District of Columbia
Green and Sustainable Remediation (GSR) Guidance
Advancement Towards DC's Sustainability

Department of Energy & Environment (DOEE)
Environmental Services Administration (ESA)
Toxic Substances Division (TSD)
Underground Storage Tanks Branch (USTB)

September 2025

Richard Jackson	: Director, DOEE
Collin R. Burrell	: Deputy Director, ESA
Dave R. Tomlinson	: Assistant Director, TSD
Fianna Phill	: Branch Chief, USTB
Nazmul Haque	: GSR Guidance Leader, UST Branch
Natalie Hendricks, Temesgen Yimanie, and Deepak Singh	: Leaking UST Program Staff

Purpose and Scope

The UST Branch introduces this Green and Sustainable Remediation (GSR) Guidance to advance the goals of Sustainable ***DC 2.0*** and uphold the DOEE's mission, vision, and values[1]. While adopting GSR practices remains voluntary, our aim is to inform and encourage the regulated community and stakeholders to incorporate GSR principles into their remediation efforts. Our long-term objective is to ensure that all Underground Storage Tank (UST) and Leaking Underground Storage Tank (LUST) cleanups are conducted using sustainable practices as outlined and recommended in this guidance, promoting environmental responsibility and sustainable outcomes.

Disclaimer

This document is prepared uniquely as guidance and does not contain any mandatory requirements with the exception at requirements found in the District of Columbia Underground Storage Tank Regulations, as set forth in Title 20 of the District of Columbia Municipal Regulations (DCMR), Chapters 55-70 (20 DCMR §§ 5500-7099. This guidance does not establish or affect legal rights or obligations and is not finally determined of any of the issues addressed. This guidance does not create any rights enforceable by any party in litigation with the DOEE.

This guidance will be updated as needed. The current GSR Guidance Team includes LUST Case Managers [Nazmul Haque, Natalie Morales Hendricks, Deepak Singh, Temesgen Yimanie] and the Branch Chief [Fianna Phill]. Comments and concerns may be sent to "GSR Guidance," UST Branch – 1200 First Street NE, 5th Floor, Washington, DC 20001, ust.doee@dc.gov, or to Nazmul Haque at 202.535.1330 or Nazmul.haque@dc.gov.

[1] https://doee.dc.gov/page/about-doee

Table of Contents

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS

AFCEE	:	Air Force Center for Engineering and the Environment
ASTM	:	American Society for Testing and Materials
BMPs	:	Best Management Practices
BTU	:	British Thermal Unit

CAP	:	Corrective Action Plan
CCAD	:	Conceptual Corrective Action Design
CCP	:	Construction Contingency Plan
CERCLA	:	Comprehensive Environmental Response and Liability Act
CLU-IN	:	Contaminated Site Clean-Up Information
CO_2e	:	Carbon Dioxide Equivalents
CSA	:	Corrective Site Assessment
DCMR	:	District of Columbia Municipal Regulations
DCRBCA	:	District of Columbia Risk Based Corrective Action
DOEE	:	Department of Energy & Environment
EPA	:	U.S. Environmental Protection Agency
ERA	:	Ecological Risk Analysis
ESA	:	Environmental Services Administration (DOEE)
FS	:	Feasibility Study
GHGs	:	Greenhouse Gases
GRST	:	Green Remediation Screening Tool
GSR	:	Green and Sustainable Remediation
HFCs	:	Hydrofluorocarbons
HVAC	:	Heating, Ventilation, and Air Conditioning
IDW	:	Investigative Derived Waste
ITRC	:	Interstate Technology and Regulatory Council
LCA	:	Life Cycle Assessment
LEED	:	Leadership in Energy and Environmental Design
LSI	:	Limited Site Investigation
LTM	:	Long-Term Monitoring
LUGs	:	Local Units of Government
LUST	:	Leaking Underground Storage Tank
NEBA	:	Net Environmental Benefit Analysis
NOx	:	Nitrogen Oxides
NRC	:	National Research Council
NRDA	:	Natural Resource Damage Assessment

PBP	:	Petroleum Brownfield Program
PFCs	:	Perfluorocarbons
PQOs	:	Project Quality Objectives
PRP	:	Potential Responsible Party
QAPP	:	Quality Assurance Project Plan
RACER	:	Remedial Action Cost Engineering and Requirements
RAP	:	Response Action Plan
RA-O	:	Remedial Action-Operation
RI	:	Remedial Investigation
RPs	:	Responsible Parties
ROI	:	Return on Investment
SRT	:	Sustainable Remediation Tool
SURF	:	Sustainable Remediation Forum
TSD	:	Toxic Substances Division
USACE	:	US Army Corps of Engineers
USTB	:	Underground Storage Tank Branch
VFDs	:	Variable Frequency Drives
VRAP	:	Voluntary Remediation Action Program

1.0 INTRODUCTION

1.1 Overview

Green and Sustainable Remediation (GSR), in its broad strokes, is a concept and practice that involves thoughtfully planned and deliberate measures to effectively reduce or eliminate carbon emissions, reduce waste, reduce total energy, material, and water consumption during remediation of contaminated sites. Conventional remediation in years and decades past and present has focused mainly on the cost and efficacy of remedial strategies to achieve regulatory compliance and site cleanup goals. Methods and strategies involve a myriad of approaches that revolve around efficacy, feasibility, and implementation costs. Although site cleanups have been successfully occurring, often, it is done completely without consideration and acknowledgment of the environmental impact of the cleanup effort itself (e.g., carbon emissions of equipment, vehicles, drilling rigs, waste haulers, waste treatment, energy consumption of active remediation systems, renewable energy, sample collection, shipping, and lab analysis, etc.). GSR is an approach to environmental cleanup that integrates sustainability principles into the remediation process. The objective of GSR is to minimize the **environmental, social, and economic impacts** of remediation while maximizing the net benefits to the environment and impacted communities. It involves evaluating and optimizing remediation activities to achieve cleanup goals in a manner that conserves resources, reduces greenhouse gas emissions, and enhances long-term site and community resilience.

Since the turn of the century, there has been a growing recognition of the need to incorporate GSR into cleanup goals that has gained worldwide acceptance. It is practiced throughout the United States and abroad as we work to combat the global climate crisis and reverse anthropogenic environmental impact. The District of Columbia as a city is actively pursuing sustainable and greener livability at an ambitious and achievable pace as established in the District's more recent Sustainable DC 2.0 plan "to make DC the greenest, healthiest, most livable city."

DOEE's mission is to improve the quality of life for the residents and natural inhabitants of the nation's capital by protecting and restoring the environment, conserving our natural resources, mitigating pollution, increasing access to clean and renewable energy, and educating the public on ways to secure a sustainable future. Both DOEE and USTB have been working diligently to achieve this mission. For example, in 2009, former DOEE Director, Tommy Wells crafted "*The Anacostia River Clean Up and Protection Act of 2009*", to implement $0.05 fee on disposable bags. This landmark legislation prompted thousands of District residents to curb the use of plastic bags and instead opt for reusable, green alternatives.

The USTB has implemented GSR at LUST sites toward successful case closure. For instance, in 2017, phytoremediation was selected as the remedial technology for corrective action for LUST #90050 at 2800 12th Street, NE (**Figure 1**). A brief overview of phytoremediation is presented in **Figure 1**. The use of solar panels to run the remediation system at 3670 New Hampshire Avenue NW, Washington DC 20001, to

clean up groundwater has set another milestone to achieve DOEE's mission (**Figure 2**). Thermal remediation was successfully used at a contaminated site located at 1818 New York Avenue, NE, Washington DC 20002, to clean petroleum and non-petroleum hydrocarbons (**Figure 3**). **Figure 1** through **Figure 3** are presented in **Appendix A**. These are simply two examples of greener remedial strategies, and additional LUST cases have included GSR approaches (e.g., other in-situ/subsurface applied remedial strategies such as bioventing, microbial injection, etc. for groundwater cleanup).

USTB has established two goals: short-term and long-term, to implement GSR throughout our nation's capital. The short-term goal is to evaluate and quantify the GSR practice at the LUST site(s) using the numerical tool presented in this guidance. The long-term objective will be to use these guidelines in addition to other robust qualitative/quantitative tools (Sitewise, Carbon Footprint Calculator, etc.) for any environmental projects to include GSR methods into their plans, selecting and prioritizing best management practices (BMPs), and tracking and documenting the BMPs implementation.

DOEE's USTB has developed this guidance to advance the ***Sustainable DC 2.0*** within DC's UST stakeholder community. Although DOEE has developed this GSR plan, it is not its sole user or facilitator. As the plan outlines, there are many stakeholders involved, including residents, developers, local (state) and federal government, and others.

1.2 Tracking and Reporting

GSR practices implemented at any UST and/or LUST Sites in the District are tracked internally within the UST-LUST database system. The site will also be reported to the Environmental Protection Agency (EPA) as a part of the green cleanup. GSR metrics may be shared with other state or federal agencies for trend analyses and similar study.

1.3 Incentives

In the absence of regulatory requirements, GSR practice is largely a voluntary practice driven by the goals and mission to reduce energy consumption, reduce waste and harmonize site cleanup with sustainable and meaningful outcomes. Stakeholder will typically find incentives to consider GSR is simply more cost effective in the long term, and often short term of project planning and forecasting to case closure. Incentive identification should be conducted in conjunction with the stakeholder identification process. Potential incentives could include grants, project recognition/award, reduced permit fee, expedite reviews and processing time for applications, reduced voluntary remediation action program (VRAP) application fee, carbon credits, etc. Sustainable DC 2.0 Program can provide acknowledgement/promotion for those GSR cleanups conducted at LUST sites. GSR Certifications will contribute beneficial value to DC's Environmental Sustainability Initiative. GSR Certification will recognize contributors who add value to other sustainable initiatives such as Leadership in Energy and Environmental Design (LEED) buildings, Energy Star, emission vehicles, and value to other sustainable initiatives such as LEED buildings, Energy Star, emission vehicles, and carbon footprint values.

2.0 PRINCIPLES OF GREEN AND SUSTAINABLE REMEDIATION

The concept of sustainability is derived from the realization that the earth's natural resources are limited, that man's activity is depleting these resources at an alarming rate, and that this activity significantly affects the environment and quality of life. The concept of sustainability first manifested itself in the form of sustainable development, which was defined in the Brundtland Commission's 1987 report to the United Nations (United Nations, 1987) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." With the increasing focus on the environment spurred by global climate change and resource conservation issues, the need for sustainability as a holistic approach to environmental management is of vital importance.

Sustainable practices consider economic, environmental and social asepects of a project in a nexus as shown in the Venn diagram below (**Figure 4**).

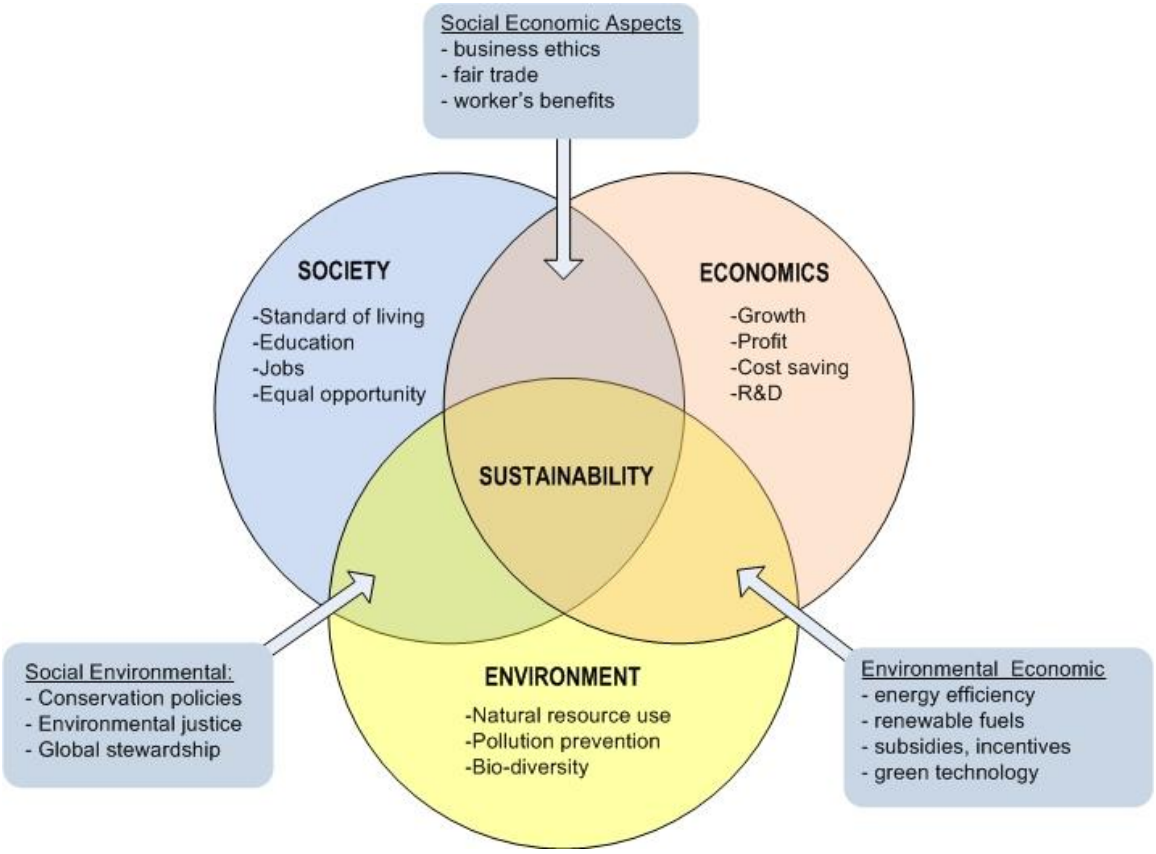


Figure 4: Pillars of Sustainability Aspect (Source: Rodriguez et al., 2002)

2.1 Definitions

GSR involves incorporating sustainable principles, practices, and measurable outcomes into every phase of a remediation project, starting from the initial site investigation planning and continuing through to the final closure of the site. This approach emphasizes minimizing the environmental impact, or "footprint," of remediation

activities. Key areas of focus include reducing energy consumption, lowering greenhouse gas (GHG) emissions, conserving water and raw materials, and promoting the beneficial reuse of the property after cleanup (Interstate Technology & Regulatory Council (ITRC), 2011a; Ellis & Hadley, 2009). By addressing these factors, GSR ensures that remediation efforts are efficient, environmentally conscious, and supportive of long-term sustainability goals (American Society for Testing and Materials (ASTM) International, 2013).

Although the terms green and sustainable remediation are sometimes used interchangeably, they have generally evolved to mean different things. For the purposes of this document, green remediation and sustainable remediation are defined in Sections 2.1.1 and 2.1.2. with the main differences lying in socioeconomic impact and extent of application.

2.1.1 Green Remediation

Green remediation is crucial in remedial actions to minimize environmental impacts, such as reducing greenhouse gas emissions (EPA, 2023). This practice takes place **after** a specific remedy has already been chosen and is implemented without formally incorporating environmental considerations into the earlier stages of evaluation and remedy selection (ASTM, 2013). Because the decision-making process for selecting the remedy does not take these environmental factors into account, green remediation is typically seen as uncontroversial (National Academies, 2011).

The fundamental idea behind green remediation is to integrate sustainability principles into every phase of the cleanup process. This means considering how energy use, emissions, waste generation, and ecosystem disturbances can be reduced or managed efficiently throughout remediation activities (EPA, 2024). In this context, green remediation focuses on improving the chosen remedy's environmental performance during its implementation rather than influencing which remedy is selected in the first place (ITRC, 2011a). Over time, green remediation practices have primarily concentrated on environmental metrics such as energy efficiency, carbon footprint reduction, and waste minimization while generally excluding considerations of social and economic impacts (Suthersan et al., 2017).

2.1.2 Sustainable Remediation

Sustainable remediation encompasses the principles of green remediation and extends the practice to include detailed analyses of remedies as part of the design and selection of various alternatives. This approach integrates not only traditional environmental considerations but also an evaluation of economic and societal costs and benefits (EPA, 2024). Unlike green remediation, which focuses primarily on the environmental impacts of how to remediate a site, sustainable remediation broadens the scope to address broader questions, such as whether remediation should occur and the extent to which it is needed (Sustainable Remediation Forum (SURF), 2011).

Analyses conducted under sustainable remediation are typically performed during the remedy selection phase and continue to be applied throughout the project lifecycle. This iterative process ensures that decisions remain aligned with environmental, social, and economic objectives as conditions evolve (National Research Council (NRC), 2013). By incorporating these comprehensive evaluations, sustainable remediation enhances decision-making, balancing protecting human health and the environment with broader sustainability goals.

2.2 Consideration of Green and Sustainable Remediation (GSR)

The U.S. EPA has established a comprehensive framework aimed at integrating sustainability principles into the remediation process. This framework recommends evaluating a set of five core elements, either qualitatively or quantitatively, to enhance the protectiveness of remedial actions without compromising their effectiveness or safety. It is designed to support active remediation processes and not serve as a deterrent to thorough clean-up efforts. Instead, it provides a structured approach to ensure that remedies remain robust while aligning with sustainability objectives (U.S. EPA, 2010). The overarching goal of this approach is to provide a remedy that reduces GHGs, energy and water use and promotes the use of renewable energy and resources, recycling and waste minimization, and land revitalization. The U.S. EPA core elements are depicted in **Figure 5**.

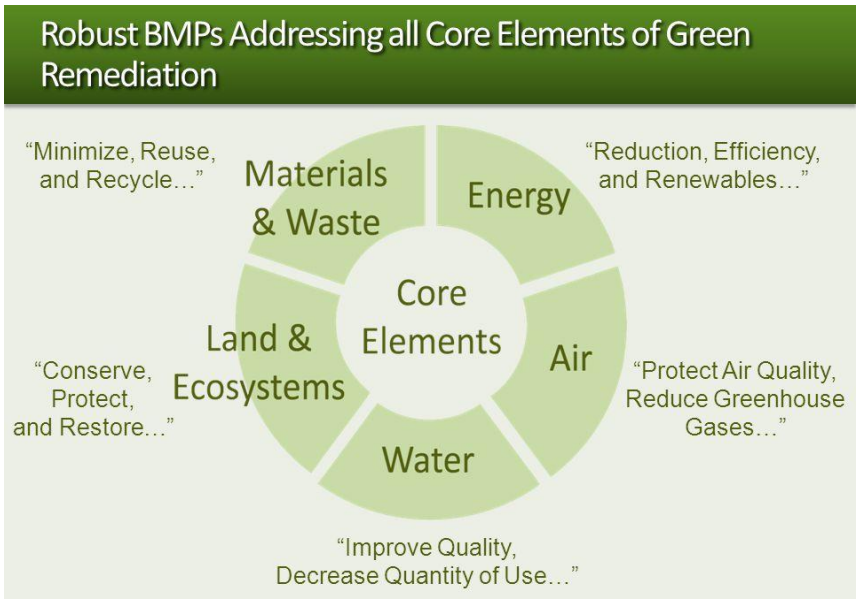


Figure 5: Core elements of green remediation (Source: USEPA, 2011).

2.2.1 AIR: Greenhouse Gas Consideration

Increasing concerns regarding climate change have prompted major efforts across the globe to reduce GHG emissions caused by activities such as fossil fuel consumption. The six GHGs covered by the U. N.'s 1997 Kyoto Protocol[2] include carbon dioxide (CO_2),

[2] What is the Kyoto Protocol? | UNFCCC

methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). The U.S. EPA's current strategic plan calls for significant reductions in GHG emissions, as well as increases in energy efficiency as required by federal mandates such as Executive Order 13423: Strengthening Federal Environmental, Energy, and Transportation Management (Executive Order 13693, 2015).

2.2.2 ENERGY: Energy Consumption

Energy consumption is a critical consideration in GSR because the energy used during remediation activities directly impacts the environmental footprint of the project (Contaminated Site Clean-up Information (CLU-IN), 2019). High energy use, particularly from non-renewable sources, contributes to GHG emissions, resource depletion, and increased costs (SURF, 2011; ITRC, 2011a). GSR aims to minimize energy consumption while maintaining the protectiveness and effectiveness of remediation efforts, aligning cleanup activities with broader sustainability goals (ASTM International, 2013).

2.2.3 WATER: Water Use and Reuse

Water is an increasingly important resource. Water use and reuse in the context of GSR focuses on optimizing water management to align with sustainable practices during remediation efforts. It ensures efficient utilization of water resources while minimizing waste, pollution, and the ecological impact of remediation projects. This is a crucial element in advancing DC's sustainability goals, which prioritize resource efficiency, resilience, and environmental stewardship. In DC where water was thought to be abundant, development and growth have taxed this resource to the point where resource protection and conservation has become a major concern. This emphasizes the importance of efficient water use and the implementation of sustainable practices across various sectors to achieve the city's long-term sustainability targets.

2.2.4 LAND & ECOSYSTEMS: Land Use

Land is also considered a limited resource and critical to both ecological balance and socio-economic development. Recognizing its limited availability underscores the importance of sustainable management practices, particularly in the context of remediation and redevelopment. Evaluating the intended end use or potential reuse of contaminated or underutilized sites is pivotal in conserving existing green spaces and mitigating urban sprawl. By prioritizing sustainable land management, such practices not only preserve natural ecosystems but also foster the rejuvenation of communities through the transformation of brownfields into functional and productive spaces. The end use or potential reuse of the impacted site will aid in the conservation of existing green space and assist in the revitalization of communities through brownfields redevelopment.

2.2.5 Waste and Material Use and Recycling

In recent years, an increased emphasis has been placed on waste material use and recycling due to concerns about limited landfill space, the introduction of pollution into the environment, and the need to conserve natural resources. Modifying remedies to

reduce waste and increase recycling opportunities has a significant impact in decreasing the environmental footprint of the remedy. This approach aligns with the principles of sustainability by conserving resources, reducing greenhouse gas emissions, and mitigating the impacts of waste disposal.

There are several good reasons why project managers and responsible parties (RPs) should consider incorporating GSR into their remedial programs:

- Although not currently required by code, DOEE Case managers and RPs can incorporate sustainable aspects into remedy selection and implementation, which will result in more sustainable and cost-effective remedies. However, environmental protection is the ultimate goal during remedy selection. At no time should incorporating sustainable aspects into selected remedies compromise environmental protection.

- There is a growing awareness of sustainability within U.S. EPA and the regulated community. U.S. EPA issued the Superfund Green Remediation Strategy (USEPA, 2016a) that outlines a number of initiatives in this area. Organizations such as, the Department of Defense have already developed sustainable remediation policies and programs.

- Implementing GSR should result in fewer resource - and energy-intensive remedies, which generally translates into lower environmental impacts and lower costs.

3.0 INTEGRATING GSR INTO ALL PHASES OF THE PROJECT CYCLE

The planning stage, prior to selecting and implementing a remedy, presents the most significant opportunity to minimize the environmental footprint of remediation efforts. Although the most significant opportunity to influence sustainability metrics is at the remedy selection stage, there are opportunities to make a project more sustainable in all phases of the project life cycle. Sustainable concepts can be integrated during the planning phase, allowing for the identification and exclusion of less sustainable technologies. There may be occasions where the most sustainable remedy is not implemented at a site due to the increased time required to clean up the site, a potential increased public health risk, litigation-driven remediation, or a perceived or proven lack of effectiveness of the sustainable remedy. In these cases, once a final remedy is selected, project managers should look for ways to implement the selected remedy in the most sustainable or greenest manner possible.

3.1 Regulatory Status

Site remediation in DC is currently covered under the Underground Storage Tank Management Act of 1990 (D.C. Code § 8-113.01 et seq.) (the "Act") and the District of Columbia UST Regulations, as set forth at Title 20 of the DCMR, Chapters 55-70 (20 DCMR §§ 5500-7099) (DCMR, 2020). Specifically, DC Risk Based Corrective Action (DCRBCA), dated June 2011, describes in detail the various steps of comprehensive site assessment (CSA) and corrective action plan (CAP) for a LUST site remediation and closure. Currently, sustainability concepts may be incorporated into remediation projects voluntarily, as there is no codified requirement to incorporate or document sustainability considerations in either the remedy selection or implementation sections of the regulations. Future code revisions may require an evaluation of GSR considerations during remedy selection, implementation and throughout the project's life cycle.

3.2 Sustainability Metrics

Sustainable remediation incorporates the pillars of Environmental, Economic, and Social/Community influences. As such, this guidance document categorizes metrics so that they correlate to each of the pillars. The following are metrics that can be used to measure the sustainability of a remediation project organized under each of these pillars. All metrics are not applicable to all sites, and some metrics may be unique to specific sites that aren't presented below. No standard set of metrics currently exists for evaluating the relative sustainability of remedial alternatives.

3.2.1 Environmental Metrics

Environmental metrics are the nuts and bolts of remediation and, in many ways, the simplest to measure. They can be segregated into basic categories that cover energy, GHG emissions, water, waste, and contaminant mass removal.

Energy metrics cover the energy needed to conduct the remediation and include electricity, natural gas, propane and other solid or liquid fuels that are used or consumed

during the remediation process. These metrics also include any renewable forms of energy that are incorporated into or are generated by the remediation process. Metrics used to measure energy include kilowatt hours for electricity, pounds or cubic meters for propane and natural gas, and gallons for liquid fuels.

GHG emissions are presented in pounds, kilograms, or tons of carbon dioxide equivalents (CO_2e) and is a sum of all the GHGs emitted by the implementation and execution of the remedy. The environmental metric which measures water includes water consumed by the remedy, water produced or extracted by the remedy, and potential stormwater runoff. The output of this metric is presented in gallons. Waste generation and recycling is typically measured in tons. This metric is used to measure the total waste generated by remedy implementation at a site and the amount of material that can potentially be salvaged or recycled. Land use and ecosystem can be measured in total area disturbed or enhanced by the remedy.

Contaminant mass removal rates are measured in units such as pounds, kilograms, or tons on a daily, monthly, or yearly basis. This metric measures the mass of contaminants that have been removed from a site or that has been remediated through a treatment process and the rate at which this occurs.

3.2.2 Economic Metrics

Cost is an integral part of remediation efforts and is a primary consideration following the priority of protecting human health and the environment. Economic metrics present the developed environmental metrics in terms of costs. Economic metrics consider the life cycle costs of the remediation, including capital costs and ongoing operation and maintenance costs. These costs can be expressed in terms such as dollars per unit of contaminant removed, costs for energy in dollars per kilowatt hour or dollars per British thermal unit (BTU), and costs for implementing green building/LEED applications.

3.2.3 Social and Community Metrics

Social and community metrics are used to measure the impact of the remedy on the community. These metrics can focus on quantitative criteria such as safety (which can be measured in total reportable incidents), traffic (which can be measured in vehicles per day), and fugitive dust, vapor, and noise (which can be measured in their relevant units). Social and community metrics may also include more qualitative metrics such as land reuse, engagement, jobs, building community assets (e.g. parks, greenspace, etc.), and transparency around community involvement in the remedial process. These metrics emphasize the importance of stakeholder engagement, public health, and equitable outcomes, ensuring that remediation activities not only address environmental concerns but also foster social well-being and community trust. **Figure 6** shows some of the new metrics to consider when evaluating sustainability for a site.

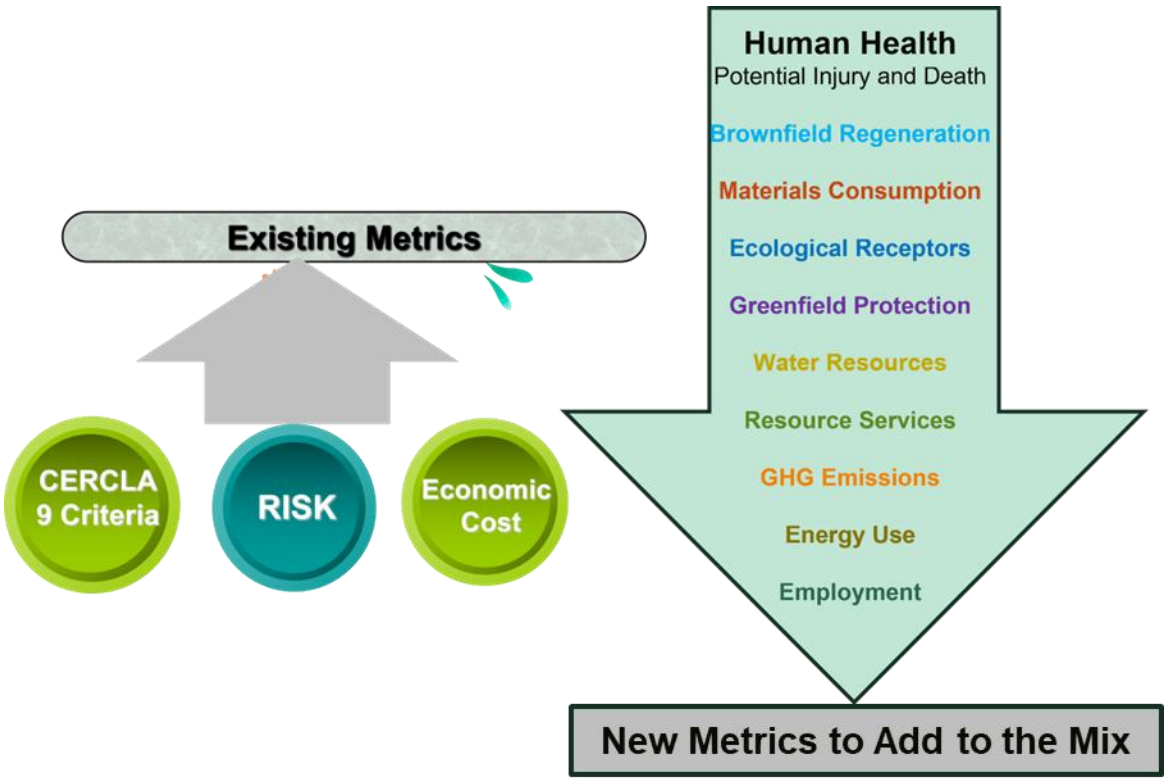


Figure 6: New Metrics to Consider during Sustainability Evaluations

3.3 Quantitative Vs. Qualitative Metrics

As noted above, sustainability metrics can either be measured quantitatively, where there is an actual measurement taken, or qualitatively, where assumptions are made based on observation.

Quantitative metrics are very focused and narrow in scope. The metrics are based on hard data and on what is empirically known about the remedy. They may include data related to the consumption and costs of energy and water, contaminant mass removal, how much waste is generated, etc. These metrics generally involve intricate engineering of the remedy.

Qualitative metrics may be simpler to understand since they deal with the broader issues of sustainability and they can be better communicated to a non-technical audience. Qualitative metrics may be better suited to evaluate community and social benefits where hard data is difficult to discern. Qualitative metrics can also be used at small or simple sites where a detailed sustainability analysis to develop quantitative metrics is not warranted.

Integration of Quantitative and Qualitative Metrics ensures a more comprehensive evaluation of remediation efforts. This integration provides both the precision of quantitative data and the contextual richness of qualitative insights. Integrating both

qualitative and Quantitative metrics can achieve balanced, transparent, and effective sustainability outcomes.

3.4 Implementation Process of GSR

The goal of the GSR process is to incorporate sustainability into all phases of the project life cycle: from site investigation through remediation and closure (**Figure 7**). Sustainability should be considered wherever possible, as long as environmental protection is not compromised.

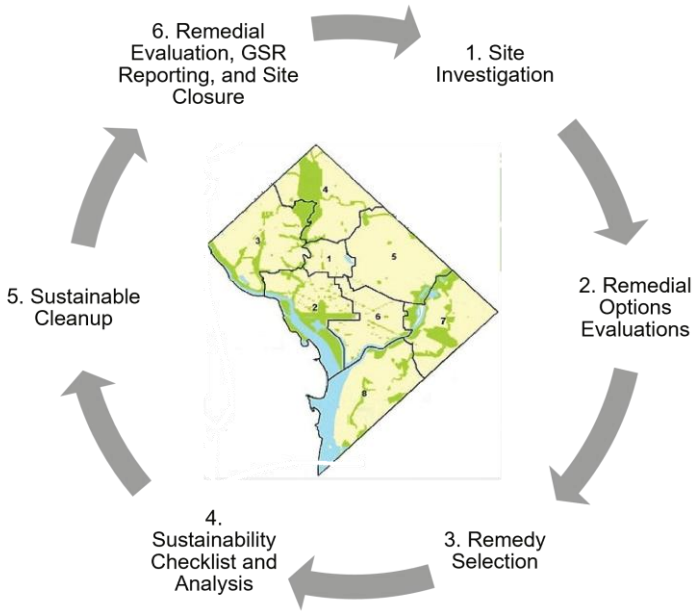


Figure 7: The GSR Process

The opportunity to implement a sustainable remedial option should not be considered an occasion to implement a "do nothing approach" to remediation. When sustainability is applied correctly to remedial actions, it can have the benefit of reducing the overall environmental footprint of the remedy, as well as provide potential cost savings.

When project managers go through the process of selecting and implementing remedial options, their thought process should first focus on the core elements of sustainability, how these elements can be measured or quantified, and what green management practices or considerations can be incorporated into the remediation to make it more sustainable. **Figure 8** shows where sustainability can be implemented within DC's remedial process.

Generally speaking, the opportunities for applying sustainable remedial solutions increase along with the size and complexity of the project (**Figure 9**). As this figure also represents, opportunities for incorporating sustainability metrics also increase as the life cycle progresses, peaking at the remedy selection stage.

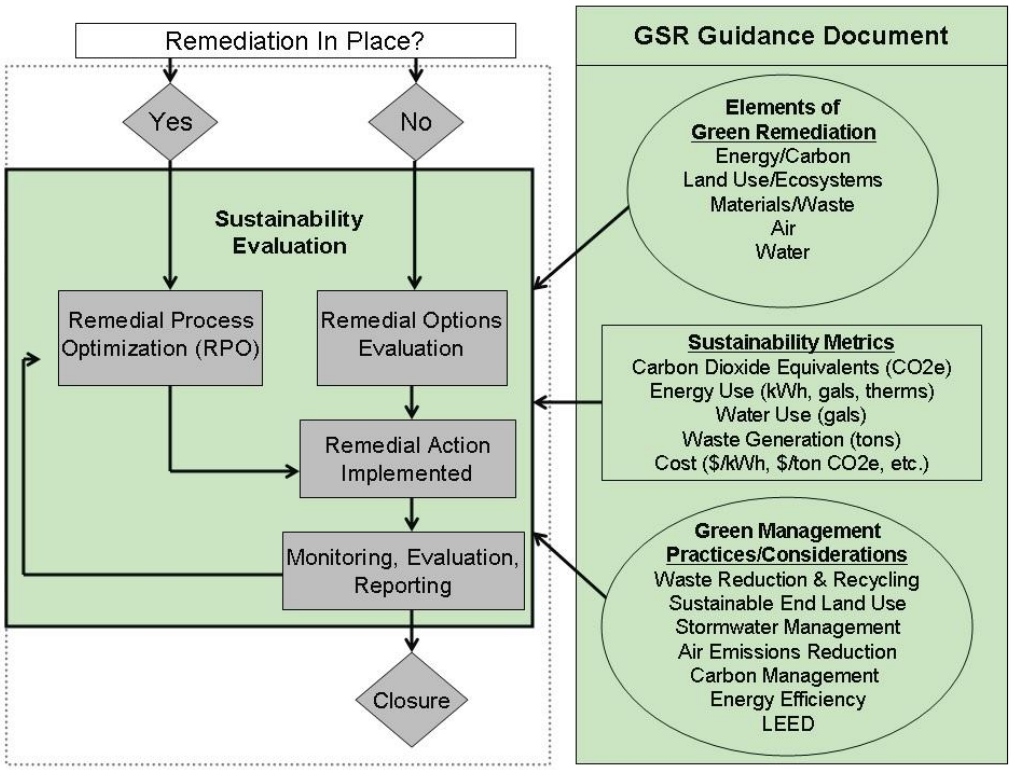


Figure 8: Consideration of Green and Sustainable Remediation (SURF, 2011)

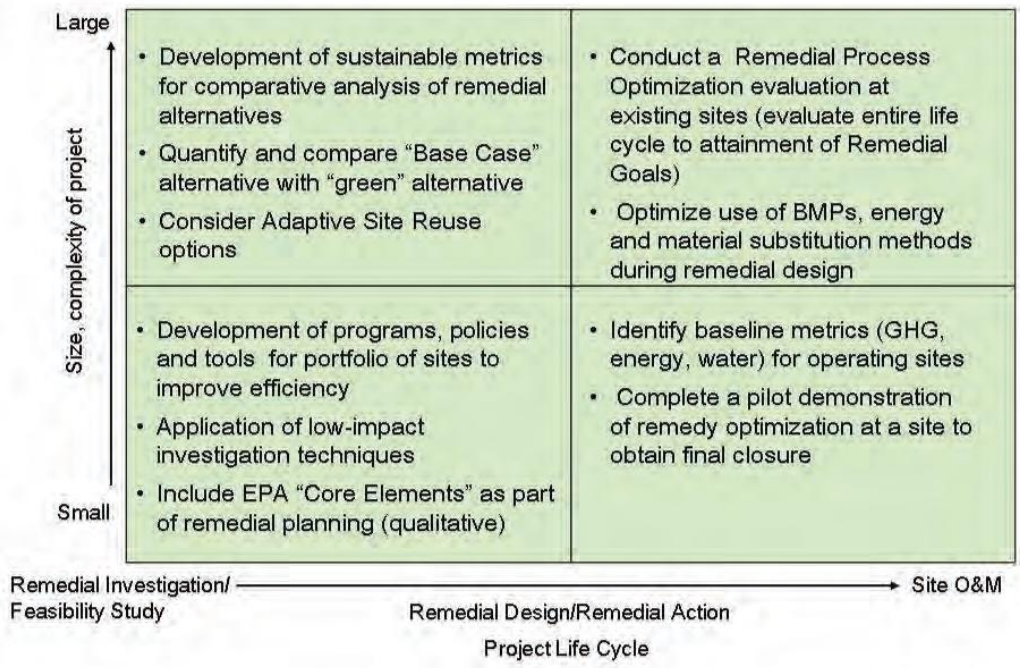


Figure 9: Opportunities for Incorporating Green and Sustainable Remediation Examples of activities that can be integrated at different points in the project life cycle are shown in *Table 1* (SURF, 2011).

Table 1
Examples for Integrating GSR into Site Investigation and Remediation Projects

	Environmental	Social	Economic
Site Investigation	✓ Collect data to understand risks associated with on-site treatment and containment of contaminated media ✓ Use direct push tools to reduce investigative derived waste (IDW) and energy consumption ✓ Use passive diffusion or grab-type samplers for groundwater samples to reduce IDW and energy consumption	✓ Conduct community outreach to communicate site conditions and risks and to engage in planning of site cleanup and reuse options ✓ Create key contacts list to facilitate communications	✓ Use field screening technologies to reduce IDW and off-site sample shipping
Feasibility Study/Response Action Plan	✓ Evaluate on-site and in-situ treatment and containment technologies ✓ Conduct energy use and emissions calculations to compare alternatives ✓ Identify opportunities to create habitat as part of site remediation ✓ Consider green technologies and green products	✓ Communicate site remediation options and risk reduction achieved ✓ Obtain input on site cleanup alternatives and community concerns/needs	✓ Determine short-term and long-term cost of site remediation alternatives contrasting with environmental and social costs/benefits
Remedial Design	✓ Identify low-energy, low-emission and low water intensive equipment ✓ Minimize water consumption and maximize water reuse ✓ Minimize impacts to local natural resources and habitats ✓ Maximize use of renewable energy and fuels ✓ Minimize off-site transport of contaminated materials ✓ Identify recycling options or use of green materials ✓ Utilize on-site treatment and containment approaches ✓ Integrate remote monitoring features into design	✓ Engage community leaders in design meetings to obtain input on configurations and timing of site work ✓ Communicate site remediation plan including short-term community impacts and long-term risk reduction ✓ Consider use of local materials and labor ✓ Evaluate community impacts and safety issues from site remediation actions	✓ Use on-site approaches to management of contamination to reduce costs of site cleanup and potential long-term liabilities associated with off-site disposal ✓ Use adaptive site-reuse approach incorporating existing structures into site reuse options ✓ Evaluate opportunities for capturing value of eco-assets such as wetlands credits or carbon sequestration
Remedial Action Implementation/ Construction Management	✓ Minimize equipment engine idling ✓ Control and mitigate dust, odors, noise and light impacts ✓ Conduct monitoring of air and, if needed, odors, noise and light ✓ Set-up comprehensive on-site recycling program for all wastes and residuals	✓ Conduct community meetings to inform of project progress ✓ Post information on monitoring programs and project progress/plans	✓ Determine cost impact to project from use of GSR approaches
Operations, Monitoring and Maintenance (OM&M)	✓ Utilize remote monitoring system to monitor effectiveness of treatment systems and reduce field travel ✓ Recycle sampling residuals ✓ Use recycled materials for sampling and monitoring to reduce IDW and fabrication of new material ✓ Design adaptive monitoring programs to reduce sampling frequency over time	✓ Communicate site remediation status using website and other public communication approaches	✓ Utilize low-energy intensive approaches to reduce energy costs ✓ Use on-site sample testing/screening approaches to reduce transportation of samples ✓ File electronic reports to reduce paper consumption

4.0 GSR PROCESS, EVALUATION AND IMPLEMENTATION

The creation of a baseline or base case scenario allows for the comparison of a "standard" cleanup with "green or sustainable" cleanup options. The development of a baseline also helps identify opportunities for implementing sustainable remediation. The baseline evaluation quantifies a remedy's sustainability footprint in terms of the core elements, allowing the project manager or RP to identify the core elements most adversely impacted by the remedy. Once the major impacts are known, sustainable strategies or techniques can be deployed to address these impacts, allowing for the greatest potential improvement in the sustainability of the remedy.

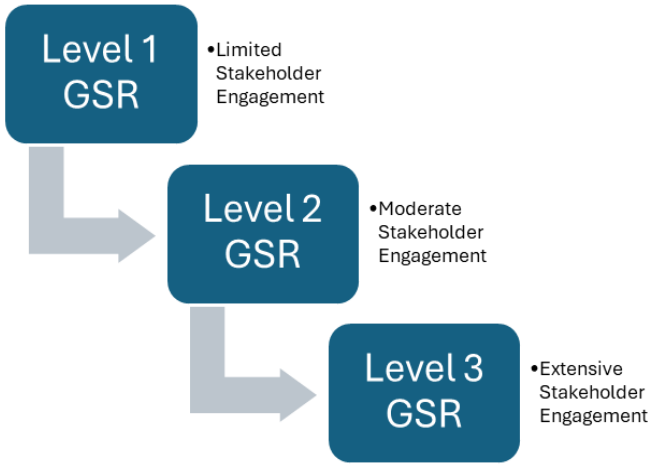
4.1 Stakeholder Engagement

Stakeholders collaborate with regulators, local communities, and other stakeholders to identify key concerns and opportunities. Site stakeholders are typically identified prior to selecting a remedy and may include federal and state regulators, local units of government (LUGs), responsible parties, the site owner or occupant, Native American tribes, local residents, and others such as neighborhood associations or economic development organizations. Additional examples of stakeholders are provided in the "Framework for Integrating Sustainability into Remediation Projects" by the SURF organization (SURF, 2011).

Stakeholders for the GSR evaluation are usually a subset of this group, as not all stakeholders will be interested in the GSR evaluation or results. Stakeholders may be engaged at appropriate points throughout the GSR evaluation process. Prior to contact, their role in the GSR evaluation should be defined and documented in the planning step, including the extent of their potential impact on the project decisions. The mitigation of risks to receptors may not be undermined by the additional consideration of social or stakeholder concerns.

In communicating GSR to stakeholders, it is important to begin with the objectives of the site investigation and risk evaluation towards the overall protection of human health and the environment. It is important to present a balanced message of the corrective action goals and site-specific considerations that collectively form the decision criteria for the selection of a remedy when corrective action is required. In most cases, more than one alternative will meet the corrective action goals. GSR is not a means of justifying a no-action remedy ("greenwashing") or justifying less remediation. The objective of GSR is to reduce remediation projects' environmental, social, and economic impacts.

Specific to the potentially responsible party (PRP), stakeholder engagement should go beyond the Petroleum Release Notification requirements, Potential Receptor Surveys and Risk Evaluation Procedures at Petroleum Release Sites. Level I GSR should include stakeholder outreach beyond that completed in standard investigation or corrective action procedures to the degree possible without being cost or time-prohibitive. At this level, examples of additional outreach efforts could include public signage at the site or electronic correspondence sharing. Other ideas such as newsletter, public meeting, flyers, etc. should be discussed with PRP staff before completion.



If conducting a Level II GSR evaluation, the user should plan to conduct additional outreach to the surrounding community members, organizations, and city planning office to provide information on the intended investigation and/or corrective actions planned for the site and engage these stakeholders to participate in an exchange of information/ideas. Particularly, the user should gather information and opinions on beneficial historical uses of the site from the community/neighborhood perspective or city plan information that may assist in directing the end use of the site in concert with said plans or other city initiatives.

If conducting a Level III GSR evaluation, the user should consider these and other avenues of community/stakeholder engagement, including concepts outlined by the US EPA Office of Community Engagement, found at https://www.epa.gov/ports-initiative/environmental-justice-primer-ports-effective-community-engagement-methods (USEPA, 2024).

4.2 Level Selection

The tools and resources used to complete a GSR evaluation range from simple BMPs and qualitative approaches to complex life cycle assessments (LCA). The user can start by selecting the appropriate level of detail/effort for the GSR evaluation from the following sections. Tools and approaches specific to each level are presented in Section 4.3 of this document.

4.2.1 Level I - BMPs

The objective of this approach is to adopt practices based on common sense, promoting resource conservation and process efficiency, without attempting to quantify their net impact on the environment, community, or economics.

4.2.2 Level II – BMPs and Simple Evaluation

The objective of this approach is to combine BMPs with a simple evaluation of the three GSR aspects of economic, social, and environmental components. A quantitative evaluation at this level will mean selecting a simple tool to evaluate remedial options.

4.2.3 Level III – BMPs and Advanced Evaluation

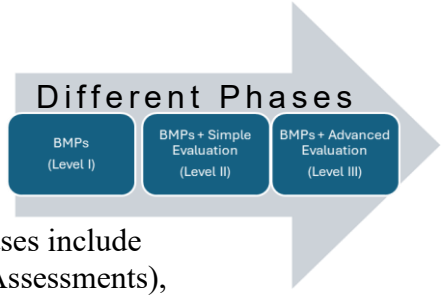
This approach includes BMPs and an in-depth quantitative evaluation, which is intended to be utilized on projects where corrective actions are anticipated to last longer than five

years. Most Level III evaluations determine the best approach using an LCA-type evaluation of different alternatives, combined with weighting criteria. Applying LCA to a remedial activity would track the effects of production, transportation, use, and disposal of different materials and products associated with the activity. LCA accounts for energy and resource inputs as well as polluting outputs to land, water, and air.

4.3 Perform GSR Evaluation

This section provides users with a framework identifying how to evaluate, select, and implement GSR practices in each phase of a PRP project.

- PRP project phases may include Limited Site Investigation or Remedial Investigation (LSI or RI),
- Conceptual Corrective Action Design (CCAD),
- Simple Corrective Action or Complex Corrective Action (Focused Investigation, Pilot Test, etc.), and Implementation/Operation and Monitoring.
- Petroleum Brownfield Program (PBP) project phases include investigation (Phase I and II Environmental Site Assessments),
- Response Action Plan (RAP)/Construction Contingency Plan (CCP), and
- RAP/CCP Implementation.



During planning, the user should have identified the appropriate GSR level they wish to employ.

4.3.1 Level I - BMPs

EPA has identified numerous BMPs, which are introduced and described at https://www.enviro.wiki/images/5/52/USEPA-2016-Best_Management_Practice_Fact_Sheets.pdf (EPA, 2016b). Additional BMPs for site specific or contaminants specific are listed below:

- ITRC Green and Sustainable Remediation Technical and Regulatory Guidance Document BMP tables per phase (ITRC, 2011b).
- OSWER's "Green Remediation BMPs: Sites with LUST Systems" (USEPA, 2019).

4.3.2 Levels II and III – Qualitative and Quantitative Tools

If either a qualitative or quantitative (simple or advanced) approach is selected, identifying metrics for each evaluation is necessary. Qualitative and quantitative assessment tools have been developed to calculate environmental metrics to help consider all factors in designing and implementing remediation systems. These tools can range from simple decision trees and Excel spreadsheets to comprehensive life cycle assessments. The ITRC GSR Overview Document (2011) provides a number of tools

available for consideration in a GSR evaluation (see **Appendix B**: "Tools Designed for Site Remediation" of the Overview Document). Examples of publicly available, free, quantitative environmental aspect tools include:

- SiteWise™ (SURF, 2011) developed by Battelle, US Navy, and US Army Corps of Engineers (USACE)
- Net Environmental Benefit Analysis (NEBA), developed by the Oak Ridge National Laboratory (Ecological Risk Analysis (ERA), 2003)
- Any additional proprietary tools
- DOEE Green Remediation Screening Tool (GRST)

In the current state of the science of GSR, the DOEE USTB anticipates that the tools identified above will be most frequently utilized. If the user selects a proprietary tool to perform their GSR analysis, they should anticipate sharing the tool, assumptions, and calculations/derivatives with DOEE LUST Case Managers.

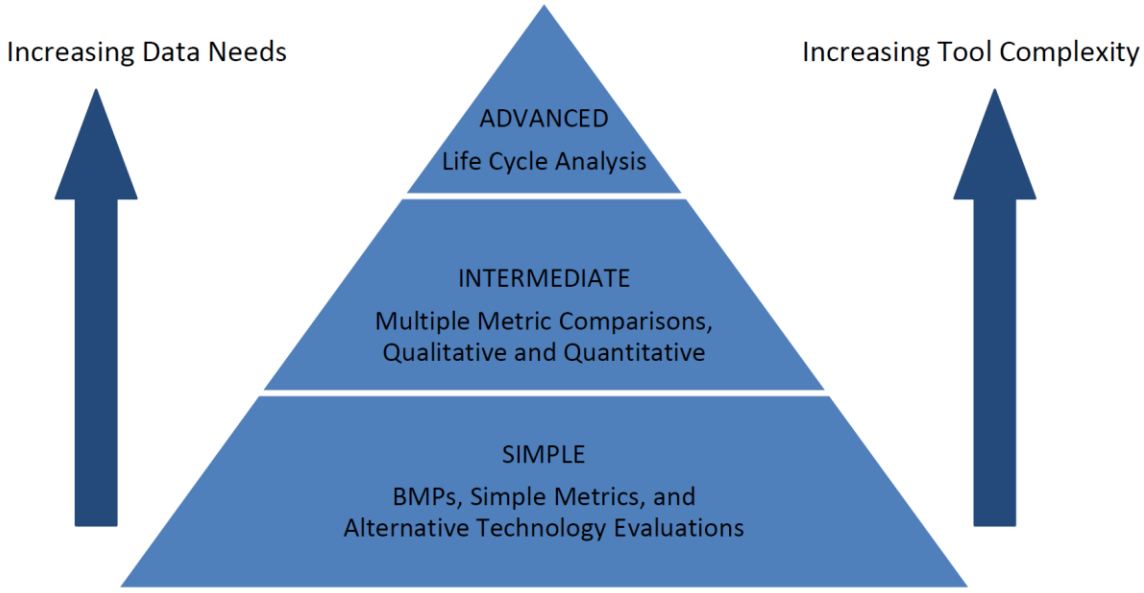


Figure 10: Level Pyramid for GSR Selection (Source: SURF, 2011)

The user should be cognizant of the complexity and data demands required of performing a Level II or III GSR evaluation. Resource demands are depicted in the graphic above, per the complexity of the evaluation tool.

4.3.2.1 Sustainable Remediation Tool (SRT)

SRT calculates certain environmental metrics, such as emissions, for specific remediation technologies and processes. The tool is comprised of a series of Microsoft Excel spreadsheets with two tiers of evaluation. Each corrective action technology may be evaluated at either tier. For each technology and in each tier of evaluation, sustainability metrics are calculated. These metrics are the following:

- Carbon Dioxide Emissions (CO2)
- Nitrogen Oxide Emissions (NOx)
- Sulfur Oxide Emissions (SOx)
- Particulate Matter (PM10)
- Total Energy Consumed
- Change in Resource Service
- Technology Cost
- Safety / Accident Risk

After calculating output metrics, several other features are available to help interpret the results. Users have the option to consider various scenarios for future costs of carbon dioxide offsets and energy. These costs consider the net present value over the project lifetime. Also available to users is a Stakeholder Roundtable, in which various parties can weigh each metric's importance. The group's weights are then compiled into a consensus set of metrics, which represents an equal compromise of metric weights for the group. These features allow users more flexibility and aid in the decision-making process.

4.3.2.2 Site Wise™ Version 3.2

Together with the USACE and Battelle, the Navy developed a tool called SiteWise™ which can assist in calculating certain GSR metrics such as GHG footprint, energy consumption, water impacts, criteria air pollutants, and worker safety for different remedial alternatives. Tools such as SiteWise™ or the Sustainable Remediation Tool (SRT™), developed by the Air Force, help determine more sustainable options among different feasible remedial alternatives that are protective of human health and the environment.

SiteWise™ is a stand-alone tool developed jointly by the Navy, USACE, and Battelle that assesses the footprint of a remedial alternative/technology in terms of a consistent set of metrics, including (1) GHG emissions; (2) energy use; (3) air emissions of criteria pollutants such as NOx, SOx, and PM, (4) water impacts; and (5) worker safety. SiteWise™ first divides every remedy into four phases: 1) remedial investigation; 2) remedial action construction; 3) remedial action operations; and 4) long-term monitoring. Each of these phases includes activities undertaken, such as transportation, material production, equipment use, and residual management that impact the environment. The tool has been updated to include incremental costs due to footprint reduction activities. SiteWise™ has also been updated to include life cycle impacts for all global impacts of all remedial activities included in the tool. SiteWise™ Version 3.2 is available on the SURF website (SURF, 2011).

4.3.2.3 National Laboratory Environmental Sciences Division NEBA

According to the Oak Ridge National Laboratory, Environmental Sciences Division, a NEBA is a methodology for comparing and ranking the net environmental benefit associated with multiple management alternatives. NEBAs can be conducted for various stressors and management options, including chemical contaminant mitigation, hydropower mitigation, global climate change mitigation (e.g., carbon sequestration), etc.

NEBA for chemically contaminated sites typically involves the comparison of the following management alternatives: (1) leaving contamination in place; (2) physically, chemically, or biologically remediating the site through traditional means; (3) improving ecological value through on-site and off-site restoration alternatives that do not directly focus on removal of chemical contamination, or (4) a combination of those alternatives.

NEBA involves goals common to both Natural Resource Damage Assessment (NRDA) and remedial alternatives analysis for the Comprehensive Environmental Response and Liability Act (CERCLA) and related state regulations, e.g., valuing ecological entities, assessing adverse impacts, and evaluating restoration options. Oak Ridge National Laboratory is developing a framework for NEBA, with special application to petroleum spills in terrestrial, wetland, and aquatic environments. This framework is funded by the National Petroleum Technology Office of the U. S. Department of Energy. Primary information gaps related to NEBA include non-monetary valuation methods, exposure-response models for all stressors, the temporal dynamics of ecological recovery, and optimal strategies for ecological restoration.

4.3.2.4 Additional Tools

Several additional tools can also be used to quantify GSR at any site. A few of them are presented below.

CleanSWEEP: CleanSWEEP, software specific to the evaluation of using renewable wind or solar energy on remediation sites, is currently being beta-tested by Air Force Center for Engineering and the Environment (AFCEE) and their partners and is expected to be released publicly in the coming months. CleanSWEEP assesses the potential to switch from non-renewable energy to renewable energy to power remediation systems. It also evaluates the potential of using renewable energy based on a site's location away from the power grid. EPA provides facts and lessons-learned from modifying remedial systems with renewable energy alternative technologies through the following BMP fact sheet: https://www.clu-in.org/greenremediation/docs/Integrating_RE_into_site_cleanup_factsheet.pdf.

Remedial Action Cost Engineering and Requirements (RACER): AFCEE has also developed and utilizes the RACER software (Federal Remediation Technologies Roundtable, 2021), which estimates costs for all phases of environmental remediation projects, from site investigation through site closeout. The system enables users to develop and update cost estimates, evaluate and compare the cost of various treatment options, attempt to quantify environmental liability for budgeting or regulatory/financial disclosures, and develop a consistent approach for project budgeting.

Life Cycle Assessment (LCA): LCA tools include:

- Guidance for Performing Footprint Analyses and Life-Cycle Assessments for the Remediation Industry (SURF, Remediation Journal Summer 2011)
- SimaPro LCA software at https://simapro.com/ (requires license)

Note that there are intensive resources for the above-mentioned tools, which are time-sensitive and continuously upgraded. The SURF reference mentioned above is tailored to the needs of the environmental remediation industry. However, it may provide crucial data to consider in determining the total environmental, social, and economic impacts of a long-term remediation project (any system designed and operated for more than five years).

4.3.2.5 DOEE Green Remediation Screening Tool (GRST)

DOEE USTB developed a simple green remediation screening tool with a scoring system (**Appendix C**). There are more than 25 questionnaires under different categories, such as energy classification, recycling, ecological impact, and so on. Stakeholders go through each question and answer as yes/no and score accordingly. Once the scoring is completed, a site-specific grading can be calculated considering the total number of questions that are applicable to that site. The following grading system will be considered:

A: > 80%	C: 40~60%
B: 60~80%	D: <40%

4.4 GSR Results Reporting

Regardless of the tool being used, any GSR evaluation (Level 2 or 3) requires some method of comparing the multiple impacts of each alternative. For example, excavation may restore a parcel of land for community redevelopment faster than in situ bioremediation but generate more waste and cost more.

Reporting requirements have been tailored to each PRP guidance document and phase of remediation. The results of the GSR evaluation should be documented or reported in each applicable PRP standard report form. If conducting a Level II or III evaluation, the user may opt to submit a separate GSR document after discussing the details of the evaluation with the assigned PRP project team. The level of documentation will vary depending on the approach used to conduct the GSR evaluation.

Descriptions of the GSR practices should be concise but, above all, only pertaining to the site-relative activities. This information should document all assumptions, sources of information, and methods used to evaluate the effectiveness of GSR practices. Enough information should be provided to determine if the results are verifiable and to document the limits of the evaluation. The GSR evaluation should consider the environmental, social, and economic factors, including energy consumption, resource consumption, greenhouse gas emissions, critical pollutant air emissions, ecological impacts, impacts of pollutants on water, water use, worker safety, and community impacts.

4.5 Best Practices for GSR Evaluation

There are several best practices to keep in mind during any GSR evaluation, including the following:

- *Use the simplest level of GSR evaluation that is needed to meet GSR goals.* Advanced tools (Level 3) require additional data, time, and cost compared with simple tools (Level 2) or BMPs only (Level 1). Choose the level of analysis needed to meet site goals. For example, if a remedial technology has already been selected and implemented at a small UST site and the primary GSR goal is to make the remedy implementation process greener, BMPs would likely be appropriate. To improve awareness and conceptually evaluate remedial tradeoffs from a GSR perspective, a simple tool (Level 2) would be appropriate. Finally, if a detailed quantitative assessment is needed for various GSR metrics, an advanced tool (Level 3) is needed. GSR is more likely to be frequently implemented if the process is scalable and the appropriate level of detail is selected.

- *Keep the GSR process transparent.* GSR evaluations are very site specific and require several different assumptions. Value judgments are inherent in the process of selecting GSR goals and metrics, as well as the relative importance of different metrics (i.e., the weighting process). In addition, the quantification of different GSR impacts varies based on the boundaries selected and the assumptions used. Combined with the relative newness of the practice, these aspects make it very important to keep the GSR process transparent.

- *Conduct an uncertainty analysis of GSR results.* An uncertainty analysis aims to indicate how sensitive the GSR results are to changes in key assumptions. This may be as simple as evaluating how a change in relative weights used for GSR metrics could affect GSR results. For advanced Level 3 GSR evaluations, an uncertainty analysis can be conducted by changing key assumptions. Some tools (e.g., The BalancE3™ Tool) have built-in methods to take a range of input estimates and generate a range of probable outcomes (Ung et al. 2010). The uncertainty analysis might reveal that two alternatives have very similar GSR impacts, but a third alternative is consistently better or worse than the other two.

As described in this document, the GSR process is adaptive and site-specific rather than prescriptive. The level of analysis is highly scalable. GSR has been implemented at a variety of sites ranging from small sites to large, complex sites, as illustrated by case studies (**Appendix D**). Finally, the GSR process outlined in this document provides an opportunity to integrate diverse stakeholder values and ideals into the overall remedy. Following the GSR process will improve stakeholder support for GSR, encourage GSR evaluations, and facilitate the implementation of greener and more sustainable practices during site remediation.

5.0 GSR APPLICATION PHASES

GSR should be considered throughout all project phases including site characterization, remedy selection, remedial design and construction, and remedial operation and long-term monitoring. Each phase incorporates sustainability considerations to ensure environmental, economic, and social benefits throughout the project lifecycle. These phases align with standard remediation project workflows, including site assessment, remedy selection, design, implementation, and long-term management.

5.1 GSR Considerations During Site Characterization

Site characterization is the initial phase of a remediation project where the nature and extent of contamination are assessed. GSR should be considered throughout all project phases, including site characterization. Activities typically performed during site characterization that result in a significant footprint include well installation, soil borings and transportation of personnel, investigative derived waste (IDW) and samples. The primary impacts associated with these activities include increased GHG and criteria pollutant emissions, consumption of energy, and accident risk.

There are several proven methods to optimize site characterization. The application of site characterization BMPs promotes improved efficiency and quality and minimizes environmental impacts and overall site cleanup costs. An EPA fact sheet provides BMP guidance on how to include green remediation practices in site investigation activities (EPA, 2019).

Typical methods to reduce the footprint during site characterization include:

- **Efficient Data Collection:** Use systematic planning during the development of the Uniform Federal Policy Quality Assurance Project Plan (QAPP) (USEPA, 2005) to ensure only the data necessary to meet the project quality objectives (PQOs) are collected;
- **Streamline Characterization Process:** Use the Triad approach to improve the efficiency of the site characterization process;
- **Use Efficient Sampling Techniques:** Implement efficient sampling techniques such as passive sampling and proper equipment management; and
- **Minimize and Manage IDW:** Use the above-described methods to minimize the generation of IDW. For any IDW generated, ensure its disposal is managed efficiently.

Incentives will be provided to contractors to encourage green and sustainable approaches during site characterization. A cost analysis should be performed for each potentially applicable footprint reduction method to estimate the footprint reduction that would be achieved and the cost or cost savings associated with implementing it.

Appendix E (SURF, 2011) describes in detail how to consider GSR during site characterization phase.

An overall footprint reduction method checklist during the site characterization is presented below (SURF, 2011):

- ❑ Systematic planning - identify the PQOs and data required to meet the project objectives
- ❑ Triad approach for site characterization
- ❑ Use efficient sampling techniques, where applicable, such as geoprobe and passive groundwater sampling.
- ❑ Minimize generation of IDW through use of efficient sampling techniques.
- ❑ Energy efficient lighting and heating, ventilating, and air-conditioning (HVAC) systems for all site trailers and buildings
- ❑ Energy conservation using premium efficiency motors and variable frequency drives (VFDs) for equipment
- ❑ Idle management control plan
- ❑ Alternative fuels use
- ❑ Alternative transportation such as rail and hybrid cars for personnel, equipment, and material transportation
- ❑ After treatment retrofits for diesel engine vehicles
- ❑ Considerations for contractor procurement to be local disadvantaged subcontractors
- ❑ Local material sourcing for all site activities
- ❑ Minimal ecological impact considerations to reduce destruction of site natural resources
- ❑ Site worker safety and health plans
- ❑ Proper protective equipment for all site work
- ❑ Daily log of any site accident to reach zero accident work
- ❑ Inventory of fuel, energy, water, material, and chemical
- ❑ Proper documentation and records to verify sustainability metrics later in the remedial action
- ❑ Efficient project management to bundle site activities and reduce personnel travel, where applicable
- ❑ Consider electronic submittals rather than hard copies where appropriate

5.2 GSR Considerations During Remedy Selection

Remedy selection provides the greatest opportunity to lower the overall remedy footprint. Selecting the most sustainable remedial option among the alternatives identified in a feasibility study (FS) or corrective measure study establishes a lower remedy footprint from the start. Most importantly, a selected remedial alternative must meet all of the applicable threshold criteria or performance standards, including the overall protectiveness of human health and the environment. Suppose more than one remedial alternative meets the threshold criteria. In that case, GSR evaluation of alternatives

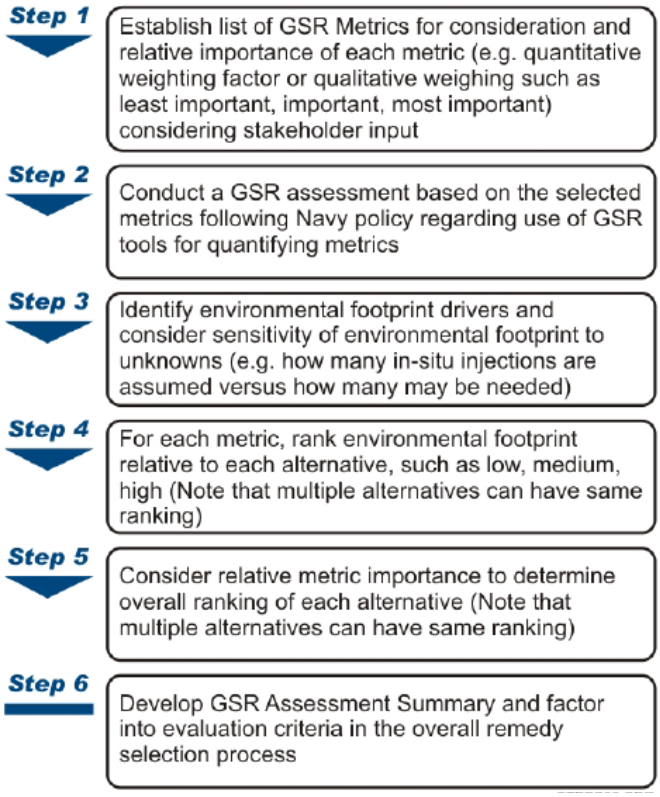
should be included in the remedial alternative evaluation process to select the most feasible and sustainable process.

Remedy selection is the most critical phase in a project for footprint minimization. While it is possible to minimize the footprint during the later stages of the project, the greatest benefit can be achieved by selecting the remedy that generates the smallest footprint at the start. In general, remedies that tend to have a small footprint are those that make appropriate use of passive systems and enhance natural processes. Examples of such technologies, as stated in the SURF memorandum (SURF 2011) include:

- Consider using less intrusive sampling methods such as direct push and passive sampling methods during long-term monitoring (LTM) where appropriate.
- Consider using remedial technologies that rely on plants to achieve remediation goals and sequester CO2, such as phytoremediation, evapotranspiration covers, and engineered wetlands.
- Consider using in situ remediation technologies such as enhanced bioremediation, biowalls, and composting.

When a technology is found not to be effective in meeting the cleanup goals and fails to achieve protectiveness, it is not suitable for that site. Highly energy-sensitive remediation systems should play an important role in site cleanup with a proper exit strategy.

Appendix F (SURF, 2011) describes in detail how to consider GSR during the remedy selection phase. A GSR Assessment steps undertaken during the remedy selection stage are presented below (SURF, 2011):



5.3 GSR Considerations during Remedy Design and Evaluation

Once a sustainable remedial alternative is chosen, there are still opportunities to reduce the remedy footprint through carefully selecting footprint reduction methods that make sense for the project. The key here is to perform the analysis required to determine which footprint reduction methods are cost-effective means of reducing the overall footprint. Activities undertaken during construction, such as transportation of material and personnel, residual handling, and material consumption all lead to adverse environmental impacts. During the design phase, the contribution of remedial activities during construction, remedial action-operation (RA-O) and LTM phases to the overall remedy footprint must be understood. This allows footprint reduction methods to target activities that contribute the most to the overall remedy footprint. During the design phase, it is also necessary to evaluate the cost and benefit of implementing each potential footprint reduction technique so they can be prioritized and selected for implementation. Some potential footprint reduction methods that could be evaluated during the remedy design phase are:

- Retrofits to existing equipment to reduce emissions,
- Material and waste minimization,
- Energy conservation and efficiency,
- Local material procurement,
- Local contractor procurement to spur local jobs and reduce transportation needs,
- Enhanced site worker safety measures and
- Increased stakeholder engagement.

A cost analysis can be performed to determine which methods will be most cost-effective in reducing the overall remedy footprint. It is important to consider the life-cycle cost impacts because many footprint reduction methods result in increased initial cost but have a reduction in operating cost, usually due to savings in the use of energy, water, emissions, resources, and materials. Depending on economic conditions, some of these methods will have a short payback period and a high return on investment (ROI). In other cases, the payback period may be longer, requiring a judgment on whether the approach will be cost-effective in the long term. Therefore, the approach to include footprint reduction methods into the remedy design phase would be:

- Perform or update the baseline sustainability assessment.
- Identify high footprint elements in a remedial action.
- Develop a list of potential footprint reduction methods.
- Perform cost and footprint sensitivity analysis.
- Prioritize footprint reduction methods for implementation.
- Include the selected footprint reduction methods in the remedial action design.

This approach is also represented as a flowchart in **Figure 11**. In cases where a formal remedy design is not completed, this approach for identifying footprint reduction methods can be completed during the procurement process:

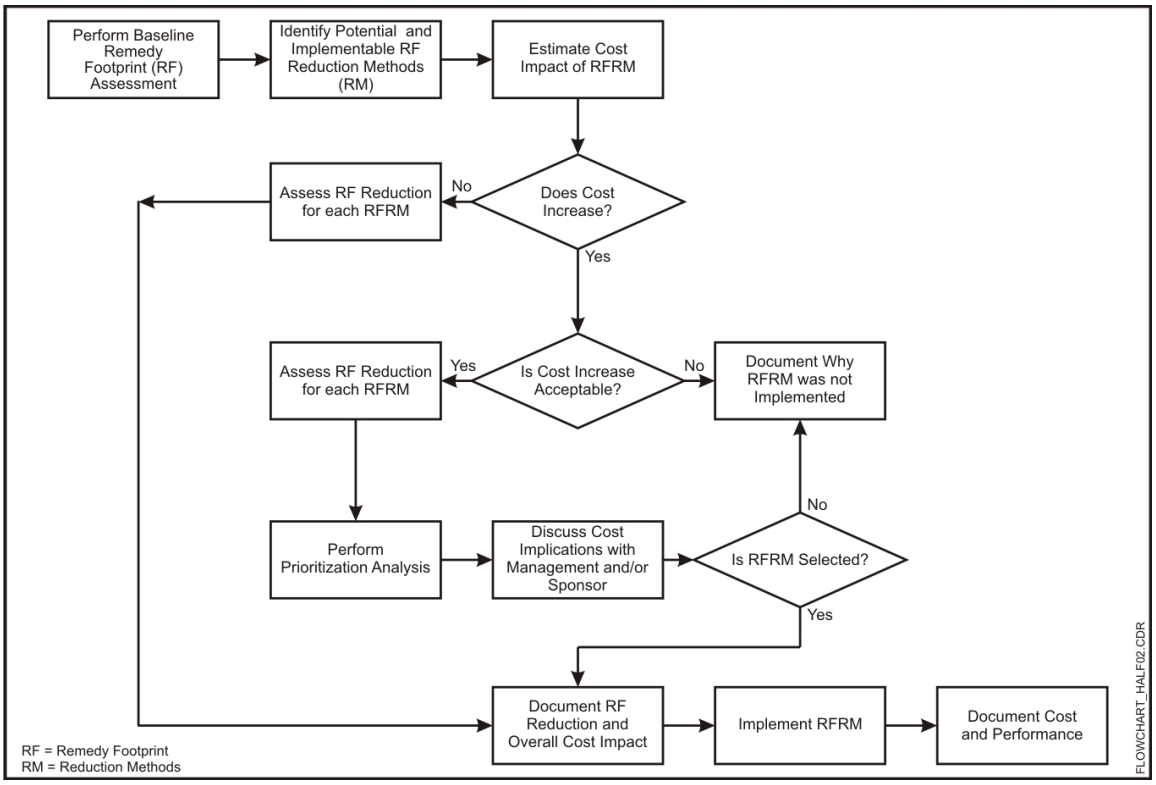


Figure 11: Flowchart Representing the General Methodology That Can be Adopted to Reduce the Remedy Footprint During the Design Phase

An overall footprint reduction methods checklist during the remedial design and construction phase is presented below (SURF, 2011) and in **Appendix G**:

- Energy star products use
- Energy efficient lighting and heating, ventilation, and air conditioning (HVAC) systems for all site trailers and buildings
- Energy conservation using premium efficiency motors and variable frequency drives (VFDs) for equipment
- LEED principles consideration for all landscaping and construction
- Idle management control plan
- Alternative fuels use
- Alternative transportation, such as rail and hybrid cars for personnel, equipment, and material transportation
- After treatment, retrofits for diesel engine vehicles
- Considerations for contractor procurement to be local disadvantaged subcontractors
- Local material sourcing for all site activities
- Minimal to zero waste generation by reduction, reuse, and recycling of all construction and demolition debris
- Sourcing waste to waste-to-energy plants
- Considering minimal invasive and least energy-intensive site activities
- Considering the use of products that have EPA Water Sense certification (http://www.epa.gov/WaterSense)

- Passive sampling technologies (where applicable)
- Consider remote data procurement or telemetry for monitoring to reduce travel
- Minimal ecological impact considerations to reduce destruction of site natural resources
- Consider low-impact drilling options such as direct push technology if feasible
- Comply with all applicable health and safety requirements, including site worker safety and health plans, proper protective equipment for all site work, daily log of any site accident to reach zero accident work
- Stakeholder communication and engagement on all issues
- Land use controls and restrictions are always in sight
- Minimize community impact of remedial activities
- Inventory of fuel, energy, water, material, and chemical
- Proper documentation and records to verify sustainability metrics later in the remedial action
- Consider site restoration using native plants

5.4 GSR Considerations during Remedial Action Operation and Long-Term Monitoring

The implementation of GSR during the RA-O and LTM phases is very similar to what is done during the design and construction phases with two important differences. The first difference is that optimization reviews must be performed periodically, and during each of these reviews, GSR should be included in the analysis. Undertaking GSR practices during remedial operation and optimization will often lower energy and material use, ultimately leading to cost avoidance. The second difference is that exit strategies should be continually evaluated, and GSR should be part of that exit strategy. To achieve this objective, it is essential to track performance data as well as GSR metrics, documenting all system inputs and outputs.

The following stepwise approach should be used to implement GSR practices during RA-O and optimization (SURF, 2011):

- Perform an optimization review, including evaluating RAOs, CSM, remedy performance, operating cost, and alternative remedial options.
- Perform a sustainability assessment of any recommended alternative remedial options.
- Compare remedy performance and sustainability metrics for the existing remedial system and any recommended alternative remedial options.
- Evaluate potential footprint reduction techniques for the recommended remedial approach (i.e., the existing remedial system or recommended alternative remedial option).
- Implement any footprint reduction techniques as appropriate based on evaluating the impact on overall remedy footprint and costs.
- Oversee proper implementation of selected footprint reduction methods and document activities to verify sustainability metrics.
- Track contaminant removal with GSR metrics to implement exit strategies and support system shut-down recommendations.

6.0 CONCLUSIONS

The primary benefit of GSR is maximizing the overall net environmental benefit of a remedial action by minimizing the remedy footprint resulting from the remedial action activities. Implementing GSR can help to identify methods for using natural resources and energy efficiently, reducing negative environmental impacts, minimizing or eliminating pollution at its source, and reducing waste to the greatest extent possible. GSR improves the remedial action by maximizing the overall environmental benefit while still meeting the existing requirements for site cleanup.

Implementing GSR also helps achieve goals set forth by DOEE's mission and vision, which require reducing GHGs, energy consumption, and potable and industrial water use by federal agencies. Using GSR to identify methods to minimize the footprint of a remedial action supports the mission for effective site remediation in an environmentally, economically sound, and sustainable manner. GSR also supports the DOEE's goal to decrease energy demand for existing and future remedial systems and consider other systems options to minimize systems environmental impact.

GSR considerations should be made at every phase of the remedial action. Agencies and stakeholders should be engaged early in the process to assist with reviewing GSR assessments and footprint reduction methods throughout the remedial action. The general approach to include GSR metrics during any remedial phase is to determine and prioritize metrics for the site, establish a methodology to quantify or characterize each metric, obtain consensus on metric weighing against each other and traditional criteria, identify footprint reduction methods, and prioritize, select, and document the footprint reduction methods implemented within the stipulated budget. This approach can easily be tailored for remedy selection, design, construction, operation, and long-term management.

During the remedy selection phase, selecting a relatively more sustainable option by conducting a baseline assessment of the footprint of the feasible remedial alternatives using SiteWise^{TM} or similar tools provides the greatest benefit to reduce the overall footprint of the environmental remediation program. After selecting a sustainable option, further footprint reduction technologies can be evaluated based on a sensitivity analysis. During RD, selecting a footprint reducing technology for the activities that contribute the most to the overall footprint of the remedial action leads to a more sustainable remedial alternative than initially selected. It is important that all aspects of footprint reduction technologies be evaluated. For example, the use of alternative fuels is site-specific because the increased NOx emissions may have a greater impact than the carbon emissions of conventional fuel.

Some footprint reduction technologies that are cost-effective in the long term can be capital intensive, requiring budget appropriation accordingly. A proper cost analysis and GSR sensitivity analysis should be performed to ensure that the most cost-effective GSR practices are implemented, considering the project's lifecycle. Considering sustainability during the development of exit strategies will also help to reduce the overall remedy footprint further. Tracking GSR metrics during RA-O and LTM is also important to verify the success of any footprint reduction technologies implemented.

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APPENDICES

Appendix A

Figure 1 through **Figure 3**

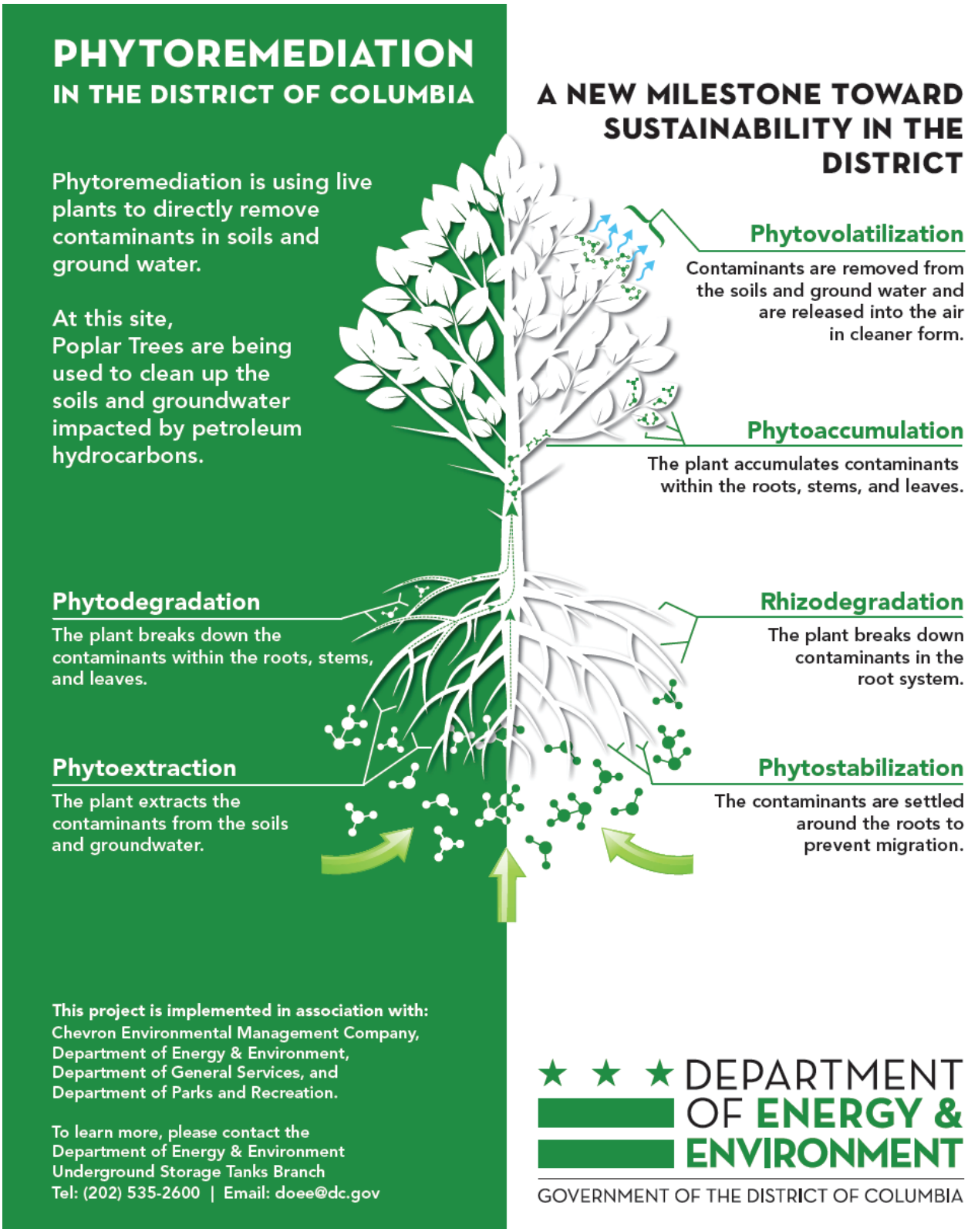

Figure 1: Phytoremediation Application at a DC Site to cleanup petroleum hydrocarbons

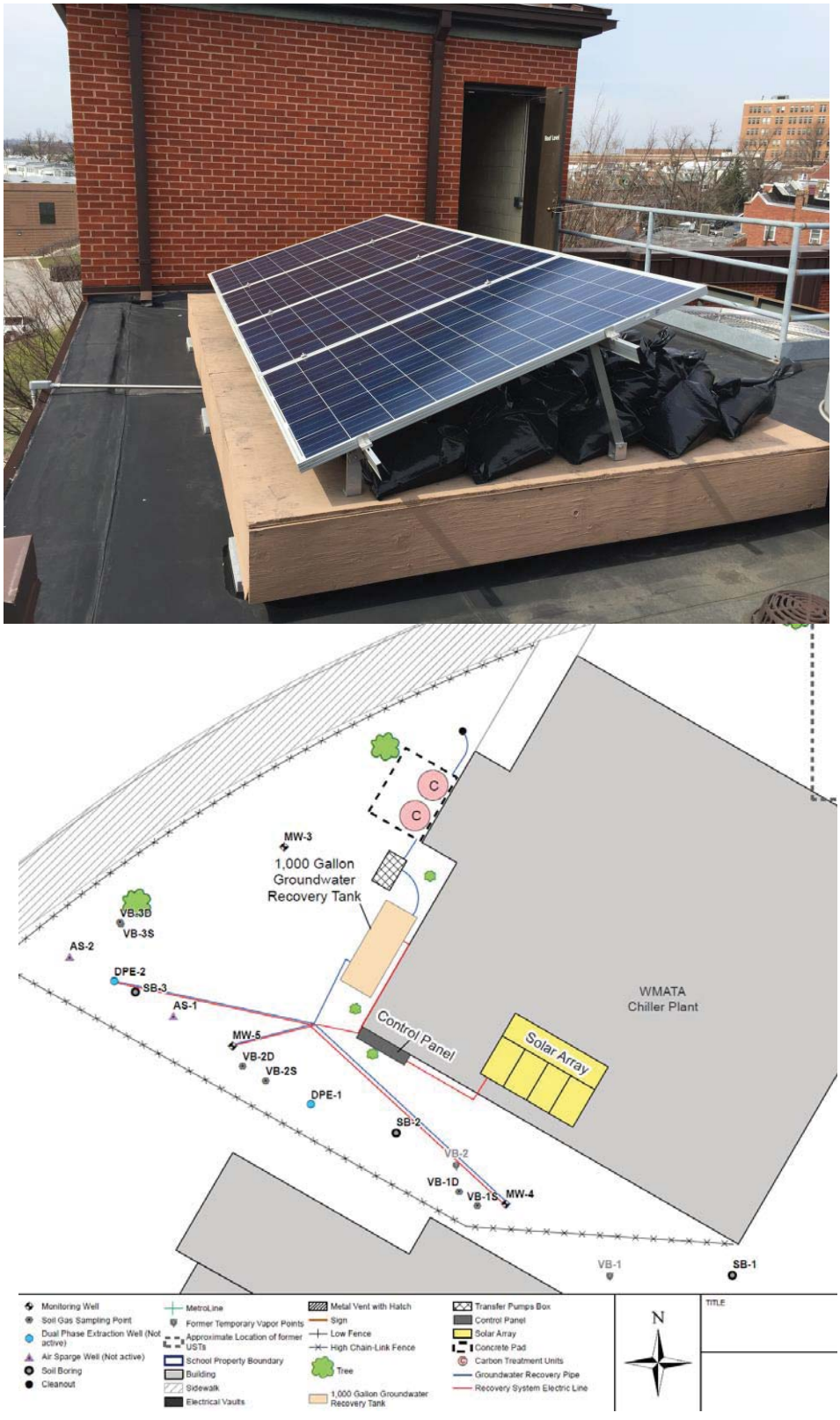

Figure 2: Use of solar panels to run remediation system at a DC Site to clean up petroleum impacted groundwater

Figure 3: In-situ thermal remediation at a former IBM Site located in DC to cleanup petroleum and non-petroleum impacted groundwater

Appendix B

Tools Designed for Site Remediation

TOOLS DESIGNED FOR SITE REMEDIATION

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Free to Public													
ATHENA® Impact Estimator for Buildings and ATHENA® Eco Calculator for Assemblies	Athena Institute, University of Minnesota, Green Building Initiative	Athena software evaluates whole buildings and assemblies based on LCA for material manufacturing, including resource extraction and recycled content; related transportation; on-site construction; regional energy use, transportation, and other factors; building type and assumed lifespan; maintenance, repair, and replacement effects; demolition and disposal; and operating energy emissions and precombustion effects. www.athenasmi.org/tools/impactEstimator		X			X	X		X	X	X	X
Building for Environmental and Economic Sustainability (BEES)	National Institute of Standards and Technology (NIST), EPA Environmentally Preferable Purchasing Program	BEES 4.0 evaluates green building products categorized under 24 elements, taking into account U.S. methodology for U.S. life-cycle assessment. Evaluated impacts include global warming, acidification, eutrophication, fossil fuel depletion, indoor air quality, habitat alteration, ozone depletion, water intake, criteria air pollutants, smog, ecological toxicity, cancerous effects, and noncancerous effects. To date, NIST has evaluated and scored over 230 products on BEES environmental and economic performance. The EPA Office of Resources Conservation and Recovery (ORCR) currently uses BEES model components to assess benefits associated with beneficial use of fly ash, ground granulated blast furnace slag, and silica fume in concrete building products. www.bfrl.nist.gov/oae/software/bees			X	X				X	X	X	X
Beneficial Reuse Model (BenReMod)	University of Toledo	The Beneficial Reuse Model is a suite of modules for comparing different materials that can be used for road construction in different scenarios. Modules address life-cycle assessment; human cancer and noncancer risk and ecological toxicity potential (for freshwater aquatic, terrestrial, and freshwater sediment systems); and a multicriteria decision analysis with an algorithm for ranking scenarios where no material consistently performs better. Model development continues, in part under an EPA Region 5 grant. http://benremod.eng.utoledo.edu/BenReMod		X			X	X		X	X	X	X

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Free to Public													
Diesel Emissions Quantifier	EPA	The quantifier can calculate emission estimates of NO_x, PM, hydrocarbons, CO, and CO_2 for a fleet of highway/nonroad vehicles or marine vessels with various diesel emissions control technologies. The tool supports diesel retrofit projects but is not designed to meet regulatory requirements for air or transportation reporting. An associated spreadsheet lists retrofit and clean diesel technology parameters. http://cfpub.epa.gov/quantifier/view/info.cfm, www.epa.gov/otaq/diesel/documents/appl-fleet.xls	X			X	X				X		
EIO-LCA	Carnegie Mellon–Green Design Institute	The Economic Input Output–Life Cycle Assessment (EIO-LCA) contains a series of publicly available Web-based models that allow the user to estimate the overall environmental impacts from producing a certain dollar amount of any of 500 commodities or services in the United States. Most recent U.S. models (1997) reflect impacts in terms of 1997 U.S. dollars. www.eiolca.net		X		X	X	X	X	X	X	X	X
Energy and Materials Flow and Cost Tracker (EMFACT™)	Northeast Waste Management Officials' Association	EMFACT is designed to be used within companies for systematically tracking materials and energy use; releases, discharges, and wastes; and associated costs. The tool helps manufacturers to apply environmental management accounting when setting pollution prevention priorities, identifying value-added opportunities for sustainable production, and implementing materials and energy-efficiency improvements. www.newmoa.org/prevention/emfact/about.cfm		X			X	X		X	X		X
Green Remediation Evaluation Matrix	California Department of Toxic Substances Control	The Green Remediation Evaluation Matrix uses life-cycle thinking to evaluate treatment alternatives based on substance release/production, thermal releases, physical disturbances/disruptions, and resource depletion/gain (recycling). www.dtsc.ca.gov/OMF/Grn_Remediation.cfm			X		X	X		X	X	X	X

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Free to Public													
Greener Cleanups Matrix	Illinois Department of Environmental Protection	The Greener Cleanups Matrix helps maximize the environmental benefits of site remediation by evaluating the level of difficulty and feasibility (cost, schedule, and technical complexity) for actions associated with site assessment, planning and design, and cleanup. Matrix information is based on evaluation of certain cleanups from the LUST, Site Remediation Program (SRP), CERCLA, and RCRA programs using site-specific questionnaires, field visits, and consultations with green remediation practitioners. www.epa.state.il.us/land/greener-cleanups/matrix.pdf			X		X	X	X	X	X	X	X
Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET)	DOE Office of Energy Efficiency and Renewable Energy	GREET is a full life-cycle model to evaluate various vehicle and fuel combinations on a fuel-cycle/vehicle-cycle basis, including material recovery and vehicle disposal. For a given vehicle and fuel system, GREET calculates consumption of total energy (renewable and nonrenewable), fossil fuels, petroleum, coal, and natural gas; emissions of CO_2-equivalent GHG; and emissions of VOCs, CO, NO_x, PM_{10}, $PM_{2.5}$, and SO_x. The model includes more than 100 fuel production pathways and more than 70 vehicle/fuel systems. www.transportation.anl.gov/modeling_simulation/GREET/index.html		X		X	X	X	X		X		X
Greenscapes	EPA	This suite of tools includes six spreadsheet-based calculators for use in GreenScapes project decision making and cost comparisons regarding virgin materials versus environmentally preferable products or methods. Individual calculators address recycling and reusing landscape waste, resource conserving landscaping cost, erosion control, decking cost, subsurface drip irrigation cost, and pallets cost. www.epa.gov/epawaste/conserve/rrr/greenscapes/tools/index.htm		X		X				X		X	X

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Free to Public													
Hybrid2	DOE National Renewable Energy Laboratory, University of Massachusetts	The Hybrid Power System Simulation Model (version 2) simulates performance of renewable energy systems involving combinations of different electrical loads, types of wind turbines, photovoltaics, diesel generators, battery storage, and power conversion devices. The tool also compares long-term performance of comparable systems. www.nrel.gov/applying_technologies/engineering_finance.html		X			X		X				
Industrial Waste Management Evaluation Model (IWEM)	EPA	IWEM software helps determine the most appropriate waste management unit design to minimize or avoid adverse groundwater impacts. Evaluation parameters include liner types, hydrogeologic conditions of a site, and toxicity and expected leachate concentrations from anticipated waste constituents. IWEM lookup tables cover approximately 60 organic or inorganic constituents with established maximum contaminant levels. www.epa.gov/epawaste/nonhaz/industrial/tools/iwem/index.htm		X			X			X		X	
PaLATE Model	University of California–Berkeley	The PaLATE Model is an environmental life-cycle model for the transportation sector. EPA's ORCR currently uses the tool to assess benefits for reuse of industrial materials such as fly ash, foundry sand, construction and demolition debris in concrete pavement, asphalt pavement, and road base. www.ce.berkeley.edu/~horvath/palate.html			X	X				X	X		X
Performance Tracking Tool (PTT)	AFCEE	A simple Excel-based tool to evaluate systems to find whether contaminant rate removal is consistent with projected reduction rates and project costs. Using normalized data to graphically display the results, one can easily visualize the understanding of system operations with respect to existing environmental conditions. PTT can assist in decision making from the existing site-specific data by helping identify system end points in the remediation process, revise extraction points as needed, evaluate effects of remedial decisions, and then adjust accordingly to enhance the efficiency of the systems. www.afcee.af.mil/shared/media/document/AFD-100113-032.xls		X			X	X		X		X	X

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Free to Public													
RETScreen	Natural Resources Canada	RETScreen evaluates energy production and savings, costs, emission reductions, financial viability, and risk for various types of renewable-energy and energy-efficient technologies. The tool includes product, project, hydrology, and climate databases; a user manual; and a case study–based college/university–level training course. Companion information includes a training course on legal aspects of energy projects. www.retscreen.net		X			X	X	X				
SiteWise™ Sustainable Environmental Restoration Tool	Battelle, U.S. Navy, and USACE	SiteWise, a sustainable environmental remediation tool, is designed to calculate the environmental footprint of remedial alternatives generally used by the industry. The tool is a series of Excel sheets and currently provides a detailed baseline assessment of several quantifiable sustainability metrics including GHGs; energy usage; criteria air pollutants, including SO_x, NO_x, and PM; water usage; and accident risk. The tool is being jointly developed by Battelle, U.S. Navy, and USACE and expected to be available as freeware in spring 2010. (Battelle point of contact: Mohit Bhargava)		X			X	X	X	X	X		X

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Free to Public													
Sustainable Remediation Tool (SRT)	AFCEE	The SRT is designed to evaluate particular remediation technologies on the basis of sustainability metrics. The tool, programmed in Microsoft Office Excel®, facilitates sustainability planning and evaluation, which is intended to aid environmental professionals in achieving remedial process optimization goals and complying with regulations (e.g., EO 13423, which affects DOD). The SRT allows users to estimate sustainability metrics for specific technologies for soil and groundwater remediation. The current technology modules included in the SRT are excavation, soil vapor extraction, pump and treat, and enhanced bioremediation. Additional technologies and metrics are under development. For each technology and in each tier of evaluation, the following sustainability metrics are calculated: GHG emissions, total energy consumed, technology cost, safety/accident risk, and natural resource service. The SRT is structured into two levels of input complexity. Tier 1 calculations are based on rules-of-thumb information that are widely used in the environmental remediation industry. Tier 2 calculations are more detailed and incorporate site-specific factors. The output metrics are presented in both a nonnormalized and a normalized/cost-based format. www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/index.asp		X			X	X		X	X	X	X
Waste Reduction Model (WARM)	EPA	EPA's ORCR uses WARM to assess benefits of the WasteWise program and specific benefits from reusing material such as fly ash, municipal solid waste recycling matter, and yard trimming compost (as a proxy for GreenScapes benefits). WARM also helps the public estimate GHG reductions of different waste management practices such as source reduction, recycling, combustion, composting, and landfilling for (currently 34) material types. epa.gov/climatechange/wycd/waste/calculators/Warm_home.html	X			X					X		X

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Proprietary/Restricted													
BalancE3™	ARCADIS	BalancE3 is a quantitative, Web-based tool used to evaluate different GSR approaches and incorporate them in remedy evaluation, selection, and design on a site-specific or portfolio-wide basis. It aggregates diverse sustainability metrics; provides the flexibility to prioritize any combination of eight metrics (energy, air emissions, water requirements, land impacts, waste generation and material consumption, long-term stewardship, health and safety, and life-cycle costs) for a given analysis; applies statistical methods and trade-off analyses to facilitate alternatives comparison; identifies key metrics to improve remedies through the practical application of greener remediation concepts; and provides a solution to calculate and manage carbon. (Point of contact: Kurt Beil, ARCADIS U.S. Inc., Newtown, PA]	X	X			X	X		X	X	X	X
Boustead Model	Boustead Consulting Ltd.	The Boustead Model is a tool for life-cycle inventory calculations of industrial processes. Version 5 links site-specific input to core data on fuel production, materials processing, stand-alone aspects, air emissions, water emissions, solid waste, solid waste regulated by the European Union, raw materials, fuels, feedstocks, and activity functions. www.boustead-consulting.co.uk/introduc.htm					X	X		X	X	X	X
Clean Me Green	Malcolm Pirnie, Inc., University of California–Santa Barbara Bren School of Environmental Science and Management	This spreadsheet tool was developed to improve the sustainability of site remediation by quantifying the cost, energy, and carbon savings associated with selecting or optimizing different remedial technologies. Use of this tool promotes creative and sustainably oriented thinking and emphasizes the benefits associated with greener approaches to remediation (Points of contact: Maryline Laugier and Elisabeth Hawley, Malcolm Pirnie]		X			X	X	X	X	X		

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Proprietary/Restricted													
Cleanup Sustainability Framework	DuPont, EPA Region 3	The framework was developed under a pilot project to evaluate sustainability of potential remedies and identify the optimal remedy at three RCRA sites in EPA Region 3. Metrics of a related credit/debit system focus on CO_2 equivalents, energy consumption, water use, soil use/ disposal, material use, and land. (Points of contact: Deb Goldblum, EPA Region 3 and David Ellis, DuPont]			X		X	X		X	X	X	X
GaBi	PE Consulting (Germany)	Originally developed by the University of Stuttgart, GaBi now is a commercially available suite of software and databases for life-cycle assessment (ISO 14040/44), carbon footprints (PAS 2050), GHG accounting, designs, energy efficiency, green supply chains, and material flow analysis. Software/database cost information is available through direct inquiries. www.gabi-software.com		X			X	X			X		X
GoldSET	Golder Associates Ltd.	GoldSET assesses the sustainability performance of remedial options based on site-specific scoring and weighting of environmental, social, and economic impacts. Over the past 3 years, GoldSET has been used in the United States, Canada, and Australia by the public and the private sectors. It is presently being customized to the requirements of a large corporation as well as for a Canadian federal agency. www.gold-set.com	X	X	X		X	X	X	X	X	X	X

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Proprietary/Restricted													
Green Remediation Analysis	EPA Region 9	Green Remediation Analysis is a spreadsheet tool for quantifying the environmental footprint of a remedy, using a life-cycle assessment approach. The spreadsheet tool may be used to compare alternative remedies at a cleanup site or to identify opportunities for reducing the environmental footprint of an existing remedy. Analytical parameters include resource use (fresh water, construction materials, remediation materials, gasoline and diesel fuel, and electricity), air emissions (CO_2, NO_x, SO_x, particulates, and air toxics), solid and hazardous waste generation, and wastewater discharge. Off-site manufacturing and transport are included in the analysis. Pilot testing of the spreadsheet tool is under way at three cleanup sites. When pilot testing is completed, the spreadsheets are intended for use by regulators, their contractors, and regulated site owners at other cleanup sites. (In development, Point of contact: Karen Scheuermann, EPA Region 9)					X	X		X	X		X

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Proprietary/Restricted													
Green Remediation Spreadsheets	EPA	This methodology considers contributions to the footprints from multiple components of remedies, including site investigation, construction, operations and maintenance and long-term monitoring. Both on- and off-site activities associated with each remedy component are included in the study. The method documents a process for estimating the footprints, provides the library of resources and reference values used in the study, documents findings specific to the evaluated remedies, and presents both site-specific and more generalized observations and lessons learned from conducting the study. Other primary objectives include, but are not limited to the following: • identifying or developing appropriate and applicable "footprint conversion factors" to calculate the footprints from various types of energy, materials, and services used in the remedy • estimating the footprints of up to 15 environmental parameters for three remedial alternatives • estimating the contribution to the various footprints from on-site activities, transportation, and nontransportation off-site activities • identifying those components of the various remedial alternatives that have a significant effect on the environmental footprint and those components that have a negligible effect on the environmental footprint • conducting a sensitivity analysis for variations in the remedy design information, footprint conversion factors, or other input values			X		X	X	X	X	X	X	X

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Proprietary/Restricted													
Sustainability Assessment Framework	CH2M Hill	The Sustainability Assessment Framework and methodology tool helps with both tasks by providing a framework for identifying sustainability criteria and a methodology for evaluating the greatest value sustainability options for the customer. This framework helps decision makers select from a universe of potential sustainability metrics (over 100) and includes a decision-making tool that facilitates input of life-cycle inventory information that can be integrated into a analytical hierarchy process for decision making and stochastic assessment of uncertainties. The decision-making process can be used for sustainability decisions alone or be used to integrate sustainability decisions with other project decision factors. (Point of contact: Paul Favara, CH2M Hill)		X	X	X	X	X	X	X	X	X	X
Net Environmental Benefit Analysis (NEBA)	DOE Oak Ridge National Laboratory, EPA National Center for Environmental Assessment, CH2MHill	NEBA is a risk management tool for evaluating trade-offs associated with environmental response actions. The tool can be supplemented with the nine NCP remedy selection criteria to evaluate site cleanup benefits related to increases in human use value, ecological service value, and economic value to society. (Points of contact: Rebecca Efroymson, Oak Ridge National Laboratory; Glenn Suter, NCEA; and Paul Favara, CH2M Hill]			X		X	X	X	X	X	X	X
SimaPro	Product Ecology Consultants	SimaPro is LCA software which collects, analyzes, and monitors the environmental performance of products and services. The tool can model and analyze complex life cycles in a systematic and transparent way, following the ISO 14040 series recommendations. www.pre.nl/simapro/simapro_lca_software.htm		X	X	X	X	X	X	X	X	X	X
Sustainability Assessment Tool	BP	This tool evaluates sustainability of existing remedies at specific sites. The tool has been used to evaluate remediation technologies such as (but not limited to) soil vapor extraction and pump and treat at an urban service station and sludge-pit treatment at a Superfund site in Texas. (In development, Point of contact: Stephanie Fiorenza, BP)			X		X			X	X	X	

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Proprietary/Restricted													
Sustainable Principles for Site Remediation	Good Earthkeeping Organization, Inc.	This commercial framework helps improve the efficiency of soil vapor extraction and multiphase extraction systems, with a focus on alternative methods for off-gas treatment. (In development, Point of contact: Lowell Kessel, Good EarthKeeping Organization, Inc.)			X		X	X			X		
Sustainable Remediation Assessment Tool	Haley & Aldrich	This tool evaluates the sustainability impacts of different remediation alternatives throughout a remediation project life cycle (including potential site redevelopment) and subsequently provides recommendations to reduce sustainability impacts. The tool addresses environmental, social, and economic impact indicators, for example, GHG emissions, criteria pollutant emissions, ecosystem disturbance, water consumption, natural resource use, solid waste production, impacts to the local community/ environmental justice, occupational risk, transportation risk, and total cost of remediation. (In development, Point of contact: Karin Holland, Haley & Aldrich, Inc.]		X			X	X	X	X	X	X	X
Sustainable Remediation: Cost/Benefit Analysis (CBA)	Shell Global Solutions (UK)	The CBA tool provides a risk-based framework to help balance decision making during remedy selection, with a focus on finding the economic optimum. (In development, Point of contact: David Reinke, Shell Global Solutions]			X		X	X		X	X	X	X

Title or common name	Sponsor	General description and access information	Web calculator	Decision software	Decision matrix	Policy/industry tool	Site specific	Energy efficiency	Renewable energy	Water	Air emission	Land & ecosystem	Materials & waste
Proprietary/Restricted													
Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI)	EPA Office of Research and Development	EPA developed TRACI to assist in impact assessment for sustainability metrics, life-cycle assessment, industrial ecology, process design, and pollution prevention. The LCA process may include both the consideration of material and energy inputs and outputs and the impacts associated with the emissions related to these material and energy flows. An example of one such model is TRACI. Impacts fit generally into two categories: (1) depletion: impacts related to resource, land, and water use and (2) pollution: impacts related to ozone, global warming, smog, human and ecotoxicology, acidification, eutrophication, radiation, waste heat, odor, and noise. Many emissions or factors related to remediation, such as diesel emissions, fugitive VOCs, emissions associated with electricity production, methane emissions, as well as emissions associated production of materials and treatment chemicals, can be associated with these impact categories. www.epa.gov/nrmrl/std/sab/traci		X			X			X	X	X	X

Appendix C

Green Remediation Screening Tool (GRST)

DEPARTMENT OF ENERGY & ENVIRONMENT

Underground Storage Tank Branch (USTB)
1200 First Street, NE, 5th Floor
Washington, DC 20002

LUST Case #:		**Facility Name:**	
Facility ID:		**Prepared By:**	
Facility Address:		**Reviewed By:**	
		Date:	

Green Remediation Screening Tool (GRST)

Stressors	Primary Impacted Media	Fate, Effect, & Processes	Y/N	Score
Energy Classification				
Renewable Energy Used	None	Remediation systems run by solar panels, batteries, geothermal*	Y	1*
Diesel/Gasoline Power	Air	Adding CO_2, SO_2 to the Environment	N	0
Batteries or rechargable sources	Land	Solid wate could be reduced by using rechargable batteries.		
Recycling				
Construction Materials (soil, plastics, etc.)	Land	Reusable material reduces landfill		
Water	Water, Land	Water could be recycled or reuse		
Waste Categorization	Land	Categorization of waste produced at the Site		
Remediation Unit	Land	Reclying of remediation system from site to site instead of dismantling		
Temperature Deviations				
Release of Hot Water	Ground	Habitat Distrubance		
Release of Hot Water	Aqueous Media	Habitat and Ecological Impact		
Release of Hot/Warm Vapor	Air	High Humidity affecting Human Health		
Release of Cold Water	Ground	liquid water such as purge water is treated and released immediately instead of storing at the site and release later as very cold water		
Ecological Impact				
Releasing Secondary Chemicals (NO_x, SO_x, etc)	Soil, Aqueous Media	Impacting Water Quality (>MCL)		
Releasing Acid/Base Materials	Aqueous Media	Nutrification Problem		
Soil structure disruption	Land	Disruption of habitate, impacting soil infertility		
Releasing hot or cold liquids	Soil, Aqueous Media	Disruption of habitate, impacting soil infertility		

DEPARTMENT OF ENERGY & ENVIRONMENT

Underground Storage Tank Branch (USTB)
1200 First Street, NE, 5th Floor
Washington, DC 20002

LUST Case #:		**Facility Name:**	
Facility ID:		**Prepared By:**	
Facility Address:		**Reviewed By:**	
		Date:	

Green Remediation Screening Tool (GRST)

Resources				
Surface Water or Groundwater	Water, Land	For the remediation purposes, if needed, groundwater or surface water is used. Impoundment, Sequester, Reuse		
Mineral	subsurface	Consumption of the minerals		
Biological resources such as trees, plants, animals, microorganism	Air, water, land, forest subsurface	Disapperenance of species or scarcity, diversity reduction, reducing reproduction		
Location (land and Space)	subsurface	Impoundment, public space occupied		
Waste Generation				
Acid gases such as NO_x, SO_x, HCl, CFC Vapors, H_2S	Air	Acid rain, ozone layer depletion, global warming, the greenhouse effect		
Liquid waste and/or secondary chemicals production	Aqueous Media	Increase water and sediment toxicity. Sulfate could be generated from the ISCO event when using persulfate as oxidant. Diminsh the sulfate reducing bacteria essential for biodegradation		
Generation of solid waste	Land	Do not apply if soil excavation is the remediation technology. Land use and toxicity.		
Transporation for Site Visit				
Electric Vehicles	None	All transportation used are EV, no pollution		
Hybrid Vehicles	Air	Less polution comparing with gasoline/diesel enginees		
Regular Vehicles	Air	Producing Acid gases		

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		Date:	

Green Remediation Screening Tool (GRST)

Miscellaneous				
Noise/Odor/Vibration	General Environment	Nuisance, Safety, Impacting surrounding neighborhood		
Traffic Pattern		Safety of the surrounding vicinity of the Site, Long term inconvenience		
Stagnation/Long-term disturbance		Decreasing remediation efficiency, economical impact, and hindering development		
			Total Score (N)	

* = Details of the scoring system. For example, if "Y" is answered. Then explain why "Y" is selected.

Scoring System: Yes = 1, No = 0, N/A = No score

Maximum Possible Score =X

Grading Calculation: % = (N/X)*100

Appendix D

Case Studies

CASE STUDIES

C.1 LEVEL 1: BEST MANAGEMENT PRACTICES (BMPS)

C.1.1 Former Refinery Site

Site Name	Former Refinery Site
Site Location	Wellsville, New York
Contact Name	Stephanie Fiorenza, Ph.D., BP, Stephanie.Fiorenza@bp.com
Regulatory Program	RCRA Superfund, New York State Department of Environmental Conservation
Affected Media	Groundwater, soil
Contaminants of Concern	Petroleum hydrocarbons
Time to Completion	10 years
Estimated Cost	Not available

Site Description

The site has a groundwater extraction system using a constructed wetland as the treatment system.

GSR Metrics Considered

Initial consideration of GSR metrics was not provided; however, treatment effectiveness, energy consumption, and cost are recorded and monitored.

GSR Recommendation(s)

Not applicable.

GSR Practices or BMPs Implemented

Phytoremediation technology has been implemented.

Challenges

Electricity costs increased due to change in metering location.

Lessons Learned

Use of an explanation of significant difference allowed a change in the remedy without changing the ROD. Community involvement was a key contributor to the success of the change in remedy.

Benefits from GSR remedy implemented at site include the following:

- reduced energy consumption by 56,000 kwh/year
- eliminated 105,000 pounds of treatment chemicals, including granular activated carbon

The remediation system was optimized by changing from conventional chemical treatment of extracted groundwater to constructed wetland treatment.

Habitat and biodiversity were improved by changing conventional grass covering of landfill to native grasses.

Stakeholder involvement, including communication and outreach efforts, improved, and the community benefited from trails installed on new cap cover to river and educational opportunities and collaboration with local college. See www.bpwellsville.com for more information.

Overall cost savings were realized from the elimination of chemical consumption.

C.1.2 Travis Air Force Base

Site Name	Travis Air Force Base (AFB)
Site Location	Oil Spill Area, SS016
Contact Name	Lonnie Duke, U.S. Air Force, lonnie.duke@travis.af.mil
Regulatory Program	U.S. Environmental Protection Agency Superfund Program
Affected Media	Groundwater, soil
Contaminants of Concern	Volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs)
Time to Completion	Not available
Estimated Cost	Not available

Site Description

Travis AFB has constructed an in situ bioreactor to treat the source of the largest and most challenging groundwater site on base. Known as the "Oil Spill Area," its large solvent plume originates near an industrial building that cleaned metal parts, and most of the plume lies beneath a large portion of the aircraft parking ramp.

The contamination was treated by a thermal oxidation unit that used a vacuum to draw the solvents out of the soil and burned contaminated vapor with natural gas. Although successful in treating the contaminants, the unit did not achieve any measureable amount of cleanup. Contaminant concentrations in groundwater remained very high, and the unit used significant quantities of natural gas and generated significant GHG emissions.

The bioreactor which replaced the thermal oxidation system uses solar power to run an extraction pump that recirculates nutrient-rich treated water around the contaminated area. The bioreactor is not connected to the base's electrical system and is not expected to generate GHG emissions.

GSR Metrics Considered

Time to completion, cost to complete, energy savings, and GHG emissions were considered.

GSR Recommendation(s)

Elimination and replacement of thermal oxidation units and energy-intense vacuum systems were recommended.

GSR Practices or BMPs Implemented

The bioreactor creates the groundwater conditions that allow microbes to reductively dechlorinate solvents into harmless compounds. Microbes attach themselves to gravel particles in the reactor and subsist from carbon in the mulch. Emulsified vegetable oil sprayed into the mulch during construction kick-starts the biological activity. The bottom of the bioreactor is lined with iron pyrite, which promotes the chemical treatment of solvents and their intermediate breakdown products. This system ensures a complete conversion of solvents into harmless compounds.

The system operates entirely on solar-generated electricity and is not connected to the base electrical system. Solar panels power an extraction pump that recirculates nutrient-rich treated water around the contaminated area. Groundwater recirculation increases the effective range of the treatment zone.

Challenges

The construction of the bioreactor involved the excavation of a large volume of solvent-contaminated soil from the source area, speeding up the cleanup process. Although any excavation project can be expensive and generate large amounts of waste that must be sent to a landfill for disposal, it is still relatively inexpensive compared to the long-term cost of operating an extraction system for years to remove the same amount of contaminant mass.

Lessons Learned

The bioreactor has the potential to complete the remediation decades before the site's original estimated cleanup time and will avoid significant energy use and GHG emissions. Finally, there was a reduction in life-cycle costs to run the overall remediation system.

C.2 LEVEL 2: BEST MANAGEMENT PRACTICES (BMPS) + SIMPLE EVALUATION

C.2.1 Rhode Island

Site Name	"Policy for Considering Environmental Justice in the Review of Investigation and Remediation of Contaminated Properties"
Site Location	State of Rhode Island
Contact Name	Terrence Gray, P.E., Assistant Director of Air, Water and Compliance, Rhode Island Department of Environmental Management (RI DEM), terry.gray@dem.ri.gov
Regulatory Program	State of Rhode Island and Providence Plantations Department of Environmental Management Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases
Affected Media	Not applicable
Contaminants of Concern	Not applicable
Time to Completion	Not applicable
Estimated Cost	Not applicable

Site Description

The "Policy for Considering Environmental Justice in the Review of Investigation and Remediation of Contaminated Properties" (Policy) was drafted in July 2007 as a means to consider environmental justice in the review of investigation and remediation of contaminated properties. The goals of the Policy are as follows:

- to help RI DEM make more informed decisions, improve work quality through collaborative efforts, and build mutual understanding and trust between the department and the public it serves
- to ensure that RI DEM staff understand the characteristics of the communities surrounding the sites that they are assigned to regulate
- to increase awareness in the urban centers about RI DEM, the site remediation program, and the opportunities for assistance offered by RI DEM to residents living in these neighborhoods
- to provide a clear process for residents to identify potentially contaminated sites to RI DEM, monitor the initial consideration of those sites, and understand the results of the evaluation
- to encourage investment and development in environmental justice areas that balance the needs of residents, municipalities, and the redevelopment community
- to provide a clear and effective process for ongoing two-way communication and understanding as a site is investigated and cleaned up
- to help RI DEM staff engage residents within their own community and neighborhoods in order to help build capacity of residents and community groups within urban areas to support progress towards the goals of this Policy
- to provide an opportunity to raise concerns about environmental justice and ensure they are considered by RI DEM

The policy can be found at www.dem.ri.gov/envequity/pdf/ejfinal.pdf.

Policy development history

The stakeholder group discussed herein was convened via a court agreement in response to a lawsuit filed by residents in Providence, R.I. over the construction of the Springfield Street School complex on a former city landfill (Hartford Parks Tenants Association v. RI Department of Environmental Management/City of Providence).

The Policy has been incorporated into all programs governed by the RI DEM's "Rules and Regulations for the Investigation and Remediation of Hazardous Materials Releases." These rules were amended, integrating the Policy. The programs affected by the Policy incorporate specific aspects of the Policy into existing program guidance language. Although the effective date of the Policy is June 26, 2009, elements called out in the policy were implemented under draft policy as of July 31, 2007 for new sites entering their respective program(s). Additionally, the Policy is not retroactive for existing sites or those entering prior to July 31, 2007.

The process

RI DEM's "Policy for Considering Environmental Justice in the Review of Investigation and Remediation of Contaminated Properties" is an example of one state agency's attempt to include social or sustainable practices in the existing regulatory cleanup structure. The Policy provides avenues or "action items" for the regulator to perform throughout the cleanup investigation planning and scoping phases, as well as after the site findings/reporting, and post-closure phases of the project. These items include engaging the public through informational outreach in multiple formats, listening and education meetings, mailings, and online resources.

RI DEM project staff may undertake the outreach efforts themselves, directed to the responsible party or its consultant. The degree to which the outreach effort is attempted varies and is dependent on the site size and may depend on the intensity of site interest from the surrounding community. The full array of communication tools described herein has not been tested to date on a singular project/site.

The outreach efforts are specifically targeted to inform those communities identified as "Environmental Justice Focus Areas" as follows:

> The United States Environmental Protection Agency (EPA) uses data from the census to develop population maps in Geographic Information Systems (GIS). In establishing their mapping criteria, EPA calculated (on a regional basis) the percent of the census block group that is minority *and* the percent of the block group that is low-income (under 2x Federal Poverty Level). Areas mapped by EPA are both (% minority & % low-income) high enough to rank in the top 15% of block groups. RI DEM adopted similar criteria; however, it compared the block groups on a state-wide basis instead of a regional basis. In addition, DEM mapped areas where the percent of the block group that is minority *or* the percent of the block group that is low-income (under 2x Federal Poverty Level) are high enough to rank in the top 15% of block groups state-wide. For purposes of implementing

the policy, the census blocks meeting these criteria shall be designated Environmental Justice Focus Areas.

GSR Metrics Considered

When in compliance with this policy, a site may include the following metrics in site evaluations:

- number of outreach meetings, mailings, and responses
- online access attempts
- staff training sessions completed

GSR Recommendation(s)

Site cleanup decisions are likely to be heightened with improved community understanding and acceptance when cognition of community impacts and concerns become part of the holistic evaluation of cleanup remedies. This form of environmental justice policy is a primary example of how the sustainable components of cleanup can be attained through specific action items for regulatory staff. These items have the potential to become an extension of the investigative work guidance requirements.

GSR Practices or BMPs Implemented

RI DEM provided numerous action items for regulators to use in their effort to engage community stakeholders. A sample of the action items is provided below:

Site discovery and public petitioning action items

- Establish multilingual complaint hotline and website (currently under development).
- Accept all public petitions for suspected contaminated sites and investigate the suspicions promptly.
- Communicate, in writing, the results of the initial investigation and anticipated next steps back to the complainant in their native language whenever possible.

Identifying communities of concern

- Maintain GIS mapping site showing Environmental Justice Focus Areas.
- Compare all sites reported to RI DEM with the Environmental Justice Focus Area overlay map to determine whether the site is in such areas.

Challenges

None provided.

Lessons Learned

Use of this type of policy may result in community benefits through knowledge base, engagement, sense of community ownership, and overall participation in the cleanup process. From the regulator's perspective, these action items can be tracked and reported. Finally, benefits may be realized in overall site management decisions that result in more efficient site closures.

C.2.2 Resource Conservation and Recovery Act Corrective Action Interim Remedial Measure, Ohio

Site Name	Confidential
Site Location	Confidential, Ohio
Contact Name	Nick M. Petruzzi, P.E., Cox-Colvin & Associates, Inc., 614-526-2040, nick_petruzzi@coxcolvin.com
Regulatory Program	RCRA, Ohio Environmental Protection Agency (Ohio EPA)
Affected Media	Soil, groundwater
Contaminants of Concern	39 contaminants of concern (COCs) consisting of VOCs and SVOCs
Time to Completion	6 months
Estimated Cost	$4,000,000

Site Description

The facility is located in a highly prolific buried valley aquifer system which serves as a sole source aquifer in the area. Highly permeable sand and gravel outwash deposits are the predominant material within the buried valley system, with near-surface deposits consisting of less-permeable glacial till. A localized perched unit of groundwater consisting of sand and gravel exists at the facility's primary operations area, with the regional aquifer water table at a depth of approximately 45 feet below ground surface (bgs).

The site is a commercial treatment, storage, and disposal facility. The facility maintains a Hazardous Waste Renewal Permit regulated through the Ohio EPA. Implementation of RCRA Corrective Action is a condition of the facility's permit.

In 2009, an explosion and fire destroyed much of the operations area of the facility and resulted in the release of various liquid materials, which impacted (often through preferential pathways) subsurface soil, perched groundwater, and the regional aquifer. Given that contaminants in subsurface soil and perched groundwater would act as a continuing source of contamination to the regional aquifer and may result in unacceptable risk to a site worker and possibly off-site receptors if not addressed, the facility elected to conduct the cleanup as an interim measure through the RCRA Corrective Action program.

Excavation and disposal of subsurface soil and perched groundwater was selected as the preferred remedial alternative. The extent of excavation, approximately 70,000 tons, was guided by site-specific remedial goals that were protective of a site worker and would prevent leaching to the regional aquifer above unacceptable concentrations.

GSR BMPs were identified and employed to the extent possible during the investigation and remedy design/implementation phases of the cleanup. As part of the remedial evaluation phase, GSR concepts were identified and evaluated against the potential remedial alternatives and played a role in the selection of a preferred remedial alternative.

GSR Metrics Considered

The evaluation of potential remedial alternatives relied on RCRA's threshold and balancing criteria for remedy selection. Therefore, a GSR evaluation of potential remedial alternatives was integrated into this regulatory framework. GSR concepts that were considered inherent in the seven existing balancing criteria were identified. Additional and relevant GSR concepts were then used to develop an eighth new balancing criterion. The eighth criterion consisted of five GSR categories, including consumption of resources and materials, CO_2 emissions, waste minimization and reuse, community benefit, and corporate image and corporate sustainability. A weighting factor was used in the CO_2 emissions category. The resulting evaluation scores for the GSR criterion were incorporated into the scores of the other balancing criteria to select a preferred remedial alternative.

Depending on the GSR category, some evaluations were qualitative while others were quantitative. Professional judgment was required in the development of the GSR criterion and the evaluation approach for the GSR categories as limited guidance was available. A brief description of the metrics associated with each GSR criterion category is provided below:

- consumption of resources and materials—quantitative and qualitative consideration of water, clean soil, construction materials, and other consumables
- CO_2 emissions—quantitative consideration of direct CO_2 emissions from fuel used for transportation, construction equipment (on and off site), and on-site treatment; indirect CO_2 emissions from power plans for the generation of on-site electricity
- waste minimization and reuse—quantitative consideration of the volume of soil disposed off site and the volume of treated soil used as backfill
- community benefit—quantitative and qualitative consideration of the effects of increased traffic with respect to noise pollution, the eyesore factor, travel delays, and "wear and tear" on roadways
- corporate image and corporate sustainability—quantitative consideration of stakeholder perception and the avoidance of potential future liability in terms of regulatory enforcement and human health–related risk

Three potential remedial alternatives (RAs) satisfied all of the threshold criteria requirements and were carried through to the balancing criteria and GSR evaluation. These potential remedial alternatives included excavation, off-site disposal, and backfill with clean material from an off-site source (RA-1); excavation with on-site ex situ thermal desorption mobile unit and backfill with the treated material (RA-2); and in situ electrical resistance heating, hotspot excavation and off-site disposal, and hotspot backfill with clean material from an off-site source (RA-3). RA-1 and RA-2 tied as the most green and sustainable remedial alternatives.

GSR Recommendation(s)

Incorporation of GSR into the cleanup project allowed for various benefits to be realized, including slight improvement in the time to completion, reduction in fuel use and CO_2 emissions, and positive perception among stakeholders (including nearby neighbors, the general public, and Ohio EPA). Costs throughout the cleanup project were impacted only slightly (some higher, some lower). One example of an increase in cost related to GSR is the possible purchase of carbon offset credits. The facility is currently evaluating the purchase of a sufficient number of credits to claim a carbon-neutral cleanup.

GSR Practices or BMPs Implemented

A formal evaluation was not necessary for GSR BMPs. Based on professional judgment various GSR BMPs were recommended to the facility to be performed as part of the investigation and remedy design/implementation phases. GSR BMPs recommended during the investigation phase included the Triad approach, direct-push soil sampling, limiting/compressing off-site sample shipments, and a mobile wastewater treatment system. GSR BMPs recommended during the remedy design/implementation phase included exhaust particulate filters/oxidation catalysts for construction equipment, low-sulfur diesel or biodiesel blend for trucks and construction equipment, routine maintenance on construction equipment, anti-idling policy, recycling concrete and demolition debris, transportation of backfill during return trips from the landfill, identifying preferred truck routes with local officials, green concrete, promoting public awareness/education/involvement, and purchase of carbon offset credits.

Challenges

Various GSR barriers and uncertainties were encountered due to the lack of consensus, the constantly evolving nature, and limited guidance associated with the GSR initiative. In an effort to overcome some of these barriers and uncertainties, professional judgment was heavily relied on. Uncertainties and barriers related to the following:

- identification of inherent GSR similarities in existing balancing criteria
- development of the GSR criterion categories
- evaluation weighting
- GSR BMP implementation
- facility benefits, incentives, and recognition

Lessons Learned

In general, this case study provides a successful demonstration with respect to GSR evaluation and implementation, given guidance limitations, permit-required constraints, complexities associated with site-specific conditions (e.g., time frame, COCs, and hydrogeology), and a situation where the most feasible options were not considered the most green and sustainable.

Based on research and conversations with U.S. EPA and Ohio EPA, this case study appears to represent the first documented RCRA Corrective Action cleanup project within EPA Region 5

(and possibly further) which devoted a significant level of effort to incorporate GSR into all applicable phases of the project and included a qualitative/quantitative GSR evaluation of potential remedial alternatives.

C.2.3 Florida Department of Environmental Protection Resource Conservation and Recovery Act

Site Name	Kennedy Space Center
Site Location	Cape Canaveral, Florida
Contact Name	Rebecca Daprato, Ph.D., P.E., GeoSyntec, RDaprato@GeoSyntec.com
Regulatory Program	RCRA Superfund, Florida Department of Environmental Protection (FDEP)
Affected Media	Groundwater, soil
Contaminants of Concern	Trichloroethylene (TCE)
Time to Completion	4 years
Estimated Cost	Not available

Site Description

The site is a launch pad surrounded by wetlands and the Merritt Island National Wildlife Refuge. The remedy included recirculating enhanced anaerobic bioremediation system using biostimulation and bioaugmentation. Initially, potassium lactate was used as the electron donor, but later Emulsified Oil Substrate (EOS™) was used as the substrate. KB-1 was the microbial culture, and sodium bicarbonate was added as the buffer. Two injection wells were used for recirculation, and two extraction wells with 12 volt (V) centrifugal pumps running 2–4 gallons per minute (gpm), 24 hours per day, 7 days per week were powered by a mobile solar unit. The sun-hours averaged 4.5 per day; the two batteries had a 2-day reserve. The batteries were 12 V, 265 amp-hours each. A charge controller was used to prevent the batteries from overheating. The four photovoltaic (PV) modules were Sharp 123 watt, 17.2 V, 7.16 amps.

GSR Metrics Considered

CO_2 equivalents were considered.

GSR Recommendation(s)

None provided.

GSR Practices or BMPs Implemented

A corrective measures study compared the carbon footprints of bioremediation, pump and treat, air sparge, and multiphase extraction. The CO_2 equivalents in metric tons were 5–15, 40, 30–60, and 50–100, respectively.

The selected remedy minimized impacts to habitat and reduced risks to surface water receptors.

Challenges

The remediation substrate needed to be optimized to improve remediation performance.

Lessons Learned

The mobile solar unit was easy to install, mobilize, and demobilize and can be reused at other sites.

C.2.4 New Jersey Terminal

Site Name	Former Terminal
Site Location	Paulsboro, New Jersey
Contact Name	Stephanie Fiorenza, BP, Stephanie.Fiorenza@bp.com
Regulatory Program	NJDEP
Affected Media	Groundwater, soil
Contaminants of Concern	Petroleum hydrocarbons, chlorinated solvents
Time to Completion	5 years
Estimated Cost	$5–$10 million

Site Description

A former terminal included 16 remedial management units (RMUs) on site. This case-study focuses on site-wide groundwater and remediation of hot spots in two RMUs.

The uppermost saturated zone is 5–10 feet bgs and 60–100 feet thick. It overlies a clay unit above an intermediate aquifer and another clay unit. The lower aquifer, beneath the lower clay unit, is used as a drinking water aquifer by the borough.

GSR Metrics Considered

The metrics considered were as follows:

- GHG and criteria pollutant emissions
- performance efficiency—emissions per pound of COC removed
- energy consumption
- solid waste consumption
- occupational and transportation risk
- remediation life-cycle cost
- return on investment for sustainability enhancements (direct and indirect)
- community outreach/participation

GSR Recommendation(s)

A solar plant eliminates 570,000 pounds of CO_2, 1600 pounds of SO_2, and 1100 pounds of NO_x annually and saves $40,000–$150,000.

GSR Practices or BMPs Implemented

A post-selection assessment is being conducted using a proprietary private tool.

Environmental: Renewable energy supplies part of the power required by the groundwater extraction system. Waste is minimized through careful planning and reuse. Air emissions are reduced by use of renewable energy. The ozone remediation system was redesigned to require less power. Trip management reduces mileage.

Social/community involvement: Local and state civic leaders proposed the location for the new port facility and issued bonds for port construction. The city has 99-year lease, and the county has issued bonds for redevelopment of the site as a port facility.

Economic: It is anticipated that the marine terminal will create 2,500 full-time direct and indirect jobs as well as 500 construction jobs. Power reduction has led to a cost savings for this remediation project.

Challenges

The redevelopment of the site defined remedial options and dictated the course of remediation construction.

Lessons Learned

Combining site remediation with redevelopment requires commitment and frequent communication among all parties so that construction and remediation efforts can be coordinated to the advantage of all.

C.3 LEVEL 3: BEST MANAGEMENT PRACTICES (BMPS) + ADVANCED EVALUATION

C.3.1 Tucson Air National Guard

Site Name	162nd Fighter Wing, Arizona Air National Guard (AANG)
Site Location	Tucson, Arizona
Contact Name	James D. Colmer, P.E., BB&E, 248-489-9636 x309, jcolmer@bbande.com Richard McCoy, NGB/A7OR, 240-612-8541, Richard.mccoy@ang.af.mil
Regulatory Program	EPA Superfund Program, Arizona Department of Environmental Quality (ADEQ)
Affected Media	Groundwater
Contaminants of Concern	VOCs, mainly TCE
Time to Completion	Not available
Estimated Cost	Not available

Site Description

In 1987, EPA designated the 162nd Fighter Wing installation as a principal responsible party for the Area B contamination beneath the AFB property. As part of the RI and other investigations, more than 70 groundwater monitoring wells have been installed on the base. EPA prepared a ROD for the Tucson International Airport Area (TIAA) Superfund site specifying a groundwater extraction, treatment, and recharge system (GWETRS) remedy. In May 1997, the GWETRS was installed and began operation.

The current COCs in groundwater include VOCs (mainly TCE). On-site historical TCE concentrations have ranged from nondetect to 46 parts per billion (ppb). Currently, TCE concentrations range from nondetect to about 8.4 ppb. The EPA maximum contaminant level (MCL) for TCE in drinking water is 5 µg/L.

The GWETRS currently consists of 10 operating extraction wells, including 8 extraction wells screened in the upper subunit and 2 in the lower subunit. Extracted groundwater is treated via air stripping prior to reinjection into an infiltration gallery consisting of 5 reinjection wells screened in the vadose zone. The reinjection gallery is located in the northeast portion of the base, distant from the extraction wells. Air-stripping off-gases are treated with vapor-phase carbon prior to discharge to the atmosphere.

Site hydrogeology

The vadose zone at the AANG project area extends from the surface to a depth of approximately 88 feet bgs and is composed of silty sands, caliche deposits, and gravelly sands. The upper zone of the regional aquifer in the AANG project area consists of two subunits and a middle aquitard. All of the known groundwater contamination at the AANG project area is found in these

subunits. The upper subunit consists of well-graded, gravelly, course sand and is found at a depth of approximately 88–103 feet bgs. Near Site 5 the upper subunit is generally silt free. The middle aquitard separates the upper and lower subunits and is composed of tight sandy silt with scattered pebbles. At Site 5, the middle aquitard lies at a depth of about 103–128 feet bgs. The lower subunit is found at a depth of approximately 128–138 feet bgs and is composed primarily of course-grained sand. There is also a northwest-southeast trending sand channel in the lower subunit along the south-central portion of the AANG base. The groundwater flow direction in the upper and lower subunits is toward the northwest, and the depth to groundwater is approximately 90 feet bgs.

GSR process

The scope of this sustainable remediation evaluation is the operation, maintenance, and monitoring of the existing GWETRS located at the base. As part of its RPO program, AANG conducted a sustainable remediation evaluation (SRE) of the existing remediation system located at the 162nd Fighter Wing. A simplified SRE process was developed by AANG based on EPA's green remediation primer (EPA 2008) to identify opportunities for optimizing the sustainability of existing remedies. The primer provided focused core elements that framed the SRE. In addition, AANG's targeted scope was critical in the efficient and cost-effective completion of the evaluation. Within the bounds of the evaluation, a sustainable aspect inventory was completed for each core element and associated impacts noted. Alternatives to mitigate the impacts identified by the sustainable aspect inventory were developed for consideration and potential implementation.

GSR Metrics Considered

The following metric were considered for this site:

- gallons of water pumped
- pounds of contaminant removed
- kilowatt-hours of energy consumed
- metric tons of CO_2 equivalents generated
- metric tons of CO_2 generated

GSR Findings

The following were key findings of the SRE:

- Significant amounts of water had been pumped (708 million gallons) with little removal of TCE (approximately 37 pounds).
- Considerable energy was expended in operating systems (265,184 kwh annually, or 2.34% of the base's electrical consumption).
- Approximately 250 metric tons of CO_2 equivalents was created annually, based on energy usage.
- An opportunity for solar power use existed if the energy demand was reduced.

- Significant tailpipe emissions (approximately 14 metric tons of CO_2 per year) were generated from sampling events, nonregional suppliers, etc.
- Large amounts of sampling materials (approximately 9 miles of polyethylene tubing per year) and associated disposal of the used sampling materials, were needed.
- Some sustainable principles had already been applied, such as RPO processes, passive cooling, groundwater recharge, etc.

GSR Recommendation(s)

The following recommendations were generated during the GSR evaluation:

- Evaluate and discontinue the use of noncontributing extraction wells (wells pumping water with TCE concentrations below the MCL) based on current groundwater treatment needs.
- Evaluate elimination of the air stripper, the associated 15 hp blower, and the off-gas heater, as well as use of the current influent tank to strip VOCs by the action of falling water.
- Conduct a validation study using passive diffusion sampling bags for groundwater monitoring, with regulatory approval.
- Review the sampling schedule for potential sampling reduction opportunities, with regulatory approval.
- If the GWETRS must continue operating, continue to recharge treated groundwater to the aquifer and not divert treated water for irrigation or other purposes, since the aquifer is a shared community resource.
- Evaluate the use of local/regional vendors and suppliers that can meet cost and quality objectives.

It should be noted that to implement many of these recommendations, the ROD may require modification.

One of the recommendations that has been implemented is an ISCO pilot test without the GWETRS. This test was successful, and there do not appear to be additional health risks by using ISCO versus continuing operation of the GWETRS.

Another recommendation that has been implemented to some degree is the installation of PV units to provide solar power. While the return on investment and limited space were not favorable for a specific PV array for the GWETRS, it was more economically feasible to address GWETRS power needs as part of a broader base effort. To some extent this is being accomplished as the Base is installing some PV arrays where feasible.

GSR Practices or BMPs Implemented

One of the recommendations that has been implemented is an ISCO pilot test without the GWETRS. This test was successful, and there do not appear to be additional health risks by using ISCO versus continuing operation of the GWETRS.

Another recommendation that has been implemented to some degree is the installation of PV units to provide solar power. While the return on investment and limited space were not

favorable for a specific PV array for the GWETRS, it was more economically feasible to address GWETRS power needs as part of a broader base effort. To some extent this is being accomplished, as the base is installing some PV arrays where feasible.

The projected benefits from the proposed recommendations include the following:

- annual reduction in energy use of over 50%
- nearly 75% reduction in tailpipe emissions
- significant reduction in material use (e.g., 9 miles of polyethylene tubing per year)
- retention of water in the aquifer
- potential reduction or elimination of the need for NaHx (sodium hexametaphosphate, aka SHMP).

Challenges

Various GSR barriers and uncertainties were encountered due to the lack of consensus, the constantly evolving nature, and limited guidance associated with the GSR initiative. In an effort to overcome some of these barriers and uncertainties, professional judgment was heavily relied on. Uncertainties and barriers related to the following:

- identification of inherent GSR similarities in existing balancing criteria
- development of the GSR criterion categories
- evaluation weighting
- GSR BMP implementation
- facility benefits, incentives, and recognition

Lessons Learned

There has been interest from AANG for some time to discontinue the use of the GWETRS and move to a more passive remedy due to the limited amount of TCE removed and high annual cost of operation. However, with a ROD in place, regulators seemed reluctant in replacing the active treatment with a more passive remedy.

In April 2008 (and since amended), EPA's green remediation primer was published, signaling a potential shift in thinking by considering how to achieve cleanup goals in a more sustainable fashion. Acting on the information presented in the primer, AANG embarked on creating a streamlined GSR evaluation approach that could frame remedial system performance in terms of sustainability. In August 2009, the results of the 162nd Fighter Wing GSR evaluation were shared with EPA and ADEQ.

The GSR findings presentation did not result in an immediate position change by the regulators. However, in September 2009, EPA Region 9 issued a green remediation policy letter, and the policy message began moving through the organization. With policy in place, the GSR findings presented contributed to the collaborative project team effort to improve the sustainability parameters of the GWETRS. In early 2010, at a project team meeting, EPA presented the possibility of discontinuing active treatment in favor of ISCO with MNA. In March 2011, at a

ROD amendment working group meeting, AANG presented a proposed ISCO plan that was well received and will likely be included in a ROD amendment, tentatively scheduled for late 2011.

C.3.2 Air Force Sustainable Remediation Tool

Site Name	TCE Site, Confidential
Site Location	Air Force Base
Contact Name	Doug Downey, CH2M Hill, 303-674-6547, Doug.downey@ch2m.com
Regulatory Program	CERCLA, state agency
Affected Media	Groundwater, soil
Contaminants of Concern	TCE
Time to Completion	40 years
Estimated Cost	$2–$3 million

Site Description

In general, the site geology consists of silt/clay underlain by sands and then bedrock at the bottom. The groundwater is approximately at 60 feet bgs. TCE was found at concentrations up to 2000 ppb in groundwater. The source was located above the water table. The FS for the site was in progress. The FS compared an in situ oxidation to in situ bioreactor approach and evaluated sustainability impacts using the AFCEE SRT.

GSR Metrics Considered

A GSR study was conducted as part of the FS for the site. All SRT metrics were considered with the exception of natural resources. These metrics include the following:

- GHG
- NO_x
- SO_x
- PM production
- energy use
- public and worker risk

GSR Recommendation(s)

The GSR evaluation showed that the in situ bioreactor provided a more sustainable remediation over the 40-year life cycle. For example, GHG production for the bioreactor was less than half the GHG production estimated for in situ oxidation. Worker and public risk potential was also higher for in situ oxidation.

GSR Practices or BMPs Implemented

A GSR assessment was conducted using the AFCEE SRT.

Challenges

None provided.

Lessons Learned

The GSR evaluation added a new dimension to the FS evaluation and confirmed that in situ bioremediation provides a safer and environmentally friendly remediation alternative. The FS recommendation for an in situ bioreactor was supported by the regulatory agency.

The GSR evaluation was easily rolled into the short-term effectiveness criteria of the FS document. The approach used was to provide a separate paragraph for each alternative describing SRT results. SRT information was visible but did not change the standard FS report format. The GSR evaluation was completed in less than a day once all the FS conceptual design information was available.

C.3.3 New Jersey Department of Environmental Protection Brownfields Site

Site Name	NJDEP Brownfields Site
Site Location	New Jersey
Contact Name	Maria D. Watt, P.E., CDM, 732-590-4659, wattmd@cdm.com Michael Burlingame, NJDEP, 609-292-1424, Michael.burlingame@DEP.state.nj.us
Regulatory Program	NJDEP
Affected Media	VOCs and chlorinated organic compounds
Contaminants of Concern	Groundwater, soil
Time to Completion	Not available
Estimated Cost	Not available

Site Description

An 85-acre municipal landfill is located within a 200-acre brownfield development area (BDA). The BDA consists of eight abandoned brownfield sites along 2 miles of the New Jersey shoreline along the Delaware River, overlooking the Philadelphia skyline and within a highly urbanized area of New Jersey. The municipality has received significant brownfields funding to stimulate redevelopment and revitalization. Redevelopment plans for this landfill include a state-of-the-art, 132,000-square-foot community center that will feature an atrium-style town plaza, a family service center, indoor and outdoor recreational facilities, an aquatic center, and a child care center, as well as community enrichment, job-training, and antipoverty programs. To meet the aggressive construction and redevelopment schedule, an expedited Triad approach was used to comprehensively delineate a contaminated industrial source area within this site.

The unlined landfill operated 1952–1971, when it was closed with a vegetative soil cover. The preliminary investigations revealed it contained mainly municipal solid waste. An area of industrial chemical waste material saturated with chlorobenzene (CB) and dichlorobenzenes

(DCB) was identified in the southeast portion of the landfill. This material is approximately 20–30 feet bgs and acts as a continuing source of groundwater contamination and localized soil vapor contamination.

Although operations at the landfill ceased in 1971, illegal dumping activities continued at the site through the 2000s. While evaluating the property for redevelopment in 2006, a source area of VOC contamination was identified in the southeast quadrant of the landfill.

Investigations at the site identified concentrations of benzene, CB, isomers of DCB (1,2-, 1,3-, 1,4-), and 1,2,4-trichlorobenzene above the state cleanup standards in both soil and groundwater. More specifically, it was identified that a grey-black clay layer situated below the waste fill was highly contaminated and was likely acting as the source of groundwater contamination in this area of the parcel.

An interim remedial measure (IRM) was performed to excavate the majority of the unsaturated source area from the landfill to expedite the redevelopment of the site and leverage grant funding currently available within a specified time frame. A Triad investigation was performed to expedite the comprehensive delineation of any residual source material remaining within the saturated zone. Additional IRMs were considered that included ISCO, in situ thermal remediation (ISTR), and MNA.

Site hydrology

The site is located in the New Jersey Coastal Plain and is underlain by the Potomac-Raritan-Magothy (PRM) aquifer system. The PRM aquifer system consists of three principal layers of fine to coarse sand and gravel separated by stiff clay layers 20–50 feet thick. The three sand/gravel layers are referred to as the lower, middle, and upper aquifers of the PRM system. At the site, only the middle and lower aquifers of the PRM are present, and in the hot spot area, only the middle aquifer of the PRM is contaminated. Depth to groundwater in the middle aquifer of the PRM in the source area ranges approximately 27–29 feet bgs, and groundwater flow is to the east-southeast.

The waste fill is 15–20 feet thick and consists of fine tan sand, black silt, lenses of clay, gravel, rocks, concrete, wood, roots, construction and demolition (C&D) debris, and municipal solid waste. The C&D debris includes pieces of brick, asphalt, cement, plastic, glass, paper, tires, drums, metal scraps, wood, and cinders. The municipal solid waste includes plastics (e.g., bags, bottles), glass bottles, cans, cardboard and paper, clothing, fabrics and rags, ceramic fragments, car metal fragments, wires, large rubber belts, and Styrofoam. The waste fill is underlain by 6–12 feet of dark grey to black medium plasticity clay/silty-clay. The clay has a hydraulic conductivity ranging from 2.0×10^{-6} to 7.7×10^{-8} cm/sec. Clay surface contouring suggests that the topography of the clay forms a "U" shape to the east of the excavated area, with highs to the northwest and southeast and an undulating trough running southwest to northeast.

The clay layer is underlain by the middle aquifer of the PRM, a light brown to gray fine to medium sand to silty-sand, with trace to some gravel. This unit is approximately 25 feet thick.

Beneath the middle aquifer of the PRM is a red fat clay layer with a very low hydraulic conductivity of 2.2×10^{-8} cm/sec extending about 55–97 feet bgs. The clay is underlain by the lower aquifer of the PRM, a light brown to gray fine to coarse sand with gravel, which extends to bedrock.

GSR Metrics Considered

Metrics included the following:

- pounds of contaminant removed
- kilowatt-hours of energy consumed
- metric tons of CO_2 equivalents generated
- metric tons of CO_2, NO_x, SO_x, and PM10 generated
- gallons of water consumed
- accident risk

An extensive community engagement process was developed to ensure that local community needs were met. An extensive waterfront master plan was developed that preserved bald eagle foraging areas, design spaces, and recreation amenities and provided safe gathering spaces, civic services, and employment opportunities as well as leveraged local investment.

A Triad investigation expedited the delineation of the residual source area and ensured that redevelopment could be initiated in a safe and sustainable manner. Three-dimensional visualization and modeling provided real-time graphic representation of data, optimizing the placement of sampling locations. All heavy equipment used biofuels to reduce GHG emissions during the characterization phase. Based on source investigations, redevelopment plans were revised to ensure exposure to the source area was mitigated by altering area-specific uses.

Remedial alternatives including excavation, ISTR, ISCO, and MNA were evaluated, and the carbon footprint of each alternative was calculated. To provide a comprehensive assessment of the tools used, a comparison of the two leading publically available tools (SRT and SiteWise) was developed for the ISTR alternative and is presented in the table on the next page.

GSR Recommendation(s)

Site cleanup decisions are likely to be heightened with improved community understanding and acceptance when cognition of community impacts and concerns become part of the holistic evaluation of cleanup remedies. This form of environmental justice policy is a primary example of how the sustainable components of cleanup can be attained through specific action items for regulatory staff. These items have the potential to become an extension of the investigative work guidance requirements.

SiteWise output for in situ thermal remediation

Activities	GHG emissions (metric tons)	Total energy used (millions BTUs)	Water consumption (gallons)	NO_x emissions (metric tons)	SO_x emissions (metric tons)	PM10 emissions (metric tons)	Accident risk fatality	Accident risk injury
Consumables	108.18	1.00E+03	NA	NA	NA	NA	NA	NA
Transportation-personnel	19.35	2.20E+02	NA	3.30E+01	6.90E+00	1.60E+00	1.20E-04	8.30E-03
Transportation-equipment	0	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Equipment use and miscellaneous	2856.43	5.70E+04	2.80E+06	4.10E+00	1.90E+01	9.90E-04	1.60E-05	7.00E-03
Residual handling	0.71	1.70E+01	NA	7.60E-04	1.80E-04	1.10E-04	1.90E-06	3.90E-04
Totals	2984.67	5.81E+04	2.80E+06	3.69E+01	2.63E+01	1.57E+00	1.38E-04	1.56E-02

GSR Practices or BMPs Implemented

A GSR assessment was performed and integrated in to all phases of this project, originating from the planning and redevelopment, through site characterization and remedy selection, design, and construction. The green and sustainable elements that were considered during this project include the following:

- significant community outreach and planning for site redevelopment
- Triad investigation to expedite source delineation
- biofuel usage for all on-site heavy equipment
- environmental footprint analysis to compare remedial alternatives
- environmental footprint tool comparison analysis between SiteWise and SRT

There were numerous benefits from holistically considering the social, economic and environmental factors of the “triple bottom line” in the remediation of an impacted site.

From a social perspective, the following benefits were achieved:

- Redevelopment and reuse of an otherwise impacted and stagnant property, which is consistent with smart growth principals developed to reduce urban sprawl.
- Strengthened community institutions and catalyzed neighborhood revitalization.
- A state-of-the-art, 132,000-square-foot community center is currently under construction.
- A family service center, indoor and outdoor recreational facilities, an aquatic center, and a child care center will provide the needed civic services to spur community enrichment.
- Redevelopment plans were modified based on the expedited source area delineation to prevent potential exposure.

From an economic perspective, the following benefits were achieved:

- Redevelopment within this urban blighted area will generate local jobs and increase the prosperity of the local community.
- Reduction in poverty, building of assets, and contribution to the local economy by providing a stable source of jobs and income.
- An increase in local wages and the tax base will support the growth of the local government and governmental services and may leverage local investment in future economic development and prosperity.

From an environmental perspective, the following benefits were achieved:

- Triad expedited the complete delineation optimizing the design of the integrated remedial strategy and reducing project uncertainty and provided comprehensive site data on an expedited basis to accurately evaluate remedial alternatives in a cost-effective manner.
- Generation of waste was significantly reduced by implementing GSR principles.
- The remedial approach was dovetailed into the redevelopment plans to ensure that source areas were addressed in a timely fashion. To expedite redevelopment and treatment, objectives were aligned with future uses of each area within the redevelopment plans.
- A greater than 50% reduction in project carbon footprint was realized through an integrated remedial approach.
- A greater than 30% reduction was realized in characterization and remediation project schedules.
- The impacts to ecological habitat and wetland areas were minimized and areas were restored.

Challenges

None provided.

Lessons Learned

The following lessons were recognized on completion of this GSR evaluation:

- Upfront community engagement and involvement are critical in determining local community needs and desires and facilitate support for redevelopment project.

- Concurrent remedial and redevelopment activities allow synergies in redevelopment planning and remedial strategy development to provide a cost-effective remedial solution that not only is protective of human health and the environment but meets the social and economic needs of the local community.

- The Triad approach reduced project uncertainty and expedited the characterization of the source area facilitating the execution of the remedial approach and redevelopment of the property.

- The following factors significantly impacted the carbon footprint of a remedial alternative:
  - ISCO: Supply chain considerations in manufacturing of oxidant can have a significant impact on carbon footprint. The use of green oxidants would significantly reduce the carbon footprint.
  - ISTR: Direct on-site emissions from fuel usage were the significant driver in the overall carbon footprint. Thus, renewable energy or renewable energy credits would assist in reduction of the overall carbon footprint.
  - Excavation: Indirect off-site transportation was the significant contributor to the carbon footprint. Thus, location of disposal site is a major consideration in lowering the carbon footprint.
  - MNA: Even though this alternative has the lowest carbon footprint, monitoring well sampling was the major contributor to carbon footprint. Using passive sampling techniques would further reduce the carbon footprint of this alternative

- The SRT and SiteWise results were comparable. SRT did not require extensive design information for input parameters and is better used prior to the development of detailed alternatives. However, as a technology-based model, SRT does not allow for significant flexibility in modeling an integrated remedial approach or site-specific complexities. As an activity-based model, SiteWise allows the accurate assessment of an integrated remedial approach that may include several different technologies. Even though more design data are necessary for SiteWise, it better assesses a complex integrated remedial strategy. Also, SiteWise output tables and graphs allow the user to readily determine the significant drivers in the carbon footprint, which facilitates the optimization of the remedial approach with respect to minimizing sustainable impacts.

C.3.4 U.S. Environmental Protection Agency Superfund Region 4

Site Name	Cabot Carbon/Koppers Superfund Site
Site Location	Gainesville, Florida
Contact Name	Jessica Gattenby, ARCADIS, U.S., 267-685-1851, Jessica.Gattenby@arcadis-us.com Alexis Troschinetz, ARCADIS, U.S., 612-373-0245, Alexis.Troschinetz@arcadis-us.com
Regulatory Program	RCRA Superfund, EPA Region 4
Affected Media	Groundwater, soil
Contaminants of Concern	Phenols, polyaromatic hydrocarbons, arsenic, chromium, dioxins, furans
Time to Completion	Not applicable
Estimated Cost	Not applicable

Site Description

The site has operated as a wood-treating facility for more than 90 years and is still in operation. The Cabot Carbon/Koppers site was proposed for the NPL in September 1983 and listed as final

in September 1984. Several remedial technologies were evaluated as components of the final remedial alternatives, including the following:

- no action
- hydraulic containment
- passive dense, nonaqueous-phase liquid (DNAPL) extraction
- excavation
- slurry wall
- cover
- in situ solidification/stabilization (ISS/S)
- ISCO

The following remedial alternatives were compiled and evaluated in terms of GSR impact. For each remedial alternative, the estimated time frame for O&M and projected costs were compiled, as described below.

Site remediation system	Proposed lifetime (years)	Projected cost ($ millions)
1. No action	---	---
2. Continue current actions • Hydraulic containment • Passive DNAPL extraction	>30	7.31
3A. Surficial aquifer excavation • Excavation to 25 feet • Slurry wall to 65 feet • Cover	5 (3 for active remedy)	66.10
3B. Excavation to the Hawthorn Group middle clay unit • Excavation to 65 feet • Slurry wall to 65 feet • Cover	5	172.55
4A. ISS/S to the Hawthorn Group middle clay unit • ISS/S to 65 feet • Cover • Storm-water monitoring	5	96.95
4B. ISS/S to the Hawthorn Group upper clay unit and in situ biogeochemical stabilization (ISBS) in the Upper Hawthorn • ISS/S to 25 feet • ISCO to 65 feet • Cover	5 (2 for active remedy)	57.60
5A. Vertical flow barrier • Slurry wall to 65 feet • Cover • Hydraulic containment • Passive DNAPL extraction	30 (3 for slurry wall and cover)	19.30

Site remediation system	Proposed lifetime (years)	Projected cost ($ millions)
5B. Vertical flow barrier with ISBS in the Upper Hawthorn • Slurry wall to 65 feet • ISCO 35–65 feet • Covers • Hydraulic containment	30 (3 for active remedy, 30 for hydraulic containment)	36.82
5C. Vertical flow barrier with ISBS in the surficial aquifer • Slurry wall to 65 feet • ISCO 0–25 feet • Covers • Hydraulic containment • Passive DNAPL extraction	30 (3 for active remedy, (30 for passive DNAPL extraction)	25.20
5D. Vertical flow barrier with ISS/S in the surficial aquifer • Slurry wall to 65 feet • ISS/S 0–25 feet • Covers • Hydraulic containment • Passive DNAPL extraction	30 (3 for active remedy, 30 for passive DNAPL extraction)	46.42

GSR Metrics Considered

Several green remediation metrics were evaluated:

- energy use
- air emissions
- water use and impacts
- land and ecosystem impacts
- material consumption
- waste generation

Other balancing criteria were also evaluated, including the following:

- health and safety considerations
- an assessment of the community impacts
- other social and economic implications of the remedial alternatives

Life-cycle costs were incorporated into the proprietary GSR tool but were not used as a metric for this site.

GSR Recommendation(s)

The GSR evaluation predicted the following metrics for each remedial alternative:

Alternative number	Energy (millions kilowatt-hours)	GHG emissions (metric tons CO_2 equivalent)	Water (millions gallons)	Land impacts (acres)	Materials and waste generation (millions cubic feet)	Health and safety (1–10 scale)	Stewardship (1–10 scale)
1	--	--	--	--	--	--	--
2	2.05	3.9	647	1	87	4.3	2
3A	3.26	1,414	136	31	124	2.6	1.4
3B	6.41	4,038	175	49	36	5.5	2.7
4A	5.23	1,246	133	31	23	3.2	1.4
4B	3.61	851	112	31	8	3	1.3
5A	2.28	1,554	35	39	108	2	2.7
5B	2.75	1,665	38	39	109	2.5	2.6
5C	2.38	1,577	36	39	108	2	2.6
5D	3.61	1,926	37	39	108	2	2.7

Health and safety of site workers evaluates the inherent risks associated with site location, working conditions, and remediation activities. Risks associated with site location include geography-dependent hazards, such as those associated with weather, flora, and fauna. Working condition risks consider the site layout and the dangers of doing the work (e.g., work at high heights or near water bodies). There are inherent risks associated with any remediation activity. Some of these risks are similar among varying remedial approaches for a given site (e.g., potential injuries during construction activities and exposure to COCs), and some risks differ greatly depending on the remedial approach (e.g., reagent storage and handling for chemical oxidation in situ remediation versus decalcification maintenance of an air stripper in a pump-and-treat system).

Stewardship is the reflection of project impacts on the short- and long-term sustainability of a surrounding community, the ecosystem, and the local economy. The social element of sustainability includes involving the local community as a stakeholder in the decision making and considering quality-of-life issues, such as noise, lighting, and traffic impacts on the community. Hiring a local workforce and purchasing from local businesses provides economic stimulus to the local community. Stewardship incorporates the environmental element by considering emissions of gases with global climate change potential and use of renewable forms of energy.

GSR results were reviewed by EPA Region 4 and taken into consideration when selecting the final remedy. A remedy that was most similar to RA #4B was selected for implementation. The selected remedy also included a vertical flow barrier wall (an element of Alternatives 3A and the 5 series), a low-permeability cap (not included in any of the original alternatives), and chemical oxidation injection wells (included as a contingency in all of the original alternatives and therefore not included in the GSR comparison of alternatives assessment).

GSR Practices or BMPs Implemented

A formal GSR assessment was performed to estimate the relative impact of each remedial alternative on GSR metrics. The GSR assessment considered GSR impacts of materials used on site as well as GSR impacts associated with transporting materials to the site. The GSR analysis was conducted using a proprietary GSR tool which is a quantitative, web-based tool used to evaluate different GSR approaches and incorporate them in remedy evaluation, selection, and design on a site-specific or portfolio-wide basis.

Challenges

Many of the stewardship considerations are decided on a project basis, not necessarily on a remedy alternative basis. Therefore, it was challenging to see stark differences among remedy alternatives for stewardship.

Lessons Learned

The GSR analysis results also indicate that the selected remedy was a relatively safer remedy for site workers when compared to the other alternatives. The GSR analysis also demonstrated that the project as a whole scored well for stewardship (all alternatives have low values on its scale of 1–10). Remedial selection for this site included participation from an array of stakeholders, and therefore the project coordinators' attention to stewardship topics were heightened.

Appendix E

SURF Metrics Toolbox – Remedial Investigation

SURF Metrics Toolbox – Remedial Investigation

Parameter	Objective	Metrics	QN, QL	EN, S, EC	Data Source(s)*	Implementation Guidance and Comments	External Benefits	Challenges
Element: **Sampling Plan**								
Site and source characterization	Characterize site and source areas efficiently.	Number of samples collected, number of resampling events, and completion time	QN	EC	Sampling cost, project tracking sheet, and project schedule	Design sampling plan to ensure that appropriate media are addressed. Consider including field screening and step-out sampling. Select sampling equipment that facilitates sampling and analysis plan implementation. Consider future use to ensure that initial media and exposures are address and conceptual site model is confirmed.	--	Because the initial cost for sampling may be higher, a cost-benefit analysis may be required to show a reduction in overall project costs. Step out samples with single mobilization requires prior regulator buy-in.
		Regulatory stakeholder satisfaction	QL	EN	Stakeholder survey and number of regulatory orders, complaints, and correction letters	Review sampling logic and data quality objectives with regulators and stakeholders. Discuss future use with regulators and stakeholders.	--	Determining future land use may be an iterative process and, initially, longer if sampling is needed to determine the potential future use options. However, this effort may streamline future discussions.
Sampling event	Implement sampling event efficiently.	Energy use	QN	EC	Fuel cost accounting	Track energy costs for each field task.	--	Determining the degree of energy reduction requires baseline data which may be difficult to quantify.
		Environmental impacts**	QN	EN	Fuel use data, emissions estimate, and mass of waste	Track effect of scope change, if any.	--	The sampling plan must first meet data quality objectives and then the efficiencies of impacts can be explored.
		Reduced personnel exposure and costs	QN	S, EC	Project costs and exposure hours	--	--	--
Mobilization	Reduce number of mobilizations.	Air emissions	QN	EN	Project records, utility use, and fuel use	Use carbon / energy model to calculate carbon emissions. Consider the impacts of off-site stationary vs. mobile (with footprint) laboratory and impact on operational efficiency. Track mobilization impacts as sampling plan revisions evolve to quantify improvements from the initial (i.e., baseline) plan.	Increases operational efficiency (EC).	The sampling and analysis plan should identify opportunities for reduced mobilizations. However, it must first meet data quality objectives before the efficiencies of impacts can be explored.
		Cost of mobilizations	QN	EC	Cost accounting	--		

Notes:
* Data sources in this table support predictive sustainability analyses conducted before remedial implementation. SURF is developing guides for post-implementation assessments (www.sustainableremediation.org/library/guidance-tools-and-other-resources) to support evaluation of in-place remedies and scoping of bid documents, technical specifications, and operation and maintenance plans to ensure that necessary data are collected for future evaluation.
** Environmental impacts: air emissions (global warming potential, nitrogen oxides, sulfur oxides, particulate matter, toxics), water demand, and waste generation
QN = quantitative S = social
QL = qualitative EC = economic
EN = environmental

SURF Metrics Toolbox – Remedial Investigation

Parameter	Objective	Metrics	QN, QL	EN, S, EC	Data Source(s)*	Implementation Guidance and Comments	External Benefits	Challenges
	Reduce travel footprint.	Automobile and airline miles	QN	EC	--	Balance operational efficiency and cost of using local contractor and staff.		
		Air emissions and energy use	QN	EN	Fuel use data emissions estimate	Consider the impact of vehicle choice on air emissions and energy. Use carbon/energy model.		
		Use of public transportation or carpool	QN	EN	Field staff survey	Reduce carbon footprint through use of alternative transportation. Minimize number of field staff.	Reduces greenhouse gas emissions (EN).	Determining the availability of public transportation or coordinating carpooling prior to mobilization requires time to inform field staff and resources.
		Travel and fuel costs	QN	EC	Costs associated with travel	Track cost as sampling plan revisions evolve to quantify improvements from the initial (i.e., baseline) plan.	--	--
Local labor pool	Increase use of local labor.	Number of staff and commuting mileage	QN	EC	Employee data and staff pay per diem	Increase local economy through additional jobs.	Reduces energy use (EN, EC) and per diem costs of industry service providers (EC). Minimize environmental impacts of field staff (EN).	Utilizing the local labor pool could be counter-productive (e.g., lack of necessary technical knowledge or health and safety capabilities).
			QL	S	Employee surveys	Increase community satisfaction	Increased awareness regarding safety due to employee getting more rest.	
Element: Investigation-Derived Waste								
Investigation-derived waste generation	Minimize waste generation.	Total waste mass	QN	EN	Manifest data and weight of solid nonhazardous wastes	Balance the costs of and time needed to weigh, segregate, and characterize nonhazardous waste with the impact on the total waste stream.	Reduces trucking emissions (EN), costs (EC), community traffic (S), local trucking labor (S), and amount of waste disposed of in landfill (EC). Increases landfill longevity (EN, S).	Small waste quantities (e.g., laboratory) may not be captured when considering waste mass only.
	Reduce off-site disposal of purge water.	Quantity of purge water disposed off-site	QN	EN	Purge water volume	Address the potential for the reinjection of purge water in the sampling plan if appropriate. Use no-purge (passive diffusion bag) or very low purge (BarCad-type) samplers.	Reduce time on-site and the use of pumps or bailers to purge wells.	Some regulations may not permit purge water reinjection without early consensus from regulators. Some regulatory agencies may require demonstration that equivalent samples can be obtained with alternative techniques. May require more mobilizations to the site.

Notes:
* Data sources in this table support predictive sustainability analyses conducted before remedial implementation. SURF is developing guides for post-implementation assessments (www.sustainableremediation.org/library/guidance-tools-and-other-resources) to support evaluation of in-place remedies and scoping of bid documents, technical specifications, and operation and maintenance plans to ensure that necessary data are collected for future evaluation.
** Environmental impacts: air emissions (global warming potential, nitrogen oxides, sulfur oxides, particulate matter, toxics), water demand, and waste generation
QN = quantitative S = social
QL = qualitative EC = economic
EN = environmental

SURF Metrics Toolbox – Remedial Investigation

Parameter	Objective	Metrics	QN, QL	EN, S, EC	Data Source(s)*	Implementation Guidance and Comments	External Benefits	Challenges
	Recycle waste.	Total recycle mass	QN	EN	Recycle receipt and collected data	Weigh recycled wastes.	Reduces waste disposed of in landfill (EC). Increases landfill longevity (EN, S). Mitigates use of raw materials for manufacturing (EN, S, EC).	--
	Reuse products and materials.	Use of reusable materials (e.g., reusable overalls)	QL	EN	Identification of items used	Consider maintaining an inventory of reusable products and materials in lieu of disposable items. Determine the energy used to produce disposable products and materials vs. the energy needed to clean reusable items.	Reduces trucking emissions (EN), costs (EC), community traffic (S), local trucking labor (S), waste disposed of in landfill (EC). Increases landfill longevity (EN, S). Mitigates the use of raw materials for manufacturing (EN, S, EC).	The benefits or "costs" of using disposable products and materials must be balanced those associated with reusable items.
			QN	EC	Purchase cost, disposal cost, and cleaning cost	Balance cost of cleaning used materials and products with cost of purchasing new materials and products and disposing of used items.		Decontamination (if necessary) may be difficult or costly. Simple cost comparisons may not include disposal costs.
Element: **Local Community Impacts and Community Involvement**								
Communication and outreach	Increase community involvement and knowledge.	Community contacts and/or meetings, publications, direct contacts, complaints, and community survey	QN, QL	S	Community survey results and communication logs	--	Increases community satisfaction through outreach and involvement (S).	Communication and outreach efforts may increase short-term schedule and costs; however, long-term benefits include early buy-in and/or consensus on future use and remedial action.
Public health	Reduce health concerns	Dust mitigation and air monitoring results	QN	EN	Field data	--	--	--
Physical disturbances and disruptions	Minimize road closures, noise, traffic, and light pollution.	Road closures, complaints, and noise mitigation measures	QN, QL	EN, S	Field data	Document number and length of road closures; number of complaints; and noise, monitoring, and mitigation measures employed.	Supports social/community values (S).	Noise and odor are difficult to quantify.

Notes:
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** Environmental impacts: air emissions (global warming potential, nitrogen oxides, sulfur oxides, particulate matter, toxics), water demand, and waste generation
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Appendix F

SURF Metrics Toolbox – Remedial Selection

SURF Metrics Toolbox – Remedy Selection

Parameter	Objective	Metrics	QN, QL	EN, S, EC	Data Source(s)*	Implementation Guidance and Comments	External Benefits	Challenges
Element: **Alternatives Analysis**								
Consumables	Select minimum-essential materials.	Environmental impacts**	QN	EN, EC	Conceptual design estimate, experience, and estimation resources	Because consumables are often a significant contributor to impacts, include life-cycle impacts from raw materials, manufacturing, energy, and transportation.	Incrementally reduces generation (EN, EC).	Emission factors may not be available for all consumables.
	Select minimum-essential transportation options.	Air emissions and worker hours	QN	EN, S		Use transport distance to estimate energy and worker hours.	Incrementally reduces generation (EN, EC).	Shipment distances can be difficult to predict.
	Select minimum-essential energy needs.	Energy use	QN	EN		Evaluate the availability of alternate energy sources and more detailed evaluation in design phase.	Enhances demand for alternate energy sources (EN, S, EC).	--
Physical disturbances and disruptions	Minimize traffic, odor, and noise.	Vehicle trips and volatile organic compound emissions	QN, QL	S	Conceptual estimate of deliveries and solid waste disposal volume	Model volatile organic compound emission estimates.	Supports social/community values (S).	Noise and odor are difficult to quantify.
Land stagnation	Maximize future land use and area.	Type of future use and area	QN	S, EC	Remedial objectives	Match with local planning.	Enhances community integrity, quality of life, and local economy (S).	--
	Minimize timing to achieve future use.	Time to achieve future use			Conceptual design, experience	--	Serves as catalyst for cohesive development (EC).	--
Air impacts	Minimize air emissions.	Air emissions	QN	EN, S	Conceptual design scope, experience, and estimation of resources	Determine on-site and off-site transportation electricity and fuel consumption, and compare to more efficient transportation (e.g., rail, larger trucks)	Incrementally reduces emissions (EN).	Determining air emissions from offsite power generation (hydroelectric versus coal versus nuclear)
Water impacts	Select minimum-essential water use and discharge.	Volume, biochemical oxygen demand, suspended solids, and toxicity	QN	EN	Conceptual design estimate and experience	Reuse water on-site as permissible to reduce potable water demand. Identify water efficiencies for design, construction, and operations and maintenance.	Makes water available for other, more productive uses (S). Reduces energy used for municipal water treatment prior to use (EN, EC).	Treatability tests are may be needed to refine impacts.

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Parameter	Objective	Metrics	QN, QL	EN, S, EC	Data Source(s)*	Implementation Guidance and Comments	External Benefits	Challenges
Solid waste	Maximize recycle and reuse waste.	Total recycle mass	QN	EN	Waste characterization data.	Identify opportunities for on-site soil reuse or off-site material recycle. .	Incrementally reduces waste generation (EN, S).	Additional time may be required to determine amount of recycled materials.
	Minimize off-site disposal.	Air emissions and highway miles	QN	EC, EN	Conceptual design estimates and waste disposal options, including transport.	--	Minimizes impact to the community near the receiving landfills (S).	Impacts due to construction and operation of the disposal facility are difficult to predict.
Job creation	Align with community land use and re-development.	Space available for commercial development or recreation	QN	S, EC	Economic development plan, economic and/or marketing analysis	Alternatively, use area as predictor for benefit.	Supports local economic growth and job creation (S, EC).	Predicting job creation and quality of life from future use acreage can be difficult.
Remediation labor	Determine minimum-essential labor.	Occupational exposure hours	QN	S	Conceptual design estimate	Reduce the potential for unsafe acts and conditions by increased safety focus and tools in the design and construction phases.	--	Additional training, communication, and a potential shift in safety cultures are necessary (e.g., focus on behavior-based safety).

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Appendix G

SURF Metrics Toolbox – Remedial Design

SURF Metrics Toolbox – Remedial Design

Parameter	Objective	Metrics	QN, QL	EN, S, EC	Data Source(s)*	Implementation Guidance and Comments	External Benefits	Challenges
Element: **Conceptual Design (including pre-design activities)**								
Remedial technologies	Optimize treatment (e.g., wells, injection points, treatment chemicals).	Environmental impacts** and energy usage	QN	EN, S, EC	Design plan	Consider including facility-wide footprint, waste generation and water discharge, number of mobilizations, equipment sizing, site plan, and infrastructure. Identify opportunities to specify recycled materials, reuse materials on-site, or recycle wastes at off-site facility. Consider an on-site weigh station. Develop an adaptive design to reduce footprint, power, and labor as remediation progresses.	Reduces water use (EN, S), energy consumption (EN), vehicle emissions (EN), costs (EC), waste required to be disposed of in landfill (EN, S), and demand for virgin materials (S) and associated production impacts (EN). Increases operational efficiency (EC) and landfill longevity (EN, S).	--
		Cost	QN	EC	Cost estimates			--
		Material use	QN	EN, S, EC	Design plan			Nontraditional materials may increase project costs and be difficult to source.
	Minimize land use for remediation life cycle.	Area	QL	S	Design plan	Minimize impact to and include restoration of the potential loss of land function, loss of aesthetic value, or inconvenience to the community.	Integrates with future long-term use (S).	The size of the remediation site and other site users (including at-risk populations or protected wetlands) may dictate placement and staging areas.
	Minimize toxic emissions to air and/or water.	Contaminant emissions	QN	EN	Emissions estimate	Optimize system design and move to less energy-intensive processes as remediation progresses (i.e., move to monitored natural attenuation or replace vapor incineration with activated carbon).	Provides long-term contaminant control (EN). Reduces local discharge of contaminants (EN).	The benefits or "costs" of the alternative technology must be balanced against the advantages and disadvantages of the incumbent technology.
	Design to minimize community impacts.	Noise, traffic, and odor	QN	S	Design plan	--	Reduces long-term negative effects on the community (S).	--
Future use	Maximize future land use and area.	Type of future use and area	QL	EN, S, EC	Design plan and remedial action objectives	Match with local planning. Identify future use and needed covenants with stakeholders early in design process.	Maintains focus on future use and stakeholder expectations (S, EC).	Long-term use may not be established at the remedial design phase.
	Increase local jobs.	Jobs created or maintained	QN	S, EC	Local planning agency	Consult local planning boards for estimates of job creation resulting from re-development.	Promotes stronger local communities (S, EC).	Estimates can be difficult to obtain.

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SURF Metrics Toolbox – Remedial Design

Parameter	Objective	Metrics	QN, QL	EN, S, EC	Data Source(s)*	Implementation Guidance and Comments	External Benefits	Challenges
Pre-design activities	Consolidate and minimize mobilization and on-site field tasks, resources, equipment, and materials.	Environmental impacts**	QN	EN	Fieldwork scope estimate, experience, and estimation of resources	When possible, build field screening, flexible (step-out) sampling protocol, and on-site laboratories into scope; and use direct push rather than rotary drill for well installation. If possible, locate pre-design well locations where useful in subsequent remedy actions.	Reduces vehicle emissions (EN), costs (EC), and traffic through the community (S).	Some regulations may not permit on-site laboratories without early consensus from regulators.
		Transport mileage	QN	EC				
		Materials consumed	QN	EN	Mass of materials used	Select the most appropriate materials for well installation. Specify reusable equipment that can be decontaminated. Include recycled materials in specifications and bid documents.	Reduces demand for virgin materials (S) and associated production impacts (EN).	Variances from traditional construction methods and materials may increase project costs.
		Waste generated	QN	EN	Waste manifests	Reduce or eliminate waste spoils generated during well installation. Use in-situ treatment technologies. When possible, use low-flow or passive groundwater sampling techniques to avoid purge water generation. Field screen or analyze to minimize treatment and/or disposal. Segregate waste to minimize hazardous waste quantities.	Reduces waste required to be disposed of into landfill (EC) and off-site energy, air, and water emissions related to waste treatment (EN). Increases landfill longevity (EN, S).	Nontraditional sampling methodologies and waste handling and disposal methodologies may require early consensus from regulators.
Element: **Construction Material Specifications**								
Material selection	Design for minimum-essential materials of construction.	Environmental impacts** and energy	QN	EN, S, EC	Design plan, manufacturer bid, cut sheets, or manufacturer information	Consider material durability and replacement rate for project life cycle, local availability of materials, materials manufacturing, and renewable resources.	Reduces long-term operations and maintenance costs (EC) and material costs, including off-site energy, air, and water requirements for manufacturing (EC).	Because the initial cost for durable materials may be higher, a cost-benefit analysis may be required to show a reduction in overall project costs.
	Use recyclable, renewable, and/or reusable materials.	Percent recyclable, renewable, or reusable	QN	EN, S	Design plan, manufacturer bid, cut sheets, or manufacturer information	Include recycled materials in specifications.	Reduces waste being disposed of in landfill (EC); the demand for virgin material (S); and air, water, waste, and energy emissions associated with manufacturing processes (EN). Increases landfill longevity (EN, S).	Nontraditional materials and new material sources may increase project costs.
	Optimize materials transport and source.	Air emissions, fuel usage	QN	EN, S	Design plan	Consider locally available materials.	Creates local jobs (S).	Local materials may not be available or of sufficient quality.

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SURF Metrics Toolbox – Remedial Design

Parameter	Objective	Metrics	QN, QL	EN, S, EC	Data Source(s)*	Implementation Guidance and Comments	External Benefits	Challenges
	Minimize the toxicity of the construction materials.	Toxic emissions and human, marine, and freshwater toxicity potential	QL	EN	Third party certification, material safety data sheets, manufacturer information	Specify materials that minimize off-gas emissions during the remedial construction phase. Control potential health impacts to on-site workers during implementation, and provide additional air monitoring as necessary.	--	Alternative materials may increase project costs.
Element: **Energy Mix (on-site vs. off-site power)**								
On-site renewable energy	Identify opportunities for on-site renewable energy.	Environmental impacts**	QN	EN	Design plan	Evaluate feasibility of on-site energy generation equipment and infrastructure (e.g., solar, wind) and "green" energy where practicable.	Reduces load to local utility (S) and air and water emissions at the electrical generation plant (EN) and transmission line infrastructure and associated impacts (EN,EC).	Alternative energy may increase project costs.
		Cost	QN	EC	Cost estimates	Evaluate local government and utility incentive programs to defer initial costs.	Reduces local electrical grid usage (S) and improves power mix (S).	--
		Area required for on-site energy	QL	S	Community survey	Include loss of land use and community visibility.	Aligns with community interests (S).	--
	Purchase carbon offsets.	Global warming potential	QN	EN	Design plan	Include carbon offsets in cost estimates.	Directly benefits the off-site location where the offset program is purchased and implemented (S).	Offsets are a direct project cost with no direct economic return.
Element: **Value Engineering**								
Design plan	Optimize design and synergies.	Design metrics	QN, QL	EN, S, EC	Design plan, specifications, and schedule	Include sustainability metrics in the value engineering process.	Improves project team collaboration.	The flexibility to optimize may be limited by regulatory decisions.

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