Thermal Remediation – Is it Worth the Price?

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One Partner. Many Solutions.

Agenda

- Overview of Thermal Remediation
- Applicability – When to Consider Thermal Solutions
- Cost Breakdown
- Factors Affecting Cost
- Owner’s / Consultant’s Options to Reduce Cost
- Conclusions
- Questions

The BIG Question:

Is Thermal Remediation Worth the Price??

Perception vs Reality: Cost of Thermal Remediation

- **Perception: Thermal remediation is too expensive** compared to other remediation methods.
- **Reality**: **In many cases, thermal remediation may provide the best value for your remediation dollar.**
- Thermal remediation is capable of near complete destruction / removal of source-zone contaminants.
- Thermal remediation is reliable, effective, proven, quick and safe.
- Factors to consider: Life cycle cost, shorter remediation time frames and rapid return to beneficial use.

What is Thermal Remediation?

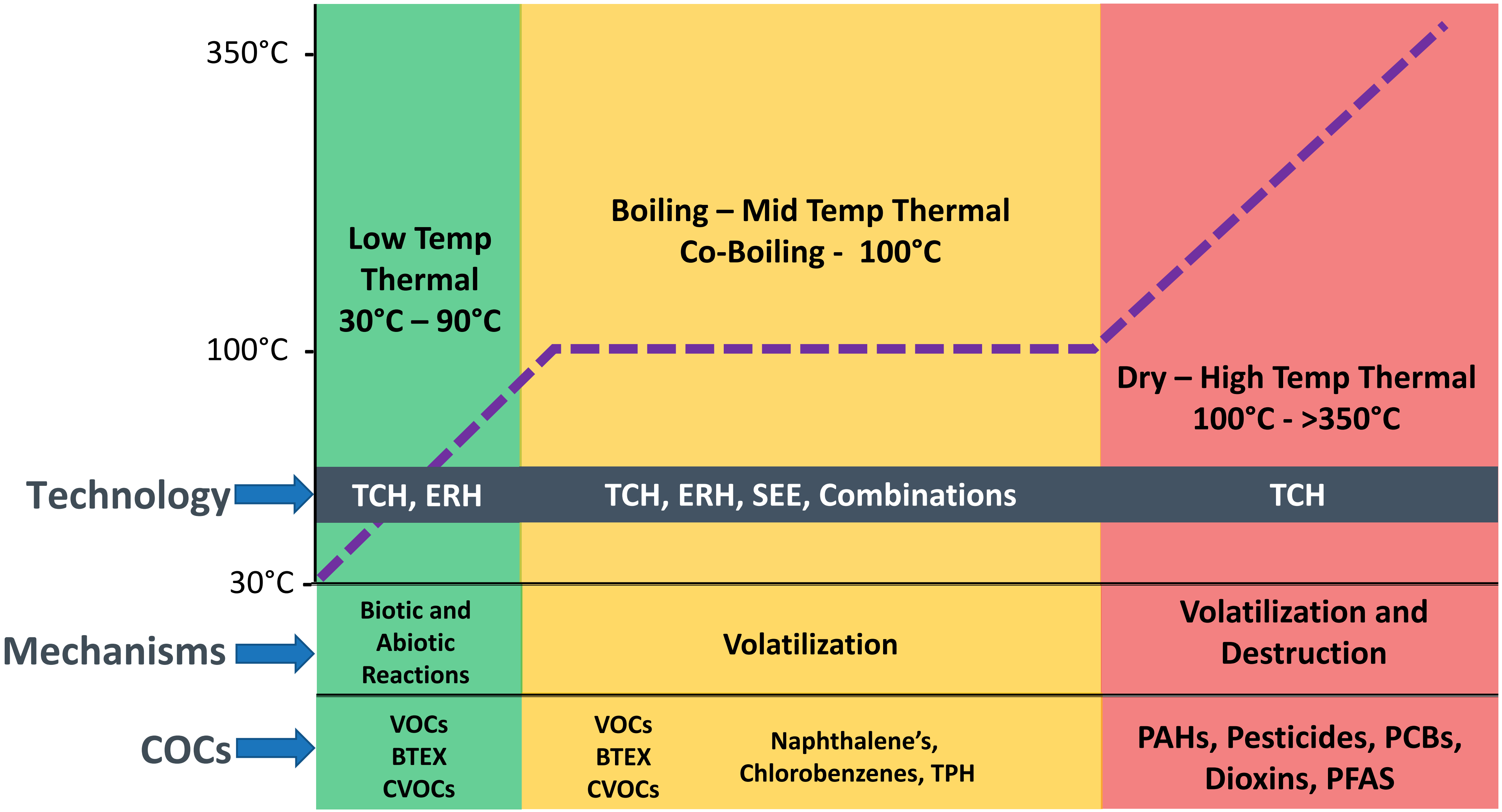
Technology Overview & Applicability

What is Thermal Remediation?

Traditional Thermal Remediation is *Fast!*

- Source zone technology – sweet spot
- Employs heat to volatize organic chemicals
- Chemical and water vapors are:
  - Captured by vacuum
  - Brought to the surface
  - Treated before discharge
- Multiple Heating Methods:
  - Thermal Conduction Heating (TCH)
  - Electrical Resistance Heating (ERH)
  - Steam Enhanced Extraction (SEE)

ISTR Capabilities



Typical Thermal (ISTR) Wellfield

Sweet Spot for ISTR Technologies

- High concentration/mass contaminant source zones
- Strong remediation driver
- Recalcitrant contaminants
- Challenging geologic conditions
- Deep sites
- Beneath valuable infrastructure
- Tight timeline
- Low cleanup goals
- Other remediation efforts have failed…

Thermal Technology Cost Factors

How Much Does ISTR Cost?

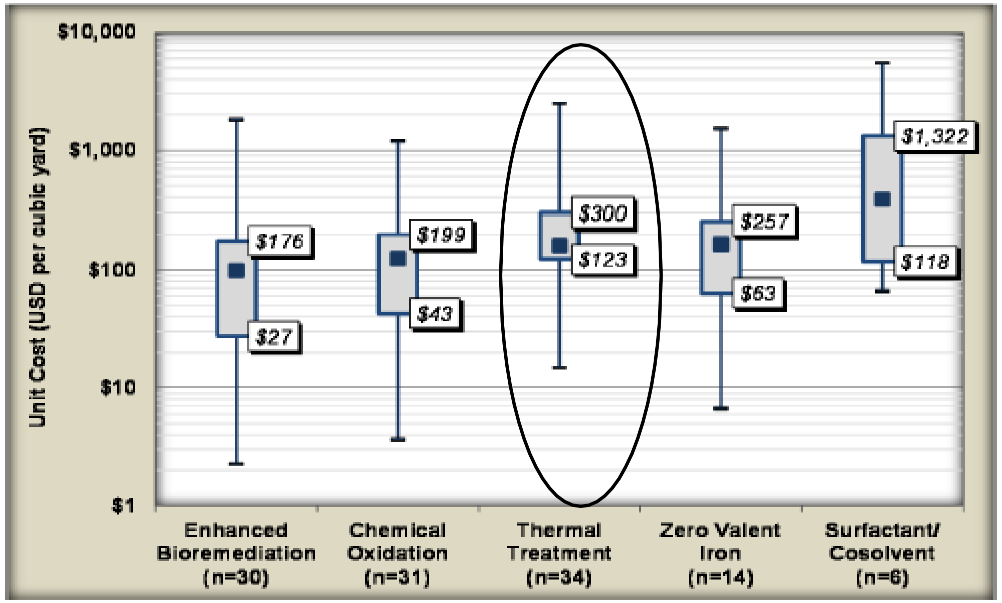


Figure 4.19. **Unit Cost Distribution for 115 In-Situ Remediation Projects (Log Scale).**
Data Shown: *Unit cost of in-situ treatment in US dollars per cubic yard.*

McGuire, et al. 2016. ESTCP Project ER-201120

Average unit costs (2012 – 2019):

- >10,000 CY: $142/CY
- <10,000 CY: $259/CY

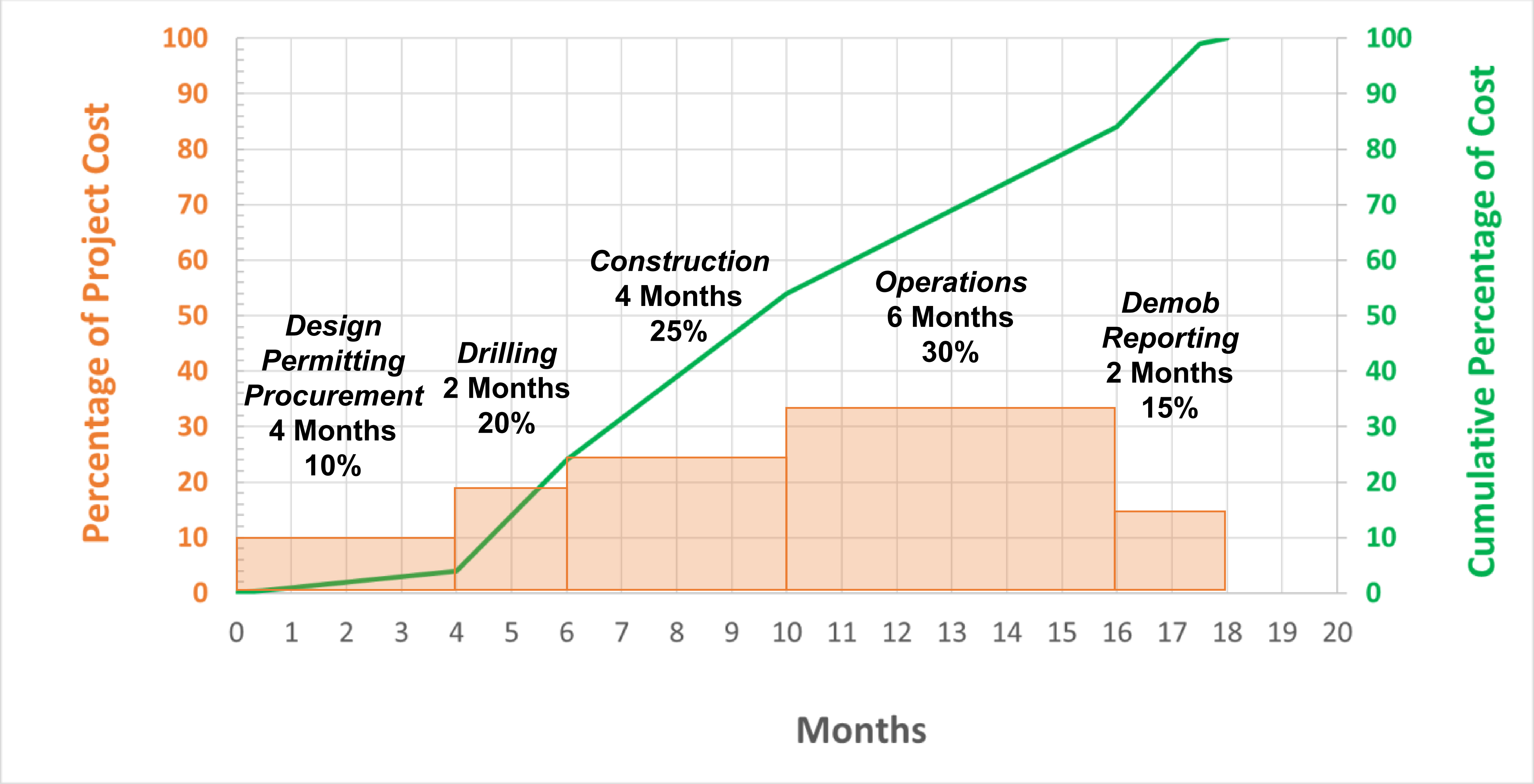
J. Horst et al. 2020 Groundwater Monitoring & Remediation

TerraTherm's Experience

Volume	Average Unit Price ($/CY)	Range	
		Min	**Max**
>100,000 CY	**$ 58**	$ 32	$ 84
15,000-100,000 CY	**$ 210**	$ 81	$ 400
5000 - 15,000 CY	**$ 303**	$ 153	$ 510

- Data from 28 recent sites
- Site specific factors and conditions affect price

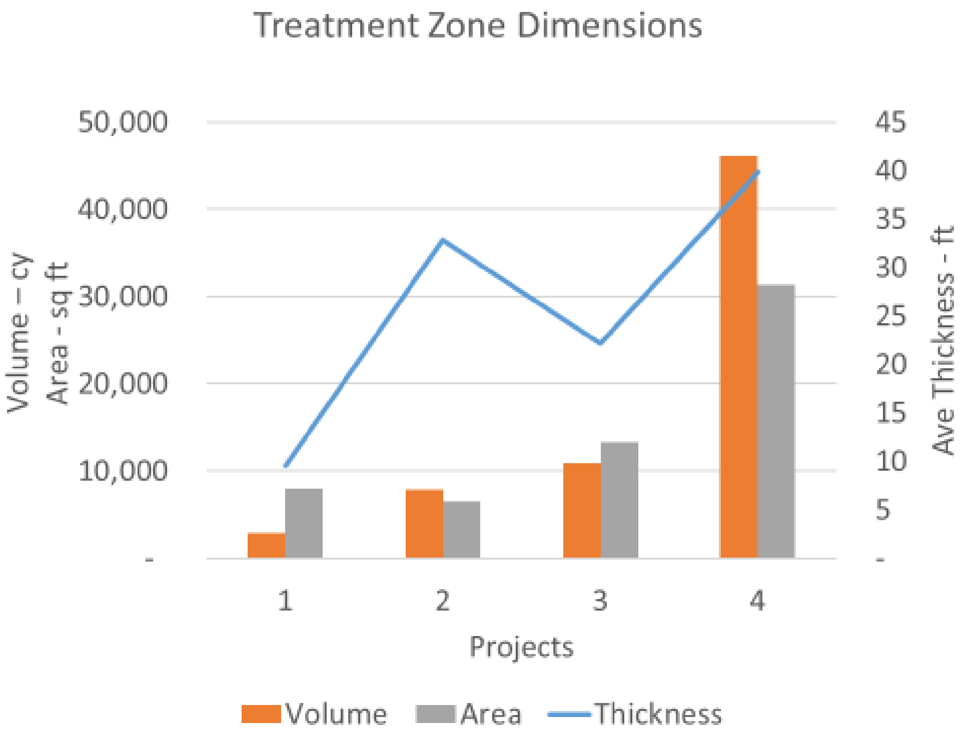
Example ISTR Cost Schedule



Sample Project Overview

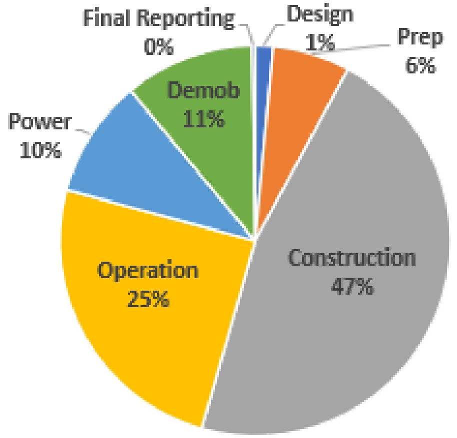
4 Recent CVOC Projects in US, targeting 100°C

Project	1	2	3	4
Size (cy)	Small (2,800)	Small to Med (7,900)	Small to Med (10,900)	Med to Large (46,000)
Client	Commercial	Federal	Commercial	Commercial
Depth (ft bgs)	8 to 12-21	0 to 20-66	0 to 15-27	0 to 20-50
Thickness (ft)	10	33	22	40
Technology	TCH	TCH	TCH	TCH
Energy Density (kWh/cy)	516	280	209	215
Vapor Cover	Liner	Insulated	Insulated	Insulated
Total Cost	$2.6M	$3.1M	$2.9M	$6.3M



ISTR Costs by Phase

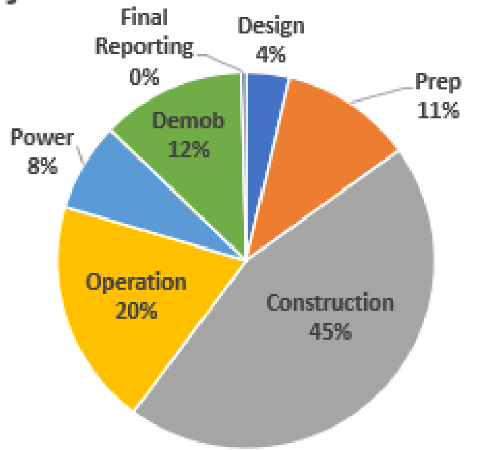
Project 1



Cost ($M)	$2.6M
Unit Cost ($/cy)	$915
Size (cy)	2,800
Depth (ft bgs)	8 to 12-21
Ave Thickness (ft)	10
Energy Density (kwh/cy)	516

Factors: Small, High Surface Area: Volume (SA:V), power drop – $400K

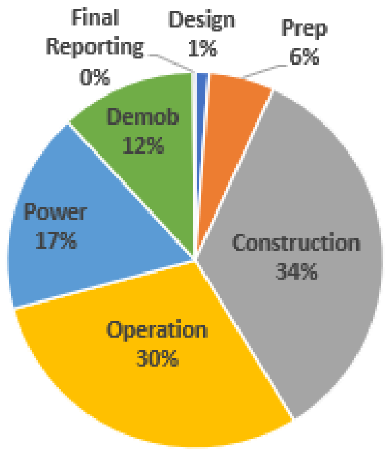
Project 2



Cost ($M)	$3.1M
Unit Cost ($/cy)	$366
Size (cy)	7,900
Depth (ft bgs)	0 to 20-66
Ave Thickness (ft)	33
Energy Density (kwh/cy)	280

Factors: Small - Medium, Federal Project w/ more oversight

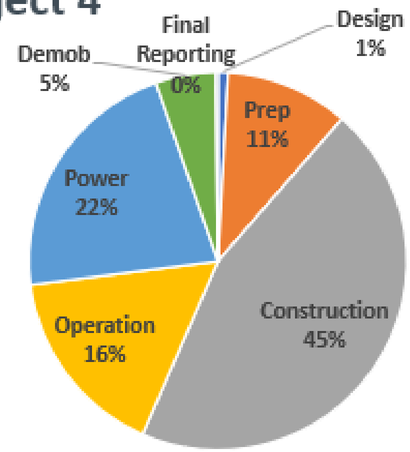
Project 3



Cost ($M)	$3.0M
Unit Cost ($/cy)	$272
Size (cy)	10,900
Depth (ft bgs)	0 to 15-27
Ave Thickness (ft)	22
Energy Density (kwh/cy)	209

Factors: Small / Medium size, commercial client

Project 4



Cost ($M)	$6.3M
Unit Cost ($/cy)	$136
Size (cy)	46,000
Depth (ft bgs)	0 to 20-50
Ave Thickness (ft)	40
Energy Density (kwh/cy)	215

Factors: Medium to large size, commercial client, Low SA:V

Factors Affecting Cost

Site Factors

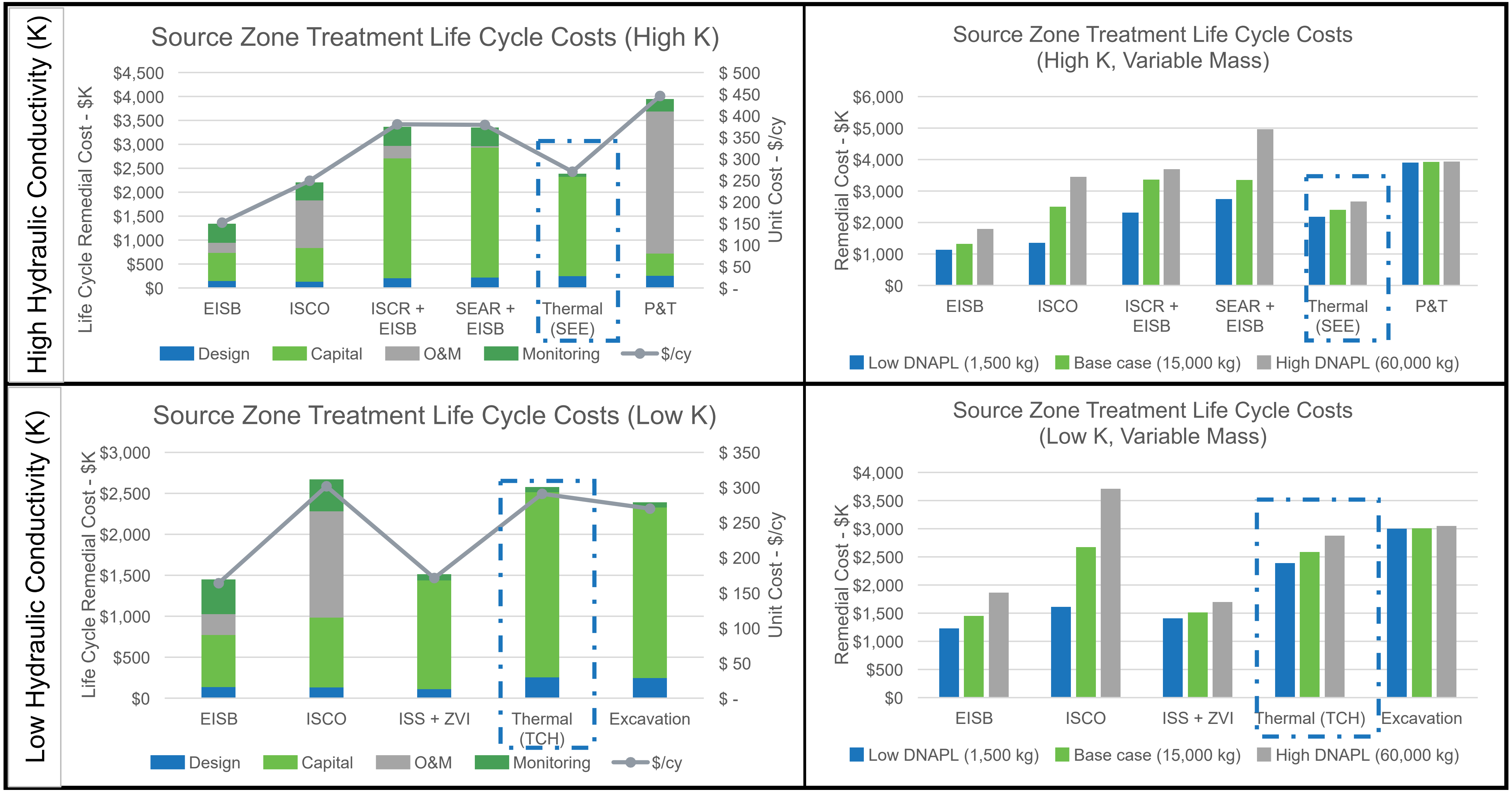
- Site configuration
  - Area, Depth
  - Surface cover requirements
- Contaminant type (VOC, SVOC)
- Contaminant mass
- Groundwater flux
- Cleanup goals
- Access limitations / restrictions
- Utilities / infrastructure

Other Factors

- Accurate TTZ Definition
- Contract terms, risk allocation
- Performance metrics
- Utility availability, unit cost

Life Cycle Cost Comparisons

Source Zone Treatment - Life Cycle Cost Comparison



Reference data from:
Chlorinated Solvent Source Zone Remediation. Kueper et al, 2014.

Life Cycle Cost Comparison- GW Source

Technology	Source Mass (kg)	Remedy Duration (years)	Total Cost of Remedy ($) 2010 dollars	Total Cost of Remedy ($) 2024 dollars
Natural attenuation	5600	235	na	na
Source area pump-and-treat, 5 gpm	5600	34	$3,268,491	$4,566,296
Source area bioremediation, passive approach	5600	55	$1,737,483	$2,427,378
Source area bioremediation, passive approach	5600	29	$1,393,532	$1,946,856
Source area ISCO recirculation, 85% removal / followed by MNA	5600	40	$2,801,206	$3,913,468
Source area ISCO recirculation, 85% removal / followed by source area bioremediation	5600	10	$2,613,724	$3,651,544
Source Area ISTR - TCH Heating	5600	**1**		**$4,141,000**
Notes: na – not applicable Starting Conditions, TCE 175 mg/L TCE MCL, 5 mg/L				

Reference: ESTCP Cost and Performance Report 200116. 2010.
ISTR Source Area treatment cost from TerraTherm 2024
Other 2024 costs scaled from 2010 costs using CPI 2010 to 2023

- 2010 ESTCP study evaluating ISCO/Bio for DNAPL source at LC-134 Cape Canaveral

Takeaway:

- ISTR may not always be cheapest
- Consider remedy cost and duration to reach goals

Conclusion

Groundwater Monitoring&Remediation Advances in Remediation Solutions

In Situ Thermal Remediation for Source Areas: Technology Advances and a Review of the Market From 1988–2020

by John Horst, Jonah Munholland, Paul Hegele, Mark Klemmer, and Jessica Gattenby

With at least 643 installations over the past 31 years, **ISTR has consistently proven itself to be a reliable and aggressive source zone treatment technology that is capable of successfully achieving a high degree of mass removal in a relatively short duration**.

Even without the addition of amendments, **ISTR is so adept at driving contamination out of lower-permeability strata and mitigating back-diffusion that concentrations in the downgradient plume have repeatedly been observed to decrease substantially after thermal operations are suspended** (e.g., Baker et al. 2016; Heron et al. 2016). For instance, Baker et al. (2016) presented data from 10 separate DNAPL source areas at five sites where post-ISTR groundwater concentrations were reduced by 2 to 4 orders of magnitude and downgradient concentrations achieved drinking water standards in approximately 5 to 10 years, allowing the existing pump-and-treat systems to be shut down early.

Questions?

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