The Rise and Future of Green and Sustainable Remediation

Prepared by The Horinko Group

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FORWARD

At the advent of our nation's cleanup programs, the U.S. was tackling serious and daunting risks: Valley of the Drums; leaking municipal landfills; acid mine drainage; and waterways marred by the visible sheen of oil. In response, the U.S. Congress and the states enacted a number of laws that enabled the remediation of these contaminated properties. Many of the techniques employed in the early years of implementing these laws were often invasive and resource intensive. Mass removal of soil and sediments, long-term extraction and treatment of groundwater, and treatment by means of incineration were common elements of any cleanup.

Like medical science, however, our remedies have matured and become more sensitive to the needs of the "patient"—the environment that we are treating. We have found that much more surgical removal techniques, combined with innovative *in situ* treatment may be better than complete excavation. Construction of near-shore confined disposal facilities for dewatered sediments can prevent greenhouse gas emissions caused by long-term off-site transportation. Most importantly, considering near and long-term community impacts of the remediation leads to cleanups where the future of the ecosystem—including the cleanup and its neighbors—are much more socially and economically successful.

The U.S. is fortunate to have pioneered the environmental remediation of contaminated sites. Now, as we enter our third decade, we are poised to share our experience with the global community. Even more critically, we are prepared to lead by example as the economy recovers, in part due to a resurgence in our manufacturing base and enhanced domestic energy supplies. Our nation has always excelled at technical innovation and our ability to work collectively for the greater good. Green and Sustainable Remediation (GSR) is the perfect example of that innovation and collaboration leading to better results for our environment and our culture.

Our hope is that this white paper will spur practitioners and policymakers to consider GSR practices in all of our efforts to repurpose and enhance our lands.

Marianne L. Horinko
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ABOUT THE HORINKO GROUP

The Horinko Group is an environmental consulting firm operating at the intersection of policy, science, and communications. Founded in 2008, our firm has established itself as an innovator and a trusted, third-party convener. We have a proven track record of addressing complex natural resource challenges, while meeting the needs of the broader community.

The Horinko Group advocates for efficiency, sustainability, and holistic solutions based on cutting-edge science and sound business practice. We work alongside federal, state, and local governments, NGOs, and the private sector to achieve measurable results for our clients, partners, and the communities and markets in which they operate. There are unique challenges and opportunities given the fiscal and regulatory uncertainty of these times. We assist all stakeholders in thinking strategically about these opportunities and capitalizing on the business advantages of sustainability.

ACRONYMS & ABBREVIATIONS

AFCEC (AFCEE)	Air Force Civil Engineering Center (formerly Air Force Center for Engineering and the Environment)
ALGA	Australasia Land and Groundwater Association
ARAR	Applicable, Relevant and Appropriate Requirements
ASTSWMO	Association of State and Territorial Solid Waste Management Officials
BDA	Brownfield Development Area
BMP	Best Management Practice
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
cDCE	Dichloroethylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CETESB	São Paulo Environmental Agency
CL:AIRE	Contaminated Land: Applications in Real Environments
CleanSWEEP	Clean Solar and Wind Energy in Environmental Programs
CLU-IN	Clean-Up Information
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide equivalent
COC	Contaminant of Concern
CRC CARE	Cooperative Research Centre for Contamination Assessment and Remediation of the Environment
CSGSS	Center for Sustainable Groundwater and Soil Solutions
CSGR-NET	Chinese Soil and Groundwater Remediation Network
CVOC	Chlorinated Volatile Organic Compound
CWA	Clean Water Act
DEC	Department of Environmental Conservation
DER	Division of Environmental Remediation
DER-31	NY Department of Environmental Conservation, Division of Environmental Remediation, Program Policy on Green Remediation
DNR	Department of Natural Resources
DOD	Department of Defense
DOE	Department of Energy
DTSC	Department of Toxic Substances Control
EO	Executive Order
EPA	Environmental Protection Agency
ER	Environmental Restoration
FUDS	Formerly Used Defense Sites
GHG	Greenhouse Gas
GR	Green Remediation
GREM	Green Remediation Evaluation Matrix
GSR	Green and Sustainable Remediation
HDPE	High-Density Polyethylene
HERA	Human and Environmental Risk Assessment
ISO	International Organization for Standardization
ITRC	Interstate Technology and Regulatory Council
LCA	Life-Cycle Assessment
LTM	Long-Term Monitoring
LUST	Leaking Underground Storage Tank
MassDEP	Massachusetts Department of Environmental Protection
MCLB	Marine Corps Logistics Base
MGP	Manufactured Gas Plant
MNA	Monitored Natural Attenuation
MOU	Memorandum of Understanding
MPCA	Minnesota Pollution Control Agency
NAVFAC	Naval Facilities Engineering Command
NCP	National Contingency Plan

NICOLE	Network for Industrially Contaminated Land in Europe
NJDEP	New Jersey Department of Environmental Protection
NO_2	Nitrogen Dioxide
OSRTI	Office of Superfund Remediation and Technology Innovation
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
P&T	Pump and Treat
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethylene
PCP	Pentachlorophenol
PTT	Performance Tracking Tool
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
ROD	Record of Decision
SEP	Supplemental Environmental Project
SO_2	Sulfur Dioxide
SR	Sustainable Remediation
SRNL	Savannah River National Laboratory
SRT™	Sustainable Remediation Tool
SURF	Sustainable Remediation Forum
TCE	Trichloroethylene
TSCA	Toxic Substances Control Act
USACE	United States Army Corps of Engineers
USAF	United States Air Force
USDA	United States Department of Agriculture
VC	Vinyl Chloride
VOC	Volatile Organic Compound
WDEQ	Wyoming Department of Environmental Quality
WISRR	Wisconsin Initiative for Sustainable Remediation and Redevelopment

INTRODUCTION

Traditionally, the technologies and practices used for remediation of contaminated sites in the United States are chosen based on health protection criteria, cost, efficacy, technical practicability, and regulatory acceptance.[1] In many cases, however, relying on established criteria and traditional cleanup approaches may overlook negative environmental externalities as well as beneficial opportunities for communities and economic growth.

Emerging recently is a movement to include net environmental and societal benefits as criteria for decision-making and site management practices of a remediation project. This concept, known as green or sustainable remediation, has been adopted and defined by many stakeholder organizations. Each definition is a slight variation on the following principle: green or sustainable remediation refers to decision-making during cleanups that minimizes the environmental footprint of a cleanup while meeting regulatory requirements and weighing community goals and cost. These decisions may influence actions and technologies at all phases of the cleanup and may relate to everything from management practices (e.g., recycling materials at the site or powering site operations with renewable energy), to the very nature of the cleanup technology, to planning for the sustainable long-term use of the site.

The rise and proliferation of green and sustainable remediation exemplifies the strength of innovation and collaboration to rethink the status quo and, in doing so, advance shared environmental and cultural goals.

Defining Green and Sustainable Remediation

There has been disagreement over the use of the terms "green" versus "sustainable" remediation. Depending on how the concept is defined, the metrics used to determine the remedial approach may vary; thus, the dialogue is an important one.

The U.S. Environmental Protection Agency (EPA) defines **Green Remediation** as: *The practice of considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprints of cleanup actions*.[2] Green remediation focuses mainly on the use of environmentally conscious practices throughout the cleanup process and typically relies on Best Management Practices (BMPs) to reduce the environmental impact of a remedial action.

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[1] U.S. Sustainable Remediation Forum (SURF), "Sustainable Remediation White Paper—Integrating Sustainable Principles, Practices, and Metrics Into Remediation Projects," Eds. P. Hadley and D. Ellis, *Remediation Journal,* 19(3), 2009, p. 11.
[2] U.S. Environmental Protection Agency (EPA), Office of Solid Waste and Emergency Response, "Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites," Apr 2008, p. 1.
[3] U.S. Sustainable Remediation Forum, "SURF Report—Summer 2013," SURF Newsletter, 4(3), 2013, p. 2.

The Sustainable Remediation Forum (SURF) defines Sustainable Remediation as: Remediation that protects human health and the environment while maximizing the environmental, social, and economic benefits throughout the project life cycle.3 As this definition suggests, sustainable remediation takes into account environmental, economic, and social impacts of remedial activities and goes beyond environmental stewardship during the cleanup, placing equal importance on site restoration and revitalization.

The Interstate Technology and Regulatory Council (ITRC) takes a somewhat different approach, defining the integrated concept of **Green and Sustainable Remediation (GSR)** as: *The site-specific employment of products, processes, technologies, and procedures that mitigate contaminant risk to receptors while making decisions that are cognizant of balancing community goals, economic impacts, and net environmental effects*.[4]

In order to comprehensively cover these concepts, this report will use the integrated concept of "Green and Sustainable Remediation" and will regularly refer to it as GSR.

Purpose Statement

This white paper aims to provide insight into the past development, current state, and future trajectory of GSR. The report is divided into four sections. The first summarizes the development of green and sustainable practices in the remediation field and includes a timeline of major milestones in the history of GSR. The second outlines the state of GSR today: the major actors, including federal and state agencies, partner organizations, and international groups, as well as current tools, best management practices, frameworks, guidance documents, and other resources available to various stakeholders working to implement and disseminate information about GSR. The third section investigates the benefits of and concerns about GSR. It includes a number of detailed case studies of remedial sites where GSR practices have been implemented. The fourth section will discuss the future of GSR in practice, examining challenges to implementation, strategies for incentivizing its use, and how these approaches fit within the existing regulatory framework.

This report is intended to serve as a tool and resource guide to stakeholders involved in all facets of GSR implementation, advocacy, policy development, or otherwise. It is intended to inform remediation stakeholders unfamiliar with GSR about the concept, practices, and available resources. As standards develop and the GSR concept matures, it is essential that the many organizations and stakeholders supporting GSR continue in coordination toward their shared goal. Thus this report serves to consolidate and summarize the many ongoing GSR efforts. Finally, in analyzing the advantages, concerns, challenges, and incentives surrounding GSR, it aims to complement current efforts to advance a greater and more widespread understanding of GSR.

[4] Interstate Technology & Regulatory Committee (ITRC), "Green and Sustainable Remediation: State of the Science and Practice," GSR-1, May 2011, p. 6.

I. HISTORY & DEVELOPMENT

GSR concepts took hold at various organizations and in the regulatory community in the U.S. around the early 2000s. Prior to this, efforts had been site specific and largely were a follow on to the application of life-cycle assessment[5] to remediation; a trend that originated in Ontario in 1998 when a life-cycle framework was developed for remediation for the Ontario Ministry of the Environment.[6] A group of remediation professionals who had been engaged in a similar rethinking of remediation processes came together to form the Sustainable Remediation Forum (SURF) in 2006, the first coalition dedicated specifically to sustainable remediation.[7] The 2009 SURF *Sustainable Remediation White Paper—Integrating Sustainable Principles, Practices, and Metrics Into Remediation Projects* was fundamental to a more formal establishment of GSR, as it aggregated and documented the various related efforts for the first time. Federal agencies, states, remediation companies, and consultants had been developing tools and resources for GSR based on successful examples of "greener" cleanups that had been previously undertaken. The establishment of SURF and publication of their white paper began to centralize some of these parallel but distinct efforts.

Figure 1: An innovative sustainable treatment method uses bioremediation and photolysis (sunlight) to treat surface water contaminated with pentachlorophenol (PCP) in Minnesota. Source: AECOM

Still, various organizations established implementation tools, BMPs, and framework documents, and the effort to provide guidance to the cleanup community was somewhat fragmented. In 2009, this began to shift with the commencement of the ASTM International process to develop a standard guide for GSR, a process launched at the request of EPA. The original task force for this effort included representatives from EPA, the Department of Energy, SURF, state and local governments, and industry.[8] The publishing of the first ASTM standard guides in 2013 does not represent the final stage in the evolution of GSR, but it promises to give direction to the GSR community, incorporating many elements and principles from previously published resources.

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[5] Life-cycle assessment (LCA) is an International Organization for Standardization (ISO) standard used to determine environmental and human health effects of products and services (ISO 14040). SURF, "Sustainable Remediation White Paper," p. 40.
[6] SURF, "Sustainable Remediation White Paper," p. 46.
[7] Ibid, p. 6.
[8] Adele Bassett, "Making Cleaner Greener," *ASTM Standardization News,* Mar/Apr 2010, http://www.astm.org/SNEWS/MA_2010/bassettgreen_ma10.html.

The rise of GSR has been and continues to be a story of forward thinking individuals and groups collaborating to positively influence a well-established industry at the ground level and at a policy level.

Timeline		
1980	**December**	EPA Superfund Program begins
1999	**June**	President Clinton issues Executive Order 13123
2006	**November**	SURF established
2007	**January**	President Bush issues Executive Order 13423
	October	ASTSWMO Sustainability Subcommittee creates Greener Cleanups Task Force
2008	**April**	EPA publishes Green Remediation Technical Primer
	September	EPA/State Greener Cleanup Standard Workgroup created
	December	EPA OSWER publishes first of its green remediation BMPs
2009	**Summer**	SURF publishes Sustainable Remediation White Paper
	August	EPA OSWER Assistant Administrator Mathy Stanislaus outlines his "Greener Cleanup Principles" in a policy message
	September	ASTM kick-off meeting
	October	President Obama issues Executive Order 13514
2010	**August**	New York State issues Program Policy on Green Remediation (DER-31)
	September	EPA publishes *Superfund Green Remediation Strategy*
2011	**May**	ITRC publishes overview document (GSR-1)
	November	ITRC publishes technical guidance document (GSR-2)
2012	**August**	President Obama issues Executive Order 13624
2013	**June**	ASTM publishes Sustainable Cleanup Standard Guide
	November	ASTM publishes Greener Cleanups Standard Guide
	December	EPA OSWER Assistant Administrator Stanislaus memo encourages use of ASTM Greener Cleanups Standard
		SURF publishes Groundwater Conservation White Paper

II. CURRENT ACTIVITIES & ACTORS

Green and sustainable remediation as a concept and a practice has involved a host of regulatory actors, both state and federal, as well as local governments, industry practitioners, environmental consultants, and standard-developing organizations. The following institutions are those most prominently involved with advancing GSR and demonstrate the numerous groups and forces that have acted in parallel and in tandem to influence the rise of GSR.

Federal Government

Executive Orders—Executive Orders (EOs) applicable to sustainability measures have provided support for GSR efforts and are often cited as reason to implement such efforts. The relevant EOs include:

- EO 13123 (June 3, 1999): *Greening the Government through Efficient Energy Management*—Set goals for the Federal Government for greenhouse gas reduction, energy efficiency improvement, industrial and laboratory facility energy consumption reduction, renewable energy projects, petroleum reduction, source energy reduction, and water conservation. Many of these goals would be applicable to federal agency remediation efforts.

- EO 13423 (January 24, 2007): *Strengthening Federal Environmental, Energy, and Transportation Management*—Requires that federal agencies conduct their environmental, transportation, and energy-related activities in an environmentally, economically, and fiscally sound, integrated, continuously improving, efficient, and sustainable manner.

- EO 13514 (October 5, 2009): *Federal Leadership in Environmental, Energy, and Economic Performance*—Requires federal agencies to:
  - Increase energy efficiency;
  - Measure, report, and reduce GHG emissions from direct and indirect sources;
  - Conserve and protect water resources through efficiency, reuse, and stormwater management;
  - Eliminate waste, recycle, and prevent pollution;
  - Leverage agency acquisitions to foster markets for sustainable technologies and environmentally preferable materials, products, and services;
  - Design, construct, maintain, and operate high performance buildings in sustainable locations; and
  - Strengthen vitality and livability of communities where federal facilities are located.

  EO 13514 applies to the operations of the federal government and thereby to federally operated or funded remediation projects and programs. It also specifies that, "'sustainability' and 'sustainable' mean to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations."[9]

- EO 13624 (August 30, 2012): *Accelerating Investment in Industrial Energy Efficiency*—Requires a number of federal agencies (including DOE, USDA, EPA and others) to coordinate policies to encourage investment in industrial efficiency.

[9] Executive Order 13514, "Federal Leadership in Environmental, Energy, and Economic Performance," 5 Oct 2009, §19(l), http://www.gpo.gov/fdsys/pkg/FR-2009-10-08/pdf/E9-24518.pdf.

U.S. Environmental Protection Agency (EPA)—EPA has been an essential driver in the development and proliferation of "Green Remediation" practices. Green Remediation has been recognized by the Agency and is referred to as part of EPA's Strategic Plan for 2011-2015.[10]

The Office of Solid Waste and Emergency Response (OSWER) and especially its subsidiary Office of Superfund Remediation and Technology Innovation (OSRTI), which manages the Superfund program, are the primary EPA Offices involved. In an August 2009 policy, OSWER Assistant Administrator Mathy Stanislaus introduced EPA's *Principles for Greener Cleanups* and announced that, "OSWER's goal is to evaluate cleanup actions comprehensively to ensure protection of human health and the environment and to reduce the environmental footprint of cleanup activities, to the maximum extent possible."[11] The Assistant Administrator also signed a memo in December 2013 recommending that EPA Regional Administrators encourage and facilitate use of ASTM International's *Standard Guide for Greener Cleanups*[12] in their efforts to advance greener cleanup practices.[13]

The Agency focuses on the environmental piece of the sustainability triple bottom line (environmental, economic, and social) in part because the social and economic aspects are addressed through existing requirements of Superfund and other remediation programs. Social aspects are factored in through community involvement requirements and economic aspects through anticipated reuse considerations in remedy selection, and local hiring, job training, and other economic sustainability efforts in remedy implementation.[14]

OSWER has published a number of key guidance documents and BMPs, hosts regular seminars on Green Remediation, and has worked closely with stakeholders to develop these and many other tools and resources. The majority of EPA information related to Green Remediation is available through the Clean-Up Information (CLU-IN) website, the OSWER Greener Cleanup website, and the Superfund and Green Remediation website.

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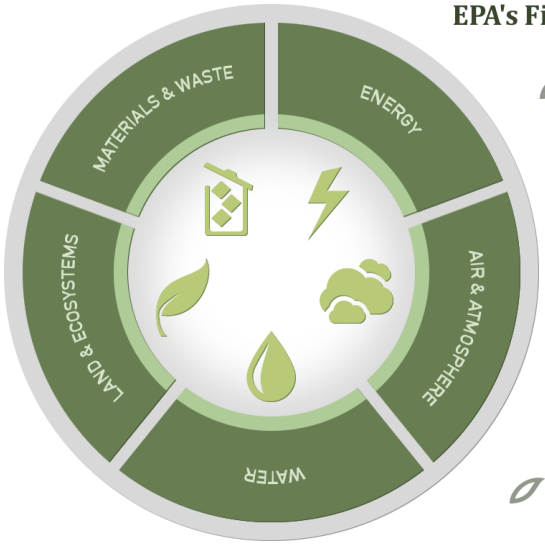
[10] Under Goal 3: Cleaning Up our Communities and Advancing Sustainable Development, the Strategic Plan reads, "EPA's hazardous waste programs are working to reduce the energy use and environmental footprint during the investigation and remediation of sites. As part of this effort, EPA's Superfund program will implement its green remediation strategy to reduce the energy, water, and materials used during site cleanups while ensuring that protective remedies are implemented." U.S. Environmental Protection Agency (EPA), "FY 2011-2015 EPA Strategic Plan," Sep 2010, p. 17, http://www.cluin.org/greenremediation/docs/EPA_Strategic_Plan.pdf.

[11] U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, "Principles for Greener Cleanups," 27 Aug 2009, http://www.epa.gov/oswer/greenercleanups/pdfs/oswer_greencleanup_principles.pdf.

[12] For details about the ASTM International standards, see page 15.

[13] Mathy Stanislaus Memo to Regional Administrators et. al, "Encouraging Greener Cleanup Practices through Use of ASTM International's Standard Guide for Greener Cleanups," U.S. Environmental Protection Agency, 23 Dec 2013.

[14] U.S. Sustainable Remediation Forum, "SURF 21 Meeting Minutes," Dec 2012, p. 33, www.sustainableremediation.org/library/meeting-minutes/.



EPA's Five Core Elements of Greener Cleanups include:

- **Energy:** Minimize total energy use and maximize use of renewable energy
- **Air & Atmosphere:** Minimize air pollutants and greenhouse gas emissions
- **Water:** Minimize water use and impacts to water resources
- **Materials & Waste:** Reduce, reuse, and recycle material and waste
- **Land & Ecosystems:** Protect land and ecosystems

Key EPA Resources

- *Technical Primer*— Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites (April 2008)
- Principles for Greener Cleanups (August 2009)
- Superfund Green Remediation Strategy (September 2010)
- GR Best Management Practices available on CLU-IN website, e.g. Pump and Treat Technologies (2008-2012)
- Methodology for Understanding and Reducing a Project's Environmental Footprint (February 2012)
- *Case Studies*—Site-Specific Profiles (30)

EPA Regions—Each of the 10 EPA regional offices have implemented green remediation policies tailored to the specific characteristics and needs of their region. Most regions have implemented a version of the "Clean & Green Policy" first issued in March of 2009 by Region 2. This policy relies on a number of "touchstone" practices that serve as the point of departure for Superfund cleanups. These practices are standard until site-specific evaluation demonstrates a need for their flexibility. Examples of such practices include:

- Use of 100% of electricity from renewable sources;
- Methane capture at landfill sites; and,
- Capture geothermal energy with pump and treat remediation systems to heat/cool structure.

U.S. Department of Defense (DOD)—DOD began to incorporate GSR into its cleanup practices following the August 2009 "Consideration of Green and Sustainable Remediation Practices in the Defense Environmental Restoration Program" memo from the Deputy Under Secretary of Defense for Installations and the Environment. Citing the requirements of Executive Order 13423, the memo explains that DOD's commitment to sustainable practices and reducing its energy demand, as required by the order, extends to its incorporation of GSR into its cleanup strategies. In doing so, DOD aims to, "use natural resources and energy efficiently, reduce negative impacts on the environment, minimize or eliminate pollution at its source, protect and benefit the community at large, and reduce waste to the greatest extent possible."[15] This memo catalyzed action by each DOD component to evaluate opportunities to implement GSR. Many of the tools and resources developed in response by the Army, Navy, and Air Force involved the close collaboration of SURF, other government agencies, and/or private companies.

Key DOD Resources

- *Memo*—Consideration of Green and Sustainable Remediation Practices in the Defense Environmental Restoration Program (August 2009)
- *Briefing*—DOD Green Remediation Policy Update (May 2011)

Department of the Navy—The Navy Facilities Engineering Command (NAVFAC) incorporates GSR as part of its existing Environmental Restoration (ER) program. It does so by evaluating GSR opportunities at every phase of the ER process and implementing them where practicable. The Navy also conducts remedy footprint analyses to identify areas for footprint reduction and incorporates GSR metrics into the remedy selection process. Information on the Navy's related efforts is available through their Green and Sustainable Remediation online portal. The Navy, in collaboration with Battelle and the U.S. Army Corps of Engineers (USACE), has developed a GSR metrics tool called SiteWise™. The tool, based on LCA concepts, provides baseline assessments of quantifiable GSR metrics including greenhouse gases (GHGs), energy use, criteria air pollutants, water usage, and accident risk. Use of the SiteWise™ tool during the Feasibility Study is now a Navy requirement. NAVFAC has made many web-based learning tools on innovative solutions for environmental restoration available through the technology transfer program T2 web page including one focused specifically on green and sustainable remediation.

[15] Dorothy Robyn Memo to Assistant Secretary of the Army et. al, "Consideration of Green and Sustainable Remediation Practices in the Defense Environmental Restoration Program," Office of the Under Secretary of Defense, 1 Aug 2009, http://www.smithcollaboration.com/wp-content/uploads/2012/09/DoD-Green-and-Sustainable-Remediation-Policy.pdf.

Key Navy Resources

- *Briefing*—Green and Sustainable Remediation (Spring 2010)
- Green and Sustainable Remediation Fact Sheet (August 2010)
- Department of the Navy Guidance on Green and Sustainable Remediation (April 2012)
- Integrating Green and Sustainable Remediation Metrics within the CERCLA Process during the Feasibility Study (July 2012)
- SiteWise™ Version 3 (October 2013)

Department of the Army—Consistent with the 2009 DOD memo, the Army has taken numerous steps to incorporate GSR and reported on these in a June 2010 briefing. Green Remediation is specifically included in the FY10-11 Army Environmental Cleanup Strategic Plan. Numerous branches of the Army are tasked with cleaning up retired or active military sites. Primary among these is the U.S. Army Corps of Engineers, responsible for Formerly Used Defense Site (FUDS) cleanups, which comprise the major remediation activities of the Army. In addition to their work on the SiteWise™ tool, USACE has developed a decision framework for incorporating GSR into Army environmental remediation projects.

Key Army Resources

- USACE Decision Framework for Incorporation of Green and Sustainable Practices into Environmental Remediation Projects (March 2010)
- *Briefing*—Army Green and Sustainable Remediation: Policy and Implementation (June 2010)

Department of the Air Force—Air Force Civil Engineering Center's (AFCEC's) Environmental Directorate is responsible for U.S. Air Force (USAF) environmental programs including regulatory compliance, environmental restoration, hazardous waste management, and environmental assessments. Since the 1990s, USAF has used sustainable metrics and remediation approaches such as monitored natural attenuation and enhanced *in situ* bioremediation.[16] USAF approaches such as environmental restoration program optimization, long-term monitoring optimization, groundwater modeling, performance-based environmental management, and remediation risk management integrate GSR concepts and technologies. USAF is also including sustainability requirements in contractual language and using GSR as part of its selection criteria for performance-based remediation contracts.[17]

USAF's environmental restoration program was previously run under the Air Force Center for Engineering and the Environment (AFCEE) before it merged with another USAF agency to become the AFCEC. AFCEE and its partners have developed several GSR tools. The first is the Sustainable Remediation Tool (SRT™), developed with industry partners, which compares remediation approaches based on sustainability metrics for soil and groundwater remediation.[18] This tool is referenced in AFCEE contracting language, included in the Air National Guard GSR policy, and used by several agencies in their GSR efforts. The second tool, the Performance Tracking Tool (PTT) evaluates the historic performance and costs of remedial methods so that the most appropriate remedial technologies for the site needs may be identified. USAF has also developed the Clean Solar and Wind Energy in Environmental Programs tool, or CleanSWEEP, which assesses the costs, benefits, and feasibility of using renewable energy at a remediation site.

Key Air Force Resources

- *Presentation*—U.S. Air Force Environmental-Restoration-Program-Optimization Lessons Learned, and Return on Investment (November 2009)
- Sustainable Remediation Tool (SRT™) (2008)
- Performance Tracking Tool (PTT) (2009)
- CleanSWEEP (2012)

[16] ITRC, GSR-1, p. 22.
[17] Ibid, p. 24.
[18] Amy Ausley and Susan Walker, "Cleaning up with renewable energy," U.S. Air Force Civil Engineer Center, 22 Mar 2012, http://www.afcec.af.mil/news/story.asp?id=123320327.

Figure 2: DOE technology stimulates microbes to degrade solvents in the vadose zone before they reach the groundwater. Source: DOE

U.S. Department of Energy (DOE)— DOE's Strategic Sustainability Performance Plan for implementing EO 13514 includes a commitment to incorporate green remediation practices into its environmental cleanup program.[19] DOE has used GSR in several containment and remediation projects, reducing its cleanup costs and energy consumption. The Savannah River National Laboratory (SRNL) is conducting research in support of DOE Office of Environmental Management's national cleanup mission to identify methods for increasing the sustainability of remediation for metal- and radionuclide-contaminated groundwater.[20] This research program is housed under SRNL's *Center for Sustainable Groundwater and Soil Solutions (CSGSS)*, operating with the philosophy that remediation solutions should "synergistically combine technologies, meet remedial objectives, minimize the problem, minimize the collateral environmental impacts, and emphasize low energy use and sustainability."[21] Information on this effort is available through the CSGSS website.

Key DOE Resources

- Strategic Sustainability Performance Plan (2011)

State Programs

The following table describes a number of ongoing state efforts to advance GSR. The list covers only a selection of states that have developed GSR policy and tools and is not intended to serve as a comprehensive analysis of every state with GSR efforts underway. The many state efforts described below provide further evidence of the multi-stakeholder collaboration that has brought GSR to where it is today.

[19] Jerry DiCerbo, Presentation, "Green and Sustainable Remediation," Department of Energy, Office of Environmental Policy and Assistance, http://homer.ornl.gov/sesa/environment/training/lm_presentation_on_gsr.pdf.
[20] ITRC, GSR-1, p. 25.
[21] "About the Center and Program," *Center for Sustainable Groundwater and Soil Solutions*, U.S. Department of Energy, Office of Environmental Management, 12 Dec 2009, http://srnl.doe.gov/csgss/index.htm.

State Green and Sustainable Remediation Efforts

State *Relevant Body*	Overview	Resources
California Environmental Protection Agency's Department of Toxic Substances Control (DTSC)	The California DTSC's Green Remediation Team was formed in 2007 to promote green practices in site cleanups. The team partnered with EPA Region 9 and the Groundwater Resources Association to host a symposium titled Global Perspectives on Green Remediation—Making Clean "Green" in 2009. Following the conference, DTSC published a guidance document and the Green Remediation Evaluation Matrix (GREM) tool intended for project managers, responsible parties, and environmental consultants performing sustainable remediation assessments.	• DTSC Green Remediation Webpage • Green Remediation Evaluation Matrix • Interim Advisory for Green Remediation
Illinois Environmental Protection Agency	Illinois EPA's Bureau of Land defines greener cleanups as "less polluting, more efficient cleanup activities and technologies designed to increase the environmental benefits of remediation." The Bureau has set five guiding principles for greener cleanups and established matrices to assist site owners and consultants with choosing sustainable practices. They have also developed tools specifically for leaking underground storage tank (LUST) cleanup sites.	• Illinois EPA Bureau of Land Green Remediation • Greener Cleanups Simple Matrix • Greener Cleanups Expanded Matrix • Greener Cleanup Strategies Mind Map: All Sites • Greener Cleanup Strategies Mind Map: LUST Sites • LUST Decision Trees
Massachusetts Department of Environmental Protection (MassDEP)	MassDEP's Bureau of Waste Site Cleanup, to advance the departments' clean energy policy goals, is promoting the incorporation of sustainability into remedy selection, implementation, and optimization at cleanup sites. In part, the state focuses on redeveloping Brownfields properties to promote economic and environmental goals. The Massachusetts Contingency Plan requires the evaluation of the relative consumption of energy resources as well as the potential damages to natural resources in the remedy selection process. MassDEP is currently engaged in overhauling cleanup regulations and among the proposed changes is the incorporation of green principles in cleanup decisions. MassDEP has developed an online system, eDEP, for submitting environmental permits, transmittals, certifications, and reports. The system has numerous user benefits and environmental benefits.	• Massachusetts Sustainable Remediation FAQ • Examples of Sustainable Remediation Sites in MA

Minnesota
 	
Pollution Control Agency (MPCA)
	MPCA has developed a toolkit for business, site development, and site cleanups to embrace sustainability. The Showcase of Ideas and Option List in the toolkit detail innovative or greener cleanup methods such as *in situ* treatment, groundwater treatment through a restored wetland, enhanced or restored habitat, product recovery and reuse, among others. Another part of the toolkit, the Decision Tree, helps practitioners determine which methods are appropriate for their site cleanups. MPCA has issued draft recommendations to toolkit users for performance measures, database tracking fields, and responsibilities to ensure adequate tracking of the toolkit's implementation. Such tracking is also required under the MPCA's funding agreement with EPA.	• Toolkit for Greener Practices
		  ○ Showcase of Ideas
		  ○ Option List
		  ○ Decision Tree
		• Performance Tracking: Measures, Database Tracking Fields, and Responsibilities

New York Department of Environmental Conservation (DEC), Division of Environmental Remediation (DER)	The New York State DER issued a Program Policy on Green Remediation (DER-31) in August 2010, which became effective in September. The policy applies to all phases and most every cleanup program (e.g. Superfund, Brownfields, RCRA etc.). It focuses in particular on the remedy selection process stating, "all remedial parties, DER staff, and DER standby consultants and contractors should now consider sustainability/green remediation concepts when assembling and evaluating remedial alternatives." The policy defines no particular documentation form for GSR efforts but does require documentation and submittal of related GSR activities as part of the required work reports throughout the site investigation and cleanup process. The policy is one of the first government-issued GSR policies in the U.S. Following its issuance, AECOM experts developed a new tool called GSRx™ to identify and assess GSR BMPs in order to comply with DER-31 provisions.[1]	• NYS DEC Environmental Cleanup & Brownfields • Program Policy on Green Remediation (DER-31) ○ Related AECOM Tool: GSRx ™
Wisconsin Department of Natural Resources (DNR) Remediation and Redevelopment Program, Wisconsin Initiative for Sustainable Remediation and Redevelopment (WISRR)	The Wisconsin DNR has established the WISRR to foster the use of environmentally friendly cleanup practices. WISRR emphasizes the applicability of sustainable technologies and practices in site remediation and during the redevelopment process to save energy, reduce greenhouse gases, and minimize waste. They have developed a comprehensive Green and Sustainable Remediation Manual to assist environmental professionals with GSR implementation as well as a companion document of case studies, *Site Specific Sustainability Analyses*.	• Wisconsin Remediation & Redevelopment Program Greener Cleanups • Green & Sustainable Remediation Manual • Site Specific Sustainability Analyses • Quick Reference Guide: Greener Remediation Optimization Techniques • Quick Reference: Greener Site Investigation Techniques

Partnership Organizations

Sustainable Remediation Forum (SURF)—SURF was initiated in 2006 and incorporated as a non-profit organization to promote the use of sustainable practices during cleanup activities. SURF defines sustainable remediation in the three-pronged sustainability approach, emphasizing the objective of balancing economic viability, conservation of natural resources and biodiversity, and the enhancement of the quality of life in surrounding communities. SURF's primary activities include supporting the advancement of science and application of sustainable remediation, developing technical best practices, and serving as a forum for professional knowledge exchange, education, and outreach. The SURF website has a robust library of guidance documents and tools, issue papers, and case studies published by SURF as well as a comprehensive collection of resources from around the GSR community.

Key SURF Resources

- Sustainable Remediation White Paper—Integrating Sustainable Principles, Practices, and Metrics Into Remediation Projects (Summer 2009)
- Framework for Integrating Sustainability Into Remediation Projects (Summer 2011)
- Guidance for Performing Footprint Analyses and Life Cycle Assessments (Summer 2011)
- Metrics for Integrating Sustainability Evaluations into Remediation Projects (Summer 2011)
- Groundwater Conservation and Reuse at Remediation Sites (December 2013)
- Case Studies

Interstate Technology and Regulatory Council (ITRC)—ITRC is a state-led coalition with representatives from the environmental regulatory agencies of every state, three federal agencies, tribes, and public and industry stakeholders. The organization was founded in 1995 and is "devoted to reducing barriers to, and speeding interstate deployment of, better, more cost-effective, innovative environmental techniques."[22] ITRC's GSR team consists of members from numerous state departments for environmental protection, federal agencies, public and academic stakeholders, and industry representatives. ITRC's webpage for Green and Sustainable Remediation details the team's efforts and provides access to related resources.

ITRC has published two guidance documents on GSR that describe current approaches and provide regulators and practitioners with a clear path for implementing GSR. To compliment these documents, ITRC offers Internet Based Training covering the basics and potential benefits of GSR principles, outlining case studies, and providing practical information on how to apply GSR to remediation projects.

[22] ITRC, GSR-1.

Key ITRC Resources

- Green and Sustainable Remediation: State of the Science and Practice (May 2011)
- Green and Sustainable Remediation: A Practical Framework (November 2011)

Association of State and Territorial Solid Waste Management Officials (ASTSWMO)—ASTSWMO's Greener Cleanups Task Force is working to encourage greener cleanups by providing information and assistance to state waste management and remediation programs. The workgroup also provides a state perspective in their review and comment on EPA documents. The Task Force operates with the mission to "facilitate cleanup decisions that increase net environmental benefits of remediation and contribute to site sustainability."[23] Its members consist of ASTSWMO staff from various committees within the organization including CERCLA, Brownfields and Voluntary Cleanups, RCRA, Federal Facilities, and Tanks.[24] ASTSWMO's GSR resources can be accessed at their Greener Cleanups Information Resources webpage.

Key ASTSWMO Resources

- Implementing Greener Cleanups Strategies in the States (January 2009)
- *Presentation*—Discussion of Barriers to Greener Cleanups (April 2009)
- Incentives for Greener Cleanups (June 2009)
- Green Remediation Myth Busters (August 2009)
- Incorporating Greener Cleanups into Remedy Reviews (August 2009)
- Green Remediation at Federal Facilities Cleanups (January 2011)

ASTM International—In response to a formal request from EPA, ASTM initiated work on a voluntary standard for greener cleanups. Prior to development, EPA undertook the initial research and planning phases. The Agency maintained a transparent approach, solicited and incorporated feedback on the standard from potential users, and raised widespread awareness about the standard's potential value for businesses. EPA also coordinated with the ASTSWMO Greener Cleanups Task Force and the ITRC Green and Sustainable Remediation Team to leverage shared goals and activities and ensure consistency in future national training.[25]

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[23] Dan Scheppers, Presentation, "ASTSWMO Green Remediation Task Force," 2009, http://e2s2.ndia.org/pastmeetings/2009/tracks/Documents/8081.pdf.
[24] Association of State and Territorial Waste Management Officials (ASTSWMO), "Introduction: Greener Cleanups Workgroup and Greener Cleanups," 2 Aug 2013, http://www.astswmo.org/Pages/Policies_and_Publications/Sustainability/Greener_Cleanups.html#.
[25] U.S. Environmental Protection Agency, "Green Cleanup Standard Initiative September 2009 Update," Sep 2009, http://www.clu-in.org/greenremediation/docs/GCS%20Proj%20Update%20Sep%2009.pdf.

Early on in the standard development process, it became clear that there was stakeholder interest for both a greener cleanup standard and a broader standard that addressed the triple bottom line of sustainability. ASTM Subcommittee E50.04 ultimately established two task groups. Each task group consists of a broad range of representatives from the cleanup community, including regulators, industry, and environmental consultants. The outcome was two standard guides released in 2013.

In June 2013, ASTM published a *Standard Guide for Integrating Sustainable Objectives into Cleanups* E2876-13. This document provides a broad framework for addressing sustainable aspects (economic, environmental, and social) into cleanups. Based on the sustainable objectives identified for the site, users implement one or more best management practices that substantially benefit each of the sustainable aspects.

In November 2013, ASTM issued the *Standard Guide for Greener Cleanups* E2893-13. This resource provides a process for evaluating, prioritizing, implementing and reporting greener cleanup best management practices as well as guidelines for performing a quantitative evaluation. It also includes an appendix with over 160 best management practices. The guide can be used for contracting purposes or for integration into state regulatory programs.

Key ASTM Resources

- E2876 Standard Guide for Integrating Sustainable Objectives into Cleanup (June, 2013)
- E2893 Standard Guide for Greener Cleanups (November, 2013)

International Organization for Standardization (ISO)— ISO develops standards based on global expert opinion and consensus. ISO has been influential to GSR in multiple ways. First, the ISO Life-cycle assessment (LCA) standards, ISO 14040 series, has served as the foundation for many of the tools and resources that exist for GSR implementation today. LCA is a method to determine the environmental and human-health impacts of a product or service, and its application to remediation preceded the emergence of the process now termed green or sustainable remediation. ISO 14040 defines LCA as the "compilation and evaluation of the inputs, outputs, and potential environmental impacts of a system throughout its life cycle."[26]

LCA can be applied to remediation activities in a number of ways including benchmarking for existing systems, identifying and prioritizing opportunities to decrease the impacts of future cleanups, and comparing different remediation options during the technology selection phase.[27] Overall, a life-cycle approach enables remediation professionals to quantify externalities at every step of a cleanup and balance trade-offs to positively impact the environment, economy, and society.[28]

[26] SURF, "Sustainable Remediation White Paper," p. 40.
[27] Ibid, p. 45.
[28] SURF has a comprehensive list of life-cycle assessment documents and guidance at http://www.sustainableremediation.org/life-cycle-assessment/.

In addition to the foundation LCA standards have provided, ISO's Technical Committee on Soil Quality, Subcommittee on Soil and Site Assessment is currently drafting a standard for sustainable remediation titled *Soil quality—Guidance on sustainable remediation*.[29] The proposed standard would provide terminology and information about key components and implementation of sustainable remediation. An ISO standard would increase the regulatory visibility of GSR principles and encourage their adoption in ways the existing literature cannot.[30] SURF (US) is currently weighing its options for involvement in the development of the ISO standard. SURF groups in voting countries (Italy, UK, Australia, and Japan) and observing countries (Canada and China) are set to be involved.[31]

Summary of U.S. GSR Implementation Resources [34,35]

BMPs and Implementation Guidelines:

- EPA BMPs
- SURF Framework for Integrating Sustainability into Remediation Projects
- ITRC GSR Guidance Documents
- ASTM Standards for Integrating Sustainable Objectives into Cleanup
- ASTM Standard Guide for Greener Cleanups
- ISO Life-Cycle Assessment 14040 Series
- AECOM's GSRx™ Process
- Wisconsin's Green & Sustainable Remediation Manual

Decision Trees:

- Illinois EPA Greener Cleanup Matrix
- Minnesota Toolkit for Greener Practices
- California's Green Remediation Evaluation Matrix (GREM)
- USACE Decision Framework for Incorporation of Green and Sustainable Practices into Environmental Remediation Projects

Calculators:

- SiteWise™ / USACE & DON (developer: Battelle)
- Sustainable Remediation Tool (SRT™) / AFCEC (developers: AECOM, GSE Environmental, CH2M Hill)
- Holistic Tool / AECOM
- Performance Tracking Tool (PTT) / AFCEC
- Clean Solar and Wind Energy in Environmental Programs (CleanSWEEP) / AFCEC (developer: CH2M Hill)
- EPA's Methodology for Understanding and Reducing a Project's Environmental Footprint and corresponding Spreadsheets for Environmental Footprints Analysis (SEFA) / EPA
- Power Profiler / EPA-emissions from energy use
- Motor Vehicle Emissions Simulator (Moves) / EPA (developer: SSAI)-emissions from transportation
- Recycled Content (ReCon) Tool / EPA-energy and emissions from waste
- Waste Reduction Model (WaRM) / EPA-emissions from waste disposal methods

[29] International Organization for Standardization, "Soil quality—Guidance on sustainable remediation," http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=62688.
[30] U.S. Sustainable Remediation Forum, "SURF Report—Winter 2013," SURF Newsletter, 4(1), 2013, p. 4.
[31] Ibid.
[34] Thomas Potter, Presentation, "Green Remediation Update," ASTSWMO's Greener Cleanups Workgroup and the Commonwealth of Massachusetts, ASTSWMO Mid-Year Meeting, 24 Apr 2013.
[35] Scott McDonough and Dustin Krajewski, Presentation, "Synopsis of current green and sustainable remediation tools, practices, and applications," Sustainable Remediation International Conference, University of Massachusetts, Amherst, 2011.

Other International Efforts

Europe

Sustainable Remediation Forum UK (SuRF-UK)—SuRF-UK was established in 2007, and like its counterpart in the United States, it aims to further the understanding of sustainable remediation. SuRF-UK is an initiative run under the Contaminated Land: Applications in Real Environments or CL:AIRE organization, a non-profit committed to stimulating the regeneration of contaminated land in the UK. Like SURF US, SuRF-UK takes part in international meetings with SURF representatives from around the world (Canada, Australia/New Zealand, Netherlands, Italy, Brazil, China, and others). SuRF-UK has developed a framework for identifying opportunities for considering sustainability at key points in a site cleanup as well as a supporting document of environmental, social, and economic indicators for use in sustainability assessments and remediation decision-making. They have also developed a template for case studies and request that organizations using their framework submit a case study using the template. The next step for the organization will be developing a series of case studies and guidance on best management practices for remediation projects.

Key SuRF-UK Resources

- SuRF-UK: A Framework for Assessing the Sustainability of Soil and Groundwater Remediation (March 2010)
- SuRF-UK Phase 2 Case Study Template (December 2010)
- SuRF-UK Applying Sustainable Development Principles (March 2011)
- ANNEX 1: SuRF-UK Indicator Set for Sustainable Remediation FINAL (November 2011)

European SURF organizations were also established in Italy in 2012, SURF-Italy, and the Netherlands in 2011, SURF-NL.

Network for Industrially Contaminated Land in Europe (NICOLE)— NICOLE is a leading forum on contaminated land management in Europe, aiming to support European industry in managing industrially contaminated land efficiently, cost-effectively, and within a framework of sustainability. NICOLE created a Sustainable Remediation work group in 2008 to assess and further incorporate environmental, social, and economic sustainability elements into cleanups. The results of this investigation are published in the Road Map for Sustainable Remediation. The working group's focus has since turned to the implementation and evaluation of this road map, and a report was published in 2012 around that focus.

Key NICOLE Resources

- Sustainable Remediation Roadmap (2010)
- How to Implement Sustainable Remediation in a contaminated land management project? (2012)

Canada—In a 1998 guideline document entitled *Soil Protection and Contaminated Sites Rehabilitation Policy*, the Ministry of the Environment of the Province of Quebec introduced site remediation principles that addressed some social and economic, but not environmental, externalities of site remediation. Most soil remediation in Quebec today is still traditional excavation and off-site landfill or ex-situ treatment.[36]

Canada's Environmental Protection Act was implemented in March 2000 and followed by the Clean Air Regulatory Agenda in April 2007, a national approach to regulate GHGs and air pollutant emissions.

SURF Canada's first meeting was held in Toronto in May 2011, and the organization has since developed its membership, partnered in conferences, and formalized outreach and technical initiatives to plan for future growth. SURF Canada plans to publish a document describing the status of sustainable remediation in Canada and include comparisons with programs in other countries.[37]

Environment Canada has developed a proposed Federal Contaminated Sites Action Plan for Sustainable Strategy and Implementation that is pending approval and may assist provinces with sustainable remediation. Sustainable remediation practices are also being implemented at many federal sites in Canada.[38]

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[36] SURF, "Sustainable Remediation White Paper," p. 23.
[37] SURF, "SURF 21 Meeting Minutes," p. 7.
[38] Jody Klassen, Presentation, "Sustainability in the Federal Contaminated Sites Action Plan," Real Property Institute of Canada Regional Workshop, 19 Jun 2013, http://www.rpic-ibic.ca/documents/RPIC_FCS_REG_2013/Presentations/2_Klassen-Truax_E.pdf.

Brazil—Environmental policy is largely managed on the state level in Brazil, and the São Paulo Environmental Agency (CETESB) is therefore a role model to other agencies in Brazil and throughout Latin America. In 1999, the State of São Paulo implemented a risk-based corrective action remediation approach based on U.S. EPA protocol for conducting risk assessments.[39] In February 2011, São Paulo incorporated sustainable remediation concepts into state environmental law. [40]

SURF-Brazil was formed in 2010 and organized its first roundtable discussion on sustainable remediation in October 2011. A survey conducted at the meeting revealed that participants were most concerned about social impacts and land reuse among the many aspects of sustainable remediation.[41] SURF-Brazil aims to transfer knowledge about sustainable remediation across the country via social networks, a blog, and word of mouth.

As remediation policy has developed in Brazil, companies with remediation responsibilities have often led the way on sustainability. For instance, Petrobras, the largest oil company in South America, uses ten social and environmental principles to govern all of its activities including those related to remediation and contaminated sites.[42]

Australia & New Zealand—Australia's national research priorities, established in 2002, included the commitment to "An Environmentally Sustainable Australia". This priority focuses on new, cost-effective, and safe means to remediate contaminated sites to enable sustainable land use.[43]

Since 2012, SURF ANZ has been facilitating contact with international GSR associations, organizing meetings and forums for dialogues, presenting at international conferences, developing tools, and contributing to a National Remediation Framework being developed with the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) and the Australasia Land and Groundwater Association (ALGA).[44]
SURF ANZ has a variety of working groups developing documents including one working on the importance of regional planning as a sustainable remediation consideration. Another working group has developed a template for documenting case studies.[45]

Key ANZ Resources

- Framework for Assessing the Sustainability of Soil and Groundwater Remediation (April 2011)
- Case Studies and Template (Dec 2012)

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[39] SURF, "Sustainable Remediation White Paper," p. 25.
[40] In the 2011 law, companies bidding for remediation work are required to include a sustainability assessment of their proposed cleanup approach. SURF, "SURF 21 Meeting Minutes," p. 4.
[41] Ibid.
[42] Ibid.
[43] Ibid, p. 25.
[44] Dr. Garry Smith, "State of SuRF ANZ: Resources and Interactive Dialogues for Sustainable Land and Groundwater Contaminant Remediation Practice," Jun 2013, http://www.surfanz.com.au/pdfs/Report%20up%20to%20June%202013.pdf.
[45] SURF, "SURF 21 Meeting Minutes," p. 6.

- SURF ANZ working group discussion papers on:
  - An ANZ Sustainable Remediation Framework (March 2013)
  - Planning aspects of Sustainable Remediation (April 2013)

Asia

China—The Chinese Remediation industry has grown significantly since 2008. Part of the impetus for this growth was the shutdown or relocation of over 86,000 industrial companies from 2001-2007.[46] Since then, many Chinese environmental remediation consulting and engineering firms have been established, and many major U.S. firms have opened offices in Beijing and Shanghai.[47]

In its five-year plan for 2011-2015, the Chinese government committed to tackling soil and groundwater contamination issues, and the government is currently evaluating options for establishing its own versions of the Superfund and Brownfields programs.[48] A small but growing network has begun to focus on sustainable remediation in China and in 2009 published a draft document titled *Technical Guidelines for Risk Assessment for Contaminated Sites*. Remediation practitioners also began using human and environmental risk assessment (HERA) software in 2012 to determine site risks.[49] Groups like the Chinese Soil and Groundwater Remediation Network (CSGR-NET) have also collaborated in international sustainable remediation efforts, and plans are in place to establish a SURF China in the near term.[50]

Taiwan—Taiwan enacted the Soil and Groundwater Pollution Remediation Act in 2000 to manage site investigation and cleanup activities, which includes a provision for risk-based remediation goals. In 2012, the Taiwan Environmental Protection Administration issued the *Framework for Green and Sustainable Remediation*, a top-down approach that considers all three sustainability components. Currently under development is a draft process for applying green and sustainable remediation that emphasizes best management practices in the first three remediation phases followed by an evaluation of the environmental footprint. Pilot studies are informing the development of this guidance, which the Taiwan Environmental Protection Administration is set to release in 2013 or 2014.[51] SURF-Taiwan was established in 2012.

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[46] Ibid, p. 12.
[47] "China Remediation Today," China Environmental Remediation, 2011, http://www.chinaremediation.com/china_remediation_today.html.
[48] Ibid.
[49] SURF, "SURF 21 Meeting Minutes," p. 12.
[50] Ibid, p. 13.
[51] Ibid, p. 17.

Japan—In 2003, Japan enacted the Soil Contamination Countermeasures Law. The law was amended in 2009 to strengthen it, and the amendments included provisions related to sustainable remediation such as measures to minimize and prevent unnecessary excavation and off-site disposal. Japan's Ministry of the Environment has also developed and promoted cost- and energy- efficient investigation technologies with environmental benefits such as reducing GHG emissions.[52] Sustainable remediation practices in Japan are relatively new but are expected to spread as the remediation program develops. A SURF affiliate group is also in the early phases of development in Japan.

Global Businesses—Companies that have adopted GSR practices and are conducting cleanups around the world are directly spreading such practices into areas where no official organizations or policies have been established. For instance, Shell Oil applies sustainable remediation concepts in 90 countries.[53] Other international companies responsible for cleanups that have implemented GSR practices include Dow Chemical, Boeing, DuPont, Eaton Corporation, and BP.

Environmental consulting and engineering companies have likewise been instrumental to advancing the GSR field. These companies inform regulators and partner organizations on best practices and case studies, collaborate to create tools and frameworks, and spread information on GSR via conferences, publications, and other outreach. GSR has largely witnessed an organic development via the companies that have pioneered the use of these approaches and shared their experiences with stakeholders, regulators, and others in the remediation industry. Both domestic and international propagation of GSR principles owes much to companies like ARCADIS, ENVIRON, CH2M HILL, AECOM, CDM Smith, AMEC, Geosyntec Consultants, Gnarus Advisors, Battelle, Tetra Tech, URS, and others.

[52] Ibid, p. 12.
[53] Ibid, p. 8.

SECTION III. BENEFITS & CONCERNS OF GSR

Benefits

Environmental Benefits

Implementing GSR practices at remediation sites has various benefits for the environment, the party conducting the cleanup, and the surrounding community. These benefits may vary significantly depending on the specific cleanup site and requirements. Primary among them is the reduced environmental footprint, the central goal of GSR. Green and sustainable practices may reduce energy, water and raw material consumption, waste generation, impacts to surrounding ecosystems, and emissions of air pollutants and greenhouse gases. EPA's five core elements of greener cleanups capture these environmental benefits and are described in further detail below with case-specific examples for each.[54]

Figure 3: Former MGP Site in Massachusetts where 1,395 solar modules generate enough electricity to reduce CO2 emissions by 590,000 lbs. Source: McDonough

Energy: Where many traditional cleanup practices involve energy intensive technologies, GSR strategies encourage energy efficiency and the use of renewable energy technologies.

Frontier Fertilizer Superfund Site
Davis, CA
Installation of two photovoltaic systems to power the groundwater treatment has offset 100% of the pump-and-treat (P&T) system's demand for grid-supplied electricity. The P&T system is addressing pesticides, carbon tetrachloride, and other contaminants of concern (COCs) in groundwater at this 18-acre former industrial site.

Operating Industries, Inc. Landfill Superfund Site
Monterey Park, CA
GSR strategies have been implemented to convert Operating Industries, Inc. landfill gas to electric power for use in onsite removal of volatile organic compounds (VOCs) and other COCs from the landfill emissions. Six 70-kW microturbines were installed to produce energy from 460 gas extraction wells instead of managing gas via flaring. This generated more than 15,000 MWh of electricity over seven years of operation, offsetting the energy requirements of the landfill gas treatment system and resulting in a cumulative net savings of $647,000.

[54] U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Office of Superfund Remediation and Technology Innovation, "Superfund Green Remediation Strategy," Sep 2010, p. 2. http://www.epa.gov/superfund/greenremediation/sf-gr-strategy.pdf.

Air & Atmosphere: Emissions of GHGs and harmful air pollutants are inevitable when treatment processes involve operation of heavy machinery and high volumes of vehicle and cargo truck transportation. Advanced technologies and BMPs in the field as part of GSR techniques may reduce this impact.

BP Voluntary Cleanup Site
Paulsboro, NJ
A solar field is used at this site to power a P&T system cleaning up the petroleum products and chlorinated compounds from groundwater near the Delaware River port. Solar energy operates six recovery wells, pump motors, aerators, and blowers, and has eliminated 571,000 pounds of CO_2, 1,600 pounds of SO_2, and 1,100 pounds of NO_2 emissions annually.

Aerojet-General Corporation Superfund Site
Cordova, CA
Two solar farms were installed to offset the need for utility-supplied electricity for the extraction and treatment of contaminated groundwater at this former rocket engine and propellant manufacturing site. This has prevented 6,000 tons of CO_2, 4 tons of SO_2, and 5 tons of NO_2 from being emitted each year.

Lawrence Aviation Industries Superfund Site
Port Jefferson Station, NY
This former titanium-sheeting manufacturing facility has utilized a number of GSR practices in the design of the cleanup at two offsite treatment plants (to remediate VOC and PCB contaminated groundwater). Among these is the use of geothermal energy to power water treatment processes, offsetting an estimated 4.1 to 4.8 metric tons of CO_2e at both plants annually, as well as filtration vessels to treat air before it is emitted from the plant.

Water: Traditional contaminated site treatment processes typically involve significant amounts of water and may degrade water quality. GSR focuses on reducing water use, reusing treated water, and using efficient techniques to protect surface and groundwater.

NASA Jet Propulsion Laboratory
Pasadena, CA
NASA, in partnership with the City of Pasadena, took measures to treat the wastewater generated from periodic flushing and backwashing of a groundwater treatment plant installed to remove residual VOCs and perchlorate. Treatment and onsite discharge to a spreading basin (rather than discharge of untreated water to a sanitary sewer) resulted in an estimated aquifer recharge of nearly 100 acre-feet each year.

Massachusetts Military Reservation Superfund Site
Cape Cod, MA
At this site, approximately 85% of treated water was diverted for beneficial reuse as irrigation for an adjoining property that serves as a Veterans Administration cemetery prior to returning to the underlying aquifer. The Air Force is also considering reusing treated water for geothermal heating and cooling of onsite buildings in the future.

Land & Ecosystems: Remediation activities can in some instances disturb the surrounding land and ecosystems. By focusing on remedial actions that use minimally invasive technologies and reduce habitat disturbances, GSR protects land and ecosystems and encourages ecological, economic, or social reuse.

California Gulch Superfund Site
Leadville, CO
The remedial activities at this former mining site have focused on *in situ* remedies using soil amendments consisting natural byproducts instead of synthetic products. This approach aims to minimize additional disturbance to soil and existing vegetation, maximize use of onsite plant material and rocks rather than imported material to stabilize river banks, and integrate remediation processes into future land uses for agriculture, recreation, and native wildlife. As a result, protected riverbanks have enhanced fish habitat, native species and non-invasive grasses were selected for re-seeding about 170 acres, and roads were constructed in optimal locations to minimize impacts to bird habitats and for long-term use by the community.

Materials & Waste: Significant amounts of raw materials are often required at cleanup sites. The cleanup process may also generate further wastes including materials and debris. GSR practices offer strategies to reduce materials consumption and waste generation by using recycled, local, or environmentally preferable materials. Further efforts are being made to recycle contaminated materials and wastes back into remediation or commerce to displace the manufacture of new materials.

Elizabeth Mine Superfund Site
South Stratford, VT
This Superfund project to restore the surface water of Copperas Brook and other resources downstream of historic iron sulfate and copper mining sites has taken measures to reduce the impact of materials required in the cleanup. Some of these measures include:
+ Identifying onsite resources to generate materials needed for constructing the cap system instead of trucking them in from offsite, avoiding nearly 6,200 truck trips or 945,00 pounds of CO_2 emissions.
+ Reusing 1,000 cubic yards of soil material, previously used as backfill at the site, for capping material during remedy implementation.
+ Recycling 30 cubic yards of HDPE geomembrane liner and 96 HDPE liner cores in one year.
+ Using onsite wood debris for slope stabilization.
+ Using biodegradable and/or organic materials to the greatest extent possible. For example, tubular devices made from organic materials like recycled compost were installed on ground surfaces along the soil cap to control sediment and contain and filter stormwater runoff prior to subsurface infiltration. In comparison to a typical silt fence, performance monitoring suggests this sustainable material replacement has contained 50% more surface water runoff, returned more nutrients to the subsurface, and involved less maintenance.

Community Benefits

The reduced environmental footprint is, in its own right, a benefit to the surrounding community. Fewer emissions, natural resource requirements, and waste production all serve the interests of the community and have implications for protecting public health. At the same time, communities may in some cases benefit from shorter cleanup times and reduced disruption as compared to machinery-intensive cleanups.[55] An expanded definition of GSR that takes into account community sustainability includes added benefits such as transforming contaminated sites to uses that meet the needs of the surrounding communities (e.g., recreational facilities) or locally sourcing raw materials needed for the cleanup. When the application of GSR principles results in beneficial reuse of otherwise unused sites, communities may also gain from economic development, job creation, and increased real estate values.

User Benefits

In most cases, it is in the best interest of the company or agency responsible for a contaminated site cleanup to implement GSR practices. The use of these practices has been shown to improve stakeholder relations and enable the user to engage a community beyond the status quo of a traditional cleanup. In some cases, GSR implementation also leads to cost and time savings for the site owner, though these aspects vary on a case-by-case basis.

Concerns

Justification for Less Protective Cleanups

EPA and other regulators are concerned that GSR concepts may be misused as a justification for cleanups that are less protective than traditional practices. This includes concern that cleanup objectives will be undermined, cleanup activities avoided, minimized, or delayed, or cleanup activities selected that compromise stakeholder interests or goals for a site. Regulatory requirements, however, must be satisfied for all cleanups, including those where GSR is used. Every agency and organization promulgating guidance on GSR makes clear that the cleanup requirements and standards must be achieved. EPA clearly states in all of its green remediation guidance documents that cleanups involving green remediation practices occur, "in a manner that is consistent with statutes and regulations governing EPA cleanup programs and without compromising cleanup objectives, community interests, the reasonableness of cleanup timeframes, or the protectiveness of the cleanup actions."[56] Similar specifications are made in the ASTM *Standard Guide for Greener Cleanups*.[57]

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[55] The time intensiveness of cleanups that rely on GSR approaches is variable. The Harris Avenue Landfill case study described in this report is one example where GSR expedited cleanup time, but there are also examples where GSR practices that rely on natural chemical or physical processes such as bioremediation or phytoremediation may take longer than energy intensive cleanups designed to speed up these chemical or physical rates. SURF, "Sustainable Remediation White Paper," p. 105.

[56] EPA, "Principles for Greener Cleanups," p. 2.

[57] Mathy Stanislaus Memo to Regional Administrators et. al, p. 2.

Greenwashing

Greenwashing refers to instances where an organization claims that a cleanup is better for the environment, but GSR practices have not been appropriately evaluated or documented. In some cases, related issues develop around misuse of the terms "sustainable" or "sustainability", and misuse any of these terms may discourage acceptance of GSR concepts across the environmental industry. Transparency in documenting GSR evaluations and relying upon accepted sources for validating GSR performance is essential when GSR is claimed for a site cleanup. The potential for greenwashing may be lessened if a certification process is developed that uses specific green and sustainable metrics. Such a certification would encourage acceptance, use, and credibility of GSR practices.[58]

Cost

The cost questions surrounding GSR must be handled on a case specific basis. While some remediation methods may cost more, it is often the case that GSR implementation results in efficiencies that can reduce the overall project cost.[59] Still others may be cost neutral. Costs will be examined in further detail in Section IV of this report.

Regulatory Burden

GSR may be viewed as an additional regulatory burden that agencies will impose on remediation projects and responsible parties. At present, GSR is encouraged by state and federal agencies but is a voluntary approach. Though, in some cases, more planning and assessment at the outset of a remediation project may be required, the GSR process is no more burdensome and may often be less burdensome than traditional approaches. Many companies and remediation practitioners are finding that the benefits of utilizing GSR are incentive enough to engage in the practices voluntarily. For instance, Eaton Corporation, a global power management company, used GSR principles and replaced a pump-and-treat system with in-situ bioremediation to clean up a site with soil and groundwater VOC contamination. The company concluded that the application of green remediation met remedial action goals, was embraced by regulatory authorities, reduced Eaton's environmental footprint, and saved the company time and money.[60] If GSR is to be integrated into policies or mandated by statutes in the future, care will have to be taken to avoid compounding regulatory burdens with existing requirements.

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[58] Interstate Technology & Regulatory Council (ITRC), "Green and Sustainable Remediation: A Practical Framework," GSR-2, Nov 2011, p. 4.
[59] ASTSWMO Sustainability Subcommittee, Greener Cleanups Task Force, "Green Remediation: Getting Started by Debunking Some Myths," ASTSWMO, Aug 2009, p. 2.
[60] Steven Fesko and Jeff Allen, Presentation, "Green Remediation at Eaton Corporation," Sustainable Remediation International Conference, University of Massachusetts, Amherst, Jun 2011,
http://www.umass.edu/tei/conferences/SustainableRemediation/PDF/Presentatio nPDFs/Fesko.pdf.

Metrics

One frequently cited inadequacy of the current state of GSR is the lack of consensus around which metrics or set of metrics ought to be used in the remedial decision making process and to measure and evaluate GSR actions.[61] Further issues arise in deciding on the boundaries of these measurements and on how to balance the chosen metrics.

Various agencies and organizations have developed their own guidelines of key metrics. For instance, NAVFAC describes eight metrics for GSR at the Navy's cleanup sites: energy consumption, GHG emissions, criteria pollutant emissions, water impacts, ecological impacts, resources consumption, worker safety, and community impacts.[62] NAVFAC also notes that as a baseline requirement, all remedial approaches must be protective and meet the National Contingency Plan (NCP) Threshold Criteria. EPA evaluates five environmental metrics, or core elements, as previously described.

GSR tools also evaluate remedies based on varying metrics. The SiteWise™ tool evaluates five metrics: energy consumption, GHG emissions, criteria pollutant emissions, water impacts, and worker safety. The Air Force's SRT™ evaluates five similar but slightly varying metrics: energy consumption, GHG emissions, technology cost, safety/accident risk, and natural resources services.[63]

SURF has responded to the need to standardize metrics to assess and monitor the effectiveness of remedies by compiling a Metrics Toolbox available through the SURF website. This gives the user a starting point for choosing which metrics to consider in remedial decisions. The Toolbox categorizes metrics by remedial phase and includes metrics that reflect all three aspects of sustainability and are both qualitative and quantitative.[64]

ITRC, in its May 2011 *Green and Sustainable Remediation: State of the Science and Practice* report, compiled a table of GSR metrics which draws upon those included in the SURF 2009 White Paper and EPA's 2008 Green Remediation Primer. Each metric is flagged based upon its association with environmental, social, and/or economic elements.[65] While most of these have concrete units by which to evaluate the GSR action (e.g., gallons of freshwater used, MWh of nonrenewable energy avoided, or tons of CO_2 emissions avoided), many are subjective or can be measured using more than one unit or more than one approach (e.g., public access to open space or community impacts) making comparisons more difficult. Social metrics are especially difficult to measure quantitatively. ITRC has therefore concluded that more research is needed in order to reach any degree of certainty about the quantitative measurements of social impacts.[66] A number of organizations have been working to improve the measurement of social impacts for LCA and related analyses, but thus far, the strategies remain rather qualitative.[67]

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[61] ITRC, GSR-2, p. 9.
[62] ITRC, GSR-1, p. 31.
[63] Ibid.
[64] Paul Butler et al., "Metrics for Integrating Sustainable Evaluations Into Remediation," SURF, *Remediation Journal*, 21(3): 81-87, Summer 2011.
[65] ITRC, GSR-1, Table 4-1, p. 29-31.
[66] Ibid, p. 31.
[67] The World Business Council for Sustainable Development and the United Nations have both issued documents on this issue. World Business Council for Sustainable Development,

Case Studies

The following selection of green and sustainable remediation case studies demonstrate in practical terms how GSR has been implemented and what impacts it might have. The cases include instances where GSR frameworks have been used under various cleanup authorities and at various phases of the cleanup process.

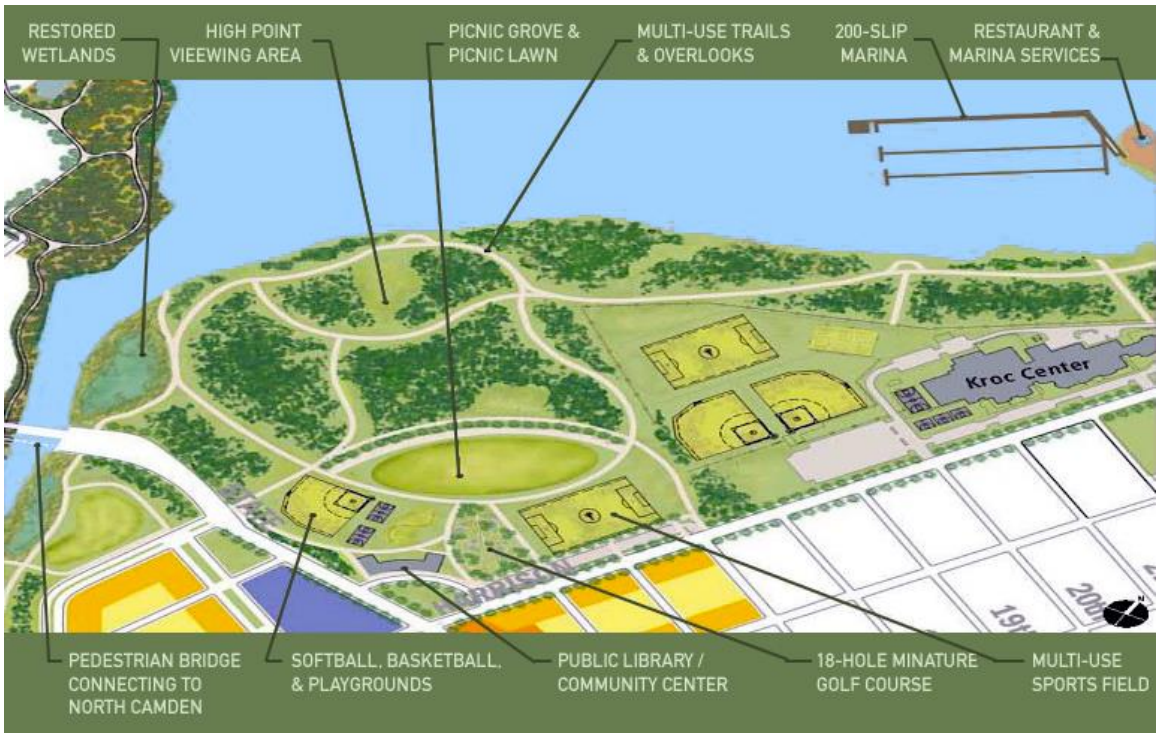

Figure 4: Harris Avenue Landfill Waterfront Park Master Plan. For the full details about the community-based redevelopment at this former landfill, see the case study on page 32. Source: Koberle

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"Measuring socio-economic impact: A guide for business," Feb 2013, http://www.wbcsd.org/Pages/EDocument/EDocumentDetails.aspx?ID=15357&NoSearchContextKey=true and United Nations Environment Programme, "Guidelines for Social Life Cycle Assessment of Products," 2009, http://www.unep.fr/shared/publications/pdf/DTIx1164xPA-guidelines_sLCA.pdf.

British Petroleum Former Refinery[1]

Location: Casper, WY
Regulatory Authority: WDEQ Voluntary Remediation Program
Parties Involved: BP & Naturally Wallace Consulting
Site and Cleanup Basics: This former refinery operated from 1908-1991, and as a result, an estimated 30 million gallons of oil leaked into the shallow alluvial aquifer adjacent to the North Platte River.

GSR practices implemented: A wetland was constructed to treat the biodegradable hydrocarbons. A radial-flow wetland was engineered in tandem with free-water surface wetlands and a cascading aeration system. The wetlands treat up to 700,000 gallons of contaminated groundwater each day.

Resulting Site Use: The site was converted to an office park and recreational facilities including walking trails, a river park, a whitewater kayaking course, and a golf-course.

Environmental Impacts:
- 50% reduction in BTEX concentrations compared to influent of pre-wetlands aeration process
- Concentrations of benzene and other hydrocarbons are not detectable in water prior to discharge
- Beneficial reuse of onsite demolition material in radial-flow treatment beds
- Passive energy system to treat contaminants reduces GHG emissions

Economic Impacts:
- Business development and job creation associated with site repurposing
- Surrounding area property values likely increased as a result of the redevelopment

Social Impacts:
- Recreational and business uses of previously unused brownfield site
- Designed wetland components for subsurface locations to the greatest extent possible to reduce offensive odors or insects
- Office park occupation possible within 10 months after wetland system began operating

Practitioner Impacts:
- An estimated $12.5 million saved in construction costs as compared to a conventional pump-and-treat plant
- An estimated $15.7 million saved in operating costs over the first 50 years of site remediation

[1] Natural System Utilities; WDEQ; and EPA CLU-IN.

NASA Former Drum Storage Area[1]

Location: Kennedy Space Center, Cape Canaveral, Florida
Regulatory Authority: RCRA, Florida DEP
Parties Involved: NASA & Geosyntec Consultants
Site and Cleanup Basics: This 170-acre launch pad facility is surrounded by wetland areas and the Merritt Island National Wildlife Refuge. Chlorinated volatile organic compounds (CVOCs) including trichloroethylene (TCE), dichloroethylene (cDCE), and vinyl chloride (VC) were found in groundwater through an interim RCRA Facility Investigation (RFI) completed in 2003. The contaminated area includes a 1.2-acre high concentration TCE plume and larger low concentration plume.

GSR practices implemented: The high concentration plume remediation used (1) enhanced bioremediation using biostimulation and bioaugmentation with aquifer buffering and (2) groundwater recirculation using a solar powered extraction system to mitigate the potential discharge of impacted groundwater to an adjoining surface water body and provide enhanced mixing within the dissolved plume. The low concentration plume remediation used monitored natural attenuation. Following remedy implementation, the site was evaluated against the five EPA core elements of green remediation and results demonstrated that the optimization strategy is effective

Resulting Site Use: The site continues to be used as launch pad facility.

Environmental Impacts:
- CO_2 footprint for enhanced bioremediation was much smaller than for other technologies evaluated (ranging from 15 tons per year to 95 tons per year CO_2 emissions reductions compared to alternatives)
- No demand for external power
- Minimal construction equipment, dust, habitat disturbance, and soil erosion
- Recirculated about 30,000 gallons of groundwater per week
- Mitigated potential plume discharge to surface waters
- Mobile solar system can be reused
- Minimal investigation-derived waste

Economic Impacts:
- Solar powered recirculation was the most cost-effective of any conventional design
- Material and equipment usage decreased as a result of limiting injection locations to focus on higher concentration zones, using a recirculation system, implementing solar power, and optimizing the amount of bioremediation substrate

Social Impacts:
- Passive remedy was less disruptive
- Remediation system effective in achieving the overall goals of preventing the migration of contaminated groundwater to surface water and reducing CVOC concentrations in groundwater

Practitioner Impacts:
- Solar powered system enables quick installation, mobilization, and demobilization
- Solar system was the most cost-effective alternative and costs for material and equipment were reduced

[1] Daprato et. al and ITRC, GSR-2, C-10.

Harris Avenue Landfill[1]

Location: Camden City, New Jersey
Regulatory Authority: NJDEP Brownfields Program
Parties Involved: NJDEP & CDM Smith
Site and Cleanup Basics: The site is an 85-acre municipal landfill located within a 200-acre brownfield development area (BDA) comprised of eight abandoned brownfield sites along the Delaware River. The unlined landfill, which stores municipal waste and industrial chemical waste, has resulted in groundwater and soil contamination from VOCs and chlorinated organic compounds.

GSR practices implemented: A GSR assessment was performed and practices integrated into all cleanup phases from planning through construction included:

- Community outreach and planning for site redevelopment
- Triad investigation to expedite source delineation[2]
- Biofuels used for all on-site heavy equipment
- Environmental footprint analysis conducted for remedial alternatives
- Environmental footprint tool comparison analysis between SiteWise™ and SRT™ for one remedial alternative

Resulting Site Use: A 132,000-square-foot community center was constructed on the site.[3]

Environmental Impacts:

- Triad investigation expedited the design of the remedial strategy, reduced uncertainty, and provided data to expedite the evaluation of remedial alternatives
- Generation of waste was significantly reduced
- More than 50% reduction in carbon footprint through integrated remedial approach

Economic Impacts:

- Redevelopment will generate jobs and increase reinvestment in the local community
- Building of assets and an increase in local wages and tax base will support growth of local economy and strengthen local government

Social Impacts:

- Redevelopment of an otherwise stagnant property
- Strengthened community institutions and catalyzed neighborhood revitalization
- 132,000-square-foot community center with family service center, indoor and outdoor recreational facilities, an aquatic center, and a childcare center

Practitioner Impacts:

- Triad approach saved over 250 hours of operation during the Remedial Investigation phase in comparison to a traditional sampling program
- 50% reduction in analytical costs and schedule
- 40% reduction in field effort

[1] ITRC, GSR-2, C-18 and Koberle.
[2] The triad approach refers to systemic project planning, dynamic work strategies, and real-time measurement technologies. ITRC, GSR-2, p. 5.
[3] The community center construction was made possible by a $54 million grant. NJDEP.

Marine Corps Logistics Base (MCLB) Albany, Operable Unit (OU) 6[1]

Location: Albany, GA
Regulatory Authority: CERCLA
Parties Involved: NAVFAC & Tetra Tech
Site and Cleanup Basics: The MCLB is a 3,579-acre supply and logistics facility for the U.S. Marine Corps that has had remedial activities underway for several years. OU 6 refers to the groundwater throughout the site in which COCs including tetrachloroethylene (PCE), TCE, and others have been detected. The original remedy included source contamination control through an evapotranspiration cap, a pavement cap, and soil cover, and the groundwater remedy included injecting sodium permanganate in 190 locations as well as monitored natural attenuation (MNA) for the entire site.

GSR practices implemented: The optimized remedy focused on targeting higher concentration areas for source contaminant reduction, using only 39 injection locations along with continued MNA. A subsequent revealed that this optimized remedy was effective in meeting ROD goals and reducing residual COC concentrations. The groundwater long-term monitoring (LTM) program was also optimized by reducing in the number of monitoring locations and sampling frequency and by shifting focus to COCs identified in the ROD. A sustainability evaluation was conducted to assess the impact of the remedy and LTM optimizations.

Resulting Site Use: Land use controls are in place until cleanup levels are met. The site met conditions for its third EPA five-year review approval in September 2011.

Environmental Impacts:
- Remedy optimization:
  - Net energy reduction of approximately 3,700 MWh
  - Life-cycle total reductions in GHG emissions by 1,475 tons CO_2e (or 75%)
  - Decreased life-cycle water usage by 1.1 million gallons
  - Reduced life-cycle emissions of NO_x, SO_x, and PM_{10}
- LTM optimization:
  - Net energy reduction of approximately 130 MWh
  - Life-cycle total reduction in GHG emissions by 57 tons CO_2e
  - Decreased life-cycle water usage by 90,000 gallons

Economic Impacts:
- Remedy and monitoring optimization have been estimated as yielding over $10 million in cost avoidance over the life-cycle of the remedy

Social Impacts:
- Reduced disturbance while ensuring protection and restoration of natural resources on and around the base
- Precautionary extra steps taken to provide community with necessary knowledge and tools to prevent any on-base pollution from affecting off-base residences[2]

Practitioner Impacts:
- Significant cost avoidance
- Lessons applicable to future projects including which elements of the remedy have the greatest impact on the environmental footprint and the importance of optimization reviews and sustainability evaluations at each phase

[1] NAVFAC; Maughon; and EPA
[2] U.S. Marine Corps.

SECTION IV. FUTURE OF GREEN & SUSTAINABLE REMEDIATION

Potential Challenges to Implementation

A basic challenge that has hampered GSR for some time is the lack of a universal definition. Defining "sustainability" within the context of remediation poses difficulty in part because most of the expertise in the remediation industry is concentrated in geology and engineering, not social science or economics. Furthermore, there is an inherent disconnect between the term "sustainability", which implies a holistic and long-term approach, and the term "remediation", which implies a specific timeframe related to land use and reuse. This definitional discrepancy contributes to varying levels of acceptance within and across cleanup programs and issues with communication broadly, but it has not prevented collaboration from occurring or progress from being made to advance GSR.

Multiple surveys have been conducted that provide insight into what stakeholders perceive to be the greatest challenges to the implementation and promulgation of GSR. ASTSWMO conducted a survey in January 2009 regarding barriers and incentives of GSR.[68] Though the survey was small—with only 44 responses from 27 states—the results are indicative of what those in the cleanup world identify as the greatest challenges to GSR's success. There were four categories of barriers from which the participants were asked to select the top three. The options are included in the table below.

ASTSWMO Survey: Identified GSR Barriers

Regulatory Barriers	Technical Barriers	Industry/Market Barriers	Societal Barriers
• Varying degrees of understanding • Not explicitly included in existing regulations/lack of authority • Established process of remedy selection threshold criteria • Acceptance of remedial methods • Inflexible cleanup standards or requirements • Areas to integrate greener cleanups • Lack of ability to offer incentives • Beneficial reuse/permitting issues • Fear that it supports the "do nothing" option	• No universal definition • Lack of guidance • Metrics not established • Validation of green remedies are few • Availability of resources varies	• Economics-may be more upfront costs • Funding sources • Cost/benefit • Lack of incentives • Need certainty in the process • Timeframes to completion • Additional requirement may lengthen process • Mandates/goals of industry vs. government • Goals vs. missions • Materials reuse/recycling markets not available	• Lack of knowledge/awareness of greener cleanup practices • Current acceptance/comfort with conventional practices • Little knowledge of reliability of green remedies • Lack of understanding of cost/benefit • Impacts not quantifiable • Resistance to risk-based cleanups

[68] ASTSWMO Sustainability Subcommittee, Greener Cleanups Task Force, "Incentives for Greener Cleanups," ASTSWMO, Jun 2009, p. 13.

Based on the survey results, the top barriers to greener cleanups include:

1. Lack of knowledge/awareness of greener cleanup practices
2. Economics—may be more upfront costs[70]
3. Not explicitly included in existing regulations/lack of authority
4. Lack of ability to offer incentives

Progress has been made in addressing some of these challenges. The following section will consider each individually, noting what has been done thus far and what actions or possibilities still exist for lowering these barriers.

1) Proliferation of GSR awareness

Regarding the first challenge, lack of knowledge or awareness of greener cleanup practices, it is notable that the same survey also identified this as the barrier that is most easily overcome. Government and non-government agencies alike are engaging in outreach and partnerships in an attempt to educate regulators, consultants, industry, and the public on GSR. The guidance documents, trainings, and conferences provided by SURF, ASTSWMO, ITRC, EPA and others demonstrate the substantial progress made in this effort. There is still need, however, for further dissemination of GSR. The involvement of industry, consultants, engineers, and others to create the ASTM principles likewise speaks to the momentum that GSR has gained. Once widely implemented, the ASTM standards may provide a platform and common language essential to further disseminating GSR.

Environmental service providers hold an important role in the awareness building effort as well. Companies hired to advise or conduct cleanups are poised as gatekeepers for spreading GSR to their clients and to cleanup sites in which they are operating. The service providers and consultants who make the initial investments to adopt GSR practices stand to gain and benefit their clients in the long term, especially as regulator and public preference for greener cleanups strengthens.

Federal and state agencies who are incorporating green and sustainable practices as criteria in selecting contractors for cleanup work are champions of the effort to spread awareness about GSR, as by doing so they encourage companies to adopt these practices. Encouragement from regulators, especially at the state level, for companies to incorporate GSR and rely on guidance like the ASTM standards will be integral to the sustainable future of the remediation industry.

[70] ITRC conducted a similar survey to understand state understanding and concerns in 2010. The results also showed concerns about cost outranking those of regulatory barriers. For details see ITRC, GSR-2, Appendix A.

2) A Closer Look at Costs

Figure 5: Processing of decontaminated tunnel sections for recycling at Linde Site, Tonawanda, NY. Source: USACE

Case studies detailed in this report and throughout the GSR literature demonstrate that any additional costs required by a GSR project are often incurred early in a project and in most cases result in long-term net savings. GSR remedies focus on the use of less material and/or energy, which often directly equates to cost savings. There are numerous examples where this is the case and where net overall savings result. Some specific examples include:

- Microturbines used to create electricity from methane gas at Operating Industries, Inc. Landfill in Monterey Park, CA resulted in a net project savings of $647,000. The turbine equipment and installation cost $1.25 million some of which was offset by grants and a rebate from the California Energy Commission. The remaining upfront cost was recovered through approximately $1.75 million in energy cost savings over seven years of operation.[71,72]
- At the Linde Air Products site in Tonawanda, NY, a cost savings of $8.7 million was achieved by recycling clean soils on the site for use as backfill.[73]

The above are just a sample of the many cases where GSR has led to cost savings over a remedial project lifetime. In some cases, GSR practices are cost neutral and may not result in additional spending or savings. There are few examples, or few publicly available case studies, where implementing GSR practices has a greater net cost than a traditional approach.

It is also worth noting the competitive advantage that consulting and engineering firms may gain by building GSR practices and BMPs into their standard procedures. As GSR takes hold across the remediation industry, firms will be advantaged as clients seek service providers experienced with GSR.

With the correct incentives to overcome any upfront cost or guidance to overcome misconceptions about cost, it seems that cost is a surmountable challenge. In fact, the

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[71] "Operating Industries, Inc. Landfill, Monterey Park, CA," *Contaminated Site Cleanup Information (CLU-IN)*, U.S. Environmental Protection Agency, 27 Mar 2012, www.clu-in.org/greenremediation/subtab_d10.cfm.

[72] "Innovative Evapo-transpirative Monocover and Groundwater Remediation at the OII Landfill Superfund Site," Geosyntec Consultants, http://www.geosyntec.com/UI/Default.aspx?m=ViewProject&p=63.

[73] U.S. Army Corps of Engineers (USACE), "Formerly Utilized Sites Remedial Action Program Update 2012," Jan 2013, http://www.usace.army.mil/Portals/2/docs/Environmental/FUSRAP/FUSRAP_Stakeholder_Report_2012_Final.pdf, p. 8.

frequency with which companies cut costs by implementing GSR and the competitive advantage that firms stand to gain should serve more often as encouraging factors for these practices to be used more widely.

3) Regulatory Framework

The implementation of GSR tools, practices, or strategies is at present a voluntary undertaking. As the benefits of GSR become better understood and practices more widespread, many stakeholders are advocating for a structured, policy-based approach that would make GSR practices a requirement under federal or state cleanup statutes. Enacting new legislation or regulations to formally integrate GSR into cleanup statutes is likely to be far too time consuming and politically challenging to be a viable option. On the other hand, establishing regulatory guidance for integrating GSR into existing statutes where appropriate may be a more efficient and more manageable approach. The regulatory entities involved in cleanup projects include federal agencies, tribal organizations, state agencies, and local agencies. These entities are responsible for enforcing regulations from a variety of programs that regulate hazardous waste management and contaminated site cleanups including the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Clean Water Act (CWA), the Toxic Substances Control Act (TSCA), and others. Among these, CERCLA, also referred to as Superfund, and the corrective action provisions of RCRA are the two primary statues with authority for remedial actions.

Both RCRA and CERCLA use a number of specific criteria to evaluate remedial alternatives. Under CERCLA, nine criteria are used in the decision making process. Every remedy must meet two threshold criteria: 1) protection of human health and the environment and 2) compliance with applicable or relevant and appropriate requirements (ARARs). The remedies are then evaluated against one another using the five balancing criteria: 1) long-term effectiveness and permanence, 2) reduction in toxicity, mobility, and volume of contaminants, 3) short-term effectiveness, 4) implementability, and 5) cost. Finally, two modifying criteria are used to determine if the remedy is acceptable to other stakeholders: 1) state acceptance and 2) community acceptance.

A similar set of criteria prevails under the RCRA Corrective Action Program for evaluating remedial alternatives. There are three performance standards that all remedial alternatives must meet: 1) attainment of media cleanup standards, 2) control of the source of the release, and 3) protection of human health and the environment. The seven balancing criteria include: 1) long-term reliability and effectiveness, 2) reduction of toxicity, mobility, or volume of wastes, 3) short-term effectiveness, 4) implementability, 5) cost, 6) community acceptance, and 7) state acceptance.

While neither program explicitly includes considerations of greener or more sustainable methods, such considerations may still be voluntarily undertaken in the evaluation and selection of alternatives. Moreover, GSR concepts may be implied in a number of the existing criteria, perhaps opening the door for future, more explicit, inclusion in the regulations. Such criteria include, for instance, “protection of human health and the environment” as well as “long-term effectiveness and permanence.” Certain green and sustainable remediation factors could be incorporated as elements for consideration under these or other criteria.

EPA is actively working to determine how best to establish GSR within the Superfund structure. EPA's Office of Superfund Remediation and Technology Innovation (OSTRI), in its 2010 *Superfund Green Remediation Strategy* document, established the action item to clarify how green remediation practices fit within CERCLA and the NCP, including the extent to which the Superfund program can incorporate green remediation practices under existing laws and regulations.

4) Options for Incentives

There are a number of means to incentivize greener cleanups, despite their voluntary nature. The standards developed through the collaborative ASTM process may serve a key role in such incentives, offering a common guidance for regulators to point to and for practitioners to rely on.

Based on their 2009 study of barriers and incentives, ASTSWMO identified nine potential incentives for encouraging GSR approaches at state site cleanups including LUST, Brownfields, Federal Facility, RCRA, and Superfund sites.[74] These are described and analyzed below.

Loans and grants: EPA and states currently use loan and grant programs to fund Brownfields redevelopment. Including GSR practices as criteria for or objectives of these loans and grants would be one avenue to encourage greener cleanups. Specific grants could be created for providing technical support on incorporating GSR into the site cleanup. Loans could be made available to site managers to overcome any higher upfront costs associated with greener technologies. These could then be paid off from the net savings over time. DOE already has a grant program in place to incentivize industry and other agencies to research renewable energy and energy efficiency. A creative grant application to a program like this could enable the user to implement renewable energy or energy efficient technologies. EPA also established a Brownfields Sustainability Pilot program in 2008 and provided funding for sustainable practices such as reuse and recycling of materials, green building design, energy efficiency, water conservation, and renewable energy development.[75] This type of program could be expanded to sites outside the Brownfields realm and built upon with specific funds allocated to hire sustainable remediation consultants with expertise in GSR.

Reduced Processing Time and Fees for Remedy Documents: Expedited reviews or cost reductions for GSR projects in the review and documentation process could serve as another incentive. For instance, those projects that have used the ASTM standards, or otherwise meet some threshold to qualify as a GSR project, might be assigned to a project manager is knowledgeable about GSR for review. Other methods might include developing presumptive remedies that incorporate GSR for similar sites or developing a memorandum of understanding (MOU) between the various oversight programs for permitting projects that use the ASTM standard so as to streamline the approval of remedial action plans.[76]

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[74] ASTSWMO Sustainability Subcommittee, Greener Cleanups Task Force, "Incentives for Greener Cleanups," ASTSWMO, Jun 2009.
[75] U.S. Environmental Protection Agency, "Building a Sustainable Future: A Report on the Environmental Protection Agency's Brownfields Sustainability Pilots," Oct 2009, http://www.epa.gov/brownfields/sustain_plts/reports/sustain_report_web_final.pdf.
[76] The State of Missouri's Water program has undertaken such an MOU with its Hazardous Waste Program so that the Waste program may issue underground injection control permits provided they meet all the permit requirements. ASTSWMO, "Incentives," p. 5.

There are a number of fees associated with remediation reviews and projects that could be reduced or eliminated in order to incentivize GSR. These might include oversight costs, permit fees, enforcement fees, or long-term stewardship fees. Another economic incentive might include giving priority to GSR projects for reimbursement from applicable funds such as the State Underground Storage Tank Funds or State Dry Cleaner Remediation Funds.

Fee Incentives for Green Remediation: Tax credits or fees serve as another option for influencing a practitioner to choose a greener remedial alternative. Tax credits might for instance be issued to reduce or cover the cost of recycling concrete or construction debris from remediation projects. Positive incentives like tax credits and process fee reductions as outlined earlier are preferable to added fees for unsustainable or less-green practices, as the latter may be challenged since GSR is not required under existing laws. Fees might be raised at all sites and then discounted for those sites meeting GSR criteria, but such a change would require legislation. Examples of higher fees include: raising landfill fees if it is determined that there is a greener disposal alternative, assessing fees for inefficient use of water resources using discharge permits, or a utility surcharge for energy used in remedies that is not sustainably generated.

Contract Incentives: Through federal facility cleanups, federal Superfund cleanups, and state-led cleanups, millions of dollars in government contract work is awarded each year. In the process to decide winners of such contracts, preference might be given to bidders using more energy efficient and sustainable equipment or who plan to incorporate GSR BMPs and practices, potentially those outlined in the ASTM standards. There may be other opportunities to integrate awards or incentives via the contracting process.

Publicity and Recognition: States or third party organizations could develop a ranking or award system to recognize the best practitioners in green and sustainable cleanups. This could be aimed at specific project sites as well as companies as a whole. Eligibility requirements, selection criteria, and metrics by which to judge the level of sustainability of a cleanup would all have to be developed. The ASTM standards might provide a baseline to work from for an effort like this.

Consultant Education and Accreditation: An accreditation process or certification program could be developed so that consultants may demonstrate their knowledge and expertise with respect to GSR. They could use such an accreditation as a marketing tool and companies seeking to implement the GSR process could easily locate consultants with the skills and experience to support such an effort. If this were employed in conjunction with other incentives that encouraged cleanup parties to use GSR practices in the first place, more parties would be seeking accredited consultants making the advantage of accreditation even greater.

Increase Credit for LEED or Other Green Building Programs: Under the 2009 LEED Green Building Certification process for newly constructed buildings or major redevelopment, locating the building on a redeveloped Brownfields site will earn the building one point (of 110 possible).[77] Increasing this number or adding additional credit for sites where green remediation practices were used might further propagate GSR practices and inform more individuals about GSR and the importance of remediated site reuse.

Supplemental Environmental Projects: A supplemental environmental project (SEP) under environmental law is an environmentally beneficial project undertaken by the responsible party as an alternative to a monetary penalty for a violation of a settlement agreement. The SEP involves activities that would not otherwise be legally required, thereby reallocating funds that would be paid in penalties to advance the environmental benefit of the cleanup. The penalty is then recalculated using a multi-step process that considers the net cost of the SEP.[78] GSR practices might be implemented through this mechanism. This is complicated by the fact that at times GSR practices can save money. In those instances, no amount of the penalty would be offset. There are instances where GSR activities would be appropriate however. For example, if a violation were to occur where the cleanup party failed to design and implement corrective action plans in a timely manner, a green remediation focused SEP might involve an assessment of the sustainability impacts of the planned cleanup and potentially the evaluation and selection of environmentally-preferable cleanup options.

Relying on SEPs as a means to encourage GSR practices, however, is not likely to contribute much to institutionalizing GSR practices within the cleanup field. SEPs are actions taken that are not legally required under the administrative order or agreement, thus they are often above and beyond the normal realm of cleanup responsibilities. Though they may be applicable in certain cases, SEPs would not be a means to the long-term inclusion of GSR practices into environmental cleanups.

Carbon Offsets and Carbon Credits: Regional carbon cap-and-trade systems are being considered in the U.S. whereby emitters of CO_2 are given a certain amount of emissions allowances that can be traded or sold to other entities. Under such a system, GHG reductions from green and sustainable technologies or practices at a remedial site would become valuable carbon offsets, therefore encouraging the use of clean, low carbon remediation technologies. This incentive requires, however, that a cap-and-trade system exists. Thus far in the U.S., only one such system is underway in California, but it is expected that the Western Climate Initiative, a group of western U.S. states, will soon follow suit. Voluntary cap-and-trade emission reduction programs exist elsewhere, and other regional groups like the Regional Greenhouse Gas Initiative, a collaboration of northeastern U.S. states, are investigating similar schemes.

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[77] U.S. Green Building Council, "LEED 2009 for New Construction and Major Renovations," 2009, http://www.usgbc.org/sites/default/files/LEED%202009%20RS_NC_10-2013_1b.pdf.
[78] The process for calculating the final penalty under EPA's 1998 SEP policy is more complicated than a simple deduction of the net cost of the SEP and involves calculating a mitigation percentage as well as meeting a minimum value. Steve Herman Memo to Regional Administrators, "Issuance of Final Supplemental Environmental Projects Policy," U.S. Environmental Protection Agency, 10 Apr 1998, http://www2.epa.gov/sites/production/files/documents/fnlsup-hermn-mem.pdf.

The above incentives outline a handful of those that have been proposed to encourage GSR. Many are imperfect and would require significant changes to be made before they could become viable but fundamentally demonstrate that options are available. With some creativity, it is possible to incentivize and spread GSR practices with the regulatory tools available today. Knowledge sharing on efforts like these will be essential moving forward so that incentive programs attempted by one regulatory entity may be a lesson to others and, if successful, adapted for cleanup programs across the U.S. and internationally.

CONCLUSION

The activities surrounding green and sustainable remediation are extensive. The number of organizations, federal agencies, private businesses, local governments, and international groups advancing the goal of minimizing the environmental impact and maximizing the social and/or economic benefits of remediation is remarkable. The tools, frameworks, guidance documents, matrices, and innovative technologies that have been developed are all signals that GSR has intrinsic momentum as an approach that companies, project managers, and agency leaders want to adopt, despite it not being required by law. The extent to which GSR practices have been spread thus far demonstrates that the inherent incentives are strong, whether these are cost savings, time savings, community and stakeholder engagement, or otherwise.

***International Implications*:** GSR principles have been embraced globally as a better way to do business. Nascent remediation programs developing around the world have benefited from the experience of mature remediation programs. Countries with cleanup programs in their early stages may benefit greatly from integrating GSR into these programs early on, in tandem with the development of remediation regulations. In Brazil, China, and Taiwan this integrated development seems to be occurring to varying extents, and in countries like these, it ought to be seriously pursued. If sustainable practices can become firmly established in the laws and policies upon which the programs are based, these countries might avoid the more difficult retroactive incorporation of GSR into established cleanup programs and structures.

Efforts such as SURF-International meetings and conferences have provided a platform to share experiences and influence young cleanup programs. It is essential that these actions continue and that communication with international counterparts remains robust and frequent. One piece of this effort is a white paper on global perspectives of sustainable remediation that SURF intends to publish.[79] Based in part on ideas shared at the SURF December 2012 conference on global sustainable remediation, the paper would serve as a progress update and an opportunity for experience sharing from the various efforts underway around the world. These exchanges of knowledge, experience, best practices, and lessons learned that have and will benefit all parties involved.

A model for this type of an international collaboration is observed in the Brownfields program where global relations through peer mentoring, communicating BMPs, and sharing lessons learned with international counterparts has helped foreign programs develop in the most streamlined manner possible. A parallel seems warranted for GSR and is especially appropriate while cleanup programs around the world are still in their early phases of development.

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[79] SURF, "SURF 21 Meeting Minutes," p. 2.

To bolster this international effort, it may be appropriate that the recently finalized ASTM standards or the ISO standards now being developed be adopted as a global standard for green and sustainable remediation. Having standards set by a major standard agency like ISO may increase the likelihood that they will be put to use internationally. The common terminology and implementation guidance that these standards provide would also serve to unite and propel the many ongoing efforts to advance green and sustainable remediation.

***Incentivizing*:** The challenges to widespread implementation are not too difficult to overcome and, in some cases, are not true challenges, but rather misconceptions. Where challenges exist, there is ample opportunity to introduce incentives that could be effective in overcoming these.

There are many options for incentivizing GSR practices within the existing regulatory framework in the United States. Some are particularly promising like the consultant or engineer accreditation program. The ASTM standard may provide the needed common baseline for developing such a certification and rating system. Other incentives that would reduce upfront costs of GSR implementation include loan programs, grants (including existing grants like those for energy efficiency), tax credits, or reduced processing time and fees. Continued creative thinking and information sharing on the success of such incentives is needed.

***Communication, Openness, Collaboration*:** A strong network of communication between actors implementing and aiming to share knowledge about GSR has been crucial to its success. Collaborations between agencies, businesses, and partner organizations have been instrumental to the growth and development of GSR and the many resources that are now available.

The momentum that has brought GSR to this point can still be built upon, utilizing many of the same methods that have brought it this far. In order to continue this process of scaling up and turning GSR into the status quo, continued communication, outreach and coordination between those already experienced in GSR is critical. The sharing of case studies, BMPs, implementation frameworks, tools, and lessons learned is being accomplished through organizations like SURF, ITRC, ASTSWMO, international conferences, and other forums. To this end, SURF has an initiative underway to develop standards for case studies and to serve as an international database of case studies. The leveraging of existing knowledge and past experience is essential to avoid duplicative efforts, while sharing the most efficient path to common goals and successes.

***Progressing Together*:** GSR has developed in a bottom-up manner. Some of the most innovative methods and technologies are derived from state-led initiatives and businesses operating at the frontier of the GSR movement. GSR is taking root internationally in a similar manner; through global businesses and partner organizations like SURF convening stakeholders to share their experiences.

With so many stakeholders acting to advance the field, it risks being guided in too many directions. The ASTM and ISO standards are great steps towards the next level of proliferating GSR practices in a consistent manner not only in the U.S., but globally. These standards, along with the continued exchange of knowledge going forward, will hopefully guide all actors in a similar direction with increased regulatory visibility. Of course, flexibility across the regulatory structures in different countries will be necessary, but a consistent direction with common messaging would be beneficial.

Finally, the evidence within this report, and within the many resources it has drawn upon, suggests that green and sustainable approaches to remediation are beneficial for businesses, for communities, and for the further protection of our shared environment. Furthering the incorporation of GSR into the environmental remediation field, both domestically and internationally, is a pursuit deserving the furthered attention, effort, and collaboration of all stakeholders.

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Figure 1
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Figure 3
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