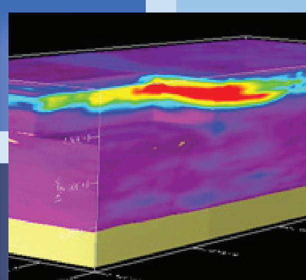
Streamlining Site Cleanup in New York City



U.S. Environmental Protection Agency, Brownfields and Land Revitalization Technology Support Center

NYC Mayor's Office of Operations, Office of Environmental Remediation

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Streamlining Site Cleanup in New York City

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Office of Solid Waste and Emergency Response
Brownfields and Land Revitalization Technology Support Center
Washington, DC 20460

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This document can be obtained from EPA's Brownfields and Land Revitalization Technology Support Center at *www.brownfieldstsc.org*.

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(Top right) Schaefer Landing, during demolition — NYC Department of Housing Preservation and Development, Kent Waterfront Associates LLC.; (Bottom left) Schaefer Landing, today — NYC Department of Housing Preservation and Development; Kent Waterfront Associates LLC; (All others) U.S. Environmental Protection Agency.

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Technology Support Center

NYC Mayor's Office of Operations
Office of Environmental Remediation

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ACRONYMS

2-D	two-dimensional
3-D	three-dimensional
AA	Atomic Absorption
AOC	Area of Concern
AST	Aboveground Storage Tank
BIG	Brownfield Incentive Grant
BMP	Best Management Practice
BOA	Brownfield Opportunity Area
BTSC	Brownfields and Land Revitalization Technology Support Center
CLU-IN	Hazardous Waste Clean-Up Information Web Site
COC	Contaminant of Concern
CoP	Community of Practice
CPA	Chlorobenzene Plume Area
CPT	Cone Penetrometer Testing
CSM	Conceptual Site Model
DC	Direct Current
DDT	Dichlorodiphenyltrichloroethane
DNAPL	Dense Non-Aqueous Phase Liquid
DPT	Direct-Push Technology
DWS	Dynamic Work Strategy
EC	Electrical Conductivity
EC/IC	Engineering Controls / Institutional Controls
ECD	Electron Capture Detector
EPA	United States Environmental Protection Agency
ERI	Electrical Resistivity Imaging
ESA	Environmental Site Assessment
FID	Flame-Ionization Detector
FFD	Fuel Fluorescence Detector
FPXRF	Field-Portable X-Ray Fluorescence
GC	Gas Chromatography
GPR	Ground Penetrating Radar
GPS	Global Positioning System
IA	Immunoassay
ICP	Inductively Coupled Plasma
LIF	Laser-Induced Fluorescence
LTM	Long-Term Monitoring
MEC	Munitions and Explosives of Concern
MIP	Membrane Interface Probe
mgals	Milligals
MOA	Memorandum of Agreement
ms/m	milliseconds per meter
mS/m	milliSiemens per meter
NAPL	Non-Aqueous Phase Liquids
NJDEP	New Jersey Department of Environmental Protection
ns/m	Nanoseconds Per Meter
nT	nanoTesla
nT/m	nanoTesla/meter
NYC	New York City
NYC BCP	New York City Brownfield Cleanup Program
NYSDEC	New York State Department of Environmental Conservation
NYSDEC BCP	New York State Department of Environmental Conservation Brownfield Cleanup Program
OER	Office of Environmental Remediation
OP-FTIR	Open Path Fourier Transform Infrared
ORD	EPA Office of Research and Development
OSRTI	EPA Office of Superfund Remediation and Technology Innovation
OSWER	EPA Office of Solid Waste and Emergency Response
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated biphenyl
PDB	Passive Diffusion Bag
PID	Photoionization Detector
PPRDA	Paterson Plank Road Redevelopment Area
PPM	Parts per Million
RCRA	Resource Conservation and Recovery Act
ROST	Rapid Optical Screening Tool
ROW	Right-of-Ways
SPEED	Searchable Property Environmental e-Database
SPP	Systematic Project Planning
SVOC	Semivolatile Organic Compound
TPH	Total Petroleum Hydrocarbon
µgals	Microgals
USACE	U.S. Army Corps of Engineers
USDA NRCS	U.S. Department of Agriculture, National Resource Conservation Service
UST	Underground Storage Tank
UV	Ultraviolet
UVF	Ultraviolet Fluorescence
VPD	Vacant Property Database
VI	Vapor Intrusion
VOC	Volatile Organic Compound
XRF	X-Ray Fluorescence
XSD	Halogen Specific Detector

EXECUTIVE SUMMARY

The United States Environmental Protection Agency (EPA) Brownfields and Land Revitalization Technology Support Center (BTSC) and the New York City (NYC) Mayor's Office of Environmental Restoration (OER) have jointly prepared this document as a technical transfer resource for organizations and individuals involved in the redevelopment of contaminated properties in NYC. This joint effort, supported by New York State, advances the environmental cleanup goals of PlaNYC 2030, the City's comprehensive sustainability plan. The purpose of this document is to present how Triad Approach best management practices (BMP) for site investigation and remediation advance EPA's and NYC Mayor's Office initiatives in the areas of community revitalization and Brownfields redevelopment.

In April 2007, NYC announced PlaNYC, a plan developed by the City to meet the challenges of growth over the next 25 years and create a sustainable NYC. PlaNYC recognizes that land area in NYC is finite and that to accommodate the expected growth of one million people over the next two decades, land must be effectively reutilized through Brownfields redevelopment. As a result, the reuse of low to moderate contaminated land is an important component of PlaNYC because it provides opportunities to maximize available space for commercial, residential and recreational development.

PlaNYC includes 11 Brownfields initiatives. Initiative 1 is to adopt on-site testing to streamline the cleanup process. One of the core elements of Triad is the use of real-time measurements, which allows dynamic field programs and on-site decision making. These BMPs result in effective and reliable environmental investigations at Brownfields sites, providing stakeholder confidence that the appropriate cleanup approach has been selected and cleanup levels achieved for the intended reuse.

The use of Triad in the New York metropolitan area (and other urban settings nationwide) has shown significant advantages for Brownfields redevelopment programs, including those involving the redevelopment of historic fill areas and waterfront properties.

- **Historic Fill Areas.** As much as 20 percent of the urban areas in and around NYC contain historic fill, placed years ago to raise the elevation of land primarily around coastal areas and heads of bays. Fill material typically contains low to moderate levels of metals and PAHs. Brownfields redevelopment experience, however, has shown that these lands can be safely reused if the appropriate precautions are taken to protect human health and the environment. Key to this is a thorough environmental investigation that determines the thickness and content of the fill as well as the nature and distribution of chemicals secondarily released into the fill originating from past industrial uses. Direct sensing tools, on-site measurement technologies, area-wide investigation programs, advanced conceptual site models (CSMs), and other aspects of Triad provide the framework to effectively investigate and redevelop historic fill lands. Since much of the land available to NYC for reuse is historic fill, streamlined methods for redeveloping these lands provides a directly significant benefit.
- **Waterfront Property.** Waterfront property is another area that will be critical to NYC development needs over the next 25 years. Waterfront properties have several common aspects, including the presence of historic fill, secondary contaminants, groundwater discharges to a water body, and nearshore sediments. Triad can provide an effective cleanup management approach for waterfront properties by streamlining redevelopment-related investigation efforts. For example, the common characteristics found at these properties can expedite the development and design of the investigations approach. The use of direct sensing tools, real-time measurement, and dynamic work strategies (DSW) can also streamline the investigation and remediation of waterfront properties.

NYC OER will be integrating Triad into its existing programs to help the City achieve its PlaNYC Brownfields redevelopment goals. To be successful, it will be important for environmental practitioners to build skills and capacity in the application of Triad through NYC OER and EPA supported education and training programs. These consist of guidance manuals, seminars, web-based technical training, individual mentoring and case histories/ demonstration projects. NYC OER and EPA BTSC support the expansion of Triad methods on Brownfields sites by working with other entities involved with Brownfield reuse planning and funding. For example, NYC OER has developed a Memorandum of Agreement (MOA) with the New York State Department of Environmental Conservation (NYSDEC) to allow more moderately contaminated sites in NYC to participate in the NYC Brownfields Cleanup Program (BCP). More participation can increase the use of Triad techniques in the New York metropolitan area.

These are a few examples of how an intergovernmental partnership between EPA and NYC OER supports regional and national goals of site cleanup and reuse, economic development, environmental stewardship and community engagement. A sustained Brownfields partnership will provide enhanced value to NYC and reinforce to others the value of Triad Approach BMPs.

INTRODUCTION

With the ever increasing demand for sustainable development in the city of New York, and available land already scarce, sites with low to moderate environmental concerns offer both a challenge and an opportunity to leverage underutilized land assets. To do so more effectively, it is critical to provide all land redevelopment stakeholders with access to the latest strategies and tools for environmental assessment and cleanup.

To respond to this need, the United States Environmental Protection Agency (EPA) Brownfields and Land Revitalization Technology Support Center (BTSC) and the New York City (NYC) Mayor's Office of Environmental Remediation (OER) have jointly prepared this document as a technology transfer resource for organizations and individuals involved in the redevelopment of contaminated properties in NYC. Supported by the New York State Department of Environmental Conservation (NYS DEC), this joint effort advances the environmental cleanup goals of PlaNYC 2030, the city's comprehensive sustainability plan.

The purpose of this document is to present how the Triad Approach best management practices (BMP) for site investigation and remediation advance the initiatives of EPA and the NYC Mayor's Office in the areas of community revitalization and Brownfields redevelopment.

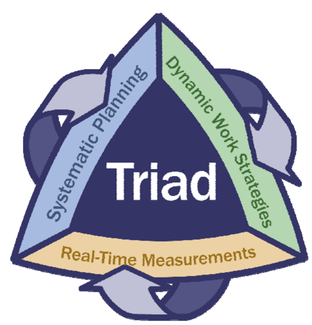
Community Revitalization – A key component of redevelopment, community revitalization is the effort to renovate and rebuild vacant, commercial, industrial, and residential sites to help stimulate jobs and investment in the local community. In addition to benefitting from new public and private infrastructure, community revitalization programs are intended to ensure equal access to the economic benefits that stem from the process of redevelopment. In order to realize these benefits, small businesses and citizens need to be as informed and engaged as those undertaking the development. Investing in training for environmental services and other development-related employment provide options to community members to maximize their potential and opportunities.

Brownfields Redevelopment – Brownfields sites are generally defined as vacant, abandoned or underutilized industrial or commercial properties where redevelopment is complicated by actual or perceived environmental contamination. With certain legal exclusions and additions, the regulatory term "Brownfields site" means real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant (Public Law 107-118 (H.R. 2869). Brownfields vary in type, size, location, age, and history of use. They typically have lower levels of contamination than other regulated sites which can be mitigated using appropriate science and engineering. Brownfields redevelopment is often stigmatized by uncertainties of their past use.

The Triad Approach – The Triad Approach to Site Characterization and Remediation (i.e., Triad) supports effective and efficient decision-making for cleanup of sites contaminated with hazardous waste. Triad provides a technically defensible methodology for managing decision uncertainty based on use of innovative BMPs, strategies and tools, including systematic project planning, conceptual site models, dynamic work strategies, and real-time measurement technologies.

NYC has a history of award-winning redevelopment efforts, including the Rheingold Brewery Redevelopment Project in Brooklyn and the Fulton Fish Market at Hunts Point in The Bronx. NYC's initiative to Streamline Site Cleanup is intended to improve and shorten the process of realizing the benefits of high quality redevelopment efforts, building on lessons learned from past sites.

THE TRIAD APPROACH



The Triad Approach is a three-pronged approach for managing all forms of project uncertainty in order to improve decision-making and streamline environmental cleanup projects. Triad draws on science and technology advancements and practitioner experience to develop strategies for making site work more scientifically-defensible, resource-effective, adaptive to changing project needs, and responsive to stakeholder concerns. The Triad Approach can be used to streamline site investigation and remediation, enhance stakeholder communication, and improve the quality of project and site decisions.

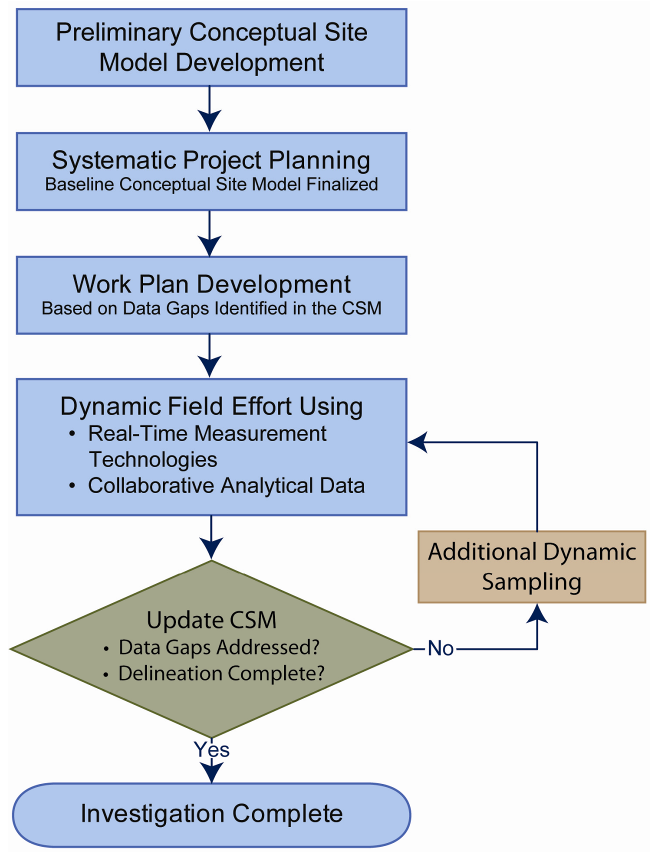
The three primary BMPs of the Triad Approach are:

- **Systematic Project Planning (SPP)** – An efficient method for comprehensive planning design and implementation for all stages of site investigation and cleanup projects. Generally recognized to be common practice for all projects, SPP is uniquely applied and critical to the successful design and execution of a Triad-based project.
- **Dynamic Work Strategies (DWS)** – An agreed upon sequence of dynamic data collection activities that efficiently addresses identified project concerns. DWS activities are implemented and managed in the field using real-time information to target and manage data and decision uncertainty. Streamlined workplans, developed in the context of a project's regulatory framework, are used to document DWS for project team use.
- **Real-time Measurement Technologies** – Data generation that enables reliable measurement, collection or analysis of environmental media in a time frame that facilitates real-time decision making (i.e., execution of a DWS). These measurements typically result in a much greater density of information and are available to direct field activities in time frames shorter than those commonly achieved with conventional sampling and analytical methods. Together with the DWS, real-time measurement technologies are used to focus when and where collaborative sampling and analyses can provide the greatest benefit.

A major emphasis of Triad is its use of the conceptual site model (CSM) as the basis from which data needs are identified, strategies for collecting data to reduce uncertainty are designed, and site uncertainties are managed throughout the life cycle of a project. A CSM is a representation of contamination concerns that are present as well as predictions of the nature, exposure, and extent of the contamination. They can be expressed through text, tabular data and/or simplified graphic renderings or more complex visualization tools in order to capture, communicate, and leverage existing information. The CSM enhances stakeholder understanding of site conditions and helps to focus future investigation and remediation efforts on key uncertainties or data gaps.

Figure 1 illustrates the life cycle of a Triad Approach-based project.

Figure 1 – Triad Approach Project Life Cycle



WHY TRIAD IS PART OF PLANYC

The supply of land in New York City (NYC) is fixed and, as a result, land must be used more efficiently to accommodate growth while preserving the city's quality of life. The City needs to maximize the value of every piece of land, even those considered Brownfields or sites where previous uses have resulted in environmental impacts such as soil and groundwater contamination. As much as 7,600 acres in NYC have been impacted in this manner and in many cases the presence of low to moderate levels of contamination has stalled development.

In April 2007, the City announced PlaNYC, a plan to address the critical challenges that lay ahead in moving toward the goal of creating a sustainable city. Brownfields redevelopment was included in PlaNYC because it was recognized that in order to support a healthier and more prosperous city, there was a need to unlock the potential of contaminated land to provide critical space for commercial, residential, and recreational development.

In PlaNYC, the City has committed to promote the redevelopment of sites by making Brownfields cleanup programs faster and more efficient. The goal of PlaNYC is to enroll more sites in NYC's Brownfield Cleanup Program (BCP) and increase public involvement in the process. To accomplish this, PlaNYC includes 11 Brownfields initiatives, including ***Initiative 1: Adopting on-site testing to streamline the cleanup process.*** On-site testing relates directly to Triad's use of real-time measurement technologies to streamline investigation and remediation.

One of the most important aspects of Brownfields redevelopment is determining the nature and extent of contamination with the appropriate level of detail and accuracy needed to make critical cleanup and redevelopment decisions. Conventional approaches using non-dynamic work strategies specify the exact type, quantity, quality, and location of data collection prior to any field activities. In addition, conventional uncertainty management can neglect sampling uncertainty and instead focus primarily on analytical uncertainty, which is often one of the smallest contributors to overall site decision uncertainty. Alternatively, DWS focus on heterogeneity, spatial, and temporal factors, which tend to be the largest contributors to overall decision uncertainty. DWS approaches also consider real-time management of project resources, enhancing efforts to collect the appropriate data necessary to comply with the requirements of the sampling and analysis plan. The increased flexibility, real-time feedback and reduced timeframes embodied in the DWS approach results in significant decreases in data gaps, which is the primary driver of repeated site mobilizations and extended characterization efforts.

Streamlining Cleanups

Using Triad can streamline the investigation and cleanup process by significantly reducing the number and length of field effort mobilizations, expediting report and plan writing, maximizing the efficiency and value of project meetings, and focusing desktop investigation activities. The field-based dynamic decision-making framework of Triad allows project teams to monitor project progress via maturation of the CSM as the field program unfolds. Ideally, project teams will leave the field after a single mobilization with a mature CSM which is ready for use in determining the type and magnitude of remediation needed to support site redevelopment. Thus, the need to remobilize to collect and analyze additional samples is eliminated or significantly reduced. As a result, the stakeholders can focus their collective resources on redevelopment rather than a potentially protracted period of uncertainty determining whether characterization efforts have been adequate.

Table 1 presents a summary of a number of projects showing Triad's benefits to the investigation and remediation process.

Table 1 – Example Sites That Have Implemented Triad BMPs

Site	On Time, On Budget	End Goals Met Expectations	Minimized Workload, Maximized Control	No Surprises, Ensures Information Quality	Profitability	Maximized Protectiveness and Reuse Potential
Poudre River Site, Fort Collins, CO	✓	✓	✓	✓	✓	✓
Cos Cob, Greenwich, CT	✓	✓	✓	✓	✓	✓
Hartford Hydrocarbon Plume Site, Hartford, IL	✓	✓	✓	✓	✓	✓
Ellsworth Industrial Park, Downers Grove, IL	✓		✓	✓		
Tree Fruit, Wenatchee, WA	✓	✓	✓	✓	✓	✓
Fort Lewis Small Arms Firing Range, Tillicum, WA	✓	✓	✓	✓	✓	✓

From "Advanced Triad Training for Practitioners" as prepared and presented by EPA via the CERCLA Education Center, August 2009

Benefits to Local Communities, Property Owners, Developers and Practitioners

Two fundamental BMPs of the Triad Approach are systematic planning and transparency in decision making. Triad encourages all stakeholders to participate in the process of characterizing and remediating contaminated sites. Stakeholders typically include community leaders, property owners, developers and the scientists, engineers, lenders, planners, and regulators who are the practitioners of Brownfields redevelopment.

Significant benefits can arise from using Triad to support Brownfields redevelopment, including:

- Increasing confidence of local communities that Brownfields redevelopment decisions are properly accounting for protection of human health and the environment.
- Improving site cleanup-related communications between communities, property owners, developers and practitioners.
- Improving environmental quality and health of communities through carefully planned and controlled redevelopment based on effective characterizations of sites.
- Moving underutilized properties back on to local tax roles quickly, providing increased revenue to the city and citizens that can be used to upgrade other services and infrastructure.
- Streamlining cleanup activities to support the redevelopment plans and schedules of developers, investors, and other key Brownfields stakeholders.

Triad can enhance the quality and effectiveness of active stakeholder engagement by providing comprehensive and consistent opportunities for information sharing. Open collaboration is specifically beneficial to community organizations and local officials, who might not be fully involved with Brownfields redevelopment, but are directly affected by the results. The CSM, a Triad BMP for maintaining stakeholder consensus, is a highly-effective method of presenting site and project-related information to the public.

PROGRAMMATIC APPLICATIONS OF TRIAD

Triad can be applied to virtually any environmental regulatory program. In fact, Triad has been used to perform projects in every major federal program, and a significant number of state regulatory programs, including projects regulated by New York State Department of Environmental Conservation (NYSDEC). The NYC OER has also endorsed Triad as an investigation program that can help streamline Brownfields redevelopment and expedite the redevelopment of the properties. For NYC, Triad is anticipated to provide value to sites in both the NYSDEC BCP and the new NYC BCP.

Brownfields

Brownfields properties represent one of the City's greatest assets for economic development and quality of life improvement. This is particularly true for low income communities where contaminated properties are commonly concentrated into zones and corridors. The Triad Approach is ideally suited for Brownfields redevelopment because of its emphasis on creating and sustaining effective project stakeholder involvement. Community engagement initiated during SPP and sustained throughout the project fosters trust and provides confidence in investigation results and remedy selection. It is for these reasons that a key aspect of PlaNYC is the adoption of Triad as the basis for streamlining efforts to define the extent of site impacts and develop remedial solutions.

Triad provides the opportunity for all interested parties to participate in the investigation, understand the extent of impacts, and develop an appropriate cleanup plan. In many instances, Brownfields properties are found to be only marginally impacted by contamination and cleanup can be confined to "hot spot" removal and engineering controls / institutional controls (EC/IC). Even at sites with significant contaminant presence, Triad can provide an approach to effectively and more confidently address contamination.

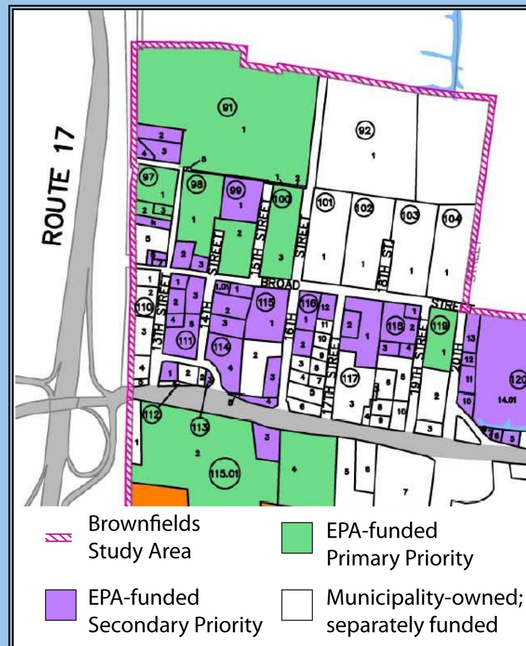
Triad supports cleanup and redevelopment as a function of several key elements:

- Clear investigation and remediation goals based on redevelopment plans.
- Dynamic decision-making, coupled with real-time measurement, significantly reduces repeated field mobilizations, report and work plan writing, and regulatory interface/review time.
- The use of CSMs to quickly build and sustain stakeholder consensus and agreement on investigations design.
- The utilization of high-resolution sampling methods increases the accuracy, thoroughness, and comprehensiveness of an investigation and provides more accuracy in identifying and targeting contamination.

Case Study: Engaging Stakeholders to Characterize Multiple Brownfields Properties

New Jersey Meadowlands / Paterson Plank Road Redevelopment Area, NJ

The New Jersey Meadowlands Commission designated a 201-acre area of the district as the Paterson Plank Road Redevelopment Area (PPRDA). The PPRDA consisted of 148 properties that included a mixture of commercial, industrial, underutilized, and/or abandoned properties. A number of the small-parcel Brownfields properties needed to be combined to accommodate the planned redevelopment. In addition, Triad-based site characterization work was confined to public right-of-ways (ROWs) because of property access issues and municipal concerns regarding property owner responses. Systematic planning was performed with stakeholders, and included direct mail outreach to a large number of property owners, a property owner workshop, and planning with local officials regarding use and access to the public ROWs. The area is currently undergoing transportation improvements associated with the new New York Giants Stadium and Sports Complex.



Map of PPRDA Showing Numerous Brownfields Properties and Right-of-Ways

Defining clear goals early before significant field work begins allows the investigation team to focus the sampling specifically to the property's use. By considering the type of reuse and the redevelopment design during SPP, a focused yet comprehensive investigation of a property can be designed. Remediation goals are clearly identified, allowing project scientists and engineers to design an investigation to achieve them. In addition, the advance planning ensures that the information collected meets the diverse needs of end users of data such as communities, developers, practitioners and regulators.

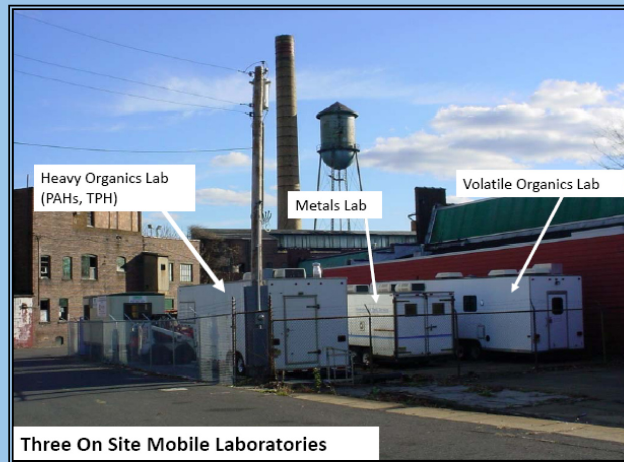
Dynamic decision-making using field-generated data reduces the need for multiple mobilizations to the field. Over a Triad project's life cycle, the CSM is refined, enabling the team to leave the site with confidence that it has been characterized adequately to make reliable site decisions, saving time and money. The Triad Approach provides the weight of evidence necessary to ensure that the CSM is accurate and site impacts have been identified and delineated. Eliminating or reducing these uncertainties can minimize delays that might otherwise be caused by lack of information on the effectiveness of the remediation to protect future users of the property.

The use of real-time measurement technologies increases sample density by allowing more measurements to be taken without significantly increasing time and project costs. Direct read instruments, such as the field portable X-Ray Fluorescence (FPXRF) detector collect measurements with the press of a button enabling the user to collect hundreds of readings in a relatively short period of time. High resolution data density provides more confidence in the delineation of the impact zone, thus reducing uncertainty about the distribution and concentration of contamination at a site. When properties contain only low to moderate impacts from contamination, realistic remedial approaches can be used that both protect human health and support cost-effective redevelopment. The success of EC/IC approaches to site risk management is based, in part, on the confidence that these controls are placed at the right location and provide the level of protection needed. The quantity and quality of sampling and analytical data produced by Triad programs generate the

Case Study: Use of Triad Approach to Support Brownfields Redevelopment

Milltown Ford Avenue Redevelopment Area, NJ

In 2002, Milltown Borough, New Jersey designated a 22 acre former industrial property for redevelopment to mixed residential, commercial and senior housing. An Environmental Site Assessment (ESA) was needed to determine the extent of impacts from 130 years of industrial use to properly design the redevelopment and establish site sales pricing. During systematic planning, the ESA was divided into five investigations consisting of a site-wide investigation and four specific studies based on past facility operations. Additional systematic planning resulted in agreement on remedial action criteria, analytical methods, field testing instruments and methods, sample and data management protocols, and a communications plan to support decision-making. Sample locations were identified daily using a global positioning system (GPS), transferred to an on-site mapping system and co-plotted with chemical data generated by three on-site mobile laboratories. Data were displayed in three-dimensional (3-D) imagery and communicated to project team members during weekly on-site meetings and via secure internet access for monthly stakeholder meetings. Localized contaminated zones were excavated, residual material capped and restricted-use covenants incorporated in property records. Final redevelopment plans have been submitted for local planning board review and approval.



Three Mobile Laboratories Generated Real-Time Analytical Data to Support DWS Investigations

robust information that allows regulators and stakeholders to support EC/IC approaches.

Voluntary Cleanup vs. "At Risk Development"

The State of New York provides a Brownfield Opportunity Area (BOA) as well as its BCP program to encourage voluntary cleanup under regulated conditions. Both programs are incentive-based to encourage participation.

Voluntary cleanups are those where a developer or site owner makes a commitment to undertake certain remedial activities under regulatory oversight. PlaNYC encourages property owners and developers to participate in voluntary cleanup programs, specifically the NYSDEC BCP or the new NYC BCP. OER's intention to streamline Brownfields redevelopment efforts is demonstrated by its commitment to using the Triad Approach. A direct benefit to developers and site owners is an increase in the confidence of investigation results (for example, that "hot spots" have been identified and addressed) as well as confidence that the redevelopment can be achieved without significant delays and cost overruns related to the cleanup process.

Cleanups performed as part of "at-risk development" are those where the developer performs investigation and/or remediation without active regulatory involvement, thus potentially risking a situation where cleanup may be deemed incomplete upon regulatory review. A good example of this is vapor intrusion (VI) mitigation, a site condition where volatile vapors from organic chemicals in groundwater and soil can migrate up into homes or other structures built over contaminated areas. A development that proceeds without addressing the potential for VI could be significantly impacted by the discovery of VI after the completion of construction. The thoroughness of Triad systematic planning is such that VI concerns would more often than not be addressed before investigation begins, whereupon appropriate testing would be included in site investigation plans. This occurs because Triad systematic planning is performed with the "end in mind." Since Brownfields redevelopment usually results in some type of human interaction with the site, VI issues are a common concern. Soil gas and other vapor samples can be collected early in the site evaluation so that mitigation techniques can be incorporated into the reuse design.

Uncertainty Management

A significant impediment to Brownfields redevelopment is uncertainty with regard to the nature and extent of contamination and the level of cleanup needed to prepare the property for reuse. Site contamination can impact the ability to develop properties because of the uncertainties related to cost of cleanup, timeframes and risks related to residual contamination.

Uncertainty can be particularly acute when considering reuse of low to moderately-impacted sites. In these circumstances the perceived impacts or site-related risks are commonly greater than the actual impacts or risks. In many cases, remediation efforts can be a combination of surgically-applied extraction of localized contamination, and EC/IC approaches to prevent development design and site use from posing potential risks of direct contact to residual contamination. However, the investigation must be robust enough to clearly identify such areas and delineate them with sufficient detail to support a CSM that will gain the confidence of regulators and other site stakeholders. Triad provides the framework for performing investigations with adequate data density to reduce site uncertainty to levels that will facilitate cleanup and redevelopment planning.

Historic fill underlying long-term commercial, industrial, and even residential properties poses inherent uncertainty due to the presence of localized areas of contamination within a matrix of low- to moderately-impacted material. The Triad Approach is well-suited for addressing properties with historic fill due to its utilization of adaptive, high resolution sampling strategies.

The use of Triad is particularly relevant to NYC because historical fill is commonly reported to be as much as 20 percent of NYC's land (Walsh and LaFleur, 1995). Brownfields sites are frequently located in areas with historic fill. Studies in New York and New Jersey, however, have shown historic fill to contain a fairly consistent mixture of contaminant types and physiochemical properties. Typically, the chemicals are poorly-soluble with low mobility which from a reuse perspective can be managed with EC/IC approaches such as engineered covers and use restrictions. Site uncertainty, therefore, is primarily driven by the need to distinguish between the baseline conditions of the historic fill and those superimposed from subsequent industrial or other use-driven impacts. By carefully locating and removing the localized contamination zones, remediation efforts can substantially reduce site risks in a cost-effective and streamlined manner.

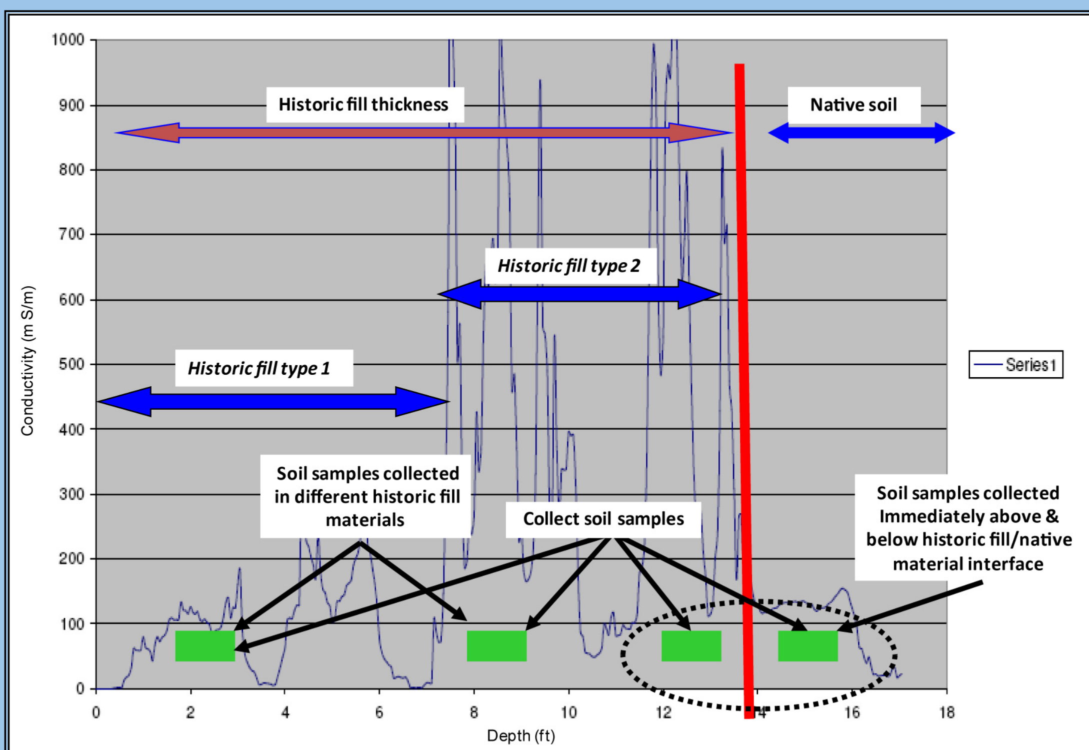
The CSM-based approach of Triad is a highly-effective method for addressing the unique conditions posed by historic fill. A DWS based on a thoroughly considered CSM and conducted using real-time, field-based measurements allows investigation teams to focus on the impact areas and isolate them from the rest of the site material. The use of direct sensing and other real-time measurement tools, coupled with targeted soil and groundwater sampling, can produce the high resolution data density required to differentiate generally widespread conditions from isolated zones of contamination. The data from this type of program can be visualized in 3-D using off-the-shelf software, allowing depiction of the impacts. Data visualizations help to effectively communicate the CSM to build stakeholder consensus on the completeness of the investigation, thus providing a reliable basis to support remediation decision-making. Detailed information on the process of using Triad to characterize historic fill is presented on page 12.

Once defined and isolated from the historic fill matrix, localized contamination can be surgically targeted with a number of *in situ* treatment technologies (applied to media in place) or addressed using *ex situ* treatment technologies (applied to relocated media) that have proven applications. For example, over the last 10 years, significant advances have been made in the application of *in situ* technologies for the treatment of volatile organic compound (VOC) impacted zones. Under appropriate geochemical conditions, VOCs will go through a degradation process that results in non-toxic residual constituents. For example, groundwater with low dissolved oxygen content, known as anaerobic conditions, support bacteria that can degrade VOCs. A naturally occurring process, anaerobic degradation has been documented in the NYC metropolitan area. *In situ* VOC treatment technologies seek to optimize the geochemical conditions by adding supplements to the subsurface and promote more rapid degradation.

Case Study: Brownfields Redevelopment on Historic Fill

Harrison Commons, Harrison, NJ

In the early 2000's, the Harrison Commons area of Harrison, New Jersey, was designated for redevelopment. It had been an area of extensive urban and industrial activities and was to be developed into a mixed residential and commercial area with a parking garage for a commuter rail station. Up to 15 feet of historic fill material had been placed in former marsh areas from the late 1800's to the 1940's. The fill consisted of mixed construction debris, demolition waste, coal and incinerator ash, solid waste, soil, and other urban source material. Direct push electrical conductivity (EC) probe investigations were effective in identifying the historic fill/native material interface and two distinct layers of fill material. EC data also assisted in determining in the field where to collect soil and groundwater samples within and immediately below the fill interface for real-time screening and off-site analysis. Remediation consisted of removal of concentrated impact areas, construction of a small-scale groundwater treatment system, and engineered cap/deed restriction risk management.



Soil Sample Intervals Selected in Field Based on Real Time Computer Readout from an EC Probe

Similar technologies are available for localized petroleum hydrocarbon contamination. However, because Triad practices, such as high resolution characterization, provide clear definition of the impact zone and total petroleum hydrocarbons (TPH) releases typically remain relatively near-surface, simple excavation is often appropriate. Metals can also be excavated or treated *in situ*. The common aspect of these remedial approaches is that the high resolution sampling programs under Triad allow distinction between the general historic fill conditions and the localized contamination impacts. Once these areas are isolated, engineers can design treatment applications using a variety of technologies and strategies.

Once localized contamination within the historic fill has been addressed, risks to redevelopment from the remainder of the material are typically associated with direct contact exposure to the low to moderate concentrations of metals and polycyclic aromatic hydrocarbons (PAHs) in the fill. Acceptable levels of risks related to these contaminant types are typically managed through engineered covers, deed notice/restrictions, and regular integrity inspections/reporting. Inherent in this approach is the assumption that the areas of historic fill have been identified and noted on a map attached to the site management plan and identified in the property deed. Triad methods for mapping historic fill can provide more accuracy and assurance that the fill is covered with protective surfaces and that risk has been mitigated.

HOW TRIAD CAN BE APPLIED IN NYC

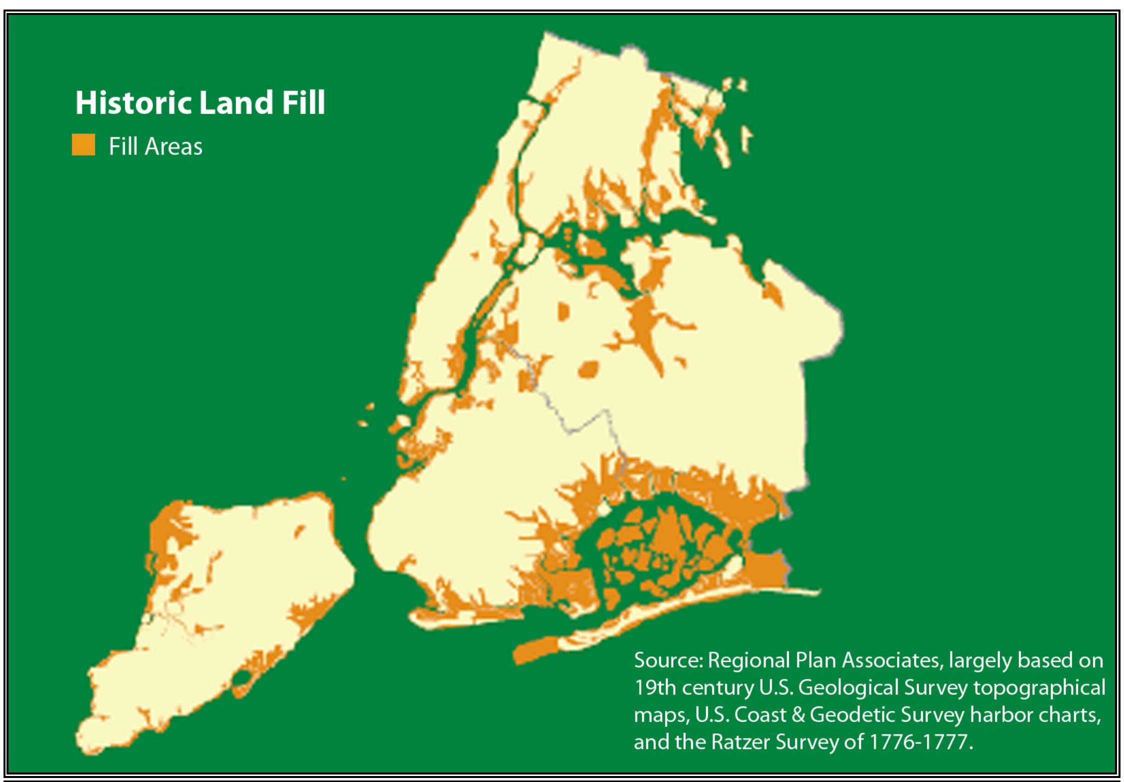
NYC is developing a streamlined, city-administered cleanup program (i.e., NYC BCP) for moderately contaminated sites including those with historic fill. Utilizing the Triad Approach can streamline the cleanup and redevelopment of these properties by providing generally consistent testing and remediation methods that account for the unique aspects of each property, while capitalizing on efficiencies driven by their city-wide similarities. Since large areas of the city include historic fill and/or are on the waterfront, use of the Triad Approach will help support the revitalization of these properties.

Use of Triad to Perform Environmental Investigations of Historic Fill

The historic fill material or urban fill soil present in areas of NYC is a reflection of over 400 years of human activity and a common occurrence in older industrialized cities in the Northeast United States. Fill was commonly used to increase the elevation of topographically low terrain and to reclaim marsh areas for new development. Significant filling activities primarily began in the late 1800's and early 1900's and progressed until strict State and Federal environmental regulations such as the Resource Conservation and Recovery Act (RCRA) prevented random disposal through close tracking of waste material (Walsh and LaFleur, 1995).

As land for development has become increasing scarce in the New York metropolitan area, redevelopment of historic fill properties has become a necessity. Much of the historic fill land is along waterways and coastal areas of the city, which are attractive for residential development. Today, fill may be present on as much as 20 percent of the City's land, primarily along the coastal areas and in the headlands of the bays (Figure 2).

Figure 2 – Historic Fill Lands in New York City



Composition of Historic Fill

Historic fill material is a typically a heterogeneous mixture of various waste products, including construction and demolition debris, roadway construction debris, rubble, backfill soil, boiler ash, industrial debris, and/or coal and municipal incinerator ash. Historic fill material does not include any material which is substantially chemical production waste or waste from processing of metal or mineral ores, residues, slag, or tailings. In addition, historic fill material does not include a municipal solid waste landfill site built after 1962 when NYS Landfill regulations emerged. Because of this heterogeneous content and unregulated disposal, the environmental and geotechnical characteristics of fill materials are critical considerations when planning and performing redevelopment. Similarly, environmental investigations must consider site geotechnical characteristics to ensure that selected field investigation technologies will be effective at each site.

Subsequent to infilling, areas of historic fill were developed and used for a variety purposes, including industrial and commercial activities. These activities impacted the fill through general use and through specific actions such as disposal of solid and chemical waste materials from manufacturing processes, as well as waste materials. Thus, many properties have environmental impacts embedded in the historic fill material that may or do pose potential health risks. Fortunately, many of these properties pose only a low to moderate health risk through direct contact with materials of concern.

Regulatory agencies now recognize that the presence of historic fill material must be incorporated into the ESAs of redevelopment projects and accounted for during remedial action evaluation. The primary issue for regulators and Brownfields redevelopers with regard to projects on sites with historic fill is the legacy impact from past industrial operations. Potential contaminant presence is the basis in some jurisdictions for historic fill material needing to be mapped and tested to determine its condition and extent. Information regarding any concentrations of contaminants that remain on site above the standards is commonly recorded with the property deed. Typically, historic fill contains metals and PAHs which exceed the low residential soil standards, which when isolated by engineering controls do not pose a health threat.

The primary issues in redevelopment of property underlain by historic fill are prevention of direct contact with the surface materials and geotechnical suitability for structures. Using the Triad Approach, historic fill sites can be investigated thoroughly and efficiently to ensure that impacts have been properly identified and remediated. Subsequently, these sites can be redeveloped using constructed covers and other engineering-based or land-use controls.

Delineation of Fill Materials

Under the Triad Approach, the plan for delineation of fill materials would be developed during systematic planning, based on review of the CSM and determination of specific data gaps that need to be addressed. In addition, the nature of fill and the immediate surroundings of the site would be considered in order to select the most appropriate, efficient and cost-effective technical methods of delineating the fill. A common and effective starting point for Triad project planning is the review of Sanborn fire insurance maps and other historical information sources to determine if contaminants of concern (COC) in background soil may have resulted from past industrial activities, waste-disposal activities, or other potential sources.

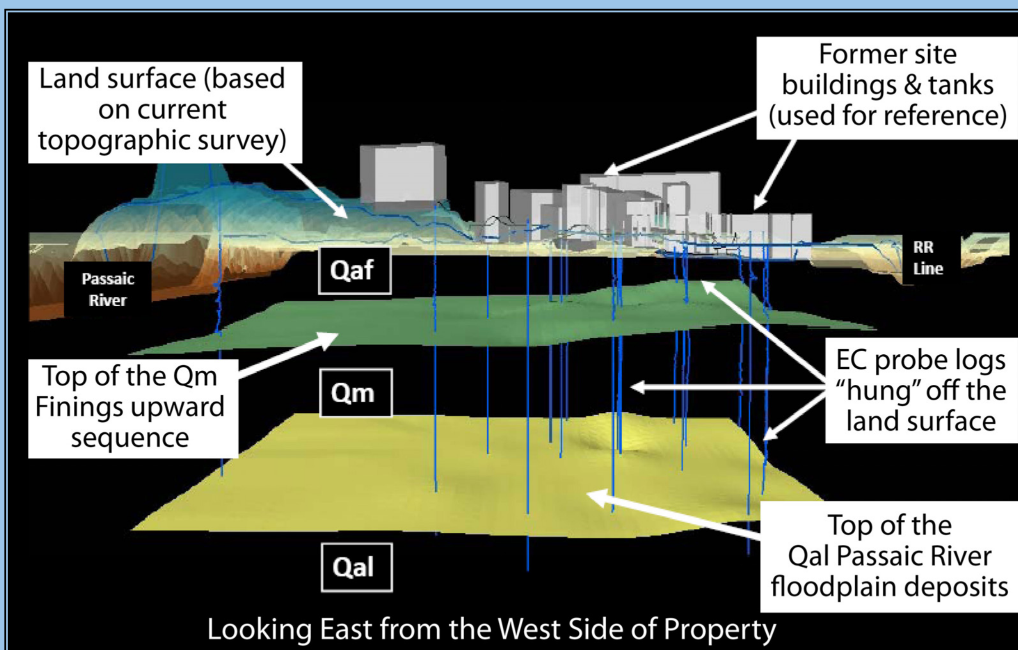
By its very nature, historic fill lends itself to a fairly consistent CSM which can be used to select investigation tools. In most cases, fill has been placed directly on top of a former marsh surface and there is a sharp contrast between the composition of the historic fill and marsh material. Compositional contrast can quickly be detected by geophysical systems and/or direct sensing probes because of the significant variation in electrical conductivity (EC) and other properties of the two materials.

Another element of the CSM is the characteristic of the fill itself. Because urban fill material is primarily anthropogenically-derived and extremely heterogeneous, it creates a unique signature when assessed with an EC probe driven with direct push technology (DPT). Highly-conductive layers, such as ash layers within the fill, are clearly discernable as large spikes in conductance in the instrument read out logs produced at the surface by the field computer. Voids or gaps are identified by very low conductance. These extremes are not found in nature and give historic fill a unique EC log signature.

Case Study: Delineation of Historic Fill for Brownfields Redevelopment

Former Chemical Manufacturing Facility, Port of Newark, NJ

A former chemical manufacturing facility built on top of historic fill was designated for redevelopment to support an increase in trade at the Port of Newark, New Jersey. The fill material consisted of 5 to 15 feet of construction debris, demolition waste, coal and incinerator ash, solid waste, and other urban material. It was believed that 50 years of manufacturing resulted in the fill being impacted by metals and PAHs associated with two areas of concern (AOC); a wastewater lagoon and an aboveground storage tank (AST) farm. Data from an electrical conductivity (EC) probe was used to define the native material/historic fill boundary, distinguish between the different native soils and fill layers, and create a 3-D lithologic model for understanding contaminant distribution and for communicating site conditions to stakeholders. Soil cores were collected to verify EC results that the boundary was impervious to downward migration of metals. Soils were sampled and analyzed, confirming that the majority of contamination was indicative of historic fill versus releases from facility operations. Contaminants in fill were determined to be stable and not a source to groundwater impacts and, therefore, manageable through removal of concentrated areas of impact, and placement of capping and deed notice/restrictions for historic fill.



3-D Visualization of Site Lithology and Other Features

Historic fill can also be investigated through a parcel-by-parcel or an area-wide approach. As most fill activities occurred before the land was subdivided into parcels for development, its distribution is a regional issue and overlaps parcel boundaries. Area-wide mapping can establish the overall extent and characteristics of historic fill material, whose composition can vary with disposal practices. In certain areas, incinerator ash, which can contain elevated metals and PAHs, was disposed along with clean fill. EC testing will detect the differences in these fill layers and through multiple test locations, provide data on the area-wide distribution of the materials. In certain cases, fill at individual parcels could potentially be confirmed by simply verifying that the material at the site is consistent with the area's historic fill. Taking this action could streamline decisions regarding the environmental contamination investigation-related phases of an overall Brownfields redevelopment strategy, by eliminating the need for multiple workplans, mobilizations and reports, and allowing remedial strategies to be developed earlier in the redevelopment planning.

Real-Time Measurement Technologies

Direct sensing tools, which provide instantaneous measurement data, can be used to evaluate the bulk properties of the historic fill and delineate chemical impacts. A surface geophysical survey, using technologies such as ground penetrating radar (GPR) or magnetometer, is a quick method to survey historic fill sites for buried objects such as foundations, tanks, metal debris, and pockets of rubble. Since these methods do not provide definitive determination of the object, it is common to use a backhoe to excavate certain anomalies.

The EC probe is a rugged, downhole probe that can be hammered or advanced into the subsurface using DPT to determine the general stratigraphy of historic fill materials based on the characteristic patterns of typical fill materials in the instrument field read out log. The tool is especially applicable to historic fill conditions because it is hardened and can be deployed in the semi-obstructive conditions often encountered in historic fill situations. The instrument read-out pattern of historic fill is readily distinguishable from naturally-occurring soil, thus the interface between the fill and the underlying native soil can be identified with high confidence. Real-time data allows rapid mapping of fill thickness and bulk properties. To confirm the field interpretation of instrument read out patterns, select soil borings are advanced to visually inspect the fill and underlying soil.

Table 2 presents examples of direct sensing tools and applications that can be used for physical delineation of historic fill.

Common Fill Contaminants

Historic fill in the New York metropolitan area commonly contains PAHs and a relatively standard suite of metals. These compounds are usually spread throughout fill materials at low to moderate concentrations. If investigated and managed properly, the presence of these compounds in historic fill should not preclude Brownfields redevelopment. Further, if investigated using the Triad Approach, historic fill containing these compounds can be addressed in a streamlined manner, avoiding potential delays in redevelopment. Table 3 presents PAH compounds and metals commonly found in historic fill material.

Table 2 – Example Direct Sensing Tools and Applications for Fill Delineation

Technology	Matrices	Data Provided
Geophysical survey technologies - Total field and Gradient Magnetometry - Gravimetry / Microgravimetry - Seismic Reflection / Refraction - Electrical Resistivity Imaging (ERI) - Frequency Domain Terrain Conductivity - Time Domain Metal Detection - Ground Penetrating Radar (GPR) - Direct Current (DC) Resistivity	Soil, fill, bedrock	Sources, pathways, macro-stratigraphy, and buried objects
Downhole geophysical testing - Natural gamma ray - Self potential - Resistivity - Induction - Porosity/density - Caliper	Soil, fill, bedrock	Lithology, groundwater flow, structure, permeability, porosity, and water quality
Membrane Interface Probe (MIP) and electrical conductivity (EC) probe	Soil, fill, water	EC-based lithology, volatile organic compounds (VOCs), hydrocarbons, and dense non-aqueous phase liquid (DNAPL)
Neutron Gamma Monitors	Soil, water, material surfaces	Radiation
Hydraulic conductivity profilers	Soil, water	Hydraulic conductivity, lithology
Cone penetrometer testing (CPT), high-resolution piezocone	Soil, water	Lithology, groundwater flow

For additional information concerning the technologies listed in this table, readers should refer to the resources available on EPA's Hazardous Waste Clean-Up Information (CLU-IN) Web site (www.clu-in.org).

The following are summaries of the nature, common sources, and distribution of these contaminants, and examples of commonly used testing methods to identify them in the field.

PAHs

PAHs are commonplace in the environment, and are also found in petroleum products including oil, diesel fuels, aircraft fuels, coal, tar, asphalt, and even some edible oils. They are produced from the combustion of petroleum-based fuels and firewood. PAHs are lipophilic, meaning they mix more easily with oil than water, and as a result, are found primarily in soil, sediment, and oily substances, rather than in water or air. They are present in fill material from buried road construction materials, building construction materials, and disposed coal and other ash.

Table 3 – Contaminants Typically Found in Historic Fill Material

PAHs	Metals
Benzo(a)anthracene	Arsenic
Benzo(a)pyrene	Beryllium
Benzo(b)fluoranthene	Cadmium
Benzo(k)fluoranthene	Copper
Dibenz(a,h)anthracene	Lead
Indeno(1,2,3-cd)pyrene	Mercury

PAHs can be detected in the field using a variety of test methods, including immunoassay or ultraviolet fluorescence (UVF) test kits and field-portable gas chromatographs (GC).

Metals

Metals come from natural sources such as soils and bedrock, as well as a variety of anthropogenic sources. As common constituents of historic fill, metals can be considered components of fill separate from other contaminant species that might be present on site in high concentrations due to subsequent industrial and commercial-related contamination. With the exception of mercury, these metals can be detected with a variety of methods including screening or analysis using FPXRF technology (See Figure 3) and standard analysis conducted in mobile laboratories using atomic absorption (AA) or inductively coupled plasma (ICP) analytical methods.

Figure 3 – Field Portable X-Ray Fluorescence (FPXRF) Analyzer

The following are summary descriptions of metals commonly associated with historic fill and information on their origins.

- Arsenic is commonly found in historic fill materials, pesticide treatments, and disposed coal and other ash. Obtaining regulatory approval of an arsenic issue can be difficult because of the metal's relatively ubiquitous presence in natural and urban environments and because New York's residential soil cleanup standard for arsenic is near natural background concentrations. Therefore, it is important during redevelopment to ensure there is a reliable approach to determining background concentrations, such as available literature or actual background measurements in adjacent environments. While arsenic is frequently found at elevated concentrations in historic fill, due to its relative immobility and low solubility, arsenic can be addressed through the combination of engineered covers or barriers and ICs such as well restrictions.
- Beryllium is commonly found in fill materials as a function of disposed coal and other ash and miscellaneous petroleum compounds mixed into fill during transportation and placement. Beryllium is a hardening agent that is added to other metals. Beryllium copper alloys are used in many applications because of their high strength and hardness and can become embedded in historic fill as a consequence of disposal of these materials. Beryllium is poorly soluble and the principal health concern is inhalation of beryllium containing dust. Concentrations in historic fill are usually low and can be managed through the combination of

engineered covers or barriers and ICs such as well restrictions.

- Cadmium can be present in historic fill as a result of being a minor component of zinc ores, pigments in paint, or corrosion resistant plating on steel and battery electrodes. Cadmium is much less mobile in soil than in air and water. At Brownfields properties in the metropolitan area, cadmium may be the result of a variety of processes, including petroleum refinement, fertilizer production, and historic agricultural practices. Crumb rubber produced from the wear of vehicle tires is believed to be one of the primary sources of cadmium (and zinc) found in road dust. The primary health risk from cadmium at Brownfields properties is inhalation and dermal contact. If concentrations are high, soils are typically removed. Low concentrations can be managed through the combination of engineered covers or barriers and ICs. Typical residential soil cleanup standards for cadmium are usually in the low parts per million (ppm) range.
- Copper is commonly found in fill materials as a function of electrical products containing copper-based materials, demolition debris from former industrial facilities, incinerator and coal ash, and pigments from industrial paints. It is used as a thermal and electrical conductor, found in plumbing in building materials, and is a constituent of various metal alloys. Copper is fairly common in historic fill because of its widespread use. Under certain circumstances, copper can be soluble and, therefore, high concentrations (hundreds of ppm) found in soil are typically excavated.
- Lead is commonly found in fill materials as a function of the presence of construction materials coated with lead-based paint, coal and incinerator ash, demolition waste, lead acid battery parts and miscellaneous disposal of petroleum compounds. Common in the urban environment, lead is a neurotoxin that can accumulate in soft tissue and bone over time. Elemental lead, which is poorly soluble and has low mobility, is the most common form of lead found in historic fill. Typical lead soil cleanup standards are near 400 ppm. The primary health risk from lead at Brownfields properties is inhalation and dermal contact. Low concentrations can be managed through the combination of engineered covers or barriers and ICs.
- Mercury is commonly found in fill materials as a function of municipal waste disposal and incinerator ash, as well as building demolition wastes. Mercury is unique in that it has the highest solubility in water of any metal and easily vaporizes into the air; thus these two properties make it very mobile in the environment. Mercury can be detected in the field using various mercury vapor analyzers, as well as specialty analytical methods in a mobile laboratory.
- Zinc is commonly found in fill materials as a function of coal ash, demolition wastes containing galvanized metals, rubble coated with industrial paint and other painted wastes, incinerator ash, and petroleum compounds. Zinc has a fairly low toxicity and thus soil cleanup standards are in the 1,000 to 3,000 ppm range. Zinc in historic fill soil can be managed through the combination of engineered covers or barriers and ICs such as deed restrictions and notices.

Additional information on the sources and human health and environmental impact of these metals can be found at www.clu-in.org/contaminantfocus.

Identifying and Delineating Contamination in Fill

Once historic fill is mapped and basic bulk properties have been defined (i.e., thickness, variability, basic distribution, and concentrations of COCs), real-time information produced by direct sensing tools can be used to select intervals of interest for sampling and analysis for known and suspected fill-related contamination. The targeted soil samples obtained from the fill and underlying native soils can then be analyzed on site with field-generated data technologies and testing methods (such as XRF, IA test kits and PID instruments) and USEPA SW-846 standard analytical methods performed in mobile laboratories. In addition, certain direct sensing tools can be used to identify and delineate impacts from other contaminant types, such as VOCs and heavier petroleum compounds, such as fuel oils, coal tar and heating oils.

Table 4 presents various direct sensing, sampling and analytical technologies that can be used for contaminant identification and delineation.

For additional information concerning the technologies listed in this table readers should refer to the resources available at www.clu-in.org/technologies.

In many cases, several technologies can be used together to investigate unique site conditions in urban environments like NYC. For example, often the source of airborne contamination is not readily obvious and might even appear to come from several sources at adjacent sites. The first step in addressing this situation would be to identify airborne contaminants using real-time air measurement devices to track them back to the source areas, and then identify the specific contaminants in soil or groundwater using other intrusive techniques.

Table 4 – Example Sensing, Sampling and Analytical Technologies for Contaminant Delineation

Technology	Matrices	Data Provided
Direct push samplers	Water, soil, fill, active soil gas	Sample, physical / visual data
Field-XRF analyzer (screening and bench-top analysis modes)	Soil, sediments, fill, material surfaces	Metals
Laser-induced fluorescence (LIF), UV methods (UVF, UV lamp)	Water, soil, fill	Total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH), petroleum as light and dense non-aqueous phase liquid (LNAPL / DNAPL)
Immunoassay (IA) test kits	Water, soil, fill, material surfaces	Semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), PAHs, pesticides, and dioxins/furans, explosives, mercury
Miscellaneous colorimetric kits	Water, air	Water quality, hazardous vapor
Mobile laboratory – definitive data	Water, soil	VOCs, SVOCs, pesticides, PCBs, explosives, metals, and wet chemistry
Field GC and GC/MS – screening data	Water, soil	VOCs, SVOCs, pesticides, PCBs, and explosives
Active and passive soil gas samplers	Soil gas	VOCs, unstable SVOCs
SUMMA canisters	Soil gas, indoor air	VOCs, unstable SVOCs
Passive diffusion samplers	Water, soil gas	VOCs, SVOCs, and contaminant flux
Open-Path Fourier Transform Infrared (OP-FTIR) Spectroscopy	Air, water, soil	VOCs (water), TPHs (soil and water), VOCs and other gases (air)
Permeameter	Soil	Hydraulic conductivity
Membrane Interface Probe – - photoionization detector (PID) - flame ionization detector (FID), - electron capture detector (ECD), - halogen specific detector (XSD)	Soil, fill, water	VOCs, petroleum hydrocarbons, and DNAPL
Conventional drilling technologies	Water, soil, fill, bedrock	Physical/visual data, multiple constituents

For additional information concerning the technologies listed in this table readers should refer to the resources available on www.clu-in.org.

These field techniques provide real-time results which enable decisions to be made in the field, a fundamental element of performing dynamic work strategy field efforts under Triad. In addition to supporting dynamic investigation, field-generated data can streamline projects by bypassing the need to submit samples to a fixed-base laboratory analysis. As a result, large areas of historic fill can be quickly and cost-effectively mapped in urban redevelopment areas and on individual properties.

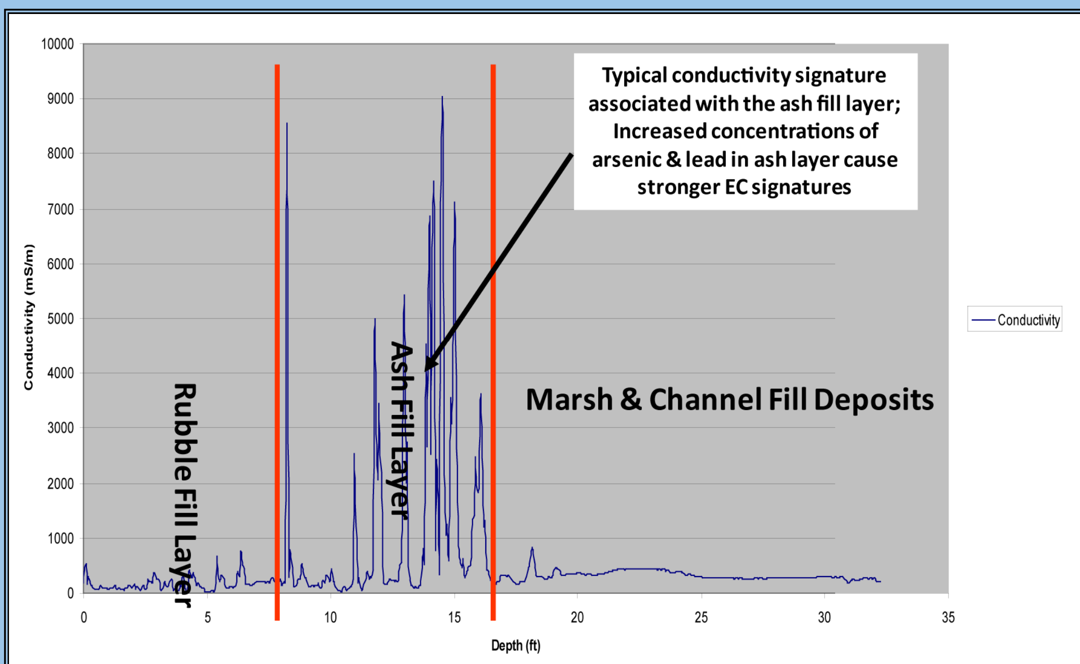
It is important to note, however, that some probes can only be used after much of the bulk characteristics of the historic fill have been defined because they are less rugged and more sensitive to damage by subsurface obstructions. In addition, if contaminants are found at elevated concentrations during a field screening effort at a Brownfields property, confirmation samples may need to be submitted to a fixed-base laboratory for analysis.

In summary, direct sensing tools are an efficient and cost-effective method for delineating the extent and structure of fill. Similarly, field-testing technologies are an effective way of confirming and delineating contaminants in real-time. Together, they directly

Case Study: Delineation of Metals in Historic Fill Using Direct Sensing Methods

Brownfields School Redevelopment Project, Camden, NJ

The Camden, New Jersey Board of Education and the School Development Authority determined that an existing school was deteriorating and needed to be replaced. Construction was halted during installation of the foundation for the new school due to high arsenic levels being encountered in historic fill. A Triad Approach investigation was used to quickly define the extent of arsenic impacts so that construction could be restarted. An electrical conductivity (EC) probe was used to distinguish between historic fill and underlying marsh/channel fill deposits. A clear EC probe signature also identified a coal ash fill layer in a former stream bed, which allowed targeted soil sample intervals to be selected in the field for arsenic analysis. A field portable x-ray fluorescence (FPXRF) analyzer was used for field analysis with results confirmed by fixed base laboratory analysis. The high-density, collaborative data set substantially reduced site uncertainty and enabled the selection of a remedial strategy consisting of soil and asphalt caps over the entire site, isolated soil excavation in utility corridors, deed notice, and a groundwater classification exemption area. School construction resumed and the school was opened to the public in January 2009.



Ash Fill Layer Defined by a Clear EC Signature Caused by the Higher Conductance of the Metals in the Ash Material

support the use of a Triad DWS approach to assess fill material, and as a result, their combined use is a highly-effective means of streamlining site redevelopment.

Use of Triad to Perform Environmental Investigations at Waterfront Property

The NYC waterfront has changed substantially over the years as the marshes and other low lying areas have been filled and the shoreline has grown outward. The city is a collection of islands and waterfront property is abundant. Land uses have changed as the needs for these properties have shifted from industrial/maritime to residential/commercial and recreational/open space. City waterfront land is highly valuable and underused, and redevelopment would provide significant economic, recreational, and social benefits for the people of NYC. Waterfront redevelopment has the added benefit of acting to control contaminated runoff and groundwater discharge which can otherwise degrade surface water quality in the adjacent water bodies. Thus redevelopment of waterfront property not only provides economic benefits to NYC, but can also improve surface water and sediment quality in the canals, bays, and other water bodies that ring the City.

Waterfront property is one of the great assets of the City of New York. Many waterfront properties are also Brownfields sites. Under PlaNYC, NYC has developed programs to facilitate redevelopment of its Brownfields sites, and doing so will benefit all residents of the City. However, waterfront properties have certain unique environmental challenges that pose a significant hurdle to redevelopment if they are not properly characterized. The Triad Approach provides an investigation framework and tools to effectively investigate these properties and position them for productive reuse.

Waterfront properties are sometimes the hardest areas to redevelop because historic fill and past industrial uses are intermingled which results in complicated environmental conditions. Using the Triad Approach to assess environmental concerns at these sites helps to effectively address such site conditions and support site redevelopment.

Redevelopment Opportunities and Challenges

Of the five boroughs, Manhattan is almost completely developed and there are relatively few opportunities for major new developments on its waterfront beyond redevelopment of existing piers. However, in the outer boroughs there are many significant opportunities for redevelopment of waterfront land, particularly along the Brooklyn waterfront near Williamsburg, portions of Queens, the north shore of Staten Island, and southeast Bronx. These areas were once industrialized with business that relied on the water for transportation and maritime access. Much industry has since withdrawn leaving these properties underutilized. With the growing need for space in NYC, there is increased interest in redevelopment of these areas.

An example of this is Schaefer Landing, a 1.7-acre waterfront redevelopment project in the Williamsburg section of Brooklyn. After the area's manufacturing sector declined in the 1970's, the City foreclosed on the site for failure to pay taxes. The City decided to rezone the property from manufacturing to residential in an effort to produce affordable housing and reclaim the waterfront. Currently, 12,000 square feet of commercial space and 350 units of housing, including 140 affordable units, are available at Schaefer Landing. The site also improves water taxi service, which increases transit to Lower Manhattan for the growing neighborhood of South Williamsburg.

Redevelopment of waterfront property can face many environmental challenges, both from the historic uses of the uplands portion of the property as well as the nearshore sediment conditions. Because waterfront property is often filled land, one common characteristic is that historic fill will most likely be present. Investigation of the historic fill conditions using the approaches discussed in the previous section should, therefore, be included in a waterfront property assessment. Another environmental challenge associated with waterfront property is the environmental impact after filling that can occur from industrial and commercial uses. These uses can leave behind contaminants not normally found in historic fill such as CVOCs, PCBs, and petroleum compounds such as fuel oil, motor oils and lubricants. Thus, a significant environmental challenge when redeveloping waterfront properties is identifying and separating the standard suite of historic fill contaminants from the subsequently introduced industrial chemicals.

A further environmental challenge is the interaction between upland properties and the adjacent water bodies of concern. The two primary issues associated with this environmental challenge are discharge of impacted groundwater to the water body and overland flow of water and sediment. Triad programs can be used to streamline the identification of the sources of these discharges.

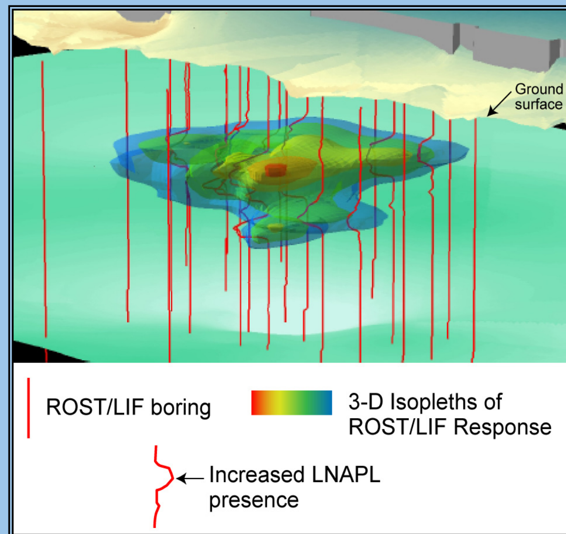
Common Characteristics of Waterfront Properties Can Be Used to Build a CSM

As with historic fill sites, Triad practices can provide an effective site characterization approach for waterfront properties that can provide increased accuracy and thoroughness. Waterfront properties have a common aspect, namely that they are in proximity to a surface water body. In this context, there are common components to waterfront properties that produce similarities in their CSMs. The common elements of a waterfront CSM can be used to inform the design of investigation programs and establish characterization goals which can be applied to multiple waterfront Brownfields projects.

Case Study: Brownfields Redevelopment of Waterfront Property

BCF Oil Site, Brooklyn, NY

The BCF Oil Site is a former oil distribution and waste oil recycling facility that borders English Kills and is adjacent to Newtown Creek in Brooklyn, New York. The site requires investigation and remediation work to support its commercial redevelopment due to the detected presence of polychlorinated biphenyls (PCBs) and petroleum compounds in soils and sediment, non-aqueous phase liquids (NAPL) (i.e., free phase product), and dissolved volatile organic compounds (VOCs) in groundwater. Complex near-surface geology consisting of historic fill and marine and glacial deposits prevented clear definition of site lithology. The extent of contaminant impact to soils, groundwater, and surface waters was also not delineated. A variety of direct sensing tools were used in a Triad Approach investigation to delineate contamination, including cone penetrometer testing (CPT), rapid optical screening tool (ROST)/ laser-induced fluorescence (LIF), electrical resistivity imaging (ERI), and ground penetrating radar (GPR), as well as PCB field testing methods. Results verified that PCB concentrations were generally below the action levels anticipated for the site. LIF results were used to place small gauge wells and piezometers across the site to measure free product; which was measured in a significant quantity in only one well. Stratigraphic heterogeneity was found to be extremely high at the site and free product was determined not to be pervasive. Permanent monitoring wells were installed and sampled. Site closure requirements and remedy implementation under the NYSDEC Underground Storage Tank (UST) program are anticipated for 2010. The collaborative use of LIF and PCB sampling data assured that the low level PCBs will not likely need to be addressed via aggressive remediation.



3-D Image of a Petroleum Hydrocarbon Impacted Area

The diagram shows an example of petroleum compound imaging using direct sensing technology. Sensors on probes detect the presence of fuels in the subsurface and 3-D visualization software is used to illustrate the petroleum impact area. The red lines in the figure indicate locations of probes and where lines divert from vertical, petroleum compounds are detected. An approximation of the concentration of the petroleum compounds is determined by the extent to which the lines divert from the vertical.

Common aspects of waterfront property CSMs that can be used to plan investigations include:

- **Historic Fill** – Many waterfront properties are underlain by land that was former marshland prior to being filled in. The typically sharp interface between the historic fill and former marsh surface can be used to define an investigation surface using real-time sensing technologies in a Triad project framework.
- **Secondary Contaminants** – Since early industrial development in the City began along creeks, canals, and other waterways, many Brownfields waterfront redevelopment sites are characterized by industrial releases mixed with historic fill. The potential presence of contaminants requires delineation of historic fill horizons, and identification of areas of elevated concentrations of industrial chemicals.
- **Groundwater Discharge to a Water Body** – Due to site proximity to waterways, groundwater underneath waterfront properties is usually a shallow water table condition with flow being toward the surface water body.

Under these conditions, groundwater impacted by upland contaminants may migrate and discharge into the waterway. One of the critical questions that need to be addressed with regard to redevelopment of waterfront areas, therefore, is to confirm whether and where impacted groundwater is discharging to an adjacent water body.

- **Nearshore Sediments –** Ongoing nearshore impact to sediment can result from past industrial operations in the upland areas. Nearshore sediments in City water bodies are known to contain metals, petroleum hydrocarbons and PCBs. Redevelopment needs to consider these conditions, particularly if the site includes opportunities for public access to the nearshore environment.

Using these common CSM components to streamline project planning, Triad field efforts can be quickly designed. In addition, they can take advantage of the common use of direct sensing tools, real-time measurement technologies, and DWS to efficiently delineate historic fill. Contamination related to subsequent industrial releases to historic fill can then be isolated and distinguished by their unique characteristics.

Identifying and Delineating Intermingled Contaminants

When historic fill contains metals and PAHs in relatively low concentrations, a common remedial strategy consists of engineering controls and deed restrictions. However, when industrial chemicals are mixed with the historic fill, impacts can be more significant. Under these circumstances, the non-historic fill impacts need to be isolated and treated. The following describes attributes of contaminants not typically associated with historic fill:

- **VOCs** – Historic fill is derived from earlier periods and contains primarily metals and PAHs, which are generally not volatile. VOCs on the other hand are very volatile and produce off gases that can be detected using direct sensing probes. The membrane interface probe (MIP) is a cost-effective tool that can be used to map VOC impacts because it only detects vapors from VOCs not typically associated with historic fill.
- **Petroleum Compounds** – Petroleum compound impacts can be detected with a variety of direct sensing tools. The typically low to moderate concentration of PAHs frequently present in historic fill are not sufficient to effect performance of these instruments. Of the several different tools available, such as the MIP or LIF, the particular tool used needs to be selected based on petroleum type and field conditions conducive to direct push technologies.
- **Concentrated Metals Impacts** – While a certain amount of metal impacts are typically associated with historic fill, secondary metals impacts can also originate from such industrial operations as plating, photochemical manufacturing and ore processing. These impacts can be delineated in real-time using FPXRF technology. Prior to defining the impact zone, however, an understanding of metals contained in the historic fill is necessary in order to isolate the zone of elevated metals relative to background fill conditions.

Additional information on the sources and human health and environmental impact of the contaminant classes listed above can be accessed at www.clu-in.org/contaminantfocus.

Direct sensing tools produce real-time, near-continuous logs of the vertical profile of contamination. When viewed in conjunction with other direct sensing logs (such as the EC probe that provides information on lithology and interfaces), specific intervals for soil and groundwater sampling can be selected. Narrowing the impacts down to one or two groups of contaminants allows analytical methods to focus on these compounds alone, thereby streamlining the cleanup process. Important considerations for selecting soil and groundwater sampling intervals include:

- Interfaces such as the boundary between historic fill and underlying native materials which effect vertical migration of certain contaminants,
- Obtaining soil samples with analytical results below action criteria to bound the impact zone, and
- Collecting a range of soil and groundwater samples from different portions of the core impact zone for design of a site remedy.

Groundwater Discharge to a Water Body

Discharge of impacted groundwater originating from an upland source into a water body can also be addressed with Triad techniques. One key issue is the need to identify and abate the upland contamination source so the plume diminishes over time. Another key issue is determining where the discharge is occurring along the boundary between the site and the waterway. Because groundwater under waterfront sites is typically shallow, flows toward the water body, and where unimpeded by rip-rap or concrete retaining walls, can be easily accessible with DPT-driven tools, the groundwater plume can be efficiently mapped with direct sensing technology and real-time interval-specific groundwater sampling. Plume data can then be visualized in 3-D and the on-site source areas identified. Subsurface features can also be mapped using surface geophysical survey technologies. Unless broadly-impacted by contaminants from other properties, removing or treating source areas as part of site redevelopment will improve the quality of water bodies adjacent to waterfront redevelopment sites.

Finding groundwater to surface water discharge points can also be accomplished using the high resolution site characterization techniques inherent in Triad methods. Changes in the permeability of subsurface material (such as an interface between historic fill and a former marsh surface) can channel groundwater so that discharges of impacted water can be isolated to sections of the shoreline rather than as uniform flux front across the groundwater-surface water interface. Samples collected at multiple points distributed along the shoreline can identify the discharge points.

An example of how the Triad approach was used to characterize groundwater discharge at a Brownfields waterfront redevelopment project is shown below in Figures 4-6. At this property, background research had indicated that an industrial operation associated with rubber manufacturing had occurred 300 feet inland. A Triad investigation had mapped a shallow groundwater chlorobenzene plume that originated from an industrial vat under the manufacturing building and was migrating toward the water body. Figure 4 shows the distribution of the sampling points used to map the plume distribution. A combination of several testing methods were used to map the plume including direct sensing, soil and groundwater sample analysis using an on-site mobile laboratory, and fixed based laboratory analysis of select samples.

A collaborative data set was used to generate a 2-D visualization which is illustrated in Figure 5. Visualization of the plume indicated that two zones along the shoreline appeared to be the primary discharge points. One possible explanation for this channeling of the groundwater flow was that a large interceptor sewer line had been placed through the study area in the past. The gravel envelope of the sewer line was believed to be causing preferential groundwater flow pathways. These discoveries resulted in an immediate and significant modification to the site CSM, a clear example of why use of a flexible data management and visualization system can be very effective.

To verify and calculate the flux of contaminants into the water body, a series of passive diffusion bag (PDB) samplers were placed along the shoreline and allowed to remain for 2 weeks to reach equilibrium (Figure 6). Analytical results of the water contained in the PDB samplers subsequently confirmed the exact locations of the discharge points and was used to begin design of discharge control.

Data Management, Visualization, and Communication

Triad-based investigations benefit from effective management, visualization, and communication of data. Information accuracy and deliverable production efficiency are particularly important when multiple stakeholders need to evaluate data and make decisions in real-time or near real-time.

A critical aspect of a Triad project is high resolution sampling, which results in more horizontal and vertical sample points targeted in optimal locations to provide meaningful data. Targeted increases in data density integrate well with data visualization methods such as 3-D imaging. In the last few years a number of off-the-shelf 3-D imaging software packages have become available which provide powerful visualization tools and capabilities for data communication.

Figure 4 – Direct Push Groundwater Screening Locations

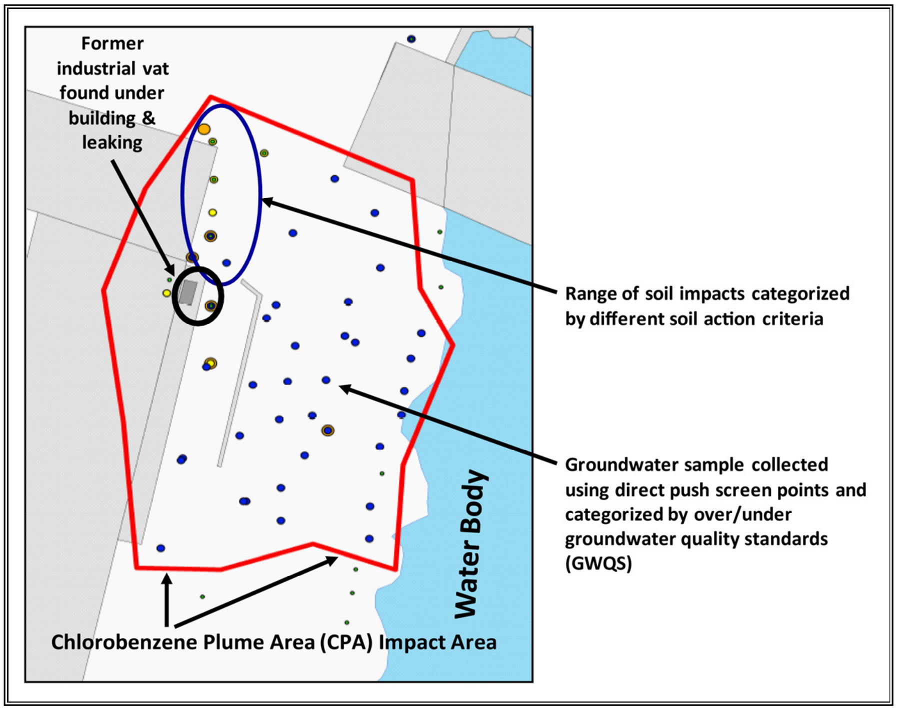


Figure 5 – Delineated Chlorobenzene Plume

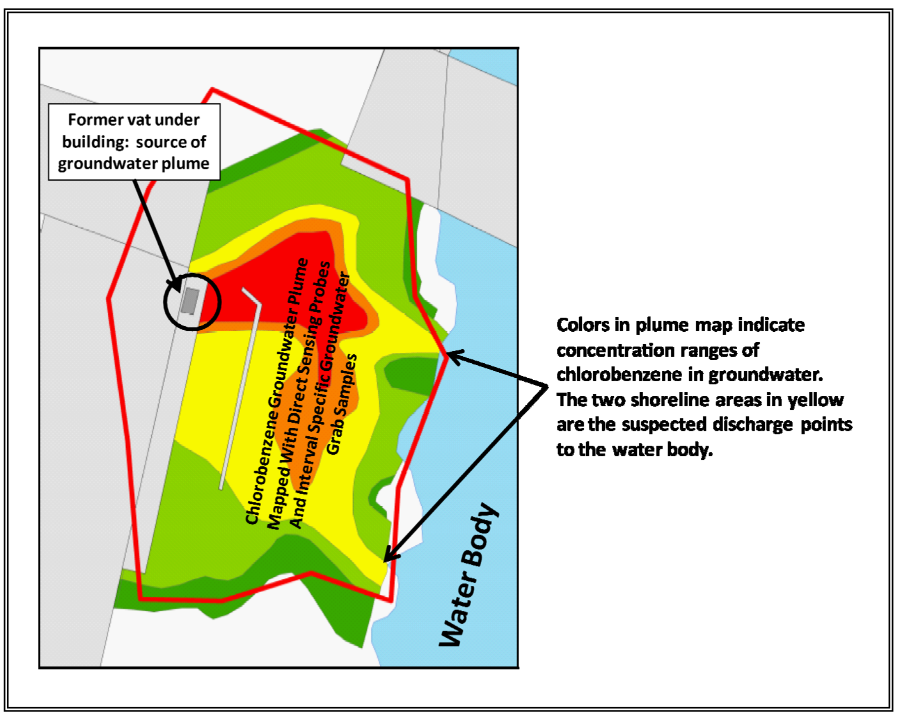


Figure 6 – Correlation of PDB Samples and Chlorobenzene Plume Discharge Points

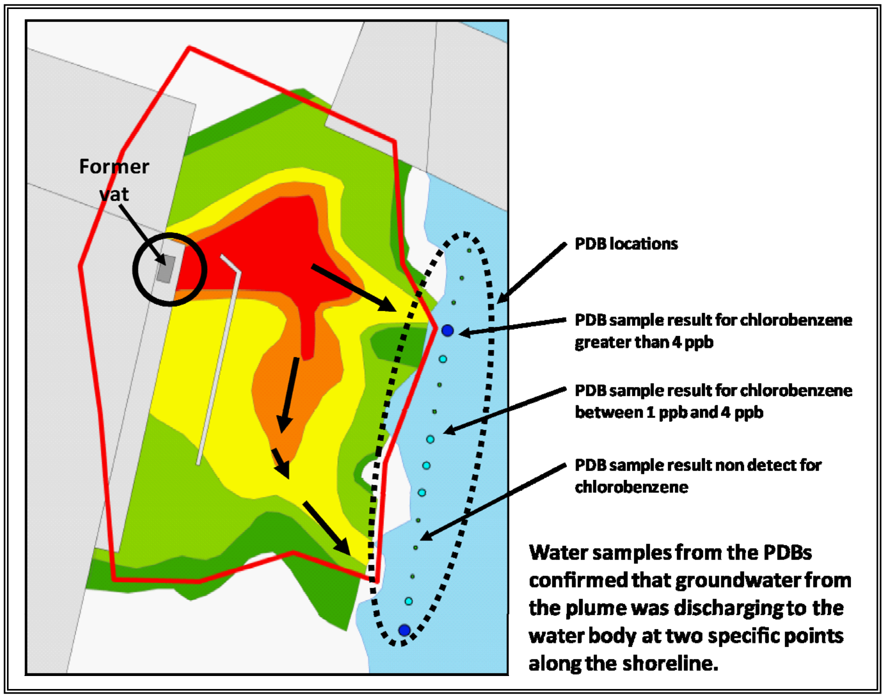
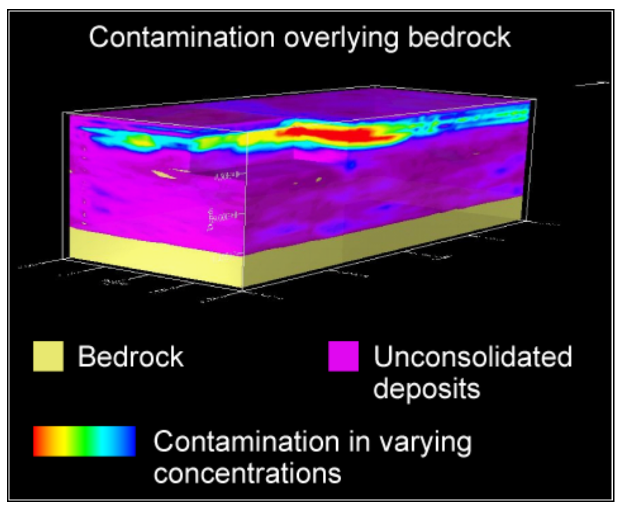


Figure 7 – 3-D Visualization of Contamination Overlying Bedrock



A data management approach should be developed during systematic planning that addresses all meta-data requirements for sample entry, tracking, and reporting. A computerized data base management system should be established at the start of the project and used to record all sampling and analytical information. Sample locations can be recorded daily using GPS instruments. Maps showing sampling results can then be generated daily or weekly for the field team to use in making real-time decisions.

Data visualization is particularly useful when presenting results with community organizations and other stakeholders. These methods are effective in conveying site characterization results to non-technical individuals. Stakeholders can see the extent of impacts and more easily understand any related risks. Figure 7 is an example of how 3-D visualization tools can be used to clearly present characterization data, in this case soil contamination overlying bedrock.

CONCLUSION

The partnership between EPA and the New York City and State governments supports regional and national goals of site cleanup while advancing the environmental cleanup goals of PlaNYC 2030 to leverage the City's underutilized land assets. By using Triad BMPs for site investigation and remediation, NYC intends to streamline cleanup and redevelopment of historic fill and waterfront properties to promote economic opportunity, environmental stewardship, and community engagement. EPA supports the NYC Mayor's Office efforts to utilize Triad to streamline cleanup and revitalization of low to moderate contaminated land under its Brownfields Cleanup Program.

RESOURCES

A variety of resources are available to obtain additional information on NYC's initiative to streamline environmental cleanup. Following are additional resources provided by NYC and EPA, respectively.

NYC Resources

New York City Brownfield Cleanup Program (BCP)

NYC has a strong interest in the cleanup and redevelopment of contaminated and underutilized property and has taken unprecedented steps towards municipal Brownfields management. By creating the NYC BCP, which is the first municipal Brownfields cleanup program in the nation, NYC will ensure that Brownfields sites with light to moderate levels of contamination have the opportunity to be cleaned up under governmental oversight utilizing remedies that are protective of human health and the environment. Benefits that result from environmental cleanup and Brownfields redevelopment include neighborhood revitalization, job creation, an increase in local amenities and an increase in City tax revenue. Properties that are properly remediated through the NYC BCP receive a Notice of Completion, which includes NYC liability limitation against future environmental claims on the property, and issuance of a NYC Green Property Certification that symbolizes the City's confidence that the property is protective of public health and the environment.

Brownfield Incentive Grant (BIG) Program

To accelerate Brownfield cleanup and redevelopment across NYC, OER in collaboration with the New York City Economic Development Corporation created the Brownfield Incentive Grant (BIG) Program to assist with costs associated with the transformation of Brownfields from contaminated, underutilized sites into protective, marketable, and productive properties. BIG program resources are available to provide financial assistance for qualifying Brownfields properties, preferred community development projects, and applicants for and recipients of BOA grants. Grants can be used towards Pre-Development Design studies, Environmental Investigations, Environmental Cleanups, the purchase of Environmental Insurance, technical assistance services for not-for-profit groups, technical assistance services for groups interested in developing applications for the BOA program, and Local Match Funding for existing BOA groups. The BIG Program also offers bonus grants for permanent (i.e., Track 1) cleanups, for BOA strategic properties enrolled in the NYC BCP and for properties that have a zoning map E-Designation or a Hazardous Materials Restrictive Declaration following cleanup. Maximum grant awards range up to $60,000 or $100,000 depending upon the project and grant type.

Searchable Property Environmental e-Database (SPEED)

As OER's NYC BCP, BIG Program, and community education events continue to increase interest in Brownfields, the City is ready to assist developers and other Brownfields stakeholders in identifying potential project sites in a completely new way. The *SPEED* portal is an on-line application that enables users to examine environmental and other data on properties throughout NYC. One Important data layer in the *SPEED* portal, the Vacant Property Database (VPD), provides previously difficult-to-access historic land use and Phase I ESA-type environmental information for over 3,000 vacant privately-owned commercial and manufacturing lots. The *SPEED* portal will be accessible from OER's Web site beginning in 2010.

The *SPEED* portal also allows users to access information about sites that has been collected from city, state, and federal environmental remediation programs. Furthermore, *SPEED* incorporates a variety of map tools, aerial photos, political and geographic districts, and building footprint maps. Users can browse by navigating with the map interface or by searching for desired properties or locations, create reports, or print maps showing spatial information.

OER's Green Team

OER has developed the Green Team in an effort to assist OER's program enrollees throughout the remedial process with basic information and technical guidance on the submittal process and procedures for various City permits and applications. The Green Team is a group of OER project managers who are available to assist NYC BCP and E-Designation enrollees in the acquisition of permits from various City agencies required for activities during the investigation and remedial phases of Brownfields redevelopment. OER Green Team members serve as liaisons between OER and various City agencies such as: the Department of Environmental Protection, the Department of Buildings, the Department of Transportation, the Department of Parks and Recreation, the Department of Sanitation, the Business Integrity Commission, and the NYC Fire Department. Enrollees are encouraged to contact their OER project manager to obtain Green Team assistance.

Financial Incentive Consultation

In addition to OER's BIG Program funds, there are a wide range of other financial incentives that are offered by the City, State and Federal government. OER provides a complimentary financial incentive consultation to any property owner, developer, or other interested party who may be interested in learning about these various resources. Financial incentives for Brownfields investigation and remediation expenses include grants, loans, technical assistance, and tax incentives. In addition to incentives that are available for Brownfields investigation and remediation, additional incentives are available to assist with land acquisition costs, business development opportunities, building construction and renovation, reduced energy consumption, and affordable housing projects. For more information about these funding opportunities, contact OER to set up a financial incentives consultation to discuss which ones may be right for your Brownfields project.

NYC Brownfield Partnership

Environmental resources available to all NYC community members include those offered through the NYC Brownfield Partnership (The Partnership), a voluntary association of NYC's Brownfields industry including developers, environmental consulting firms, law firms, remediation contracting firms, not-for-profit Brownfields development firms, academic institutions, and community-based organizations. The Partnership was founded by OER in 2008 to provide services and benefits to NYC communities and residents and to promote sustainable Brownfields management in the City. Specific services the Partnership offers include: Pro-Bono Environmental Counseling, support for Green Jobs Training programs, Brownfield Internships and Scholarships and an annual Brownfield awards program. The Partnership is not an agency of the City of New York.

Pro-Bono Environmental Counseling

Under the NYC Brownfield law and the NYC BCP, citizens are entitled and encouraged to review and comment on Remedial Action Work Plans (cleanup plans) for all NYC cleanup projects. However, these plans can often be highly technical and difficult for citizens to understand. As a result, community representatives have expressed the need for assistance in understanding and evaluating these cleanup plans. To address this need, members of the Partnership that are environmental consultants are available to provide pro-bono counseling services. The consultant will provide timely document review and communication including a candid, impartial assessment and consultation on the cleanup plan. Member organizations of the Partnership provide these services free of charge and independent of NYC government.

Green Job Training

To sustain and support the growing Brownfields cleanup industry in NYC, it is essential to have a local, well-qualified environmental workforce that is capable of conducting Brownfields site investigation and cleanup. The Partnership envisions that local workforce training can occur through a two-step process. The first step is for local, unskilled workers to complete preparatory employment training and environmental technician training provided by community workforce development organizations, including STRIVE's Green Construction Skills Training Program, St. Nick's Alliance Environmental Remediation Technician Training Course, and BuildingWorks Pre-Apprenticeship Training Program. These training organizations provide certifications in areas such as hazardous waste operator training, soil vapor intrusion, lead abatement, asbestos abatement, asbestos handling, confined space entry and OSHA construction safety. The second step is for newly qualified workers to obtain entry-level jobs in the environmental industry. Under the Partnership's Green Job Training Program, member organizations in the Partnership generally agree to provide specialized, on-the-job training for one or more qualified trainees each year.

For more information about the range of community services offered by OER or to download OER's Brownfield Community Service Report visit www.nyc.gov/CSR.

EPA Resources

EPA develops and distributes environmental technology transfer through a variety of resource media, including Web sites, guidance documents, instructor-led training, and archived Web-accessible training.

Web Sites

The following are several EPA Web sites that offer a myriad of information ranging from online training and Web presentations, to requesting technical assistance, to reading case studies and profiles where Triad BMPs have been implemented.

- **Hazardous Waste Clean-Up Information (CLU-IN) Web site (**www.clu-in.org**)** – Information about innovative treatment technologies and site characterization approaches can be found on www.clu-in.org. The Web site includes descriptions of programs, organizations, publications, and other tools for federal and state personnel, consulting engineers, technology developers and vendors, remediation contractors, researchers, community groups, and individual citizens. CLU-IN also provides access to online streaming videos, archives of internet seminars, and schedule/registration information for upcoming seminars and conference Web casts.
- **Triad Resource Center Web site (**www.triadcentral.org**)** – The Triad Resource Center provides information that hazardous waste site managers and cleanup practitioners need to implement the Triad Approach effectively. The Web site includes: an introduction to key Triad concepts, principles, and benefits; documents and resources for technical staff implementing the Triad Approach; regulatory information; project descriptions where Triad BMPs have been implemented; and references.
- **Brownfields and Land Revitalization Technology Support Center Web Site (**www.brownfieldstsc.org**)** – The Brownfields and Land Revitalization Technology Support Center (BTSC) provides technical support to federal, state, local, and tribal officials for questions related to the use of innovative technologies and strategies for site assessment and cleanup. Partners in the BTSC include EPA's Office of Solid Waste and Emergency Response (OSWER) and Office of Research and Development (ORD); the U.S. Army Corps of Engineers (USACE); and Argonne National Laboratory. As a Center partner, EPA's Brownfields Program helps to identify support needed by EPA's Brownfields Program participants.

Guidance Documents

- *Brownfields Technology Primer: Vapor Intrusion Considerations for Redevelopment* (EPA 542-R-08-001), March 2008 www.brownfieldstsc.org/newPublications.cfm?tabS=2
- *Brownfields Technology Primer: Requesting and Evaluating Proposals that Encourage Innovative Technologies for Investigation and Cleanup* (EPA-542-R-01-005), February 2001 www.brownfieldstsc.org/pdfs/rfpfinal.pdf
- *Demonstrations of Method Applicability under a Triad Approach for Site Assessment and Cleanup Technology Bulletin* (EPA-542-F-08-006), August 2008 www.brownfieldstsc.org/pdfs/Demonstrations_of_Methods_Applicability.pdf
- *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (EPA 542-R-08-002), April 2008 www.brownfieldstsc.org/pdfs/green-remediation-primer.pdf
- *Green Remediation: Best Management Practices for Excavation and Surface Restoration* (EPA-542-F-08-012), December 2008 www.clu-in.org/greenremediation/docs/GR_Quick_Ref_FS_exc
- *OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (Subsurface Vapor Intrusion Guidance), (EPA-530-D-02-004), November 2002 www.epa.gov/osw/hazard/correctiveaction/eis/vapor.htm
- *Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Cleanup, Fourth Edition* (EPA-542-B-03-002), September 2005 www.clu-in.org/download/misc/roadmap4.pdf

- *Technical and Regulatory Guidance for the Triad Approach: A New Paradigm for Environmental Project Management*, Interstate Technology & Regulatory Council, December 2003 www.itrcweb.org/Documents/SCM-1.pdf
- *Triad Implementation Guide*, Interstate Technology & Regulatory Council, May 2007 www.itrcweb.org/Documents/SCM-3.pdf
- *Triad Issue Paper: Using Geophysical Tools to Develop the Conceptual Site Model* (EPA-542-F-08-007), December 2008 www.brownfieldstsc.org/pdfs/Geophysics%20Issue%20Paper%20FINAL_Dec%203%2020081.pdf
- *Understanding Procurement for Sampling and Analytical Services Under a Triad Approach* (EPA-542-R-05-022), June 2005 www.clu-in.org/download/char/procurement.pdf
- *Use of Dynamic Work Strategies Under a Triad Approach for Site Assessment and Cleanup* - Technology Bulletin (EPA-542-F-05-008), September 2005 www.clu-in.org/download/char/dwsbulletin.pdf
- *Using the Triad Approach to Streamline Brownfields Site Assessment and Cleanup* – Brownfields Technology Primer Series, June 2003 www.epa.gov/swertio1/download/misc/triadprimer.pdf

Instructor-Led Training

The following courses are in-person training that is offered by EPA Office of Superfund Remediation and Technology Innovation (OSRTI). Additional information about these and various other training opportunities can be found on the Training Exchange Web site (www.trainex.org), otherwise known as Trainex.

Advanced Triad Training for Practitioners

Advanced Triad Training for Practitioners is based on BMPs implemented by the EPA and is designed to educate environmental professionals from EPA's regulated partnership organizations, other federal and state partners, and consultants. In this 2.5-day course, participants learn how the Triad Approach and its BMPs can be used to efficiently perform projects in a legal, technically sound, and cost-effective manner.

Triad Training for Managers

Triad Training for Managers introduces the Triad process, which can be applied to site characterization, remedial design, remedy implementation, remedy operation and maintenance, and remedy optimization. In this 1-day course, participants learn how the Triad process consists of systematic planning, dynamic work strategies, and real-time measurement tools; learn how to design new procurements and use existing contracting vehicles to facilitate use of the Triad Approach; explore how the CSM serves as the foundation of the Triad Approach and how dynamic work strategies are planned and implemented; and review the importance of devising an exit strategy before beginning a project.

Archived Web-Accessible Training

The following are archived Internet seminars that are available on the CLU-IN Web site (www.clu-in.org). Additional information about these and various other seminars can be found on CLU-IN's Training and Events Archived Internet Seminars & Podcasts Web site (www.clu-in.org/live/archive).

- **Implementation of Triad for Petroleum Brownfield's Cleanup and Reuse**

  This presentation features the redevelopment of a former Petroleum Bulk Terminal into residential reuse in Alexandria, VA. The site operated as a fuel depot since the late 1800's. Environmental work began in the early 1980's with a reported release. In the early 2000's, the Triad philosophy was adopted. The property has since been redeveloped into 18 townhomes and 40 condominiums with a below-grade parking structure. The discussion covers the process from investigation up to redevelopment and the perspective of the State Department of Environmental Quality and City Office of Environmental Quality.

- **"Triad Month" Sessions 1 through 7**

  Over 260 individuals gathered from the U.S. and abroad at UMass-Amherst in Massachusetts to discuss the use of the Triad Approach to conduct investigations and remedial actions. The Triad Community of Practice (CoP) decided to update and repackage several of those same sessions to benefit the greater CLU-IN audience that either may not have been able to attend the conference, or were not able to attend a specific presentation while at the conference. Archived Triad Month sessions include:

  - Session 1: Introduction to Triad
  - Session 2: Triad Communications and Systematic Planning

- Session 3: Triad During RD/RA
- Session 4: Triad Measurement Techniques
- Session 5: Triad Implementation
- Session 6: Triad Case Studies
- Session 7: Dynamic Work Strategies

- **Management and Interpretation of Data Under a Triad Approach**

  This session covers the BTSC bulletin on implementing a data management program for a Triad project. It includes a brief introduction to the Triad Approach, answers to frequently asked questions about data management on Triad projects, three examples of data management with state agencies as the primary regulatory body, and sources of additional information for project teams and stakeholders who develop or provide input on a data management.

- **Triad: Beyond Characterization to Long-Term Management of Groundwater Contaminant Plumes**

  This workshop is similar to one presented at the June 2008 Triad Conference. It covers field analytical approaches, followed by LTM network design and implementation, then integration of sensors and logistics into the development of the CSM, and finally wraps up with examples of automated monitoring (which includes contouring and model update). The workshop covers best-of-class approaches for CSM development with an emphasis on DPTs, and then integrates new approaches to update this in the most time/cost-effective manner. While the models are conceptual, the workshop discusses analytical components to the model to make quantification possible.

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The United States Environmental Protection Agency (EPA) Brownfields and Land Revitalization Technology Support Center (BTSC) and the New York City (NYC) Mayor's Office of Environmental Remediation (OER) have jointly prepared this document as a technical transfer resource for organizations and individuals involved in the redevelopment of contaminated properties in NYC. This joint effort, supported by New York State, advances the environmental cleanup goals of PlaNYC 2030, the city's comprehensive sustainability plan. The purpose of this document is to present how Triad Approach best management practices (BMP) for site investigation and remediation advance EPA's and NYC Mayor's Office initiatives in the areas of community revitalization and Brownfields redevelopment.

EPA 542-R-10-005

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