A Green and Sustainable Remediation Tool Review and Comparison

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Outline

- Need for Green and Sustainable Remediation framework
- Criteria and Metrics
- Tools
- Comparison of tool output
  - Case study 1: Feasibility Study (selection of remedial approach)
  - Case study 2: Project evolution
- Summary

GSR Framework: Work in Progress

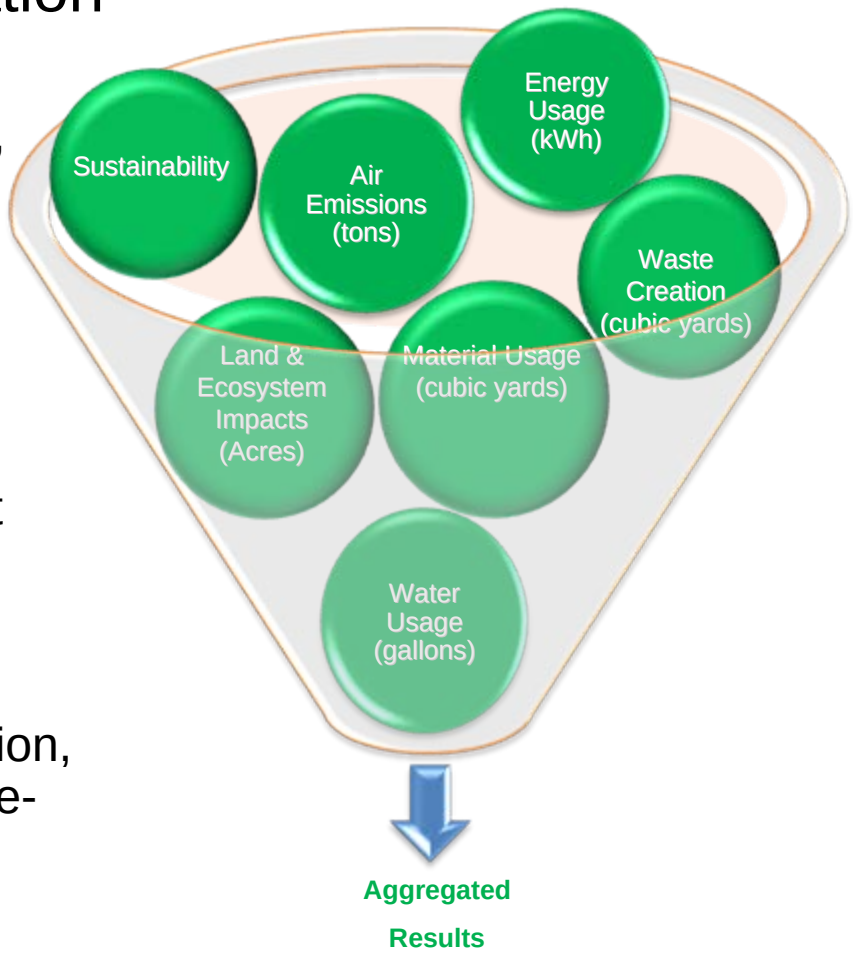
- Framework is needed to assess GSR
- Definition of framework
  - Basic conceptual structure or foundation upon which something is built
  - “A set of assumptions, concepts, values, and practices that constitutes a way of viewing reality” - *American Heritage® Dictionary, 4th Ed., 2000*
- Remediation industry is seeking regulatory context, working in groups towards common approaches, driving consensus
  - Framework already exists within the spectrum of environmental sites
  - Consensus likely achieved through compelling demonstrations of applied greener solutions
  - Voluntary actions and assessment will be the new proving ground

GSR Criteria/Metrics

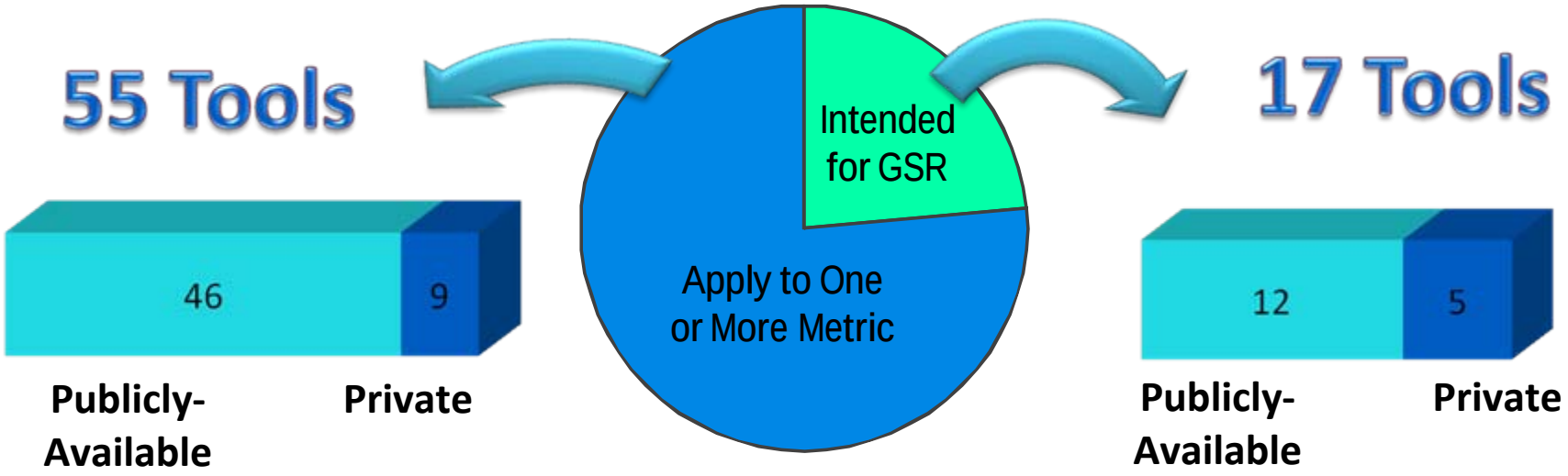
- USEPA-defined core elements of green remediation
  1. Energy efficiency – Total energy use, renewable energy use
  2. Air emissions – Greenhouse gas emissions, other air pollutants
  3. Water usage – Water use, impacts to water resources
  4. Land impacts – Land management, ecosystems protection
  5. Waste generation – Construction materials management, waste reduction
- Sustainability metrics include short- and long-term impacts:
  - Environmental protection
  - Social equity
  - Economic prosperity

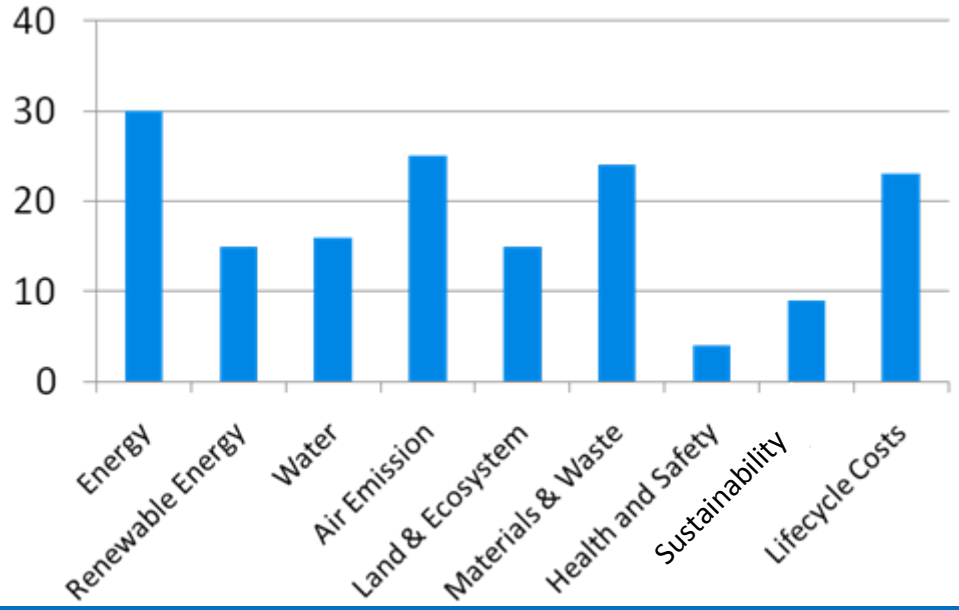
Key Challenges with GSR Metrics

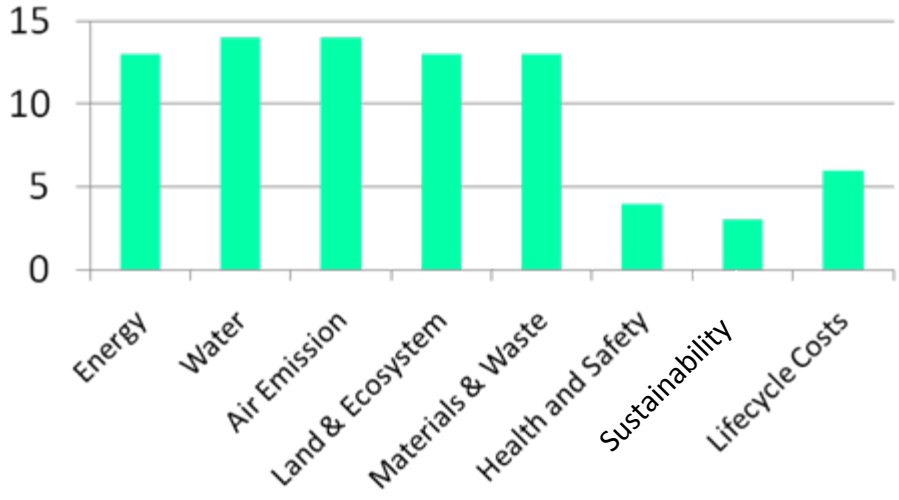
- Multiple approaches to quantification
  - Site conditions and possible remedial actions, Implemented remedial solutions, Compilation field activity information
  - Each has different degree of certainty
- Aggregation challenges
  - Diverse units, interdependent variables, different relative magnitudes, not straight forward calculations
- Weighing importance
  - May vary based on site geographic location, state of industry, stakeholder interest, site-specificity



Industry GSR Assessment Tools and Calculators







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Select GSR Assessment Tools

Publicly-Available

- Qualitative
  - Green Remediation Evaluation Matrix (GREM) by CA DTSC
  - Greener Cleanups Matrix by IL DEP
- Quantitative
  - Green Remediation Analysis by USEPA Region 9
  - SiteWise™ by Battelle, US Navy, US Army, US Army Corps of Engineers
  - Sustainable Remediation Tool (SRT) by AFCEE
  - Remedy Tradeoff Evaluation Tool NFESC by USACE and AFCEE
  - LUST Cleanup Footprint Calculator by USEPA Region 9

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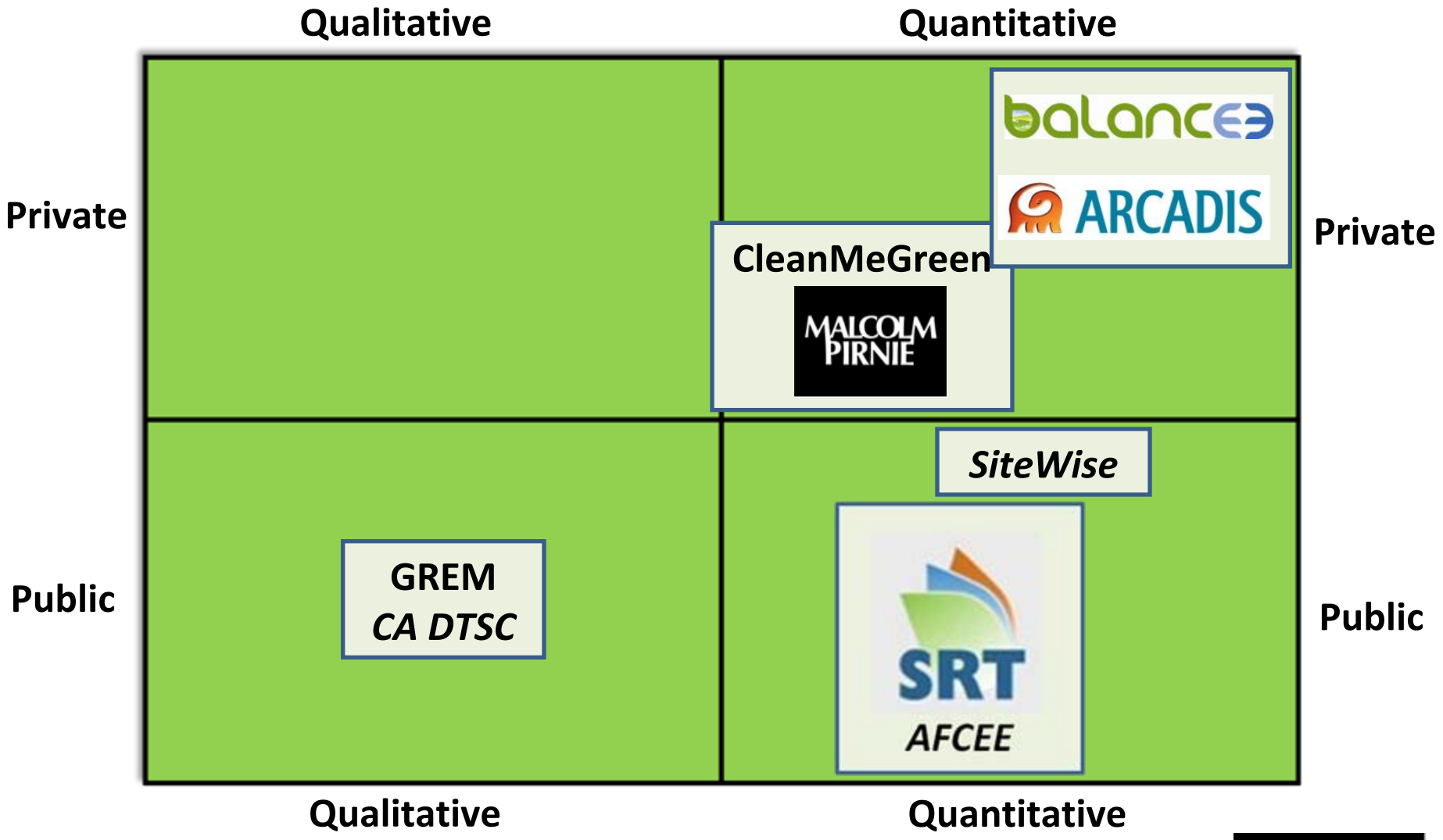
Select GSR Assessment Tools

Privately Developed/Licensed

- Quantitative
  - The BalancE3™ Tool by ARCADIS
  - CleanMeGreen by Malcolm Pirnie, Inc.
  - Cleanup Sustainability Framework by DuPont and USEPA Region 3
  - Maximizing Remediation Value and Sustainability by CH2M Hill
  - Sustainable Remediation Assessment Tool by Haley and Aldrich
  - Sustainability Screening Tool for Site Remediation by Golder Associates Ltd

Five Selected GSR Tools



Descriptions of 5 Selected Tools

- Green Remediation Evaluation Matrix (GREM) – California Department of Toxic Substance Control (CA DTSC)
  - Excel-based table, Version 1 available
  - Perform qualitative comparisons of treatment alternatives using a matrix identifying stressors, affected media, and mechanism/effect
- SiteWise – Battelle, US Navy, US Army, US Army Corps of Engineers
  - Excel-based tool
  - Calculate the environmental footprint of remedial alternatives and compare up to 6 remedial alternatives
  - Activity-based (4 phases), 4 green remediation metrics (GHG, energy usage, criteria pollutants, water usage) and accident risk

Tool Descriptions (Cont'd)

- Sustainable Remediation Tool (SRT) - Air Force Center for Engineering and Environment (AFCEE)
  - Excel-based tool - Version 2.1 Available
  - Evaluate implementation and optimization scenarios using Tier structure similar to in Risk-Based Corrective Action (RBCA) Tool Kit (Tier 1-simple and Tier 2-detailed)
  - Technology-based, 3 soil and 5 GW technologies, 5 metrics: atm. emissions, energy use, resources consumption, technology cost, safety
  - Normalized to $

Tool Descriptions (Cont'd, 2)

- CleanMeGreen - Malcolm Pirnie, Inc.
  - Excel-based tool - Currently under development
  - Compares traditional and green remediation methods at high level to aid in decision-making and to estimate changes when using renewable energy and/or alternative fuels
  - Technology-based, 5 technologies, 3 metrics (CO2, energy use, costs)
- The BalancE3™ Tool – ARCADIS
  - Stand-alone private program - Beta Test Version Available
  - Evaluate remedy selection, optimization, project evolution, and portfolio of site for two life-cycle phases (Tier 1 onsite use and tier 2 transport)
  - Normalized to statistical z-scores and aggregated to "Balance Score"
  - Technology-based, 12 technologies, LCA Tiers, 5 green remediation metrics, stewardship, health and safety, lifecycle costs

Comparison of Tools

Metrics

Criteria	BalancE3 Tool	SRT	SiteWise	CleanMeGreen	GREM
Energy use	X	X	X	X	X
Carbon emissions	X	X	X	X	X
Air emissions	X	X	X		X
Water use and impacts	X		X		X
Land and ecosystem impacts	X	X			X
Material consumption and waste generation	X		X		X
Health & safety	X	X	X		X
Costs	X	X		X	

Comparison of Tools

Remedial Alternatives

- SiteWise and GREM can be used with any remedial alternative

Remedial Alternative	CleanMeGreen	BalancE3 Tool	SRT
Excavation	X	X	X
Pump-and-treat	X	X	X
Enhanced in-situ biological degradation	X	X	X
In-situ thermal treatment	X	X	X
Soil vapor extraction	X	X	X
In-situ chemical oxidation		X	X
Permeable reactive barrier		X	X
Monitored natural attenuation	X	X	X

How to Apply the Tools

Examples of GSR Assessment

- Remedial alternatives analysis/Remedy selection ★
  - Incorporate GSR into feasibility analysis; use as differentiator for remedy selection
  - Choose greener remediation strategies
- Project evolution ★
  - Evolution of remedial action/management
  - Compare GSR footprint of original remedial action with proposed changes
- Remedy optimization
  - Life-cycle optimization to reduce footprint, balance active and passive remedial components
  - Focus on key metrics and values (energy, carbon, etc.)

Case Study 1:
Feasibility Assessment

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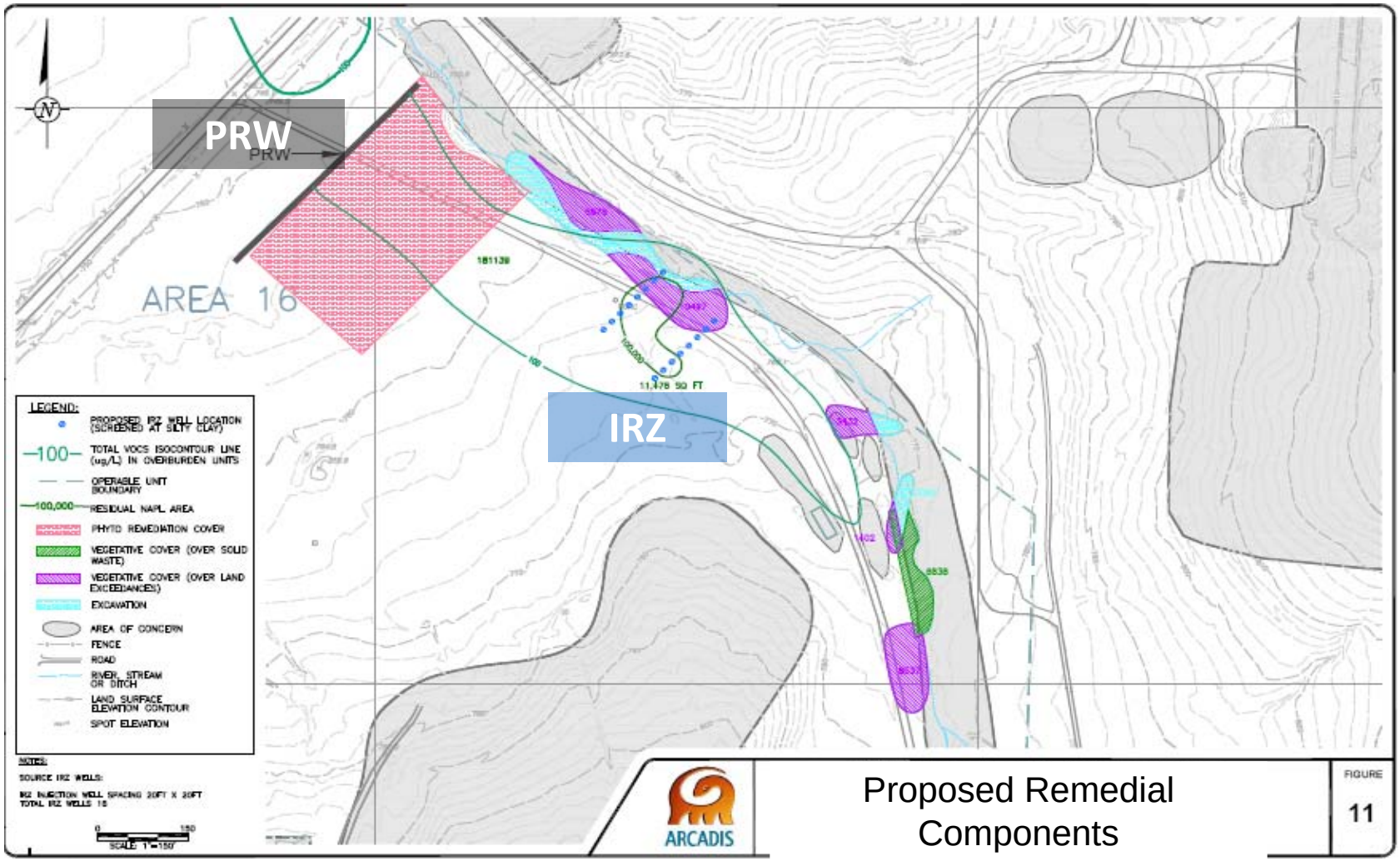
Case Study 1: Site Description

- Site located in Northwest Missouri
- Low-land setting near creek and roadside
- Buried waste and disposed of waste in pits (1960-1975)
- Impacts:
  - Lead in surface soils
  - TCE, cis-1,2-DCE and vinyl chloride in groundwater
- Remedial action objectives
  - Prevent exposure to chlorinated solvents and lead
  - Prevent contaminant migration from source area and off-site

Case Study 1: Site Map



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Case Study 1: Remedial Alternatives

	Alternative 1	Alternative 2	Alternative 3
Soil Remedial Approach	Complete Excavation Vegetative Cover*	Focused Excavation Vegetative Cover*	Focused Excavation Vegetative Cover*
Duration O&M (yrs)	164	164	15
Groundwater Remedial Approach	Permeable Reactive Wall	Permeable Reactive Wall	Source area IRZ; Permeable Reactive Wall
Duration O&M (yrs)	30	30	15

SiteWise
The BalancE3 tool
SRT
GREM

GSR Footprint

*Not run with SRT and SiteWise

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Case Study 1: Results

Tool	Alt. No.	Energy Use (kWh)	CO2 Emissions (metric tons)	Water Usage (gallons)	Health and Safety	Project Costs
The Balance E3 Tool	1	656,300	2,600	124,400	7.70 Semi-quantitative hazard assessment	$14,566,000
	3	340,700 *(49%)*	200 *(92%)*	36,900 *(97%)*	6.70 Semi-quantitative hazard assessment	$4,336,000 *(70%)*
SRT (Tier 1)	1	1,380,000	1,360	N/A	0.23 as injury risk 11.1 as lost hours	$4,550,000
	2	590,000 *(57%)*	1,142 *(16%)*	N/A	0.113 as injury risk 5.4 as lost hours	$3,930,000 *(13%)*
SiteWise	1	1,000,000	429	45,000	0.024 as injury risk 7.0 E-05 as risk fatality	N/A
	2	860,000 *(14%)*	409 *(5%)*	6,400 *(85%)*	0.005 as injury risk 2.0 E-05 as risk fatality	N/A

Case Study 1: Results

Common Themes

- All tools predicted that Alternatives 2 and 3 are greener than Alternative 1
- Alternative 3 is greener than 2 using The BalancE3 Tool, except for land and ecosystem impacts, material consumption & waste generation, and health and safety (<8%)
- Alternatives 2 and 3 are similar using SRT (Tier 1); Alternative 2 slightly better than 3 in all criteria
- Alternatives 2 and 3 are similar using SiteWise; Alternative 2 is slightly greener (except for H&S) and uses much less water
- GREM output is consistent with quantitative models, with Alternative 3 being greener than Alternative 2

Case Study 2:
Project Evolution

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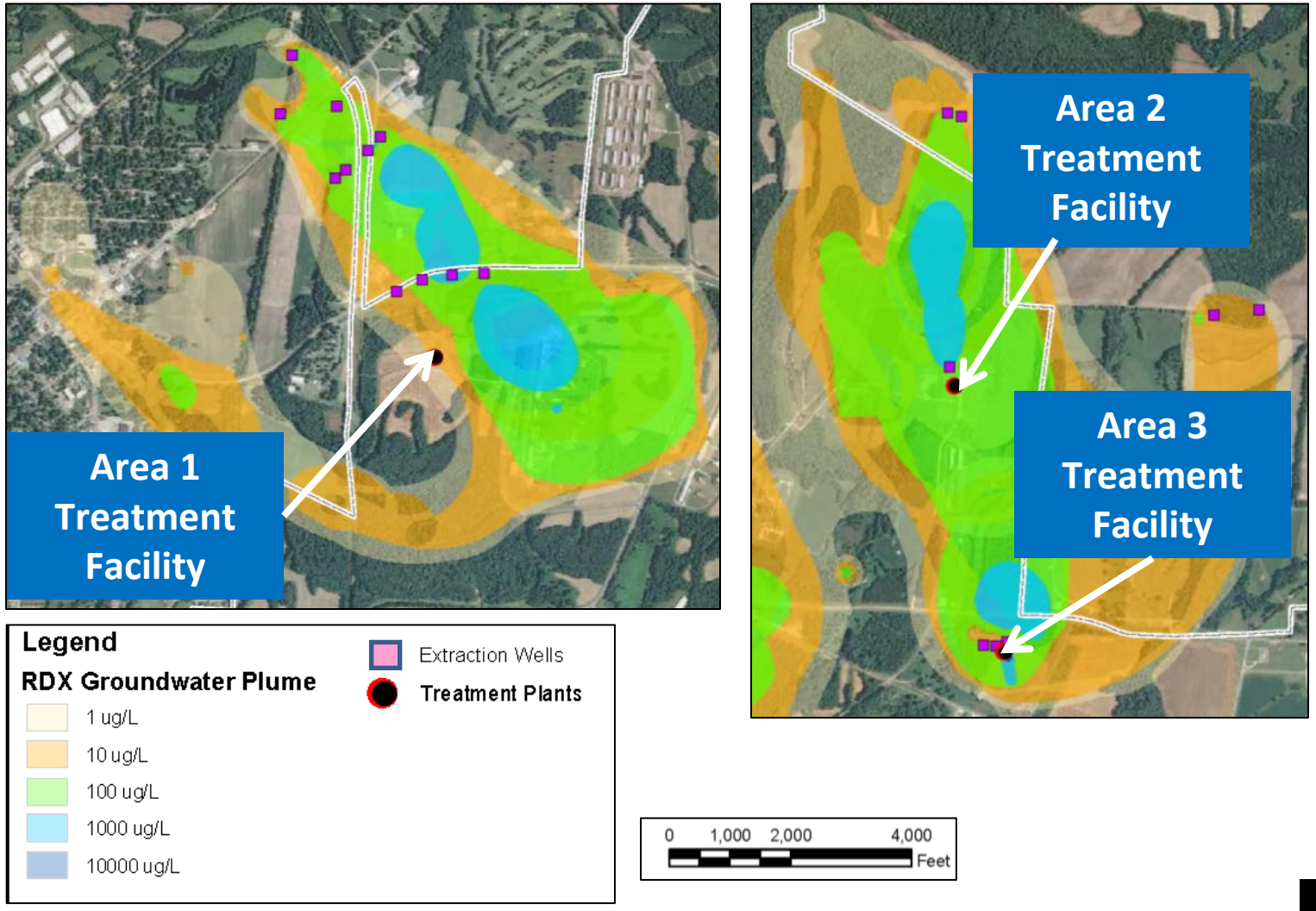
Case Study 2: Site Description

- Site located in Western Tennessee
- Site is located in low-land near creek and farmland
- Historically used for manufacturing explosives, starting in 1942
- Groundwater is impacted by RDX and TNT
- Remedial action objective is to prevent contaminant migration from source area and off-site

Case Study 2: Original Groundwater Remediation (2006)



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Case Study 2: Project Evolution

- Three groundwater treatment facilities:

Area	Capacity (gpm)	Actual flow (gpm)
Area 1	800	240
Area 2	1350	800
Area 3	1350	1000

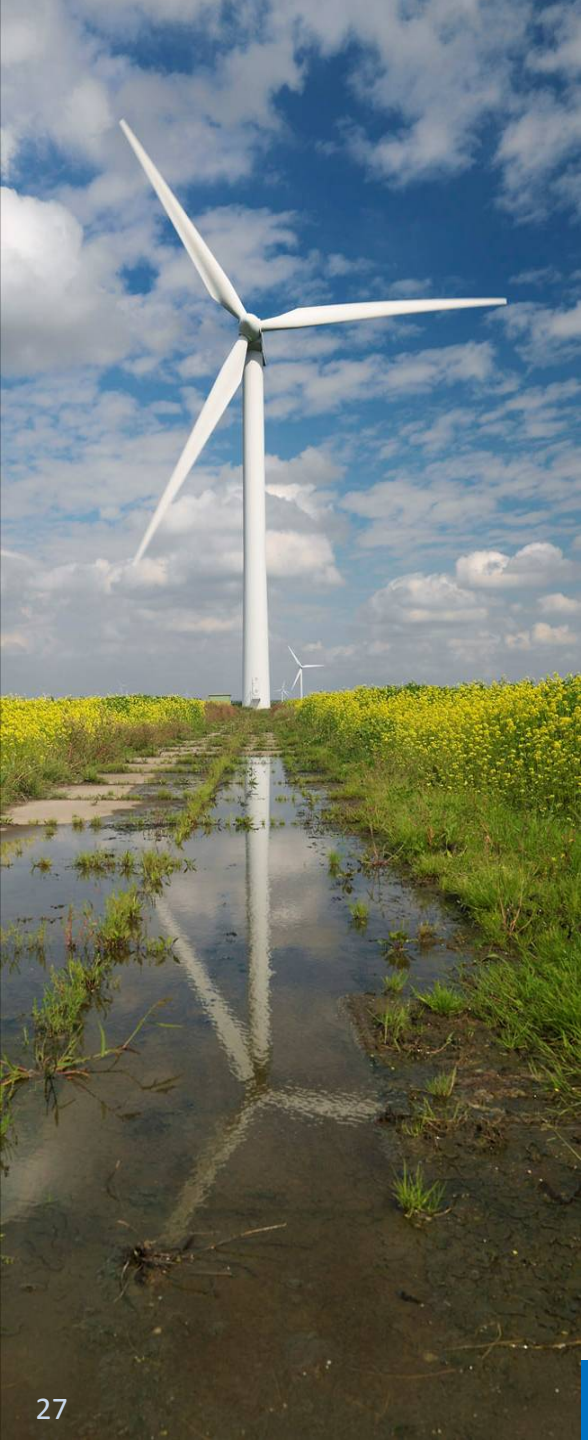
- Reduction in facility operations
  - Treatment facilities: 3 ➡ 2
  - Reroute Area 1 wells to Area 2 system
- Expect GSR footprint to be reduced. By how much?

Case Study 2: Results

- Tools all predicted GSR footprint reductions. Footprint savings over 1 year:

Tool	Energy Use (kWh)	CO2 Emissions (metric tons)	Water Usage (gallons)
The Balance E3 Tool	66,587,000 *(32%)*	3,513 *(12%)*	312,000 *(1%)*
Clean Me Green	1,820,856 *(33%)*	717 *(50%)*	N/A
SRT (Tier 2)	17,000,000 *(25%)*	3,000 *(20%)*	N/A
SiteWise	2,800,000 *(18%)*	2,174 *(10%)*	80,000 *(5%)*

- No changes in health and safety, minimal changes in costs (0-5%)
- GREM's output was consistent with quantitative models



Summary

- All phases of remediation offer opportunities for greener solutions
- GSR assessment is on its way to becoming a standard component of remedy selection, implementation, and optimization
  - Need credible and verifiable methods, clear and transparent metrics to measure true value of GSR
- Quantification makes success measurable, incremental, establishes validity of greener solutions
- Quantitative assessments are time-consuming
- Tools predicted consistent trends but they have different units, metrics, input requirements, and outcome numbers
- Results are highly dependent on assumptions and human factor, which makes comparison challenging

Questions?

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