2. Importance and Value of Sustainable Resilient Remediation

This section provides the following:

- background and context on evolution to and value of SRR
- brief overview of the history of hazardous waste cleanup and the importance of GSR
- climate change impacts from extreme weather events, sea-level rise, and wildfires to the integrity of environmental remediation solutions and, in turn, the public health and environment of the surrounding communities
- case study matrix that summarizes projects where SRR has been implemented
- frequently asked questions (FAQs) about misperceptions and the value of SRR that prove the case for using SRR, along with references to case studies

2.1 Evolution of Environmental Remediation to SRR

Approaches to cleaning up contaminated sites became more standardized in the United States following the establishment of transformative federal regulations (and subsequent state regulations) governing their remediation. Since the early days of site cleanup activities, the remediation industry has progressed through several cycles representing different approaches for achieving cleanup objectives (Figure 2-1). Until recently, the development of remedial approaches relied mostly on a static site characterization (for example, current and historical

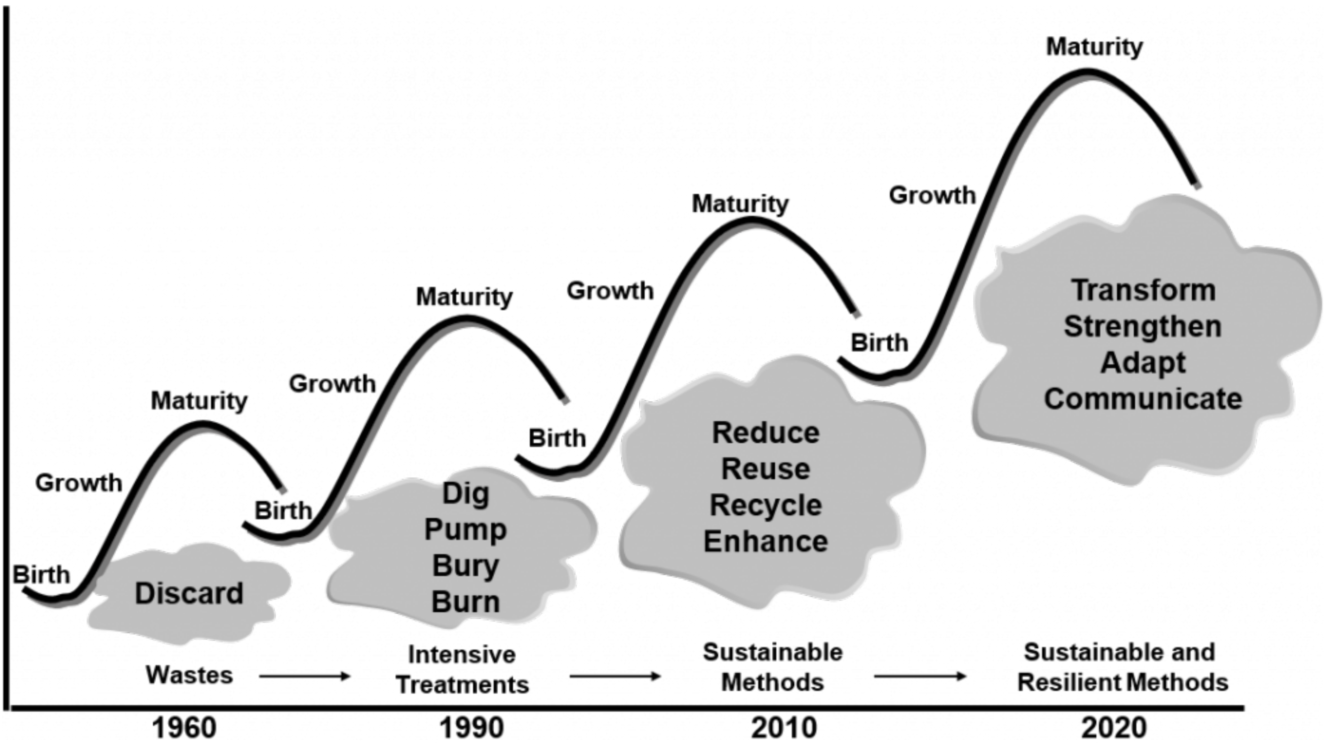

Figure 2-1. Evolution of environmental remediation to SRR.
Source: Adapted from Ellis and Hadley (2009).

groundwater elevations, flow directions, precipitation rates) that reflected conditions at a single point in time. Conceptual site models (CSMs) have generally placed more emphasis on how past site activities created current site conditions, and little attention on what could happen at a site in the future.

Since 2000, cleaning up contaminated sites has generally consisted of a risk-based approach while maintaining the primary objective of protecting human health and the environment. As a result, many contaminated sites are being addressed through long-term management (for example, institutional and engineering controls, land-use restrictions, hydraulic control, source containment, passive treatment, monitoring, and natural attenuation) rather than resource-intensive, active source removal. In long-term management, protecting human health and the environment is not a static objective to be achieved, but a condition that must be maintained throughout the lifespan of the remedy.

2.1.1 Introduction of Sustainability Principles and Practices

When introduced in 2008, GSR was a fresh look at how to best manage environmental assessment and remediation to maximize the benefits of such efforts. The integration of sustainability practices into remediation was launched through a series of seminal guidance documents published between 2008 and 2011:

- USEPA published Green Remediation: Incorporating Sustainable Practices into Remediation of Contaminated Sites in 2008 (USEPA 2008).
- The Sustainable Remediation Forum (SURF) published a sustainable remediation white paper in 2009: Sustainable Remediation White Paper—Integrating Sustainable Principles, Practices, and Metrics into Remediation Projects (SURF 2009).
- ITRC published Overview Document: Green and Sustainable Remediation: State of the Science and Practice in May 2011 (ITRC 2011b) and Technical and Regulatory Guidance: Green and Sustainable Remediation: A Practical Framework in November 2011 (ITRC 2011a).

The above documents not only provided guideposts on what was considered practical for implementation based on general industry stakeholder acceptance, they provided industry with tools and practices that could be applied. These tools and practices place as much emphasis on ensuring sustainability in the *process* of cleanup as they do in the long-term impacts of the remedy. GSR is not a means of justifying a less effective remedial action, but instead a case for weighing the additional measures of environmental, social, and economic effectiveness alongside remediation potential at all stages. The *intentionality* of considering these GSR elements is its key distinguishing feature.

Many lessons have been learned about GSR (for example, the importance of stakeholder engagement), the science has advanced (social and economic impact evaluations), and new tools have emerged since the ITRC published its guidance documents in 2011. Many of these attributes are summarized in a review (Favara et al. 2019). This new ITRC guidance, Sustainable Resilient Remediation (SRR-1), presents these lessons learned as resources for state agencies and other decision makers, remediation and resilience practitioners, and affected communities.

The evolution described above has provided a mechanism with which to address resilience in remediation. There is growing evidence that shifting short- and long-term climatic conditions will critically influence the performance of many types of infrastructure, including contaminant management and remediation measures intended to protect human health and the environment (Maco et al. 2018, O'Connell and Hou 2015, Reddy, Kumar, and Du 2019).

2.1.2 Impact of Extreme Weather, Sea-Level Rise, and Wildfires

In 2019, the Government Accountability Office (GAO) published a report entitled Superfund, U.S. EPA Should Take Additional Actions to Manage Risks from Climate Change, which highlights several National Priorities List (NPL) sites' vulnerability to extreme weather. The GAO reported that 60% of all nonfederal NPL sites are in areas that may be impacted by flooding, storm surge, wildfires, and/or sea-level rise. The GAO noted that their findings may not fully account for the number of nonfederal NPL sites because (1) federal data are generally based on current or past conditions; (2) data are not available for some areas; and (3) there may be other climate change effects (such salt-water intrusion, drought, precipitation, hurricanes, winds, and average and extreme temperatures) that could impact nonfederal NPL sites (GAO 2019).

A 2018 report by SURF found that:

Extreme weather events can undermine the effectiveness of the original site remediation design and can also impact contaminant toxicity, exposure, organism sensitivity, fate and transport, and long-term operations, management, and stewardship of remediation sites. In the U.S., nearly two million people—the majority in low-income communities—live within one mile of one of 327 Superfund sites in areas prone to flooding or vulnerable to sea-level rise caused by climate change. In 2017, the federal government reported that "…extreme weather events have cost the United States $1.1 trillion since 1980…" (Maco et al. 2018, page 8).

2.1.3 Resilience Considerations

Federal, state, and local agencies; emergency response departments; nongovernmental organizations; and private companies have led numerous planning and organizational efforts in response to increasing environmental threats (for example, intense storms, extreme drought, coastal and inland flooding, and wildfires). Efforts have focused on reducing the impacts of these adverse events and doing so efficiently by maximizing social, economic, and environmental benefits (Marchese et al. 2018). The result is an increased interest in both sustainability and resiliency.

The Shark River Marina case study (Appendix A) exemplifies a multiorganizational partnership and the benefits of an SRR project. The State of New Jersey, Federal Emergency Management Agency (FEMA), Township of Neptune, and Monmouth

Conservation Foundation provided funding for site cleanup, purchase of the property, and redevelopment as a full-service marina and a disaster assistance center during emergencies. The environmental benefits included in situ treatment that reduced contaminant concentrations and limited excavations to contaminant hotspots. Solar panels provide sustainable resilient power. A new drainage system recharges groundwater, avoiding costs and disruptions that would result from extreme weather events. The full-service marina also provides the public health benefits associated with outdoor recreation.

Resilience is the capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption (USEPA 2020b). Understanding resilience requires an understanding of vulnerability, which includes both site vulnerability and social vulnerability. As discussed in Section 6.2.5.1, each of these terms is a balance of several quantifiable characteristics:

- Site Vulnerability = Extreme Weather & Wildfire Exposure + Site Sensitivities – Remedial System Adaptive Capacity
- Social Vulnerability = Extreme Weather & Wildfire Exposure + Community Sensitivities – Community Adaptive Capacity

The National Contingency Plan (NCP) established nine criteria for evaluating remedial alternatives to ensure that all important considerations are factored into remedy selection. While all nine criteria must be considered, two of these criteria serve as useful examples of how sustainability and resilience can be considered in remediation projects:

- Long-term effectiveness and permanence are criteria that address the need for reliable protection of human health and the environment over time. To effectively evaluate a remedy with respect to this criterion, vulnerabilities to extreme weather, sea-level rise, and wildfire events over the expected lifetime of the remedy should be considered. Where vulnerabilities are identified, adaptation measures can be developed and integrated into the remedial design to maintain the integrity and resilience of the remedy over time.
- Short-term effectiveness addresses the time needed to implement the remedy and potential adverse impacts to the community, workers, and the environment during construction and operation until cleanup standards are achieved. This criterion can consider the direct and indirect beneficial and unintended environmental, social, and economic impacts of remedial alternatives. Site management practices should be identified and integrated into the remedial design to maximize benefits and minimize unintended impacts.

The steadily increasing economic, environmental, and social losses from natural disasters and the awareness of the potential effects of catastrophic events on vulnerable infrastructure require policies and procedures for implementing and measuring resilience to be more consistently applied. Integrating resilience with sustainability planning and management (Section 6) is expected to minimize conflicts and maximize synergies when compared with separate implementation strategies.

2.1.4 Managing Changing Risk Factors

The anticipated risks of extreme weather events, wildfires, and changing climatic conditions on contaminated sites are substantial. Vulnerabilities to critical infrastructure in the vicinity of the site must also be considered. For example, upstream dams or levees with high hazard ratings could lead to different resilience and adaptation measures for contaminated sites downstream. Beyond the anticipated direct impacts to the remedy itself, indirect impacts may also need to be addressed (see Section 7, Key Sustainable Best Management Practices for Climate Change Resilience to Extreme Weather Events and Wildfires).

2.1.5 The Case for SRR

There is growing evidence that resilience measures have favorable economic returns on investment. A recent study of federal government hazard mitigation projects found that hazard mitigation funding can save the United States $6 in future disaster costs for every $1 spent on hazard mitigation (NIBS 2018).

While sustainability considers the remedy's impact on the environment, resilience considers the environment's impact on the remedy. However, this distinction is not so simple. For example, a remedy that is vulnerable to extreme weather—that is, not resilient when exposed to an extreme weather event—may fail to reach its design life, thereby causing significant adverse impacts to the surrounding environment. These environmental impacts, in turn, may have associated economic impacts (for example, the cost to clean up a release caused by extreme weather and reestablish the remedy) and social impacts (for example, the impacts to the community from the release caused by the extreme weather or the additional costs to reestablish the remedy at the expense of using those funds for another cleanup action). To be truly sustainable, a remedy must maintain functionality for the duration of its design life and do so by being resilient to extreme events and changing conditions. The interconnectedness of sustainability and resilience, particularly as they relate to the cleanup of contaminated sites, reemphasizes the importance of an integrated approach.

To help readers better recognize examples of SRR integrated into cleanup projects, Appendix A is a summary of SRR case studies. The case studies summarized in the appendix were selected from USEPA's CLU-IN "Profiles in Green Remediation," SURF's case study website, other published sources, or other work that is summarized in this document for the first time. The case study matrix outlines the following information for the case studies:

- Case study name (which may be referenced in other parts of this document)
- Location of case study
- Overview of remediation activities conducted
- Elements of SRR activities performed at site
- Examples of environmental, economic, social, and resilience benefit(s) derived from the work
- Offset/avoidance achieved
- Tools used to support SRR work
- Literature references or links to full case study
- Regulatory program work was completed under

Appendix A was designed for readers to look at each of the above components by project or to quickly scan the matrix for examples of environmental, economic, social, resilience, or avoidance/offset benefits achieved. The reader is encouraged to read the full case study (if a link is available in the matrix), as not all information from the case study could be summarized in the matrix. While the SBMPs developed for this document were not available when the case study projects were being completed, examples of how particular SBMPs might be applicable to a case study project are provided in the "tools footprint, BMPs, LCA, MCDA, surveys, etc…" column of Appendix A.

This ITRC SRR guidance is the first to integrate sustainable remediation and resilience. In summary, SRR:

- can be good business and good government (Appendix A and full case studies in this document highlight the value of SRR).
- creates trust or earns valuable trust (see 2nd Street Park; Tar Ponds and Coke Ovens; and California Gulch case studies in Appendix A).
- can focus on underserved, most vulnerable communities (see Phoenix Park case study, Section 5.10).
- helps expedite cleanup and redevelopment (see Pharmacia and Upjohn case study in Appendix A).
- decreases public health risks (see Appendix A for examples of reductions of air emissions in the "environmental" and "offset/avoidance" columns).
- creates jobs, parks, wetlands, and resilient energy sources (see Harrison Avenue Landfill/Cramer Hill Waterfront Park Project, Appendix A).

2.2 Frequently Asked Questions (FAQs)

Key messages were developed to support responses to questions about the value proposition and potential misperceptions of SRR.

2.2.1 Why is SRR Valuable?

Table 2-1 addresses FAQs related to the value of SRR. The table states a FAQ and provides a concise answer. The table also provides examples for how the components of the FAQ were included in a case study in Appendix A and/or Section 5.10.

Table 2-1. The value of SRR and references to case studies reflective of answers.

FAQ	Answer	Case Study Match(es)*
Do sustainable and resilient remedies improve long-term risk management?	Yes. Practitioners identify project risks not normally considered. Sustainable risk management includes emissions mitigation and community revitalization. Resilient risk management maximizes adaptive capacity to changing climatic conditions.	Santa Susana Field Laboratory, Area IV—used cost/risk reduction tools. Senator Joseph Finnegan Park used risk management in determining remedy scope that limits long-term risk.

How can stakeholder involvement benefit SRR?	Stakeholder collaboration identifies unintended impacts and perceived risks of site activities. These perspectives inform community remediation performance metrics. Integrating stakeholder values maximizes site cleanup benefits.	Tar Ponds and Coke Ovens Canada—stakeholder involvement was described as critical to completion.
What are some examples of how SRR planning maximizes the potential of local and regional benefits from cleanup and restoration activities?	Best management practices transcend site impacts. Sustainable materials management considers local waste streams and socially conscious sourcing. Resilient environmental restoration contributes to regional climate adaptation efforts.	Bellingham Bay Waterfront—started as a multiagency (including local and regional partners) pilot project. Iron Mountain Mine Superfund Site, Shasta County, California—considered regional climate impacts as part of the Remedial Investigation/Feasibility Study and worked with local and regional fire authorities to minimize potential impacts. SURF Groundwater Conservation and Reuse—Unidynamics Superfund Site, worked with local authorities to allow groundwater reinjection to support regional resources. Port Sunlight River Park, U.K.—funded long-term management and specifically funded a local social services agency (autism) to provide long-term management and educational benefits. Tar Ponds and Coke Ovens Canada—partnered with local college to create groups to bridge technology/staffing gaps. Elizabeth Mine—worked with local landowners and organizations to limit adverse cleanup effects on historic resources at site (eligible for National Register of Historic Places). Grove Landfill—partnered with local nonprofit group to assist land donation, and welcomed weekend volunteers for development of nature trails, small-scale farming, community garden beds, and commercial composting. Reuse of waste materials targeted educational sustainability demonstrations, leading to full conversion of property to environmental education center. Pharmacia and Upjohn—included extensive community outreach to engage local stakeholders in selection of remedy and the future of the site.

Does SRR align with corporate social responsibility and (the United Nations) sustainable development goals?	Yes. The ensemble of sites worldwide has compounding impacts. Shareholders, elected officials, and community stakeholders have sustainability and resilience goals. These initiatives can aid remedial and restoration decision making.	All case study sites reflect some aspect of corporate or global sustainable development aspects. Specific examples: Tar Ponds and Coke Ovens Canada—reflects social considerations. Frontier Fertilizer Superfund Site, focuses on documenting emissions offsets. Pharmacia and Upjohn—includes emissions offset, land management, and social/economic considerations.
Does adaptive management have a role in SRR?	Yes. Site regulatory and physical conditions continuously change. SRR practices consider mitigation and adaptation to these future events, including reuse scenarios, stakeholder concerns, flooding, wildfires, and drought.	Phoenix Goodyear Airport Superfund Site—existing and future extremes in weather conditions required adaptive planning. Iron Mountain Mine Superfund Site, Shasta County, California—responses to wildfire impacts required adaptation in engineering, planning, and maintenance.
Where is the return on investment for implementation of SRR achieved?	Cost savings occur during sustainable materials management and remedy optimization. The earlier in the process changes are made the greater the potential impact. Affected stakeholders can benefit from site cleanup and restoration. Long-term savings can be realized by adapting to projected climate vulnerabilities.	Former Nebraska Ordnance Plant—found significant energy savings in multiple processes. Frontier Fertilizer Superfund Site—produced significant energy savings, including an example of a less than 3-year return on investment. Havertown PCP Site—resulted in significant energy savings, including life-cycle cost analysis.
How can SRR evaluation findings inform an assessment of remedial alternatives and other site-related strategies?	SRR tools identify differences among environmental, socioeconomic, and community impacts of alternatives. Short-term effectiveness considers unintended impacts from remedial scenarios. Long-term permanence considers vulnerability to dynamic site conditions. (See Section 2.1.3 for information about SRR remedy selection and implementation within the NCP criteria.)	Santa Susana Field Laboratory, Area IV—SRR tools and process were used in evaluating remedial alternatives.
Is SRR applicable to any cleanup site within the U.S. or U.S. territories, such as Puerto Rico and the Virgin Islands?	SRR practices are applicable to all environmental hazards and physical conditions. Long-term projects likely have more opportunities. Federal and state agencies offer guidance and resources. (See State Resource Map for state guidance and resources related to GSR, climate resilience, and wildfires.)	Former St Croix Aluminum Plant, U.S. Virgin Islands – ran a solar “sipper” with on-site solar power, transferred recovered product to adjacent reclamation facility, operations remained off the grid.
Does SRR provide an opportunity to look at a project through a different lens and promote innovation?	Yes. Considering SRR facilitates innovative solutions. Setting SRR goals early in project planning provides a new path toward alternative(s) development. Subsequently, innovation is integrated in remedy planning and execution.	Santa Susana Field Laboratory, Area IV—SRR tools and process were used in evaluating remedial alternatives.

2.2.2 What Are Common Misperceptions about SRR?

Table 2-2 addresses FAQs related to common misperceptions about SRR. The table is formatted to state a FAQ and provide a concise answer. The table also provides examples for how the components of the FAQ were included in a case study in Appendix A and/or Section 5.10.

Table 2-2. Common misperceptions about SRR and references to case studies reflective of answers.

FAQ	Answers	Case Study Match(es)
Does SRR just add cost to a remediation project with little added value?	a. No. SBMPs result in short- and long-term cost savings. Sustainable risk management refines remediation footprint and unintended impacts. Resilient risk management minimizes effects of future vulnerabilities. (See Section 7).	Phoenix Goodyear Airport Superfund Site—used SBMPs and reuses 500K gallons of water per year.
	b. No. Refining the active remediation footprint results in immediate cost savings (for example, reduced consumption of embedded materials, energy, and water).	Frontier Fertilizer Superfund Site—significant energy savings and emissions offsets reported. Lawrence Aviation Industries—wastewater discharge and energy choices are featured in this example.
Is the outcome of an SRR evaluation predictable and, therefore, not worth performing?	No. Specific technologies or approaches are not necessarily preferable over another. Site characteristics and stakeholder values inform sustainability and resilience metrics. An evaluation of metrics informs remedial decision making.	Frontier Fertilizer Superfund Site—SRR processes developed identification of beneficial reuse options for treated groundwater. Santa Susana Field Laboratory, Area IV—SRR tools were used in developing remedial alternatives.
If stakeholders are engaged early to define SRR metrics, will we have to do remedial activities above and beyond the cleanup objectives?	a. No. Early stakeholder engagement is an opportunity to set site assessment boundaries. SRR practices should be fiscally responsible. Rationale for inability to meet applicable practices should be communicated.	Pharmacia and Upjohn—included extensive community outreach to engage local stakeholders in selection of remedy and the future of the site. SURF Tar Ponds and Coke Ovens Canada—Earlier stakeholder involvement could have diminished controversy around the project and would likely have resulted in decreases in project duration and cost.
	b. Stakeholder engagement provides an opportunity for social sustainability awareness. Practitioners are informed of site-related stakeholder concerns and needs. Cleanup can incorporate broader objectives to maximize socioeconomic benefits.	California Gulch—engaged stakeholders ranging from landowners, local authorities, state park, natural resource trustees, and potentially responsible parties, resulting in the use of soft engineering approaches such as root wads placement and bendway weirs for bank stabilization instead of riprap.

The regulator did not accept our SRR assessment submittal. What best practices can we implement to avoid this in the future?	Collaborate with regulators early to formulate site objectives, including identifying values, metrics, and evaluation tools, and format to integrate findings in remedial decision making. Educating the regulators about the SRR process at the start of the project, up front and transparently, reduces the possibility of objections that may cause delays.	Harrison Avenue Landfill/Cramer Hill Waterfront Park—illustrates success when bringing in state regulators as early as possible into the SRR process.
Are cleanup sites that were resilient to recent severe weather events still vulnerable to future events?	Yes. The frequency and severity of climate change impacts is dynamic. Future precipitation, temperature, and sea-level rise projections evolve with new data. Changes in land use also occur.	Iron Mountain Mine Superfund Site, Shasta County, California—impacts from current wildfire threats informed the evaluation of climate change potential impacts in the Remedial Investigation/Feasibility Study. Port Sunlight River Park, U.K.—the sustainability assessment included climate change projected impacts.
Is a technical and quality review by a "subject matter expert" required for an SRR evaluation?	Yes. Experts advise on site practices, tools, and guidance. Data inventory, assumptions, and evaluation findings are reviewed for consistency and accuracy. Support also includes outreach and goal setting. SRR experts have the experience and long-term perspective necessary for successful SRR implementation.	BP Site, Busy Bee's Laundry, and California Gulch—are all case study sites that noted good engineering judgment as being important to the success of SRR implementation.
Is an SRR evaluation labor-intensive?	It depends. Required labor is tailored to meet site-specific SRR goals. Identifying SBMPs and performing a qualitative assessment is less intensive. Assessing SRR return on investment (ROI) highlights value of labor-intensive evaluations. Refer to value-added aspects of SRR implementation presented in Table 2-1 FAQ #6 (Where is the return on investment for implementation of SRR achieved?) and Table 2-2 FAQ#1 (Does SRR just add cost to a remediation project with little added value?).	Jet Propulsion Laboratory—example of a complex SRR evaluation. Phoenix Goodyear Airport Superfund Site, example of a best management practice (BMP) evaluation site.
Can social metrics be quantified with existing methods and tools?	Yes. Social metrics can be quantified using economic valuation tools. Quantifying social metrics is not always necessary. Semiqualitative tools include rating systems, surveys, and community input sessions.	Port Sunlight River Park, U.K.—part of the remedy was establishing a set-aside to ensure that stakeholders had contract opportunities that provide jobs and long-term engagement with the remedy.

Are there metrics, methods, or tools to evaluate social impacts of cleanup sites in a technically sound manner?	Yes. Integrating environmental economics and social science methodologies builds technical integrity in an assessment. Sustainability experts advise on metrics and tools. These should represent beneficial and unintended impacts.	Port Sunlight River Park, U.K.—social impact considerations were a major part of this remedy. Tar Ponds and Coke Ovens Canada—this is *the* social impacts case study. A single example for this case study includes: "annual community surveys, annual accountability reports and tracking documents, partnered with local college to create groups to bridge technology/staffing gaps."
Is tracking SRR metrics and SBMP performance during implementation a costly, labor-intensive process? What tools are readily available regardless of those identified during project planning?	No. SRR can be considered at any phase of a cleanup project. SBMPs align with value engineering. Cost-effective tracking tools are available.	Elizabeth Mine—is currently using value engineering hand in hand with SRR. Havertown PCP Site—used life-cycle cost analysis.
Are there benefits to starting SRR early in the development of the remediation project?	Yes. Early Conceptual Site Model (CSM) development can consider potential risk to climate and other extreme event impacts. Early SBMP implementation maximizes SRR opportunities and outcomes. Early stakeholder engagement facilitates collaboration.	Whitney Young Branch Library—an example of a site that saw time and cost savings through early use of SRR tools. Port Sunlight River Park, U.K.—used SRR tools during development of the CSM.
What is the point of transitioning to an SRR approach if traditional remedial efforts are known to work effectively?	Additional benefits can be realized when SRR approaches are integrated. Traditional approaches may overlook stakeholder values, which can cause project delays, especially at the end of the project. Anticipating stakeholder needs and concerns up front can result in a project more people support and limits project risk. Transitioning to SRR maximizes benefits and minimizes unintended impacts of cleanup and also factors in resilience considerations that may not have been previously considered.	Pharmacia and Upjohn—extensive community outreach to engage local stakeholders in selection of remedy and the future of the site. Tar Ponds and Coke Ovens Canada—"Earlier stakeholder involvement could have diminished controversy around the project and would likely have resulted in decreases in project duration and cost." Santa Susana Field Laboratory, Area IV, included use of benefit/cost analysis, cost/risk reduction analysis, to anticipate unintended impacts by the remediation and to the remediation.

* Harrison Ave Landfill and Senator Joseph Finnegan Park appear in both Appendix A and Section 5.10. Phoenix Park, Camden and Bellingham Waterfront only appear in Section 5.10. The rest of the sites only appear in Appendix A.