REMEDIAL ACTION WORK PLAN
For the
75-20 ASTORIA BOULEVARD SITE
JACKSON HEIGHTS, QUEENS, NEW YORK

VCA NO.: W2-0854-9906

CONSULTANT PROJECT NO.: 821687

January 30, 2008

Prepared for:

Bulova Corporation

Prepared by:

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LIST OF ACRONYMS

BGS	Below Grade Surface
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CA	Chloroethane
CO_2	Carbon Dioxide
CQAP	Construction Quality Assurance Plan
DCA	1,1-Dichloroethane
DCE	Dichloroethene
DNAPL	Dense Non-Aqueous Phase Liquids
ELAP	Environmental Laboratory Acceptance Program
EOS	Emulsified Oil Substrate
EPA	Environmental Protection Agency
EW	Extraction Well
FER	Final Engineer Report
GTI	Groundwater Technology, Inc.
HVAC	Heating, Ventilation, Air Conditioning
ITRC	Interstate Technology Regulatory Council
IW	Injection Well
MAC	MAC Consultants, Inc.
MNA	Monitored Natural Attenuation
mV	Milli Volt
MW	Monitoring Well
NaOH	Sodium Hydroxide
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
ORP	Oxidation-Reduction Potential
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated Biphenyls
PCE	Tetrachloroethene
ppm	Parts Per Million
PSIW`	Pilot Study Injection Well
PSMW	Pilot Study Monitoring Well
PID	Photo-Ionization Detector
PVC	Polyvinyl Chloride
QAPP	Quality Assurance Project Plan
RAO	Remedial Action Objectives
RAS	Remedial Action Selection
RAWP	Remedial Action Work Plan
RIR	Remedial Investigation Report
RSCO	Recommended Soil Cleanup Objectives

SCG	Standards, Criteria & Guidance
SMP	Site Management Plan
SoMP	Soil/Materials Management Plan
SVOC	Semi-Volatile Organic Compound
TAGM	Technical and Administrative Guidance Manual
TCA	1,1,1-Trichloroethane
TCE	Trichloroethene
µg/L	Micrograms Per Liter
UV	Ultraviolet
VCA	Voluntary Cleanup Agreement
VOC	Volatile Organic Compounds

CERTIFICATIONS

I, August Arrigo, am currently a registered professional engineer licensed by the State of New York. I have primary direct responsibility for implementation of the remedial program for the 75-20 Astoria Boulevard Site (NYSDEC VCA Index No. W2-0854-9906, Site No. 002453).

I certify that the Site description presented in this RAWP is identical to the Site descriptions presented in the Voluntary Cleanup Agreement for 75-20 Astoria Boulevard Site and related amendments.

I certify that this plan includes proposed use restrictions, Institutional Controls, Engineering Controls, and plans for all monitoring requirements applicable to the Site. This RAWP requires that if residual impacts remain, a Site Management Plan must be submitted by the Volunteers for the continual and proper operation, maintenance, and monitoring of all Engineering Controls employed at the Site, including the proper maintenance of all remaining monitoring wells, for approval by the Department.

I certify that this RAWP has a plan for transport and disposal of all soil, fill, fluids and other material removed from the property under this Plan, and that all transport and disposal will be performed in accordance with all local, State and Federal laws and requirements. All exported material will be taken to facilities licensed to accept this material in full compliance with all Federal, State and local laws.

I certify that all information and statements in this certification are true. I understand that a false statement made herein is punishable as Class "A" misdemeanor, pursuant to Section 210.45 of the Penal Law.

____________________	__________	____________________
NYS Professional Engineer #	Date	Signature

It is a violation of Article 130 of New York State Education Law for any person to alter this document in any way without the express written verification of adoption by any New York State licensed engineer in accordance with Section 7209(2), Article 130, New York State Education Law.

EXECUTIVE SUMMARY

Site Description/Physical Setting/Site History

Remedial activities are being completed pursuant to VCA #W2-0854-9906 between the New York State Department of Environmental Conservation (NYSDEC), Bulova Corporation (Bulova) and LaGuardia Corporate Center Associates, LLC (LaGuardia).

The Site is located at 75-20 Astoria Boulevard, Jackson Heights, New York. Jackson Heights is located near the north shore of Queens County. The Site is located north of ~~listed as block number 1027 and lot 50, and is bordered to the south by~~ 25th Avenue and west of ~~, to the east by~~ 77th Street~~, to the north by Astoria Boulevard and Grand Central Parkway, and to the west by the Brooklyn-Queens Expressway and a retail center~~.

In 1951, Bulova purchased the undeveloped property from Mow Bray Realtor. In 1952, Bulova built ~~developed the Site with~~ a two-story building and a parking lot. Between 1952 and 1986, Bulova occupied the building ~~Site~~ as its corporate headquarters, for research and development activities, and for the manufacturing of watch movements. In 1985, the Site was sold to LaGuardia, which later developed the ~~existing~~ building into a multi-tenant office complex. During Bulova's ownership, various chemical products were stored in several underground storage tanks. These tanks have since been removed.

Summary of the Remedial Investigation

Between March 2004 and December 2006, a Remedial Investigation (RI) was completed. As part of this RI, a total of 42 soil, 66 groundwater and 25 soil gas samples were collected and analyzed. In addition, precautionary soil vapor intrusion (SVI) testing was completed at the Site building and at nine (9) nearby residences. Results of the RI identified the following:

- The general stratigraphy at the Site can be described as fill material (sand, gravel and construction debris) overlying a low permeable silt layer. Underlying the low permeable silt layer is a fine sandy zone.
- The primary VOC contaminants included 1,1-dichloroethane (DCA) and 1,1,1-trichloroethane (TCA). Sporadic detections of other VOCs, including 1,1-dichloroethene (DCE), trichloroethene (TCE) and tetrachloroethene (PCE) above groundwater standards were also detected;
- The highest soil and groundwater concentrations were detected beneath a parking lot area, and were located within the low-permeable silt layer. Figures depicting the horizontal and vertical extent of soil impacts is presented below; and
- Soil and groundwater data indicate that TCA and DCA are being degraded naturally via biotic and/or abiotic mechanisms, but at insufficient rates.

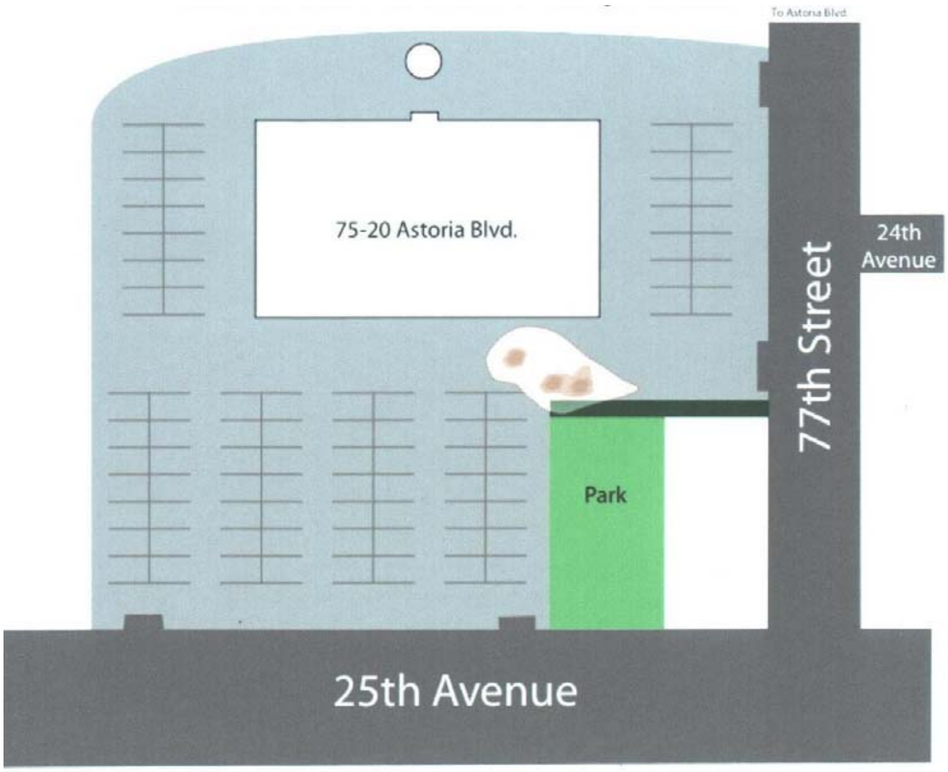

Figure 1 – Areal Placement of Soil Impacts

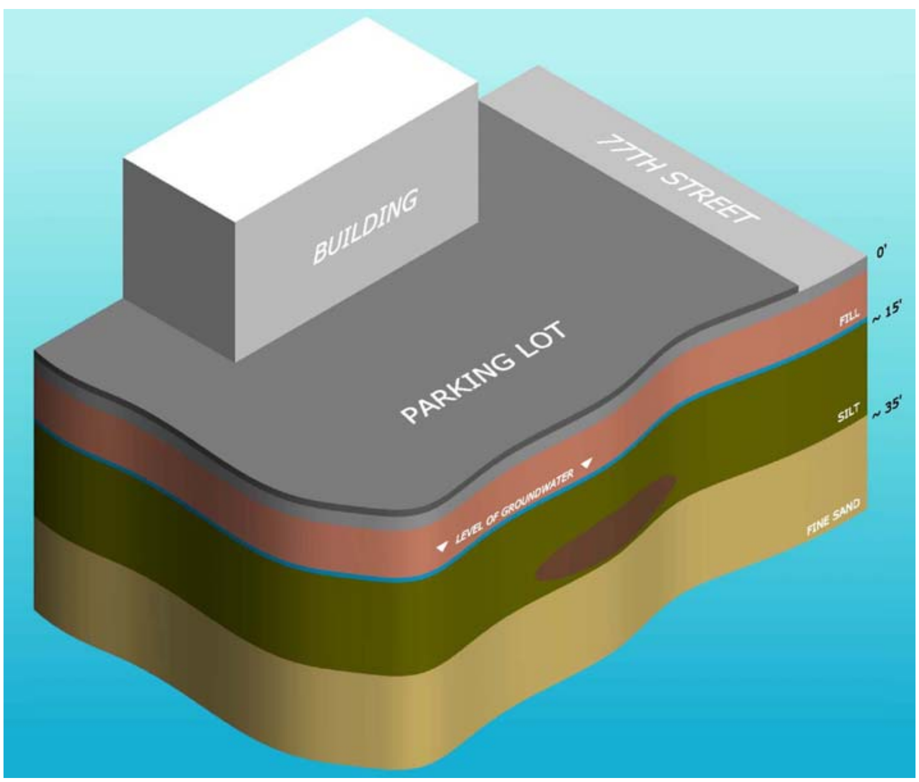

Figure 2 – Vertical Placement of Soil Impacts

In 2005, an anaerobic biostimulation treatability study was performed to screen this technology for implementation at the Site. The study was completed by adding lactate and nutrients to serum bottles containing Site soil and groundwater. Results of the biostimulation treatability study determined that TCA and DCA biodegradation rates in the source area (silt) soils were enhanced by the addition of lactate and nutrients.

Between October 2005 and October 2006, a biostimulation pilot study was completed. The purpose of the pilot study was to determine whether full-scale biostimlation treatment is feasible and practical. To complete the biostimulation pilot study, lactate and nutrients were added to the subsurface. This was initially implemented by pumping groundwater into a holding tank, amending the holding tank with the lactate/nutrients and injecting the groundwater/lactate mixture into the subsurface. Post injection monitoring identified a lactate consumption rate greater than expected; therefore, a continuous injection system was installed. This continuous injection system operated by constantly pumping groundwater from an extraction well, amending the extracted water with lactate/nutrients and reinjecting it into an injection well. The operation of this system provided a continuous supply of lactate/nutrients into the subsurface. Following completion of the pilot study, it was concluded that anaerobic biostimulation can effectively treat the Site contaminants.

Qualitative Human Health Exposure Assessment

A qualitative exposure assessment was completed as part of the RI. Evaluation of the exposure pathways concluded the following:

- Groundwater: There are no current or proposed uses for onsite groundwater; therefore, an exposure pathway does not exist. While the presence of private wells downgradient of the Site cannot be ruled out, it is highly unlikely that groundwater downgradient of the Site would be used for drinking water purposes since all of Queens County is on the New York City public water system, which gets its water from upstate reservoirs. While the use of these private downgradient wells (if any exist) for other purposes (e.g. lawn watering, car washing) also cannot be completely ruled out, it is highly unlikely that such wells would be installed into the same strata where elevated levels were identified (i.e., the silt layer) due to poor yields.
- Soil: Soils impacted by Site contaminants are present within the 15’ to 35’ below grade interval. Physical contact with these impacted soils is not possible due to the depth; therefore, an exposure pathway does not exist. In addition, the majority of the surface is covered with an asphalt parking lot.
- Soil Gas: Soil gas sampling indicated that VOC-impacted soil gas had migrated to the north (beneath the Site building) and east (across 77th Street). Based on this, the Site building as well as nine (9) adjacent residential structures were identified for precautionary soil vapor intrusion (SVI) testing. Results of the SVI testing determined that vapor intrusion had not occurred at either the Site building or at any of the adjacent residences.

Summary of the Proposed Remedy

The proposed remedy is as follows:

1. Composite Cover System: The existing composite cover cap in the vicinity of the former underground storage tanks and area of the plume will be maintained;

2. Treatment System: An *in-situ* bioremediation system will be constructed and operated to reduce contaminant levels;

3. If residual impacts remain after the remedy, ~~Recording of~~ Deed Restrictions will be ~~to be~~ executed and recorded before a Release of Liability is issued. ~~prior to approval of the Final Engineering Report.~~ Included in the Deed Restrictions will be the following:

   - Prohibition of vegetable gardens and farming at the Site;
   - Prohibition of using groundwater underlying the Site without treatment rendering it safe for its intended purpose (groundwater is not currently being used);
   - Prohibition of using the Site other than for commercial purposes;
   - Prohibition of using the Site for a higher level of use, such as ~~restricted~~ residential, without an amendment or extinguishment of the Deed Restrictions with NYSDEC approval;
   - All future activities that will disturb residual contaminated material within the treatment area require ~~are prohibited without~~ NYSDEC approval; and
   - Grantor agrees to submit to NYSDEC a written statement that certifies, under penalty of perjury, that: (1) controls employed at the Controlled Property are unchanged from the previous certification or that any changes to the controls were approved by the NYSDEC; and, (2) nothing has occurred that impairs the ability of the controls to protect public health and environment or that constitute a violation or failure to comply with the SMP. NYSDEC retains the right to access such Controlled Property at any time in order to evaluate the continued maintenance of any and all controls. This certification shall be submitted annually, or an alternate period of time that NYSDEC may allow. This statement must be certified by an expert that the NYSDEC finds acceptable. If controls are no longer required, certifications can be discontinued following NYSDEC approval.

4. If residual impacts remain after the remedy, d~~D~~evelopment of an approvable Site Management Plan that defines Site management practices following during implementation of the remedy, including 1) an Engineering Control Plan; 2) a Monitoring Plan; 3) an Operation and Maintenance Plan; and 4) a Reporting Plan; and

5. Submission of a Final Engineering Report documenting all elements of the Remedy.

1.0 Introduction

Pursuant to the Voluntary Cleanup Agreement (VCA) and on behalf of Bulova Corporation (Bulova), Shaw Environmental and Infrastructure, Inc. (Shaw) has prepared this Remedial Action Work Plan (RAWP) covering remedial activities at the 75-20 Astoria Boulevard Site, Jackson Heights, Queens, New York (the Site). This work has been completed pursuant to VCA # W2-0854-9906 between the New York State Department of Environmental Conservation (NYSDEC), Bulova, and LaGuardia Corporate Center Associates, LLC (LaGuardia). This RAWP summarizes the investigative work performed at the site, presents pertinent conclusions on the nature and extent of the contamination, and presents a work plan for the selected remedial alternative. In developing this RAWP, Shaw reviewed all available environmental investigation reports for the Site. Shaw recently completed a Remedial Investigation Report (RIR, November, 2004) to update the characterization of the nature and extent of Site groundwater contamination; completed computer modeling and laboratory treatability studies in February 2005; and performed a biostimulation pilot demonstration from November 2005 to October 2006. Based on the RIR conclusions/recommendations and recent data obtained from the laboratory treatability studies and field pilot test, Shaw has proposed an aggressive remedial strategy that will remediate contamination such that residual DNAPL sources are eliminated and groundwater impacts are reduced to acceptable levels as determined by NYSDEC.

1.1 Purpose and Organization of Work Plan

This RAWP was prepared to summarize the historical and recent environmental quality data on the Site and provide a plan for Site remediation. Sections 1 through 3 provide the background for the proposed remedy. Sections 4 and 5 provide a remedial action scope of work and implementation schedule, respectively. Section 6 summarizes the governing remedial documents. Sections 7 through 9 discuss the Engineering and Institutional Controls. Section 10 discusses the Final Engineering Report, and Section 11 summarizes the remedy.

1.2 ~~Site~~ Location

The Site is located at 75-20 Astoria Boulevard, Jackson Heights, Queens County, New York City, New York (Figure 1). Jackson Heights is located near the north shore of Queens County. ~~The property is listed as block number 1027 and lot number 50.~~ The ~~S~~site is located north of ~~bordered to the south by~~ 25th Avenue and west of ~~, to the east by~~ 77th Street. ~~, to the north by Astoria Boulevard and Grand Central Parkway, and to the west by the Brooklyn-Queens Expressway and a retail center.~~

~~The site encompasses approximately 17 acres and contains one building. The building is multi-story, measuring approximately 350 feet by 450 feet. Parking lots are located on all sides of the building.~~ A ~~S~~site map depicting the voluntary cleanup area, as described in the existing Voluntary Cleanup Agreement, is presented as Figure 2. Volunteers are in discussions with the Department to modify the Site boundaries to the treatment area.

The surrounding area includes residential and commercial properties. ~~A retail center is located to the west, residential properties and a park to the east and south, and the Grand Central Parkway to the north.~~

The closest body of water to the site is Bowery Bay, located approximately 3,000 feet to the north-northeast. Flushing Bay and the East River are located approximately 8,000 feet to the northeast and north-northwest, respectively.

1.3 ~~Site~~ History

In 1951, Bulova purchased the property at 75-20 Astoria Boulevard ~~Site~~ from Mow Bray Realtor. At that time, the property ~~Site~~ was undeveloped. In 1952, Bulova built ~~developed the Site with~~ a two-story building and a parking lot on the property. Between 1952 and 1986, Bulova occupied the building ~~Site~~ as its corporate headquarters, for research and development activities, and for the manufacturing of watch movements. In late 1985, the property ~~Site~~ was sold to LaGuardia, which later developed the existing building by constructing a third floor and renovating the existing two floors into a multi-tenant office complex. LaGuardia has owned and operated the building ~~Site~~ as an office complex since 1986.

1.4 Site Geology

There has been a considerable number of subsurface investigations completed at the site since the late 1990s. Based on these investigations, the subsurface can be generally characterized as fill material consisting of soil (sands and silts) and construction debris (i.e. brick, concrete, wood) in the upper 10-15 feet; underlying these fill materials is a low permeability silt layer which is approximately 20 feet thick. This silt layer is underlain by fine sands to the maximum depth of 60 feet below ground surface. One deep sample suggests that a silt layer underlies these fine sands.

Shallow groundwater flow in the fill material (overlying the silt layer) is in a generally southeasterly direction across the site. Depth to groundwater is approximately 15 feet below ground surface and is first encountered either in the fill as minor perched zones on top of the silt layer, or within the silt layer.

2.0 Site Characterization Activities

2.1 Previous (Through 2001) Remedial Investigations

Investigations have been conducted at the Site since the late 1990s. Thirty one monitoring wells and over 50 borings have been completed to date across the Site. The following is a list of previously prepared reports, data and correspondence regarding this Site.

- Groundwater Sampling-February 1995, MAC Consultants, Inc.
- Monitoring Well Installation and Groundwater Sampling, MAC Consultants, July 20, 1995.
- Groundwater Sampling, Groundwater Technology, Inc., April 1996.
- Draft Voluntary Cleanup Site Assessment Report and Additional Investigation and Remediation Workplan, Fluor Daniel GTI, March 5, 1997.
- Draft Voluntary Cleanup Supplemental Site Assessment Report, IT Corporation, February 21, 2002.

A summary of findings from these investigations is presented below. Historical sampling locations referenced are depicted on Figure 3.

2.1.1 MAC Consultants Investigations

In February 1995, MAC Consultants, Inc. (MAC) performed a soil and groundwater investigation in the shallow fill material. MAC collected soil and groundwater samples from monitoring wells MW-1 through MW-9/9A for analysis of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). Total benzene, toluene, ethylbenzene and xylene (BTEX) concentrations in groundwater ranged from non-detect (ND) to 15 µg/l (ppb). Total chlorinated VOCs in groundwater ranged from 21 ppb to 2,777 ppb. Total SVOCs in groundwater ranged from ND to 8.8 ppb.

In June 1995, MAC installed four additional shallow (fill) monitoring wells (MW-10, MW-11, MW-12 and MW-13); sampled six (6) monitoring wells (MW-2, MW-9/9A, MW-10, MW-11, MW-12 and MW-13); and collected soil samples from MW-13. Total VOCs in groundwater were detected at concentrations of 13 ppb, 3 ppb, and 2 ppb from MW-11, MW-12, and MW-13, respectively. No VOCs were detected in MW-10. Wells MW-2 and MW-9/9A were not sampled for VOCs. Total SVOCs in groundwater were detected at concentrations of 7 ppb, 708 ppb, and 2 ppb from MW-11, MW-12, and MW-13, respectively. Samples from wells MW-2, MW-9/9A and MW-10 did not contain any SVOCs.

2.1.2 Groundwater Technology Investigation

Groundwater Technology, Inc. (GTI) conducted a Site investigation for groundwater in the shallow fill material during March 1996. The results of this investigation were as follows:

- No measurable liquid phase hydrocarbons (free product) were present in site wells;
- Groundwater flow in the fill was to the east-southeast;
- VOC concentrations exceeded NYSDEC class GA standards in MW-1 through MW-5, and MW-9/9A with the highest concentration being DCA;
- SVOC concentrations were within NYSDEC class GA standards; and
- Benzene at a concentration of 3.2 ppb in MW-4 was the only petroleum hydrocarbon above class GA standards.

2.1.3 Fluor Daniel GTI Investigation

Fluor Daniel GTI conducted an additional Site investigation in the shallow fill materials during November 1996. Based upon the results of this investigation, Fluor Daniel GTI concluded the following:

- The soil at the Site consists of fill material containing silty and clayey sand, medium sand, gravel and construction debris (i.e.: concrete, brick and wood) overlying marsh deposits and silt/clay from approximately 16 to 20 feet below grade, underlain by sand;
- The groundwater may be perched or partially perched above the silt/clay layer. This is likely since groundwater flow beneath the site is apparently to the southeast and easterly direction, while regional groundwater flow is to the north.
- All soil samples were below state standards with the exception of two samples, B-8 (12’-17’ below grade surface (bgs)) and B-10 (15’-18’ bgs), that contained elevated levels of DCA;
- No source locations for VOCs were obvious in the area around the former underground storage tanks (USTs), except for an area in the vicinity of the former supply line location;
- Along the downgradient side of the property and off site, concentrations of DCA exceeded Class GA standards in MW-14, MW-15, MW-16, MW-17 and MW-18 and TCA concentrations exceeded class GA standards in MW-14, MW-15, and MW-16. All other parameters were below Class GA standards in the downgradient wells.

2.1.4 IT Corporation Investigation

A report entitled, “Voluntary Cleanup Supplemental Site Assessment Report”, (February 21, 2002) was submitted to NYSDEC describing the results of additional investigations at the Site.

A soil boring program was conducted in February 2001 to delineate VOCs in the shallow fill materials in the vicinity of the suspected chemical storage supply lines. The supply lines consisted of underground piping that distributed product from the former chemical storage underground storage tanks to the rear of the building. Replacement of monitoring wells MW-6, MW-7 and MW-8 due to groundwater recharge issues was also completed. Groundwater samples were also obtained from the soil borings and from monitoring wells across the Site as part of the supplemental assessment.

The soil borings did not indicate levels of VOCs above Recommended Soil Cleanup Objectives (RSCO). SVOCs and metals were detected above RSCO but these were determined to be unrelated to the presence of chemical USTs at the Site.

In the groundwater samples, elevated levels of chlorinated VOCs were reported. SVOCs, pesticides and PCBs were either not detected or were below groundwater standards. Metals were also determined to be unrelated to the presence of USTs at the site, but were related to sediment loading in the groundwater samples.

As part of the assessment, a well search was completed at the NYSDEC office to locate surrounding public wells and industrial or private water supply wells. No public supply wells are located in this part of Queens County. Public water is supplied by reservoirs located in upstate New York. Several industrial wells were located upgradient and crossgradient to the property at a minimum distance of approximately 1/5 of a mile. It is unknown if these wells are still in operation. There were no records of private wells on file at the NYSDEC office. Three industrial wells were installed on the property itself, but they were never utilized and have been properly removed and abandoned due to poor yields.

Based on the results of the investigation, IT Corporation recommended quarterly sampling and reporting for VOCs to allow for trend analysis and determination of the stability of the plume.

On April 29, 2002, the NYSDEC sent a comment letter on the above investigation requiring additional investigative activities at the Site, including additional boring/monitoring well installation; soil gas sampling; and the preparation of a qualitative exposure assessment. A subsequent meeting was held with the NYSDEC to discuss the Department’s requirements. Based on those discussions, additional activities have been conducted, which are described in the following sections of this report.

2.2 Recent Site Investigations (2002 to 2006)

Since the completion of the February 2002 Supplemental Site Assessment Report and discussions with the NYSDEC, additional investigative activities have been conducted at the Site to provide a more focused assessment on the nature and extent of contamination. In particular, soil and groundwater in the silt and sand layers that underlie the fill materials have been investigated. The NYSDEC has been kept apprised in monthly progress reports, quarterly status reports, and investigation work plans that have summarized Site activities and results. The following describes the Site activities and the results of the recent investigations at the Site.

2.2.1 Soil and Groundwater Sampling

A groundwater-sampling event was conducted on April 15, 2003. During this sampling event groundwater samples were collected from all existing monitoring wells, including MW-23 through MW-27, which were installed in January, 2003. Groundwater samples were analyzed for VOCs.

Laboratory analysis identified significantly elevated concentrations within monitoring well MW-26 (deep well, screened in the underlying sand) relative to the concentrations detected in the shallow wells. In particular, a concentration of 11,000 ppb of DCA was detected in MW-26, which was several times greater than concentrations detected in the shallow wells across the site. Resampling of this well was conducted during May 2003, which confirmed the elevated concentration.

During the original drilling of MW-26, the silt layer was penetrated by the advancement of drill augers through the stratum. The high concentrations identified based on the April 2003 and May 2003 sampling suggested a potential for the presence of Dense Non Aqueous Phase Liquids (DNAPLs) and a concern that a pathway for DNAPL to migrate beneath the silt layer may have been created. Accordingly, MW-26 was properly abandoned on June 24, 2003.

Following the abandonment of MW-26, a replacement well, MW-26R, was installed on October 22, 2003, as a double-cased monitoring well to eliminate the possibility of creating a pathway through the silt layer. MW-26R was installed upgradient of MW-26 to eliminate concerns of being within the zone of influence of MW-26.

Concurrent with the installation of MW-26R, an additional well MW-28 was installed on top of the silt layer adjacent to MW-26R. The purpose of this installation was to determine the presence or absence of a DNAPL on top of the silt layer. Measurements were taken with a free product interface probe and samples were collected for VOC analysis before and after purging. The interface probe did not indicate the presence of free product, and concentrations of VOCs before and after purging were similar (i.e. several hundred parts per billion) indicating that no measurable DNAPL existed on the top of the silt layer at that location.

VOC levels in MW-26R were found to be comparable to those in MW-26 which indicated that the previous drilling of MW-26 through this layer did not result in the migration of contamination from the shallow to deeper groundwater regimes. This led to the conclusion that the silt layer was not serving as a barrier for dissolved DNAPL components, and was not preventing the migration of dissolved VOCs to the underlying sandy aquifer.

Based on the above, additional investigations were initiated during March, April and May 2004 to delineate the horizontal and vertical extent of contamination within and beneath the silt layer. The scope of work that was approved by the Department called for the collection of groundwater samples from borings beneath the silt layer at approximately 25 foot intervals, north, east, and west of MW-26R.

During the March 2004 investigation, nine borings (GW-1 through GW-9) were completed north, east and west of MW-26R at 25-foot intervals for the purpose of delineating the contamination. The borings were completed in such a manner as to avoid cross contamination from the upper groundwater aquifer to the lower groundwater aquifer. Soil and groundwater samples were collected from each boring for analysis of VOCs in accordance with EPA Method 8260.

During drilling activities through the silt layer, elevated PID readings (>2,000 parts per million) were detected. In addition, there were olfactory indications of soil impacts within the silt. Accordingly, soil and groundwater samples were obtained from within this unit in addition to groundwater samples beneath the silt as originally proposed. A groundwater sample was collected from within the silt layer through the use of a two-inch temporary well with the well screen residing completely in the clay strata, utilizing a disposable bailer.

A soil sample obtained from the installation of GW-8 at 25 feet bgs (corresponding to 10 feet into the silt layer) contained total VOCs of 2,127,000 μg/kg; of this total, the concentration of TCA was 2,100,000 μg/kg. A groundwater sample obtained from GW-8 within the silt layer (15-25 feet bgs or 0-10 feet into the silt) exhibited total VOCs of over 315,000 μg/L with TCA comprising the majority of the contamination (310,000 μg/L). These elevated detections coupled with high PID readings (>2,000 ppm) and odor indicated a potential source area of the VOC contamination (i.e., residual DNAPL) at the Site. Table 1 summarizes the detections of VOCs in the silt and underlying sand layers across the Site.

Cross sectional perspectives of the relative distribution of VOCs are provided in Figures 4 through 6. Figure 4 presents the locations of geologic cross sections A-A' which traverses the Site in an east west direction; B-B' provides a north to south cross sectional perspective. The continuity and stratigraphic correlations of the fill, silt, and underlying fine sand deposits as well as the distribution of DCA and TCA, are shown in Figures 5 (cross section A-A[1]) and 6 (cross section B-B[1]). The vast majority of the contaminant mass resides in the silt layer (15'-35' bgs) which, although not impermeable, does appear to hinder the downgradient migration of DNAPL into the deeper groundwater regime. Thus, residual DNAPL sources appear to reside within the silt zone.

Based on these initial results, additional investigations were conducted during the April and May 2004 investigation; 22 borings (GW-10 through GW-31) were completed. The borings were completed in 25-foot increments in all directions until the extent of the impact was delineated. This investigation again concentrated on the soil and groundwater impacts within the silt layer and underlying sand layer.

2.2.2 Soil and Groundwater Sampling Results

2.2.2.1 Soil

The primary VOC contaminants in the soil at the Site, based on concentrations detected and the number of locations where RSCO values were exceeded, are DCA and TCA. There were also sporadic detections of other VOCs (e.g., 1,1-Dichloroethene (1,1-DCE), Trichloroethene (TCE), and Tetrachloroethene (PCE)) that exceeded RSCOs but concentrations were generally substantially lower than the DCA and TCA levels. Detections of these other VOCs occurred at those locations where DCA and TCA were most elevated.

Table 1 summarizes the detections of VOCs in the silt soil unit across the Site. The highest soil concentrations of DCA and TCA were detected at locations GW-3, GW-8 and GW-17. DCA concentrations at these 3 boring locations ranged from 6,300 μg/kg at GW-3 to 11,000 μg/kg at GW-8. TCA concentrations were highest in GW-8 where 2,100,000 μg/kg of this constituent was detected. GW-3 and GW-17 exhibited TCA concentrations of 170,000 μg/kg and 1,000,000 μg/kg, respectively. These concentrations were well in excess of the RSCOs, and are indicative of the presence of residual DNAPL.

2.2.2.2 Groundwater

Tables 2 and 3 summarize the detections of VOCs in the silt groundwater and deep groundwater, respectively, across the Site. Within the context of this investigation, the silt groundwater refers to the zone encountered within the silt unit and generally at a depth of 15-25 feet below ground surface. The deep groundwater refers to the sandy zone beneath the silt layer where groundwater samples were obtained at 47-49 feet below ground surface. (The groundwater from GW-6 was obtained from 49-51 feet below ground surface.) Similar to the soil analytical results, the highest VOC detections were associated with DCA and TCA. With few exceptions, the silt and deep groundwater samples exhibited DCA and TCA concentrations above groundwater quality standards. Other VOCs detected above groundwater quality standards included CA, 1,1-DCE and TCE. Elevated detections of these constituents were generally associated with the most contaminated groundwater sample locations for DCA and TCA.

In general, both DCA and TCA concentrations in the deep groundwater were orders of magnitude less than in corresponding silt groundwater. For example in GW-25, DCA concentrations decreased from 55,000 μg/L in the silt groundwater sample to 89 μg/L in the underlying deep sample. Likewise TCA concentrations decreased in GW-25 from 280,000 μg/L in the silt groundwater to 10 μg/L in the underlying deep groundwater. Soil concentrations were also generally lower in the underlying sand than in the silt layer. These data are consistent with the presence of a residual DNAPL source contained in the low permeability silt layer.

In addition to obtaining groundwater from the 47-49 foot bgs interval, additional groundwater samples were collected at greater depths at two locations (GW-8 and GW-11) to vertically delineate the contamination. At GW-8, additional samples were collected at 57-59 feet bgs and 66-68 feet bgs. Samples collected in the 57-59 feet bgs interval suggested that contaminant concentrations were decreasing substantially with depth, as DCA concentrations decreased from 4,200 μg/L (47'-49' bgs) to 26 μg/L (57'-59' bgs) and TCA concentrations decreased from 2,800 μg/L (47'-49' bgs) to 27 μg/L (57'-59' bgs). However, DCA and TCA concentrations increased to 5,200 μg/L and 6,500 μg/L (respectively) in the underlying 66-68 feet bgs interval. Despite these elevated DCA and TCA groundwater concentrations, based on soil concentrations of DCA and TCA at this depth (27 μg/kg and 17 μg/kg, respectively), a DNAPL source does not appear to be present in this deep sand layer.

During this investigation, laboratory analysis of groundwater samples collected at GW-16 identified groundwater impacts in both the silt/clay layer zone as well as in the underlying sandy zone that would be indicative of DNAPL being present; however, soil VOC concentrations were minimal. Additionally, USTs or associated lines have never been present within this area, thereby adding to the unlikelihood that a DNAPL source would exist. Based on this information, it was decided to resample GW-16 to confirm the results. On December 2, 2006, a Geoprobe® was mobilized to the Site to resample GW-16. Groundwater was collected from the silt/clay zone (19'-23' bgs) and the underlying sandy zone (45'-49' bgs), and a soil sample was collected from the silt/clay zone (30'-35' bgs). Analysis of the groundwater samples identified dramatically reduced concentrations in the groundwater, and the soil analysis confirmed a DNAPL source does not exist. The results of the soil and groundwater samples have been included in Tables 1 through 3.

2.2.3 Hydrogeologic Evaluation & Contaminant Transport

In October 2004, a total of three monitoring well clusters were installed, designated as monitoring wells MW-29S,D, MW-30S,D, and MW-31S,D. These clusters, located proximate to GW-8, GW-17 and GW-18 (see Figure 7), each contained two monitoring wells, one screened within the silt layer, and one screened in the underlying sandy zone. Appendix A contains soil boring and well construction logs for these monitoring locations.

Each monitoring well was drilled using hollow stem augers. To install the monitoring wells set into the silt layer, 4½" augers were advanced to approximately two-feet above the lower extent of the silt/clay layer. Split spoon soil samples were collected continuously in the area in which the monitoring well screen would be installed. All split spoon soil samples were screened with a photo-ionization detector (PID), inspected and logged.

Upon obtaining the required depth, a 4" Sch. 40 PVC monitoring well containing a 5-foot well screen was inserted into the borehole. Well sand was then placed around the well screen to approximately three feet above the top of the well screen, followed by three feet of bentonite.

Grout was then injected under pressure from the top of the bentonite to a depth above the silt layer. Sand was then filled to the surface and a flush-mounted roadbox installed.

To install the monitoring wells set into the underlying sandy zone, 4½“ augers were advanced to a depth in which the silt layer was identified (approximately 25 to 30 feet below grade). Following identification of the silt layer, the 4½” augers were removed and 10¼” augers were drilled into the silt layer. The 4½”augers were then advanced inside the 10½” augers to the required depth. This auger-in-auger method was completed to avoid cross contamination from the upper groundwater aquifer to the lower groundwater aquifer. Split spoon soil samples were collected continuously in the area in which the monitoring well screen would be installed. All split spoon soil samples were screened with a photo-ionization detector (PID), inspected and logged.

After obtaining the required depth, a 2” Sch. 40 PVC monitoring well containing 10-foot of well screen was inserted into the borehole. Sand, bentonite and grout were then added to the borehole in a manner similar to the wells installed in the silt layer.

Recovery tests were performed at each of the newly installed monitoring well clusters in November 2004. Results indicated that the hydraulic conductivity in the silt zone was approximately 0.014 ft/day, and that the hydraulic conductivity in the sand zone was approximately 0.072 ft/day. The hydraulic conductivity in the silt zone was higher than expected, and is likely due to the presence of interbedded sands within the silt. A pump test was performed at MW-29D in May, 2005 to confirm the hydraulic conductivity value in the sand measured by the recovery test. Pump test results indicated that the hydraulic conductivity of the sand zone was approximately 0.3 ft/day, which is in reasonable (factor of approximately 4) agreement with the recovery test data.

Groundwater flow velocity was calculated by using Darcy’s Law (assuming a porosity of 0.3) and by measuring the hydraulic gradient in both the sand and the silt zones. The measured hydraulic gradient in the silt was 0.015 to the southeast, resulting in a calculated groundwater flow of 0.25 ft/yr to the southeast. The measured hydraulic gradient in the sand was 0.0084 to the northeast, resulting in a calculated groundwater flow of 0.70 ft/yr to the northeast.

Rates of lateral DCA and TCA migration through the silt groundwater and sand groundwater were conservatively estimated by dividing the groundwater velocity by the contaminant retardation factor. The contaminant retardation factor (R) for both DCA and TCA was calculated as follows:

$$R = 1 + \frac{\rho K}{\varepsilon} \qquad \text{Eq. 1}$$

where ε is the porosity (estimated at 0.3), ρ is the soil bulk density (estimated at 1.4 kg/L), and K is the soil-water sorption coefficient (L/kg). Values of K were calculated based on data from the laboratory treatability study (Appendix B). Values of K for DCA in the silt and sand were 1.3 L/kg and 0.28 L/kg, respectively; values of K for TCA in the silt and sand were 1.1 L/kg and 0.49 L/kg, respectively. Using these K values in Equation 1, rates of dissolved DCA and TCA migration through the silt are less than one inch per year; rates of convective DCA and TCA migration through the sand are on the scale of approximately two inches per year. Thus, contaminant sources on-Site are not expected to migrate towards downgradient receptors at any appreciable rate. *NOTE: These migration estimates do not take into account any additional attenuation mechanisms, such as dilution, diffusion/dispersion, abiotic/biotic degradation mechanisms, or volatilization.*

3.0 Remedial Action Selection (RAS)

The purpose of the RAS is to identify and evaluate the most appropriate remedial action for a particular site. In developing the remedial strategy, the selected remedial alternative needs to satisfy a set of remedial action objectives (RAOs). The proposed RAOs are described below.

1. **Protection of Public Health and the Environment – Ensure that on-site contaminant levels in soil and groundwater do not pose unacceptable risks to the public health:**

   The selected remedial approach should not create a exposure pathway. Currently there is no use of groundwater at the Site and no other potential for the building occupants to contact subsurface contaminants. The only potential exposure pathway of concern is vapor intrusion into indoor air. This has been shown not to be a concern, based on indoor air sampling previously conducted at the Site and at nearby residences (see Shaw's letter reports entitled "Soil Vapor Study – 75-20 Astoria Boulevard" and "Soil Vapor Study – Various Residential Dwellings", both dated June 6, 2005, for sampling details and results).

2. **Standards, Criteria & Guidance (SCGs):**

   To the extent practical, the objective is to achieve applicable SCGs; however, at a minimum, the goal of the remedial action will be the elimination of the DNAPL sources, reduction of dissolved-phase contaminant mass to an extent acceptable to NYSDEC and preventing future exposure to residual impacts by implementation of Deed Restrictions. For evaluation of the data the following SCGs will be used: Soil: NYSDEC's TAGM 4046 - Recommended Soil Cleanup Objectives (RSCOs); Groundwater: NYSDEC's Class GA standards; and Vapor: NYSDOH's Guidance for Evaluating Soil Vapor Intrusion in the State of New York.

3. **Short-term Effectiveness:**

   The selected remedial approach should be able to achieve significant short-term (i.e. within 2 years) reductions.

4. **Long-term Effectiveness and Permanence:**

   The remedial approach selected must have the ability to achieve permanent results following completion of the remedial action.

5. **Reduction of Toxicity, Mobility or Volume with Treatment:**

   The remedial approach must have the ability to reduce the toxicity, mobility or volume of the contaminants for each media (i.e. soil, groundwater, etc.)

6. **Implementability:**

The remedial approach must be technically and economically feasible for all aspects of the project, including construction, maintenance and monitoring.

3.1 Technology Screening

During the RAS process the following remedial technologies were reviewed:

Technology	Pro	Con	Selected for Further Evaluation (Y/N)
AS/SVE	• Proven technology • TCA/DCA/CA can be easily stripped	• Difficult to implement in site geology	N
Pump & Treat	• Proven technology	• Long time frame • Low well yield rates	N
Thermal-SVE (ERH)	• Effective in saturated zone • Effective for target VOCs	• Vapor recovery may be difficult in site geology • Cost prohibitive	N
Permanganate	• Easy to distribute	• Not effective for chlorinated ethanes • High soil oxidant demands (SOD) can impede	N
Fenton’s Reagent	• Relatively quick reaction	• High SOD can impede • Fast CO_2 generation • Health & Safety considerations	N
Surfactant / Co-solvent Flushing	• Enhances removal of DNAPL • Can stimulate biodegradation	• Potential spread of DNAPL • Ex situ treatment required	N
Excavation	• Effective for soil impacts	• Does not address groundwater impacts • Potential creation of pathway for silt-layer groundwater impacts to migrate into underlying sandy zone • Disruptive to Site operations • Cost prohibitive	No; however, is being considered as a contingency

Technology	Pro	Con	Selected for Further Evaluation (Y/N)
Biostimulation	• Easy to distribute • Low-cost • Sustained activity • Treats dissolved and sorbed contaminants	• Possible slow/incomplete dechlorination needs to be evaluated in treatability studies	**Y**
Persulfate	• Easy to distribute • Rapid reaction	• High pH activation • High SOD can impede	**Y**

3.2 Laboratory Treatability Studies

In-situ biostimulation and chemical oxidation were the two treatment approaches that were considered for the Site. The effectiveness of these approaches in the subsurface depends on several site-specific factors, including soil/groundwater geochemistry, the presence of additional organic or inorganic compounds (e.g., non-target or unidentified compounds), and dissolved target compound concentrations. Laboratory treatability studies were conducted using site materials (soil and groundwater) to screen these potential treatment technologies for implementability at the Site. Appendix B contains the complete treatability study report. Highlights of the report are presented in the following subsections.

3.2.1 Biostimulation Treatment Options for TCA and DCA

In-situ biostimulation involves stimulating the degradative activity of indigenous microbial populations by introducing oxygen, a co-metabolite, electron donors, and/or nutrients into the subsurface. The assumption with this approach is that the indigenous microbial population is competent to degrade the target compounds at a site, but is unable to maintain high levels of degradative activity due to unfavorable redox or other geochemical conditions.

Biodegradation of TCA has been reported under aerobic conditions via co-metabolism, utilizing propane or ethane as the co-substrate[1]. This removal mechanism has not been studied as frequently or as thoroughly as has anaerobic degradation, but it appears to be an effective treatment option in some circumstances.
However, the groundwater characteristics within the silt layer indicate that conditions are mildly reducing, with oxidation-reduction potential (ORP) values ranging from -50 mV to -

[1] Yagi, O., Hashimoto, A., Iwasaki, K., and Nakajima, M. "Aerobic Degradation of 1,1,1-Trichloroethane by Mycobacterium spp. Isolated from Soil", *Appl. Environ. Micro*., 65, 4693-4696, 1999.

150 mV. The presence of DCA and CA indicate that anaerobic biodegradation of TCA is likely occurring. The presence of cis-1,2-dichloroethene (1,2-DCE), a daughter product of PCE and TCE anaerobic biodegradation, further indicates that reducing conditions are present within the silt source area. The presence of 1,1-DCE, a dechlorination product of *abiotic* degradation of TCA[2], suggests that abiotic transformation of TCA is also occurring at the Site. The presence of VC is likely due to the anaerobic biodegradation of PCE and TCE, and/or the abiotic degradation of TCA and 1,1-DCE.

In addition, distribution of oxygen in low permeability soil can be difficult. Thus, for this Site, anaerobic biostimulation is preferred as a treatment approach in lieu of aerobic biostimulation. Several studies have shown that TCA is amenable to anaerobic biodegradation[3]. Use of biostimulation to enhance the naturally occurring biodegradation rates has the potential to accelerate DNAPL removal and mitigate release of dissolved contaminants to the underlying aquifer. Bioremediation, in general, has been shown to be an effective *in situ* treatment technology for DNAPL source zones[4]. Shaw has extensive experience with the application of electron donors (e.g., lactate, ethanol) for anaerobic biostimulation for treatment of chlorinated organic contaminants. The use of a “slow release” electron donor (e.g., vegetable oil) has been shown to be effective at creating biological barriers to prevent the downgradient migration of chlorinated compounds. This “slow release” electron donor approach was considered for the sandy aquifer zone. Thus, an anaerobic biostimulation treatability study was proposed and implemented for both the silt zone and the underlying sandy aquifer.

3.2.2 Chemical Oxidation Treatment Options for TCA and DCA

Despite the use of biostimulation, anaerobic biodegradation rates (in some cases) may prove insufficient for removal of DNAPL sources within a reasonable timeframe. This may be due to limited microbial population, DNAPL toxicity effects, and/or geochemical conditions. In these instances, *in situ* chemical oxidation is often an effective alternative for treatment of DNAPL-contaminated soils. *In-situ* chemical oxidation is an abiotic treatment option that involves the use of chemical oxidants to chemically degrade the target compounds.

Several oxidants have been used to successfully treat volatile organic contamination in soil and groundwater by chemical rather than biological means, including hydrogen peroxide, Fenton’s reagent (hydrogen peroxide and iron catalyst), persulfate, permanganate, ozone, and ultraviolet (UV) oxidation. Typically, abiotic oxidation treats target contaminants much more rapidly than biological treatment, especially in the presence of DNAPL sources. Several instances of advanced oxidation of chlorinated ethanes using a combination of hydrogen

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[2] Howard, P.H., Boethling, R.S., Jarvis, W.F., Meylan, W.M., and Michalenko, E.M., *Handbook of Environmental Degradation Rates*, Lewis Publishers, 1991.
[3] Reviewed in: Dobson, S. and Jensen, A.A., *International Program on Chemical Safety – 1,1,1-Trichloroethane*. World Health Org., 1990.
[4] The Interstate Technology and Regulatory Council (ITRC). “Overview of In Situ Bioremediation of Chlorinated Ethene DNAPL Source Zones”, October, 2005.

peroxide and ultraviolet (UV) radiation have been reported in the literature, but application of UV treatment requires that the groundwater be pumped to the surface and treated by UV and would not be an effective *in situ* option. Distribution of ozone in low permeability soils would be difficult. Permanganate oxidation is not an effective treatment for chlorinated ethanes.

For the treatment of chlorinated ethanes, numerous successful applications of Fenton's oxidation have been reported by vendors of commercially available Fenton's reagents. Treatment can occur at neutral pH if a chelated iron is used. However, gaseous CO_2 is produced from this reaction, which will likely be difficult to mitigate within the silt and interbedded sands in a field-scale application. Persulfate oxidation at high pH, elevated temperatures, or in the presence of hydrogen peroxide has also been demonstrated as an effective treatment for TCA. Use of persulfate at elevated pH is not expected to result in rapid CO_2 production. Thus, a treatability study using persulfate was also conducted for the silt source area.

3.2.3 Implementation of Treatability Studies

The following approaches were tested in the treatability studies:

- Anaerobic biostimulation (silt source area soil and underlying sandy aquifer soil)
- Chemical oxidation (silt source area soil only)

Both studies were performed at Shaw's Laboratory in Lawrenceville, NJ. The laboratory studies were performed as microcosm studies, prepared by adding site soil, groundwater and amendments to glass serum bottles. As such, the microcosms represented fully mixed conditions and were used in order to screen site-specific treatment technologies.

3.2.4 Conclusions Derived from the Treatability Studies

Results of the laboratory treatability studies indicate the following:

- Chemical oxidation of TCA in the Source Area soil via persulfate with heat or caustic activation was ineffective, as high dosages of NaOH and persulfate (relative to the soil mass) were needed to obtain even a 60% TCA mass removal. The ineffectiveness of this treatment is due primarily to the buffering capacity and oxidant demand of the soil;
- TCA and DCA biodegradation rates in the Source Area (silt) soil were enhanced by addition of lactate and nutrients. No accumulation of CA (or any other detectable VOC) was observed;
- Using a simple first-order decay expression, and using the rate constants measured in this laboratory study, the time needed for TCA and DCA groundwater concentrations in the GW-8 Source Area to decrease to 5 µg/L is estimated at roughly 6 to 10 years

(conservatively assuming initial TCA and DCA groundwater concentrations of 500 mg/L and 30 mg/L, respectively);

- Use of Emulsified Oil Substrate (EOS) was effective at enhancing biodegradation of TCA and DCA in the Underlying Sand. A sequential biodegradation pathway of TCA to DCA to CA was identified. However, CA accumulation was observed, and CA degradation to ethane proceeded slowly, at best.

Overall, biostimulation using lactate and nutrients showed the potential to degrade TCA and DCA in the Source Area soil without accumulation of CA, thereby serving as a viable remedial option for evaluation in a pilot scale demonstration. However, due to the relatively long (6 to 10 year) time frame, additional laboratory studies using microorganisms enriched from the Site were performed. These organisms could, if needed, be used to supplement a biostimulation remedy (thereby becoming a bioaugmentation remedy). Use of bioaugmentation could potentially increase the rate of TCA, DCA, and CA biodegradation, thus reducing the overall treatment time. However, as discussed in the following section, results from the pilot test show that the estimated time frame for an *in-situ* biostimulation remedy is on the order of two years, and that bioaugmentation will not be necessary.

3.3 Anaerobic Biostimulation Pilot Test

Based on the treatability study findings, a biostimulation pilot test using lactate as the electron donor was performed between October 2005 and October 2006. Details of the pilot test are discussed in the following sections.

3.3.1 Anaerobic Biostimulation Pilot Test Objectives

The overall goal of the pilot test was to determine if progression to full-scale biostimulation treatment is feasible and practical. The specific objectives of the anaerobic biostimulation pilot test were as follows:

- <u>Confirm that anaerobic biostimulation effectively remediates Site soils and groundwater at the Site</u> – As previously stated, the primary goal of the remedial project is to treat DNAPL sources. As such, groundwater monitoring and soil sampling during the pilot test were used to confirm that this remedial objective was achieved in the pilot test, thereby serving as a tool to evaluate the potential for project success at full-scale;

- <u>Demonstrate that CA accumulation does not occur as a result of TCA and DCA degradation</u> - During the biostimulation laboratory treatability study, TCA and DCA were biodegraded in the silty soil without accumulation of CA. However, accumulation of CA was observed in treatments using emulsified vegetable oil as an electron donor, and in treatment performed at elevated (30 degrees C) temperature. In these latter two treatments, subsequent degradation of

CA proceeded slowly (at best). Thus, data collected during the pilot test was used to assess CA accumulation concerns;

- Estimate contaminant biodegradation rates – Rates of contaminant degradation were measured. These rates were used to estimate the site-wide remedial timeframe, and facilitate development of the most appropriate monitoring frequency;

- Verify the ability to effectively deliver the amendment solution – Performance of the pilot test was used to confirm our ability to sufficiently distribute biological amendments in the subsurface;

- Determine the proper injection well spacing – Due to the relatively low permeability of source area soil, injection well spacing was expected to be relatively close. Thus, determining the radius of influence during the pilot test provided essential information for full scale design and implementation;

- Estimate the required amendment dosage and consumption rate – The rate of electron donor consumption measured during the pilot test was used to design the most appropriate amendment delivery system for full-scale treatment.

3.3.2 Test Plot Layout

The pilot test location (as presented on Figure 9) was selected based on the following:

- High contaminant levels – Substantial contaminant reduction (including reduction of residual DNAPL sources) was expected during the pilot test.

- Nearby monitoring wells screened in the targeted treatment zone and monitoring zones – This mitigated the upfront capital costs of drilling/installing new wells.

- Site accessibility – The pilot test location was selected so as to limit disruption to site activities.

The test area was approximately 16 feet by 16 feet, oriented as shown on Figure 9. The treatment zone was assumed to be the bottom 10 feet of the silt layer, corresponding to the location of suspected residual DNAPL sources. Therefore, the test plot injection and monitoring wells were screened appropriately based on the geology, as described in the following paragraphs.

The first phase of the pilot test consisted of well installations. Each monitoring well location was drilled using 4½" ID hollow stem augers. Split spoon samples were collected in the area in which the monitoring well screen would reside. All split spoon samples were screened with a PID, inspected and logged.

Two (2) amendment injection wells (PSIW-1 & PSIW-2) were installed approximately 8 feet apart, down to a total depth of approximately 29 feet below ground surface (2 feet above the bottom of the silt layer (see Figure 10). The screen/sand pack interval was from approximately 21-29 feet below ground surface, insuring that the top of the interval is at least 2 feet below the top of the silt layer. Keeping the screen/sand pack at least 2 feet from the top and bottom of the silt layer would help limit short-circuiting of amendment as it is injected into the well. The target zone for the amendment (lactate & nutrients) was the silt layer, not the sandy material above or below. The injection wells were constructed of 4-inch Schedule 40 PVC.

Nine (9) additional pilot test monitoring locations were drilled within the test plot area as shown on Figure 9. Four of these locations (PSMW-1, 4, 5, & 6) contained nested monitoring points (2 wells per borehole) to monitor two distinct intervals within the target treatment zone (silt layer). The monitoring wells were constructed of 2-inch Schedule 40 PVC, as presented on Figure 10. Pilot test monitoring well PSMW-9, screened within the sandy layer below the silt, was monitored for amendment seepage (short-circuiting) during injection activities as well as to evaluate groundwater quality within the underlying sandy zone throughout the pilot test.

Pilot test well construction logs are included in Appendix A.

3.3.3 Baseline Groundwater Monitoring

Following well installation, Shaw performed baseline groundwater monitoring to characterize the current chemical, biological, and geochemical conditions within the pilot test treatment zone. Two sampling events were performed, one four weeks prior to amendment injection and one two weeks prior to amendment injection. A round of synoptic groundwater levels were measured prior to commencement of each sampling event. Sixteen (16) wells (MW-29S, MW-29D, PSMW-1 through PSMW-9, and PSIW-2) were sampled during each event using standard low flow purge sampling techniques. A multi-parameter sampling meter (YSI 6820) was used in the field to measure groundwater geochemical parameters including:

Dissolved Oxygen	pH	Oxidation-Reduction Potential (ORP)
Turbidity	Temperature	Conductivity

These readings not only were used to characterize the geochemistry of the groundwater at each well, but their stability was also used to serve as criteria for sample collection. Samples from each location were analyzed for VOCs, natural attenuation parameters (NAPs), and volatile fatty acids (VFAs, including lactate). NAPs to be analyzed for include the following:

Total Dissolved Solids	Chloride	Methane	Sulfate

Total Phosphorus	Nitrate	Ethane	Sulfide
Alkalinity	Nitrite	Ethene	

One trip blank was analyzed for VOCs for each cooler. For the first baseline sampling event, Chemtech Laboratories, located in Mountainside, New Jersey, conducted the VOC analyses, while Shaw's in-house laboratory located in Lawrenceville, New Jersey, conducted all other analyses. For the second baseline sampling event and all future sampling rounds, Shaw's in-house laboratory conducted all analyses.

Pilot test baseline groundwater sampling results have been included as part of Table 4.

3.3.4 Pilot Test Implementation Procedures

Between October 1 and 16, 2005, approximately 2,800-gallons of groundwater was collected into a tank and subsequently amended with electron donor (sodium lactate to a concentration of approximately 2,500 mg/L) and nutrients (yeast extract and diammonium phosphate to concentrations of approximately 200 mg/L each). Injection of the amended groundwater into PSIW-1 was then initiated on October 17, 2005 and continued until October 31, 2005. Following the completion of the injection, three rounds of post-amendment injection groundwater sampling was performed. These sampling events commenced on November 7, November 14, and November 21, 2005.

As will be discussed in Section 3.3.5, the observed rate of electron donor consumption during this initial phase of the pilot test was substantially greater than the rate of electron donor consumption observed during the laboratory microcosm testing. To maintain an electron donor supply sufficient to facilitate biodegradation of the chlorinated ethanes, the pilot test methodology was modified to include a continuous groundwater injection-extraction approach. The re-injected groundwater was amended with electron donor and nutrients at concentrations similar to the initial batch injection. Design and installation of the injection/extraction system was completed in the first week of February 2006. Photographs of the pilot test continuous injection system has been included as Appendix D.

Starting February 10 through March 30, 2006, the continuous flow recirculation system operated utilizing MW-29D as the extraction well and PSIW-1 as the injection well. The groundwater recirculation flow rate was approximately 0.1 gpm. Groundwater monitoring events during this phase were conducted on March 1, March 15, and March 29, 2006.

Between April 4 and June 1, 2006, monitoring well MW-6D was utilized as the extraction well, and PSIW-1 continued as the injection well. This modification was made to limit decreases in chlorinated ethane concentrations in the source area due to dilution, as chlorinated ethane concentrations in MW-29D were relatively low compared to pilot test area wells. The groundwater recirculation flow rate extracted from MW-6D (and subsequently injected into

PSIW-1) was approximately 0.06 gpm. Groundwater monitoring events were conducted on April 12, April 27, May 10 and May 25, 2006.

Between June 1 and July 19, 2006, monitoring well MW-29S was utilized as the extraction well, and PSIW-1 continued as the injection well. This modification was made to limit VOC loading into the bioreactive zone, as MW-6D was located outside the bioreactive zone and thus was not being influenced during the pilot study activities. The groundwater recirculation flow rate was approximately 0.04 gpm. Groundwater monitoring events were conducted on June 7, June 22, July 5, and July 19, 2006.

Following shutdown of the groundwater recirculation system on July 19, 2006, three post-injection groundwater sampling events were performed to evaluate potential contaminant rebound, and/or to evaluate chlorinated ethane decay in the absence of active recirculation. These sampling events were conducted on August 1, September 6 and October 17, 2006.

A summary of the pilot treatment schedule and operating conditions is presented in Table 6.

On September 5, 2006, two soil borings (GW-32 and GW-33) were completed for the collection and analysis of soil samples. These borings were collected to confirm that chlorinated ethanes were effectively treated in the soil and/or undissolved phase. Soil cores were collected from the approximate center of the pilot test area (Figure 9). Two soil samples from each soil boring were selected for laboratory VOC analysis (EPA Method 8260), and were selected based on PID readings or, in the absence of elevated PID readings, the screened zones of the nested monitoring wells. At GW-32, soil samples were collected from 10’-15’ bgs and 20’-25’ bgs, and at GW-33 soil samples were collected at 20’-25’ bgs and 25’-30’ bgs.

3.3.5 Results

Groundwater monitoring results for each phase of the pilot test are summarized in Table 4. Depth-to-water measurements measured at baseline, and at 24 and 72 hours after commencing batch injection, are summarized in Table 7. Observations for each phase are discussed in the sub-sections below.

Initial Batch Injection

Results of the initial batch injection showed the following:

- A radius of influence of at least 9 feet, as indicated by elevated water table levels and/or the presence of lactate fermentation products (e.g., acetic, propionic, formic, or butyric acids), was observed. In addition, amendments were effectively delivered radially and vertically throughout the targeted treatment zone, as only two monitoring locations (PSIW-2 and MW-8) did not have any detectable levels of VFAs during the first phase of injections.

- Elevated water table levels and VFA concentrations at MW-9 indicate that amendments were also delivered in the shallow sandy zone (immediately below the targeted interval) at a rate similar to the silt source area.

- ORP and sulfate concentrations decreased, indicating that biological activity (facilitated by the addition of the electron donor) was creating reducing conditions in the aquifer.

- CA concentrations increased at several monitoring locations, likely due to dechlorination of TCA and DCA.

- Lactate concentrations were below the analytical detection limit in all monitored wells, presumably due to rapid consumption of this readily-biodegradable electron donor. In addition, concentration of the other fermentable VFAs were generally low (i.e., <100 mg/L). These data suggest that electron donor demand in the aquifer was greater than anticipated, and that a constant supply of lactate was required to maintain the needed biogeochemical conditions. The reason for the increased rate of lactate consumption, relative to the laboratory data, is not readily explained, but may be due to increased microbial growth in the natural aquifer compared to the closed microcosm system.

Recirculation from MW-29D, MW-6D, and MW-29S into PSIW-1

Groundwater monitoring during groundwater extraction from MW-29D, MW-6D, and MW-29S (Phases 2 through 4, respectively) confirmed the observations identified during the initial batch injection. Injection of the electron donor resulted in a continued decrease in sulfate concentrations, generation of methane, decreases in TCA and DCA, and transient increases in CA. These observations are all consistent with a sequential reductive dechlorination process. As suggested by the laboratory microcosm studies, as well as by published chlorinated ethane studies (Galli and McCarty, 1989; Chen et al., 1999), the biodegradation end-product was likely acetic acid (and ultimately CO2). However, these end products were also generated due to the lactate fermentation, so evaluation of a chlorinated ethane mass balance was not possible. As such, a quantitative interpretation of the varying chlorinated ethane concentrations throughout the course of the pilot test was performed using a three-dimensional numerical groundwater flow and transport model, as discussed in Section 3.3.6.

It is noted that monitoring well MW-31S, which is located far outside of the pilot test area, had measurable concentrations of acetic acid. Elevated chlorinated ethane levels are also present at this location. This observation suggests that (consistent with the studies cited in the previous paragraph) naturally occurring biodegradation of chlorinated ethanes to acetic acid may be occurring at the site, and that biostimulation likely accelerated this process.

Post-Injection Rebound Monitoring

Post-injection monitoring provided an opportunity to observe the fate of DCA and CA in the absence of any substantial groundwater flow (based on the low natural groundwater flow velocities discussed in Section 2.2.2, contaminant migration due to groundwater flow over the duration of the rebound phase was expected to be negligible). Monitoring results during the post-injection period showed that, at locations where sulfate reducing conditions were maintained and electron donor was still present (e.g., monitoring well MW-5S, MW-29S), decreases in DCA and CA continued. These decreases are likely due to the continued dechlorination of the chlorinated ethanes. In comparison, post-injection monitoring at PSIW-2, MW-6S, and MW-6D showed VFA concentrations below the analytical detection limit, and sulfate concentrations greater than 200 mg/L; no substantial chlorinated ethane degradation was observed at these locations during the post-injection monitoring.

Soil Sampling

A summary of soil analytical results for GW-32 and GW-33 are included as part of Table 1. Soil boring logs for these locations have also been included in Appendix A. Post-treatment soil results show that chlorinated ethane sources are likely not present within the core (i.e., between PSIW-1 and PSIW-2) of the pilot test area.

3.3.6 Data Evaluation

Due to the simultaneous fate and transport processes (e.g., groundwater flow, dispersion, sorption, biodegradation) that were occurring during the pilot test, confirmation of complete chlorinated ethane biodegradation and estimation of degradation rates during active injection/extraction is difficult. As such, a three-dimensional conceptual model was developed using the widely-implemented and commercially available MODFLOW and RT3D models (US Geological Survey, 1996; Clement, 1997). Model development, including key assumptions and parameters, are presented in Appendix C. Hydraulic parameters were estimated based on slug test data and measured water table elevations during pilot test start-up. TCA, DCA, and CA biodegradation rates were estimated based on both the laboratory data, as well as the degradation rates observed during the post-injection monitoring (discussed in Appendix C). Estimated first-order biodegradation rate constants for TCA, DCA, and CA were 0.35, 0.35, and 0.1/day, respectively.

Simulated and measured groundwater DCA concentrations are shown for the four monitoring wells in the core of the pilot test treatment area (i.e., monitoring wells MW-29S, PSMW-4S, PSMW-4D and PSMW-5S) in Figures 11 through 14. Results show that the simulated concentrations are in reasonable agreement with the measured values, confirming that the simulated first-order DCA biodegradation rate constant of 0.35/day is an appropriate estimate of the DCA decay rate. NOTE: Monitoring well MW-5D was excluded from the analysis because this well appeared to have a short-circuit pathway to the injection well (PSIW-1), as indicated by the relatively large increase in water table elevation during active injection.

Simulated and measured groundwater CA concentrations are shown for the same four monitoring wells in Figures 15 through 18. To facilitate evaluation, simulated first-order CA biodegradation rate constants of 0.0, 0.05, and 0.1/day are presented. Results show that simulated concentrations using a biodegradation rate constant between 0.05 and 0.1/day provide a reasonable estimate of the measured values; this estimated range of the first-order biodegradation rate constant is consistent with the measured CA degradation rate during the post-injection period, as discussed in Appendix C.

TCA groundwater concentrations within the core treatment area were generally less than 5 mg/L at baseline, as (presumably) most of the TCA present had already degraded to DCA prior to the pilot demonstration. After the initial batch injection, TCA levels generally decreased to below or near the analytical detection limit in all monitoring locations.

Simulated TCA, DCA, and CA concentrations in the pilot test area are shown in Figures 19A through 21C. These simulation results are provided at t=2 days (start of pilot study) and 146 days (completion of pilot study), and illustrate the biodegradation of the TCA and DCA during the pilot test. Decreases in TCA and DCA concentrations over the duration of the treatment period are evident. However, during the pilot study, increases in CA concentrations were observed, as illustrated in Figure 21A and 21B. To determine if CA biodegradation was occurring, a simulation was run under the assumption that NO biodegradation of CA would occur. The result of this simulation is included as Figure 21C. A comparison of Figures 21B and 21C demonstrate that CA concentrations did decrease during the pilot demonstration as a result of biodegradation. Thus, simulation results presented in these figures are consistent with the results shown in Figures 15 through 18.

3.3.7 Conclusions Derived from the Pilot Test

Overall conclusions derived from the pilot test are as follows:

- Using a single injection well, at least a 9-foot radius of influence was attained
- Amendment distribution was observed in both the silt and sand directly below the silt layers
- In situ TCA, DCA, and CA biodegradation rate constants of approximately of 0.35, 0.35, and 0.1/day were attained using lactate-enhanced biostimulation
- Degradation of CA is occurring. Evidence of this fact is demonstrated in the observed decreases in CA concentrations (and corresponding model simulations) shown in Figures 15 through 18, and the continued decay in CA concentrations during the post-injection monitoring in locations maintaining sulfate reducing conditions (e.g., monitoring locations MW-29S and MW-5S in Table 4)

The pilot test was also used to verify a site conceptual model, describing both groundwater flow and chlorinated ethane fate.

The estimated first-order rate constants provide a basis for calculating the treatment timeframe for full-scale implementation, as described in Appendix C. Assuming the following:

- an initial soil concentration of 2,100 mg/kg TCA (maximum value, measured at soil boring location GW-8);
- an initial groundwater concentration in the DNAPL source area of 300 mg/L (average of groundwater monitoring locations in the DNAPL source area);
- sorption and kinetic parameters, as well as DNAPL dissolution kinetics, presented in Appendix C; and
- a CA degradation rate constant of 0.1/day,

A treatment time frame of 1.9 years is calculated for dissolving the DNAPL sources and reducing the total chlorinated ethane (TCA + DCA + CA) mass by 99%. Thus, based on the parameters used in this simulation, the extent and rate of TCA, DCA, and CA degradation observed during the pilot test are sufficient for treating the full-scale system within a reasonable timeframe.

3.4 Comparison of Anaerobic Biostimulation to RAOs

Since anaerobic biostimulation will remediate the contaminants *in-situ*, exposure to the contaminated soil and groundwater does not occur, thus protecting public health. Additionally, there are no special issues regarding protection of human health and the environment since the amendments being injected into the subsurface are non-toxic.

The applicable SCGs for this project include the NYSDEC's TAGM 4046 RSCOs for soil, NYSDEC's Class GA standards for groundwater, and NYSDOH's Guidance for Evaluating Soil Vapor Intrusion in the State of New York for soil vapor. To the extent practical, the objective is to achieve these applicable SCGs; however, at a minimum, the goal of the remedial action will be the elimination of the residual DNAPL sources and a 99% reduction in overall chlorinated ethane contaminant mass.

Based on the laboratory and pilot study data, this goal of eliminating the residual DNAPL and achieving a 99% reduction in overall chlorinated ethane contaminant mass is possible. Furthermore, this goal can be achieved in a timeframe of approximately 1.9 years, and is therefore a very effective short-term remedial alternative. Since the remediation occurs *in-situ* and the amendments are non-toxic, there are no risks to the community, workers or the environment during operation of the remedial system. However, during construction of the remedial system, workers will follow strict OSHA requirements to minimize the possibility of accidents, and air monitoring will be completed to protect the community. If necessary, dust suppressant measures (i.e., misting) will be used to control particulates.

Because an active microbial population will remain, biostimulation will continue to occur, resulting in long-term and permanent results. The remedy does not rely on containment. As with any remedial technology, rebound monitoring should be completed following post-system operation. If concentrations rebound to levels above the RAOs goals, system reactivation can occur. Following completion of the remedy, there will be no significant threats to the public health or environment. Any remaining residual impacts will be addressed through a Site Management Plan.

Anaerobic biostimulation both reduces the toxicity of the contaminants through reductive dechlorination and reduces the volume by increasing the dissolution rate of the DNAPL into the aqueous phase where reductive dechlorination occurs. It is anticipated that a complete removal of the DNAPL sources and a 99% reduction in overall chlorinated ethane contaminant mass will occur. Because the contaminants are dechlorinated, the process is not reversible. The installation of extraction wells along the perimeter of the treatment area will serve to maintain hydraulic containment, thus preventing the mobilization of contaminants beyond the treatment zone during injection activities.

Finally, anaerobic biostimulation is technically and economically feasible and achievable. There are no anticipated construction or O&M difficulties, and the materials necessary are readily available. There are no permitting requirements for construction or operation of the remedy.

4.0 Remedial Action Scope of Work

4.1 Full-Scale Area

The treatment system will focus biostimulation amendment delivery over the extent of the residual DNAPL source area. The DNAPL source area is conservatively defined as the region where the sum of TCA and DCA soil concentrations exceed 100,000 µg/kg. This concentration is based on contaminant partitioning between the groundwater and soil phases, as measured during the laboratory treatability testing, where total "soil" concentrations less than 100,000 µg/kg indicate that the chlorinated ethane mass resides in the aqueous and soil phases. Concentrations in excess of 100,000 µg/kg suggest that undissolved TCA and DCA (i.e., residual DNAPL) likely exist. A detailed discussion of the mass balance approach used for this analysis is provided in Schaefer et al. (1998).

Full scale treatment also will address the area of elevated groundwater impacts (defined as total TCA and DCA concentrations greater than 500 µg/L).

Vertically, the treatment zone is assumed to be the silt layer. This full-scale treatment area is depicted on Figure 22. *NOTE: Groundwater sampling will be performed during installation of extraction well locations on the western boundary of the treatment area to improve delineation of the DNAPL zone between GW-17 and GW-27. If elevated chlorinated ethane concentrations (>500 µg/L) are detected at these locations, additional injection/extraction well pairs will be added to extend the treatment area.*

4.2 Full-Scale Well Network

The first step in the implementation of the full-scale system will be well installation activities. Each monitoring well location will be drilled using 10¼" ID hollow stem augers. Split spoon samples will be collected in the interval in which the monitoring well screen would reside. All split spoon samples will be screened with a PID, inspected and logged.

A total of forty-eight (48) extraction wells (EW-1 through EW-48) and thirty-three (33) amendment injection well locations (IW-1 through IW-33) will be installed throughout the treatment area.

The extraction and amendment injection wells will be constructed of 4" Sch 40 PVC with eight (8) feet of 0.20-slot screen. The wells will be installed down to a total depth of approximately 2 feet above the bottom of the silt layer. The screen/sand pack interval will be from approximately 2 to 10 feet above the bottom of the silt layer, insuring that the top of the interval is at least 2 feet below the top of the silt layer. Keeping the screen/sand pack at least 2 feet from the top and bottom of the silt layer will help limit short-circuiting of amendments into the underlying sandy zone as it is injected into the well.

Eight (8) additional monitoring locations (MW-26S and MW-32 through MW-38) will be installed within or surrounding the treatment area as shown on Figure 23. All but three of these locations (MW-26S, MW-33S and MW-38D) will contain nested monitoring points (2 wells per borehole) to monitor both the groundwater contained in the silt layer and the groundwater contained in the underlying sand. MW-26S will be installed next to MW-26R to monitor groundwater conditions within the silt layer in this area. MW-33S will be installed in the silt layer to monitor groundwater conditions downgradient (groundwater flow within the silt is to the southeast) of the DNAPL area, while MW-38D will be installed in the underlying sand layer to monitor groundwater downgradient (groundwater flow within the underlying sand is to the northeast) of the treatment area. The nested monitoring wells will be constructed of 2-inch Schedule 40 PVC with eight (8) feet of 0.10-slot screen set in the silt layer zone, and five (5) feet of 0.10-slot screen set in the underlying sandy zone.

A layout of the extraction, injection and monitoring wells is presented as Figure 23, and construction details are presented as Figure 24.

4.3 Full Scale Conceptual System Design

The continuous amendment injection system will operate by extracting groundwater from the extraction wells (EWs), amending the extracted groundwater with electron donor and nutrients, and re-injecting the amended groundwater into the amendment injection wells (IWs). Full scale system design is based on the groundwater flow and contaminant transport model developed for the pilot test (Appendix C). Specifically, the model was used to determine the following:

- Number and spacing of injection/extraction wells
- Rate of chlorinated ethane biodegradation

The injection/extraction well layout for the full-scale design is shown in Figure 23. The model was used to ensure that perimeter extraction well spacing was sufficient for maintaining hydraulic capture within the treatment area, and to ensure injection/extraction well spacing was sufficient for amendment delivery.

Groundwater will be extracted from each extraction well using bladder pumps at an approximate rate of 0.04 gpm per extraction well (conservatively estimated based on pump and pilot test data), for a total system extraction rate of approximately 2.0 gpm. Water level sensors placed within each extraction well will monitor for low level groundwater conditions. If a low-level condition were to occur within an EW, a relay will active a solenoid valve stopping the bladder pump until the low-level condition no longer exists. The purpose of the low-level monitoring is to assure that groundwater levels do not decrease to the point in which air enters the bladder pump. If this were to occur, the anaerobic conditions of the extracted groundwater could be altered.

Each EW is directed back to the system enclosure where the individual EWs are manifolded to a common header pipe. A chemical metering pump would then feed amendments into the common header pipe at a rate variable to the influent flow rate to achieve consistent lactate, diammonium phosphate (DAP) and yeast concentrations of 3,000 mg/L, 150 mg/L and 150 mg/L, respectively within the amendment stream. Immediately following the injection feed point will be a static mixer to assure adequate mixing of the amendments with the groundwater stream. The amended water stream will then be split and directed to the IWs at an approximate injection rate of 0.0625 gpm each, for a total injection rate of approximately 2.0 gpm. Rotameters will be used to control the flow of amended water to each of the IWs. Water level sensors placed within each extraction well will monitor for high-level groundwater conditions. If a high level condition were to occur, relays will active a solenoid valve closing off the IW until the high-level condition no longer exists.

A conceptual process diagram has been included as Figure 25.

As discussed in Section 3.3.7, the expected duration of active treatment is approximately 1.9 years.

4.4 Full-scale Monitoring

4.4.1 System Monitoring

Data collected from the remedial system (extraction and injection flow rates, amendment levels, water levels, etc.) will be recorded on monitoring forms specifically prepared for the Site, which will be retained and summarized in a quarterly report. A description of critical maintenance activities is included below.

Bladder Pumping System: Monitoring will consist of collecting pumping rates from the individual EWs and injection rates into the individual IWs, and confirming bladder pump control settings including charge, exhaust and pressure settings. On a periodic basis, the bladder pumps will be pulled from the EWs to conduct a visual inspection of the bladders, and if necessary, replacement of the bladder. Interim indications of the bladder conditions will be determined based on individual pumping rates from visit to visit.

The objective of the bladder pumping system is to extract and inject approximately the same volume of groundwater from each area of the treatment zone, thereby limiting the possibility of mobilizing DNAPL/groundwater impacts into areas outside of the treatment zone. In addition, groundwater extracted from the DNAPL area will only be reinjected in the DNAPL zone, thus eliminating the potential to distribute DNAPL outside of the DNAPL zone.

Amendment Metering System: Monitoring of the amendment metering system will consist of measuring the total combined flow rate and inspecting the metering pump for settings and prime. In addition, the amendment tank will be checked for volume and, if necessary, the amendment tank will be replenished with additional amendment.

The objective of the amendment metering system is to supply a continuous consistent supply of lactate, DAP and yeast into the subsurface to facilitate biological activity.

4.4.2 Groundwater Monitoring

4.4.2.1 Baseline Groundwater Sampling

Prior to activation of the continuous-injection system, Shaw will perform full-scale baseline groundwater monitoring to characterize the chemical, biological, and geochemical conditions within and around the treatment zone. Similar to the pilot test monitoring, two sampling events will be performed, one four weeks prior to amendment injection and one two weeks prior to amendment injection. A round of synoptic groundwater levels will be measured prior to commencement of sampling during each event. Each of the monitoring wells will be sampled during each event using standard low flow purge sampling techniques. A multi-parameter sampling meter (e.g., YSI 6920 or equivalent) will be implemented in the field to measure groundwater geochemical parameters including:

ORP	DO	pH
Turbidity	Temperature	Conductivity

These readings will not only be used to characterize the geochemistry of the groundwater at each well, but their stability will also serve as criteria for sample collection. Samples from each location will be analyzed for VOCs, NAPs and VFAs (including lactate). NAPs to be analyzed for include the following:

Chloride	Nitrate	Methane	Ethane
Phosphate	Nitrite	Ethane	Sulfate

One trip blank will be analyzed for VOCs for each cooler.

A NYSDOH ELAP-certified laboratory will conduct the VOC analysis, while Shaw's in-house analytical laboratory will conduct the NAP and VFA analyses.

4.4.2.2 Full-scale Groundwater Monitoring

Monitoring of the twenty (20) wells within and around the full-scale treatment area will be implemented following activation of the continuous-injection system, and will occur based on the following frequency:

- Months 1 through 6 – sample monthly;
- Months 7 through 12 – sample bi-monthly;
- Months 12 through system deactivation – sample quarterly; and
- Post-system monitoring – sample quarterly.

During each sampling event, the groundwater samples will be collected and analyzed for the following:

VOCs	Chloride	Nitrate	Methane	Ethane
VFAs	Sulfate	Nitrite	Ethane	Phosphate

Sample analyses will be performed by Shaw's in-house analytical laboratory, with the exception of VOC sample analyses conducted for decision making purposes, which will be analyzed by a NYSDOH ELAP-certified laboratory. *NOTE: Sampling frequency, locations, and parameters will be re-evaluated throughout the full-scale operational period and changes will be subject to NYSDEC approval.*

4.4.3 Air Quality Monitoring

Although laboratory analytical data demonstrate that levels of VOCs inside and outside the Site building are below the NYSDOH guidelines, which NYSDOH established after an extensive evaluation of scientific information about health effects, some VOCs were identified in limited areas beneath the building under the concrete slab. To confirm future migration of these VOCs into the building does not occur, monitoring of the sub-slab, indoor and outdoor air will be completed.

A total of four (4) sub-slab sampling locations, four (4) indoor air sampling locations, and two (2) outdoor air sampling locations will be monitored during the heating season. The proposed sub-slab and indoor sampling locations are depicted on Figure 26. Air Toxics Ltd. of Folsom, CA, an ELAP-certified analytical laboratory, will report selected chlorinated VOCs in accordance with EPA Method TO-15. Collection of the samples will be completed as follows:

4.4.3.1 Sub-Slab Sampling

To collect the sub-slab samples, a 5/8-inch diameter hole will be drilled through the concrete slab using an electric drill. The drill bit will be advanced approximately 3-inches into the sub-slab material to create an open cavity. The vapor probe will consist of a length of 3/8-inch diameter Teflon™ tubing, which will then be inserted no farther than 2-inches into the sub-slab material. The tubing will be sealed to the surface with a non-VOC containing material consisting of permagum grout or beeswax or equivalent.

Prior to collection of the sub-slab soil vapor samples, the tubing will be purged of 1-3 volumes to eliminate air within the tubing. During purging, a tracer gas (helium) will be used to verify the integrity of the seal. Purged air will not be discharged to the indoor air. Following purging, the tubing will be attached to a 6L Summa canister fitted with an in-line filter and an 8-hour flow regulator. Prior to opening the Summa canister, the initial vacuum will be noted. After 8 hours, the Summa canister will be closed and the final vacuum noted. Based on the sample volume of 6L and a sample period of 8 hours, the sub-slab samples will be collected at a flow rate of approximately 0.0125 liters per minute.

Following collection of the sub-slab foundation, the drilled hole in the foundation will be sealed with concrete slurry.

4.4.3.2 Indoor Air Sampling

Prior to the collection of indoor air samples, a pre-sampling inspection of each area to be sampled will be performed. These pre-sampling inspections will include the completion of a product inventory survey and an evaluation of the physical layout and conditions of the building. This information will be used to help identify conditions that may interfere with the proposed sampling study.

The four (4) indoor air samples will be collected as close to sub-slab sampling points as possible. At each sampling point, a 6L Summa canister fitted within an in-line filter and an 8-hour flow regulator will be placed at a level approximately three feet above the floor. Prior to opening the Summa canister, the initial vacuum will be noted. After 8 hours, the Summa canister will be closed and the final vacuum noted. During this 8-hour sampling period, all windows will remain closed and the facility’s HVAC systems will operate as normal. Based on the sample volume of 6L and a sample period of 8 hours, the indoor air samples will be collected at a flow rate of approximately 0.0125 liters per minute.

4.4.3.3 Outdoor Air Sampling

Two (2) outdoor air samples will be collected concurrently with the indoor and sub-slab sampling. One sample will be collected near the HVAC air intake located on the north side of the building and one sample will be collected near the HVAC air intake located on the south side of the building. Samples will be collected away from wind obstructions and obvious sources of VOCs and at a height above the ground to represent typical breathing zones (i.e. 3 to 5 feet).

To collect the outdoor air samples, 6L Summa canisters fitted within an in-line filter and an 8-hour flow regulator will be used. Prior to opening the Summa canister, the initial vacuum will be noted. After 8 hours, the Summa canister will be closed and the final vacuum noted. Based on the sample volume of 6L and a sample period of 8 hours, the outdoor air samples will be collected at a flow rate of approximately 0.0125 liters per minute.

4.4.4 Soil Monitoring

Once groundwater concentrations decrease to a point indicative of DNAPL no longer being present, soil sampling activities will commence. The purpose of the soil sampling activities is to confirm the DNAPL has been successfully remediated. A criterion that will be considered by the NYSDEC to determine if DNAPL sources have been effectively removed is TCA groundwater concentrations less than 1,000 µg/L and DCA groundwater concentrations less than 5,000 µg/L in the source area. These concentrations are equivalent to less than 0.1% of TCA and DCA solubilities, and are 10-times lower than the 1% solubility "rule of thumb" used to indicate the potential presence of DNAPL (ITRC, 2005). The 0.1% solubility criterion serves as a conservative marker of DNAPL removal (i.e. by an order of magnitude). In addition, the soil analytical results will be compared to NYSDEC TAGM 4046 soil guidance values.

Soil samples will be collected within the silt layer at locations and depths approximate to the soil samples collected at GW-3, GW-8 and GW-17. These locations represent the highest impacted areas identified during the Site investigation.

4.5 Achievement of Remedial Goals

As previously discussed in the RAO's, the specific goals for the Site remediation include the complete removal of the DNAPL sources; reduction of dissolved-phase chlorinated ethane mass to NYSDEC groundwater standards or until implementation of a MNA program is acceptable, and the implementation of Deed Restrictions to prevent future exposure to residual impacts.

A criterion that will be considered by NYSDEC to verify that DNAPL sources have been effectively removed is TCA groundwater concentrations less than 1,000 µg/L and DCA groundwater concentrations less than 5,000µg/L in the source area. These concentrations are equivalent to less than 0.1% of TCA and DCA solubility's, and are 10-times lower than the 1% solubilities "rule of thumb" used to indicate the potential presence of DNAPL (ITRC, 2005). The 0.1% solubility criterion serves as a conservative marker of DNAPL removal (i.e. by an order of magnitude). It is anticipated that the timeframe to complete the DNAPL removal is approximately 23 months.

Thereafter, the continuous amendment injection system will continue to operate until NYSDEC groundwater standards are achieved or until asymptotic groundwater conditions occur as determined by NYSDEC. If asymptotic conditions occur at levels above NYSDEC groundwater standards, then a monitored natural attenuation (MNA) program will be implemented to track these remaining residual impacts as demonstrated through groundwater sampling.

5.0 Schedule

5.1 Remedy Implementation Schedule

The anticipated schedule for implementation of the proposed remedy, following NYSDEC approval, is as follows:

Activity	Timeframe
Treatment System Construction (6 months)	Months 1-6
Treatment System Operation (23 months)~~Site Management Plan~~	Months 6-29~~3-8~~
~~Recording of Deed Restrictions~~Groundwater Monitoring (24 months following system deactivation)	Months 29-53~~7-8~~
Final Engineering Report (3 months)	Months 53-56~~7-8~~
Total Timeframe	**4 years, 8 months**

The monitoring program to track the expected reductions has been summarized in Section 4.4. During implementation of the remedy, progress reports will be submitted monthly. Following completion of the remedy (i.e., startup of the *in-situ* bioremediation system), progress reports will be submitted quarterly.

Following commencement of system operation, it is anticipated that a 50% reduction in chlorinated ethane mass will occur after approximately 9 months, a 75% reduction after 15 months and a 99% reduction after 23 months. Although it is currently anticipated that the system will operate for a timeframe of 23 months, if the remedial goals are not achieved within the anticipated timeframe, system operation will continue until the remedial goals are met.

If residual impacts remain after the remedy is implemented, a site Management Plan will be developed and deed restrictions will be filed prior to approval of the Final Engineering Report.

~~5.2Post-Remedy Implementation Schedule~~

~~Activity~~	~~Timeframe~~
~~Continuous-Injection System Operation (23 months)~~	~~Months 9-31~~
~~Groundwater Monitoring (24 months following system deactivation, 47 months total)~~	~~Months 9-55~~
~~Final Data Analysis and Reporting (3 months)~~	~~Months 56-58~~
~~Total Timeframe~~	**~~4 years, 2 months~~**

~~Following commencement of system operation, it is anticipated that a 50% reduction in chlorinated ethane mass will occur after approximately 9 months, a 75% reduction after 15 months and a 99% reduction after 23 months. Although it is currently anticipated that the system will operate for a timeframe of 23 months, if the remedial goals are not achieved within the anticipated timeframe, system operation will continue until the remedial goals are met.~~

~~5.3~~5.2 Contingency

After a period of two (2) years following completion of the remedy (i.e., startup of the *in-situ* bioremediation system), an evaluation report will be prepared and submitted to the NSYDEC. This evaluation report will compare the progress which the remedy has achieved versus the original anticipated reductions, provide an updated remedial timeframe (if necessary), as well as make recommendations on future remedial actions (if necessary). If a contaminant reduction of 99% is not achieved, continued biostimulation may be required by NYSDEC. If significant progress, defined as chlorinated ethane mass reduction of more than approximately 50%, has not been achieved, then an alternative remedial action may be implemented. Alternative remedial actions that may be required by the NYSDEC include source-zone (i.e., DNAPL) excavation, bioaugmentation or another remedial technology as approved by the NYSDEC.

6.0 Remedial Action Program

6.1 Governing Documents

6.1.1 Site Specific Health & Safety Plan (HASP)

All remedial work performed under this plan will be in full compliance with governmental requirements, including Site and worker safety requirements mandated by Federal OSHA.

The Volunteers and associated parties preparing the remedial documents submitted to the State and those performing the construction work, are completely responsible for the preparation of an appropriate Health and Safety Plan and for the appropriate performance of work according to that plan and applicable laws.

The Health and Safety Plan (HASP) and requirements defined in this Remedial Action Work Plan pertain to all remedial and invasive work performed at the Site.~~ until the issuance of a Certificate of Completion.~~

The Site Safety Coordinator will be Mr. Garrett Passarelli. A resume will be provided to NYSDEC prior to the start of remedial construction.

6.1.2 Quality Assurance Project Plan (QAPP)

A QAPP has been prepared and is included as Appendix G. Sampling procedures for soil, groundwater, sub-slab vapor and indoor and outdoor air are described in Section 4.4.

6.1.3 Construction Quality Assurance Plan (CQAP)

A CQAP has been prepared and is included as Appendix H.

6.1.4 Soil/Materials Management Plan (SoMP)

6.1.4.1 Soil Screening Methods

Visual, olfactory and PID soil screening and assessment will be performed by a qualified environmental professional during installation of the injection, extraction and monitoring wells.

All wells installed as part of the remedial action will be surveyed by a surveyor licensed to practice in the State of New York. This information will be provided on maps in the Final Engineering Report.

Screening will be performed by qualified environmental professionals. Resumes will be provided for all personnel responsible for field screening (i.e. those representing the Remedial Engineer) of invasive work for unknown contaminant sources during remediation and development work.

6.1.4.2 Stockpile Methods

Stockpiling of soils will not be necessary during construction activities. All soil drill cuttings will be contained within DOT-approved 55-gallon steel drums for transportation and disposal.

6.1.4.3 Materials Load Out

The Remedial Engineer or a qualified environmental professional under his/her supervision will oversee the load-out of all drummed materials.

The Volunteers and their contractors are solely responsible for safe execution of all invasive and other work performed under this Plan.

The presence of utilities and easements on the Site has been investigated by the Remedial Engineer. It has been determined that no risk or impediment to the planned work under this Remedial Action Work Plan is posed by utilities or easements on the Site.

Loaded vehicles leaving the Site will be appropriately manifested and placarded in accordance with appropriate Federal, State, local, and NYSDOT requirements (and all other applicable transportation requirements).

Development-related grading cuts and fills will not be performed without NYSDEC approval and will not interfere with, or otherwise impair or compromise, the performance of remediation required by this plan.

Mechanical processing of historical fill and contaminated soil on-Site is prohibited.

All wells installed during the remedial action will be surveyed by a surveyor licensed to practice in the State of New York. The survey information will be shown on maps to be reported in the Final Engineering Report.

6.1.4.4 Materials Transport Off-Site

All transport of materials will be performed by licensed haulers in accordance with appropriate local, State, and Federal regulations, including 6 NYCRR Part 364. Haulers will be appropriately licensed and trucks properly placarded.

6.1.4.5 Materials Disposal Off-Site

The disposal facility for both the soil and water is Vexor Technology, Inc., located at 955 West Smith Road, Medina, Ohio. Any disposal location(s) established at a later date will be reported to the NYSDEC Project Manager. The wastes will be transported by Freehold Cartage, Inc. of Freehold, New Jersey.

The total quantity of material expected to be disposed off-Site is approximately 77 yd3 soil cuttings and approximately 1,100 gallons of development/decon water. It is anticipated that the wastes will be characterized as non-hazardous wastes.

All soil/fill/solid waste removed from the Site will be treated as contaminated and regulated material and will be disposed in accordance with all local, State (including 6NYCRR Part 360) and Federal regulations. If disposal of soil/fill from this Site is proposed for unregulated disposal (i.e. clean soil removed for development purposes), a formal request with an associated plan will be made to NYSDEC's Project Manager. Unregulated off-Site management of materials from this Site is prohibited without formal NYSDEC approval.

Material that does not meet unrestricted use, as identified Table 375-6.8(a) of 6NYCRR Part 375, is prohibited from being taken to a New York State recycling facility (6NYCRR Part 360-16 Registration Facility).

The following documentation will be obtained and reported by the Remedial Engineer for each disposal location used in this project to fully demonstrate and document that the disposal of material derived from the Site conforms with all applicable laws: (1) a letter from the Remedial Engineer or Volunteer to the receiving facility describing the material to be disposed and requesting formal written acceptance of the material. This letter will state that material to be disposed is contaminated material generated at an environmental remediation Site in New York State. The letter will provide the project identity and the name and phone number of the Remedial Engineer. The letter will include as an attachment a summary of all chemical data for the material being transported (including Site Characterization data); and (2) a letter from all receiving facilities stating it is in receipt of the correspondence (above) and is approved to accept the material. These documents will be included in the FER.

Non-hazardous historic fill and contaminated soils taken off-Site will be handled, at minimum, as a Municipal Solid Waste per 6NYCRR Part 360-1.2.

Historical fill and contaminated soils from the Site are prohibited from being disposed at Part 360-16 Registration Facilities (also known as Soil Recycling Facilities).

Soils that are contaminated but non-hazardous and are being removed from the Site are considered by the Division of Solid & Hazardous Materials (DSHM) in NYSDEC to be Construction and Demolition (C/D) materials with contamination not typical of virgin soils. These soils may be sent to a permitted Part 360 landfill. They may be sent to a permitted C/D processing facility without permit modifications only upon prior notification of NYSDEC Region 2 DSHM. This material is prohibited from being sent or redirected to a Part 360-16 Registration Facility. In this case, as dictated by DSHM, special procedures will include, at a minimum, a letter to the C/D facility that provides a detailed explanation that the material is derived from a DER remediation Site, that the soil material is contaminated and that it must not be redirected to on-Site or off-Site Soil Recycling Facilities. The letter will provide the project identity and the name and phone number of the Remedial Engineer. The letter will include as an attachment a summary of all chemical data for the material being transported.

The Final Engineering Report will include an accounting of the destination of all material removed from the Site during this Remedial Action, including excavated soil, contaminated soil, historic fill, solid waste, and hazardous waste, non-regulated material, and fluids.

Documentation associated with disposal of all material must also include records and approvals for receipt of the material. This information will also be presented in a tabular form in the FER.

Bill of Lading system or equivalent will be used for off-Site movement of non-hazardous wastes and contaminated soils. This information will be reported in the Final Engineering Report.

Hazardous wastes derived from on-Site will be stored, transported, and disposed of in full compliance with applicable local, State, and Federal regulations.

Appropriately licensed haulers will be used for material removed from this Site and will be in full compliance with all applicable local, State and Federal regulations.

Waste characterization will be performed for off-Site disposal in a manner suitable to the receiving facility and in conformance with applicable permits. Sampling and analytical methods, sampling frequency, analytical results and QA/QC will be reported in the FER. All data available for soil/material to be disposed at a given facility must be submitted to the disposal facility with suitable explanation prior to shipment and receipt.

6.1.4.6 Materials Reuse On-Site

The reuse of materials on-Site will not necessary for this project.

Concrete crushing or processing on-Site is prohibited.

Organic matter (wood, roots, stumps, etc.) or other solid waste derived from clearing and grubbing of the Site is prohibited for reuse on-Site.

Contaminated on-Site material, including historic fill and contaminated soil, removed for grading or other purposes will not be reused within a cover soil layer, within landscaping berms, or as backfill for subsurface utility lines. This will be expressed in the final Site Management Plan.

6.1.4.7 Fluids Management

All liquids to be removed from the Site, including decontamination water and well development water will be handled, transported and disposed in accordance with applicable local, State, and Federal regulations. Liquids will be contained within DOT-approved 55-gallon steel drums.

6.1.5 Community Air Monitoring Plan

A CAMP has been prepared and is included as Appendix I. Odor, dust and nuisance controls have been included as part of the CAMP.

6.1.6 Contractors Site Operations Plan (SOP)

Construction of the *in-situ* bioremediation system is being completed by Shaw as part of a design-build project. Specifications on the design will be forward to the NYSDEC under separate cover.

6.1.7 Community Participation Plan

A certification of mailing will be sent by the Volunteers to the NYSDEC project manager following the distribution of all Fact Sheets and notices that includes: (1) certification that the Fact Sheets were mailed, (2) the date they were mailed; (3) a copy of the Fact Sheet, (4) a list of recipients (contact list); and (5) a statement that the repository was inspected on (specific date) and that it contained all of applicable project documents.

No changes will be made to approved Fact Sheets authorized for release by NYSDEC without written consent of the NYSDEC. No other information, such as brochures and flyers, will be included with the Fact Sheet mailing.

Document repositories have been established at the following locations and contain all applicable project documents:

Queens Borough Public Library	Community Board No. 3	NYSDEC Region 2

Jackson Heights Branch	Or	82-11 37th Avenue, Suite 606	Or	47-40 21st Street
35-51 81st Street		Jackson Heights, NY 11372		Long Island City, NY 11101
Jackson Heights, NY 11372				Attn: Sondra Martinkat

6.2 General Remedial Construction Information

6.2.1 Project Organization

An organization chart is included in Figure 27.

Resumes of key personnel involved in the Remedial Action are included in Appendix F.

6.2.2 Remedial Engineer

The Remedial Engineer for this project will be Mr. August Arrigo. The Remedial Engineer is a registered professional engineer licensed by the State of New York. The Remedial Engineer will have primary direct responsibility for implementation of the remedial program for the 75-20 Astoria Boulevard Site (NYSDEC VCA Index No. W2-0854-9906, Site No. 002453). The Remedial Engineer will certify in the Final Engineering Report that the remedial activities were observed by qualified environmental professionals under his supervision and that the remediation requirements set forth in the Remedial Action Work Plan and any other relevant provisions of ECL 27-1419 have been achieved in full conformance with that Plan. Other Remedial Engineer certification requirements are listed later in this RAWP.

The Remedial Engineer will coordinate the work of other contractors and subcontractors involved in all aspects of remedial construction, including soil excavation, stockpiling, characterization, removal and disposal, air monitoring, emergency spill response services, import of back fill material, and management of waste transport and disposal. The Remedial Engineer will be responsible for all appropriate communication with NYSDEC and NYSDOH.

The Remedial Engineer will review all pre-remedial plans and will certify compliance in the Final Engineering Report.

The Remedial Engineer will provide the certifications listed in Section 10.1 in the Final Engineering Report.

6.2.3 Remedial Action Construction Schedule

6.2.3.1 Work Hours

The hours for operation of remedial construction will conform to the New York City Department of Buildings construction code requirements or according to specific variances issued by that agency. DEC will be notified by the Applicant of any variances issued by the Department of Buildings. NYSDEC reserves the right to deny alternate remedial construction hours.

6.2.3.2 Site Security

Site security is provided by security personnel for the Bulova Corporate Center operations. In addition, the Site is completely fenced.

6.2.3.3 Traffic Control

Traffic control will only be required on-Site. Traffic control will be handled through the use of fencing and safety cones/barrels.

6.2.3.4 Worker Training

All construction, operation, maintenance and monitoring activities will be performed by health and safety trained personnel in accordance with 29 CFR 1910.

6.2.3.5 Agency Approvals

Local, regional or national governmental permits, certifications or other approvals or authorization are not required for this scope of this remedial action.

The current use for the Site is in conformance with the current zoning for the property as determined by New York City Department of Planning

6.2.4 Pre-Construction Meeting with NYSDEC

Notification of the construction “kick-off meeting” will be made to the NYSDEC.

6.2.5 Emergency Contact Information

An emergency contact sheet with names and phone numbers is included in Table 8. That document will define the specific project contacts for use by NYSDEC and NYSDOH in the case of a day or night emergency.

6.2.6 Remedial Action Costs

The total estimated cost of the Remedial Action is $2,500,000. Of this, approximately $1,100,000 is for the remedial system construction and approximately $1,400,000 for operation, maintenance and monitoring activities. This will be revised based on actual costs and submitted as an Appendix to the Final Engineering Report.

6.3 Site Preparation

6.3.1 Mobilization

Equipment that will be mobilized to the Site include a hollow-stem auger (HSA) drill rig(s) and a small backhoe.

6.3.2 Utility Marker and Easements Layout

The Volunteers and their contractors are solely responsible for the identification of utilities that might be affected by work under the RAWP and implementation of all required, appropriate, or necessary health and safety measures during performance of work under this RAWP. The Volunteers and their contractors are solely responsible for safe execution of all invasive and other work performed under this RAWP. The Volunteers and their contractors must obtain any local, State or Federal permits or approvals pertinent to such work that may be required to perform work under this RAWP. Approval of this RAWP by NYSDEC does not constitute satisfaction of these requirements.

The presence of utilities and easements on the Site has been investigated by the Remedial Engineer. It has been determined that no risk or impediment to the planned work under this Remedial Action Work Plan is posed by utilities or easements on the Site.

6.3.3 Equipment and Material Staging

All equipment and materials that need to be staged onsite will be staged within secured areas.

6.3.4 Site Fencing

Existing fencing bordering the Site include 6’ chain-link fencing and 6’ stockade fencing. In addition, the Site has 24-hour security personnel.

6.3.5 Demobilization

Prior to demobilizing from the Site, restoration of areas that have been disturbed will be completed. This restoration includes, but is not limited to, the asphalt parking area, concrete walkways and grass area.

6.4 Reporting

All daily and monthly reports will be included in the Final Engineering Report.

6.4.1 Daily Reports

During periods of active construction, daily reports will be submitted to NYSDEC and NYSDOH Project Managers by the end of each day following the reporting period and will include:

- An update of progress made during the reporting day;
- A summary of any and all complaints with relevant details (names, phone numbers);
- A summary of CAMP finding, including excursions; and
- An explanation of notable Site conditions.

Daily reports are not intended to be the mode of communication for notification to the NYSDEC of emergencies (accident, spill), requests for changes to the RAWP or other sensitive or time critical information. However, such conditions must also be included in the daily reports. Emergency conditions and changes to the RAWP will be addressed directly to NYSDEC Project Manager via personal communication.

The NYSDEC assigned project number will appear on all reports.

6.4.2 Monthly Reports

Monthly reports will be submitted to NYSDEC and NYSDOH Project Managers within one week following the end of the month of the reporting period and will include:

- Activities relative to the Site during the previous reporting period and those anticipated for the next reporting period, including a quantitative presentation of work performed (i.e. tons of material exported and imported, etc.);
- Description of approved activity modifications, including changes of work scope and/or schedule;
- Sampling results received following internal data review and validation, as applicable; and,
- An update of the remedial schedule including the percentage of project completion, unresolved delays encountered or anticipated that may affect the future schedule, and efforts made to mitigate such delays.

6.4.3 Other Reporting

Photographs will be taken of all remedial activities and submitted to NYSDEC in digital (JPEG) format. Photos will illustrate all remedial program elements and will be of acceptable quality. Representative photos of the Site prior to any Remedial Actions will be provided. Representative photos will be provided of each contaminant source, source area and Site structures before, during and after remediation. Photos will be submitted to NYSDEC on CD or other acceptable electronic media and will be sent to NYSDEC's Project Manager (2 copies) and to NYSDOH's Project Manager (1 copy). CD's will have a label and a general file inventory structure that separates photos into directories and sub-directories according to logical Remedial Action components. A photo log keyed to photo file ID numbers will be prepared to provide explanation for all representative photos. For larger and longer projects, photos should be submitted on a monthly basis or another agreed upon time interval.

Job-site record keeping for all remedial work will be appropriately documented. These records will be maintained on-site at all times during the project and be available for inspection by NYSDEC and NYSDOH staff.

6.4.4 Complaint Management Plan

Upon receipt of any complaints, verbal or written, the NYSDEC Project Manager will be immediately notified.

6.4.5 Deviations from the Remedial Action Work Plan

If any deviations from this RAWP are necessary, the NYSDEC Project Manager will be immediately notified. In addition, deviations will be noted in the daily and monthly reports.

7.0 Engineering Controls

7.1 Composite Cover System

Exposure to residual contaminated soils will be prevented by the existing composite cover system at the Site. This composite cover system is comprised of the asphalt parking lot, concrete covered sidewalks, and the Site building. This composite cover system will be maintained in the vicinity of the former USTs and over the plume.

7.2 Treatment System

An *in-situ* bioremediation system will be constructed and operated to reduce contaminant levels. This *in-situ* bioremediation system will operate by pumping groundwater via the extraction wells back to the equipment shed. There, the extracted groundwater will be amended with lactate, DAP and yeast to make a consistent solution of 3,000 mg/L, 150 mg/L and 150 mg/L, respectively. The amended groundwater will then re-enter the subsurface via the injection wells.

As the amended groundwater passes through the subsurface, the degradative capabilities of the existing microbial population will increase.

A detailed description of the in-situ bioremediation system is discussed in Sections 4.0 through 4.3.

As-built drawings and process diagrams will be presented in the FER.

7.2.1 Criteria for Completion of Remediation/Termination of Remedial Systems

7.2.1.1 Composite Cover System

The composite cover system is a permanent control and the quality and integrity of this system will be inspected at defined, regular intervals.

7.2.1.2 In-situ Bioremediation System

The in-situ bioremediation system will not be discontinued without written approval by NYSDEC and NYSDOH. A proposal to discontinue the system may be submitted after residual contamination concentrations in groundwater: (1) are cleaned up to levels below NYSDEC standards, (2) have become asymptotic over an extended period of time as mandated by the NYSDEC and the NYSDOH, or (3) if NYSDEC has determined that the in-situ bioremediation system has reached the limit of its effectiveness. This assessment will be based in part on post-remediation contaminant levels in groundwater collected from monitoring wells located throughout the Site. The system will remain in place and operational until permission to discontinue its use is granted in writing by NYSDEC and

NYSDOH. These sampling/monitoring activities will adhere to stipulations outlined in the Monitoring Plan section of the SMP.

7.2.1.3 Monitored Natural Attenuation

Groundwater monitoring activities to assess natural attenuation will continue, as determined by NYSDOH and NYSDEC, until residual groundwater concentrations are found to be below NYSDEC standards or have become asymptotic over an extended period. Monitoring will continue until permission to discontinue is granted in writing by NYSDEC and NYSDOH. Monitoring activities will be outlined in the Monitoring Plan of the SMP.

8.0 Deed Restrictions

Deed Restrictions may ~~will~~ be implemented to address any residual contamination that is left on-Site after the remedy. ~~Remedial Action is complete. As part of this remedy,~~ Deed Restrictions approved by NYSDEC will be filed and recorded with the Queens County Clerk. ~~The proposed Deed Restrictions will be submitted as part of the draft Final Engineering Report and will be executed and recorded prior to approval of the Final Engineering Report.~~

The Deed Restrictions render the Site a Controlled Property. The Deed Restrictions must be recorded with the Queens County Clerk before the Release of Liability can be issued by NYSDEC. The Deed Restrictions will limit the use of the Site to commercial use only.

The Site restrictions that may apply to the Controlled Property are:

- Vegetable gardens and farming on the Controlled Property are prohibited;
- Use of groundwater underlying the Controlled Property is prohibited without treatment rendering it~~s~~ safe for intended purpose (groundwater is not currently being used);
- The Controlled Property may be used for commercial use only;
- The Controlled Property may not be used for a higher level of use, such as ~~restricted~~ residential use, without an amendment or extinguishment of the Deed Restrictions with NYSDEC approval;
- All future activities that will disturb residual contaminated material within the treatment area require ~~are prohibited without~~ NYSDEC approval; and
- Grantor agrees to submit to NYSDEC a written statement that certifies, under penalty of perjury, that: (1) controls employed at the Controlled Property are unchanged from the previous certification or that any changes to the controls were approved by the NYSDEC; and, (2) nothing has occurred that impairs the ability of the controls to protect public health and environment or that constitute a violation or failure to comply with the SMP. NYSDEC retains the right to access such Controlled Property at any time in order to evaluate the continued maintenance of any and all controls. This certification shall be submitted annually, or an alternate period of time that NYSDEC may allow. This statement must be certified by an expert that the NYSDEC finds acceptable. If controls are no longer required, certifications can be discontinued following NYSDEC approval.

9.0 Site Management Plan

If residual impacts remain after the remedy, the ~~The~~ Site Management Plan (SMP) must address or otherwise be amended ~~is intended~~ to provide a detailed description of the procedures required to address residual impacts and would include~~during implementation of the Remedial Action in accordance with the VCA with the NYSDEC. This includes~~: (1) ~~development, implementation, and~~ management of the in-situ bioremediation system; (2) development and implementation of monitoring systems and a Monitoring Plan; (3) submittal of Site Management Reports, performance of inspections and certification of results, and demonstration of proper communication of Site information to NYSDEC; and (4) defining criteria for terminating operation of the in-situ bioremediation system, or implementing a contingency plan.

To address these needs, and unless previously submitted to the NYSDEC, this SMP will include four plans: (1) an Engineering Plan for ~~implementation and~~ management of the in-situ bioremediation system; (2) a Monitoring Plan for implementation of Site Monitoring; (3) an Operation and Maintenance Plan for implementation of the in-situ bioremediation system; and (4) a Site Management Reporting Plan for submittal of data, information, recommendations, and certifications to NYSDEC. The SMP will be prepared in accordance with the requirements in NYSDEC Draft DER-10 Technical Guidance for Site Investigation and Remediation, dated December 2002, and the guidelines provided by NYSDEC.

Certified Site management reporting will be scheduled on an annual basis. The Site Management Plan will be based on a calendar year and will be due for submission to NYSDEC by March 1 of the year following the reporting period.

The Site Management Plan will include a monitoring plan for groundwater at the down-gradient Site perimeter to evaluate Site-wide performance of the remedy. Appropriately placed groundwater monitor wells will also be installed immediately down-gradient of all VOC remediation areas for the purpose of evaluation of the effectiveness of the remedy that is implemented.

10.0 Final Engineering Report

A Final Engineering Report (FER) will be submitted to NYSDEC following implementation of the Remedial Action defined in this RAWP. The FER provides the documentation that the remedial work required under this RAWP has been completed and has been performed in compliance with this plan. The FER will provide a comprehensive account of the locations and characteristics of all material removed from the Site including the surveyed map(s) of all sources. The Final Engineering Report will include as-built drawings for all constructed elements, certifications, manifests, bills of ladings as well as the complete Site Management Plan (formerly the Operation and Maintenance Plan). The FER will provide a description of the changes in the Remedial Action from the elements provided in the RAWP and associated design documents. The FER will provide a tabular summary of all performance evaluation sampling results and all material characterization results and other sampling and chemical analysis performed as part of the Remedial Action. The FER will provide test results demonstrating that all mitigation and remedial systems functioned properly. The FER will be prepared in conformance with DER-10.

The Final Engineering Report will include written and photographic documentation of all remedial work performed under this remedy.

The FER will provide a thorough summary of any contamination that remains and will be addressed after the remedy is implemented at the Site. This summary will include all VOC contamination that exceeds Unrestricted Use as identified in Table 375-6.8(a) of 6NYCRR Part 375. A table and figure summarizing the locations of impacts that exceed Table 375-6.8(a) unrestricted use values will be included with the FER.

The Final Engineering Report will include an accounting of the destination of all material removed from the Site, including excavated contaminated soil, historic fill, solid waste, hazardous waste, non-regulated material, and fluids. Documentation associated with disposal of all material must also include records and approvals for receipt of the material. It will provide an accounting of the origin and chemical quality of all material imported onto the Site.

Before approval of a FER and issuance of a Release of Liability~~Certificate of Completion~~, all project reports must be submitted in digital form on electronic media (PDF).

10.1 Certifications

The following certification will appear in front of the Executive Summary of the Final Engineering Report. The certification will be signed by the Remedial Engineer who is a Professional Engineer registered in New York State. This certification will be appropriately signed and stamped. The certification will include the following statements:

I, ________________________, am currently a registered professional engineer licensed by the State of New York. I had primary direct responsibility for implementation of the remedial program for the 75-20 Astoria Boulevard Site (NYSDEC VCA Index No. W2-0854-9906, Site No. 002453).

I certify that the Site description presented in this FER is identical to the Site description presented in the Voluntary Cleanup Agreement for 75-20 Astoria Boulevard Site and related amendments.

I certify that the Remedial Action Work Plan dated [month day year] and approved by the NYSDEC was implemented and that all requirements in that document have been substantively complied with.

I certify that the remedial activities were observed by qualified environmental professionals under my supervision and that the remediation requirements set forth in the Remedial Action Work Plan and any other relevant provisions of ECL 27-1419 have been achieved.

I certify that, if necessary, all use restrictions, Institutional Controls, Engineering Controls, and all operation and maintenance requirements applicable to the Site are referenced in deed restrictions recorded with the Queens County Clerk. If necessary, a~~A~~ Site Management Plan has been submitted by the Applicant for the continual and proper operation, maintenance, and monitoring of all Engineering Controls employed at the Site, including the proper maintenance of all remaining monitoring wells, and that such plan has been approved by the NYSDEC.

I certify that the export of all contaminated soil, fill, water or other material from the property was performed in accordance with the Remedial Action Work Plan, and were taken to facilities licensed to accept this material in full compliance with all Federal, State and local laws.

I certify that all import of soils from off-Site, including source approval and sampling, has been performed in a manner that is consistent with the methodology defined in the Remedial Action Work Plan.

I certify that all invasive work during the remediation and all invasive development work were conducted in accordance with the CAMP.

I certify that all information and statements in this certification are true. I understand that a false statement made herein is punishable as Class "A" misdemeanor, pursuant to Section 210.45 of the Penal Law.

It is a violation of Article 130 of New York State Education Law for any person to alter this document in any way without the express written verification of adoption by any New York State licensed engineer in accordance with Section 7209(2), Article 130, New York State Education Law.

11.0 Summary of the Remedy

A summary of the proposed remedy contained within this RAWP is as follows:

1. Composite Cover System: The existing composite cover cap in the vicinity of the former underground storage tanks and area of the plume will be maintained;

2. Treatment System: An in-situ bioremediation system will be constructed and operated to reduce contaminant levels;

3. If residual impacts remain after the remedy, r~~R~~ecording of Deed Restrictions will ~~to~~ be executed and recorded before a Release of Liability is issued. ~~prior to approval of the Final Engineering Report.~~ Included in the Deed Restrictions will be the following:

   - Prohibition of vegetable gardens and farming at the Site;
   - Prohibition of using groundwater underlying the Site without treatment rendering it safe for its intended purpose (groundwater is not currently being used);
   - Prohibition of using the Site other than for commercial purposes;
   - Prohibition of using the Site for a higher level of use, such as ~~restricted~~ residential, without an amendment or extinguishment of the Deed Restrictions with NYSDEC approval;
   - All future activities that will disturb residual contaminated material within the treatment area require ~~are prohibited without~~ NYSDEC approval; and
   - Grantor agrees to submit to NYSDEC a written statement that certifies, under penalty of perjury, that: (1) controls employed at the Controlled Property are unchanged from the previous certification or that any changes to the controls were approved by the NYSDEC; and, (2) nothing has occurred that impairs the ability of the controls to protect public health and environment or that constitute a violation or failure to comply with the SMP. NYSDEC retains the right to access such Controlled Property at any time in order to evaluate the continued maintenance of any and all controls. This certification shall be submitted annually, or an alternate period of time that NYSDEC may allow. This statement must be certified by an expert that the NYSDEC finds acceptable. If controls are no longer required, certifications can be discontinued following NYSDEC approval.

4. If residual impacts remain after the remedy, d~~D~~evelopment of an approvable Site Management Plan that defines Site management practices following ~~during~~ implementation of the remedy, including 1) an Engineering Control Plan; 2) a Monitoring Plan; 3) an Operation and Maintenance Plan; and 4) a Reporting Plan; and

5. Submission of a Final Engineering Report documenting all elements of the Remedy.

12.0 Signatures of Environmental Professionals

Shaw Environmental and Infrastructure, Inc. (Shaw) has prepared this Remedial Action Work Plan (RAWP) for the 75-20 Astoria Boulevard Site located at 75-20 Astoria Boulevard, in Jackson Heights, Queens County, New York.

SHAW ENVIRONMENTAL AND INFRASTRUCTURE, INC.

____

Erik Gustafson
Client Program Manager

____

Charles Schaefer, Ph.D.
Senior Technology Applications Engineer

____

Graig Lavorgna
Project Engineer

____

August Arrigo, P.E.
Business Line Manager

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FIGURES

TABLES

APPENDIX A

APPENDIX B

APPENDIX C

APPENDIX D

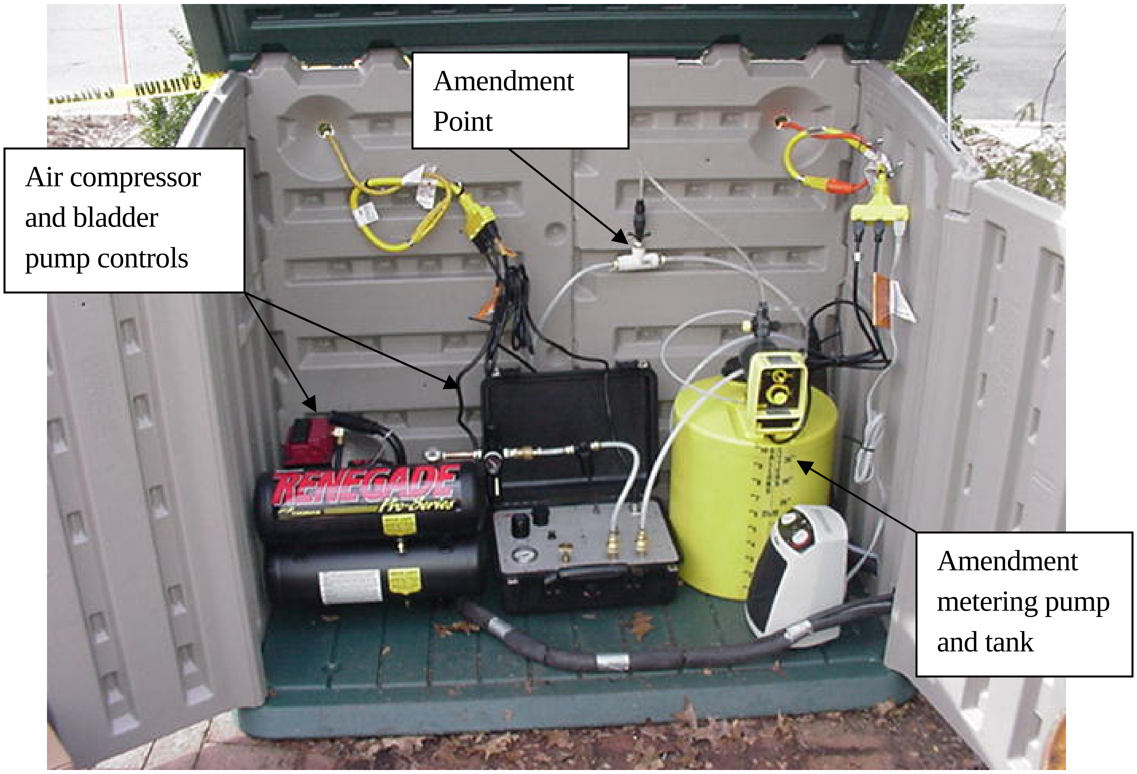

Photo 1: Pilot test system.

Photo 2: Extraction and Injection points (Phase 2, extraction from MW-29D, Injection into PSIW-1.

APPENDIX E

APPENDIX F

APPENDIX G

APPENDIX H

APPENDIX I