Integrating Groundwater Conservation and Reuse into Remediation Projects

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Groundwater remediation projects generally involve extraction and treatment of contaminated groundwater. The current state of the practice does not include an emphasis on conservation and reuse of groundwater. Consequently treated groundwater is typically disposed in sanitary or storm sewers. Longstanding water conservation and reuse practices in the municipal wastewater industry provide a body of experience available to the remediation industry. Case studies of conservation and reuse options for groundwater at remediation sites have been found across a broad range of geographic settings and regulatory jurisdictions. The intent of this article is to stimulate a more holistic view of the groundwater associated with remediation projects and to promote conservation and beneficial reuse of a vital natural resource. ©2014 US Sustainable Remediation Forum

INTRODUCTION

Sustainable remediation protects human health and the environment while maximizing environmental, social, and economic benefits throughout the project life cycle (SURF, 2009). Sustainable remediation, by definition, includes groundwater conservation and reuse principles and practices. However, contaminated groundwater is commonly remediated using energy-intensive pump and treat systems where the treated effluent is disposed to a sanitary sewer. In contrast, sustainable remediation principles would lead to a more holistic approach to managing, conserving, and reusing contaminated groundwater, by leveraging the analogous experiences and applications of the municipal wastewater industry, and by using currently available tools and guidance to evaluate, select, and design more sustainable groundwater remedies. Exhibit 1 presents a "word cloud" of terms commonly used to describe and discuss conservation and reuse of wastewater and groundwater.

While some guidance is available regarding the disposition of treated groundwater resulting from remediation projects (USEPA, 2007), documents specifically summarizing existing reuse options and potential challenges and benefits are not readily available. This article explores the value of integrating groundwater conservation and reuse practices into remediation projects to increase their sustainability, and to protect and conserve water resources for future generations. Additional goals of this article are to increase awareness of effective strategies for groundwater conservation and reuse, and to provide guidance to stakeholders interested in integrating sustainable practices into a remediation effort.

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Exhibit 1. Water reuse word cloud (SURF, 2013)

BACKGROUND AND CURRENT STATUS

Although water conservation and reuse practices have been implemented by the municipal wastewater industry for many years (USEPA, 2012a), analogous practices are infrequently applied in the remediation industry. Remediation professionals, regulatory entities, and responsible parties appear to increasingly be asking the logical question, "Why expend all of that effort, expense, and energy to clean up groundwater and then discard it without trying to reuse it?" Case studies presented in this paper highlight efforts throughout the United States to conserve or repurpose groundwater associated with cleanups. Although some efforts were initiated due to the beneficial economics of reusing treated groundwater rather than paying for a new supply, others seem to be motivated by the clear perception that water in and of itself has intrinsic value and is a vital resource.

The environmental remediation industry is a multibillion dollar per year segment of the U.S. economy (Farkas & Frangione, 2010), with a large portion of the expenditure being used to address groundwater contamination. Although the typical volumes of water associated with groundwater cleanup are significantly smaller than those associated with municipal wastewater treatment, the aggregated amount of treated groundwater resulting from all cleanups within even relatively small areas can approach the volume of public water supply required by a reasonably large city. Every gallon of remediated groundwater reused means one less gallon of fresh water removed from the limited global available supply.

Remediation professionals, regulatory entities, and responsible parties have a significant opportunity to conserve or reuse groundwater. However, these individuals face several challenges when considering opportunities for conservation (i.e., water that remains in its location and is used as originally intended) and reuse (i.e., water that is removed, processed, and then used for a purpose other than originally intended). The remediation industry faces some particularly unique challenges related to water conservation and reuse compared to the municipal wastewater treatment industry (Exhibit 2).

The remediation industry and municipal wastewater treatment industry share the challenge of long-term liability concerns associated with previously undetected

Exhibit 2. Challenges of water conservation and reuse unique to remediation industry

Remediation Industry	Municipal Wastewater Treatment Industry
Groundwater cleanup required regardless of reuse	Wastewater treatment requirements are determined by discharge or reuse options
Relatively small quantities of water generated	Large amounts of water generated
Requires local short-term reuse strategy	Can implement larger-scale long-term reuse strategy
Uncertainty/difficulty complying with regulations	Precedence has been established for reuse
Re-injection requires meeting drinking water levels	Similar challenges have been met, though with great effort and attention
Sufficient cleanup of the aquifer may be technologically limited	Multiple processes are sometimes involved in meeting goals for treated water, but aquifer cleanup is not involved
Difficulty in justifying additional costs	High demand for water and rising costs of finding new sources add to justification for reuse of treated wastewater

contaminants unexpectedly emerging in groundwater and wastewater. As analytical tools and techniques improve and lower detection limits are realized, some previously undetected contaminants in groundwater and wastewater have been observed. Based on the prospects for future advancements in analytical capabilities, the potential exists that, once the water has been repurposed, newly observed contaminants might be detected at concentrations that prompt regulatory action.

Along with the significant potential issue of emerging contaminants, additional obstacles to conservation of *in situ* groundwater or repurposing treated groundwater include:

- Compliance with various regulatory agencies can be difficult or unclear
- Performance limits of cleanup technologies
- Additional costs associated with more extensive or more advanced treatment
- Uncertainties associated with the implementation of *in situ* technologies
- Remediation of groundwater can be complex (technologies are often coupled with soil remediation, completed in a staged or sequential approach, etc.) and successfully meeting short-term groundwater cleanup objectives can be difficult to achieve

A TEMPLATE FOR SUCCESS: A GROUNDWATER REPLENISHMENT SYSTEM IN CALIFORNIA

In Orange County, California, the growing population, arid climate, and increasing limitations on the volume of water able to be imported inspired innovative solutions from the Orange County Water District's (OCWD) water managers. In 1976, Orange County was the first in the world to perform advanced treatment of wastewater for injection into coastal drinking water aquifers (Water Factory 21, later named the Groundwater Replenishment System, or GWRS).

The purpose of this system is to provide a supply of reliable, high quality, potable water; protect the groundwater basin from seawater intrusion; and reduce the volume of discharged wastewater into the Pacific Ocean. This indirect potable water supply can be

Exhibit 3. Water reuse in the news

New York Times—February 9, 2012

In a February 9, 2012 article, the New York Times discussed the "yuck factor" concerns expressed as San Diego, California moved forward with a pilot facility to treat household wastewater with advanced technologies followed by more traditional treatment before heading back to the tap. This certainly offers an opportunity for learning about how to address similar objections that might arise from proposed conservation and reuse options at remediation sites, notably wellhead treatment (Barringer, 2012).

provided at less than half the energy consumption that is currently required to import water and one third the cost of desalination, resulting in significant reductions in greenhouse gas emissions and energy costs (OCWD, 2012a). Currently, the OCWD treats 70 million gallons per day (MGD) of secondary wastewater effluent from the Orange County Sanitary District.

Influent from the Orange County Sanitary District is processed through a three-step purification process, which includes microfiltration, reverse osmosis, and advanced oxidation utilizing ultraviolet light and hydrogen peroxide (UV/H_2O_2). Reclaimed wastewater is injected to create a protective hydraulic barrier that prevents seawater intrusion and, thus, further water quality degradation of coastal aquifers which are used for public water supply. The OCWD has also addressed what can be significant public perception concerns associated with reuse (Exhibit 3).

Emerging Contaminants

In 2000 and 2001, the unregulated and potentially carcinogenic organic compounds N–nitrosodimethylamine and 1,4-dioxane were detected in the influent and effluent of Water Factory 21. As a precautionary measure treated wastewater injection was immediately halted until the removal of these compounds could be adequately addressed. The OCWD conducted a pilot study and determined that an advanced oxidation UV/H_2O_2 system would best meet project goals. The findings of one of the pilot studies released in 2001 concluded that "the water would be safe for consumers and actually improve the groundwater basin's overall quality" (OCWD, 2004, p. 1).

The OCWD proactively embarked on a successful outreach program to educate the public on removal efficiencies and safety of the proposed, upgraded water purification system, and public support was obtained (OCWD, 2012b). Within one year, an advanced oxidation UV/H_2O_2 system was installed, which successfully removed N-nitrosodimethylamine and 1,4-dioxane to concentrations below the proposed standards, and operations resumed (Mohr et al., 2010). As part of the ongoing public outreach the GWRS website continues to provide informational videos on reverse osmosis and the UV/H_2O_2 oxidation process and a running total of gallons of recycled water produced.

Ongoing Success

Currently, of the 70 MGD of secondary wastewater received by OCWD, 30 MGD are used as a seawater barrier and 40 MGD are conveyed 13 miles from the facility to

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percolation ponds located in the inland cities of Anaheim and Orange (National Academy of Sciences, 2012; OCWD, 2012b). The percolation ponds are designed to allow water to pass through gravel and sand beds and replenish the principal drinking water supply aquifers. The GWRS reserves and replenishes sufficient water to supply 600,000 Orange County residents in such a way that preserves and improves the quality of Orange County's primary source of potable water: the groundwater basin.

Groundwater reuse approaches may not be equally practical for cleanups in all geographical regions of the country based on the relative availability of and demand for this resource. However, appropriate studies documenting potential uses for treated groundwater should be completed to determine whether environmental, social, or economic benefits can be realized from reusing treated groundwater rather than simply accepting traditional disposal options without further deliberation. The OCWD approach of seeking out sustainable, win-win solutions in a transparent and precautionary manner can provide useful guidelines for all water reuse projects, including those involving groundwater remediation. The experiences of the OCWD may provide inspiration and a roadmap for professionals within the remediation industry exploring groundwater conservation and reuse options.

CASE STUDIES

Exhibit 4 summarizes the key elements of 14 case studies presented by the Sustainable Remediation Forum (SURF, 2013). These case studies provide examples of water conservation and reuse of treated groundwater and municipal wastewater. These case studies also show that a variety of water conservation and reuse approaches are being applied to small and large projects and sites. Geographically, the case studies spanned much of the continental United States. However, a large percentage of these sites are located in the West, particularly in California.

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THE TRIPLE BOTTOM LINE APPROACH

Sustainable remediation uses the triple bottom line approach of evaluating the environmental, social, and economic aspects of potential groundwater conservation and reuse options in remediation projects. This involves establishing metrics for evaluating all three components of the triple bottom line.

Exhibit 5 (SURF, 2013) provides a brief description of several common groundwater remediation approaches. A qualitative evaluation of environmental footprint relative to the "no action" remedial approach is included in this table. The relative environmental footprints of various groundwater remediation approaches are discussed herein to raise awareness and encourage the use of sustainability metrics in the evaluation, selection, and design of groundwater remediation systems.

Conducting a sustainability assessment during remedy selection can facilitate a more holistic evaluation of groundwater reuse and conservation approaches, and may shine a different but brighter light on remedial alternatives. For example, groundwater pump and treat systems are historically considered as a last resort for groundwater restoration projects because of the difficulty in removing contaminants from aquifer matrix materials and the long duration of operation required. However, from a groundwater reuse

Exhibit 4. Case studies of water conservation and reuse (SURF, 2013)

Case Study	COCs*	Regs†/ Permits	Overview	Water Reuse Application
#1—San Francisco Bay Area, CA	1	A	An evaluation was performed in 2010 and updated in 2012 of VOC treated groundwater reuse in the San Francisco Bay Area.	Reinjection (1 site), Industrial Supply (3 sites), Decorative Pond (1 site), and Irrigation (1 site)
#2—United Technologies Corporation, Santa Clara County, CA	1–5	A	Reuse is a method of water management in the onsite storage ponds that treated groundwater is discharged to.	Irrigation and Dust Control since 1991
#3—Former Unidynamics Phoenix, Inc. Facility, Goodyear, AZ	1	B	Superfund site: Series of groundwater pump and treat systems for VOC contamination	100% Reused: Reinjection, Cooling Water, Irrigation, and Dust Control
#4—NPL Site, Nebraska	1	C–E	Superfund site: Groundwater extraction system used for VOC contamination.	Potable Water
#5—Hydraulic Containment Reinjection System	1, 5	C, F	Hydraulic containment/reinjection system achieves 100% reuse of treated groundwater.	Reinjection
#6—Glendale Water Treatment Facility, Los Angeles County, CA	1, 6	C, E, G	One of the first large-scale VOC removal plants in southern California and is the first project in California to be permitted under the state's new policy 97–005 for treatment of highly impaired water sources	Drinking Water
#7—Aerospace Facility, Huntington Beach, CA	1	A, G	Provides for reuse of over 100 gallons per minute of groundwater treated to remove VOCs	Industrial Use (Primarily cooling towers, but flexibility is built into system to allow for other reuse opportunities on the facility)
#8—Fast Fuel Facility, North Hollywood, CA	1	A	A pump and treat system was implemented to address fuel constituent impacts to the groundwater. Approximately 29.9 million gallons of the treated groundwater re-injected back into the aquifer.	Reinjection
#9—Reuse of Groundwater for Industrial Process Water Supply, US	1	D	The extracted groundwater is pumped directly into the steel mill contact cooling water system, where the CVOCs are volatilized in the steel cooling process.	Industry Cooling Water
#10—Railyard Facility, Eugene, OR	1	D	*In situ* reductive dechlorination remedy utilizing carbon amendment and recirculation	Substrate Delivery (instead of discharging to the storm drain or sanitary sewer)

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Exhibit 4. Continued

Case Study	COCs*	Regs†/ Permits	Overview	Water Reuse Application
#11—Former Marine Corps Air Station, El Toro, Irvine, CA	1	A, C, D, G	Groundwater pump and treat remedies in place for chlorinated solvent extraction and containment; >86% of extracted water is being reused	Non-Potable Water Distribution System (used largely for irrigation)
#12—Groundwater Replenishment System (GWRS), Orange County Water District (OCWD), CA	5, 7	A, E, G	Advanced purification of Orange County Sanitation District's wastewater to use for aquifer recharge; maintaining an indirect potable water source that is less energy intensive than long distance transport.	Aquifer Recharge: Seawater Intrusion Barrier and Sustainable Potable Water Source
#13—Recycled Water Irrigation and Groundwater Study (August 2011), Santa Clara Valley Water District, San Jose, CA	1, 7–9	A	Recycled water assessment including a pilot study, impact evaluation, literature review, proposed screening levels, and best management practices.	Irrigation Use
#14—Former Carswell AFB, Fort Worth, Texas	1	B, D	Discharge water from pump and treat switched from POTW discharge to golf course irrigation	Irrigation Use

*COCs: 1—volatile organic compounds; 2—polychlorinated biphenyls (PCBs); 3—total petroleum hydrocarbons (TPH); 4—perchlorate; 5—1,4-dioxane; 6—chromium; 7—N-nitrosodimethylamine (NDMA); 8—haloacetic acids (HAAs); 9—perfluorinated compounds (PFCs).

†Regulatory/Permitting: A—California Regional Water Quality Control Board; B—National Priority List Phoenix-Goodyear Airport North (NPL PGA-N); C—United States Environmental Protection Agency (USEPA); D—State Environmental Agency; E—State Department of Health; F—Land Use Restrictions and/or Postclosure Permit; G—Local Municipality.

perspective, groundwater pump and treat systems might be viewed quite differently where the demand for water is high if beneficial reuse of the extracted and treated groundwater could be accomplished. In some cases, the increase in environmental footprint and overall reduction in sustainability associated with a pump and treat remedy might be offset by the benefits of reusing the treated groundwater.

Environmental

Evaluating environmental aspects of water conservation and reuse can be undertaken using sustainability tools, such as SiteWise™, Spreadsheet Environmental Footprint Analysis (USEPA, 2012b), Green Remediation Evaluation Matrix (GREM; DTSC, 2009), and the Sustainable Remediation Tool (SRT™). These tools can be used to evaluate the difference, from an environmental and economic standpoint, between disposing of and reusing treated groundwater. The types of outputs that can lead to a robust evaluation of the environmental effects of disposal versus reuse include the following:

Exhibit 5. Remediation, water conservation and reuse (SURF, 2013)

Technology	Description	Advantages	Disadvantages	Commentary
Miminal action				
Institutional controls	This type of remedy leaves groundwater with concentrations above performance criteria in place and restricts access to the public.	Low capital cost and initial environmental footprint (long-term monitoring may have high cost and environmental burdens); administrative controls are placed on a specific area that can be demonstrated as stable in order to reduce the potential for exposing receptors.	Groundwater is not remediated and cannot be used as a potable source without treatment; groundwater may inadvertently be accessed resulting in exposure to receptors; long-term monitoring will be required to demonstrate contamination is not migrating.	Groundwater is left in place and is not remediated. Access to contaminated groundwater is restricted by modifications to the deed and completion of a due care plan.
Passive *in situ* remediation				
Natural attenuation	Natural subsurface biological systems are used without input of external energy sources to contain or degrade the contaminant to concentrations below regulatory thresholds prior to reaching a compliance point.	Energy is not expended to achieve remedial goals; groundwater is not further altered or extracted from the subsurface.	Contaminants are degraded very slowly; monitoring, institutional controls, and financial assurance is required to remain in place for many decades; often times the degree of natural degradation of contaminants can be complicated, thus, presenting many significant technical challenges in demonstrating effectiveness; if used as a standalone strategy the regulatory and public perceptions are generally poor; typically used for groundwater with relatively low concentrations of contaminants.	Natural attenuation uses natural biological systems to reduce the concentration of contaminants in groundwater without addition of amendments or removal of groundwater. This results in a low environmental footprint and low initial capital. However, long-term monitoring is typically required for decades. In recent years, natural attenuation has been considered a component of groundwater remedies, however, not typically as a standalone technology if contaminant levels are high compared to remediation goals.

Exhibit 5. Continued

Technology	Description	Advantages	Disadvantages	Commentary
Permeable Reactive Barriers (PRB) 	Contaminated groundwater flows under natural hydraulic gradients through a reactive medium to reduce contaminant levels.	After installation minimal energy is expended; groundwater is not extracted from the subsurface; wall failure due to exhaustion of reactive material has not been observed.	Mixing of clean groundwater exiting the PRB with contaminated groundwater immediately downgradient still results in groundwater above remediation goals for many years after installation; potable water usage will likely not be realized in the near term; environmental footprint may be high depending on the source of reactive material; high cost; if the reactive material is consumed, the PRB will need to be replaced.	PRBs are typically used in order to passively treat groundwater *in situ*. Use of this technology results in no net loss of groundwater; however, the concentration of contaminants in groundwater immediately downgradient of the PRB may not see significant reductions in concentrations for many years.
Active *in situ* remediation				
In situ bioremediation 	Amendments (i.e., vegetable oils, oxygen) are added to the groundwater in order to stimulate natural biological systems to degrade contaminants in groundwater.	No net loss of groundwater resource; minimal energy expended to produce and inject amendments; using natural systems to degrade contaminants.	Groundwater cannot be used immediately as a potable source due to addition of amendments; biological population increases slowly over time sometimes resulting in long lead times between addition of amendment and significant reduction in contaminant; may not be an adequate technology to address downgradient contamination; monitoring, institutional controls may be required to remain in place for many years or decades; adequate delivery of amendments to groundwater in low hydraulic conductivity zones may limit effectiveness.	Enhanced bioremediation can be a good source area remediation technique in conducive environments which results in no net loss of the groundwater resource. However, large downgradient plumes often cannot be treated using this technology; increase of biological activity to required levels may take a long time to achieve, and the groundwater cannot typically be used as a potable source in the near term.

Exhibit 5. Continued

Technology	Description	Advantages	Disadvantages	Commentary
In situ chemical oxidation 	Chemical oxidants (i.e., permanganate, hydrogen peroxide) are added to the groundwater in order to oxidize contaminants in source area.	No net loss of groundwater resource; minimal energy expended to inject amendments.	Treatment of downgradient plumes is likely not cost effective and may not be a suitable standalone treatment strategy for the site; high energy requirements to produce the oxidant; rebound of contaminant concentrations often persist due to diffusion from soil into groundwater over time; groundwater cannot be used immediately as a potable source due to presence of residual oxidant in the treatment area	Chemical oxidation can be a good source area remediation technique that results in no net loss of the groundwater resource. However, downgradient plumes often cannot be treated, rebound of contaminants in the source area may persist, and the groundwater cannot typically be used as a potable source in the near term.
In situ thermal 	Groundwater temperatures are raised to the boiling point where volatile organic compounds are transferred to the vapor phase in the soil vadose zone. Soil vapor extraction is typically used to remove vapor for aboveground treatment and then discharged to the air.	Generally, minimal net loss of groundwater resource; groundwater within treatment zone achieves remedial goals in a short-time period (relative to other technologies); technology can achieve groundwater remedial goals in the presence of very high concentrations.	Energy intensive; technology may not be cost effective if source area contains low concentrations of contaminants; may not be an adequate technology to address downgradient contamination.	Thermal remediation is typically used to treat high concentration in source areas in a short period of time (as compared to other technologies). This technology is extremely energy intensive and requires significant infrastructure to implement; however, when viewed over the project life cycle, the short duration may result in a smaller environmental footprint than other technologies.

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Exhibit 5. Continued

Technology	Description	Advantages	Disadvantages	Commentary
Active *ex situ* remediation				
Pump and treat 	Primary purpose is to gain hydraulic control of migration of contaminated groundwater. This is accomplished through physical removal of groundwater, treatment, and then discharge.	Produced water can be repurposed for beneficial use (potable water, industrial makeup water, etc.).	High energy demand; produced water volumes may not be reliable enough to be adequately used for repurposed process; additional capital cost and O&M required to instrument, install, and monitor supply water for repurpose; systems are typically operated for decades.	Groundwater is physically extracted from the subsurface for the purposes of gaining hydraulic control of the local groundwater flow. Groundwater is transferred via piping to a treatment system in order to remove contaminants from the groundwater. Extracted groundwater may be repurposed; however, in most cases the least costly method of handling treated groundwater is to discharge to sanitary or storm sewers.
Well-head treatment 	Water contaminated at supply well (for potable or industrial use) is treated at the point of generation for subsequent use.	Contaminated water is extracted for the purpose of beneficial use.	Public concerns as well as historical preferences have limited this approach as a remedy; is identical to pump and treat systems in most instances, but of a generally larger scale.	Well-head treatment is generally perceived as a "last resort" by regulatory agencies; has perception issues with shifting responsibilities from responsible parties to public agencies; liability concerns over emerging contaminants and other issues are significant barriers.

Note: Footprints represent the simplified relative magnitude of environmental impacts of the technology. All projects and technology implementation practices are different and site-specific; this scale should be considered as a simple broad-spectrum representation. Low-impact technologies are generally *in situ*, passive, or technologies that mimic natural processes; moderate-impact technologies are generally active *in situ*, materials intensive, or operationally complex; high-impact technologies are generally energy-intensive, have high maintenance requirements, or operate for long periods of time.

 : low-impact technology.

 : moderate-impact technology.

 : high-impact technology.

- Energy and materials consumption
- Change in resource service
- Greenhouse gas emissions
- Ecological system stress

Social

Evaluating the social aspects of projects associated with groundwater conservation or reuse considers the social benefits or impacts of disposal versus conserving or reusing treated groundwater locally or regionally. Such an evaluation includes assessing the following:

- Preservation of ecosystems and potential aesthetic benefits to the local or regional communities.
- Repurposing treated groundwater to fulfill water needs, potable or non-potable, of other public or private partners (or potential future partners).
- Mitigation of future negative impacts on public health, agriculture, cost of potable water treatment, and many more social necessities caused by aquifer/surface water overuse.
- Increases in employee/community health, safety, and satisfaction.

In addition, remediation practitioners should engage stakeholders in the decision process when developing groundwater remediation and reuse scenarios. In this way, project-level "anticipatory capacity" is developed so that remediation practitioners can react to and resolve uncertainties and unforeseen complexities associated with these projects. For example, if groundwater from a pump and treat system can be repurposed, the operator of the groundwater pumping system may be viewed in a favorable light due to their ability to make positive contributions to the community, particularly in areas where water is scarce in the first place. The case studies outlined in Exhibit 4 and provided in more detail by SURF (2013) further demonstrate the value of this approach.

Economic

Evaluating the difference in cost between disposal and reuse of treated groundwater is critical to fully evaluate the viability of a reuse approach. In some cases reuse may require additional upfront expenses for planning or technology needs. Considerations that can be used to complete this evaluation include the following:

- Cost savings to the end user when incorporating recycled water into an existing process
- Elimination of costs associated with implementation of a discharge permit to a river or stream (e.g., sampling, inspections)
- Reduction of water volume discharged outside the site boundary (which can reduce the cost of public storm sewer infrastructure maintenance and operation)
- Reduction of sanitary disposal fees
- Eliminating redundant cost to sanitary facility for retreating groundwater
- Potential for added cost to end user if recycled water delivery volume and/or contaminant load is unpredictable

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Additionally, the indirect costs associated with integrating recycled water into existing processes can provide a holistic review of water reuse options. The avoided indirect costs derived from reusing treated water include the following:

- Energy costs required to transport potable water to existing processes
- Future cost increases (i.e., economic and social) due to potable water scarcity because of aquifer and surface water overuse

While much of the discussion surrounding economic aspects of water conservation and reuse focuses on costs, in every regard water is central to every economy. The central role of water is most apparent in water-starved regions. In such areas, the value of conserving and reusing groundwater from cleanups includes not just current and projected costs, but the value of helping to assure an adequate supply and the economy that will have to depend on that water. It is not surprising that a majority of the case studies provided in Exhibit 4 are located in the arid West.

Documents and Tools

Over the last decade, documents have been published and tools have been developed to address the evaluation of the environmental, social, and economic impacts of remediation. Remediation practitioners should use these documents and tools as appropriate to develop and define sustainability metrics and indicators as well as the triple bottom line objectives for site cleanup and groundwater reuse.

Often times, societal costs and other externalities are not included in impact assessments of site remediation projects (Favara et al., 2011; Lee et al., 2009). The indicators and objectives established for the remedial activities should not only focus on site-specific risks, but should consider external social and economic impacts beyond identified environmental impacts in order to protect human health and the environment (ITRC, 2011).

Documents

The documents listed below can facilitate in evaluation of the triple bottom line impacts to different groundwater conservation and reuse scenarios.

- In 2008, the USEPA developed the *Superfund Green Remediation Strategy* (USEPA Strategy) with the goal to reduce greenhouse gas emissions and other negative environmental impacts that may occur during remediation. The USEPA Strategy recommended the development of white papers focusing on the incorporation of sustainable remediation practices under existing laws and regulations.
- The *Decision Framework for Incorporation of Green and Sustainable Practices into Environmental Remediation Projects* was issued by the U.S. Army Corps of Engineers in 2010 (USACE, 2010).
- SURF issued the following three documents in 2011:
    - "Framework for Integrating Sustainability into Remediation Projects" (Holland et al., 2011)

  - "Metrics for Integrating Sustainability Evaluations into Remediation Projects" (Butler et al., 2011)
  - "Guidance for Performing Footprint Analyses and Life-Cycle Assessments for the Remediation Industry" (Favara et al., 2011)

- In 2011, the Interstate Technology & Regulatory Council (ITRC) issued *Technical/Regulatory Guidance – Green and Sustainable Remediation: A Practical Framework*.
- In 2012, the USEPA (2012b) issued *Methodology for Understanding and Reducing a Project's Environmental Footprint*.
- In 2013, ASTM International published a *Standard Guide for Integrating Sustainable Objectives into Cleanup (E2876—13)*.

Tools

The tools listed below are appropriate to help quantify the impacts associated with different groundwater reuse scenarios.

- Environmental footprint analyses can be conducted by using tools such as the USEPA's Spreadsheet for Environmental Footprint Analysis (SEFA), the Air Force Center for Engineering and the Environment (AFCEE) Sustainable Remediation Tool (SRT^{TM}), and Naval Facilities Engineering Command (NAVFAC) SiteWise^{TM} program. These tools assist remediation practitioners in evaluating sustainability metrics associated with greenhouse gas emissions, carbon footprint, energy use, and water use.
- The Institute of Sustainable Infrastructure has developed the Envision^{TM} tool and rating system to evaluate the community (i.e., social), environmental, and economic benefits of infrastructure projects, including water treatment and distributions systems.
- Previously developed tools for life cycle assessments and environmental impact assessments can also be used to help evaluate the sustainability of groundwater remediation systems.

Continued Research of Groundwater Conservation and Reuse

Conservation and reuse of groundwater are desirable attributes of any groundwater remedy, and can result in win-win outcomes for all stakeholders involved. Continued research on the topic of groundwater reuse is vital to achieving water conservation goals on a larger scale. Potential areas of future research include, but are not limited to, the following:

- Sustainability assessments comparing a variety of groundwater conservation and reuse methods versus conventional approaches.
- Evaluation of the costs and benefits to local and regional communities from remediated groundwater reuse implementation.
- Socioeconomic evaluations analyzing the impacts of treated groundwater reuse on the consumer price of water.

- Quantification of the differences in ecosystem service impacts of treated groundwater reuse versus conventional permitted disposal to a storm drain or sanitary sewer.
- Identification and resolution of regulatory barriers that impede groundwater conservation and reuse at remediation sites or encourage practices that eliminate opportunities for conservation and reuse.

AFTERWORD

SURF is a professional, nonprofit organization dedicated to advocating for an increase in sustainable practices within the remediation industry and at remediation sites. By learning from the accomplishments of successful water conservation and reuse projects presented in this article and promoting further research in this area SURF hopes to encourage the remediation industry to embrace a more holistic view of groundwater conservation and reuse possibilities when evaluating approaches for attaining remediation goals. A more comprehensive dive into this important remediation issue has been explored in a recent publication entitled "Groundwater Conservation and Reuse at Remediation Sites," which can be found on the SURF website (www.sustainableremediation.org).

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