In Situ Stabilization/Solidification as a Sustainable Alternative for the Remediation of Heavy Hydrocarbon Sites

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1. *In Situ* Stabilization/Solidification (ISS) Technology Overview
2. Objectives of Study
3. Study Site Overview
4. Study Approach
5. Results
6. Recommendations for Future ISS Implementations
7. Study Summary

Source: Provided by Geo-Solutions, Inc.

1. ISS Overview

TREATMENT

- Mixing of contaminated materials with cementitious reagents:
  - **Result: Reduce contaminant migration via Advection, Hydrodynamic Dispersion and Diffusion**

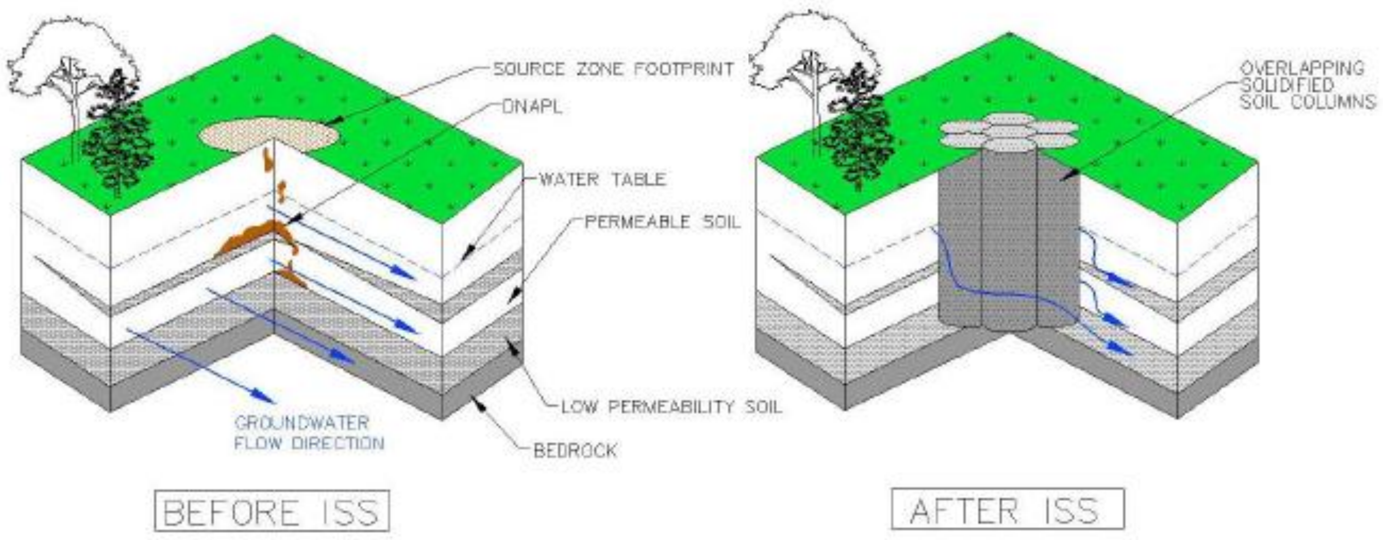
STABILIZATION

- Chemical reaction between reagents and contaminated materials - designed to reduce the leachability of targeted contaminants by:
  - *Binding free liquids*
  - *Immobilizing targeted contaminants*
  - *Reducing solubility of the contaminated material*

SOLIDIFICATION

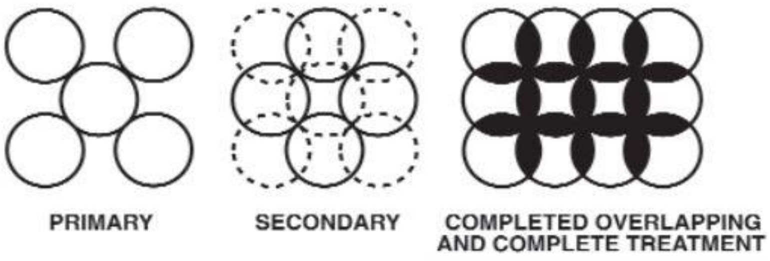
- Contaminated materials are encapsulated (physically trapped) to form a solid material that restricts contaminant migration by:
  - *Reduction of permeability and effective porosity*
  - *Increasing compressive strength and media durability*

1. ISS Overview – Conceptual Site Model



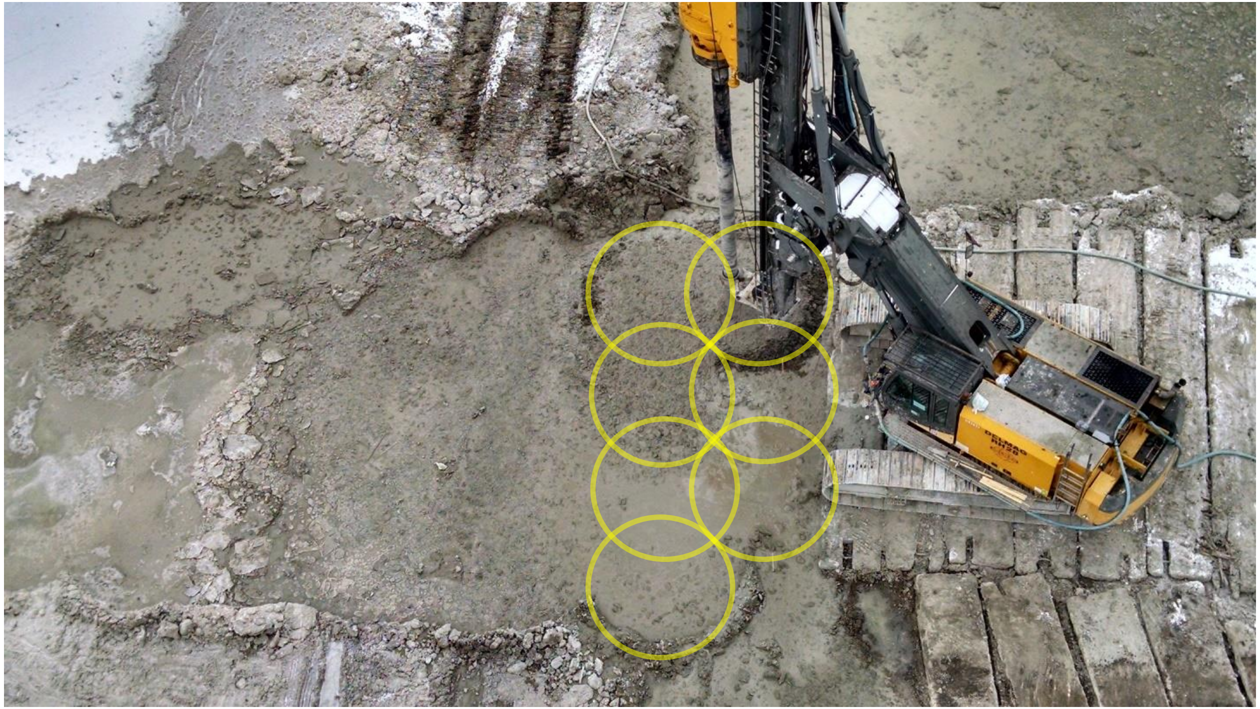
Source: Interstate Technology & Regulatory Council (ITRC). (2011). "Development of Performance Specifications for Solidification/Stabilization".

1. ISS Overview – Column Layout



Source: Jayaram, V., Marks, M. D., Schindler, R. M., Olean, T. J., & Walsh, E. (2002). “In Situ Soil Stabilization of a Former MGP Site,” Portland Cement Association, Skokie, IL.

1. ISS Overview – Column Layout



Source: Provided by Geo-Solutions, Inc.

1. *In Situ* Stabilization/Solidification Overview

ISS can be designed to provide additional benefits:

- Increased strength/stability
- Reduce/mitigate contaminant leaching
- Eliminate the need for excavation of saturated soil
- Decreased subsurface permeability
- Reduce dewatering requirements
- Treatment of low permeability formations and recalcitrant impacts

Source: *WRScompass. N.d. http://www.geoengineer.org/education/web-based-class-projects/geoenvironmental-remediation-technologies/stabilization-solidification?showall=1&limitstart=. Web. 27 Jan. 2016*

2. Objectives of Study

a) Quantify benefits of implementing ISS as a sustainable alternative to traditional dig and haul operations for the remediation of heavy hydrocarbon sites.

b) Identify ISS components with potential to reduce overall carbon footprint.

Source: Provided by Geo-Solutions, Inc.

3. Study Site Overview

- Manufactured Gas Plant (MGP) Site in Central Florida
- Completed in 2011
- Purpose:
  - Solidify MGP impacts
  - Prevent contamination of groundwater
- Average depth of impacts:
  - 30 ft bgs
- Average depth to groundwater:
  - 2-8 ft bgs

Source: Photo courtesy of NorthStar.

3. Study Site Overview

- Total ISS Volume: 143,532 cubic yards (CY)
- Included excavation and disposal of 62,910 tons of non-hazardous material
- ISS with crane mounted rig
- Used 8,10, and 12 ft diameter augers

Source: Photo courtesy of NorthStar.

3. Study Site Overview

- Targeted Permeability:
  - < $1x10^{-6}$ cm/sec
- Targeted Unconfined Compressive Strength (UCS):
  - > 50 pounds per square inch (psi)

Source: Photo courtesy of NorthStar.

4. Sustainability Study Approach

- Used two tools to quantify sustainability metrics for:
  - Alternative 1 – ISS
  - Alternative 2 – Excavation & Off-Site Disposal

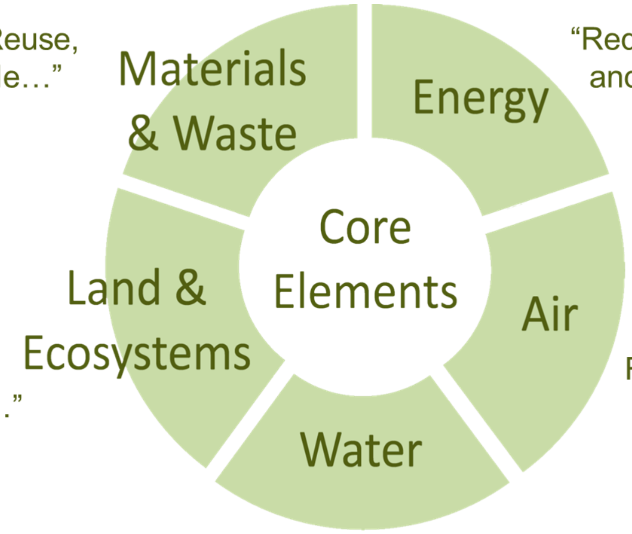
A. USEPA's Methodology for Understanding and Reducing a Project's Environmental Footprint

B. Basic Cost Analysis

4. Approach – USEPA Methodology

“Minimize, Reuse, and Recycle…”

“Reduction, Efficiency, and Renewables…”



“Conserve, Protect, and Restore…”

“Protect Air Quality, Reduce Greenhouse Gases…”

“Improve Quality, Decrease Quantity of Use…”

Source: EPA’s Methodology for Understanding and Reducing a Project’s Environmental Footprint. Seminar. May 22 2013.

Geosyntec consultants

4. Approach – USEPA Methodology

➢ Alternative 1 – ISS

Equipment
- Drill Rigs (2)
- Support Excavators
- Batch Plant
- Pumps
- Generators
- Air Compressors
- Loaders
- Haul Trucks

Materials
- Portland Cement
- Granulated Blast Furnace Slag

Water
- POTW for mixing grout
- Reuse of contact water for mixing grout

Energy
- Electricity for batch plant operations
- Biodiesel fuel used (drill rigs)
- Fuel for support equipment
- Fuel for haul trucks

Land
- Equipment laydown areas
- Purchased wetland credits to offset forested wetlands removal
- Non hazardous off-site disposal

problems solved

4. Approach – USEPA Methodology

Alternative 2 – Excavation & Off-Site Disposal

Equipment
- Excavators
- Loaders
- Haul Trucks

Materials
- Imported backfill
- Steel sheet pile for deep excavation

Water
- Extracted groundwater (dewatering excavation) and off-site disposal

Energy
- Fuel for support equipment
- Fuel for haul trucks to disposal facility

Land
- Non-hazardous off-site disposal
- Purchased wetland credits to offset forested wetlands removal
- Equipment laydown areas
- Stockpile areas

4. Approach – USEPA Methodology

Key Assumptions:

- Equipment
- Materials
- Off-Site Disposal
- Schedule
- Productivity
- Reuse

Alternative 1
ISS

Crane mounted drill rigs
Water for grout production
1,000 CY/day
5-6 months
Minimal
Cement/Slag

Alternative 2
Excavation

Clean Fill/ Sheet Piles
Majority
13-14 months
Haul Trucks
Excavation: 800 CY/day
Backfill: 1,000 CY/day
Clean soil for backfill

Source: Provided by Geo-Solutions, Inc.

4. Approach – Cost Analysis

- Used completed ISS implementation cost data
- Used rates from Alternative 1 ISS excavation data to develop Alternative 2 Excavation & Off-Site Disposal cost analysis
- Compared cost only for implementation of technology

Source: Provided by Geo-Solutions, Inc.

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5. Results – USEPA Methodology

INPUT → CALCULATIONS → OUTPUT

On-Site Equipment Use and Transportation

Equipment Type*	HP*	Load Factor (%)*	Equipme nt Fuel Type
Drilling - large rig (500 HP)	440	75%	Biodiesel
Telescopic handler (60 HP)	64	75%	Diesel
Excavator - large (250 HP)	270	75%	Diesel
Other - HP varies	300	75%	Diesel
Generator - HP varies	189	75%	Diesel
Rotary-screw air compressor - 250 cfm (60 HP)	60	75%	Diesel

**HP and Load Factor must be entered by user in Columns C and D. Pl*

5. Results – USEPA Methodology

Contributors to Footprints	Units	Usage	Energy Conv. Factor	Energy MMBtus	GHG Conv. Factor	GHG lbs CO2e
On-Site						
On-site Renewable Energy						
Renewable electricity generated on-site	MWh	0	3.413	0		
Landfill gas combusted on-site for energy use	ccf CH4	0	0.103	0	-262	0
On-site biodiesel use	gal	51909	0.127	6592.443	22.3	1157570.7
User-defined on-site renewable energy use #1	TBD	0	0	0	0	0
User-defined on-site renewable energy use #2	TBD	0	0	0	0	0
On-site Renewable Energy Subtotals				**6,592**		**1,157,571**
Notes:						
On-site Conventional Energy						
Grid electricity	MWh	0	3.413	0		
On-site diesel use	gal	79129.05	0.139	10998.938	22.5	1780403.6
On-site gasoline use	gal	0	0.124	0	19.6	0
On-site natural gas use	ccf	0	0.103	0	13.1	0
User-defined on-site conventional energy use #1	TBD	0	0	0	0	0
User-defined on-site conventional energy use #2	TBD	0	0	0	0	0
On-site Conventional Energy Subtotals				**10,999**		**1,780,404**

5. Results – USEPA Methodology

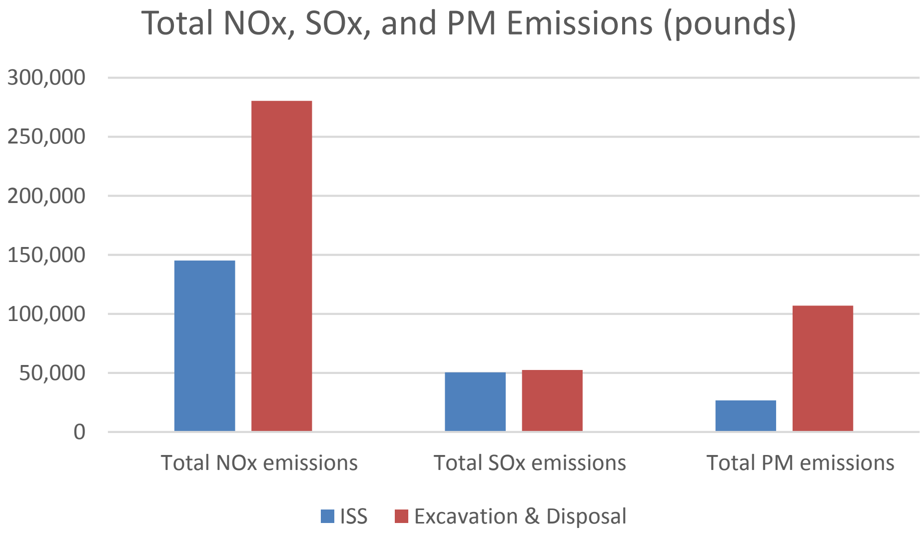
INPUT → CALCULATIONS → OUTPUT

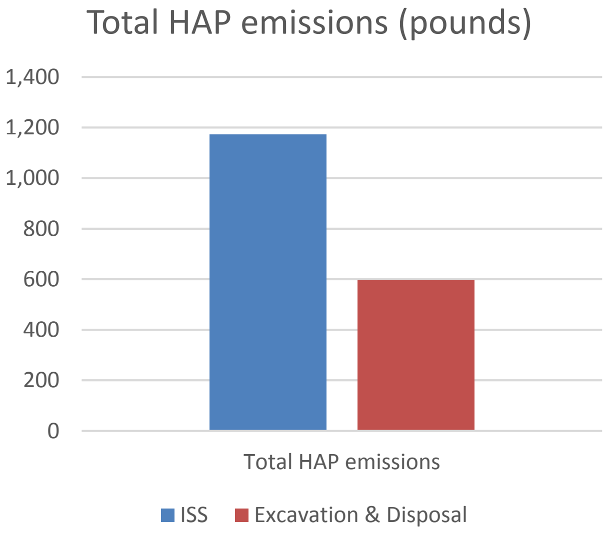
Alternative 1 - ISS
Environmental Footprint Summary

Core Element	Metric		Unit of Measure	Footprint				
				Drilling Operations	Batch Plant	Swell Management	Excavation & Off-Site Disposal	Total
Materials & Waste	M&W-1	Refined materials used on-site	Tons	0.0	0.0	0.0	0.0	0.0
	M&W-2	% of refined materials from recycled or reused material	%					
	M&W-3	Unrefined materials used on-site	Tons	0.0	17,670.0	0.0	0.0	17,670.0
	M&W-4	% of unrefined materials from recycled or reused material	%		0.0%			0.0%
	M&W-5	On-site hazardous waste disposed of off-site	Tons	0.0	0.0	0.0	0.0	0.0
	M&W-6	On-site non-hazardous waste disposed of off-site	Tons	0.0	0.0	0.0	62,910.0	62,910.0
	M&W-7	% of total potential waste recycled or reused	%				13.1%	13.1%
Water (used on-site)	W-1	Public water use	MG	0.0	1.0	0.0	0.0	1.0
	W-2	Groundwater use	MG	0.0	0.0	0.0	0.0	0.0
	W-3	Surface water use	MG	0.0	0.0	0.0	0.0	0.0
	W-4	Reclaimed water use	MG	0.0	0.0	0.0	0.0	0.0
	W-5	Storm water use	MG	0.0	0.0	0.0	0.0	0.0
	W-6	Other water resource #1	MG	0.0	0.0	0.0	0.0	0.0
	W-7	Other water resource #2	MG	0.0	0.0	0.0	0.0	0.0
Energy	E-1	Total energy used (on-site and off-Site)	MMBtu	20,596.8	80,001.0	104.8	46,968.4	147,671.0
	E-2	Energy voluntarily derived from renewable resources						
	E-2A	On-site renewable energy generation or use + on-site biodiesel use + biodiesel and other renewable resource use for transportation	MMBtu	6,592.4	0.0	84.9	0.0	6,677.3
	E-2B	Voluntary purchase of renewable electricity	MWh	0.0	0.0	0.0	0.0	0.0
	E-3	Voluntary purchase of RECs	MWh	0.0	0.0	0.0	0.0	0.0
	E-4	On-site grid electricity use	MWh	0.0	52.9	0.0	0.0	52.9
Air	A-1	On-site NOx, SOx, and PM emissions	Pounds	24,581.5	4,506.4	134.3	24,741.5	53,963.7
	A-2	On-site HAP emissions	Pounds	0.4	0.1	0.0	0.7	1.3
	A-3	Total NOx, SOx, and PM emissions	Pounds	28,879.0	108,028.9	169.6	85,208.2	222,285.8
	A-3A	Total NOx emissions	Pounds	25,315.1	69,508.4	146.3	50,138.5	145,108.2
	A-3B	Total SOx emissions	Pounds	3,173.2	38,268.3	22.1	9,029.4	50,493.0
	A-3C	Total PM emissions	Pounds	390.8	252.3	1.2	26,040.3	26,684.5
	A-4	Total HAP emissions	Pounds	9.9	1,046.4	0.0	117.4	1,173.8
	A-5	Total greenhouse gas emissions	Tons CO_2e[1]	1,142.7	10,656.5	1.9	3,738.6	15,539.6

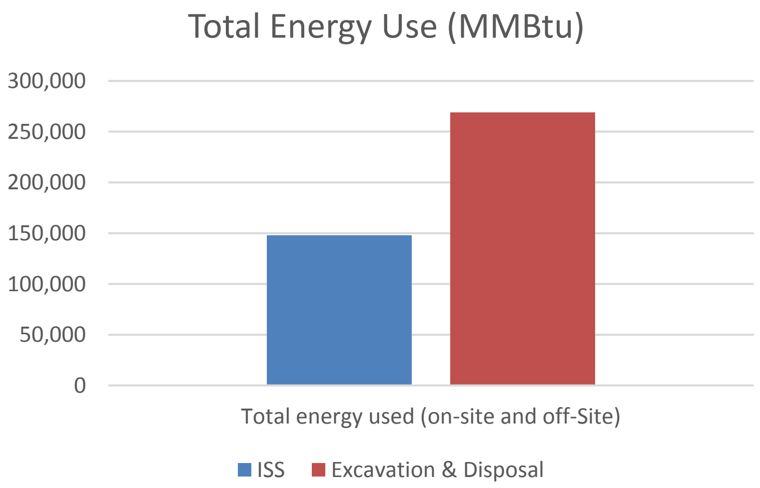
problems solved

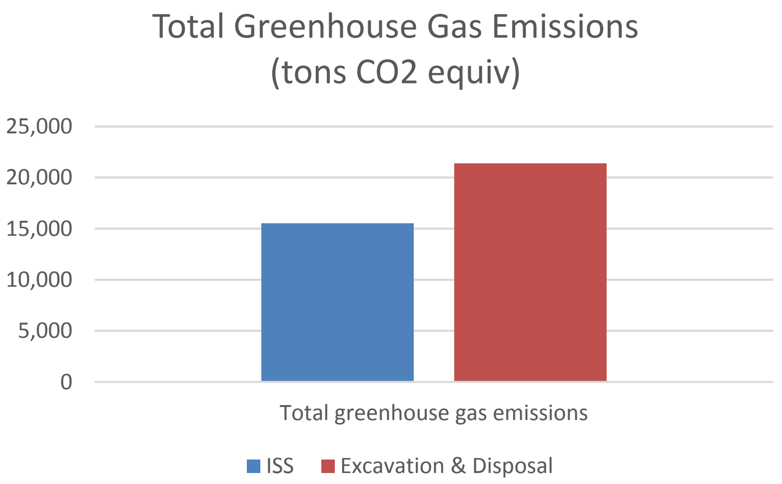
5. Results – USEPA Methodology





5. Results – USEPA Methodology

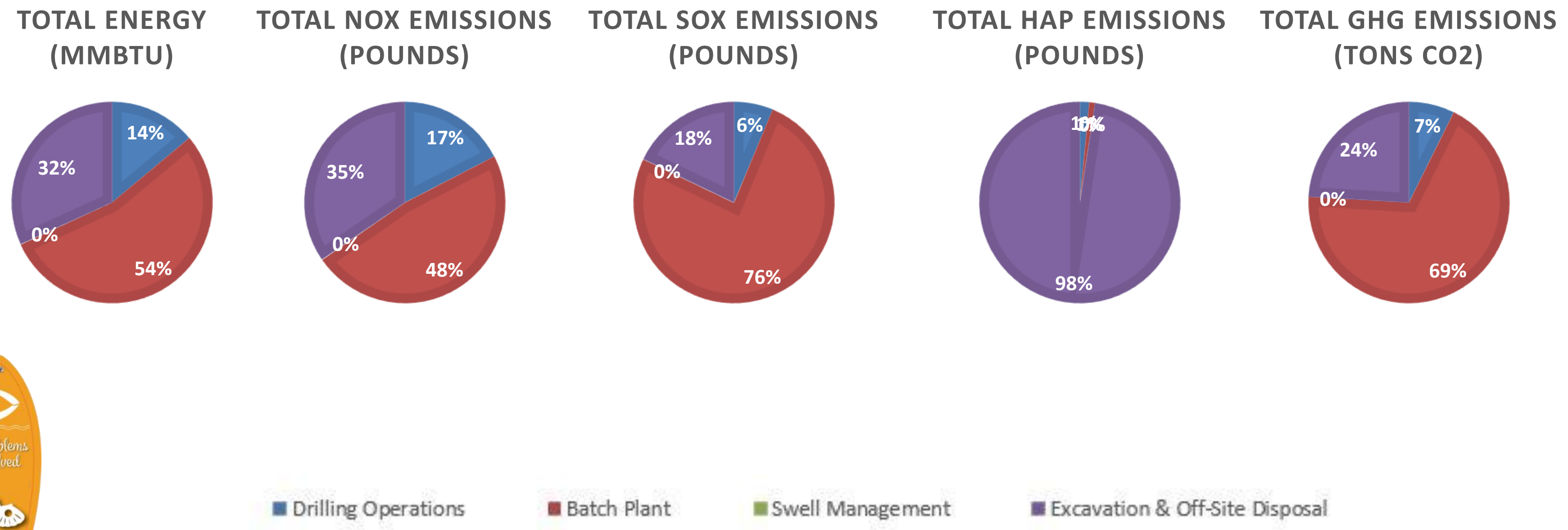




5. Results – Cost Analysis

	Alternative 1	Alternative 2
	ISS	Excavation & Off-Site Disposal
Treatment Volume (CY)	143,530	182,350
Debris Removal (CY)	38,820	-
Off-Site Disposal Volume (tons)	62,910	251,095
Backfill Reuse Percentage	13%	15%
Total Cost ($)	7,000,000	13,800,000

6. Recommendations for Future ISS Implementations



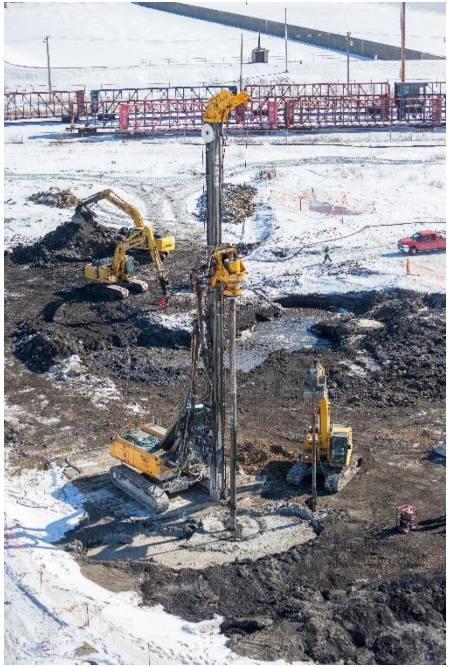
problems solved

6. Recommendations for Future ISS Implementations

- Preconstruction Bench Scale Study
  - Reusable reagents
  - Locally sourced reagents
- Delivery of reagents in bulk to reduce transportation costs
- Reduction of water to cement ratio as feasibility possible for pumpability to reduce water usage
- Reuse of contact water for grout production
- Use of larger augers to reduce amount overlap mixed material

Source: *Robb, C., deGrood, T., Weber, R. "In Situ Stabilization/Solidification (ISS), Another Tool for Remediation of Contaminated Sediments." Western Dredging Association, Midwest Chapter Meeting, Milwaukee, WI, March 11-13, 2015*

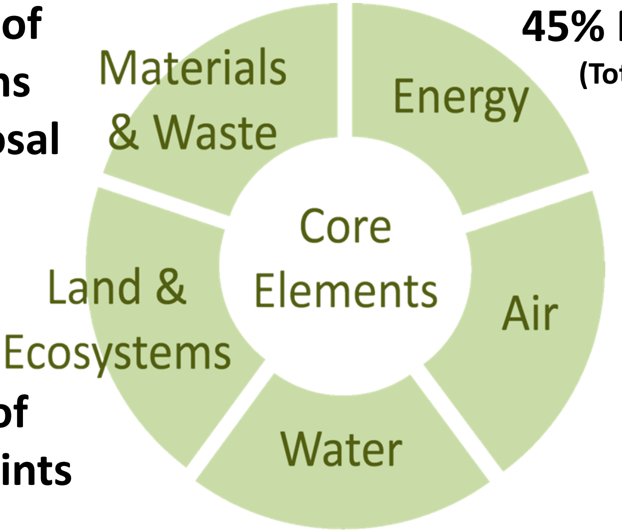
7. Study Summary



Source: Provided by Geo-Solutions, Inc.

Elimination of 188,000 tons off-site disposal

Reduction of space constraints



45% Reduction
(Total Energy)

64% Reduction
(Total NOx, SOx, and PM emissions)

27% Reduction
GHG emissions (Tons CO2 equiv)

6.4 Million Gallons

Cost savings of $6.8 million

Thank You!

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Source: Provided by Geo-Solutions, Inc.