping	45
7.3.	.4	Electrical Installation	45
7.3.	.5	Process Components	47
7.3.	.6	Liquid Treatment	53
7.3.	.7	Backup Power	54
7.3.	.8	Control Systems	54
7.3.	.9	Expected Water Discharge Rates to the POTW System	55
8.0 State	emen	t of Regulatory Compliance	57
8.1	Perr	nit Equivalency	57
8.2	Air F	Permit Equivalency	57
8.3	Con	npliance with Project Specific ARARs	58
9.0 The	rmal I	Remediation Operations	61
9.1	Ope	rational Sequence	61
9.2	The	rmal System Start-up	61
9.2.	.1	Meeting and Readiness Review	61
9.2.	.2	Commissioning/Shakedown Period	62
9.3	Ope	ration	62
9.4	Shu	tdown	63
9.5	Dec	ommissioning and Demobilization	64
9.6	Site	Restoration	64
9.7	Re-I	Equilibration of Subsurface Temperatures - Heat Dissipation Model	64
10.0 Tre	eatme	ent Performance Evaluation	65
10.1	Prin	ciples of Monitoring and Sampling	65
10.2	Dail	y Operations Staffing Plan	65
10.3	Rem	note Monitoring	66



10.4	Manual Process Data Collection	.66
10.5	Screening Level Sampling	.66
10.6	Grab Samples for Laboratory Analysis	.67
10.7	Energy Balance Calculations	.67
10.	7.1 Energy Injected	.68
10.	7.2 Energy Stored	.68
10.	7.3 Energy Removed	.68
10.8	Subsurface Temperatures	.68
10.9	Soil Sampling Events	.68
10.10	Performance Criteria	.71

- Appendix A Operations & Maintenance Plan, Example Table of Contents
- Appendix B Pre-Design Studies/Modeling Reports Materials Compatibility Test(s) Analysis of Non Aqueous Phase Liquid (NAPL) Sample Numerical Simulation Model System Design Evaluation
- Appendix C Standard Operating Procedures Air Monitoring Hot Soil Sampling Calibrating the YSI Hot Groundwater Sampling Emission Sampling
- Appendix D Site Specific Health & Safety Plan



Appendix E – Design Drawings

- TS1 Drawing Index & Location Map
- C101 Existing Conditions
- C102 Depth to Bedrock
- C103 Division of Thermal Treatment Zone
- C104 Wellfield Layout
- C105 Proposed Startup Phases
- C106 Thermal Conduction Heater and Vapor Extraction Well Details Zone A
- C107 Thermal Conduction Heater and Vapor Extraction Well Details Zone B
- C108 Thermal Conduction Heater and Vapor Extraction Well Details Zone C
- C109 Typical Vapor Extraction Well Details
- E101 One Line Electrical (2 sheets)
- M101 Vapor Extracting Piping Layout
- M102 Mechanical Site Plan
- P101 Process Flow Diagram (PFD) (2 sheets)
- P102 Piping and Instrumentation Diagram (P&ID) (2 sheets)

Appendix F - Typical Equipment Specifications

Appendix G - Heat Dissipation Model Results



EXECUTIVE SUMMARY

This Conceptual Design/Remedial Action Work Plan (CD/RA WP) 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 (Attachment A to the RDWP) 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 above ground 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. United States Environmental Protection Agency (USEPA) approval of the PIPP was received on August 11, 2009.

This report presents a combined CD/RA WP for the ISTR system. As such, this report presents both the design basis for the ISTR system and it describes implementation of the various activities necessary to address the remedial 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 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. The Interim NAPL Cleanup Levels for soils have been defined as concentrations that are not indicative of the presence of pooled or residual NAPL, and are as follows:

Trichloroethene – 222 mg/Kg Tetrachloroethene – 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 thermal treatment zone (TTZ) covers an approximate area of 74,195 square feet with a target treatment depth ranging between 12 and 24 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).

The ISTR system will heat the western portion of the TTZ from 0-15 ft below ground surface (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. 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 feet 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 a depth of 15 ft bgs, 18 ft bgs, or 24 ft bgs, dependent on their location.
- Vapor extraction wells to extract vapors from the vadose zone. VEWs will be installed approximately 3 ft from each heater well.
- Horizontal vapor extraction wells to extract vapors in the shallowest eastern most part of the TTZ to extract vapors from the vadose zone.
- Combined pressure and water level monitoring points will be installed throughout the wellfield to monitor and document pneumatic and hydraulic control.
- Temperature sensors will be installed throughout the wellfield to monitor heating.
- A non-permeable vapor cap to cover the TTZ, limit precipitation infiltration, assist in the capture of the contaminant vapors and help to 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 by dual thermal oxidizers (TO) 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 DNAPL from water, if present. LNAPL and DNAPL, if present, will be collected in drums and the effluent water will be conveyed to an air stripper for treatment followed by a liquid



phase carbon absorber for final polish prior to discharge to the Publically 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 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 [COC] loads) and provides a means to heat the site 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°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 kWh of electrical power will be delivered to the heater wells.

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 Volatile Organic Compound (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.

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



1.0 INTRODUCTION

TerraTherm, Inc. has been contracted by the SRSNE Site Group to design, install and operate a thermal conduction heating based In-Situ Thermal Remediation (ISTR) system within the Overburden NAPL Area at the SRSNE Site in Southington, Connecticut. The work will be performed pursuant to a Remedial Design/Remedial Action (RD/RA) Consent Decree (CD) and Statement of Work (SOW) that has been negotiated with the United States Environmental Protection Agency (EPA) Region I and the Connecticut Department of Environmental Protection (CTDEP) by the SRSNE Site Group, an unincorporated association of Settling Defendants to the CD and SOW for the RD/RA activities at the Site.

1.1 **Project Delivery Status**

This document, known as the Conceptual Design/Remedial Action Work Plan (CD/RA WP), combines the conceptual design for the thermal treatment system and the Remedial Action Work Plan as required in the RD/RA SOW. It is intended for this submittal presenting the thermal design system to be reviewed by the US EPA and the Connecticut Department of Environmental Protection (CTDEP). Comments on the CD/RA WP will be addressed in a Response to Comments memorandum and those responses will be included in the final thermal design work plan submittal.

This CD/RA WP addresses all of 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;
- Refinement of the TTZ based on the July 2009 Dense Non Aqueous Phase Liquid (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

1.2 Requirements of the SOW

The SOW requires that the Conceptual Design and Remedial Action work plans address the following:

- Results of pre-design activities
- Basis of design/assumptions
- Plans, drawings, sketches, calculations and technical specifications, as needed
- Project delivery status
- Draft statement of regulatory compliance
- Draft construction environmental monitoring plan
- Independent Quality Assurance Team (IQAT) Work Plan (submitted by *de maximis, inc*. under separate cover)



- Sampling program to determine if Overburden NAPL Cleanup Levels have been met
- Award of project contracts, including off-site treatment and/of 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 Remedial Design Work Plans (RDWP) to evaluate and further define unknown conditions at the Site:

- Materials Compatibility Test(s)
- Analysis of NAPL samples collected from the thermal treatment area
- Thermal Simulation Model
- 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 4.

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 Project Operations Plan (POP) specific to the construction and operation of the thermal treatment system. The ISTR POP and supporting sections are addendums to the site-wide RD POP. The ISTR POP can be found in Section 5 and includes the following:

- ISTR Specific Site Management Plan
- Schedule for implementation and reporting
- Modifications to the Sampling and Analysis Plan including the Quality Assurance Project Plan and Field Sampling Plan previously prepared by ARCADIS as part of the PIPP (Standard Operating Procedures – Appendix C)
- Site Specific Health and Safety Plan (Appendix D)

A POP was also prepared by ARCADIS for the Pre-ISTR Preparation Plan (PIPP), which pertains to the overall fieldwork including but not limited to site grading, relocation of utilities, abandonment of down gradient monitoring wells, etc. Where applicable, the ISTR POP builds on and references the PIPP POP.

1.3 Document Format

This CD/RA WP is divided into the following sections:

- 1. Introduction Includes a discussion on the project delivery strategy.
- 2. **Project Objectives** Defines the cleanup goals for the overburden NAPL zone.
- 3. **Thermal Technology Background** Provides an overview of thermal conduction heating.
- 4. **Design Basis and Results of Pre-Design Studies -** Discusses the results of the predesign studies and development of the basis for the design of the ISTR system.



- 5. **ISTR 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; modifications to project SAP, and the HASP.
- 6. **Construction Environmental Monitoring Plan** describes the monitoring that will be conducted during drilling and construction of the ISTR system.
- 7. **ISTR System Design and Construction** Provides a detailed discussion of the design and implementation of the thermal remedy.
- 8. **Regulatory Compliance** Summarizes how the design of the ISTR system addresses the ARARs relevant to the overburden NAPL zone.
- 9. **Thermal Remediation Operations** Discusses the sequence for construction, operation, shut down, and demobilization.
- 10. **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 at this point in the design process. These appendices will be completed and included in the Final Design/Remedial Action Work Plan following completion of the design.

- Appendix A presents an example Table of Contents for the Operation and Maintenance (O&M) Manual which will be provided with the Final Design submittal.
- 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 includes the Standard Operating Procedures.
- Appendix D is the Site-specific Health & Safety Plan for ISTR.
- Appendix E contains the design drawings (22x34 sized submitted under separate cover).
- Appendix F provides the equipment specification sheets.
- Appendix G contains the results of the heat dissipation evaluation results.



2.0 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 Remedial Action Objectives (RAOs) for the Site established in the Record of Decision (ROD); as well as to meet the performance standards (cleanup levels) for the Overburden NAPL Area as described below.

2.1 Remedial Action Objectives

Human Health

- 1. Reduce or stabilize the NAPL mass that would otherwise result in groundwater concentrations that pose an excess carcinogenic risk of 1 x 10⁻⁴ to 1 x 10⁻⁶, non-carcinogenic
- 2. Hazard Index greater than 1, a cumulative risk from multiple contaminants exceeding a lifetime cancer risk of 1 x 10⁻⁵, or that exceed applicable or relevant and appropriate requirements (ARARs).

Protection of the Environment

- 1. Shorten the timeframe 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.

2.2 Performance Standards

Section IV.1 of the SOW establishes Interim Cleanup Levels for groundwater contamination. 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 groundwater plume, except for under the cap that will be installed subsequent to ISTR. The thermal treatment zone will be completely within the footprint of the cap.

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

Trichloroethene	222 mg/Kg
Tetrachloroethene	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 thermal treatment zone. At the time that all the Interim NAPL Cleanup Levels are attained, EPA will evaluate whether to continue to operate the ISTR system in areas where EPA determines that appreciable recovery of NAPL continues to occur. The maximum amount of time that EPA may



require continued operation in any area shall not exceed the amount of time necessary to achieve the Interim NAPL Cleanup Standards.

2.3 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's closure 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 the 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 down gradient of 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 Feasibility Study (FS) were completed between 1996 and 2004, and the 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, April 2009).

2.4 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 Remedial Investigation, 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, April 2009).

2.5 Target Treatment Zone

The Overburden NAPL Delineation Plan (Attachment A to the RDWP) 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 northwest portion of the Overburden NAPL Area. During activities completed in support of the Feasibility Study 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 northwest 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 results of the overburden NAPL delineation activities described above were provided for Agency review I in the Overburden NAPL Investigation Delineation Summary Memorandum (ARCADIS, November 2009), and approved by USEPA on December 16, 2009. The revised interpretation of the extent of NAPL in the overburden is shown on Figure 2.1. 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 24 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). The TTZ is shown below in Figure 2.1.

Conceptual Design/Remedial Action Work Plan In Situ Thermal Remediation at Solvents Recovery Service of New England April 2010 Page 14











3.0 THERMAL TECHNOLOGY BACKGROUND

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

Figure 3.1 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 3.1. 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, steam injection wells, 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 for housing 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, fluids are extracted, cooled, separated, and treated. The subsurface process is monitored using temperature and pressure sensors and detailed sampling and analysis of subsurface fluids.



3.1 In Situ Thermal Desorption Background

TCH, also known as ISTR, is a field-proven remediation technology licensed by TerraTherm that has been successfully used to remediate the full range of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs)¹ at over 30 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 TCH².

- 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 1000-1500°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.
- 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 vapor extraction wells from the process system will draw the vapors through the soils and into the off-gas piping network for subsequent treatment.

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 3.2.

¹ Stegemeier, G.L., and Vinegar, H.J. 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.





Figure 3.2. 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 3.3 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 3.3. Example ISTR Wellfield (not specific to actual site)



3.2 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 elements³, 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.

³ Baker, R.S. and M. Kuhlman. "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, 2002.

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.



4.0 DESIGN BASIS AND RESULTS OF PRE-DESIGN STUDIES

4.1 Introduction

In accordance with the SOW, an RDWP was prepared and submitted to the USEPA. The RDWP included 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.

4.2 System Design Evaluation

The System Design Evaluation Work Plan (Attachment E of RDWP) 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 above ground piping.

4.2.1 Numerical Simulation Model

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 that uses nine distinct layers, each with different model inputs. A detailed description of the thermal model simulations is included in Attachment A.

This section summarizes the model setup, equations, and principles. The Site is divided into layers as shown in Figure 4.1. 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 4.1. Model Setup with Individual Layers. Note that the average treatment depths are used.

Table 4.1 below shows the parameters used for each of the model layers.



Layer	Geology	Top [ft]	Bottom [ft]	Thickness [ft]	Porosity [-]	Initial saturatio n [-]	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

Table 4.1.	Input Parameters for the Numerical Model

A phased heating approach will be used in order to spread out the VOC loading on the vapor treatment system. Specifically, 50% of the wellfield will be operated for the first 60 days; the other 50% of the wells will be turned on at day 60. This sequence is shown in Figure 4.2.





Figure 4.2. Phased Operation. Each phase represents 50% of the area and heater borings.

Under this approach, each phase will be operated for 135 days, with a total operating period of 195 days.

4.2.2 Discussion of Simulation Results for the Base Case Scenario

4.2.2.1 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 4.2. Sizes and Propertie	s of the Thermal Treatment Zone
--------------------------------	---------------------------------

	Value	Unit
Treatment zone footprint	74,195	ft ²
Depth of remediation	15, 18 or 24 (varies)	ft bgs
Treatment zone volume	47,298	су

Note: ft^2 – square feet ft bgs – feet below ground surface

cy – cubic yards

Table 4.3 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

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 1,000 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.

Volume and Heat Capacity	Value	Unit
Volume, Thermal Treatment Zone	47,298	су
Solids volume	34,200	су
Pore volume	12,900	су
Soil weight	152,786,000	lbs soil
Water weight	18,396,000	lbs 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 towards 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
Note:		

Table 4.3. Heat Capacity and Energy Calculations

Note: cy – cubic yards lbs – pounds BTU – British thermal unit F - Fahrenheit kW – kilowatt

Due to the unknown COC mass present at the Site, the wellfield will be divided into phases (Figure C105). 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. Total operating duration is estimated at 195 days. This will allow for a phased startup of the heaters and treatment of a mass of up to 1 million pounds of COCs. Additionally, phasing the operation 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 4.4 contains the estimated power usage for the ISTR heating system.



Table 4.4. 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 for thermal remediation of the SRSNE site.

4.2.2.2 Subsurface Temperature Progression

Figure 4.3 shows the predicted vertical temperature distribution in the thermal treatment zone 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 thermal treatment zone, which typically correspond to the midpoints between the heater wells, also called "centroid locations."





Figure 4.3. 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 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 treatment and polishing after reaching the boiling point.

Figure 4.3 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.

4.2.2.3 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.

Days 125-135: Extraction and maintenance of pneumatic control, with some initial cooldown.

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

4.2.2.4 Estimated Effluent 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, Table 4.5 and 4.6 present design parameters and effluent discharge estimates resulting from the numerical model calculations.

 Table 4.5.
 Process Equipment

Process Equipment	Estimate Based on Model	Units
ISTR power supply, max	4,052	kW
Vapor extraction rate, max total	5,400	scfm
Non-condensable vapor, max	1,300	scfm
Condensed liquid rate, max	11	gpm

Notes:

kW - kilowatt

scfm - standard cubic feet per minute

gpm – gallons per minute

Based on the calculated values, the vapor treatment system is designed to treat up to 5,400 scfm of vapor from the wellfield. In addition, the air stripper discharge will be treated. More detail is provided in Section 7.

Table 4.6.	Water	and	Vapor	Discharge
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		Water Discharge		Vapor Discharge	
	Days	Average Rate (gpm)	Total Volume (gallons)	Rate (scfm)	Total Volume (million CF)
Period 1	30	4.2	181,000	650	28
Period 2	30	5.4	233,000	650	28
Period 3	30	9.6	414,000	1,300	56
Period 4	30	10.9	470,000	1,300	56
Period 5	30	7.5	323,000	1,300	56
Period 6	45	5.0	323,000	1,300	84
Total	195		1,944,000		309

Notes:

gpm – gallons per minute

scfm – standard cubic feet per minute

CF - cubic feet

Over the course of the thermal treatment, an estimated 1.9 million gallons of liquid and approximately 309 million cubic feet of vapor will be treated and discharged.



4.2.2.5 Sensitivity Analysis

Appendix B contains a sensitivity analysis performed, using the described scenario as the base case. The 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 5-6 ft of the heaters in order 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 0.15 W/(mK) (1.04 BTU-in/hr ft²-F) and a thickness of 12 inches is satisfactory. Different vapor cap designs with the same insulating capacity are acceptable.

These results have been incorporated into the design.

4.2.3 Materials Compatibility Test(s)

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 tests are included as 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 carbon steel having 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 one year and the material thicknesses the 3-inch diameter Schedule 40 C.S. pipe used for the heaters will be 0.22 inches (220 thousandths of an 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.

4.2.4 Analysis of Non Aqueous Phase Liquid (NAPL)

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 ppm (32% by mass) and the presence of large quantities of non-chlorinated petroleum hydrocarbons including 1t,2-dimethylcyclopentane (11 Vol %), methylcyclohexane (1.1 Vol %), n-nonane (1.2 Vol %), 1-3 ethylmethylbenzene (1.4 Vol %), 1,3,5-trimethylbenzene (0.9 Vol %). These petroleum hydrocarbons were not reported in the



previous volatile organic compound analysis. These data results suggest a higher heat load to the oxidizer and a lower salt production due to the lower chlorine content.

4.3 Vapor Treatment Needs Evaluation

Attachment D of the RDWP describes 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 (Attachment A) and are summarized below.

The design basis for the off-gas treatment system is 1,000,000 lbs of COC mass, but the system has the flexibility to treat the COC mass range estimated in the Feasibility Study (i.e., 500,000 to 2,000,000 lbs) in the most efficient way. The RDWP original concept for the Site intended to utilize Regenerative Thermal Oxidizers (RTOs) to treat extracted vapors. Instead, non-regenerative thermal oxidizers 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 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. If required to handle unexpectedly high COC mass loading, additional cooling can be added to the system to further cool the influent vapors. This additional cooling (which is not part of the planned system) would have the ability to condense a portion of the NAPL and thereby reduce the fuel loading to the oxidizer. If necessary, these adjustments will be made following startup.

4.4 Thermal Treatment Monitoring

The Thermal Treatment Monitoring Work Plan (Attachment B of the RDWP) was prepared to describe the scope and approach for monitoring air quality within and around the perimeter of the In-Situ Thermal Remediation (ISTR) treatment area during implementation of the thermal treatment to minimize potential impacts to onsite workers and the community.

4.5 Thermal Treatment Performance Criteria

The Thermal Treatment Performance Criteria Work Plan (Attachment C of the RDWP) 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 discharges from the system.

The results of this Work Plan are incorporated in Section 10 of this CD/RA WP.



4.6 NAPL Delineation

The NAPL Delineation Work Plan, Attachment A of the RDWP, was prepared to further delineate the extent of NAPL along the northwestern border of the Site. The results of this work provide the basis for the final delineation of the TTZ as presented in Figure 2.1.



5.0 PROJECT OPERATIONS PLAN

5.1 Site Management Plan

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

5.1.1 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. Signage will be posted to identify the work area and specify access only for authorized personnel. Signage may include yellow construction site tape and signs stating "Authorized Personnel Only", "High Voltage", or similar.

5.1.2 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). The road will be relocated around the wellfield as described in the PIPP to allow for vehicle access to the wellfield during construction and operation.

5.1.3 Utilities

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

5.1.4 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 or in the wellfield itself. Tools, safety equipment, and office equipment will be kept in the job trailer that will also be located east of the wellfield.

5.1.5 Field Oversight/Construction Management

During all phases of the drilling, construction and operation, TerraTherm staff will be onsite to coordinate efforts. During system operation, the TerraTherm operator will be within 30 minutes of the site, in the event it is necessary to respond after hours.

5.1.6 Independent Quality Assurance Team (IQAT)

All phases of drilling, construction and 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, inc.** The IQAT will report results of all inspections independently to



USEPA and CTDEP. As mentioned in Section 1.2, an IQAT Work Plan is being submitted to USEPA and CTDEP under separate cover.

5.2 Subcontracts

It is anticipated that four subcontractors will perform work at the Site: 1) driller(s) for well installations, 2) contractor for cover installation; 3) an electrician; and 4) facility(ies) for off-site disposal of remediation derived wastes, including drill cuttings, spent carbon, NAPL, etc. 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.

5.3 Schedule and Reporting

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

Mobilization	March 2011		
Field Construction	March – August 2011		
Thermal Treatment Operations	August – January 2012		
Decommissioning/Demobilization	February – March 2012		
Final Reporting	February – March 2012		

Data reporting schedules are discussed in Section 10.0.

5.4 Mobilization, Site Preparation and Utility Hook-Ups

Mobilization, site preparation and utility hook-ups including electric, gas, water, sanitary sewer and telecommunications will be provided for the thermal treatment equipment in accordance with the PIPP Design Report prepared by ARCADIS.

5.5 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 7.0. Operations of the thermal treatment system are described in Section 9.0.

5.6 Modifications to Project Sampling and Analysis Plan

A site-wide Sampling and Analysis Plan (SAP) was prepared to ensure that sampling activities are performed in a safe and efficient manner, as well as meet the data objectives for the Site. The site-wide SAP has been amended with the inclusion of the follow Standard Operating Procedures (SOPs) specific to sampling during thermal operations. The SOPs included are:

- Air Monitoring
- Emissions Sampling
- Calibrating the YSI
- Hot Groundwater Sampling
- Hot Soil Sampling

These SOPs can found in Appendix C.



5.7 Health and Safety Plan

A site-wide Health and Safety Plan (HASP) has been developed to ensure that onsite workers and nearby workers or visitors are protected. TerraTherm has developed a site-specific HASP (Appendix D) 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 (AHA's) 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.



6.0 CONSTRUCTION ENVIRONMENTAL MONITORING PLAN

During drilling and installation of the heater wells, vapor extraction wells, and sensors, real-time VOC and particulate air monitoring will be performed at representative perimeter locations as described by ARCADIS in the RAWP for the PIPP, to assess the potential for dust or VOC concentrations to exceed action levels protective of surrounding populations, and to trigger control measures if action levels are exceeded.

Ambient air monitoring will be conducted hourly, or when odors are observed, with a hand-held PID to monitor the breathing zone of field personnel.



7.0 ISTR SYSTEM DESIGN AND CONSTRUCTION

7.1 Wellfield

7.1.1 Wellfield Layout

The TCH heater wells are laid out on a triangular grid pattern with a spacing of approximately 14 feet. 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 will be placed over the ground surface and horizontal VEWs will be installed. Combined temperature/pressure and groundwater level monitoring wells are distributed evenly throughout the wellfield. The proposed layout of the operational wells is presented in drawings C104 in Appendix E.

The total number of wells for the thermal treatment zone is as follows:

- 593 heater wells (based on a spacing of 14 feet),
- 550 vertical vapor extraction wells across the unsaturated zone,
- 260 linear feet of horizontal vapor extraction wells,
- 50 boreholes for temperature monitoring, and
- 25 combined temperature/pressure and groundwater level.

7.1.2 Wellfield Design

Figure 7.1 shows a conceptual cross-section with operational wells, including the heater and vapor extraction wells. The different types of wells that will be installed include:

- Heater wells to supply heat by thermal conduction from the ground surface to a depth of 15 ft bgs, 18 ft bgs, or 24 ft bgs, dependent on their location.
- Vertical vapor extraction wells 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 at the time of placement of the fill.
- Combined 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. Twenty-five combined wells will be installed evenly throughout the wellfield. Five additional combined monitoring points will be installed downgradient along the eastern edge of the TTZ.
- Temperature sensors within the TTZ will be installed per the following:
 - o 60% will be at centroids
 - o 20% will be approximately 3 ft from a heater well
 - o 20% will be approximately 1 ft from a heater well





Figure 7.1. Conceptual Cross Section

The treatment zone area has been divided into three zones of similar overburden thickness and a custom length/depth has been set for the wells in each zone (Figure 7.1). Table 7.1 summarizes the drilling and heating depths for each zone.
	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

Table 7.1. Summar	y of Drilling and Heated Depths
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These depths will, on average, result in the bottom of the heater casing extending approximately 3-4 ft into the top of bedrock. The vapor collector 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 each of these wells is 8 ft and 2-8 ft, respectively

As indicated in Table 7.1, thermal remediation will extend from ground surface to a depth between 12 and 21 ft bgs (varies across the site). Heating will extend to depths of between 15 and 24 ft bgs across the site. The thermal conduction heaters will be boosted from 10-15 ft bgs, 12-18 ft bgs, and 18-24 ft bgs, to provide additional energy input into the lower 5-6 feet of the heated zone. 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 ensuring that the potential for vertical mobilization of DNAPL is minimized.

7.1.3 Construction Details

Drawings C106 through C109 included with the Design Drawings in Appendix E, provide construction details for TCH and vapor extraction wells; and temperature and pressure monitoring points. Figures 7.2 and 7.3 below provide construction schematics for the TCH heaters and combined vapor extraction points, temperature monitoring points, and pressure/water level monitoring wells.

Conceptual Design/Remedial Action Work Plan In Situ Thermal Remediation at Solvents Recovery Service of New England April 2010 Page 37





Figure 7.2. Well Construction Detail for TCH Well and Combined Vapor Extraction Well for Average Site Conditions



Figure 7.3. Well Construction Detail for Temperature (50 total) and Pressure Monitoring Points (25 total)



The temperature monitoring points will consist of 1.5-inch threaded carbon steel pipe with an end cap, extending to a depth of on average 18 ft (i.e., top of bedrock). Efforts will be made during drilling and temperature monitoring point installation to determine the depth of bedrock below the ground surface to minimize drilling into the bedrock. See Section 6.5.

The combined 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 8 ft and 2-8 ft, respectively. These wells will be installed using the same methods as used for installing the vapor extraction wells 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 3-4 ft (see Section 7.1.5).

Each heater well will have a vapor extraction well. The vapor extraction wells 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 2-8 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 vapor extraction wells, the eastern most section of the Zone C will have horizontal vapor extraction wells, rather than vertical vapor extraction wells. 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 1-2 feet of clean fill.

Table 7.2 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.



Well Type	Depth (ft bgs)	Number of Locations	Well Casing/ Pipe Specifications	Screen Interval (if present)	Borehole & Sandpack Specs
Heater-Only Wells	15, 18, 24	593	3" Sch. 40 carbon steel (CS) Pipe (welded joints)	N/A	Min. 4" Bore; 20-40 Sand; High Temp Grout 0-2'bgs
Vapor Extraction Wells	Same	550	3" Pipe w/ 3" screen	Fully screened	Sawcut trenches backfilled with native sand and sealed with concrete
Horizontal Vapor Extraction Wells	G.S.	Approximately 260 linear ft	3" Pipe w/ 3" screen	Fully screened	Pipe will be installed prior to the additional of clean fill by ARCADIS
Temperature Monitoring Points	15	50	1.5" CS pipe	N/A	Min. 3" bore; Grout full length
Pressure/Water Level Monitoring Points	8	25	2" CS pipe w/ 2" SS screen 10 slot	N/A	Min. 4" Bore; 20-40 Sand at Screen; Grout Above Screen

Table 7.2	Well	Construction	Details
		Construction	Detano

Drill cuttings generated during the installation of the wells will be either incorporated into the TTZ beneath the insulated cover for treatment or transferred to appropriate containers, analyzed, and disposed of off-Site at a permitted disposal facility.

7.1.4 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, 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" 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.

Sonic drilling will provide significant protection against unintended NAPL migration during drilling and well installation:

The sonic method results in a tight seal between the outside of the drill casing and the borehole wall, unlike Hollow-Stem Augers (HSA), which actively mixes soil along the entire length of the borehole and does 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.

Furthermore 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.

7.1.5 Installation of Borings/Wells

Figures 7.4a through 7.4c below provide a summary of the drilling and well installation methods for the heater wells.

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" core barrel (4.5" OD, 3.75" ID) and a 6" outer casing (5.5" OD, 4.75 ID). The core barrel fits snugly within the outer casing with ~1/8" 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.

The well installation procedures and designs selected for the SRSNE Site have been carefully developed to minimize the potential for NAPL to migrate during installation and construction to the extent practicable. The following summarizes the approach for installing the TCH heater wells:

- Advancement of core barrel 5-10' (depending on the depth of bedrock) using sonic means.
- Advancement of outer casing 5-10' (depending on the depth of bedrock) using sonic means such that the bottom of core barrel and outer casing are at same depth.
- The core barrel will be retrieved and emptied into a covered roll-off.
- The emptied core barrel will be placed back down the inside of the outer casing and advanced until rig pressure readings indicate that the top of bedrock has been reached or the anticipated bedrock depth has been reached if the rig pressure is found to be an ineffective indicator of the top of bedrock. In some areas the depth to the top of bedrock is expected to be as shallow as 5 ft bgs, while in others, the depth to bedrock could be as much as 22 ft. The average depth to bedrock is expected to be approximately 18 ft.
- The rig response will be calibrated by first drilling borings adjacent to previous Geoprobe locations outside or on the edge of the treatment zone and comparing the downhole pressures with physical observations of the lithology in the sonic cores and historic Geoprobe refusal data. Specifically, the ability of the rig to sense when the bedrock has been reached based on changes in rig pressure will be assessed.



- Upon reaching the top of bedrock with the core barrel, the outer casing will be advanced to the top of bedrock and the core barrel will be removed from the casing. Bentonite will then be added to the inside of the casing and allowed to settle to the bottom.
- The outer casing will then be retracted and lowered a few inches several times in quick succession to ensure a good seal between the shoe of the outer casing and the top of the bedrock.
- The core barrel will then be advanced approximately 3-4 ft into the rock, to the predetermined design depth (e.g., an estimated average of 21 ft) and retrieved.
- The contents of this core run will be extracted into a clear plastic bag and examined for confirmation of bedrock and evidence of DNAPL.
- A tape measure will be lowered to the bottom of the core hole to determine if there was any collapse of the bedrock socket.
- If there was no collapse, a bottom loading clear PVC bailer will be lowered to the bottom of the core hole and "bounced" several times on the bottom of the borehole in an attempt to retrieve any DNAPL that may be present. The bailer will be inspected at the surface for evidence of DNAPL.
- If DNAPL is observed upon removal of the bailer, an effort will be made to remove DNAPL from the boring using a bailer and/or pump. Contents of the bailer and/or the pump will be emptied into a 55-gal drum placed on a secondary containment palate capable of holding 110% of the drum volume.
- If no DNAPL is observed upon removal of the bailer or DNAPL is no longer recoverable, grout will be tremied into the bedrock core hole and the lower portion of the casing and a heater well casing will be immediately installed.
- The outer casing will then be pulled while grout is added and resonant energy is applied to the outer casing. This will increase the density of the grout and knit it into the borehole wall making a good seal between the heater can and the soil.
- If there is collapse within the bedrock core hole, an attempt will be made to clear the collapsed material by advancing the core barrel again and/or using a sand bailer.
- Once the material is cleared from the core hole, the bottom of the hole will be checked for DNAPL and DNAPL removal and/or well installation will proceed as described above.



- If the material cannot be cleared using the core barrel, sand bailer, or other means, then the outer casing will be advanced to the desired depth and the hole will be cleared of debris and checked for DNAPL.
- DNAPL removal and/or well installation will then proceed as described above.
- The drill casing and core barrel will be visually inspected in between boreholes. If gross contamination/DNAPL is observed, the casing/core barrel will be decontaminated prior to drilling of the next borehole.



Figure 7.4a. Drilling Approach

Conceptual Design/Remedial Action Work Plan In Situ Thermal Remediation at Solvents Recovery Service of New England April 2010 Page 43





Figure 7.4b. Setting of Thermal Well and Initial Grouting Process



Figure 7.4c. Thermal Well Grouting and Completion

The temperature monitoring points and the combined vacuum/pressure and water level monitoring points will be installed using the same methods as proposed for the heater wells;



however, the diameter of the cased hole for the temperature monitoring points will be smaller (3-4 inches).

The vapor extraction wells will also be installed using sonic drilling methods; however, the vapor extraction wells will be installed to a total depth of approximately 8 ft and 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 summary, none of the 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 which are grouted in place within a few minutes of drilling. The soil vapor extraction screens and the combined vacuum/pressure and water level monitoring screens will be installed to a depth of 12 ft, and not penetrate a significant distance into the saturated zone. 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 that was presented in the RDWP (Attachment F of the RDWP).

7.1.6 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.

7.2 Surface Cover

A surface cover will be installed over the treatment area, extending approximately 8 to 10 ft outside in all directions. An insulating cover will be used to minimize surface heat losses, prevent precipitation infiltration into the TTZ and prevent uncontrolled vapor/steam emissions from the treatment zone. The insulating surface cover will be placed on top of the existing asphalt or new fill following installation of the ISTR wellfield, sealing the thermal wells in place.

The surface cover will consist of approximately 12" lightweight air-entrained insulating concrete (minimum R = 0.15 W'mK) to minimize water infiltration, provide a vapor seal, and minimize heat losses. The steep slopes of the terraces will be covered separately using a composite approach consisting of a layer of shotcrete sprayed on the sloped surface, followed by several layers of insulation board and a top layer of shotcrete. The total R-value of the slope cover will equivalent to the R-value of the general surface cover.

The surface cover may be left in place or it can be easily removed with standard earthwork construction equipment at the end of the project. The lightweight concrete material will be crushed and re-used as on-site aggregate or placed in a dumpster for off-site disposal/recycling. Typically, the surface cover material is disposed of as normal construction debris.



7.3 Vapor Treatment System

7.3.1 Process Design

A Process Flow Diagram (PFD, Drawing P101 in Appendix E), including a material Mass and Energy (M&E) balance, has been developed based on the system design. The vapor M&E balances can be found on Sheet 2 of Drawing P101.

7.3.2 Piping, Mechanical and Electrical Installations

A Piping and Instrumentation Diagram (P&ID) has been developed and is included as Drawing P102 (2 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.

7.3.3 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 a main header trunk line with branches extending to the individual extraction wells. Because the vapor conveyance piping between the wellfield and the treatment equipment operates under vacuum, any leakage should be inward into the pipe, minimizing the potential for fugitive emissions.

The conveyance piping will be sloped to prevent condensate from accumulating in the lines. If necessary, condensate collection drains will be located at low points along the manifold. Condensate will be pumped from the drains/collection sumps to the separator for subsequent treatment prior to discharge.

7.3.4 Electrical Installation

The electrical installation consists of three major components: the service drop and transformer/distribution equipment feeds; the wellfield electrical installation; and the process equipment and instrumentation wiring. All of these activities will be performed in accordance with the Site-specific Health and Safety Plan (HASP) and NFPA 70 (National Electrical Code) 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 Connecticut Light & Power to select appropriately sized transformers for the power distribution system. It is anticipated that two step-down transformers will be used to reduce the utility company line voltage from 23kV nominal to 13.8 kV then from 13.8kV to 480V, 3-phase, 4 wire system for subsequent distribution throughout the site from TerraTherm's main switchboards.

TerraTherm's electrical contractor will be responsible for wiring from the secondary side of the 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 National Electrical Code. 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 Stop 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 Single 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.

Silicon Controlled Rectifiers (SCRs) will regulate the power delivered to the TCH heaters. The SCRs can operate in either manual (% output) or automatic (temperature/power) control modes to provide optimal heating of the TTZ. The SCR cabinets will be outfitted with fuses and an onboard temperature controller to monitor the power to each heater circuit and the temperature of the controlling thermocouples.

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 2 provides a basic electrical schematic for the process equipment that will be backed up by the generator. Emergency shut-down (ESD) switches will be provided at several locations around the wellfield to shut down power to the entire Site, including the treatment system and heater wells, immediately in the event of a system emergency. ESD switches will be interlocked with the generator to prevent the generator from starting if an ESD is activated.



7.3.5 Process Components

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

- Heat exchanger
- Cooling tower(s)
- Moisture separator
- Vacuum blower
- Heat exchanger
- Chiller
- Moisture separator
- Duct heater
- Combustion blower
- Thermal oxidizer(s)
- Scrubber

A summary description of each major component is presented in the following paragraphs. Calculation sheets used to size major equipment are provided in on sheet 2 of the PFD. Typical equipment specification sheets are included as Appendix F.

7.3.5.1 Heat Exchanger

The vapors from the wellfield are initially processed in multiple a pair of heat exchangers to knock down 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 supplied water. The cooling tower loop circulation rate is adjusted to only reduce the temperature of the vapor stream to the point required to remove moisture from the wellfield vapors, with minimal or no COC removal/condensation. Both the vapor and liquid side of the heat exchangers are instrumented with temperature indicators to allow adjustment of the recirculation loop flow to maintain proper moisture removal. Design specifications for the heat exchanger are summarized as follows:

Incoming air flow	1300 scfm
Incoming steam flow	2381 scfm
Cooling need	2.42MM Btu/hr
Surface area	700 ft ²
Material of construction	graphite



7.3.5.2 Cooling Tower

The cooling tower supplies a cooled liquid stream to the heat exchanger. In general, the temperature of the cooled liquid will rise about ten degrees Fahrenheit as it passes through the heat exchanger. The returning liquid is delivered to the top of the cooling tower where it is cooled by evaporation and 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:

Nominal Capacity	200 tons
Cooling Water Discharge temperature	100 F
Cooling Water Return Temperature	110 F
Recycle flow rate	500 gpm

7.3.5.3 Moisture Separator

After exiting the heat exchangers, the cooled vapor stream will be drawn through a moisture separator to remove condensate and entrained liquid droplets. Water collected in the moisture separator will be pumped to the oil/water separator for treatment prior to discharge.

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. The moisture separator includes a demister pad to prevent moisture carryover in the vapor exhaust. A manway is located on top of the moisture separator for inspection and cleaning of the vessel, and servicing the demister pad.

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. Design specifications for the moisture separator are summarized as follows:

Vapor flow	3587 acfm
Liquid flow, inlet	4 gpm
Material of construction	FRP
Pressure rating	10 psig
Exhaust port	10" diameter



7.3.5.4 Vacuum Blowers

Positive displacement or induced draft vacuum blowers are used to create the vacuum in the wellfield and to create a high enough pressure to complete the remaining process steps. The vacuum blowers cause the vapor phase temperature to increase as a result of raising the pressure level. Design specifications for the vacuum blowers are summarized as follows:

Inlet temperature	175 F
Inlet pressure	0.94 atm
Inlet flow	2807 scfm
Outlet temperature	205 F
Outlet pressure	1.05 atm

7.3.5.5 Heat Exchanger

The vapors from the vacuum blowers are cooled in a second heat exchanger. The goal of this cooling step is to reduce the dewpoint of the vapor stream so that the vapor exhaust stream from the air stripper and any additional dilution air produces a combined stream with a dewpoint that will not condense prior to the oxidizer. Design specifications for the second heat exchanger are summarized as follows:

Incoming air flow	1300 scfm
Incoming steam flow	1409 scfm
Cooling need	3.48 MM Btu/hr
Surface area	650 ft ²
Material of construction	graphite

7.3.5.6 Chiller

A chiller is used to supply the cooling liquid for the second heat exchanger. The chiller is refrigeration-based as opposed to the evaporative cooling tower used for the first heat exchanger. The refrigeration allows for a lower temperature cooling liquid and therefore a higher driving force temperature differential between the cooling liquid and the hot vapors. This greater driving force reduces the area requirement of the heat exchanger. Design specifications for the chiller are summarized as follows:

Nominal Capacity	300 tons
Cooling Fluid Discharge temperature	40 F
Cooling Fluid Return Temperature	50 F
Recycle flow rate	700 gpm

7.3.5.7 Moisture Separator

After exiting the second heat exchanger, the cooled vapor stream will be drawn through a moisture separator to remove condensate and entrained liquid droplets. Water collected in the moisture separator pot will be pumped to the oil/water separator for treatment prior to discharge. The moisture separator is constructed and instrumented in a similar manner to the previously described moisture separator vessel.

7.3.5.8 Duct Heater



Exiting the second moisture separator, the combined vapor stream will be heated approximately 14 to 20°C (25 to 35°F), to adjust the temperature above the dew point of the stream by approximately 19°C (35°F) and minimize condensate formation in the 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 vacuum, it may generate sufficient heat that the duct heater may not need to operate. Design specifications for the duct heater are summarized as follows:

Vapor flow	2088 scfm
Pressure rating	15 psig
Heating rate	30 kW
Material of construction	Inconel 600

7.3.5.9 Combustion Blower

Supplemental combustion/dilution air may be needed in the oxidizer. The combustion air performs two functions, ensuring that the LEL is below 25% and providing enough total air flow so that the evaporation in the quench can sufficiently reduce the oxidizer outlet gas temperature. The combustion blower needs to be able to produce a discharge pressure equal to or greater than the vacuum blowers in order to ensure that the combustion/dilution air can overcome the existing system pressure.

Inlet temperature	80 F
Inlet pressure	1.0 atm
Inlet flow	205 scfm
Outlet temperature	95 F
Outlet pressure	1.05 atm

7.3.5.10 Thermal Oxidizers

The thermal oxidizers are the primary component of the proposed vapor treatment system. Dual thermal oxidizers are proposed for use at this Site. The proposed thermal oxidizers are nominal 1100 SCFM oxidizers, with a rated hydrocarbon Destruction/Removal Efficiency (DRE) greater than 99%. The oxidizer is designed to automatically maintain a specific temperature profile within the thermal reaction zone (the oxidation chamber), typically in the range of 800°C (1,500°F), which is above the auto-ignition point for natural gas.

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 HCI. The concentration of the HCI produced depends on the concentration of the chlorinated COCs in the vapors entering the unit.

Heating and treatment processing will occur in two segments. There is expected to be some overlap between the segments. Initially, only one oxidizer will be used until the fuel loading exceeds the single oxidizer capacity of about 2.5 MM Btu/Hr. This is expected to occur about 40 days into the project. The second oxidizer will then be brought on line, providing a total capacity of up to 5MM Btu/Hr. Both units are expected to continue operating concurrently until the fuel loading drops below 2.5 MM Btu/hr. This final transition is expected to occur about 150



days into the project. At this point, one of the oxidizers will be shut down and the other will continue to run for the remainder of the operation period.



Design specifications for the thermal oxidizers are summarized as follows:

Total vapor flow	2200 scfm
Pressure rating	20"wc
Required DRE	99%
Material of construction	AL6XN
Natural gas firing rate, peak each	2.5 MM Btu/hr
Chamber temperature	1500 F

7.3.5.11 Scrubber

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 will flow upward through polypropylene 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 surfaces of the packing media provide 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 (CaCl₂), potassium chloride (KCl), etc.] that precipitate out as products of the neutralization reaction.

The pH of the scrubbing water will be automatically adjusted using a 50% sodium hydroxide solution (NaOH) 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 the pH in the scrubber sump between 5.5 and 9.0 pH units. If it is necessary to operate in cool weather (below approximately 55°F), the 50% NaOH caustic solution may be replaced with either a 25% NaOH solution or a blended sodium/potassium hydroxide solution to avoid the freezing point issues associated with 50% NaOH. Caustic will be stored in a tank and delivered to the scrubber recirculation lines by a local chemical feed pump.

The scrubber sump solution will be continuously discharged to maintain total dissolved solid levels in the circulating loop within an acceptable range. The scrubber is equipped with a conductivity probe that will monitor the conductivity (i.e., salinity) in the scrubber sump. At peak extraction and COC production, it is estimated that up to 7300 lb/day of salt could be generated as a result of the neutralization reaction in the scrubber. Lower make-up flow rates would be required during periods of lower COC loading.

The salinity will be maintained between approximately 3 and 5% (field adjustable) and the scrubber will automatically "blow down" the salt solution from the scrubber sump. The scrubber sump blow down will be discharged to the POTW sewer line.

Vapor flow	2500 scfm
Inlet temperature rating	61500 F
Material of construction	AL6XN
Quench water rate	9 gpm
Water circulation rate	75 gpm
Caustic usage, peak rate	13,700 #/day
Brine water dump rate	32 gpm

Design specifications for the scrubber are summarized as follows:



7.3.6 Liquid Treatment

Water from various sources, including the moisture separator and scrubber will be subject to treatment prior to discharge to the POTW sewer. The peak estimated flow rate is estimated to be 60 gpm based on the mass and energy balance. 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)

7.3.6.1 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, 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.

7.3.6.2 Oil/Water Separator

The oil-water separator is a HydroQuip model AG-4CS-HP-1H, parallel-corrugated plate coalescing oil water separator rated for a 30 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 weir 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 NAPL accumulation tank. Accumulated DNAPL (if present) will be automatically transferred from the separator to the NAPL accumulation tank by pneumatic diaphragm pumps, operated by an intrinsically-safe conductivity level controller. (Note: the conductivity controller senses the break in conductivity between coated rods when the accumulated non-conductive NAPL displaces the conductive water). Effluent water from the final clear-water stilling chamber of the oil/water separator is pumped to the bag filters and air stripper for further treatment.

7.3.6.3 Bag Filter(s)

A Rosedale Model 6 (or similar) duplex bag filter will be installed downstream of the oil-water separator to remove emulsion globules or particulates prior to entering the air stripper.

7.3.6.4 Air Stripper

The air stripper for this project is a shallow-tray style air stripper, rated for a minimum flow rate of 1 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



160°F, will further enhance the vapor phase partitioning within the air stripper and will provide excellent air stripping performance.

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.

7.3.6.5 Granular Activated Carbon Vessel(s)

Two liquid phase activated carbon absorbers will be installed downstream of the air stripper to provide a final effluent polish prior to discharging to the POTW. The carbon absorbers will be TetraSolv AF2000, or comparable, containing 2000 pounds of carbon and rated for a flow rate greater than 80 gpm. The carbon beds provide additional effluent polishing downstream of the air stripper and an added measure of protection in the event that an emulsion occurs prior to implementation of an emulsion breaking system. The carbon bed is equipped with isolation valves, pressure gauges and sample ports.

7.3.6.1 Backup Granular Activated Carbon Vessel(s)

A backup granular activated carbon (GAC) system will be present at the site at the time of startup. The GAC system will consist of two vessels configured and piped to operate in a lead/lag scenario. In the event that both oxidizers and/or the scrubber require maintenance for an extended length of time (e.g., >12hrs), a backup GAC system will be temporarily connected to allow minimal extraction and treatment of vapors. These vessels will not be sized to operate as a primary contaminant treatment, but rather as temporary until the equipment is operating properly.

7.3.7 Backup Power

A backup generator working in concert with an ATS will provide power to the vapor treatment system to maintain pneumatic control in the event of a power loss or failure. The generator will power the effluent treatment system to maintain hydraulic and pneumatic control; however, the generator will not provide power for the TCH heaters during a power outage.

7.3.8 Control Systems

The control systems are addressed sequentially through the process.

The vapor flow for the process is provided from the vapor extraction wells. The vapor flow rate extracted from the wellfield is controlled by manually adjusting the vacuum level applied to the vapor manifold as measured by a vacuum gauge. The vacuum level is controlled by adjusting the variable frequency drive (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 varies during the project and represents the dew point of the wellfield vapor stream. The exit temperature of the heat exchanger is controlled by the temperature of the cooled fluid provided by the cooling tower or chiller. The cooling tower or chiller exit temperature is controlled by manually setting the temperature control on the unit. The exit temperature of the cooling tower may be somewhat 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. High temperature alarms are provided at the inlet and outlet of the heat exchangers.

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.

Manual control of the vacuum blowers was discussed in the description of the wellfield vapor flow. The discharge stream from the vacuum blowers flows through a duct heater which 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 and SCR. Downstream, a high-temperature limit switch and flow switch 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(s). The oxidizer(s) oxidizes, or burn, the COCs carried in the vapor stream. The temperature of the combustion chamber is automatically maintained in a temperature range of 1500-1600°F. Natural gas is used to provide supplemental fuel for combustion if the COC loading alone is not sufficient to maintain the combustion chamber in the desired temperature range. Operation of the oxidizer is controlled by a programmable logic controller (PLC). Permissive and shutdown signals from the oxidizer's on-board flow, pressure and temperature sensors, along with inputs from the scrubber, are interfaced with the oxidizer PLC to maintain or safely shut down operation of the oxidizer.

The oxidizers are followed by a quench and wet scrubber. The quench is supplied with potable city water. In the event of a loss of city water supply pressure, a flow switch sends a signal to the oxidizer PLC to shut down the oxidizer so that the scrubber section does not overheat. 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 hydrochloric acid (HCI) generated in the combustion process. Conductivity of the liquid in the sump is monitored to allow automatic adjustments to prevent buildup of excessive solids in the sump and circulating loop. The scrubber circulating loop is fitted with a discharge control valve that will automatically discharge waste water 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, along with blow-down from the cooling tower, 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.

7.3.9 Expected Water Discharge Rates to the POTW System

The expected flow rates are as follows:



- Condensate: Discharge rates between 0 and 10 gpm, daily average between 2 and 6 gpm.
- Blow-down and backwash: Typical 30 to 40 gpm combined, may be higher or lower depending on chlorinated VOC loading.
- Total water rate discharged to POTW: Expected discharge rate between 0 and 60 gpm. Maximum 60 gpm instantaneous at maximum capacity for several minutes.



8.0 STATEMENT OF REGULATORY COMPLIANCE

8.1 Permit Equivalency

Permit equivalencies will be coordinated with appropriate local and state agencies to obtain the permits, or permit equivalents, required during operation of the thermal remediation system. Anticipated required permits specifically for the in-situ thermal program will include:

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

8.2 Air Permit Equivalency

Since the remediation is being performed as part of a Superfund remedial action, a Connecticut Department of Environmental Protection (CTDEP) air permit is not required; however, in accordance with CTDEP, the proposed vapor phase control system will be designed to meet or exceed Best Available Control Technology (BACT) criteria, which will demonstrate compliance with applicable requirements, including but not limited to the following:

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

Conceptual Design/Remedial Action Work Plan In Situ Thermal Remediation at Solvents Recovery Service of New England April 2010 Page 58



8.3 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.

Comply with ARAR	>	Y
Compliance with ARAR	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. The treated and neutralized in a caustic scrubber, which is expected to maintain a minimum 99% DRE for neutralization of HCl vapors. The treated and neutralized in a caustic scrubber, which is expected to maintain a minimum 99% DRE for neutralization of HCl vapors. The TCE P. 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 HQP, as both are considered to be Hazardous Air Pollutants (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 1500 lb/day or ~63 lb/hr. With a minimum 99% DRE in the oxidizer and 99% HCI neutralization in the scrubber, expected VOC emissions should be below 2 lb/hr, which is well below the anticipated emission standards.	Same as above.
Citation	40 CFR 264 Subpart BB	40 CFR 264 Subpart AA
Requirement	RCRA Air Emission Standards for Equipment Leaks	RCRA Air Emission Standards for Process Vents
Regulatory Level	Federal	

Conceptual Design/Remedial Action Work Plan n Situ Thermal Remediation at Solvents Recovery Service of New England April 2010
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Comply with	ARAR							;	~											≻						>				
	Compliance with ARAR	Wastes generated during the thermal remediation process may include:	Recovered NAPL;	 Liquid condensate; 	 Spent media (e.g., activated carbon, etc.) 	 Decontamination fluids; 	 Used PPE; and, 	 Normal construction debris. 	Hazardous and potentially hazardous wastes including drill cuttings,	NAPL, decontamination fluids and spent media will be sampled and	profiled and disposed at a properly licensed disposal facility.	Alternatively, drill cuttings may be incorporated into the TTZ, beneath the	surface cover, and treated in-situ during operations. Liquid condensate is	expected to be treated on-site by the liquid treatment train. Used PPE	and construction debris will be managed and disposed at appropriately	licensed facilities. All manifests, shipping documents, weight tickets, etc.	will be maintained in the project file.	Real-time VOC and particulate air monitoring will be performed at	representative perimeter locations. The purpose of this monitoring is to	assess the potential for dust or VOC concentrations to exceed action	levels protective of surrounding populations, and to trigger control	measures if action levels are exceeded.	To minimize noise in and around the thermal treatment area, drilling and	construction efforts will occur Monday through Friday from 7 am to 5 pm.	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.
	Citation	CGS 22a ch ⊿л5 PC≤∆	§22a-449(c)															CGS 22a ch	446c RCSA	§22a-174-1	to 33		RCSA §22a-	69-1 to 7.4						
	Requirement	Hazardous Waste	Regulations															Air Pollution Control					Control of Noise							
Regulatory	Level	State of																												

Conceptual Design/Remedial Action Work Plan In Situ Thermal Remediation at
Solvents Recovery Service of New England
April 2010
Page 60



Comply with ARAR	A/A	N/A
Compliance with ARAR	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. Neutralization of hydrogen chloride gas and HCl condensate. Expected air stripper effluent flows are on the order of 10 to 15 gpm. 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 frectulation 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 lowdown 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 blowdown will contain 3% to 5% salt by volume, with an average discharge flow rate of supproximately 30-40 gpm. It is expected that the discharge discharge discharge discharge flow rate discharge.	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.
Citation		
Requirement	Liquid	Storage of Caustic
Regulatory Level	Other	



9.0 THERMAL REMEDIATION OPERATIONS

9.1 Operational Sequence

Based on the model calculations, operational durations have been estimated. A numerical model 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 US in the last ten years. Results are presented in Section 4. The site is divided into two segments of near 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 cooldown.

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

9.2 Thermal System Start-up

9.2.1 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.

9.2.2 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:

- 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 five to 10 days.

9.3 Operation

Thermal remediation operations are expected to last approximately 195 days. 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 to the inlet and outlet to the treatment system, selected manifold legs, and at selected vacuum extraction wells based on field observations.

Operators will be on site daily for approximately 8 to 10 hours per day weekdays and 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 shutdown 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. Wellfield block valve automatically closes. Operator automatically notified. Emergency generator automatically starts within 30 seconds of power loss. Operator reports to site within 30 mins (if not already on site). Operator re-starts oxidizers and off-gas treatment system on dilution air. Wellfield block valve is opened and vapors are extracted and treated from subsurface. Heaters remain off until line power is restored. 	 None. Extraction and treatment typically restored within 1-2 hours.
Failure of thermal oxidizer, scrubber, and/or other major equipment	 Duplicative TOs, blowers, pumps and other equipment with meters and alarms to monitor operating parameters. Automatic shut down and by-passing to second TO if one TO goes off-line. If both TOs, scrubber, and/or other major components go off-line, off-gas treatment system automatically shuts down. Wellfield block valve automatically closes. Operator automatically notified. Operator reports to site within 30 mins (if not already on site). If the operator, in conjunction with the project engineer, determine that the repairs will take longer than 2-4 hours the heaters will be shutdown. Operator makes repairs and re-starts oxidizers and off-gas treatment system on dilution air. Wellfield block valve is opened and vapors are extracted and treated from subsurface. 	 None. Extraction and treatment typically restored within 2-6 hours. Significant deviation from specified operating ranges and/or prolonged repairs would cause shutdown of the heating system. The treatment zone could remain bottled up with the heaters off for up to 12 hours with little to no pressure build up in the subsurface or releases to the atmosphere. If the off-gas treatment system will be off-line for more than 12 hours, the backup GAC system will be temporarily connected to allow minimal extraction and treatment of vapors.

9.4 Shutdown



Once it is determined that the thermal remediation objectives have been achieved (see Section 10.0), 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 groundwater treatment systems will operate, and the subsurface temperature and pressure monitoring will continue. Following the cooling period, the system will be shut down and decommissioning will continue.

9.5 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 the following procedure. 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 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.

9.6 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 may remain in place.

9.7 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 down gradient of 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 as Appendix G. Based on the results, select NTCRA wells were determined to be too close to the heated zones, and were decommissioned. It was also shown that minimal temperature impacts (less than 10°C) are expected for the NTCRA water treatment system. Finally, the model indicated that the site will cool to within 10°C of ambient temperature approximately 1-1.5 years after the thermal treatment.



10.0 TREATMENT PERFORMANCE EVALUATION

The Thermal Treatment Performance Criteria Work Plan, dated April 2009, 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. A summary of this document is presented below.

10.1 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 is 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;
- 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 reports.

During operation, a monthly report will be submitted to **de maximis** that includes energy balance and energy input plots, snapshots of subsurface temperatures, temperature versus time plots for select locations, 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 vacuum extraction rate (total and individual well);
- Install additional TCH heater wells.

10.2 Daily Operations Staffing Plan

An experienced TerraTherm lead Operator, with engineering staff as needed, will be on-Site during the testing and commissioning phase. As the system transitions into full TCH operation mode, TerraTherm's Lead Operator will be 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 Operator will be available to respond to the Site within approximately 30 minutes if the monitoring system detects any issues with the system.



10.3 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.). 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 shut-down conditions will result in automatic notification of TerraTherm's Operator by cell phone.

10.4 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.

10.5 Screening Level Sampling

A handheld PID (MiniRae 3000, or similar) will be used to screen the vapor concentrations at numerous locations 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. The screening data will be included in the daily data collection sheet.

In addition, weekly vapor samples will be collected from each operational manifold leg at the points were they enter the main manifold line. These samples will be collected in Tedlar[™] bags using a dedicated sample pump and sent to the laboratory for screening analysis using a gas chromatograph for VOCs. 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 verification sampling and, in conjunction with the soil data,



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 10.6).

TerraTherm may also chose 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.

10.6 Grab Samples for Laboratory Analysis

Since 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 of the air stripper);
- Destruction Removal Efficiency (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. As a minimum, vapor effluent and water discharge samples will be collected three times for the first week, weekly for the first month, and monthly thereafter. Additional sampling will be performed as appropriate to facilitate optimization of the system and evaluation of system performance. It is anticipated that the following grab sampling will be required:

- Vapors conveyed to the oxidizer: one grab sample on Day 1, Day 2, Day 4, Day 7, and then once per month during operation, thereafter. These samples will be collected in Summa canisters and will be analyzed for VOCs using EPA method TO-15.
- Condensate samples: collected monthly. These samples will be collected in 40 mL vials and be analyzed for VOCs using EPA method 8260.
- Samples discharged to the POTW: currently assumed to be collected monthly for VOCs using EPA method 8260. In addition, samples will be collected for total suspended solids and pH. The final list of parameters and sampling frequencies will be determined by the POTW.

Additional samples may be collected at the discretion of TerraTherm.

10.7 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 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.



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.

10.7.1 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.

10.7.2 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).

10.7.3 Energy Removed

Energy will be removed from the Site in the form of hot water and vapors. The water will either be pumped from the MPE wells or entrained with the extracted vapors from the MPE and vapor extraction wells. The hot vapors from the vapor extraction wells 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).

10.8 Subsurface Temperatures

Data from the temperature sensors will be used to evaluate heating progress. The data will be collected and organized using a project web-page. The following data representations are used:

- Individual borehole temperature profiles.
- Plots of temperature versus time for all sensors.
- Average temperature in the vadose zone.
- Average temperatures at different depths from top to bottom of the saturated zone.

10.9 Soil Sampling Events

Two interim 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. Approximately 15 soil samples will be collected in each segment (30 total) after approximately 60-70 days of operation of each segment. Approximately 35 soil samples will be collected from each segment (70 total) after approximately 90-110 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.



Once the data from the interim soil sampling events indicate that VOC concentrations are sufficiently reduced, temperatures within the wellfield have achieved design temperatures, and wellfield vapor samples verify that individual site segments are almost depleted, thermal treatment verification sampling will be conducted in each segment (phase). 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 in Figure 10.1. To the extent possible, the main manifold pipe runs have been configured to allow sampling equipment to access the wellfield. It may also be possible to incorporate flanged joints or removable pipe spools into specific sections of the manifold piping to facilitate access to specific areas of the thermal wellfield that would otherwise be difficult to access. 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.

Conceptual Design/Remedial Action Work Plan In Situ Thermal Remediation at Solvents Recovery Service of New England April 2010 Page 14

TERRATHERM







10.10 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 50 temperature monitoring locations within the treatment volume.
- 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 lbs/day of COCs will be seen as an indication that very little, if any, DNAPL exists in the treatment volume, 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 interim soil sampling event 1 and 2, when some areas are expected to have met the remediation goals.
- Well-field 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 thermal treatment zone 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 triggers the performance sampling will be discussed with the Project Coordinator and based on all available data collected during treatment.


Appendix A

Operations and Maintenance Plan (example table of contents)

THERMALLY ENHANCED REMEDIATION OPERATION & MAINTENANCE MANUAL TABLE OF CONTENTS

1	INTR	RODUCTION	.1				
	1.1	Intent of O&M Manual	.1				
	1.2 Overview of O&M Manual						
	1.3	Site Description	.2				
	1.4	ISTD Process Description	.2				
2	COM	IMUNICATIONS	.4				
	2.1	Organization	.4				
	2.2	TerraTherm Contact List	.5				
	2.3	Contact List	5				
3	PRO	CESS EQUIPMENT DESCRIPTION	.6				
	3.1	Thermal Well Field Heaters	.6				
	3.2	Well Field Mechanical Piping	.6				
	3.2.1	Vapor Collection Piping	.6				
	3.2.2	2. Extracted Groundwater Piping	.7				
	3.2.3	Steam Piping	.7				
	3.3	Vapor Extraction and Treatment System	.8				
	3.3.1	Moisture Separator-Scrubber (G-102)	.8				
	3.3.2	2 Vacuum Blowers (B-103 A/B)	.9				
	3.3.3	B RTO (M-1001)	10				
	3.3.4	Wet Scrubber (G-105)	12				
	3.3.5	Caustic Supply System (G-106)	19				
	3.4	Groundwater Extraction and Treatment System	20				
	3.4.1	Groundwater Pumps (GWP-101 to 109)	20				
	3.4.2	Pump Supply Air Compressor (AC-101)	21				
	3.4.3	Oil-Water Separator (TK-203)	21				
	3.5	Steam Injection Equipment	25				
	3.5.1	Steam Boiler (SB-101)	25				
	3.5.2	Water Conditioner	26				
	3.6	Electrical Distribution Systems	26				
	3.6.1	Electrical Service and Distribution Equipment	26				
	3.6.2	Well Field ISTD Wiring	27				
	3.6.3	Instrumentation and DataCom Wiring	27				
	3.7	Backup Power	28				
	3.8	RIO Process Control System Alarms & Interlocks	28				
	3.8.1 2.0.0	PLC CONTROL SET POINTS	20 20				
	3.8.2	C RIO Fault Alarms	29				
	3.8.3 DDF		ວ∠ າາ				
4			33				
	4.1	Uverview	33				
	4.Z	Pre-Start Charlieto	33				
	4.3		33				

	4.4 Testing, Balancing, Commissioning	33
	4.4.1 Test System Components for Proper Operation	33
	4.4.2 Shakedown/Startup System	34
	4.4.2.1 Start Wet Scrubber	35
	4.4.2.2 Start RTO - Fresh Air Only	35
	4.4.2.3 Conduct Manifold Leak Testing	35
	4.4.2.4 Start First Well Heater Circuit	36
	4.4.2.5 Begin Drawing Air from Well Field	36
	4.4.2.6 Balance Well Field Air Flow	37
5	OPERATIONS	38
	5.1 Overview	38
	5.2 Daily Operations Review	38
	5.3 Process Monitoring and Control	38
	5.4 Performance Monitoring	38
	5.4.1 Well Field Temperature and Pressure Monitoring	39
	5.4.2 Process System Performance Monitoring	39
	5.4.3 Emissions Monitoring	39
	5.4.4 Dust and Odor Monitoring	39
	5.5 General Record Keeping	40
	5.5.1 Log Books	40
	5.5.2 Data Submittal	41
	5.6 Unit Shutdown Procedure	41
	5.7 Emergency Shutdown Policy & Procedure	41
	5.8 Unit Restart Procedure	42
	5.9 Job Shutdown Procedure	42
6	SAFETY	43
	6.1 Overview	43
	6.2 Safety Procedures	10
		43
	6.3 Process & Equipment Safety Checklists	43 43
	 6.3 Process & Equipment Safety Checklists 6.4 Site Safety & Security 	43 43 43
	 6.3 Process & Equipment Safety Checklists 6.4 Site Safety & Security 6.5 Emergency Evacuation Procedure 	43 43 43 43
	 6.3 Process & Equipment Safety Checklists 6.4 Site Safety & Security 6.5 Emergency Evacuation Procedure 6.6 Lockout/Tagout 	43 43 43 43 44
7	 6.3 Process & Equipment Safety Checklists 6.4 Site Safety & Security 6.5 Emergency Evacuation Procedure 6.6 Lockout/Tagout MAINTENANCE	43 43 43 43 44 45
7	 6.3 Process & Equipment Safety Checklists	43 43 43 43 43 44 45
7	 6.3 Process & Equipment Safety Checklists	43 43 43 43 44 45 45 46
7	 6.3 Process & Equipment Safety Checklists	43 43 43 43 44 45 45 46
7	 6.3 Process & Equipment Safety Checklists	43 43 43 43 44 45 45 46 46 47
7	 6.3 Process & Equipment Safety Checklists	43 43 43 43 43 44 44 45 45 45 46 46 46 47 47
7	 6.3 Process & Equipment Safety Checklists	43 43 43 44 43 44 44 45 45 45 46 46 46 47 47 47 47
7	 6.3 Process & Equipment Safety Checklists	43 43 43 44 45 45 45 46 46 47 47 47 48
7	 6.3 Process & Equipment Safety Checklists	43 43 43 43 44 45 45 46 46 46 47 47 47 47 48 48
7	 6.3 Process & Equipment Safety Checklists	43 43 43 43 43 44 45 45 45 46 45 46 47 47 47 47 47 47 47 48 48 48 48
7	 6.3 Process & Equipment Safety Checklists	43 43 43 43 43 43 45 45 45 46 47 47 47 47 47 48 48 48 48
8	 6.3 Process & Equipment Safety Checklists 6.4 Site Safety & Security 6.5 Emergency Evacuation Procedure 6.6 Lockout/Tagout MAINTENANCE	43 43 43 44 43 44 45 45 45 46 46 46 47 47 47 47 47 47 47 47 47 48 48 48 48 48 49
8	 6.3 Process & Equipment Safety Checklists 6.4 Site Safety & Security	43 43 43 43 43 44 45 45 45 46 45 46 47 47 47 47 47 47 47 47 47 47 47 47 47
8	 6.3 Process & Equipment Safety Checklists 6.4 Site Safety & Security	43 43 43 43 43 43 45 45 45 45 45 45 46 47 47 47 47 47 48 48 48 48 49 50 51
8	 6.3 Process & Equipment Safety Checklists 6.4 Site Safety & Security 6.5 Emergency Evacuation Procedure	43 43 43 43 43 43 45 45 45 45 46 47 47 47 47 47 47 48 48 48 48 49 51 51
8	 6.3 Process & Equipment Safety Checklists	43 43 43 43 43 43 45 45 45 46 46 47 47 47 47 47 47 48 48 48 49 50 51 51
8	 6.3 Process & Equipment Safety Checklists 6.4 Site Safety & Security 6.5 Emergency Evacuation Procedure	43 43 43 44 43 44 45 45 46 46 46 46 47 47 47 47 47 47 47 47 48 48 48 48 48 48 50 51 51 51 51 52
8	 6.3 Process & Equipment Safety Checklists 6.4 Site Safety & Security	43 43 43 43 43 45 45 45 46 47 47 47 47 47 47 48 48 48 48 49 50 51 51 52 52

	8.5.2	2 Transfer and Metering Pump Troubleshooting	. 53
	8.5.3	3 Wet Scrubber	. 53
	8.5.4	4 RTO	. 55
9	OPE	RATING CONTINGENCY PLANS	.64
	9.1	Grid Power Interruption	. 64
	9.2	Loss of Well Field Vacuum	. 64
	9.3	Well Field Surface Cover Failure	. 64
	9.4	Insufficient Subsurface Heating	. 65
	9.5	Heater Can Failure	. 66
	9.6	Manifold Piping Failure	. 66
	9.7	Heater Element Failure	. 66
	9.8	Main Blower Failure	. 67
	9.9	Pump Failure	. 67
	9.10	Quench/Wet Scrubber Failure	.67
	9.11	RTO Failure	.67

APPENDICES

- Appendix A: Health and Safety Plan (HASP)
- Appendix B: Checklists and Log Forms
- Appendix C: Drawings
- Appendix D: Process Equipment Manual
- Appendix E: Switchgear Manual
- Appendix F: Instrumentation Manual



Appendix B

Pre-Design Studies and Modeling Reports





January 26, 2010

Transmitted Via Email Email Address: lconant@terratherm.com

Mr. Larry Conant TerraTherm, Inc. 10 Stevens Road Fitchburg, MA 01420

Subject: Laboratory Evaluation of 12 Corrosion Tested Coupons (Intertek-APTECH Report AES 09087234-3-1) (Final Report)

Dear Mr. Conant:

Intertek-APTECH is pleased to submit this report to TerraTherm, Inc. regarding the results of the laboratory evaluation of 12 corrosion-tested coupons.

INTRODUCTION

Intertek-APTECH performed laboratory evaluation for corrosion mechanisms on 12 coupons. Two coupons from 6 different materials, as listed in Table 1, were selected by TerraTherm for corrosion testing at Kemron Industrial Services. The coupons were initially sent to Intertek-APTECH for weight and dimensional measurements prior to the corrosion testing. The first set of coupons referred as "Well samples" were then (reportedly) tested at 650°C hydrochloric acid vapor environment for 10 days (240 hours). The second set of coupons referred as" Piping samples" was tested in condensing hydrochloric acid environment at 100°C for 5 days (120 hours). At the end of the testing, Well samples and Piping samples were returned to Intertek-APTECH for evaluation.

The objective of the laboratory evaluation was to:

- 1. Evaluate the coupons for corrosion mechanisms.
- 2. Calculate corrosion rate based on weight loss.

APPROACH

TerraTherm provided 12 coupons for initial weight and dimensional measurements. The coupons were documented in the as-received condition (Figures 1 and 2). The as-received dimensions of the coupons are summarized in Table 2.

16100 Cairnway Drive, Suite 310 Houston Texas 77084-3597 832.593.0550 FAX 832.593.0551 601 West California Avenue Sunnyvale California 94086-4831 408.745.7000 FAX 408.734.0445 139,11215 Jasper Avenue Edmonton Alberta T5K 0L5 780.669.2869 FAX 780.669.2509 Website: www.aptechtexas.com Photographs were taken to document the post-test appearance of the coupons. The coupons were weighed before cleaning. The coupons were ultrasonically cleaned using citronox and rust remover to remove the corrosion products. The coupons were weighed after cleaning and documented in the as-cleaned condition (Figures 3 through 14). The general corrosion rates of the coupons were calculated (using Equation 1) by measuring the weight loss of test coupons. All the coupons were visually and microscopically examined for evidence of pitting/crevice corrosion.

The corrosion rate¹ of the coupons is calculated using:

Corrosion Rate = $(K \times W) \div (A \times T \times d) \rightarrow$ Equation 1

Where

 $\begin{array}{l} \mathsf{K}-\mathsf{Corrosion\ constant\ (534)}\\ \mathsf{W}-\mathsf{Weight\ loss,\ mg}\\ \mathsf{A}-\mathsf{Surface\ area,\ in}^2\\ \mathsf{T}-\mathsf{Time\ of\ exposure,\ hrs}\\ \mathsf{D}-\mathsf{Density\ of\ material,\ gm/cm}^3\\ \mathsf{Corrosion\ rate\ -\ mils\ per\ year\ (mpy)} \end{array}$

Table 1

ROSTER OF COUPON DESIGNATIONS AND THEIR RESPECTIVE MATERIAL GRADES

	Coupon ID	Coupon ID
Material Class	[650°C (1202°F)]	[100°C (212°F)]
Stabilized Austenitic Stainless Steel (Alloy 20)	20CB3-13	20CB3-12
Austenitic Stainless Steel	304-03	304-01
Super Austenitic Stainless Steel	AL6XN-2	AL6XN-1
Hastelloy	B3-01	B3-02
Carbon Steel	C1023-1	C1023-2
Nickel-Chromium-Molybdenum Alloy	C276-2	C276-1

Table 2

Coupon No.	Length (in)	Width (in)	Thickness (in)
20CB3-12	3.006	0.5005	0.075
20CB3-13	3.005	0.497	0.074
304-01	3.000	0.495	0.056
304-03	3.001	0.494	0.0565
AL6XN-1	3.003	0.501	0.0585
AL6XN-2	3.003	0.501	0.0595
B3-01	3.009	0.506	0.075
B3-02	3.011	0.505	0.075
C1023-1	3.008	0.510	0.0565
C1023-2	3.008	0.512	0.0565
C276-1	3.004	0.502	0.063
C276-2	3.005	0.501	0.064

DIMENSIONS OF AS-RECEIVED COUPONS

RESULTS

Visual and Microscopic Examination of the Well samples exhibited uniform corrosion on Coupons 304-03, AL6XN-2, and C1023-1. The other coupons in this batch did not exhibit pitting/crevice corrosion, but the surface appears to be tarnished. Representative photographs of the coupons are provided in Figures 3 through 8.

Examination of the Piping samples did not exhibit corrosion or pitting. The coupons 304-01 and C1023-2 exhibited discoloration even after cleaning. Representative photographs of the coupons are provided in Figures 9 through 14.

The weight loss and corrosion rate results of the tested coupons are presented in Tables 3 and 4.

Table 3

WEIGHT LOSS AND GENERAL CORROSION RATE OF WELL SAMPLE	ES AT 650°C (Vapor Phase)
---	---------------------------

Coupon ID number	Density (g/cm3)	Time (hr)	Surface Area (sq. in)	Initial Weight (g)	Weight Before Cleaning (g)	Weight After Cleaning (g)	Weight Change (mg)	Corrosion Rate (mpy)
20CB3-13	8.08		3.51	14.485	14.50	14.49	-8.0	N/R
304-03	7.9		3.36	10.656	10.49	10.43	223.0	18.7
AL6XN-2	8.06	240	3.43	11.552	11.56	11.55	3.0	0.2
B3-01	9.22	240	3.57	17.009	17.02	17.01	0.0	N/R
C1023-1	7.86		3.47	11.020	11.98	9.06	1961.2	160.2
C276-2	8.94		3.46	13.415	13.42	13.42	-3.0	N/R

^{*}Negative values indicates weight gain N/R - Not reported due to weight gain

Table 4

WEIGHT LOSS AND GENERAL CORROSION RATE OF PIPING SAMPLES AT 100°C (Condensing Environment)

Coupon ID number	Density (g/cm3)	Time (hr)	Surface Area (sq. in)	Initial Weight (g)	Weight Before Cleaning (g)	Weight After Cleaning (g)	Weight Change (mg)	Corrosion Rate (mpy)
20CB3-12	8.08		3.53	14.49	14.49	14.49	1.8	0.3
304-01	7.90	120	3.36	10.63	10.63	10.62	2.3	0.4
AL6XN-1	8.06		3.42	11.53	11.53	11.53	0.9	0.1
B3-02	9.22		3.57	16.66	16.66	16.66	0.9	0.1
C1023-2	7.86		3.48	11.02	11.02	11.01	14.0	2.3
C276-1	8.94		3.46	13.44	13.44	13.44	1.2	0.2

DISCUSSION

The corrosion rate calculation for the Well samples determined that carbon steel (C1023-1) and stainless steel (304-03) experienced the highest corrosion rates of 160.2 and 18.7 mpy, respectively. The other coupons in this batch showed no corrosion during the testing. Coupons 20CB3-13 and C-276 exhibited weight gain suggesting oxidation may have occurred during testing. High temperature oxidation typically results in oxide film on the surface resulting in weight gain. The thickness of the film formed depends on the exposure time and temperature.

The corrosion rate of the carbon steel and 304 stainless steel is not unusual, as they are expected to corrode in the hydrochloric acid at elevated temperatures. The corroded coupons exhibited uniform

corrosion, with no localized corrosion (i.e., pitting, crevice) observed on these coupons. The other coupons (C 276-2, B3-01, AL6XN-2, and 20 CB3-13) exhibited a tarnished appearance, which is likely due to the oxidation of the coupons and possible solution contamination at elevated temperatures.

Based on the corrosion rate and examination, the Piping samples were unaffected by the testing conditions. Carbon steel exhibited the maximum corrosion rate (2.3 mpy), while the other coupon materials exhibited a corrosion rate between 0.1 and 0.4 mpy. The random discoloration observed on 304-01 and C1023-2 may be due to the contamination or initiation of random oxidation from the testing solution.

CONCLUSION

Based on the characterization of the corrosion-tested coupons, the following conclusions were made:

- Among the group of Well samples, carbon steel coupon (C1023-1) and stainless steel coupon (304-03) showed the highest corrosion rates. The super austenitic stainless steel, stabilized austenitic stainless steel, and nickel alloys showed good corrosion resistance. None of the Well samples exhibited any evidence of pitting or crevice corrosion.
- 2. The Piping samples showed a negligible corrosion rate (except carbon steel). The samples in this group did not exhibit pitting or crevice corrosion.

RECOMMENDATIONS

- 1. Should TerraTherm select one of the materials for application, Intertek-APTECH could perform a cost analysis on the selected materials. This cost analysis would involve a comparison of the purchase price of the material (cost of production, fixed costs) and cost of ownership (service life, inspection frequencies, etc).
- 2. If TerraTherm does not have a Risk Based Inspection (RBI) program for piping, Intertek-APTECH recommends implementation of a RBI program on the new piping material and existing piping to monitor corrosion, minimize inspection intervals, and plan for turnaround activities in the future.

Should you have any questions regarding this report, please contact me at Intertek-APTECH's Houston office (832-593-0550) or by email at *velu.palaniyandi*@intertek.com.

Sincerely,

PVD

Velu Palaniyandi Supervisor, Metallurgical Services

VP/rje cc: HOU File SV File

REFERENCES

1. Denny .A .Jones, Principles and Prevention of Corrosion, 2nd Edition, P-31.

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Figure 3 — B3-01 Coupons before (Top) and after Cleaning (Bottom).



Figure 4 — C-276 Coupons before (Top) and after Cleaning (Bottom).



Figure 5 — AL6XN-2 Coupons before (Top) and after Cleaning (Bottom).



Figure 6 — 20 CB3-13 Coupons before (Top) and after Cleaning (Bottom).



Figure 7 — 20 C1023-1 Coupons before (Top) and after Cleaning (Bottom).



Figure 8 — 304-03 Coupons before (Top) and after Cleaning (Bottom).



Figure 9 — C1023-2 Coupons before (Top) and after Cleaning (Bottom).





Figure 10 — B3-02 Coupons before (Top) and after Cleaning (Bottom).





Figure 11 — 304-01 Coupons before (Top) and after Cleaning (Bottom).



Figure 12 — 20CB3-12 Coupons before (Top) and after Cleaning (Bottom).





Figure 13 — AL6XN-1 Coupons before (Top) and after Cleaning (Bottom).



Figure 14 — C276-1 Coupons before (Top) and after Cleaning (Bottom).

SRSNE MATERIALS COMPATIBILITY STUDY` SOUTHINGTON, CONNECTICUT

KEMRON PROJECT #: SE-0313

January 25, 2010

Prepared for:

TerraTherm, Inc. 10 Stevens Road Fitchburg, MA 01420



Prepared by:



KEMRON Environmental Services, Inc. 1359-A Ellsworth Industrial Boulevard Atlanta, Georgia 30318

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4

Mark Clark Project Manager

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INTRODUCTION

KEMRON Environmental Services, Inc. (KEMRON) is pleased to present the results of the Materials Compatibility Testing study. The treatability study was performed to evaluate the resistance of construction materials to degrade when subjected to site materials and conditions anticipated during full-scale thermal treatment. This report includes the methodology followed during each phase of the study, photographic documentation, and visual and weight degradation.

KEMRON received duplicate samples of six metallic construction materials (coupons). These coupons were labeled B3, 20CB3, 304, AL6XN, C1023, and C276. In addition to the material coupons, KEMRON received a sample of Dense Non-aqueous Phase Liquid (DNAPL). TerraTherm indicated that this DNAPL material contained chlorinated contaminants from the site.

Compatibility testing was conducted in two distinct phases. Initially, a sample of the DNAPL was heated to boiling, producing vapors which may be encountered during full-scale activities. This vapor was then passed through one reactor containing sand which was maintained at a temperature of approximately 700 degrees Celsius (°C). This reactor provided heating and retention of the vapors in order to degrade or break-down compounds in a manner anticipated during full-scale treatment. It was anticipated that in the first reactor chlorinated vapors from the DNAPL form hydrochloric acid. The hot acidic vapors were then passed into a second reactor containing samples of the test coupons and sand. The second reactor was maintained at a temperature of approximately 650 °C. This reactor served to expose the coupons to the highly degrading acid vapors. Finally, vapors from the second reactor were condensed and retained for use in Phase II of the study.

Phase II of testing included subjecting the construction materials to lower temperatures and constantly condensing and vaporizing acidic compounds as may be experienced in the periphery of the thermal treatment areas. This phase was accomplished by boiling the acidic condensate from Phase I. The metal coupons were placed into Soxhlet columns connected to the condensate boiling flask. A cold water condenser was situated on the top Soxhlet column to condense the acidic vapors. As the acidic condensate boiled vapors passed over the coupons and were condensed in the condenser and allowed to fall back into the Soxhlet columns which exposed the coupons to the acidic liquid. When the volume of liquid reached the appropriate level within the columns the liquid siphoned back to the heating pot and the process was repeated.

PHASE I TESTING

The high temperature phase of the testing was conducted using two cylindrical titanium reactors measuring approximately 6 inches in length and 3 inches in diameter. Each reactor was fitted with bolt-on end caps which contained stainless steel Swagelok fittings to allow the connection of inlet and outlet tubing to the reactors. Note that in further sections of this section of the report one end will be referred to as inlet and the other as outlet. Glass fiber material was placed over the opening of each Swagelok fitting, inside of the reactor, to prevent sand in the reactors from entering the tubing. The first reactor was filled with pre-cleaned sand only. The second reactor contained a coupon for each construction material furnished. KEMRON prepared this reactor by securing one end-cap onto the reactor. Approximately 3 inches of sand was then placed into the reactor. The coupons were then inserted into the sand so that they were oriented parallel to

the long axis of the reactor. Note that care was taken so that the coupons were surrounded on all sides by sand. The remainder of the reactor was filled with sand and then capped.

The following is a sample photograph of the coupons prior to testing:



Prior to testing each coupon was cleaned using Alconox, dried and weighed. The following is a summary of the weights of each coupon utilized in Phase I.

TABLE 1					
COUPON	INITIAL				
ID	WEIGHT (g)				
B 3	17.0097				
20CB3	14.4856				
304	10.6564				
AL6XN	11.5524				
C1023	11.0208				
C276	13.4156				

The reactors were placed into separate Fisher Isotemp muffle furnaces. A steam generating vessel consisting of a kitchen pressure cooker placed on a heating plate was connected to a breathing quality air source via a Swagelok connector. Stainless steel tubing was connected from the steam generator to a heating pot containing the site DNAPL material. This heating pot was also placed on a heating plate to allow heating of the DNAPL. Additional stainless steel tubing was used to connect the DNAPL heating pot to the inlet port of Reactor #1. Tubing was then utilized to attach the outlet port of Reactor #1 to the inlet port of Reactor #2. Finally, the outlet port from Reactor #2 was connected to a cold water condensing system using stainless steel tubing.

The following is a depiction of the test set-up for Phase I.



The picture below was taken during the actual set-up of during Phase I. In addition to the equipment shown a cold water condenser and condensate collection vessel was connected to Reactor #2 left of the picture.



Throughout testing activities in Phase I, air was passed through the steam generator and the remainder of the system at a rate of approximately 10 milliliters per minute (ml/min). Once the system was prepared KEMRON began treatment by heating each reactor to the appropriate operating temperature. Once the reactor target temperatures were achieved, KEMRON began heating the steam generator and DNAPL source. Specifically, the steam generator was heated to a target temperature of 110 °C, and the DNAPL source was heated to approximately 80 °C. TerraTherm had requested that the steam generator be used to constantly pass a flow of steam through the system at a rate equal to 10% of the quantity of condensate being collected during testing. However, KEMRON was unable to consistently maintain this rate of steam generation. In order to provide the appropriate amount of steam through the system, KEMRON periodically injected water into the hot generator at an amount equal to 10% of the condensate being collected being collected. In the absence of water the steam generator provide heating of the air being injected into the treatment system.

KEMRON tested the pH of the condensate being recovered on a daily basis. Results indicated that the average pH of the condensate was approximately 5 standard units. The pH monitoring was performed using both pH indicator paper and direct read instrument.

Following 10 days of DNAPL heating the testing was terminated and the system was dismantled. The material coupons from Reactor #2, rinsed, photographed and forwarded to a metallurgical laboratory contracted by TerraTherm for further evaluation. The following is a photograph of the post treatment coupons.



Note that due to the amount of damage to the coupons KEMRON had difficult identifying two of the coupons. Specifically, coupons C1023 and 304 labeled in the above picture were in question during coupon identification.

TABLE 2						
INITIAL	FINAL					
WEIGHT (g)	WEIGHT (g)					
17.0097	17.0241					
14.4856	14.4966					
10.6564	10.4960					
11.5524	11.5639					
11.0208	12.1520					
13.4156	13.4230					
	TABLE 2 INITIAL WEIGHT (g) 17.0097 14.4856 10.6564 11.5524 11.0208 13.4156					

Table 2 presents the final weights of each material coupon.

The data in Table indicates that with the exception of coupon C1023, all of the coupons increased in weight due to the testing conditions.

As previously mentioned KEMRON collected condensate from Phase I testing. During testing KEMRON encountered several occurrences where condensate collection was interrupted. It was determined that the outlet lines from the reactors had gotten clogged. At these instances KEMRON disconnected the outlet lines from the reactors and removed the blockage. Upon dismantling of the system KEMRON observed that the glass fiber material used to prevent sand from entering the outlet lines had melted. KEMRON believes that this glass fiber material was the cause of the majority of the blockages. Over the 10 day testing period, KEMRON collected approximately 750 grams of clear condensate with a pH of 5 s.u.

On inspection of the titanium reactors used during Phase I testing, KEMRON observed significant oxidation and pitting of the inside of Reactor I, the sand only reactor. Specifically, KEMRON has outlined the portion of the reactor showing significant pitting.



PHASE II TESTING

As previously outlined, Phase II testing was designed to evaluate the degradation of construction material when subjected to lower temperatures and acidic liquids and vapors. Testing was performed by boiling the condensate material from Phase I. The acidic vapors were passed through two Soxhlet columns containing the material test coupons and condensed in a colder water condenser. The condensed liquid fell back into the columns where they collected. When the liquid level in the columns reached a certain level they were returned to the heating pot via siphon tubes in the columns.

The coupons were held within the columns using glass holders and glass fiber material. Specifically, coupons B3, 20CB3, and 304 were placed into one holder and coupons AL6XN, CL023, and C276 were placed into the second holder. The following is a photograph of the coupons within the glass holder:



The following is a diagram of the system set-up utilized for Phase II:





The photograph presented below is of the actual test set-up used for Phase II testing:
Testing was conducted for a period of 10 days. Over this 10-day period KEMRON calculated that the system cycled approximately 420 times, or once every 45 minutes. That is, liquid collected in the Soxhlet columns to the level it was siphoned back into the heating pot. During this 10 day period the condensate in the heating pot turned from clear to cloudy in the heating pot. At the completion of the 10 day period, testing was terminated and the system dismantled. The coupon materials were then removed from the system, rinsed, weighed and forwarded to TerraTherm's metallurgical laboratory. The photograph below shows the coupons after the 10 day testing study.



	TABLE 3	
COUPON	INITIAL	FINAL
ID	WEIGHT (g)	WEIGHT (g)
B 3 20CB3 304 AL6XN C1023 C276	16.6013 14.4763 10.6211 11.5402 11.0019 13.4330	16.6603 14.4896 10.6256 11.5343 11.0225 13.4397

Table 3 summarizes the initial and final weights of the coupons used during Phase II testing:

Photographs and review of the coupon weights before and after testing indicate that the coupons in Phase II were less affected by the test conditions than those in Phase I.

KEMRON Environmental Services, Inc. appreciates the opportunity to provide treatability testing to TerraTherm.





January 26, 2010

Transmitted Via Email Email Address: lconant@terratherm.com

Mr. Larry Conant TerraTherm, Inc. 10 Stevens Road Fitchburg, MA 01420

Subject: Laboratory Evaluation of 12 Corrosion Tested Coupons (Intertek-APTECH Report AES 09087234-3-1) (Final Report)

Dear Mr. Conant:

Intertek-APTECH is pleased to submit this report to TerraTherm, Inc. regarding the results of the laboratory evaluation of 12 corrosion-tested coupons.

INTRODUCTION

Intertek-APTECH performed laboratory evaluation for corrosion mechanisms on 12 coupons. Two coupons from 6 different materials, as listed in Table 1, were selected by TerraTherm for corrosion testing at Kemron Industrial Services. The coupons were initially sent to Intertek-APTECH for weight and dimensional measurements prior to the corrosion testing. The first set of coupons referred as "Well samples" were then (reportedly) tested at 650°C hydrochloric acid vapor environment for 10 days (240 hours). The second set of coupons referred as" Piping samples" was tested in condensing hydrochloric acid environment at 100°C for 5 days (120 hours). At the end of the testing, Well samples and Piping samples were returned to Intertek-APTECH for evaluation.

The objective of the laboratory evaluation was to:

- 1. Evaluate the coupons for corrosion mechanisms.
- 2. Calculate corrosion rate based on weight loss.

APPROACH

TerraTherm provided 12 coupons for initial weight and dimensional measurements. The coupons were documented in the as-received condition (Figures 1 and 2). The as-received dimensions of the coupons are summarized in Table 2.

16100 Cairnway Drive, Suite 310 Houston Texas 77084-3597 832.593.0550 FAX 832.593.0551 601 West California Avenue Sunnyvale California 94086-4831 408.745.7000 FAX 408.734.0445 139,11215 Jasper Avenue Edmonton Alberta T5K 0L5 780.669.2869 FAX 780.669.2509 Website: www.aptechtexas.com Photographs were taken to document the post-test appearance of the coupons. The coupons were weighed before cleaning. The coupons were ultrasonically cleaned using citronox and rust remover to remove the corrosion products. The coupons were weighed after cleaning and documented in the as-cleaned condition (Figures 3 through 14). The general corrosion rates of the coupons were calculated (using Equation 1) by measuring the weight loss of test coupons. All the coupons were visually and microscopically examined for evidence of pitting/crevice corrosion.

The corrosion rate¹ of the coupons is calculated using:

Corrosion Rate = $(K \times W) \div (A \times T \times d) \rightarrow$ Equation 1

Where

 $\begin{array}{l} \mathsf{K}-\mathsf{Corrosion\ constant\ (534)}\\ \mathsf{W}-\mathsf{Weight\ loss,\ mg}\\ \mathsf{A}-\mathsf{Surface\ area,\ in}^2\\ \mathsf{T}-\mathsf{Time\ of\ exposure,\ hrs}\\ \mathsf{D}-\mathsf{Density\ of\ material,\ gm/cm}^3\\ \mathsf{Corrosion\ rate\ -\ mils\ per\ year\ (mpy)} \end{array}$

Table 1

ROSTER OF COUPON DESIGNATIONS AND THEIR RESPECTIVE MATERIAL GRADES

	Coupon ID	Coupon ID
Material Class	[650°C (1202°F)]	[100°C (212°F)]
Stabilized Austenitic Stainless Steel (Alloy 20)	20CB3-13	20CB3-12
Austenitic Stainless Steel	304-03	304-01
Super Austenitic Stainless Steel	AL6XN-2	AL6XN-1
Hastelloy	B3-01	B3-02
Carbon Steel	C1023-1	C1023-2
Nickel-Chromium-Molybdenum Alloy	C276-2	C276-1

Table 2

Coupon No.	Length (in)	Width (in)	Thickness (in)
20CB3-12	3.006	0.5005	0.075
20CB3-13	3.005	0.497	0.074
304-01	3.000	0.495	0.056
304-03	3.001	0.494	0.0565
AL6XN-1	3.003	0.501	0.0585
AL6XN-2	3.003	0.501	0.0595
B3-01	3.009	0.506	0.075
B3-02	3.011	0.505	0.075
C1023-1	3.008	0.510	0.0565
C1023-2	3.008	0.512	0.0565
C276-1	3.004	0.502	0.063
C276-2	3.005	0.501	0.064

DIMENSIONS OF AS-RECEIVED COUPONS

RESULTS

Visual and Microscopic Examination of the Well samples exhibited uniform corrosion on Coupons 304-03, AL6XN-2, and C1023-1. The other coupons in this batch did not exhibit pitting/crevice corrosion, but the surface appears to be tarnished. Representative photographs of the coupons are provided in Figures 3 through 8.

Examination of the Piping samples did not exhibit corrosion or pitting. The coupons 304-01 and C1023-2 exhibited discoloration even after cleaning. Representative photographs of the coupons are provided in Figures 9 through 14.

The weight loss and corrosion rate results of the tested coupons are presented in Tables 3 and 4.

Table 3

WEIGHT LOSS AND GENERAL CORROSION RATE OF WELL SAMPLE	ES AT 650°C (Vapor Phase)
---	---------------------------

Coupon ID number	Density (g/cm3)	Time (hr)	Surface Area (sq. in)	Initial Weight (g)	Weight Before Cleaning (g)	Weight After Cleaning (g)	Weight Change (mg)	Corrosion Rate (mpy)
20CB3-13	8.08		3.51	14.485	14.50	14.49	-8.0	N/R
304-03	7.9		3.36	10.656	10.49	10.43	223.0	18.7
AL6XN-2	8.06	240	3.43	11.552	11.56	11.55	3.0	0.2
B3-01	9.22	240	3.57	17.009	17.02	17.01	0.0	N/R
C1023-1	7.86		3.47	11.020	11.98	9.06	1961.2	160.2
C276-2	8.94		3.46	13.415	13.42	13.42	-3.0	N/R

^{*}Negative values indicates weight gain N/R - Not reported due to weight gain

Table 4

WEIGHT LOSS AND GENERAL CORROSION RATE OF PIPING SAMPLES AT 100°C (Condensing Environment)

Coupon ID number	Density (g/cm3)	Time (hr)	Surface Area (sq. in)	Initial Weight (g)	Weight Before Cleaning (g)	Weight After Cleaning (g)	Weight Change (mg)	Corrosion Rate (mpy)
20CB3-12	8.08		3.53	14.49	14.49	14.49	1.8	0.3
304-01	7.90		3.36	10.63	10.63	10.62	2.3	0.4
AL6XN-1	8.06	120	3.42	11.53	11.53	11.53	0.9	0.1
B3-02	9.22	120	3.57	16.66	16.66	16.66	0.9	0.1
C1023-2	7.86		3.48	11.02	11.02	11.01	14.0	2.3
C276-1	8.94		3.46	13.44	13.44	13.44	1.2	0.2

DISCUSSION

The corrosion rate calculation for the Well samples determined that carbon steel (C1023-1) and stainless steel (304-03) experienced the highest corrosion rates of 160.2 and 18.7 mpy, respectively. The other coupons in this batch showed no corrosion during the testing. Coupons 20CB3-13 and C-276 exhibited weight gain suggesting oxidation may have occurred during testing. High temperature oxidation typically results in oxide film on the surface resulting in weight gain. The thickness of the film formed depends on the exposure time and temperature.

The corrosion rate of the carbon steel and 304 stainless steel is not unusual, as they are expected to corrode in the hydrochloric acid at elevated temperatures. The corroded coupons exhibited uniform

corrosion, with no localized corrosion (i.e., pitting, crevice) observed on these coupons. The other coupons (C 276-2, B3-01, AL6XN-2, and 20 CB3-13) exhibited a tarnished appearance, which is likely due to the oxidation of the coupons and possible solution contamination at elevated temperatures.

Based on the corrosion rate and examination, the Piping samples were unaffected by the testing conditions. Carbon steel exhibited the maximum corrosion rate (2.3 mpy), while the other coupon materials exhibited a corrosion rate between 0.1 and 0.4 mpy. The random discoloration observed on 304-01 and C1023-2 may be due to the contamination or initiation of random oxidation from the testing solution.

CONCLUSION

Based on the characterization of the corrosion-tested coupons, the following conclusions were made:

- Among the group of Well samples, carbon steel coupon (C1023-1) and stainless steel coupon (304-03) showed the highest corrosion rates. The super austenitic stainless steel, stabilized austenitic stainless steel, and nickel alloys showed good corrosion resistance. None of the Well samples exhibited any evidence of pitting or crevice corrosion.
- 2. The Piping samples showed a negligible corrosion rate (except carbon steel). The samples in this group did not exhibit pitting or crevice corrosion.

RECOMMENDATIONS

- 1. Should TerraTherm select one of the materials for application, Intertek-APTECH could perform a cost analysis on the selected materials. This cost analysis would involve a comparison of the purchase price of the material (cost of production, fixed costs) and cost of ownership (service life, inspection frequencies, etc).
- 2. If TerraTherm does not have a Risk Based Inspection (RBI) program for piping, Intertek-APTECH recommends implementation of a RBI program on the new piping material and existing piping to monitor corrosion, minimize inspection intervals, and plan for turnaround activities in the future.

Should you have any questions regarding this report, please contact me at Intertek-APTECH's Houston office (832-593-0550) or by email at *velu.palaniyandi*@intertek.com.

Sincerely,

PVD

Velu Palaniyandi Supervisor, Metallurgical Services

VP/rje cc: HOU File SV File

REFERENCES

1. Denny .A .Jones, Principles and Prevention of Corrosion, 2nd Edition, P-31.

NOTICE: This report was prepared by Intertek-APTECH as an account of work sponsored by the organization named herein. Neither Intertek-APTECH nor any person acting on behalf of Intertek-APTECH: (a) makes any warranty, express or implied, with respect to the use of any information, apparatus, method or process disclosed in this report or that such use may not infringe privately owned rights; or (b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.



















Figure 3 — B3-01 Coupons before (Top) and after Cleaning (Bottom).



Figure 4 — C-276 Coupons before (Top) and after Cleaning (Bottom).



Figure 5 — AL6XN-2 Coupons before (Top) and after Cleaning (Bottom).



Figure 6 — 20 CB3-13 Coupons before (Top) and after Cleaning (Bottom).



Figure 7 — 20 C1023-1 Coupons before (Top) and after Cleaning (Bottom).



Figure 8 — 304-03 Coupons before (Top) and after Cleaning (Bottom).



Figure 9 — C1023-2 Coupons before (Top) and after Cleaning (Bottom).





Figure 10 — B3-02 Coupons before (Top) and after Cleaning (Bottom).





Figure 11 — 304-01 Coupons before (Top) and after Cleaning (Bottom).



Figure 12 — 20CB3-12 Coupons before (Top) and after Cleaning (Bottom).





Figure 13 — AL6XN-1 Coupons before (Top) and after Cleaning (Bottom).



Figure 14 — C276-1 Coupons before (Top) and after Cleaning (Bottom).



TERRATHERM 10 Stevens Road Fitchburg, MA 01420 Phone: (978) 343-0300 Fax: (978) 343-2727

August 20, 2009

Bruce Thompson *de maximis, inc.* 200 Day Hill Road Suite 200 Windsor, CT 06095

Re: Summary of Analytical Results

Dear Bruce:

Attached please find the laboratory data report for the non aqueous phase liquid (NAPL) collected from the source area at the Solvents Recovery Service of New England, Inc. (SRSNE) Superfund Site in Southington, Connecticut.

Data results indicate that the heat of combustion was higher than previous samples at 13,012 BTU/lb. This is consistent with the chloride content being lower than earlier estimates at 319,957 ppm and the presence of large quantities of non-chlorinated petroleum hydrocarbons including 1t,2-dimethylcyclopentane (11 Vol %), methylcyclohexane (1.1 Vol %), n-nonane (1.2 Vol %), 1-3 ethylmethylbenzene (1.4 Vol %), 1,3,5-trimethylbenzene (0.9 Vol %). These petroleum hydrocarbons are not reported in the previous volatile organic compound analysis.

These data suggest a higher heat load to the oxidizer and a lower salt production due to the lower chlorine content. Given the variability of the DNAPL and NAPL present in the treatment zone, we expect to use these and other available data to establish the upper ranges of the design criteria (e.g., heat load and salt production rates) for the off-gas treatment system.

Please contact me at the number above with any questions.

Sincerely,

TerraTherm, Inc.

Robin Swift Project Manager

cc: John Hunt, de maximis, inc.

Encl.



HOUSTON LABORATORIES 8820 INTERCHANGE DRIVE HOUSTON, TEXAS 77054 PHONE (713) 660-0901

July 07, 2009

Certificate of Analysis

Number: 1030-2009060590-001A

Robin Swift Terra Therm, Inc. 10 Stevens Road Fitchburg Maine 01420

Sample ID: Project Name : Project Number : Project Location: Sample Point: DNAPL SRSNE

Sampled By: Sample Of:	RS Liquid	
Sample Date:	03/27/2009	11:30
Sample Condition: PO / Ref. No:	9101-002	

ANALYTICAL DATA

Test	Method	Result	Unit	Detection Limit	Lab Tech.	Date Analyzed
Heat of Combustion	ASTM-D-240	13012	Gross BTU /	b	EM	07/07/09
Heat of Combustion	ASTM-D-240	NR	Net BTU/lb		EM	07/07/09
Heat of Combustion	ASTM-D-240	NR	Gross BTU/G	ial	EM	07/07/09
Heat of Combustion	ASTM-D-240	NR	Net BTU/Ga	al	EM	07/07/09
Flash Point, (PM)	ASTM-D-93	72	°F		MES	07/01/09

Comments: NR= No result Sample On: 03/27/2009 11:30

Cles Staley

Hydrocarbon Laboratory Manager

Quality Assurance: The above analyses are performed in accordance with ASTM, UOP or GPA guidelines for quality assurance, unless otherwise stated.



HOUSTON LABORATORIES 8820 INTERCHANGE DRIVE HOUSTON, TEXAS 77054 PHONE (713) 660-0901

11:30

Certificate of Analysis

Number: 1030-2009060590-001A

July 08, 2009

Robin Swift Terra Therm, Inc. 10 Stevens Road Fitchburg Maine 01420

Sample ID: Project Name : Project Number : Project Location: Sample Point: DNAPL SRSNE Sampled By:RSSample Of:LiquidSample Date:03/27/2009Sample Conditions:9101-002

ANALYTICAL DATA

ASTM D86 Distillation

% Recovery	° F @ 762 mm Hg	Lab Tech.	Date Analyzed
Initial Boiling Point	168	BAC	07/08/09
5	170		
10	216		
20	228		
30	252		
40	262		
50	280		
60	306		
70	366		
80	640		
85	662		
90	670		
95	NR		
Final Boiling Point	672		
Volume % Recovery	94.0		
Volume% Residue	5.0		
Volume % Loss	1.0		

Comments: Modified: Used 50 mL of sample, due to foaming. Visual color is dark straw. Residue and loss are observed. Temperatures are uncorrected for baromteric pressure. Sample cracked at 672°F and 94 volume % recovery. NR - No Result

Sample On: 03/27/2009 11:30

Clas Staley

Hydrocarbon Laboratory Manager

Quality Assurance: The above analyses are performed in accordance with ASTM, UOP or GPA guidelines for quality assurance, unless otherwise stated



Certificate of Analysis

HOUSTON LABORATORIES 8820 INTERCHANGE DRIVE HOUSTON, TEXAS 77054 PHONE (713) 660-0901

Analysis Number:	2009060590-001A					
Sample ID: Project:	DNALP SRSNE		Date of Sample: Time Sampled:	06/24/09		
Project Location:			Date Sample Analyzed:	07/06/09		
Client Address Suife / Department	TerraTherm, Inc. 10 Stevens Road		Contact(s):	Robin Swift		
City	Fitchburg		State	Maine	Zip	6241
Phone	(978) 343-0300	Ext	E-Mail	rswift@terrather	m.com	
Fax	(978) 343-2727					
Color:	Dark		Odor:	Aromatic		
Specific Gravity @ 60° F.	1.0452		API @ 60° F.	3.75		
Carbon Range	C5 - C26, C30+		Major Range	C7 - C10		
Paraffin	7.1161	wt%	N-Hexane	0.475	wt%	
Isoparaffins	12.1770	wt%	Benzene	0.020	wt%	
Naphthenics	24.3064	wt%	Ethyl Benzene	6.957	wt%	
Aromatics	55.1495	wt%	Toluene	12.989	wt%	
Olefins	1.1291	wt%	Meta-Xylene	12.045	wt%	
Unknowns	N/D	wt%	Para-Xylene	3.434	wt%	
2,2,4-Tri Methylpentane	N/D	wt%	Ortho-Xylene	4.913	wt%	
			Xylenes	20.392	wt%	
Calculated Research Octane	N/A		EDB	N/A	wt%	
Lead / Manganese	N/A		EDC	N/A	wt%	
Oxygnates	0.0598	wt%	Ethanol	N/D	wt%	
C ₁₇	0.074	wt%	C ₁₈	0.061	wt%	
Pristane	N/D	wt%	Phytane	N/D	wt%	
Naphthalene	0.162	wt%	2-Methyl Naphthalene	N/D	wt%	
1-Methyl Naphthalene	0.033	wt%				
	Gasoline Range:	C4-C13 Indicators:	2,2,4-TMP; MTBE; Olefins,	Lead		
	Diesel Range:	C7-C20 Indicators:	Pristane, Phytane			
	Condensate Range:	C2-C25+ Indicators:	No Olefins, Light & Heavies	3		
	Heavy Oil:	C ₂₀₊				
Comments:	N/A Not Applicable	N/D None Detecte	d			

as Staley

Chris Staley Hydrocarbon Laboratory Manager

Detailed Hydrocarbon Analysis Summary Report -

Report Date: 7/6/2009 1:37:30 PM

RawFile: M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf Sample: 2009060590-001A JL Processed 214 Peaks Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA Comments: Acquired: 07/06/09 06:07:02 Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

		รเ	JMMARY REP	ORT		
	Group Type	Total(Mass%	<u>)</u> <u>Total</u>	<u>(Vol%)</u>	<u>Total(Mol%)</u>	
	Paraffins:	7.1161	7,612	24	6.1009	
	I-Paraffins:	12.1770	12.85	523	10.3308	
	Olefins:	1.1291	1.271	17	1.4815	
	Napthenes:	24.3064	24.61	142	26.3440	
	Aromatics:	55.1495	53.52	287	55.5128	
	Total C30+:	0.0621	0.062	21	0.0167	
Tota	I Unknowns:	0.0000	0.000	00	0.0000	
Ovurgenetee:						
		0.0509/140009/1	0.059604	-196)		
l otal:		0.0596(Wass %)	0.0000(10	JI 70)		
Total Oxyge	en Content:	0.0299(Mass%)				
Multisubstituted Aromatic	S:	12.4159(Mass%)	11.0073(\	/ol%)		
Average Molecular Weig	ht: 114.2696					
Relative Density: 0.7745						
Vapor Pressure: 0.3383						
Calculated Octane Numb	er: 87.9106					
	IBP	T10	T50	Т90	FBP	
Boiling Point (Deg F)	145.89	197.37	277.16	354.68	695.48	
Percent Carbon: 89.8540)	Percent Hy	drogen: 10.116	1		

Bromine Number (Calc): 2.0700

Report Date: 7/6/2009 1:37:30 PM

RawFile: M:\ExtendedGas Resul	s\CDF\2009060590-001A	dat-Detector 1.cdf		Acquired: 07/06/09 06:07:02
Sample: 2009060590-001A JL				Analyzed: 7/6/2009 1:31:39 PM
Processed 214 Peaks				
Reference File: H:\DHA Applicati	ion Software\References\E	DHA REF0906 JL_0604200	9.DHA	
Comments:				Normalized to 100.0000%
)xygenates <u>Compound</u>	<u>Mass%</u>	<u>Mass% Oxygen</u>	<u>Vol%</u>	
)xygenates <u>Compound</u> methanol : X1	<u>Mass%</u> 0.060	<u>Mass% Oxygen</u> 0.030	<u>Vol%</u> 0.059	

Group	Avg ww.	Avg Rel. De
C1	0.000	0.000
C2	0.000	0.000
C3	0.000	0.000
C4	0.000	0.000
C5	70.847	0.634
C6	84.955	0.685
C7	95.326	0.797
C8	118.172	0.744
C9	122.517	0.823
C10	138.237	0.793
C11	152.735	0.777
C12	157.697	0.832
C13	184.370	0.756
C14	198.390	0.763
C15	205.000	1.020
C16	226.450	0.773
C17	233.964	0.776
C18	242.605	0.778
C19	268.530	0.777
C20	272.904	0.781
C21	287.532	0.790
C22	310.610	0.794
C23	324.640	0.797
C24	332.426	0.798
C25	352.690	0.800
C26	352.690	0.800
C27	0.000	0.000
C28	0.000	0.000

Acquired: 07/06/09 06:07:02 RawFile: M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf Analyzed: 7/6/2009 1:31:39 PM Sample: 2009060590-001A JL Processed 214 Peaks Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA Normalized to 100.0000% Comments:

C29	370.000	0.800
Total Sample:	114.00	0.77

Octane Number

Research Octane Number: 87.90 (Calculated from Individual Component Values)

Contribution to Total by:

Paraffins:	4.45
Iso-Paraffins:	9.29
Aromatics:	51.80
Napthenes:	20.80
Olefins:	1.49
Oxygenates:	0.06

Report Date: 7/6/2009 1:37:30 PM

RawFile: M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf Sample: 2009060590-001A JL Processed 214 Peaks Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA

Comments:

Normalized to 100.0000%

Acquired: 07/06/09 06:07:02 Analyzed: 7/6/2009 1:31:39 PM

Totals by Group Type & Carbon Number (in Mass Percent)

	<u>Paraffins</u>	<u>I-Paraffins</u>	<u>Olefins</u>	<u>Napthenes</u>	<u>Aromatics</u>	<u>Total</u>
C1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C5	0.02603	0.01251	0.02834	0.00000	0.00000	0.06688
C6	0.47467	0.46119	0.78717	0.43464	0.02031	2.17798
C7	0.70913	1.19301	0.31361	11.90179	12.98879	27.10634
C8	0.79310	0.78089	0.00000	10.06922	27.34829	38.99150
C9	1.12467	2.29221	0.00000	0.94171	9.35776	13.71635
C10	1.79466	3.93828	0.00000	0.95905	4.50203	11.19402
C11	1.16308	2.12563	0.00000	0.00000	0.70634	3.99505
C12	0.22563	0.52756	0.00000	0.00000	0.22594	0.97913
C13	0.11350	0.00000	0.00000	0.00000	0.00000	0.11350
C14	0.07249	0.00000	0.00000	0.00000	0.00000	0.07249
C15	0.08867	0.00000	0.00000	0.00000	0.00000	0.08867
C16	0.06105	0.00000	0.00000	0.00000	0.00000	0.06105
C17	0.07439	0.06076	0.00000	0.00000	0.00000	0.13515
C18	0.06105	0.32316	0.00000	0.00000	0.00000	0.38421
C19	0.06032	0.00000	0.00000	0.00000	0.00000	0.06032
C20	0.05133	0.10768	0.00000	0.00000	0.00000	0.15901
C21	0.04422	0.07676	0.00000	0.00000	0.00000	0.12098
C22	0.03742	0.00000	0.00000	0.00000	0.00000	0.03742
C23	0.03261	0.00000	0.00000	0.00000	0.00000	0.03261
C24	0.06320	0.04859	0.00000	0.00000	0.00000	0.11179
C25	0.04488	0.00000	0.00000	0.00000	0.00000	0.04488
C26	0,00000	0.19051	0.00000	0.00000	0.00000	0.19051
C27	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C28	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C29	0.00000	0.03823	0.00000	0.00000	0.00000	0.03823
Total:	7.11609	12.17697	1.12913	24.30641	55.14947	99.87806
	Oxygenates	0.05981		Total C30+:	0.06213	
	Total Unknow	vns: 0.0000	0	Grand Total:	100.00000	

Totals by Group Type & Carbon Number (in Volume Percent)

	Paraffins 1	<u>l-Paraffins</u>	<u>Olefins</u>	<u>Napthenes</u>	<u>Aromatics</u>	<u>Total</u>
C1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C5	0.03222	0.01564	0.03384	0.00000	0.00000	0.08170
C6	0.55784	0.54297	0.89973	0.44383	0.01791	2.46227
C7	0.80377	1.34472	0.33811	12.24896	11.60969	26.34525
C8	0.87489	0.86012	0.00000	10.06504	28.81349	40.61353

Report Date: 7/6/2009 1:37:30 PM

RawFile: M:\E Sample: 2009 Processed 2' Reference Fi	ExtendedGas Resu 9060590-001A JL 14 Peaks le: H:\DHA Applicat	Acquired: 07/06/09 06:07:02 Analyzed: 7/6/2009 1:31:39 PM				
Comments:						Normalized to 100.0000%
C9	1,21455	2.46600	0.00000	0.92661	8.31416	12.92131
C10	1.90515	4.14446	0.00000	0.92975	3.96227	10.94164
C11	1.21146	2.16049	0.00000	0.00000	0.61447	3.98641
C12	0.23221	0.48358	0.00000	0.00000	0.19674	0.91253
C13	0.11628	0.00000	0.00000	0.00000	0.00000	0.11628
C14	0.07364	0.00000	0.00000	0.00000	0.00000	0.07364
C15	0.06737	0.00000	0.00000	0.00000	0.00000	0.06737
C16	0.06118	0.00000	0.00000	0.00000	0.00000	0.06118
C17	0.07410	0.06088	0.00000	0.00000	0.00000	0.13499
C18	0.06090	0.32189	0.00000	0.00000	0.00000	0.38279
C19	0.06013	0.00000	0.00000	0.00000	0.00000	0.06013
C20	0.05044	0.10734	0.00000	0.00000	0.00000	0.15778
C21	0.04329	0.07543	0.00000	0.00000	0.00000	0.11872
C22	0.03650	0.00000	0.00000	0.00000	0.00000	0.03650
C23	0.03171	0.00000	0.00000	0.00000	0.00000	0.03171
C24	0.06129	0.04725	0.00000	0.00000	0.00000	0.10854
C25	0.04347	0.00000	0.00000	0.00000	0,00000	0.04347
C26	0.00000	0.18454	0.00000	0.00000	0.00000	0.18454
C27	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C28	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C29	0.00000	0.03703	0.00000	0.00000	0.00000	0.03703
Total:	7.61238	12.85235	1.27167	24.61418	53.52873	99.87931
	Oxygenates	0.05856		Total C30+:	0.06212	
	Total Unknow	wns: 0.000	000	Grand Total:	100.00000	

Report Date: 7/6/2009 1:37:30 PM

RawFile: M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf Sample: 2009060590-001A JL Processed 214 Peaks Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA

Comments:

Acquired: 07/06/09 06:07:02 Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Totals by Group Type & Carbon Number (in Mol Percent)

	<u>Paraffins</u>	<u>I-Paraffins</u>	<u>Olefins</u>	<u>Napthenes</u>	<u>Aromatics</u>	<u>Total</u>
C1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C5	0.04125	0.01982	0.04686	0.00000	0.00000	0.10794
C6	0.62977	0.61190	1.06941	0.59047	0.02974	2.93129
C7	0.80915	1.36127	0.36519	13.85926	16.11747	32.51235
C8	0.79383	0.78162	0.00000	10.25963	25.89138	37.72647
C9	1.00260	2.04342	0.00000	0.85291	8.90176	12.80069
C10	1,44215	3.16733	0.00000	0.78175	3,86751	9.25873
C11	0.85076	1.59425	0.00000	0.00000	0.54571	2.99071
C12	0.15145	0.39927	0.00000	0.00000	0.15920	0.70992
C13	0.07039	0.00000	0.00000	0.00000	0.00000	0.07039
C14	0.04178	0.00000	0.00000	0.00000	0.00000	0.04178
C15	0.04945	0.00000	0,00000	0.00000	0.00000	0.04945
C16	0.03082	0.00000	0.00000	0.00000	0.00000	0.03082
C17	0.03537	0.03068	0.00000	0.00000	0.00000	0.06605
C18	0.02742	0.15365	0.00000	0.00000	0.00000	0.18107
C19	0.02568	0.00000	0.00000	0.00000	0.00000	0.02568
C20	0.02077	0.04585	0.00000	0.00000	0.00000	0.06662
C21	0.01705	0.03106	0.00000	0.00000	0.00000	0.04811
C22	0.01377	0.00000	0.00000	0.00000	0.00000	0.01377
C23	0.01148	0.00000	0.00000	0.00000	0.00000	0.01148
C24	0.02134	0.01711	0.00000	0.00000	0.00000	0.03845
C25	0.01455	0.00000	0.00000	0.00000	0.00000	0.01455
C26	0.00000	0.06176	0.00000	0.00000	0.00000	0.06176
C27	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C28	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C29	0.00000	0.01181	0.00000	0.00000	0.00000	0.01181
Total:	6.10085	10.33080	1.48146	26.34401	55.51276	99,76989
	Oxygenates	0.21343		Total C14+:	0.01668	
	Total Unknow	wns: 0.0000	0	Grand Total:	100.00000	

Report Date: 7/6/2009 1:37:30 PM

RawFile: M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf Sample: 2009060590-001A JL Processed 214 Peaks Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA Comments: Acquired: 07/06/09 06:07:02 Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Components Listed in Chromatographic Order Pa							
<u>Minutes</u>	Index	Group	Component	<u>Mass %</u>	Volume %	<u>Mol %</u>	
8.183	378.330	X1	methanol	0.060	0.059	0.213	
9.810	474.970	15	i-pentane	0.013	0.016	0.020	
10.550	500.000	P5	n-pentane	0.026	0.032	0.041	
10.967	512.150	05	t-pentene-2	0.015	0.018	0.024	
11.663	529.730	O5	3-methylbutadiene-1,2	0.014	0.016	0.023	
11.957	536.330	16	2,2-dimethylbutane	0.017	0.020	0.022	
13.533	565.950	16	2,3-dimethylbutane	0.035	0.041	0.047	
13.770	569.740	16	2-methylpentane	0.217	0.257	0.287	
14.723	583.760	16	3-methylpentane	0.193	0.225	0.256	
15.310	591.520	06	hexene-1	0.787	0.900	1.069	
16.003	600.000	P6	n-hexane	0.475	0.558	0.630	
18.133	626.980	17	2,2-dimethylpentane	0.025	0.029	0.029	
18.343	629.350	N6	methylcyclopentane	0.281	0.291	0.382	
18.710	633.380	17	2,4-dimethylpentane	0.033	0.038	0.037	
19.143	637.980	17	2,2,3-trimethylbutane	0.328	0.369	0.375	
20.680	653.040	A6	benzene	0.020	0.018	0.030	
21.330	658.900	17	3,3-dimethylpentane	0.021	0.023	0.024	
21.713	662.230	N6	cyclohexane	0.154	0.153	0.209	
22.760	670.900	17	2-methylhexane	0,250	0.285	0.285	
22.957	672.460	17	2,3-dimethylpentane	0.090	0.100	0.102	
23.270	674.910	N7	1,1-dimethylcyclopentane	0.048	0.049	0.055	
23.783	678.820	17	3-methylhexane	0.294	0.332	0.336	
24.547	684.420	N7	1c,3-dimethylcyclopentane	0.092	0.095	0.107	
24.997	687.610	N7	1t,2-dimethylcyclopentane	10.668	11.003	12.423	
25.220	689.160	17	3-ethylpentane	0.153	0.170	0.174	
26.860	700.000	P7	n-heptane	0.709	0.804	0.809	
28.193	711.430	07	3-methyl-t-hexene-2	0.314	0.338	0.365	
29.463	721.670	N7	methylcyclohexane	1.094	1.102	1.274	
29.907	725.110	N8	1,1,3-trimethylcyclopentane	0.100	0.104	0.102	
30.610	730.420	18	2,5-dimethylhexane	0.117	0.130	0.117	
31.080	733.890	18	2,2,3-trimethylpentane	0.082	0.089	0.082	
31.273	735.290	N8	1c,2t,4-trimethylcyclopentane	0.064	0.065	0.065	
31.540	737.210	18	3,3-dimethylhexane	0.097	0.106	0.097	
32.320	742.710	N8	1t,2c,3-trimethylcyclopentane	0.083	0.084	0.085	
32.533	744.190	18	2,3,4-trimethylpentane	0.033	0.035	0.033	
33.353	749.740	18	1	0.080	0.086	0.080	
34.243	755.570	A7	toluene	12.989	11.610	16.117	
35.370	762.680	N8	1,1,2-trimethylcyclopentane	0.093	0.093	0.094	

Report Date: 7/6/2009 1:37:30 PM

RawFile: M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf Sample: 2009060590-001A JL Processed 214 Peaks Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA Comments: Acquired: 07/06/09 06:07:02 Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Components Listed in Chromatographic Order Page: 8							
<u>Minutes</u>	<u>Index</u>	Group	Component	<u>Mass %</u>	<u>Volume %</u>	<u>Mol %</u>	
36.290	768.280	18	2-methylheptane	0.373	0.414	0.373	
36.517	769.630	N8	1c,2c,4-trimethylcyclopentane	0.110	0.112	0.112	
36.777	771.170	N8	1c,3-dimethylcyclohexane	0.037	0.037	0.037	
37.463	775.170	N8	1t,4-dimethylcyclohexane	0.269	0.273	0.274	
37.680	776.420	N8	1,1-dimethylcyclohexane	0.386	0.383	0.393	
37.993	778.200	19	2,2,5-trimethylhexane	0.151	0.165	0.134	
38.907	783.290	N8	3c-ethylmethylcyclopentane	0.051	0.051	0.052	
39.497	786.500	N8	3t-ethylmethylcyclopentane	0.037	0.038	0.038	
39.877	788.540	N8	2t-ethylmethylcyclopentane	0.042	0.042	0.042	
40.087	789.660	N8	1,1-methylethylcyclopentane	0.069	0.068	0.070	
40.970	794.280	N8	1t,2-dimethylcyclohexane	0.169	0.169	0.172	
41.590	797,450	N8	1t,3-dimethylcyclohexane	8.185	8.173	8.339	
42.097	800.000	P8	n-octane	0.793	0.875	0.794	
42.287	801.090	N8	1c,4-dimethylcyclohexane	0.095	0.094	0.097	
46.073	821.840	N8	N2	0.029	0.029	0.030	
46.947	826.340	N8	N3	0.092	0.091	0.094	
48.087	832.070	19	2,2-dimethylheptane	0.334	0.364	0.298	
48.420	833.710	N8	N4	0.160	0.159	0.163	
49.327	838.110	19	2,2,3-trimethylhexane	0.180	0.195	0.161	
49.917	840.930	19	4,4-dimethylheptane	0.153	0.166	0.136	
52.253	851.710	A8	ethylbenzene	6.957	6.218	7.492	
53.007	855.070	19	13	0.082	0.087	0.073	
54.500	861.560	A8	m-xylene	12.045	13.674	10.909	
54.777	862.740	A8	p-xylene	3.434	3.899	3.110	
55.103	864.130	N9	1c,3c,5c-trimethylcyclohexane	0.131	0.130	0.118	
57.053	872.200	19	15	0.139	0.148	0.124	
57.307	873.230	19	4-ethylheptane	0.200	0.215	0.178	
58.613	878.440	19	3-ethylheptane	0.802	0.856	0.715	
58.787	879.120	19	3-methyloctane	0.251	0.270	0.224	
59.627	882.390	A8	o-xylene	4.913	5.023	4.380	
60.993	887.600	N9	N18	0.061	0.061	0.055	
61.210	888.410	N9	N19	0.193	0.191	0.174	
61.660	890.090	N9	N20	0.119	0.118	0.108	
64.390	900.000	P9	n-nonane	1.125	1.215	1.003	
64.770	902.900	N9	1,1-methylethylcyclohexane	0.167	0.160	0.151	
66.050	912.530	A9	i-propylbenzene	0.296	0.266	0.282	
66.573	916.410	110	11	0.107	0.114	0.086	
66.963	919.280	N9	i-propylcyclohexane	0.066	0.064	0.060	

Report Date: 7/6/2009 1:37:30 PM

RawFile: M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf Sample: 2009060590-001A JL Processed 214 Peaks Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA Comments:

Acquired: 07/06/09 06:07:02 Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Components Listed in Chromatographic Order Pag							Page: 9
<u>Minutes</u>	Index	Group	<u>Component</u>	<u>Mass %</u>	<u>Volume %</u>	<u>Mol %</u>	
67.353	922.130	110	112	0.034	0.037	0.028	
67.683	924.530	110	2,4-dimethyloctane	0.146	0.156	0.117	
68.447	930.020	N9	N29	0.090	0.088	0.081	
68.747	932.160	110	2,6-dimethyloctane	0.292	0.311	0.235	
68.877	933.090	110	2,5-dimethyloctane	0.149	0.159	0.120	
69.310	936.150	N9	n-butylcyclopentane	0.117	0.115	0.106	
69.533	937.730	N10	N30	0.075	0.073	0.061	
70.253	942.760	110	3,3-dimethyloctane	0.400	0.419	0.321	
70.540	944.740	N10	N31	0.068	0.065	0.055	
70.800	946.540	A9	n-propylbenzene	0.686	0.617	0.653	
71.100	948.600	110	3,6-dimethyloctane	0.077	0.081	0.062	
71.310	950.040	110	3-methyl-5-ethylheptane	0.160	0.171	0.129	
71.670	952.490	N10	N32	0.047	0.045	0.038	
71.953	954.410	A9	1,3-methylethylbenzene	1.582	1.418	1.505	
72.237	956.330	A9	1,4-methylethylbenzene	0.730	0.657	0.694	
72.793	960.060	N10	N33	0.139	0.134	0.113	
73.080	961.970	A9	1,3,5-trimethylbenzene	1.014	0.908	0.964	
73.227	962.940	110	2,3-dimethyloctane	0.566	0.595	0.455	
73.373	963.920	110	115	0.118	0.124	0.095	
73.700	966.070	110	116	0.069	0.073	0.056	
74.003	968.070	110	5-methylnonane	0.104	0.110	0.084	
74.243	969.640	110	4-methylnonane	0.286	0.299	0.230	
74.363	970.420	A9	1,2-methylethylbenzene	0.832	0.732	0.792	
74.603	971.990	110	2-methylnonane	0.337	0.360	0.271	
74.853	973.610	110	C10-Iso-Paraffin	0.063	0.068	0.051	
75.027	974.730	110	3-ethyloctane	0.151	0.158	0.121	
75.233	976.060	N10	N35	0,106	0.103	0.087	
75.457	977.500	110	3-methylnonane	0.335	0.354	0.269	
75.660	978.800	N10	N36	0.156	0.151	0.127	
76.017	981.080	110	119	0.110	0.116	0.089	
76.387	983.430	A9	1,2,4-trimethylbenzene	3.342	2.957	3.179	
76.637	985.010	N10	i-butylcyclohexane	0.253	0.247	0.206	
76.993	987.250	110	121	0.254	0.266	0.204	
77.123	988.070	110	122	0.046	0.048	0.037	
77.287	989.090	110	123	0.042	0.044	0.034	
77.467	990.210	N10	N37	0.053	0.051	0.043	
77.613	991.130	110	C10-Iso-Paraffin	0.045	0.044	0.037	
78.110	994.210	N10	1t-methyl-2-n-propylcyclohexan	e0.033	0.032	0.027	

Report Date: 7/6/2009 1:37:30 PM

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Normalized to 100.0000%

Components Listed in Chromatographic Order						
<u>Minutes</u>	Index Group	Component	<u>Mass %</u>	<u>Volume %</u>	<u>Mol %</u>	
78.317	995.480 A10	i-butylbenzene	0.080	0.073	0.068	
78.717	997.940 A10	sec-butylbenzene	0.118	0.106	0.100	
78.833	998.650 I10	C10-lso-Paraffin	0.043	0.039	0.037	
79.053	1000.000 P10	n-decane	1.795	1.905	1.442	
79.287	1002.350 11	126	0.050	0.052	0.036	
79.740	1006.920 A9	1,2,3-trimethylbenzene	0.875	0.758	0.833	
80.003	1009.550 A10	1,3-methyl-i-propylbenzene	0.165	0.149	0.141	
80.380	1013.310 A10	1,4-methyl-i-propylbenzene	0.148	0.134	0.126	
81.000	1019.440 A10	2-3-dihydroindene	0.198	0.159	0.192	
81.360	1022.990 N10	sec-butylcyclohexane	0.030	0.028	0.024	
81.543	1024.780 11	130	0.276	0.289	0.202	
81.877	1028.040 A10	1,2-methyl-i-propylbenzene	0.439	0.388	0.374	
82.270	1031.860 [11	3-ethylnonane	0.126	0.131	0.092	
82.417	1033.280 111	31	0.373	0.390	0.273	
82.870	1037.650 111	132	0.088	0.085	0.065	
83.073	1039.600 A10	1,3-diethylbenzene	0.164	0.147	0.140	
83.167	1040.500 11	C11-Iso-Paraffin	0.072	0.064	0.061	
83.357	1042.310 A10	1,3-methyl-n-propylbenzene	0.413	0.372	0.352	
83.623	1044.860 A10	1,4-diethylbenzene	0.110	0.099	0.093	
83.763	1046.190 A10	1,4-methyl-n-propylbenzene	0.142	0.128	0.121	
83.887	1047.360 A10	n-butylbenzene	0.139	0.125	0.119	
84.100	1049.380 A10	1,3-dimethyl-5-ethylbenzene	0.249	0.220	0.213	
84.313	1051.400 A10	1,2-diethylbenzene	0.042	0.037	0.036	
84.507	1053.220 11	C11-Iso-Paraffin	0.052	0.046	0.044	
84.673	1054.790 [11	C11-Iso-Paraffin	0.181	0.159	0.154	
84.980	1057.660 A10	1,2-methyl-n-propylbenzene	0.199	0.176	0.169	
85.147	1059.220 11	135	0.038	0.040	0.028	
85.527	1062.760 11	137	0.315	0.330	0.230	
85.847	1065.720 11	138	0.200	0.209	0.146	
86.063	1067.720 A10	1,4,dimethyl-2-ethylbenzene	0.190	0.168	0.162	
86.227	1069.230 A10	A3	0.395	0.356	0.336	
86.423	1071.040 11	139	0.135	0.141	0.099	
86.850	1074.950 A10	1,2-dimethyl-4-ethylbenzene	0.438	0.388	0.373	
87.433	1080.260 A10	1,3-dimethyl-2-ethylbenzene	0.094	0.081	0.080	
87.683	1082.520 11	142	0.076	0.080	0.056	
88.060	1085.920 11	143	0.060	0.062	0.044	
88.190	1087.080 J11	C11-Iso-Paraffin	0.037	0.039	0.027	
88.457	1089.480 A12	1,3-di-n-propylbenzene	0.049	0.043	0.034	
Detailed Hydrocarbon Analysis Detail Report -

Report Date: 7/6/2009 1:37:30 PM

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Normalized to 100.0000%

Hold

		Components Listed in Chrom	atographic	Order		Page: 11
<u>Minutes</u>	Index Group	<u>Component</u>	<u>Mass %</u>	<u>Volume %</u>	<u>Mol %</u>	
88.680	1091.470 A11	1,4-methyl-t-butylbenzene	0.076	0.069	0.058	
88.830	1092.810 A10	1,2-dimethyl-3-ethylbenzene	0.135	0.117	0.115	
89.293	1096.930 A11	1,2-ethyl-i-propylbenzene	0.053	0.047	0.041	
89.407	1097.930 11	C11-Iso-Paraffin	0.047	0.041	0.036	
89.640	1100.000 P11	n-undecane	1.163	1.211	0.851	
89.897	1103.100 A11	1,4-ethyl-i-propylbenzene	0.050	0.043	0.038	
90.020	1104.590 A10	1,2,4,5-tetramethylbenzene	0.159	0.139	0.136	
90.333	1108.370 A11	1,2-methyl-n-butylbenzene	0.203	0.177	0.157	
90.517	1110.570 A10	1,2,3,5-tetramethylbenzene	0.096	0.083	0.082	
90.973	1116.030 A11	1,2-methyl-t-butylbenzene	0.044	0.039	0.034	
91.430	1121.470 12	C12-lso-Paraffin	0.084	0.073	0.064	
91.900	1127.030 A10	5-methylindan	0.141	0.123	0.122	
92.047	1128.760 112	C12-Iso-Paraffin	0.063	0.055	0.055	
92.293	1131.660 112	l44	0.136	0.140	0.091	
92.487	1133.930 A10	4-methylindan	0.036	0.031	0.031	
92.763	1137.170 A11	1,2-ethyl-n-propylbenzene	0.206	0.179	0.159	
93.200	1142.260 12	C12-Iso-Paraffin	0.113	0.098	0.087	
93.313	1143.570 A12	1,3-di-i-propylbenzene	0.030	0.026	0.021	
93.720	1148.280 A11	n-pentylbenzene	0.041	0.036	0.032	
94.600	1158.400 [12	C12-lso-Paraffin	0.063	0.055	0.049	
94.723	1159.810 A12	1,4-di-i-propylbenzene	0.057	0.050	0.040	
95.047	1163.500 A10	tetrahydronaphthalene	0.051	0.041	0.044	
95.237	1165.660 12	C12-Iso-Paraffin	0.036	0.029	0.031	
95.360	1167.060 A10	naphthalene	0.162	0.122	0.144	
95.963	1173.870 A12	1,4-ethyl-t-butylbenzene	0.052	0.045	0.036	
96.270	1177.320 12	145	0.034	0.034	0.022	
98.313	1200.000 P12	n-dodecane	0.226	0.232	0.151	
99.580	1217.240 A12	1,3,5-triethylbenzene	0.039	0.034	0.027	
104.407	1280.830 A11	1-methylnaphthalene	0.033	0.025	0.026	
105.910	1300.000 P13	n-tridecane	0.113	0.116	0.070	
112.807	1400.000 P14	C14	0.072	0.074	0.042	
118.990	1498.400 P15	C15	0.089	0.067	0.049	
124.280	1598.940 P16	C16	0.061	0.061	0.031	
128.150	1682.930 17	C17-Iso-Paraffin	0.061	0.061	0.031	
128.893	1698.790 P17	C17	0,074	0.074	0.035	
129.147	1704.880 18	C18-Iso-Paraffin	0.032	0.031	0.015	
130.447	1736.970 18	C18-Iso-Paraffin	0.192	0.192	0.091	
131.363	1759.400 18	C18-Iso-Paraffin	0.099	0.099	0.047	

Detailed Hydrocarbon Analysis Detail Report -

Report Date: 7/6/2009 1:37:30 PM

RawFile: M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf Sample: 2009060590-001A JL Processed 214 Peaks Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA Comments: Acquired: 07/06/09 06:07:02 Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Hold

	C	omponents Listed in Chrom	atographic(Order		Page: 12
<u>Minutes</u>	Index Group	<u>Component</u>	Mass %	<u>Volume %</u>	<u>Mol %</u>	
133.017	1799.430 P18	C18	0.061	0.061	0.027	
136.763	1895.130 P19	C19	0.060	0.060	0.026	
137.687	1922.110 120	C20-Iso-Paraffin	0.108	0.107	0.046	
140.233	1998.320 P20	C20	0.051	0,050	0.021	
141.807	2047.880 121	C21-Iso-Paraffin	0.077	0.075	0.031	
143.477	2100.000 P21	C21	0.044	0.043	0.017	
146.553	2196.980 P22	C22	0.037	0.037	0.014	
149.767	2300.000 P23	C23	0.033	0.032	0.011	
150,150	2310.270 24	C24-Iso-Paraffin	0.049	0.047	0.017	
153.360	2395.280 P24	C24	0.063	0.061	0.021	
157.530	2496.880 P25	C25	0.045	0.043	0.015	
158.283	2512.420 126	C26-Iso-Paraffin	0.158	0.153	0.051	
159.760	2541.660 126	C26-Iso-Paraffin	0.032	0.031	0.010	
162.660	2598.260 P26	C26	0.000	0.000	0.000	
184.330	2890.320 (29	C29-Iso-Paraffin	0.038	0.037	0.012	
185.250	2900.080 +	C30+	0.000	0,000	0.000	
186,383	2910.220 +	C30+	0.062	0.062	0.017	















D	Signal 	turas Puras
ю́-Т 55	69.5333 : N30	Time
5-		: 69.5(
	予 0.2533 : 3,3-dimethyloctane	005
70,5	∽70.5400 : N31	
- Ľ	〒70.8000 : n-propylbenzene	ime:8
	ブ1.1000 : 3,6-dimethyloctane テ1 2100 : 2 methyl & ethylheptane	30.00
71.5		
2-	71.6700 : N32	
10	$\overline{7}$ 2.2367 : 1.4-methylethylbenzene	
+ 72.5		
7	¹ √72.7933 : N33	
- تى -	73.0800 : 1,3,5-trime wybenzene	
73.5	73.3733 : 115	
	¹ 73.7000 : I16	
4-	T4.0033 : 5-methylronane	
74.5	〒4.2433 : 4-methylnopane 74.3633 : 1,2-methylethylbenzene	~
5 Vinute	74.6033 : 2-methylnonane	
s 75	$\frac{1}{2}5.0267$: 3-ethylociane	
75	75.2333: N35 (75.4567: 3 mothylespane	
5	「54507 : Shieldynonalie 「5.6600 : N36	
76	一 万 6.0167 : I19	
76	T _{76.3867} : 1.2.4-trimethylbenzene	
5	予 6.6367 : i-butylcyclohexane	
7-	<u></u> <u></u> <u></u>	
7	$\begin{bmatrix} 77.1233 : 122 \\ 77.2867 : 123 \end{bmatrix}$	
7.5	ブ7.4667:N37 ブ7.6133:C10-Iso-Faraffin	
7 8		
7	☐78.1100 : 1t-methyl-2-n-propylcyclohexane ☐78.3167 : i-butylbenzene	
8-5 -5		
79	T/8./16/: sec-butylbenzene 78.8333 : C10-Iso-Raraffin T	
	79.0533 : n-decane 了9.2867 : I26	
- 79.5		
<u> 8</u> _	¹ 79.7400 : 1,2,3-trimethylbenzene	

	Signal	8 N
79.7)0906 ant Ti
л Л	Ξ_0 7400 · 1 2 3 trim thylbenzene	3059 me:
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-	80.0033:1,3-metnyl-i-propyldenzene	ALC 00
80 -	T80.3800 : 1,4-methyl-i-propylbenzene	ц Ч
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<u> 8</u> -		fend
	81.0000 ; 2-3-ainyatoinaene	edG 90.0
81.	至81.3600 : sec-butyleyclohexane	00 a 7
01	¹ 81.5433 : I30 (lesu
82 -	T81.8767 : 1,2-methyl-i-propylbenzene	0) stil
		DPV
82 -	82.2700 : 3-emylnomane	6005
5		060
8-	^王 82.8700 : 132	590-
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83.5	¹ 83.3567 : 1,3-methy{-n-propylbenzene	Adat
0,	T83.6233 : 1,4-diethylbenzene	Det
84 -	83.8867 : n-butylbe zene	čtor
	*84.1000 : 1,3-dimethyl-5-ethylbenzene	, 2
 	T84.3133 : 1,2-diethylbenzene T84.5067 : C11 Iso-Paraffin	(H
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× 8-	× 84.9800 : 1.2-methyl-n-propylbenzene	
	¹ 85.1467 : I35	
85.5	H _{85,5267,137}	
8-		
	86.2267 : A3	
86.5 -	¹ 86.4233 : 139	
87 -	86.8500 : 1,2-dimethyl-4-ethylbenzene	
- 87.5	₩ ₩ 87.4333 : 1,3-dimethyl-2-ethylbenzene	
	¹ 87.6833 : I42	
8 -		
	- 88,1900 : C11-lso-Faraffin	
38.5 -	*88.4567 : 1,3-di-n-propylbenzene	
	±88.6800 : 1,4-methyl-t-butylbenzene	
- 88		
~	基9.2933 : 1,2-ethyl-hpropylbenzene	
3 <u>9</u> -5	89.4067 : C11-Isó-Flaraffiń	
	89.5400 : n-undecane	
8-	-89.8967 : 1,4-ethyl-Apropylbenzene	

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9-	590.9733	8 : 1,2-r	nethy	l-t-buty	lbenz	ene												nded(≥:100
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2009060590-001A JL (M\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)

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2009060590-001A JL (M\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf) Start Time: 179.500 - End Time: 190.000

2009060590-001A JL (M\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 189.500 - End Time: 200.000



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Minutes



SPL, Inc.

Certificate of Analysis Number:										
<u>09071163</u>										
Report To:	Project Name: 2009060590/RRR03865A									
SPL, Inc.	Site: Houston, TX									
Chris Staley	Site Address:									
8820 Interchange Drive										
Houston	PO Number:									
TX	<u>State:</u> Texas									
77054-	State Cert. No.: T104704205-06-TX									
ph: (713) 660-0901 fax:	Date Reported:									

This Report Contains A Total Of 14 Pages

Excluding This Page, Chain Of Custody

And

Any Attachments

7/29/2009

Test results meet all requirements of NELAC, unless specified in the narrative.

Date



Case Narrative for:

SPL, Inc.

Certific	ate of Analysis Number:										
<u>09071163</u>											
Report To:	Project Name: 2009060590/RRR03865A										
SPL, Inc.	Site: Houston, TX										
Chris Staley	Site Address:										
8820 Interchange Drive											
Houston	PO Number:										
TX	<u>State:</u> Texas										
77054-	State Cert. No.: T104704205-06-TX										
ph: (713) 660-0901 fax:	Date Reported:										

SAMPLE RECEIPT:

All samples were received intact. The internal ice chest temperatures were measured on receipt and are recorded on the attached Sample Receipt Checklist.

GENERAL REPORTING COMMENTS:

Results are reported on a wet weight basis unless dry-weight correction is denoted in the units field on the analytical report (" mg/kg-dry " or " ug/kg-dry ").

Matrix spike (MS) and matrix spike duplicate (MSD) samples are chosen and tested at random from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data only for those samples which are spiked by the laboratory. Since the MS and MSD are chosen at random from an analytical batch, the sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group. The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The Laboratory Control Sample (LCS) and the Method Blank (MB) are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process.

Some of the percent recoveries and RPD's on the QC report for the MS/MSD may be different than the calculated recoveries and RPD's using the sample result and the MS/MSD results that appear on the report because, the actual raw result is used to perform the calculations for percent recovery and RPD.

Any other exceptions associated with this report will be footnoted in the analytical result page(s) or the quality control summary page(s).

Please do not hesitate to contact us if you have any questions or comments pertaining to this data report. Please reference the above Certificate of Analysis Number.

This report shall not be reproduced except in full, without the written approval of the laboratory. The reported results are only representative of the samples submitted for testing.

SPL, Inc, is pleased to be of service to you. We anticipate working with you in fulfilling all your current and future analytical needs.

I certify that this data package is in compliance with the terms and conditions of the contract, both technically and for completeness, for other than the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or by his designee, as verified by the following signature.

Agnes V. Vichaire

09071163 Page 1 7/29/2009

Agnes V. Vicknair Project Manager



SPL, Inc.

Certificate of Analysis	Number:
--------------------------------	---------

<u>09071163</u>					
<u>Report To:</u>	SPL, Inc. Chris Staley 8820 Interchange Drive			<u>Project Name:</u> <u>Site:</u> <u>Site Address:</u>	2009060590/RRR03865A Houston, TX
Fax To:	Houston TX 77054- ph: (713) 660-0901	fax: (713) 660-6035		<u>PO Number:</u> <u>State:</u> <u>State Cert. No.:</u> Date Reported:	Texas T104704205- 06 -TX

Client Sample ID	Lab Sample ID	Matrix	Date Collected	Date Received	COC ID	HOLD
2009060590-001B	09071163-01	Liquid	3/27/2009	7/22/2009 3:04:00 PM	H55633	

Ignes V. Vichaire

Agnes V. Vicknair Project Manager

7/29/2009

Date

Kesavalu M. Bagawandoss Ph.D., J.D. Laboratory Director

> Ted Yen Quality Assurance Officer

> > 09071163 Page 2 7/29/2009 2:03:15 PM



HOUSTON LABORATORY 8880 INTERCHANGE DRIVE HOUSTON, TX 77054

(713) 660-0901

Client Sample ID:2009060590-001B

Collected: 03/27/2009 0:00 Houston, TX

Site:

SPL Sample ID: 09071163-01

Analyses/Method	Result	QUAL Rep.Limi	t DII. Fac	tor Date Analyzed	Analyst	Seq. #
VOLATILE ORGANICS BY	METHOD 8260B		MCL	SW8260B U	nits: ug/Kg	
1,1,1,2-Tetrachloroethane	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
1,1,1-Trichloroethane	2400000 J	500000) 1000000	07/22/09 19:41	LU_L	5127155
1,1,2,2-Tetrachloroethane	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
1,1,2-Trichloroethane	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
1,1-Dichloroethane	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
1,1-Dichloroethene	94000	5000) 10000	07/22/09 18:19	LU_L	5127154
1,1-Dichloropropene	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
1,2,3-Trichlorobenzene	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
1,2,3-Trichloropropane	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
1,2,4-Trichlorobenzene	160000	5000) 10000	07/22/09 18:19	LU_L	5127154
1,2,4-Trimethylbenzene	7400000	500000) 1000000	07/22/09 19:41	LU_L	5127155
1,2-Dibromo-3-chloropropane	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
1,2-Dibromoethane	ND	50000) 10000	07/22/09 18:19	LU_L	5127154
1,2-Dichlorobenzene	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
1,2-Dichloroethane	ND	5000) 10000	07/22/09 18:19	ເບ_ເ	5127154
1,2-Dichloropropane	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
1,3,5-Trimethylbenzene	2100000 J	500000) 1000000	07/22/09 19:41	LU_L	5127155
1,3-Dichlorobenzene	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
1,3-Dichloropropane	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
1,4-Dichlorobenzene	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
2,2-Dichloropropane	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
2-Butanone	ND	20000) 10000	07/22/09 18:19	LU_L	5127154
2-Chloroethyl vinyl ether	ND	100000) 10000	07/22/09 18:19	LU_L	5127154
2-Chlorotoluene	ND	50000) 10000	07/22/09 18:19	LU_L	5127154
2-Hexanone	ND	100000) 10000	07/22/09 18:19	LU_L	5127154
4-Chlorotoluene	ND	50000) 10000	07/22/09 18:19	LU_L	5127154
4-Isopropyltoluene	320000	5000) 10000	07/22/09 18:19	LU_L	5127154
4-Methyl-2-pentanone	ND	100000) 10000	07/22/09 18:19	LU_L	5127154
Acetone	ND	100000) 10000	07/22/09 18:19	LU_L	5127154
Acrylonitrile	ND	50000) 10000	07/22/09 18:19	LU_L	5127154
Benzene	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
Bromobenzene	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
Bromochloromethane	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
Bromodichloromethane	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
Bromoform	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
Bromomethane	ND	100000) 10000	07/22/09 18:19	LU_L	5127154
Carbon disulfide	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
Carbon tetrachloride	ND	5000) 10000	07/22/09 18:19	LU_L	5127154
Chlorobenzene	ND	50000) 10000	07/22/09 18:19	LU_L	5127154

Qualifiers:

ND/U - Not Detected at the Reporting Limit

B/V - Analyte detected in the associated Method Blank

* - Surrogate Recovery Outside Advisable QC Limits

J - Estimated Value between MDL and PQL

E - Estimated Value exceeds calibration curve

TNTC - Too numerous to count

>MCL - Result Over Maximum Contamination Limit(MCL) D - Surrogate Recovery Unreportable due to Dilution

MI - Matrix Interference

09071163 Page 3 7/29/2009 2:03:24 PM



HOUSTON LABORATORY

8880 INTERCHANGE DRIVE HOUSTON, TX 77054 (713) 660-0901

Client Sample ID:2009060590-001B

Collected: 03/27/2009 0:00

SPL Sample ID: 09071163-01

		Sit	e: Hous	ton, TX		
Analyses/Method	Result	QUAL Re	əp.Limit	Dil. Factor	Date Analyzed	Analyst Seq. #
Chloroethane	ND		100000	10000	07/22/09 18:19 LU	J_L 512715
Chloroform	ND		50000	10000	07/22/09 18:19 LU	J_L 512715
Chloromethane	ND		100000	10000	07/22/09 18:19 LU	J_L 512715
Dibromochloromethane	ND		50000	10000	07/22/09 18:19 LU	J_L 512715
Dibromomethane	ND		50000	10000	07/22/09 18:19 LU	J_L 512715
Dichlorodifluoromethane	ND		100000	10000	07/22/09 18:19 LU	J_L 512715
Ethylbenzene	16000000	ŧ	5000000	1000000	07/22/09 19:41 LU	J_L 512715
Hexachlorobutadiene	ND		50000	10000	07/22/09 18:19 LU	J_L 512715
Isopropylbenzene	750000		50000	10000	07/22/09 18:19 LU	J_L 512715
Methyl tert-butyl ether	ND		50000	10000	07/22/09 18:19 LU	J_L 512715
Methylene chloride	ND		50000	10000	07/22/09 18:19 LU	J_L 512715
Naphthalene	220000		50000	10000	07/22/09 18:19 LU	J_L 5127154
n-Butylbenzene	330000		50000	10000	07/22/09 18:19 LU	J_L 5127154
n-Propylbenzene	1600000		50000	10000	07/22/09 18:19 LU	J_L 512715
sec-Butylbenzene	260000		50000	10000	07/22/09 18:19 LU	J_L. 5127154
Styrene	1500000		50000	10000	07/22/09 18:19 LU	J_L 512715
tert-Butylbenzene	ND		50000	10000	07/22/09 18:19 LU	J_L 5127154
Tetrachloroethene	82000000	ŧ	5000000	1000000	07/22/09 19:41 LU	J_L 512715
Toluene	29000000	E	5000000	1000000	07/22/09 19:41 LL	J_L 512715
Trichloroethene	100000000	e	5000000	1000000	07/22/09 19:41 LU	J_L 512715
Trichlorofluoromethane	ND		50000	10000	07/22/09 18:19 LU	J_L 5127154
Vinyl acetate	ND		100000	10000	07/22/09 18:19 LU	J_L 5127154
Vinyl chloride	ND		100000	10000	07/22/09 18:19 LU	J_L 5127154
cis-1,2-Dichloroethene	5200000	e	5000000	1000000	07/22/09 19:41 LU	J_L 512715
cis-1,3-Dichloropropene	ND		50000	10000	07/22/09 18:19 LU	J_L 5127154
m,p-Xylene	33000000	e	5000000	1000000	07/22/09 19:41 LU	J_L 512715
o-Xylene	9900000	ť	5000000	1000000	07/22/09 19:41 LU	J_L 512715
trans-1,2-Dichloroethene	ND		50000	10000	07/22/09 18:19 LU	J_L 5127154
trans-1,3-Dichloropropene	ND		50000	10000	07/22/09 18:19 LU	J_L. 5127154
Xylenes,Total	42900000	£	5000000	1000000	07/22/09 19:41 LU	J_L 512715
1,2-Dichloroethene (total)	5200000	£	5000000	1000000	07/22/09 19:41 LU	J_L 512715
Surr: 1,2-Dichloroethane-d4	86.1	%	78-116	10000	07/22/09 18:19 LU	J_L 5127154
Surr: 1,2-Dichloroethane-d4	88.8	%	78-116	1000000	07/22/09 19:41 LU	J_L 512715
Surr: 4-Bromofluorobenzene	96.3	%	74-125	10000	07/22/09 18:19 LU	J_L 5127154
Surr: 4-Bromofluorobenzene	97.7	%	74-125	1000000	07/22/09 19:41 LU	J_L 512715
Surr: Toluene-d8	98.9	%	82-118	10000	07/22/09 18:19 LU	J_L 5127154
Surr: Toluene-d8	97.9	%	82-118	1000000	07/22/09 19:41 LU	J_L 512715

Prep Method	Prep Date	Prep Initials	Prep Factor
SW5030B	07/22/2009 16:29	XML	1.00

Qualifiers:

ND/U - Not Detected at the Reporting Limit

B/V - Analyte detected in the associated Method Blank

* - Surrogate Recovery Outside Advisable QC Limits

- J Estimated Value between MDL and PQL
- E Estimated Value exceeds calibration curve

TNTC - Too numerous to count

>MCL - Result Over Maximum Contamination Limit(MCL) D - Surrogate Recovery Unreportable due to Dilution MI - Matrix Interference

> 09071163 Page 4 7/29/2009 2:03:25 PM

Quality Control Documentation

09071163 Page 5 7/29/2009 2:03:25 PM



SPL, Inc. 2009060590/RRR03865A

Analysis: Method:	Volatile Organics by SW8260B	Method 826)B		WorkOrder: Lab Batch ID:	09071163 R279002
	Meth	od Blank		Samples in Analytica	al Batch:	
RunID: K_09072	2C-5127153	Units:	ug/Kg	Lab Sample ID	<u>Client San</u>	nple ID
Analysis Date:	07/22/2009 17:25	Analyst:	LU_L	09071163-01A	200906059	90-001B

Analyte	Result	Rep Limit
1,1,1,2-Tetrachioroethane	ND	250
1,1,1-Trichloroethane	ND	250
1,1,2,2-Tetrachioroethane	ND	250
1,1,2-Trichloroethane	ND	250
1,1-Dichloroethane	ND	250
1,1-Dichloroethene	ND	250
1,1-Dichloropropene	ND	250
1,2,3-Trichlorobenzene	ND	250
1,2,3-Trichloropropane	ND	250
1,2,4-Trichlorobenzene	ND	250
1,2,4-Trimethylbenzene	ND	250
1,2-Dibromo-3-chloropropane	ND	250
1,2-Dibromoethane	ND	250
1,2-Dichlorobenzene	ND	250
1,2-Dichloroethane	ND	250
1,2-Dichloropropane	ND	250
1,3,5-Trimethylbenzene	ND	250
1.3-Dichlorobenzene	ND	250
1,3-Dichloropropane	ND	250
1,4-Dichlorobenzene	ND	250
2,2-Dichloropropane	ND	250
2-Butanone	ND	1000
2-Chloroethyl vinyl ether	ND	500
2-Chlorotoluene	ND	250
2-Hexanone	ND	500
4-Chlorotoluene	ND	250
4-Isopropyltoluene	ND	250
4-Methyl-2-pentanone	ND	500
Acetone	ND	5000
Acrylonitrile	ND	2500
Benzene	ND	250
Bromobenzene	ND	250
Bromochloromethane	ND	250
Bromodichloromethane	ND	250
Bromoform	ND	250
Bromomethane	ND	500
Carbon disulfide	ND	250
Carbon tetrachloride	ND	250
Chlorobenzene	ND	250
Chloroethane	ND	500
Chloroform	ND	250
Chloromethane	ND	500
Dibromochloromethane	ND	250
Dibromomethane	ND	250
Dichlorodifluoromethane	ND	500
Ethylbenzene	ND	250

Qualifiers:

ND/U - Not Detected at the Reporting Limit

MI - Matrix Interference

B/V - Analyte detected in the associated Method Blank J - Estimated value between MDL and PQL

D - Recovery Unreportable due to Dilution * - Recovery Outside Advisable QC Limits

E - Estimated Value exceeds calibration curve

N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.

TNTC - Too numerous to count

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

09071163 Page 6 7/29/2009 2:03:27 PM



HOUSTON LABORATORY 8880 INTERCHANGE DRIVE

HOUSTON, TX 77054 (713) 660-0901

SPL, Inc. 2009060590/RRR03865A

			24	JURRINGBUGA		
Analysia Method:	SW8260B	s by Method 826	0B	WorkOrder: Lab Batch ID:	09071163 R279002	
	-	Method Blank				
RunID:	K_090722C-5127153	Units:	ug/Kg			

Runio.	1(_030722	0-0121100	Units.	uyny
Analysis I	Date:	07/22/2009 17:25	Analyst:	LU_L

Analyte	Result	Rep Limit
Hexachlorobutadiene	ND	250
Isopropylbenzene	ND	250
Methyl tert-butyl ether	ND	250
Methylene chloride	ND	250
Naphthalene	ND	250
n-Butylbenzene	ND	250
n-Propylbenzene	ND	250
sec-Butylbenzene	ND	250
Styrene	ND	250
tert-Butylbenzene	ND	250
Tetrachloroethene	ND	250
Toluene	ND	250
Trichloroethene	ND	250
Trichlorofluoromethane	ND	250
Vinyl acetate	ND	500
Vinyl chloride	ND	500
cis-1,2-Dichloroethene	ND	250
cis-1,3-Dichloropropene	ND	250
m,p-Xylene	ND	250
o-Xylene	ND	250
trans-1,2-Dichloroethene	ND	250
trans-1,3-Dichloropropene	ND	250
1,2-Dichloroethene (total)	ND	250
Xylenes,Total	ND	250
Surr: 1,2-Dichloroethane-d4	92,4	78-116
Surr: 4-Bromofluorobenzene	97.5	74-125
Surr: Toluene-d8	100.0	82-118

Laboratory Cor	ntrol Sampl	<u>e (LCS)</u>
K 090722C-5127152	l inite:	ua/Ka

RuniD:	K_090722C-5127152	Units:	ug/Kg
Analysis Date:	07/22/2009 16:56	Analyst:	LU_L

Analyte	Spike Added	Result	Percent Recovery	Lower Limit	Upper Limit
1,1,1,2-Tetrachloroethane	20.0	23.3	116	71	128
1,1,1-Trichloroethane	20.0	18.5	92.7	61	135
1,1,2,2-Tetrachloroethane	20.0	20.1	100	60	133
1,1,2-Trichloroethane	20.0	21.7	109	77	127
1,1-Dichloroethane	20.0	15.8	78.9	68	132

Qualifiers:

B/V - Analyte detected in the associated Method Blank

J - Estimated value between MDL and PQL

ND/U - Not Detected at the Reporting Limit

E - Estimated Value exceeds calibration curve

MI - Matrix Interference

D - Recovery Unreportable due to Dilution

* - Recovery Outside Advisable QC Limits

N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.

TNTC - Too numerous to count

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

09071163 Page 7 7/29/2009 2:03:27 PM



SPL, Inc. 2009060590/RRR03865A

Analysis:	Volatile Organics by Method 8260B	WorkOrder:	09071163			
Method:	SW8260B	Lab Batch ID:	R279002			
Laboratory Control Sample (LCS)						

RunID:	K_090722C-5127152	Units:	ug/Kg
Analysis Date:	07/22/2009 16:56	Analyst:	ԼՍ_Լ

Analyte	Spike Added	Result	Percent Recovery	Lower Limit	Upper Limit
1,1-Dichloroethene	20.0	17.6	87.9	65	134
1,1-Dichloropropene	20.0	18.7	93.7	68	126
1,2,3-Trichlorobenzene	20.0	23.3	117	36	154
1,2,3-Trichloropropane	20.0	19.8	98.9	38	153
1,2,4-Trichlorobenzene	20.0	22.8	114	69	144
1,2,4-Trimethylbenzene	20.0	21.4	107	64	128
1,2-Dibromo-3-chloropropane	20.0	19.6	97.8	44	141
1,2-Dibromoethane	20.0	21.8	109	75	124
1,2-Dichlorobenzene	20.0	21.8	109	68	124
1,2-Dichloroethane	20.0	16.9	84.6	61	138
1,2-Dichloropropane	20.0	20.7	103	76	123
1,3,5-Trimethylbenzene	20.0	20.4	102	61	127
1,3-Dichlorobenzene	20.0	23.1	115	68	127
1,3-Dichloropropane	20.0	20.4	102	76	125
1,4-Dichlorobenzene	20.0	20.5	102	68	124
2,2-Dichloropropane	20.0	17.8	89.0	42	142
2-Butanone	20.0	12.6	63.0	22	183
2-Chloroethyl vinyl ether	20.0	19.5	97.3	10	179
2-Chiorotoluene	20.0	22.6	113	64	132
2-Hexanone	20.0	15.2	76.2	31	178
4-Chlorotoluene	20.0	21.6	108	61	132
4-Isopropyltoluene	20.0	21.1	105	63	136
4-Methyl-2-pentanone	20.0	17.7	88.6	10	159
Acetone	20.0	7.67	38.3	10	200
Acrylonitrile	20.0	14.8	74.1	54	155
Benzene	20.0	19.9	99.5	74	123
Bromobenzene	20.0	21.1	106	68	125
Bromochloromethane	20.0	18.9	94.4	71	124
Bromodichloromethane	20.0	20.0	100	72	128
Bromoform	20.0	22.0	110	73	143
Bromomethane	20.0	15.6	78.0	53	130
Carbon disulfide	20.0	17.6	88.2	41	143
Carbon tetrachloride	20.0	21.8	109	59	142
Chlorobenzene	20.0	21.8	109	75	125

Qualifiers:

ND/U - Not Detected at the Reporting Limit B/V - Analyte detected in the associated Method Blank J - Estimated value between MDL and PQL MI - Matrix Interference

ethod Blank D - Recovery Unreportable due to Dilution

* - Recovery Outside Advisable QC Limits

E - Estimated Value exceeds calibration curve

N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.

TNTC - Too numerous to count

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

09071163 Page 8 7/29/2009 2:03:27 PM



SPL, Inc. 2009060590/RRR03865A

Analysis:	Volatile Organics by Method 8260B					WorkOrder:	09071163
Method:	SW8260B					Lab Batch ID:	R279002
			~	 			

	Laborator	Control Sample	e (LCS)
RunID:	K_090722C-51271	52 Units:	ug/Kg
Analysis D	Date: 07/22/2009 16:56	Analyst:	ւս_ւ

Analyte	Spike Added	Result	Percent Recovery	Lower Limit	Upper Limit
Chloroethane	20,0	14.7	73.5	60	134
Chloroform	20.0	18.4	91.8	71	127
Chloromethane	20.0	15.5	77.5	50	139
Dibromochloromethane	20.0	22.0	110	65	130
Dibromomethane	20.0	20.0	100	79	124
Dichlorodifluoromethane	20.0	15.4	76.8	22	162
Ethylbenzene	20.0	21.3	107	72	127
Hexachlorobutadiene	20.0	28.2	141	45	152
Isopropylbenzene	20.0	19.0	94.9	58	130
Methyl tert-butyl ether	40.0	29.6	73.9	63	123
Methylene chloride	20.0	16.5	82.6	61	135
Naphthalene	20.0	19.8	99.2	33	148
n-Butylbenzene	20,0	22,6	113	62	136
n-Propylbenzene	20.0	21.0	105	57	131
sec-Butylbenzene	20.0	22.3	111	63	131
Styrene	20,0	21.5	108	69	120
tert-Butylbenzene	20.0	21.2	106	59	131
Tetrachloroethene	20.0	20.7	103	45	173
Toluene	20.0	21.3	106	74	126
Trichloroethene	20.0	21.4	107	79	131
Trichlorofluoromethane	20.0	17.6	88.2	49	153
Vinyl acetate	20.0	13.4	67.2	10	167
Vinyl chloride	20.0	15.2	76.1	51	148
cis-1,2-Dichloroethene	20.0	19,1	95.7	71	128
cis-1,3-Dichloropropene	20.0	21.6	108	67	128
m,p-Xylene	40.0	43.6	109	71	129
o-Xylene	20.0	22,0	110	74	130
trans-1,2-Dichloroethene	20.0	17.2	86.0	66	128
trans-1,3-Dichloropropene	20.0	19.8	99.2	60	128
1,2-Dichloroethene (total)	40.0	36.3	90.9	66	128
Xylenes,Total	60.0	65.6	109	71	130
Surr: 1,2-Dichloroethane-d4	50.0	44	88.1	78	116
Surr: 4-Bromofluorobenzene	50.0	50.1	100	74	125
Surr: Toluene-d8	50.0	50.3	101	82	118

Qualifiers: ND/U - Not Detected at the Reporting Limit

B/V - Analyte detected in the associated Method Blank

MI - Matrix Interference

D - Recovery Unreportable due to Dilution J - Estimated value between MDL and PQL

* - Recovery Outside Advisable QC Limits

E - Estimated Value exceeds calibration curve

N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.

TNTC - Too numerous to count

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

09071163 Page 9 7/29/2009 2:03:27 PM



HOUSTON LABORATORY 8880 INTERCHANGE DRIVE

HOUSTON, TX 77054 (713) 660-0901

SPL, Inc. 2009060590/RRR03865A

Analysis:	Volatile Organics by Method 8260B	WorkOrder:	09071163
Method:	SW8260B	Lab Batch ID:	R279002

Matrix Spike (MS) / Matrix Spike Duplicate (MSD)

Sample Spiked: RunID: Analysis Date: Preparation Date:

09070822-01 K_090722C-5127157 Units: 07/22/2009 20:35 Analyst: 07/20/2009 14:03 Prep By:

s: ug/kg-dry yst: LU_L By: Method SW5030B

Analyte	Sample	MS	MS	_MS %	MSD	MSD	MSD %	RPD	RPD	Low	High
	Result	Spike	Result	Recovery	Spike	Result	Recovery		Limit	Limit	Limit
		Audeu			7 Judeu						
1,1,1,2-Tetrachloroethane	ND	1120	1150	103	1120	1130	101	1.65	20	68	124
1,1,1-Trichloroethane	ND	1120	919	82.1	1 120	930	83.0	1.15	20	69	123
1,1,2,2-Tetrachloroethane	ND	1120	1000	89.6	1120	992	88.6	1.15	20	69	130
1,1,2-Trichloroethane	ND	1120	1150	102	1120	1160	103	0.973	20	75	126
1,1-Dichloroethane	ND	1120	792	70.7	1120	817	72.9	3.04	20	65	129
1,1-Dichloroethene	ND	1120	869	77.6	1120	882	78.8	1.54	22	61	139
1,1-Dichloropropene	ND	1120	944	84.3	1120	942	84.2	0.173	20	69	121
1,2,3-Trichlorobenzene	ND	1120	904	80.7	1120	987	88.2	8.84	20	53	127
1,2,3-Trichloropropane	NĐ	1120	1010	90.6	1120	1010	90.1	0.456	20	79	124
1,2,4-Trichlorobenzene	ND	1120	1000	89.6	1120	1040	92.6	3.32	20	58	118
1,2,4-Trimethylbenzene	ND	1120	1130	101	1120	1140	102	0.552	20	43	132
1,2-Dibromo-3-chloropropane	ND	1120	884	79.0	1120	909	81.2	2.80	20	46	131
1,2-Dibromoethane	ND	1120	1140	101	1120	1100	97.9	3.48	20	76	122
1,2-Dichlorobenzene	ND	1120	1130	101	1120	1190	106	5.18	20	74	110
1,2-Dichloroethane	ND	1120	778	69.5	1120	783	69.9	0.601	20	60	129
1,2-Dichloropropane	ND	1120	1080	96.6	1120	1110	98.8	2.18	20	76	116
1,3,5-Trimethylbenzene	ND	1120	1040	93.1	1120	1080	96.5	3,59	20	51	121
1,3-Dichlorobenzene	ND	1120	1160	103	1120	1180	105	1.94	20	71	110
1,3-Dichloropropane	ND	1120	1030	92.4	1120	1040	92.5	0.0546	20	80	119
1,4-Dichlorobenzene	NÐ	1120	1010	90.2	1120	1070	95.1	5.32	20	69	110
2,2-Dichloropropane	ND	1120	828	74.0	1120	847	75.7	2.26	20	52	122
2-Butanone	ND	1120	886	79.2	1120	916	81.8	3.28	20	10	133
2-Chloroethyl vinyl ether	ND	1120	1130	101	1120	1130	101	0.173	20	10	182
2-Chlorotoluene	ND	1120	1120	100	1120	1190	107	6.21	20	69	112
2-Hexanone	ND	1120	725	64.7	1120	717	64.0	1.07	20	10	163
4-Chlorotoluene	ND	1120	1050	93.8	1120	1150	102	8.78	20	37	110
4-Isopropyitoluene	ND	1120	1010	89.8	1120	1040	92.6	3.13	20	65	116
4-Methyl-2-pentanone	ND	1120	932	83.2	1120	921	82.2	1.21	20	10	103
Acetone	ND	1120	0	43.9	1120	0	50.0	12.9	20	10	160
Acrylonitrile	ND	1120	746	66.6	1120	756	67.5	1.32	20	45	155

Qualifiers: ND/U - Not Detected at the Reporting Limit

B/V - Analyte detected in the associated Method Blank

MI - Matrix Interference

D - Recovery Unreportable due to Dilution
 * - Recovery Outside Advisable QC Limits

J - Estimated value between MDL and PQL E - Estimated Value exceeds calibration curve

N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.

TNTC - Too numerous to count

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

09071163 Page 10 7/29/2009 2:03:27 PM



HOUSTON LABORATORY 8880 INTERCHANGE DRIVE HOUSTON, TX 77054

(713) 660-0901

SPL, Inc. 2009060590/RRR03865A

Analysis: Method:	Volatile Organics by Method 8260B SW8260B	WorkOrder: Lab Batch ID:	09071163 R279002	
	Matrix Spike (MS) / Matrix Spike Dupli	icate (MSD)		
	Sample Spiked: 09070822-01			

Sample Spiked: RuniD: K_090722C-5127157 Analysis Date: 07/22/2009 20:35 Preparation Date: 07/20/2009 14:03

Units: ug/kg-dry Analyst: LU_L Prep By: Method SW5030B

Analyte	Sample Result	MS Spike Added	MS Result	MS % Recovery	MSD Spike Added	MSD Result	MSD % Recovery	RPD	RPD Limit	Low Limit	High Limit
Benzene	ND	1120	1120	99.9	1120	1100	98.6	1.30	22	70	124
Bromobenzene	ND	1120	1060	94.9	1120	1110	98.8	4.07	20	72	111
Bromochloromethane	ND	1120	972	86.8	1120	1030	92.3	6.19	20	73	126
Bromodichloromethane	ND	1120	1030	92.3	1120	1040	92.9	0.669	20	68	125
Bromoform	ND	1120	1030	92.2	1120	1060	94.4	2.32	20	44	132
Bromomethane	ND	1120	707	63.2	1120	733	65.4	3.54	20	50	140
Carbon disulfide	ND	1120	828	74.0	1120	835	74.6	0.807	20	46	143
Carbon tetrachloride	ND	1120	1080	96.4	1120	1040	93.2	3.35	20	66	126
Chlorobenzene	ND	1120	1140	101	1120	1120	100	1.43	21	68	123
Chloroethane	ND	1120	672	60.0	1120	669	59.8	0.367	20	59	134
Chloroform	ND	1120	933	83.3	1120	955	85,3	2.35	20	68	127
Chloromethane	ND	1120	783	69.9	1120	797	71.2	1.78	20	51	137
Dibromochloromethane	ND	1120	1080	96.3	1120	1040	93.1	3.33	20	58	131
Dibromomethane	ND	1120	1010	90,1	1120	1040	93.0	3.18	20	82	123
Dichlorodifluoromethane	ND	1120	788	70,4	1120	804	71.8	1.97	20	35	143
Ethylbenzene	ND	1120	1290	115	1120	1200	107	7.34	20	76	122
Hexachlorobutadiene	ND	1120	1250	111	1120	1300	116	4.24	20	43	137
Isopropylbenzene	ND	1120	1230	109	1120	1220	109	0.637	20	57	124
Methyl tert-butyl ether	ND	2240	1430	63.7	2240	1490	66.6	4,35	20	10	200
Methylene chloride	ND	1120	812	72.5	1120	851	76.0	4.61	20	70	134
Naphthalene	ND	1120	1850	165 *	1120	1900	170 *	2.90	20	42	140
n-Butylbenzene	ND	1120	1190	106	1120	1230	110	2.86	20	82	112
n-Propylbenzene	ND	1120	1940	173 *	1120	1970	176 *	1.47	20	73	108
sec-Butylbenzene	ND	1120	1130	101	1120	1170	105	3.21	20	76	110
Styrene	ND	1120	1120	100	1120	1130	101	0,559	20	58	152
tert-Butylbenzene	ND	1120	1020	91.5	1120	1060	94.7	3.50	20	66	120
Tetrachloroethene	ND	1120	1790	160 *	1120	1570	140 *	12.9	20	71	130
Toluene	ND	1120	1270	114	1120	1200	107	6.07	24	80	117
Trichloroethene	ND	1120	1640	147 *	1120	1480	132 *	10.4	21	82	121
Trichlorofluoromethane	ND	1120	885	79.0	1120	893	79.7	0.837	20	74	138
Vinyl acetate	ND	1120	733	65.5 *	1120	739	65.9 *	0.714	20	66	135
Vinvl chloride	ND	1120	497	44.4 *	1120	493	44.0 *	0.699	20	45	143

ND/U - Not Detected at the Reporting Limit Qualifiers:

B/V - Analyte detected in the associated Method Blank

MI - Matrix Interference

D - Recovery Unreportable due to Dilution J - Estimated value between MDL and PQL

* - Recovery Outside Advisable QC Limits

E - Estimated Value exceeds calibration curve

N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.

TNTC - Too numerous to count

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

09071163 Page 11 7/29/2009 2:03:27 PM



SPL, Inc. 2009060590/RRR03865A

Analysis:	Volatile Organics by Method 8260B	WorkOrder:	09071163	
Method:	SW8260B	Lab Batch ID:	R279002	
	Matrix Spike (MS) / Matrix Spike Duplicate (MSD)			

 Sample Spiked:
 09070822-01

 RunID:
 K_090722C-5127157

 Analysis Date:
 07/22/2009 20:35

 Preparation Date:
 07/20/2009 14:03

Units: ug/kg-dry Analyst: LU_L Prep By: Met

r. Method SW5030B

Analyte	Sample Result	MS Spike Added	MS Result	MS % Recovery	MSD Spike Added	MSD Result	MSD % Recovery	RPD	RPD Limit	Low Limit	High Limit
cis-1,2-Dichloroethene	ND	1120	991	88.5	1120	1020	91.2	2.97	20	67	132
cis-1,3-Dichloropropene	ND	1120	1100	98.0	1120	1140	102	3.99	20	67	116
m,p-Xylene	ND	2240	2570	115	2240	2520	113	2.02	20	69	127
o-Xylene	ND	1120	1200	107	1120	1190	106	0.840	20	84	114
trans-1,2-Dichloroethene	ND	1120	855	76.4	1120	883	78.8	3.18	20	68	131
trans-1,3-Dichloropropene	ND	1120	1000	89.4	1120	1000	89.7	0.332	20	56	131
1,2-Dichloroethene (total)	ND	2240	1846	82.44	2240	1903	85.01	3.068	20	67	132
Xylenes,Total	ND	3360	3770	112	3360	3710	110	1.64	20	69	127
Surr: 1,2-Dichloroethane-d4	ND	2800	2470	88.1	2800	2520	89.9	2.04	30	78	116
Surr: 4-Bromofluorobenzene	ND	2800	2760	98.5	2800	2740	97.8	0.753	30	74	125
Surr: Toluene-d8	ND	2800	2720	97.1	2800	2710	96.9	0.137	30	82	118

Qualifiers: ND/U - Not Detected at the Reporting Limit

B/V - Analyte detected in the associated Method Blank

J - Estimated value between MDL and PQL

MI - Matrix Interference

od Blank D - Recovery Unreportable due to Dilution

* - Recovery Outside Advisable QC Limits

E - Estimated Value exceeds calibration curve

N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.

TNTC - Too numerous to count

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

09071163 Page 12 7/29/2009 2:03:28 PM
Sample Receipt Checklist And Chain of Custody

> 09071163 Page 13 7/29/2009 2:03:28 PM



HOUSTON LABORATORY 8880 INTERCHANGE DRIVE HOUSTON, TX 77054 (713) 660-0901

Sample Receipt Checklist

Workorder: 09071163 Date and Time Received: 7/22/2009 3:04:00 PM Temperature: 24.0°C		Received By: Carrier name; Chilled by:	T_B SPL Not Chilled
1. Shipping container/cooler in good condition?	Yes 🗹	Νο	Not Present
2. Custody seals intact on shippping container/cooler?	Yes 🗌	No 🗌	Not Present
3. Custody seals intact on sample bottles?	Yes 🗌	No 🗆	Not Present
4. Chain of custody present?	Yes 🔽	No 🗌	
5. Chain of custody signed when relinquished and received?	Yes 🔽	No 🗌	
6. Chain of custody agrees with sample labels?	Yes 🗹	No 🗔	
7. Samples in proper container/bottle?	Yes 🔽	No 🗌	
8. Sample containers intact?	Yes 🗹	No 🗆	
9. Sufficient sample volume for indicated test?	Yes 🗹	No 🗔	
10. All samples received within holding time? Received sample out of holding time logged with analysis, date on sample 3/27/09.	Yes 🗹	No 🗌	
11. Container/Temp Blank temperature in compliance? Received sample with low coolant.	Yes 🗌	No 🗹	
12. Water - VOA vials have zero headspace?	Yes		Vials Not Present 🗹
13. Water - Preservation checked upon receipt (except VOA*)?	Yes 🗌	No 🗔	Not Applicable
*VOA Preservation Checked After Sample Analysis			
SPL Representative:	Contact Date 8	k Time:	
Non Conformance Issues:			×
Client instructions:			
Client Instructions:			

SPL, Inc. Analysis Request Chain of Custody Record

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Page 1 of 1

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HOUSTON LABORATORIES 8820 INTERCHANGE DRIVE HOUSTON, TEXAS 77054 PHONE (713) 660-0901

[®]CERTIFICATE OF ANALYSIS

Number : 1030-2009060590-001C

Terra Therm, inc. Robin Swift 10 Stevens Road Fitchburg, Maine. 01420

Sample ID: Project Name: Project Number: Project Location: Sample Point:

DNAPL SRSNE Report Date: Sample of / Type: Sample Date: Sample Conditions: PO / Ref. No.:

07/06/09 Liquid / Spot 03/27/2009 N.G. psi, @ N.G. °F 9101-002

Analytical Data										
Test	Method	Results	Unit	Detection Límit	Lab Tech	Date Analyzed				
Carbon, Hydrogen and Nitro	ogen by Instrumenta	al Method								
Carbon Content	ASTM D 5291	58.61	wt%		тот	7/6/2009				
Hydrogen Content	ASTM D 5291	7.44	wt%		TOT	7/6/2009				
Nitrogen Content	ASTM D 5291	<0.3	wt%		TOT	7/6/2009				
Total Chlorides By Bomb-Method-Ion Select	ASTM D 808	319,957	ppm		тот	7/6/2009				

Cas Staley Hydrocarbon Laboratory Manager

SPL, Inc. Analysis Request Chain of Custody Record

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SPL, Inc. Analysis Request Chain of Custody Record

	-7						SPL Work	Order No.:		SPL	Work	Order	No.:		Acct.	Mate	Code:		Dept	. Code	e	SPL			
							RRRC	23379-	02													Page <u>1</u> of <u>1</u>			
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Address	10 Stevens F	Road					SRSNE																24	4hr *	
City/State/Zip	Fitchburg, M	A 01420					Special Ins	tructions:	uctions: Client requesting analysis on both phases.									4	8hr *						
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Client Code: TERRA02

SPL, Inc. 8820 Interchange Drive Houston, TX 77054 P: 713-660-0901 F: 713-660-6035

ORDER CONFIRMATION - Delivery 24 hour

Qu Sold	ote/ To:	Terra Therm, Inc. Robin Swift 10 Stevens Road				Order Date Order # Ref. Doc. #	RRRO3865
Ph	one.	978 343 0300	Evt.		Project/Station Project/Station # Location Purchase Order #		
E	Fax: mail:	rswift@terratherm.com			Need Date SPL Work Order#	7/17/2009 2009060590	
_					Amex/Visa/MC Name on Card CC # Ending	:	
Rep Ship	ort/ To:	Terra Therm, Inc. Robin Swift		Bill To:	Terra Therm, Inc.		
		10 Stevens Road Fitchburg, Maine 01420			Robin Swift 10 Stevens Road Fitchburg, Maine 01420)	
Phe	one:	978-343-0300	Ext:	Phone:	978-343-0300	Ext:	
E	Fax: mail:	rswift@terratherm.com		Fax: Email:	rswift@terratherm.com		
Speci	al Inst	tructions:					
Ln #	Qty	Analytical Parameter		Metho	dology	Price/Unit	Ext. Price
1	2	Total VOC, SW-846 8015	BZ (W)	VOCBZ	W	\$81.00 ea	\$162.00
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Numerical Calculations of Heating Solvents Recovery Service of New England (SRSNE) Southington, Connecticut

Prepared for:

SRSNE Site Group

April 2010

Prepared by:



TerraTherm is an exclusive licensee/owner of (a) U.S. Patent Nos. 4,984,594; 5,076,727; 5,114,497; 5,190,405; 5,221,827; 5,229,583; 5,244,310; 5,271,693; 5,318,116; 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; 6,951,436; 6,962,466; and 7,004,678, (b) U.S. Patent Publication 2004-0228690, and (c) certain non-U.S. counterpart applications/patents of the above-referenced patents and application.

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TABLE OF CONTENTS

1.0 Introduction	. 1
2.0 Model Setup	.2
2.1 Description of Calculations	.2
3.0 Site-Specific Calculations Set Up	.9
3.1 Treatment Area and Volume	.9
3.2 Calculations Layers 1	0
3.2.1 Input Parameters for Calculations1	1
3.2.2 Heat Capacity1	2
3.3 Duration1	2
3.4 Heater Numbers and Boosting1	3
3.5 Groundwater Influx 1	4
4.0 Results – base case1	5
4.1 Heating of Each Segment1	5
4.2 Heating of Entire Site1	8
4.3 Basic System Design Parameters	20
4.3.1 Process Equipment	20
4.3.2 Energy Demand	20
5.0 Sensitivity Analysis	22
5.1 Base Case Scenario	22
5.2 Heater Spacing Versus Duration	23
5.3 Vapor Cap Insulation	24
5.4 Horizontal and Vertical Groundwater Flux2	26
5.5 Heater Boosting	29
6.0 References	34



1.0 INTRODUCTION

The purpose of the water and energy balance calculations is to investigate the importance of groundwater flux, heater spacing, power input, heater boosting, and thickness of vapor cover for the temperatures that can be achieved in-situ. Calculation output includes sizing parameters for the thermal treatment system.

A water and energy balance has been developed by TerraTherm to estimate the addition, removal, and loss of energy in each layer of the site separately, with the layers exchanging both fluids (water, steam, air) and energy along their boundaries. The calculations also estimate crucial heat losses along the top, sides, and bottom of the treatment zone, and the impact of groundwater flow into the treatment area, such that relatively accurate total energy demands are derived.

These water and energy balance calculations are referred to in the following sections as the "calculations."

The result of the calculations will be used to select the heating approach and for sizing of the off-gas treatment system.

In the following sections the basic calculation setup is described along with the results of the conducted water and energy balance calculations.



2.0 MODEL SETUP

2.1 Description of Calculations

The calculations are based on simplified mass and energy balance principles relevant for ISTD operation. The calculations can include up to 9 layers, each with different input and derived parameters, including:

- Surface area of the treatment zone
- Depth of each calculation layer
- Area of perimeter of each calculation layer
- Porosity of each calculation layer
- Initial water saturation in each calculation layer
- Initial bulk density for each calculation layer
- Initial heat capacity for each calculation layer
- Initial thermal conductivity for each calculation layer

During the calculations, parameters such as thermal conductivity and heat capacity are changed automatically based on the water saturation of each layer, This means, for instance, that as a zone is drying out due to boiling and steam removal, the water saturation is reduced, and therefore both the heat capacity and thermal conductivity are reduced, such that only the remaining water contributes to these parameters. This gives a more realistic heating prediction than if constant values are assumed.







Figure 2.1. Schematic Cross-Section of the Calculations Setup for the SRSNE Site.

2.1.1.1 Water Mass Balance Methods

For each layer, the water mass balance is calculated as follows:

M_{net extraction} = M_{out, liquid} + M_{out,vapor}

Where M denotes cumulative water masses. Note that no fluids are injected when using the ISTD technology.



The mass removal in the liquid form is a simple summation of flow rate measurements:

 $M_{out, liquid} = \Sigma (m_{liquid} \times \Delta t)$

Where the values for the flow rate m_{liquid} is determined manually for each operational phase.

For this site, small amounts of entrained liquids are expected in the vapor extraction system. No pumping wells are included in the design.

Influx of groundwater in the calculations are based on numbers from the site-specific groundwater model provided by ARCADIS and as used in the Heat Dissipation Model /Ref. 1/.

The water mass removal in the form of vapor (steam, water vapor) is calculated as follows:

 $M_{out,vapor} = \Sigma (m_{steam} \times \Delta t) = \Sigma (m_{total vapor} - m_{non-cond}) \times \Delta t$

Where m_{steam} is the vapor flow rate made up of steam, $m_{total vapor}$ is the total incoming vapor flow rate, and $m_{non-cond}$ is the vapor flow rate minus the steam component (air mostly).

For these calculations, the steam extraction rates are calculated based on the energy injected by the ISTD system. The equation calculating the ratio between injected energy and extracted steam is derived based on observations made on several recent full-scale ISTD projects. Figure 2.2 illustrates the streams that take part in the water mass balance in the Heated Zone (HZ).





Total water extraction rates are estimated by the sum of the measured flows:

 $m_{extraction} = m_{liquid} + m_{steam}$



The calculations keep track of the volume or mass of water stored in each layer, based on extracted water and estimates for the influx of water from the sides, bottom, and top by infiltration (the perimeter and bottom arrows shown on Figure 2.2).

M_{present, t1} = M_{present, t0} - M_{liquid} - M_{steam} + M_{bottom} + M_{perimeter}

Where M denotes cumulative water masses.

The quantity of water removed from the subsurface is readily measured during operations. Therefore, this quantity can be compared to a relatively accurate estimate of the pre-treatment quantity of water within each layer in the vadose zone, based on values of porosity and saturation for the different zones below the vapor cap and to the water table.

Water entering the model domain in the saturated zone and not extracted as steam will leave the site on the down gradient edge of the Heated Zone. The energy carried away by the heated water is included in the calculations.

For the SRSNE-Site it will be assumed that the surface cover is intact and graded to promote runoff to minimize any standing surface water thus reducing the potential for infiltration from the top through the vapor cover.

2.1.1.2 Energy Balance Estimation Methods

Cumulative energy (E) is calculated as a summation of enthalpy fluxes (Q):

$$E = \Sigma (Q \times \Delta t)$$

An estimated energy balance is maintained for each layer in the calculations based on energy delivered by the ISTD-heaters, energy extracted in the vapor and liquid streams and heat loss to the areas outside of the Heated Zone (HZ).

$$E_{in} = E_{out} + E_{storage} + E_{loss}$$

The energy fluxes are related for each time step as follows:

 $Q_{in} = Q_{out} + Q_{storage} + Q_{loss}$

Where Q denotes enthalpy flux (in BTU/hr). Figure 2.3 shows the schematic energy balance for one layer.





Figure 2.3. Energy Balance Schematic (One Layer Shown for Simplicity).

The estimate for Q_{in} will be based on ISTD energy input. The need for boosting heaters is addressed in the basic calculations layout. By boosting the heaters it will be possible to deliver more energy in layers difficult to heat.

The total energy removal from each layer is estimated as follows:

Q_{out} = Q_{liq} + Q_{non cond. gas} + Q_{steam out}

The energy flux in the extracted liquid is given by:

 $Q_{liq} = m_{liquid} \times cp_{,water} \times (T - T_0)$

Where cp is heat capacity, and T_0 is the ambient temperature.

For the extracted vapor stream, the energy flux in vapor and steam is estimated as follows:

 $Q_{\text{non cond. gas}} = m_{\text{air}} \times cp_{\text{, air}} \times (T - T_0)$

 $Q_{steam out} = m_{condensate} \times \Delta H_{steam-ambient}$

Where m is mass flux, H is specific enthalpy (in BTU/lb), cp is heat capacity (in BTU/lb/F), and T is temperature. The enthalpy of the steam can be estimated from steam tables.



The actual heat loss cannot be calculated using accurate measures. An estimate can be made based on thermal profiles at the bottom and top of each layer, and along the perimeter, using the following equation:

$Q_{heat loss} = A \times KT \times dT/dz$

Where A is the surface area through which energy is conducted, KT is the thermal conductivity of the subsurface material, and dT/dz is the temperature gradient across the surface also expressed as $(T_1-T_2)/(z_1-z_2)$.

For the loss through the vapor cap, the temperature difference between the top and bottom of the layer can be used to calculate the gradient. For the calculations, it is assumed that the top of the vapor cap remains near ambient temperatures due to a combination of wind cooling, ventilation, and simple heat radiation. The area of the heated zone may be estimated based on the zone designated HZ, which is slightly larger than the footprint of the wells due to the heat migration outside.

Heat loss through the bottom and sides are accounted for in a similar manner. The layers exchange energy by thermal conduction such that energy leaves the warmer layer and enters the cooler layer.

All heat migration through the sides and through the vapor cap and the bottom layer are considered lost from the calculation domain. Heat migration from the bottom of a layer and into the top of the underlying layer remains as energy in the calculations if both layers are in the heated zone.



In the calculations average layer temperatures are calculated based on the energy balance and the estimated heat capacity of each layer. The stored energy is related to the heated zone heat capacity, and the average temperature as follows:

 $E_{storage} = Cp x (T_{avg} - T_0) + m_{steam} x 6H_{steam-ambient}$

Where Cp_{,site} is the overall heat capacity of the heated layer, estimated from the volume, saturation, and specific heat capacity of the soil and water:

Cp = V_{soil} x cp_{, soil} x V_{water} x cp_{, water}

The steam energy stored as a vapor at any given time is relatively small, and will be neglected in the calculations. For comparison with the measured temperatures, the energy balance can be used to estimate the average temperature ($T_{energybal}$) of the heated volume:

 $T_{energybal} = T_0 + Es_{torage}/Cp_{site} = T_0 + (E_{in} - E_{out} - E_{loss})/Cp_{site}$

The steam energy stored as a vapor at any given time is relatively small, and will be neglected in the calculations.



3.0 SITE-SPECIFIC CALCULATIONS SET UP

3.1 Treatment Area and Volume

The thermal treatment area at SRSNE is divided into three regions (Area 1, Area 2 and Area 3) as shown in Figure 3.1. Area 1 represents the shallow western portion of the Target Treatment Zone (TTZ), Area 2 represents the intermediate middle portion of the TTZ, while Area 3 represents the deeper eastern portion of the TTZ. The treatment depth in the three areas is 12 feet, 15 feet and 21 feet respectively.



Figure 3.1. Thermal Treatment Areas at SRSNE.

For simplicity, the calculations have been set up based on average depths across the entire TTZ. This simplification is not considered to affect the calculation results significantly since the important parameters for the mass and energy balances is the area and volume of the heated zone.

Table 3.1 presents the estimated thermal treatment area and volume.



Location	Treatment Area [ft ²]	Treatment Depth [ft]	Treatment Volume [cy]
Area 1	6,855	12	3,047
Area 2	36,560	15	20,311
Area 3	30,780	21	23,940
Total	74,195		47,298

Table 3.1. Area and Volume of the Thermal Treatment Zone.

The average treatment depth is calculated to be 17 feet based on the areas and volumes shown in Table 3.1.

3.2 Calculations Layers

In the calculations, the TTZ was divided into nine layers based on the predominant geological properties of the formation present at the site, water saturation and the contaminant distribution. Layers 2 through 6 in the model are all within the TTZ, while the remaining layers are outside of the TTZ. Layer 1 represents the surface cover, while layers 7-9 represent the bedrock underlying the thermal treatment zone. Layers 5-9 are all considered to be initially saturated in the calculations. The layers and general geology in the calculations are shown in Figure 3.2.





Figure 3.2. Calculation Layers and Geology.

3.2.1 Input Parameters for Calculations

Input values of porosity, initial saturation and ambient temperature for the model layers appear in Table 3.2. These values serve as the starting basis for the energy balance calculations conducted in the model.



Table 3.2. Porosity	y, Initial	Saturation	and	Ambient	Temperature	for	Each	Layer	in	the
Treatment Zone.										

Layer	Geology	Тор	Bottom	Thickness	Porosity	Initial saturation	Ambient temp
		[ft]	[ft]	[ft]	[-]	[-]	[°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

Porosity and saturation throughout the various layers of the TTZ may vary within the individual layers.

3.2.2 Heat Capacity

Table 3.3 provides a summary of the heat capacity in the modeled zones.

 Table 3.3. Volume and Heat Capacity.

Heat Capacity	Number	Unit
Total volume, TTZ	47,298	су
Solids volume	34,311	су
Air volume	2,063	су
Water volume	10,924	су
Soil weight	152,786,000	lbs soil
Water weight	18,396,000	lbs water
Soil heat capacity	38,197,000	BTU/F
Water heat capacity	18,396,000	BTU/F
Total heat capacity, TTZ	56,593,000	BTU/F

While the soil within the TTZ comprises nearly nine times the weight of the water within the TTZ, the heat capacity of the water in the TTZ is nearly half of that of the soil. Thus, it is apparent that the heat capacity of the water in the TTZ and therefore the flux of water moving through the TTZ are critical considerations in the design of the thermal remediation system.

3.3 Duration



In order to spread out the VOC loading on the vapor treatment system, a phased approach was chosen where 50% of the well-field is operated for the first 60 days, then the remaining 50% of the well-field is turned on. This sequence is shown in Figure 3.3.



Figure 3.3. Phased operation. Each segment represents 50% of the treatment volume.

Each segment is operated for 135 days with a total operations period of 195 days. The sequences shown in Figure 3.3. have been included in the calculations.

3.4 Heater Numbers and Boosting

The amount of energy added to the treatment area in the calculations appears in Table 3.4. All heaters extend 3 feet below the TTZ. All heaters are boosted at the bottom in the base case to allow more energy to be supplied in the deep part of the TTZ. The boosted section is 5 feet in Area 1 and 6 feet in Area 2 and Area 3.

	Table 3.4. Heater numbers	, depth and boos	sted section in base	e case calculation.
--	---------------------------	------------------	----------------------	---------------------

Location	Heater count [-]	Heater depth [ft]	Heater boosting per heater [ft]
Area 1	80	15	5
Area 2	262	18	6
Area 3	251	24	6
Total	593		

The boosted section of the heater delivers 435 W/ft while the remaining part delivers 300 W/ft.

Based on the numbers above the average heater length has been calculated to be 20 feet while the average boosted heater length is 5.9 feet.



3.5 Groundwater Influx

For the base case, a water influx of 10 gpm was assumed. This value corresponds to the base case scenario in the Heat Dissipation Model described in /Ref. 1/.

The water is assumed to flow only into the saturated part of the treatment zone (layer 5 and 6 in the model). The amount of water flowing into each layer is distributed based on the thickness of each of the two layers. In the base case 6.25 gpm is flowing into Layer 5 while 3.75 gpm is flowing into layer 6.

Layer 7 only receives an inflow of groundwater corresponding to the amount of water extracted as steam from the layer.



4.0 RESULTS – BASE CASE

This section presents the result of the base case scenario. Two calculations were conducted.

The first calculation is performed on a single of the two segments to simulate the predicted average heat up of each layer in the TTZ as a function of time. The duration of the heating is 135 days in the calculation corresponding to the actual predicted operation time for each of the two segments.

The second calculation is completed for the entire site with phased operation corresponding to a total duration of 195 days. The results from this calculation provide design numbers for the overall ISTD system design.

In the base case the following input parameters are applied:

- Heater spacing 15 feet, corresponding to a total of 593 heaters
- Heaters extend 3 feet into the bedrock
- Vapor cap thickness is 1 feet. Thermal conductivity for the cap is 0.15 W/m*K.
- 10 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.

4.1 Heating of Each Segment

The heat-up and boiling of soil pore water occur simultaneously as the heat front moves away from the ISTD heater wells. The last regions to boil and achieve sufficient steam stripping and contaminant removal are the coolest locations within the TTZ, which typically correspond to the mid-points between the ISTD wells, termed "centroid" locations. Figure 4.1 shows the predicted average temperature in each segment as a function of time.





Figure 4.1. Average Temperature Curves for Layer 2 to Layer 8 for a Segment. (*Note: Layer 7 and 8 are both outside the TTZ*)

The results of the calculations indicate that the entire TTZ (layers 2 through 6) reaches average temperatures between 120°C and 160°C during the 135 day treatment period. The temperature reflects that the areas close to the heaters may reach temperatures above the boiling point due to drying-out.

The upper part of the TTZ (layer 2) and the lower part (layers 5 and 6) have the lowest average temperatures (approximately 120 to 135°C) and are the last to achieve target temperature. This is due to the higher heat loss at the upper and lower boundary of the layer compared with the remainder of the treatment zone and for layers 5 and 6 due to cooling from the groundwater flowing into the treatment area. However, the simulation results indicate that these areas will achieve the target treatment temperature after approximately 85-90 days of operation.

The calculations indicate a maximum average temperature in layers 3 and 4 (unsaturated outwash) of up to 160°C.

Figure 4.2 depicts the temperature profiles at 25-day increments during operation including the final temperature at day 135 of operation, using the average temperature for each layer. Figure 4.3 shows the same plot, but with temperatures corrected for the local boiling points, which represents the temperatures achieved at the centroid locations.





Figure 4.2. Average Temperature Profiles for a Segment.



Figure 4.3. Average Temperature Profiles at Coolest Locations (Centroids) for a Segment.



Note that the heating progresses fastest in unsaturated zone from 2 to 9 ft bgs (the unsaturated outwash).



Figure 4.4 shows the calculated saturations for each layer during the thermal operations.

Figure 4.4. Average Saturation for a Segment.

Note that all zones below the water table stay relatively wet since inflowing groundwater will resaturate zones where a substantial amount of steam is produced and removed. The unsaturated zone (layers 2 through 4) is predicted to reach low saturations during the thermal treatment due to the water removed a steam without substantial recharge by inflowing water.

4.2 Heating of Entire Site

The following sections show average temperatures and saturations for the entire site, taking into account that the two segments do not operate simultaneously during operation. These numbers are not important with respect to the remedy in each segment but indicate what average treatment temperatures to expect during the 195 days operation period.

Figure 4.5 shows the predicted average temperature for the entire site as a function of time.





Figure 4.5. Average Temperature Curves for Layer 2 to Layer 8 for a Segment. (*Note: Layers 7 and 8 are both outside the TTZ.*)

The calculations indicate that all layers in the TTZ (layers 2 through 6) reaches average temperatures above 100°C.

Figure 4.6 shows the calculated average saturations for each layer of the entire site during the thermal operations.



Figure 4.6. Average Temperature Profiles at Coolest Locations (Centroids) for a Segment.



The final saturation for each layer in the calculation for the entire site is the same as indicated in Figure 4.4. The only difference is that the saturation decreased slower due to the longer operation period.

4.3 Basic System Design Parameters

Based on the conducted calculations for the staged operation of the two segments, key numbers for sizing of the thermal treatment system and the ISTD system were obtained.

4.3.1 Process Equipment

Tables 4.1 and 4.2 below present design parameters and effluent discharge estimates resulting from the calculations.

Table 4.1. Process Equipment

Process Equipment	Estimate Based on Model	Units
ISTD power supply, max	4,052	kW
Non-condensable vapor, max	1,300	scfm
Condensable vapor (steam), max	5,386	lbs/hr
Condensed liquid rate, max	10.8	gpm

Based on the calculated values, the vapor treatment system is designed to treat a minimum of 1,300 scfm of non-condensable vapor plus a minimum of 5,386 lbs of steam/hr. The liquid treatment system is designed to treat a minimum of 10.8 gpm of condensate.

Table 4.2 shows the predicted water and vapor extraction rates and quantities.

Table 4.2.	Water and V	apor Extraction	Rates and Total Volumes
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		Water		Vap	oor extracted
		Average Rate	Total Volume	Rate	Total volume
	Days	gpm	Gallons	SCFM	Million CF
Period 1	30	4.2	181,000	650	28
Period 2	30	5.4	233,000	650	28
Period 3	30	9.6	414,000	1,300	56
Period 4	30	10.9	470,000	1,300	56
Period 5	30	7.5	323,000	1,300	56
Period 6	45	5.0	323,000	1,300	84
Total	195		1,944,000		309

Over the course of the thermal treatment, an estimated 1.9 million gallons of water and approximately 323 million cubic feet of non-condensable vapor will be extracted from the subsurface.

4.3.2 Energy Demand



Table 4.3 summarizes the power usage by the ISTD and steam systems along with the effluent treatment system throughout the duration of the thermal treatment system operation.

Table 4.3 Power Usage

Power and Steam Usage	Duration Days	Power Usage ISTD kWh	Power Usage Effluent Treatment kWh	Total Power Usage kWh
Period 1	30	1,016,000	390,000	1,405,000
Period 2	30	1,306,000	445,000	1,751,000
Period 3	30	2,321,000	501,000	2,822,000
Period 4	30	2,612,000	501,000	3,113,000
Period 5	30	1,814,000	473,000	2,287,000
Period 6	45	1,814,000	612,000	2,426,000
Total	195	10,883,000	2,922,000	13,805,000

Based on the numerical calculations, it is estimated that a total energy input of approximately 10.9 million kW-hr of electricity must be injected into the subsurface. With the additional approximate 2.9 million kW-hr power demand of the effluent treatment system, the total estimated electrical energy consumption for the project is estimated at approximately 14 million kW-hr for the full scale remediation.

The resulting total energy demand is larger than the energy needed just to heat the site to the target treatment temperatures. This is due to the removal of heat as steam, heat losses through the perimeter and the need to vaporize a minimum of approximately 30% of the pore water in the ISTD zone, which TerraTherm has found is necessary to achieve the required removal of CVOC contaminants.



5.0 SENSITIVITY ANALYSIS

After setting up the basic scenario, a sensitivity analysis was performed to determine the sensitivity of heater spacing versus duration, vapor cap insulation and horizontal and vertical groundwater flux. In addition, the effect of boosting the heater output in the deepest sections was evaluated.

Prior to deciding the proposed heating strategy as presented in the base case scenario described above, similar preliminary sensitivity calculations were performed to confirm the appropriateness of the design, and to make small adjustments for improved heating performance.

The sections below present the impact of changes in important base case scenario assumptions and compared them to the actual final design (base case design).

5.1 Base Case Scenario

Figure 5.1 shows the average temperature profiles at coolest locations (centroids) for a segment. This temperature profile is the base case for the sensitivity analysis, and all sensitivity calculations are compared to the base case average temperature profile.



Figure 5.1. Average Temperature Profile for Base Case Scenario.



5.2 Heater Spacing Versus Duration

For the ISTD method, the duration of heating is closely associated with the spacing between each of the heater wells. A sensitivity analysis was conducted using two different heater spacings apart from the 15 foot spacing as presented in the base case.

Figures 5.2 and 5.3 presents the temperature profile with a heater spacing of 14 feet and 16 feet, respectively. In the base case 593 heaters will be placed in the treatment zone. If a 14 foot well spacing were chosen approximately 650 wells would have been used, while a 16 foot heater spacing would require a total of approximately 480 wells.



Figure 5.2. Average Temperature Profile with a 14 Foot Heater Spacing





Figure 5.3. Average Temperature Profile with a 16 Foot Heater Spacing

A 14 foot heater spacing would speed up the overall heating process and the boiling point in the entire TTZ would be reached after approximately 85 days of operation compared to approximately 100 days in the base case. By using a 16 foot heater spacing it would not be possible to reach the boiling point at the very bottom of the treatment zone within 135 days of operation.

5.3 Vapor Cap Insulation

The sensitivity for vapor cap insulation and its impact on achievable temperatures in the upper part of the treatment zone was evaluated by running calculations with three different vapor cap thermal conductivities. In the base case the thermal conductivity was assumed to be 0.15 W/m*K. A sensitivity analysis was conducted using a vapor cap thermal conductivity value of 0.25 and 0.35 W/m*K.

Figures 5.4 and 5.5 present the temperature profile with a vapor cap thermal conductivity of 0.25 and 0.35 W/m*K. The latter value corresponds to the insulation value of a wet or poor vapor cap.





Figure 5.4. Average Temperature Profile with a Vapor Cap Thermal Conductivity of 0.25 W/m*K.





Figure 5.5. Average Temperature Profile with a Vapor Cap Thermal Conductivity of 0.35 W/m*K.

None of the proposed higher thermal conductivity values will be acceptable at the SRSNE site. The increase in thermal conductivity for the vapor cap would lead to a much higher heat loss at the surface and thus insufficient heat-up of the upper part of the treatment zone. By using a 0.25 W/m*K thermal conductivity for the vapor cap in the calculations, the temperature in the upper layer in the model reaches a steady state temperature at about 90 °C. For the 0.35 W/m*K vapor cap the steady state temperature is as low as 75 °C.

The insulation value of the vapor cap can either be improved by using a material with low thermal conductivity or by increasing the thickness of the cap. A 1 foot thick 0.15 W/m*K vapor cap as used in the base case scenario is acceptable for the SRSNE site.

5.4 Horizontal and Vertical Groundwater Flux

Calculations have been performed to investigate the overall sensitivity of water influx into the treatment area. Scenarios have been run with a horizontal influx of 0 and 20 gpm respectively, and with a vertical influx of 3 and 6 gpm. In the base case scenario, a horizontal influx of groundwater to the target area of 10 gpm was assumed. No vertical influx of groundwater was applied in the base case scenario.

The resulting average temperature profiles when the horizontal influx is varied are shown in Figures 5.6 through 5.7.





Figure 5.6. Average Temperature Profile with 0 gpm Horizontal and 0 gpm Vertical Influx of Groundwater.




Figure 5.7. Average Temperature Profile with 20 gpm Horizontal and 0 gpm Vertical Influx of Groundwater.

The figures show that the sensitivity for horizontal groundwater influx is modest. The higher groundwater influx increase the time to get the lower part of the treatment area up to temperature, but even when assuming a horizontal influx of 20 gpm the entire treatment zone is up to temperature after 100 days of operation. It should be noted that this is true for the site as an average, but may not hold true at the up-gradient edge where the cool water enters.

The resulting average temperature profiles when the vertical influx of groundwater is varied are shown in Figures 5.8 through 5.9.



Figure 5.8. Average Temperature Profile with 10 gpm Horizontal and 3 gpm Vertical Influx of Groundwater.





Figure 5.9. Average Temperature Profile with 10 gpm Horizontal and 6 gpm Vertical Influx of Groundwater.

According to the sensitivity calculations, the temperature in the bottom of the treatment zone is almost not affected by varying th vertical influx of groundwater between 3 and 6 gpm. It should be noted that this is true for the site as an average, but may not hold true locally for zones of higher flow.

5.5 Heater Boosting

The effects of adding more energy per unit length of heater near the bottom have been evaluated.

In the base case scenario the lower approximately 6 feet of the heaters are boosted and the heaters are drilled 3 feet into the bedrock. The boosted sections of the heaters are able to deliver approximately 435 W per foot of heater to the treatment zone. By comparison the non-boosted sections only deliver approximately 300 W/ft.

The effects of installing non-boosted heaters 3 and 5 feet into the bedrock was evaluated together with scenarios with boosted heaters installed 2 and 5 feet into the bedrock. The boosted section of the heaters starts approximately 3 feet above the bedrock in all scenarios where boosting is used e.g. the length of the boosted sections are approximately 5 and 8 feet in the two scenarios.



Figures 5.10 and 5.11 shows the situation where the heaters are installed 3 and 5 feet into the bedrock and none of the heaters are boosted.



Figure 5.10. Average Temperature Profile with Non-Boosted Heaters Installed 3 feet into the Bedrock.





Figure 5.11. Average Temperature Profile with Non-Boosted Heaters Installed 5 feet into the Bedrock.

The sensitivity analysis shows that non-boosted heaters need to be installed 5 feet into the bedrock to ensure to heat up the bottom of the target zone. If heaters are kept 3 feet into the bedrock the bottom of the treatment zone will not get up to temperature.

Figures 5.12 and 5.13 show the case where the heaters are boosted and installed 2 and 5 feet into the bedrock.





Figure 5.12. Average Temperature Profile with Boosted Heaters Installed 2 feet into the Bedrock.



Figure 5.13. Average Temperature Profile with Boosted Heaters Installed 5 feet into the Bedrock.



The calculations show that a 2 foot boosted heater installation into the bedrock will not be sufficient to get the temperature at the bottom of the target zone up to temperature. By using boosted heaters and installing those 5 feet into bedrock, the bottom will be heated sufficiently during treatment. In the base case, the boosted heaters are installed 3 feet into the bedrock (see Figure 5.1) which also is found to be sufficient.



6.0 REFERENCES

/Ref. 1/ Heat Dissipation Model, Solvents Recovery Service of New England (SRSNE) Southington, Connecticut, TerraTherm, Inc. March 2010

Memo



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To: John Hunt, Bruce Thompson, de maximis, inc.

From: Larry Conant, John LaChance, TerraTherm, Inc.

Date: December 4, 2009

Re: SRSNE Superfund Site Treatment Process Options

This memorandum presents a review of vapor treatment system options for the planned thermal remediation of the Observed NAPL in the Overburden Groundwater Unit (ONOGU) area at the Solvents Recovery Systems of New England Superfund Site (SRSNE) in light of new data and analyses, and provides our revised recommended approach for vapor treatment. We begin with an evaluation of the design basis and the approach put forth in our proposal that was the basis for our Best and Final Offer (BAFO) and the contract award. Next, we present recently acquired information that was used to revise the design basis; then, we summarize our review by presenting three treatment scenarios and treatment approaches that frame the issues and options for designing a treatment system for the site. Finally, we present our revised recommended approach for the SRSNE site.

Attached to this memorandum is a table of system components for each option, with estimated equipment, operation, waste disposal, fuel, and energy costs. Please note that fuel and energy costs were estimated using today's market rate and may change at the time of project startup.

Original Design Basis Used for Proposal/Bid

The design basis for the vapor treatment system presented in our proposal and assumed for the contract award is as follows:

- NAPL characteristics: fuel load of 8,000 BTU/lb with 80% chlorides
- Design for 1,000,000 lbs present within treatment volume (however, actual mass unknown and thought to likely be in the range of 500,000 to 2,000,000 lbs)
- Minimize duration of operational phase in order to reduce potential for EPA requested add-on days of operation

de maximis, Inc. Attn: John Hunt and Bruce Thompson December 4, 2009 Page 2



Original Treatment System Design as Awarded

The original treatment system design, as presented in our BAFO and shown below (Figure 1), used two Regenerative Thermal Oxidizers (RTO) to destroy constituents of concern (COCs) in the vapors extracted from the wellfield. For this system, vapors from the wellfield would be processed through a heat exchanger to condense out the moisture/steam from the wellfield prior to the RTOs. This reduces the flow rate and size requirements and operating costs of the RTOs. Additional process steps included an oil/water separator to recover organic material that also condensed out and two scrubbers to neutralize any acids created in the oxidizers (e.g., HCL). The operational period over which the mass present in the treatment volume (assumed to be 1,000,000 lbs) would be removed and sent to the treatment system was 135 days. As indicated above, this design was based on laboratory data which indicated that the contaminant mass (i.e., NAPL) had a fuel load of 8,000 BTU/lb and was comprised of 80% chlorides.



Figure 1. Treatment System Presented in Proposal

Revised Treatment System Considerations

Recent laboratory data from the NAPL sample collected from the SRSNE site for the materials compatibility testing indicated a higher BTU value and a lower chlorine content than the data used for the original design. These new values are 13,000 BTU/lb and 30% chlorine. A vapor stream rich with NAPL with these characteristics would not be handled efficiently in the original design. The primary concern is thermal overload of the RTOs due to the high BTU or fuel value of the vapor stream. The regenerative concept of the RTO relies on recycling energy from the exhaust into the inlet to pre-heat the incoming vapors. This recycling concept reduces the supplemental fuel load, and also cools the exiting gas. This is the most efficient approach for a vapor stream with a moderate to low BTU fuel load. However, a vapor stream with a high BTU fuel value will create temperatures within the RTOs above the operating limits of the units and very hot exhaust. This can be addressed by adding dilution air to the inlet vapor stream, but this would require significant increases in the size and/or number of RTOs and the size and capacities of all of the down stream piping and equipment (e.g., blowers and scrubbers). Given the potential for relatively high BTU loads



and the uncertainty in the actual mass present in the treatment volume and thus the peak loading rate, this approach was determined to not be satisfactory.

In addition, based on the chemical composition of the NAPL, it was determined that several lowboiling point azeotropes would be formed and that the NAPL would boil in the presence of water at a temperature around 75°C (this has been confirmed in the laboratory during the initial condensate production phase of the materials compatibility testing). What this means is that a significant portion of the mass present in the treatment volume (e.g., 80-90%) will be produced over a period of 4-6 weeks as the average temperature approaches 75°C, well before the target temperature of 100°C is reached. Furthermore, due to thermal coasting (i.e., the treatment volume will continue to heat-up even if the heater wells are shut down due to heat dissipation), it will not be possible to effectively control the arrival or duration of the peak loadings. If the mass present in the treatment volume is closer to 2M lbs than 1M lbs, then the peak loadings could easily be more than the treatment system can handle.

For example, if the entire treatment volume was heated all at once, and the total mass of COCs present was closer to 2M lbs than 1M lbs, and 80% of this mass was produced over a 4 week period corresponding to achieving temperatures around 75°C, the average loading to the treatment system would be ~2,400 lbs/hr or 31M BTU/hr. Peak loading rates could be 2-3 times higher.

Installation and operation of a system large enough to handle these potential maximum peak loadings would be very expensive and may not be necessary if the actual mass present in the treatment zone is significantly lower than what is assumed. Therefore, as described below, we evaluated: 1) different equipment designs that could handle higher mass/fuel loadings and 2) different operational strategies to control and reduce the potential peak loadings to ranges that would be economically more feasible to design for. For instance, the treatment systems proposed for the three design scenarios evaluated below all use Thermal Accelerators (TA) instead of the original RTO's. A TA does not have as much thermal recycling capability as the RTO, and therefore is designed for a higher BTU vapor load. In addition, we evaluated extending the operation phased from 135 to 195 days and dividing the treatment area up into quarters and phasing the start of heating of each quarter by 2-3 weeks. This has the distinct advantage of providing a means to regulate the loading rates and attenuating and spreading out the peak loadings.

Each scenario and treatment approach will be explained in detail below, including which of the three is our recommended approach.

<u>Scenario 1</u>

Summary of Assumptions and Objectives:

• Design and size treatment system for 1,000,000 lbs of mass, but be prepared to treat unknown mass (up to 2,000,000 lbs) in most economical way.

Summary of Approach:

- Replace RTOs with TAs.
- Extend treatment period from 135 to 195 days to allow phased startup and treatment and control/regulation of peak loadings to treatment system. This provides flexibility and will allow



treatment of more than 1,000,000 lbs without sizing and building an overly large and expensive treatment system.

 System will be designed and run primarily to minimize condensation and removal of NAPL from vapor stream (condense out water only). However, the system can be easily adjusted to facilitate the removal of NAPL from the vapor stream by simply lowering the cooling temperature of the heat exchanger in front of the knock out pot. This would only be done if the mass loadings were too high and could not be controlled by phasing the operation of the heaters. The condensed NAPL would have to be sent off for disposal at a regulated disposal facility.

The treatment system for Scenario 1 consists of replacing the original RTO's with two TAs and removing one scrubber while still using a single incoming heat exchanger/moisture knockout and an oil/water separator similar to the original design (see Figure 2). In addition to replacing the original RTO's with TAs, this option extends the processing time from 135 days to 195 days which would allow for a phased startup of the heaters and treatment of additional mass over 1,000,000 pounds. This extension of time also allows for a gradual ramp-up of the wellfield temperature and therefore a control of the removal rate from the wellfield.



Figure 2. Treatment System for Scenario 1



Scenario 2

Summary of Objectives:

• Design and size system for 2,000,000 lbs of mass in 135 days.

Summary of Approach:

- Replace RTOs with TAs.
- Treatment period from remains at 135 (no phased startup).
- System will be designed and run primarily to minimize condensation and removal of NAPL from vapor stream (condense out water only). However, the system can be easily adjusted to facilitate the removal of NAPL from the vapor stream by simply lowering the cooling temperature of the heat exchanger in front of the knock out pot. This would only be done if the mass loadings were too high and could not be controlled by phasing the operation of the heaters. The condensed NAPL would have to be sent off for disposal at a regulated disposal facility.

The treatment system for Scenario 2 consists of replacing the original RTO's with four TAs (see Figure 3). Everything else would remain the same as the original design. The increase in oxidizer capacity will handle up to 2,000,000 pounds in the same operational period as the original proposal (i.e., 135 days).

The major disadvantage of this option is the higher capital cost for the extra TAs and scrubber and the significantly higher operations costs, including natural gas for the TAs.



Figure 3. Treatment System for Scenario 2



Scenario 3

Summary of Objectives:

• Design and size system for 2,000,000 lbs in 135 days.

Summary of Approach:

- Replace RTOs with TAs;
- Treatment period remains at 135 (no phased startup).
- An additional heat exchanger and knockout will be added to allow two-stage condensing of water and petroleum hydrocarbon NAPL. The system will be designed and run to maximize removal of petroleum hydrocarbon NAPL while keeping chlorinated volatile organic compounds (CVOCs) in vapor phase for destruction in the TAs.
- NAPL condensate will require disposal at an approved regulated facility.

The treatment system for Scenario 3 consists of replacing the original RTO's with two heat exchangers and two TAs with a single scrubber (see Figure 4). The assumed operational time period is the same as the original at 135 days, but the mass to be removed is assumed to be 2,000,000 pounds. The mass and fuel load would be attenuated by the two-stage condensing of water and petroleum hydrocarbons. The first heat exchanger and knock out would be configured and operated to primarily remove the petroleum hydrocarbons while leaving the CVOCs in vapor stream for treatment by the TAs. By removing the petroleum hydrocarbons the fuel load can be reduced to levels that two TAs can handle. Leaving the CVOCs in the vapor stream ensures that the petroleum hydrocarbon NAPL can be disposed of as non-hazardous and therefore reduces the cost of disposal.

This option has a higher capital cost than the treatment approach for Scenario 1 due to the added heat exchanger and cooling tower and generates a NAPL waste stream that has to be sent for off-site disposal.





Figure 4. Treatment System for Scenario 3

Conclusion and Recommendation

The original process design was based on the NAPL having an 8,000 BTU/lb fuel loading rate and consisting of 80% chlorine. The most recent laboratory data indicates a 13,000 BTU/lb vapor fuel loading rate with only 30% chlorine. The change in chlorine isn't a concern, but the higher BTU value cannot be processed in the original design without severely limiting the process rate. Therefore, three revised scenarios/treatment options have been proposed.

All of the treatment approaches replace the RTOs with TAs which are designed to handle the higher BTU fuel.

The treatment approach for Scenario 1 increases the operating time but has the lowest capital cost and greatest flexibility to handle the unknown amount of mass present in the treatment volume.

The treatment approach for Scenario 2 doubles the number of oxidizers and scrubbers increasing the capital cost over the system for Scenario 1, but brings the process time back to the original 135 days without creating a condensate stream requiring offsite disposal.

The treatment approach for Scenario 3 doubles the heat exchange capacity increasing the capital cost over the system for Scenario 1, but still uses two oxidizers. The process time is the original 135 days; however, there is an additional NAPL waste stream produced that requires off-site disposal.

Our recommended approach for the SRSNE site is to use the treatment approach outlined for Scenario 1 for the following reasons:

- Its total cost is similar to the original proposal,
- It allows for flexibility and control of the removal rate of contaminants, specifically if the estimated mass exceeds 1,000,000 pounds, and
- The NAPL waste stream requiring off-site disposal is estimated to be minimal.

		Assumed Total										
Scenario/		Treatment Quantity	Operating				Estimated	Estimated	Estimated Waste	Power	Fuel	
Option	Feed	Pounds	Days	Major Equipment	Quantity	Size/Description	Equipment Cost	Operation Cost	Disposal Cost	kWh	Therms	Total Costs
Proposed												
Original												
Approach	8,000 Btu/#	1,000,000	135	Heat Exchanger/Condenser	1	259 ft2						
	80% CI			Cooling Tower	1	200 Tons						
				Duplex Blower Skid	1	2,500 ACFM						
				Moisture Sep Skid	1	1,700 SCFM						
				Thermal Oxidizer	2	2,000 SCFM						
				Scrubber	2	2,000 SCFM						
				Oil Water Seperator	1	10 gpm						
				Air Stripper Skid	1	11 gpm						
				Venturi Quench	2	Hastelloy 2,000 SCFM						
				Caustic Feed & Tank	2							
Total							\$1,100,000	\$500,000	\$0	\$57,000	\$5,000	\$1,662,000
1	13,000 Btu/#	1,000,000	195	Heat Exchanger	1	259 ft2						
		capable of efficiently	Phased									
		treating between	startup of									
		500,000 to 2,000,000	heaters									
	30% CI	lbs		Cooling Tower	1	100 Tons						
				Venturi Quench	1	Hastelloy 2,000 SCFM						
				Duplex Blower Skid	1	2,500 ACFM						
				Thermal Accelerators	2	4 million Btu/hr						
				Oil-Water Sep	1	10 gpm						
				Air Stripper	1	11 gpm						
				Caustic Package	1							
				Scrubber	1	1600 scfm						
Total							\$890,000	\$750,000	<u>\$0</u>	\$83,000	<u>\$25,000</u>	\$1,748,000
2	13,000 Btu/#	2,000,000	135	Heat Exchanger	1	259 ft2						
	30% CI			Cooling Tower	1	100 Tons						
				Venturi Quench	2	Hastelloy 2,000 SCFM						
				Duplex Blower Skid	1	2,500 ACFM						
				Thermal Accelerators	4	4 million Btu/hr						
				Oil-Water Sep	1	10 gpm						
				Air Stripper	1	11 gpm						
				Caustic Package	2	1000						
T 1 1 1				Scrubber	2	1600 SCIM	¢4 500 000	¢500.000	60	657 000	¢24.000	¢2.001.000
Total	12 000 R+++ /#	3,000,000	4.25	Heat Evenander	-	250.42	\$1,500,000	\$500,000	Ş0	\$57,000	\$34,000	\$2,091,000
5	15,000 Blu/#	2,000,000	155		2	100 Tana						
	30% CI			Cooling Tower & Chiller	2	Lestelleu 2 000 SCEM						
				Venturi Quench	1							
						2,500 ACHVI						
					2							
				cil Mater Car	2							
				Oll-water Sep		10 gpm						
				Air Stripper		11 gpm						
				Caustic Package		1.con (
				Scrubber	1	1600 scfm	A	4				64.000 A.
Total							\$1,100,000	\$500,000	\$225,000	\$57,000	\$17,000	\$1,899,000

Note: Actual costs to be finalized upon completion of the treatment design.



Appendix C

Standard Operating Procedures

St	andard Operating Procedure		Terra ⁻	Therm, Inc.
			Issued Date:	November 2009
	AIR MONITORING	_	Revision:	1.0
			Approved:	John M. Binschark
				John M. Bierschenk, President

1 PURPOSE

To ensure that TerraTherm, Inc. (TerraTherm) follows a consistent program to monitor personal breathing space. The preferred monitoring method will be defined in the project specific work plan, sampling and analysis plan, and/or quality assurance project plan, but should be confirmed by the Project Manager prior to monitoring.

2 DISCUSSION

For the purpose of this Standard Operating Procedure (SOP), air monitoring may be perimeter monitoring, system vapor monitoring or personal air space monitoring. Each of these monitoring methods will be defined in the sections below. Additionally, calibration of volatile organic compound (VOC) instruments, such as hand-held Photo Ionization Detectors (PIDs), permanent PIDs, hand-held Flame Ionization Detectors (FIDs), permanent Continuous Emissions Monitoring Systems (CEMS), and compound specific Dräger pumps will also be discussed.

3 APPLICATION

Data collected in the field is used to identify any potential safety hazards; as well as evaluate the efficiency and progress of the remediation effort; therefore, it is extremely important that these data be reliable and accurate. This Standard Operating Procedure (SOP), although maybe not entirely, applies to most TerraTherm projects and the personnel responsible for the construction, operation and maintenance of them.

4 **DEFINITIONS**

Hand-held PID: Compact monitor designed as a broadband volatile organic compound (VOC) gas monitor and datalogger for use in hazardous environments. Depending on the unit, concentrations of gases can be detected from the sub parts per billion (ppb) to 10,000 parts per million (ppm).

Permanent PID: Similar to hand-held PID except instrument is permanently mounted to a fixed-point gas monitoring system.

Hand-held FID: Compact monitor best for detecting hydrocarbons, including methane, and other easily flammable components. Depending on the unit, concentrations of VOCs can be detected from 0.1 to 50,000 ppm. One drawback of the FID is that it destroys most - if not all - of the compounds it is detecting, making additional sample measurements impossible.



Air Sampling SOP



CEMS: A permanent flue gas analyzer designed to monitor VOC concentrations in hazardous environments.

Dräger pump: Manual gas detector pump that draws a calibrated 100 mL sample through a Dräger gas detection tube. Typical application is to monitor personal breathing space from airborne pollutants, rather than environmental sample medias.

5 CALIBRATION PROCEDURES

For maximum safety, the accuracy of the instruments should be checked by exposing them to a known concentration calibration gas before each day's use.

Calibrating the Hand Held PID

- Turn on the unit and allow to equilibrate for approximately 10-15 minutes.
- Press "Mode" and "N/-" keys together for about three seconds to enter the program menu.
- "Calibrate/Select Gas?" Press the "Y/+" key.
- "Fresh Air Cal?" Press "Y/+" key. Make sure the PID is connected to the fresh air source. Follow the instructions on the screen.
- "Span Cal?" Press the "Y/+" key.





- "Cal gas = isobutylene" "span value = 0100.0 ppm".
 These two entries must match the type of gas and concentration used for calibration.
- "Apply gas now" and follow instructions on screen. Do not attach the canister of gas directly to the PID unless fitted with a 500 cc/min regulator; rather attach a dedicated Tedlar bag filled with calibration gas.
- Note the reading (it should be within 10% of the calibration concentration). Disconnect from gas.
- Press MODE to exit programming menu.

Calibrating the Permanent PID

- Press above the "Mode" circle or the triangles labeled [+] and [-] keys to enter the program menu.
- Access the calibration menu by keying MODE.

The PID is calibrated using a two point calibration process. First, use a "zero gas"; then use a "span gas" of known concentration. Any gas can be applied, but the greatest accuracy comes from calibrating with the same gas as is being measured.

Air Sampling SOP

Standard Operating Procedure



• "Calibrate/Select Gas?" Press the "Y/+" key.

Calibrating the FID

- Turn on the hydrogen
- Wait about three minutes for the hydrogen flow to regulate.



- Confirm the hydrogen flow by removing the exhaust port from the detector assembly and placing the inlet of the flow meter on the hydrogen outlet. The flow should read 13.9 mL/min +/- 0.5.
- Press the toggle switch to turn the unit on.
- Press the enter key.
- "Detector? Start Flame".
- Press enter to start the flame.
- Allow the unit to run for approximately five minutes.
- Press the "Cal" button.
- Select the Cal memory.
- Enter the desired response factor and press enter (usually 1.0).
- Select low or high range and press enter. Low range is for expected concentrations between 0.5 and 2,000 ppm (methane equivalents); high range is for expected concentrations between 10 and 50,000 ppm.
- Connect the zero air, carbon filter or fresh air and press enter.
- Enter the concentration of the span gas and press enter.
- Connect the span gas and press enter.
- After approximately 60 seconds, calibration should be complete.
- Remove the span gas.

Calibrating the CEMS

Some CEMS units have an automatic calibration function that enables the instrument to switch to locally stored standard gas cylinders and perform a span calibration without intervention. Other CEMS installations will require manual calibration at set intervals. Check with the operation manual and/or project manager prior to calibration.

Calibrating a Dräger pump

No calibration is needed; however, the counter, if present, shall be reset with each new Dräger tube insertion.

6 PROCEDURES

Data collected directly with the PID, FID, CEMS, or Dräger pump are typically used to evaluate personal breathing space. All of these instruments, with the exception of the Dräger pump, can be set to record total VOCs continuously while performing field duties.

Both the PID and FID can be easily placed and/or transported in or near work areas. Both instruments record continuously; typically displaying total VOC concentrations in parts per million (ppm). Both are programmed to alarm if total VOC concentrations exceed OSHA limits. If the alarm sounds, immediately move to fresh air and

Standard Operating Procedure



contact the project manager for further instructions.

The Dräger pump is used to evaluate specific organic and some inorganic compounds. Specific compound tubes are placed into the pump. The pump, similar to an accordion, is squeezed several times (number determined by compound). The color change in the tube is evaluated against a color scale provided by the vendor. Should concentrations exceed project specific emission limits, or predetermined health and safety limits, immediately move to fresh air and contact the project manager for further instructions.



7 CALIBRATION RELATED FORMS

Included with this SOP are related calibration forms. It is important that calibration of these instruments be documented and retained on site through the life of the project.

8 SAMPLE RELATED FORMS

Total VOC readings shall be recorded in the project specific field book. Concentrations shall be recorded, at a minimum, hourly unless conditions warrant otherwise.

9 **REFERENCES**

RAE Systems, MiniRAE 2000, Operation and Maintenance Manual, Document: 011-4001-000, Revision E, May 2005.

RAE Systems, RAEGuard PID, FGM 1000 Series, Operation and Maintenance Manual, pn 033-4001-000, Revision B.

U.S. Environmental, Photovac Micro FID Maintenance and Calibration Guide.

10 RESPONSIBILITIES

The Site Supervisor, Site Safety Officer or the Project Manager will conduct periodic inspections of the sampling procedures established by this SOP. The purpose of the inspection is to verify that the procedures and the requirements of the SOP are being followed. Any deviations or inadequacies that are identified during the inspection will be immediately corrected.

Air Sampling SOP

Standard Operating Procedure		TerraTherm, Inc.
EMISSION SAMPLING	Issued Da	te: December 2009
	Approved	John M. Bienschenk
		John M. Bierschenk, President

1 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to ensure that TerraTherm, Inc. (TerraTherm) follows a consistent program in collecting emission samples.

2 DISCUSSION

For the purpose of this SOP, emissions sampling refers to vapor samples collected at the influent, midfluent effluent or any other location along the vapor treatment train. Sampling locations may be added, modified, or deleted depending on the treatment equipment at the site. Refer to the project Process and Flow Diagram for process equipment components, controls, and sample ports. Also for the purposes of this SOP, emissions sampling may also be referred to as vapor sampling.

This SOP describes sample collection into Tedlar[™] bags, Summa canisters, or screening with a hand-held Photo Ionization Detector (PID).

3 APPLICATION

This SOP, although maybe not in its entirety, applies to most TerraTherm projects and the personnel responsible for vapor collection.

4 PROCEDURES

If collecting vapor samples in Tedlar[™] bag for screening, connect both a moisture filter and a humidity filter to the calibrated PID prior to attaching to the collected sample. In general, a new humidity filter should be used for each day of sampling. If the humidity filter becomes discolored during sample collection, the filter should be replaced prior to collection of the next sample.

Collection into a Tedlar[™] Bag

The vacuum pump, bag, and tubing shall be screened with a hand-held PID prior to sample collection. The pump can be screened by connecting a Tedlar[™] bag to the vacuum pump with fresh Tygon[®] tubing and filling the bag with ambient air. Screen the bag by attaching it to the PID. The bag and tubing can be screened by attaching them (separately) directly to the PID.



If the PID detects concentrations above background in the pump, the pump shall be disassembled and cleaned. If the PID detects concentrations above background in the tubing, a fresh length of tubing shall be cut and used for sample collection.

Attach the sample location to the inlet of the vacuum pump with Tygon[®] tubing. Connect the outlet from the vacuum pump to a Tedlar[™] bag. Ensure that seals do not leak. Place the vacuum pump at least three feet downwind of the field sampling team. Ensure that the valve on the sample location is closed. Turn the vacuum pump on and check that there are no leaks in the sampling equipment. Open the valve on the bag. Fill the bag to its full volume, being careful not to overfill and burst the bag. Once the Tedlar[™] bag is full, close the sample port. Close the bag's inlet valve and disconnect the bag from the vacuum pump. Place the Tedlar[™] bag in a warm room or car and allow approximately 10 to 15 minutes for the temperature of vapor in the bag to reach ambient temperatures. Once temperatures are ambient, attach the Tedlar[™] bag to the PID. Record the maximum reading on the project specific Process Equipment Data Sheet.

Collection into Tedlar[™] Bag using a Vacuum Chamber

The tubing shall be screened with a hand-held PID prior to sample collection. The tubing can be screened by attaching it directly to the PID. If the PID detects concentrations above background, a fresh length of tubing shall be cut and used for sample collection.

Attach the sample location to the inlet of the lung box with Tygon[®] tubing. Connect the vacuum pump to the outlet of the lung box with Tygon[®] tubing, ensuring that seals do not leak. Place the vacuum pump at least three feet downwind of the field sampling team. Ensure that the valve on the sample location is closed. Turn the vacuum pump on and check that there are no leaks in the sampling equipment. Place a 3L Tedlar[®] bag inside the lung box, connecting it to the Tygon[®] tube. Open the Tedlar[®] bag inlet valve. Close the lid of the lung box. Start the vacuum pump, open the ball valve and fill the Tedlar[®] bag. Close the ball valve on the sample location. Open the lung box and close the Tedlar[®] bag valve. Remove the Tedlar[®] bag from the lung box and close the lid. Record the readings on the project specific Process Equipment Data Sheet.

Collection into Summa Canister

The tubing shall be screened with a hand-held PID prior to sample collection. The tubing can be screened by attaching it directly to the PID. If the PID detects concentrations above background, a fresh length of tubing shall be cut and used for sample collection.

Remove the Summa canister and passive flow controller from the shipping box and record the canister identification number, time, and location in the project specific Field Logbook. Remove the Swagelock[™] cap on the top of the Summa canister using a small, adjustable wrench. Remove the Swagelock[™] cap and plug on the passive flow controller. Attach the passive flow controller to the canister. Attach the Tygon[®] tubing from the sample location to the flow controller. To start sampling, open the valve on the sample location. Open the canister at least one turn. The pressure will increase as the sample fills the canister.

Close the valve after the sample has been collected (vacuum will be approximately 5"Hg); do not over tighten the valve. Record the sampling time, initial and final pressure, and the sample canister identification number in the Field Logbook and on the chain of custody. The passive flow controller can be removed after the valve has been closed and the chain of custody recorded.



5 RESPONSIBILITIES

The Site Supervisor will conduct periodic inspections of the sampling procedures established by this SOP. The purpose of the inspection is to verify that the procedures and the requirements of the SOP are being followed. Any deviations or inadequacies that are identified during the inspection will be immediately corrected.

Emmissions Sampling SOP



TerraTherm, Inc.

	WATER QUALITY METER CALIBRATION (YSI MODEL)	Issued Date:	May 2005		
		Revision:	1.0		
		Approved:	John M. Bienschenk		
			John M. Bierschenk, President		

1 INTRODUCTION

This standard operating procedure (SOP) provides instructions for calibrating sondes that measure water quality parameters in groundwater and surface water sampling. This SOP is written specifically for the calibration of the YSI Model 6-Series Sonde (600XL). Water quality parameters include pH, temperature, conductivity/specific conductivity, oxidation-reduction potential (ORP), and dissolved oxygen.

This SOP complies with EPA protocols for the calibration of YSI model 6-series sondes (EPA, 2002).

2 HEALTH AND SAFETY

Consult specific Material Safety Data Sheets (MSDS) for the chemicals listed below for descriptions of hazards and first aid measures associated with each chemical.

Conductivity/Specific Conductivity

Calibration solutions for conductivity contain *iodine* and *potassium chloride*. When using this standard, avoid inhalation, skin contact, eye contact or ingestion. If skin contact occurs, remove contaminated clothing immediately. Wash the affected area(s) thoroughly with large amounts of water. If inhalation, eye contact or ingestion occurs, remove to fresh air immediately and call 9-1-1.

<u>рН</u>

Calibration solutions for pH contain the following:

- pH 4: potassium hydrogen phthalate, formaldehyde, water
- pH 7: sodium phosphate, potassium phosphate, water
- pH 10: potassium borate, potassium carbonate, potassium hydroxide, sodium ethylenediamine tetraacetate, water

When using these standards, avoid inhalation, skin contact, eye contact or ingestion. If skin contact occurs, remove contaminated clothing immediately. Wash the affected area(s) thoroughly with large amounts of water. If



inhalation, eye contact or ingestion occurs, remove to fresh air immediately and call 9-1-1.

<u>ORP</u>

Zobell Solution, the most commonly used calibration standard for ORP, contains **potassium chloride**, **potassium ferricyanide**, and **potassium ferrocyanide**. When using this standard, avoid inhalation, skin contact, eye contact or ingestion. If skin contact occurs, remove contaminated clothing immediately. Wash the affected area(s) thoroughly with large amounts of water. If inhalation, eye contact or ingestion occurs, remove to fresh air immediately and call 9-1-1.

Dissolved Oxygen

Sodium sulfite mixed with deionized water is used to check the dissolved oxygen performance of the sonde. When in the powder form, avoid inhalation or ingestion, especially if you are prone to asthma. If inhalation occurs, remove to fresh air. If ingestion occurs, induce vomiting immediately. If skin contact occurs, remove contaminated clothing immediately and wash for at least 15 minutes. If eye contact occurs, flush with plenty of water, lifting upper and lower eyelids for at least 15 minutes. Call 9-1-1.

3 EQUIPMENT AND MATERIALS

The items listed in the following equipment and materials list are required to calibrate the YSI accurately in accordance with this SOP. It should be noted that different solutions and/or additional solutions/equipment may be required depending on your field conditions and project requirements. Consult your project manager and/or quality assurance project plan (QAPP).

- YSI 600 XL Sonde with temperature, pH, conductivity, ORP, and dissolved oxygen probes
- YSI 650 Multiparameter Display System (MDS), or datalogger
- pH standards 4, 7, 10
- Conductivity standard (1413 µs/cm, or similar)
- ORP standard (Zobell 231 mV, or similar)
- Sodium sulfite
- DO membrane replacement kit
- Deionized (DI) or distilled water
- Small knife or scissors
- Q-tips
- Paper towels



- Calibration cups
- Write-in-the-Rain pen or similar
- Field book or calibration form

4 CALIBRATION PROCEDURES

Calibration of the YSI must be performed on each day of use prior to collecting any water quality parameters. Calibration checks should be done, at a *minimum*, at the end of each sampling day **and** when readings become erratic. Consult your project manager and/or QAPP for the required calibration frequency.

Prior to calibrating the Sonde, both the Sonde and calibration standards must stabilize with the atmospheric temperature for about 15 minutes. Failure to do so could result in incorrect water quality parameter readings.

If possible, pre-rinse the probe with a small amount of the solution you are going to calibrate with. This will eliminate potential cross contamination of solutions. Discard the rinsate after use.

Sonde Menu Setup

When first operating a Sonde, the report format on the MSDS should be set to display the correct parameters and the time and date should be verified and corrected if necessary.

Setting Calibration Parameters on the MDS

- At the main menu, highlight SONDE MENU, press ENTER
- Highlight REPORT, press ENTER
- Select the following parameters by pressing ENTER next to the parameters that are currently unselected. Set units to match those listed below. When complete, these parameters should appear as below. (Note: DO CHG and pH mV are only used during calibration and can be unselected for sampling. See Section 5.)
 - Date (optional)
 - Time (optional)
 - ⊙ Temperature (C)
 - ⊙ SpCond (µS/cm)
 - Cond (µS/cm)
 - DOsat (%)



- DO (mg/L)
- ⊙ DO CHG
- ⊙ pH
- ⊙ pH mV
- ORP (mV)
- Press ESC to return to the REPORT menu

Setting the Date and Time (bottom of MDS)

- At the main menu, highlight SYSTEM SETUP, press ENTER
- Highlight DATE & TIME, press ENTER
- Select display format (m/d/y), press ENTER (black dot appears next to display format)
- Use the arrow keys to scroll down to DATE
- Enter date
- Arrow down to Time
- Enter time (military)
- Press ESC twice to return to the main menu

Setting the Date and Time (display as parameters)

- Highlight SONDE MENU, press ENTER
- Highlight STATUS, press ENTER
- Scroll down to date, type current date, press ENTER
- Scroll down to time, type current time, press ENTER
- Press ESC twice to return to main menu

Temperature

The temperature sensor should be calibrated at least once a year against a thermometer that is traceable by the National Institute of Standards and Technology (NIST). Verify with your rental company that this has been completed.



Dissolved Oxygen

Dissolved oxygen (DO) in water is measured using a membrane electrode. The DO membrane should be inspected daily for any signs of damage (tears, holes) or air bubbles trapped under the membrane surface. If damage or air bubbles are present, the membrane must be changed (see below for instructions). The electrode contacts (two small silver rectangles seen under the membrane) should also be inspected for any corrosion or discoloration. If either of these conditions exists, the electrode contacts should be cleaned (as described below).

Changing the DO Membrane

- Pull membrane and O-ring off the probe
- Rinse end of probe with DI water and dry with a Q-tip
- Clean the electrode contacts with a piece of fine sand paper (included in the membrane kit)
- Rinse the tip of the probe with KCl solution and place enough drops of KCl solution to cover the tip of the probe (included in the membrane kit)
- Stretch a new membrane over the tip of the probe being careful not to push **all** of the KCl solution out (some will leak out)
- Starting with the side of the probe closest to you, roll the O-ring over the tip to secure the membrane
- Inspect the new membrane to ensure NO air bubbles or wrinkles are present
- Trim excess membrane away using small scissors or knife

Dissolved Oxygen

- Put probe, with probe guard on, in storage container with moist sponge OR place storage container cap with 1/8 inch of water on Sonde loosely (twist one or two threads)
- At the main menu, highlight SONDE MENU, press ENTER
- Highlight CALIBRATE, press ENTER
- Highlight DISSOLVED OXY, press ENTER
- Highlight DO %, press ENTER (the barometric pressure should be displayed)
- Verify this pressure against the pressure displayed in the lower right hand corner of the display
- If pressures differ, enter the value shown in right hand corner, press ENTER. If not, press ENTER
- Once DO% is stable (allow at least 10 minutes), write down the value on the METER CALIBRATION REPORT



- Press ENTER
- Press ENTER to return to DO calibration menu
- Press ESC to return to the CALIBRATE menu

Conductivity/Specific Conductivity

Electrical conductivity is a measure of water's capacity to conduct electricity, and therefore a measure of the water's ionic activity and content. It is measured by placing two plates in the sample and applying a potential across the plates. There is a direct correlation between the concentration in water of dissolved ionic constituents and the electrical conductivity of the water. The conductivity of water changes substantially as its temperature changes; specific conductivity is conductivity normalized to a temperature of 25°C.

- Highlight CONDUCTIVITY, press ENTER
- Highlight SpCond, press ENTER
- Completely submerge probe in standard
- Enter value of standard (pay close attention to units), press ENTER
- Verify that the value of DO CHG is between 25 75. If it is not in this range, change the DO membrane.
- Check SpCond and Cond readings. If a drastic spike is seen every four seconds, change the DO membrane. If readings are not within ±10% of the standard, use a new standard.
- Once the SpCond and Cond readings have stabilized, write them down on the meter calibration report and count to 10.
- Press ENTER; the SpCond and Cond reading will calibrate.
- Press ENTER to return to the conductivity calibration menu screen.
- Press ESC to return to the main menu.
- Rinse probe with DI water and dry with paper towel.

To check (from RUN menu):

• From run menu, submerge probe in the solution again. If the displayed value is not within ±10% of the standard value, repeat calibration procedures.

<u>рН</u>

The pH of a sample is determined electrometrically using a glass electrode (small glass bulb). Calibrate with pH

TerraTherm, Inc.

standards that will span the expected pH values of the groundwater (typically 4, 7 and 10).

- Highlight ISE1 pH, press ENTER.
- Highlight 3-POINT, press ENTER.
- Always start with pH 7 standard.
- Completely submerge probe in pH 7 standard.
- Enter 7.0 at "enter value" prompt, press ENTER.
- Verify pH mV readings are within specifications listed below. If not, call rental company for technical assistance.

pH 7.0 = ±40 mV

 $pH 4.0 = (180 mV - pH 7.0 value) should be \pm 170 mV$

 $pH 10.0 = (180 mV - pH 7.0 value) should be \pm 170 mV$

- Once readings have become stable, write down the value on the meter calibration report, count to 10, and press ENTER.
- Press ENTER again to proceed to next pH value.
- Rinse probe with DI water and dry with paper towel.
- Continue for pH 4 and pH 10, being sure to clean and dry the probes in between each solution.
- Press ENTER to return to pH CALIBRATION menu.
- Press ESC to return to the CALIBRATION menu.
- Rinse probe with DI water and dry with paper towel.

To check (from RUN menu):

• From run menu, submerge probe into the pH 7 solution again. If the reading is not accurate to within ±0.05 units, repeat the calibration procedures.

Oxidation Reduction Potential (ORP)

ORP or Redox Potential is related to the concentration of oxidizers or reducers in a solution, and their activity or strength. The ORP value (in mV) of the solution quantifies the true ability or potential that the solution has to oxidize or reduce.



You need to know the temperature of the solution to calibrate the probe for ORP.

- At main menu, highlight SONDE RUN.
- Submerge probe (or pH/ORP probes) in ORP standard.
- After the temperature of the solution has stabilized, write it down on the meter calibration report.
- Press ESC to return to the main menu.
- Highlight SONDE MENU, press ENTER.
- Highlight CALIBRATE, press ENTER.
- Highlight ISE2ORP, press ENTER.
- Enter value corresponding to the <u>temperature of solution (refer to Calibration Temperature</u> <u>Correction Chart)</u> at ENTER VALUE prompt, press ENTER.
- Once stable, write ORP value on meter calibration form.
- Press ENTER to calibrate.
- Press ENTER to return to calibration menu.
- Press ESC to return to the main menu.
- Rinse probe with DI water and dry with paper towel.

Dissolved Oxygen Check

This function should only be used as a check. Never calibrate this value. This can be performed from either the RUN or CALIBRATE menu.

- Submerge the probe in a saturated sodium sulfite solution (25 grams sodium sulfite to 1000 mL DI water)
- Verify that the probe reads < 1.0 mg/L. If not:
 - 1. mix a new solution
 - 2. change the DO membrane.
- Rinse probe with DI water and dry with paper towel.



5 FIELD MEASUREMENTS

Setting Field (Report) Parameters in the MDS

- Highlight Sonde menu, press ENTER
- Highlight REPORT, press ENTER
- Unselect the following parameters (if selected) by pressing ENTER next to the ones that are currently selected (black dots).
 - DO CHG
 - ⊙ pH mV
- When you are finished, the following parameters should be displayed.
 - Date (optional)
 - Time (optional)
 - ⊙ Temperature (C)
 - ⊙ SpCond (µS/cm)
 - ⊙ Cond (µS/cm)
 - DOsat (%)
 - DO (mg/L)
 - ⊙ pH
 - ORP (mV)

Datalogging

- From Sonde Main Menu, highlight SONDE RUN, press ENTER
- Highlight START LOGGING, press ENTER
- Use right arrow key to select CONFIGURE, press ENTER
- Type in your recording interval (e.g., 00:00:10)
- Arrow down to highlight EDIT SITE LIST, press ENTER
- Press ENTER to add monitoring well ID
- Press ENTER to populate entry

Standard Operating Procedure



- Press ESC three times to return to the RUN menu
- Verify START LOGGING is highlighted, press ENTER
- Select well you just added, press ENTER
- Once well is stable, press ENTER to STOP LOGGING
- Repeat steps above for each new monitoring well

Uploading Data to PC

- Load EcoWatch software on your computer (included with YSI)
- Connect MDS to hard drive using cable included
- At Main Menu, highlight FILE, press ENTER
- Highlight UPLOAD to PC, press ENTER
- Highlight file(s) to upload, press ENTER
- Select file type (e.g., binary, comma & " " delimited, ASCII text)
- Launch program
- Select the Sonde icon
- Select the COMM 1, OK
- Press ENTER on handset to send file to PC

View Uploaded Files on PC

- Close COM 1 dialog box
- Select Real-Time, open
- Select all file types
- Select file, OK
- View as table, graph, or both

6 CALIBRATION CHECKS

As with any instrument, Sondes have a tendency to "drift" which may cause them to operate outside the acceptable quality control ranges. The calibration should be checked at a minimum at the end of each sampling



day. These checks should be documented on the calibration form.

Calibration checks are done from the run menu. The Sonde is placed into each of the calibration standards. Verify that the values displayed are within the acceptable range of each calibration standard. If values are outside of the range, recalibrate.

7 TROUBLESHOOTING

In some instances, it may be necessary to "uncalibrate" a parameter to return to factory settings. This should not be done unless instructed by technical support.

- Access the desired parameter to uncalibrate in the calibrate menu
- Hold the ENTER and ESC keys down
- Highlight YES, press ENTER

8 **REFERENCES**

US EPA, Standard Operating Procedure for Calibration and Field Measurement Procedures for the YSI Model 6-Series Sondes, Revision 1, 05/31/02.

US Environmental, YSI Field Calibration Guide.

YSI, 2001, 650 MDS Operation Manual.

YSI, 2001, YSI Environmental Monitoring Systems Operational Manual (6-Series).

St	andard Operating Procedure	- 💗 Terra	aTherm, Inc.		
		Issued Date:	April 2010		
	HOT GROUNDWATER SAMPLING	Revision: Approved:	2.2 John M. Binschuk		
			John M. Bierschenk, President		

1 PURPOSE

To ensure that TerraTherm, Inc. (TerraTherm) follows a consistent program to collect groundwater samples. For the purpose of this SOP, groundwater may be at or above ambient conditions. As such, it is extremely important to follow established sampling methods including any health and safety protocols.

The preferred sampling method will be defined in the project specific work plan, sampling and analysis plan, and/or quality assurance project plan, but should be confirmed by the Project Manager prior to monitoring.

2 DISCUSSION

For the purpose of this Standard Operating Procedure (SOP), groundwater sampling may refer to the collection of water, whether extracted from the ground or processed through the treatment system. Data collected in the field is used to identify any potential safety hazards; as well as evaluate the efficiency and progress of the remediation effort; therefore, it is extremely important that these data be reliable and accurate.

3 APPLICATION

This SOP, although maybe not in its entirety, applies to most TerraTherm projects and the personnel responsible for groundwater collection.

4 PROCEDURES

Low-flow sampling and purging techniques are used in an effort to collect the most representative samples and to reduce the production of investigative-derived waste. Peristaltic and/or bladder pumps (depending on the sample intake depth) are used for purging and sampling. A dedicated ¼-inch Teflon™ sample tube is installed in each monitoring well for groundwater sampling. The tubing sample inlet is set in the well in the middle of the screen length. Each sample tube has a ¼-inch sample valve above the wellhead.

The following low-flow groundwater sampling procedure is adapted from the methods provided in the B&R Environmental, Technical Memo for Purging and Groundwater Sampling Using Low Flow Purging and Sampling Techniques (B&R Environmental, 1998). The apparatus used to perform sample cooling is shown in Figure 1 below.

Prior to initial sampling, a cooling coil is formed by wrapping a 10-ft length of ¼-inch stainless steel tubing around a 4-inch diameter pipe until six full turns have been made. The ends of the tubing are fashioned such that both



ends of the tubing extend upward. During sampling the tubing will be inspected, and any droplets formed on the exterior of the tubing will be wiped off before sampling.

- Connect ¹/₄-inch sample tubing to the cooling coil and place the coil in a bucket or cooler with ice to form the ice bath.
- Connect the cooling coil and peristaltic/bladder pump to the Teflon tube in the well.
- Purge the well at an initial rate of ~1 liter per minute to minimize drawdown of the formation water. The well should be purged until field indicator parameters stabilize **OR** the minimum purge volume is removed.

The minimum purge volume is two times the static saturated well volume. The equation to calculate the minimum purge volume is:

$$V = 7.48 \kappa rw^{2} (td-12)$$

where V = one purge volume in gallons rw = radius of well casing in feet; td = total depth of well in feet; 12 = typical depth to groundwater in feet.

- The pumping rate is recorded on purge data sheets every 3 to 5 minutes during purging. Any adjustments made to the pumping rate during purging are recorded. Adjustments to the pumping rate are best made within the first 15 minutes of purging to minimize purging time.
- At the initiation of well purging and during the purging effort, water quality parameters including turbidity, specific conductance, pH and dissolved oxygen (DO) are measured with a multi-parameter meter with a flow through cell such as a YSI (or equivalent). Readings are recorded on the purge data sheets every 3 to 5 minutes. Field parameters are monitored until stabilization occurs. Stabilization is complete when three consecutive readings are within the following criteria: Specific conductance and DO readings within 10 percent pH within +/-0.2 standards units turbidity at 10 NTUs or less 8.
- After the minimum purge volume is purged and all water quality parameters have stabilized, sampling may begin. If all parameters have stabilized, but turbidity remains above 10 NTUs, decrease the pump rate and continue monitoring. If the pump rate cannot be reduced and turbidity remains above 10 NTUs, the information will be recorded and sampling begun.
- For low yield wells, the well should be purged dry and allowed to recover. Sampling commences as soon as the well has recovered sufficiently to collect the appropriate volume for the anticipated sample analysis.
- Volatile organic compounds are collected first, followed by semivolatile, other organics, and finally
 inorganics utilizing the following method: a column of water is drawn in the cooling coil tubing with the
 pump; the well sample valve and the pump inlet valve are closed and the pump shut off; the cooling coil is
 disconnected from the well sample valve; the cooling coil is carefully removed from the ice bath; the
 pump inlet valve is opened; the sample is decanted into the sample vials from the pump end of the tubing
 via gravity flow. The process is repeated until the sample volume is collected.




5 RESPONSIBILITIES

The Site Supervisor will conduct periodic inspections of the sampling procedures established by this SOP. The purpose of the inspection is to verify that the procedures and the requirements of the SOP are being followed. Any deviations or inadequacies that are identified during the inspection will be immediately corrected.

6 ATTACHMENTS

• Low Flow Purging Record

Hot Groundwater Sampling SOP

_Standard	Operating	Procedure	_
-----------	-----------	-----------	---



Low Flow Purging Record

Project:	
Purged by:	
Date Sampled:	
Well ID:	
Casing Diameter:	
Depth to Groundwater:	
Depth to Bottom:	
Screen Length:	

Sample ID:	
Sampled by:	

Samples Collected:

 TIME (24 hr)
 PUMP RATE (mL/min)
 pH (SI unit)
 SPEC. COND. (µS/cm°C)
 DO (mg/L)
 TURBIDITY (NTU)
 Depth To Water (ft)

 Image: Specific conduction of the second of th

Notes:

Hot Groundwater Sampling SOP

St	andard Operating Procedure	– 衬 Terra	aTherm, Inc.
	HOT SOIL SAMPLING FOR	Issued Date:	December 2009
	CHLORINATED VOLATILE ORGANIC COMPOUNDS	Revision:	1.0
		Approved:	John M. Binschuck
			John M. Bierschenk, President

1 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to ensure that TerraTherm, Inc. (TerraTherm) follows a consistent program in performance of hot soil sampling, when such sampling is required. This SOP is specifically intended for sampling of soils to be submitted for chlorinated volatile organic compound analysis. Such soils are heated in excess of 100°C and this SOP establishes a set of procedures to ensure collection of soil samples that are representative of field conditions and to minimize the potential for loss of volatile organic compounds during sample collection.

2 DISCUSSION

TerraTherm is typically responsible for overseeing or performing a soil sampling program for each major project. Sampling may be performed as progress sampling during In Situ Thermal Desorption (ISTD) operation or as confirmatory sampling at the conclusion of ISTD operation. This SOP outlines the methodology of such sampling, to help ensure consistency from one project to the next, and to ensure that sampling is performed in accordance with industry standard methods (Gaberell et al., 2002). It is recognized, however, that project specific goals may differ, and that sampling methodologies may change accordingly to some degree. It is the ultimate responsibility of the Project Manager to ensure that the plans meet both corporate and client requirements prior to their submittal.

3 APPLICATION

This SOP applies to all major TerraTherm projects, and to personnel responsible for performing or overseeing soil sampling activities. All work must be done in accordance with the project specific work plan, sampling and analysis plan, and/or quality assurance project plan procedures.

The procedures for performing hot soil sampling are as follows:

Sampling Tool

The length and diameter of the sampling tool may vary depending on the driller used to perform the work and the sampling tool selected. Soil samples will be collected using a core barrel type sampler equipped with four to eight 6-inch stainless steel sleeves. Figure 1 shows a 2 ft core barrel equipped with four 6-inch stainless steel sleeves.

Standard Operating Procedure



Figure 1. Typical 2-foot Long Core Barrel.

Decontamination

All down-hole equipment (augers, core barrel, drive rods) must be decontaminated prior to use, between sampling locations, and at the end of each day. Sampling sleeves and end caps, which may be used more than once must be decontaminated prior to each use. Decontamination will consist of the following:

1) Removal of any gross contamination (e.g., wet soils stuck to the auger) by steam cleaning or other appropriate method;

TerraTherm, Inc.

- 2) Cleaning with a biodegradable soap (e.g., Alconox) and water solution using a scrub brush;
- 3) Rinsing off the soapy solution with clean water; and,
- 4) Rinsing with distilled water.

Sample Collection

There are two different methods described for sample collection below. The sample collection method shall be approved by the Project Manager to ensure that data results meet project goals.

Method 1

The decontaminated core barrel sampler and sample sleeve will be assembled and advanced to the desired depth. Once removed from the borehole, the core barrel will be disassembled, using temperature-rated gloves, and the sample sleeves will be removed sequentially, one-by-one. The ends of each sample sleeve (typically 6-

Hot Soil Sampling SOP

Standard Operating Procedure



TerraTherm, Inc.

inches long) will be immediately covered with sections of Teflon tape and then capped with PVC end caps (Figure 2). One of the sleeves will be selected and a thermometer will be inserted through the end cap into the soil sample for temperature monitoring (Figure 2). The capped and sealed sleeves will then be placed into an ice bath for cooling. The ice bath will contain drain holes to allow melt water to freely drain rather than accumulate around the sample holder. A picture of an ice bath is included as Figure 3. The sample ID will be marked on each ice bath for reference when processing the cooled samples for labeling and shipping.





Figure 2. Removal and Capping of Sleeved Samples





Figure 3. Ice Bath for Cooling Samples

Once cooled to a temperature no higher than 50°F, the sample sleeve will be removed from the ice bath, labeled and sealed tightly in a plastic bag for shipment to the laboratory on ice in an insulated cooler. The laboratory will open and extrude five grams of soil from the middle of the sleeve and place in pre-cleaned, pre-preserved vials (deionized water and methanol).

The following information for each sample will be documented in a Field Logbook: brief soil description, depth interval of sample, temperature of sample collected at time of collection, time and date of sample collection, name of sampler/s. A photographic record of each sample collected, with identification label, is desirable. Figure 4 shows a typical setup for processing hot soil samples.



Figure 4. Typical Sample Processing Setup

Method 2

Alternatively, the cooled samples may be processed in the field by extruding five grams of soil from the middle of the sleeve and placing the extruded soil in pre-cleaned, pre-preserved vials (deionized water and methanol) provided by the laboratory. Vials will be properly labeled and stored on ice in an insulated cooler.



QA/QC Samples

Trip blanks, equipment blanks, duplicates and any other Quality Assurance/Quality Control (QA/QC) samples will be collected in accordance with the project specific Quality Assurance Project Plan.

4 **RESPONSIBILITIES**

The Site Supervisor will conduct periodic inspections of the sampling procedures established by this SOP. The purpose of the inspection is to verify that the procedures and the requirements of the SOP are being followed. Any deviations or inadequacies that are identified during the inspection will be documented and immediately corrected.

5 REFERENCE

Gaberell, M., A. Gavaskar, E. Drescher, J. Sminchak, L. Cumming, W.-S. Yoon, and S. De Silva. 2002. "Soil Core Characterization Strategy at DNAPL Sites Subjected to Strong Thermal or Chemical Remediation." in: A.R. Gavaskar and A.S.C. Chen (Eds.), *Remediation of Chlorinated and Recalcitrant Compounds—2002. Proceedings of the Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds* (Monterey, CA; May 2002). ISBN 1-57477-132-9. Battelle Press, Columbus, OH.



Appendix D

Site Specific Health and Safety Plan (provided under separate cover)



Appendix E

Design Drawings (22 x 34 drawings provided under separate cover)



3

THERMAL REMEDIATION SITE SOUTHINGTON, CT

DRAWING INDEX

NG TITLE				DRAWIN	GNO.
CATION MAP				ELECTR E101	ONE LINE
TREATMENT ZONE PHASES HEATER & VAPOR E> HEATER & VAPOR E> HEATER & VAPOR E> ACTION WELL DETAIL	(TRACTION WELL (TRACTION WELL (TRACTION WELL	DETAIL Z DETAIL Z DETAIL Z	ZONE A Zone b Zone c	<u>MIECHA</u> M101 M102 <u>PROCES</u> P101 P102	VAPOR E MECHANIO
	SITE	LOCA	tion 7		
	STREET MA		Actio	Dr Dr	
	5	2	4		3













	5	4	
		·	

(0'-0") TOP OF EXISTING GRADE/CONCRETE

TOP OF GRADE AFTER COVER

(0'-0") TOP OF EXISTING GRADE/CONCRETE	CONCRETE R=0.15 W/mK
(1'-0")	
	TOP OF FINE SAND
(2'-0")	TOP OF VAPOR SCREEN
(3'-0")	
(4'-0")	
(5'-0")	
(6'-0")	
(7'-0")	BOTTOM OF VAPOR SCREEN
(8'-0")	ESTIMATED DEPTH TO WATER

(9'-0") (10'–0")

(11'–0") (12–0") (13–0")

(14–0") (15'–0") (16'–0")

(17'–0")

5

4

3

SURFACE COVER

12" AIR-ENTRAINED-

REEN

WATER TABLE

3

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5	\checkmark	4	L. L

\checkmark

A B C D E	STREAM ID# AIR STREAM FROM WELL FIELD WATER STREAM FROM WELL FIELD BACKGROUND SOIL WELLS HX-1 INLET HX-1 OUTLET, BLOWER INLET BLOWER OUTLET, HX -2 INLET	dry bulb deg F 55 190 190 175	abs. press atm 1 0.96 0.95	rel. press. "wc 0 -16	Dew Point F 54.9	Sat Temp F	Rel. Humidity %	Humidity #/# Dry 0.92290	Enthalpy Btu/# Dry Air	Dry Mass Flow #/min	Wet Mass flow #/min	Wet Density #/Ft^3	
A B C D E	STREAM ID# AIR STREAM FROM WELL FIELD WATER STREAM FROM WELL FIELD BACKGROUND SOIL WELLS HX-1 INLET HX-1 OUTLET, BLOWER INLET BLOWER OUTLET, HX -2 INLET	dry bulb deg F 55 190 190 175	abs. press atm 1 0.96 0.95	rel. press. "wc 0 -16	Dew Point F 54.9	Sat Temp F	Rel. Humidity %	Humidity #/# Dry 0.92290	Enthalpy Btu/# Dry Air	Dry Mass Flow #/min	Wet Mass flow #/min	Wet Density #/Ft^3	
A B C D E	STREAM ID# AIR STREAM FROM WELL FIELD WATER STREAM FROM WELL FIELD BACKGROUND SOIL WELLS HX-1 INLET HX-1 OUTLET, BLOWER INLET BLOWER OUTLET, HX -2 INLET	dry bulb deg F 55 190 190 175	abs. press atm 1 0.96 0.95	rel. press. "wc 0 -16	Dew Point F 54.9	Sat Temp F	Rel. Humidity %	Humidity #/# Dry 0.92290	Enthalpy Btu/# Dry Air	Dry Mass Flow #/min	Wet Mass flow #/min	Wet Density #/Ft^3	
A B C D E	STREAM ID# AIR STREAM FROM WELL FIELD WATER STREAM FROM WELL FIELD BACKGROUND SOIL WELLS HX-1 INLET HX-1 OUTLET, BLOWER INLET BLOWER OUTLET, HX -2 INLET	deg F 55 190 190 175	atm 1 0.96 0.95	"wc 0 -16	F 54.9	F	%	, #/# Dry 0.92290	Btu/# Dry Air	#/min	#/min	, #/Ft^3	
A B C D E	AIR STREAM FROM WELL FIELD WATER STREAM FROM WELL FIELD BACKGROUND SOIL WELLS HX-1 INLET HX-1 OUTLET, BLOWER INLET BLOWER OUTLET, HX -2 INLET	55 55 190 190 175	1 0.96 0.95	0 -16	54.9	211.7		0.92290	, ,	,		,	•
A B C D E	WATER STREAM FROM WELL FIELDBACKGROUND SOILWELLSHX-1 INLETHX-1 OUTLET, BLOWER INLETBLOWER OUTLET, HX -2 INLET	55 190 190 175	1 0.96 0.95	0 -16	54.9	211 7				97.5			
A B C D E	BACKGROUND SOILWELLSHX-1 INLETHX-1 OUTLET, BLOWER INLETBLOWER OUTLET, HX -2 INLET	55 190 190 175	1 0.96 0.95	0 -16	54.9	211 7					89.98		
A B C D E	WELLS HX-1 INLET HX-1 OUTLET, BLOWER INLET BLOWER OUTLET, HX -2 INLET	190 190 175	0.96 0.95	-16									
B C D E	HX-1 INLET HX-1 OUTLET, BLOWER INLET BLOWER OUTLET, HX -2 INLET	190 175	0.95		184.6	210.0	76	0.92290	1143.86	97.5	187.48	0.04739	3
C D E	HX-1 OUTLET, BLOWER INLET BLOWER OUTLET, HX -2 INLET	175		-20	184.6	209.6	74	0.92290	1143.86	97.5	187.48	0.04713	3
D E	BLOWER OUTLET, HX -2 INLET		0.94	-24	174.4	209.2	100	0.58448	728.77	97.5	154.49	0.04795	2
E		205	1.05	20	178.9			0.57854	746.34	97.5	153.91	0.06247	2
	HX-2 OUTLET	130	1.04	15	129.7	213.3	100	0.10589	150.86	97.5	107.82	0.06577	1
F	AIR STRIPPER VAPOR INFLUENT	80	1	0	63.6	211.7	57	0.01252	32.72	29	29.36	0.07281	
G	AIR STRIPPER VAPOR EFFLUENT	130	1.04	15	133.6	213.3	100	0.10589	150.86	29	32.07	0.06577	
													<u> </u>
Н	DUCT HEATER INLET	130	1.04	15	129.8	213.3	100	0.10589	150.86	126.5	139.90	0.06577	2
<u> </u>	DUCT HEATER OUTLET	165	1.04	15	129.8	213.3	32	0.10581	162.87	126.5	139.88	0.06294	2
													<u> </u>
J	COMBUSTION/DILUTION AIR	80	1	0	63.6	211.7	57	0.01252	32.72	15	15.19	0.07281	
<u> </u>	DILUTION AIR BLOWER OUTLET	95	1.04	15	65.1	213.3	36	0.01272	36.73	15	15.19	0.07344	
			1.04	4 -	10C F	212.2	27	0.00504	1 40 00	70.75		0.00074	\vdash
L		157.58	1.04	15	126.5	213.3	37	0.09594	148.88	70.75	//.54	0.06374	
			1.03		139.7			0.14594	/24.85	/0.75	81.08	0.01934	┝─┸
		157 58	1.04	15	126 5	212.2	37	0 0050/	1/18 88	70 75	77 5/	0.0637/	
L M2		1500	1.04	12	139 7	213.5	57	0.09594	724 85	70.75	81.08	0.00374	
			1.00		100.7			0.11001	721.00	/0./5	01.00	0.01331	
N	COMBINED STREAM, SCRUBBER INLET	1500	1.03	12	139.7			0.14594	724.85	141.5	162.15	0.01934	2
0	POST VENTURI QUENCH	178.2	1.02	7	177.5	212.5	100	0.57810	723.89	141.5	223.30	0.05162	4
Р	VAPOR DISCHARGE	179	1.00	1	176.9	211.8	94	0.57842	724.91	141.5	223.35	0.05115	4
	G H I J K K L M1 L M2 N O P	G AIR STRIPPER VAPOR EFFLUENT H DUCT HEATER INLET I DUCT HEATER OUTLET J COMBUSTION/DILUTION AIR K DILUTION AIR BLOWER OUTLET L OXIDIZER 1 INLET M1 OXIDIZER 1 OUTLET L OXIDIZER 2 INLET M2 OXIDIZER 2 OUTLET N COMBINED STREAM, SCRUBBER INLET O POST VENTURI QUENCH P VAPOR DISCHARGE	GAIR STRIPPER VAPOR EFFLUENT130HDUCT HEATER INLET130IDUCT HEATER OUTLET165JCOMBUSTION/DILUTION AIR80KDILUTION AIR BLOWER OUTLET95LOXIDIZER 1 INLET157.58M1OXIDIZER 1 OUTLET1500LOXIDIZER 2 INLET1570LOXIDIZER 2 INLET1500NCOMBINED STREAM, SCRUBBER INLET1500OPOST VENTURI QUENCH178.2PVAPOR DISCHARGE179	G AIR STRIPPER VAPOR EFFLUENT 130 1.04 H DUCT HEATER INLET 130 1.04 I DUCT HEATER OUTLET 165 1.04 J COMBUSTION/DILUTION AIR 80 1 K DILUTION AIR BLOWER OUTLET 95 1.04 L OXIDIZER 1 INLET 157.58 1.04 M1 OXIDIZER 1 OUTLET 1500 1.03 L OXIDIZER 2 INLET 157.58 1.04 M2 OXIDIZER 2 OUTLET 1500 1.03 N COMBINED STREAM, SCRUBBER INLET 1500 1.03 O POST VENTURI QUENCH 178.2 1.02 P VAPOR DISCHARGE 179 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Appendix F

Typical Equipment Specifications

1.0 GENERAL

This proposal is for standard Two (2) 1,100 SCFM **Thermal Oxidizers and One** (1) **Quench and Scrubber** package designed to treat the process gas stream described as under.

Assumption:

Total Process Gas Flow: 1,100 SCFM each Afterburner VOC Loading: 375 Lbs/hr each Afterburner Temp: 150 °F

INLET Avg. TEMP.	150°F
OPERATING TEMP	1400 -1500 <i>°</i> F
HEATING VALUE	3891 Btu/LB
LEL	8.0%
%LEL PROCESS	18.36%
COMPONENT	LB/HR
TCE	Approx. 187.5 Lbs/hr
PCE	Approx. 187.5 Lbs/hr
Moisture	0.174 Lbs Water/ Lbs Dry Air
Air	Balance (Approx. 827 SCFM)

2.0 SCOPE OF SUPPLY

- 2.1 Two (2) 1,100 SCFM **Afterburners** and One (1) **Quench and Scrubber** will be provided with the following:
 - 2.1.1 Two (2) Burner Systems (One for each Afterburner)
 - 2.1.2 One (1) Exhaust Air Fan (Induced Draft Fan)
 - 2.1.3 Two (2) Combustion Air Fans (One for each Afterburner)
 - 2.1.4 Choke and ring to insure proper mixing and create high turbulence to achieve higher rate of destruction efficiency
 - 2.1.5 Two (2) Fuel Gas Train (pre-piped and pre-wired) (One for each Afterburner)
 - 2.1.6 Two (2) Pilot Train (pre-piped and pre-wired) (One for each Afterburner)

- 2.1.7 One (1) Quench and Scrubber
- 2.1.8 One (1) UL Listed NEMA 4 Control Panel with Chart Recorder for Oxidizer and the Quench and Scrubber.

3.0 COMBUSTION / RETENTION CHAMBER (One for each Afterburner)

- 3.1 Residence Time: 1.0+ seconds
- 3.2 Operating Temperature: 1400-1500 °F (or sufficient to achieve the desired destruction efficiency)
- 3.3 Turbulence shall be sufficient to achieve the desired temperature profile.
- 3.4 Materials of construction
 - 3.4.1 Inner shell: 12 Ga. thick AL6XN
 - 3.4.2 Outer Shell (Jacketing): 20 Ga. 316/316L Stainless Steel
 - 3.4.3 Structural reinforcements as required to withstand the systems static pressure, load, and wind forces.
 - 3.4.4 Insulation: ceramic fiber block insulation, 2,200 °F rated
 - 3.4.5 Insulation thickness shall be sufficient to maintain the shell design, with a target temperature <140 °F.
- 3.5 Personnel access to the inside is provided via a man-way door for inspection purposes.

4.0 **BURNER(S)** (One for each Afterburner)

- 4.1 Two (2) Burners (One for each Afterburner)
- 4.2 One (1) 2.5 MMBTUH Maxon "Oven Pak" (Or Equal) burner with 20:1 turndown will operate on natural gas.
- 4.3 Sizing shall be for a maximum burner output of 2.5 MMBTUH total. During the process gas treatment mode the burner will utilize its thermal turndown to adjust to varying conditions as determined by the temperature controller.
- 4.4 A regulator will reduce the incoming natural gas pressure from 10.0 psig to the required operating pressure at the burner.

5.0 COMBUSTION AIR FAN(S) (for each Afterburner)

- 5.1 Qty.: 2 (One for each Afterburner)
- 5.2 Capacity: 580 SCFM
- 5.3 Type: Integral Type
- 5.4 Motor: 3/4 HP, TEFC, 480V/3PH/60HZ

6.0 ONE (1) EXHAUST AIR FAN (INDUCED DRAFT FRP FAN)

- 6.1 Capacity: 6,000 ACFM
- 6.2 Static Pressure: 16" W.C.
- 6.3 Material: FRP
- 6.4 Motor: 40 HP, TEFC, 480V/3PH/60HZ

7.0 VARIABLE FREQUENCY DRIVE (SEPARATELY PRICED) (for Exhaust Air Fan)

The variable frequency drive shall be housed in the control panel, or freestanding by the panel. The VFD shall adjust the fan capacity as per the temperature inside the oxidizer. The variable frequency drive shall increase the RPM of the fan as the temperature increases.

The drive is a microprocessor based adjustable frequency drive, designed to provide exceptional reliability when controlling three phase induction motors. The drive produces a 3-phase, adjustable frequency output that controls and adjusts motor speed. Drive output voltage blower speed requirements can be adjusted to match motor. The input signal can be fed to the drive, either directly from the process or through a PLC. In either option, the variable frequency drive is required to control air volume.

13.0 ONE (1) VERTICAL QUENCH AND VERTICAL PACKED TOWER

- 13.1 INLET EXHAUST:
 - 13.1.1 Gas Volume: 2,748 SCFM
 - 13.1.2 Gas Temperature: 1600 °F
 - 13.1.3 Cl₂ Loading: approximately 624 lb/hr
- 13.2 PERFORMANCE CRITERIA (AT SCRUBBER OUTLET):
 - 13.2.1 Outlet Exhaust Gas Volume (saturated): 5,469 ACFM
 - 13.2.2 Gas Temperature: 177 ℉
 - 13.2.3 Pressure Drop: 3" W.C.
 - 13.2.4 Cl₂ content: 6.24 lb/hr (99% Removal)
- 13.3 OPERATING DATA (WATER FLOWS):
 - 13.3.1 Recycle Liquid Rate: 75 GPM
 - 13.3.2 Evaporation Rate: 9 GPM
 - 13.3.3 Bleed Rate @ 10% dis. Solid concentration: 19 GPM
 - 13.3.4 Make-up Rate: 28 GPM @ 60psig (min.)
 - 13.3.5 Alkali Requirement, (NaOH) estimated: 685 lb/hr
 - 13.3.6 @ 25% concentration: 4.3 GPM
- 13.4 QUENCH DUCT:
 - 13.4.1 Material of Construction : C-276 (or equal)
 - 13.4.2 Thickness : 3/16"
 - 13.4.3 Diameter: 28 inch
 - 13.4.4 Length: 10.5 ft

13.5 VERTICAL PACKED TOWER:

13.5.1 Material of Construction: FRP (or Equal)

- 13.5.2 Vessel Thickness: 1/4"
- 13.5.3 Diameter: 4.0 ft
- 13.5.4 Height: 24.0 ft
- 13.5.5 Packing Bed Height: 10 ft
- 13.5.6 Packing Type: Random Dump
- 13.5.7 Packing Material: Glass-linked Polypropylene
- 13.6 MIST ELIMINATOR:
 - 13.6.1 Type: HE mesh pad
 - 13.6.2 Material of Construction: polypropylene (or Equal)
- 13.7 EQUIPMENT DATA:
 - 13.7.1 System Weight (Empty): 4,000 lbs
 - 13.7.2 Weight, Operating: 5,600 lbs
- 13.8 RECIRCULATION PUMP(S):
 - 13.8.1 Quantity: 1
 - 13.8.2 Capacity: 75 gpm
 - 13.8.3 Discharge Pressure: 80 ft head
 - 13.8.4 Drive Type: Direct
 - 13.8.5 Casing Material: FRP
 - 13.8.6 Impeller Material: FRP
 - 13.8.7 Seal: Single Mechanical
 - 13.8.8 Motor: 5 HP

13.8.9 Voltage: 480V/3P/60HZ

13.8.10 Speed: 3000 RPM

13.8.11 Enclosure: TEFC

13.9 INSTRUMENTATION AND CONTROLS:

- 13.9.1 One (1) Differential Pressure Transmitter
- 13.9.2 One (1) Flow Indicator/Transmitter
- 13.9.3 One (1) Conductivity Indicator/Transmitter
- 13.9.4 One (1) Level Indicator/Transmitter
- 13.9.5 One (1) pH Indicator/Transmitter with diaphragm pump
- 13.9.6 One (1) Temperature Indicator/Transmitter
- 13.9.7 One (1) Junction Box, NEMA 4.
- 13.10 RECIRCULATING LIQUID PIPING:
 - 13.10.1 Scope: Pump discharge to Scrubber inlet to pump inlet
 - 13.10.2 Material: CPVC

14.0 UTILITIES

- 14.1 Electric Power: 480VAC/3Ph/60HZ
- 14.2 Air: 100 Psi
- 14.3 Natural Gas: 10 Psi
The QED VOC Removal Advantage

Proven equipment, expert help with its selection and installation, and support you can o

Exclusive Online Performance Modeler has been developed to assist you in selecting the most effective air stripping package for your groundwater cleanup project

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E-Z Tray[®] Model 6.4





Air Stripper Specifications

Model	Maximum	Dry	Operating	Shell Dimension	Travs
No.	Flow Range	Weight	Weight	(LxWxH)	Per Tier
4.4	1-50 gpm (4-189 Lpm)	630 lbs. (286 kg)	985 lbs. (447 kg)	29 x 27 x 82 in. (74 x 69 x 208 cm)	4 x 29 lbs. (4 x 13 kg)
4.6	1-50 gpm (4-189 Lpm)	780 lbs. (354 kg)	1,219 lbs. (553 kg)	29 x 27 x 102 in. (74 x 69 x 259 cm)	6 x 29 lbs. (6 x 13 kg)
6.4	1-65 gpm (4-246 Lpm)	790 lbs. (358 kg)	1,285 lbs. (583 kg)	37 x 27 x 82 in. (94 x 69 x 208 cm)	4 x 40 lbs. (4 x 18 kg)
6.6	1-65 gpm (4-246 Lpm)	978 lbs. (443 kg)	1,591 lbs. (722 kg)	37 x 27 x 102 in. (94 x 69 x 259 cm)	6 x 40 lbs. (6 x 18 kg)
8.4	1-75 gpm (4-284 Lpm)	955 lbs. (433 kg)	1,580 lbs. (717 kg)	49 x 27 x 82 in. (124 x 69 x 208 cm)	4 x 50 lbs. (4 x 23 kg)
8.6	1-75 gpm (4-284 Lpm)	1,182 lbs. (536 kg)	1,956 lbs. (887 kg)	49 x 27 x 102 in. (124 x 69 x 259 cm)	6 x 50 lbs. (6 x 23 kg)
12.4	1-120 gpm (4-454 Lpm)	1,165 lbs. (528 kg)	2,105 lbs. (955 kg)	73 x 27 x 82 in. (185 x 69 x 208 cm)	4 x 60 lbs. (4 x 447 kg)
12.6	1-120 gpm (4-454 Lpm)	1,442 lbs. (654 kg)	2,606 lbs. (1,182 kg)	73 x 27 x 102 in. (185 x 69 x 259 cm)	6 x 60 lbs. (6 x 447 kg)
16.4	1-150 gpm (4-566 Lpm)	1,625 lbs. (737 kg)	2,870 lbs. (1,302 kg)	49 x 52 x 84 in. (124 x 132 x 213 cm)	8 x 50 lbs. (8 x 23 kg)
16.6	1-150 gpm (4-566 Lpm)	2,011 lbs. (912 kg)	3,553 lbs. (1,612 kg)	49 x 52 x 104 in. (124 x 132 x 264 cm)	12 x 50 lbs. (12 x 23 kg)
24.4	1-250 gpm (4-946 Lpm)	2,100 lbs. (953 kg)	3,980 lbs. (1,805 kg)	73 x 52 x 84 in. (185 x 132 x 213 cm)	8 x 60 lbs. (8 x 27 kg)
24.6	1-250 gpm (4-946 Lpm)	2,599 lbs. (1,179 kg)	4,926 lbs. (2,234 kg)	73 x 52 x 104 in. (185 x 132 x 264 cm)	12 x 60 lbs. (12 x 27 kg)
48.4	1-500 gpm (1,893 Lpm)	5,000 lbs. (2,268 kg)	12,500 lbs. (5,670 kg)	98 x 71 x 84 in. (249 x 180 x 213 cm)	16 x 60 lbs. (16 x 27 kg)
48.6	1-500 gpm (1,893 Lpm)	5,500 lbs. (2,495 kg)	13,000 lbs. (5,897 kg)	98 x 71 x 104 in. (249 x 180 x 264 cm)	24 x 60 lbs. (24 x 27 kg)
96.4	1-1,000 gpm (3,785 Lpm)	11,000 lbs. (4,990 kg)	25,000 lbs. (11,340 kg)	142 x 98 x 84 in. (361 x 249 x 213 cm)	32 x 60 lbs. (32 x 27 kg)
96.6	1-1,000 gpm (3,785 Lpm)	11.500 lbs. (5.216 kg)	30.000 lbs. (13.608 kg)	142 x 98 x 104 in (361 x 249 x 264 cm)	48 x 60 lbs (48 x 27 kg)

Standard construction is 304 SS, other alloys upon request. *Allow additional space for accessory components. (blower, piping, etc.)

COMPONENTS

Direct Driven Axial Fan with Galvanized Steel PVC Coated Screen Guard





2 ½" N.P.T. ABS-Spray nozzles with interchangeable internal devices

Fiberglass-reinforcedpolyamide adjustable pitch blades with Die Cast Aluminum Hub





PVC Fill and Drift Eliminator

DIMENSIONS









0

Single Fan



Double Fan

Quadruple Fan







HRFG	DI	MENSIO	NS		CON	NECTION	DIAMET	TER.		BASIN	WEIGHT		
MODEL	L	W	Н	2	3	4	8	13	14	CAP.	SHIPPING	OPERATING	
3031	36	36	108	2 1/2	2	1/2	2%	2	1/2	92	727	1427	
4041	48	48	121.5	4	2	1/2	2%	2	1/2	143	1022	2234	
5051	61	61	126.5	4	2	1/2	4	2	3/4	206	1366	3189	
6061	72	72	126.5	6	2	1/2	4	2	3/4	281	1890	4415	
7071	84	84	135.5	6	2	1	6	2	3/4	337	2553	5624	
7081	96	84	135.5	8	2	1	6	2	3/4	380	2717	6230	
7091	108	84	135.5	8	2	1	6	2	3/4	425	2912	6863	
7142	168	84	135.5	2-6	2-2	2-1	2-6	2-4	2-3/4	674	4674	10818	
8081	96	96	156	8	2	1	6	2	3/4	431	2986	6992	
8091	96	106	156	8	2	1	6	2	3/4	480	3182	7681	
8101	120	96	156	8	2	1	6	2	3/4	530	3548	8522	
8111	132	96	156	8	2	1%	8	2	3/4	580	3801	9256	
8121	144	96	156	8	2	1 %	8	2	3/4	629	4028	9965	
8162	192	96	165	2-8	2-2	2-1	2-6	2-4	2-3/4	828	5476	13213	
14144	168	168	135.5	2-8	2-2	2-1%	2-8	4-2	2-1	1992	9349	21637	
16164	192	192	165	2-10	2-2	2-1%	2-8	4-2	2-1	2602	10953	26427	

1. All dimensions, weights and capacities are in inches, pounds and gallons. Physical dimensions of each tower are approximate and are subject to change. 2. All double and quadruple models have double fittings and connections.

POLYBLOC II HEAT EXCHANGER SPECIFICATION SHEET 2 CARBONE LORRAINE **US Units** 3 4 Carbone Quote #: 17308 5 Customer Terratherm Reference No 6 Address Customer Reference #: Plant Location 7 Date 8-Jan-10 Rev 0 8 Service of Unit Unit 1 Item No 9 Size PBC24SL-4PU-1-1 PBC 1 Parallel Туре Connected In 1 Series hor 10 Surf/Shell (Gross/Eff) 421.57 ft2 Shell/Unit Surf/Unit (Gross/Eff) 421.57 ft2 1 11 PERFORMANCE OF ONE UNIT 12 Fluid Allocation Shell Side Tube Side 13 Fluid Name Chilled Water Humid Air 14 Fluid Quantity, Total lb/h 282969 10041 15 Vapor (In/Out) 3347 776 16 Liquid 282969 282969 2571 17 Noncondensable 6694 18 Temperature (In/Out) F 40 50 200 130 19 Dew / Bubble point F 172 20 Density 62.3 62.3 lb/ft3 0.047 61.1 21 Viscosity 1.572 1.336 0.017 0.555 ср 22 Molecular Weight, Vapor 27.24 24.08 23 Molecular Weight, Noncondensable 28.96 24 Specific Heat BTU/(lb*F) 1.0031 1.002 1.0025 0.3239 25 Thermal Conductivity BTU/(ft*h*F) 0.331 0.335 0.017 0.363 26 Latent Heat BTU/lb 996 1016 27 Inlet Pressure 14.0 psi 58.8 28 Velocity ft/s 67.16 3.43 29 Pressure Drop, Allow/Calc 7 0.85 0.181 0.1 psi 30 Fouling Resistance (min ft2*h*F/BTU 0.001 0.0005 31 Heat Exchanged BTU/h 2,837,613 MTD (Corrected) 111.1 F 32 Transfer Rate, Service 60.6 BTU/(h*ft2*F) 97.4 BTU/(h*ft2*F) 115.2 BTU/(h*ft2*F) Dirtv Clean CONSTRUCTION OF ONE SHELL 33 Sketch (Bundle/Nozzle Orientation 34 Shell Side Tube Side 35 Design/Test Pressure Ī Code psi 75 Code 75 1 36 Design Temperature F 260 260 0000 37 No Passes per Shell 4 (1 Per Block) 1 38 Corrosion Allowance in 0.0625 0.0 39 Connections In in 8 150 ANSI 16 **150 ANSI** 40 Size & Out 150 ANSI in 8 12 150 ANSI 41 Rating Intermediate 150 ANSI 150 ANSI 42 Tube No 404 ID 0.63 in Length 75.9 in 43 Tube Type Cylindrical holes Material Graphite 44 Shell CS 25.25 26.00 ID OD inch Shell Cover 45 Channel or Bonnet Channel Cover 46 Fixed header Graphite/CS Floating header Graphite/CS 47 Impingement protection None 48 Baffles-Cross PTFE 49 Expansion Joint NO Type 50 Rho-V2-Inlet Nozzle 815 lb/(ft*s2) Bundle Entrance 297 **Bundle Exil** 275 51 Gaskets-Shell Side PTFE Tube Side Graphite filled PTFE 52 -Floating Head PTFE 53 Code Requirements ASME Code Sec VIII Div 1 TEMA Class B 54 Weight/Shell 4147 Filled with Water 4698 lb 55 Remarks Carbone Polybloc II Impervious Graphite Cylindrical Block Heat Exchanger: Graphilor XBS 56 Model: PBC24SL-4PU-1-1 57 Approximate Dimensions: 26in[660] OD X 94.9in[2410] Tall 58 59 60 61 62 63 64

Physical data



30XA080-500 - ENGLISH

				_	-							
	080	090	100	110	120	1	40	160	180		200	220
Al-Cu Condenser Coils Cu-Cu Condenser Coils MCHX Condenser Coils	7,674 8,398 7,234	9,959 10,924 9,382	10,186 11,151 9,603	10,326 11,291 9,738	10,471 11,436 9,877	12, 13, 12,	760 966 023	13,003 14,209 12,255	13,5 15,0 12,6	90 37 99	13,712 15,159 12,810	14,727 16,295 13,748
REFRIGERANT TYPE Refrigerant Charge (Ib) Ckt A/Ckt B/Ckt C Refrigerant Charge (Ib) Ckt A/Ckt B/Ckt C (MCHX)	86/86/ 85/85/	97/97/— 81/81/—	108/108/— 83/83/—	F 135/108/ 100/83/	-134a, EXV 135/135/- 100/100/-	Controlled – 202/1 – 130/	System 15/ 85/	225/135/ 159/100/	/ 205/20 / 145/14	5/— 5/—	225/225/— 161/161/—	270/225/
COMPRESSORS Quantity	2	2 1	2	Se 2	mi-Hermetic	Twin Rotar	y Screws	2	1 2		2	1 2
Speed (rpm) (Oty) Compressor Model Number Ckt A (Oty) Compressor Model Number Ckt B (Oty) Compressor Model Number Ckt C Oli Charge (gal), Ckt A/Ckt B/Ckt C Minimum Capacity Step (%)	(1) 06TS-137† (1) 06TS-137† N/A 5.5/5.5/	(1) 06TS-137 (1) 06TS-137 N/A 5.5/5.5/—	(1) 06TS-155 (1) 06TS-155 N/A 5.5/5.5/—	(1) 06TS-186 (1) 06TS-155 N/A 5.5/5.5/	(1) 06TS-1 (1) 06TS-1 N/A 5.5/5.5/-	3500 86 (1) 06 86 (1) 06 86 (1) 06 - 6.25/	TT-266 TS-155 /A 5.5/	(1) 06TT-: (1) 06TS- N/A 6.25/5.5/	301 (1) 06T 186 (1) 06T N/4 (6.25/6.3	T-266 T-266 25/	(1) 06TT-301 (1) 06TT-301 N/A 6.25/6.25/—	(1) 06TT-356 (1) 06TT-301 N/A 6.75/6.25/
Optional	15 9	15 9	15 9	14 8	15 10	1	1 7	11 8	15 10		15 10	14 10
COOLER Net Fluid Volume (gal.) Maximum Refrigerant Pressure (psig) Maximum Water Side Pressure Without Pumps (psig) Maximum Water Side Pressure With Pumps (psig)	16.5 220 300 —	18.5 220 300 150	18.5 220 300 150	20.0 220 300 150	Flooded, She 23.0 220 300 150	and Tube	e Type 5.5 20 00 50	27.5 220 300 150	31.0 220 300	5))	34.0 220 300	37.0 220 300
WATER CONNECTIONS Drain (NPT, In.) Standard, Inlet and Outlet, Victaulic (in.) Number of Passes Minus 1 Pass, Inlet and Outlet, Victaulic (in.) Number of Passes Plus 1 Pass, Inlet and Outlet, Victaulic (in.) Number of Passes	3/a 5 2 5 1 4 3	^{3/8} 5 5 1 4 3	3/8 5 2 5 1 4 3	^{3/8} 5 2 5 1 4 3	³ /8 5 2 5 1 4 3	3	Va 5 2 5 1 5 3	3/6 5 2 5 1 5 3	3/8 6 2 8 1 6 3		3/8 6 2 8 1 6 3	3/8 6 2 8 1 6 3
CONDENSER FANS Fan Speed (rpm) Standard/High Ambient** No. BiadesDiameter (in.) No. Fans (Ckt A/Ckt B/Ckt C) Total Airflow (cm) 850 rpm Total Airflow (cfm) 1140 rpm	850/ 930 3/3/ 55,800	850/— 930 4/4/— 74,400 —	850/— 930 4/4/— 74,400	Shron 850/— 930 4/4/— 74,400	uded Axial Ty 850/ 930 4/4/ 74,400 	pe, Vertica 850/ 9 6/4 93 124	I Discha 1140 .30 V— .000 .000	ge 850/114 930 6/4/ 93,000 124,000	40 850/1 93 6/6/ 0 111,6 0 148,8	140 0 	850/1140 930 6/6/ 111,600 148,800	850/1140 930 7/6/— 120,900 161,200
CONDENSER COILS No. Coils (Ckt A/Ckt B/Ckt C)	3/3/—	4/4/	4/4/	4/4/—	4/4/	6/4	⊮— I	6/4/—	6/6/-	- 1	6/6/	7/6/—
Total Face Area (sq π) HYDRONIC MODULE (Optional)	141 N/A	188 Pu	188 Imp(s) with pre	188 ssure/tempera	188 ture taps and	2: combinati	34	234 281			281 N/A	305
CHASSIS DIMENSIONS (ft-in.) Length Width Height	11-10		15	Single or Di	ual, 3600 rpm	 7-4 ³ /4 7-6 ⁷ /16	19	8	1	23-	-7	27-6
UNIT 30XA	240	260	280	300)	325	3	50	400	T	450	500
OPERATING WEIGHT (lb)* Al-Cu Condenser Colls Cu-Cu Condenser Colls MCHX Condenser Colls	14,887 16,455 13,897	16,853 18,662 15,720	17,022 18,831 15,878	17,30 19,29 16,14	62 1 92 2 41 1	8,834 1,005 7,467	19, 21, 17,	040 211 659	24,578 26,990 23,038		26,600 29,254 24,901	26,894 29,547 25,167
REFRIGERANT TYPE Refrigerant Charge (Ib) Ckt A/Ckt B/Ckt C Refrigerant Charge (Ib) Ckt A/Ckt B/Ckt C (MCHX)	270/270/— 170/168/—	375/220/ 247/165/	375/270/- 240/170/-	– 415/27 – 245/17	R-134a, EXV 0/	Controlled 5/375/— 0/240/—	System 415/3 245/2	375/— 240/—	270/270/375	41	5/205/415	415/270/415 243/177/227
COMPRESSORS Quantity	2	1 2	1 2	St 1 2	mi-Hermetic	Twin Rota	ry Screw	s 2 I	3	1	3 1	3
Speed (rpm) (Oty) Compressor Model Number Ckt A (Oty) Compressor Model Number Ckt B (Oty) Compressor Model Number Ckt C Oli Charge (gal), Ckt A/Ckt B/Ckt C Minimum Capacity Step (%) Standard	(1) 06TT-356 (1) 06TT-356 N/A 6.75/6.75/—	(1) 06TU-483 (1) 06TT-301 N/A 7.5/6.75/	(1) 06TU-4 (1) 06TT-3 N/A 7.5/6.75/-	1	1-554 (1) (1-356 (1) (5/ 7.1	3500 06TU-483 06TU-483 N/A 5/7.5/—	(1) 06 (1) 06 N 7.5/7	- TU-554 TU-483 /A Y.5/	(1) 06TT-356 (1) 06TT-356 (1) 06TU-483 6.75/6.75/7.5	(1) (1) (1) (1) 7.	06TU-554 06TT-266 06TU-554 5/6.25/7.5	(1) 06TU-554 (1) 06TT-356 (1) 06TU-554 7.5/6.75/7.5
Optional	10	8	9	7		10	<u> i</u>	ŏ	6		4	5
Net Fluid Volume (gal.) Maximum Refrigerant Pressure (psig) Maximum Water Side Pressure Without Pumps (psig) Maximum Water Side Pressure With Pumps (psig)	39.0 220 300 —	42.0 220 300	44.0 220 300 —	48.9 220 300 	Flooded, Sh	ell and lub 50.5 220 300 —	6 Type 53 21 34	8.4 20 00 	68.0 220 300		75.0 220 300 —	83.0 220 300
WATER CONNECTIONS Drain (WPT, in.) Standard, Inlet and Outlet, Victaulic (in.) Number of Passes Minus 1 Pass, Inlet and Outlet, Victaulic (in.) Number of Passes Plus 1 Pass, Inlet and Outlet, Victaulic (in.) Number of Passes	3/8 6 2 8 1 6 3	³ /8 8 2 8 1 8 3	3/8 8 2 8 1 8 3	³ /8 8 2 8 1 8 3		³ /8 8 2 8 1 8 3	3	/a 3 2 8 1 8 3	^{3/8} 8 1 — —		³ /8 8 1 — —	3/8 8 1
CONDENSER FANS Fan Speed (rpm) Standard/High Ambient** No. BladesDiameter (in.) No. Fans (Cki A/Cki B/Cki C) Total Airflow (cfm) 850 rpm Total Airflow (cfm) 1140 rpm	850/1140 930 7/6/— 120,900 161,200	850/1140 930 9/6/— 139,500 186,000	850/1140 930 9/7/— 148,800 198,400	Shro 850/1 93 10/6/ 148,8 198,4	uded Axial Ty 40 85 0 5 5 00 10 00 22	/pe, Vertica 0/1140 930 9/9/ 57,400 23,200	al Discha 850/ 9 9/9 167 223	rge 1140 .30)/— ,400 ,200	850/1140 930 6/6/8 186,000 248,000	8	950/1140 930 8/6/8 204,600 272,800	850/1140 930 8/6/8 204,600 272,800
CONDENSER COILS No. Coils (Ckt A/Ckt B/Ckt C) Total Face Area (so ft)	7/6/	9/6/	9/7/-	10/6/	- 1 9	9/9/—	9/9	∦— I	6/6/8	1	8/6/8	8/6/8
HYDRONIC MODULE (Optional) Pump		002	1 3/3	13/5	1	N/A	1 47	<u>~ </u>	409	1	010	516
CHASSIS DIMENSIONS (ft-in.) Length Width Height	27-6	1	31-5		ا 7. 7.	35 -4 ³ / ₄ -6 ^{7/} 16	5-4	1	39-3	I	43-	2
LEGEND				*Oneration	woight includ	oc 2 oumo			000 100 No.		and available	

Cu — Copper AI — Aluminum EXV — Electronic Expansion Valve MCHX — Microchannel Heat Exchanger N/A — Not Applicable

^{*}Operating weight includes 2 pumps on models 30XA090-160. No pumps are available on 30XA080 or 30XA180-500. See pages 8-19 for mounting weights for units without pumps and units with single pump packages. †30XA080 unit does not have an economizer.
**The high ambient temperature option is not available on 30XA080-120 units.

Company:	ROOTS Division									
Address:	16240 Port Northwest Dr	ive, Hou	ston,	Texas	7704	1				
	Ph: 832-590-2305/1-877-	393-7668	Fa	ax: 832	-590-2	2326				
ROOTS BLOWER	PERFORMANCE SUMMARY :	Program	Vers	ion 6.0	000 E	Relea	se Date	2/2	8/200	8
Program Mode	: SELECTION	Run Dat	e:	03/01	2010			,	-,	
· y · · · · · ·				,,						
AMBIENT COND	TTTONS:									
Gas		ATR								
Relative	Humidity	908								
Molecula	r Weight	25 291								
k-Voluo	ir werght	1 250								
K-vaiue Specifie	. Crossiter	1.352								
Specific	Gravity	.8/6								
Ambient	Temperature	68		deg F						
Ampient	Pressure	14.59		PSIA						
Elevatio	n	200		feet						
STANDARD CON	DITIONS:									
Pressure	2	14.7		PSIA						
Temperat	ure	68		deg F						
Relative	Humidity	36		8						
INPUT CONDIT	IONS:									
Actual I	nlet Volume	2600		ICFM	+/-5	8				
Standard	l Volume	1428		SCFM						
Mass/Wei	ght Flow	134.2		#/min	+/-5	8				
System I	nlet Pressure	13.86		PSIA						
Inlet Pr	essure Loss	8.0		in H2O						
Blower I	nlet Pressure	13.57		PSIA						
Blower D	ischarge Pressure	15.61		PSIA						
Discharg	e Pressure Loss	8.0		in H2O						
System D	ischarge Pressure	15.3		PSIA						
Inlet Te	mperature	162		dea F						
	-	-		5						
SELECTED UNI	T DETAIL:									
Model			600		RAM	х				
Speed			2387		RPM		78.3%			
Blower D	ifferential Pressure		2.04		PSI		13.6%			
Power at	Blower Shaft		30.2	0	BHP		+/- 5%			
Temperat	ure Rise		31	-	dea	ਸ	18 4%			
Discharg	e Temperature		193		der	- ਸ	10.10			
System D	vischarge Volume		2372		ມ ເມ	-				
Relief V	alve Setting		NO P	י סקד.דא			רפיזבים			
V-Rolt.	Est B10 Brg Lifo		1901	1367 \ //367	hours	OFEC.	LT TRD			
Coupling	· Fet B10 Brg Life:		1250	30501	noui	- 5				
Eat Dea	. Est. BIO BIG DITE:		1332	50524	ו - תו-	Jours				
Lat. Fre	e treta Notse	3 3	87.8	01 - 1 - 1	asa				-	
meas	ured as sound pressure .	rever bei	C TRO	2121:5	2004E	with	+/-3 dE	SA t	orera	nce.



Appendix G

Heat Dissipation Modeling Results

Heat Dissipation Model

Solvents Recovery Service of New England (SRSNE)

Southington, Connecticut

Prepared for:

SRSNE Site Group

March 2010

Prepared by:



TerraTherm is an exclusive licensee/owner of (a) U.S. Patent Nos. 4,984,594; 5,076,727; 5,114,497; 5,190,405; 5,221,827; 5,229,583; 5,244,310; 5,271,693; 5,318,116; 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; 6,951,436; 6,962,466; and 7,004,678, (b) U.S. Patent Publication 2004-0228690, and (c) certain non-U.S. counterpart applications/patents of the above-referenced patents and application.

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TABLE OF CONTENTS

1.0 IN I RODUCTION	1
2.0 MODEL SETUP	2
2.1 Model Domain	2
2.2 Model Scenarios	4
2.3 Energy Balance Estimation Methods	6
2.4 Starting Conditions	8
2.5 Simulation Output	10
3.0 RESULTS	13
3.1 Estimated Time for Return to Equilibrium	13
3.2 Predicted Downgradient Temperatures	15
3.3 Temperature Variation at the NTCRA Extraction Wells	15

APPENDIX

Appendix A: Simulation Results for Scenarios 1 through 5



1.0 INTRODUCTION

The SRSNE Site Group has elected to undertake an evaluation to determine the dissipation of heat outside of the treatment area during and after heating of the treatment zone. TerraTherm has set up a two dimensional heat dissipation numerical model to simulate the down gradient transport of heat during the thermal remedy and subsequent cooling. The purpose of the evaluation has more specifically been 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 down gradient of 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 following sections describe the basis of the heat dissipation model and present the results of the modeling.



2.0 MODEL SETUP

2.1 Model Domain

A finite-element, numerical model has been developed to simulate the heat transport by advection and conduction. Figure 1 shows a map of the site with the selected orientation of the two dimensional, vertical simulation domain.



Figure 1. Location of Simulated Vertical Transect from West to East. Note the varying thickness of the saturated overburden (red numbers).

The model is set up to calculate the temperatures in a 142.5 meter (m) (468 ft) cross section through and downgradient of the Target Treatment Zone (TTZ). Seventy-five m (246 ft) of the model cross section are located in the TTZ and 67.5 m (221 ft) are located in the unheated area downgradient of the TTZ.

The model is divided into five simplified layers based on the geology at the site, as presented in Figure 2.





Figure 2. Model Layers in Heat Dissipation Model

Layer 1 is the insulated cover on top of the treatment zone while Layer 2 is the vadose zone. Both Layer 1 and 2 are modeled assuming a constant thickness, but only Layer 2 is located in the TTZ.

Layer 3 represents the saturated overburden and is within the TTZ. It is 1.8 m (6 ft) thick throughout the majority of the TTZ, but the thickness increases from the eastern edge of the TTZ and toward the NCTRA 1 sheet pile wall (Figure 1) to reflect the actual geological settings at the site. At the sheet pile wall, Layer 3 is 11 m (36 ft). The depth of Layer 3 is increased by linear interpolation.

Layers 4 and 5 are the upper and the lower bedrock below the site. Layers 4 and 5 have a constant thickness for the purpose of the model.

Figure 3 shows the vertical transect/slice and a simplified model domain.





Figure 3. Conceptual Cross-Section of the Model, and Model Grid. Note that not all blocks are shown in the figure

The grid-blocks are 1.5 m (5 ft) long (95 cells) in the flow direction, 50 of the cells are within the TTZ. The simulation slice is 142.5 m long and contains 475 grid-blocks.

Aquifer properties and pumping data provided by ARCADIS have been used for the simulations. These include a porosity of 0.275 for the saturated overburden. Heat capacities and thermal conductivity have been derived by assuming that the solid matrix is quartz, and that the pores are water saturated. The thickness of the overburden will be varied along the model to represent the deepening of the saturated overburden, as indicated in Figure 3.

2.2 Model Scenarios

To test the importance of horizontal and vertical groundwater flow on the thermal analysis, the following scenarios have been modeled:

1) No vertical flow – model starts from day 125 of operation (assumes TTZ has reached 100 °C and heaters are turned off)

• Scenario 1: No water flow (shows only diffusive heat transport). Model starts from the day the heat is terminated in TTZ.



- Scenario 2: 5 gallons per minute (gpm) water flow through TTZ. All 5 gpm assumed to flow through model horizontally (no inflow of water from bedrock). Model starts from the day the heat is terminated in TTZ.
- Scenario 3 (Base case): 10 gpm water flow through TTZ. All 10 gpm assumed to flow through model horizontally (no inflow of water from bedrock). Model starts from the day the heat is terminated in TTZ.
- Scenario 4: 15 gpm water flow through TTZ. All 15 gpm assumed to flow through model horizontally (no inflow of water from bedrock). Model starts from the day the heat is terminated in TTZ.

2) Vertical flow – model from day 125 of operation (assumes TTZ has reached 100 °C and heaters are turned off)

- Scenario 3A: 13 gpm water flow through TTZ. 10 gpm assumed to flow through model horizontally. 3 gpm is inflow of water from bedrock. Model starts from the day the heat is terminated in TTZ.
- Scenario 3B: 16 gpm water flow through TTZ. 10 gpm assumed to flow through model horizontally. 6 gpm is inflow of water from bedrock. Model starts from the day the heat is terminated in TTZ.

3) No vertical flow – model from day 1 of operation

• Scenario 5: 10 gpm water flow through TTZ. All 10 gpm assumed to flow through model horizontally. Model starts from day 1 of operation (heat-up period is included).

The model scenarios are summarized in Table 1 below.

	Horizontal flow	Vertical flow	Start of model
Scenario	[gpm]	[gpm]	[day of operation]
Scenario 1	0	0	125
Scenario 2	5	0	125
Scenario 3 (base case)	10	0	125
Scenario 4	15	0	125
Scenario 3A	10	3	125
Scenario 3B	10	6	125
Scenario 5	10	0	1

 Table 1. Table Summarizing the Seven Model Runs

Scenario 3 is considered the most representative scenario and is set up as the base scenario for the modelling. This scenario assumes that hydraulic control is maintained during the thermal remedy and no hot water is leaving the TTZ.

Heat Dissipation Model Solvents Recovery Service of New England March 2010 Page 6



The simulation period was 550 days. Scenario 1 through 4 start at day 125 of operation and extend through day 675 after startup of operation. Scenario 5 ran from day 1 of operation. After 125 days of operation the heat was turned off in the model, and the model ran for another 425 days assuming no additional heat added to the model domain.

2.3 Energy Balance Estimation Methods

For each time-step, an energy balance is kept for each grid-block. The equations used are described below.

Cumulative energy (E) for a block is calculated as a summation of enthalpy fluxes (Q), for the time-step Δt :

$$\mathsf{E} = \Sigma \left(\mathsf{Q} \times \Delta t \right)$$

An estimated energy balance will be maintained for each block in the model.

$$E_{in} = E_{out} + E_{storage} + E_{loss}$$

The energy fluxes are related for each time step as follows:

$$Q_{in} = Q_{out} + Q_{storage} + Q_{loss}$$

where Q denotes enthalpy flux (in BTU/hr). Figure 3 shows the schematic energy balance for one layer.

All the water transport in the model occurs in the saturated overburden and the bedrock. For the vadose zone grid-blocks, heat only migrates by thermal conduction. In scenarios without any vertical groundwater flow, heat in the bedrock only migrates by thermal conduction. This is not a precise representation of field conditions, but will make the simulations conservative – the heat dissipation will not be overestimated.

The energy flux in the flowing groundwater is given by:

$$Q_{\text{liq}} = m_{\text{liquid}} \times c_{p, \text{ water}} \times (T - T_0)$$

where c_p is heat capacity, T is the temperature of the grid-block, and T_0 is the ambient temperature.

An estimate of the diffusive (conductive) heat loss can be made based on thermal profiles at the bottom and top of each layer, and along the perimeter, using the following calculations:

$$Q_{heat loss} = A \times K_T \times dT/dz$$



where A is the surface area through which energy is conducted, K_T is the thermal conductivity of the subsurface material, and dT/dz is the temperature gradient across the surface also expressed as $(T_1-T_2)/(z_1-z_2)$.

For the loss through the vapor cap, the temperature difference between the top and bottom of the layer can be used to calculate the gradient. For the calculations, it is assumed that the top of the vapor cap remains near ambient temperatures due to a combination of wind cooling and simple heat radiation.

Heat loss calculations through the bottom are accounted for in a similar manner. The layers exchange energy by thermal conduction such that energy leaves the warmer layer and enters the cooler layer.

The model calculates average layer temperatures based on the energy balance and the estimated heat capacity of each layer. The stored energy is related to the heated zone, heat capacity, and the average temperature as follows:

$$\mathsf{E}_{\mathsf{storage}} = \mathsf{C}_{\mathsf{p}} \mathsf{x} (\mathsf{T} - \mathsf{T}_{\mathsf{0}})$$

where C_p is the heat capacity of the grid-block, estimated from the volume, saturation, and specific heat capacity of the soil and water:

$$C_p = V_{soil} \times C_p \times V_{water} \times C_{p, water}$$

In each time-step, the energy balance can be used to estimate the temperature of each grid-block (T_{energybal}):

 $T_{energybal} = T_0 + E_{storage}/C_p = T_0 + (E_{in} - E_{out} - E_{loss})/C_p$

The model uses 550 time steps of 24 hours each, with 160,000 energy balance calculation steps.



2.4 Starting Conditions

The starting temperature condition for Scenario 1 to 4 in the model is shown in Figure 4.



Figure 4. Starting Temperatures for Scenario 1 through 4 in the Model

The temperature distribution represents the condition within the footprint of the TTZ at the end of thermal treatment, where the target treatment volume has been heated to 100°C. The upper 1.5 m of the bedrock is expected to have an average temperature of 50°C. Both the vapor cap and the bedrock deeper than 1.5 m below the overburden will have varying temperatures due to the heat transport through those zones during thermal treatment.

The starting temperature conditions within the TTZ for Scenario 5 are shown in Figure 5. Note that the heat transferred downgradient from the TTZ from day 1 to day 100 is not shown in Figure 5, but is included in the model calculations.



Starting Conditions (Scenario 5): Day 1								
Varying trickness								
Gradient ☐ Gradient ☐ 100°C ☐ 10°C ☐ 10°C ☐ Gradient								

Figure 5. Starting Temperatures in the Model for Scenario 5.

The temperature distribution at day 1 represents the condition at startup of operation. After 100 days of heating the average temperature in the heated zone is expected to be 100 °C and kept there until day 125 of operation where the heating is terminated and the target treatment volume has been heated to 100° C.

From day 1 and until day 100 of operation the temperature in the heated zone (Layer 2 and 3 in the model) is increased from ambient temperatures (10 °C) to the boiling point (100 °C) according to the graphs shown in Figure 6. The graphs present the expected heat up of the heated zone. From day 100 to day 125 of operation, the average temperature in Layer 2 and 3 is kept at 100 °C to represent expected field conditions.

In Scenario 5, the upper 1.5 m of the bedrock (layer 4) is expected to have an average temperature of 50 °C after 100 days of operation. Figure 6 shows the assumed heat up of the upper bedrock layer (Layer 4 in the model).





Figure 6. Assumed Heat-up of Layer 2 to 4 in Scenario 5

Both the vapor cap and the bedrock deeper than 1.5 m below the overburden will have varying temperatures due to the heat transport through those zones during thermal treatment.

2.5 Simulation Output

The model calculates temperature data for the saturated overburden, the vadose zone, and the upper 1.5 m of the bedrock. Example output data are provided for the saturated overburden for the base case (Scenario 3) in Figure 7 and 8.





Figure 7. Saturated Overburden Temperatures along the Flow Path for Scenario 3 (Base Case). Horizontal flow is 10 gpm and vertical flow is zero.

Figure 7 shows the temperature along the flow path from the time when heating is terminated in the TTZ (day 0) until 550 days after shutdown. The existing NTCRA wells are located between 15 m (50 ft) and 55 m (180 ft) from the TTZ, corresponding to 90 - 130 m (295 - 427 ft) along the flowpath.

The base case results indicate that the temperature impact at the pumping wells will be between 5 and 20 °C *above* the ambient temperature of 10 °C (i.e., between 15 and 30 °C predicted temperature), depending on specific well locations.





Figure 8. Saturated Overburden Temperatures with Time for Scenario 3 (base case). Horizontal flow is 10 gpm and vertical flow is zero.

Figure 8 shows the temperature with time for modeling points located at different distances from the upgradient edge of the TTZ (distances indicated in the legend). In addition, labeled data sets shown in the graph indicate distances from the downgradient edge of the TTZ. Different locations within and downgradient of the TTZ will experience different temperature increases, as illustrated in the figure. The soil and water temperature, for example, 15 m (49 ft) from the TTZ is predicted to reach a temperature of 30 °C and the temperature is predicted to peak approximately 130 days after the heat is turned off.

Appendix A contains the simulation results for Scenarios 1 to 5.



3.0 RESULTS

The following sections address the questions of concern listed in the opening of this document. All results are focused on the temperatures in the saturated overburden (Layer 3 in the model), where water flows towards the NCTRA wells located downgradient of the treatment area.

3.1 Estimated Time for Return to Equilibrium

Based on the calculations, the cooling of the site can be predicted. The ambient soil temperature at the site has been assumed to be 10 °C. Furthermore, due to natural variability and fluctuation in groundwater temperatures, it is assumed that a temperature within 10 °C of ambient temperature, e.g. below 20 °C, will be considered close to the equilibrium state. This is consistent with natural variations in groundwater temperature, which have shown to fluctuate seasonally by up to 12 °C.

Table 2 summarizes the time for the TTZ to return to temperatures below 20 °C. For comparison, the corresponding times to cool down the areas below 15 °C are shown. The table shows both the time to reach an average temperature of 15 and 20 °C, and the time before the maximum temperature within the TTZ is below 15 and 20 °C.

	Horizontal flow	Vertical flow	Max 20 °C	Max 15 °C	Average 20 °C	Average 15 °C
	[gpm]	[gpm]	[days]	[days]	[days]	[days]
Scenario 1	0	0	241	316	234	309
Scenario 2	5	0	240	317	210	275
Scenario 3 (base case)	10	0	239	307	182	235
Scenario 4	15	0	220	270	156	199
Scenario 3A	10	3	231	296	176	227
Scenario 3B	10	6	224	285	171	220
Scenario 5	10	0	364	432	307	360

Table 2. Time for TTZ to Return to Ambient Temperature

Excluding Scenario 5, the model predicts the average temperature in the TTZ to be below 20 °C after 156 to 234 days after the energy input to the TTZ is terminated. The time to reach a maximum temperature in the TTZ below 20 °C is between 220 and 241 days.



In Scenario 5 where the heat-up period is included in the calculations, the corresponding time to reach an average and maximum temperature in the TTZ is 307 and 364 days. Subtracting 125 days to account for the different starting time for this scenario, the resulting times to average and maximum temperatures in the TTZ (182 and 239 days) are within the ranges predicted by the other scenarios.

Table 3 summarizes the time for the treatment area and the area downgradient of the treatment area to return to temperatures below 15 and 20 °C.

	Horizontal flow	Vertical flow	Max 20 °C	Max 15 °C	Average 20 °C	Average 15 °C
	[gpm]	[gpm]	[days]	[days]	[days]	[days]
Scenario 1	0	0	241	316	164	239
Scenario 2	5	0	244	335	165	241
Scenario 3 (base case)	10	0	267	387	160	235
Scenario 4	15	0	292	437	153	228
Scenario 3A	10	3	266	392	160	235
Scenario 3B	10	6	264	396	159	235
Scenario 5	10	0	428	<550	300	381

Table 3. Time for TTZ and Downstream Area to Return to Ambient Temperature

If the downgradient area is included in the model, it predicts the average temperature in the TTZ and the downgradient area to be below 20 °C after 153 to 165 days after the energy input to the TTZ is terminated. The time to reach a maximum temperature in the TTZ and the downgradient area below 20 °C is between 241 and 292 days.

In Scenario 5, where the heat-up period is included in the calculations, the corresponding time to reach an average and maximum temperature below 20 °C in the TTZ is 300 and 428 days.

Please note that the stated times in Table 2 and 3 are from the time the heaters are shut down for Scenario 1 to 4 (corresponding to day 125 of operation), while the time stated for Scenario 5 is from startup of operation.



3.2 Predicted Downgradient Temperatures

The model was used to calculate groundwater temperatures expected to occur in downgradient NTCRA area wells as a result of heating within the TTZ.

The model calculates the downgradient temperature up to 67.5 m (221 ft) from the edge of the treatment area. Since the NTCRA monitoring wells are located in different distances from the edge of the treatment zone, the maximum expected temperature to be observed at a distance of 10 m (33 ft), 20 m (66 ft), 40 m (131 ft) and 67.5 m (221 ft) from the downgradient edge of the treatment zone are summarized in Table 4.

Table 4. Predicted Maximum Temperatures along the Flowpath in the Model Domain.All distances are measured from the downgradient edge of the heated zone, whichcorresponds to 75 m along the flowpath in the model.

	Horizontal flow	Vertical flow	Maximum temperature 10 m from edge of TTZ	Maximum temperature 20 m from edge of TTZ	Maximum temperature 40 m from edge of TTZ	Maximum temperature 67.5 m from edge of TTZ
	[gpm]	[gpm]	[°C]	[°C]	[°C]	[°C]
Scenario 1	0	0	10	10	10	10
Scenario 2	5	0	22	14	10	10
Scenario 3 (base case)	10	0	35	24	14	10
Scenario 4	15	0	44	32	18	12
Scenario 3A	10	3	38	26	15	11
Scenario 3B	10	6	40	28	17	12
Scenario 5	10	0	52	33	16	10

The predicted maximum temperature 10 m (33 ft) from the edge of the TTZ is up to 52 °C. The temperature decreases dramatically with distance from the TTZ. 67.5 m (220 ft) downgradient of the TTZ, the expected increase in temperature is in the order of a few degrees Centigrade.

Graphs showing the maximum temperatures as a function of the distance along the flowpath are attached in Appendix A.

3.3 Temperature Variation at the NTCRA Extraction Wells

The average NTCRA extraction well is located approximately 34 m (110 ft) from the TTZ corresponding to 109 m (358 ft) along the flowpath in the model. In Appendix A, the temperature variation over time is shown for the different model scenarios.



The average temperature increase in the water extracted by the NTCRA wells over time is predicted to be in the order of 5-10 °C assuming an average distance and equal flow rate through the TTZ and the downgradient area.



Appendix A

Simulation Results for Scenarios 1 through 5

Scenario 1

No pumping. Model starts at shut down of thermal system (Day 125 of thermal operation)

Scenario 1 - No pumping. Model starts at shut down of thermal system.





Scenario 1 - No pumping. Model starts at shut down of thermal system.

Scenario 2

5 gpm pumping. Model starts at shut down of thermal system.

Scenario 2 - 5 gpm pumping. Model starts at shut down of thermal system.





Scenario 2 - 5 gpm pumping. Model starts at shut down of thermal system

Scenario 3

10 gpm pumping. Model starts at shut down of thermal system

Scenario 3 - 10 gpm pumping. Model starts at shut down of thermal system



Scenario 3 - 10 gpm pumping. Model starts at shut down of thermal system



Scenario 4

15 gpm pumping. Model starts at shut down of thermal system

Scenario 4 - 15 gpm pumping. Model starts at shut down of thermal system






Scenario 3 – with vertical upflow of water

Scenario 3 A -10 gpm horizontal flow, 3 gpm vertical upflow of water, total 13 gpm Scenario 3 B -10 gpm horizontal flow, 6 gpm vertical upflow of water, total 16 gpm Scenario 3A: 10 gpm horizontal – 3 gpm vertical. Model starts at shut down of thermal system



Scenario 3A: 10 gpm horizontal – 3 gpm vertical. Model starts at shut down of thermal system



Scenario 3A - Bottom Layer: 0 gpm horizontal – 3 gpm vertical. Model starts at shut down of thermal system



Distance (m)

Scenario 3B: 10 gpm horizontal – 6 gpm vertical. Model starts at shut down of thermal system



Scenario 3B : 10 gpm horizontal – 6 gpm vertical. Model starts at shut down of thermal system



Scenario 3B - Bottom Layer: 0 gpm horizontal – 6 gpm vertical. Model starts at shut down of thermal system



Scenario 5 – Model starts at startup of thermal system (day 1 of thermal operation)

Scenario 5: Model start at startup of thermal system



Scenario 5: Model start at startup of thermal system

