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BROWNFIELD CLEANUP PROGRAM
ALTERNATIVES ANALYSIS AND REMEDIAL WORK PLAN

Union, New York

Prepared for IBM Corporate Environmental Affairs
File No. 3025.00
December 2012

8976 Wellington Road
Manassas, VA 20109

December 19, 2012

Mr. Jonathan Greco
NYSDEC
625 Broadway
Albany, NY 12233-7016

Re: Brownfield Cleanup Program
Alternatives Analysis and Remedial Work Plan
IBM Gun Club – Former Burn Pit Area
BCP Agreement #C704044
Union, New York

Dear Mr. Greco,

Enclosed is a report summarizing the Alternatives Analysis and Remedial Work Plan for the IBM Gun Club – Former Burn Pit Area. The report was prepared by Sanborn, Head Engineering, PC. and is placed in the public information repositories for the project.

The work was conducted according to New York State Department of Environmental Conservation (NYSDEC) guidance documents and consistent with IBM's discussions with NYSDEC and New York State Department of Health (NYSDOH).

If you have any questions regarding the enclosed report, please contact me at 703-257-2582.

Very truly yours,

K Whalen

Kevin Whalen
IBM Program Manager

Enclosures: Brownfields Alternatives Analysis and Remedial Work Plan

cc: Justin Deming (NYSDOH)

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Building Trust. Engineering Success.

Mr. Kevin Whalen
IBM Corporate Environmental Affairs
8976 Wellington Road
Manassas, VA 20109

December 19, 2012
File No. 63025.00

Re: Brownfield Cleanup Program
Alternatives Analysis and Remedial Work Plan
BCA #C704044
IBM Gun Club – Former Burn Pit Area
Union, New York

Dear Mr. Whalen:

We are transmitting copies of the Alternatives Analysis and Remedial Work Plan document for your records. With your consent, copies are also being transmitted to the New York State Departments of Environmental Conservation (NYSDEC) and Health (NYSDOH) (Agencies) and to the public information repositories for the project.

An initial draft report was submitted to the Agencies on March 20, 2012. This final document addresses review comments and other input provided by the Agencies and reflects our present design concepts for the recommended remedy that were refined through additional design development concurrent with Agency review of the first draft. We understand that this report will be made available for public comment along with the Proposed Agency Decision Document.

The undersigned New York State Professional Engineers had primary responsibility for the preparation of this document and certify that this Alternatives Analysis and Remedial Work Plan Report was prepared in accordance with all applicable statutes and regulations and in substantial conformance with the DER Technical Guidance for Site Investigation and Remediation (DER-10)."

We trust that this report satisfies you present needs. We greatly appreciate the opportunity to be of service to IBM on this important project.

Very truly yours,
SANBORN, HEAD ENGINEERING, P.C.

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cc: Jonathan Greco (NYSDEC) and Justin Deming (NYSDOH).

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EXECUTIVE SUMMARY

This report presents the findings of a detailed analysis of remedial alternatives (Alternatives Analysis) with a Work Plan for implementing the recommended remedy (Remedial Work Plan). This document represents the culmination of nearly three years of remedial engineering work associated with the former Burn Pit Area of the IBM Gun Club (BPA). The work was conducted by Sanborn, Head Engineering P.C. (SHPC) for IBM under the New York State Brownfield Cleanup Program (BCP) administered by the New York State Department of Environmental Conservation (NYSDEC). The focus of this work is on addressing environmental conditions remaining from the residuals from a historical disposal practice where solvents and oils were burned in an excavated pit.

The work included screening of a broad set of remedial technologies as well as completion of programs of laboratory bench and field pilot testing of two emerging technologies that were believed to offer potential for application at the site. Pilot testing was necessary to demonstrate the effectiveness of the technologies, to support full scale design, and assess potential level of effort and cost.

The Remedial Work Plan outlines the design concepts for the recommended alternative that involves application of In Situ Enhanced Biochemical Degradation (EBD) technology along with capping with an engineered soil fill, and application of phytoremediation technology. The selection of this alternative is founded on the detailed analysis of alternatives included as Section 3.0 and is supported by nearly two years of field pilot testing.

We believe that this combination of technologies offers the greater potential for progress against the three active remedial goals established for the site while offering less potential for worker safety, risk, and community disruption. This alternative is focused on harnessing and enhancing natural biochemical and phytoremediation processes that have already been active at the site for decades, consistent with sustainable and green remediation practices.

EBD and phytoremediation are intended to address the apparent on-going presence of certain volatile organic compounds (VOCs) in groundwater and bedrock beneath the site. The surficial soil remedy is intended to address the presence of residuals of certain metals remaining in the surficial soil on IBM lands within the vicinity of the BPA while improving surface drainage and limiting infiltration and potential for breakout of groundwater at seeps and springs.

This remedy is proposed although private or public water supplies are not at risk nor is there risk of human exposure via subsurface vapor migration under present property uses. There is low potential for human exposure to IBM site trespassers to contaminated surficial soils and limited potential for human exposure via direct contact with VOC-containing water reaching the ground surface at seeps and springs at discrete points. The Agencies have concluded that these conditions do not pose an unacceptable risk under present land uses.

The goals of the active remedy components are to:

1. Substantially limit the transport of VOCs from the identified source area as to materially reduce concentrations in groundwater within and outside the source area and in water flowing to surface seeps and springs;

2. Reduce VOC source mass to the extent practicable which would reduce the time and effort to maintain goal number 1; and

3. Further limit potential for direct contact with surficial soils containing non mobile residuals of the former BPA operations.

As depicted on the attached Figure ES-1, construction of the remedy will include:

- Capping the primary VOC source area and residual surficial soils with an engineered low permeability clean soil fill providing a minimum of 2 feet cover over surficial soils containing certain metals at concentrations above New York State soil clean up objectives established for residential property use (Residential SCO);

- Placement and compaction of engineered soil fill within a topographic depression south of the Burn Pit Area where VOC-containing groundwater has been observed to breakout to the ground surface seasonally as seeps and springs.

- Establishing and maintaining grass and tree cover to both limit infiltration recharge and enhance direct uptake of VOC-containing shallow groundwater, a process known as phytoremediation The tree planting is to include fast growing tree species that have been commonly applied to VOC phytoremediation projects and native species; and

- Engineered introduction of amendments shown to enhance biochemical destruction of VOCs in site-specific pilot testing. The amendment used in pilot testing was an edible soybean oil product commercially produced for biochemical remediation applications. The amendment will be injected into vertical boreholes designed for this application and open to the upper 20 or so feet of subsurface.

After completion of construction, based on the available soil characterization data alone we believe that over 90% of the site will be suitable for residential development without restriction, classifying as a Track 2 cleanup, meeting generic soil cleanup objectives established by the Agencies for residential use. About 1.28 acres capped by a 2-foot clean soil thickness will constitute a Track 4 surficial soil remedy subject to institutional controls on excavation and agricultural uses. Of course residential development would not proceed until the active groundwater remedy is substantially complete and therefore is a future use.

The active remedy and institutional controls are intended to preclude the vapor intrusion pathway for future uses and prevent ingestion of groundwater that does not meet drinking water standards. The Remedial Action Work Plan included as Section 4.0 outlines a detailed program of performance monitoring to be implemented as part of a Site Management Plan to support demonstration of performance of the remedy against specific goals for short and long-term time horizons.

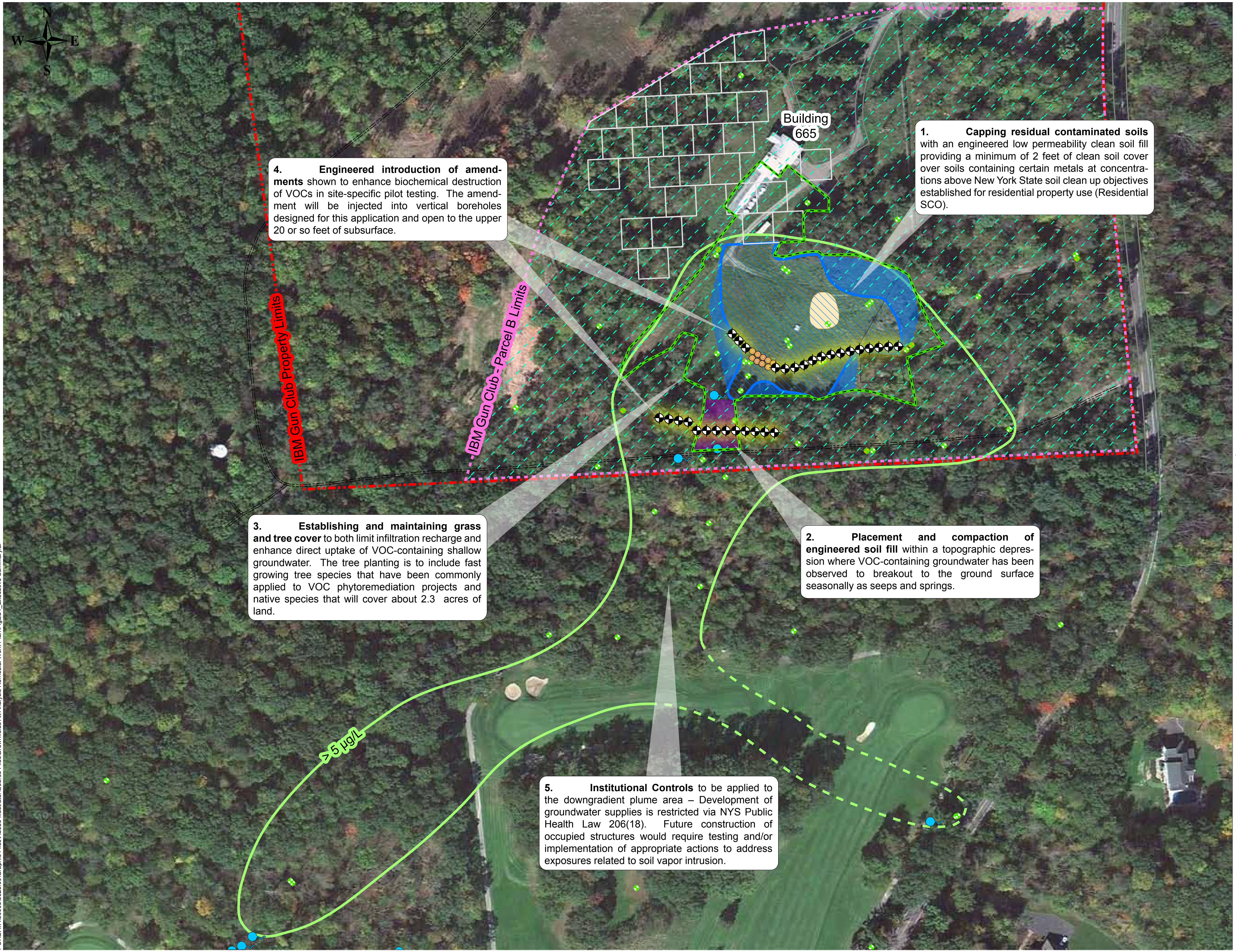

Figure ES-1

Executive Summary

Brownfield Cleanup Program
Alternatives Analysis and
Remedial Work Plan

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By: S. Warner
Designed By: A. Horneman
Reviewed By: D. Carr / D. Shea
Project No: 3025.00
Date: December 2012

Figure Narrative

This figure is intended as a component of the executive summary describing recommended alternative remedy associated with environmental remediation of the IBM Former Burn Pit under the New York State Brownfield Cleanup Program.
The remedy involves excavation and capping of surficial soils and enhancing in situ biochemical processes already active at the site and the planting and maintenance of trees to enhance uptake of VOC-containing groundwater.

Please refer to the executive summary text for additional details and to Figures 1 and 2 for additional notes and legend.

Legend

- Proposed Injection Boring Location
- Former Burn Pit Disposal Area
- Surveyed boundaries of Burn Pit Property (Parcel B). Entire parcel to be subject to deed restrictions associated with groundwater development/use, and construction of human occupied structures.
- Area of property to meet Track 2 residential SCOs
- Inferred limits of groundwater TCE concentrations exceeding New York Standards (>5 µg/L)
- Proposed limits of Tree Planting
- Track 4 Surficial Soil Remedy Area - Propsed 1.28-Acre area requiring two-feet of Soil Fill Cap meeting soils standards for residential use (Residential Soil Cleanup Objectives or SCO)
- Approximate Limit of Soil Cap Extension - resulting from proposed final grading of imported soils.
- Approximate limit of additional fill required for filling topographic depression
- Surveyed limits of soil removal conducted under Interim Remedial Measure (IRM) in May 2012 to meet residential SCO

Feet: 75 37.5 0 75 150

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Last Edited By: swarner

1.0 INTRODUCTION

This final report presents the detailed analysis of alternatives (Alternatives Analysis) and a Remedial Work Plan for the alternative recommended for application to the former Burn Pit Area (BPA) of the IBM Gun Club (Gun Club) property (the site). International Business Machines Corporation (IBM) engaged Sanborn, Head Engineering, P.C., assisted by Sanborn, Head & Associates, Inc. (collectively Sanborn Head), to perform the Alternatives Analysis and prepare the Remedial Work Plan.

This work was conducted under the New York State Brownfield Cleanup Program (BCP) administered by the New York State Department of Environmental Conservation (NYSDEC), with IBM as a Participant. The site is covered under BCP Agreement No. C704044 executed by IBM and NYSDEC on August 22, 2005. The site boundaries were established via a BCA Amendment dated April 26, 2012 that followed IBM's submittal of a letter and surveyor's description of the property on January 31, 2012 (Appendix B.1).

We believe that the work and this report were completed in accordance with applicable provisions of New York State Environmental Conservation Law 6 NYCRR Part 375[1]. As referenced throughout this document the work was completed in consideration of applicable Guidance including DER-10[2], New York State's Brownfield Cleanup Program (Brownfield Guidance)[3], as well as DER-31 Green Remediation Guidelines[4]. Our work and this report are subject to the limitations provided in Appendix A. We understand that IBM will transmit this final report to NYSDEC and the New York State Department of Health (collectively, the Agencies) who will make it available for public stakeholder review along with a document outlining a rationale for the Agency Decision regarding the remedy (Decision Document).

This report is termed final in that it reflects comments, questions, and discussions with representatives of the Agencies derived from their review of a draft report submitted to them on March 20, 2012. The Remedial Work Plan included as Section 4.0 of this final report also presents design concepts for the proposed remedy reflecting additional design development conducted concurrent with Agency review of the draft. The draft document specifically outlined the next steps of design development which were largely completed concurrent with the four month Agency review period.

1.1 Background and Summary

1.1.1 Site Location and Description

As shown on the Locus Plan included as Figure 1, the IBM Gun Club property is a 53.4-acre parcel of land located at 1395 Robinson Hill Road in the Town of Union in Broome County, New York. The IBM Gun Club property is identified as parcel 126.18-20 in Broome County

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[1] NYSDEC, Effective December 14, 2006, 6 NYCRR Part 375, Environmental Remediation Programs, Subparts 375-1 to 375-4 and 375-6.

[2] NYSDEC, May 3, 2010, DEC Program Policy DER-10/Technical Guidance for Site Investigation and Remediation.

[3] NYSDSEC, May 2002, Brownfield Cleanup Program Guide.

[4] NYSDEC, August 11, 2010, DEC Program Policy DER-31/Green Remediation.

Tax records. The property is currently zoned "Planned Unit Development" (PUD), which allows for uses from Industrial to Open Space, but does not allow for agricultural use. Town of Union records correctly list the historical land use as "commercial;" however, we understand that the PUD zoning allows for residential use.

The Parcel that is the subject of this report, and the referenced BCP Agreement, is 15.591 acres of the total property, referred to as Parcel B. The Parcel B metes and bounds dividing it from Parcel A as shown in Appendix B.1 provided for at least 100-foot of buffer around the primary VOC plume associated with the BPA. Parcel B includes the buildings associated with the former B665 commercial research and testing facility that was used by IBM for nearly 30 years until 2009. The building has been maintained to support office and storage space for IBM-led remediation support work and is not occupied on a regular basis. This facility and the BPA are surrounded by a 7-foot high chain link fence.

Parcel A, the former shooting range portion of the Gun Club totaling about 41.38 acres, has been addressed under a separate agreement (BCP Agreement No. C704043). Remediation of Parcel A has been largely completed by excavation and off-site disposal of surficial metal shot-containing soils from a former trap and skeet shooting range. A certificate documenting Agency acceptance of the completion of the remediation of Parcel A was issued by the NYSDEC in July 2012.

1.1.2 Findings of Site Characterization and Site Conceptual Model

An executive summary of pertinent site conditions relevant to this alternatives analysis is included as Figure 2. The figure reflects the findings of remedial investigations (RI) completed in 2009[5] and subsequent investigations and testing conducted as a part of pilot testing of remedial technologies. For additional details, please refer to the RI report. Figure 3 depicts a site plan with the relevant conditions that are a focus of this remedial alternatives analysis.

As shown by red and orange shading on the figures, the primary on-going source of VOCs in groundwater, i.e., VOC mass diffused into and sorbed to the unfractured rock matrix, underlies about 1.6 acres, inclusive of the open field BPA and a smaller area of forested land that extends in a southerly direction from the BPA. Nearly all (>99%) of the VOC mass is found within the upper 15 feet of subsurface. The primary source rock is estimated to contain over 90% of the VOC mass present in the subsurface, most of which is located beneath lands owned by IBM.

VOC concentrations between tens of thousands down to hundreds of micrograms per liter (μg/L) continue to be observed in groundwater sampling of monitoring devices screened directly within the primary source rock. The volumetric and mass flux out of the primary source rock is estimated to be on the order of a few gallons per minute and a few tenths of a pound of VOCs per year.

[5] Sanborn, Head & Associates, Inc. August 5, 2009, Report of Findings – Brownfield Cleanup Program Remedial Investigation, IBM Gun Club – Former Burn Pit Area, Union, New York.

Generally, groundwater concentrations in the tens of µg/L or lower have been observed in sampling of wells screened within the area of secondary sourcing shown in yellow shading on the Figures. This secondary sourcing area is believed to reflect VOCs mass diffused into the matrix from historical downgradient dissolved phase transport, which has been predominantly in a southerly direction onto property owned by the Binghamton Country Club. This secondary sourcing area is estimated to constitute about 10% of the total VOC mass present in environmental media.

The downgradient extent of VOCs in groundwater as shown on Figure 2, and in more detail on Figure 3, is expected to reflect a near steady-state condition that is not expanding, but appears to be retracting due to uptake by plants, biochemical degradation, and discharge of water to seeps and springs. Human exposure via drinking water consumption or vapor migration has not been found and is not expected under present land uses. The site subsurface is not particularly conducive to vapor migration. Vapor migration would be a consideration if buildings were to be built over the VOC plume area that could be addressed through testing or engineered controls.

The assessment completed as a part of the RI identified limited potential for human exposure via direct contact with VOC-containing water reaching the ground surface at seeps and springs at discrete points noted by blue symbols on Figure 3. These seeps and springs are insufficient volume to serve as significant drinking water sources. On the basis of the RI characterization the Agencies have concluded that these conditions do not pose an unacceptable risk under present land uses. Institutional controls (ICs) founded on existing NYS Statutes and project specific deed restrictions will be required to ensure that this condition does not change under future sites uses until an active remedy leads to retraction and remediation of the VOC presence in groundwater.

The present land surface within much of the BPA is relatively flat with surface slopes between 0.7% and 1.5% and without positive drainage to promote runoff. Surface depressions in this area have been observed to pond water seasonally. The lack of positive drainage is believed to reflect seasonal increased recharge and variability in water levels that drive groundwater flow, mass transport and seasonal discharge of VOC-containing water to seeps and springs.

As shown on Figures 2 and 3, surficial soils in the general vicinity of the BPA and extending onto the westerly wooded portion of the site has been found to contain concentrations of certain metals and metaloids including arsenic (As), chromium (Cr), lead (Pb), cadmium (Cd), nickel (Ni), zinc (Zn) and copper (Cu) at concentrations exceeding potentially applicable soil cleanup objectives (SCOs). In certain areas, these soils were also found to contain polychlorinated biphenyls (PCBs). Although these soils do not constitute a source of groundwater contamination and are located within a fenced area there is limited potential for human and biotic exposure via direct contact.

At the northwestern limit of Parcel B, the surficial soils had exhibited the presence of lead and arsenic attributable to metal shot deposition from the former trap and skeet shooting activity. As agreed upon with the Agencies, excavation, stabilization, and off-site disposal of lead shot containing surface soils was conducted as an Interim Remedial Measure (IRM). This IRM was coordinated, observed and logged by Omega Environmental Engineering PC (OMEGA) under and IRM Work Plan submitted to NYSDEC on March 2, 2012 and approved by the Agencies. The work was completed in May 2012 using methodologies consistent with prior lead shot remediation work on Parcel A that was conducted in 2010 through 2011. The surveyed limits of IRM excavation are shown on Figure 4. Documentation of the IRM will be submitted to NYSDEC under separate cover and is not discussed further in this report.

1.1.3 Overview of Alternatives Analysis

Exhibit 1.1 presents the remedial goals and visions of success discussed in the RI Report that were developed in consideration of site conditions and the exposure assessment.

Exhibit 1.1- Primary Goals of Active Remediation:
1. **Reduce the downgradient VOC mass flux from the BPA primary source zone –** Success would mean realizing a material reduction in VOC concentrations in groundwater outside the source zone and in water reaching seeps and springs.
2. **Reduce VOC Source Mass –** To the extent practicable, reduce the mass of VOCs in source zone bedrock. Success in meeting this goal would mean realizing a reduction in the time, effort, and/or cost to establish and maintain goal No. 1.
3. **Limit potential for direct contact with PCB- and metals-containing soils in the vicinity of the BPA** – Success would mean that soil contaminants would be effectively precluded from potential human or ecological receptors.

The term "active remediation" is intended to denote engineered control actions intended to address site conditions under present land uses, distinguished from institutional controls that may be included as a part of a remedy to address possible future site uses. In this case, institutional controls will be a component of the remedy to address the goals or preventing human exposure under future site uses via either ingestion of contaminated groundwater and/or potential exposure via vapor intrusion.

Six remedial technologies identified for potential application against these goals included:

▪ Monitored Natural Attenuation (MNA);	▪ Enhanced Biochemical Degradation (EBD);
▪ Hydraulic Containment;	▪ Permeable Reactive Barrier;
▪ In-Situ Thermal desorption (ISTD);	▪ Excavation and disposition of the soils and primary source rock.

Phytoremediation, capping, and fencing were identified as potential components of one or more remedial alternatives.

The results of the initial screening of combinations of technologies as remedial alternatives identified ISTD and EBD as requiring site-specific pilot testing to assess potential effectiveness. This screening was conducted in consideration of nine of the remedy selection criteria listed in the Brownfield Guidance (2004) and is discussed further in Section 2.

The Alternatives Analysis as outlined in Section 3.0 presents the detailed analysis of two alternatives that were carried forward from the screening and pilot testing evaluation, including: 1) limited soil removal, soil consolidation and capping, and implementation of EBD and phytoremediation technologies, and 2) excavation and disposal of soil and primary source rock – this alternative is considered to be the option that could get the site closest to an unrestricted use state. Section 4.0 outlines a Remedial Work Plan for the recommended implementation of Alternative 1, which is believed to offer potential to materially address all three remedial goals while also limiting disruption of the community and risks to human health and safety.

1.2 Organization of Report

Section 2.0 summarizes the Initial Screening of Remedial Alternatives (Appendix B.2) and summarizes the findings and conclusions of bench and field pilot studies. Section 3.0 presents the detailed Alternatives Analysis that leads to the recommended alternative. Section 4.0 presents the Remedial Work Plan that outlines the present design concepts developed for the recommended alternative and concepts regarding the scope and schedule of implementation updated concurrent with NYSDEC's review of the draft Alternatives Analysis and Remedial Work Plan that IBM provided to the Agencies on March 20, 2012.

2.0 SCREENING OF REMEDIAL ALTERNATIVES

2.1 Compilation and Initial Screening of Remedial Alternatives.

An initial screening of remedial technologies to address the subsurface presence of VOCs was conducted following the RI. The process and findings were documented in a memorandum report included as Appendix B.2. The stated intent of this screening was to identify alternatives that offer greater potential for application at the site and are worthy of additional focused assessment, including pilot testing. The screening was conducted based on Sanborn Head experience with similar work, input from technology vendors, vendor quotations, and standard estimating references.

Based on the initial screening, four alternatives were carried forward, including MNA, EBD, hydraulic containment, and ISTD. ISTD and EDB were perceived to offer similar order-of-magnitude cost on a present value basis and greater potential for application to the site compared to hydraulic containment. However, both ISTD and EBD bring uncertainty related to their performance in fractured rock settings, and a program of bench- and field pilot-testing was recommended. The initial concept for application of in situ EBD included active recirculation of water through extraction and reinjection. The actual pilot testing was focused on an amendment emplacement approach based on injection via boreholes, and that is not reliant on pumping and reinjection by mechanical means.

As discussed in Appendix B.2, hydraulic containment was considered to limit VOC mass flux across the southerly Parcel B property boundary, but was eliminated recognizing that it would not materially address downgradient secondary source mass. Further assessment of permeable reactive barriers was ruled out because this technology was believed to have practicability and cost limitations in bedrock application, with no real advantage over more conventional hydraulic containment technology or EBD.

2.2 Findings of Bench and Pilot Testing of Technologies

2.2.1 Thermal Desorption Bench Scale Testing

Bench scale testing of thermal desorption performed in the fall of 2009 and reported to the Agencies in 2010[6] included controlled heating of crushed and whole core samples of primary source rock. The testing indicated 60% to about 99% removal of VOC mass from whole core and crushed rock samples, respectively. Most of the mass reduction is believed to occur with loss of the pore water to steam in the first 48 hours of heating, with little additional reduction through additional heating time. The observed reduction of VOC mass is believed to represent a best case idealized scenario for a field scale application, and it is unlikely that the same magnitude of mass removal could be achieved on a field scale.

At even the most optimistic outcome of more than 90% source removal, ISTD is unlikely to achieve VOC source reduction to an extent where groundwater quality would comply with drinking water quality standards. To achieve such standards, a 2 to 4 order of magnitude (OoM) reduction in source concentrations would be necessary, a level of treatment that is not consistent with historical full scale thermal treatment applications. This assertion is supported by the available peer reviewed literature and project summaries from applications of thermal technology to both simpler soil and bedrock settings.

In 2009, the U.S. Geological Survey and others conducted a thermal conductive heating demonstration pilot test at the former Naval Air Warfare Center (NAWC) in West Trenton, New Jersey. Based on pre-treatment VOC concentrations of 280 milligram per kilogram (mg/kg) and post-treatment VOC concentrations ranging 100 to 280 mg/kg, we estimate that the reduction in source rock concentrations adjacent to fractures after 98 days of heating ranged from <1% to 64%. The available information did not indicate successful reduction in groundwater concentrations within or downgradient of the thermally treated zone.

A peer-reviewed literature case study of 84 thermal treatment applications performed in the period 2000 to 2007[7] included data on four applications to fractured or weathered rock, with only one full-scale application in rock. The observed reductions of chlorinated VOC concentrations in groundwater associated these applications have been about an order of magnitude or less, consistent with our estimates derived from bench scale testing.

[6] Sanborn, Head Engineering, P.C., October 7, 2010, Report of Findings, Thermal Desorption Bench Scale Testing, Brownfield Cleanup Program Remedial Alternatives Analysis, IBM Gun Club Pit Area, Union, New York.

[7] Jennifer L. Triplett Kingston, Paul R. Dahlen, and Paul C. Johnson, 2010, State-of-the-Practice Review of In Situ thermal technologies, Ground Water Monitoring & Remediation **30** (4).

The post-treatment groundwater concentrations within the treatment zone have ranged from 100s to 1,000s of µg/L, with less than an order of magnitude improvement in water quality downgradient. As such, these applications would still require implementation of a secondary remedy to contain groundwater and/or further reduce concentrations toward applicable water quality standards.

We eliminated ISTD from further consideration given significant uncertainties and limitations in application toward achieving an unrestricted use condition, coupled with the high cost and highest energy consumption and potential greenhouse gas emissions among the technologies evaluated.

2.2.2 Enhanced Biochemical Degradation Field Pilot Testing

The EBD pilot testing conducted between April 2010 and June 2011 involved multiple injections of a small mass and volume of commercially produced soybean oil amendment through a nine borehole injection gallery constructed within the primary source rock. The loading was intended to support a short-term (9 month) testing period, accounting for less than 5% of the possible upper bound amendment demand associated with VOCs and inorganics in groundwater and rock matrix.

Measures of success established as goals before initiating the work included:

1. Over one order of magnitude (>1 OoM) decrease in groundwater TCE concentrations in the vicinity of the injection zone, accompanied by an increase in the presence of terminal breakdown products.

2. A material reduction in TCE concentrations by about an OoM, concurrent with an increase in the presence of terminal breakdown products in monitoring wells in a much larger area downgradient of the injection site.

3. A shift from nitrogen and manganese/iron reducing towards sulfate reducing/ methanogenic geochemical conditions throughout this larger downgradient area, indicative of conditions more conducive to biochemical degradation of TCE and its breakdown products.

As outlined in reporting to the Agencies,[8] twelve months of monitoring data supports that the testing largely met the first and third measures of success, whereas the second measure was partially met. We observed apparent reductions of up to one-half order of magnitude in TCE concentrations timed with the passage of tracer introduced with the first injection, followed by a rebound to pre injection conditions. The data support complete breakdown without adverse accumulation of more toxic intermediate vinyl chloride (VC)[9]. Based on

[8] Sanborn, Head Engineering, P.C., October 5, 2011, Report of Findings, Pilot Testing of Enhanced In Situ Biochemical Degradation, IBM Gun Club – Former Burn Pit Area, Union, New York.

[9] *We believe that the relatively modest amendment quantity and transience in geochemical conditions may explain why we observed no adverse accumulation of more toxic VC. As noted in the pilot test report of findings, our experience is very different from one other pilot and full scale application of at the Naval White Oak Surface Warfare center where the amendment mass loading was on the order of 100 gal/100sf under naturally more reducing conditions. Although as much as 97% reduction in PCE and TCE concentrations were observed, much of the mass remained as cis-1,2 dichloroethene (cDCE) and vinyl chloride (VC).*

the findings we recommended, and the Agencies agreed, that EBD be carried forward through the detailed analysis of alternatives.

On-going monitoring over a year after the second injection has indicated continued suppression of TCE concentrations within the injection zone by about 2.5 to over 3 OoM, indicating continued biological activity at rates that must exceed the rate of TCE diffusion out of the rock matrix. Only traces of TCE have been detected in the most recent sampling and total chlorinated ethene concentrations have been reduced by two orders of magnitude[10].

The continued activity of biochemical processes is consistent with the relative persistence of substrate and the findings of published peer reviewed studies of full-scale applications of chlorinated solvent source depletion technologies. The study by McGuire et al.[11] reviewed data from applications of EBD, chemical oxidation, thermal treatment, and surfactant/co-solvent treatment with a focus on observed reductions in groundwater concentrations within and downgradient of source areas during the treatment period, and later on-going monitoring, for evidence of post-treatment rebound of groundwater concentrations.

Data from 21 full scale applications of EBD for source reduction indicated 30% to 100% reduction in parent CVOC concentrations within the active injection treatment period; with 77% to 100% reductions in ¾ of the cases; and a median value of over 95%. Reductions in total CVOC concentrations including breakdown products were more modest, with the upper half of performance ranging from about 60% to 100%. In 25% to 30% of the cases, the total CVOC concentrations actually increased in the source zone, which is believed to reflect biologically enhanced dissolution and desorption of CVOC mass.

Post-treatment monitoring at EBD sites indicated the lowest percentage (40%) of post-remediation rebound, with continued reduction of parent CVOC source concentrations in 60% of the cases, yielding total reductions ranging from about 65% to 100%. In about ¾ of the cases, continued reductions in parent VOC concentrations after cessation of injections reached 95% to 100%, which is believed to be attributable to persistence of biochemical degradation processes.

Although we continue to observe sulfate reducing or methanogenic conditions in a larger downgradient area, TCE concentrations in this area have largely rebounded to near pre injection conditions, and geochemical conditions appear to be reverting towards a less reduced oxidation state. Although there is evidence that additional biochemical degradation may be occurring in the greater downgradient area, the rate of degradation is not exceeding the rate of TCE diffusion out of the matrix to water migrating in the fractures.

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[10] Sanborn, Head & Associates, Inc. July 16, 2012, Letter Report, Semi-Annual Review of Water Quality Monitoring Data.

[11] McGuire, T.M., McDade, J.M., and Newell, C.J., 2006, Performance of DNAPL Source Depletion Technologies at 59 Chlorinated Solvent Impact Sites, *Groundwater Monitoring and Remediation, 26, No. 1 Winter 2006, pgs 73-84.*

The relatively modest and temporary improvement in downgradient water quality is believed to reflect: 1) the relatively modest introduction of amendment mass at a loading rate of 0.09 gallons per 100 square feet (gal/100sf) that was intentionally designed to meet the estimated carbon demand for up to a 6 to 9 month period; 2) limited downgradient migration of organic carbon that may reflect that actual carbon demand may have been higher than that assumed in design; and 3) groundwater flow around the injection gallery.

Seasonal increased recharge exacerbated by poor surface drainage conditions in the primary source area may in part explain the variability of geochemical conditions observed in EBD pilot testing and the seasonal nature of seeps and springs within the IBM property. Grading for more proper shedding of surface runoff and drainage should allow for more modest and spatially consistent recharge.

2.3 Alternatives for Detailed Analysis

The initial screening of remedial alternatives, subsequent bench and pilot studies, and discussions with NYSDEC and NYSDOH, narrowed the alternatives to:

1. In situ EBD combined with surficial soil capping and phytoremediation technologies (EBD Remedy); and

2. Excavation and disposal of the soil and primary source rock as an alternative that may bring the site closest to an unrestricted condition.

Table 1 provides a summary of the two alternatives listed as Alternatives 1 and 2. The Table includes a capsule summary of the design concept, approximate area and volume of media addressed, monitoring or verification to be conducted following construction, and reliance on deed restrictions or other institutional controls. Section 1A of Table 1 discusses the surficial soil component of Alternative 1 and Section 1B focuses on the groundwater and source rock component. Figures 4, 5, and 6 depict concepts relevant to the possible application of Alternative 1. Design concepts for Alternative 2 are presented in Appendix B.2. As noted in Table 1, both the alternatives rely to some degree on environmental easement deed restrictions/institutional controls. The engineering and institutional controls are discussed further in Section 4.0.

3.0 REMEDIAL ALTERNATIVES ANALYSIS

This section describes the detailed analysis of the two alternatives against remedy selection factors or evaluation criteria outlined under the general remedial program requirements specified by NYCRR Part 375-1.8(f) and the Brownfield Cleanup Program selection requirements specified under Part 375-3.8 (c). The nine major categories of remedy evaluation criteria include:

- Overall protectiveness of public health and the Environment- All remedies must eliminate or mitigate threats to public health and the environment through proper application of
- Short-Term Impacts and Effectiveness- preferring remedies that are effective in the short term while limiting adverse impacts during implementation.

science and engineering principles.

- Compliance with Applicable Standards, Criteria and Guidance (SCGs) - to the extent practicable remedies should conform to applicable SCG.
- Long-Term Effectiveness and Permanence- preferring remedies that provide for permanent cleanup.
- Reduction in mobility, toxicity, and volume of contamination through treatment.
- Community Acceptance – the remedies should be acceptable to the community stakeholders.
- Implementability- preferring remedies that can reliably be implemented with conventional proven technology.
- Cost-effectiveness – remedies that efficiently achieve results with stewardship of resources.
- Land Use- remedies that are consistent with and do not detract from existing nearby and future land uses.

Section 3.1 provides a summary of the analysis of alternatives against these criteria which is detailed in tabular form as Table 2. Section 3.2 provides a summary of the evaluation of the two alternatives against criteria for sustainable and remediation practices and objectives that we believe meet and exceed the NYSDEC DER-31Green Remediation Guidance.

3.1 Analysis against Remedy Evaluation Criteria

3.1.1 Overview

The tabular graphic included as Exhibit 3.1 is intended to provide a qualitative summary of the findings of the detailed analysis of alternatives as outlined in Table 2. This graphical overview and summary is followed by a discussion of the remedy selection criteria and our rationale for the qualitative order of magnitude (OoM) rating.

Exhibit 3.1 – Rating of Alternatives Against Remedial Goals & Selection Evaluation Criteria

Alternative	Goal 1	Goal 2	Goal 3	Protection	Compliance	Short Term	Long Term	Reduce MTV	Implement	Safety	Cost Effective	Community	Land use
1) In Situ EBD								MTV					
2) Excavation								MV MV					

OoM Ratings for Goals and Criteria

- Relatively Favorable or Favorable
- Partial or More Favorable
- No Clear Benefit or Less Favorable
- Concerns Regarding Adverse Outcome

The color shading is intended to provide a relative scaling of the alternative against the three remedial goals discussed in Section 1.0 and the remedy evaluation criteria.

Alternative 1 offers more favorable ratings, including reduction of mobility, toxicity, and volume, implementability, safety, and cost efficiency. Supported by the findings of field pilot testing, this Alternative offers potential to quickly reduce groundwater concentrations local to injection areas in the primary source rock, and so offers promise of short-term benefit; however, it remains somewhat uncertain as the amount of time that may be necessary for the full benefits to be reached in the downgradient secondary source rock. The primary uncertainties are: 1) to what degree sustainable biochemical activity can be stimulated in the secondary source rock, and 2) the degree to which biochemical degradation occurs directly within the unfractured matrix where the bulk of the VOC mass resides (Goal 2).

Alternative 2, excavation, offers the larger number of less favorable ratings and a greater possibility of adverse outcomes, including worker safety risk associated with heavy equipment, and greater potential for objectionable impacts/conflicts with neighboring residential and recreational land use during construction. Excavation is unlikely to materially improve downgradient water quality conditions in the short term.

3.1.2 Discussion of Table 2 - Detailed Analysis of Alternatives

As a summary of the detailed analysis outlined in Table 2, **Alternative 1 Combining EBD, capping and phytoremediation technologies** offers potential for progress towards all three stated active goals and towards meeting SCG. It offers potential for reducing toxicity and mobility of VOCs by direct, permanent in situ destruction to non-toxic by-products using intrinsic biochemical processes and uptake by plants. EBD is not, however, a presumptive technology with a proven track record in fractured rock applications, and it carries some potential for adverse outcomes, such as generation and accumulation of VC or mobilization of certain metals and metaloids (arsenic) under reducing conditions. These adverse outcomes were not observed in the small scale field pilot testing.

We believe that the potential for realizing adverse outcomes can be limited through a staged application of amendment; and if needed bioaugmentation with a commercially available VC degrading microorganism culture. Combined with site capping and planting of trees to increase evapotranspiration and uptake of VOC mass, EBD offers potential for removal and destruction of VOC mass through enhancing natural processes already active at the site.

Finally, this alternative is believed to be more cost-effective than excavation. If full scale application can largely limit downgradient transport from the primary source rock while enhancing biological degradation in the secondary source rock, it offers greater potential for improving downgradient water quality in the short- and long-term at much lower cost compared to excavation. In addition, EBD would not materially preclude later application of other technologies. Maintenance of tree cover as designed would limit site development with structures while the remedy is in active operation.

Alternative 2, Excavation and Disposal, would bring the primary source rock area near to an unrestricted condition, but would involve transfer or relocation of the contaminants to another location without reducing toxicity. This option would permanently remove much of the VOC mass from the site, but would actually increase the volume of soil and rock waste to be handled, and create more surface area for VOC mass transfer increasing mobility. Furthermore, excavation could adversely affect groundwater flow patterns by altering groundwater recharge patterns and introducing cracks and fractures more conducive to vertical groundwater flow and transport.

Our preliminary estimates of cost outlined in Appendix C.1 assume that rock excavation could be accomplished by ripping and hoe ramming; however if massive rock was encountered that cannot be hoe rammed, either the rock would have to be left in place or blasting would have to be considered. We believe that excavation offers greater risk to worker safety during construction and greatest potential for community disruption due to noise, dust, and large volumes of heavy vehicle traffic. Alternative 2 is the least cost effective alternative by a wide margin. In comparison, Alternative 1 offers the potential to achieve similar or greater improvement in water quality conditions as excavation at an OoM below the capital and present value cost. It is readily modified and would not conflict with application of another technology should some highly promising technology emerge.

3.2 Relative Sustainability and Conformance with DER-31 Green Remediation Guidelines

Table 3 provides a qualitative evaluation of the two alternatives against criteria for sustainable remediation practices and objectives. The evaluation was completed using a peer-reviewed framework developed by the Sustainable Remediation Forum (SURF) that was in turn developed in consideration of emerging United States Environmental Protection Agency (USEPA) and State Guidance for Green or sustainable remediation[12]. The SURF framework is one of the leading models for considering sustainability in remediation practice that attempts to consider net environmental benefits in concert with economic and social considerations. Accordingly, we believe that this assessment meets and exceeds the provisions outlined in NYSDEC DER-31 Green Remediation Guidance.

Table 3 lists 50 potential practices and objectives that are components of three elements of sustainability, including environmental, economic, and/or social gain that are referred to as "Triple-Bottom-Line Elements". This listing should be viewed as potential criteria for consideration of the relative merits of alternatives, but should also be considered a listing of practices to be carried through into implementation to the extent practicable. For example, use of treated groundwater or other non-potable source for a source for drilling water or dust suppression can be incorporated into work planning for implementation of either of the two alternatives.

The EBD remedy offers less greenhouse gas emissions compared to excavation and limits reliance on land disposal saving landfill space and reducing the need for landfill expansion. Planting and maintenance of trees including native locally sourced species will transform the open field into forested cover while accelerating VOC mass removal from the subsurface.

[12] Ellis D. E. and Hadley, P.W., Sustainable Remediation White Paper – Integrating Sustainable Principles, Practices, and Metrics into Remediation Projects, *Remediation Journal*, Summer, 2009, http://sustainableremediation.org/library/issue-papers/

Excavation offers a larger number of less favorable ratings, in particular due to significantly higher waste generation, energy usage, and greenhouse gas emissions associated with trucking. This option would involve thousands of heavy truck trips to and from the site for disposal of soil and rock, as well as return of clean backfill, with certain damage to roads and higher risk to workers and public. Alternative 1 is assessed to be more favorable in part due to more likely reduction in contaminant toxicity, mass, and mobility using in situ technology.

3.3 Recommended Alternative

We recommend proceeding with Enhanced Biochemical Degradation as the alternative of choice. This recommendation is founded on the detailed analysis of the alternatives outlined above, and it is supported by about two years of lab and field pilot testing. We believe that selection of EBD is a logical and responsible outcome. EBD offers greater potential to meet the three stated active remedial goals, including fewer and more manageable risk of adverse outcomes, more limited risk for worker safety. **Exhibit 3.3** provides a summary of the recommended remedy against evaluation criteria that is detailed in Table 2.

Exhibit 3.3 Capsule Summary of the Recommended Alternative Against Primary Remedy Evaluation Criteria

Criteria	Discussion
1. Protection of Public Health and the Environment	The site conditions do not pose an unacceptable threat to public health under present site use and the potential exposures identified during the remedial investigation. The recommended alternative incrementally further reduces potential for human and exposure through reducing the physical presence of seeps and springs, plume containment and stabilization and capping of surficial soils.
2. Compliance with SCGs	Complies with the statutory requirements for Remedial Programs under 6 NYCRR Environmental Conservation Law ECL Part 375, 1.8 (C) in that it addresses source removal(1), containment (2) elimination of exposure (3); and complies with statutory requirements for groundwater projection and control measures (d) related to source removal (1,i) and plume containment and stabilization. (1, ii). Intended to further stabilize and contain the VOC presence in groundwater migrating in fractures through establishment and maintenance of biochemically active zones limiting off-site transport while addressing VOC source mass. Achieving a 0.5 to 1 order of magnitude reduction in groundwater concentrations downgradient off-site would result in water quality largely meeting applicable standards under 6 NYCRR Part 703.5. Complies with generic soil standards for residential site use and groundwater protection established in 6 NYCRR Part 375 over the majority of the site, and restricted residential use for the capped area. Institutional restriction for water supply development is consistent with New York State Department of Health regulation 10 NYCRR Part 5, Subpart 5-1 Standards for Water Wells - Appendix 5. Meets or exceeds NYSDEC DER-31Green Remediation Guidelines.
3. Short Term Effectiveness and Impacts	Construction can be completed in ½ year or less and be effective immediately in limiting direct contact exposures, based on pilot testing results, positive improvements in water quality conditions can be expected within weeks to months within the injection zone and about ½ year downgradient. Short term impacts during construction such as dust, noise, and traffic can be mitigated. Heavy construction work is to be limited to normal business hours.
4. Long Term Effectiveness and	Metal shot containing soils exceeding residential SCOs have been permanently removed from the site. EBD and Phytoremediation are intended to result in permanent in-situ destruction and permanent removal of the principal VOC contaminants from the environment. Reduces mobility, toxicity and

Exhibit 3.3 Capsule Summary of the Recommended Alternative Against Primary Remedy Evaluation Criteria	
Criteria	**Discussion**
Permanence	volume of VOC-containing media. With proper maintenance should permanently reduce potential exposure via surficial soils and seeps and springs. Years or tens of years may be required for the full effect to be realized at downgradient points.
5. Reduction of Mobility Toxicity and Volume	Reduces volume and environmental mobility of metal shot-containing soils while reducing mobility and availability of soils related to the former burn pit disposal. Reduces mobility, toxicity and volume of VOC-containing media. Pilot testing demonstrated reduction in toxicity through complete destruction of VOCs to non-toxic by-products. Intended to reduce the mass/volume of groundwater and source rock.
6.Implement ability	Construction through readily available and conventional technologies and is readily implemented. Capping and Phytoremediation are technologies with a proven track record in similar application. Application of EBD to fractured sedimentary rock is not a presumptive technology with an extensive track record of application. Would not preclude later application of other technologies.

We believe that this remedy represents cost effective and responsible action that will result in risk reduction in a sustainable manner while limiting waste generation, energy usage, and greenhouse gas emissions. It is a remedy that is consistent with and will not detract from local land use. The following Section 4.0 provides a Work Plan for EBD with concepts of implementation at greater than the 50% preliminary level of design development required under NYS rules. The section also outlines a projected scope and schedule for proceeding with implementation, assuming Agency support and concurrence with the recommended selection.

4.0 REMEDIAL ACTION WORKPLAN

This section provides a summary of the remedy present design concepts for implementation of the recommended alternative, a discussion supported by figures and Appendices. The content of this section and the supporting figures and appendices were prepared in consideration of the requirements for Remedial Design and Remedial Action Work Planning as outlined in NYS Guidance DER-10, Sections 5.2 and 5.3. This Work Plan addresses the surficial soil and EBD components of the remedy associated with residuals remaining from the former BPA.

The figures and the text to follow present design concepts at the present level of development, where detailed construction drawings have been drafted and technical specifications have are in the process of being prepared.

The remedy elements at this design stage are discussed under Section 4.1 along with the additional design steps that are planned concurrent with Agency review of this document. Section 4.2 outlines our present understanding of permitting requirements, while Section 4.3 outlines remedial performance objectives and Appendix C.2 details a program of initial performance monitoring for the biochemical degradation component of the remedy. Section 4.4 discusses the environmental easement for the site and institutional controls to be established as a part of the remedy. A projected schedule is outlined in Section 4.5 that depicts a sequence of work through completion of construction and submittal of a Final Engineering Report in the 2013.

4.1 Design Concepts

The design concepts for the recommended remedy are depicted on Figures 4 through 6. Figure 4 provides a summary of the surficial soil conditions and depicts the area to receive two feet of clean soil cap meeting soil quality standards for residential use and the greater limit of placement of clean soil fill as needed to provide for final grading. Allowing for proper grading, the clean soil fill placement will extend to and beyond the contaminated soil area as shown on the figures. As such the capped area will be conservatively larger than the defined footprint of metals-containing soils.

Figure 5 depicts the updated layout of lines of injection borings to be used to introduce amendment to the subsurface as a part of the EBD component of the remedy. EBD is intended to address the presence of VOCs in the uppermost highly fractured bedrock--the primary site condition that is the focus of this Remedial Action Work Plan. As outlined in prior text and tables, certain site work will also be conducted to both aid in supporting the implementation of the EBD remedy and to address surficial soils.

Figure 6, depicts the overall sequence of site work and the proposed final grading and areas of tree planting. Grass and tree cover will be established and maintained on and around the capped area to promote evapotranspiration and removal of VOC-containing water from the subsurface (phytoremediation component). The capping and phytoremediation component are intended to limit infiltration that drives seasonal breakout of VOC containing groundwater through seeps and springs and accelerate removal of VOC mass from above the rock soil interface. Capping also would bring the site to a condition where the surficial soils would meet residential SCOs. Implementation of this site work will also require relocation of fencing.

The completion of the construction will be guided by a set of design drawings and technical specifications. The design includes final grading plans, storm water pollution prevention, sediment and erosion control plans and details, a material and placement specification for soil fill, procedures and practices for dust suppression, and specifications for planting and maintenance of vegetative cover.

The field implementation will be governed by a site-specific health and safety plan to be prepared under separate cover in accordance with applicable regulations for construction and Hazardous Waste Operations. The work will be coordinated, observed, and logged by a representative of the Engineer of Record to:

- document completion of construction against the plans and specifications;
- implement the Community Air Monitoring Plan (CAMP) included as Appendix F;
- coordinate and implement construction quality assurance (CQA) testing including testing of soil borrow material and confirmation of fill placement and compaction; and
- obtain photo-documentation and support preparation of as-built/record drawings to be included in the final engineering report with CQA documentation.

As discussed below, the final boundaries of the contaminated soil footprint will be marked in the field and surveyed for the deeded record.

4.1.1 Soil Excavation and Consolidation

To facilitate final cap grading before placement of the clean soil cap, soil will be excavated from the areas shown on Figure 6 and relocated within the footprint of the area to be capped. This re-grading of the metals-containing soils is necessary to result in a smooth transition of final cap grades to the existing undisturbed grade. We estimate that the amount of soil to be relocated as a part of this preparatory step will be about 420 cubic yards on an in-place compacted basis.

If excavation and consolidation of contaminated soils results in complete removal of soil down to refusal on rock, effectively reducing the contaminated soil footprint the revised area will be documented through field survey to be reflected in a reduction in the area constituting a Track 4 surficial soil remedy and subject to associated deed restrictions. Regardless, clean soil will still be placed and compacted to the grades shown on Figure 6.
The placement and compaction of the excavated soils will be according to a specification to at least 90% of the optimum density as determined by Modified Proctor soil moisture density testing. The excavation areas will be backfilled with clean soil placed and compacted consistent with the specifications discussed in Section 4.1.2 to the approximate grades shown on Figure 6.

4.1.2 Soil Cap Material, Placement, and Grading

It is the design intent to import clean soil fill of a similar texture and physical properties as the native glacial till soil that exhibits between 30% and 60% fines content. A review of soil borrow sources is underway with the assistance of local contractors guided by a gradation specification. The intention is to obtain a well graded soil from a virgin soil borrow pit local to the area. The goal would be to find soil fill that when properly placed and compacted, provides for an in-place permeability equivalent to or below the native soil.

The soil fill sources are being subject to the suite of chemical testing outlined in Table 5.4(e) 10 of DER-10. The imported soil fill will need to substantially meet the analytical requirements under 375-6.8(b) for residential site use and groundwater protection. IBM will seek NYSDEC pre-approval of the soil borrow sources to be used in construction. A pre-approved soil borrow source may obviate the need for or limit the additional testing would be conducted during construction. However if a pre-approval waiver is not obtained, sampling and analytical laboratory analysis would be conducted during construction[13].
The cap fill will be placed and compacted according to a specification to be developed in consideration of the available soil borrow sources. The grading plan was prepared to

[13] *Without pre-approval of the soil borrow source waiving the need for additional testing, during construction additional soil samples would need to be collected and analyzed before the soil was transported to the site. Assuming a total of about 4,900 cubic yards of in-place volume and about a 20% expansion factor for truck volumes, about 17 samples would be tested for VOCs and seven samples for SVOCs, inorganics, and PCBs/pesticides.*

provide a minimum of two feet of compacted engineered soil fill inclusive of topsoil over the footprint of soils exceeding residential SCOs and a minimum slope of about 3%. The limits of clean soil fill placement as shown on Figure 6 encompass about 1.6 acres about 0.3 acres larger than the 1.28 acre area to be capped.

Assuming an average of about 4 feet of existing soil thickness over bedrock, the placement of soil fill would result in 6 feet of soil over bedrock increasing the volume available for soil moisture retention to support evapotranspiration. The soil will be placed and compacted to a specified soil moisture and density that would be determined through soil laboratory testing on samples of soil borrow conducted as part of the design. Testing to confirm gradation would be conducted on composite samples from about every 500 cubic yards of imported soil and field density testing will be conducted during placement to document compliance with the specification.

As shown on Figure 6, about 2 feet of soil fill will also be placed on the wooded slope between the present fence line and the southerly access road in the area shown on the photo included as Exhibit 4.1. This fill is to be placed to fill a topographic depression where groundwater has been observed to breakout as seeps and springs.

Exhibit 4.1 – View of topographic depression where soil fill will be placed to limit breakout of seeps and springs. The photo was taken in March 2012 looking northeast from the vicinity of monitoring well BP-9A. The colored flagging marks more mature trees for field survey.

This soil fill placement is intended to limit the potential for groundwater breakout and is not part of the Track 4 surficial soil remedy. The filled area reflects the goal of limiting the amount of fill and disturbance in areas to protect mature trees (nominally >3 to 4 inch caliper) which were flagged and surveyed as a part of design development completed since submittal of the draft report.

As shown on Figures 5 and 6, gravel access lanes will be constructed along the injection borehole alignment by placing and compacting NYSDOT Type 4 crushed stone to a minimum thickness of about 5-inches on top of a geotextile filter fabric. These lanes will be used to access the borehole locations for drilling, amendment injection and monitoring.

4.1.3 Establishment of Vegetative Cover/Phytoremediation Elements

The present design concept is to cover the soil fill cap with nominally 6-inches of either an approved screened borrow topsoil or commercially available compost product. The completed cap surface will be seeded with a grass mixture, and trees will be planted and maintained. Samples of the compost/topsoil will be tested to support selection of nutrient amendments.

The present concept for planting is to seed the cap and beyond to the approximate limits of work with an annual rye grass cover crop to stabilize the soil surface. Between the limits of cap placement and the limits of work, the existing grassed ground surface will be mowed then tilled before tree planting and seeding. Relatively quick growing hybrid poplars will be planted on an 8-foot grid and slower growing native red spruce will be planted on about a 50-foot spacing. On the present wooded slope, additional trees will be planted among the native vegetation to achieve a similar planting density. The gross area to be planted with trees extends between the existing tree lines north, south and east of the BPA and covers about 2.6 acres and would include about 1,400 poplar trees and 40 red spruce. The density of planting of about 600 trees per acre allows for some mortality.

As shown on Figure 6 and discussed with NYSEDEC, the present concept is to plant 9" rooted hybrid polar whips over the approximately 1.28 acre Track 4 cap area so as not to penetrate the 2-foot clean soil cap. Outside of the Track 4 cap area, seven to nine-foot poplar poles will be planted in augured holes extended 4 to 5 feet below grade or to refusal on bedrock. The deeper pole plantings offer greater potential for quick rooting near water table depth and result in better rates of survival.

Given the nominally 3 to 6 foot depth to rock in the area of planting, ultimately root penetration is expected to reach the top of bedrock across the entire area allowing for direct contact with seasonally high water. The available literature indicates potential for 10 to 15 foot growth in two seasons with potential evapotranspiration rates on the order of 10 to 50 gallons per day per tree[14].

[14] USEPA, August 1997, Phytoremediation of TCE using Populus, USEPA Technology Innovation Office.

The trees would be planted with soil amendment/compost and mulched in accordance with a planting schedule and specification. The initial planting of annual grass is intended to stabilize the soil with limited competition for water to allow the trees to root without the use of herbicides. Once the trees are established in one growing season, the tree buffers would be over-seeded with a perennial mix of grasses consistent with NYSDOT No-Mow seed mix[15].

4.1.4 Drilling and Completion of Injection Boreholes

Two rows of injection boreholes are to be drilled and maintained to facilitate delivery of amendments into the saturated and unsaturated portion of the uppermost highly fractured rock where the majority of VOC mass resides. The current concept is to extend the borings to a depth to the first inferred aquitard or the inferred bottom of the primary source rock whichever is greater.

The design concept for injection boring locations has been refined to protect mature trees along alignment B-B' and to allow for amendment injection at or near the highpoints of the aquitard surface (A-A') to increase the potential for efficient downgradient distribution of amendment. The data and inference used to refine the alignments is shown on Figure D.2 in Appendix D. The present design concept is to drill 30 injection borings spaced 16 ft apart along the east to west oriented Alignments A (17 borings) and B (13 borings) shown on Figure 5. The boring alignments will be staked through field survey that establishes the final surface grade. As outlined in Section 4.3.3 IBM would also consider adding injection capacity at a later date to further disperse the amendment emplacement.

The drilling will be performed using rotary sonic techniques that offer potential for completing the drilling program within a shorter timeframe (about 3 weeks) while limiting drilling water use relative to coring[16]. The boring installations and development will be performed in general accordance with methodologies consistent with those employed in the Pilot Study, and as described in more detail below.

We intend to use treated ground water in lieu of potable water, with the goal of reducing the non-consumptive use of potable water and to avoid the introduction of chlorinated water into the subsurface, which would suppress subsurface biological activity. The drilling return water will settle in a fractionation tank and possibly be reused either during drilling, borehole development, or mixed with amendment and injected. The borings will be completed as 6-inch nominal diameter open boreholes with 8-inch inner diameter steel surface casing seated 1 foot into rock. The boreholes will be developed by pumping and manual surging until the turbidity stabilizes, ideally at less than 10 Nephelometric Turbidity Units (NTU).

[15] New York State Department of Transportation, May 5, 2011, Supplemental Landscape Development Specifications, 427A1 or equivalent.

[16] *In past application at the site, drilling water usage as measured by gallons of water delivered to the site was on the order of 10 gallons per foot of borehole, which is about 20 to 40% less than IDW generation when drilling using rotary core techniques.*

Assuming that construction of the injection borehole arrays proceeds after cap placement, solid cuttings derived from drilling through the contaminated soil footprint will be contained in drums and characterized to support off-site transportation and proper disposal. Assuming that borehole drilling proceeds after placement of soil fill, the water-borne rotary sonic drill cuttings will be directed to a fractionalization tank. Solid or slurry drilling cuttings will be transferred to labeled drums and characterized to support transport and off-site disposal. If the drilling is completed before completion of the cap, the solids would be consolidated beneath the cap.

4.1.5 Initial Amendment Injection

Rational design of organic carbon loading is based on VOC mass present in both the saturated and unsaturated portion of primary source rock and considering sulfate as the primary electron acceptor. As outlined in the pilot test report, accounting for mass in the vadose zone, we had estimated an approximate 30 year design loading the equivalent of 6,000 gallons of undiluted edible oil substrate (EOS) for the 1.6 acre primary sourcing area. The actual demand will be greater or less in full scale application and can be later adjusted based on performance monitoring observations and inference. EOS was shown to successfully stimulate EBD in the pilot study, and was observed to be long lasting, which is consistent with experience elsewhere when compared to more mobile substrates such as lactate. As discussed in Section 4.3.3, we have not ruled out the possible testing of other potential amendments.

An initial annual total dosing of 200 gallons of undiluted oil assuming a 30 year design life corresponds to a mass loading of:

- About 0.3 gal/100 square feet beneath the 1.6 acre area which compares with the pilot test mass loading of 0.09 gal/100 square feet (sf) over the 1,200 sf injection zone.
- About 35 gallons of undiluted oil per 100 feet of injection line (gal/100lf) which compares to the 4 to 12 gal/100 lf for the initial and second pilot injection, respectively.

An initial loading of 200 gallons of EOS soybean oil diluted 10 times would result in 2,000 gallons of diluted amendment, which is roughly equivalent to about 25% of the fracture pore volume in the primary source rock[17]. Proportioned by length of injection boreholes, about 1,300 gallons of diluted edible oil would be injected along A-A', with the remaining 700 gallons injected along B-B'. This is equivalent to about 50 gallons per borehole, over twice the bedrock borehole volume assuming 15 feet of borehole. If the amendment injection is "chased" with a volume of water equal to one borehole volume (about 20 gallons), the net injection may displace the fracture pore space within 30 feet of the line of boreholes. Sampling of wells within 50 feet of the injection alignment will be conducted after completing the injection to confirm the displacement of amended water into the fracture system.

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[17] *The pore volumes and net displacement are computed assuming 15 feet of saturated thickness and the median fracture porosity of $5x10^{-4}$.*

An initial injection only along A-A' followed by an appropriate performance monitoring period will allow for a better understanding of the downgradient extent of effective biochemical degradation and screen for vinyl chloride accumulation. Assuming travel times of about 50 to 60 days between the A and B alignments, a minimum of two monitoring events could be completed before initiating injection along Alignment B.

The injection is about 2 OoM greater volume than what was performed during the pilot test and would likely require moderate injection pressures to transfer the volume in a reasonable period of time. We have assumed use of single and double packer assemblies to aid in the injection process. Use of a single packer assembly may allow for some enhancement of fracturing local to the boreholes that would aid in the distribution of amendment. We will refine the materials and methods for injection during the next phase of design. Permitting associated with underground injections is discussed in the following Section 4.2.

The amendment would be diluted with treated groundwater or site water [18]that will be "stripped" of oxygen by bubbling with nitrogen prior to mixing to limit subsurface introduction of atmospheric air that may limit the EBD processes. The mechanical mixing will be performed under a nitrogen atmosphere.

A performance monitoring program for the first year after the initial injection is outlined in Appendix C.2. The program is designed based on observed bromide tracer travel times and estimates of advective travel times. It incorporates more frequent monitoring during the first 12 months after the first injection event, and would include, but not necessarily be limited to:

- Water quality parameter probe measurements of temperature, specific conductance, oxidation-reduction potential (ORP), dissolved oxygen (DO), and pH;
- Field geochemical analysis by spectrophotometer and ion specific electrode for bromide, sodium, chloride, ferrous and ferric iron, sulfate, sulfide and DO; and
- Collection and submittal of water samples for laboratory analysis for VOCs, total organic carbon (TOC) volatile fatty acids (VFAs), and light gasses (including methane, ethene and ethane).

The current concepts also include deployment of water quality probe data loggers that in combination with telemetry would provide a continuous record of data that may be used to select the timing of performance monitoring events. Longer term monitoring will likely be less frequent, but would be adjusted based on findings monitoring in the first year. Section 4.3 outlines our longer term goals and monitoring projections.

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[18] *The term site water is meant to denote water from the existing potable supply well or recycled return water from the drilling process that was clarified to settle out solid cuttings and/or treated with activated carbon to remove VOCs.*

4.2 Permitting

Remedial actions involving underground injection are regulated by the U.S. Environmental Protection Agency (EPA) through CFR Part 144. Injection permitting will be provided by Underground Injection Control (UIC) Program, which for this site would be administrated by the EPA, Region 2. The injection of a carbon amendment would require a Class V-5B permit, "to be used for beneficial use in subsurface environmental remediation," for underground injection that does not endanger underground sources of drinking water.

IBM will submit a Class V-5B permit application to EPA, Region 2, concurrent with the next phase of design. The application would incorporate current concepts for annual amendment mass injection per year. Future V-5B permit applications will incorporate adjustments and optimizations from the first 5 years of EBD operations and may be expanded to support 10 years of future operations.

The site construction will be conducted under a storm water pollution prevention plan as required for construction activity under NYSEC Construction Stormwater General Permitting (GP-0010-001). We understand that field review of compliance with the stormwater general permitting is administered by the Town of Union, New York.

4.3 Performance Objectives and Means of Demonstrating Performance

The performance objectives and measures of success as outlined below were developed in consideration of the pilot test observations and site specific fate and transport modeling. A detailed outline of the proposed monitoring program for the initial year after amendment injection is included as Appendix C.2. A final monitoring program plan will be included in the Site Management Plan.

The pilot testing demonstrated that natural intrinsic biochemical degradation can be stimulated by injection of even a modest amendment mass loading. One to two orders of magnitude reductions in TCE concentrations were observed directly within the injection zone in the first six months after injection. The most recent data 1.5 years later support continued and sustained reduction in TCE parent concentrations of 2.5 to more than 3 OoM. Evidence of downgradient transport of bromide and expansion of biochemical conditions more conducive to EBD were observed within the first six months after the initial injection. Based on a simplified first order model, the estimated degradation half life for TCE ($T_{1/2}$) within the injection zone appears to be on the order of tens of days to months, orders of magnitude below half lives used in site-specific modeling.

Based on the modeling results documented in Appendix E, we believe that intrinsic biochemical processes in concert with physical processes has limited the extent of groundwater contamination to about 1,000 ft downgradient of the BPA, and resulted in the current observed conditions that are believed to reflect a steady state or receding condition. A modest doubling of downgradient biochemical degradation rates coupled with a reduction in mass flux out of primary source rock would be expected to accelerate contraction of the plume with measureable progress toward water quality standards within a few decades.

The aspirational goals of full scale EBD are to:

- produce sustained EBD throughout the primary source rock;
- limit mass flux out of the area with primary sourcing in rock, in particular across the site boundary; and
- enhance the intrinsic biochemical processes outside and downgradient of the primary source rock.

Current concepts of EBD performance objectives incorporate short and longer term measures of success.

4.3.1 Short Term Performance Objectives and Measures of Success

The following discussion outlines short term performance objectives to be assessed on a time horizon of 5 years or less following the initial injection. Within this time period, our operational goal would be to refine dosing mass, volume, and frequency based on observational performance monitoring. We believe that the initial net effect of EBD will be largely measurable within six to nine months in monitoring of water table wells within the primary source rock. The primary measure of success will be a sustained reduction in parent VOC concentrations of 2 OoM or greater within the vicinity of the injection borings.

This metric of success will be assessed through water quality data for a representative number of the injection borings and monitoring wells within the displacement zone shown on Figure 5. Ideally within this short term period, the parent VOC concentrations in water withdrawn from these wells would largely be below NYSDEC water quality standards.

Given that the injection boreholes span the primary source rock, substantially meeting this goal would indicate material reduction in VOC mass flux across the southern site boundary. We have estimated the VOC mass flux across the general location of the B-B' alignment to be on the order of a few tenths of a pound TCE per year. Not accounting for groundwater volume flux reductions attributable to capping and phytoremediation, an average 2 OoM reduction in TCE concentrations across the B-B' borehole alignment would indicate a proportional reduction in TCE mass flux, achieving source containment. As TCE concentrations presently range from tens to the low thousands of μg/L a two order of magnitude reduction in TCE concentrations would result in groundwater largely meeting NYSDEC ambient groundwater quality standards across a substantial portion of the property line.

Within one to two quarterly monitoring rounds of the initial injection in A-A', and before completing the second injection, we would expect to see geochemical conditions more conducive to EBD and evidence of VOC breakdown at B-B'. This monitoring will enable us to assess the scale and timing of downgradient transport of amendment by-products resolved from the effects of direct injection in B-B'. Amendment injection in Alignment B will proceed assuming that during performance monitoring, we observe:

- No compelling evidence of incomplete degradation reflected in downgradient migration of VC or evidence of adverse reductive dissolution of arsenic; and

- A point of diminishing returns in the downgradient effect of the initial injection via A-A' in the form of less than a 2 Oom sustained VOC reduction.

Monitoring at locations elsewhere in the primary source rock would focus on evidence of a sustained response in VOC concentrations in water table monitoring wells ideally indicating a 1 OoM reduction in parent TCE without evidence of adverse accumulation of breakdown products or increase in total VOC concentration. Assuming 1 OoM reduction, the resulting TCE concentrations in these wells would generally range in the tens to hundreds of μg/L, with some possible outliers (e.g. BP-34A) may be in the hundreds or thousands of μg/L.

As outlined in the projected schedule included as Figure 7, the Final Engineering Report will be prepared when construction is complete and after the first injection. We understand that the NYSDEC would be prepared to issue a certificate of completion when the primary short-term performance objective has been met for two consecutive monitoring events.

4.3.2 Long Term Performance Objectives and Measures of Success

The effect of the amendment injections should propagate from the emplaced amendment mass to downgradient locations. Site-specific modeling indicates that it may take decades for the full effect to be reflected at the most downgradient seeps and springs in a wet area on Binghamton Country Club property about 1,000 ft downgradient from the BPA. Assuming that a substantial effect of EBD propagates downgradient at less than 100 ft/year, it would be about 10 to 20 years before the full effect could be observed 1,000 ft downgradient from the BPA.

The long term performance objectives (beyond 5 years) would include meeting the objectives stated in Section 4.3.1 and making progress towards reducing TCE concentrations on Binghamton Country Club property, including:

1. Evidence of sustained EBD beneath the wooded slope on Binghamton Country Club property just south of the property line following a shift to biochemical conditions more conducive to EBD. Success will be measured by decreasing concentrations of TCE and increasing concentrations of breakdown products. A 0.5 to 1 OoM reduction below this area would correspond to TCE concentrations largely meeting NYSDEC water quality standards.

2. On a 10 to 20 year timescale, we would expect the cumulative effect of reduced mass flux out of the primary source rock and downgradient migration of EBD to reduce concentrations at downgradient seeps and springs at points of shallow groundwater discharge. Reducing TCE concentrations by a factor of 2 in this area would result in water quality largely meeting the NYSDEC ambient groundwater water quality standard for TCE.

Monitoring and reporting of progress towards short and long term goals will be implemented under a NYSDEC approved Site Management Plan (SMP).

4.3.3 Contingencies and Possible Modifications to the Remedy

Modifications to the remedy that will be considered in preparation of a SMP as possible contingencies to certain conditions, if encountered, include but are not limited to:

- Use of blends of EOS and other more soluble amendments that may increase the downgradient transport of organic carbon/volatile fatty acids. Although EOS 598 B42 soybean oil was successfully used in the pilot study, we are reviewing other amendments and may consider testing the use of more soluble and mobile amendments, e.g. sodium lactate or acetate, that are likely to more readily migrate downgradient, but also have a shorter residence time in the injection area.

- Bioaugmentation with a commercially available vinyl chloride degrader. Should the performance monitoring data indicate potentially adverse accumulation of vinyl chloride, we may consider bioaugmentation that has been shown to improve vinyl chloride degradation.

- Addition of more injection points to aid in focusing or further dispersing the amendment emplacement to address hotspots or areas of increased total VOC concentrations. Increases in total VOC concentrations can result from enhanced dissolution/desorption of VOC mass. In particular, the present design layout was developed assuming that the northerly component of flow from the primary source area is controlled by existing biological activity. If monitoring indicates continued increases in parent VOC concentrations at downgradient locations to the north, we may consider adding a line of injection points near the northerly limit of primary source rock.

- At some point cease injections and move to a monitored natural attenuation as we observe diminishing VOC concentrations and diminishing returns from subsequent injections.

The agencies will be informed prior to such changes and the UIC permits will be updated as necessary to support these contingency activities.

4.4 Environmental Easement and Institutional Controls

We understand based on discussions with NYSDEC staff that once construction and initiation of the remedy is underway, the site would be under "Field Implementation Status" where the remedy is in place and under operation, and human exposures are controlled by deed restrictions or engineering controls.

IBM is prepared to enter into an environmental easement for the Parcel B site as required under New York ECL Article 71, Title 36 that will include by reference a Site Management Plan (SMP) that will specify institutional and engineering controls to be implemented and maintained as discussed below. Under the SMP, IBM will submit to the NYSDEC a periodic certification documentation of the status of the site relative to institutional and engineering controls in accordance with Part 375-1.8 (h)(3).

- The soil cap will be considered an engineering control. Annual or semi-annual inspection and maintenance of the soil cover will be conducted as a part of the SMP. The site fencing is intended to maintain security for site buildings and features to remain, but is not considered by IBM to be an integral part of the site remedy. Absent the need for operation and monitoring of the groundwater remedy, there would be no material need for the buildings or security fencing.

- The SMP will acknowledge that the NYS Agencies would allow for use and development of the capped area for restricted residential, commercial and industrial uses as defined by Part 375-1.8(g); and for residential, commercial and industrial uses as defined by Part 375-1.8(g) throughout the remainder of the site. Agriculture or vegetable gardening use would be restricted from the capped portion of site and conditions for excavation in the capped area will be outlined as an excavation plan;

- The SMP would acknowledge that in the event of planned building construction anywhere within Parcel B or the downgradient plume, the vapor intrusion pathway would be addressed through testing and/or the application of engineered controls;

- Finally, the use of groundwater as a source of potable or process water, without necessary water quality treatment will be restricted in accordance with NYS Public Health Law.

New York State standards applicable for development of domestic and public water supplies under NYS Public Health Law 206(18)[19] specify "Required Minimum Setback Distances" to protect water wells from contamination. The required distance from waste disposal areas is 300 feet subject to the condition that the well shall not be located in a direct line of flow or in any contaminant plume without a provision for hydraulic containment, sentinel wells or source water treatment. IBM understands that full compliance with this standard would preclude the development of water wells within the entire plume area or provision of point of use treatment to mitigate potential exposure. Regular reporting under the SMP would reporting that would document continuance of conditions of land use within the downgradient plume area and that conditions considered in the RI exposure assessment remain substantially unchanged.

4.5 Projected Schedule

Figure 7 depicts an updated schedule projection that reflects the Agency review and design development work completed since submittal of the draft report in March 2012 and the input from the Agencies regarding their projection of the regulatory review process going forward. It projects construction in the second and third quarter of calendar year 2013. The schedule project is organized by line identification numbers (ID) on the left hand column that are referenced in the discussion to follow.

[19] New York State, Department of Health, March 2010,NCRR Title 10, Part 5, Subpart 5-1, Appendix 5b. Standards for Water Wells.

The schedule projects IBM receipt of a letter accepting the remedy (Acceptance Letter) in mid-December 2012; allowing a 45-day public notice period (ID 17), and 30 days for the Agencies to issue a final Decision Document (ID 18). Notable milestones in the months following receipt of the Acceptance Letter leading toward completing construction in 2013 include:

- Submittal of the 95% complete design package to the NYSDEC in the 4th quarter of 2012 (ID 22);

- Contracting for construction implementation and construction phase engineering in allowing for start of construction in the second quarter of 2013 (ID 24); and

- Preparation of the Site Management Plan and submittal to the NYSDEC in the 1st Quarter of 2013 (ID 67).

During the same period, IBM would seek Agency concurrences on source(s) of soil borrow to be used as cap fill and topsoil and draft an Environmental Easement working with NYSDEC.

The schedule depicts an allowance of up to 120 days would be available for site work allowing for seeding and planting of the filled area within the New York Department of Transportation (NYDOT) preferred planting season. The NYSDOT preferred planting season for grass cover from August to late October is shown by line ID 28.

The schedule depicts construction of the injection boreholes after completion of site work through placement of soil fill leading to submittal of the Final Engineering Report (FER) in late 2013.

TABLES

Table 1
Summary of Alternatives for Detailed Analysis
Brownfield Cleanup Program --Alternative Analysis and Remedial Work Plan
IBM Gun Club -Former Burn Pit Area

	Alternative	Technologies/Components	Estimated Area and Volume of Media addressed/Design Basis	General Nature of Post Construction Monitoring/verification	Reliance on Deed Restrictions/Institutional Controls	Discussion
Alternative 1 - Enhanced In Situ Biochemical Degradation Combined with a Surficial Soil Capping and Phytoremediation						
Alternative 1 - Enhanced In Situ Biochemical Degradation (EBD) Combined with a Surficial Soil Capping and Phytoremediation	1A) **Surficial Soil and Phytoremediation Components**	**a.** Excavation of meta shot containing surficial soil exceeding Residential SCO was conducted in Mary 2012 under the March 2, 2012 IRM; along with:	**a.** To be summarized in the IRM Constructon Completion Report	**a.** Verification sampling of soils and re establishment of vegetation.	Parcel B to be subject of an Environmental Easement under Article 71, Title 36 of New York ECL that will specify institutional and engineering controls through a Site Management Plan (SMP). See Section 4.4 text of Brownfield Alternative Analysis and Remedial Work Plan for further discussion.	The cap will consist of imported soil placed and compacted to an engineered specification graded to increase run-off and limit infiltration. Groundwater recharge will be further reduced by additional tree cover. A reduction in infiltration recharge should limit the source of water feeding seasonal seeps and springs breaking out at the southern boundary and reduce seasonal fluctuations in groundwater levels and geochemical conditions. Should result in a material reduction in groundwater flux through the primary source rock increasing residence times. It is possible that groundwater concentrations and mass flux may not be materially reduced.
		b. Excavation and consolidation of surficial soil within the primary source rock footprint to allow for capping.	**b.** 0.44 acres, excavation of soil down to 2 ft bgs or to bedrock if found at less than 2 ft bgs. 420 cy of in place volume soil. Backfilled with imported fill and topsoil that is compacted, graded and seeded as c) below.	**b.** Regular inspection of the capped area for evidence of erosion, burrowing animals, or other disturbance.		
		c. Capping surficial soils and primary source rock with vegetated, low-permeability soil graded to promote surface drainage and limit infiltration.	**c.** 1.6 acres of area. At least 2 ft of soil cover over a 1.28 acre footprint placed to blend with the existing grade for a total of 4,900 cy (in-place volume) of imported soil fill and topsoil. Seeded with a mix similar to a NYSDOT No-Mow roadside mix.	**c.** Ditto		
		d. Planting and Maintenance of Tree Cover - enhance evapotranspiration and promote uptake and transpiration of VOC-containing groundwater within and outside of the capped area.	**d.** 2.6 acres and approximately 500 trees per acre planted in accordance with horticulturalist recommendations and perceived water balance.	**d.** Regular inspection of tree coverage and replacement of dead or damaged trees.		
		e. Fencing - To maintain limited access to the site and active remediation area.	**e.** 1,300 linear feet of new or moved fencing.	**e.** Monitoring of water levels and quality at monitoring points including seeps and springs.		
	1B) **Enhanced Biochemical Degradation (EBD) Component**	**f. Construction** of gravel access lanes along injection boring alignments to facilitate ingress and egress for drilling of injection borings and periodic amendment injections.	**f.** 1,000 linear feet of nominally 12-foot wide new gravel access lane.	**f.** Regular inspections and maintenance of access lanes and repairs as necessary.	Parcel B to be subject of an Environmental Easement under Article 71, Title 36 of New York ECL that will specify institutional and engineering controls through a Site Management Plan (SMP). See Section 4.4 text of Brownfield Alternative Analysis and Remedial Work Plan for further discussion.	Intention to achieve marked reduction in groundwater concentrations at downgradient points within primary and secondary source rock.
		g. Drilling and completion of injection borings along injection alignments.	g. Injection borings located along two alignments across the primary source rock, including a transect along a topographic high that largely corresponds to a groundwater divide, and a second transect along the southerly property boundary totaling 1,000 linear feet. Additional lines or clusters of injection borings may result based on observations and inferences from EBD performance monitoring.	**g.** Regular inspections and maintenance of injection boring surface completions.		
		h. Injection of organic carbon amendment to promote EBD within the primary source rock and reduce off-site migration and concentrations of CVOCs both within and downgradient of the primary source rock.	**h.** Present concepts for amendment dosing is to inject 200 gallons of undiluted EOS substrate oil per year or 6,000 gallons over a 30 year period or the equivalent.	**h.** EBD performance groundwater quality monitoring program. Annual or bi-annual injection of amendment.		
Alternative 2 - Excavation and Disposal						
Alternative 2 - Excavation and Disposal	2) **Excavation**	**As a) through e) above for 1A EBD plus:** **a. Excavation** of metals containing soils and primary source rock along with transport and disposal at an approved disposal facility.	**As a) through e) above for 1A EBD plus:** **a.** Move and stockpile soil from 1.6 acre area equivalent to about 7,700 cubic yards. Excavate, off-site transport and disposal of 21,000 in-place cubic yards of primary source rock.	**As a) through e) above for 1A EBD plus:** a. Verification sampling of soil and rock at the limit of excavation.	As above for EBD, Parcel B would be subject of an Environmental Easement Under Article 71, Title 36 of New York ECL and a SMP. IBM easement with BCC would also be required. Assuming that remediation is successful, the institutional control against construction (residential or otherwise) could be removed from the BPA. Water supply for any development would have to be from public sources. It is probable that the institutional requirement for groundwater monitoring on Parcel B would not be removed.	**As a) through e) above for 1A EBD plus:** Excavation of source rock is the alternative that may approach near unrestricted conditions. Secondary source rock, constituting about 10% of the total VOC mass and exhibiting 10s of µg/L TCE in groundwater will remain in place.
		b. Backfill the excavated rock zone with imported materials and place stockpiled overburden soil	**b.** Backfill excavated rock zone with 25,000 cy imported material and overlay with 7,700 cubic yards stockpiled soil.	b. Confirmatory sampling of imported fill material to confirm NYSDEC applicable standards are met.		

Note:
1. This table provides a capsule summary of the three remedial alternatives. It includes a listing of technologies and components, the estimated volume and area of media addressed, and post construction considerations.

2. Please refer to the Report Text and Figures for additional details.

Table 2
Detailed Analyses of Alternatives
Brownfield Cleanup Program
Alternative Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area

Alternative		Evaluation Against Remedy Selection Evaluation Criteria (See Note 1)								
		Protection of Public Health and the Environment	Standards, Criteria, and Guidance (SCG)	Short-term Impact and Effectiveness	Long-tem Effectiveness and Permanence	Reduction of Toxicity, Mobility, and/or Volume	Implementability	Cost Effectiveness	Land Use	Potential for Community Acceptance[5.]
Alternative 1 - Enhanced In Situ Biochemical Degradation (EBD), Surficial Soil Remedy and Phytoremediation	1A. **Surficial Soil Component**	Consolidation and capping of surficial soils, plus a perimeter fence, will reduce potential for human exposure to BPA soils and low concentrations of VOCs reaching seeps/springs between BPA and the southerly property boundary.	Capping and enhancement of vegetative cover will increase evapotranspiration, which is expected to reduce groundwater flux through the primary source rock.	Soil removal has been completed. Soil consolidation, and capping can be completed in as little as 2 to 3 months during which there would be some increased noise and increased heavy traffic on public roads transporting excavated soil and fill material.	Lead shot containing soils exceeding residential SCOs have been permanently removed from the site.	Would reduce volume and potential mobility (erosion) of lead shot containing soils. Similarly expected to reduce the footprint, mobility, and availability of BPA contaminated soils.	Based on conventional technology and is readily implemented.	The estimated capital cost for the Surficial Soil components as outlined on Table 1, is $1.5M including $240K in contingencies.	Incrementally reduces the area of soil that would be restricted for residential and commercial uses by about 1.8-acres.	To be determined by community input to be received during public notice period.
		Removal of lead shot containing soil reduces potential for exposure to lead, arsenic and related metals.	Following soil excavation, consolidation and capping, based on the available data surficial soils will comply with NYCRR Part 375 generic surficial soil standards for residential site use (SCO) over the majority of the site, and restricted residential use for the capped area.	Effective immediately upon completion for limiting direct contact exposures. Full benefits of capping and tree planting on groundwater conditions would be realized in the first five years.	With proper maintenance, alternative would permanently reduce potential for exposure to BPA soils exceeding residential SCOs and should limit potential for exposure to low level VOCs at seeps and springs between the BPA and the site boundary.	The capping would incrementally and perhaps marginally address volume and perhaps mobility by reducing groundwater levels and volumetric flux through source rock.	Capping and phytoremediation are technologies with a proven track record in similar application.	O&M over 30 years is estimated at $100K and includes site maintenance, inspection and reporting.	Future land use will be limited by deed restrictions/ institutional controls as discussed in Table 1.	To our knowledge, past lead shot removal work has not drawn objections, complaints, or negative input from the community related to dust, noise, and truck traffic. Implementation of this alternative would be of shorter duration and cover only a fraction of the land area than this prior work.
		Capping may incrementally reduce the groundwater and mass flux through and from the primary source rock.		Work to be conducted during normal business hours to limit noise impact. Dust, erosion and sedimentation to be controlled through an air monitoring and dust suppression program, equipment decontamination, and engineered Construction SWPP.	Phytoremediation are intended to result in permanent in-situ destruction and permanent removal of the principal contaminants.		Monitoring readily implemented using existing monitoring wells, multi-level systems, and surface water sampling points.	Present value considering 30 years of O&M cost is estimated at about $1.6M.		

Table 2
Detailed Analyses of Alternatives
Brownfield Cleanup Program
Alternative Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area

	Alternative	Evaluation Against Remedy Selection Evaluation Criteria (See Note 1)								
		Protection of Public Health and the Environment	Standards, Criteria, and Guidance (SCG)	Short-term Impact and Effectiveness	Long-tem Effectiveness and Permanence	Reduction of Toxicity, Mobility, and/or Volume	Implementability	Cost Effectiveness	Land Use	Potential for Community Acceptance[5.]
Enhanced Biochemical Degradation (EBD) Continued	1B. **Enhanced Biochemical Degradation (EBD) Component**	Only alternative under consideration with potential to actively reduce source mass and groundwater concentrations within both primary and secondary source rock and in the process further limit potential for human exposure by reducing concentrations reaching seeps and springs.	The remedy complies with the statutory requirements for Remedial Programs under 6 NYCRR Environmental Conservation Law ECL Part 375, 1.8 (C) in that it addresses source removal (1) , containment (2), and elimination of exposure (3); it complies with statutory requirements for groundwater projection and control measures (d) related to source removal (1,i) and plume containment and stabilization (1,ii).	Would require additional construction of gravel access lanes, drilling and completion of injection borings and periodic injection of amendment. We estimate that construction, testing and the initial injection could be performed within a 3 month period. Based on Pilot Study performance, we expect EBD to be active within weeks of the initial injection.	We believe that it may take years or tens of years for the full effect to be realized at downgradient monitoring points. Limited fate and transport modeling indicates that a relatively modest doubling in rates of biochemical degradation may accelerate plume reduction over a few decades. Biochemical degradation provides for permanent destruction of CVOC mass.	In ideal application, EBD reduces toxicity through complete degradation of VOCs including TCE to non-toxic by products. Present concept for application is to also reduce mobility/flux of VOC out of the primary source rock. Intended to reduce mass/volume of groundwater exceeding SCG, and over time reduce the source rock indirectly and possibly directly by increasing mass diffusion out of the rock matrix and enhancing biochemical degradation within the rock matrix, respectively.	Application of EBD to the fractured sedimentary rock setting is not a presumptive remedial technology with a proven track record. Application of EBD would not preclude later application of other technologies. Pilot testing and 2 years of performance monitoring have provided concepts for injection of amendment, however, concepts for dosing and dosing frequency can be further refined by long term performance monitoring of EBD.	Offers the potential for permanent in situ destruction of contaminant mass with less energy inputs and without transferring contaminants to another media and is more cost efficient in achieving the remedial goals.	Incrementally reduces the area of soil that would be restricted for residential and commercial uses by about 1.8-acres.	To be determined by community input to be received during public notice period.
			A 0.5 to 1 OoM reduction in downgradient groundwater concentrations would result in off-site water quality largely meeting applicable standards under 6 NYCRR Part 703.5.	Pilot testing observations support relatively rapid advective travel rates and the potential for positive changes in downgradient water quality within 6 months of injection. If sustainable under larger scale application, positive improvements in water quality may be realized in this time frame. Workers' safety to be addressed with a site-specific HASP. Will require management of investigation derived waste (drilling return water and cuttings) and decontamination of drilling equipment.	If biochemical degradation can be enhanced directly within the rock matrix, source reduction would be further accelerated. Evidence of biochemical activity within primary pore space is an area of on-going academic research.	Some potential for increased toxicity through accumulation of vinyl chloride or dissolution and mobilization of certain metals. These negative outcomes were not realized in pilot testing and can be limited through staged application of injections, performance monitoring, and possible introduction of vinyl chloride degrading microorganism cultures.	Will require permitting of underground injection of amendment. Construction of injection boreholes and injection delivery use relatively conventional drilling and packed injection technology. Although not observed in shorter duration pilot testing, there is some potential for clogging of fractures with biological mass potentially reducing the efficiency of later injections.	The estimated capital cost for EBD is about $470K and includes $110K in contingencies. The O&M at present day value over 30 years is about $1.5M. The total present value capital cost and O&M on a 30-year basis including surficial soil component is estimated at $3.5M.	Future land use will be limited by deed restrictions/ institutional controls as discussed in Table 1.	Presumably would be perceived more favorably given the potential to permanently destroy contaminant mass within primary source rock and at downgradient locations with only limited additional construction beyond what is contemplated for the surficial soil component.

Table 2
Detailed Analyses of Alternatives
Brownfield Cleanup Program
Alternative Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area

Alternative		Evaluation Against Remedy Selection Evaluation Criteria (See Note 1)								
		Protection of Public Health and the Environment	Standards, Criteria, and Guidance (SCG)	Short-term Impact and Effectiveness	Long-tem Effectiveness and Permanence	Reduction of Toxicity, Mobility, and/or Volume	Implementability	Cost Effectiveness	Land Use	Potential for Community Acceptance[5.]
Alternative 2 - Excavation and Disposal	2. **Excavation**	**As above for 1A plus:** Potential to more rapidly restore the approximately 3.2 acre area, inclusive of lead shot soils and primary source rock, to near unrestricted conditions. Unlikely to materially change water quality conditions at downgradient locations at point of potential exposure - at least in the short term. Has the potential for uncertain outcomes regarding enhanced fracturing of secondary source rock and increasing infiltration and groundwater recharge perhaps markedly.	**As above for 1A plus:** If excavation is complete, groundwater concentrations within the excavated zone are more likely to meet applicable water quality standards for VOCs (Goals 1 and 2). Some residual presence of VOCs outside the excavated area is likely. Complies with the statutory requirements for Remedial Programs under 6 NYCRR for source removal. Excavation could permanently remove an estimated 90% of the source mass from the site. (Goal 2). Since this aggressive source reduction would not materially address secondary source rock, at best, water quality conditions at downgradient locations would improve over long time (Goal 1).	**As above for 1A plus:** We had estimated that excavation may be completed in on the order of 6 months with a concerted effort and without significant delays for permitting. If successful, the reduction in contaminant source mass would be permanent. Excavation and transport of rock would involve heavy truck traffic, noise and dust. Excavation is associated with greater concern for safety for workers and the public using nearby roads. Site-specific modeling supports that absent downgradient biochemical degradation, primary source removal is unlikely to be reflected in materially improved water quality within secondary source rock and at the plume front in the short term.	**As above for 1A plus:** The effects in excavated zone should be permanent; if successful, has potential to remove 90% of the VOC mass estimated to be present. Over time, conditions may improve at down-gradient locations; however, the alternative would require on-going long-term groundwater quality monitoring, similar to other alterna-tives. Absent downgradient biochemical degradation, limited site-specific fate and transport modeling indicates that 50 years after source contain-ment or removal, positive reductions in downgradient water quality may only propagate 300 to 400 feet downgradient of the primary source rock.	**As above for 1A plus:** Would reduce the total mass and volume of rock serving as the primary source of VOCs in groundwater at the site, through transfer to another location or media. Excavation would increase the volume of soil and rock waste to be handled and more surface area for VOC mass transfer, potentially increasing mobility. With time, would reduce the concentration, toxicity, and volume of groundwater exceeding SCOs.	**As above for 1A plus:** Excavation would employ conventional technology proven in rock excavation elsewhere; however, excavation and on-site handling of the excavated materials would require: 1) Considerable footprints of land for stockpiling of excavated materials prior to loading onto trucks. 2) Dust and noise control. 3) Management and/or treatment of runoff and groundwater inflow, and 4)Post excavation confirmatory sampling. Extremely large volume of heavy truck traffic would add wear to local public roads that would likely require reparations.	Involves handling of very large volumes and mass of soil and rock to result in permanent removal of what is estimated to be a few thousand pounds of VOC mass, which would likely be relocated to a secure landfill site. Large premium cost for potentially returning about 3 acres of land to near an unrestricted state. The estimated capital cost for excavation and off-site disposal is \$16.8M and includes \$2.8M in contingencies. The total capital cost and 30 years of O&M on a present value basis is estimated at \$18.9M. Road repairs are not included in this estimate. Site improvements that could be necessary to facilitate redevelopment of the primary source rock footprint are not included.	Offers potential to reduce the need for institutional controls or deed restrictions for about 3 acres of land.	To be determined by community input to be received during public notice period. The alternative is less likely to receive community acceptance as a consequence of the heavy truck traffic, noise and dust.

Notes:
1. The table is intended to summarize the detailed analysis of remedial alternatives to address IBM Gun Club - Former Burn Pit Area and assesses the two alternatives against the remedy selection evaluation criteria outlined in New York Department of Environmental Conservation Guidance, including the May 3, 2010 DER-10/Technical Guidance for Site Investigation and Remediation.
2. Alternative 1 is divided into two components including 1A the surficial soil cap and phytoremediation components and 1B discusses the EBD groundwater and primary source rock component.
3. The three goals discussed under SCG refers to the remedial goals discussed in the Brownfield Alternatives Analysis and Remedial Work Plan text.
4. The cost estimates were generated based on vendor quotes, Sanborn, Head & Associates, Inc. experience from prior projects, and IBM's experience from the Former Shooting Range soil cleanup. By convention the estimates of cost have an accuracy of approximately +50% to -30%. See Appendix C for additional details.
5. Community Acceptance will be revisited following the Public Notice Period.
6. Please refer to Table 1, report text, and Appendices for additional details.

Table 3
Review of Green and Sustainable Remediation Practices and Considerations

Brownfield Cleanup Program
Alternatives Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area
Union, New York

Line ID	Sustainable Remediation Practices and Objectives	Triple-Bottom-Line Element			Alternative	
		Environmental	Economic	Social	1) EBD	2) Excavation
1	Limit fresh water consumption					
2	Increase water reuse					
3	Conserve groundwater resources					
4	Limit long-term erosion, surface runoff, and off-site water quality impacts					
5	Use native vegetation requiring little or no irrigation					
6	Limit bioavailability of contaminants through source and plume control					
7	Support biodiversity				X	X
8	Limit soil and habitat disturbance and create or enhance habitat or usable land					
9	Favor minimally invasive *in situ* technologies					
10	Favor low-energy technologies (e.g., bioremediation, phytoremediation) where possible and effective					
11	Protect native ecosystem and avoid introduction of non-native species				X	X
12	Limit risk to ecological receptors					
13	Preserve natural resources				X	X
14	Use automated data collection when possible					
15	Use passive sampling devices where feasible					
16	Use or generate renewable energy to the extent possible					
17	Reduce emissions of greenhouse gases contributing to climate change					
18	Reduce emissions of criteria pollutants					
19	Limit offsite migration of contamination					
20	Integrate flexibility into long-term controls to allow for future efficiency and technology improvements					
21	Invest in carbon offsets				X	X
22	Limit material extraction and use					
23	Limit waste generation					
24	Increase materials reuse					
25	Recycle or reuse project waste streams					
26	Use operations data to continually optimize and improve the remedy					
27	Consider the net economic result					
28	Improve the tax base/economic value of the property/local community					
29	Increase employment and educational opportunities				X	X
30	Limit O&M cost and effort					
31	Limit health and safety risk during remedy implementation					
32	Enhance acres of a site available for reuse					
33	Increase number of sites available for reuse				X	X
34	Use locally sourced materials					
35	Limit noise, odor, and lighting disturbance					
36	Favor technologies that permanently destroy contaminants					
37	Limit environmental and human health impacts in already disproportionately impacted communities				X	X
38	Consider new positive/negative impact of the remedy of local community					
39	Assess current, potential, and perceived risks to human health, including contractors and public, over the remedy life cycle					
40	Limit cultural resource losses				X	X
41	Integrate stakeholders into decision-making process					
42	Solicit community involvement to increase public acceptance and awareness of long-term activities and restrictions					
43	Maintain or improve public access to open space				X	X
44	Create goodwill in the community through public outreach and open access to project information					
45	Consider future land uses during remedy selection and choose remedy appropriately					
46	Conserve natural resources such as soil and water; promote the sequestration of carbon through reforestation or afforestation					
47	Limit use of heavy equipment to save energy and reduce emissions					
48	Limit equipment and truck idling and use sustainably produced biofuels to reduce discharges of pollutants and GHGs to the atmosphere					
49	Limit truck travel for disposal to save energy, reduce emissions, reduce localized noise, vibration, and wear and tear on roads					
50	Use clean diesel (new or retrofitted) equipment to reduce emissions to the atmosphere					

Notes:

1. The table summarizes a qualitative evaluation of the two alternatives against criteria for sustainable remediation practices and objectives. It is intended to support an assessment against practices and objectives relevant to the NYSDEC DER-31 *Green Remediation Guide* (2010) along with economic and societal considerations.

2. The listing of practices and objectives is based on a sustainable remediation framework developed by members of the Sustainable Remediation Forum and presented in Ellis D.E. and Hadley, P. W, Sustainable Remediation White Paper – Integrating Sustainable Principles, Practices, and Metrics into Remediation Projects, *Remediation Journal, Summer.* (2009). http://www.sustainableremediation.org/library/issue-papers/.

3. The blue bands denote which triple bottom line elements apply to the practice/objectives.

4. Please refer to the text for further discussion of sustainability and to Tables 1 and 2 for further discussion of the two remedial alternatives.

Qualitative Ratings for Goals and Criteria

Relatively Favorable or Favorable

Partial or more favorable

No clear benefit or less favorable

Concerns regarding adverse

X Not Applicable

FIGURES

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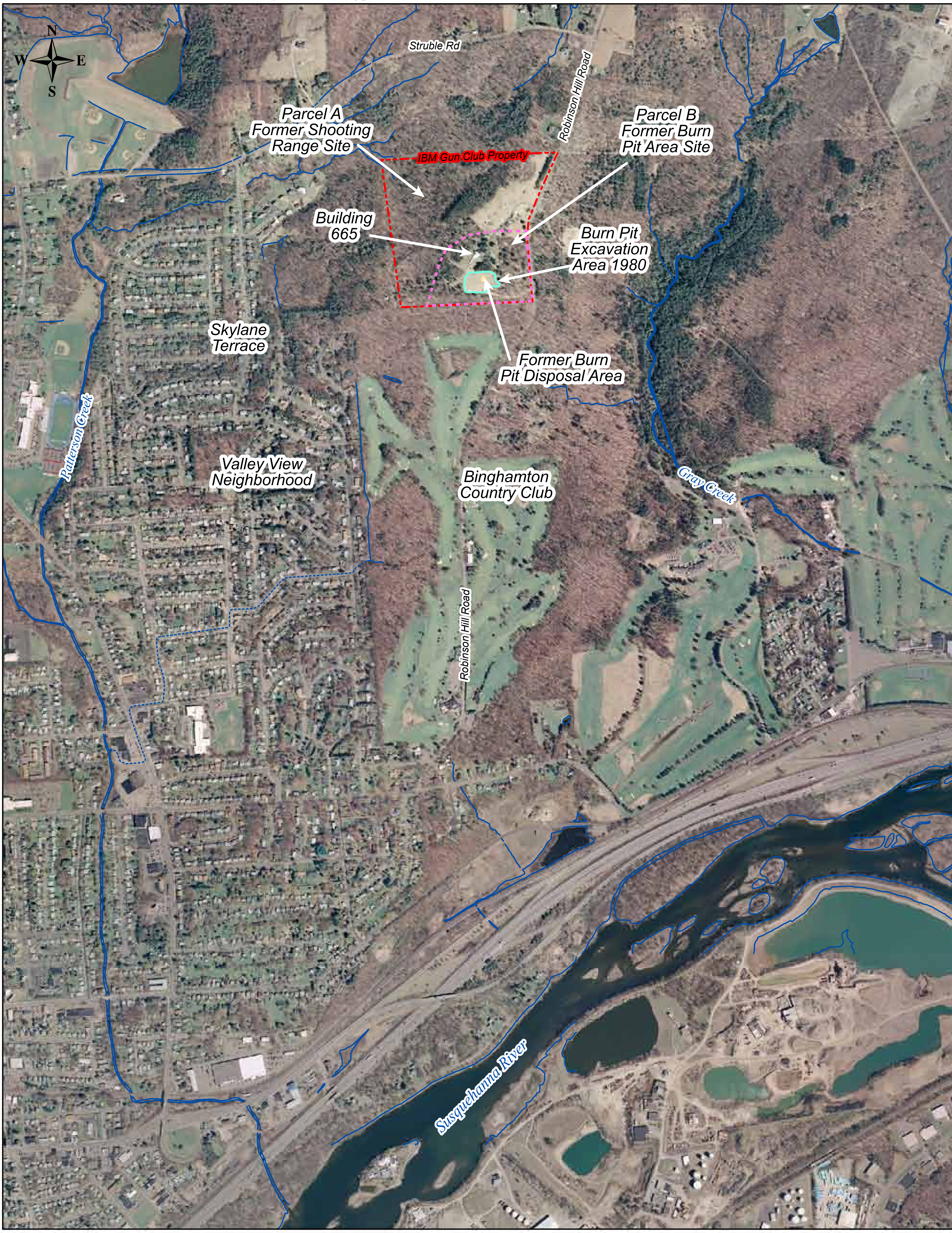

Notes:

1. The basemap consists of digital aerial photographs accessed by Sanborn Head in September 2007 via the New York State geographic information system (NYGIS) website. The aerial photographs are dated April 2006.

2. The IBM Gun Club property limits are based on information contained in two AUTOCAD drawings entitled "UNION200-.DWG" and "UNIONEAST.DWG" that were provided to Sanborn Head on October 10, 2002 by the Broome County Tax Mapping Services division.

3. The IBM Gun Club - Parcel B Former Burn Pit Area site limits are based on information contained in an IBM Gun Club - Clarification of Site boundaries letter from IBM to NYSDEC dated January 31, 2012. See Appendix B.1.

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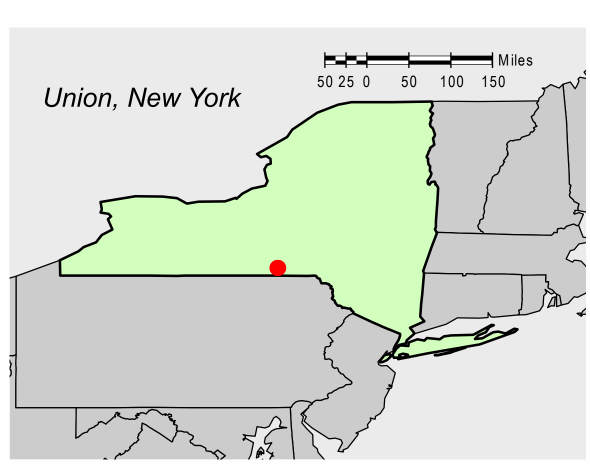


Figure 1

Locus Plan

Brownfield Cleanup Program
Alternatives Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By:	S. Warner
Designed By:	A. Horneman
Reviewed By:	D. Carr / D. Shea
Date:	December 2012

Feet
500 250 0 500 1,000 1,500

Figure 2

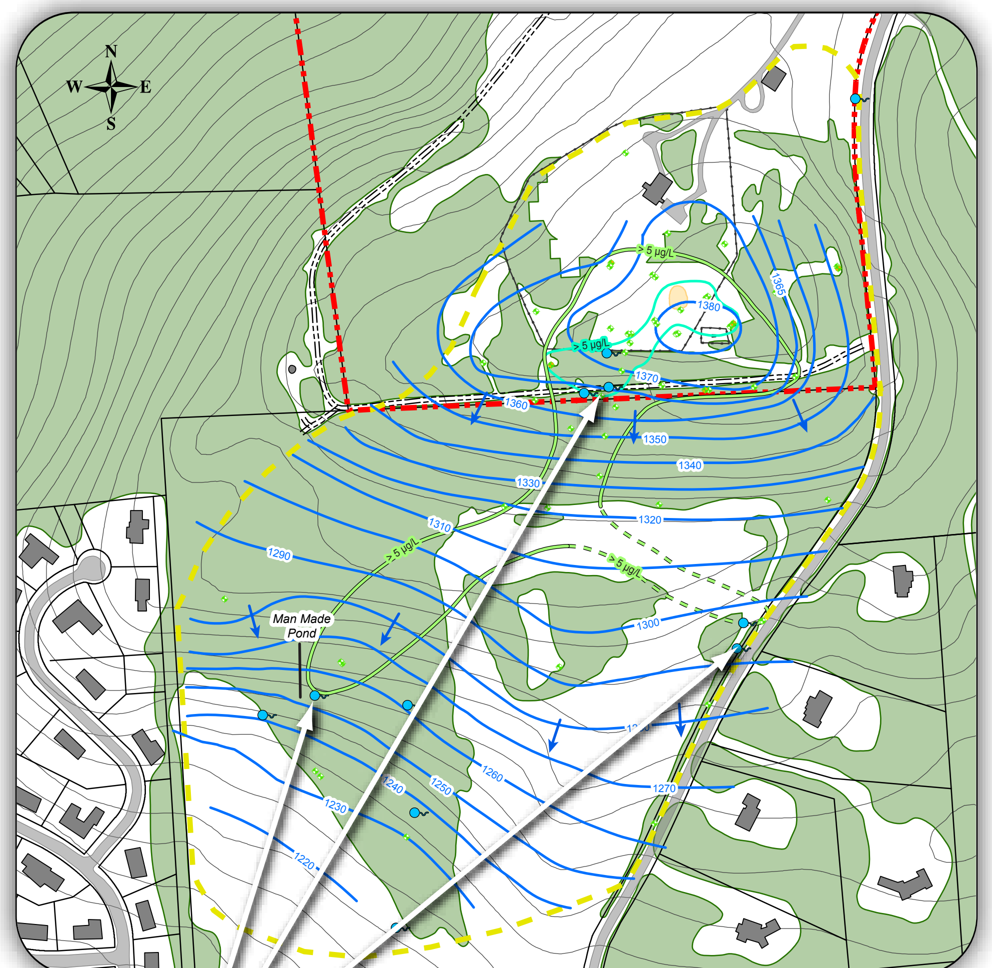
Summary of Site Conditions

Brownfield Cleanup Program
Alternatives Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By: S. Warner
Designed By: A. Horneman
Reviewed By: D. Carr / D. Shea
Project #: 3025.00
Date: December 2012

C. GROUNDWATER FLOW INFLUENCED BY HORIZONTAL FRACTURING IN UPPERMOST HIGHLY FRACTURED ROCK



RAPID GROUNDWATER TRANSPORT IN FRACTURES

Majority of VOC mass transport is through horizontal bedding-parallel fractures in the upper 40 feet of rock driven by recharge of incident precipitation through the hilltop.

The flow of groundwater through the BPA and vicinity is expected to be on the order of a few gallons per minute.

Estimated groundwater travel times to points of groundwater discharge range from a few weeks to half a year.

METAL SHOT DEPOSITION IN SURFICAL SOILS

Addressed by excavation, stabilization and off-site disposal in May 2012 under Interim Remedial Measure.

SUCCESSFUL REMOVAL OF RESIDUAL VOCs IN SOIL

1980's soil excavation was successful in removing soil containing residuals of oils and solvents from the BPA.

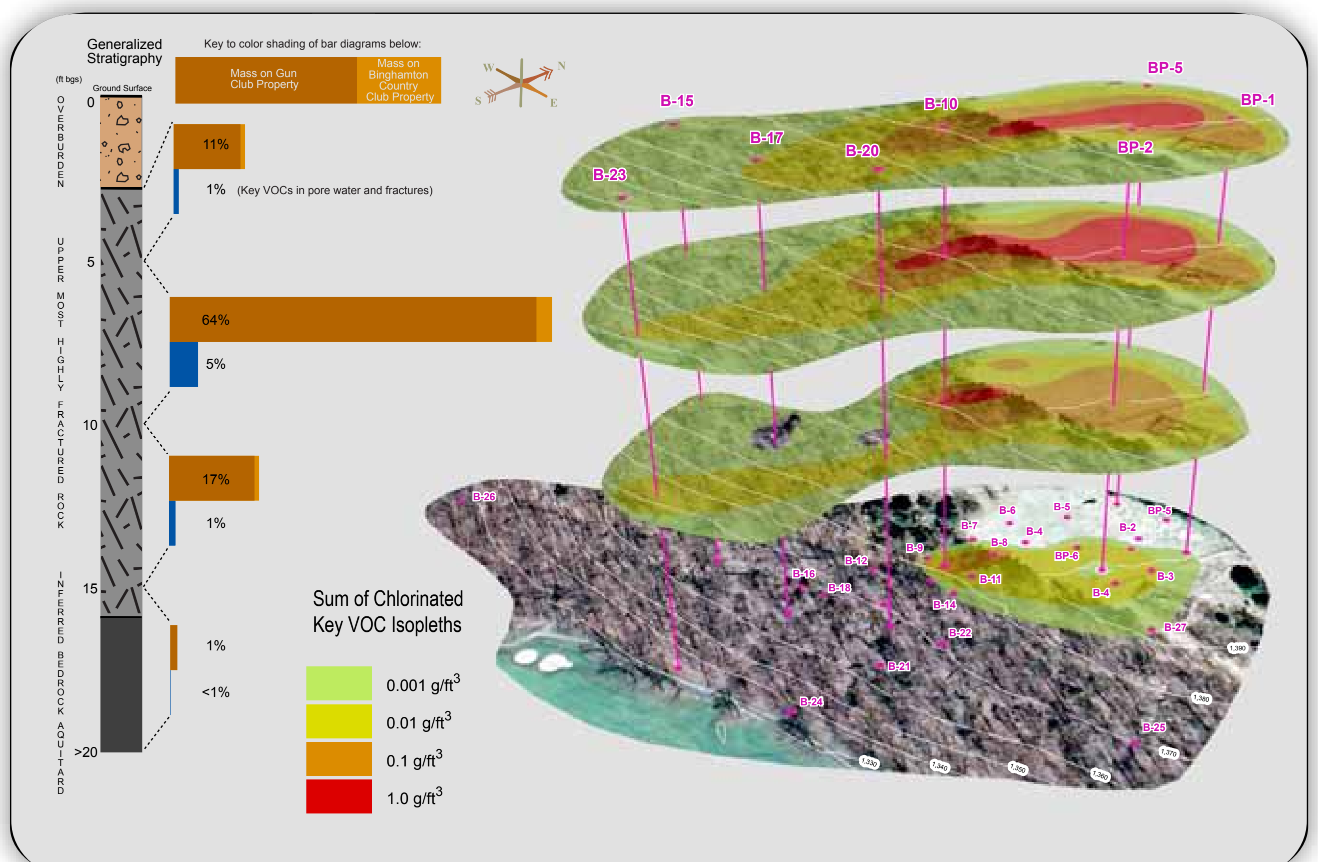
Trace metals and PCBs found in soil in the area of soil removal reflect residuals of former Burn Pit disposal, which are largely contained in the secure fenced area.

GROUNDWATER DISCHARGE AS SEEPS AND SPRINGS

The majority of water recharged at or within the BPA flows radially away in horizontal fracturing. In a few places, this flow breaks out as seeps and springs along the hill slope.

A. NATURE AND EXTENT OF CONTAMINATION UNDERSTOOD

B. VOC SOURCING FROM ROCK MATRIX DEFINED BY ANALYSIS OF ROCK CORE SAMPLES



ROCK CORE ANALYSIS DATA INDICATES A MIXTURE OF PETROLEUM AND SOLVENTS

The data definitively show that the majority of VOC mass is beneath IBM property diffused into rock at about water table depth between 5 and 10 feet below ground. The most commonly detected VOCs include chlorinated ethenes, ketones, and constituents of petroleum.

The orange and red shaded areas represent key VOCs in the primary source rock that contains over 90% of the VOC mass, principally sorbed to the rock solids. Pore water concentrations in this rock are estimated to be on the order of 10,000s to 100,000s of μg/L.

The yellow and green shading reflects rock concentrations one to two orders of magnitude lower from diffusion of VOCs dissolved in migrating groundwater.

VOC SOURCING FROM SOLVENT MASS IN LOW PERMEABILITY SEDIMENTARY BEDROCK

Primary source of on-going presence of VOCs in groundwater is VOC mass residing in the unfractured matrix of rock beneath a one and one-half acre area extending southerly from the BPA along a trough-like depression in the bedrock surface as shown by orange shading.

The shaded area is believed to reflect the probable limit of the historical penetration of a mixture of separate phase oil and solvent into fractures. See Figure B for additional details.

OBSERVED EXTENT OF VOCs IN GROUNDWATER

Largely bounded in all directions and reflects limited transport near the water table in the uppermost highly fractured rock. Transport estimated at a few tenths of a pound per year is controlled by matrix diffusion, sorption, and biological degradation and other processes.

At depth, the extent of VOCs in groundwater exceeding water quality standards is only found beneath IBM property proximate to the BPA.

Given the limited mass transport and the attenuation mechanisms the extent is not expected to increase with time. No private or public water supplies are believed to be at risk.

Legend

- Burn Pit
- Limit of Gun Club Property
- Burn Pit Area / Parcel B
- Approximate Extent of Investigation
- Monitoring Well
- Wooded Area
- Undeveloped Non Wooded Area

Hydrogeologic Conditions

- Inferred Groundwater Flow Direction
- Seeps or Springs
- Groundwater Contours (1310)
- 10 ft Topographic Contours

Contaminant Conditions

- Primary Source Zone in Rock
- Secondary Source Zone in Rock

Limits of Groundwater TCE Concentrations Exceeding New York Standards

- Water Table Monitoring Wells (> 5 μg/L)
- Deeper Well Monitoring Intervals (> 5 μg/L)
- Soil conditions believed to be associated with former burn pit disposal and exceeding residential SCOs in top two feet of soil.
- Surveyed Limits of Soil Removal Conducted Under Interim Remedial Measure (IRM) in May 2012 to Meet Residential SCO

Notes

1. The figure is intended to summarize site conditions including hydrology and the presence and extent of VOCs in groundwater and rock matrix.
2. Refer to Section 1.0 of the text for additional discussion.

Feet: 250 125 0 250 500

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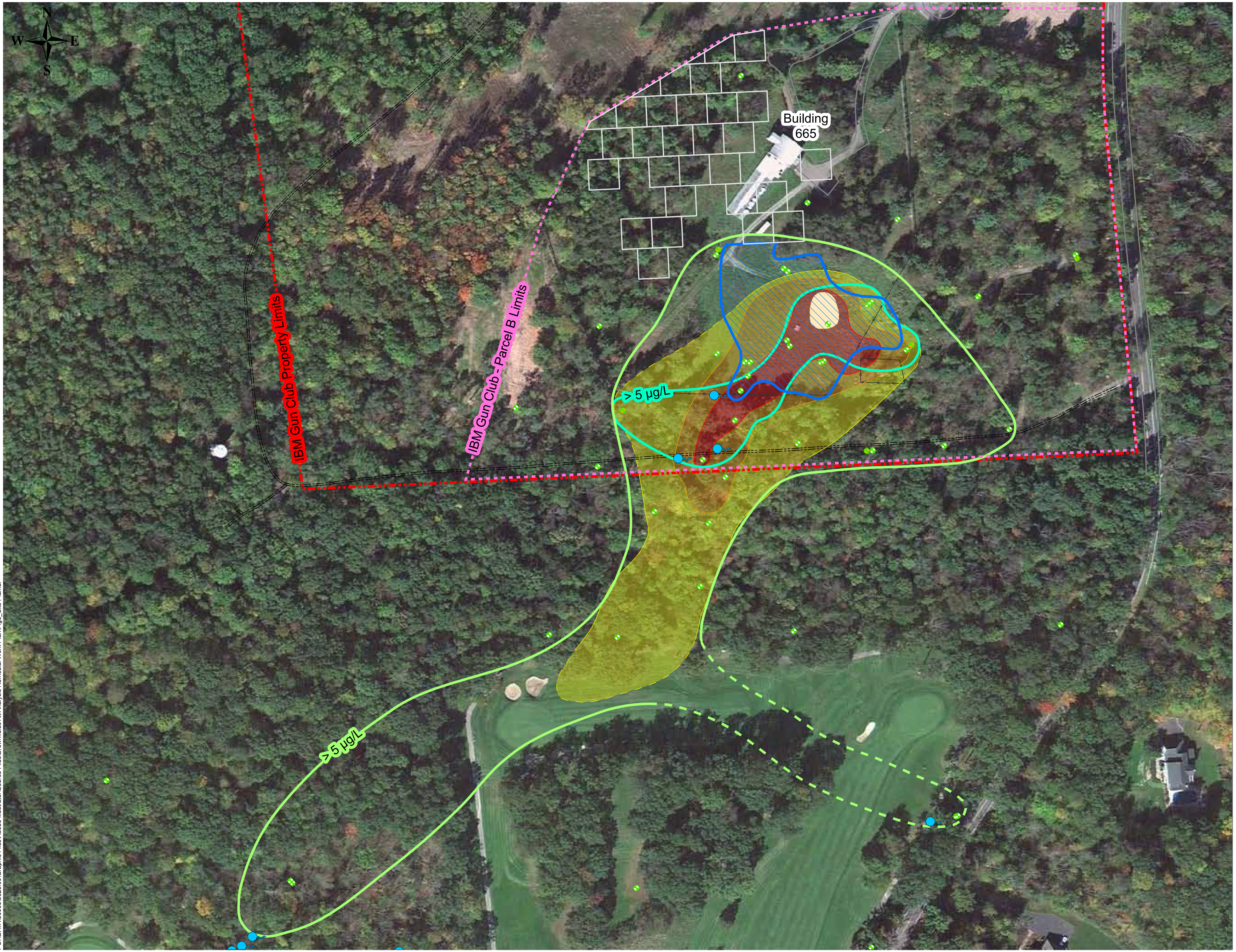

Figure 3

Site Plan

Brownfield Cleanup Program
Alternatives Analysis and
Remedial Work Plan

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By:	S. Warner
Designed By:	A. Horneman
Reviewed By:	D. Carr / D. Shea
Project No:	3025.00
Date:	December 2012

Figure Narrative

The figure summarizes site conditions believed to be relevant to this Alternatives Analysis. The figure reflects the findings of remedial investigations (RI) of the former BPA completed in 2009, by Sanborn Head and subsequent pilot testing of remedial technologies and the findings of RI associated with the Former Shooting Range completed in 2011 by others.

The locations of monitoring wells, seeps and springs, fencing, and Parcel B site limits are based on surveys by Butler Land Surveying, LLC of Little Meadows, PA, or Keystone Associates of Binghamton, NY.

Refer to Figures 1 and 2 for additional notes and legend and to the report text for additional discussion.

Legend

- Monitoring Well
- Multi Level Monitoring Well
- Seep / Spring
- Former Burn Pit Disposal Area
- Primary Source Zone in Rock
- Secondary Source Zone in Rock

Limits of Groundwater TCE Concentrations Exceeding New York Standards (>5 µg/L)

- Water Table Monitoring Wells
- Deeper Monitoring Intervals
- Soil conditions believed to be associated with former burn pit disposal and exceeding residential SCOs in top two feet of soil.
- Surveyed limits of lead shot containing soils removed by IBM in May 2012 under Interim Remedial Measures (IRM) to meet Residential SCO.

Feet: 75 37.5 0 75 150

SANBORN | HEAD ENGINEERING

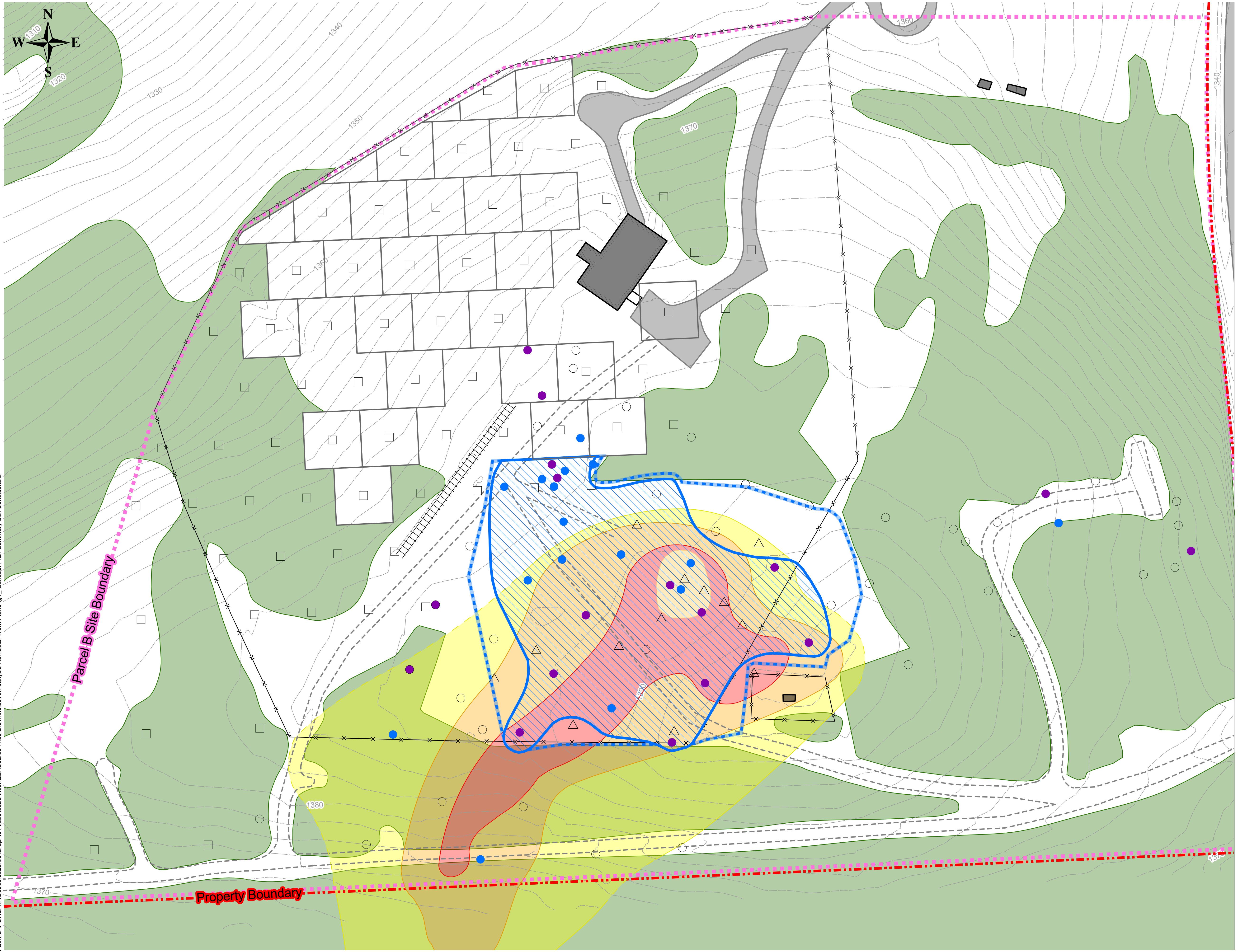

Figure 4

Summary of Soil Conditions

Brownfield Cleanup Program
Alternatives Analysis and
Remedial Work Plan
IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By:	S. Warner
Designed By:	A. Horneman
Reviewed By:	D. Carr / D. Shea
Project No:	3025.00
Date:	December 2012

Figure Narrative

The figure summarizes the available data and inference regarding where surficial soil may contain metals at concentrations exceeding NY State numerical soil cleanup objectives (SCOs) developed based on residential or commercial uses. The metals, including arsenic (As), trivalent or hexavalent chromium (Cr III, Cr VI), copper (Cu) and cadmium (Cd) are believed to be residuals remaining from former Burn Pit disposal operations.

Sporadic detections of metals outside the areas believed to be affected by former burn pit disposal are believed to reflect statistical outliers and anomalies and do not reflect site contamination.

Refer to Figures 1 through 3 for additional notes and legend, and report text for additional discussion. See Figure D.1 in Appendix D for a detailed graphic summary of the surficial soil characterization findings.

Legend

Soil Sample Location

- ○ Burn Pit Area Investigation
- □ Metal Shot Investigation
- △ Burn Pit Area Investigation - but data from >2 ft bgs considered in assessment of soil conditions.

Burn Pit Area Locations Exceeding SCO

- ● Exceeds Commercial SCO
- ● Exceeds Residential SCO

Approximate limit of Soil Cap Extension - resulting from proposed final grading of imported soils meeting residential SCO.

Soil conditions believed to be associated with former burn pit disposal and exceeding residential SCOs in top two feet of soil.

Surveyed limits of lead shot containing soils removed by IBM in May 2012 under IRM.

—1,388— Ground Surface Elevation Contour (ft)

Wooded Area

Non Wooded Area

40 20 0 40 80 Feet

SANBORN | HEAD ENGINEERING

Last Edited By: swarner

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Figure 5

Design Concepts Enhanced Biochemical Degradation

Brownfield Cleanup Program
Alternatives Analysis and
Remedial Work Plan
IBM Gun Club - Former Burn Pit Area
Union, New York

Drawn By: S. Warner/J. Pierce
Designed By: A. Horneman
Reviewed By: D. Carr / D. Shea
Project No: 3025.00
Date: December 2012

Figure Narrative

The figure depicts present concepts for the application of enhanced biochemical degradation (EBD). Injection boreholes will be constructed along lines A and B, which were sited based on considerations of apparent water quality conditions, estimates of sourcing in rock, inferred groundwater flow patterns, and surface topography.

Additional injection points may be installed based on field observations and the findings of performance monitoring.

Refer to Figures 1 through 4 for additional notes and legend and to the report text for additional discussion.

Please refer to Figure D.2 for data and inference considered in design of injection borehole locations.

Legend

- Existing Injection Borehole
- Alignment of Injection Borehole and Estimated Amendment Displacement Discussed in Report Text
- Limits of Clean Engineered 2ft Soil Cap Fill
- Proposed Fence Line
- Proposed Gravel Access Lane
- 1,388 Ground Surface Elevation Contour (ft)
- 1,388 Proposed Final Grading (ft)

40 20 0 40 80 Feet

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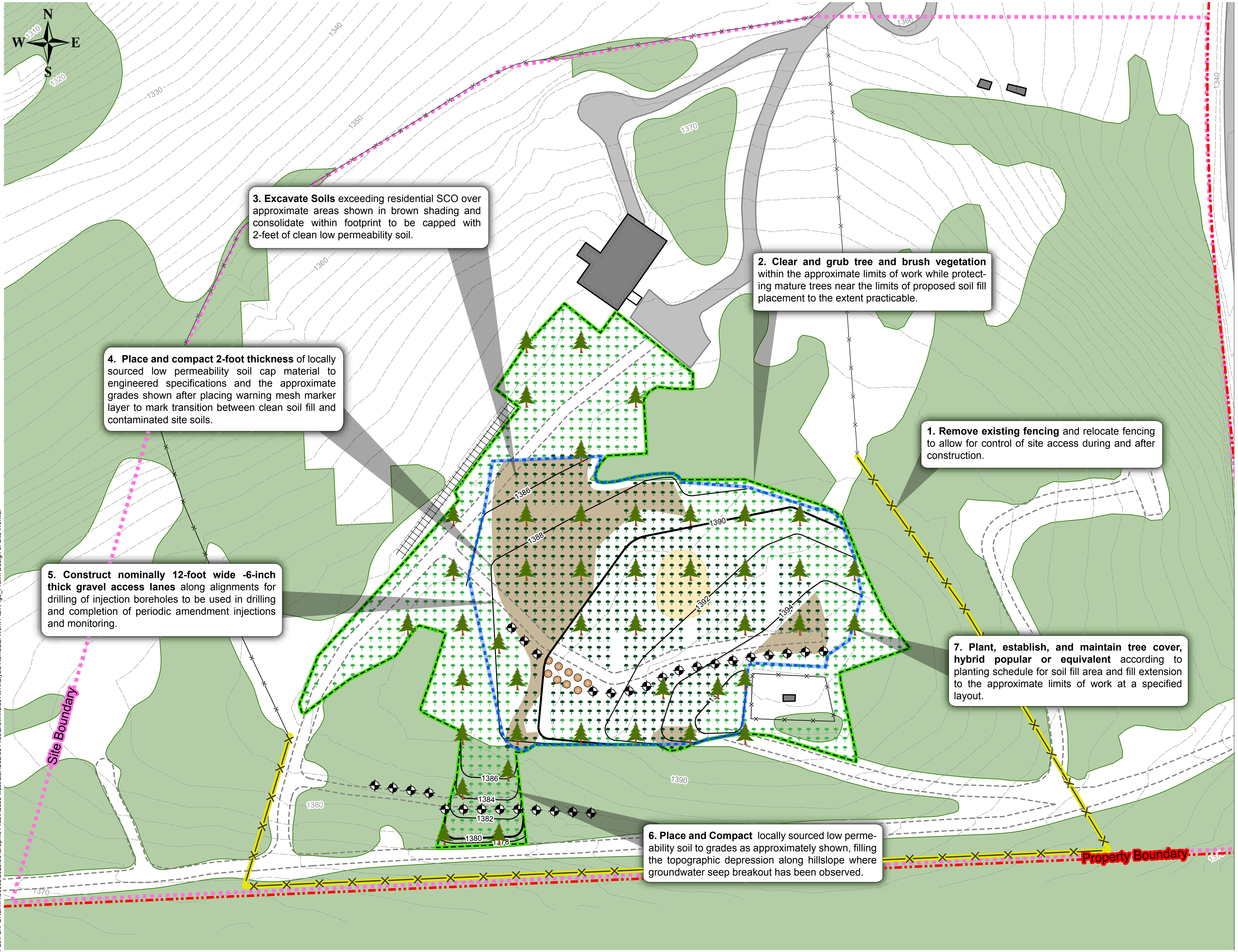

Figure 6

Design Concepts Site Work

Brownfield Cleanup Program
Alternatives Analysis and
Remedial Work Plan

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By:	S. Warner
Designed By:	A. Horneman
Reviewed By:	D. Carr / D. Shea
Project No:	3025.00
Date:	December 2012

Figure Narrative

The figure summarizes the present concepts of site work associated with the EBD alternative definded in Table 1 and includes soil excavation, capping and grading, EBD, and planting of trees for phytoremediation and enhanced evapotranspiration.

See Figures 1 through 5 for additional notes and legend, Table 1 for additional definitions, volumes and mass, and refer to Section 4.0 of the text for additional discussion.

Legend

- 1,388 Ground Surface Elevation Contour (ft)
- 1,390 Proposed Final Grading (ft)
- Proposed Area of Soil Excavation Prior to Capping
- Proposed Fence Line
- Proposed Injection Boring Location
- Approximate Limit of Soil Disturbance/Work
- Approximate limit of Soil Cap Extension - resulting from proposed final grading.

Proposed Planting Schedule

- Red Spruce (50' x 50' Grid)
- Nominal Hybrid Poplar Pole Planting (8' x 8' Grid)
- Nominal Hybrid Poplar Cutting Planting (8' x 8' Grid)

40 20 0 40 80 Feet

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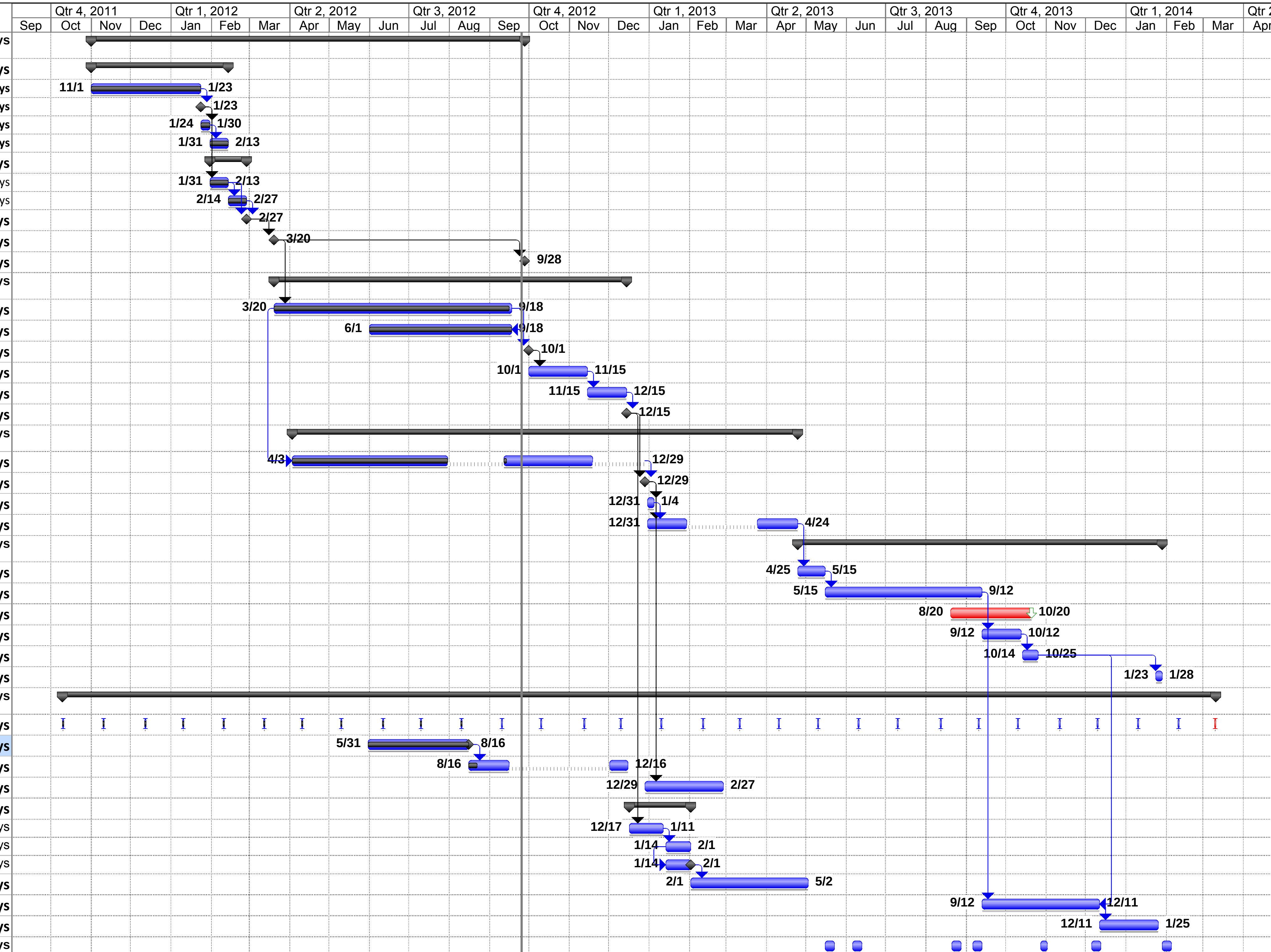
Figure 7
Schedule Projection
Alternatives Analysis through Final Engineering Report
Remedial Work Plan- IBM Gun Club Burn Pit Area

ID	Task Name	Duration
1	**1 Alternatives Analysis and Remedial Work Plan**	238 days
2	**1.1 Alternatives Analysis**	75 days
3	1.1.1 Concept Plans and Background	60 days
4	1.1.2 Meeting With NYSDEC and NYSDOH	0 days
5	1.1.3 Comparative Cost Estimates	5 days
6	1.1.4 Report Preparation	10 days
7	**1.2 Remedial Action Work Planning**	20 days
8	1.2.1 Preliminary Design Development	10 days
9	1.2.2 Report Preparation	10 days
10	**1.3 Draft Report to IBM**	0 days
11	**1.4 Draft AA and RWP to Agencies**	0 days
12	**1.5 Draft Final AA and RWP to Agencies and Repositories**	0 days
13	**2 Agency Review and Community Participation**	194 days
14	**2.1 Agency Review**	182 edays
15	**2.2 Agency Preparation of Decision Document (DD)**	109 edays
16	**2.3 Issue Public Notice**	0 days
17	**2.4 Public Notice Period**	45 edays
18	**2.5 Finalization of Decision Document**	30 edays
19	**2.6 Receipt of Approval Via Agency Acceptance Letter**	0 days
20	**3 Design Development and Contracting**	277 days
21	**3.1 95% Complete Design**	270 edays
22	**3.2 Design Submittal to Agencies**	0 days
23	**3.3 Final Design Documents**	5 days
24	**3.4 Contracting of Construction**	45 days
25	**4 Construction**	199 days
26	**4.1 Mobilization**	15 days
27	**4.2 Site Work**	120 edays
28	**4.3 NYSDOT Seeding Period**	44 days
29	**4.4 Drilling and Construction of Injection Galleries**	30 edays
30	**4.5 Initial Amendment Injection A-A' Alignment**	10 days
31	**4.6 Second Amendment Injection B-B' Alignment**	5 edays
32	**5 Reporting**	631 days
33	**5.1 Progress Reporting**	631 days
64	**5.2 Metal Shot IRM Construction Completion Report (CCR)**	77 edays
65	**5.3 Agency Review of Lead Shot CCR**	122 edays
66	**5.4 Preparation of Environmental Easement**	60 edays
67	**5.5 Site Management Plan (SMP)**	35 days
68	5.5.1 Institutional and Engineering Control Plan (IEC Plan)	20 days
69	5.5.2 Monitoring and Quality Control Plan	15 days
70	5.5.3 Operations and Maintenance Plan (O&M Plan)	15 days
71	**5.6 Agency Review of SMP**	90 edays
72	**5.7 Final Engineering Report (FER)**	90 edays
73	**5.8 Agency Review of FER**	45 edays
74	**6 Performance Monitoring First Year**	189 days



Task		Milestone	◆	Rolled Up Critical Task	
Critical Task		Summary		Rolled Up Milestone	◇
Progress		Rolled Up Task		Rolled Up Progress	
Split		Group By Summary			
External Tasks		Deadline	⇩		
Project Summary					

Project:63025.00 Burn Pit Area
Date: December 19, 2012

APPENDIX A

LIMITATIONS

APPENDIX A
LIMITATIONS

1. The findings and conclusions described in this report are based in part on representations made from a limited number of remedial technology vendors, various general public information sources, and limited bench and field scale pilot studies. These data have been generally applied to known site conditions for the purpose of providing a relative comparison of remedial technologies for the IBM Gun Club – Former Burn Pit Area.

2. Quantitative laboratory analyses were performed as part of the RI and pilot studies, as noted in this and prior reports submitted to the Agencies. SHPC has relied upon the data provided by the analytical laboratory and the findings of data validation and usability evaluations conducted by others. It should be noted that variations in the types and concentrations of contaminants and variations in their distribution may occur due to the passage of time with hydrologic variability and other factors.

3. The conclusions and recommendations contained in this report are based in part upon various types of physical and chemical data and are contingent on its validity. Should additional chemical data, historical information, or hydrogeologic information become available in the future, such information should be reviewed by SHPC and the interpretations, conclusions and recommendations presented herein may be modified accordingly.

4. This report has been prepared for, and is intended for use of, the IBM Corporation for specific application to the Brownfield Remediation of the IBM Gun Club – Former Burn Pit Area in Union, New York, in accordance with generally accepted professional practice. No other warranty is made express or implied.

5. This report contains comparative cost estimates for the purpose of comparing the possible relative cost of remedial alternatives. The estimates were prepared with preliminary engineering concepts developed with about 10% to 50% of engineering completion. As such the estimated are limited in accuracy, due to scope and unit cost uncertainty. These estimates are intended to support the screening and detailed analysis of alternatives, and are not intended for budgeting purposes. The costs provided are initial estimates; they do not represent firm pricing or fixed, lump sum bids nor do they represent guaranteed maximum costs.

6. SHPC is not responsible for any claims, damages, or liability associated with interpretation of subsurface data or re-use of the subsurface data or engineering analyses for purposes other than the purpose of this document without the express written authorization of SHPC.

APPENDIX B

SUPPORTING DOCUMENTATION

APPENDIX B.1

SITE BOUNDARY DOCUMENTATION

IBM

8976 Wellington Road
Manassas, VA 20109

January 31, 2012

Mr. Jonathan Greco
New York State Department of Environmental Conservation
625 Broadway
Albany, NY
12233-7016

Subject: IBM Gun Club – Clarification of Site boundaries
BCP #C704043 Former Shooting Range
BCP #C704044 Burn Pit

Mr. Greco,

As a follow up to my letter of January 21, 2011, IBM wishes to clarify the Site Description in the Brownfield Cleanup Agreements (BCA) for the subject projects. The current Site Descriptions in the BCAs were developed during the Brownfield Cleanup Program application process and are not in the form of a *metes and bounds surveyor's description.*

The attached drawing was prepared by Keystone Associates, a New York State licensed surveyor, and provides both the location of the Site boundaries and the *metes and bounds surveyor's description* for each Site. Permanent surveyor markers have been installed on the parcel to delineate the two Sites.

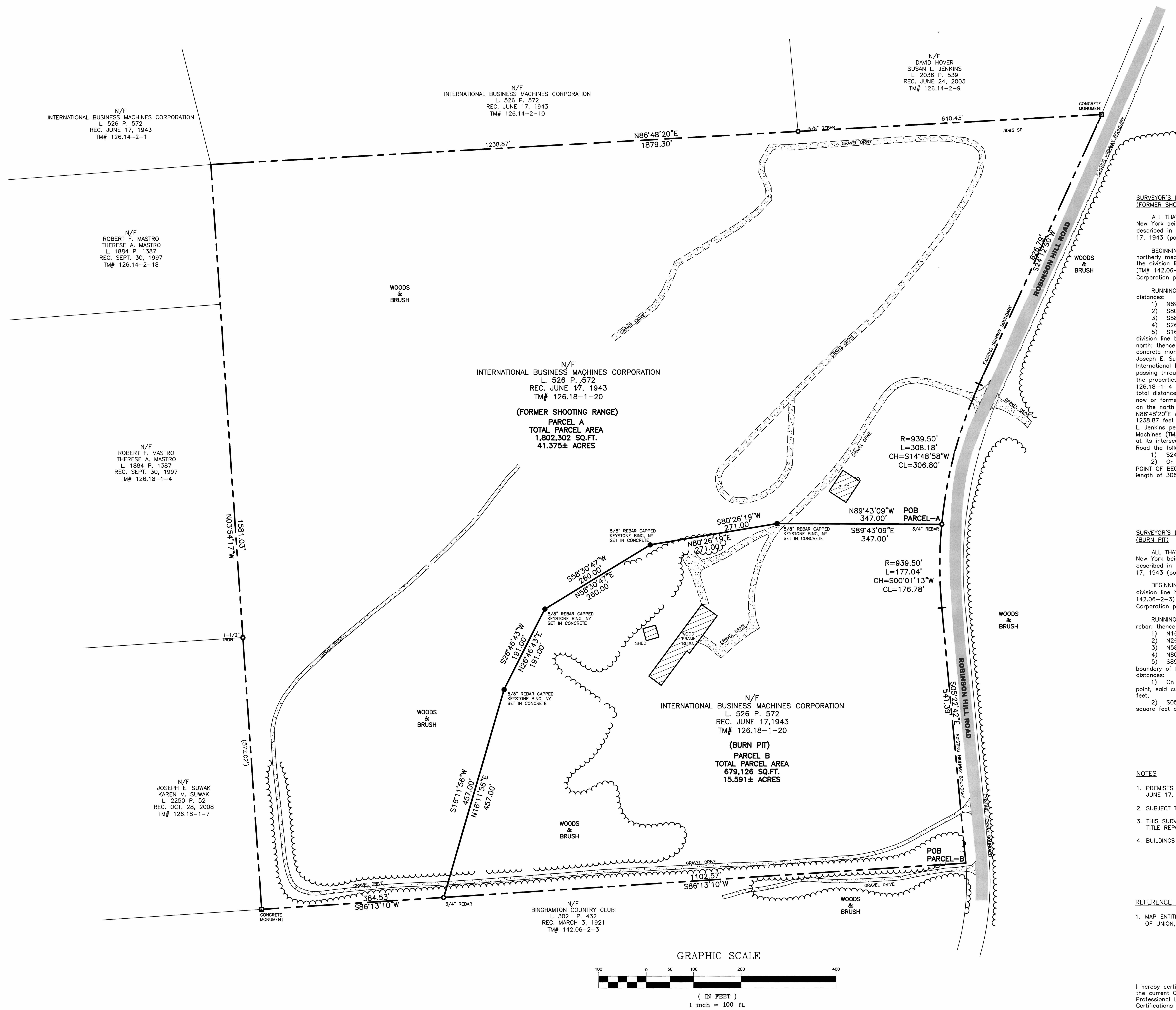
Please consider this letter a formal request to modify the Site Description in each of the subject BCAs. If you have any questions regarding this issue, please contact me at 703-257-2582.

Sincerely,

K Whalen

Kevin Whalen
IBM Program Manager

Enclosure:
Boundary Survey – Former IBM Gun Club



LEGEND

- ⊙ MONUMENT FOUND AND NOTED
- N/F NOW OR FORMERLY
- TM# TAX MAP NUMBER
- -○- UTILITY POLE
- —— PROPERTY LINE

TRUE NORTH
76°35' MERIDIAN
OF WEST LONGITUDE

SURVEYOR'S DESCRIPTION – PARCEL A
(FORMER SHOOTING RANGE)

ALL THAT TRACT OR PARCEL OF LAND situate in the Town of Union, County of Broome and State of New York being a portion of the property now or formerly of International Business Machines Corporation described in Liber 526 of Deeds at Page 572 as recorded in the Broome County Clerk's Office on June 17, 1943 (portion of TM# 126.18–1–20), bounded and described as follows:

BEGINNING at a 3/4 inch rebar on the westerly boundary of Robinson Hill Road, said point being northerly measured along said boundary, a distance of 718.43 feet from a point at its intersection with the division line between the property now or formerly of Binghamton Country Club per L. 302 P. 432 (TM# 142.06–2–3) on the south and the property now or formerly of International Business Machines Corporation per L. 526 P. 572 (TM# 126.18–1–20) on the north;

RUNNING THENCE through said International Business Machines the following five (5) courses and distances:
1) N89°43'09"W, a distance of 347.00 feet to a point;
2) S80°26'19"W, a distance of 271.00 feet to a point;
3) S58°30'47"W, a distance of 260.00 feet to a point;
4) S26°46'43"W, a distance of 191.00 feet to a point;
5) S16°11'56"W, a distance of 457.00 feet to a 3/4 inch rebar at its intersection with said division line between Binghamton Country Club on the south and International Business Machines on the north; thence S86°13'10"W along the last mentioned division line, a distance of 384.53 feet to a concrete monument at its intersection with the division line between the property now or formerly of Joseph E. Suwak & Karen M. Suwak per L. 2250 P. 52 (TM# 126.18–1–7) on the west and said International Business Machines on the east; thence N03°54'17"W along the last mentioned division line, passing through a 1–1/2 inch iron at a distance of 572.02 feet, and along the division line between the properties now or formerly of Robert F. Mastro & Therese A. Mastro per L. 1884 P. 1387 (TM# 126.18–1–4 & TM# 126.14–2–18) on the west and said International Business Machines on the east, a total distance of 1581.03 feet to a point at its intersection with the division line between the property now or formerly of International Business Machines Corporation per L. 526 P. 572 (TM# 126.14–2–10) on the north and said International Business Machines (TM# 126.18–1–20) on the south; thence N86°48'20"E along the last mentioned division line, passing through a 5/8 inch rebar at a distance of 1238.87 feet and along the division line between the property now or formerly of David Hover & Susan L. Jenkins per L. 2036 P. 539 (TM# 126.14–2–9) on the north and said International Business Machines (TM# 126.18–1–20) on the south, a total distance of 1879.30 feet to a concrete monument at its intersection with said westerly boundary of Robinson Hill Road; thence along said Robinson Hill Road the following two (2) courses and distances:
1) S24°12'50"W, a distance of 626.79 feet to a point;
2) On a curve to the left having a radius of 939.50 feet, an arc distance of 308.18 feet to the POINT OF BEGINNING, said curve being subtended by a chord having a bearing of S14°48'58"W and a length of 306.80 feet. Containing 1,802,302 square feet or 41.375 acres, more or less.

SURVEYOR'S DESCRIPTION – PARCEL B
(BURN PIT)

ALL THAT TRACT OR PARCEL OF LAND situate in the Town of Union, County of Broome and State of New York being a portion of the property now or formerly of International Business Machines Corporation described in Liber 526 of Deeds at Page 572 as recorded in the Broome County Clerk's Office on June 17, 1943 (portion of TM# 126.18–1–20), bounded and described as follows:

BEGINNING at a point on the westerly boundary of Robinson Hill Road at its intersection with the division line between the property now or formerly of Binghamton Country Club per L. 302 P. 432 (TM# 142.06–2–3) on the south and the property now or formerly of International Business Machines Corporation per L. 526 P. 572 (TM# 126.18–1–20) on the north;

RUNNING THENCE S86°13'10"W along said division line, a distance of 1102.57 feet to a 3/4 inch rebar; thence through said International Business Machines the following five (5) courses and distances:
1) N16°11'56"E, a distance of 457.00 feet to a point;
2) N26°46'43"E, a distance of 191.00 feet to a point;
3) N58°30'47"E, a distance of 260.00 feet to a point;
4) N80°26'19"E, a distance of 271.00 feet to a point;
5) S89°43'09"E, a distance of 347.00 feet to a 3/4 inch rebar at its intersection said westerly boundary of Robinson Hill Road; thence along said Robinson Hill Road the following two (2) courses and distances:
1) On a curve to the left having a radius of 939.50 feet, an arc distance of 177.04 feet to a point, said curve being subtended by a chord having a bearing of S00°01'13"W and a length of 176.78 feet;
2) S05°22'42"E, a distance of 541.39 feet to the POINT OF BEGINNING. Containing 679,126 square feet or 15.591 acres, more or less.

NOTES

1. PREMISES SOURCE OF TITLE BEING L.526 P.572, RECORDED IN THE BROOME COUNTY CLERK'S OFFICE JUNE 17, 1943.
2. SUBJECT TO ANY AND ALL EASEMENTS OF RECORD AND/OR AS FOUND IN THE FIELD.
3. THIS SURVEY WAS PREPARED WITHOUT THE BENEFIT OF AN ABSTRACT OF TITLE TO THE PROPERTY OR A TITLE REPORT.
4. BUILDINGS ARE AS SHOWN FROM 1992 AERIAL PHOTOGRAPHY.

REFERENCE DATA

1. MAP ENTITLED "SURVEY FOR JOSEPH E. & KAREN M. SUWAK & ALAN S. & SHIRLEY J. CUNDY, TOWN OF UNION, BROOME COUNTY, NEW YORK" PREPARED BY LYNN PULLIS, L.S. APRIL 21, 2005.

I hereby certify to OMEGA ENVIROMENTAL MANAGEMENT that this survey was prepared in accordance with the current Code of Practice for Land Surveys adopted by the New York State Association of Professional Land Surveyors, Inc. This certification is limited to persons for whom this map is prepared. Certifications are not transferable to additional institutions or subsequent owners.

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STATE OF NEW YORK · RODNEY LEE CAREY · No. 049642 · LICENSED LAND SURVEYOR
RODNEY L. CAREY PLS # 049642

WARNING:
It is a violation of Section 7209, Subdivision 2, of the New York State Education Law for any person unless acting under the direction of a Licensed Professional Architect, Engineer or Surveyor to alter in any way, any plans, specifications, plats or reports to which the seal of a Professional Architect, Engineer or Surveyor has been applied.
Only boundary survey maps with the surveyor's embossed seal are genuine true and correct copies of the surveyor's original work and opinion.

NO.	REVISIONS AND DESCRIPTIONS	DATE:

BOUNDARY SURVEY
FOR
OMEGA ENVIRONMENTAL MANAGEMENT
FORMER IBM GUN CLUB
1395 ROBINSON HILL ROAD
TOWN OF UNION BROOME COUNTY NEW YORK STATE

SHEET NO. **SU-1**
PROJECT NO. **357.08410**
DATE OF FIELD WORK: 05/24/10
DATE OF MAP: 01/13/11
CAD FILE NO.: 35708410SU-1.dwg

APPENDIX B.2

JUNE 2009 INITIAL SCREENING OF REMEDIAL ALTERNATIVES

SANBORN, HEAD ENGINEERING, PC
20 Foundry Street ▪ Concord, NH 03301
P (603) 229-1900 ▪ F (603) 229-1919

To: Mr. Kevin Whalen,
IBM Corporate Environmental Affairs

From: Daniel B. Carr, P.E., Vice President, and Principal
Sanborn, Head Engineering, P.C.
Allan H. Horneman, Dr.Eng.Sci, Senior Project Manager
Sanborn, Head & Associates, Inc.

File: 3025.00

Date: July 21, 2009

Re: Initial Screening of Remedial Alternatives
Brownfield Cleanup Program Alternative Assessment
IBM Gun Club Property, Former Burn Pit Area

cc: Mr. David Shea (SHPC), and Dr. Paula Mouser (SHA)

INTRODUCTION

This memorandum report provides a summary of the initial screening of remedial alternatives for the IBM Gun Club – Former Burn Pit Area and a possible path for moving forward with the Alternatives Assessment. The initial screening performed by Sanborn, Head Engineering, P.C. (SHPC), with assistance from Sanborn Head & Associates, Inc. (SHA) personnel, included development of preliminary opinions of probable cost for certain alternatives identified for additional analysis in the Remedial Investigation Report of Findings (RI Report)[1]. The intent of this initial screening is to identify alternatives that offer greater potential for application at the site and are therefore worthy of additional focused assessment that may include field and laboratory testing. We understand that IBM may share this memorandum with New York State Department of Environmental Conservation (NYSDEC) and New York State Department of Health (NYSDOH) as documentation of progress in completing the alternative analysis process.

The remedial alternatives subject of this screening and that were identified in the RI Report include:

- Monitored Natural Attenuation;

[1] Sanborn, Head & Associates, Report of Findings, Brownfield Cleanup Program Remedial Investigation, IBM Gun Club – Former Burn Pit Area, Union, New York, April 10, 2009.

- Enhanced Biochemical Degradation;
- Hydraulic Containment
- In-Situ Thermal Desorption; and
- Excavation of Primary Source Rock with a) off-site disposal, b) ex-situ thermal treatment and off-site disposal, and c) ex-situ thermal treatment and on-site disposal.

Although permeable reactive barrier technology was also identified for further analysis, this potential alternative was not carried through this initial screening in that it was considered to have practicability and cost limitations to application in bedrock without advantages over groundwater extraction and treatment. Phytoremediation and capping are technologies still in consideration for possible application to the site as technology components of one or more alternatives, but not as standalone applications.

The initial screening of alternatives was performed in consideration of the nine criteria outlined in the NYSDEC Brownfields Guidance[2, 3] including:

1) Protection of Human Health and the Environment;
2) Standards, Criteria, & Guidance;
3) Short-term Effectiveness and Impacts;
4) Long-term effectiveness and Permanence;
5) Reduction of Toxicity, Mobility, and/or volume;
6) Implementability;
7) Cost Effectiveness;
8) Community Acceptance; and
9) Land Use.

Table 1 summarizes our screening of the alternatives based on the first seven of the criteria. The text to follow discusses our impressions of Community Acceptance and Land Use considerations. These two criteria will be revisited based on input from representatives of the Binghamton Country Club. The assessment was conducted considering the primary remedial goals outlined in the RI report which were to 1) Reduce the downgradient VOC mass flux from the Burn Pit Area (BPA) primary source zone, and 2) Reduce VOC Source Mass.

The present concepts regarding the possible application of the alternatives to the site are depicted on Figures 1 through 3. A description of the alternatives is provided in the first column of Table 1. The preliminary opinions of probable cost (cost estimates), summarized below and outlined in more detail in Attachment 1, were developed based on the concepts referenced above using certain simplifying assumptions and standard cost estimating references, supplemented by SHPC and SHA experience in similar work. Unit rates provided by certain vendors including Veolia of Latham, NY (Veolia), and TerraTherm of Fitchburn, MA (TerraTherm), are reflected in the estimates. We have added a 20% contingency for scope and cost uncertainties and by

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[2] New York State Department of Environmental Conservation, Draft Brownfield Cleanup Program Guide, May 2004.

[3] New York State Department of Environmental Conservation, Draft DER-10, Technical Guidance for Site Investigation and Remediation, Section 4, December 2002.

convention the preliminary estimates have an accuracy of approximately +50% to -30%. Unless otherwise noted, the estimates do not include estimates of cost for routine monitoring which are common to all of the alternatives. The estimates do not include costs for programs of pilot testing.

The resultant estimates of the probable magnitude of cost are prepared with less than 10% of engineering completed. Accordingly, these costs represent professional opinions and are not the equivalent of a bid to complete the work such as might be generated by a construction contractor or construction cost estimator. The resultant capital and operations & maintenance cost (O&M) estimates rounded to two significant figures are outlined below and discussed further in the text to follow.

	Capital Cost		
1a. Excavation and off-site disposal	$13,000,000		
1b. Excavation, ex-situ thermal desorption, and off-site disposal	$12,000,000		
1c. Excavation, ex-situ thermal desorption, and on-site backfill	$6,800,000		
2. In-situ thermal treatment	$4,800,000		
3. Enhanced bioremediation	$370,000	annual O&M	$98,000
4. Hydraulic containment	$500,000	annual O&M	$90,000

Exhibit 1 - Summary of Preliminary Opinions of Probable Capital and O&M Cost.

Table 1 also outlines a screening of monitored natural attenuation as the baseline alternative for which to compare other alternatives. The present value of the capital and O&M costs as outlined on Table 1, were developed assuming a 30-year operating period and assuming that inflation and interest rates would be roughly equivalent for the period. We would update the analysis should IBM wish to modify this analysis under different assumptions regarding an "effective interest, or discount rate".

SUMMARY OF INITIAL ASSESSMENT OF REMEDIAL ALTERNATIVES

Based on the screening analysis, excavation and ex situ treatment/disposal of primary source zone bedrock warrants elimination from further consideration at this point (Table 1). Our conclusion is based on several factors, including:

- The probable cost is at least a factor of two higher than the remaining alternatives;

- The greater perceived level of worker and public safety risk compared to the other remedial alternatives;

- Consideration of perceived lower potential for Community Acceptance given the probable noise and dust associated with excavation and on-site ex situ treatment, and safety concerns related to heavy truck traffic associated with off-site transport and disposal;

- Uncertainty regarding the availability of technology, viability of permitting, and effectiveness of ex situ thermal treatment of excavated rock; and

- Potential for enhanced groundwater flow through the area affected by excavation and backfill.

We may revisit source zone excavation as a remedial option should new information come to light, or should the further assessment rule out the alternatives taken forward from this point.

We recommend focusing future assessment work on the remaining four other alternatives. Conclusions from the Initial Alternatives Analysis provided in Table 1 include:

- The present value estimates for Enhanced Biochemical Degradation, Hydraulic Containment, and In-situ Thermal Desorption are similar ($3.2M to $4.8M) and about twice to three times the cost of Monitored Natural Attenuation.

- Enhanced Biochemical Degradation and Hydraulic Containment should both be viewed as long-term treatments managing migration, but not significantly addressing VOC source removal from rock. As such, these measures would have to be operated for an interminable period, probably longer than the 30 years assumed by convention in the present value analysis.

- Enhanced biochemical degradation offers relatively lower capital cost, lower energy usage, and less concern for worker safety, along with the potential to permanently destroy VOC source mass located inside and outside of the primary source zone, and as such, offers some potential advantages over hydraulic containment. Enhanced biochemical degradation is the only alternative under consideration with a potential to directly address VOCs in groundwater downgradient of the primary source zone if conditions conducive to VOC degradation can be established and maintained. This alternative poses some risk of negative outcomes namely the accumulation of more toxic breakdown products and somewhat greater uncertainty as to short- and long-term effectiveness.

- In-situ thermal desorption is the only alternative of the four that has the potential to significantly address the mass in rock serving as the primary source of VOCs in groundwater. However, it should be acknowledged that Enhanced Biochemical Degradation offers at least marginal potential to accelerate mass transfer from both primary and secondary source rock by destroying mass migrating in the fractures directly within the source rock;

- Based on our present assessment of groundwater flow and transport, Hydraulic Containment may only annually remove a few tenths of a pound of VOC mass believed to be migrating from the primary source rock on an annual basis and would likely alter water levels within the primary source area such that the rate of VOC mass removal may be greater or less.

- Monitored Natural Attenuation would likely result in "status quo" at the site. In this light, please recall that the observations and inference discussed in the RI Report suggest that the nature and extent of VOCs in groundwater is not likely to materially change for the worse or better in the future without intervention.

- Monitored Natural Attenuation, Hydraulic Containment and/or Enhanced Biochemical Degradation could be implemented in sequence or in parallel with other alternatives.

We conclude that In situ technologies, including Thermal Treatment and Enhanced Biochemical Degradation, offer similar order of magnitude costs on a present value basis and greater potential for application to the site as compared with source excavation and hydraulic containment. These alternatives also are believed to offer substantially greater or similar potential for community acceptance as compared to source excavation and hydraulic containment, respectively. If effective in source reduction, Thermal Treatment would offer greater flexibility in future land use. However, both of these alternatives bring uncertainty regarding short- and long-term performance.

To move the Alternatives Assessment forward we recommend that IBM consider measures to reduce the uncertainty associated with these alternatives and support a more rigorous analysis necessary to support selection of a preferred alternative. The testing already underway or that could be undertaken to reduce the uncertainties include:

1) *Effect of migration control or source reduction/removal on downgradient water quality conditions outside of the primary source zone.* We have discussed and are proceeding with scoping a program of additional fate and transport modeling to address this uncertainty.

2) *Presence or absence of microbial populations capable of fully degrading TCE and its daughter products?* We have begun a program of testing using Biotrap technology to aid in assessing the microbial populations and potential rates of biochemical degradation under present and augmented conditions.

3) *Enhanced biological degradation of VOCs by adding source of carbon, nutrients, and/or bioaugmentatio*n. Uncertainties regarding distribution of nutrients, residence or contact time, and the possibility of accumulation of intermediate breakdown products can be assessed by pilot field studies. The findings of pilot field studies would be used to scale up to a full-scale implementation of this alternative.

4) *Treatability of IBM Gun Club fractured rock by in-situ thermal desorption.* A demonstration project is presently being reviewed by TerraTherm at a site with similar sedimentary bedrock conditions. We understand that the thermal treatment is near completion and that TerraTherm is in the process of scoping post-treatment performance testing. The findings of this work will become available over the remainder of 2009. We recommend that IBM follow the progress of this demonstration project. We have discussed the possibility of a laboratory treatability study to further assess if the rock is treatable by thermal desorption. Assuming a positive outcome IBM could choose to move the alternative forward with a field-scale pilot study.

POSSIBLE SEQUENCE

Exhibit 2 below summarizes a possible sequence of investigations and testing toward completing the Alternatives Analysis incorporating both treatability and pilot studies.

Date	Item	Comments
May to September, 2009	Biotraps	A program of Biotraps testing has been underway since May with the goal of further exploring biochemical processes and degradation rates. Biotrap devices have been deployed and are currently being sampled every 3 to 4 weeks. The laboratory analysis results will be available in late August 2009 and SHPC will prepare a report of findings in September.
July 2009 and forward	TerraTherm Trenton Demonstration Project	The physical properties of the rock at the Trenton site are similar to those at the Gun Club. The thermal desorption treatment process will be terminated in July, 2009. We will follow the results of the Trenton pilot study and stay informed through communications with the contractor.
July to September, 2009	Updated Fate and transport modeling	SHA is working with University of Guelph to prepare a scope of limited fracture transport modeling using parameters consistent with the RI findings.
August to December 2009	Potential In-situ Thermal desorption treatability study	Would involve drilling and collecting rock core samples from the site for laboratory testing. The scope of work will be developed with input from University of Guelph and TerraTherm.
Winter 2009/Spring 2010	Pilot Study, Enhanced Biochemical Degradation	Based on biotrap results, we may recommend development and execution of a field study to further explore the potential of enhanced biological degradation, both in the vicinity of the former Burn Pit Area and downgradient.
2010/2011	Pilot field study of in-situ thermal desorption	Depending on the treatability testing results IBM may choose to proceed with an in-situ thermal desorption pilot test at the site. The pilot test may take up to six months, and the monitoring and rock core sampling to confirm a positive outcome my take up to a year.
2010 to 2011	Alternative Analysis Report	The timing of the Alternative Analysis Report will depend on the scope and duration of treatability testing and field pilot testing.

Exhibit 2 - Possible Schedule for Alternative Analysis.

Should IBM find the approach outlined above acceptable and consistent with IBM's preference, we would be pleased to begin scoping field and laboratory studies concurrent with conducting meetings with the Agencies and Binghamton Country Club to present a proposed approach and seek input and approval of IBM's plans.

In recognition that the Alternatives Analysis may require a year or more to complete, IBM may wish to consider implementing certain simple short-term measures that can reduce the potential for human contact with VOC-containing water in a wet area at a southerly section of the IBM Gun Club property between the fenced area and southerly property boundary. The short-term measures that could be implemented alone or in combination include:

- Extending the fence to the southerly property boundary and further limit the potential for human access to the wet areas on IBM property;

- Installing a culvert under the perimeter road to convey seepage under the road, limiting the need for trafficking through seasonally wet roadways.

- Planting additional phreatophyte trees on the slope between the fenced area and the perimeter road. To increase uptake, at least seasonally, of VOC-containing shallow groundwater/seepage.

We would be happy to provide details regarding these potential short term measures and obtain contractor quotations to complete the work.

We appreciate the opportunity to be of further service to IBM on this important and challenging project. If you have questions or wish to discuss this matter further, please contact us.

AHH/DBC/:ahh

Encl.

Table 1	Summary of Initial Screening of Remedial Alternatives
Figure 1	In-Situ Enhanced Biochemical Degradation, Hydraulic Containment, and Treatment
Figure 2	In-Situ Thermal Desorption
Figure 3	Excavation
Attachment 1	Preliminary Estimates of Cost

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Table 1
Summary of Initial Screening of Remedial Alternatives
IBM Gun Club – Former Burn Pit Area
Union, New York

Alternate Remedial Measure	Process and Design Description	Selection Criteria							Conclusion
		Overall Protectiveness of Human Health and Environment (See Note 2)	Conformance to Standards, Criteria, and Guidance	Reduction of Toxicity, Volume, and/or Mobility	Short and Long Term Effectiveness	Implementability	Safety	Cost	
Monitored Natural Attenuation (MNA)	Monitoring of the natural or "intrinsic" processes occurring in the subsurface that are gradually reducing VOC contaminant mass and concentrations in groundwater. These processes include biodegradation, dispersion, dilution, adsorption, matrix diffusion, volatilization, and abiotic degradation. A long-term program of routine monitoring and data evaluation would be required to verify and confirm that the intrinsic attenuation processes continue to be active Could be applied in conjunction with other containment or in-situ control technologies or source reduction measures.	This alternative does not address Goal 1 or Goal 2. The exposure assessment provided in the RI Report of Findings will continue to be applicable in that exposure is not possible through private or public water supplies or soil vapor. Potential for human exposure to low concentrations of VOCs reaching seeps and springs would be unchanged.	We believe the conditions at the site are not likely to change with time if no further action is taken. Therefore, VOC concentrations in groundwater, seeps and springs exceeding potentially applicable water quality standards will likely be on-going.	Baseline condition for comparison of other alternatives. The data indicate that natural processes are present limiting mobility and reducing toxicity through biochemical degradation of TCE proximate to the primary source rock.	Existing biochemical processes in conjunction with matrix diffusion, sorption, and dilution are in part responsible for reducing the groundwater VOC concentrations to a few tens, ones, or tenths of a microgram per liter downgradient from the primary source rock. Natural attenuation is not expected to materially improve water quality conditions at the site over time.	Readily implemented using existing monitoring wells, multi-level systems, and surface water sampling points at the site. Dispersion, dilution, adsorption and matrix diffusion occurs across the site and reductive de-chlorination of VOCs appear to be occurring in groundwater within the primary source rock Outside the area of primary sourcing in rock, however, the process of biochemical degradation may be limited by the absence or low concentrations of organic carbon.	There are only limited safety issues implementing monitored natural attenuation. Monitoring offers low potential for human exposure.	O&M: $40,000 to $60,000/yr depending on scope. O&M present value @ 30 yr $1.2M to $1.8M	**Retain for further assessment.** Can be implemented in conjunction with other remedial alternatives. This alternative has the lowest cost, requires least safety precautions, and is readily implementable. Potential for human exposure could be incrementally reduced by extending fencing around seeps and springs on IBM property providing a drainage culvert beneath the southerly perimeter road.
Enhanced Biochemical Degradation (Biostimulation/ Bioaugmentation)	Bio-stimulation is the process of adding amendment(s) to the subsurface for the purpose of stimulating the growth of specific groups of bacteria that are capable of breaking down chlorinated solvents. Amendments are typically injected under pressure to the subsurface. Common amendments include sources of carbon or electron donors (acetate, lactate, whey) and sources of nutrients (ammonium, phosphate). Bioaugmentations is the injection of a collection of bacteria, typically species of *Dehalococoides* and *Dehalobacter* along with growth amendments that stimulate the reductive biodegradation of contaminants in the subsurface. Injections of amendments and/or bioaugmentations would likely occur through an array of boreholes in pneumatically fractured rock (injection gallery) or emplacement of solid electron donor material. Piping would be necessary for conveying amendments to injection points from a central location, and, if necessary re-circulating groundwater from extraction to injection locations.	The alternative has the potential to reduce VOC concentrations in groundwater within and downgradient of the primary source rock and in the water reaching springs and seeps, and thereby further reduce the potential for human exposure at the site. The alternative addresses Goal 1, but does not materially address Goal 2. The only alternative with the potential to address mass sourced from secondary source rock located off of the IBM property.	Offers incrementally greater possibility of meeting applicable water quality standards both on and off-site by addressing mass sourced from both the primary and secondary source rock. May require permitting of the injection of carbon sources or electron donors.	Complete degradation of primary contaminant TCE to non-toxic by-products including ethane, carbon dioxide and water would reduce toxicity and the volume of groundwater exceeding applicable water quality standards. Degradation of VOCs in fracture pore space within the primary source rock may increase concentration gradient conducive to diffusion out of the rock mass but will not directly address VOC within the rock matrix.	Enhanced biochemical degradation would likely start increasing contaminant degradation within weeks of beginning implementation. The alternative will only be effective as long as conditions conducive to degradation are maintained. VOC concentrations would likely rebound after active operation has been terminated long enough to reverse conditions conducive to biochemical degradation.	Design and construction could be accomplished in 6 to 12 months, assuming limited delays for permitting following successful pilot testing. Present concept involves conventional technologies that are not proven in application to sedimentary bedrock settings. Distribution and residence/contact time for amendment in fractures is a design consideration. Field scale pilot testing is recommended to aid in refining design parameters and assess performance associated with distribution and residence time of amendments.	Normal OSHA1910.12 Health and safety measures during the construction phase that includes drilling and pneumatic fracturing of boreholes. Amendments are typically non-toxic and safe to handle. This alternative offers the next lowest concern relative to MNA for worker health and to safety.	Capital Cost $370,00 O&M $98,000 O&M present value @30 yr $3M Present value Capital cost and O&M @ 30 yr $3.3M	**Retain for further assessment** Could be used in conjunction with other treatment technologies. Estimated magnitude of probable cost about twice that of MNA. At the low end of worker health and safety concern. Questions regarding performance and implementability can be addressed through the on-going Biotrap sampling program and a field pilot study. The alternative is the only alternative with potential to directly address mass in groundwater sourced from both inside and outside of the primary source rock and offers greater potential to improve water quality at downgradient seeps and springs.

Table 1
Summary of Initial Screening of Remedial Alternatives
IBM Gun Club – Former Burn Pit Area
Union, New York

Alternate Remedial Measure	Process and Design Description	Selection Criteria							Conclusion
		Overall Protectiveness of Human Health and Environment See Note 2	Conformance to Standards, Criteria, and Guidance	Reduction of Toxicity, Volume, and/or Mobility	Short and Long Term Effectiveness	Implementability	Safety	Cost	
Hydraulic Containment	Groundwater extraction from a line of borings interconnected by pneumatic fracturing within or downgradient from the contaminant source zone to provide hydraulic containment of dissolved-phase contamination moving through the upper most fractured zone of bedrock. The method would likely include an array of vertical extraction wells interconnected by pneumatic fracturing and pumps to convey recovered groundwater to an ex-situ treatment system consisting of one or more treatment technology including air stripping, activated carbon adsorption or advanced UV and chemical oxidation.	Hydraulic containment would limit mass migration from the primary source rock. It offers potential to incrementally improve the quality of water downgradient in the ground and reaching seeps and springs, and thereby reduce the potential for human exposure. Therefore it may address Goal 1, but not Goal 2.	Concentrations in GW would continue to exceed applicable water quality standards beneath the BPA upgradient of the extraction point. Additional fate and transport modeling would be necessary to better understand the effect on downgradient water quality. Permitting of the subsurface disposal of treated groundwater would likely be necessary.	Would reduce mobility of the small flux of (estimated at tenths of gallons per minute and tenths of pounds per year) VOC containing groundwater migrating within fractures from the primary source rock and therefore reduce the volume and toxicity of downgradient water. Will not materially address the bulk of the VOC mass present within the unfractured rock matrix.	Design and construction of hydraulic containment and ex-situ treatment system could be accomplished in approximately 6 months following permitting. Limiting contaminant migration will begin at the time of implementation. The alternative will only be effective as long as active pumping is maintained. Benefits of operation are likely to reverse relatively quickly after pumping ceases.	Relatively simple and proven technology that requires on-going operation and maintenance and management of treatment residuals/ emissions.	Can be conducted employing conventional health and safety during construction and operation which include drilling and pneumatic fracturing of boreholes. Incrementally greater exposure potential for workers associated with VOC containing water being conveyed under pressure from extraction point to treatment facility. This alternative ranks third lowest potential for worker health and safety concern.	Capital Cost $500,000 O&M $90,000/yr Present value @ 30 yr $3.2M	**Retain for further consideration.** Hydraulic containment offers similar cost to enhanced biochemical degradation and about twice that of MNA. It is readily implementable using conventional technology but requires incrementally greater operations and maintenance. Offers least potential to address mass within or outside of the primary source rock and as such, more limited potential to improve downgradient water quality. This can be explored further through additional fate and transport modeling.
In-Situ Thermal Desorption	In-situ thermal desorption involve the process of heating soil, rock, and groundwater to above the boiling point of water by thermal conductive heating. The process increases desorption and volatilize the VOCs and drive out mass stored within the rock matrix. The thermal heating is conducted through a close grid of vertical heating wells. Vapor and water are extracted from a grid of extraction wells and conveyed to an ex-situ treatment facility. The treated area is covered by concrete to limit both the loss of vapors and heat. The technology has a proven track record from unconsolidated soils, but is still being tested in fractured rock settings similar to the Gun Club.	Offers potential to remove primary VOC source mass constituting the majority of the mass present in the subsurface to source groundwater (Goal 2). The degree to which reduction of primary source mass improves water quality downgradient at seeps and spring is uncertain (Goal 1). Residual/fugitive heat from the thermal treatment process may damage vegetation nearby or downgradient of the treatment zone following the treatment/extraction period.	Thermal desorption, if effective, could significantly reduce the total mass within the primary source rock by several orders of magnitude and greatly reduce the total available mass to source groundwater contamination. It would follow that a commensurate reduction in groundwater concentrations may be possible. Additional fate and transport modeling would be necessary to assess the potential beneficial effect on downgradient water quality. Would require permitting of air and water discharges from the treatment system.	If effective, it would reduce the volume of rock serving as a primary source of VOCs in groundwater and hence reduce the mobility. Ex situ catalytic oxidation treatment if employed would destroy VOC mass and reduce toxicity.	Design and construction of in-situ thermal desorption and potential ex-situ treatment system could be accomplished in approximately 6 months following pilot testing. Present vendor estimates are one year from system startup to the completion of treatment, assuming a 200 day operating period. Removal of sourcing in rock will likely begin immediately after startup and effect on water quality would like also become effective both on the short and long term. Offers for permanent removal of mass from the primary source rock.	Technology applied successfully at dozens of overburden sites and currently being conducted as a demonstration project in a similar bedrock setting. Ideally 3-phase power would be available nearby without new electric transmission infrastructure. Could be operated via an on-site generator. Residuals/emissions must be managed and treated.	Health and safety measures consistent with OSHA 1910.120 would be necessary during the construction phase. Brings worker safety concerns associated with high voltage equipment and piping of hot fluids from extraction wells.	Capital Cost $4.8M	**Retain for further consideration.** The estimated probable cost is about 3 times that estimated for MNA on a present value basis and about 50% greater than hydraulic containment and enhanced biochemical degradation. In our opinion the alternative rank fourth in terms of worker safety considerations. It is the only alternative carried forward that addresses mass within the primary source rock. We recommend that IBM track performance on the on-going demonstration project and consider a limited program of treatability testing followed by a site-specific pilot study.

Table 1
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IBM Gun Club – Former Burn Pit Area
Union, New York

Alternate Remedial Measure	Process and Design Description	Selection Criteria							Conclusion
		Overall Protectiveness of Human Health and Environment (See Note 2)	Conformance to Standards, Criteria, and Guidance	Reduction of Toxicity, Volume, and/or Mobility	Short and Long Term Effectiveness	Implementability	Safety	Cost	
Excavation of Primary Source Rock	This approach would involve excavation of rock containing residual VOC mass that constitutes the primary source for GW contamination. The excavation would be performed by a combination of physical techniques such as ripping or hoe ramming and followed by either: a) Disposal off-site in a secure landfill; b) Treatment by ex-situ thermal desorption and disposal off-site in a secure landfill; or c) Treatment by ex-situ thermal desorption and disposal on-site.	Removal of primary source rock would take the majority of VOC mass from the environment reducing the longevity of sourcing (Goal 2) and presumably the concentration in groundwater downgradient (Goal 1), reducing the time period where concentrations may exceed applicable standards. Depending on the nature of backfill material, may alter the hydrology of the area increasing or decreasing the amount of groundwater recharge and discharge at seeps or springs.	Would likely reduce downgradient concentrations in groundwater towards applicable standards but additional fate and transport modeling is warranted to assess the potential magnitude of downgradient effects. Ex situ thermal treatment would require permitting /control of potential air emissions.	It would reduce the volume of rock serving as a primary source of VOCs in groundwater and hence reduce the mobility and volume of water that could become contaminated in the future. Ex-situ treatment would be intended to destroy or treat the VOC mass and reduce toxicity. Off-site disposal without treatment would not decrease toxicity but would reduce mobility but increase the volume of waste to be handled.	Design and excavation of source rock in a 1.4 acre area down to 13 ft below ground surface could be accomplished over approximately 6 months, assuming limited delays for permitting. Excavation is estimated to take up to 3 months under best conditions. The reduction in source mass would be efficient in the short term and permanent. A reduction in contaminant migration with groundwater should be immediate and permanent.	Excavation would employ conventional technology that has been proven in rock excavation however excavation and on-site handling of the excavated materials would require: - Considerable footprints of land for stockpiling of excavated materials prior to treatment and/or loading onto trucks. - Dust and noise control - Management and or treatment of runoff and groundwater inflow Treatability testing and or test burns would be required to demonstrate the use of ex-situ thermal desorption to treat rock. Heavy truck traffic would add wear to local public roads that would likely require reparations.	Bedrock excavation stockpiling and transportation brings a greater level of physical hazards for on-site workers including: - Dangers to site worker, truck drivers, and the public from heavy equipment and truck traffic transporting rock and fill material - Physical and chemical hazards to workers performing the excavation - Noise and dust. - Exposure to contaminants via direct contact and inhalation.	Capital Cost range from $6.8M for excavation, ex-situ thermal treatment, and on-site disposal to $13M for excavation and off-site disposal. The cost estimate does not include allowances for improving and repairing roads.	**Eliminate from further consideration** Potential order of magnitude greater costs at least twice the cost of the other alternatives on a present value basis with greater potential for safety concerns for workers and the public using nearby roads. The alternative is less likely to receive community acceptance as a consequence of the heavy truck traffic, noise and dust. Ex-situ thermal treatment has to our knowledge not applied to excavated rock and treatability of the rock is uncertain without further testing.

Notes:

1. The table is intended to support an initial screening of remedial alternatives for the IBM Gun Club – Former Burn Pit Area against typical selection criteria outlined in New York Department of Environmental Conservation Guidance. Please refer to the memorandum report of this same date for additional discussion and limitations.
2. The "Overall Protectiveness of Human Health and Environment" are evaluated against the "Preliminary Remedial Goals" discussed in the Remedial Investigation Report of Findings dated April 10, 2009.
   Goal 1: Reduce the downgradient VOC mass flux form the BPA primary source zone – Success would mean realizing a material reduction in VOC concentrations in groundwater outside the source zone and in water reaching seeps and springs.
   Goal 2: Reduce VOC Source Mass – To the extent practicable, reduce the mass of VOCs in source zone bedrock. Success in meeting this goal would mean realizing a reduction the time, effort, and/or cost to establish and maintain Goal 1.
3. The Preliminary estimates of cost were generated based on vendor quotes and Sanborn, Head & Associates, Inc. experience from prior projects. We have added 20% contingency for scope and cost uncertainties. By convention the preliminary estimates of cost have an accuracy of approximately +50% to -30%. See Attachment 1 for additional details.
   All alternatives would likely require continued water quality monitoring. Water quality monitoring is only included in the Monitored Natural Attenuation alternative cost estimate.

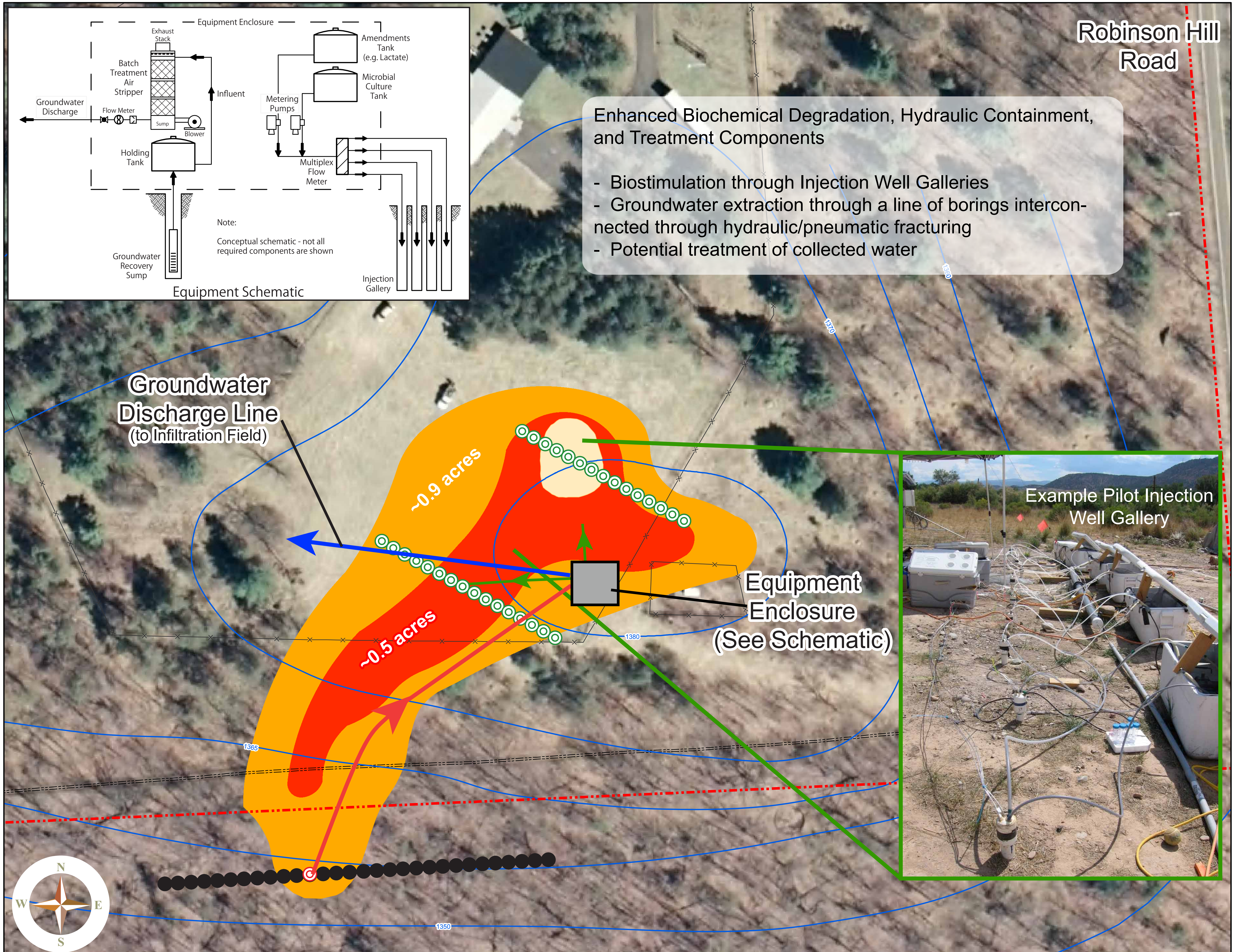

Figure 1

Enhanced Biochemical Degradation, Hydraulic Containment, and Treatment

Initial Alternatives Assessment

Union, New York

Drawn By: J. Williams/S. Warner
Designed By: P. Mouser
Reviewed By: D. Shea/D. Carr
Date: July 2009

Notes:

The figure is intended to summarize concepts for enhanced biochemical degradation and hydraulic containment. Refer to memorandum text for further discussion.

Legend

- Burn Pit
- Groundwater Recovery Sump
- Injection Gallery
- Fractured Borings
- 1330 Inferred Groundwater Contours
- Pumped Groundwater Flow Direction
- Primary Source Zone in Rock

40 20 0 40 80 120 Feet

SHPC ENGINEERS

Sanborn, Head Engineering, P.C.

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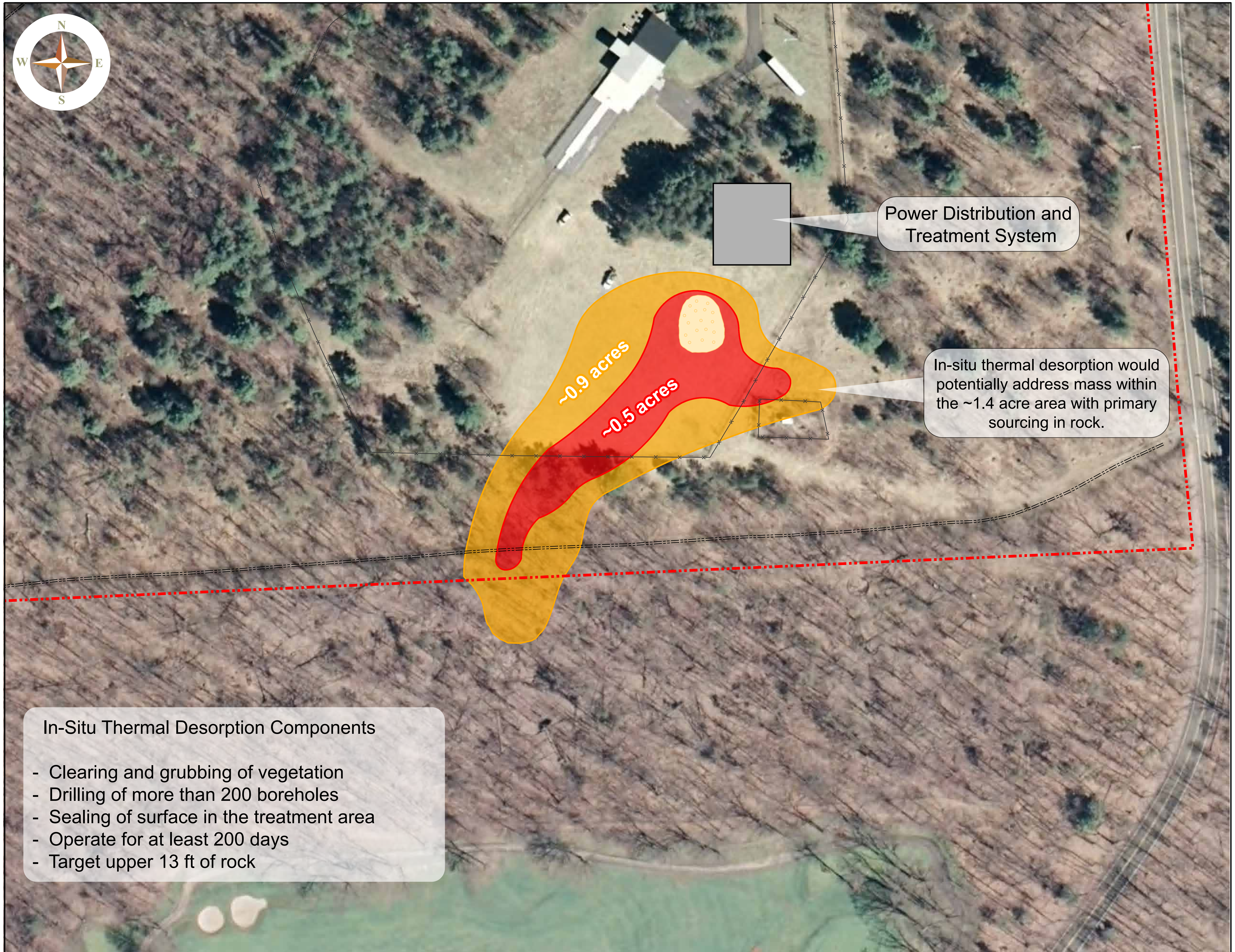

Figure 2

In-Situ Thermal Desorption

Initial Alternatives Assessment

Union, New York

Drawn By: S. Warner/J. Williams
Designed By: A. Horneman
Reviewed By: D. Carr
Date: July 2009

Notes:

The figure is intended to summarize concepts and components associated with in-situ thermal desorption. Refer to memorandum text for further discussion.

Legend

Former Burn Pit

Primary Source Zone in Rock

50 25 0 50 100 150 Feet

SHPC ENGINEERS

Sanborn, Head Engineering, P.C.

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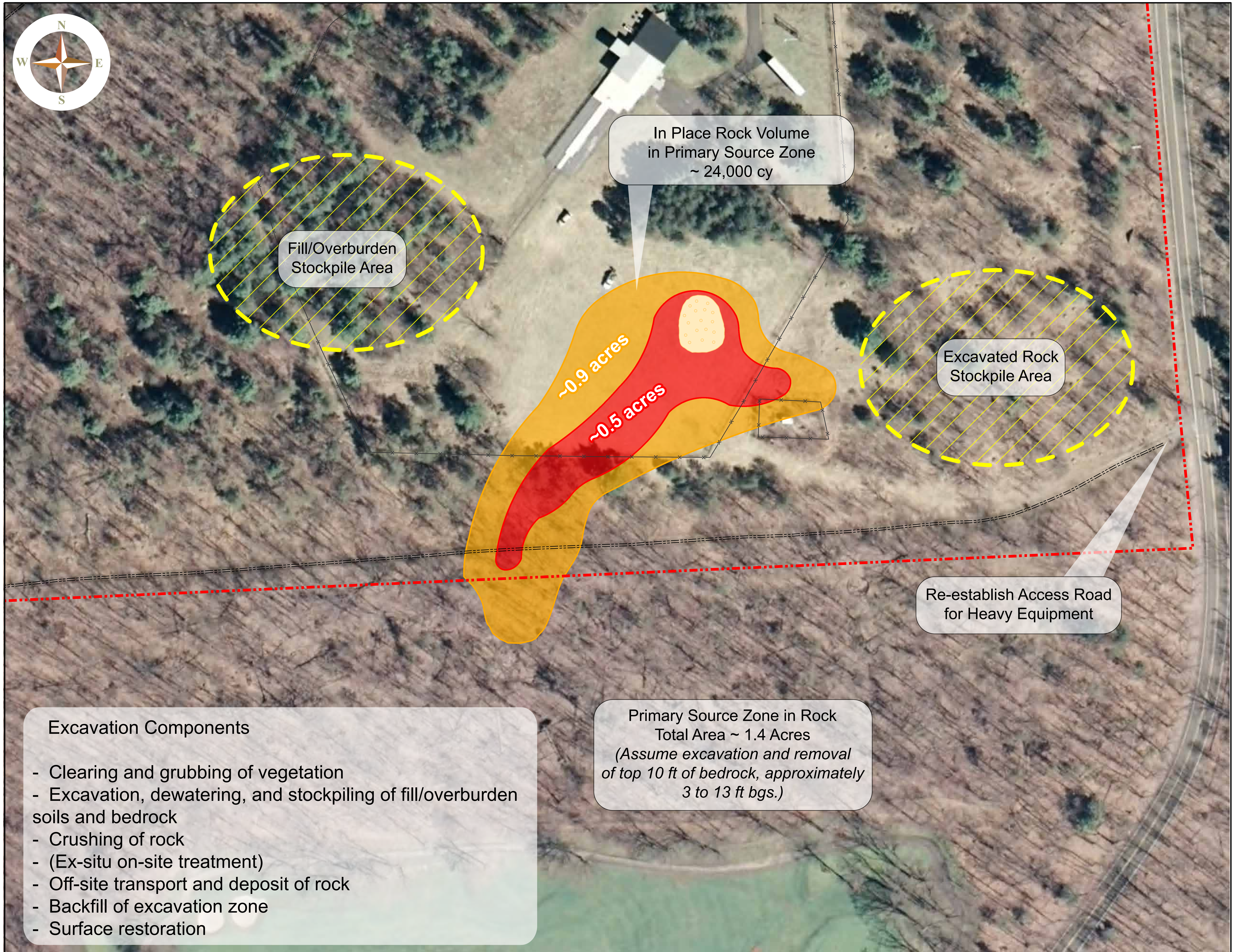

Figure 3

Excavation

Initial Alternatives Assessment

Union, New York

Drawn By: S. Warner/J. Williams
Designed By: A. Horneman
Reviewed By: D. Carr
Date: July 2009

Notes:

The figure is intended to summarize concepts and components associated with excavation of Primary Source Rock. Refer to memorandum text for further discussion.

Legend

- Former Burn Pit
- Primary Source Zone in Rock

50 25 0 50 100 150 Feet

SHPC ENGINEERS

Sanborn, Head Engineering, P.C.

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Attachment 1 Preliminary Estimates of Cost
Hydraulic Containment
Remedial Alternatives Analysis
IBM Gun Club - Former Burn Pit Area
Union, New York

This table presents a preliminary estimate of possible cost for hydraulic containment of the Burn Pit source zone. The hydraulic containment system is envisioned to include a interceptor zone constructed downgradient of the source zone. Recovered groundwater would be conveyed to an on-site groundwater treatment facility (GTF) sized to treat about 5 gpm. Treated water would be conveyed to an on-site subsurface infiltration field.

The cost projection is limited to an accuracy of about +50% to -30%, which is consistent with USEPA guidance for such estimates.

Description	Qty	Unit Cost	Units	Ext. Cost	Comments
<u>Contractor</u>					
Fractured Rock Zone for Recovery					
drilling and installation wells for fracturing	60	$500	boring	$30,000	Assume 60 four inch, 15' deep borings in a 350' long array. Wells drilled by sonic or air hammer and pneumatically fractured.
Recovery wells	5	$500	well	$2,500	Assume 5 3 inch borings, fractured and completed as wells with 2 inch pvc.
Recovery pumps	5	$2,500	ea	$12,500	Pneumatic controllerless pumps.
			Subtotal	**$45,000**	
Recovery Piping System					
Trenching	220	$50	cy	$11,000	Dig trench for piping from recovery zone to treatment bldg (500' long x 4' deep x 3' wide)
Piping	500	$5	ft	$2,500	1" HDPE piping coil
Conduit for compressed air line	500	$10	ft	$5,000	1" PVC for pump air supply
Compressed air line	500	$5	ft	$2,500	1/2" air hose
Pull boxes	5	$300	ea	$1,500	Assume 1 pull box every 100 ft for air hose
Trench bedding and backfill	220	$20	cy	$4,400	Bedding, backfill, and restore piping trench
			Subtotal	**$27,000**	
Groundwater Treatment Facility					
Site preparation	1	$10,000	lump	$10,000	Clearing and grading for GTF structure
GTF building	1	$50,000	lump	$50,000	Assume 15' x 15' pre-fab structure with slab-on-grade foundation
Electrical service	1	$15,000	lump	$15,000	
Lighting, heating, and ventilation	1	$15,000	lump	$15,000	
			Subtotal	**$90,000**	
Treatment Equipment					
Air stripper	1	$20,000	lump	$20,000	
Vapor-phase carbon	2	$2,500	lump	$5,000	Two 1,000-lb units
Air compressor	1	$2,000	ea.	$2,000	Air supply for pneumatic pumps
Extraction well manifold	1	$2,000	lump	$2,000	Valves and gauges
Instrumentation	1	$5,000	lump	$5,000	Flow meters, level switches
			Subtotal	**$34,000**	

Attachment 1 Preliminary Estimates of Cost
Hydraulic Containment
Remedial Alternatives Analysis
IBM Gun Club - Former Burn Pit Area
Union, New York

This table presents a preliminary estimate of possible cost for hydraulic containment of the Burn Pit source zone. The hydraulic containment system is envisioned to include a interceptor zone constructed downgradient of the source zone. Recovered groundwater would be conveyed to an on-site groundwater treatment facility (GTF) sized to treat about 5 gpm. Treated water would be conveyed to an on-site subsurface infiltration field.

The cost projection is limited to an accuracy of about +50% to -30%, which is consistent with USEPA guidance for such estimates.

Description	Qty	Unit Cost	Units	Ext. Cost	Comments
Installation					
Mechanical installation	1	$15,000	lump	$15,000	
Main control panel	1	$10,000	lump	$10,000	
Electrical installation	1	$25,000	lump	$25,000	
			Subtotal	**$50,000**	
Effluent Infiltration Field					
Trenching	220	$35	cy	$7,700	Dig trench for piping from GTF to infiltration gallery (500' long x 4' deep x 3' wide)
Piping	500	$10	lump	$5,000	Assume 4" sanitary drain pipe from GTF to infiltration gallery
Infiltration field	1	$50,000	lump	$50,000	Construct subsurface effluent discharge field
			Subtotal	**$63,000**	
			Subtotal, Contractor	**$310,000**	
Engineering					
Plans and Specs		10%		$31,000	Assume as a percentage of construction cost
Bidding and Contracting		5%		$16,000	"
Field Observation		15%		$47,000	"
Testing and Startup		5%		$16,000	"
Project Coordination		10%		$31,000	"
			Subtotal, Engineering	**$140,000**	
Contingency		20%		$90,000	Assume as a percentage of contractor + engineering costs
			TOTAL	**$500,000**	
Annual O&M					
Vapor-phase carbon changeouts	4	$4,500	ea	$18,000	Assume quarterly changeouts of 1,000 lbs ea
Electricity	87,600	$0.12	kw-hr	$10,512	Assume 10 kw full-time to run air stripper blower
Replacement parts	1	$10,000	lump	$10,000	
Field labor	12	$2,000	month	$24,000	
Project oversight	12	$1,000	month	$12,000	
			Subtotal	$75,000	
Contingency		20%		$15,000	Assume as a percentage of annual costs
			TOTAL	**$90,000**	

Note: Annual costs do not include routine groundwater monitoring costs likely common to all remedial alternatives.

This table presents a preliminary estimate of possible cost for enhanced biochemical degradation at the Burn Pit source zone. The system is envisioned to include an series of injection/infiltration wells drilled into bedrock and connected by hydraulic/pneumatic fracturing and a second series of injection wells located downgradient of the former Burn Pit. An organic carbon substrate would be injected on a periodic basis (quarterly to every several years, depending upon the choice of substrate) and move with the groundwater flow.

The cost projection is limited to an accuracy of about +50% to -30%, which is consistent with USEPA guidance for such estimates.

Description	Qty	Unit Cost	Units	Ext. Cost	Comments
Contractor					
Construction of Injection Gallery					
drilling and well installation	30	$500	well	$15,000	2" PVC, 15' deep, 6"x6" well box
Hydraulic/pneumatic fracturing	30	$500	boring	$15,000	
			Subtotal	**$30,000**	
Injection Piping System					
Trenching	330	$50	cy	$16,500	Dig trench for piping from amendment facility to injection wells ((3 x 250')long x 4' deep x 3' wide)
Stainless steel substrate distribution tubing	1500	$5	ft	$7,500	1/4" SS piping coil run to shallow and deep locations in each well
Conduit for substrate distribution	750	$12	ft	$9,000	2" PVC for substrate tubing
Trench bedding and backfill	330	$20	cy	$6,600	Bedding, backfill, and restore piping trench
			Subtotal	**$40,000**	
Amendment Facility					
Site preparation	1	$8,000	lump	$8,000	Clearing and grading for amendment structure
Amendment building	1	$50,000	lump	$30,000	Assume 15' x 15' pre-fab structure with slab-on-grade foundation
Electrical service	1	$15,000	lump	$15,000	
Lighting, heating, and ventilation	1	$15,000	lump	$15,000	
			Subtotal	**$68,000**	
Remediation Equipment					
Amendment tanks	2	$5,000	lump	$10,000	500 gallon poly tanks
Injection well manifolds	3	$2,000	ea	$6,000	1 per transect control valves, regulators, switches, gauges
Multiplex flow splitter	3	$2,000	ea	$6,000	1 per transect
Instrumentation	1	$5,000	lump	$5,000	Flow meters, tank level switches
			Subtotal	**$27,000**	
Installation					
Mechanical installation	1	$15,000	lump	$15,000	
Electrical service	1	$10,000	lump	$15,000	
Electrical control panel	1	$5,000	lump	$5,000	
Electrical installation	1	$15,000	lump	$12,000	
			Subtotal	**$47,000**	
		Subtotal, Contractor		**$210,000**	

Engineering					
Plans and Specs	10%			$21,000	Assume as a percentage of construction cost
Bidding and Contracting	5%			$11,000	"
Field Observation	15%			$32,000	"
Testing and Startup	5%			$11,000	"
Project Coordination	10%			$21,000	"
			Subtotal, Engineering	**$100,000**	
Contingency	20%			$60,000	Assume as a percentage of contractor + engineering costs
			TOTAL	**$370,000**	
Annual O&M					
Amendments (e.g. lactate)	4	$5,000	injection	$20,000	Assume 4 injections per year
Microbial culture	1	$10,000	lump	$10,000	Assume 1 injection per year
Potassium bromide tracer	1	$5,000	lump	$5,000	Assume 1 injection per year
Electricity	11,000	$0.12	kw-hr	$1,320	Assume 1000 kw/injection + 20 kw/day
Replacement parts	1	$10,000	lump	$10,000	
Field labor (O&M)	12	$2,000	month	$24,000	
Project oversight	12	$1,000	month	$12,000	
			Subtotal	**$82,000**	
Contingency	20%			$16,000	Assume as a percentage of annual costs
			TOTAL	**$98,000**	

Note: Annual costs do not include routine groundwater monitoring costs likely common to all remedial alternatives.

Attachment 1 Preliminary Estimates of Cost
In-Situ Thermal Treatment
Remedial Alternatives Analysis
IBM Gun Club - Former Burn Pit Area
Union, New York

This table presents a preliminary estimate of possible cost for in-situ thermal treatment that targets the VOC in in bedrock within the area with primary sourcing.

The cost projection is limited to an accuracy of about +50% to -30%, which is consistent with USEPA guidance for such estimates.

Description	Qty	Unit Cost	Units	Ext. Cost	Comments
Contractor					TerraTherm preliminary cost estimate for treatment of 1-acre area of 10 ft thickness
Contractor Design and Installation					
Design and permitting	1	$134,000	lump	$134,000	
Equipment procurement and mob	1	$117,000	lump	$117,000	
Power drop and transformer	1	$50,000	lump	$50,000	Electric service installation
Drill and install wells	1	$100,000	lump	$100,000	SHA modified contractor estimate
Vapor cover installation	1	$120,000	lump	$120,000	
Electrical construction	1	$104,000	lump	$104,000	
Mechanical construction	1	$216,000	lump	$216,000	
Power equipment	1	$90,000	lump	$90,000	
Treatment system	1	$346,000	lump	$346,000	
Commissioning	1	$82,000	ea	$82,000	
			Subtotal	**$1,400,000**	
Operations					
Maintenance hardware	1	$70,000	lump	$70,000	
Labor, travel, per diem	1	$258,000	lump	$258,000	Assumes 200 days of operations
Rental and fees	1	$45,000	lump	$45,000	
			Subtotal	**$400,000**	
Demobilization and vendor report					
Demobilization	1	$82,000	lump	$82,000	
Reporting	1	$16,000	lump	$16,000	
			Subtotal	**$98,000**	
			Subtotal, Contractor	**$1,900,000**	
Utilities					
Electricity	3,934,000	$0.12	kW-hr	$472,080	Assumes 200 days of operations
Natural gas	2,180	$18	MM BTUs	$39,240	
Caustic	1	$3,636	lump	$3,636	
GAC and waste disposal	1	$30,000	lump	$30,000	SHA estimate
			Subtotal, Utilities	**$540,000**	

This table presents a preliminary estimate of possible cost for in-situ thermal treatment that targets the VOC in in bedrock within the area with primary sourcing.

The cost projection is limited to an accuracy of about +50% to -30%, which is consistent with USEPA guidance for such estimates.

Description	Qty	Unit Cost	Units	Ext. Cost	Comments
Engineering					
Field Observation		5%		$95,000	For well drilling and construction; assume as a percentage of contractor costs
Testing and Startup		5%		$95,000	"
Project Coordination		10%		$190,000	"
		Subtotal, Engineering		**$380,000**	
Contingency		20%		$560,000	Assume as a percentage of contractor + utilities + engineering costs
			TOTAL	**$3,400,000**	For presumed 1-acre treatment area
				$4,800,000	For 1.4-acre treatment area, assume costs scale linearly

Note: Annual costs do not include routine groundwater monitoring costs likely common to all remedial alternatives.

This table presents a preliminary estimate of possible cost for soil and rock excavation, ex-situ thermal treatment, and off-site deposition of rock. The excavation targets the upper 10 ft of rock in a 1.4 area area where VOC mass in rock constitutes an ongoing source for VOCs in groundwater.

The cost projection is limited to an accuracy of about +50% to -30%, which is consistent with USEPA guidance for such estimates.

Note: Costs do not include routine groundwater monitoring costs likely common to all remedial alternatives.

	Excavation of Approx 22,500 cy In-Place				
Description	Qty	Unit Cost	Units	Ext. Cost	Assumptions/Comments
Contractor					
Excavation					
Mob/Demob	1	$20,000	lump	$20,000	
Dewatering	1	$50,000	lump	$50,000	Set-up and operate temp treatment system consisting of dewatering pumps, batch tank, solids filters, and GAC. Assume treated water discharged to ground surface down slope of excavation area.
Clear and grub	1	$25,000	lump	$25,000	Remove trees and brush between the fence line and the property line
Tree and brush disposal	1	$25,000	lump	$25,000	Dispose trees and brush
Soil excavation	6,800	$5	cy	$34,000	Excavate soil to top of rock and stockpile on site
Rock excavation (ripping)	16,200	$20	cy	$324,000	Assuming rip removal of rock (90% of in-place volume)
Rock excavation (hoe ramming)	1,800	$40	cy	$72,000	Assuming hoe ramming of rock in hard spots (10% of in-place volume)
Rock crushing	18,000	$10	cy	$180,000	SHA estimate based on construction project experience
Subtotal, Excavation				**$730,000**	
On-site Ex-situ Thermal Desorption					
Permitting	1	$50,000	lump	$50,000	
Thermal desorption	40,500	$100	ton	$4,050,000	Ballpark unit costs provided by Midwest Soil Remediation for mob/demob and operation of equipment assuming 24 hrs/day, 6 days per week at 18 tons/hr
Subtotal, Ex-situ Treatment				**$4,100,000**	
Trans & Disposal of Treated Rock					
Transport & disposal at non-hazardous (Subtitle D) facility	40,500	$95	ton	$3,847,500	Assume off-site T&D of treated rock; T&D cost provided by Veolia; Approx 330 to 880 trailer loads at 25 cy/load
Subtotal, T&D				**$3,800,000**	
Backfill/restoration					
Backfill material	27,000	$15	cy	$405,000	Buy and deliver backfill material for rock excavation zone; assume rock volume + 20% for compaction
Backfill placement and compaction - rock zone	27,000	$4	cy	$108,000	Assume backfill of soil excavation zone with stockpiled soil
Backfill and compaction - soil zone	6,800	$4	cy	$27,200	Assume backfill of soil excavation zone with stockpiled soil
Restoration and landscaping	1	$100,000	lump	$50,000	Final grading and seeding
Subtotal, Backfill				**$590,000**	
		Subtotal, Contractor		**$9,200,000**	
Engineering					
Plans and Specs		3%		$163,000	Assume as a percentage of implementation costs exclusive of T&D
Bidding and Contracting		2%		$108,000	"
Field Observation		3%		$163,000	"
Project Coordination		5%		$271,000	"
Subtotal, Engineering				**$710,000**	
Contingency		20%		$2,000,000	Assume as a percentage of overall implementation + engineering costs
			TOTAL	**$11,900,000**	

Attachment 1 Preliminary Estimates of Cost
Excavation, Ex-Situ Thermal Treatment and On-Site Deposition
Remedial Alternatives Analysis
IBM Gun Club - Former Burn Pit Area
Union, New York

This table presents a preliminary estimate of possible cost for soil and rock excavation, ex-situ thermal threatment, and on-site deposition of rock. The excavation targets the upper 10 ft of rock in a 1.4 area area where VOC mass in rock constitutes an ongoing source for VOCs in groundwater.

The cost projection is limited to an accuracy of about +50% to -30%, which is consistent with USEPA guidance for such estimates.

Note: Costs do not include routine groundwater monitoring costs likely common to all remedial alternatives.

	Excavation of Approx 22,500 cy in-place				
Description	Qty	Unit Cost	Units	Ext. Cost	Assumptions/Comments
Contractor					
Excavation					
Mob/Demob	1	$20,000	lump	$20,000	
Dewatering	1	$50,000	lump	$50,000	Set-up and operate temp treatment system consisting of dewatering pumps, batch tank, solids filters, and GAC. Assume treated water discharged to ground surface downslope of excavation area.
Clear and grub	1	$25,000	lump	$25,000	Remove trees and brush between the fenceline and the property line
Tree and brush disposal	1	$25,000	lump	$25,000	Dispose trees and brush
Soil excavation	6800	$5	cy	$34,000	Excavate soil to top of rock and stockpile on site
Rock excavation (ripping)	16200	$20	cy	$324,000	Assuming rip removal of rock (90% of in-place volume)
Rock excavation (hoeramming)	1800	$40	cy	$72,000	Assuming hoeram removal of rock in hard spots (10% of in-place volume)
Rock crushing	18000	$10	cy	$180,000	SHA estimate based on construction project experience
Subtotal, Excavation				**$730,000**	
On-site Ex-situ Thermal Desorption					
Permitting	1	$50,000	lump	$50,000	
Thermal desorption	40500	$100	ton	$4,050,000	Ballpark unit costs provided by Midwest Soil Remediation for mob/demob and operation of equipment assuming 24 hrs/day, 6 days per week at 18 tons/hr
Subtotal, Ex-situ Treatment				**$4,100,000**	
Backfill/restoration					
Backfill placement and compaction - rock zone	27000	$4	cy	$108,000	Assume backfill of rock excavation zone with treated rock
Backfill and compaction - soil zone	6800	$4	cy	$27,200	Assume backfill of soil excavation zone with stockpiled soil
Restoration and landscaping	1	$100,000	lump	$50,000	Final grading and seeding
Subtotal, Backfill				**$190,000**	
		Subtotal, Contractor		**$5,000,000**	
Engineering					
Plans and Specs		3%		$151,000	Assume as a percentage of implementation costs exclusive of T&D
Bidding and Contracting		2%		$100,000	"
Field Observation		3%		$151,000	"
Project Coordination		5%		$251,000	"
Subtotal, Engineering				**$650,000**	
Contingency		20%		$1,100,000	Assume as a percentage of overall implementation + engineering costs
			TOTAL	**$6,800,000**	

Attachment 1 Preliminary Estimates of Cost
Excavation and Off-Site Deposition
Remedial Alternatives Analysis
IBM Gun Club - Former Burn Pit Area
Union, New York

This table presents a preliminary estimate of possible cost for soil and rock excavation and off-site deposition of rock. The excavation targets the upper 10 ft of rock in a 1.4 area area where VOC mass in rock constitutes an ongoing source for VOCs in groundwater.

The cost projection is limited to an accuracy of about +50% to -30%, which is consistent with USEPA guidance for such estimates.

Note: Costs do not include routine groundwater monitoring costs likely common to all remedial alternatives.

	Excavation of Approx 22,500 cy in-place				
Description	Qty	Unit Cost	Units	Ext. Cost	Assumptions/Comments
Contractor					
Excavation					
Mob/Demob	1	$20,000	lump	$20,000	
Dewatering	1	$50,000	lump	$50,000	Set-up and operate temp treatment system consisting of dewatering pumps, batch tank, solids filters, and GAC. Assume treated water discharged to ground surface downslope of excavation area.
Clear and grub	1	$25,000	lump	$25,000	Remove trees and brush between the fenceline and the property line
Tree and brush disposal	1	$25,000	lump	$25,000	Dispose trees and brush
Soil excavation	7000	$5	cy	$35,000	Excavate soil to top of rock and stockpile on site
Rock excavation (ripping)	16200	$20	cy	$324,000	Assuming rip removal of rock (90% of in-place volume)
Rock excavation (hoeramming)	1800	$40	cy	$72,000	Assuming hoeram removal of rock in hard spots (10% of in-place volume)
Subtotal, Excavation				**$550,000**	
Off-site T&D					
Transp and disposal of rock	40500	$200	ton	$8,100,000	Assume in-place volume (1cy = 1.75 tons); Ballpark estimate from Veolia for disposal as haz waste at EQ landfill in Michigan
Fees and taxes		15%		$1,215,000	Assume 15% of disposal cost
Subtotal, T&D				**$9,300,000**	
Backfill/restoration					
Backfill material	27000	$15	cy	$405,000	Buy and deliver backfill material for rock excavation zone; assume rock volume + 20% for compaction
Backfill placement and compaction - rock zone	27000	$4	cy	$108,000	Place and compact imported fill
Backfill and compaction - soil zone	7000	$4	cy	$28,000	Assume backfill of soil excavation zone with stockpiled soil
Restoration and landscaping	1	$75,000	lump	$50,000	Final grading and seeding
Subtotal, Backfill				**$590,000**	
		Subtotal, Contractor		**$10,400,000**	
Engineering					
Plans and Specs		5%		$57,000	Assume as a percentage of implementation costs exclusive of T&D
Bidding and Contracting		3%		$34,000	"
Field Observation		10%		$114,000	"
Project Coordination		10%		$114,000	"
Subtotal, Engineering				**$320,000**	
Contingency		20%		$2,100,000	Assume as a percentage of overall implementation + engineering costs
			TOTAL	**$12,800,000**	

APPENDIX C

COMPARATIVE COST ESTIMATES AND PERFORMANCE MONITORING SCHEDULE

APPENDIX C.1

COMPARATIVE COST ESTIMATES

APPENDIX C.1.1

COMPARATIVE COST ESTIMATES – ALTERNATIVE 1

Appendix C.1.1
Comparative Cost Estimates
Alternative 1 - Surficial Soil Component of EBD
Brownfields Alternatives Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area
Union, New York

This table presents an opinion of cost for the surficial soil portion of the EBD remedy. This alternative includes consolidation and capping of Burn Pit Area surficial soils and the primary source rock with a low-permeability vegetated soil cover, fence installation to limit site access, and continued water quality monitoring. The lead shot soil removal and disposal is covered by an IRM, however the cost is included in the cost estimate.
1. In general as noted under the assumptions column, the estimates are based on unit costs from RS Means Heavy Construction Cost Data, for 2011 (RS Means).
2. The cost projection is limited to an accuracy of about +50% to -30%, which is consistent with USEPA guidance for such estimates.

Description	Qty	Unit Cost	Units	Ext. Cost	Assumptions/Comments
CAPITAL COSTS					
Construction Activities					
Site Preparation					
Mob/demob	1	$20,000	lump	$20,000	
Sedimentation and erosion control	1,360	$1	lf	$1,300	RS Means: 31 25 14.16 1000 Place approximately 1360 LF of 3' high PPE fencing at areas where sediment may be carried away in runoff.
Clear and grub, chipping and mulching, spreading	0.5	$6,100	acre	$3,000	RS Means: 31 11 10.10 0160. Remove trees and brush over about 0.5 acres - the area between existing fence and property line plus ancillary areas.
Gravel for temporary access lane	1,350	$9	sy	$12,000	RS Means: 01 54 39.70 0050. Assume 1,000 feet of 12 ft wide access lane with 4" thick gravel.
Demo and dispose old fence	220	$4	lf	$1,000	RS Means 02 41 13.60 1700
Demo and dispose of fence gate	1	$108	each	$100	RS Means 02 41 13.62 0200. Assume 1 10x12' gate
Demo/recycle Ham radio station	530	$0.33	cf	$200	RS Means: 02 41 16.13 0650. Demolition of small masonry building. Assume the building is 6'x11'x8'. Assume masonry is 80 pcf.
Demolition of slab	66	$5	sf	$300	RS Means: 02 41 19.18 0400. Assume the slab is 4" unreinforced, on grade. Assume concrete is 145 pcf
Dumpster rental	1	$166	each	$200	RS Means: 02 41 19.23 0910 & 02 41 19.23 0940 Assume 1 time delivery charge plus 1 month rent ($83/month)
Haul costs for building waste	2	$200	each	$400	RS Means: 02 41 19.23 0920 Assume 2 loads of waste associated with the building demolition
Disposal costs for building waste	25	$90	ton	$2,300	RS Means: 02 41 19.23 0950 Assume approximately 25 tons of building waste materials - this includes the 32 well protection bollards that are to be disposed of.
			Subtotal	**$40,000**	
Removal of Lead shot					
Limited Soil excavation and off-site deposition				**$400,000**	Cleanup to resdiential SCO. Activities are discussed in IRM submitted to the agencies on 3/2/2012. Bulk cost estimate was provided by Omega Env. without breakdown.
			Subtotal	**$400,000**	
Excavation BPA Soils					
Soil excavation - BPA soils	1,000	$5	cy	$5,000	Excavate 0.3 acre combined area - top two feet of soil.
Relocation of BPA soils	1,000	$6	cy	$6,000	RS Means 17 03 0422 minus loading, place and compact within cap footprint in 6"lifts compact with sheepsfoot roller.
			Subtotal	**$10,000**	
Capping					
Well protection	1	$1,000	lump	$1,000	Assume a $1,000 lump sum cost for protection of wells with 3' diameter concrete pipe during earthwork.
Bollard Demolition	32	$59	each	$1,900	RS Means 03 05 05.10 0250. Precast concrete removal, set in masonry
Well extensions	6	$12	each	$100	McMaster-Carr price for 10-ft lengths of 2" diameter Sch. 40 PVC
Well protection extensions	10	$199	each	$2,000	McMaster-Carr price for 6-ft lengths of 4" diameter steel tubing, weldable.

Appendix C.1.1
Comparative Cost Estimates
Alternative 1 - Surficial Soil Component of EBD
Brownfields Alternatives Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area
Union, New York

Description	Qty	Unit Cost	Units	Ext. Cost	Assumptions/Comments
Welding new casings	10	$109	hour	$1,100	RS Means: 05 05 21.90 0020 Assume 10 hours for welding the 20 3-foot 4" diameter steel casing extensions on the wells.
Capping and grading material	7,200	$15	cy	$110,000	Buy and deliver backfill material for soil cap; 2.4 acre area by 1.5 ft thick + 20% for compaction
Capping soil placement compaction and grading	7,200	$6	cy	$40,000	RS Means 17 03 0422 minus loading, place and compact within cap footprint in 6"lifts compact with sheepsfoot roller.
			Subtotal	**$156,000**	
Site Restoration					
Topsoil	1940	$20	cy	$40,000	Buy and deliver topsoil for cap; 2.4 acre area by 6 inches
Topsoil grading, incl. seeding	11,620	$4	sy	$50,000	RS Means: 32 91 19.13 1000. Assume 2.4 acre area
Tree planting	2.7	$14,000	acre	$40,000	Unit rates from horticulturalist recommendations and planting schedule assume hybrid poplar on a 6x10 grid using 3' whips with $1,000 an acre for soil amendment and shredded bark mulch. Applied to gross acreage.
Crushed stone for access lane	335	$19	ton	$7,000	RS Means:32 11 23.23 2030. Assume 1,000 feet of 12 ft wide and 6 inches thick gravel access lane. Assume NYDOT #4 is used, and has a density of about 110 pcf.
Geofabric for access lane	1,350	$2	sy	$2,000	RS Means: 32 11 23.23 6000. Assume 1,000 feet of 12 ft wide access lane is lined with geofabric.
Temporary fence removal at excavation	300	$25	linear ft	$7,000	RS Means: 02 41 13.60 1750. Assume 300 feet of fence along the parcel line will be temporarily removed during excavation, then placed in original location.
Relocate existing fencing	950	$25	linear ft	$23,000	RS Means: 02 41 13.60 1750. Assume 950 feet of existing fence can be reused
New fencing	850	$40	linear ft	$30,000	RS Means:32 31 13.20 0920. Assume 10 ft high with 3 strands barbed wire.
			Subtotal	**$200,000**	
			Subtotal, Construction	**$810,000**	
Contingency		30%		**$240,000**	Scope + bid contingency
			Subtotal, Construction w/Contingency	**$1,100,000**	
<u>Professional/Technical</u>					
Remedial design (plans & specs)		5%		$55,000	Assumed percentage of construction activities, exclusive of T&D costs
Project management (planning, bidding, contract admin)		10%		$110,000	Assumed percentage of construction activities, exclusive of T&D costs
Construction management (construction oversight, review submittals, construction documentation)		20%		$220,000	Assumed percentage of construction activities, exclusive of T&D costs
Deed restriction/institutional controls	1	$10,000		$10,000	
			Subtotal, Professional/Technical	**$400,000**	
			TOTAL CAPITAL	**$1,500,000**	
ANNUAL COSTS					
<u>Annual O&M</u>					
Site inspection	2	$1,000	ea	$2,000	
Mowing	3	$90	ea	$300	
Reporting/project management	1	$2,000	lump	$2,000	
			Subtotal	**$4,300**	
			Contingency	**$1,000**	Assume 20% scope contingency
			TOTAL ANNUAL COSTS	**$5,300**	

Appendix C.1.1
Comparative Cost Estimates
Alternative 1 - Surficial Soil Component of EBD
Brownfields Alternatives Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area
Union, New York

Present Value Analysis
MNA with Surficial Soil Remedy

			Discount Rate =	3%
Year	Capital	Annual	Present Value Factor	Present Value
0	$1,500,000		1.0000	$1,500,000
1		$5,300	0.9709	$5,146
2		$5,300	0.9426	$4,996
3		$5,300	0.9151	$4,850
4		$5,300	0.8885	$4,709
5		$5,300	0.8626	$4,572
6		$5,300	0.8375	$4,439
7		$5,300	0.8131	$4,309
8		$5,300	0.7894	$4,184
9		$5,300	0.7664	$4,062
10		$5,300	0.7441	$3,944
11		$5,300	0.7224	$3,829
12		$5,300	0.7014	$3,717
13		$5,300	0.6810	$3,609
14		$5,300	0.6611	$3,504
15		$5,300	0.6419	$3,402
16		$5,300	0.6232	$3,303
17		$5,300	0.6050	$3,207
18		$5,300	0.5874	$3,113
19		$5,300	0.5703	$3,023
20		$5,300	0.5537	$2,934
21		$5,300	0.5375	$2,849
22		$5,300	0.5219	$2,766
23		$5,300	0.5067	$2,685
24		$5,300	0.4919	$2,607
25		$5,300	0.4776	$2,531
26		$5,300	0.4637	$2,458
27		$5,300	0.4502	$2,386
28		$5,300	0.4371	$2,317
29		$5,300	0.4243	$2,249
30		$5,300	0.4120	$2,184
			Total Present Value	$1,600,000

Appendix C.1.1
Comparative Cost Estimates
Alternative 1- Enhanced Biochemical Degradation
Brownfields Alternatives Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area
Union, New York

This table presents an opinion of cost for enhanced biochemical degradation (EBD) within the Burn Pit source zone. The concepts of EBD are summarized in the report text, figures and tables. The bioremediation system is envisioned to include a series of injection borings drilled into rock. An organic carbon substrate would be injected into the rock via the injection borings on a periodic basis (bi-annual to every several years, depending upon the choice of substrate and field observations) and move with the groundwater.

1. In general as noted under the assumptions column, the estimates are based on unit costs from RS Means Heavy Construction Cost Data, for 2011 (RS Means).
2.The cost projection is limited to an accuracy of about +50% to -30%, which is consistent with USEPA guidance for such estimates.

Description	Qty	Unit Cost	Units	Ext. Cost	Comments
CAPITAL COSTS					
Construction Activities					
Surficial Soil Remedy				$1,500,000	RS Means: 31 11 10.10 0160. Remove trees and brush over about 0.5 acres - the area between existing fence and property line plus ancillary areas.
			Subtotal	**$1,500,000**	
EBD Activities					
Drilling of Injection Wells					
Mob and Demob	1	$4,500	Lump	$4,500	
Drilling and well installation	32	$2,500	well	$80,000	Open boreholes w/ steel surface casing, includes development of borings,
Handling of drilling derived waste	1	$20,000	Lump	$20,000	Confirmatory sampling of drilling return water and cuttings - off-site disposal.
			Subtotal	**$100,000**	
Remote Monitoring Infrastructure					
Remote monitoring equipment	1	$65,000	lump	$65,000	Procurement and installation of equipment for automated gw monitoring and data transmission (down hole sensors, data loggers, solar panels, batteries). Based on vendor quote of $12,000 for 5 units.
			Subtotal	**$65,000**	
Initial Injection of Amendment					
Amendment	3	$1,700	60 gal drum	$5,000	Assume injection EOS 598B42 oil.
Injection Equipment	1	$6,000	Lump	$6,000	Development and construction of large scale injection method in fractured rock.
Injection Subcontractor	2	$10,000	week	$20,000	Assume 2 weeks to injection in all injection borings (41 borings, including 9 pilot injection points)
			Subtotal	**$31,000**	
1st Year Performance Monitoring					
Performance Monitoring	5	$33,000	**ea**	**$165,000**	Assumes the use of PDBs and includes sampling and laboratory analysis
			Subtotal, EBD Activities	**$360,000**	
Contingency		30%		**$110,000**	Scope + bid contingency
			Subtotal, EBD Activities w/Contingency	**$470,000**	
Professional/Technical					
Remedial design (plans & specs)		2%		$9,000	Assume as a percentage of EBD activities
Project management		2%		$9,000	Assume as a percentage of EBD activities

Description	Qty	Unit Cost	Units	Ext. Cost	Comments
EBD oversight (injection oversight)		3%		$14,000	Assume as a percentage of EBD activities
		Subtotal, Professional/Technical		**$30,000**	
			TOTAL CAPITAL	**$2,000,000**	
ANNUAL / PERIODIC COSTS					
Annual Maintenance					
Site inspection	2	$1,000	ea	$2,000	
Mowing	3	$90	ea	$300	
			Subtotal	**$2,300**	
Injections					
Amendments	1	$5,000	injection	$5,000	Assume 1 injection every 2 years
Field labor (O&M)	6	$2,000	month	$12,000	
Project oversight	12	$1,000	month	$12,000	
Contingency		20%		$5,800	
			Subtotal	**$35,000**	
Remedial Performance GW Monitoring					
Performance monitoring and Laboratory analysis				**$40,000**	Average annual - year 2 to year 30, actually varies from $16,000 to $130,000 year to year, see present worth analysis.
			Subtotal	**$40,000**	
Project Management/Reporting					
Project Management	1	$5,000	lump	$5,000	
Reporting - Routine and Performance Monitoring	1	$10,000	lump	$10,000	
			Subtotal	**$15,000**	
			TOTAL ANNUAL COSTS	**$90,000**	

Note: Annual costs do not include routine groundwater monitoring costs likely common to all remedial alternatives.

Appendix C.1.1
Comparative Cost Estimates
Alternative 1 - Enhanced Biochemical Degradation
Brownfields Alternatives Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area
Union, New York

Present Value Analysis
EBD with Surficial Soil Remedy

			Discount Rate =	3%
Year	Capital	Annual	Present Value Factor	Present Value
0	$2,000,000		1.0000	$2,000,000
1		$17,300	0.9709	$16,796
2		$182,000	0.9426	$171,552
3		$83,300	0.9151	$76,231
4		$116,000	0.8885	$103,064
5		$149,300	0.8626	$128,787
6		$116,000	0.8375	$97,148
7		$83,300	0.8131	$67,731
8		$116,000	0.7894	$91,571
9		$83,300	0.7664	$63,843
10		$149,000	0.7441	$110,870
11		$49,300	0.7224	$35,615
12		$49,300	0.7014	$34,578
13		$82,000	0.6810	$55,838
14		$49,300	0.6611	$32,593
15		$65,300	0.6419	$41,914
16		$80,000	0.6232	$49,853
17		$47,300	0.6050	$28,617
18		$47,300	0.5874	$27,784
19		$47,300	0.5703	$26,975
20		$95,000	0.5537	$52,599
21		$33,300	0.5375	$17,900
22		$33,300	0.5219	$17,379
23		$33,300	0.5067	$16,873
24		$33,300	0.4919	$16,381
25		$74,000	0.4776	$35,343
26		$33,300	0.4637	$15,441
27		$33,300	0.4502	$14,991
28		$33,300	0.4371	$14,555
29		$33,300	0.4243	$14,131
30		$95,000	0.4120	$39,139
			Total Present Value	$3,500,000

Present value estimate includes estimated cost for performance monitoring . The monitoring cost is assumed to vary between years and averages about $45,000 between year 2 and year 30. The present value estimate assumes that the number of monitoring points to be sampled will be reduced over time. Furthermore, it is assumed that the injection frequency will decrease over time to once every 3 years between 10 and 20 years after initial injection and once every 5 years after 20 years.

APPENDIX C.1.2

COMPARATIVE COST ESTIMATES – ALTERNATIVE 2

Appendix C.1.2
Comparative Cost Estimates
Alternative 2 - Excavation and Off-Site Disposal
Brownfields Alternatives Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area
Union, New York

This table presents an opinion of cost for soil and rock excavation and off-site disposal of rock. The excavation would target VOCs in bedrock within the area with primary sourcing to groundwater.

1. In general as noted under the assumptions column, the estimates are based on unit costs from RS Means Heavy Construction Cost Data, for 2011 (RS Means).
2.The cost projection is limited to an accuracy of about +50% to -30%, which is consistent with USEPA guidance for such estimates.

Description	Qty	Unit Cost	Units	Ext. Cost	Assumptions/Comments
CAPITAL COSTS					
Construction Activities					
Site Preparation					
Mob/Demob	1	$20,000	lump	$20,000	
Sedimentation and erosion control	1360	$1	lf	$1,300	RS Means: 31 25 14.16 1000 Place approximately 1360 LF of 3' high PPE fencing at areas where sediment may be carried away in runoff.
Clear and grub, chipping and mulching, spreading	2.5	$6,100	acre	$15,000	RS Means: 31 11 10.10 0160. Remove trees and brush over about 2.5 acres - the lead-shot area and area between existing fence and property line
Gravel for temporary access lane	1350	$9	sy	$12,000	RS Means: 31 11 10.10 0160. Remove trees and brush over about 0.5 acres - the area between existing fence and property line plus ancillary areas.
Demo and dispose old fence	220	$4	lf	$1,000	RS Means 02 41 13.60 1700
Demo and dispose of fence gate	1	$108	each	$100	RS Means 02 41 13.62 0200. Assume 1 10x12' gate
Demo/recycle Ham radio station	530	$0.33	cf	$200	RS Means: 02 41 16.13 0650. Demolition of small masonry building. Assume the building is 6'x11'x8'. Assume masonry is 80 pcf.
Demolition of slab	66	$5	sf	$300	RS Means: 02 41 19.18 0400. Assume the slab is 4" unreinforced, on grade. Assume concrete is 145 pcf
Dumpster rental	1	$166	each	$200	RS Means: 02 41 19.23 0910 & 02 41 19.23 0940 Assume 1 time delivery charge plus 1 month rent ($83/month)
Haul costs for building waste	2	$200	each	$400	RS Means: 02 41 19.23 0920 Assume 2 loads of waste associated with the building demolition
Disposal costs for building waste	25	$90	ton	$2,300	RS Means: 02 41 19.23 0950 Assume approximately 25 tons of building waste materials - this includes the 32 well protection bollards that are to be disposed of.
			Subtotal	**$50,000**	
Removal of Lead shot					
Limited Soil excavation and off-site deposition				**$1,400,000**	Cleanup to unrestricted SCO. Activities discussed in IRM submitted to the agencies on 3/2/2012. Bulk cost estimate was provided by Omega Env. without breakdown.
			Subtotal	**$1,400,000**	
Excavation					
Dewatering	1	$50,000	lump	$50,000	Set-up and operate temp treatment system consisting of dewatering pumps, batch tank, solids filters, and GAC. Assume treated water discharged to ground surface down slope of excavation area.

Appendix C.1.2
Comparative Cost Estimates
Alternative 2 - Excavation and Off-Site Disposal
Brownfields Alternatives Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area
Union, New York

Description	Qty	Unit Cost	Units	Ext. Cost	Assumptions/Comments
Soil excavation	7700	$5	cy	$38,500	Excavate soil to top of rock and stockpile on site
Rock excavation (ripping)	18900	$20	cy	$378,000	Assuming rip removal of rock (90% of in-place volume)
Rock excavation (hoeramming)	2100	$40	cy	$84,000	Assuming hoeram removal of rock in hard spots (10% of in-place volume)
			Subtotal	**$550,000**	
Off-site T&D					
Transp and disposal of rock	47250	$200	ton	$9,450,000	Assume in-place volume (1cy = 2.25 tons); Ballpark estimate from Veolia for disposal as haz waste at EQ landfill in Michigan
Fees and taxes		15%		$1,417,500	Assume 15% of disposal cost
			Subtotal	**$11,000,000**	
Backfill					
Backfill material	25200	$15	cy	$378,000	Buy and deliver backfill material for rock excavation zone; assume rock volume + 20% for compaction
Backfill placement and compaction - rock zone	25200	$4	cy	$100,800	Place and compact imported fill
Backfill and compaction - soil zone	7700	$4	cy	$30,800	Assume backfill of soil excavation zone with stockpiled soil
			Subtotal	**$510,000**	
Monitoring Well Protection/Extension					
Well protection	1	$1,000	lump	$1,000	Assume a $1,000 lump sum cost for protection of wells with 3' diameter concrete pipe during earthwork.
Bollard Demolition	32	$59	each	$1,900	RS Means 03 05 05.10 0250. Precast concrete removal, set in masonry
Well extensions	6	$12	each	$100	McMaster-Carr price for 10-ft lengths of 2" diameter Sch. 40 PVC
Well protection extensions	10	$199	each	$2,000	McMaster-Carr price for 6-ft lengths of 4" diameter steel tubing, weldable.
Welding new casings	10	$109	hour	$1,100	RS Means: 05 05 21.90 0020 Assume 10 hours for welding the 20 3-foot 4" diameter steel casing extensions on the wells.
			Subtotal	**$6,000**	
Site Restoration					
Topsoil	1940	$20	cy	$40,000	Buy and deliver topsoil; 2.4 acre area by 6 inches
Topsoil grading, incl. seeding	11620	$4	sy	$50,000	RS Means: 32 91 19.13 1000. Assume 2.4 acre area
Gravel for access lanes	335	$19	ton	$7,000	RS Means:32 11 23.23 2030. Assume 1,000 feet of 12 ft wide and 6 inches thick gravel access lane. Assume NYDOT #4 is used, and has a density of about 110 pcf.
Geofabric for access lane	1350	$2	sy	$2,000	RS Means: 32 11 23.23 6000. Assume 1,000 feet of 12 ft wide access lane is lined with geofabric.
Temporary fence removal at excavation	300	$25	linear ft	$7,000	RS Means: 02 41 13.60 1750. Assume 300 feet of fence along the property line will be temporarily removed during excavation, then placed in original location.

Description	Qty	Unit Cost	Units	Ext. Cost	Assumptions/Comments
Relocate existing fencing	950	$25	linear ft	$23,000	RS Means: 02 41 13.60 1750. Assume 950 feet of existing fence can be reused
New fencing	850	$40	linear ft	$30,000	RS Means:32 31 13.20 0920. Assume 10 ft high with 3 strands barbed wire.
			Subtotal	**$160,000**	
			Subtotal, Construction	**$14,000,000**	
Contingency		20%		**$2,800,000**	Scope + bid contingency
			Subtotal, Construction w/Contingency	**$16,800,000**	
			Subtotal, Construction w/Contingency (w/o T&D)	**$3,600,000**	Does not include T&D of BPA soil and rock
Professional/Technical					
Remedial design (plans & specs)		5%		$180,000	Assumed percentage of construction activities, exclusive of T&D costs
Project management (planning, bidding, contract admin)		8%		$270,000	Assumed percentage of construction activities, exclusive of T&D costs
Construction management (construction oversight, review submittals, construction documentation)		15%		$540,000	Assumed percentage of construction activities, exclusive of T&D costs
Deed restriction/institutional controls	1	$10,000		$10,000	
			Subtotal, Professional/Technical	**$1,000,000**	
			TOTAL CAPITAL	**$18,000,000**	
ANNUAL COSTS					
Annual O&M					
Site inspection	2	$1,000	ea	$2,000	
Mowing	3	$90	ea	$300	
Reporting/project management	1	$2,000	lump	$2,000	
			Subtotal	**$4,300**	
			Contingency	**$1,000**	Assume 20% scope contingency
			TOTAL ANNUAL COSTS	**$5,300**	

Note: Annual costs do not include routine groundwater monitoring costs, but monitoring cost is included in present value estimate.

Appendix C.1.2
Comparative Cost Estimates
Alternative 2 - Excavation and Off-Site Disposal
Brownfields Alternatives Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area
Union, New York

Present Value Analysis
Excavation and Off-Site Disposal

			Discount Rate =	3%
Year	Capital	Annual	Present Value Factor	Present Value
0	$18,000,000		1.0000	$18,000,000
1		$45,300	0.9709	$43,981
2		$45,300	0.9426	$42,700
3		$45,300	0.9151	$41,456
4		$45,300	0.8885	$40,248
5		$45,300	0.8626	$39,076
6		$45,300	0.8375	$37,938
7		$45,300	0.8131	$36,833
8		$45,300	0.7894	$35,760
9		$45,300	0.7664	$34,719
10		$45,300	0.7441	$33,707
11		$45,300	0.7224	$32,726
12		$45,300	0.7014	$31,773
13		$45,300	0.6810	$30,847
14		$45,300	0.6611	$29,949
15		$45,300	0.6419	$29,076
16		$45,300	0.6232	$28,229
17		$45,300	0.6050	$27,407
18		$45,300	0.5874	$26,609
19		$45,300	0.5703	$25,834
20		$45,300	0.5537	$25,082
21		$45,300	0.5375	$24,351
22		$45,300	0.5219	$23,642
23		$45,300	0.5067	$22,953
24		$45,300	0.4919	$22,285
25		$45,300	0.4776	$21,636
26		$45,300	0.4637	$21,005
27		$45,300	0.4502	$20,394
28		$45,300	0.4371	$19,800
29		$45,300	0.4243	$19,223
30		$45,300	0.4120	$18,663
			Total Present Value	$18,900,000

Present value estimate incorporates annual groundwater quality monitoring cost of $40,000.

APPENDIX C.2

PROJECTED SCHEDULE YEAR 1 – PERFORMANCE MONITORING

Appendix C.2
Projected Schedule Year 1- Performance Monitoring
Brownfields Alternatives Analysis and Remedial Work Plan
IBM Gun Club - Former Burn Pit Area
Union, New York

Monitoring Location	Estimated Arrival time	Pre-Injection Monitoring/Routine Monitoring						1st Performance Monitoroing/3 months after injection						Routine and 2nd Performance Monitoroing/6 month after injection						3rd Performance Monitoroing/9 month after injection						4th Performance Monitoroing/12 month after injection					
		Field Probe	VOCs	Light Gasses	TOC	VFAs	Field Geochem	Field Probe	VOCs	Light Gasses	TOC	VFAs	Field Geochem	Field Probe	VOCs	Light Gasses	TOC	VFAs	Field Geochem	Field Probe	VOCs	Light Gasses	TOC	VFAs	Field Geochem	Field Probe	VOCs	Light Gasses	TOC	VFAs	Field Geochem
IA-1	Injection Boring	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
IB-2	Injection Boring	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
IB-7	Injection Boring	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
IA-4	Injection Boring	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
IA-5	Injection Boring	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
BP-13A	(Weeks)	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
BP-2A	(< 50 days)	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
BP-6A	**50 days**	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-4A	**Weeks**	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-37A	**50 days**	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-34A	**Weeks**	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-35A	**50 days**	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-36A	**100 days**	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
GC-2A	(>50 days)	x	x	x	x	x	x	x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-18A	(>50 days)	x	x	x	x	x	x	x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP15A	(>50 days)	x	x	x	x	x	x	x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP8A	(>50 days)	x	x	x	x	x	x	x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-9A	**50 days**	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
BP-17A	(>50 days)	x	x	x	x	x	x	x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-1A	(100 days)	x	x	x	x	x	x	x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP38A	**100 days**	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-39A	**135 days**	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
BP40A	**~ 12 months**	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-31A	**150 days**	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-23A	**80 days**	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-30A	**100 days**	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-24A	**100 days**	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	x	x	x	x	x
BP-14A	(90 days)	x	x					x						x	x					x	x	x	x	x	x	x	P	P	P	P	P
BP-16A	(>100 days)	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	P	P	P	P	P
BP-5A	**200 days**	x	x					x						x	x	P	P	P	P	x	x	x	x	x	x	x	P	P	P	P	P
BP-7A	(>200 days)	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	P	P	P	P	P
BP-12A	**150 days**	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	P	P	P	P	P
BP-11A	(>150 days)	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	P	P	P	P	P
BP-10A	(>150 days)	x	x					x	P	P	P	P	P	x	x	P	P	P	P	x	x	x	x	x	x	x	P	P	P	P	P
BP-19A	-	x	x											x	x																
BP-20A	(600 days)	x	x	x	x	x	x							x	x	P	P	P	P	x	P	P	P	P	P	x	P	P	P	P	P
BP-20	-	x	x											x	x																
BP-21A	-	x	x											x	x																
RP-9-380	-	x	x											x	x																
BP-22A	-	x	x											x	x																
BP25A	(250 days)	x	x											x	x					x	P	P	P	P	P	x	P	P	P	P	P
BP-26A	-	x	x											x	x																
BP-27A	(210 days)	x	x	x	x	x	x							x	x	P	P	P	P	x	P	P	P	P	P	x	P	P	P	P	P
BP-27	-	x	x											x	x																
BP-28A	-	x	x											x	x																
BP-29	-	x	x											x	x																
RP-13-885	-	x	x											x	x																
GC-1, P-1	-	x	x	x	x	x	x							x	x	P	P	P	P	x	x	P	P	P	P	x	x	P	P	P	P
GC-1, P-8	-	x	x											x	x	P	P	P	P	x	x	P	P	P	P	x	x	P	P	P	P
BP-12D, P1	-	x	x	x	x	x	x							x	x	P	P	P	P	x	x	P	P	P	P	x	x	P	P	P	P
BP-12D, P7	-	x	x											x	x	P	P	P	P	x	x	P	P	P	P	x	x	P	P	P	P
BP-13D, P1	-	x	x	x	x	x	x							x	x	P	P	P	P	x	x	P	P	P	P	x	x	P	P	P	P
BP-13D, P5	-	x	x											x	x	P	P	P	P	x	x	P	P	P	P	x	x	P	P	P	P
BP-14D, P1	-	x	x	x	x	x	x							x	x	P	P	P	P	x	x	P	P	P	P	x	x	P	P	P	P
BP-14D, P5	-	x	x											x	x	P	P	P	P	x	x	P	P	P	P	x	x	P	P	P	P
BP-15D, P1	-	x	x	x	x	x	x							x	x	P	P	P	P	x	x	P	P	P	P	x	x	P	P	P	P
BP-15D, P5	-	x	x											x	x	P	P	P	P	x	x	P	P	P	P	x	x	P	P	P	P

Notes:

1. The table is intended to summarize the number of groundwater monitoring events and testing parameters associated with the first year of performance monitoring related to Enhanced Biochemical Degradation. The estimated arrival times are based on Pilot Study observations of actual bromide travel times (embolden). Arrival times in parenthesis are inferred based on general hydrogeologic patterns and represents the lower range of assessed advective travel times documented in Appendix H.3 of the 2009 RI Report of Findings and the actual travel times may differ.
2. Additional field testing and water quality monitoring of injection boreholes and seeps and springs may occur during performance monitoring.
3. Field Probe testing includes estimates of bromide, pH, specific conductivity, temperature, oxidation-reduction potential (ORP), and dissolved oxygen by electrometric water quality probe.
4. Laboratory analysis of total organic carbon (TOC) and volatile organic compounds (VOCs) will be conducted by Lancaster Laboratories of Lancaster, PA. Analysis of light gasses and volatile fatty acids (VFAs) will be conducted by Microseeps, Inc. of Pittsburgh, PA.
5. Field testing will be performed for certain geochemical analytes, including dissolved oxygen (DO), iron, sulfate, sulfide, and chloride using kits and a DR800/DR2800 spectrophotometer manufactured by HACH®.
6. "x" denotes locations where samples should be collected. Where denoted "P" samples will be collected if field probe estimated ORP values are less than 20 mV.
7. Refer to Alternatives Analysis and Remedial Work Plan text for additional discussion.

Figure C.2

Performance Monitoring Network

Brownfield Cleanup Program
Alternatives Analysis and
Remedial Work Plan
IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By:	S. Warner
Designed By:	A. Horneman
Reviewed By:	D. Carr / D. Shea
Project No:	3025.00
Date:	December 2012

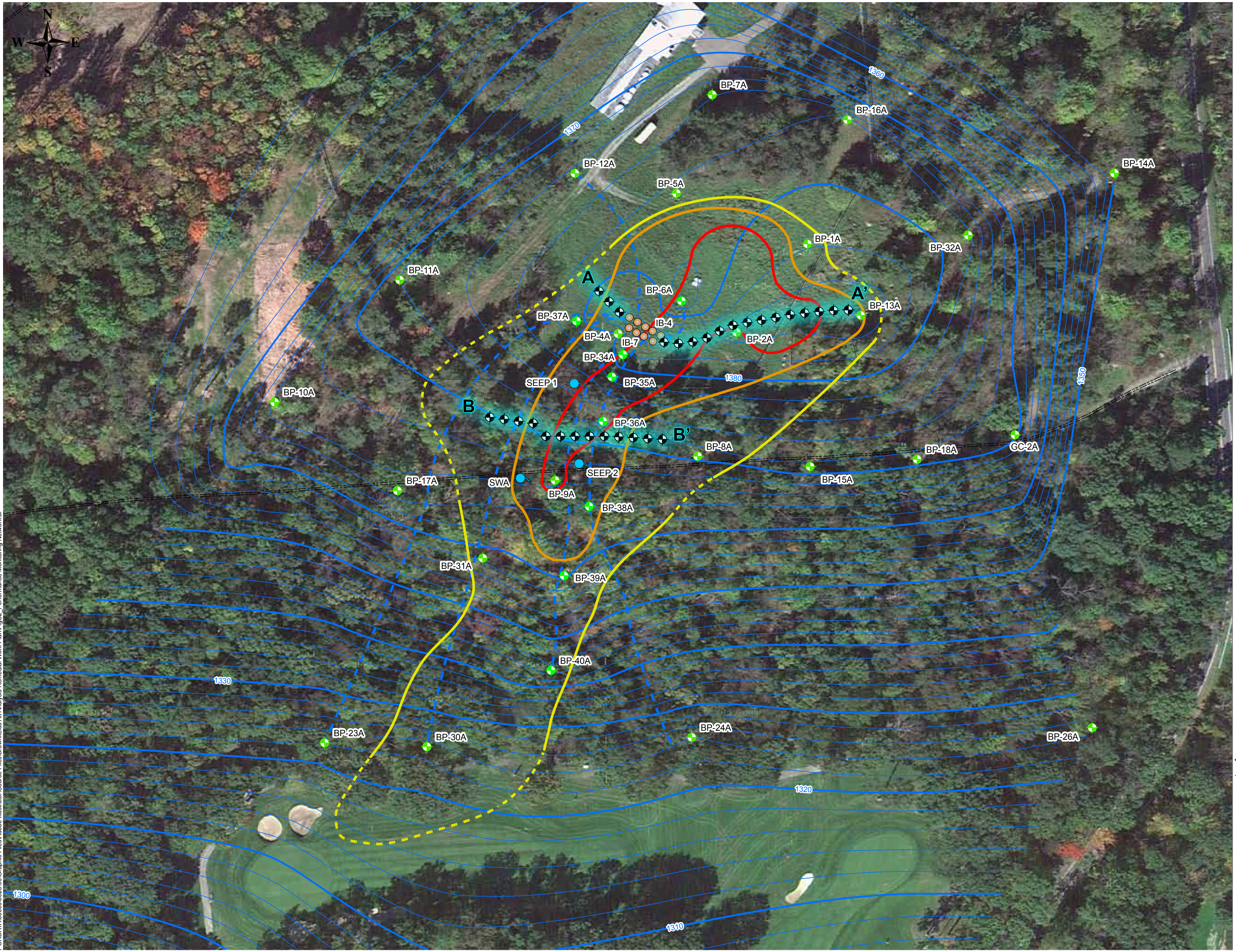

Figure Narrative

This figure summarizes locations of water table monitoring wells and seeps and springs that may be sampled as part of the EBD performance monitoring program.

Refer to Figures 1 through 6 for additional notes and legend and to the report text for additional discussion.

Legend

- Proposed Injection Boring Location
- Existing Injection Boring
- Water Table Monitoring Well
- Seeps and Springs
- Groundwater Elevation Contours (ft AMSL) (10', 2')

Feet: 50 25 0 50 100

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Last Edited By: swarner

APPENDIX D

DESIGN BASIS DOCUMENTATION

Last Edited By: swarner

Path: S:\PORDATA\3000s\3025.00\Graphic Files\GIS\Figures\Working\Soil Summary.mxd
PORDATA\3000s\3025.00\Graphic Files\Adobe Illustrator\Source Files\Brownfields Alt Analysis Remedial Work Plan\FigD1_Summary Surficial Soils.ai

Figure D.1

Summary of Surficial Soils Characterization

Brownfield Cleanup Program
Alternatives Analysis and
Remedial Work Plan
IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By:	S. Warner
Designed By:	A. Horneman
Reviewed By:	D. Carr
Project No:	3025.00
Date:	December 2012

Figure Narrative

This figure summarizes the available data recorded for soil sampling and analytical laboratory analysis which was completed as a part of remedial investigations conducted within the Burn Pit Site Parcel B of the former IBM Gun Club property. The figure is intended to support the assessment of remedial alternatives and remedial work planning for the site and components of the remedy related to soil contamination. The posted data reflect observations recorded for soil samples that exceed one or more default numerical soil quality standards established by the State of New York under New York State Rules for Environmental Remediation Programs 6 NYCRR part 375. These soil quality standards are referred to as Soil Cleanup Objectives or SCO.

As noted in the legend, locations highlighted by purple and blue color coding denote locations where soil samples from the top 2-feet below ground surface exhibited concentrations of one or more substances exceeded SCO developed for commercial or residential uses, respectively.

Please refer to figures 1 through 4 and the report text for additional notes, legend, and discussion.

Legend

Sample Location
Depth (ft)
Collection Date
Arsenic: 16
Cadmium: 2.5
Chromium: 36
Chromium III: 36
Chromium VI: 22
Copper: 270
Lead: 400
Manganese: 2,000

All posted Concentrations are in milligram per kilogram on a dry weight basis (mg/kg) for observations exceeding residential SCOs

Soil Sample Location
- Burn Pit Area Investigation
- Metal Shot Investigation

Locations Exceeding SCO
- Exceeds Commercial SCO
- Exceeds Residential SCO

Soil conditions believed to be associated with former burn pit disposal and exceeding residential SCOs in top two feet of soil.

Surveyed limits of lead shot containing soils removed by IBM in May 2012 under IRM.

40 20 0 40 80 Feet

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Figure D.2

Inferred First Aquitard Surface and Bottom of Primary Source Rock

Brownfield Cleanup Program
Alternatives Analysis and
Remedial Work Plan

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By:	S. Warner
Designed By:	A. Horneman
Reviewed By:	D. Carr / D. Shea
Project No:	3025.00
Date:	December 2012

Figure Narrative

This figure depicts certain data and inference that were considered in selecting locations and depths of drilling for boreholes to be used as injection points in implementation of enhanced in situ biochemical degradation which is a component of the selected remedy for implementation at the site. The figure depicts point estimates of the elevation of the bottom of primary source rock derived based on laboratory analysis of rock cores and the elevation of the first aquitard interval inferred from logging of rock core borings. Aquitard intervals would be expected to largely limit vertical transmission of water. It also depicts isopleths reflecting Sanborn Head inference of the relationships among these point measurements.

The aquitard elevations represent the first interval with depth where less than 10 fractures per meter of borehole were observed. The bottom of the primary source rock was defined as the interval with depth where VOC concentrations drop below 1 microgram of VOC mass per gram mass of rock on a wet field weight basis.

Please refer to Figures 2, 3, and 5 for additional notes and legend and to Section 4 of the report text for additional details.

Legend

- Monitoring Well
- Multi Level Monitoring Well
- Rock Core Location
- 1358 Inferred Elevation of First Aquitard (ft AMSL)
- 1360 Inferred Elevation of Bottom of Primary Sourcing in Rock (ft AMSL)

30 15 0 30 60 Feet

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APPENDIX E

SUPPORTING MODELING

APPENDIX E.1

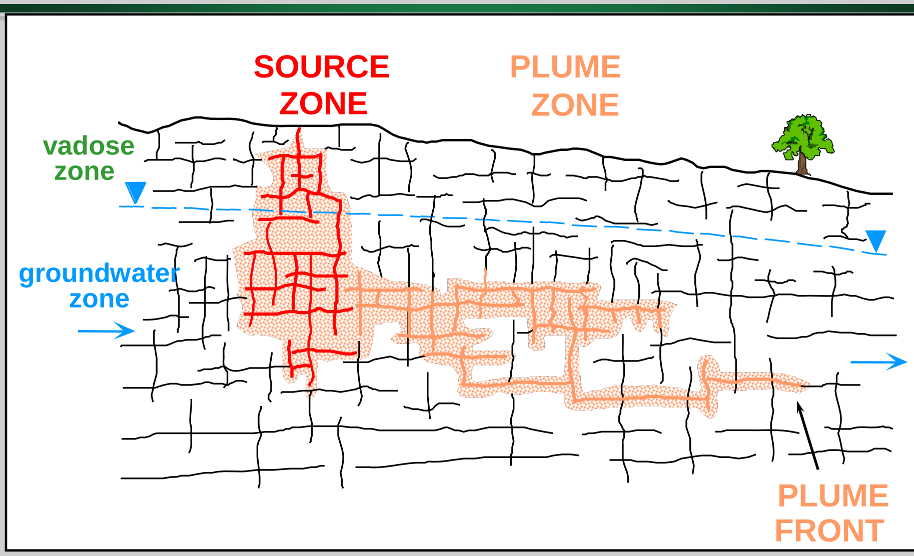
UNIVERSITY OF WATERLOO 2007 MODELING

IBM Gun Club Site Project Meeting

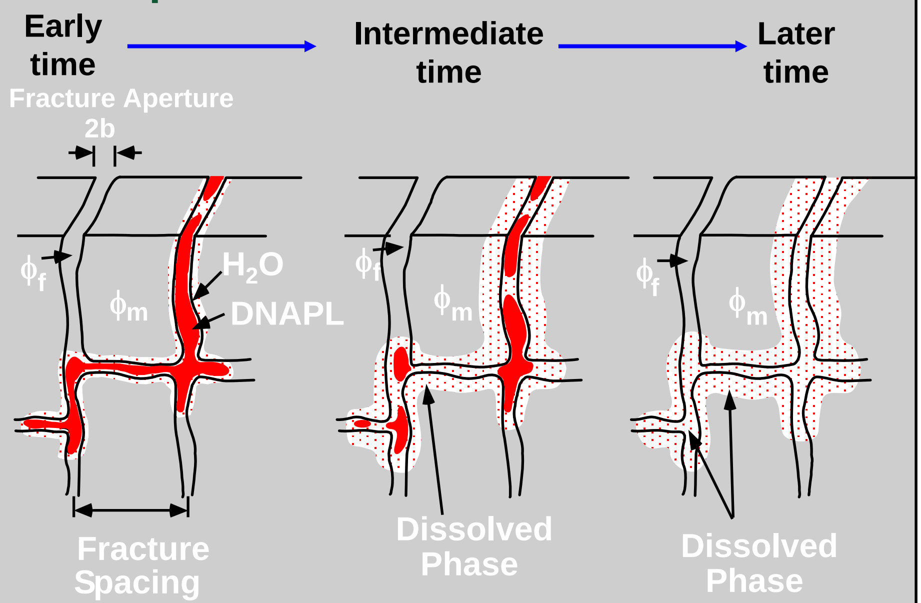
February 21, 2007

Draft February 19, 2007

DNAPL Source Zone and Plume in Fractured Sedimentary Rock

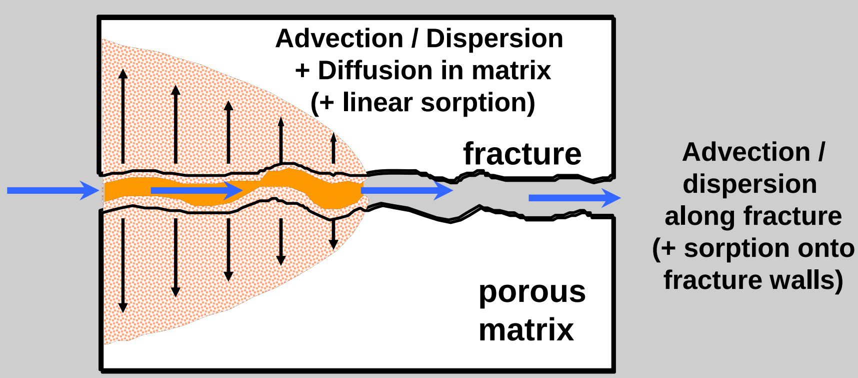


Conceptual Model for DNAPL Distribution

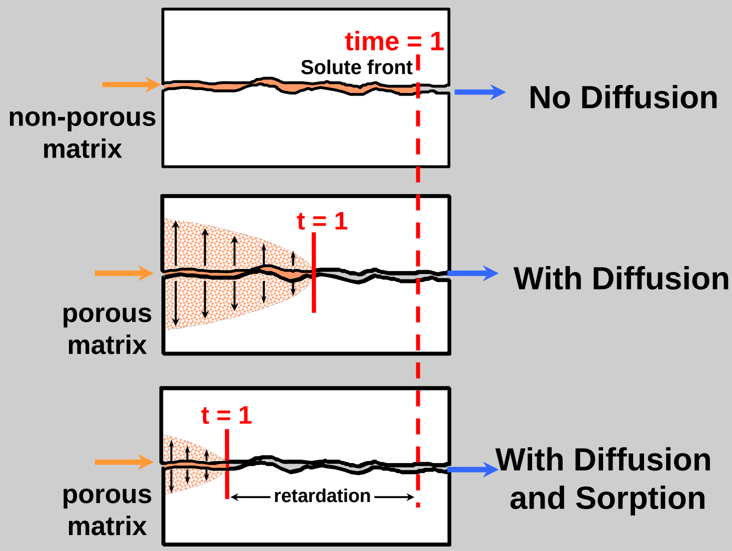


Parker et al. (1994)

Schematic of Processes



Retardation Effect Due to Matrix Diffusion

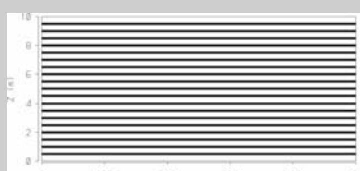


Freeze and Cherry, 1979

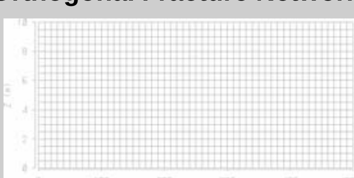
Discrete Fracture Simulations
Simple → Complex Scenarios

Single Fracture

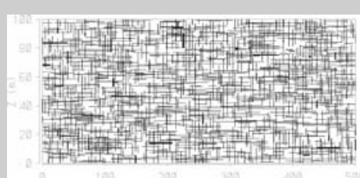
Parallel Fractures



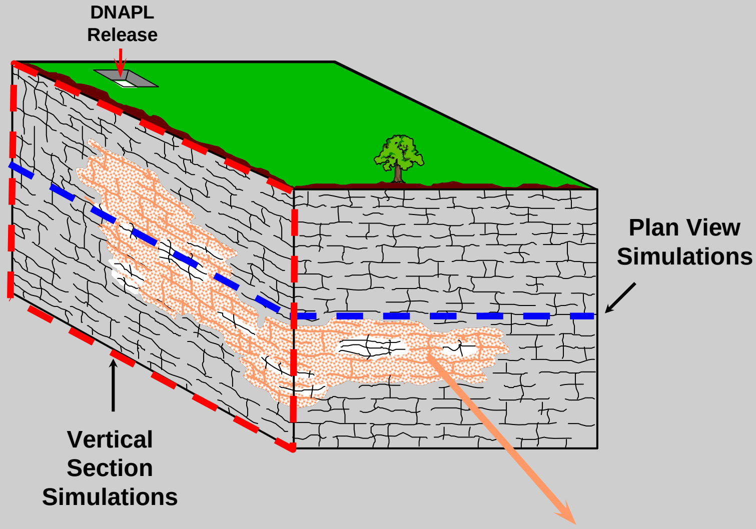
Orthogonal Fracture Networks



Random Fracture Networks



The 2-D Approach
Plan View or Vertical Cross-Section



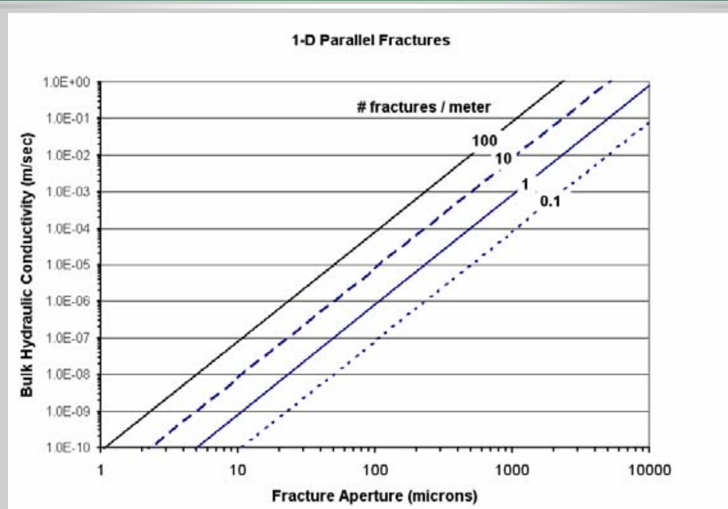
Constrain Simulations using

- Measured lab matrix parameters
  - ϕ_m, K_m, τ, $f_{oc} \rightarrow$ R, D_e
- Fracture network parameters and hydraulic data from cores, packer tests, geophysics, multilevels, slug and pumping tests, etc.
  - K_b, fracture spacing, fracture apertures, hydraulic head, fracture connectivity, etc.

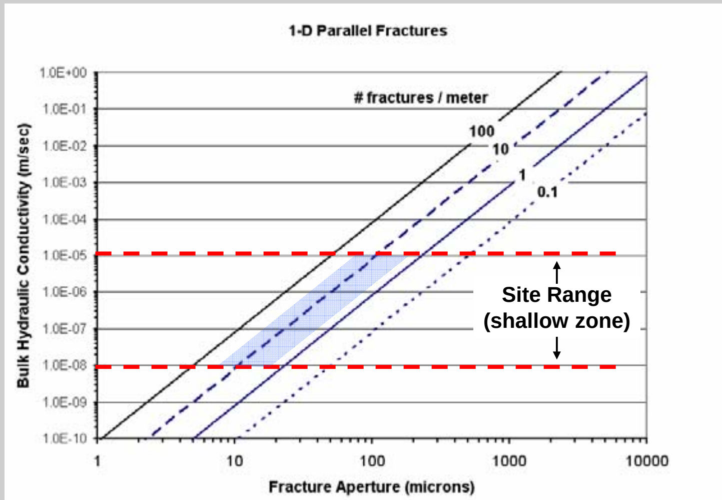
Physical Parameter Test Results Golder Associates (Mississauga, ON)

Sample ID	Sample Depth (ft bgs)	Water Content (%)	Dry Bulk Density (g/cm³)	Specific Gravity (-)	Porosity (-)	Organic Carbon Content (%)	Matrix Hydraulic Conductivity (cm/s)	Chloride Matrix Diffusion Coefficient (cm²/s)	Matrix Tortuosity Factor (-)
Phys-1 (BP-6)	8.0 - 8.2	1.2%	2.66	2.78	0.04	0.23	N/A	N/A	N/A
Phys-4 (BP-3)	6.9 - 7.2	1.1%	2.67	2.76	0.03	0.29	N/A	N/A	N/A
Phys -6 (BP -1)	19.9 - 20.3	1.0%	2.67	2.76	0.03	0.18	2.0E-10	5.0E-07	0.03
Phys -9 (BP -1)	34.6 - 35.1	1.5%	2.68	2.82	0.05	0.20	2.0E-11	8.0E-07	0.05
Phys -10 (BP -1)	37.8 - 38.4	1.5%	2.68	2.81	0.05	0.18	4.0E-10	2.5E-06	0.15
Phys -12 (BP -4)	23.5 - 24.0	1.0%	2.68	2.82	0.05	0.23	1.0E-10	7.0E-07	0.04
Phys -15 (BP -6)	24.5 - 25.0	1.2%	2.67	2.86	0.07	0.15	6.0E-11	1.0E-07	0.01
Phys -17 (BP -3)	15.0 - 15.5	0.9%	2.68	2.78	0.04	0.27	4.0E-11	2.0E-07	0.01
Phys -19 (BP -3)	38.2 - 38.7	1.4%	2.68	2.81	0.05	0.24	1.0E-10	9.0E-07	0.05
Phys -20 (BP -2)	34.7 - 35.3	1.1%	2.68	2.78	0.04	0.21	5.0E-11	3.0E-07	0.02
Phys -22 (BP -5)	26.7 - 27.2	1.5%	2.61	2.76	0.05	0.21	2.0E-10	1.0E-06	0.06
	Average	1.2%	2.67	2.79	0.05	0.22	1.3E-10	7.8E-07	0.05
	Min	0.9%	2.61	2.76	0.03	0.15	2.0E-11	1.0E-07	0.01
	Max	1.5%	2.68	2.86	0.07	0.29	4.0E-10	2.5E-06	0.15

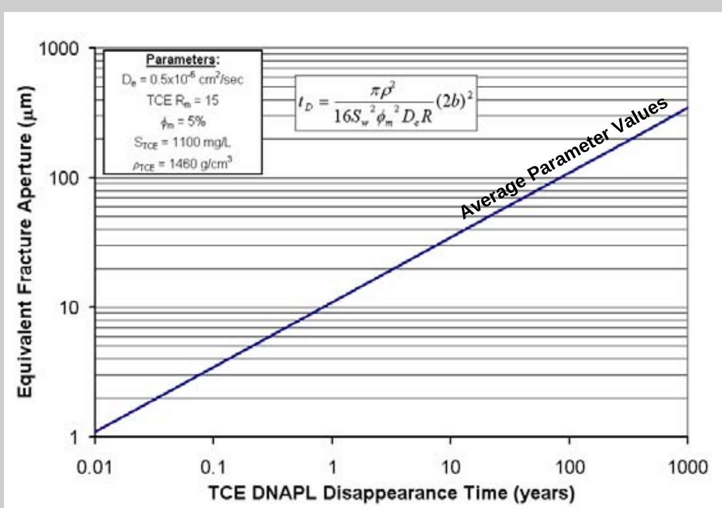
Bulk Hydraulic Conductivity for a System of Parallel Fractures



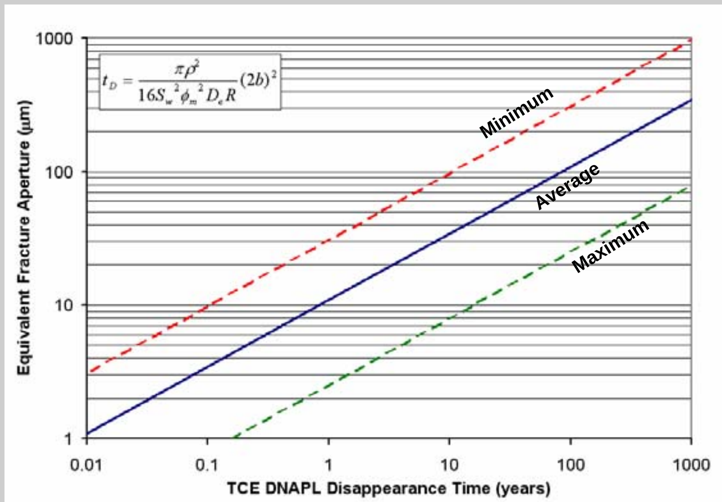
Bulk Hydraulic Conductivity for a System of Parallel Fractures



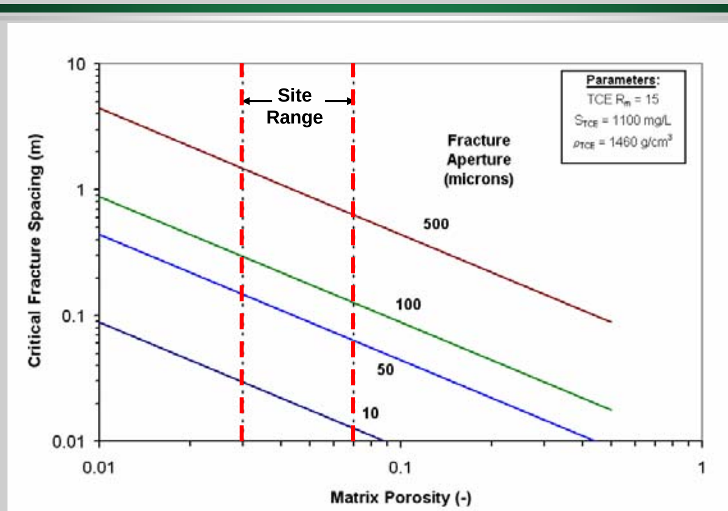
DNAPL Disappearance Time Estimates: Diffusion Only



DNAPL Disappearance Time Estimates: Diffusion Only



Critical Fracture Spacing for Complete DNAPL Disappearance: Diffusion Only



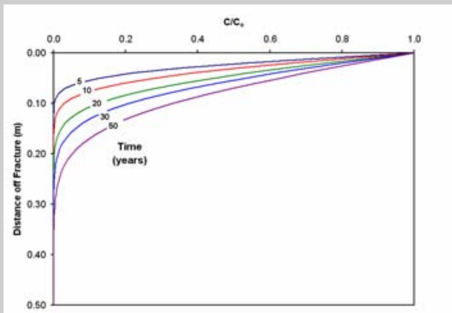
Key Points

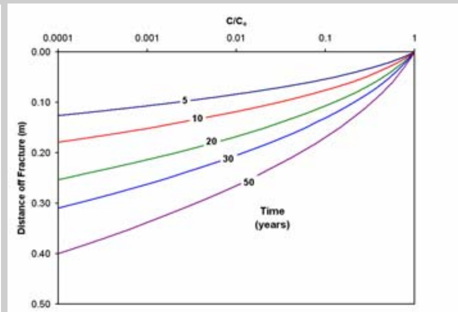
- Complete TCE DNAPL disappearance possible in a few years to a few decades by diffusion only
- Dissolution in fracture flow will speed disappearance time
- Depends on actual release conditions
  - ~ multiple releases over a few decades ?

Notes on Disappearance Time Calculations

- Neglect dissolution in groundwater flowing in fractures (and volatilization)
- Assume full fracture aperture initially saturated with DNAPL
  - ~ lead to overestimation of disappearance time
- Calculations do not account for
  - ~ multiple DNAPL releases over decades
  - ~ conditions with closely spaced fractures
  - ~ multicomponent effects on solubility, sorption, etc.

Matrix Diffusion Profiles from Constant Source





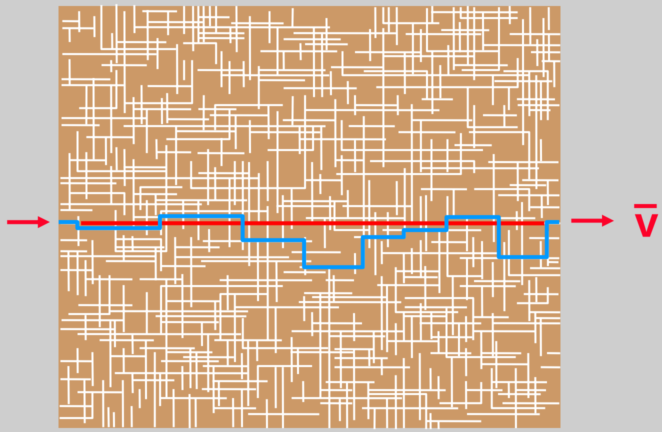
Assumes source is constant in fracture for entire period
Fracture spacing sufficient so profiles don't overlap

Plume Attenuation Due to Matrix Diffusion

Simulation Examples:

- **Attenuation of plume due to matrix diffusion / sorption**
  - ~ **assuming constant source**
- **Effect of hypothetical source zone remediation**

Average Linear Groundwater Velocity



$$\bar{v} = \frac{K_b\,[\Delta h / \Delta L]}{\phi_f}$$

where ϕ_f = bulk fracture porosity

K_b = bulk hydraulic conductivity

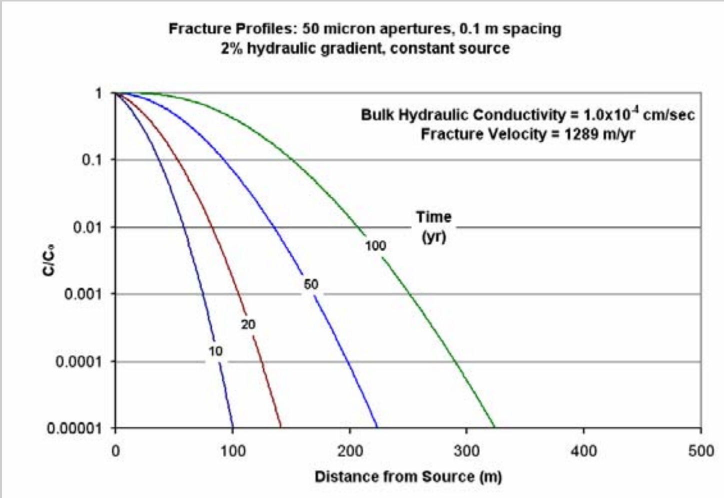
Rapid Groundwater Flow in Interconnected Fracture Network

- **Bulk K ~ 10^{-4} to 10^{-5} cm/sec**
- **Hydraulic gradient ~ 1 to 5%**
- **Fracture porosity ~ 10^{-4}**

} **typical parameters**

$\bar{v}$ ~ hundreds of meters to km / yr

Parallel Fracture Simulations: Constant Source



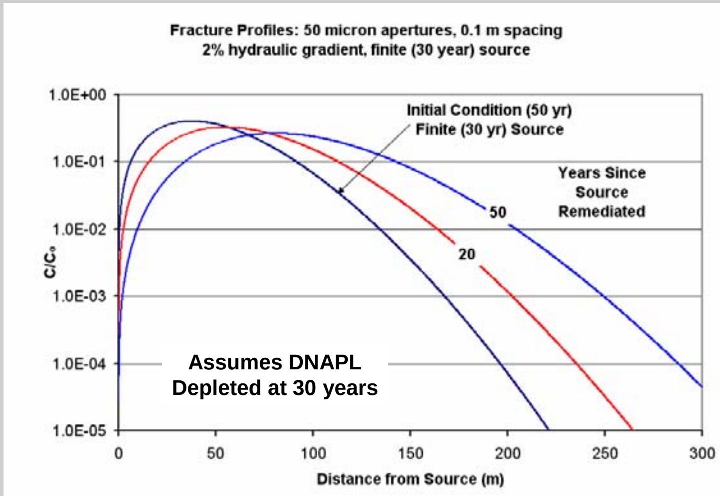
Key Point

Matrix diffusion causes plume front to travel a much smaller distance compared to groundwater

"Plume Front Attenuation Effect"

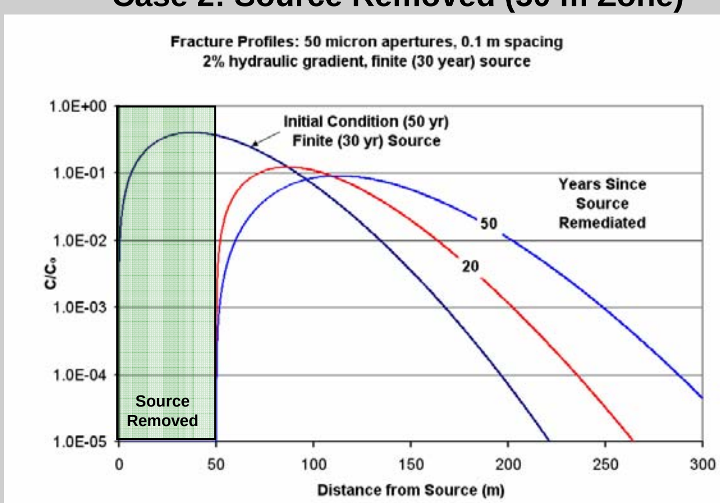
Effect of Source Removal on Downgradient Plume

Case 1: No Source Remediation



Effect of Source Removal on Downgradient Plume

Case 2: Source Removed (50 m Zone)



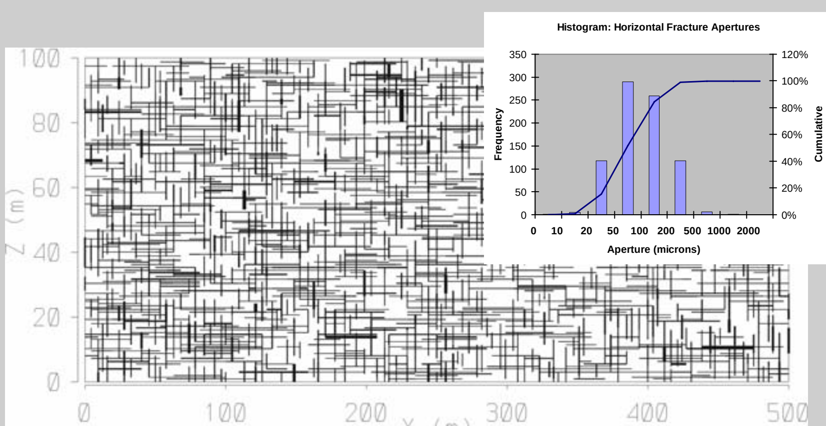
Key Point

Negligible Benefit from Source Zone Remediation on Downgradient Plume Front

BUT

Some Near-Source Reductions in Plume Concentrations

Discrete Fracture Models: More Complex Fracture Networks



2D Randomly Generated Orthogonal Fracture Network with Variable Apertures

Matrix Diffusion Implications: Source Zone

- Rock matrix has large mass storage capacity (as dissolved / sorbed phase)
- Diffusion causes disappearance of DNAPL initially present in fractures
- Much of original DNAPL mass remains proximate to release area

Matrix Diffusion Implications: Plume Transport

- Plume front travels much slower than groundwater velocities in fractures
- Plume front may become nearly stable due to diffusion only
- Degradation enhances matrix diffusion and plume attenuation

Matrix Diffusion Implications: Remediation

- Remediation is diffusion controlled assuming most mass now occurs in the rock matrix
- Source remediation activities may have limited downgradient benefits

APPENDIX E.2

UNIVERSITY OF GUELPH 2010 SUPPLEMENTAL MODELING

Supplemental Plume Fate and Transport Modeling
IBM Gun Club

Interim Output for SHA Review

Fractran 2D DFN Simulations

April 15, 2010

University of Guelph

Site Data for DFN Simulations

Parameter	Symbol	Unit	Min	Max	Mean	Reference
Matrix Parameters						
Matrix Porosity	ϕ_m	[-]	0.03	0.07	0.05	RI Report (2009) - Exhibit 3.2
Matrix Tortuosity	τ	[-]	0.01	0.15	0.05	Golder results, RI report p. 29
Matrik Hydrauic Conductivity	K_m	[cm/s]	2E-11	4E-10	1E-10	Golder Associates Report (2007) - Table 2
Dry Bulk Density	ρ_{bdry}	[g/cm3]	2.59	2.68	2.65	RI Report (2009) - Exhibit 3.2
Fraction organic carbon	f_{oc}	[%]	0.07	0.31	0.18	RI Report (2009) - Exhibit 3.2 (Golder measurements only)
TCE matrix retardation factor	R_m	[-]	5.7	21.7	13.0	Estimated using mean porosity and dry bulk density and applying f_{oc} range
Fracture Parameters						
Fracture aperture	[e]	[μm]	17	180	33	RI Report (2009) - Appendix B.6 - Table B.6.1 -- shallow zone only
Fracture porosity	ϕ_f	[-]	1.1E-04	1.4E-03	5.0E-04	RI Report (2009) - Appendix B.6 - Table B.6.1 -- shallow zone only
Fracture spacing (bedding plane)	[S_b]	[m/frac]	0.04	0.19	0.07	RI Report (2009) - Appendix B.6 - Table B.6.1 -- shallow zone only
Fracture density (bedding plane)		[fracs/m]	25.0	5.3	14.3	Calculated from fracture spacing
Fracture spacing (joints)	[S_j]	[m/frac]	??	??	??	
Fracture density (joints)		[fracs/m]	??	??	??	
Hydraulic Parameters						
Hydraulic gradient	i	[-]	0.02	0.15	0.08	RI Report (2009) - Figure 5 and text p. 22; mean value assumed for initial model runs
Bulk K	K_b	[m/s]	3.2E-08	2.6E-05	4.0E-07	RI Report (2009) - Appendix B.6 - Table B.6.1 -- shallow zone only
Contaminant Properties (TCE)						
TCE organic carbon partitioning coefficient	K_{oc}	[mL/g]	-	-	126	Table A1 - Pankow and Cherry (1996)
Distribution coefficient	$K' = K_{oc}f_{oc}$	[cm^3/g]	0.0882	0.3906	0.2268	Calculated (for HydroGeoSphere input)
TCE aqueous solubility	S_w	[mg/L]	-	-	1100	Table A1 - Pankow and Cherry (1996)
Free-solution diffusion coefficient	D_o	[m^2/s]	1.01E-09	1.01E-09	1.01E-09	Table 12.1 - Pankow and Cherry (1996)
Effective diffusion coefficient	D_e	[m^2/s]	1.01E-11	1.515E-10	5.05E-11	Calculated from D_o, τ
First-order degradation rate (TCE)	λ	[1/d]	0.001	0.009	0.005	Biotraps memo (Table 2)
Contaminant half-life (TCE)	$t_{1/2}$	[d]	700	80	140	Biotraps memo (Table 2)

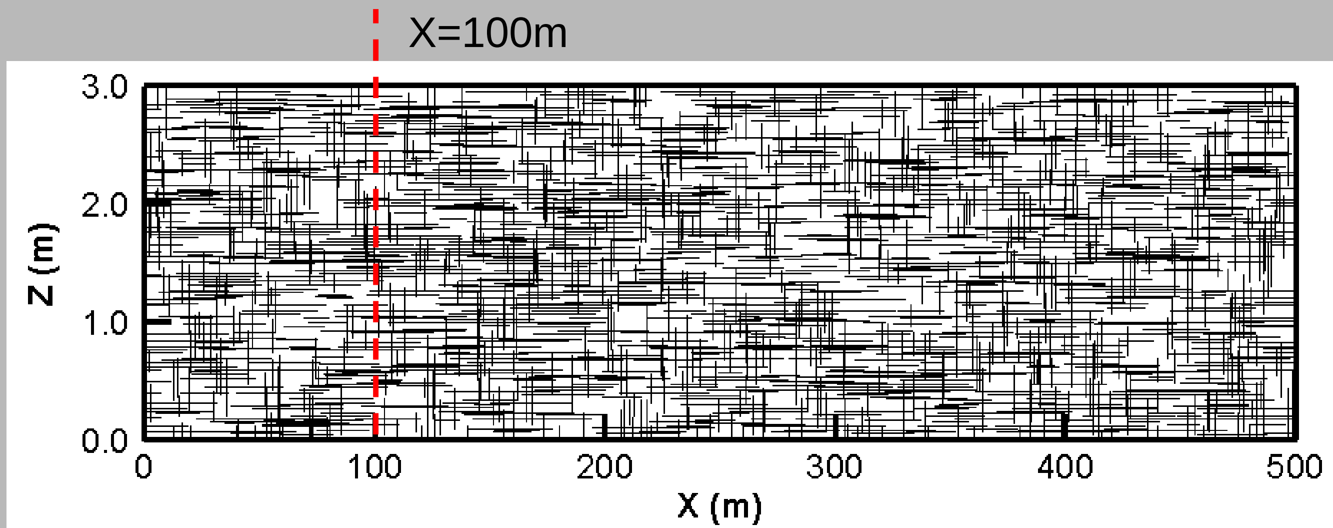
Fractran Simulations

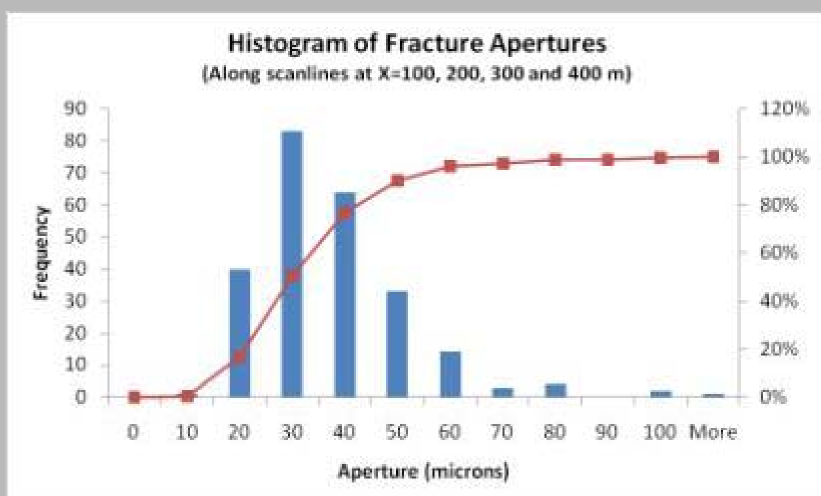
Purpose:

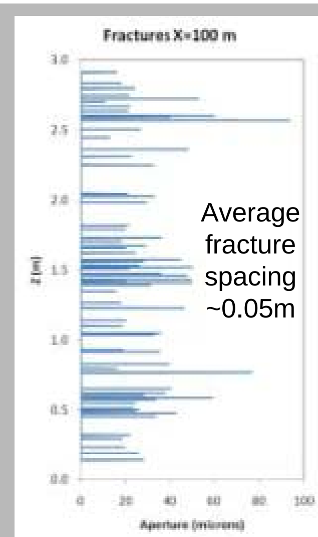
- **Attempt to create more realistic representation of fracture network and transport conditions in the upper highly fractured zone**
- **Applying mean matrix parameters (ϕ_m, τ, R, K_m)**
- **Generate fracture networks with similar range in fracture apertures, spacing and overall bulk K_h as field estimates**
- **Assuming constant source conditions for now**
- **Simulations with and without degradation (first order degradation in model)**

Fracture Network

(Single Realization of Randomly Generated Fracture Network with Statistics in Range of Upper Zone)



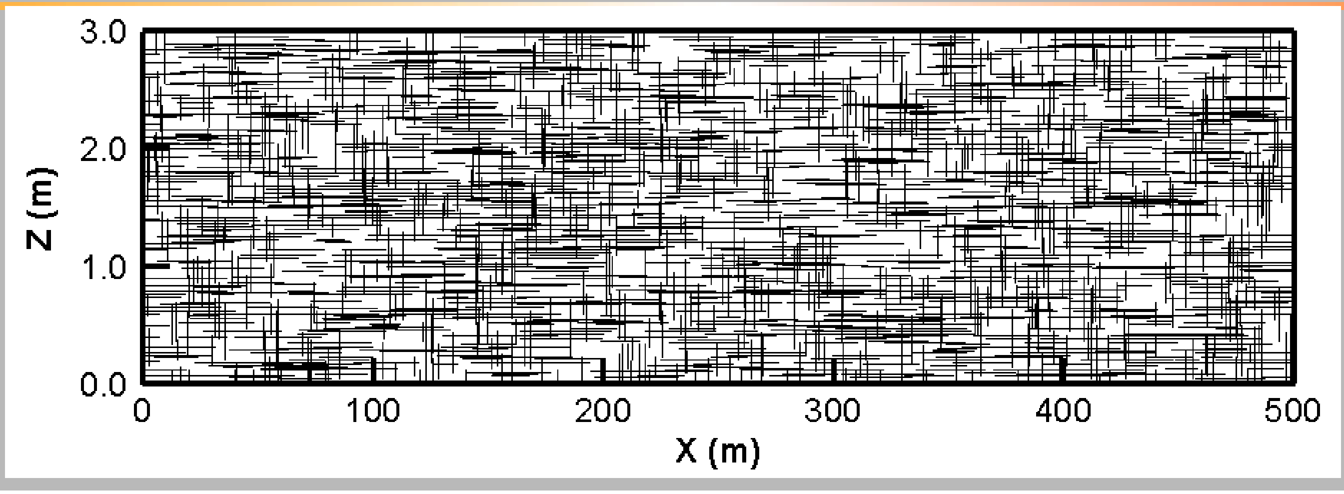


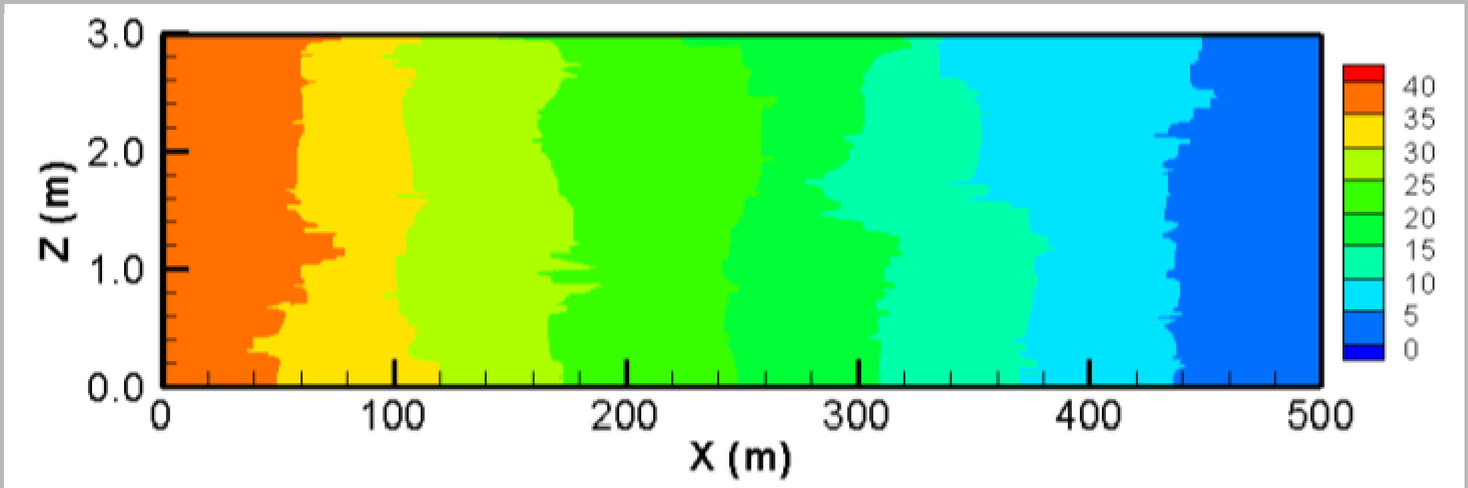


Fractran Grid Dimensions:
NX=3059
NZ=867
NN=2.65M
NHE=185,000
NVE=65,000

Very tight grid required for accurate transport simulations incorporating matrix diffusion!

Fracture Network and Hydraulic Head Distribution



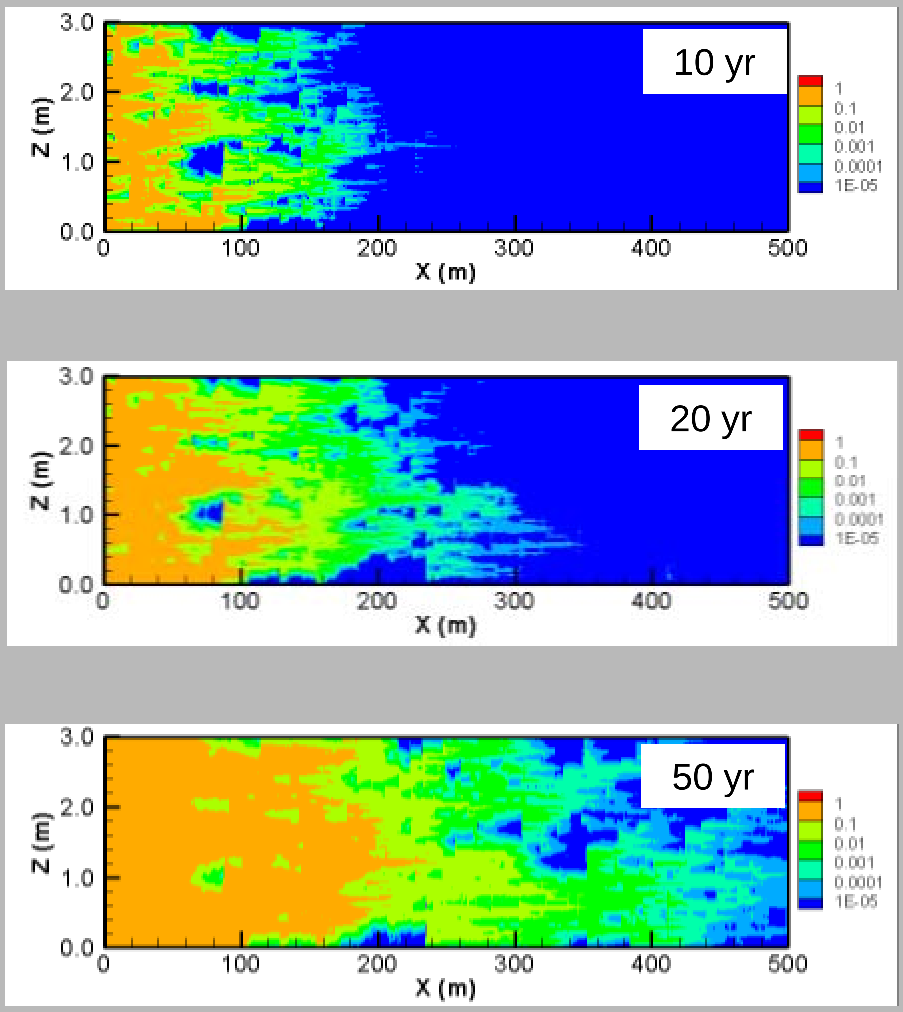


Average horizontal hydraulic gradient = 0.08

Overall bulk K_h ~ 7×10^{-7} m/s (~1.7x higher than estimated field mean value)

Overall $\phi_f = 7 \times 10^{-4}$ (both horizontal and vertical fracs)

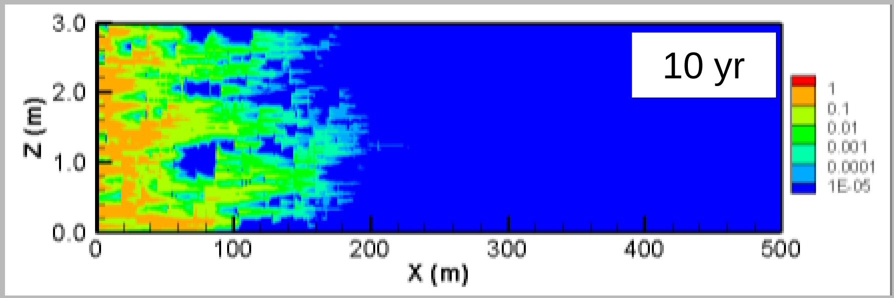
Transport Results: Constant Source No Degradation Scenario

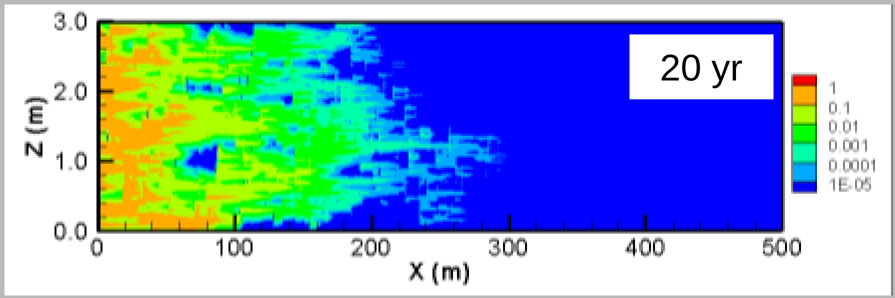


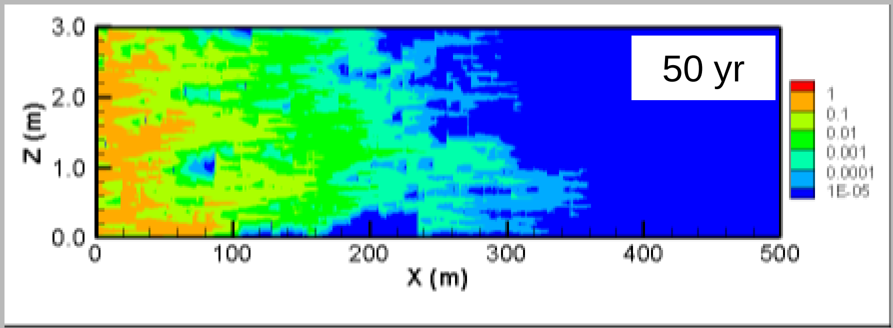
Key Point:

- **Continuing slow plume expansion in absence of degradation with constant source**

Transport Results: Constant Source With Degradation (5-yr half-life)



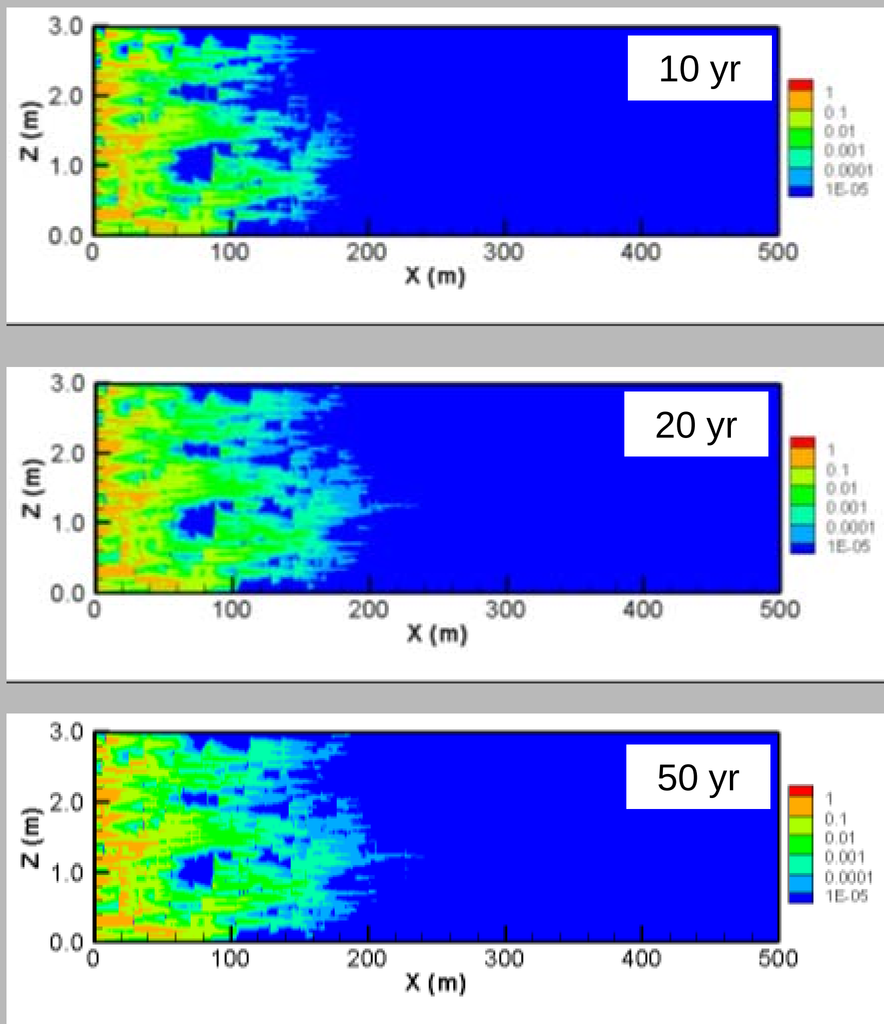




Key Point:

- **With degradation ($t_{1/2}$=5 yr) and constant source plume reaches steady state position within ~50 years**

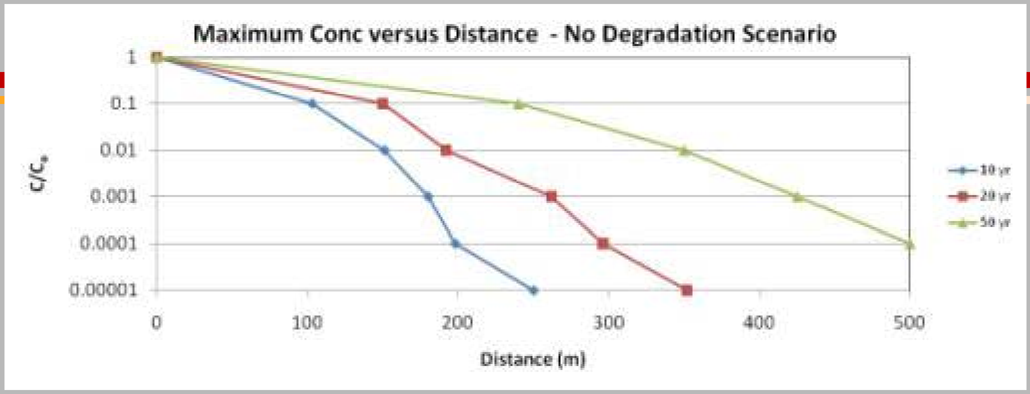
Transport Results: Constant Source With Degradation (2-yr half-life)

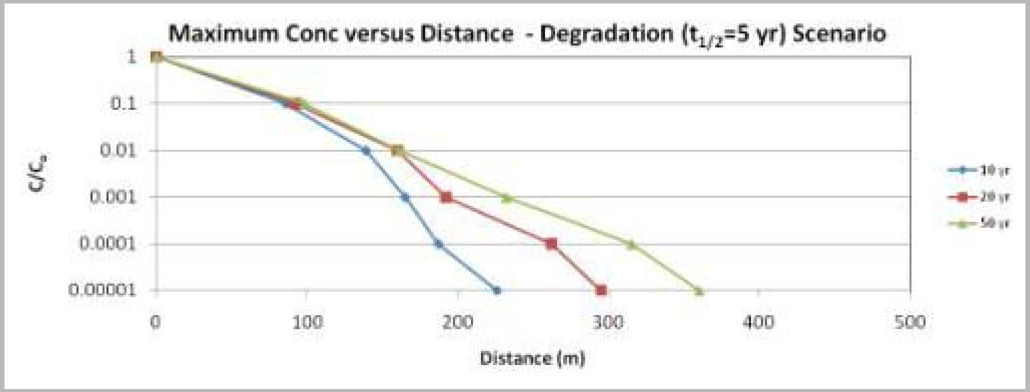


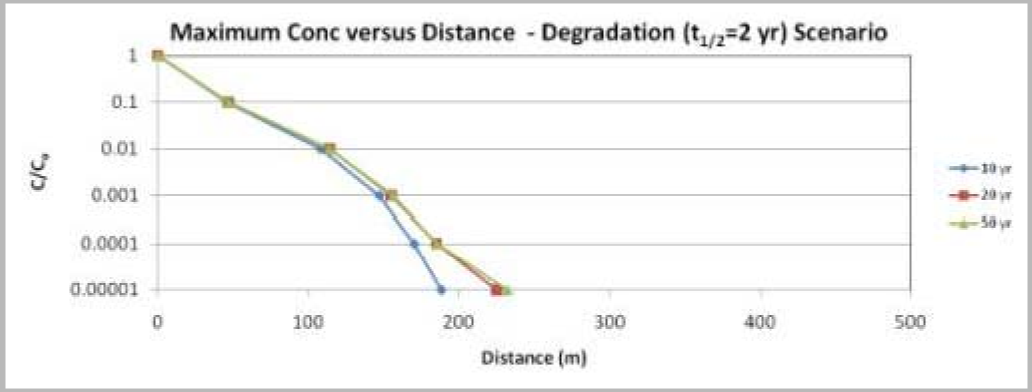
Key Point:

- **With degradation ($t_{1/2}$=2 yr) and constant source plume reaches steady state position within ~20 years**

Plots: Conc versus Distance







Key Point:

- **Plume travel distances in same ballpark as field data suggests!**

Preliminary Observations

- 2D DFN simulations incorporating more variability and tailored to field conditions produces transport distances consistent with field data
- Applying slow degradation (rates at or below low end of field measurements) causes plumes to reach steady state within a few decades with constant source
  - scenarios with declining source will produce receding plumes

APPENDIX F

CAMP, FUGITIVE DUST/PARTICULATE MONITORING

APPENDIX F

CAMP, Fugitive Dust/Particulate Monitoring

Brownfield Cleanup Program, Alternatives Analysis and Remedial Work Plan
IBM Gun Club – Former Burn Pit Area
Union, New York

Introduction

This Appendix summarizes the community air monitoring program (CAMP) associated with the work discussed in the Remedial Work Plan portion of the Brownfield Alternatives Analysis and Remedial Work Plan. The fugitive dust and particulate monitoring program associated with these activities will be performed by Sanborn, Head and Associates, Inc. (Sanborn Head).

Fugitive Dust and Particulate Monitoring

Particulate concentrations will be monitored at the upwind and downwind limit of work during remedial activities that may be associated with a potential for generating fugitive dust and particulates. The particulate monitoring will be performed using real-time monitoring equipment capable of measuring particulate matter less than 10 micrometers (10^{-6} meter) in size (PM-10) and capable of integrating over 15 minutes or less. The equipment will be equipped with an audible alarm to indicate exceedance of the applicable action levels summarized in Exhibit 1 below. Readings will be documented and made available for the Agencies upon request. Attachment 1 provides a table format that will be used in documenting observations

Exhibit 1: Particulate Screening Action Levels

Downwind PM-10 Levels 15-min. Avg. Above Background [μg/m³]	**Action**	**Comment**
100 μg/m³≤PM-10<150 μg/m³ or if dust is observed leaving the exclusion zone	Employ dust suppression techniques	Work may continue after suppressing dust.
PM-10>150 μg/m³ after employing dust suppression	Stop work and re-evaluate dust suppression activities	Work can resume when downwind PM-10 has been reduced to less than 150 μg/m³.

Attachment 1 Particulate Air Monitoring Log

Attachment 1
Particulate Air Monitoring Log

Date: ______________________________ Project: ____

Instrument: ____

Location/PM-10/15 min avg. or point	Time	Monitoring Result	Action/Comment

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