# Simultaneous Thermal Treatment of Eight DNAPL Source Areas at Memphis Defense Depot

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# Overview

Introduction to In-Situ Thermal Remediation

- Usage
- Applicability

Representative Case Study: CVOCs at Memphis Depot

All Completed Projects have Met or Exceeded Goals

# In-Situ Thermal Remediation (ISTR) is Mature and Widely Applied

- 182 ISTR Projects (ESTCP-funded study; Kingston, 2008)
- Accelerating trend
- Electrical Resistance and Thermal Conduction Heating are currently the most widely practiced

**(Kingston. 2008. *A Critical Evaluation of In-situ Thermal Technologies*. Ph.D. Dissertation, Arizona State Univ.)**

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# Reasons to Think Thermal

- Community friendly: Treats contaminated soils and groundwater in place
- Delivers robust and highly predictable results
  - Fast and final
- Meets needs of broad range of project sites and contaminants
- Provides potentially huge increases in property value
- Highly competitive costs – Often Thermal is the obvious choice

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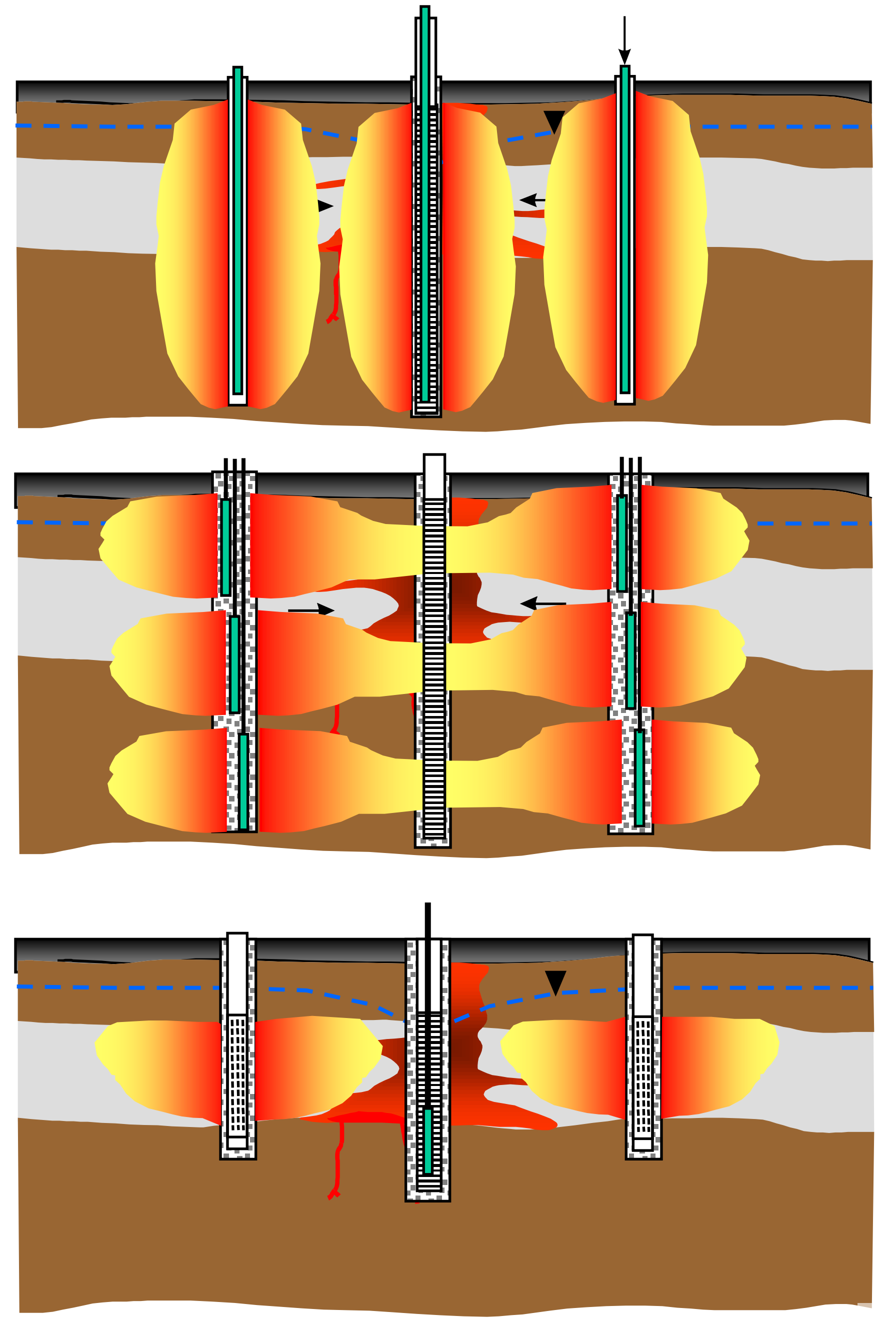
# ISTR Technologies:
## How They Work

**Thermal Conduction Heating (TCH)** or **In-Situ Thermal Desorption** (ISTD)*****

**Electrical Resistance Heating** (ERH) – Joule or Ohmic Heating, by means of the Electro-Thermal Dynamic Stripping Process (ET-DSP™)*****

**Steam Enhanced Extraction (SEE)***– Steam Injection



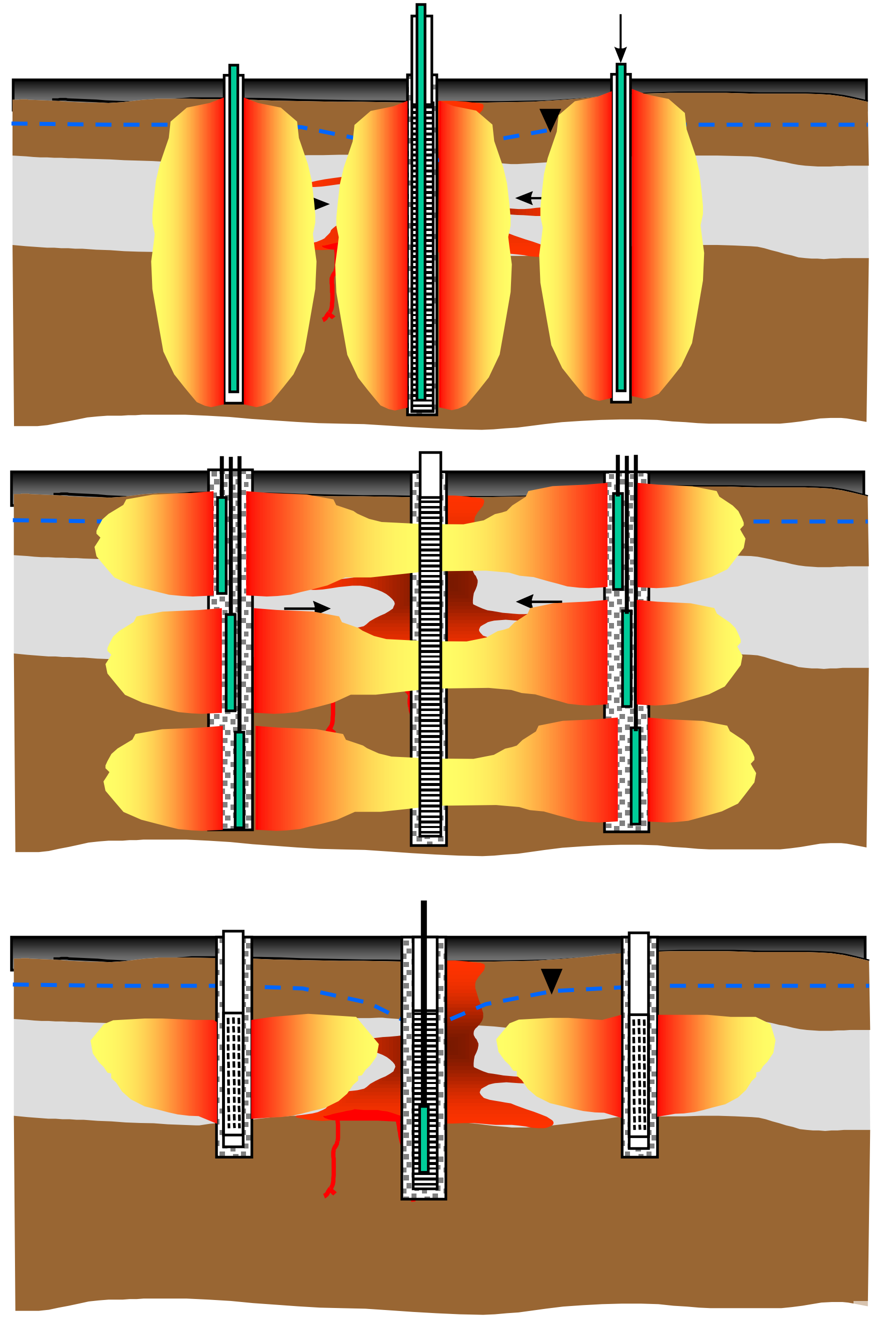
***Offered by TerraTherm, Inc.**

# ISTR Applicability

**TCH*** - Heating governed by **thermal conductivity** (*f*~3); Wide range of target temperatures; Low to moderate permeability settings

**ERH*** - Heating governed by **electrical conductivity** (*f*~200); ≤ B.P. of water; Low to moderate permeability settings

**SEE*** (SER) - Heating governed by **hydraulic conductivity** (*f*~$10^6$); ≤ B.P. of water; High permeability settings



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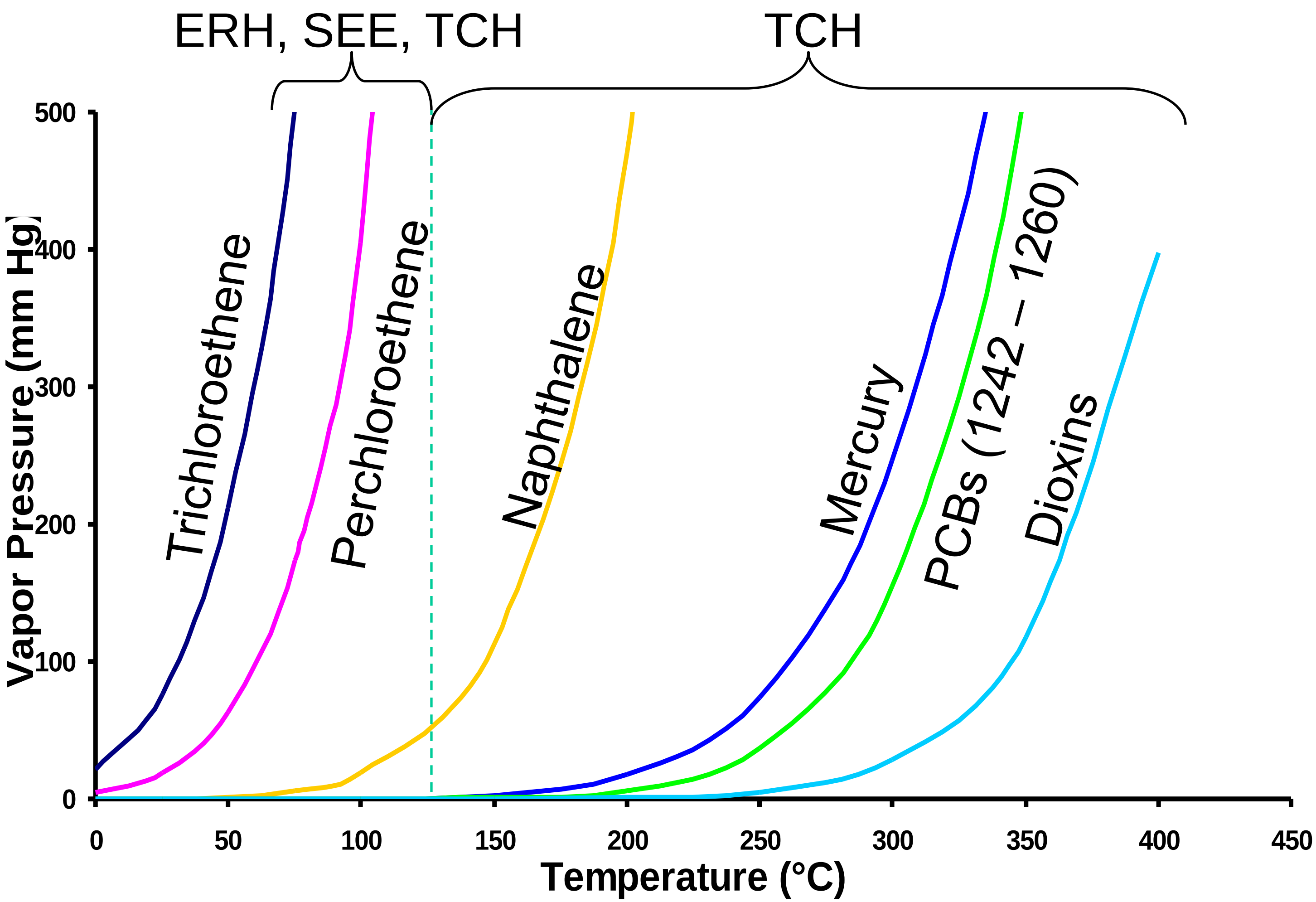
# Vapor Pressure vs. Temperature

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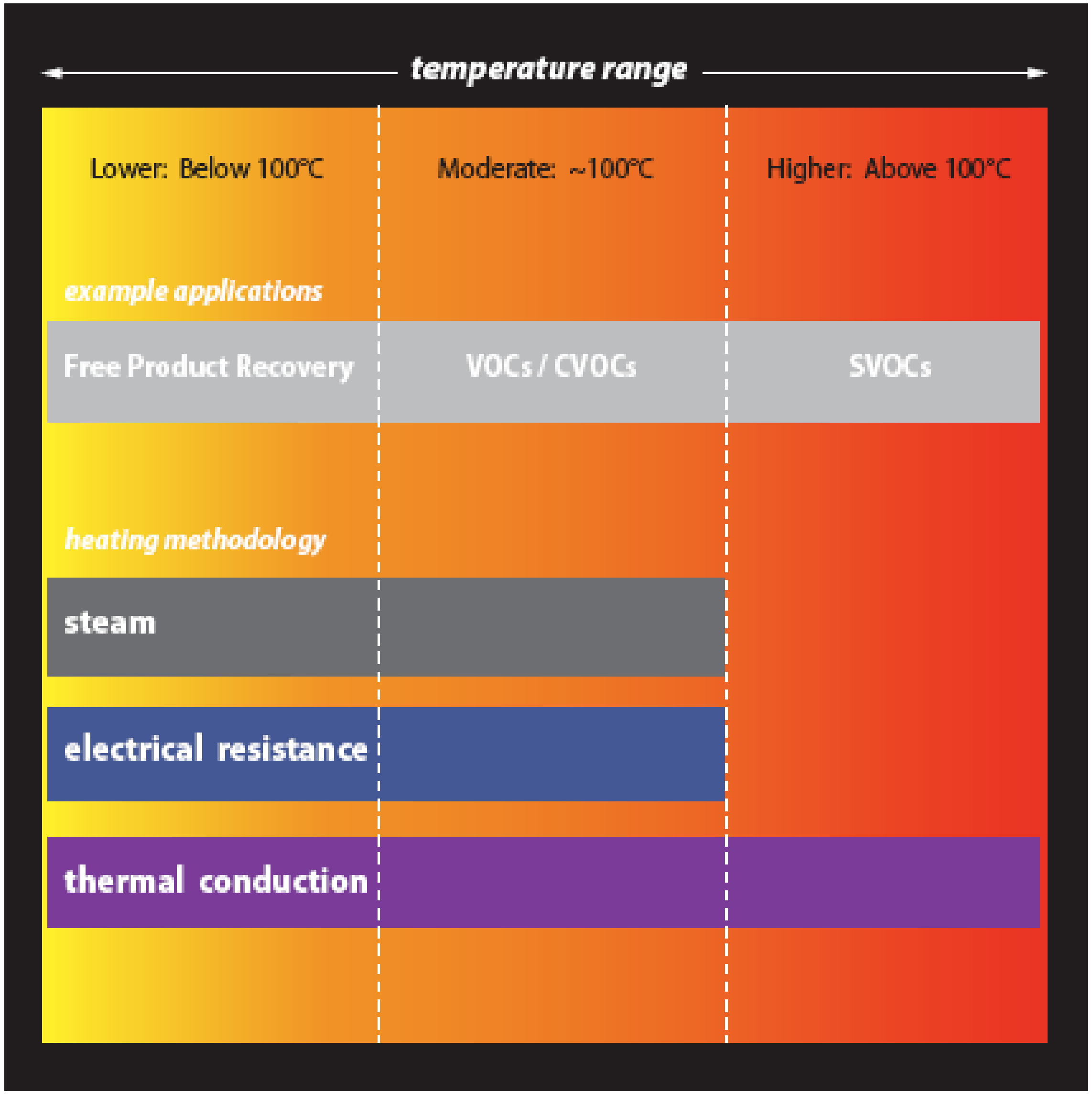
**Vapor pressures increase exponentially during heating**

# In Situ Thermal Remediation

## Lower, Moderate and Higher Temperature Applications

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# Think Thermal When…

- ✓ You have a Source Zone, or Hot Spots
- ✓ Site is Heterogeneous and/or Low in Permeability
- ✓ Stringent Cleanup Levels Must be Achieved, Quickly (or you just need to remove a lot of mass)
- ✓ Excavation is Ruled Out or Impractical

## Thermal is Especially Well Suited if:

- ✓ The Treatment Zone is Deep
- ✓ There's a Mixture of Contaminants

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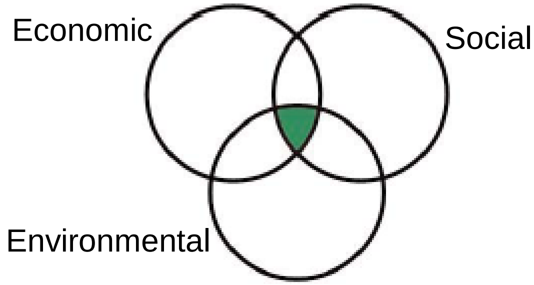
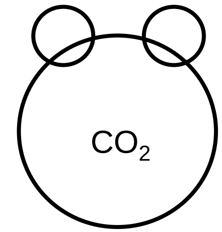
# Sustainability of Thermal




not solely




- ✓ Enables reutilization of idle Brownfields and/or restoration of groundwater resources.
- ✓ The energy cost to electrically heat a cy of contaminated soil is about the same as the cost of fuel to haul it away; meanwhile, in-situ treatment has a lower neighborhood impact, and is environmentally friendly.
- ✓ Verifiable carbon offsets can be obtained for <1% of project cost.

⇒ **Achieving predictable and rapid site closure and reuse is environmentally and socially responsible.**

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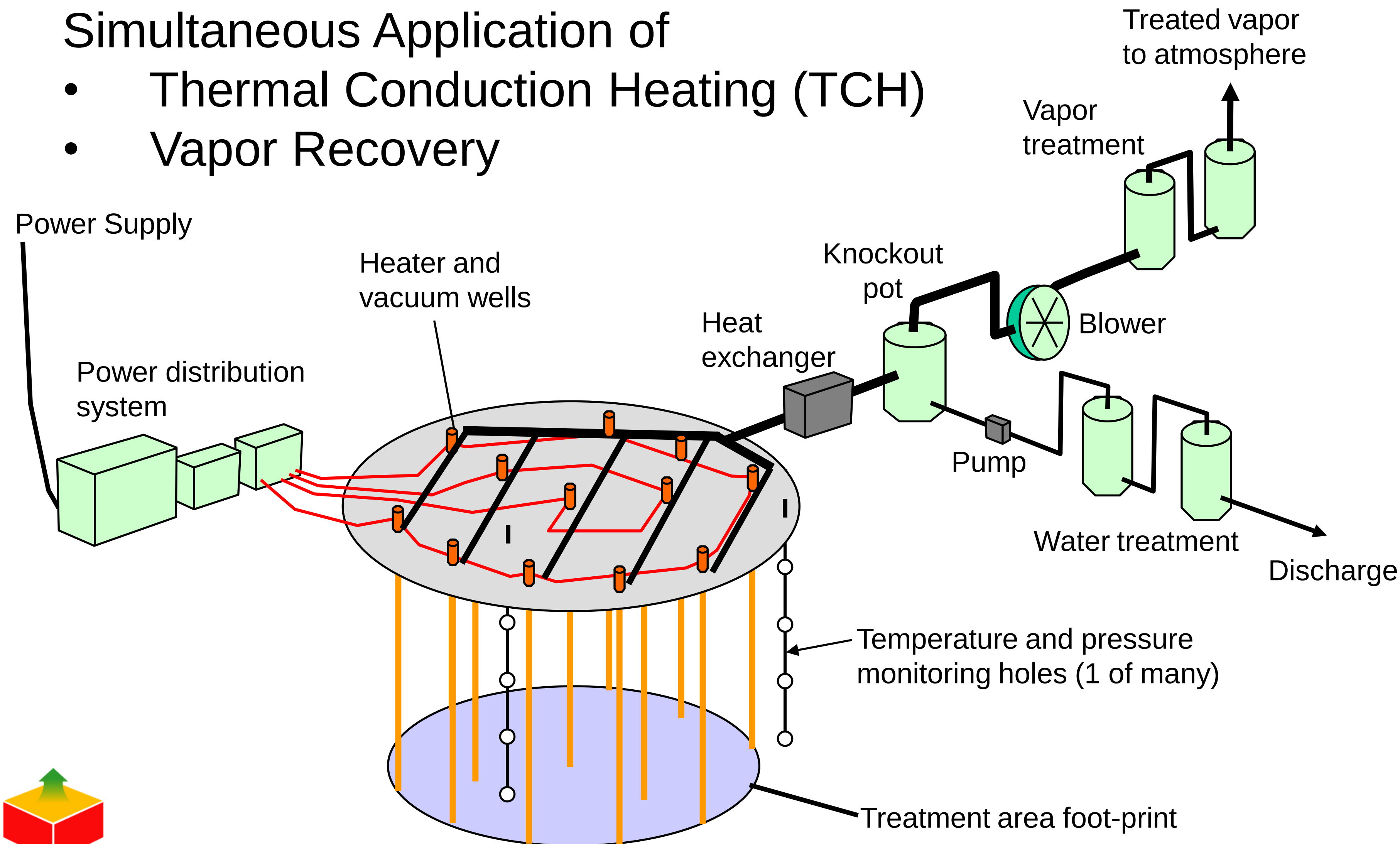
# In Situ Thermal Desorption (ISTD)

Simultaneous Application of

- Thermal Conduction Heating (TCH)
- Vapor Recovery

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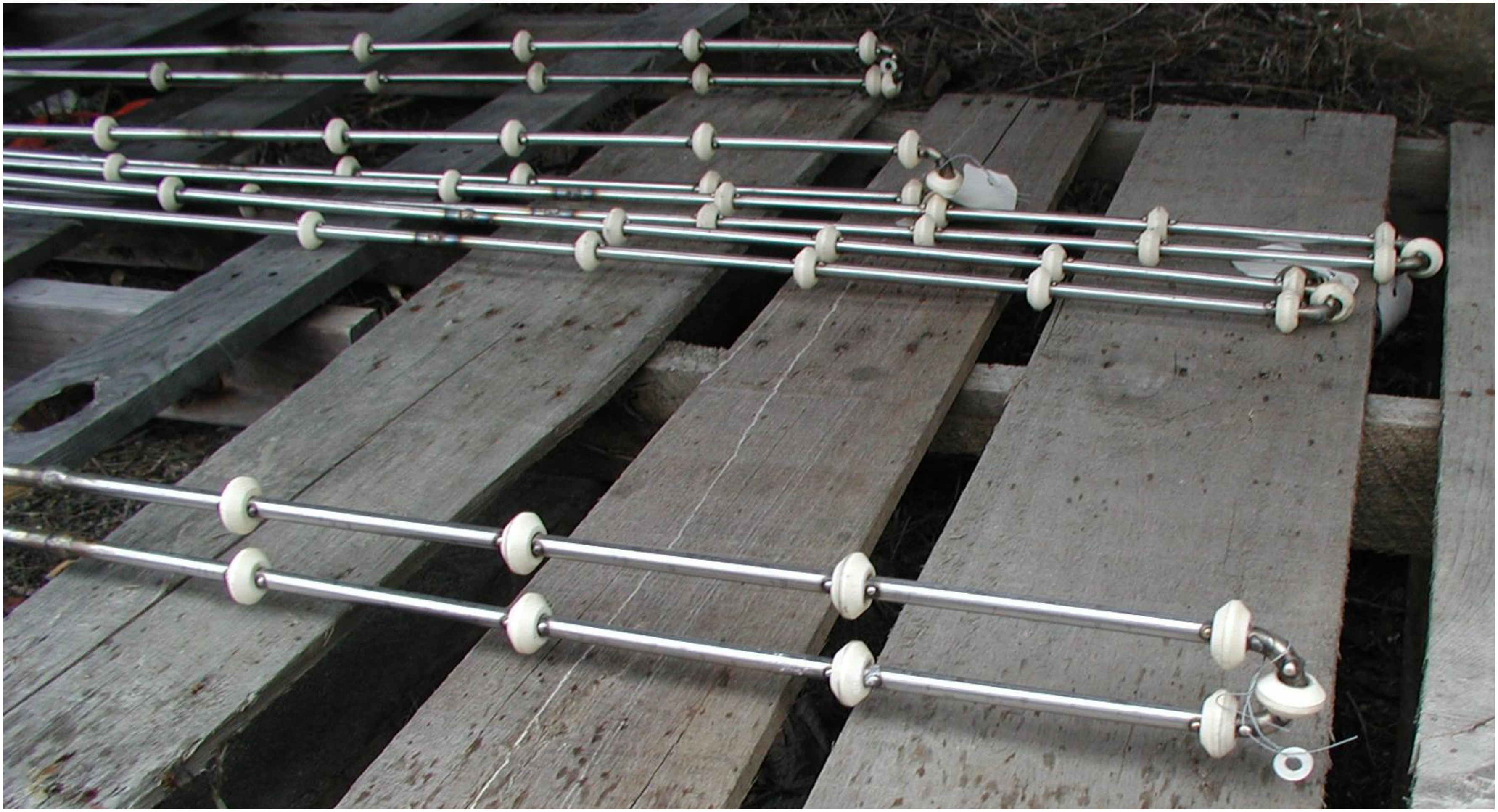
# TerraTherm Heaters



Simple, Durable, Reliable, Reusable

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**U.S. Patent Nos. 5,190,405, 5,318,116, 6,485,232 and 6,632,047. International patents granted (e.g., EPC 1272290 + 10 countries) and pending.**

# Dunn Field, Memphis Depot, TN

- Former Defense Logistics Agency site, now under the Base Realignment and Closure (BRAC) Program
- 8 DNAPL source areas
- 49,800 cubic yards
- Target criteria below 0.1 mg/kg for CVOCs
- Funded by the U.S. Air Force Center for Engineering and the Environment (AFCEE)

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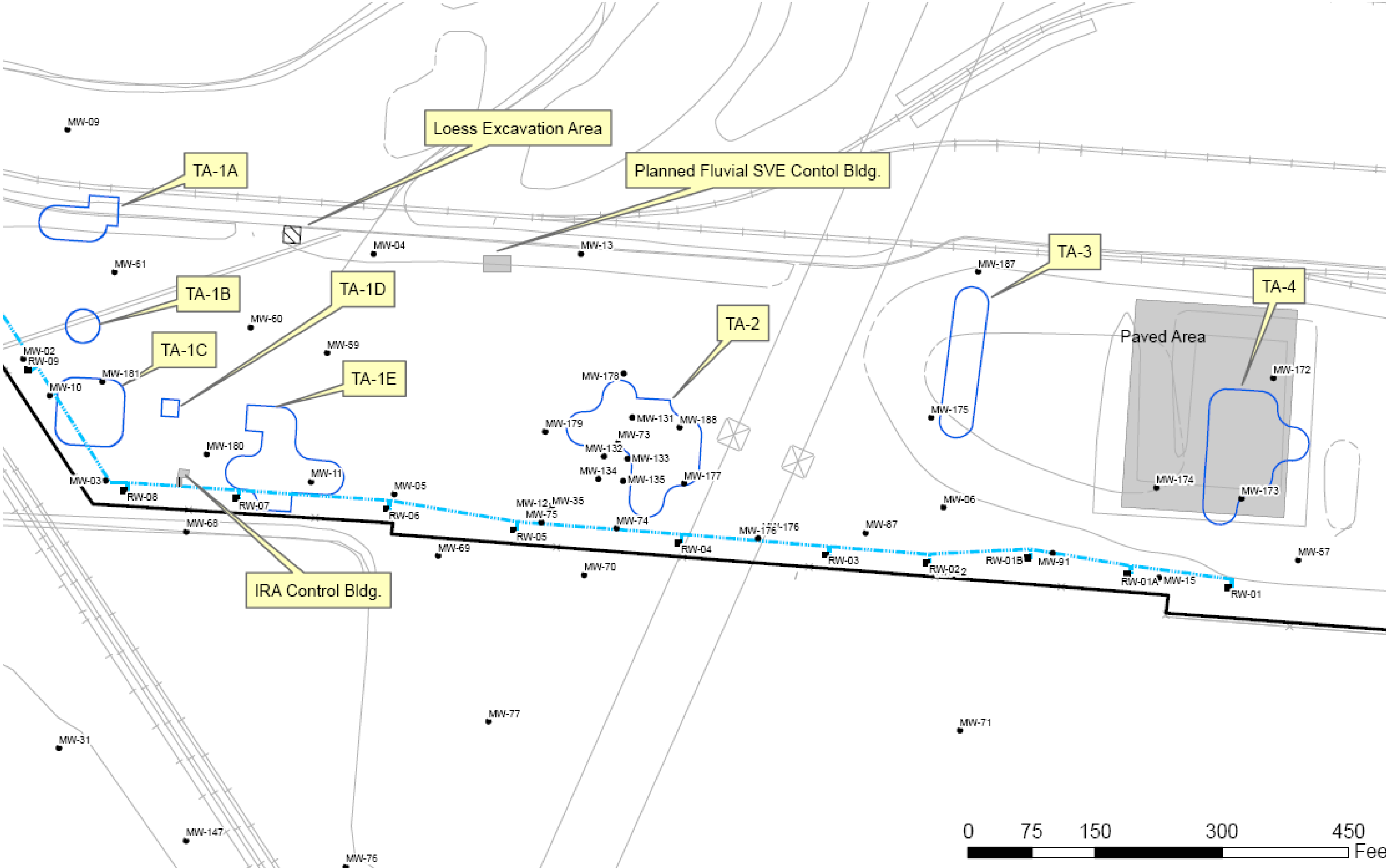
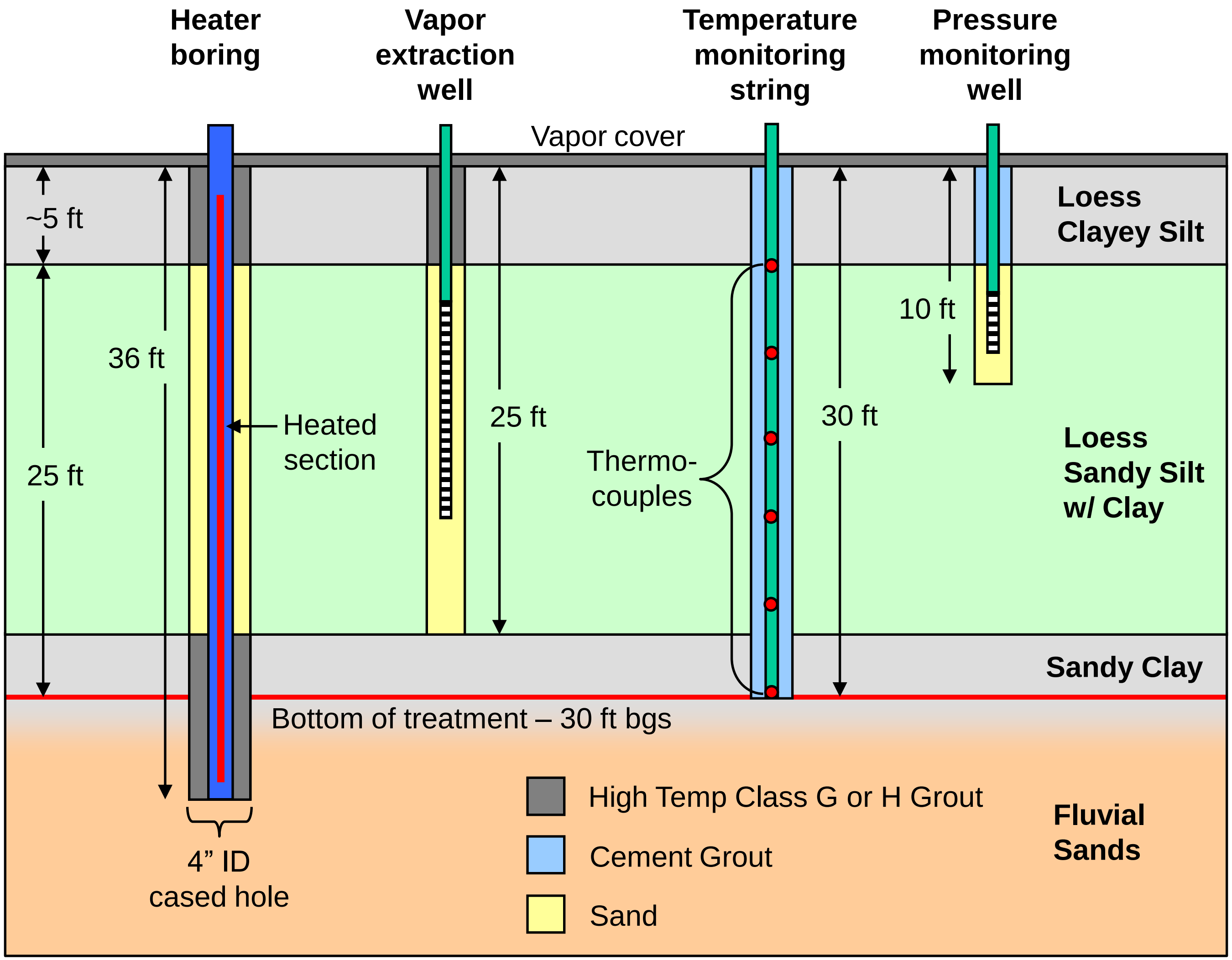
# Location of the Eight DNAPL Areas



# Contaminants of Concern and Remedial Target Concentrations

| Parameter | Remedial target concentration (mg/kg) |
|---|---|
| Carbon Tetrachloride | 0.2150 |
| Chloroform | 0.9170 |
| Dichloroethane, 1,2- | 0.0329 |
| Dichloroethene, 1,1- | 0.1500 |
| Dichloroethene, cis-1,2- | 0.7550 |
| Dichloroethene, trans-1,2- | 1.5200 |
| Methylene Chloride | 0.0305 |
| Tetrachloroethane, 1,1,2,2- | 0.0112 |
| Tetrachloroethene | 0.1806 |
| Trichloroethane, 1,1,2 | 0.0627 |
| Trichloroethene | 0.1820 |
| Vinyl Chloride | 0.0294 |

# Cross-section and Well Designs

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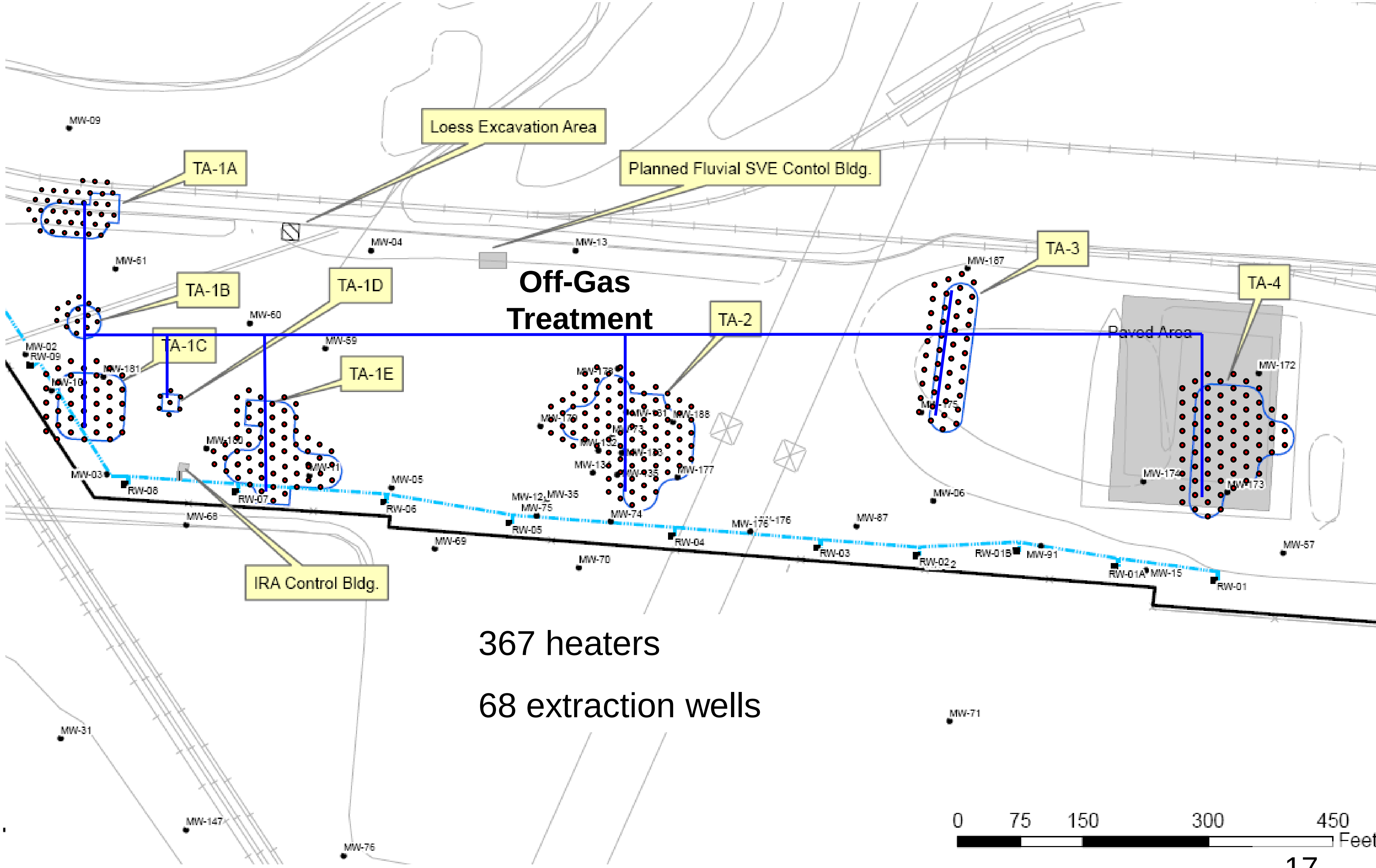
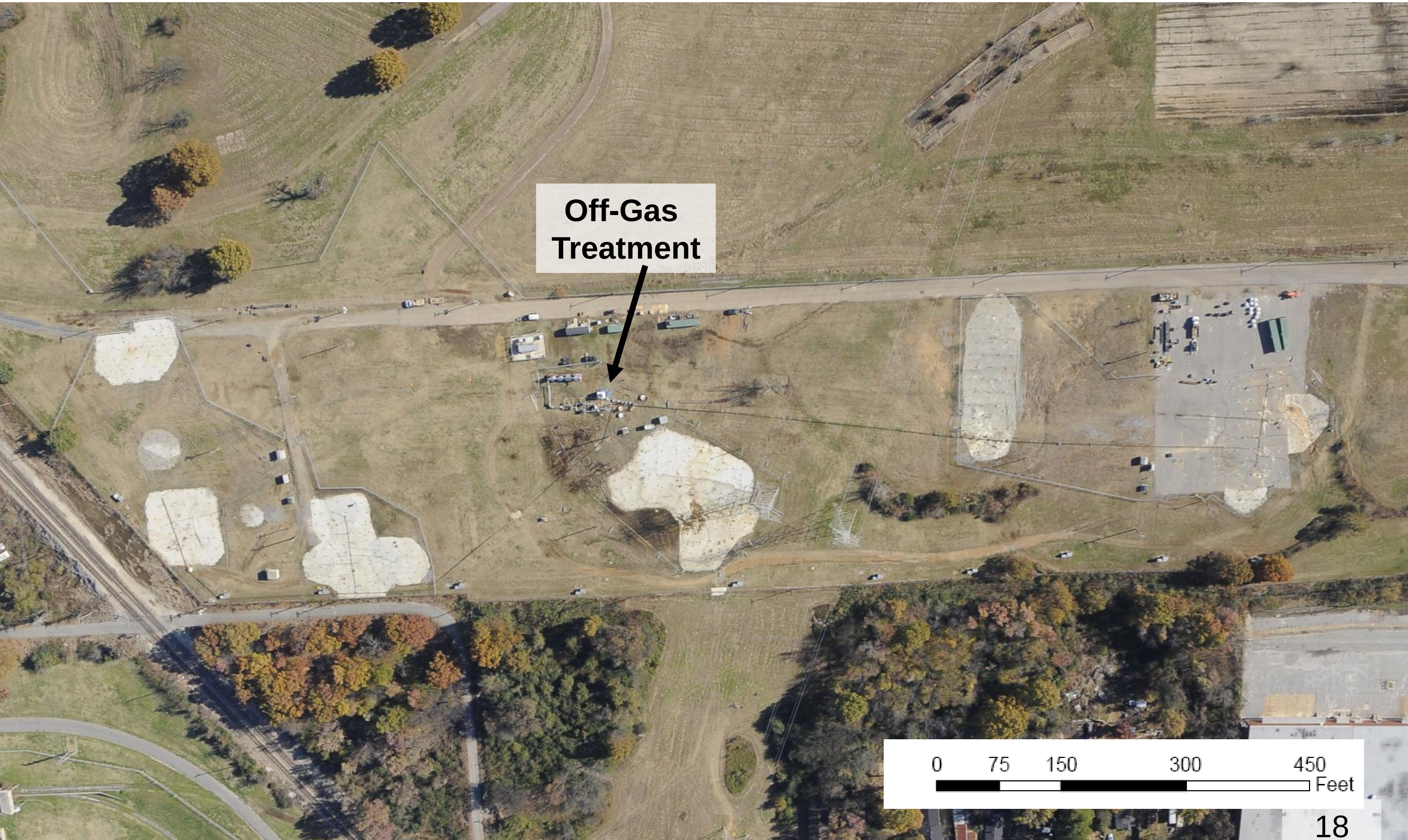
# Well-Field Layout at Dunn Field



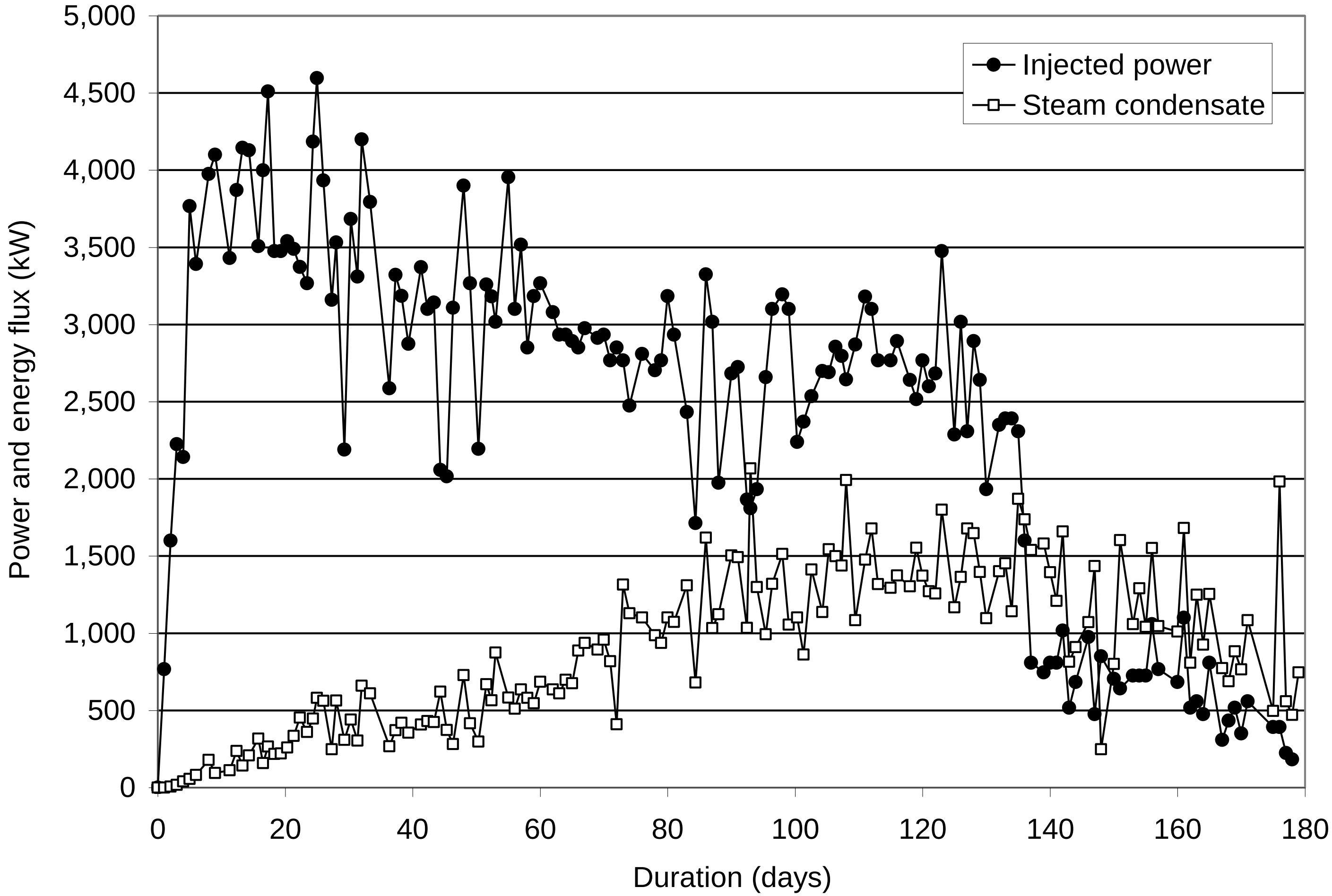

367 heaters

68 extraction wells

# Aerial View of Memphis Site (During Demob)



# Power Delivered and Steam Energy Extracted

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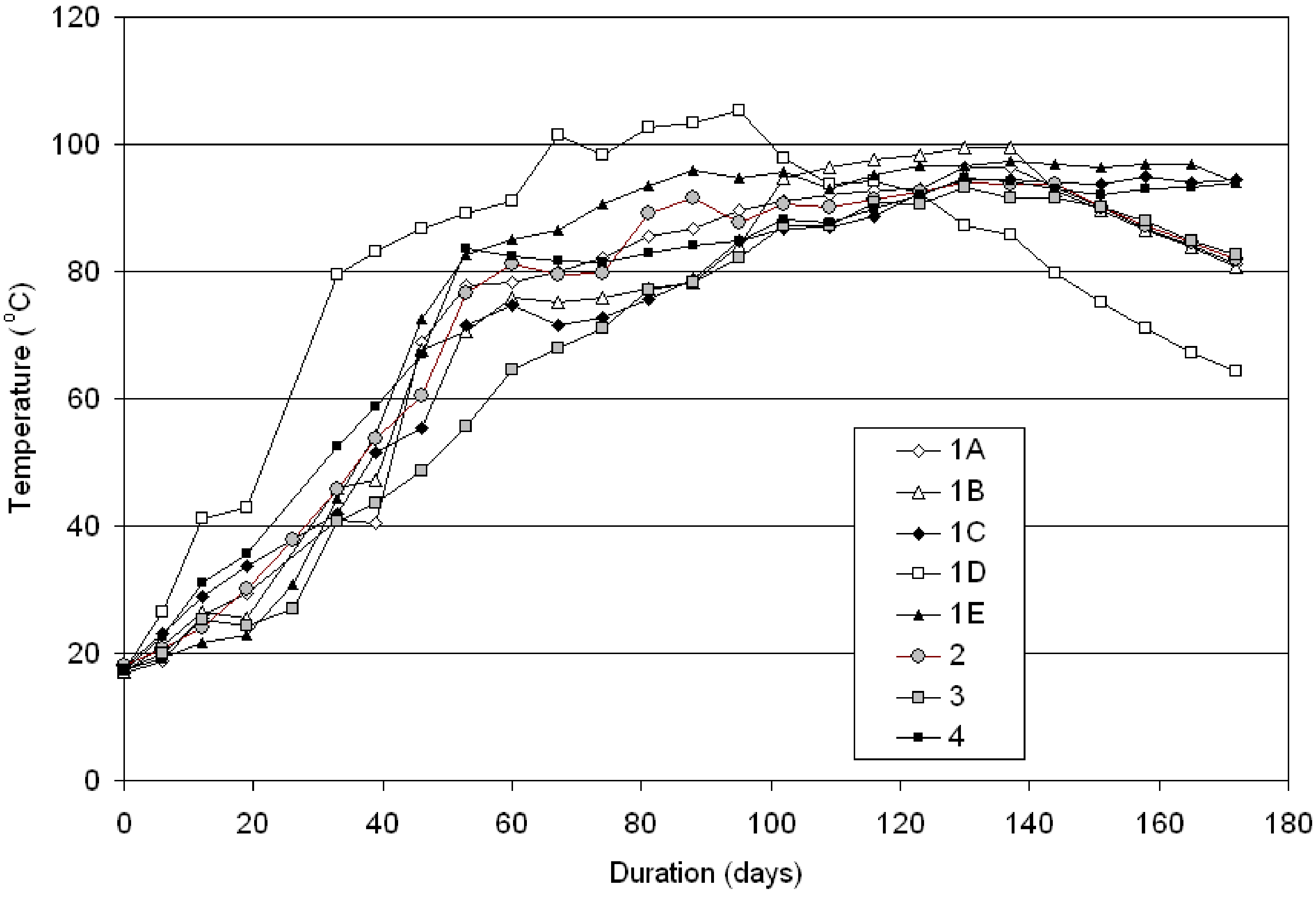
# Temperatures Achieved in Each Area

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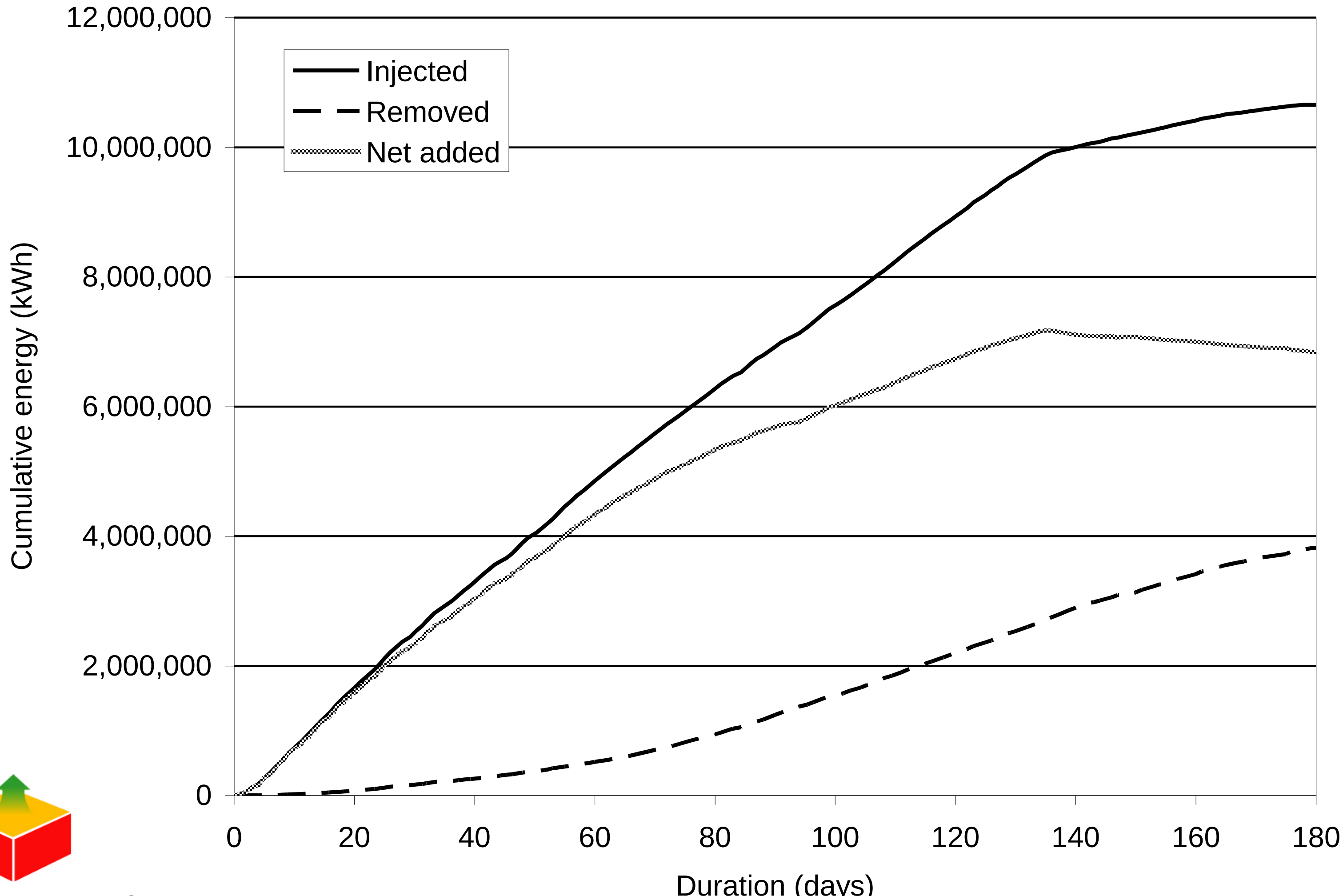
# Cumulative Energy Balance

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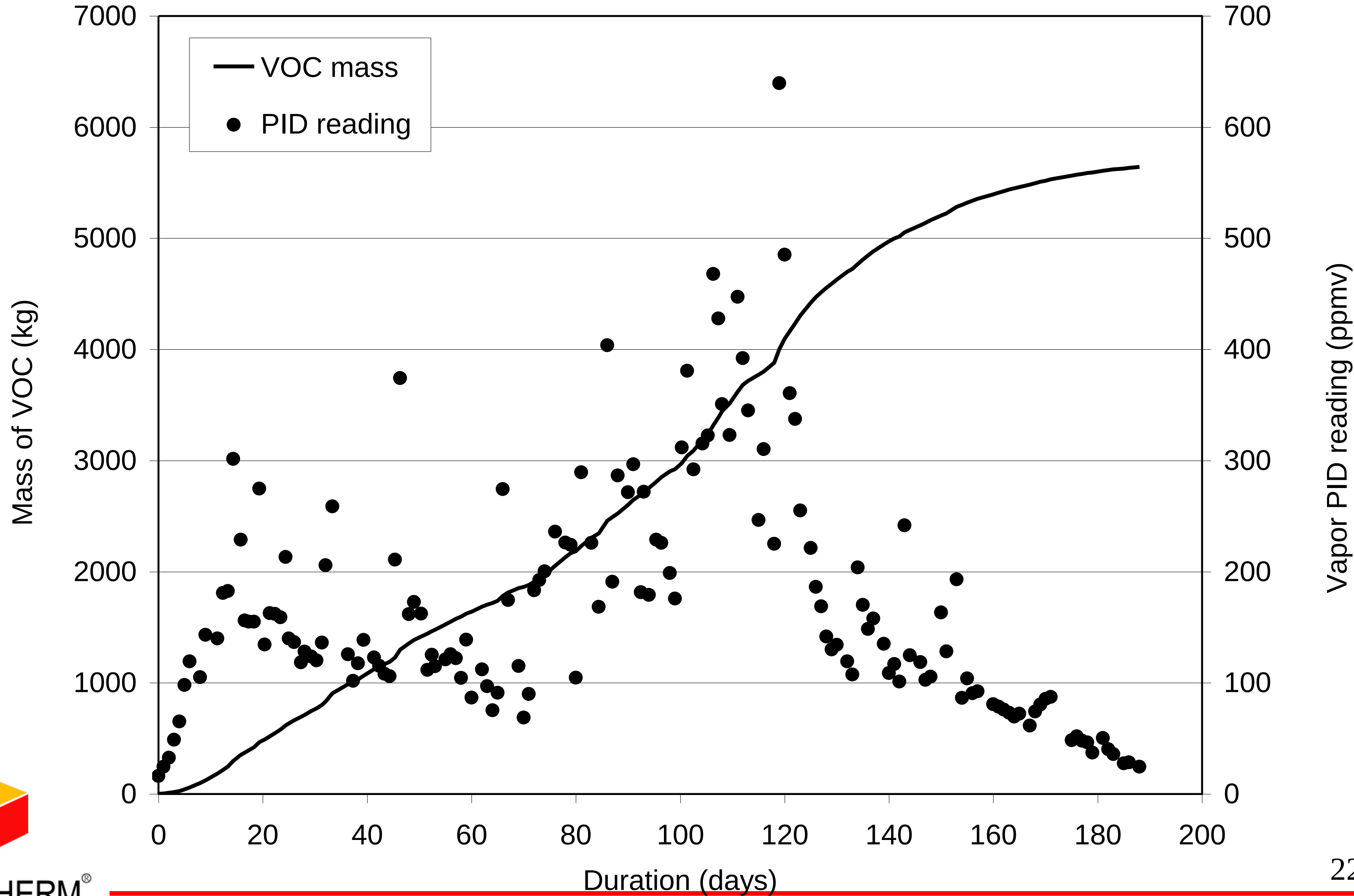
# Vapor Concentrations and Mass Removed

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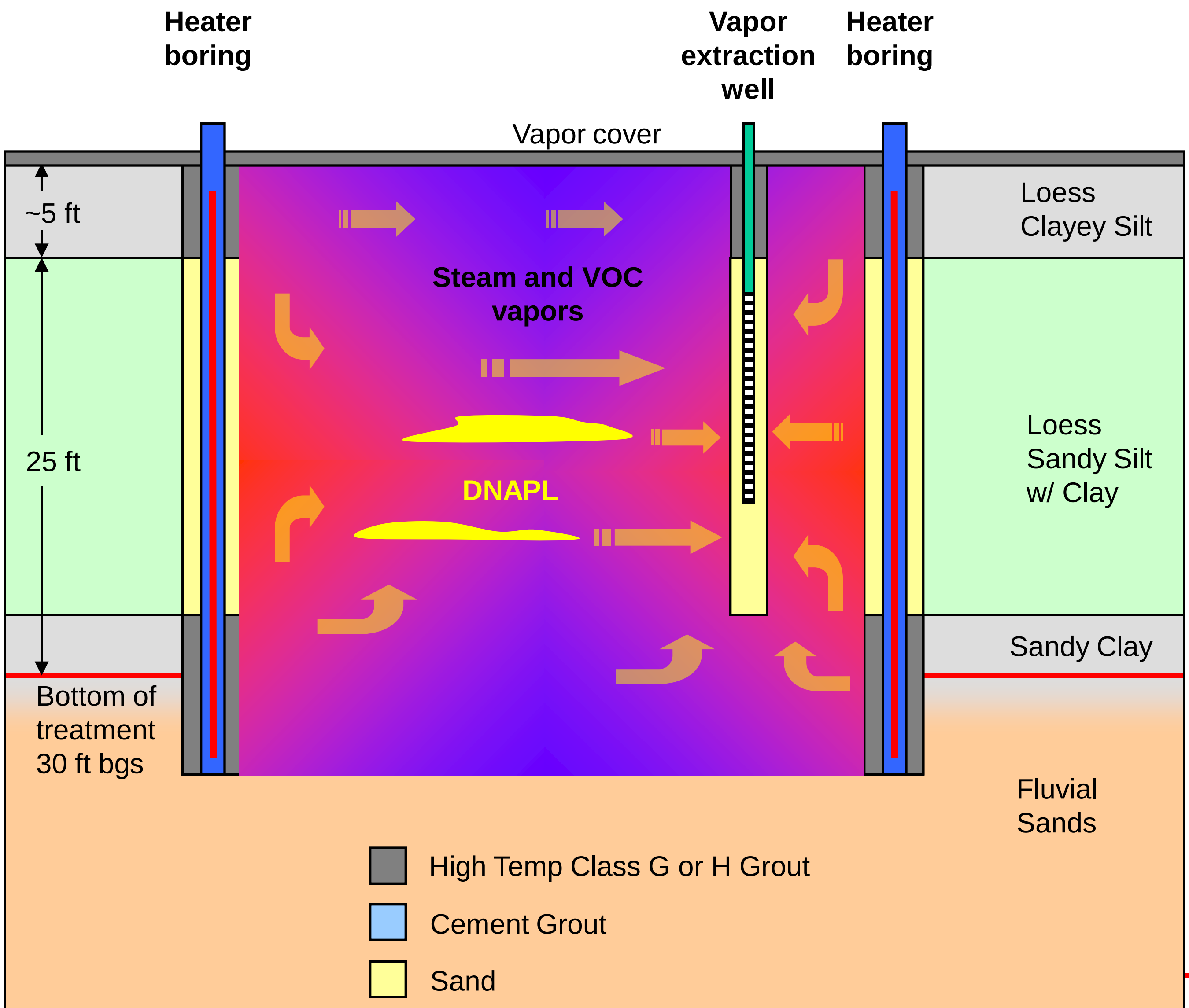
# Treatment Mechanisms and Steam Flow Paths

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# Results - Eight DNAPL Source Areas

| DNAPL source area | Area ($m^2$) | Treatment interval (m) | Volume ($m^3$) | # confirmatory samples | Governing contaminants | Max soil concentration before (mg/kg) | Max soil concentration after (mg/kg) |
|---|---|---|---|---|---|---|---|
| 1A | 345 | 1.5 to 6 | 1,578 | 3 | Carbon tetrachloride | 6.8 | <0.005 |
| | | | | | Chloroform | 14.0 | 0.053 |
| | | | | | | | |
| 1B | 117 | 1.5 to 9 | 890 | 1 | cis-1,2-Dichloroethene | 123.0 | 0.005 |
| | | | | | Tetrachloroethene | 20.8 | 0.010 |
| | | | | | Trichloroethene | 21.5 | 0.009 |
| | | | | | | | |
| 1C | 563 | 1.5 to 9 | 4,288 | 4 | 1,1,2,2-Tetrachloroethane | 2,850 | 0.005 |
| | | | | | cis-1,2-Dichloroethene | 199 | 0.132 |
| | | | | | Trichloroethene | 671 | 0.017 |
| | | | 0 | | | | |
| 1D | 37 | 1.5 to 9 | 283 | 1 | 1,1,2,2-Tetrachloroethane | 0.03 | <0.0027 |
| | | | | | | | |
| 1E | 861 | 1.5 to 9 | 6,560 | 6 | 1,2-Dichloroethane | 17.0 | <0.003 |
| | | | | | Trichloroethene | 2.42 | <0.005 |
| | | | | | | | |
| 2 | 1,233 | 1.5 to 9 | 9,396 | 8 | 1,1,2,2-Tetrachloroethane | 163 | <0.003 |
| | | | | | Tetrachloroethene | 0.85 | <0.005 |
| | | | | | Trichloroethene | 23.6 | 0.008 |
| | | | | | | | |
| 3 | 631 | 1.5 to 9 | 4,805 | 5 | 1,1,2,2-Tetrachloroethane | 3.11 | <0.003 |
| | | | | | cis-1,2-Dichloroethene | 3.35 | 0.006 |
| | | | | | Trichloroethene | 1.56 | 0.041 |
| | | | | | | | |
| 4 | 1,163 | 1.5 to 9 | 8,864 | 7 | Carbon tetrachloride | 0.53 | <0.006 |
| | | | | | Chloroform | 2.18 | 0.005 |
| | | | | | Trichloroethene | 0.97 | 0.240 |

# Project Costs and Breakdown

| | |
|---|---|
| Design and permitting | $157,000 |
| Drilling | $548,000 |
| Construction | $1,230,000 |
| Operation – contractor | $906,000 |
| Power | $1,010,000 |
| Oversight and Sampling | $817,000 |
| Other | $81,000 |
| Total | $4,749,000 |

**Unit cost** **$79/cy**

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# Summary – Memphis Depot Case Study

- 8 DNAPL source areas treated simultaneously
- 49,800 cubic yards
- All areas met stringent target criteria
- 175 days of heating
- Turnkey cost: $79/cy
- Just Announced: Defense Depot Memphis, TN received the ***2009 Secretary of Defense Environmental Award*** – the only one awarded in the Environmental Restoration category!
  - Our work was cited as "a key component of the program's success"
  - "In addition to meeting the established goals ahead of schedule, the process saved taxpayers more than $2.5 million."

    *(Defense Logistics Agency Press Release, 4/27/2009)*

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