REVISED FEASIBILITY STUDY REPORT

Operable Unit No. 1 (OU-1)

Former Columbia Cement Company, Inc. Facility

159 Hanse Avenue
Freeport, New York

SITE # 1-30-052

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Hazardous Waste Remediation
NYSDEC Region 1

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1.0 INTRODUCTION

This Feasibility Study (FS) was prepared to evaluate potential remedial actions to address subsurface contamination at Operable Unit 1 (OU-1) of the former Columbia Cement Company (CCC) site located at 159 Hanse Avenue in Freeport, New York ("Site"). URS Corporation (URS) prepared the FS at the request of the Atlantic Richfield Company, a BP affiliate (BP).

Burmah Castrol Holdings, Inc. (Burmah Castrol) is the parent corporation of OMD 87, Inc., formerly known as Columbia Cement Company, Inc., the former owner and operator of an adhesive manufacturing facility located at 159 Hanse Avenue, Village of Freeport, Town of Hempstead, Nassau County, New York. Columbia Cement produced adhesives for a variety of applications. In 1988, while CCC operated the facility, approximately 1,760 gallons of 1,1,1-trichloroethane (1,1,1-TCA) was released to a storm drain during filling of an underground storage tank (UST) due to a failure of a contractor's tanker truck. In 1996, the property was sold to TACC, International Corporation (TACC). TACC was subsequently acquired by Illinois Tool Works (ITW) in 1998. In 1998, Burmah Castrol entered into a Consent Order (Index #W1-0813-98-05) with the New York State Department of Environmental Conservation (NYSDEC) regarding the 1,1,1-TCA spill. This order was for the development and implementation of a remedial program for the Site. In 2001, BP purchased all Burmah Castrol holdings and assumed liability for the 1,1,1-TCA spill. A Remedial Investigation (RI) was conducted by Delaware Engineering and the RI Report (RIR) was submitted to NYSDEC in July 2003. In response to NYSDCE comments dated October 27, 2003, Delaware Engineering submitted a revised RIR in December 2003.

In September 2003, URS Corporation was retained by BP to prepare a Feasibility Study (FS) to evaluate remedial options for the Site. A Draft FS was prepared based on data and information in the December 2003 RIR. The Draft FS reflected site conditions at the time of preparation and was submitted to NYSDEC on April 30, 2004.

In January 2004, TACC ceased operations at the Site and vacated the building. In May 2004, ITW informed BP that ITW intended to close and remove the 10 existing USTs at the Site, in anticipation of sale of the property. The USTs were removed in August and September 2004. Since the 1,1,1-TCA spill occurred in the center of the UST area, the removal of the USTs changed conditions and access in the spill area and presented opportunities for remedial alternatives that previously were unavailable or impractical. Based on discussions with and approvals from NYSDEC, URS conducted supplemental investigation activities that would allow for refinement of site characterization to be used in preparation of a revised FS that takes the changed conditions (e.g. absence of USTs in the spill area) into consideration. A Supplemental

Remedial Investigation Report (SRIR) that included the results of the additional investigation data was prepared and submitted to NYSDEC on December 20, 2006.

A revised Draft FS was submitted to NYSDEC in January 2007. Upon review of the Draft FS, NYSDEC requested additional offsite groundwater delineation. Access to the offsite property was obtained in August 2007. In September 2007, URS installed and sampled 2 wells adjacent to Freeport Creek. When contamination was detected in one of the offsite wells, NYSDEC chose to divide the project into two Operable Units (OUs). OU-1 is the onsite project area and includes the former CCC property (Block 230, Lots 65 and 85), currently owned by ITW. OU-2 is the offsite area including Hanse Avenue and downgradient properties located between Hanse Avenue and Freeport Creek and areas immediately surrounding OU-1. This Revised FS addresses OU-1 only. Upon completion of additional investigation activities, a separate RIR and FS will be submitted to NYSDEC addressing OU-2.

1.1 PURPOSE AND REPORT ORGANIZATION

The purpose of this FS is to evaluate potential remedial measures to address subsurface contamination at the former CCC facility resulting from a 1,1,1-TCA spill in 1988. The FS will identify, develop, and screen remedial alternatives to address contaminated soil and groundwater and potential soil vapor impacts.

This FS has been divided into seven sections, in a format consistent with the outline described by the United States Environmental Protection Agency ("Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA," USEPA 1988) and the NYSDEC Inactive Hazardous Waste Site (IHWA) Regulations. Site background information, including a summary of the results of previous investigations is presented in the following subsections of Section 1.0. The remedial action objectives are presented in Section 2.0. Potential remedial technologies are identified and screened in Section 3.0. Remedial alternatives passing the initial screening are further developed in Section 4.0 and a detailed analysis and evaluation of alternatives is presented in Section 5.0. Section 6.0 contains a comparison of remedial alternatives and the selection of the preferred alternative. A description of common actions (actions to be employed regardless of selected remedial measures) is provided n Section 7.0. References are presented in Section 8.0.

1.2 BACKGROUND INFORMATION

1.2.1 SITE DESCRIPTION

The former CCC facility consists of approximately 2 acres in an area of Freeport, New York that is very developed with commercial and industrial facilities. Freeport is located in Nassau County on the south shore of Long Island. The Site is located approximately 4,000 feet south of the Sunrise Highway and about 2,000 feet west of the Meadowbrook Parkway, the two major roads in the area. The site location is shown on Figure 1.

The Site building covers approximately 65,000 square feet, and consists of former offices, material storage, production rooms, and warehousing. The building is currently vacant. Ten 8,000-gallon underground storage tanks (USTs) were located near the southwest corner of the property. The Site is bordered by a former Columbia Cement warehouse and parking spaces to the north (currently utilized as a municipal waste transfer station). Rohm & Haas Electronic Components borders the property to the east. The Knickerbocker building, with multiple tenants, is located to the south of the property. The property is bordered by Hanse Avenue to the West. Farber Plastics and Love & Quiches are located on the opposite (west) side of Hanse Avenue. A Site Plan is presented as Figure 2.

The Site is located on a peninsula on the south side of Long Island. Freeport Creek is located about 500 feet west of the Site and Stadium Park Canal is 1,000 feet east of the site. Stadium Park Canal merges with Freeport Creek approximately 1,500 feet southeast of the site. From this point, surface water flows south through tidal marshes to the Atlantic Ocean, approximately 5 miles south of the Site.

The Site is very flat, ranging from 5 to 10 feet above Mean Sea Level (ft MSL). Ground elevations at OU-1 monitoring wells ranges from 6.67 ft MSL to 8.01 ft MSL. Surface water at the site drains to the west toward Freeport Creek. Storm drains located on Site, also drain to Freeport Creek.

1.2.2 SITE HISTORY

Prior to 1969, the Village of Freeport operated the area of the site as a municipal landfill. Dumping at the landfill ceased in the 1960's when the site was developed. CCC was the first occupant of the Site building, beginning in 1969. CCC operated on Site until the sale to ITW in 1996. CCC manufactured various contact cement and other industrial and commercial adhesive products from 1969 to 1996.

From 1969 to 1988, twenty-two 1,000-gallon USTs were located in the southeast part of the site: 6 USTs contained toluene; 6 contained hexane; 5 contained acetone; 3 contained Laktane® (a proprietary petroleum-based solvent); and 2 USTs contained methylethyl ketone (MEK). All 22 USTS were removed in September 1988 by Unico Service Corporation (UNICO) of Commack, New York. To the east of the 22 USTs were four 6,000-gallon USTs, which contained acetone, hexane, Laktane®, 1,1,1-TCA and toluene. These were removed by UNICO in January 1989. A 6,000-gallon UST was also located in the southeast part of the site that collected floor drain runoff from the manufacturing areas of the building. This UST was removed by ANS Tank & Environmental Services of West Babylon, New York in 1994.

Ten 8,000-gallon USTs were installed in 1988. Five of these USTs (the southern tank farm) were installed in the spring of 1988 (prior to the 1,1,1-TCA spill) and the remaining five (the northern tank farm) were installed after the spill. Due to excessive cracking, the concrete pad around the USTs was replaced in 1989.

In 1996 CCC ceased operation and the property was sold to TACC in 1997. TACC was subsequently acquired by ITW in 1998. TACC ceased operation in January 2004. In August and September 2004, ITW closed the ten 8,000-gallon USTs. The USTs were removed and appeared to be in good condition. Details of ITW's UST closure and post-excavation sampling have been detailed in previous submittals to NYSDEC (MACTEC, 2006).

1.2.2.1 Spill Event

On April 28, 1988, Quadrell Brothers of Rahway, New Jersey was delivering 3,500 gallons of 1,1,1-TCA to CCC. While pumping into one of the 6,000-gallon USTs, the tanker truck became pressurized and ruptured. Approximately 1,760 gallons of 1,1,1-TCA was spilled to the ground surface and flowed to a storm drain (SD-1) in the UST area.

Storm drains at the site consist of a vault with a sand bottom and a drainpipe connecting it with other drains and eventually discharging to Freeport Creek. Because of this construction, some of the 1,1,1-TCA infiltrated through the base of the storm drain vault into the sandy soils and some of the 1,1,1-TCA flowed through the storm drainpipe toward Freeport Creek.

NYSDEC's Region 1 Spill Response Unit was notified of the spill. The immediate response measures included removal of about 10 cubic yards of soil from SD-1 and removal of liquid from the storm drain line by Chemical Pollution Control. The storm drain line was flushed until water at the Freeport Creek outfall measured less than 50 mg/l of 1,1,1-TCA.

1.2.2.2 Previous Investigations

Investigations into impacts from the 1,1,1-TCA spill commenced on April 30, 1988. Several phases of the investigation activities were performed from 1988 through 1997. For a summary of these investigations, the reader is referred to the RIR. Delaware Engineering performed the RI from 1998 through 2003. The RI consisted of numerous rounds of soil and groundwater sampling, as well as soil gas sampling, which are again summarized in the RIR. A site plan and sampling locations map is shown in Figure 2. The results of the RI are discussed in Section 1.2.5.

In 2003, BP retained URS to assume investigation and response activities related to the 1988 1,1,1-TCA spill and prepare an FS. URS prepared and submitted a Draft FS on April 30, 2004. The FS was prepared based exclusively on data gathered during the RI and previous investigations. The remedial alternatives evaluated in the Draft FS assumed the ten 8,000-gallon USTs would remain in place in the spill area and in use for the foreseeable future.

Shortly after submittal of the Draft FS, ITW informed URS that the USTs would be removed. Removal of the USTs from the spill area changed site conditions significantly. Without the USTs and associated piping, previously obstructed areas were accessible for additional investigation and/or remedial measures. In addition, URS noted several data gaps in the RI, including several that could be addressed after the USTs were removed. These data gaps represented information that could facilitate preparation of a more complete and comprehensive FS, including groundwater geochemical data and source area delineation. Also, NYSDEC and the New York Department of Health (NYDOH) requested offsite plume delineation and a soil vapor intrusion evaluation, respectively. For these reasons, URS conducted several supplemental investigation activities. These activities included:

- Low-flow groundwater sampling of all site monitoring wells, including collection of biofeasibility parameters.
- Collection of post-excavation soil samples during UST closure.
- Collection of direct push soil samples in the UST area after UST removal.
- Installation of 2 additional offsite monitoring wells and subsequent groundwater sampling.
- Performance of bench-scale testing of potential remedial alternatives.
- Performance of soil vapor intrusion sampling.

- Slug testing of selected monitoring wells.

Details of these activities were summarized in URS's Supplemental Remedial Investigation Report, Former Columbia Cement Company Facility, Freeport, New York, dated December 20, 2006 (SRIR).

1.2.3 SITE GEOLOGY

Soil borings advanced during investigation activities at the Site encountered five stratigraphic units beneath the site. In order of increasing depth, these units are: fill material; tidal marsh deposits; gravelly sand; gray clay and silt; and gray sand. Each of these units is discussed below.

The fill material was encountered across the entire site. The fill consists of reworked native soil, pavement sub-base (ballast), and miscellaneous debris including wood, glass, brick, metal, paper materials, gravel, asphalt and UST excavation backfill. Much of the fill material is likely related to the former use of the area as a municipal landfill. The fill ranges in thickness from 3.1 feet (ft) to 22.9 ft, with an average thickness of about 11 ft.

The tidal marsh deposits are encountered beneath the fill material over most of the site, but are absent in some areas. The tidal marsh deposits consist of brown, dark, gray and black organic clayey silt with some fine to medium sand and varying amounts of roots, wood and peat. Where present, the tidal marsh material is encountered at an average depth of 9.5 ft and has an average thickness of 4 ft. It is thickest at the eastern and western ends of the site. It is absent in the mid-northern portion of the Site (MW-97-7S) and is absent in the tank farm area, where it has likely been removed by excavation and replaced by fill material.

The gravelly sand is relatively thick and flat-lying. It is encountered beneath the tidal marsh deposits, and beneath the fill material where the tidal marsh deposits are absent. The unit consists of medium dense, brown to light gray, coarse to fine sand, with little medium to fine subrounded gravel. Minor amounts of silt and clay were found in isolated samples. The gravelly sand thickness ranges from 15 to 30 ft and is thickest in the western portion of the site. The base of the gravelly sand is relatively flat and is encountered at an average depth of about 35 ft. Impacts from the spill decrease with depth in the gravelly sand. At the base of this unit, no dense non-aqueous product layer (DNAPL) or evidence of soil contamination was observed.

The gray clay and silt underlies the gravelly sand. It consists of a medium gray clayey silt to silt and clay with little to trace sand and becomes clayier with depth. The depth to the top of the gray clay unit ranged from 34 ft in the spill area to 37 ft along the western Site boundary. Only two borings on Site penetrated the entire clay unit and the thickness ranged from 13.95 ft in MW-00-

12D near the spill area to 15.3 ft at MW-00-12D, south of the spill area. The gray clay and silt unit likely acts as a lower confining unit beneath the site. No odors or evidence of contamination was observed in this unit.

An undifferentiated light gray fine sand underlies the gray clay and silt. It is described as a gray to light gray medium to fine sand with little silt. Only two Site borings penetrated the gray sand and neither penetrated its entire thickness. Based on literature review, this unit ranges in thickness from 20 to 30 ft beneath the Site. No evidence of contamination was observed in this unit.

1.2.4 SITE HYDROGEOLOGY

The shallow water-bearing units beneath the Site are not utilized as a drinking water source. Deeper confined units include the Jameco, Magothy and Lloyd aquifers, which are used for drinking water in some areas of Long Island. Due to saltwater encroachment near the southern shore of Long Island, these units are not a source of drinking water near the Site. Groundwater beneath the site is classified as Class GSA (saline ground water).

1.2.4.1 Hydrostratigraphic Units

Shallow groundwater at the Site is encountered in the fill material at depths ranging from 5.5 to 8.0 feet below grade (ft bgs). In various areas of the site, the water table is encountered in the fill material, the tidal marsh deposits, or the gravelly sand. Due to this fact and extensive connectivity between these units, particularly where the tidal marsh unit is thin or absent, these units have been treated collectively as single unconfined aquifer. Some shallow monitoring wells are screened across all three units. Deep monitoring wells screened at the base of the gravelly sand have nearly identical groundwater elevations as adjacent shallow wells. The shallow unconfined groundwater discharges to Freeport Creek. The gray clay and silt unit likely acts as a lower confining layer or aquitard, separating the water table aquifer from the underlying gray sand. The gray sand is a separate, confined water-bearing unit.

1.2.4.2 Surface Water

The Site is situated on a peninsula of the Middle Bay drainage basin. Storm water runoff from the site flows toward Freeport Creek, about 500 ft to the west of the Site. Storm drains from the Site likewise drain to Freeport Creek. Extensive tidal wetlands are located south of the Site. Freeport Creek and Stadium Park Canal are classified as Class SC (saline surface waters). The best usage of SC surface waters is fishing, with other usages being primary and secondary contact recreation.

1.2.4.3 Groundwater Flow

As stated previously, shallow groundwater at the site is encountered from about 5.5 to 8.0 ft bgs. Groundwater flows primarily to the west, however, due to the Site's location, groundwater levels exhibit tidal influences, as described below.

1.2.4.4 Tidal Influences

As is typical in coastal areas, shallow groundwater at the site is influenced by two tidal cycles per day. As part of the RI, Delaware Engineering performed tidal monitoring on two dates in May 2000. These two tidal monitoring events were conducted over 20 and 21 hours, respectively. During the tidal monitoring, groundwater level changes of 1 ft or less were recorded on Site. The tidal range is greatest to the west, suggesting a greater hydraulic connection to Freeport Creek than to Stadium Park Canal. The timing and degree of tidal response between the shallow and deep wells suggests that, in some areas of the Site, the tidal marsh unit may restrict flow between the fill material and the gravelly sand.

During high tide, flow was generally to the west with a very shallow hydraulic gradient of 0.00095 ft/ft. During low tide, a groundwater divide forms in the north-central portion of the site. Groundwater east of this divide flows to the east and groundwater west of the divide flows to the west. Based on this observation, flow in the spill area alternates from east to west with a very minimal gradient in both directions. This alternating flow direction and slight hydraulic gradients may serve to minimize contaminant transport from the site.

Delaware Engineering calculated average groundwater elevations from the tidal measurements. Based on these calculations, the overall average groundwater flow direction is east to west, with a hydraulic gradient of 0.0002 ft/ft. Groundwater elevations and flow directions as measured from the RI during high tide, low tide and their mean values are plotted on Figures 3, 4 and 5, respectively. As stated previously, the tidal measurements were made over periods of 20 to 21 hours. Serfes (1989) states that a tidal mean can be calculated from measurements collected over a 25-hour period. A true tidal mean calculated from this method may vary slightly from that calculated in the RI.

1.2.4.5 Hydraulic Conductivity

Hydraulic conductivity for the water-bearing units at the Site was estimated by Delaware Engineering in the RI by performing slug tests in Site monitoring wells. Slug tests were performed in fifteen wells: 2 water table wells (screened in the fill, tidal marsh and gravelly sand units); 7 wells screened in the upper gravelly sand (S-series wells); 5 wells screened in the lower gravelly sand (D-series wells); and one well screened in the gray sand below the gray clay and silt (MW-00-11A). One shallow offsite well (MW-03-13S) was also tested.

The average hydraulic conductivity for the water table wells was 8.88 feet per day (ft/day) [3.13 x 10^{-3} centimeters per second] (cm/sec). The average hydraulic conductivities for the shallow and deep gravelly sand wells were 66.80 ft/day (2.36 x 10^{-2} cm/sec) and 49.26 ft/day (1.74 x 10^{-2} cm/sec), respectively. The average hydraulic conductivity for all the gravelly sand wells was 60.03 ft/day (2.12 x 10^{-2} cm/sec). The hydraulic conductivity from the single test in the lower gray sand was 48.19 ft/day (1.70 x 10^{-2} cm/sec).

In October 2005, URS performed slug tests in wells MW-05-14S, MW-97-1S, MW-98-9D and MW-97-6S. The estimated average hydraulic conductivity values for the wells screened in the gravelly sand (MW-97-1S, MW-97-6S and MW-98-9D) ranged from 34.63 ft/day (1.22 x 10^{-2} cm/sec) in MW-97-6S to 44.75 ft/day (1.58 x 10^{-2} cm/sec) in MW-97-1S. These results agree fairly well with results from the same wells during the RI slug tests. The slug test results from newly installed well MW-05-14S were notably different from results from the other Site wells. The estimated average hydraulic conductivity of 2.2 ft/day (7.77x10^{-4} cm/sec) was an order of magnitude lower than the other wells tested. The boring log for MW-05-14S indicates that it is screened in landfill-related fill material.

1.2.5 CONTAMINANT ASSESSMENT

1.2.5.1 Soil

During the RI and previous other investigations, soil sampling was performed throughout the site. However, due to the presence of the ten 8,000-gallon USTs, delineation of spill area soil contamination was not possible. Following ITW's removal of the USTs, URS performed extensive post excavation soil sampling in and around the spill area. Soil sampling was performed during ITW's UST closure activities from the open excavations and through soil borings after the excavations were backfilled. The following is a summary of all soil sampling results compiled from the Site to date. The Standard, Criteria and Guidance (SCGs) for soils are based on the Department's Cleanup Objectives ("Technical and Administrative Guidance Memorandum [TAGM] 4046; Determination of Soil Cleanup Objectives and Cleanup Levels." (January 24, 1994) and 6 NYCRR Subpart 375-6 – Remedial Program Soil Cleanup Objectives). 6 NYCRR Part 375 (December 14, 2006). A detailed description of soil contaminant distribution exceeding RSCOs is presented in the Supplemental Investigation Report. A summary of positive detections of volatile organic compounds (VOCs) and exceedances of RSCOs is presented on

Figure 6. VOCs were detected at concentrations exceeding RSCOs almost exclusively in the spill area.

Compounds detected at concentrations exceeding the RSCOs include 1,1,1-TCA, 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethene (DCE), 1,2-dichloroethane (1,2-DCA), chloroethane (CA) [spill-related compounds], benzene, toluene, ethylbenzene, xylenes (BTEX), acetone, methylene chloride and trichloroethene (TCE). Most of the RSCO exceedences were spill-related compounds, although acetone was also widespread. Most of the highest concentrations were detected in samples collected from depths ranging from 10 to 20 feet bgs. The highest 1,1,1-TCA concentration (7,000 mg/kg) was detected in boring SB-98-2 at 10.0 to 13.7 feet bgs. In the immediate vicinity of the spill, 1,1,1-TCA was detected at 2,600 mg/kg in boring MW-00-11A from 16 to 18 feet bgs. In 2004, in boring D-1, about 5 feet from MW-00-11A, 1,1,1-TCA was detected at 690 mg/kg. Cross-sections presented in the Supplemental Investigation Report show that the vertical extent of soil impacts exceeding RSCOs has been delineated. No exceedences of RSCOs were detected at depths greater than 22 feet. A summary of soil sampling results is presented as Table 1.

Based on the results described above, the extent of soil contamination in the spill area has been effectively delineated. Impacted soil at levels significantly exceeding the RSCOs is present is definable pockets. These areas are shown on Figure 7. The table on Figure 7 summarizes the vertical extent of each of the laterally delineated impacted areas. The table also shows the volume of each of the impacted areas and the volume of overlying non-impacted soil. The table shows that 535 cubic yards of soil and clean fill would need to be removed to excavate 620 cubic yards of impacted soil as a remedial measure.

1.2.5.2 Groundwater

During the RI, three rounds of groundwater samples were collected from Site monitoring wells: January 1999, April 2000, and May 2003. The groundwater data were compared to the NYSDEC Ambient Water Quality Standards and Guidance Values (GWS). Data from these three sampling events that exceeded GWS are presented on Figure 8. URS collected an additional round of groundwater samples in June 2004. Samples were analyzed for VOCs and selected wells were analyzed for a suite of parameters to evaluate evidence of biodegradation and potential limiting factors to biodegradation (biofeasibility parameters). Geochemical and biofeasibility parameter results are presented on Figure 9. In April 2005, URS installed an offsite well couplet on the west side of Hanse Avenue (in Operable Unit 2), approximately 70 feet downgradient from MW-91-1S and MW-98-9D. These wells (MW-05-14S and MW-05-15D), along with wells MW-97-1S, MW-98-9D and MW-00-13S were sampled in April 2005 for VOCs. An additional round of samples was collected from all Site monitoring wells in June 2006. Samples were analyzed for

VOCs and biofeasibility parameters. Data from this sampling event is also plotted on Figures 8 and 9.

The nature and extent of groundwater VOC contamination changed between the January 1999 event and the 2006 sampling events. Specifically, the levels of 1,1,1-TCA decreased significantly while the concentrations and extent of daughter product CA has increased. For the purposes of this FS, only the most recent data (June 2006) is considered. Contaminant contour maps for CA in shallow and deep wells are presented in Figures 10 and 11. CA is the daughter product of 1,1,1-TCA degradation and is the only spill-related compound found at the downgradient site boundary at levels exceeding the GWS.

Currently, 1,1,1-TCA is not present in any Site wells at a concentration exceeding GWS. In fact, in June 2006, 1,1,1-TCA was not detected in any Site wells at the laboratory method detection limit (MDL). The highest CA concentration is found in well MW-1S, immediately adjacent to the spill location. Along the northern boundary of the Site, only chlorobenzene is present over the GWS, and only in the northwest corner of the Site. Along the southern site boundary, 1,1-DCA and CA are present in and immediately downgradient from the spill area at concentrations over the GWS. A CA plume extends from the source area west along the southern site boundary and extends offsite to wells MW-05-14S and MW-05-15D. The offsite impacts will be addressed in separate submittals for OU-2.

Shallow Wells

In the spill area, only CA was detected in excess of its GWS (1,900 μg/l in well MW-1S) in 2006 sample data. This represents a significant decrease from the 49,000 μg/l detected in 1997. No other compounds were detected in 2006 in spill area shallow wells.

Away from the immediate vicinity of the spill, the number of compounds positively detected in shallow wells and their concentrations decrease dramatically. 1,1,1-TCA and it's immediate daughter product, 1,1-DCA were not detected in any shallow wells. CA was detected in shallow wells in the spill area and along the southern Site boundary at concentrations exceeding the GWS. In June 2006, CA concentrations decreased from 1,900 μg/l in MW-1S to 120 μg/l in MW-97-1S at the southwest Site boundary. The fact that CA is more prevalent than 1,1,1-TCA or 1,1-DCA suggests that natural attenuation processes are occurring in the shallow gravelly sand aquifer. CA was not detected along the northern Site boundary. No VOCs were detected east of the spill area in well MW-98-8S. The only other compound detected in shallow wells outside the spill area is chlorobenzene, which is not related to the spill. Furthermore, the chlorobenzene concentrations are highest at the western Site boundary, suggesting an offsite source.

Deep Wells

Data is available on-site for five deep wells (base of the gravelly sand) in Operable Unit 1. In the spill area (well MW-1D-97), 1,1-DCA was detected at 5.1 μg/l, marginally exceeding the GWS of 5.0 μg/l and CA was detected at the GWS of 5.0 μg/l in June 2006. East of the spill area, CA is detected over its GWS at 38 μg/l in well MW-98-8D. In the northwest corner of the site (MW-98-10D), only chlorobenzene was detected at concentrations over the GWS. In the southeast corner of the Site (MW-00-12D) CA (1,300 μg/l), 1,1-DCA (11 μg/l) and 1,1-DCE (5.8 μg/l) were detected at concentrations exceeding their respective GWS. In the southwest corners of the Site (MW-97-9D) CA (730 μg/l) and chlorobenzene (12 μg/l) were the only compounds present at a concentration over the GWS since June 2006. No deep well is present in the northeast area of the Site.

Well MW-00-11A in the spill area is screened in the gray sand underlying the gray clay and silt unit. In samples collected from this well in 2004 and 2006, no VOCs were detected above the laboratory detection limits. These data suggest that the gray sand underlying the gray clay and silt has not been impacted by the 1,1,1-TCA spill or other previous site activities. In addition, potentiometric surface elevations from the lower gray sand and the upper gravelly sand indicate an upward hydraulic gradient across the clay unit, further reducing the potential for migration to the lower aquifer. Therefore, the FS focuses on the units above the gray clay and silt.

Summary

As stated previously, 1,1,1-TCA is currently not present at concentrations exceeding GWS in any Site well. Its daughter products, 1,1-DCA and CA are the primary groundwater contaminants of concern. The presence of 1,1-DCA and CA are strong indicators that natural degradation of these compounds is occurring. Under typical groundwater conditions, 1,1,1-TCA will breakdown sequentially to 1,1-DCA, CA, then to harmless ethane, and eventually carbon dioxide. Groundwater data suggest that in the both the shallow and deep wells in the gravelly sand, 1,1,1-TCA degrades quickly to 1,1-DCA, which, in turn, degrades quickly to CA. 1,1-DCA is limited to deep wells in the vicinity of the spill area (MW-1D-97 and MW-00-12D). CA, however, does not degrade as quickly to ethane, but rather migrates with the groundwater west beyond OU-1 toward Hanse Avenue, and Freeport Creek in both the shallow and deep wells in the gravelly sand. A summary of groundwater sampling results is presented in Table 2.

1.2.5.3 Storm Drain Soil

The storm drains at OU-1, including SD-1 where the spill event occurred, are sand-bottom drains connected by storm drain pipes. Immediately after the spill event, some soil was removed from SD-1. During the RI, Delaware Engineering performed soil sampling in storm drains throughout the site. The following is a summary of all soil sampling results compiled from the Site to date. The Standard, Criteria and Guidance (SCGs) for soils are based on the Department's Cleanup Objectives ("Technical and Administrative Guidance Memorandum [TAGM] 4046; Determination of Soil Cleanup Objectives and Cleanup Levels." (January 24, 1994) and 6 NYCRR Subpart 375-6 – Remedial Program Soil Cleanup Objectives). 6 NYCRR Part 375 (December 14, 2006). A detailed description of soil contaminant distribution exceeding RSCOs is presented in the 2003 RI. VOCs were detected at concentrations exceeding RSCOs in storm drains SD-1, D-5 and SD-8.

In sample SD-1 (0-12"), methylene chloride (22 mg/kg) and 1,1,2,2-trichloroethane (0.97 mg/kg) were detected at concentrations exceeding their RSCOs of 0.12 mg/kg and 0.6mg/kg. In sample SD-5, total xylenes (1.75 mg/kg) was detected at a concentration exceeding the RSCO of 1.2 mg/kg. In storm drain SD-8, 1,1,1-TCA was detected at 4.8 mg/kg at 0 to 12 inches and at 0.85 mg/kg at 24 to 30 inches. These concentrations exceed the RSCO of 0.8 mg/kg. A summary of storm drain soil sampling results is presented as Table 1.

1.2.5.4 Soil Vapor

In September 2005, soil gas samples were collected from 11 soil vapor monitoring points around the UST/Spill area and the site perimeter. Soil gas sampling results are presented on Figure 12. The sampling results identified several VOCs. The most prevalently identified VOCs include 1,1,1-TCA, 1,1-DCA, CA, acetone, methylene chloride, heptane, hexane, toluene, benzene, ethylbenzene, xylene, tetrachloroethene, trichloroethene, vinyl chloride, carbon disulfide, carbon tetrachloride, chlorobenzene, cyclohexane, ethanol and freon. Some of these compounds correspond to Site related activities and/or the 1988 1,1,1-TCA spill. 1,1,1-TCA concentrations in the spill area ranged from 33 $\mu g/m^3$ (micrograms per cubic meter) (6 parts per million by volume (ppbv)) in SG-05-03 to 21,100 $\mu g/m^3$ (3,870 ppbv) in SG-05-11. 1,1,1-TCA was not detected in samples SG-05-01, SG-05-07 and SG-05-08. In the spill area, 1,1-DCA was detected at concentrations ranging from 2,770 $\mu g/m^3$ (733 ppbv) in SG-05-11 to 14,000 $\mu g/m^3$ (3,470 ppbv) in SG-05-04. 1,1-DCA was not detected in SG-050-01. CA was detected in spill area soil gas samples at concentrations ranging from 12 $\mu g/m^3$ (4.7 ppbv) to 5,040 $\mu g/m^3$ (1,910 ppbv). CA was not detected in SG-05-09. Several of the VOCs detected in soil gas were also detected in the two ambient air samples, including acetone, benzene, heptane, methylene chloride, tetrachloroethene, trichloroethene, toluene and xylenes.

Based on the results of the 2005 soil vapor sampling, NYDOH requested that BP collect additional samples, including:

- Three sub-slab vapor samples and two indoor air samples in the former Columbia Cement building.
- One outdoor ambient air sample.
- One sub-slab and one indoor air sample in the neighboring Knickerbocker Building.
- One sub-slab vapor sample at the neighboring Rohm & Haas building (along with an additional ambient air sample).
- Resample selected exterior soil vapor sampling points.

Soil vapor sampling results are presented on Figure 13.

In August 2006 three soil gas samples were collected from the spill/UST area (SG-05-01, SG-05-04 and SG-05-11) and three samples were collected from the Site perimeter (SG-05-05, SG-05-08 and SG-05-10). As observed in the 2005 sampling, soil gas concentrations were highest in the spill/UST area. 1,1,1-TCA concentrations ranged from non-detect at SG-05-01 and SG-05-08 to 50,600 $\mu g/m^3$ at SG-05-11; 1,1-DCA concentrations ranged from non-detect at SG-05-10 to 56,700 $\mu g/m^3$ at SG-05-04; and chloroethane concentrations ranged from 8.7 $\mu g/m^3$ at SG-05-08 to 17,500 $\mu g/m^3$ at SG-05-SG-05-11. Hexane concentrations ranged from 79.3 $\mu g/m^3$ at SG-05-05 to 20,700 $\mu g/m^3$ at SG-05-01. Tetrachloroethene (PCE) was detected at concentration ranging from non-detect three locations to 3,280 $\mu g/m^3$ at SG-05-04 and trichloroethene was detected at concentrations ranging from non-detect at three locations to 1,590 $\mu g/m^3$ at SG-05-04. Use and storage of PCE and TCE were not reported at the site, but given Site usage for adhesive manufacturing, past usage of these compounds is possible. Overall, the 2006 soil gas sampling results are similar to those from 2005.

Three sub-slab vapor samples were collected in the former Columbia Cement building. Sample SS-06-01 was collected in the room directly north of the spill area; sample SS-06-02 was collected in the room directly west of the spill area; and sample SS-06-03 was collected northwest of the spill area. As was the case for the soil vapor samples, highest concentrations were detected in closest proximity to the spill area, and concentrations of compounds attenuated rapidly with distance. In sample SS-06-01, 1,1,1-TCA and 1,1-DCA were detected at 189 $\mu g/m^3$ and 47.4

µg/m^3, respectively. Chloroethane was not detected. Other compounds detected in SS-06-01 at elevated concentrations include PCE (195 µg/m^3), TCE (57.5 µg/m^3), acetone (129 µg/m^3), xylenes (40 µg/m^3) and MEK (63.4 µg/m^3). In sample SS-06-02, 1,1,1-TCA, 1,1-DCA and chloroethane were detected at 86,200 µg/m^3, 30,600 µg/m^3 and 10,500 µg/m^3, respectively. Other compounds detected at elevated concentrations include PCE (2,140 µg/m^3), TCE (534 µg/m^3), 1,1-DCE (308 µg/m^3) and methylene chloride (251 µg/m^3). In sample SS-06-03, 1,1,1-TCA and 1,1-DCA were detected at 14 µg/m^3 and 8.9 µg/m^3, respectively. Chloroethane was not detected. Other compounds detected at elevated concentrations include acetone (87.9 µg/m^3), PCE (43 µg/m^3), toluene (23 µg/m^3), and xylenes (36 µg/m^3).

Exterior sub-slab vapor sample SS-06-05 was collected about 10 feet west of the Rohm & Haas building. In sample SS-06-05, 1,1,1-TCA and 1,1-DCA were detected at 38 µg/m^3 and 216 µg/m^3, respectively. Chloroethane was not detected. Other compounds detected at elevated concentrations include PCE (564 µg/m^3), TCE (58 µg/m^3), acetone (208 µg/m^3) and hexane (12 µg/m^3).

The results indicate that sub-slab vapor has been impacted in the southwest portion of the site building, but the concentrations in other areas of the building are significantly lower. Also, sub-slab vapor at neighboring buildings is not significantly impacted.

Indoor air samples were obtained from the Columbia Cement building and the adjacent Knickerbocker building. Two indoor air samples were collected within the former Columbia Cement building. Sample IA-06-01 was collected near sub-slab sample SS-06-02. Sample IA-06-02 was collected in the room immediately west of the room where sub-slab sample SS-06-03 was collected. 1,1,1-TCA, 1,1-DCA and chloroethane were not detected in sample IA-06-01. Compounds detected include toluene (18 µg/m^3), xylenes (17 µg/m^3), acetone (12 µg/m^3) and hexane (6.7 µg/m^3). In sample IA 06-02, 1,1,1-TCA was detected at a trace level of 0.93 µg/m^3. 1,1-DCA and chloroethane were not detected. Compounds detected include acetone (18 µg/m^3), toluene (8.7 µg/m^3), xylenes (7.4 µg/m^3), and hexane (3.9µg/m^3).

The indoor air sampling results indicate the presence of low levels of VOCs. These VOCs consist primarily of BTEX compounds, hexane and acetone, not the chlorinated VOCs detected in the sub-slab vapor. This suggests that the slab is currently acting as an effective barrier against vapor intrusion. In addition, the presence of some of these same compounds in outdoor ambient air samples suggests that their presence may not be related to sub-slab conditions, but rather the industrial setting of the Site.

Summary

Soil gas sampling indicated that VOCs are present in shallow soil throughout the Site. Concentrations of spill-related compounds was greatest in samples in and around the spill area, but are detected throughout Operable Unit 1. Several other VOCs were detected in multiple soil gas samples, including BTEX, PCE, TCE, methylene chloride and several other compounds. Several of these compounds were also detected in ambient air samples collected outdoors at the Site.

Sample results were compared to Matrix 1 and Matrix 2 in the NYDOH *Guidance for Evaluating Soil Vapor Intrusion in the State of New* York (NYDOH SVI Guidance Document). In the former Columbia Cement building, the indoor air concentrations of PCE, TCE and 1,1,1-TCA are three to five orders of magnitude lower than those found in the sub-slab vapor samples. The indoor air results are not at levels that would trigger any response measures based on the assessment matrices. However, the sub-slab vapor concentrations of PCE (2,140 $\mu g/m^3$), TCE (534 $\mu g/m^3$) and 1,1,1-TCA (86,200 $\mu g/m^3$) are at levels where the NYSDOH assessment matrices suggest mitigation as a potential response measure, regardless of indoor air concentrations, based on the NYSDOH 2006 Guidance Document. The presence of these elevated sub-slab concentrations present a potential risk should the slab be compromised due to cracking or activities that might require cutting or coring the slab. It should be noted that the Site building remains unoccupied, thereby eliminating current exposure concerns in the building at this time. A summary of soil vapor intrusion sampling results is presented in Table 3.

1.2.6 CONTAMINANT FATE AND TRANSPORT

The primary contaminants of concern at the Columbia Cement Company site are the chlorinated VOCs 1,1,1-TCA, 1,1-DCA, and CA. 1,1,1-TCA was the original spill contaminant, but it has subsequently degraded to its daughter products 1,1-DCA and CA. Toluene, ethylbenzene, xylene, chlorobenzene, methylene chloride and acetone have also been detected on occasion at concentrations exceeding applicable standards. Based on soil boring data, soil contamination in the spill area extends from about 8 to 20 feet below ground surfaces (ft bgs). It should be noted that no DNAPL was observed in any soil borings or wells on Site to date. Residual contamination is likely present as disconnected ganglia within the pore spaces in the saturated zone due to capillary forces.

Fate and transport is controlled by physical, chemical and biological processes including advection, dispersion, sorption, desorption, volatilization, dehalogenation and hydrolysis. From the pockets of residual contamination in the spill area, several factors affect the fate and transport of contaminants from this area. Some factors related to the contaminants themselves include solubility, density, volatility (vapor pressure and Henry's Law constant), biodegradability, and organic carbon partition coefficient. Important factors related to the aquifer environment include aquifer hydraulic conductivity, hydraulic gradient, soil organic carbon content, groundwater geochemistry (pH, dissolved oxygen, redox potential), subsurface microbial population, and the presence of other compounds (either beneficial or toxic). A summary of the physical properties of the contaminants of concern at the Site is presented in Table 4.

Solubility is the amount of a compound that will dissolve into water. Compounds with higher solubilities will tend to dissolve into groundwater and be transported with flowing groundwater. Compounds that are highly soluble tend to partition into the liquid phase rather than sorbing onto soil or volatilizing. As groundwater flows past the contaminant ganglia, the more soluble compounds will dissolve into the groundwater, while the less soluble compounds will remain in the pore spaces or sorbed onto soil particles. As indicated on Table 4, the chlorinated VOCs of concern at the site are fairly soluble.

Solubility is also used as a tool to assess the potential for the presence of free product. If the dissolved concentration of a contaminant is greater than 1 percent of that compound's solubility, the presence of free product is possible, but not certain. Data from the most contaminated wells in the spill area, MW-1S and MW-97-1D, suggest that free product is not present. This is confirmed from soil boring observations and monitoring well measurements.

The Henry's Law constant for a compound indicates the tendency of a compound to partition between the vapor and liquid phases. Compounds with high Henry's Law constants will tend to volatilize into the vapor phase. Of the compounds of concern at the Site, only methylene chloride and vinyl chloride have Henry's Law constants that suggest they would partition readily into the vapor phase. The remaining compounds have lower Henry's Law Constants, suggesting they will tend to remain in solution or sorbed onto aquifer solids. However, data from soil gas and sub-slab vapor samples indicate that chloroethane, a daughter product of the spill-related compound 1,1,1-TCA and other spill-related compounds is also present in the soil vapor under the building.

The organic carbon partition coefficient (K_{OC}) indicates the tendency of an organic compound to sorb onto soil particles rather than dissolving into groundwater. Compounds with a high K_{OC} will sorb onto soil organic material, which slows release of residual contamination into groundwater. The degree of sorption related to the compound's K_{OC} is also a factor of the amount of solid phase organic matter in the saturated zone. This effect is termed the "retardation factor." As a result of retardation, contaminant sources remain active for longer periods of time and contaminant transport rates are decreased. In simplest terms, the retardation factor (R) can be defined as:

$$R = \frac{V}{V_c}$$ Eq. 1-1

where,

R = retardation factor

V = average groundwater seepage velocity

V_c = average contaminant transport velocity.

This equation describes the transport velocity of a contaminant relative to groundwater flow velocity. The retardation factor can also be described as:

$$R = 1 + \frac{\rho_b K_d}{n}$$ Eq. 1-2

where,

ρ_b = bulk density of the aquifer

K_d = distribution coefficient

n = porosity.

The distribution coefficient can be described as

$K_d = K_{oc} \times f_{oc}$

where,

f_{oc} = the organic carbon content of the aquifer material.

Table 5 displays contaminant retardation factors and transport velocities, based on the equations above and values reported in previous section of this FS. Also included on Table 5 are the estimated travel times estimated for individual contaminants from the spill area to the western site boundary. As shown on Table 5 estimated travel times range from 7.5 years for acetone to 56.5 years for ethylbenzene, compared to a groundwater flow time of 7.5 years.

The 1988 spill consisted of 1,1,1-TCA. 1,1-DCA and CA were never used or stored at the site. These compounds, however are daughter products in the breakdown sequence of 1,1,1-TCA.

This is evidence that 1,1,1-TCA is undergoing natural biodegradation. The potential pathways of 1,1,1-TCA breakdown are shown on Figure 14. Figure 14 shows that the breakdown from 1,1,1-TCA to 1,1-DCA, and from 1,1-DCA to CA are biologically mediated reactions. The breakdown from CA to ethane is primarily abiotically mediated. Ethane analysis was performed on groundwater samples collected in June 2004. The presence of ethane, as shown on Figure 9, indicates that the degradation of CA is occurring in Site groundwater. Because of elevated method detection limits due to methane concentrations, ethane was not detected in 2006.

1.2.7 QUALITATIVE HUMAN HEALTH EXPOSURE ASSESSMENT

Soil

Soil contamination exceeding the RSCOs is present in the spill area at depths of 8 to 20 feet below grade. The extent of the soil contamination has been delineated both laterally and vertically. The USTs formerly present in the spill area were removed in 2004 and the area was repaved. Based on the depth of the soil contamination, and its location under concrete pavement in an industrialized area, the potential for human contact with contaminated soil is negligible.

Soil contamination exceeding the RSCOs is also present in three storm drains in OU-1 at depths from 0 to 30 inches the bottom of the drain. Based on the inside storm drains in an industrialized area, the potential for human contact with contaminated soil is negligible.

Groundwater

Groundwater at the Site is encountered between 5.5 and 8.0 feet below grade. Although tidally influenced, the overall groundwater flow direction is east to west, toward Freeport Creek, approximately 500 feet west of the Site. 1,1-DCA groundwater contamination exceeding GWS is limited to the southeast portion of the site, but a plume of CA extends beyond the western boundary of Operable Unit 1. Groundwater in the area of the site is saline and is not potable. No potable wells exist on site or between the site and Freeport Creek. Therefore, there is no risk to human health from groundwater resulting from the 1,1,1-TCA spill.

Soil Vapor

Sub-slab vapor and indoor air data were evaluated with respect to matrices published in the NYSDOH SVI Guidance Document. Based on the matrices, indoor air concentrations of 1,1,1-TCA, PCE and TCE do not represent an immediate risk to people, should the Site building become occupied. However, the sub-slab vapor concentrations of PCE (2,140 $\mu g/m^3$), TCE (534

$\mu g/m^3$) and 1,1,1-TCA (86,200 $\mu g/m^3$) are at levels where the matrices suggest mitigation as a potential response measure regardless of indoor air concentrations, based on the Guidance Document. The presence of these elevated sub-slab concentrations might present a potential risk if the slab were compromised by cracking or activities that might require cutting or coring the slab. It should be noted that the NYSDOH SVI Guidance Document only presents decision matrices for four compounds. The site building remains unoccupied, thereby eliminating exposure concerns in the building at the time of FS preparation.

Surface Water

The nearest surface water body is Freeport Creek, located about 500 feet west of Operable Unit 1. Risks related to Freeport will be addressed in separate submittals for Operable Unit 2. No surface water is present in Operable Unit 1. During the RI, surface water samples were collected from Freeport Creek at the sewer line outfall, as well as upstream and downstream from the outfall. No spill-related compounds were detected in any of the samples.

1.3 DATA GAP ANALYSIS

Following completion of the RI, several data gaps were identified by NYSDEC and URS. Closure of these data gaps was required before completion of the FS. These data gaps include:

- Groundwater geochemical data and biofeasibility parameter data.
- Delineation of spill/UST area residual soil impacts.
- Bench-scale testing of potential remedial technologies for soil and groundwater remediation.
- Delineation of the downgradient extent of the CA plume.
- Confirmation of RI soil gas results using new TO-15 methodologies.

During 2004 and through 2006, URS closed of these data gaps with additional investigative measures. The results of these activities are described in detail in URS' report *Supplemental Investigation, Former Columbia Cement Company Facility, Freeport, New York*, submitted to NYSDEC in December 21, 2006. Closure of these data gaps provided a more complete understanding of Site conditions and allowed for preparation of a comprehensive FS.

1.4 NATURAL ATTENUATION ASSESSMENT

One data gap addressed during the Supplemental Investigation regards information to establish the occurrence and rate of natural attenuation of 1,1,1-TCA and its daughter products. A natural attenuation assessment is required to provide the lines of evidence necessary to make use of natural attenuation as a primary or secondary remediation technology to achieve the remedial action objectives at the Site. The objectives of a natural attenuation assessment are described below:

- Determine the biodegradability of 1,1,1-TCA and daughter products (1,1-DCA and CA) in groundwater from the Site.
- Document the degradation pathway of 1,1,1-TCA and daughter products (1,1-DCA and CA) in groundwater from the Site and determine if the process can reach completion to innocuous final end products such as ethane.
- Assess whether geochemical conditions (i.e., dissolved oxygen and redox potential) in groundwater at the Site are favorable for natural attenuation.
- Document the occurrence and rate of 1,1,1-TCA degradation in the field, if present.
- Estimate the degradation rate for 1,1,1-TCA and daughter products by natural attenuation following active remediation of the source.

Details of the results of the evaluation are discussed in the evaluation of remedial alternatives in Section 5.0.

1.5 BENCH-SCALE TREATABILITY TESTING

Upon review of data from soil and groundwater sampling described above, URS performed an initial analysis of potential alternatives for remediation of contaminated soil and groundwater at the site. The analysis allowed for screening of remedial technologies based on likelihood of success, ease of implementation and cost. Certain remedial technologies that were identified required laboratory bench-scale treatability testing to evaluate their effectiveness under site conditions and to determine required dosages. These technologies include in-situ chemical oxidation (ISCO) to treat residual soil contamination in the source area and enhanced anaerobic bioremediation to treat the downgradient groundwater VOC plume. The bench scale test results and other recent site data were utilized in completing the updated FS and allowed for evaluation of updated remedial options including enhanced and natural degradation to address residual contamination associated with the 1,1,1-TCA spill. The bench-scale treatability testing was performed by Adventus Americas, Inc. (Adventus), under subcontract to URS. A detailed description of the bench-scale testing and the results is presented in URS' report *Supplemental Remedial Investigation, Former Columbia Cement Company Facility, Freeport, New York,* submitted to NYSDEC on December 21, 2006. A brief summary of the results is presented herein.

A second treatability study was performed for BP by TerraSystems, Inc. to investigate the utility of anaerobic and aerobic enhanced bioremediation to treat the downgradient groundwater VOC plume. A description of the tests and the results is provided below.

1.5.1 ISCO BENCH-SCALE TEST

For the ISCO bench-scale test, soil was collected from boring SB-042005, which was advanced through the bottom of storm drain SD-1. Groundwater for the ISCO bench-scale test was collected from well MW-1D-97. Upon receipt at Adventus' lab, the soil and groundwater were sampled for VOCs and were spiked to match previously detected values in source area soil and groundwater. Mixtures of Site soil and groundwater were placed in jars for testing. Sodium persulfate ($Na_2S_2O_8$) was used as the oxidizing agent in the testing, as it has been demonstrated to be effective at treating chlorinated solvents. Hydrogen peroxide (H_2O_2) and ethylenediaminetetraacetic acid iron (III) sodium salt (NaFe(III)EDTA) were tested as activators to increase the oxidizing effectiveness of the persulfate. Details of the ISCO bench-scale treatability study are presented in Appendix A.

The results of the testing indicated that the highest removal efficiency was seen with hydrogen peroxide activated persulfate. This combination provided removal of 98.7% and 80% of 1,1,1-TCA in soil and groundwater, respectively and 99.5% and 99.4% removal of chloroethane in soil and groundwater, respectively 6 days following treatment. The iron activated sodium persulfate was much less successful at treating 1,1,1-TCA and chloroethane. Based on the testing results, the estimated treatment dosage is 42 g of sodium persulfate per Kg of soil and 60 g of hydrogen peroxide per Kg of soil.

1.5.2 ENHANCED ANAEROBIC BIOREMEDIATION BENCH-SCALE TEST

For the enhanced anaerobic bioremediation bench-scale test, soil was collected from boring MW-05-15D, which was advanced on the west side of Hanse Avenue and converted to monitoring well MW-05-15D. Groundwater for the enhanced bioremediation bench-scale test was collected from well MW-98-9D. Upon receipt at Adventus' lab, the soil and groundwater were sampled for VOCs and were spiked to match previously detected values in downgradient soil and groundwater.

The objective of the enhanced reductive dechlorination bench scale test was to evaluate the effectiveness of HRC® and EHC® for use in a permeable reactive barrier (PRB) or other application to treat CA in downgradient Site groundwater. HRC® is a polylactic acid ester, which slowly releases lactic acid and other volatile organic acids (VFAs) including acetic, propionic, butyric and lactic acids in groundwater. The VFAs serve as electron donors and promote reductive chlorination of chlorinated VOCs.

EHC® is a combination of controlled-release solid carbon and zero-valent iron (ZVI) to stimulate reductive dechlorination. In contrast to HRC®, the organic component of EHC® is solid fibrous organic material that is nutrient rich and hydrophylic with a high surface area for growth of bacteria. Bacterial growth causes fermentation of the carbon and release of VFAs utilized by other bacteria in reductive dechlorination. The ZVI particles dechlorinate chemically (abiotically) and further reduce the redox potential, providing a more reducing environment for these processes.

The HRC® and EHC® were combined with site soil in separate columns. A total of six column systems were prepared, including sterile and non-sterile control columns. A detailed description of the test setup is provided in the *EHC and HRC Bench Scale Testing Final Report*, presented in Appendix A. Effluent samples were analyzed on six occasions over 107 days. The fifth sampling event at 94 days indicated that HRC® and EHC® were capable of treating chloroethane, with 62% and 52% removals, respectively, compared with 5% and 20% respective removals in the sterile and non-sterile controls. Overall, however, at the conclusion of the testing, the HRC and EHC amended columns did not show increased CA removal compared to the sterile and non-sterile control columns because after 107 days, the CA removal in the sterile and non-sterile controls was 51% and 88%, respectively. The EHC amended columns showed essentially the same removal (88%) as the non-sterile control. The HRC-amended columns had CA removals of 96% and 99.5%, which was only 8% to 12% greater than the non-sterile control column. Therefore, the organic substrate amendments did not provide significant enhancements over the control columns. The non-sterile control column had a chloroethane removal of 88%, indicating significant naturally occurring biological and/or chemical degradation. The lack of enhanced biotic removal of chloroethane may be due to the lack of a microbial community capable of anaerobically degrading chloroethane in downgradient soil.

1.5.3 IN-SITU BIOREMEDIATION TREATABILITY STUDY

Terra Systems, Incorporated (TSI) performed studies under the direction of BP to evaluate enhanced anaerobic and aerobic enhanced bioremediation to treat chlorinated ethanes in OU-1. The study was performed using microcosms prepared with groundwater collected from well MW-1S and soil from boring SB-06-01, advanced in the storm drain where the 1,1,1-TCA spill occurred, to evaluate source area treatability. Groundwater from well MW-97-1S and soil from nearby boring SB-06-02 were used to evaluate downgradient plume treatability. The soil and groundwater were collected in June 2006. The tests were run from July until October 2006.

The anaerobic treatability evaluated the use of a soluble carbon substrate (lactate) and a slow-release substrate (SRS™, an emulsified soy bean oil substrate produced by TSI). The results of the study indicate that addition of either lactate or SRS yields almost complete conversion of 1,1,1-TCA to CA within 4 weeks, but the SRS was longer-lasting and the lactate would require frequent re-application through either injection or recirculation wells. Neither substrate yielded significant conversion of CA to ethane.

Aerobic bench-scale studies evaluated microcosms amended with oxygen and oxygen with nutrients. The results of the studies indicate that the combination of aerobic treatment and volatilization yielded 96% removal of all VOCs in the aqueous phase, including CA. It is unclear what fraction of the removal was due to volatilization. The studies suggest aerobic treatment by addition of an oxygen substrate should effectively treat the CA produced as a result of anaerobic degradation of 1,1,1-TCA observed at the site. A description of the TSI bench-scale tests is presented in their report *In Situ Bioremediation Treatability Studies, Columbia cement, Freeport, New York*, provided in Appendix A.

2.0 REMEDIAL ACTION OBJECTIVES

2.1 REMEDIATION GOALS

Remedial Action Objectives (RAOs), which are goals for the protection of human health and the environment, are identified on a medium-specific basis. Each objective is derived from site-related contaminants of concern, exposure pathways and human and/or environmental receptors. Preliminary remediation goals are used to permit a range of treatment and containment alternatives to be considered. The preliminary remediation goals are developed on the basis of applicable or relevant and appropriate requirements (ARARs). New York State does not have ARARs in its statute, however, as stipulated by Technical and Administration Guidance Memorandum #4030 (NYSDEC, 1990), New York State Standards, Criteria and Guidelines (SCGs) are used in place of ARARs. The potentially applicable SCGs are identified in the sections below.

Location-Specific SCGs

Location-specific SCGs are restrictions placed on the concentrations of hazardous substances or the conduct of remedial activities solely because they occur in a specific geographical location. For example, restrictions may include requirements that relate to wetland protection, floodplain management, fish and wildlife conservation, and historic preservation. A list of potential SCGs are identified below.

1. Use and protection of Waters (6 NYCRR Part 608; ECL 15-0501 and 15-0505): This regulation requires a permit to change, modify or disturb any protected stream, its bed or banks, sand, gravel, or any other material; or to excavate or place fill in any marsh, estuary or wetland contiguous to any of the navigable waters of the State.

2. New York State Ambient Water Quality Standards (6 NYCRR Parts 700-705): This regulation defines surface water and aquifer classification and lists specific chemical standards.

3. Endangered and Threatened Species of Wildlife (6 NYCRR Part 182): This regulation requires that site activities must minimize impact on identified endangered or threatened species of fish or wildlife.

4. Water Quality Certification: State certification is required if a federal permit is needed for discharge into navigable waters.

5. Clean Water Act Section 404 (b)(1)/US Army Corps of Engineers Nationwide Permit Program (33 CFR 330): This Act regulates activities involving dredging or filling, or the construction or alteration of bulkheads or dikes in navigable waters, including wetlands, are regulated by the Corps of Engineers.

6. Fish and Wildlife Coordination Act (16 USC 662): This Act regulates any action that proposes to modify a body of water or wetland requires consultation with the US Fish and Wildlife Service.

7. Endangered Species Act (50 CFR 200, 402): This Act requires that site activities must minimize impacts on identified endangered plant and animal species.

Chemical-Specific SCGs

Chemical-specific SCGs are Federal or State standards or health/risk-based numerical values which, when applied to site-specific conditions, result in the establishment of acceptable amounts or concentrations of constituents in the environment. A list of potential chemical-specific SCGs are identified below.

1. New York State DEC Water Quality Regulations for Surface Waters and Groundwaters (6 NYCRR Parts 700-705): This regulation establishes Standards for surface water and groundwater quality.

2. New York State DEC Identification and Listing of Hazardous Waste (6 NYCRR Part 371): This regulation defines and regulates PCB's in New York State.

3. New York State DOH Drinking Water Standards (10 NYCRR Part 5): This regulation enforces New York State drinking water standards.

4. Toxic Substance Control Act; TSCA (40 CFR 761): This Act regulates management and disposal of material containing PCB's.

5. Resource Conservation and Recovery Act, Land Disposal Restrictions (40 CFR 268): This Act regulates management and disposal of hazardous wastes.

6. New York State DEC Technical and Administrative Guidance Memorandum (TAGM) # HWR-94-4046 "Determination of Soil Cleanup Objectives and Cleanup Levels: This guidance document provides a basis and procedure to determine soil cleanup levels.

7. New York State DEC Remedial Program Soil Cleanup Objectives (6 NYCRR Subpart 375-6). This guidance document provides remedial program soil cleanup objectives with consideration to setting (residential vs. commercial).

8. New York State Department of Health (NYSDOH), Center for Environmental Health, Bureau of Environmental Exposure Investigation. "Guidance for Evaluating Soil Vapor Intrusion in the State of New York", October 2006.

Action-Specific SCGs

Action-specific SCGs are usually technology or activity based requirements or limitations on actions taken with respect to hazardous waste management and site cleanup. They apply to specific treatment and disposal activities, and may set controls or restrictions on the design, performance and implementation of the remedial actions taken at a site. For example, RCRA requirements will be applicable if the remediation constitutes treatment, storage or disposal of a hazardous waste as defined under RCRA. Other examples of action-specific requirements are Clean Water Act standards for discharge of treated groundwater and New York State regulations at 6 NYCRR Part 703, which establish surface water and groundwater quality standards and groundwater effluent standards. A list of potential action-specific SCGs are identified below.

1. TAGM #HWR 4022 "Records of Decision for Remediation of Class 2 Inactive Hazardous Waste Disposal Sites"
2. TAGM #HWR 4025 "Guidelines for Remedial Investigations and Feasibility Studies"
3. TAGM #HWR 4030 "Selection of Remedial Actions at Inactive Hazardous Waste Site"
4. TAGM #HWR 4046 "Determination of Soil Cleanup Objectives and Cleanup Levels"
5. New York State DEC Spill Technology and Remediation Series, STARS Memo #1
6. New York State DEC Division of Fish and Wildlife, "Technical Guidance for Screening Contaminated Sediments"
7. New York State Analytical Detectability for Toxic Pollutants
8. New York State Air Guidelines for the control of Toxic Air Contaminants (Air Guide 1)
9. TAGM HWR# 4031 "Fugitive Dust Suppression and Particle Management Program at Inactive Hazardous Waste Sites"

10. New York State DEC Strategy for Groundwater Remediation Decision Making at Inactive Hazardous Waste Site and Petroleum Contaminated Sites in New York State, April 1996

11. Polychlorinated biphenyls (PCB's) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions (40 CFR 761)

12. Clean Water Act (CWA) NPDES Permitting Requirements for Discharge of Treatment System Effluent

13. CWA Discharge to Publicly Owned Treatment Works; POTW (40 CFR 403)

14. Occupational Safety and Health Standards for Hazardous Response and General Construction Activities (29 CFR 1904, 1910, 1926).

2.1.1 SOIL

As summarized in Sections 1.2.5.1 and 1.2.5.3, sub-surface soil samples collected at the Site indicate the presence of several VOCs in the immediate vicinity of the 1,1,1-TCA spill area and in storm drains. Soil concentrations were compared to site-specific Recommended Soil Cleanup Objectives (RSCO), which have been established to protect groundwater resources. Key RSCO values for constituents of concern are shown on Figure 6.

In the spill area, impacted soils are encountered from approximately 8 to 20 ft bgs and are also below the groundwater surface, which is generally approximately 6 ft bgs. Impacted soil was encountered in the storm drains from 0 to 3 ft bgs (3 to 6 ft bgs). Soil samples from unsaturated soils near the source area do not indicate significant contamination. For the purposes of this FS, remediation of unsaturated soils and impacted saturated soils that may impact groundwater (herein referred to as the source area) are discussed separately.

Remedial action objectives for soil are as follows:

- Reduce, control, or eliminate, to the extent practicable, the contamination present within the source area soils in Operable Unit 1.
- Eliminate the potential for direct contact with contaminated soils.
- Eliminate the potential for inhalation of soil vapors emanating from contaminated soils.

2.1.2 GROUNDWATER

Site groundwater has been impacted with aromatic and chlorinated solvent chemicals. Although it is not used as a source of potable water in the area of the Site, groundwater is a medium of concern because of the possibility of contact through future discharges to surface water (Freeport Creek). Groundwater concentrations were compared to NYSDEC Groundwater Quality Standards for Class GA as shown in Figure 8. As described in Section 1.2.5.2, CA is the only spill-related compound detected above its applicable standard in the June 2006 sampling event and is identified as the main contaminant of concern. The remedial action objectives for groundwater are as follows:

- Protect potential impacts to human health and the environment from site contamination.
- Reduce the possibility of expanding the size and concentration of the plume by removing or treating the source of contamination, and in doing so curtailing, to the extent practicable, migration of contaminated groundwater off site.
- Eliminate the potential for direct human contact with contaminated groundwater at the site.

2.1.3 SOIL VAPOR

Spill-related compounds have been detected in soil vapor beneath the site, under the sub-slab of the building, to a limited extent in the indoor air of the building, and in ambient air samples. The sub-slab vapor concentrations exceed the guidance values prescribed in the NYSDOH SVI Guidance Document. Consequently, although the building is currently unoccupied, it is determined that the soil vapors represent a potential exposure pathway. It is understood that soil vapor will likely not be remediated until the associated soil and groundwater sources are remediated. Therefore, the near-term goals are to mitigate the potential soil vapor impacts until the other media are remediated. Hence, the mitigation objectives for soil vapor are as follows:

- Reduce the potential for soil vapor migration and accumulation through source control.
- Reduce the potential for soil vapor migration and accumulation through engineering controls.

Soil vapor mitigation is discussed as a common action in Section 7.0.

2.2 GENERAL RESPONSE ACTIONS

General Response Actions (GRA) describe the broad categories of remedial measures that can potentially achieve the RAOs. GRA may encompass many remedial technologies and remedial technology process options. For example, in-situ active restoration is a GRA, in-situ bioremediation is a remedial technology, and sodium lactate injection is a remedial technology process option.

The GRA applicable to the Site soil, soil vapor and groundwater are:

2.2.1 NO ACTION

The National Contingency Plan (NCP) and CERCLA, as amended, require the evaluation of "No Action" alternatives as a baseline for comparison with other remedial alternatives. The "No Action" alternative does not involve any concrete remedial action; therefore, environmental media at the site or emanating from the site remain contaminated. For this reason, CERCLA as amended requires a review of site conditions every five years.

2.2.2 LIMITED ACTION

Limited Action (LA) responses do not reduce the toxicity and volume of contamination by engineered action, but are implemented to reduce the probability of physical contact with contaminated media or minimize or eliminate the mobility to environmentally sensitive receptors. LA technologies consist of institutional controls (IC), engineering controls (EC), long-term monitoring (LTM) and well-head treatment (WHT).

ICs include environmental easements, access restrictions, public education and emergency provisions. ECs include all items listed in IC with actions like fencing and paving. EC require periodic monitoring and maintenance of the pavement to make sure that the COCs are being contained. LTM includes monitoring of groundwater, surface water, sediments, soils, and soil vapor. LTM also includes monitored natural attenuation (MNA). MNA monitors selected groundwater parameters in order to ensure that COCs are attenuating due to the naturally occurring processes of volatilization, adsorption, abiotic transformation, dispersion and/or biodegradation without any enhancements. It differs from the "No Action" alternative in that it requires comprehensive documentation of the attenuating processes along with extensive monitoring of groundwater parameters. Furthermore, it requires that attenuation be "proven" by using site-specific data. WHT includes methods that destroy or modify chemical properties prior to consumer distribution.

2.2.3 EX-SITU ACTIVE RESTORATION

Ex-situ active restoration consists of groundwater extraction or soil excavation, or soil vapor extraction treatment and discharge/disposal technologies. The main advantage of ex-situ treatment is that it generally requires shorter time periods, and there is more certainty about the effectiveness of the treatment. However, ex-situ treatment requires potentially cost intensive material handling activities.

2.2.4 IN-SITU ACTIVE RESTORATION

In-Situ Active Restoration consists of technologies that remove, destroy or stabilize the contaminant mass without being brought to the surface, resulting in significant cost savings. In-Situ treatment, however, requires longer time periods to accomplish the RAO. The potentially applicable technology types and process options (grouped by their GRA) are further discussed in Section 3.0

2.3 ESTIMATION OF QUANTITIES

2.3.1 GROUNDWATER TREATMENT REQUIREMENTS

A Conceptual Site Model (CSM) was developed for the Site using the available data from the RI including pump test results, permeability and heterogeneity of each geologic unit and contaminant concentration data. Based on the CSM, groundwater treatment requirements are estimated for the purposes of the cost evaluation. A low extraction rate, estimated at around five gallons per minute (gpm) total, is expected to be achievable for recovering groundwater in the fill unit due to its low permeability and high heterogeneity. A higher extraction rate, estimated at around twenty gpm per extraction well, is expected to be achievable for recovering groundwater in the gravelly sand unit. Design concentrations in extracted groundwater are estimated based on data from the various groundwater sampling events. Design concentrations are unique to each remedial alternative since the placement of extraction wells vary and are used to determine the size and treatment requirements of the aboveground systems.

2.3.2 SOIL VOLUME/AREAL EXTENT

The area and volume of contaminated soil in the unsaturated and saturated zones at the Site was estimated based on aromatic hydrocarbon and chlorinated solvent soil contamination found exceeding site-specific RSCO as shown in Figure 7. Contamination extends from the fill layer (approximately 8 ft bgs) to the top of the gravelly sand layer located about 20 ft bgs. The areal extent of the contaminated soil was delineated through extensive soil sampling following UST closure (Figure 7). Based on the data presented in Figure 7, an estimated 610 cubic yards of soil is considered contaminated. This soil is overlain by approximately 490 cubic yards of landfill residual fill material and/or UST excavation clean backfill. A total of 1,100 cubic yards of soils would need to be excavated. The volume of impacted soil in storm drains is approximately 6 cubic yards.

3.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

In accordance with USEPA guidance (USEPA 1988), this FS includes an identification and screening of potentially applicable remedial technologies with respect to technical implementability. Specific technologies are further evaluated based on effectiveness, implementability (technical and administrative), and relative cost in achieving the General Response Actions (GRAs). No action and institutional action are included, as suggested by National Contingency Plan (NCP) and USEPA guidance.

Soil vapor intrusion presents a risk to potential building occupants, so sub-slab vapor mitigation is required while soil vapors persist. Since these mitigation measures will be required regardless of what remedies are used for soil and groundwater, soil vapor mitigation will be a common action to be included in any remedial strategy. The common actions are discussed in Section 7.0.

The following factors will be considered under the remedial technology screening criterion:

Implementability

- Technical feasibility of implementing the technology
- Availability of the technology
- Administrative feasibility of implementing the technology

The NCP instructs that 'alternatives that are technically or administratively infeasible or that would require equipment, specialists, or facilities that are not available within a reasonable period of time may be eliminated from further consideration' [40CFR300.430(e)(7)(ii)].

Effectiveness

- The remedial technology reduces toxicity, mobility, or volume through treatment;
- The remedial technology minimizes residual risks;
- The remedial technology affords long-term protection;
- The remedial technology complies with ARARs;
- The remedial technology minimizes short-term impacts; and

- The remedial technology achieves protection in a reasonable timeframe

The NCP instructs, "alternatives providing significantly less effectiveness than other, more promising alternatives, may be eliminated. Alternatives that do not provide adequate protection of human health and the environment shall be eliminated from further consideration' [40CFR300.430(e)(7)(ii)].

Cost

- Cost of construction, and
- Long-term costs to operate and maintain

The NCP instructs, "costs that are grossly excessive compared to the overall effectiveness of the alternatives may be considered as one of several factors used to eliminate alternatives. Alternatives providing effectiveness and implementability similar to that of another alternative by employing a similar method of treatment or engineering control, but at greater cost, may be eliminated" [40CFR300.430(e)(7)(ii)].

3.1 REMEDIAL TECHNOLOGIES FOR SOIL (SOURCE AREA)

The screening matrix for alternatives to treat residual contamination in the source area soils is presented in Table 6. The technologies are evaluated for effectiveness, implementability and cost. Based on site-specific knowledge and bench-scale tests, an initial applicability screening was conducted. During the screening, all technologies that were found to be technically feasible were deemed potentially applicable. Technologies that were determined to be technically infeasible were eliminated. A discussion of the technologies that were eliminated is provided below:

- Containment (both surface cap and an impermeable barrier) is eliminated because the alternative alone does not reduce toxicity or volume of contamination. Although containment can be used in combination with other technologies to meet toxicity and volume reductions, it is not considered further for this Site since the areal and vertical extent of residual soil contamination, as determined after the removal of USTs is limited. In-situ technologies can be implemented effectively since the USTs have been removed.
- The ex-situ treatment technology of stabilization/solidification is eliminated because the process is typically used for metals contamination and is not effective for treatment of volatile compounds such as 1,1,1-TCA, 1,1-DCA and CA.

- On-Site disposal is eliminated as a discharge method for excavated soil due to the limited space at the Site, property ownership and the mix of commercial/industrial surroundings, which make on-site disposal and or treatment/disposal technically difficult to implement.

- In-situ treatment technologies of soil vapor extraction (SVE) and soil flushing (SF) are eliminated from further consideration. SVE is not effective because the residual contamination resides below the water table. This would require an additional treatment technology to simultaneously drawdown the groundwater to expose the impacted zone soils. SF is eliminated because the residual contamination does not reside in a large, continuous area. SF is also effective when contaminant concentrations are high (in the ppm range).

- Dual Phase Extraction (DPE) is a high vacuum system that simultaneously removes liquid and gas from the subsurface. The DPE well includes a screened section in the zone of contaminated soils and groundwater. For DPE to be effective, the aquifer must be dewatered to expose the areas of high contamination soils. Given that the residual source zones are discontinuous and located significantly below the water table, DPE is eliminated given the significant dewatering that will have to be done to expose the contaminated soils at depth (up to 22 ft bgs).

- Enhanced Anaerobic Bioremediation via reductive dechlorination was eliminated after the bench-scale tests concluded that significant enhancements in the degradation of CA were not attained with the two substrates that were tested. The results of this study are presented in the final report by Adventus Americas of Union, NJ (Adventus) titled "EHC and HRC Feasibility Study for the Treatment of Chlorinated Solvents in Groundwater from the Former Columbia Cement Inc. Facility, Freeport, NY (The Site): Bench Scale Treatability Investigation," dated October 21, 2005. This report is provided in Appendix A.

The remaining treatment technologies that will be considered for soil treatment are presented below.

3.1.1 NO ACTION (SOIL)

No Action is not a category of technologies but is a GRA and provides a baseline to which other alternatives may be compared. No Action is carried forward for comparative purposes as suggested by the NCP and the USEPA guidance even though it is not effective in meeting the RAO for the Site.

3.1.2 INSTITUTIONAL CONTROL

Institutional Controls are actions that are intended to preclude human exposure by imposing institutional and access restrictions, educating the public, and planning for emergency situations.

Effectiveness:

Institutional action (e.g., environmental easements, use restrictions, access restrictions) would not be effective in meeting the cleanup goals for soil at the Site. However, they would contribute to preventing future exposures to subsurface contamination. The Site, including the residual source area, is already capped with concrete, and will prevent exposure of contaminants to on-site workers.

Implementability:

Typically, environmental easements are straightforward to implement, provided the responsible party has the property owner's concurrence. Currently, the Site does not belong to BP, and there may be some difficulties in getting a use and access restriction in the source area if the current or future owner has expansion plans for the Site.

Cost:

Costs required for developing the application for and obtaining the deed restrictions are low.

Overall Evaluation:

Institutional control is carried forward to the development and screening of alternatives but only as a component of alternatives incorporating other exposure controls.

3.1.3 EXCAVATION, TREATMENT AND OFFSITE DISPOSAL

Excavation, Treatment and Off-site Disposal falls under the Active Ex-Situ Restoration GRA and is discussed below.

Effectiveness:

Excavation, treatment and off-site disposal of contaminated soil would be effective in removing the source of contamination and meeting the RAOs for the residual contamination in source area soils. As contaminated soil is present below the water table, dewatering will be required, with on-site or off-site treatment of collected water.

Implementability:

This technology is widely used for remediation and would be implementable at the Site. However, successful implementation of this alternative would depend on a proper geotechnical analysis and structural design to maintain the structural integrity of the adjacent building. Further, excavation could result in potential exposure for excavation workers and other personnel at the site. A large amount (>50%) of clean soil or soil not exceeding the clean up standards will have to be removed to access the contaminated soil. Based on testing results, some portion of this soil may be reused as backfill.

Cost:

The cost of excavating contaminated soil using proper health and safety measures, and treating and disposing of the materials off site, is considered to be high considering the structural considerations, the treatment of dewatered groundwater, and the contamination of the media by chlorinated solvents as opposed to petroleum hydrocarbons.

Overall Evaluation:

Excavation and offsite disposal of contaminated soil can be an effective and implementable technology. It is carried forward into the development and screening of alternatives.

3.1.4 IN-SITU TREATMENT BY CHEMICAL OXIDATION

In-situ treatment technologies can be based on chemical, physical or biological processes. In-situ chemical oxidation (ISCO) is a technology that falls under the Active In-situ Restoration GRA and is discussed below.

ISCO is based on the delivery of chemical oxidants to contaminated media in order to achieve destruction or breakdown of contaminants into non-toxic products. Treatment time with ISCO technologies is very rapid. Liquid oxidants ate injected through injection wells or injection points. The type of oxidant to use depends on the mixture of contaminants and their concentrations. Typically used oxidants include activated hydrogen peroxide (for petroleum hydrocarbons), potassium permanganate (for chlorinated solvents) and most recently, activated sodium persulfate (for both petroleum hydrocarbons and chlorinated solvents). Hydrogen peroxide is very reactive and in the presence of iron generates the hydroxyl radical, which is a very reactive compound and instantaneously oxidizes any organic matter and reduced minerals. The products of the oxidation of chlorinated VOCs are carbon dioxide, water and chloride. Sodium persulfate is relatively less reactive. When activated with hydrogen peroxide or heat, it generates the persulfate free radical. The persulfate radical has a relatively longer half-life when compared to the hydroxyl radical. Sodium persulfate is relatively safe to handle when compared to hydrogen peroxide. When hydrogen peroxide activated persulfate is used, the benefits of both the persulfate and hydroxyl radicals are achieved. Potassium permanganate directly oxidizes the contaminants and other reduced metals unlike the very efficient free radical based oxidation that can be realized with hydroxyl and persulfate radicals. Consequently, the permanganate oxidant demand is high. Potassium permanganate is not very effective when a mixture of CVOCs and petroleum hydrocarbons is present.

Effectiveness:

Many field applications of the ISCO technology have been conducted using potassium permanganate, Fenton's reagent and activated sodium persulfate for CVOCs.

Implementability:

The oxidants can be easily injected into the subsurface soils at the Site with a relatively moderate radius of influence in the sand and fill geology. The area above where the residual soil contamination resides is vacant and easily accessible for injecting the oxidant.

Cost:

Cost for ISCO technologies are low to moderate and depend on the oxidant demand from non-contaminant related constituents in the soil matrix, which include reduced metals and natural organic matter. The oxidant demand is high in silty/clayey soils, which are rich in minerals and organic matter, and low in sandy aquifers.

Overall Evaluation:

ISCO treatment via activated sodium persulfate is carried forward into the development and screening of alternatives. Bench scale testing conducted by Adventus illustrates the effectiveness of this technology. The Adventus ISCO Bench Scale Treatability Study Report is provided in Appendix A.

3.2 REMEDIAL TECHNOLOGIES FOR GROUNDWATER

The screening matrix for remedial alternatives for groundwater is presented in Table 7. The technologies are evaluated for effectiveness, implementability and cost. Based on site-specific knowledge and bench-scale tests, an initial applicability screening was conducted. During the screening, all technologies that were found to be technically feasible were deemed potentially applicable. Technologies that were determined to be technically infeasible were eliminated. A discussion of the technologies that were eliminated is provided below:

- Containment (barriers) is eliminated from further consideration since the technology does not reduce toxicity or volume of contamination at the Site. Although implementable, the preference for treatment as stipulated by New York SCGs also restricts the use of this technology as a sole remedy for the Site.

- Groundwater collection through subsurface drains is eliminated from further consideration due to the vertical extent of the groundwater contamination. Subsurface drains are difficult to implement to capture groundwater at depth (up to 22 ft bgs) and would not be effective at this Site.

- The in-situ treatment technology of Air Sparging (AS) was eliminated from further consideration. AS would have limited effectiveness due to the physical properties (low Henry's Law constant) of the site constituents. Air sparging promotes volatilization and the physical transfer of VOCs from the liquid phase into the vapor phase. However, sparging in the presence of the high inorganic content of the groundwater may result in frequent fouling and the vapor produced may result in an added soil vapor intrusion risk.

- Enhanced Anaerobic Bioremediation via reductive dechlorination was eliminated after the bench-scale tests concluded that no significant enhancements in the degradation of CA were attained with the two substrates that were tested. The results of this study are presented in the final report by Adventus Americas of Union, NJ (Adventus) titled "EHC and HRC Feasibility Study for the Treatment of Chlorinated Solvents in Groundwater from the Former Columbia Cement Inc. Facility, Freeport, NY (The Site): Bench Scale Treatability Investigation," dated October 21, 2005, provided in Appendix A.

The remaining treatment technologies that will be considered for groundwater treatment are presented below.

3.2.1 NO ACTION (GROUNDWATER)

No Action is carried forward for comparative purposes as suggested by NCP and USEPA guidance even though it is not effective in meeting the RAO for the Site.

3.2.2 INSTITUTIONAL CONTROL

Institutional Controls are actions that are intended to preclude human exposure by imposing institutional, use and access restrictions, educating the public, and planning for emergency situations.

Effectiveness:

Institutional action (e.g., deed restrictions) would not effectively prevent or reduce contaminant transport in groundwater, and would not meet the RAO for groundwater. However, it may be useful in conjunction with other remedial technologies such as natural attenuation.

Implementability:

Institutional actions would be implementable only if exercised in conjunction with other remedial technologies, and with the property owner's consent.

Cost:

Costs required for developing the application for and obtaining the deed restrictions are small.

Overall Evaluation:

Institutional action is not considered as a stand-alone technology in the development and screening of alternatives since this technology is not effective in achieving the RAO. However, it may be used in conjunction with other remedial technologies.

3.2.3 MONITORED NATURAL ATTENUATION (MNA)

MNA falls under the Limited Action GRA. MNA is a process of long-term monitoring of groundwater not only to show a decrease in the concentration of contaminants, but also to show that parameters and conditions that are responsible for the natural degradation of the contaminants exist in the aquifer. This involves collecting information on dissolved oxygen, oxidation-reduction potential, nitrate, nitrite, iron, sulfate, methane, ethane, ethane, chloride, TOC, alkalinity and in some cases identification and enumeration of the dominant microbial species. Data was collected in 2004 and 2006 to determine the potential for natural attenuation (NA) to occur in groundwater at the site. This information is presented in URS' report Supplemental Remedial Investigation, Former Columbia Cement Company Facility, Freeport, New York, submitted to NYSDEC on December 20, 2006. Specifically, decreased concentrations of spilled parent compounds, significant concentrations of lesser chlorinated daughter products (e.g., CA), and detectable concentrations of non-chlorinated end-products (e.g., ethane) provide evidence that NA is occurring. This is also supported by low redox conditions, elevated levels of chloride, and low DO levels. The data suggests that NA is occurring under iron and/or sulfate reducing conditions.

Effectiveness:

MNA can be an effective technology for treating contaminants in groundwater. The Site exhibits some ideal conditions for natural attenuation since electron donors in the form of hydrocarbons are present together with chlorinated solvents. MNA does, however, have a longer time frame for effectiveness as opposed to the other, more active technologies. However, source control would speed up the time frame of the MNA remedy.

Implementability:

Monitoring wells for MNA are easily constructed. Supplementary sample collection, data interpretation and modeling are necessary to support MNA and require technical expertise to implement.

Cost:

Overall costs for MNA of contaminants over time at the Site are low.

Overall Evaluation:

Monitored natural attenuation is implementable and is carried forward into the development and screening of alternatives.

3.2.4 GROUNDWATER EXTRACTION, TREATMENT AND DISPOSAL

Extraction and treatment technologies fall under the Active Ex-Situ Restoration GRA. Extraction technologies involve the removal of contaminated groundwater from the aquifer followed by treatment and disposal. Disposal may be above-ground or in-ground. Extraction technologies also create a hydraulic barrier by forcing the hydraulic gradient in the direction of pumping wells. Extraction and treatment technologies may be used to reduce the volume, toxicity and mobility of the contaminants. The main advantage of the extraction system is that there is more certainty about the uniformity of the treatment. The main disadvantage is that it is very costly, both in capital and O&M costs.

Effectiveness:

Extraction and treatment technologies are effective in mass removal and for hydraulic containment. They are not very effective when the contaminant concentrations fall in the ten or single digit ppb level. Once groundwater is collected through extraction wells, effective treatment technologies for VOCs include air stripping and/or carbon adsorption. CA is relatively difficult to air-strip as compared to the parent compound 1,1,1-TCA due to its high solubility and a low Henry's constant. Effective air stripping of CA will require a high air to water ratio. Air stripping may require vapor-phase carbon adsorption to control air emissions from the air stripper. Treated groundwater can be disposed of by obtaining a SPDES permit and discharging to the local storm drain system. Based on experience at similar sites, extraction and treatment may result in asymptotic treatment levels above the RAOs and thus require a supplemental treatment technology such as MNA for polishing.

Implementability:

Groundwater extraction is readily implementable and several conventional technologies exist for contaminated groundwater treatment. The system will prevent migration of contaminated groundwater. Discharge of treated groundwater off site would be regulated and require permit(s), but such requirements can be easily met. Air stripping and carbon adsorption are readily implementable technologies for treatment of contaminated groundwater. However, due to the high metals (iron) content of Site groundwater, fouling of stripping and carbon media may require additional and frequent O&M. Furthermore, space for an aboveground treatment system at the site is extremely limited.

Cost:

The installation of standard groundwater extraction and treatment systems is considered moderate for the size of the treatment system required for this Site. However, due to the pre-treatment requirements for metals, overall costs for groundwater treatment are considered high for this Site.

Overall Evaluation:

Groundwater extraction is an effective and implementable technology. Aboveground treatment through air stripping and/or carbon adsorption is effective to treat the extracted groundwater. Air stripping may require vapor-phase carbon adsorption to control emissions from the air stripper. Groundwater extraction, treatment and disposal is carried forward into the development and screening of alternatives.

3.2.5 AEROBIC ENHANCED BIOREMEDIATION

Aerobic enhanced bioremediation falls under the Active In-Situ Restoration GRA. Most chlorinated VOCs can biodegrade under anaerobic conditions. The stepwise degradation of 1,1,1-TCA to 1,1-DCA, and 1,1-DCA to CA under anaerobic conditions has been demonstrated in numerous studies, including at the Columbia Cement Site. However, CA will subsequently biodegrade only under aerobic conditions. Site groundwater conditions are strongly anaerobic. Therefore, to promote in-situ degradation of CA requires the addition of oxygen to the impacted groundwater. This can be accomplished through sparging/venting, in which air is injected into the aquifer below the water table, or through injection of an oxygen-releasing amendment. Subsurface microbes will utilize the oxygen as an electron acceptor to consume the CA to produce Cl^-, CO_2, and water.

Effectiveness

Many field applications of aerobic enhanced bioremediation have been conducted using Oxygen Release Compound (ORC®, Regenesis, Inc.), EHC-O®, Adventus, Inc. and PermeOx® (FMC Environmental Solutions. Aerobic enhanced bioremediation has also been performed using injection and recirculation of air directly into contaminated aquifers as an oxygen source. Although there is limited data on the use of aerobic treatment to address CA, the TSI bench-scale test suggests that aerobic treatment should effectively treat CA at the Columbia Cement Site.

Implementability

Addition of an oxygen-releasing substrate can be easily accomplished by injection into a series of Direct-Push points. Depending on requirements, the injection points can be arranged in a grid to treat a large area, or in a line to form a barrier or linear treatment area.

Cost

The cost of injection of an oxygen-releasing amendment through a series of direct-push borings is considered low to moderate, depending on the oxygen demand of the aquifer, the number of borings and the number of times re-injection is required.

Overall Evaluation

Aerobic groundwater treatment is an effective and implementable technology. Aerobic treatment can be accomplished by injection of oxygen-releasing amendments through direct-push borings or by suspending "socks" of the amendment in a series of wells. Aerobic enhanced bioremediation is carried forward into the development and screening of alternatives.

3.3 REMEDIAL TECHNOLOGIES FOR STORM DRAIN SOIL

The technologies for storm drain soil are evaluated for effectiveness, implementability and cost. Based on site-specific knowledge, an initial applicability screening was conducted. During the screening, all technologies that were found to be technically feasible were deemed potentially applicable and are described below.

3.3.1 NO ACTION

No Action is not a category of technologies but is a GRA and provides a baseline to which other alternatives may be compared. No Action is carried forward for comparative purposes as suggested by the NCP and the USEPA guidance even though it is not effective in meeting the RAO for the Site.

3.3.2 REMOVAL AND OFFSITE DISPOSAL OF STORM DRAIN SOIL

Removal (by vac-truck) and Off-site Disposal falls under the Active Ex-Situ Restoration GRA and is discussed below.

Effectiveness:

Removal by vac-truck and off-site disposal of contaminated storm drain soil would be effective in removing the source of contamination and meeting the RAOs for the residual contamination in storm drain soils.

Implementability:

This technology is widely used for remediation and would be implementable at the Site. Vac-truck removal could result in potential exposure for workers and other personnel at the site

Cost:

The cost of vac-truck removal and disposing of the materials off site, is considered to be low.

Overall Evaluation:

Removal and offsite disposal of contaminated storm drain soil by vac-truckl can be an effective and implementable technology. It is carried forward into the development and screening of alternatives.

4.0 DEVELOPMENT OF ALTERNATIVES

Development of remedial alternatives must confirm to the ARARs. In general, the following guidelines must be followed when developing and evaluating remedial alternatives:

- Remedial actions involving treatment which permanently and significantly reduces the volume, toxicity and mobility of the contaminants are preferred over remedial actions not involving such treatment;
- Off-site transport and disposal of hazardous substances without treatment is considered to be the least favored alternative when practical treatment technologies are available; and
- Remedial actions using permanent solutions, alternative treatment technologies, or resource recovery technologies shall be addressed.

Based on these statutory preferences and the general response objectives, remedial alternatives are developed to satisfy the following criteria:

- Remedial alternatives are protective of human health and the environment;
- Remedial alternatives attain chemical-specific ARARs, and can be implemented consistently with location-specific and action-specific ARARs;
- Remedial alternatives that use permanent solutions/treatment technologies to the maximum extent possible; and
- Remedial alternatives are capable of achieving a remedy in a cost-effective manner.

In developing remedial alternatives, retained technologies are combined into alternatives for the Site as a whole. With the exception of the No Action alternative, alternatives must meet the remedial action objectives for both soil and groundwater.

The following alternatives were carried forward for detailed analysis in Section 5.0:

For Residual Soil Contamination

• Alternative 1	No Action (for Soil)
• Alternative 2	Soil Excavation and Off Site Disposal
• Alternative 3	ISCO of Residual Soil Contamination

5.0 DETAILED ANALYSIS AND EVALUATION OF ALTERNATIVES

The detailed analysis of alternatives presents the information needed to select a site remedy. The evaluation criteria are described in Section 5.1. The results of this assessment are summarized in Table 8 and described in detail in Sections 5.2 through 5.8. Capital, O&M, and present worth costs for all alternatives are presented on Table 9.

5.1 EVALUATION CRITERIA

In this section, alternatives are subjected to a detailed evaluation with respect to seven of the nine evaluation criteria specified in the NCP and discussed in detail in RI/FS guidance (USEPA 1988). Two of the criteria, state acceptance and community acceptance, are not addressed in this section, but will be addressed in the Record of Decision (ROD) after comments on the FS and the Proposed Remedial Action Plan are received. The seven criteria used to evaluate alternatives in this section are described below.

1. *Overall Protection of Human Health and the Environment* - Protectiveness is the primary requirement for remedial action at hazardous waste sites. Evaluation of this criterion involves an assessment of how each alternative achieves protection over time and how site risks are reduced.

2. *Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)/New York State Standards, Criteria and Guidelines (SCGs)* - Compliance with ARARs/SCGs includes compliance with chemical-specific, action-specific, and location-specific requirements, as defined in Section 2.2.

3. *Long-term Effectiveness and Permanence* - This criterion focuses on the impacts of the remedial action after remedial objectives have been met. Key components of the criteria include: (a) the magnitude of residual risk after remediation; and (b) the adequacy of controls to meet required performance specifications and the reliability of controls from an operational standpoint.

4. *Reduction of Toxicity, Mobility, or Volume (TMV)* - This criterion addresses the statutory preference, expressed in the Superfund Amendments and Reauthorization Act (SARA), for remedies that employ treatment as a principal element. It includes an assessment of the magnitude, significance, and irreversibility of treatment, as well as an evaluation of the type and quantity of residual contamination remaining after treatment.

5. *Short-Term Effectiveness* - This criterion includes the short-term impacts of the alternatives (i.e., during implementation) upon the surrounding community, on-site

workers, and the environment. It also addresses the time required for the alternative to satisfy remedial action objectives.

6. *Implementability* - Implementability includes many of the practical aspects associated with implementation of the remedial alternative, such as the ability to construct and operate remedial technologies, the reliability of the technologies, ease of undertaking additional remedial actions if necessary, ability to monitor the alternative's effectiveness, availability of required material and services, permit requirements, and need to coordinate with other agencies.

7. *Cost* - This quantitative evaluation criterion includes the capital and O&M costs associated with each alternative, as well as its total present worth. Detailed cost estimates for each technology are provided in Appendix A.

5.2 ALTERNATIVE 1 - NO ACTION FOR SOIL

5.2.1 DESCRIPTION

The no action alternative provides for no active remediation or monitoring at the Site for soil. In the absence of remediation, current Site conditions would remain the same, except insofar as natural attenuation degrades or otherwise dissipates contamination. It should be noted that some soil was removed from the source area during the 2004 UST closure.

5.2.2 ANALYSIS

Overall Protection of Human Health and the Environment

Alternative 1 does not prevent or mitigate the future potential impacts of contaminated soil on human health and/or the environment, except as noted in Section 5.2.1.

Compliance with New York SCGs

Because no action is being taken, Alternative 1 would not meet soil cleanup criteria, except as noted in Section 5.2.1.

Long-Term Effectiveness and Permanence

This alternative includes no controls for exposure and no long-term management measures.

Reduction of Toxicity, Mobility, or Volume

This alternative provides no reduction in toxicity, mobility, or volume of the contaminated soil or groundwater through treatment, except as noted in Section 5.2.1.

Short-Term Effectiveness

There are no short-term impacts on the community, workers, or the environment since no action would be taken.

Implementability

There are no implementability concerns posed by this remedy since no action would be taken.

Cost

There are no costs associated with the no action alternative.

5.3 ALTERNATIVE 2 - SOIL EXCAVATION AND OFF SITE DISPOSAL

5.3.1 DESCRIPTION

This alternative involves the excavation and off-site disposal of contaminated subsurface soils in the source area.

The excavation area consists of four impacted areas (Residual Source Area 1, 2, 3 and 4) as shown in Figure 7. These areas were identified based on a soils investigation conducted during the RI and in October 2004 as described in Section 1.2.4.1. The investigation adequately defined the areas of residual contamination and it is assumed for costing purposes that no additional delineation borings will be necessary prior to excavation activities. Residual contamination is discontinuous both in vertical and horizontal extent. The impacted vertical interval and areal extent are summarized in the following table along with estimates of impacted soil volume and overburden volume. The proposed excavation areas are shown on Figure 15.

Residual Source Area	Impacted Interval (ft below grade)	Excavation Area Sq Ft)	Total Soil Volume	Impacted Soil Volume (Cu Yd)	Overburden Volume (Cu Yd)
1	8-20	1,140	850	510	340
2	12-18				
3	10-15	225	145	50	95
4	12-22	156	160	60	100*
Total			1,155	620	535

* Assumes expanded area for upper 12 feet of excavation.

The contaminated subsurface soil for residual source areas 1 and 3 consists of three distinct geologic units; fill, tidal marsh and gravelly sand. Soil would be excavated to the interval summarized in the above table. The overburden soil, (top 8 ft bgs for Zone 1, top 10 ft bgs for Zone 3), which is mainly fill material, is not contaminated. The uncontaminated soils would be excavated and segregated as clean backfill after all contaminated soil is removed. After testing, this soil could be reused as backfill.

Residual source areas 2 and 4 are located in the footprint of the former USTs, which were removed in August and September 2004. The UST excavation was to a depth of approximately 12 ft bgs and was backfilled with clean fill. Therefore, the top 12 ft bgs for Zone 2 and 4 is considered uncontaminated and will be excavated and segregated for use as clean backfill. The total area of the four residual zones represents approximately 1,100 cubic yards of soil of which 610 cubic yards (915 tons) is estimated to be contaminated. The contaminated material will be treated and disposed of using low-temperature thermal desorption process at the nearest permitted facility.

Excavation of contaminated soils at the Site must address two main complicating factors: shallow groundwater level and the proximity to the building foundation. The contaminated soils lie below the groundwater water table, which is approximately 6 ft bgs in the source area. The excavation would require dewatering of the excavation pit. Because of the depth of excavation and the shallow groundwater table, sheet piling would be required to avoid excessive amounts of clean soil excavation adjacent to the contaminated areas that would otherwise be required to achieve stable side slopes within the excavation zone. These additional areas of excavation would also increase the amount of dewatering that would be required. The sheet pile wall could also be designed to serve as the retaining wall to protect the building foundation and features.

The first step of excavation would be to remove the existing pavement, mark, and place the sheet pile barrier around an appropriate-size cell. The sheet pile would be driven into the gray clay and silt layer to an adequate depth (approximately 38 ft bgs), to ensure that the sheet pile wall would not cave in due to pressure exerted onto it from the surrounding soil and groundwater. For costing purposes, it was assumed that the sheet pile would be driven 3 ft into the gray clay and silt layer.

After placing the sheet pile around a cell and removing the unsaturated surface soil (the top 6 ft bgs) using an excavator, the first layer of bracing would be placed. Then, the interior of the excavation area would be dewatered using dewatering pumps. Excavation would proceed until the top of the impacted interval for the respective residual source area. This soil would be kept separate for disposal or reuse at backfilling the excavation. Soil samples would be collected to confirm that the surface soils are not contaminated and therefore could be reused at the Site.

The excavation would continue to 14 ft bgs, at which point another sheet pile bracing is required. When that depth is reached, excavation workers would need to be lowered into the excavation pit to place the bracing. Appropriate measures will be taken to ensure the workers' health and safety. Excavation would continue to the bottom of excavation with another bracing placed at 22 ft bgs. After the bottom of the excavation has been reached, it would be sampled and, once the sampling results show removal of all contaminated soils, backfill would take place. The excavation would be backfilled up to the bracing layer, then workers would enter the excavation pit and would remove the bracing and the backfill would continue until the whole excavation cell has been backfilled. Then the sheet pile wall would be removed.

Water collected from the excavation and from the dewatering process would be treated through liquid-phase carbon canisters or with a trailer-mounted air stripper depending on the dewatering rate. For cost estimating purposes, it is assumed that groundwater would be treated through carbon canisters. After the water has been treated, it would be discharged to one of the nearby storm water catch basins. This would require a SPDES permit and effluent testing to ensure the effluent meets the NYSDEC surface water and groundwater discharge standards as specified under the NYCRR Parts 700-705.

Since the existing wells in the source area will have to be decommissioned during excavation activities, an additional three new monitoring wells shall be installed for post-excavation monitoring in order to monitor the groundwater remedy selected. The wells shall be screened in the fill, upper gravelly and lower gravelly sand unit, respectively.

5.3.2 ANALYSIS

Overall Protection of Human Health and the Environment

Alternative 2 reduces the levels of contamination in soil to meet chemical-specific soil criteria through direct removal of the soil contamination in the source area. The dewatering required during excavation will also remove much of the contaminated groundwater in the source area.

Compliance with New York SCGs

This alternative would meet the chemical-specific cleanup criteria for the source area through direct removal. The excavated soil would have to be disposed of and/or treated offsite. It is assumed that these soils would be treated at an off-site commercial facility to levels below chemical-specific soil standards prior to disposal or reuse

Long-Term Effectiveness and Permanence

The magnitude of residual risk is minimal since the source of contamination is removed and contamination in the groundwater is reduced through dewatering of the source area during excavation. Excavation can be readily completed to meet performance specifications and is a permanent remedy.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 2 satisfies the statutory preference for using treatment as a principal element, through the use of removal of contaminant mass in the source area. The source is removed by excavation to the extent practicable, which reduces the mobility and volume of contaminants in soil on Site. The excavated soil will be treated by offsite incineration, which permanently reduces the toxicity of the contaminants.

Short-Term Effectiveness

There would be minimal impacts to the community and the environment during the construction phase of this alternative. Fugitive dust created during the excavation activities would be controlled using engineering measures. Traffic increases due to transportation of soil would have minimal impact on the community since the volume of soil to be transported is relatively small and project duration is expected to last approximately 30 days. Also, due to the industrial setting of the site, truck traffic on Hanse Avenue is common.

During the excavation activities, workers could be exposed to risk associated with dermal contact with contaminated soil and groundwater and inhalation of soil dust particles. Risk would be mitigated through the use of the appropriate personal protective equipment, air quality would be monitored and encountered groundwater could be collected and treated through carbon adsorption. All safety practices would be addressed in a Site Health and Safety Plan.

Implementability

Excavation and off-site disposal is a proven technology. Excavation is technically implementable and reliable for meeting performance goals with a low risk of additional remedial action being necessary after completion.

Cost

The capital cost for Alternative 2 is $545,240. There are no O&M costs associated with this alternative. The total present worth costs are $545,240. Capital and present worth costs for this alternative are presented on Table 9. Further details are presented in Appendix B.

5.4 ALTERNATIVE 3 – ISCO OF RESIDUAL SOIL CONTAMINATION

5.4.1 DESCRIPTION

This alternative involves the in-situ chemical oxidation (ISCO) of contaminated subsurface soils. In April 2005, Adventus conducted an ISCO bench-scale test on Site groundwater and soil. The results of that bench-scale testing are summarized in a final report entitled "Bench Scale test for Chemical Oxidation Treatment of Chlorinated Solvent Impacted Soils" dated August 3, 2005 (provided in Appendix A). The bench-scale ISCO test utilized two activation methods (hydrogen peroxide and chelated iron). The results indicated sodium persulfate activated with hydrogen peroxide can treat the site-specific contaminants effectively. Iron activated sodium persulfate was not efficient in treating the site-specific contaminants. Based on the bench-scale testing, the estimated oxidant demand for the soil is 42 grams (g) of sodium persulfate per kilogram (kg) of soil and 60 g hydrogen peroxide per kg of soil. The costs for full-scale treatment were estimated based on these results.

Prior to injections, all necessary permits will be obtained. The oxidants will be injected in the areas of residual soil contamination (Figure 7) via several injection points. Given the limited horizontal extent of each residual source area, a 5 ft radius of influence will be utilized. Vertically, the oxidants will be injected from 1 foot below to 1 foot above the impacted intervals in each area at 2 ft increments, as shown below. Proposed ISOC injection point locations are shown on Figure 16.

IMPACTED AREA	IMPACTED INTERVAL (ft below grade)	INJECTION INTERVAL (ft below grade)
1	8 – 20	7 – 21
2	12 – 18	11 – 19
3	10 – 15	9 – 16
4	12 - 22	11 - 23

A Geoprobe along with an injection pump will be used to deliver the oxidant. Based on the bench-scale testing, two injection events are planned within a three-month period. Post treatment soil sampling will be done one and three months after the final injection event to evaluate whether the residual soil contamination has been treated to satisfactory levels. Two borings per residual soil contamination area are planned with soil sampling occurring continuously along the impacted intervals.

5.4.2 ANALYSIS

Overall Protection of Human Health and the Environment

Alternative 3 reduces the levels of contamination in soil to meet chemical-specific soil criteria through direct treatment of the soil contamination in the source area providing protection of human health and the environment from possible future exposures.

Compliance with New York SCGs

This alternative would meet the chemical-specific cleanup criteria for the source area through direct destruction /oxidation of residual contamination in soil.

Long-Term Effectiveness and Permanence

The magnitude of residual risk would be very low and this alternative would be protective over the long term since the source of contamination is removed ISCO can be readily completed to meet performance specifications and is a permanent remedy.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 3 satisfies the statutory preference for using treatment as a principal element, through the use of ISCO for the source area as a primary treatment component for soil. The source is removed by chemical oxidation to the extent practicable, which reduces the mobility and volume of contaminants in soil on Site. The contaminants are destroyed in-situ rather than being transferred to another media or transformed into more toxic compounds.

Short-Term Effectiveness

There would be minimal impacts to the community and the environment during the construction and operation phase of this alternative. The Geoprobe is low-profile equipment and will not cause disruption to commercial and business activities at the site. In fact, it is less intrusive than excavation. The injection of oxidants will be completed in two weeks time.

During the injection of oxidant, there is minimal risk for exposure to the site workers. Risk would be mitigated through the use of the appropriate personal protective equipment and air quality monitoring. All safety practices would be addressed in a Site Health and Safety Plan.

Implementability

ISCO is a proven technology and can be implemented at the site. ISCO can reliably meet performance goals with a low risk of additional remedial action being necessary after completion. Based on Site geology and current contaminant concentrations, ISCO is expected to reduce both soil and groundwater contamination significantly in the former spill and UST area.

Cost

The capital cost for Alternative 3 is $476,000 (over 6 months). The total present worth costs are $476,000. Capital and present worth costs for this alternative are presented on Table 9. Further details are presented in Appendix B.

5.5 ALTERNATIVE 4 - NO ACTION FOR GROUNDWATER

5.5.1 DESCRIPTION

The no action alternative provides for no active remediation or monitoring at the Site for groundwater. In the absence of remediation, current Site conditions would remain the same, except insofar as natural attenuation degrades or otherwise dissipates contamination.

5.5.2 ANALYSIS

Overall Protection of Human Health and the Environment

Alternative 1 does not prevent or mitigate the future potential impacts of contaminated groundwater on human health and/or the environment, except as noted in Section 5.5.1.

Compliance with New York SCGs

Because no action is being taken, Alternative 1 would not meet groundwater cleanup criteria in the short-term.

Long-Term Effectiveness and Permanence

This alternative includes no controls for exposure and no long-term management measures.

Reduction of Toxicity, Mobility, or Volume

This alternative provides no reduction in toxicity, mobility, or volume of the contaminated groundwater through treatment, except as noted in Section 5.5.1.

Short-Term Effectiveness

There are no short-term impacts on the community, workers, or the environment since no action would be taken.

Implementability

There are no implementability concerns posed by this remedy since no action would be taken.

Cost

There are no costs associated with the no action alternative.

5.6 ALTERNATIVE 5 - MONITORED NATURAL ATTENUATION

5.6.1 DESCRIPTION

Residual groundwater contamination beneath the source area and impacted groundwater downgradient of the source would be treated through MNA. MNA takes advantage of naturally occurring processes in the subsurface to degrade contamination. Data collected during the RI, during the Supplemental Investigation sampling in 2004/2005, and during the 2006 groundwater sampling events provides evidence that natural attenuation is occurring at this Site. Details of site sampling information illustrating degradation of Site VOCs is presented below.

Limited Natural Attenuation sampling was conducted in 2004, 2005 and 2006 to provide an evaluation of whether MNA is an active and effective means of contaminant degradation. Additional sampling of the contaminants of concern was completed in April 2005. The sampling rounds included the collection of several analytical parameters including:

- Chlorinated Contaminant Concentrations (1,1,1-TCA, 1,1-DCA, CA)
- Total Organic Carbon (TOC)
- Chloride
- Total Alkalinity
- Total and Ferrous Iron
- Total and Dissolved Manganese
- Sulfate
- Nitrate, Nitrate/Nitrite Nitrogen and Nitrite; and,
- Methane, Ethane and Ethene (MEE)

In addition, key field parameters were collected including pH, Oxidation/Reduction Potential (ORP), temperature, specific conductivity, Dissolved Oxygen (DO) and turbidity. Key results from the June 2004, April 2005 and June 2006 sampling are discussed below.

Contaminant Concentrations: High levels of degradation products (e.g. 1,1-DCA and CA) in relation to parent compounds (specifically 1,1,1-TCA) are the absolute requirements for establishing the occurrence of biological natural attenuation processes. In all sampling events during the RI and in the two recent sampling rounds, with the exception of source area well MW-97-1D in January 1999, all wells where chlorinated solvent contamination was detected had higher concentrations of degradation products than the presumed parent compound (1,1,1-TCA).

Chloride: Chloride is often a useful indicator of NA since it is produced during reductive dechlorination. Elevated levels of chloride were detected in all wells tested, which provides evidence that NA is occurring.

Dissolved Oxygen: Reductive dechlorination, a primary biological treatment mechanism, occurs only in anaerobic conditions (less than 0.5 mg/L of dissolved oxygen). Abiotic degradation of chlorinated compounds may occur during aerobic or anaerobic conditions. Dissolved oxygen measurements collected during June 2004 indicated all wells had dissolved oxygen levels less than 0.5 mg/L.

Total Alkalinity: The total alkalinity of a groundwater system can be indicative of the extent to which degradation processes are occurring. The presence of carbon dioxide, produced during the respiration of organic compounds, can elevate alkalinity levels by forming carbonic acid, which subsequently dissolves carbonate minerals present in the affected groundwater system. On this basis, elevated concentrations of alkalinity in areas impacted by organic compounds contained in chlorinated solvents generally can be an indicator of NA. Elevated alkalinity levels were observed in wells at the site.

ORP: ORP measures the availability of electrons, with lower levels indicating a greater availability of electrons (greater reducing power). Low redox conditions were observed throughout the plume area.

Ferrous iron: The presence of ferrous iron indicates reducing conditions and suggests conditions are favorable to promote reductive dechlorination. Ferrous iron analysis is often more effective than direct ORP measurements for evaluating reducing conditions if iron-containing minerals are present. Sampling results indicating elevated levels of ferrous iron suggest the presence of conditions favorable for reductive dechlorination or abiotic degradation.

Sulfate and Nitrate: Sulfate and nitrate are electron acceptors used under anaerobic conditions. A localized depletion of these anions compared to background suggests the occurrence of active anaerobic metabolism. Both nitrate and sulfate were non-detect in wells sampled.

Methane/Ethene/Ethane: The presence of methane suggests very strong reducing conditions, which are conducive to reductive dechlorination. Ethene and ethane are ultimate end products of reductive dechlorination, but are not often detected because they require extremely reducing conditions to be produced. Detectable concentrations of methane and ethane at the Site provide strong evidence that NA is occurring

Taken together the above lines of evidence suggest that NA is an active process at the Site. To implement MNA in accordance with USEPA Guidance provided in "Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater" (EPA 1998), additional ongoing monitoring and modeling would be required during implementation of this alternative. The cost estimate assumes that 15 existing and new wells would be sampled semi annually for five years, and then annually for an additional seventeen years. Well locations are shown on Figure 17. The samples would be analyzed for VOCs and the NA parameters discussed above.

Because the groundwater plume would remain (but because of source removal, not grow but eventually shrink due to MNA), institutional actions in the form of a deed restriction would be placed on the property where the plume is present to prevent use of the groundwater during the MNA program. The groundwater monitoring program will be incorporated into the Site Management Plan.

5.6.2 ANALYSIS

Overall Protection of Human Health and the Environment

Alternative 5 reduces the levels of contamination in groundwater to meet chemical-specific groundwater criteria through natural degradation process of reductive dechlorination thus providing protection of human health and the environment from possible future exposures.

Compliance with New York SCGs

The primary objective of MNA is to demonstrate that natural processes will reduce contaminant concentrations in groundwater to levels below chemical-specific SCGs before the point of compliance is reached. The point of compliance can be a property boundary, a well, a stream or some other potential receptor. Ongoing monitoring will be used to monitor the possibility that concentrations of constituents on the Site may stabilize at concentrations above chemical-specific SCGs upgradient of the compliance point.

Long-Term Effectiveness and Permanence

The magnitude of residual risk would be low and this alternative would be protective over the long term once it is established that reductive dechlorination is a viable and effective process at the Site. As mentioned above, there exists a possibility that concentrations of constituents on the Site may stabilize at concentrations above chemical-specific SCGs upgradient of the compliance point. Reduction of constituents of concern via reductive dechlorination is a permanent remedy.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 5, although passive and natural, is in fact a treatment technology that employs biological reductive dechlorination process to treat chlorinated solvent contaminants, significantly reducing their toxicity and volume. The process also reduces mobility by reducing contaminants before the point of compliance.

Short-Term Effectiveness

There would be minimal impacts to the community and the environment during the implementation of this alternative. Exposure to contaminated groundwater would need to be limited (e.g., via deed restrictions) in the short-term given the long treatment timeframe of MNA.

Implementability

MNA via reductive dechlorination is a well-documented process for chlorinated solvents and data collected so far at the Site supports that MNA could be effectively implemented. Long-term monitoring and installation of a monitoring well network is easily implemented at this Site.

Cost

The capital cost for Alternative 5 is $185,000, including monitoring well installation and groundwater model development. The O&M costs are $608,000 (over 22 years). The total present worth costs are $381,500. Capital, O&M, and present worth costs for this alternative are presented on Table 9. Further details are presented in Appendix B.

5.7 ALTERNATIVE 6 – GROUNDWATER EXTRACTION AND TREATMENT

5.7.1 DESCRIPTION

Residual groundwater contamination beneath the source area and impacted groundwater downgradient of the source would be treated through groundwater extraction and treatment. Three extraction wells would be placed in the locations shown in Figure 18 and would pump a total of 60 gpm maximum (40 gpm average) from the plume. The extraction wells would be installed with screen intervals in the gravelly sand unit. Data indicates no further contamination below the confining gray clay and silt geological unit.

The contaminated water would be collected into an equalization tank, from which it would be pumped through a metals pre-treatment system to remove iron and then to an air stripper and liquid-phase granular activated carbon for VOC removal. The components would be housed in a treatment building located in the immediate vicinity of the former spill area. In the air stripper, the chlorinated and hydrocarbon VOCs would transfer from the extracted groundwater to the air stream. A Division of Air (DAR-1) (Air Guide-1) analysis would need to be performed to determine if treatment of the air stripper vapor effluent is required. DAR-1 provides guidance for the control of toxic ambient air contaminants in New York State. For cost estimating purposes, it is anticipated that the air stream would require treatment. A vapor-phase granular activated carbon unit would treat the VOCs contaminated air stream through adsorption. Treated air would be discharged to the atmosphere.

Groundwater treated through the air stripper would be discharged to a nearby storm sewer. Discharge water would be monitored according to the requirements of a SPDES permit. Operation and maintenance of the system would include inspection and maintenance of system components and process groundwater and air sampling to verify system efficiency and the schedule for carbon changeout. Groundwater sampling of monitoring wells would be conducted quarterly during the first year and semi-annually during the remaining years of the seven-year treatment period. The treatment period was estimated based on the time estimated to achieve a 90% removal of CA in the aquifer. Following the treatment period, residual groundwater contamination above chemical-specific groundwater standards shall be polished using MNA processes. For costing purposes, it is assumed that MNA monitoring would be required for an additional 5 years after active groundwater treatment. The groundwater monitoring program will be incorporated into the Site Management Plan.

5.7.2 ANALYSIS

Overall Protection of Human Health and the Environment

Alternative 6 reduces the levels of contamination in groundwater to meet chemical-specific groundwater standards through collection and treatment of groundwater and natural attenuation processes providing protection of human health and the environment from possible future exposures.

Compliance with New York SCGs

Groundwater contamination would be reduced through extraction and treatment. Residual contamination that remains above chemical-specific groundwater standards in the groundwater after the treatment period shall be treated using MNA processes. For costing purposes, it is assumed that MNA monitoring would be required for 5 years after active groundwater treatment. The primary objective of MNA is to demonstrate that natural processes will reduce contaminant concentrations in groundwater to levels below chemical-specific SCGs before the point of compliance is reached. The point of compliance can be a property boundary, a well, a stream or some other potential receptor. There exists a possibility that concentrations of constituents on the Site may stabilize at concentrations above chemical-specific SCGs upgradient of the compliance point. However, the residual concentrations are expected to be low given the reduction of the source in soil and primary treatment of groundwater via extraction.

The requirements of a SPDES permit would have to be met for groundwater treatment and discharge to the storm sewer system. Furthermore, a DAR-1 analysis would have to be completed to determine whether air pollution control requirements would apply to the air stripper component of the groundwater treatment system.

Long-Term Effectiveness and Permanence

The magnitude of residual risk would be very low and this alternative would be protective over the long term since the contamination in the groundwater is reduced through extraction and treatment. Due to the high inorganic content of Site groundwater, additional treatment units (metals pretreatment) will need to be implemented to ensure air stripper performance efficiency and adequacy in meeting performance requirements for discharge.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 6 satisfies the statutory preference for using treatment as a principal element, through the use of extraction and treatment as a primary component for groundwater. The groundwater constituents are removed by extraction, which reduces the mobility and volume of contaminants. The extracted groundwater will be treated by an aboveground treatment system consisting of air stripper and liquid and vapor-phase carbon, which permanently reduces the toxicity of the contaminants. Residual groundwater constituents are treated via MNA, which reduces the toxicity, mobility and volume of contaminants through biological degradation.

Short-Term Effectiveness

There would be minimal impacts to the community and the environment during the construction and operation phase of this alternative. During the operational period for the groundwater treatment system, only occasional delivery and pickup of carbon canisters and limited maintenance would be required. During the excavation activities and construction phase (extraction well/piping installation), workers could be exposed to risk associated with dermal contact with contaminated soil and groundwater and inhalation of soil dust particles. Risk would be mitigated through the use of the appropriate personal protective equipment and air quality would be monitored. All safety practices would be addressed in a Site Health and Safety Plan.

Implementability

Groundwater extraction and treatment and MNA are proven technologies that have been employed at various remediation sites. Groundwater extraction and treatment is technically implementable. Reliability concerns associated with Alternative 6 relate to the efficiency of groundwater extraction to reduce contamination in a reasonable timeframe. Based on Site geology and current contaminant concentrations, extraction and treatment of groundwater is expected to reduce contamination. There is a high risk of additional remedial action being necessary after the treatment period since groundwater extraction and treatment may reach asymptotic treatment levels in the aquifer. Therefore, MNA has been considered as a polishing step.

MNA is easily technically implementable and preliminary groundwater modeling and field data supports its effectiveness as a remedial technology for this Site. Reliability for meeting performance is dependent on the attenuation rates of contaminants of concern and is Site-specific and will be evaluated prior to implementation and reassessed during the monitoring period.

Cost

The capital cost for Alternative 6 is $1,000,000 and the O&M costs are $1,425,000 (over 12 years). The total present worth costs are $1,784,000. Capital, O&M, and present worth costs for this alternative are presented on Table 9. Further details are presented in Appendix B.

5.8 ALTERNATIVE 7 – AEROBIC ENHANCED BIOREMEDIATION FOR GROUNDWATER

5.8.1 DESCRIPTION

Aerobic enhanced bioremediation involves injecting a slow-release oxygen source into the contaminated portion of the aquifer. Bench-scale studies have shown that chloroethane will degrade under aerobic conditions, but aquifer conditions at the Site are anaerobic. Injection of an aerobic amendment such as ORC or EHC-O would counter these conditions and provide a source of oxygen that could be utilized by aerobic microbes to use as an electron acceptor during respiration and consumption of chloroethane.

The amendment would be injected through a series of borings along the southern boundary of the Site (alley way) and along the western (Hanse Avenue) boundary of the Site. The source area treatment using ISCO will eliminate the more chlorinated ethanes, leaving the downgradient chloroethane plume. The aerobic treatment will effectively treat this chloroethane, preventing continued offsite migration of chloroethane.

Effectiveness can be monitored using existing monitoring wells. Reduced or eliminated levels of chloroethane will be the most obvious indicator of successful aerobic degradation. The longevity of the amendment can be monitored through dissolved oxygen levels in monitoring wells. If dissolved oxygen levels decline while some chloroethane remains, the amendment can be reapplied as necessary in additional borings. Groundwater monitoring will be performed in 12 Site monitoring wells quarterly for 3 years, then semi-annually for 4 years. The groundwater monitoring program will be incorporated into the Site Management Plan.

5.8.2 ANALYSIS

Overall Protection of Human Health and the Environment

Alternative 7 reduces the levels of contamination in groundwater to meet chemical specific groundwater standards accelerating processes providing protection of human health and the environment from possible future exposures.

Compliance with New York SCGs

Groundwater contamination would be reduced through destruction of contaminants. Residual contamination that remains above chemical-specific groundwater standards in the groundwater after the treatment period shall be treated through MNA processes. For costing purposes it is assumed that MNA monitoring would be required for 5 years after the aerobic amendments have been consumed. The primary objective of MNA is to demonstrate that natural processes will reduce contaminant concentrations in groundwater to levels below chemical-specific SCGs before the point of compliance is reached. The point of compliance can be a property boundary, a well, a stream or some other potential receptor. There exists a possibility that concentrations of constituents on the Site may stabilize at concentrations above chemical-specific SCGs upgradient of the compliance point. However, the residual concentrations are expected to be low given the reduction of the source in soil and primary treatment of groundwater via aerobic enhanced bioremediation.

Long-Term Effectiveness and Permanence

The magnitude of residual risk would be very low and this alternative would be protective over the long term since the contamination in the groundwater is reduced through aerobic enhanced bioremediation. Due to the anaerobic nature of the aquifer at the Site, multiple applications of the aerobic amendments will likely be needed to effectively treat residual groundwater contamination.

Reduction of Toxicity, Mobility, or Volume

Alternative 7 will result in a reduction of contaminant mass, through the use of enhanced aerobic as a primary component for groundwater. The groundwater constituents (primarily chloroethane) are converted to harmless end products through enhanced bioremediation, which reduces the toxicity, mobility and volume of contaminants. Residual groundwater constituents are treated via

MNA, which reduces the toxicity, mobility and volume of contaminants through further biological degradation.

Short-Term Effectiveness

There would be minimal impacts to the community and the environment during the implementation of this alternative. After the initial implementation, no additional maintenance would be required, with the exception of regular groundwater monitoring and possible additional injection events. During the injection activities, workers would not be exposed to risk associated with dermal contact with contaminated soil and groundwater and inhalation of soil dust particles. Based on the results of the TSI bench scale tests, the treatment will result in contaminant reduction within a short period of time.

Implementability

Aerobic enhanced bioremediation and MNA are proven technologies that have been employed at various remediation sites. Aerobic enhanced bioremediation is technically implementable. The remedy can be easily implemented by injection of amendments through a series of direct push borings. Reliability concerns associated with Alternative 7 relate to the persistence of the amendments and the ability to effectively distribute them in the subsurface. Based on Site geology, normal injection methods should adequately distribute the amendments in the gravelly sand aquifer. The amendments should last 9 to 12 months, but if monitoring data suggest depletion (through diminished DO concentrations) the amendments can be re-injected. There is a moderate risk of additional remedial action being necessary if, after the in-situ treatment, contaminant concentrations may reach asymptotic treatment levels in the aquifer. Therefore, MNA has been considered as a polishing step.

Cost

The capital cost for Alternative 7 is $181,000 and the O&M costs are $135,000 (over 7 years). The capital costs include two amendment injection events. The O&M costs include monitoring during the treatment period (2 years) and MNA for 5 years following the treatment period. The total present worth costs are $276,000. Capital, O&M, and present worth costs for this alternative are presented on Table 9. Further details are presented in Appendix B.

5.9 ALTERNATIVE 8 - NO ACTION FOR STORM DRAIN SOIL

5.9.1 DESCRIPTION

The no action alternative provides for no active remediation or monitoring at the Site for impacted storm drain soil. In the absence of remediation, current Site conditions would remain the same, except insofar as natural attenuation degrades or otherwise dissipates contamination. It should be noted that some soil was removed from SD-1 immediately following the 1988 1,1,1-TCA spill.

5.9.2 ANALYSIS

Overall Protection of Human Health and the Environment

Alternative 1 does not prevent or mitigate the future potential impacts of contaminated storm drain soil on human health and/or the environment, except as noted in Section 5.9.1.

Compliance with New York SCGs

Because no action is being taken, Alternative 1 would not meet soil cleanup criteria, except as noted in Section 5.9.1.

Long-Term Effectiveness and Permanence

This alternative includes no controls for exposure and no long-term management measures.

Reduction of Toxicity, Mobility, or Volume

This alternative provides no reduction in toxicity, mobility, or volume of the contaminated soil or groundwater through treatment, except as noted in Section 5.9.1.

Short-Term Effectiveness

There are no short-term impacts on the community, workers, or the environment since no action would be taken.

Implementability

There are no implementability concerns posed by this remedy since no action would be taken.

Cost

There are no costs associated with the no action alternative.

5.10 ALTERNATIVE 9 – STORM DRAIN SOIL REMOVAL

5.10.1 DESCRIPTION

This alternative involves the removal and off-site disposal of impacted soils in OU-1 storm srains.

Impacted soils were detected in soils in three of the sand bottom storm drains in OU-1. These storm drains are designated SD-1, SD-5 andSD-8. Impacts were detected from 0 to 30 inches below the storm drain bottom. At each storm drain, the storm grate would be removed to provide access to the soil and debris in the drain. Impacted soils and debris will be removed with a vac-truck. The soils would be removed to the water table (approximately 6 feet below grade). The storm drain bottom would then be backfilled with sand to 3 feet below grade.

5.10.2 ANALYSIS

Overall Protection of Human Health and the Environment

Alternative 9 reduces the levels of contamination in storm drain soil to meet chemical-specific soil criteria through direct removal of the soil contamination in the source area and replacement with clean backfill.

Compliance with New York SCGs

This alternative would meet the chemical-specific cleanup criteria for soil through direct removal. The soil would have to be disposed of and/or treated offsite. It is assumed that these soils would be treated at an off-site commercial facility to levels below chemical-specific soil standards prior to disposal or reuse

Long-Term Effectiveness and Permanence

The magnitude of residual risk is minimal since the source of contamination is removed Removal can be readily completed to meet performance specifications and is a permanent remedy.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 9 satisfies the statutory preference for using treatment as a principal element, through the use of removal of contaminant mass in the storm drains. The source is removed by vac-truck to the extent practicable, which reduces the mobility and volume of contaminants in soil on Site. The excavated soil will be treated by offsite incineration, which permanently reduces the toxicity of the contaminants.

Short-Term Effectiveness

There would be minimal impacts to the community and the environment during the construction and operation phase of this alternative. The vac-truck will not cause disruption to commercial and business activities at the site. The removal of storm drain soils and backfilling can be completed in a day.

During the removal, there is minimal risk for exposure to the site workers. Risk would be mitigated through the use of the appropriate personal protective equipment and air quality monitoring. All safety practices would be addressed in a Site Health and Safety Plan.

Implementability

Removal and off-site disposal is a proven technology. Vac-truck removal is technically implementable and reliable for meeting performance goals with a low risk of additional remedial action being necessary after completion.

Cost

The capital cost for Alternative 9 is $4,400. There are no O&M costs associated with this alternative. The total present worth costs are $4,400. Capital and present worth costs for this alternative are presented on Table 9. Further details are presented in Appendix B.

6.0 COMPARISON OF REMEDIAL ALTERNATIVES

6.1 COMPARATIVE ANALYSIS

In the following analysis the alternatives are evaluated in relation to one another for each of the evaluation criteria (except state and community acceptance, which will be addressed in the ROD following comments on the SRIR and FS report and Proposed Remedial Action Plan). The purpose of this analysis is to identify the relative advantages and disadvantages of each alternative.

Overall Protection of Human Health and the Environment

For soil, Alternative 1, the No Action Alternative, is the least protective of human health and the environment, as it does not prevent exposure or further reduce potential risks to human heath and the environment. Alternatives 2 and 3 provide greater protection of human health and the environment through active treatment of soil contamination.

For groundwater, Alternative 4, the No Action Alternative, is the least protective of human health and the environment, as it does not prevent exposure or further reduce potential risks to human heath and the environment. Alternatives 6 and 7 provide greater protection of human health and the environment through active treatment of groundwater contamination. Alternative 5 provides protection of human health and the environment but may take longer to achieve full protection.

For storm drain soil, Alternative 8, the No Action Alternative, is the least protective of human health and the environment, as it does not prevent exposure or further reduce potential risks to human heath and the environment. Alternative 9 provides greater protection of human health and the environment through active removal of soil contamination.

Compliance with New York SCGs

For soil, Alternative 1 is not expected to meet New York SCGs. Alternative 2 is expected to meet chemical-specific SCGs in the source area through active removal of impacted soils. Alternative 3 would reduce VOC contamination for the source area to levels below the chemical-specific cleanup criteria through in situ treatment. There is a low risk that some localized residual soil contamination may remain and not be effectively removed by ISCO. However, concentrations would not be expected to be high enough to affect groundwater VOC concentrations.

For groundwater, Alternative 4 may meet New York SCGs in the long-term through natural attenuation processes. However, because the alternative does not require monitoring, the effectiveness of meeting New York SCGs would be unknown. Alternative 5 is expected to meet

New York SCGs through passive treatment of groundwater via MNA to reduce VOC contamination to levels below the chemical-specific cleanup criteria. There is a potential that chemical-specific SCGs are met at the compliance point(s) (Site boundary, downgradient wells and/or receptors) but that the contaminants stabilize at concentrations above cleanup criteria within the Site boundary area. However, these residual concentrations are expected to be low, considering that the source area will be addressed through soil remediation. Alternatives 6 and 7 would reduce VOC contamination to levels below the chemical-specific cleanup criteria through active treatment for groundwater with MNA polishing. Similar to Alternative 5, there is a low risk that contaminants stabilize at concentrations above cleanup criteria within the Site boundary area.

For storm drain soil, Alternative 8 is not expected to meet New York SCGs. Alternative 9 is expected to meet chemical-specific SCGs in the source area through active removal of impacted soils.

Long-term Effectiveness and Permanence

For soil, Alternative 1 is not effective in removing long-term future risks posed by the Site. Alternatives 2 and 3 both utilize active treatment and are more effective in removing long-term future risks and are permanent remedies.

For groundwater, Alternative 4 may be effective in removing long-term future risks posed by the Site but effectiveness and permanence would be unknown given the lack of monitoring information. Alternative 5 is effective in removing long-term future risks but employs the passive and relatively longer-term technique of MNA to treat groundwater. Alternative 5 will require monitoring to verify that the MNA is meeting treatment goals (e.g., rate of attenuation). Alternatives 6 and 7 employ active groundwater treatment with MNA polishing that result in very low residual risk. Performance requirements for the Alternative 6 groundwater treatment system will be affected by the high inorganic content of the groundwater and will require implementation of additional treatment units (metals pretreatment) to ensure air stripper efficiency during the operational period. Performance requirements for the Alternative 7 aerobic treatment may multiple applications, followed by MNA polishing.

For storm drain soil, Alternative 8 is not effective in removing long-term future risks posed by the Site. Alternative 9 utilizes active removal and is more effective in removing long-term future risks and are permanent remedies.

Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 1 does not reduce the toxicity, mobility, or volume of contaminants at the Site. Alternatives 2 and 3 use an active treatment for soil, which reduces the toxicity, mobility and volume of contaminants.

Alternative 4 may reduce the toxicity, mobility, or volume of contaminants at the Site through natural degradation processes similar to Alternative 5. Alternative 5, although passive and natural, is in fact a treatment technology that employs biological reductive dechlorination process to treat chlorinated solvent contaminants, significantly reducing their toxicity. Alternatives 6 and 7 use an active treatment approach for groundwater that reduces toxicity, mobility and volume of contaminants.

For storm drain soil, Alternative 8 does not reduce the toxicity, mobility, or volume of contaminants at the Site. Alternative 9 uses active treatment for soil, which reduces the toxicity, mobility and volume of contaminants.

Short-term Effectiveness

For soil, Alternative 1 has no short-term impacts as no intrusive activities take place. Alternatives 2 and 3 would have low to moderate short-term impacts due to varying levels of construction and remedial activities. Duration of implementation would be relatively short (several months) for both alternatives and effectiveness would be evaluated at that time.

For groundwater, Alternative 4 and 5 have no short-term impacts as no intrusive activities take place. MNA is a long-term remedial approach with an 11-year timeframe. MNA would have limited short-term effectiveness. Alternative 6 would have moderate short-term impacts due to system installation and O&M activities. Alternative 7 would have significant short-term impacts immediately following the initial injection.

For storm drain soil, Alternative 8 has no short-term impacts as no intrusive activities take place. Alternative 9 would have minimal short-term impacts during implementation. Duration of implementation would be extremely short (one day) and effectiveness would be evaluated at that time.

Implementability

All alternatives are implementable at the Site. For soil, Alternative 2 will require special provisions to prevent undermining the structural integrity of the building foundation. Alternative

3 will require special provisions for handling and storage of chemicals involved in the ISCO injections.

For groundwater, Alternative 5 would require a Natural Attenuation Sampling (NAS), long-term monitoring, and groundwater monitoring to determine the effectiveness to take the contaminant degradation process to completion (to innocuous byproducts such as ethane). Alternative 5 would require installation of several supplemental monitoring wells on or near the site. Alternative 6 may require some temporary modifications in operations at the facility in order to install extraction wells, subsurface piping and appurtenances and a treatment shed. Alternative 7 would be easily implementable through several days of direct-push injections.

For storm drain soil, Alternative 8 is highly implemetable and can be accomplished within one day.

Cost

Alternative costs are summarized in Table 9. Costs range from $0 (Alternative 1 - No Action) to $1,784,000 (Alternative 3). The costs for Alternatives 2-9 range from $4,400 to $1,784,000.

6.2 PREFERRED ALTERNATIVE

The selected remedial alternative for the Site is Alternative 3, In Situ Chemical Oxidation (ISCO) for soil and Alternative 7, Aerobic Enhanced Bioremediation for groundwater. This Alternative provides active soil and groundwater treatment using in situ approaches. Groundwater would be polished by MNA and is expected to effectively treat the levels of contamination currently observed at the Site. Treatment of source area residuals by ISCO will speed up the time frame for groundwater remediation.

The impacted soils in the residual source area would be treated via sodium persulfate activated with hydrogen peroxide. The limited areal extent provides ideal conditions for the application of ISCO. Alternative 3 eliminates the risks presented by open excavation and also eliminates the need for offsite disposal of a large volume of contaminated soil. The remediation time frame of Alternative 3 is anticipated at 0.5 years, which is slower than Alternative 2 but still within a reasonable timeframe. Although the cost of Alternative 3 is comparable to Alternative 2, implementation of Alternative 2 will also most likely be easier than Alternative 3. For storm drain soils, Alternative 9 provides a simple, effective, and permanent remedy.

Alternative 7 Aerobic Enhanced Bioremediation, for groundwater will treat the remaining portions of the chloroethane plume in the downgradient areas of Operable Unit 1. Therefore, Alternative 7 coupled with Alternatives 3 and 9 provide an effective remedial approach for the site. ISCO treatment may temporarily oxidize the groundwater in and around the source area, which will serve to compliment the rate and effectiveness of aerobic treatment in the short-term. Table 8 provides a summary of the preferred alternatives, Alternatives 3, 7 and 9.

7.0 COMMON ACTIONS

As described in Section 3.0, sub-slab vapor mitigation measures will be required to minimize potential risks to Site building occupants during remediation of soil and groundwater. Therefore, sub-slab vapor mitigation will be a Common Action during site remediation. Regardless of what remedial measures are chosen for the other media (including No Action), mitigation measures will be implemented to address sub-slab vapor. The common actions will include institutional controls and engineering controls.

7.1 ENGINEERING CONTROLS

Engineering controls will be implemented to mitigate potential soil vapor intrusion at the Site. The engineering controls will include a sub-slab depressurization system (SSDS). The SSDS system can be very effective at this site because of the existing impermeable cap (building is constructed on slab). The purpose of the SSDS is to create a negative pressure field directly under the building and immediately outside the building in comparison to the ambient pressure inside the building. This negative pressure field becomes a "sink" for any gases present in the soil in the vicinity of the structure. VOCs caught in the advective sweep of this negative pressure field are collected and piped to an ambient air discharge point.

The negative pressure field can be created using mechanical devices such as a blower. Sometimes, the sub-slab pressures are relatively high, and just passive venting is adequate. This is particularly true at sites that formerly operated as landfills. This is also true at sites in highly urban areas where a large portion of the land is paved. Both of these conditions apply to this site. The negative pressure field is distributed beneath the slab through a network of either horizontal perforated pipes or soil vapor extraction wells screened above the water table. The SSDS will be designed to create a minimum negative pressure of –0.004 inches of water beneath the entire Site building. The design of the system will be based on several factors, including:

- Building construction;
- Sub-slab aggregate, soil, and void space conditions; and
- Pilot studies.

Extracted vapors will be piped from the blower and exhausted above the building roof. If VOC concentrations in the vapors exceed applicable NYSDEC standards, vapor treatment with activated carbon may be necessary prior to discharging. The engineering controls will include monitoring points where sub-slab vapor samples can be collected and sub-slab pressure can be measured. A sub-slab vapor sampling and pressure monitoring program will be incorporated into the Site Management Plan. The samples and pressure monitoring will be used to evaluate the effectiveness of the SSDS. The monitoring results will also be used to evaluate when the SSDS can be removed or reduced to a passive system in the future. A detailed SSDS design will be submitted to NYSDEC and NYSDOH following pre-design studies.

7.2 INSTITUTIONAL CONTROLS

During installation and operation of the SSDS, institutional controls will be implemented at the Site. The institutional controls will include an environmental easement with associated use restrictions. The environmental easement is an agreement between the Site owner and NYSDEC meant to ensure protection of human health and the environment when a remediation project leaves residual contamination at levels exceeding applicable ARARs. The environmental easement restricts certain uses and activities at the site and ensures the performance of operation, maintenance and/or monitioring requirements of remedial measures and engineering controls at the Site. All remediation, operation & maintenance and monitoring requirements, as well as use restrictions will be described in a Site Management Plan, which will be included in the environmental easement.

8.0 REFERENCES

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Table 1
Summary of Soil Sampling Data
Former Columbia Cement Company, Inc. Facility
Freeport, New York

DECEMBER 1998 RI SOIL BORINGS	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (mg/kg)	NYSDEC TAGM 4046 Recommended Soil Cleanup Objectives (mg/kg)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	25	13	ND - 7,000	0.8	5 of 25
	1,1-Dichloroethane	25	11	ND -120	0.2	5 of 25
	1,1-Dichloroethene	25	2	ND - 1.1	0.4	1 of 25
	1,2-Dichloroethane	25	0	ND	0.1	0 of 25
	Acetone	25	20	ND - 0.57	0.2	2 of 25
	Benzene	25	3	ND - 0.052	0.06	0 of 25
	Chloroethane	25	4	ND - 1.6	1.9	0 of 25
	Ethylbenzene	25	3	ND - 250	5.5	1 of 25
	Methylene Chloride	25	10	ND - 0.023	0.1	0 of 25
	Toluene	25	5	ND - 660	1.5	2 of 25
	Trichloroethene	25	1	ND - 0.35	0.7	0 of 25
	Xylene(s)	25	7	ND - 1,500	1.2	1 of 25

APRIL 2000 RI SOIL BORINGS	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (mg/kg)	NYSDEC TAGM 4046 Recommended Soil Cleanup Objectives (mg/kg)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	30	19	ND - 2,600	0.8	6 of 30
	1,1-Dichloroethane	30	8	ND - 3.40	0.2	2 of 30
	1,1-Dichloroethene	30	2	ND - 0.006	0.4	0 of 30
	1,2-Dichloroethane	30	0	ND	0.1	0 of 30
	Acetone	30	9	ND - 170	0.2	6 of 30
	Benzene	30	5	ND - 0.017	0.06	0 of 30
	Chloroethane	30	5	ND - 1.10	1.9	0 of 30
	Ethylbenzene	30	1	ND - 0.64	5.5	0 of 30
	Methylene Chloride	30	2	ND - 0.4	0.1	0 of 30
	Toluene	30	6	ND - 42.0	1.5	6 of 30
	Trichloroethene	30	1	ND - 1.2	0.7	1 of 30
	Xylene(s)	30	10	ND - 2.5	1.2	1 of 30

Table 1
Summary of Soil Sampling Data
Former Columbia Cement Company, Inc. Facility
Freeport, New York

MAY 2004 PRE-UST CLOSURE SOIL BORINGS	**Contaminants of Concern**	**Number of Samples**	**Number of Detections**	**Concentration Range Detected (mg/kg)**	**NYSDEC TAGM 4046 Recommended Soil Cleanup Objectives (mg/kg)**	**Frequency of SCG Exceedence**
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	11	1	ND - 0.0047	0.8	0 of 11
	1,1-Dichloroethane	11	1	ND - 0.0024	0.2	0 of 11
	1,1-Dichloroethene	11	0	ND	0.4	0 of 11
	1,2-Dichloroethane	11	0	ND	0.1	0 of 11
	Acetone	11	11	ND - 0.12	0.2	0 of 11
	Benzene	11	0	ND	0.06	0 of 11
	Chloroethane	11	0	ND	1.9	0 of 11
	Ethylbenzene	11	0	ND	5.5	0 of 11
	Methylene Chloride	11	0	ND	0.1	0 of 11
	Toluene	11	9	ND - 0.035	1.5	0 of 11
	Trichloroethene	11	0	ND	0.7	0 of 11
	Xylene(s)	11	0	ND	1.2	0 of 11

AUG. - SEPT. 2004 POST EXCAVATION SOIL SAMPLES	**Contaminants of Concern**	**Number of Samples**	**Number of Detections**	**Concentration Range Detected (mg/kg)**	**NYSDEC TAGM 4046 Recommended Soil Cleanup Objectives (mg/kg)**	**Frequency of SCG Exceedence**
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	13	2	ND - 0.16	0.8	0 of 13
	1,1-Dichloroethane	13	3	ND - 0.006	0.2	0 of 13
	1,1-Dichloroethene	13	0	ND	0.4	0 of 13
	1,2-Dichloroethane	13	0	ND	0.1	0 of 13
	Acetone	13	0	ND	0.2	0 of 13
	Benzene	13	0	ND	0.06	0 of 13
	Chloroethane	13	0	ND	1.9	0 of 13
	Ethylbenzene	13	1	ND - 14	5.5	1 of 13
	Methylene Chloride	13	0	ND	0.1	0 of 13
	Toluene	13	12	ND - 32	1.5	1 of 13
	Trichloroethene	13	1	ND - 0.001	0.7	0 of 13
	Xylene(s)	13	1	ND - 150	1.2	1 of 13

Table 1
Summary of Soil Sampling Data
Former Columbia Cement Company, Inc. Facility
Freeport, New York

OCTOBER 2004 POST-CLOSURE SOIL BORINGS	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (mg/kg)	NYSDEC TAGM 4046 Recommended Soil Cleanup Objectives (mg/kg)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	55	25	ND - 4,800	0.8	6 of 55
	1,1-Dichloroethane	55	27	ND - 390	0.2	8 of 55
	1,1-Dichloroethene	55	7	ND - 18	0.4	3 of 55
	1,2-Dichloroethane	55	10	ND - 0.9	0.1	2 of 55
	Acetone	55	25	ND - 0.42	0.2	5 of 55
	Benzene	55	3	ND - 1.2	0.06	2 or 55
	Chloroethane	55	20	ND - 16	1.9	6 of 55
	Ethylbenzene	55	4	ND - 0.31	5.5	0 of 55
	Methylene Chloride	55	4	ND - 1.0	0.1	2 of 55
	Toluene	55	16	ND - 4.2	1.5	1 of 55
	Trichloroethene	55	10	ND - 0.001	0.7	1 of 55
	Xylene(s)	55	5	ND - 1.4	1.2	0 of 55

STORM DRAIN SEDIMENT SAMPLES	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (mg/kg)	NYSDEC TAGM 4046 Recommended Soil Cleanup Objectives (mg/kg)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	21	11	ND - 4.8	0.8	2 of 21
	1,1-Dichloroethane	21	8	ND - 0.6	0.2	0 of 21
	1,1-Dichloroethene	21	2	ND - 0.74	0.4	0 of 21
	Acetone	21	6	ND - 0.3	0.2	1 of 21
	Benzene	21	1	ND - 0.001	0.06	0 of 21
	Chloroethane	21	5	ND - 0.780	1.9	0 of 21
	Ethylbenzene	21	11	ND - 0.270	5.5	0 of 21
	Methylene Chloride	21	11	ND - 22.0	0.1	1 of 21
	Toluene	21	13	ND - 0.56	1.5	0 of 21
	Trichloroethene	21	4	ND - 0.002	0.7	0 of 21
	Xylene(s)	21	17	ND - 1.75	1.2	1 of 21

ALL SOIL SAMPLES	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (mg/kg)	NYSDEC TAGM 4046 Recommended Soil Cleanup Objectives (mg/kg)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	134	60	ND - 7,000	0.8	19 of 155
	1,1-Dichloroethane	134	50	ND - 390	0.2	15 of 155
	1,1-Dichloroethene	134	11	ND - 18	0.4	4 of 155
	1,2-Dichloroethane	134	10	ND - 0.9	0.1	3 of 155
	Acetone	134	54	ND - 170	0.2	13 of 155
	Benzene	134	22	ND - 1.2	0.06	2 of 155
	Chloroethane	134	29	ND - 16	1.9	6 of 155
	Ethylbenzene	134	9	ND - 250	5.5	3 of 155
	Methylene Chloride	134	16	ND - 1.0	0.1	3 of 155
	Toluene	134	48	ND - 660	1.5	10 of 155
	Trichloroethene	134	13	ND - 1.2	0.7	2 of 155
	Xylene(s)	134	23	ND - 1,500	1.2	20 of 155

Table 1
Summary of Soil Sampling Data
Former Columbia Cement Company, Inc. Facility
Freeport, New York

DECEMBER 1998 RI SOIL BORINGS	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (mg/kg)	NYSDEC TAGM 4046 Recommended Soil Cleanup Objectives (mg/kg)	Frequency of SCG Exceedence
Semi-Volatile Organic Compounds (SVOCs)	Phenol	8	1	ND - 0.34	0.03	1 - 8
	1,4-Dichlorobenzene	8	1	ND -0.23	NA	NA
	4-Methylphenol	8	1	ND - 0.89	0.9	0 - 8
	Naphthalene	8	4	ND - 1.3	13	0 - 8
	4-Chloro-3-Methylphenol	8	1	ND - 0.98	0.24	0 - 8
	2-Methylnaphthalene	8	2	ND - 0.36	36.4	0 - 8
	Acenaphthene	8	2	ND - 0.74	50	0 - 8
	Dibenzofuran	8	1	ND - 0.12	6.2	0 - 8
	Fluorene	8	3	ND - 0.38	50	0 - 8
	Phenanthrene	8	6	ND - 5.3	50	0 - 8
	Anthracene	8	2	ND - 0.26	50	0 - 8
	Di-n-butylphthalate	8	5	ND - 2.9	8.1	0 - 8
	Fluoranthene	8	7	ND - 3.6	50	0 - 8
	Pyrene	8	6	ND - 0.92	50	0 - 8
	Butylbenzylphthalate	8	2	ND - 0.52	50	0 - 8
	Chrysene	8	2	ND - 2.2	0.4	2 - 8
	bis(2-Ethylhexyl)phthalate	8	8	0.18 - 96	50	3 - 8
	Di-n-octylphthalate	8	4	ND - 0.2.8	50	0 - 8

DECEMBER 1998 RI SOIL BORINGS	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (mg/kg)	NYSDEC TAGM 4046 Recommended Soil Cleanup Objectives (mg/kg)	Frequency of SCG Exceedence
Pesticides and PCBs	Dieldrin	8	1	ND - 0.006	0.044	0 - 8
	4,4'-DDD	8	1	ND - 0.025	2.9	0 - 8
	4,4'-DDT	8	1	ND - 0.21	2.1	0 - 8
	Methoxychlor	8	1	ND - 0.0086	NA	NA
	gamma-Chlordane	8	1	ND - 0.020	0.54	0 - 8

Table 1
Summary of Soil Sampling Data
Former Columbia Cement Company, Inc. Facility
Freeport, New York

DECEMBER 1998 RI SOIL BORINGS	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (mg/kg)	NYSDEC TAGM 4046 Recommended Soil Cleanup Objectives (mg/kg)	Frequency of SCG Exceedence
Inorganics	Aluminum	8	8	585 - 11600	SB	0 - 8
	Antimony	8	5	ND - 97.6	SB	1 - 8
	Arsenic	8	6	ND - 28.9	7.5 or SB	0 - 8
	Barium	8	8	0.0093 - 954	300 or SB	0 - 8
	Beryllium	8	3	ND - 0.39	0.16 or SB	1 - 8
	Cadmium	8	4	ND - 7.5	1 or SB	0 - 8
	Calcium	8	8	288 - 28800	SB	0 - 8
	Chromium	8	8	5 - 217	10 or SB	1 - 8
	Cobalt	8	6	3.5 - 19.7	30 or SB	0 - 8
	Copper	8	8	2.3 - 633	25 or SB	0 - 8
	Iron	8	8	3340 - 92900	2000 or SB	1 - 8
	Lead	8	8	0.8 - 3160	SB	0 - 8
	Magnesium	8	8	391 - 15500	SB	1 - 8
	Manganese	8	8	26 - 919	SB	0 - 8
	Mercury	8	7	ND - 0.70	0.1	4 - 8
	Nickel	8	7	ND - 82.7	13 or SB	0 - 8
	Potassium	8	4	ND - 8020	SB	0 - 8
	Silver	8	1	ND - 3.1	SB	0 - 8
	Sodium	8	3	ND - 6070	SB	0 - 8
	Thallium	8	1	ND - 2.6	SB	0 - 8
	Vanadium	8	7	4.7 - 47.2	150 or SB	0 - 8
	Zinc	8	8	10.9 - 2380	20 or SB	0 - 8

NOTES:

(mg/kg) : Micrograms per kilogram
NYSDEC TAGM 4046 : New York State Department of Environmental Conservation Technical and Administrative Guidance Memorandum
SCG : Standards, criteria and guidance values
ND : Not detected
SB : Site background
NA : Not applicable - no SCG published

Table 2
Summary of Groundwater Sampling Data
Former Columbia Cement Company, Inc. Facility
Freeport, New York

1999 GROUNDWATER SAMPLING EVENT	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (µg/l)	NYSDEC TAGM 4046 Groundwater Standards/Criteria (µg/l)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	13	4	ND - 5,100	5	3 of 13
	1,1-Dichloroethane	13	2	ND - 4,300	5	2 of 13
	1,1-Dichloroethene	13	0	ND	5	0 of 13
	Acetone	13	3	ND - 300	50	2 of 13
	Benzene	13	0	ND	1	0 of 13
	Chlorobenzene	13	1	ND - 20	5	1 of 13
	Chloroethane	13	9	ND - 11,000	5	8 of 13
	Ethylbenzene	13	0	ND	5	0 of 13
	Methylene Chloride	13	3	ND - 500	5	2 of 13
	Toluene	13	0	ND	5	0 of 13
	Trichloroethene	13	0	ND	5	0 of 13
	Vinyl Chloride	13	0	ND	2	0 of 13

2000 GROUNDWATER SAMPLING EVENT	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (µg/l)	NYSDEC TAGM 4046 Groundwater Standards/Criteria (µg/l)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	15	4	ND - 140	5	2 of 15
	1,1-Dichloroethane	15	3	ND - 2,600	5	2 of 15
	1,1-Dichloroethene	15	2	ND - 23	5	2 of 15
	Acetone	15	7	ND - 69	50	1 of 15
	Benzene	15	5	ND - 23	1	3 of 15
	Chlorobenzene	15	8	ND - 32	5	6 of 15
	Chloroethane	15	11	ND - 12,000	5	10 of 15
	Ethylbenzene	15	2	ND - 5	5	1 of 15
	Methylene Chloride	15	8	ND - 840	5	8 of 15
	Toluene	15	2	ND - 76	5	2 of 15
	Trichloroethene	15	2	ND - 9	5	1 of 15
	Vinyl Chloride	15	2	ND - 20	2	2 of 15

Table 2
Summary of Groundwater Sampling Data
Former Columbia Cement Company, Inc. Facility
Freeport, New York

2003 GROUNDWATER SAMPLING EVENT	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (µg/l)	NYSDEC TAGM 4046 Groundwater Standards/Criteria (µg/l)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	15	0	ND	5	0 of 15
	1,1-Dichloroethane	15	3	0 - 690	5	3 of 15
	1,1-Dichloroethene	15	0	ND	5	0 of 15
	Acetone	15	0	ND	50	0 of 15
	Benzene	15	0	ND	1	0 of 15
	Chlorobenzene	15	5	ND - 12	5	4 of 15
	Chloroethane	15	9	ND - 13,000	5	9 of 15
	Ethylbenzene	15	0	ND	5	0 of 15
	Methylene Chloride	15	0	ND	5	0 of 15
	Toluene	15	0	ND	5	0 of 15
	Trichloroethene	15	0	ND	5	0 of 15
	Vinyl Chloride	15	0	ND	2	0 of 15

2004 GROUNDWATER SAMPLING EVENT	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (µg/l)	NYSDEC TAGM 4046 Groundwater Standards/Criteria (µg/l)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	15	1	ND - 150	5	1 of 15
	1,1-Dichloroethane	15	2	ND - 660	5	2 of 15
	1,1-Dichloroethene	15	0	ND	5	0 of 15
	Acetone	15	0	ND	50	0 of 15
	Benzene	15	2	ND - 15	1	2 of 15
	Chlorobenzene	15	8	ND - 16	5	5 of 15
	Chloroethane	15	8	ND - 10,000	5	8 of 15
	Ethylbenzene	15	1	ND - 2	5	0 of 15
	Methylene Chloride	15	0	ND	5	0 of 15
	Toluene	15	1	ND - 4	5	0 of 15
	Trichloroethene	15	0	ND	5	0 of 15
	Vinyl Chloride	15	1	ND - 15	2	1 of 15

Table 2
Summary of Groundwater Sampling Data
Former Columbia Cement Company, Inc. Facility
Freeport, New York

2005 GROUNDWATER SAMPLING EVENT	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (µg/l)	NYSDEC TAGM 4046 Groundwater Standards/Criteria (µg/l)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	2	0	ND	5	0 of 2
	1,1-Dichloroethane	2	0	ND	5	0 of 2
	1,1-Dichloroethene	2	0	ND	5	0 of 2
	Acetone	2	0	ND	50	0 of 2
	Benzene	2	0	ND	1	0 of 2
	Chlorobenzene	2	1	ND - 3	5	1 of 2
	Chloroethane	2	2	17 - 910	5	3 of 2
	Ethylbenzene	2	0	ND	5	0 of 2
	Methylene Chloride	2	0	ND	5	0 of 2
	Toluene	2	0	ND	5	0 of 2
	Trichloroethene	2	0	ND	5	0 of 2
	Vinyl Chloride	2	0	ND	2	0 of 2

2006 GROUNDWATER SAMPLING EVENT	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (µg/l)	NYSDEC TAGM 4046 Groundwater Standards/Criteria (µg/l)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	15	1	ND - 0.4	5	0 of 15
	1,1-Dichloroethane	15	2	ND - 11	5	2 of 15
	1,1-Dichloroethene	15	1	ND - 5.8	5	1 of 15
	Acetone	15	2	ND - 7.3	50	0 of 15
	Benzene	15	0	ND - 0.4	1	0 of 15
	Chlorobenzene	15	6	ND - 16	5	4 of 15
	Chloroethane	15	8	ND - 1,900	5	7 of 15
	Ethylbenzene	15	0	ND	5	0 of 15
	Methylene Chloride	15	0	ND	5	0 of 15
	Toluene	15	0	ND	5	0 of 15
	Trichloroethene	15	0	ND	5	0 of 15
	Vinyl Chloride	15	0	ND	2	0 of 15

Table 2
Summary of Groundwater Sampling Data
Former Columbia Cement Company, Inc. Facility
Freeport, New York

ALL GROUNDWATER SAMPLING EVENTS	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (µg/l)	NYSDEC TAGM 4046 Groundwater Standards/Criteria (µg/l)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	1,1,1-Trichloroethane	75	10	ND - 5,100	5	6 of 75
	1,1-Dichloroethane	75	12	ND - 4,300	5	11 of 75
	1,1-Dichloroethene	75	3	ND - 23	5	3 of 75
	Acetone	75	12	ND - 300	50	3 of 75
	Benzene	75	7	ND - 23	1	5 of 75
	Chlorobenzene	75	29	ND - 32	5	21 of 75
	Chloroethane	75	47	ND - 13,000	5	45 of 75
	Ethylbenzene	75	3	ND - 5,100	5	1 of 75
	Methylene Chloride	75	11	ND - 840	5	10 of 75
	Toluene	75	3	ND - 76	5	2 of 75
	Trichloroethene	75	2	ND - 9	5	1 of 75
	Vinyl Chloride	75	3	ND - 20	2	3 of 75

NOTES:

(µg/l) : Micrograms per liter
NYSDEC TAGM 4046 : New York State Department of Environmental Conservation Technical and Administrative Guidance Memorandum
SCG : Standards, criteria and guidance values
ND : Not detected
NA : Not applicable - no SCG published

Table 3
Summary of Sub-Slab Vapor Sampling Data
Former Columbia Cement Company, Inc. Facility
Freeport, New York

2006 SUB-SLAB VAPOR SAMPLING	Contaminants of Concern	Number of Samples	Number of Detections	Concentration Range Detected (μg/m^3)	NYSDOH Matrix Conc. For Sub-Slab Mitigation [1] (μg/m^3)	Frequency of SCG Exceedence
Volatile Organic Compounds (VOCs)	Trichloroethene	3	3	5.9 - 534	250	1 of 3
	Vinyl Chloride	3	0	ND	250	0 of 3
	1,1,1-Trichloroethane	3	3	14 - 86,200	1,000	1 of 3
	Tetrachloroethene	3	3	43 - 2,140	1,000	1 of 3
	cis-1,2-Dichloroethene	3	2	ND - 6.7	1,000	0 of 3
	1,1-Dichloroethene	3	1	ND - 308	1,000	0 of 3
	Chloroethane	3	1	ND-10,500	NA	NA
	1,1-Dichloroethane	3	3	ND-30600	NA	NA

NOTES:

(μg/m3) : Micrograms per liter
1 : From NYSDOH Final Guidance forEvaluating Soil Vapor Intrusion in the State of New York, October 2006
SCG : Standards, criteria and guidance values
ND : Not detected
NA : Not applicable - no SCG published

Ta 4
Summary of Contaminant Physical Properties
Former Columbia Cement Company, Inc. Facility
Freeport, New York

Compound	Molecular Weight	Solubility mg/L	Vapor Pressure mm Hg at 20 degC	Henry's Law Constant atm-m3/mole	Log Kow	Log Koc
1,1,1-Trichloroethane	133.41	4400	100	8 x 10-3	2.47	2.19
1,1-Dichloroethane	98.96	5500	180	5.87 x 10-3	1.79	1.65
1,1-Dichloroethene	96.94	5000	500	8.48 x 10-3	1.81	1.81
Chloroethane	64.5	5740	1000	8.48 x 10-3	1.54	1.62
Benzene	78.11	1791	95.19	5.43 x 10-3	2.13	1.92
Toluene	92.13	534.8	28.4	5.94 x 10-3	2.69	2.06
Ethylbenzene	106.17	152	7	8.7 x 10-3	3.15	1.98
Xylene	106.17	185	6	5.7 x 10-3	3.04	2.54
Acetone	58.09	Miscible	231	3.67 x 10-5	-0.24	-0.43
Methylene Chloride	84.93	20000	349	0.01	1.4	0.94
Vinyl Chloride	62.5	1100	2660	2.78	0.6	0.39

Legend: Kow = Octanal Water Partition Coefficient
Koc = Organic Carbon Partition Coefficient

References:

Suthersan, Suthan S., 2002. Natural and Enhanced Remediation Systems. Lewis Publishers. 364 pp.

Howard, Philip H., 1990. Handbook of Environmental Fate and Exposure Data For Organic Chemicals: Volume II; Solvents. Lewis Publishers. 535 pp.

Norris, Robert D., et al, 1994. Handbook of Bioremediation. Lewis Publishers. 244 pp.

Verschueren, K., 1977. Handbook of Environmental Data on Organic Chemicals, Van Nostrand Reinhold Co., New York.

Table 5
Summary of Contaminant Fate and Transport Parameters
Former Columbia Cement Company, Inc. Facility
Freeport, New York

Compound	log Koc	Koc	Kd	R	Vc (ft/d)	Travel Time to Site Boundary (years)
1,1,1-Trichloroethane	2.19	155	0.2628	2.4900	0.0498	18.7 (1)
1,1-Dichloroethane	1.65	45	0.0763	1.4300	0.0867	10.7 (2)
1,1-Dichloroethene	1.81	64.57	0.1095	1.6204	0.0765	12.2
Acetone	-0.43	0.37	0.0006	1.0036	0.1236	7.5
Benzene	1.92	83.18	0.1410	1.7992	0.0689	13.5
Chloroethane	1.62	42	0.0712	1.4000	0.0886	10.5 (3)
ethylbenzene	2.83	680	1.1529	7.5333	0.0165	56.6
Methylene Chloride	0.94	8.7	0.0148	1.0836	0.1144	8.1
Toluene	2.06	17.82	0.0302	1.1712	0.1059	8.8
Vinyl Chloride	0.39	2.46	0.0042	1.0236	0.1211	7.7
Xylene	2.54	346.7	0.5878	4.3310	0.0286	32.5

Assumptions

Groundwater Velocity (V):	0.124	ft/d
foc:	0.0017	
Bulk Density:	1.7	g/cm3
Porosity:	0.3	

Legend:

Koc : Organic Carbon Partition Coefficient
Kd : Distribution Coefficient
R : Retardation Factor
Vc : Average Contaminant Transport Velocity
Foc : Fraction of Organic Carbon
1 : assuming degradation, model predicted 1,1,1-TCA would not leave site
2 : assuming degradation, model predicted 1,1-DCA would not leave site
3 : assuming degradation, model predicted 5.5 years

Table 6
Evaluation of Remedial Technologies for Soil
Former Columbia Cement Company, Inc. Facility
Freeport, New York

GENERAL RESPONSE ACTION	TECHNOLOGY	EFFECTIVENESS	IMPLEMENTABILITY	COST
NO ACTION	None	Does not achieve remedial action objectives	Not acceptable to local/public government	None
INSTITUTIONAL CONTROLS	Access restriction	Effectiveness depends on continued future implementation. Does not reduce contamination.	Legal requirements and authority	Negligible Cost
CONTAINMENT	Cap	Effective and reliable to reduce mobility of contamination; Does not reduce toxicity or volume of contamination	Technically implementable; Alone, not acceptable to local/public government	Moderate capital, low O&M
	Barriers	Effective and reliable to reduce mobility of contamination; Does not reduce toxicity or volume of contamination	Technically difficult to implement due to dense site surroundings and limited space. Alone, not acceptable to local/public government.	Moderate capital, low O&M
EXCAVATION	Excavation	Effective and reliable for short and long-term; Reduces toxicity, mobility and volume of contamination	Readily implementable	High capital, very low O&M
EX SITU TREATMENT	Stabilization/ Solidification	Typically used for metals; Not effective for VOCs	Readily implementable	Low capital, low O&M
	Thermal Desorption	Effective and reliable for short and long-term; Reduces toxicity, mobility and volume of contamination	Readily implementable	Moderate capital, high O&M
DISPOSAL	On-site disposal	Effective and reliable discharge method	Requires on-site treatment which is limited by industrial site surroundings and limited space	High capital, low O&M
	Off-site disposal	Effective and reliable discharge method	Readily implementable	Low capital, high O&M
IN SITU SOIL TREATMENT	Soil Vapor Extraction	Not effective alone since impacted soils are greater than 8 feet bgs and below the groundwater table. Requires additional remedial method to drawdown groundwater and expose vadose zone. Limited reduction of toxicity, mobility and volume of contamination if used alone since saturated soils would not be treated.	Readily implementable	Moderate capital, moderate O&M
	Soil Flushing	Inefficient because the residual contamination does not reside in a continuous large area and therefore large areas of clean soil would be impacted by remedial action. Most effective when contaminant concentrations are high (in the ppm range).	Technically difficult to implement given the isolated areas of soil contamination	Moderate capital, low O&M
	Dual Phase Extraction	Effective and reliable for short and long-term; Reduces toxicity, mobility and volume of contamination	Readily implementable	Moderate capital, moderate O&M
	Chemical Oxidation	Innovative technology used successfully for aromatic and chlorinated solvent compounds; Effective for short and long-term; Reduces toxicity, mobility and volume of contamination	Readily implementable	Moderate capital, moderate O&M
	Enhanced Bioremediation	Bench-scale testing indicated limited effectiveness in enhancing the natural degradation processes at the Site.	Readily implementable	Low capital, low O&M

Not Retained for Detailed Consideration (Section 3.2)

Table 7
Evaluation of Remedial Technologies for Groundwater
Former Columbia Cement Company, Inc. Facility
Freeport, NY

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	EFFECTIVENESS	IMPLEMENTABILITY	COST
NO ACTION	None	Does not achieve remedial action objectives	Not acceptable to local/public government	None
INSTITUTIONAL CONTROLS	Access restriction	Effectiveness depends on continued future implementation. Does not reduce toxicity, mobility and volume of contamination.	Technically implementable; Administrative implementability requires legal requirements and authority	Negligible Cost
GROUNDWATER CONTAINMENT	Extraction Wells to Contain Plume Downgradient	Effective and reliable for long-term; Reduces potential for offsite mobility but limited short-term effectiveness on toxicity and volume of contamination due to downgradient position of wells;	Readily implementable	High capital, high O&M
	Barriers	Effective and reliable for short and long-term reduction in mobility; Does not reduce toxicity and volume of contamination	Technically difficult to implement due to dense site surroundings and limited space.	High capital, low O&M
MONITORED NATURAL ATTENUATION	Monitoring/NA Evaluation	Potentially effective for short and long-term; requires additional data collection and analysis; Reduces toxicity, mobility and volume of contamination	Monitoring only; Readily implementable	Low capital, low O&M
GROUNDWATER COLLECTION	Extraction	Effective and reliable for short and long-term; Reduces toxicity, mobility and volume of contamination	Readily implementable	Moderate capital, low O&M
	Subsurface Drains	Not effective and reliable due to depth of contamination; Reduces toxicity, mobility and volume of collected groundwater	Technically difficult to implement based on industrial site conditions and depth of contamination	High capital, low O&M
EX SITU GROUNDWATER TREATMENT	Stripping	Effective for short and long-term; Reduces toxicity, mobility and volume of contamination; Not very reliable in long-term due to high inorganic content in gw that may affect stripping efficiency	Readily implementable	High capital, high O&M
	Carbon Adsorption	Effective and reliable for short and long-term; Reduces toxicity, mobility and volume of contamination	Readily implementable; Relatively low adsorption efficiency for site constituents, can be combined with other technologies and used for polishing	Low capital, high O&M
GROUNDWATER DISCHARGE	Off-Site Discharge	Effective and reliable discharge method	Technically implementable; Discharge permits required	Low capital, low O&M

Table 7
Evaluation of Remedial Technologies for Groundwater
Former Columbia Cement Company, Inc. Facility
Freeport, NY

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	EFFECTIVENESS	IMPLEMENTABILITY	COST
IN SITU GROUNDWATER TREATMENT	Air Sparging	Limited effectiveness due to anaerobic nature of the aquifer and properties of site constituents; Not reliable due to high inorganic content in gw that may affect efficiency; Reduces toxicity, mobility and volume of contaminants	Readily implementable	High capital, moderate O&M
	Chemical Oxidation	Innovative technology used successfully for aromatic and chlorinated solvent compounds; Effective for short-term reductions in toxicity, mobility and volume of contamination; Not effective for long-term reduction in toxicity, mobility and volume of contamination due to lower reaction rates associated with low residual concentrations in downgradient plume	Technically difficult to implement given existence of subsurface utilities and space limitations	Moderate capital, moderate O&M
	Enhanced Annaerobic Bioremediation	Bench-scale testing indicated limited effectiveness in enhancing the natural degradation processes at the Site. CA not suseptible to anaerobic degradation.	Readily implementable	Low capital, low O&M
	Enhanced Aerobic Bioremediation	Bench-scale testing indicated effectiveness in enhancing the aerobic degradation of CA at the Site. Reduces toxicity, mobility and volume of contamination.	Readily implementable	Low capital, low O&M

▨ Not Retained for Detailed Consideration (Section 3.2)

Evaluation of Alternatives
Former Columbia Cement Company, Inc. Facility
Freeport, New York

CRITERIA	Soil			Groundwater				Storm Drain Sediment	
	ALTERNATIVE 1 No Actions	**ALTERNATIVE 2 Soil Excavation and Off Site Disposal**	**ALTERNATIVE 3 In Situ Chemical Oxidation**	**ALTERNATIVE 4 No Actions**	**ALTERNATIVE 5 Monitored Natural Attenuation**	**ALTERNATIVE 6 Groundwater Extraction and Treatment**	**ALTERNATIVE 7 Aerobic Enhanced Bioremediation**	**ALTERNATIVE 8 No Actions**	**ALTERNATIVE 9 Sediment Excavation and Off Site Disposal**
OVERALL PROTECTIVENESS									
Protect Human Health and Environment	No reduction in contamination of soil.	Soil contamination source removed.	Soil contamination reduced.	No reduction in contamination of groundwater.	Groundwater quality passively protected.	Groundwater contamination reduced. Groundwater quality actively protected.	Groundwater contamination reduced. Groundwater quality actively protected.	No reduction in contamination of sediment.	Soil contamination source removed.
COMPLIANCE WITH ARARS/NEW YORK STATE SCGS									
Soil and Groundwater Cleanup Criteria	Does not meet remedial action objectives.	Source removed and will meet remedial action objectives.	Source treated and is expected to meet remedial action objectives.	Does not meet remedial action objectives.	Groundwater contamination passively reduced and eventually expected to remedial action objectives. There is a possibility that concentrations may stabilize above chemical-specific SCGs in areas upgradient of compliance points, but levels are expected to be low.	Groundwater contamination actively reduced and eventually will meet remedial action objectives.	Groundwater contamination actively reduced and eventually will meet remedial action objectives.	Does not meet remedial action objectives.	Source removed and will meet remedial action objectives.
LONG-TERM EFFECTIVENESS AND PERMANENCE									
Magnitude of Residual Risk	Remains at current levels.	Source eliminated.	Alternative would be protective over the long term with a very low magnitude of residual risk.	Remains at current levels.	Groundwater contamination reduced and eventually eliminated.	Alternative would be protective over the long term with minimal magnitude of residual risk.	Alternative would be protective over the long term with minimal magnitude of residual risk.	Remains at current levels.	Source eliminated.
Adequacy and Reliability of Controls	No controls.	Excavation can readily be completed and is reliable.	Post injection sampling is readily implementable.	No controls.	Long-term sampling of groundwater required. Monitoring and modeling program required to ensure the plume is attenuating prior to reaching any receptors and that adequacy and reliability (e.g., sustained degradation rate) is achieved.	Operation of pump and treat system and groundwater sampling. High inorganic content of groundwater requires additional pretreatment and O&M to ensure stripper efficiency.	Injection of aerobic amendments, groundwater sampling and MNA. Aerobic amendments can effectively treat VOCs. Multiple injections may be required, followed by MNA.	No controls.	Excavation can readily be completed and is reliable.

CRITERIA	Soil			Groundwater				Storm Drain Sediment	
	ALTERNATIVE 1 No Actions	**ALTERNATIVE 2 Soil Excavation and Off Site Disposal**	**ALTERNATIVE 3 In Situ Chemical Oxidation**	**ALTERNATIVE 4 No Actions**	**ALTERNATIVE 5 Monitored Natural Attenuation**	**ALTERNATIVE 6 Groundwater Extraction and Treatment**	**ALTERNATIVE 7 Aerobic Enhanced Bioremediation**	**ALTERNATIVE 8 No Actions**	**ALTERNATIVE 9 Sediment Excavation and Off Site Disposal**
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME (TMV)									
Treatment Process(es)	None	Excavation and Incineration of Soil.	In Situ Chemical Oxidation using sodium persulfate activated with hydrogen peroxide	None	Groundwater treated through natural biological degradation.	Groundwater treated by air stripping, followed by capture on carbon. Vapor treated by capture on carbon.	Groundwater treated by injection electron acceptor that enhances aerobic bioremediation.	None	Excavation and Incineration of Soil.
Reduction of TMV by Treatment	None	Source removal reduces on site volume and mobility. Toxicity is permanently reduced by offsite incineration.	Source treatment by ISCO reduces on site volume, toxicity and mobility of contaminants.	None	MNA reduces toxicity, mobility and volume of contaminants in groundwater.	Air stripping reduces volume through concentration into vapor stream and then onto carbon. Regeneration of carbon reduces toxicity.	Aerobic enhanced bioremediation reduces volume, toxicity and mobility by promoting biodegradation. Process converts chloroehtane to harmless end products.	None	Source removal reduces on site volume and mobility. Toxicity is permanently reduced by offsite incineration.
Types and Quantity of Residuals Remaining After Treatment	NA		No residuals from ISCO treatment other than innocuous byproducts (e.g., carbon dioxide, water).	NA	No residuals from MNA treatment other than innocuous byproducts (e.g., ethene).	Activated carbon residual requires regeneration to completely destroy VOC toxicity.	End products are chloride, carbon dioxide and water.	NA	None
Statutory Preference For Treatment	Does not satisfy.	Satisfies.	Satisfies.	Does not satisfy	Satisfies.	Satisfies.	Satisfies	Does not satisfy	Satisfies.

CRITERIA	Soil			Groundwater				Storm Drain Sediment	
	ALTERNATIVE 1 No Actions	**ALTERNATIVE 2 Soil Excavation and Off Site Disposal**	**ALTERNATIVE 3 In Situ Chemical Oxidation**	**ALTERNATIVE 4 No Actions**	**ALTERNATIVE 5 Monitored Natural Attenuation**	**ALTERNATIVE 6 Groundwater Extraction and Treatment**	**ALTERNATIVE 7 Aerobic Enhanced Bioremediation**	**ALTERNATIVE 8 No Actions**	**ALTERNATIVE 9 Sediment Excavation and Off Site Disposal**
SHORT-TERM EFFECTIVENESS									
Community and Worker Protection	Current conditions continue to exist.	Health and Safety measures during implementation would be protective against short-term risks from volatiles and soil dust particles. Fugitive dust controlled using engineering measures.	Health and Safety measures during implementation would be protective against short-term risks from chemical exposure during injection activities.	Current conditions continue to exist.	Health and Safety measures during monitoring activities would be protective against short-term risks from exposure to contaminants. Current conditions continue to exist in short-term but do not pose signficant risk to community.	Health and Safety measures during implementation would be protective against short-term risks from volatiles and soil dust particles. Air quality would be monitored and encountered from air stripper and groundwater would be treated through carbon absorption.	Health and Safety measures during implementation would be protective against short-term risks from volatiles and soil dust particles.	Current conditions continue to exist.	Health and Safety measures during implementation would be protective against short-term risks from chemical exposure during vac-truck excavation.
Environmental Impacts	Current conditions continue to exist.	Low Environmental Risk for Excavation.	Low Environmental Risk for Excavation. Low Environmental Impact from Groundwater Extraction.	Current conditions continue to exist.	Potential risk for the downgradient portions of the plume where MNA will be used for treatment.	Low Environmental Impact from Groundwater Extraction.	Low Environmental Impact from Aerobic Enhanced Bioremediation.	Current conditions continue to exist.	Low Environmental Risk for Excavation.
Time Until Action is Complete (years)	Not applicable.	0.5	0.5	Not applicable.	22	12	7	Not applicable.	0.5

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Evaluation of Alternatives
Former Columbia Cement Company, Inc. Facility
Freeport, New York

CRITERIA	Soil			Groundwater				Storm Drain Sediment	
	ALTERNATIVE 1 No Actions	**ALTERNATIVE 2 Soil Excavation and Off Site Disposal**	**ALTERNATIVE 3 In Situ Chemical Oxidation**	**ALTERNATIVE 4 No Actions**	**ALTERNATIVE 5 Monitored Natural Attenuation**	**ALTERNATIVE 6 Groundwater Extraction and Treatment**	**ALTERNATIVE 7 Aerobic Enhanced Bioremediation**	**ALTERNATIVE 8 No Actions**	**ALTERNATIVE 9 Sediment Excavation and Off Site Disposal**
IMPLEMENTABILITY									
Ability to Construct and Operate	No construction or operation.	Geotechnical and structural analysis will be required to ensure the stability of the adjacent building during excavation activities	Bench-scale and pilot-scale testing may be required to design implementation program	No construction or operation.	A NAS is required to fill in data gaps to determine if MNA is a strong enough process to as primary treatment for downgradient groundwater impacts.	A DAR-1 analysis is required to determine if treatment to the air stripper component is required.	Bench-scale and pilot-scale testing may be required to design implementation program	No construction or operation.	Easily implementable with vac-truck.
Ease of Undertaking Additional Action if Needed	NA.	Because of sheet piling requirements, difficult to excavate more soil than planned without new sheet pile/bracing installation.	Additional injections, if necessary, are readily implementable.	NA.	Additional wells, of necessary, are readily implementable.	Readily implementable. Space limitations may affect system design including layout of extraction wells.	Additional injections, if necessary, are readily implementable.	NA.	Additional vac-truck removal is readily implemenable.
Ability to Monitor Effectiveness	None required.	Post treatment soil sampling readily implemented.	Post treatment soil sampling readily implemented.	None required.	Groundwater monitoring readily implemented.	Possiblity that groundwater extraction could reach limited effectiveness over time and will not meet cleanup standards.	Possiblity that biodegradation could reach limited effectiveness over time and will not meet cleanup standards.	None required.	Post excavation soil sampling readily implemented.
Ability to Obtain Approvals and Coordinate with Other Agencies	None required.	NYSDEC approval for excavation and sampling program. SPDES Permit for dewatering effluent discharge.	NYSDEC approval for ISCO treatment process.	None required.	NYSDEC approval for MNA treatment process.	A SPDES Permit required for treatment system effluent discharge.	NYSDEC approval for ISCO treatment process.	None required.	None required.
Availibility of Equipment, Specialists, and Materials	None required.	No special requirements identified. Only general contractors and consultants required.	No special requirements identified. Only general contractors and consultants required.	None required.	No special requirements identified. Only general contractors and consultants required.	No special requirements identified. Only general contractors and consultants required.	No special requirements identified. Only general contractors and consultants required.	None required.	No special requirements identified. Only general contractors and consultants required.
CAPITAL COST	$0	$545,240	$476,194	$0	$184,513	$1,013,545	$181,395	NA	$4,402
TOTAL PRESENT WORTH	$0	$545,240	$476,194	$0	$381,415	$1,783,547	$275,671	$0	$4,402

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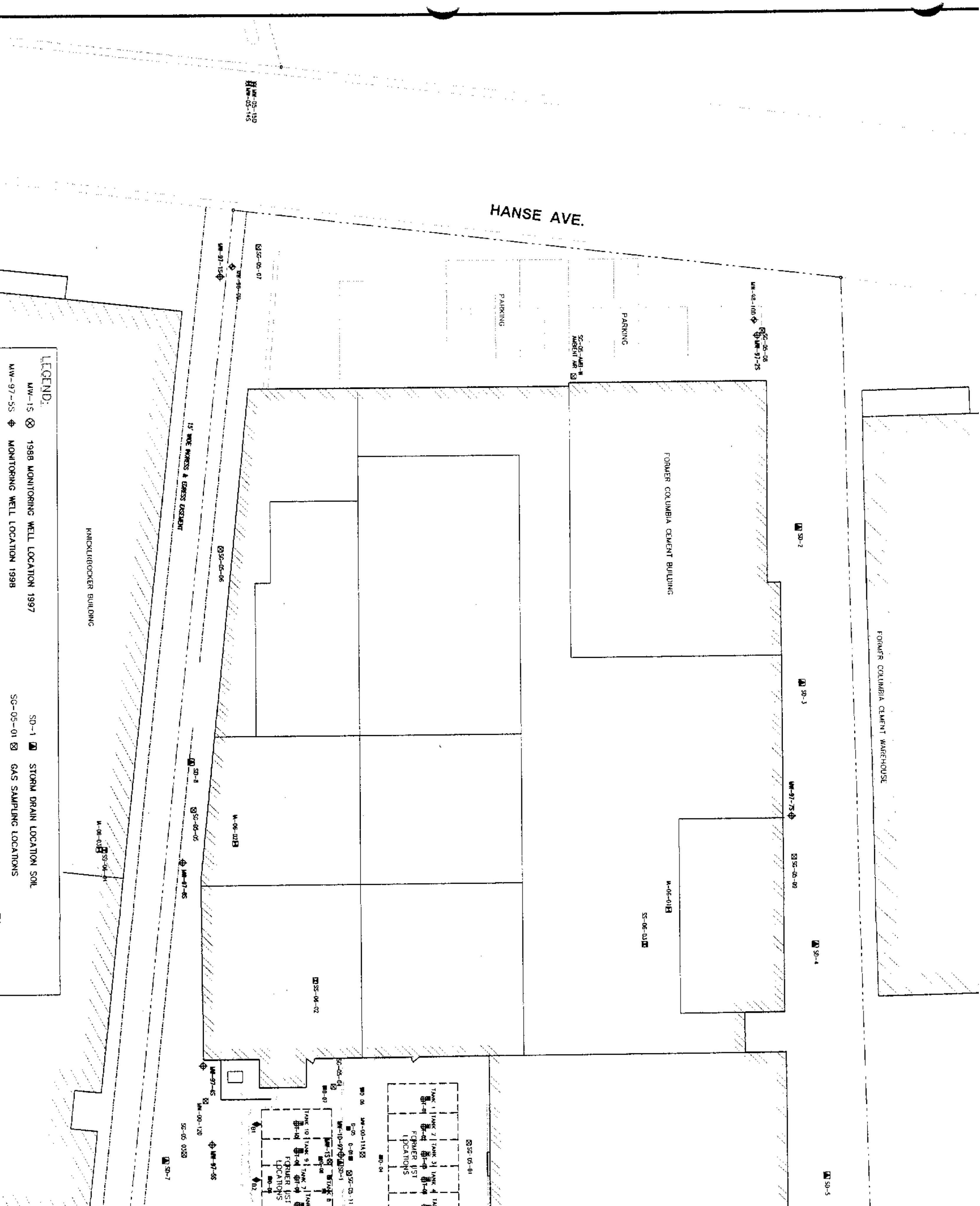
Summary of Costs
Former Columbia Cement Company, Inc. Facility
Freeport, New York

Alternative No.	Components	Capital Cost	O&M Phase	O&M Phase Cost	Time Period of Operations (years)	Annual O&M Cost	Total O&M Cost	Present Worth O&M Cost [1]	Total Present Worth of Alternative [2]
1	No Action for Soil	$0	NA	NA	0	NA	$0	$0	$0
2	Soil Excavation and Off Site Disposal	$545,240	NA	NA	0.5	NA	$0	$0	$545,240
3	In Situ Chemical Oxidation	$476,194	NA	NA	0.5	NA	$0	$0	$476,194
4	No Action	$0	NA	NA	0	NA	$0	$0	$0
5	Monitored Natural Attenuation	$184,513	Bi-Annual Sampling for 5 Years	$238,000	5	$47,600	$608,600	$196,903	$381,415
			Annaul Sampling for 17 Years	$370,600	17	$21,800			
6	Groundwater Extraction and Treatment	$1,013,545	System O&M and GW Sampling for 7 years	$1,272,980	7	$181,854	$1,424,980	$770,002	$1,783,547
			Annaul Sampling for 5 Years	$152,000	5	$30,400			
7	Aerobic Enhanced Bioremediation	$181,395	Quarterly Sampling for 3 Years	$81,000	3	$27,000	$135,000	$94,276	$275,671
			Semi-Annual Sampling for 4 Years	$54,000	4	$13,500			
8	No Action for Storm Drain Sediment	$0	NA	NA	0	NA	$0	$0	$0
9	Storm Drain Sediment Removal	$4,402	NA	NA	0.0	NA	$0	$0	$4,402

Notes:

1. For the present worth cost; a 5% annual interest rate has been assumed.
2. Total Present Worth is equal to the sum of the capital cost plus the present worth O&M cost.


HANSE AVE.
LEGEND:
MW-1S ⊗ 1988 MONITORING WELL LOCATION 1997
MW-97-5S ⊕ MONITORING WELL LOCATION 1998
SD-1 ▨ STORM DRAIN LOCATION SOIL
SG-05-01 ⊠ GAS SAMPLING LOCATIONS
KNICKERBOCKER BUILDING
15' WIDE INGRESS & EGRESS EASEMENT
PARKING
PARKING
FORMER COLUMBIA CEMENT BUILDING
FORMER COLUMBIA CEMENT WAREHOUSE
FORMER UST LOCATIONS
FORMER UST LOCATIONS
MW-05-15D
MW-05-14S
MW-97-1S
MW-98-01
SG-05-07
SG-05-06
SG-05-AMB-W AMBIENT AIR
MW-98-10D
SG-05-08
MW-97-2S
SD-2
SD-3
MW-97-7S
SG-05-09
SS-06-01
SS-06-03
SD-4
SD-8
SG-05-05
SS-06-02
SS-06-03
SG-06-01
MW-97-8S
SS-06-02
MW-97-4S
MW-00-12D
SG-05 03
SD-7
MW-97-6S
B1
B2
SG-05-04
MW-00-07
MW 06
MW-00-11A
D-05
D-01
MW-1D-97
MW-1S
SD-1
SG-05-11
MW-00-04
SG-05-01
SD-5
TANK 1
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TANK 9
TANK 10

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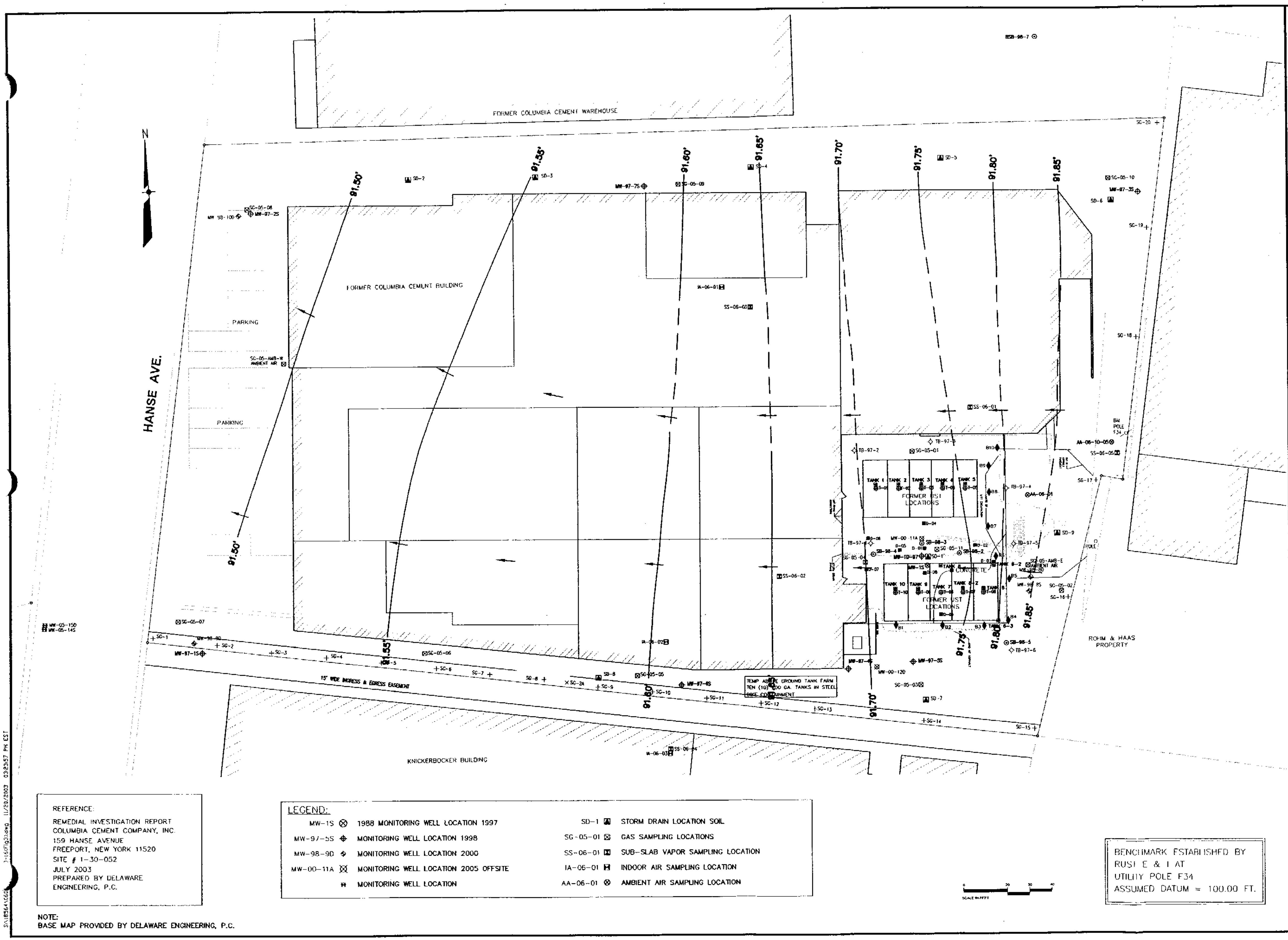


REFERENCE:
REMEDIAL INVESTIGATION REPORT
COLUMBIA CEMENT COMPANY, INC
159 HANSE AVENUE
FREEPORT, NEW YORK 11520
SITE # 1-30-052
JULY 2003
PREPARED BY DELAWARE
ENGINEERING, P.C.

LEGEND:

MW-1S ⊗	1988 MONITORING WELL LOCATION 1997	SD-1 ▨	STORM DRAIN LOCATION SOIL
MW-97-5S ⊕	MONITORING WELL LOCATION 1998	SG-05-01 ☒	GAS SAMPLING LOCATIONS
MW-98-9D ◈	MONITORING WELL LOCATION 2000	SS-06-01 ▣	SUB-SLAB VAPOR SAMPLING LOCATION
MW-00-11A ☒	MONITORING WELL LOCATION 2005 OFFSITE	IA-06-01 ▣	INDOOR AIR SAMPLING LOCATION
▪	MONITORING WELL LOCATION	AA-06-01 ⊗	AMBIENT AIR SAMPLING LOCATION

BENCHMARK ESTABLISHED BY
RUSI E & I AT
UTILITY POLE F34
ASSUMED DATUM = 100.00 FT.

NOTE:
BASE MAP PROVIDED BY DELAWARE ENGINEERING, P.C.

Atlantic Richfield Company
(A BP Affiliated Company)

URS
12 COMMERCE DRIVE
CRANFORD, NJ, 07016
PHONE: (908) 272-8300
FAX: (908) 272-3940

Issue Date: 04/20/05

Revisions		
No.	Date	Description

Project Description

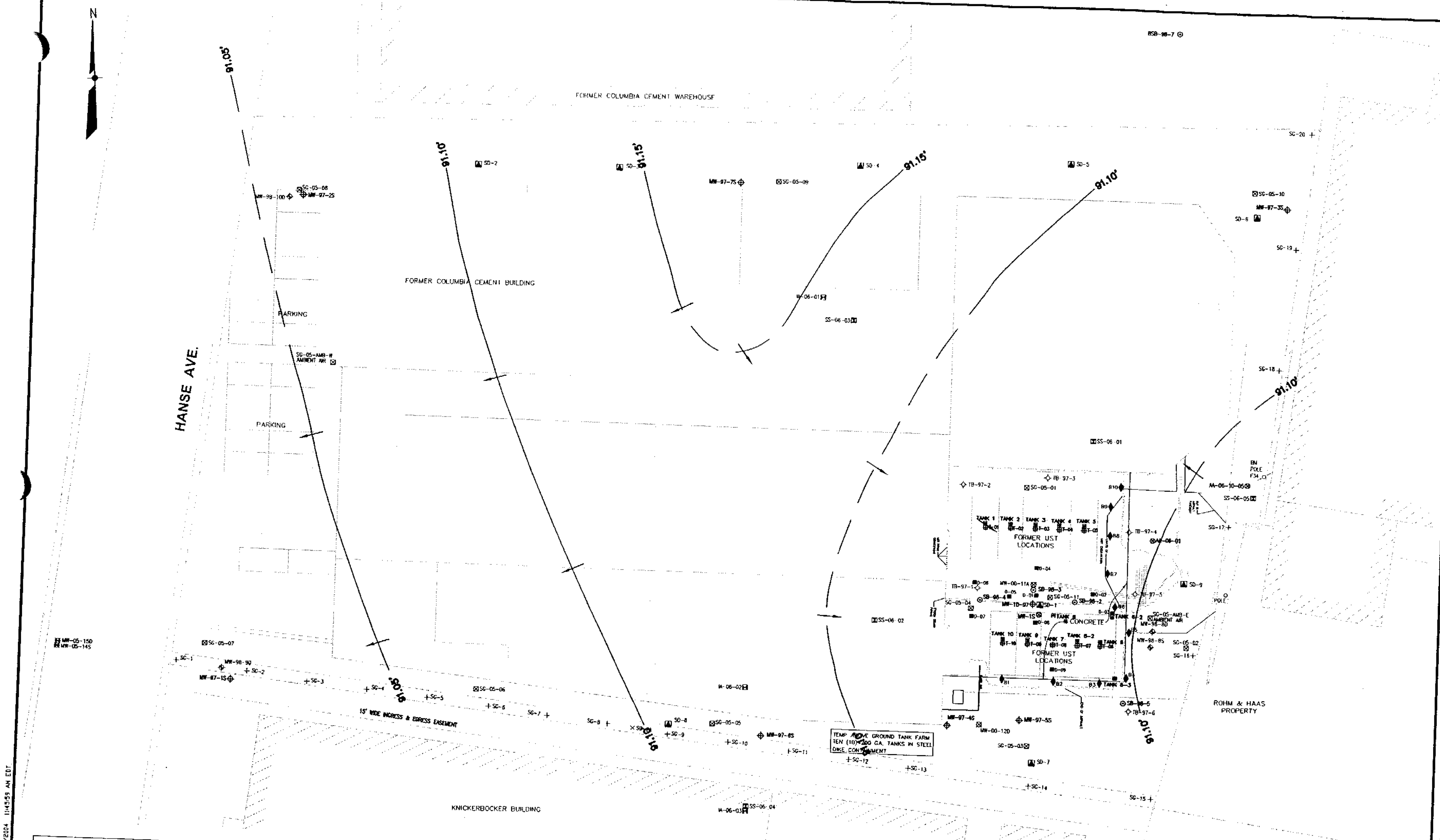
Former Columbia Cement Company. Inc.
159 Hanse Avenue
Freeport, New York

Sheet Title:

GROUNDWATER ELEVATION CONTOUR MAP (HIGH TIDE-MAY 3, 2000)

Drawn By:	J.T.	11/05/03
Checked By:	M.B.	11/07/03
Scale:	AS SHOWN	
Project Number:	38546433	

Sheet Number:
FIGURE 3



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REFERENCE:
REMEDIAL INVESTIGATION REPORT
COLUMBIA CEMENT COMPANY, INC.
159 HANSE AVENUE
FREEPORT, NEW YORK 11520
SITE # 1-30-052
JULY 2003
PREPARED BY DELAWARE
ENGINEERING, P.C.

NOTE:
BASE MAP PROVIDED BY DELAWARE ENGINEERING, P.C.

LEGEND:

MW-1S	⊗	1988 MONITORING WELL LOCATION 1997
MW-97-5S	⊕	MONITORING WELL LOCATION 1998
MW-98-9D	⊕	MONITORING WELL LOCATION 2000
MW-00-11A	☒	MONITORING WELL LOCATION 2005 OFFSITE
	▣	MONITORING WELL LOCATION
SD-1	▣	STORM DRAIN LOCATION SOIL
SG-05-01	☒	GAS SAMPLING LOCATIONS
SS-06-01	▣	SUB-SLAB VAPOR SAMPLING LOCATION
IA-06-01	▣	INDOOR AIR SAMPLING LOCATION
AA-06-01	⊗	AMBIENT AIR SAMPLING LOCATION

SCALE IN FEET

BENCHMARK ESTABLISHED BY
RUST E & I AT
UTILITY POLE F34
ASSUMED DATUM = 100.00 FT.

Atlantic Richfield Company
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URS
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CRANFORD, NJ. 07016
PHONE: (908) 272-8300
FAX: (908) 272-3940

Issue Date: 04/20/05

Revisions		
No.	Date	Description

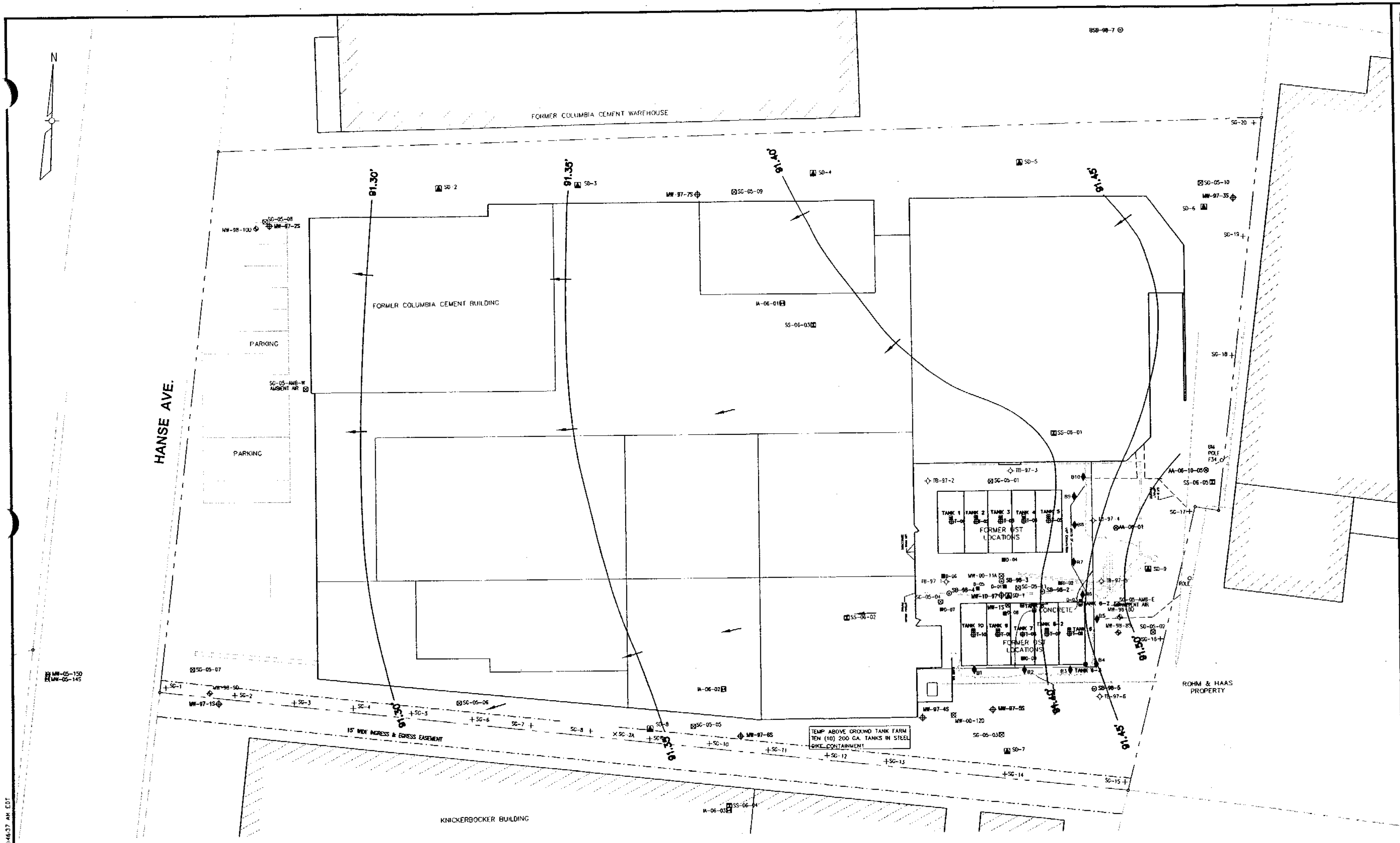
Project Description

Former Columbia
Cement Company. Inc.
159 Hanse Avenue
Freeport, New York

Sheet Title:

GROUNDWATER ELEVATION CONTOUR MAP (LOW TIDE-MAY 3, 2000)

Drawn By:	J.T.	11/05/03
Checked By:	M.B.	11/07/03
Scale:	AS SHOWN	
Project Number:	38546433	
Sheet Number:	FIGURE 4	



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REFERENCE:
REMEDIAL INVESTIGATION REPORT
COLUMBIA CEMENT COMPANY, INC.
159 HANSE AVENUE
FREEPORT, NEW YORK 11520
SITE # 1-30-052
JULY 2003
PREPARED BY DELAWARE
ENGINEERING, P.C.

LEGEND:

MW-1S	⊗	1988 MONITORING WELL LOCATION 1997
MW-97-5S	⊕	MONITORING WELL LOCATION 1998
MW-98-9D	⊕	MONITORING WELL LOCATION 2000
MW-00-11A	☒	MONITORING WELL LOCATION 2005 OFFSITE
	⊞	MONITORING WELL LOCATION
SD-1	▣	STORM DRAIN LOCATION SOIL
SG-05-01	☒	GAS SAMPLING LOCATIONS
SS-06-01	▣	SUB-SLAB VAPOR SAMPLING LOCATION
IA-06-01	▣	INDOOR AIR SAMPLING LOCATION
AA-06-01	⊗	AMBIENT AIR SAMPLING LOCATION

BENCHMARK ESTABLISHED BY
RUST E & I AT
UTILITY POLE F34
ASSUMED DATUM = 100.00 FT.

NOTE:
BASE MAP PROVIDED BY DELAWARE ENGINEERING, P.C.

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Issue Date:	04/20/05	
Revisions		
No.	Date	Description

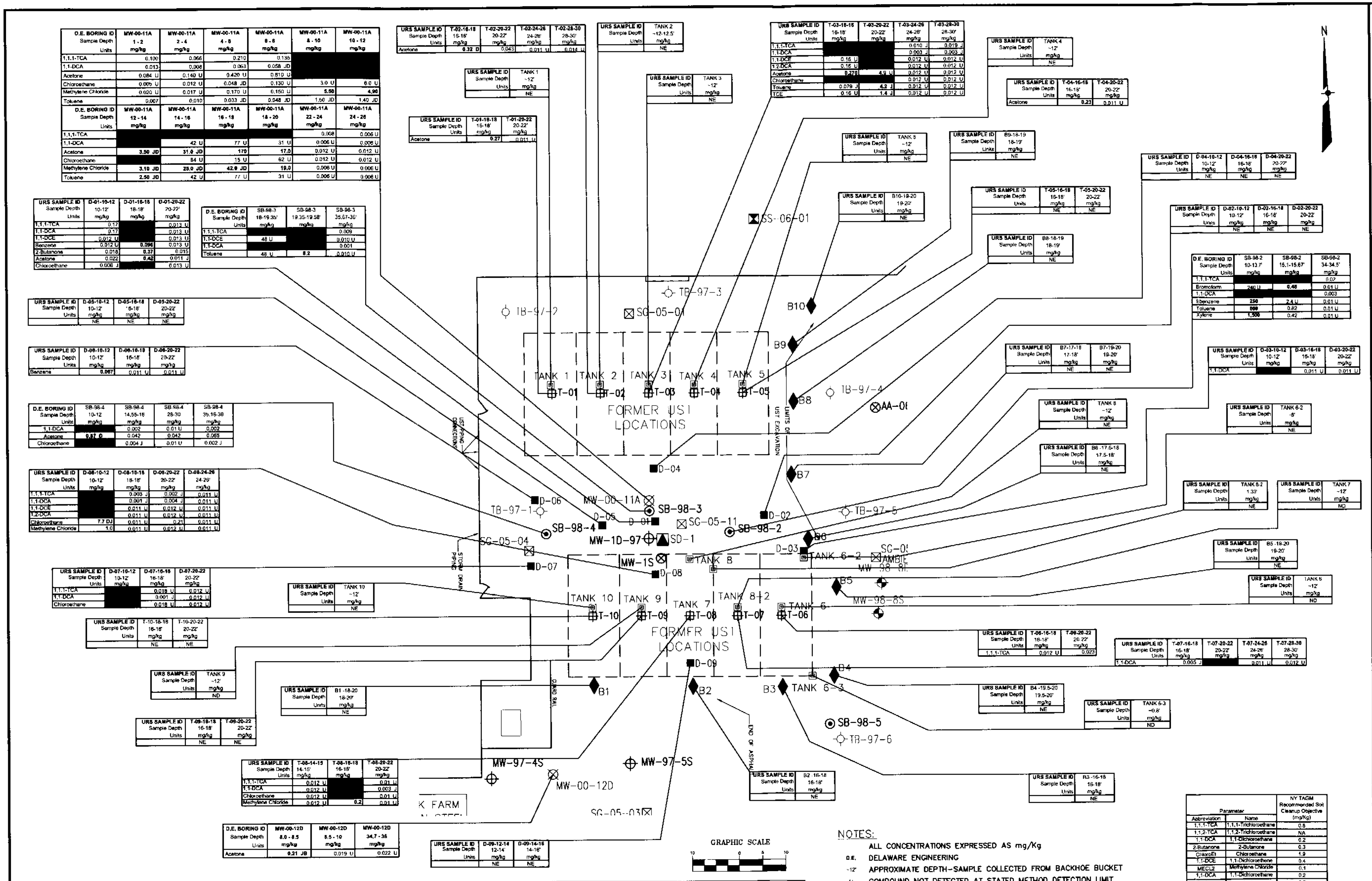
Project Description

Former Columbia Cement Company. Inc.
159 Hanse Avenue
Freeport, New York

Sheet Title:

GROUNDWATER ELEVATION CONTOUR MAP
(MEAN TIDE-MAY 3, 2000)

Drawn By:	J.T.	11/05/03
Checked By:	M.B.	11/07/03
Scale:	AS SHOWN	
Project Number:	38546433	
Sheet Number:	FIGURE 5	



D.E. BORING ID Sample Depth Units	MW-00-11A 1 - 2 mg/kg	MW-00-11A 2 - 4 mg/kg	MW-00-11A 4 - 6 mg/kg	MW-00-11A 6 - 8 mg/kg	MW-00-11A 8 - 10 mg/kg	MW-00-11A 10 - 12 mg/kg
1,1,1-TCA	0.100	0.066	0.210	0.135	■	■
1,1-DCA	0.013	0.008	0.063	0.058 JD	■	■
Acetone	0.084 U	0.140 U	0.420 U	0.810 U	■	■
Chloroethane	0.005 U	0.012 U	0.048 JD	0.130 U	3.0 U	6.0 U
Methylene Chloride	0.020 U	0.017 U	0.170 U	0.150 U	**5.50**	**4.90**
Toluene	0.007	0.010	0.033 JD	0.048 JD	1.50 JD	1.40 JD

D.E. BORING ID Sample Depth Units	MW-00-11A 12 - 14 mg/kg	MW-00-11A 14 - 16 mg/kg	MW-00-11A 16 - 18 mg/kg	MW-00-11A 18 - 20 mg/kg	MW-00-11A 22 - 24 mg/kg	MW-00-11A 24 - 26 mg/kg
1,1,1-TCA	■	■	■	■	0.008	0.006 U
1,1-DCA	■	42 U	77 U	31 U	0.006 U	0.006 U
Acetone	**3.50 JD**	**31.0 JD**	**170**	**17.0**	0.012 U	0.012 U
Chloroethane	■	84 U	15 U	62 U	0.012 U	0.012 U
Methylene Chloride	**3.10 JD**	**25.0 JD**	**42.0 JD**	**19.0**	0.006 U	0.006 U
Toluene	**2.50 JD**	42 U	77 U	31 U	0.006 U	0.006 U

URS SAMPLE ID Sample Depth Units	D-01-10-12 10-12' mg/kg	D-01-16-18 16-18' mg/kg	D-01-20-22 20-22' mg/kg
1,1,1-TCA	0.17	■	0.013 U
1,1-DCA	0.17	■	0.013 U
1,1-DCE	0.012 U	■	0.013 U
Benzene	0.012 U	**0.096**	0.013 U
2-Butanone	0.018	**0.37**	0.015
Acetone	0.022	**0.42**	0.011 J
Chloroethane	0.006 J	■	0.013 U

D.E. BORING ID Sample Depth Units	SB-98-3 18-19.35' mg/kg	SB-98-3 19.35-19.58' mg/kg	SB-98-3 35.67-36' mg/kg
1,1,1-TCA	■	■	0.009
1,1-DCE	48 U	■	0.010 U
1,1-DCA	■	■	0.001
Toluene	48 U	**8.2**	0.010 U

URS SAMPLE ID Sample Depth Units	D-05-10-12 10-12' mg/kg	D-05-16-18 16-18' mg/kg	D-05-20-22 20-22' mg/kg
	NE	NE	NE

URS SAMPLE ID Sample Depth Units	D-06-10-12 10-12' mg/kg	D-06-16-18 16-18' mg/kg	D-06-20-22 20-22' mg/kg
Benzene	**0.067**	0.011 U	0.011 U

D.E. BORING ID Sample Depth Units	SB-98-4 10-12 mg/kg	SB-98-4 14.55-16 mg/kg	SB-98-4 28-30 mg/kg	SB-98-4 35.16-36 mg/kg
1,1-DCA	■	0.002	0.01 U	0.002
Acetone	**0.57 D**	0.042	0.042	0.065
Chloroethane	■	0.004 J	0.01 U	0.002 J

URS SAMPLE ID Sample Depth Units	D-08-10-12 10-12' mg/kg	D-08-16-18 16-18' mg/kg	D-08-20-22 20-22' mg/kg	D-08-24-26 24-26' mg/kg
1,1,1-TCA	■	0.003 J	0.002 J	0.011 U
1,1-DCA	■	0.001 J	0.004 J	0.011 U
1,1-DCE	■	0.011 U	0.012 U	0.011 U
1,2-DCA	■	0.011 U	0.012 U	0.011 U
Chloroethane	7.7 DJ	0.011 U	0.21	0.011 U
Methylene Chloride	1.0	0.011 U	0.012 U	0.011 U

URS SAMPLE ID Sample Depth Units	D-07-10-12 10-12' mg/kg	D-07-16-18 16-18' mg/kg	D-07-20-22 20-22' mg/kg
1,1,1-TCA	■	0.018 U	0.012 U
1,1-DCA	■	0.001 J	0.012 U
Chloroethane	■	0.018 U	0.012 U

URS SAMPLE ID Sample Depth Units	TANK 10 ~12' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	T-10-16-18 16-18' mg/kg	T-10-20-22 20-22' mg/kg
	NE	NE

URS SAMPLE ID Sample Depth Units	TANK 9 ~12' mg/kg
	ND

URS SAMPLE ID Sample Depth Units	B1 -18-20 18-20' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	T-09-16-18 16-18' mg/kg	T-09-20-22 20-22' mg/kg
	NE	NE

URS SAMPLE ID Sample Depth Units	T-08-14-15 14-15' mg/kg	T-08-16-18 16-18' mg/kg	T-08-20-22 20-22' mg/kg
1,1,1-TCA	0.012 U	■	0.01 U
1,1-DCA	0.012 U	■	0.003 J
Chloroethane	0.012 U	■	0.01 U
Methylene Chloride	0.012 U	**0.2**	0.01 U

D.E. BORING ID Sample Depth Units	MW-00-12D 8.0 - 8.5 mg/kg	MW-00-12D 8.5 - 10 mg/kg	MW-00-12D 34.7 - 36 mg/kg
Acetone	**0.21 JB**	0.019 U	0.022 U

URS SAMPLE ID Sample Depth Units	D-09-12-14 12-14' mg/kg	D-09-14-16 14-16' mg/kg
	NE	NE

URS SAMPLE ID Sample Depth Units	T-02-16-18 16-18' mg/kg	T-02-20-22 20-22' mg/kg	T-02-24-26 24-26' mg/kg	T-02-28-30 28-30' mg/kg
Acetone	**0.32 D**	0.043	0.011 U	0.014 U

URS SAMPLE ID Sample Depth Units	TANK 2 ~12-12.5' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	TANK 1 ~12' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	TANK 3 ~12' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	T-01-16-18 16-18' mg/kg	T-01-20-22 20-22' mg/kg
Acetone	**0.27**	0.011 U

URS SAMPLE ID Sample Depth Units	T-03-16-18 16-18' mg/kg	T-03-20-22 20-22' mg/kg	T-03-24-26 24-26' mg/kg	T-03-28-30 28-30' mg/kg
1,1,1-TCA	■	■	0.010 J	0.019 J
1,1-DCA	■	■	0.003 J	0.003 J
1,1-DCE	0.16 U	■	0.012 U	0.012 U
1,2-DCA	0.16 U	■	0.012 U	0.012 U
Acetone	**0.270**	4.9 U	0.012 U	0.012 U
Chloroethane	■	■	0.012 U	0.012 U
Toluene	0.079 J	**4.2 J**	0.012 U	0.012 U
TCE	0.16 U	**1.4 J**	0.012 U	0.012 U

URS SAMPLE ID Sample Depth Units	TANK 4 ~12' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	T-04-16-18 16-18' mg/kg	T-04-20-22 20-22' mg/kg
Acetone	**0.23**	0.011 U

URS SAMPLE ID Sample Depth Units	TANK 5 ~12' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	B9-18-19 18-19' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	B10-19-20 19-20' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	D-04-10-12 10-12' mg/kg	D-04-16-18 16-18' mg/kg	D-04-20-22 20-22' mg/kg
	NE	NE	NE

URS SAMPLE ID Sample Depth Units	T-05-16-18 16-18' mg/kg	T-05-20-22 20-22' mg/kg
	NE	NE

URS SAMPLE ID Sample Depth Units	D-02-10-12 10-12' mg/kg	D-02-16-18 16-18' mg/kg	D-02-20-22 20-22' mg/kg
	NE	NE	NE

URS SAMPLE ID Sample Depth Units	B8-18-19 18-19' mg/kg
	NE

D.E. BORING ID Sample Depth Units	SB-98-2 10-13.7' mg/kg	SB-98-2 15.1-15.67' mg/kg	SB-98-2 34-34.5' mg/kg
1,1,1-TCA	■	■	0.02
Bromoform	240 U	**0.46**	0.01 U
1,1-DCA	■	■	0.003
Ebenzene	**250**	2.4 U	0.01 U
Toluene	**660**	0.82	0.01 U
Xylene	**1,500**	0.42	0.01 U

URS SAMPLE ID Sample Depth Units	B7-17-18 17-18' mg/kg	B7-19-20 19-20' mg/kg
	NE	NE

URS SAMPLE ID Sample Depth Units	D-03-10-12 10-12' mg/kg	D-03-16-18 16-18' mg/kg	D-03-20-22 20-22' mg/kg
1,1-DCA	■	0.011 U	0.011 U

URS SAMPLE ID Sample Depth Units	TANK 8 ~12' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	TANK 6-2 -8' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	B6 -17.5-18 17.5-18' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	TANK 8-2 1.33' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	TANK 7 ~12' mg/kg
	ND

URS SAMPLE ID Sample Depth Units	B5 -19-20 19-20' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	TANK 6 ~12' mg/kg
	ND

URS SAMPLE ID Sample Depth Units	T-06-16-18 16-18' mg/kg	T-06-20-22 20-22' mg/kg
1,1,1-TCA	0.012 U	0.023

URS SAMPLE ID Sample Depth Units	T-07-16-18 16-18' mg/kg	T-07-20-22 20-22' mg/kg	T-07-24-26 24-26' mg/kg	T-07-28-30 28-30' mg/kg
1,1-DCA	0.005 J	■	0.011 U	0.012 U

URS SAMPLE ID Sample Depth Units	B4 -19.5-20 19.5-20' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	TANK 6-3 ~0.8' mg/kg
	ND

URS SAMPLE ID Sample Depth Units	B2 16-18 16-18' mg/kg
	NE

URS SAMPLE ID Sample Depth Units	B3 -16-18 16-18' mg/kg
	NE

Parameter		NY TAGM Recommended Soil Cleanup Objective (mg/Kg)
Abbreviation	Name	
1,1,1-TCA	1,1,1-Trichloroethane	0.8
1,1,2-TCA	1,1,2-Trichloroethane	NA
1,1-DCA	1,1-Dichloroethane	0.2
2-Butanone	2-Butanone	0.3
ChloroEt	Chloroethane	1.9
1,1-DCE	1,1-Dichloroethene	0.4
MECL2	Methylene Chloride	0.1
1,1-DCA	1,1-Dichloroethane	0.2
Acetone	Acetone	0.2
Benzene	Benzene	0.06
CDisulfide	Carbon Disulfide	2.7
Cbenzene	Chlorobenzene	1.7
PCE	Tetrachloroethene	1.4
Ebenzene	Ethylbenzene	5.5
TCE	Trichloroethene	0.7
Toluene	Toluene	1.5
Xylene	Xylenes (Total)	1.2
4-m-2p	4-methyl-2-pentanone	1.0
2-Hexanone	2-Hexanone	NA

NOTES:

DATA FROM SB-98-2, SB-98-3, SB-98-4, SB-98-5, MW-00-11A AND MW-00-12A FROM DELAWARE ENGINEERING REMEDIAL INVESTIGATION REPORT, DECEMBER 2003.

LEGEND:

T-1 ⊕	UST CONFIRMATION BORING
D-6 ■	SOURCE DELINEATION BORING
B1 ◆	PRE-CLOSURE SOIL BORING
MW-00-11A ☒	2000 MONITORING WELL LOCATION
SD-1 ▲	STORM DRAIN
SB-98-1 ◉	1998 SOIL SAMPLING LOCATION
TANK 1 ▣	UST CLOSURE POST-EXCAVATION SAMPLE LOCATION

NOTES:

	ALL CONCENTRATIONS EXPRESSED AS mg/Kg
D.E.	DELAWARE ENGINEERING
~12'	APPROXIMATE DEPTH-SAMPLE COLLECTED FROM BACKHOE BUCKET
U	COMPOUND NOT DETECTED AT STATED METHOD DETECTION LIMIT
J	ESTIMATED CONCENTRATION
D	RESULT FROM DILUTED SAMPLE ANALYSIS
E	RESULT EXCEEDS INSTRUMENT CALIBRATION RANGE
ND	NO POSITIVE DETECTIONS
NE	NOT EXCEEDENCES OF TAGM RECOMMENDED SOIL CLEANUP OBJECTIVES
BOLD	RESULTS EXCEEDS TAGM RECOMMENDED SOIL CLEANUP OBJECTIVES
■	EXCEEDENCE OF COMPOUND RELATED TO 1988 1,1,1-TCA SPILL
☐	EXCEEDENCE OF COMPOUND NOT RELATED TO 1988 1,1,1-TCA SPILL

Atlantic Richfield Company
(A BP Affiliated Company)

URS
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Issue Date: 04/20/05

Revisions		
No.	Date	Description

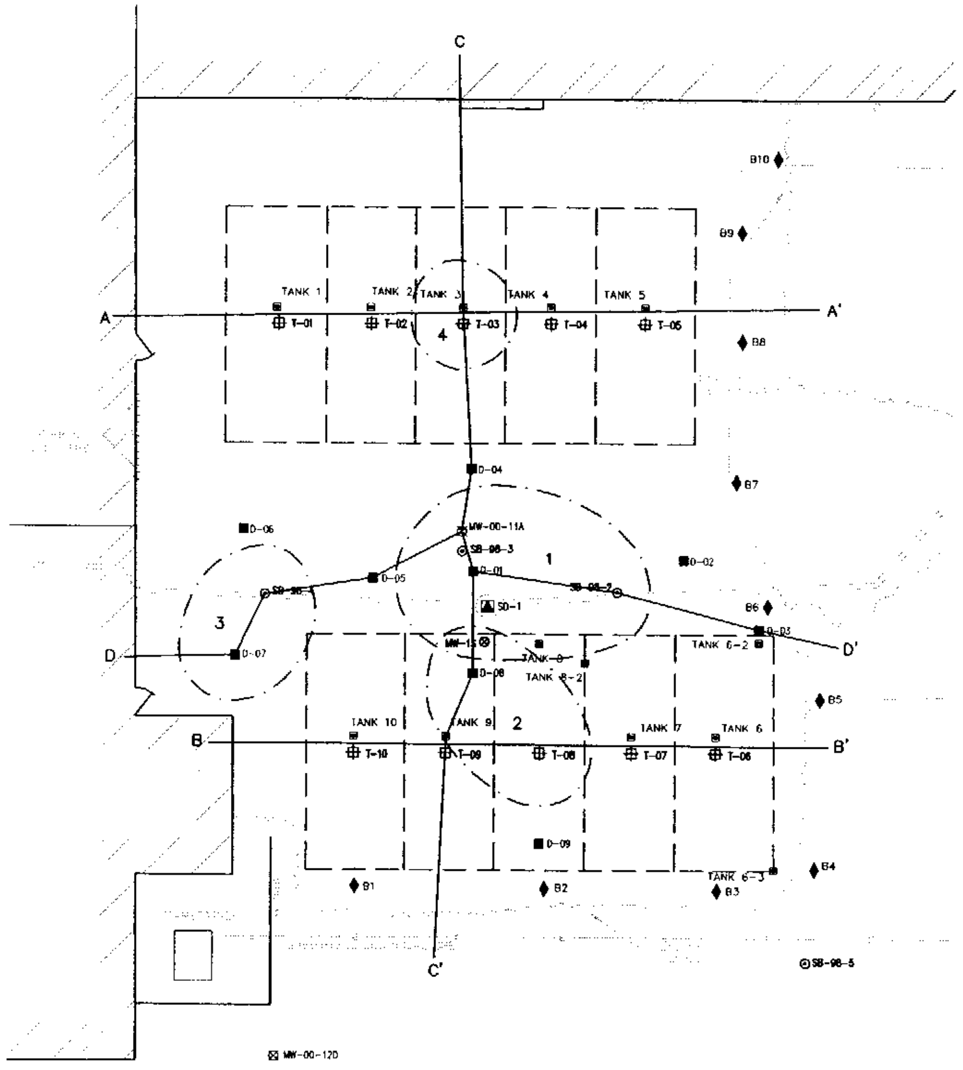
Project Description

Former Columbia Cement Company. Inc.
159 Hanse Avenue
Freeport, New York

Sheet Title:

SOIL BORING VOLATILE ORGANIC DATA

Drawn By:	J.T.	12/18/06
Checked By:	M.B.	12/18/06
Scale:	AS SHOWN	
Project Number:	38546433	
Sheet Number:	FIGURE 6	



N

RESIDUAL SOURCE AREA	IMPACTED INTERVAL (AT BELOW GRADE)	AREA (SQ. FT)	IMPACTED SOIL VOLUME (CU YD)	OVERBURDEN VOLUME (CU YD)
1	6-20	1140	507	337
2	12-16			
3	10-15	225	42	83
4	12 22	156	58	69
TOTAL			607	489

LEGEND:

SB-98-1 ⊙ 1998 SOIL SAMPLING LOCATION
TANK 1 ▣ UST CLOSURE POST-EXCAVATION SAMPLE LOCATION
T-1 ⊕ UST CONFIRMATION BORING
MW-00-11A ⊠ 2000 MONITORING WELL LOCATION
SD-1 ▲ STORM DRAIN
D-6 ■ SOURCE DELINEATION BORING
B1 ◆ PRE-CLOSURE SOIL BORING
▭ FORMER UST LOCATION
○ RESIDUAL SOURCE AREA
A——A' CROSS-SECCTION LINE

NOTE:
BASE MAP PROVIDED BY DELAWARE ENGINEERING, P.C.

GRAPHIC SCALE
10 0 5 10

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(A BP Affiliated Company)

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Revisions		
No.	Date	Description

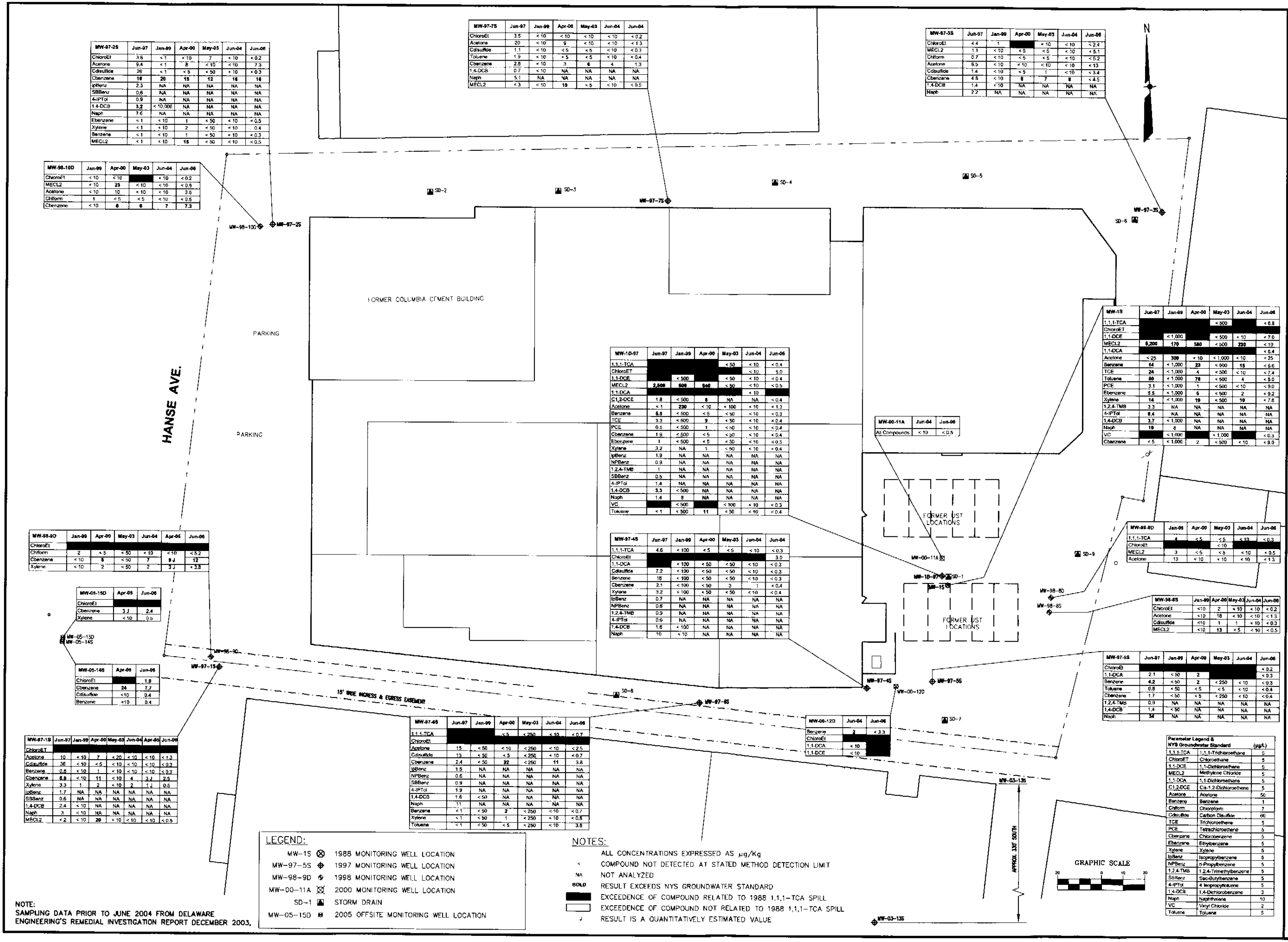
Project Description

Former Columbia Cement Company. Inc.
159 Hanse Avenue
Freeport, New York

Sheet Title:

RESIDUAL SOIL SOURCE AREAS

Drawn By:	J.T.	12/18/06
Checked By:	M.B.	1218/06
Scale:	AS SHOWN	
Project Number:	38546433	
Sheet Number:	FIGURE 7	



MW-97-2S	Jun-97	Jan-99	Apr-00	May-03	Jun-04	Jun-06
ChloroEt	3.6	< 1	< 10	7	< 10	< 0.2
Acetone	9.4	< 1	8	< 10	< 10	7.3
Cdisulfide	26	< 1	< 5	< 50	< 10	< 0.3
Cbenzene	**16**	**20**	**15**	**12**	**16**	**16**
IpBenz	2.3	NA	NA	NA	NA	NA
SBBenz	0.6	NA	NA	NA	NA	NA
4-IPTol	0.9	NA	NA	NA	NA	NA
1,4-DCB	**3.2**	< 10,000	NA	NA	NA	NA
Naph	7.6	NA	NA	NA	NA	NA
Ebenzene	< 1	< 10	1	< 50	< 10	< 0.5
Xylene	< 1	< 10	2	< 50	< 10	0.4
Benzene	< 1	< 10	1	< 50	< 10	< 0.3
MECL2	< 1	< 10	**15**	< 50	< 10	< 0.5

MW-98-10D	Jan-99	Apr-00	May-03	Jun-04	Jun-06
ChloroEt	< 10	< 10	■	< 10	< 0.2
MECL2	< 10	**23**	< 10	< 10	< 0.5
Acetone	< 10	10	< 10	< 10	3.5
Chlform	1	< 5	< 5	< 10	< 0.5
Chenzene	< 10	**6**	**6**	**7**	**7.3**

MW-97-7S	Jun-97	Jan-99	Apr-00	May-03	Jun-04	Jun-04
ChloroEt	3.5	< 10	< 10	< 10	< 10	< 0.2
Acetone	20	< 10	9	< 10	< 10	< 1.3
Cdisulfide	1.1	< 10	< 5	< 5	< 10	< 0.3
Toluene	1.9	< 10	< 5	< 5	< 10	< 0.4
Cbenzene	2.6	< 10	3	**6**	4	1.3
1,4-DCB	0.7	< 10	NA	NA	NA	NA
Naph	5.1	NA	NA	NA	NA	NA
MECL2	< 3	< 10	**19**	< 5	< 10	< 0.5

MW-97-3S	Jun-97	Jan-99	Apr-00	May-03	Jun-04	Jun-06
ChloroEt	4.4	1	■	< 10	< 10	< 2.4
MECL2	1.1	< 10	< 5	< 5	< 10	< 5.1
Chlform	0.7	< 10	< 5	< 5	< 10	< 5.2
Acetone	6.5	< 10	< 10	< 10	< 10	< 13
Cdisulfide	1.4	< 10	< 5	1	< 10	< 3.4
Cbenzene	4.8	< 10	**8**	**7**	**8**	< 4.5
1,4-DCB	1.4	< 10	NA	NA	NA	NA
Naph	2.2	NA	NA	NA	NA	NA

MW-10-97	Jun-97	Jan-99	Apr-00	May-03	Jun-04	Jun-06
1,1,1-TCA	■	■	■	< 50	< 10	< 0.4
ChloroET	■	■	■	■	< 10	5.0
1,1-DCE	■	< 500	■	< 50	< 10	< 0.4
MECL2	**2,500**	**600**	**640**	< 50	< 10	< 0.5
1,1-DCA	■	■	■	■	< 10	■
C1,2-DCE	1.8	< 500	**6**	NA	NA	< 0.4
Acetone	< 1	**230**	< 10	< 100	< 10	< 1.3
Benzene	**5.5**	< 500	< 5	< 50	< 10	< 0.3
TCE	3.3	< 500	**9**	< 50	< 10	< 0.4
PCE	0.5	< 500	1	< 50	< 10	< 0.4
Cbenzene	1.9	< 500	< 5	< 50	< 10	< 0.4
Ebenzene	1	< 500	< 5	< 50	< 10	< 0.5
Xylene	3.2	NA	1	< 50	< 10	< 0.4
IpBenz	1.9	NA	NA	NA	NA	NA
NPBenz	0.9	NA	NA	NA	NA	NA
1,2,4-TMB	1	NA	NA	NA	NA	NA
SBBenz	0.5	NA	NA	NA	NA	NA
4-IPTol	1.4	NA	NA	NA	NA	NA
1,4-DCB	**3.3**	< 500	NA	NA	NA	NA
Naph	1.4	8	NA	NA	NA	NA
VC	■	< 500	■	< 100	< 10	< 0.3
Toluene	< 1	< 500	**11**	< 50	< 10	< 0.4

MW-97-4S	Jun-97	Jan-99	Apr-00	May-03	Jun-04	Jun-04
1,1,1-TCA	4.6	< 100	< 5	< 5	< 10	< 0.3
ChloroEt	■	■	■	■	■	3.0
1,1-DCA	■	< 100	< 50	< 50	< 10	< 0.3
Cdisulfide	7.2	< 100	< 50	< 50	< 10	< 0.3
Benzene	16	< 100	< 50	< 50	< 10	< 0.3
Cbenzene	2.1	< 100	< 50	3	1	< 0.4
Xylene	3.2	< 100	< 50	< 50	< 10	< 0.4
IpBenz	0.7	NA	NA	NA	NA	NA
NPBenz	0.6	NA	NA	NA	NA	NA
1,2,4-TMB	0.9	NA	NA	NA	NA	NA
4-IPTol	0.6	NA	NA	NA	NA	NA
1,4-DCB	1.6	< 100	NA	NA	NA	NA
Naph	10	< 10	NA	NA	NA	NA

MW-00-11A	Jun-04	Jun-06
All Compounds	< 10	< 0.5

MW-1S	Jun-97	Jan-99	Apr-00	May-03	Jun-04	Jun-06
1,1,1-TCA	■	■	■	< 500	■	< 6.8
ChloroET	■	■	■	■	■	■
1,1-DCE	■	< 1,000	■	< 500	< 10	< 7.0
MECL2	**6,200**	**170**	**580**	< 500	**230**	< 10
1,1-DCA	■	■	■	■	■	< 6.4
Acetone	< 25	**300**	< 10	< 1,000	< 10	< 25
Benzene	**14**	< 1,000	**23**	< 500	**15**	< 6.6
TCE	**24**	< 1,000	4	< 500	< 10	< 7.4
Toluene	**80**	< 1,000	**78**	< 500	4	< 8.0
PCE	3.1	< 1,000	1	< 500	< 10	< 9.0
Ebenzene	**5.5**	< 1,000	**6**	< 500	2	< 9.2
Xylene	**14**	< 1,000	**19**	< 500	**19**	< 7.6
1,2,4-TMB	3.3	NA	NA	NA	NA	NA
4-IPTol	**6.4**	NA	NA	NA	NA	NA
1,4-DCB	**3.7**	< 1,000	NA	NA	NA	NA
Naph	**19**	8	NA	NA	NA	NA
VC	■	< 1,000	■	< 1,000	■	< 0.3
Cbenzene	< 5	< 1,000	2	< 500	< 10	< 9.0

MW-98-8D	Jan-99	Apr-00	May-03	Jun-04	Jun-06
1,1,1-TCA	4	< 5	< 5	< 10	< 0.3
ChloroEt	■	■	< 10	■	■
MECL2	3	< 5	< 5	< 10	< 0.5
Acetone	13	< 10	< 10	< 10	< 1.3

MW-98-8S	Jan-99	Apr-00	May-03	Jun-04	Jun-06
ChloroEt	<10	2	< 10	< 10	< 0.2
Acetone	<10	18	< 10	< 10	< 1.3
Cdisulfide	<10	1	1	< 10	< 0.3
MECL2	<10	**13**	< 5	< 10	< 0.5

MW-97-5S	Jun-97	Jan-99	Apr-00	May-03	Jun-04	Jun-06
ChloroEt	■	■	■	■	■	< 0.2
1,1-DCA	2.1	< 50	2	■	■	< 0.3
Benzene	**4.2**	< 50	**2**	< 250	< 10	< 0.3
Toluene	0.8	< 50	< 5	< 5	< 10	< 0.4
Cbenzene	1.7	< 50	< 5	< 250	< 10	< 0.4
1,2,4-TMB	0.9	NA	NA	NA	NA	NA
1,4-DCB	1.4	< 50	NA	NA	NA	NA
Naph	**34**	NA	NA	NA	NA	NA

MW-98-9D	Jan-99	Apr-00	May-03	Jun-04	Apr-05	Jun-06
ChloroEt	■	■	■	■	■	■
Chlform	2	< 5	< 50	< 10	< 10	< 5.2
Cbenzene	< 10	**5**	< 50	**7**	**9 J**	**12**
Xylene	< 10	2	< 50	2	3 J	< 3.8

MW-05-15D	Apr-05	Jun-06
ChloroEt	■	■
Cbenzene	3 J	2.4
Xylene	< 10	0.5

MW-05-14S	Apr-05	Jun-06
ChloroEt	■	1.0
Cbenzene	**24**	**7.7**
Cdisulfide	<10	0.4
Benzene	<10	0.4

MW-97-1S	Jun-97	Jan-99	Apr-00	May-03	Jun-04	Apr-05	Jun-06
ChloroET	■	■	■	■	■	■	■
Acetone	10	< 10	7	< 20	< 10	< 10	< 1.3
Cdisulfide	36	< 10	< 5	< 10	< 10	< 10	< 0.3
Benzene	0.6	< 10	1	< 10	< 10	< 10	< 0.3
Cbenzene	**6.8**	< 10	**11**	< 10	4	3 J	2.5
Xylene	3.3	1	2	< 10	2	1 J	0.5
IpBenz	1.7	NA	NA	NA	NA	NA	NA
SBBenz	0.6	NA	NA	NA	NA	NA	NA
1,4-DCB	2.4	< 10	NA	NA	NA	NA	NA
Naph	3	< 10	NA	NA	NA	NA	NA
MECL2	< 2	< 10	**20**	< 10	< 10	< 10	< 0.5

MW-97-6S	Jun-97	Jan-99	Apr-00	May-03	Jun-04	Jun-06
1,1,1-TCA	■	■	< 5	< 250	< 10	< 0.7
ChloroEt	■	■	■	■	■	■
Acetone	15	< 50	< 10	< 250	< 10	< 2.5
Cdisulfide	13	< 50	< 5	< 250	< 10	< 0.7
Cbenzene	2.4	< 50	**32**	< 250	**11**	3.8
IpBenz	1.5	NA	NA	NA	NA	NA
NPBenz	0.6	NA	NA	NA	NA	NA
SBBenz	0.9	NA	NA	NA	NA	NA
4-IPTol	1.9	NA	NA	NA	NA	NA
1,4-DCB	1.6	< 50	NA	NA	NA	NA
Naph	11	NA	NA	NA	NA	NA
Benzene	< 1	< 50	**2**	< 250	< 10	< 0.7
Xylene	< 1	< 50	1	< 250	< 10	< 0.8
Toluene	< 1	< 50	< 5	< 250	< 10	3.8

MW-00-12D	Jun-04	Jun-06
Benzene	**2**	< 3.3
ChloroEt	■	■
1,1-DCA	< 10	■
1,1-DCE	< 10	■

Parameter Legend & NYS Groundwater Standard		(µg/L)
1,1,1-TCA	1,1,1-Trichloroethane	5
ChloroET	Chloroethane	5
1,1-DCE	1,1-Dichloroethene	5
MECL2	Methylene Chloride	5
1,1-DCA	1,1-Dichloroethane	5
C1,2-DCE	Cis-1,2-Dichloroethene	5
Acetone	Acetone	50
Benzene	Benzene	1
Chlform	Chloroform	7
Cdisulfide	Carbon Disulfide	60
TCE	Trichloroethene	5
PCE	Tetrachloroethene	5
Cbenzene	Chlorobenzene	5
Ebenzene	Ethylbenzene	5
Xylene	Xylene	5
IpBenz	Isopropylbenzene	5
NPBenz	n-Propylbenzene	5
1,2,4-TMB	1,2,4-Trimethylbenzene	5
SBBenz	Sec-Butylbenzene	5
4-IPTol	4 Isopropyltoluene	5
1,4-DCB	1,4-Dichlorobenzene	3
Naph	Naphthalene	10
VC	Vinyl Chloride	2
Toluene	Toluene	5

LEGEND:

MW-1S	⊗	1988 MONITORING WELL LOCATION
MW-97-5S	⊕	1997 MONITORING WELL LOCATION
MW-98-9D	◆	1998 MONITORING WELL LOCATION
MW-00-11A	⊠	2000 MONITORING WELL LOCATION
SD-1	▲	STORM DRAIN
MW-05-15D	▪	2005 OFFSITE MONITORING WELL LOCATION

NOTES:

	ALL CONCENTRATIONS EXPRESSED AS µg/Kg
<	COMPOUND NOT DETECTED AT STATED METHOD DETECTION LIMIT
NA	NOT ANALYZED
BOLD	RESULT EXCEEDS NYS GROUNDWATER STANDARD
■	EXCEEDENCE OF COMPOUND RELATED TO 1988 1,1,1-TCA SPILL
□	EXCEEDENCE OF COMPOUND NOT RELATED TO 1988 1,1,1-TCA SPILL
J	RESULT IS A QUANTITATIVELY ESTIMATED VALUE

NOTE:
SAMPLING DATA PRIOR TO JUNE 2004 FROM DELAWARE ENGINEERING'S REMEDIAL INVESTIGATION REPORT DECEMBER 2003.

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Issue Date: 04/20/06

Revisions

No.	Date	Description

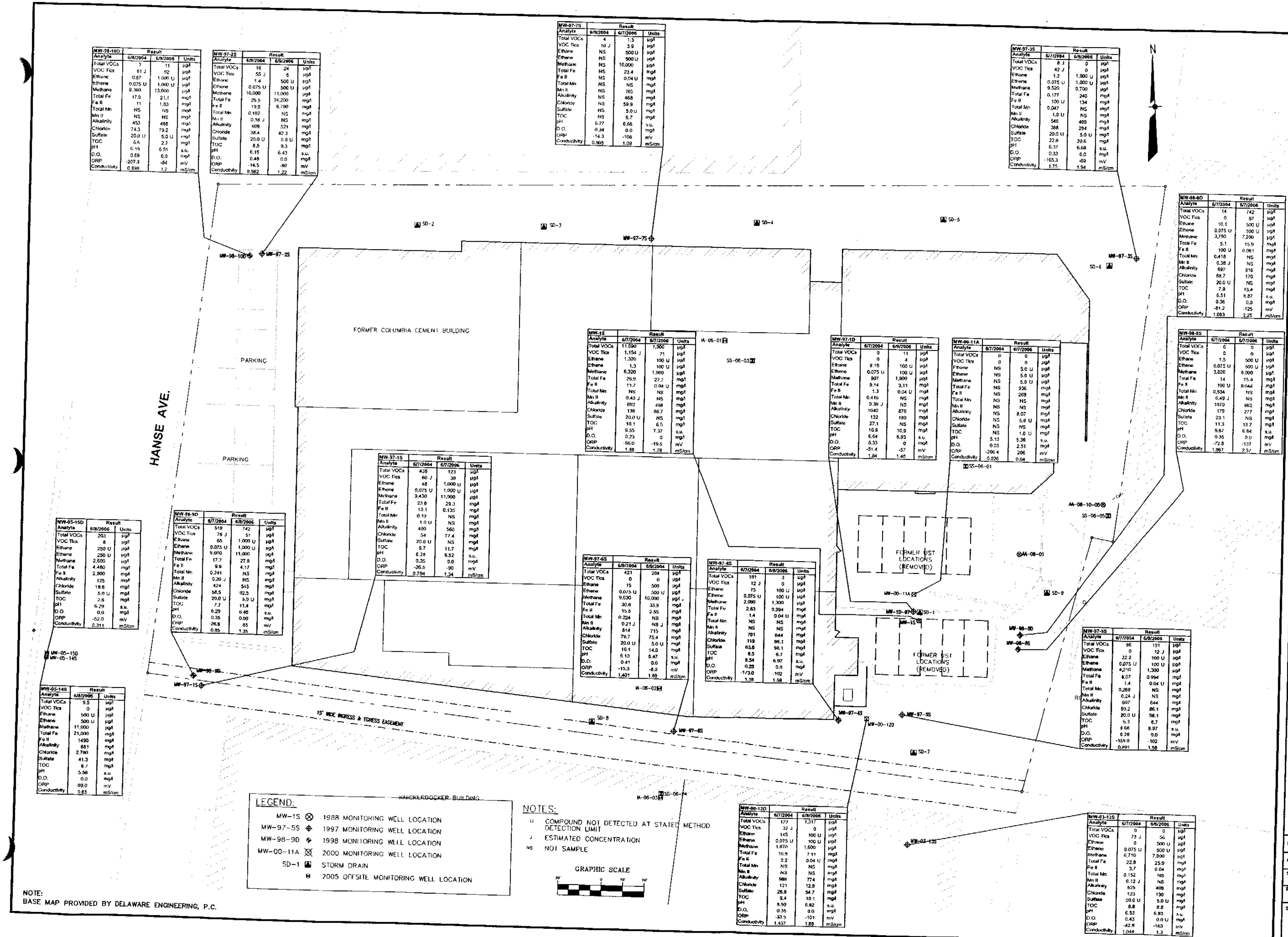
Project Description

Former Columbia
Cement Company. Inc.
159 Hanse Avenue
Freeport, New York

Sheet Title:

GROUNDWATER VOC SAMPLING LOCATIONS AND RESULTS

Drawn By:	J.T.	12/18/06
Checked By:	M.B.	12/18/06
Scale:	AS SHOWN	
Project Number:	38646433	
Sheet Number:	FIGURE 8	



MW-98-10D	Result		
Analyte	6/8/2004	6/9/2006	Units
Total VOCs	7	11	µg/l
VOC Tics	61 J	92	µg/l
Ethane	0.67	1,000 U	µg/l
Ethene	0.075 U	1,000 U	µg/l
Methane	9,360	13,000	µg/l
Total Fe	17.9	21.1	mg/l
Fe II	11	1.63	mg/l
Total Mn	NS	NS	mg/l
Mn II	NS	NS	mg/l
Alkalinity	453	488	mg/l
Chloride	74.3	79.2	mg/l
Sulfate	20.0 U	5.0 U	mg/l
TOC	6.6	2.2	mg/l
pH	6.19	6.51	s.u.
D.O.	0.69	0.0	mg/l
ORP	-207.3	-84	mV
Conductivity	0.899	1.2	mS/cm

MW-97-2S	Result		
Analyte	6/8/2004	6/9/2006	Units
Total VOCs	16	24	µg/l
VOC Tics	55 J	6	µg/l
Ethane	1.4	500 U	µg/l
Ethene	0.075 U	500 U	µg/l
Methane	10,000	11,000	µg/l
Total Fe	29.5	34,200	mg/l
Fe II	19.9	6,790	mg/l
Total Mn	0.192	NS	mg/l
Mn II	0.18 J	NS	mg/l
Alkalinity	606	521	mg/l
Chloride	38.4	42.3	mg/l
Sulfate	20.0 U	5.0 U	mg/l
TOC	8.5	9.3	mg/l
pH	6.15	6.43	s.u.
D.O.	0.48	0.0	mg/l
ORP	-14.5	-80	mV
Conductivity	0.982	1.22	mS/cm

MW-97-7S	Result		
Analyte	6/9/2004	6/7/2006	Units
Total VOCs	4	1.3	µg/l
VOC Tics	10 J	3.9	µg/l
Ethane	NS	500 U	µg/l
Ethene	NS	500 U	µg/l
Methane	NS	10,000	µg/l
Total Fe	NS	23.4	mg/l
Fe II	NS	0.04 U	mg/l
Total Mn	NS	NS	mg/l
Mn II	NS	NS	mg/l
Alkalinity	NS	468	mg/l
Chloride	NS	59.9	mg/l
Sulfate	NS	5.0 U	mg/l
TOC	NS	6.7	mg/l
pH	6.27	6.66	s.u.
D.O.	0.34	0.0	mg/l
ORP	-14.3	-108	mV
Conductivity	0.905	1.09	mS/cm

MW-97-3S	Result		
Analyte	6/7/2004	6/9/2006	Units
Total VOCs	8 J	0	µg/l
VOC Tics	42 J	0	µg/l
Ethane	1.2	1,000 U	µg/l
Ethene	0.075 U	1,000 U	µg/l
Methane	9,520	9,700	µg/l
Total Fe	0.177	240	mg/l
Fe II	100 U	134	mg/l
Total Mn	0.047	NS	mg/l
Mn II	1.0 U	NS	mg/l
Alkalinity	549	499	mg/l
Chloride	388	294	mg/l
Sulfate	20.0 U	5.0 U	mg/l
TOC	22.9	20.6	mg/l
pH	6.37	6.68	s.u.
D.O.	0.33	0.0	mg/l
ORP	-165.3	-69	mV
Conductivity	1.75	1.94	mS/cm

MW-98-8D	Result		
Analyte	6/7/2004	6/7/2006	Units
Total VOCs	14	742	µg/l
VOC Tics	0	57	µg/l
Ethane	10.1	500 U	µg/l
Ethene	0.075 U	500 U	µg/l
Methane	3,790	7,200	µg/l
Total Fe	5.1	15.9	mg/l
Fe II	100 U	0.081	mg/l
Total Mn	0.418	NS	mg/l
Mn II	0.38 J	NS	mg/l
Alkalinity	697	916	mg/l
Chloride	68.7	170	mg/l
Sulfate	20.0 U	NS	mg/l
TOC	7.9	13.4	mg/l
pH	6.51	6.87	s.u.
D.O.	0.36	0.0	mg/l
ORP	-81.2	-125	mV
Conductivity	1.083	2.25	mS/cm

MW-98-8S	Result		
Analyte	6/7/2004	6/7/2006	Units
Total VOCs	0	0	µg/l
VOC Tics	0	0	µg/l
Ethane	1.5	500 U	µg/l
Ethene	0.075 U	500 U	µg/l
Methane	3,820	8,000	µg/l
Total Fe	14	15.4	mg/l
Fe II	100 U	0.044	mg/l
Total Mn	0.534	NS	mg/l
Mn II	0.49 J	NS	mg/l
Alkalinity	1070	862	mg/l
Chloride	179	277	mg/l
Sulfate	23.1	NS	mg/l
TOC	11.3	13.7	mg/l
pH	6.67	6.84	s.u.
D.O.	0.35	0.0	mg/l
ORP	-72.8	-137	mV
Conductivity	1.967	2.57	mS/cm

MW-1S	Result		
Analyte	6/7/2004	6/7/2006	Units
Total VOCs	11,090	1,900	µg/l
VOC Tics	1,154 J	71	µg/l
Ethane	1,320	100 U	µg/l
Ethene	1.3	100 U	µg/l
Methane	6,320	1,900	µg/l
Total Fe	26.9	27.7	mg/l
Fe II	11.7	0.04 U	mg/l
Total Mn	NS	NS	mg/l
Mn II	0.43 J	NS	mg/l
Alkalinity	893	498	mg/l
Chloride	138	86.7	mg/l
Sulfate	20.0 U	NS	mg/l
TOC	10.1	6.5	mg/l
pH	6.55	7.37	s.u.
D.O.	0.23	0	mg/l
ORP	-86.0	-19.5	mV
Conductivity	1.48	1.28	mS/cm

MW-97-1D	Result		
Analyte	6/7/2004	6/9/2006	Units
Total VOCs	0	11	µg/l
VOC Tics	0	4	µg/l
Ethane	8.19	100 U	µg/l
Ethene	0.075 U	100 U	µg/l
Methane	907	1,900	µg/l
Total Fe	9.14	3.11	mg/l
Fe II	1.3	0.04 U	mg/l
Total Mn	0.416	NS	mg/l
Mn II	0.39 J	NS	mg/l
Alkalinity	1040	876	mg/l
Chloride	132	180	mg/l
Sulfate	27.1	NS	mg/l
TOC	10.9	10.9	mg/l
pH	6.64	6.93	s.u.
D.O.	0.33	0	mg/l
ORP	-51.4	-57	mV
Conductivity	1.84	1.46	mS/cm

MW-00-11A	Result		
Analyte	6/7/2004	6/7/2006	Units
Total VOCs	0	0	µg/l
VOC Tics	0	0	µg/l
Ethane	NS	5.0 U	µg/l
Ethene	NS	5.0 U	µg/l
Methane	NS	5.0 U	µg/l
Total Fe	NS	936	mg/l
Fe II	NS	268	mg/l
Total Mn	NS	NS	mg/l
Mn II	NS	NS	mg/l
Alkalinity	NS	8.07	mg/l
Chloride	NS	5.0 U	mg/l
Sulfate	NS	NS	mg/l
TOC	NS	1.0 U	mg/l
pH	5.13	5.36	s.u.
D.O.	0.25	2.51	mg/l
ORP	-206.4	206	mV
Conductivity	0.026	0.04	mS/cm

MW-97-1S	Result		
Analyte	6/7/2004	6/7/2006	Units
Total VOCs	436	123	µg/l
VOC Tics	60 J	39	µg/l
Ethane	48	1,000 U	µg/l
Ethene	0.075 U	1,000 U	µg/l
Methane	9,430	11,000	µg/l
Total Fe	23.8	29.3	mg/l
Fe II	13.1	0.135	mg/l
Total Mn	0.13	NS	mg/l
Mn II	1.0 U	NS	mg/l
Alkalinity	400	560	mg/l
Chloride	54	77.4	mg/l
Sulfate	20.0 U	NS	mg/l
TOC	6.7	11.7	mg/l
pH	6.28	6.52	s.u.
D.O.	0.35	0.0	mg/l
ORP	-26.6	-90	mV
Conductivity	0.794	1.34	mS/cm

MW-05-15D	Result	
Analyte	6/8/2006	Units
Total VOCs	203	µg/l
VOC Tics	8	µg/l
Ethane	250 U	µg/l
Ethene	250 U	µg/l
Methane	2,600	µg/l
Total Fe	4,480	mg/l
Fe II	2,900	mg/l
Alkalinity	125	mg/l
Chloride	18.6	mg/l
Sulfate	5.0 U	mg/l
TOC	2.6	mg/l
pH	6.29	s.u.
D.O.	0.0	mg/l
ORP	-52.0	mV
Conductivity	0.311	mS/cm

MW-98-9D	Result		
Analyte	6/7/2004	6/8/2006	Units
Total VOCs	519	742	µg/l
VOC Tics	78 J	51	µg/l
Ethane	65	1,000 U	µg/l
Ethene	0.075 U	1,000 U	µg/l
Methane	9,600	11,000	µg/l
Total Fe	17.7	27.8	mg/l
Fe II	9.9	4.17	mg/l
Total Mn	0.241	NS	mg/l
Mn II	0.20 J	NS	mg/l
Alkalinity	424	545	mg/l
Chloride	58.5	92.5	mg/l
Sulfate	20.0 U	5.0 U	mg/l
TOC	7.7	11.4	mg/l
pH	6.29	6.46	s.u.
D.O.	0.35	0.00	mg/l
ORP	-26.6	-85	mV
Conductivity	0.85	1.35	mS/cm

MW-97-6S	Result		
Analyte	6/9/2004	6/9/2004	Units
Total VOCs	421	204	µg/l
VOC Tics	0	0	µg/l
Ethane	15	500	µg/l
Ethene	0.075 U	500 U	µg/l
Methane	9,030	10,000	µg/l
Total Fe	30.8	33.9	mg/l
Fe II	15.5	2.55	mg/l
Total Mn	0.224	NS	mg/l
Mn II	0.21 J	NS J	mg/l
Alkalinity	814	715	mg/l
Chloride	79.7	75.4	mg/l
Sulfate	20.0 U	5.0 U	mg/l
TOC	10.1	14.0	mg/l
pH	6.13	6.47	s.u.
D.O.	0.41	0.0	mg/l
ORP	-15.3	-8.0	mV
Conductivity	1.401	1.69	mS/cm

MW-97-4S	Result		
Analyte	6/7/2004	6/8/2006	Units
Total VOCs	191	3	µg/l
VOC Tics	12 J	0	µg/l
Ethane	75	100 U	µg/l
Ethene	0.075 U	100 U	µg/l
Methane	2,090	1,300	µg/l
Total Fe	2.63	0.994	mg/l
Fe II	1.4	0.04 U	mg/l
Total Mn	NS	NS	mg/l
Mn II	NS	NS	mg/l
Alkalinity	701	644	mg/l
Chloride	119	86.1	mg/l
Sulfate	63.6	98.1	mg/l
TOC	6.5	6.7	mg/l
pH	6.54	6.97	s.u.
D.O.	0.25	0.0	mg/l
ORP	-173.0	-102	mV
Conductivity	1.18	1.58	mS/cm

MW-05-14S	Result	
Analyte	6/8/2006	Units
Total VOCs	9.5	µg/l
VOC Tics	0	µg/l
Ethane	500 U	µg/l
Ethene	500 U	µg/l
Methane	11,000	µg/l
Total Fe	21,000	mg/l
Fe II	1490	mg/l
Alkalinity	681	mg/l
Chloride	2,780	mg/l
Sulfate	41.3	mg/l
TOC	8.7	mg/l
pH	5.56	s.u.
D.O.	0.0	mg/l
ORP	-99.0	mV
Conductivity	9.65	mS/cm

MW-97-5S	Result		
Analyte	6/7/2004	6/9/2006	Units
Total VOCs	86	191	µg/l
VOC Tics	0	12 J	µg/l
Ethane	22.2	100 U	µg/l
Ethene	0.075 U	100 U	µg/l
Methane	4,210	1,300	µg/l
Total Fe	8.07	0.994	mg/l
Fe II	1.4	0.04 U	mg/l
Total Mn	0.268	NS	mg/l
Mn II	0.24 J	NS	mg/l
Alkalinity	607	644	mg/l
Chloride	59.2	86.1	mg/l
Sulfate	20.0 U	98.1	mg/l
TOC	6.3	6.7	mg/l
pH	6.66	6.97	s.u.
D.O.	0.28	0.0	mg/l
ORP	-159.0	-102	mV
Conductivity	0.891	1.58	mS/cm

MW-00-12D	Result		
Analyte	6/7/2004	6/8/2006	Units
Total VOCs	122	1,317	µg/l
VOC Tics	32 J	0	µg/l
Ethane	145	100 U	µg/l
Ethene	0.075 U	100 U	µg/l
Methane	1,870	1,600	µg/l
Total Fe	10.9	7.11	mg/l
Fe II	2.2	0.04 U	mg/l
Total Mn	NS	NS	mg/l
Mn II	NS	NS	mg/l
Alkalinity	988	774	mg/l
Chloride	121	12.8	mg/l
Sulfate	26.9	54.7	mg/l
TOC	9.4	10.1	mg/l
pH	6.59	6.82	s.u.
D.O.	0.35	0.0	mg/l
ORP	-33.5	-101	mV
Conductivity	1.437	1.88	mS/cm

MW-03-13S	Result		
Analyte	6/7/2004	6/6/2006	Units
Total VOCs	0	0	µg/l
VOC Tics	73 J	56	µg/l
Ethane	0	500 U	µg/l
Ethene	0.075 U	500 U	µg/l
Methane	6,710	7,800	µg/l
Total Fe	22.8	25.9	mg/l
Fe II	3.7	0.04	mg/l
Total Mn	0.152	NS	mg/l
Mn II	0.12 J	NS	mg/l
Alkalinity	525	408	mg/l
Chloride	123	130	mg/l
Sulfate	20.0 U	5.0 U	mg/l
TOC	8.8	8.8	mg/l
pH	6.53	6.83	s.u.
D.O.	0.43	0.0 U	mg/l
ORP	-42.8	-163	mV
Conductivity	1.044	1.3	mS/cm

LEGEND:

MW-1S	⊗	1988 MONITORING WELL LOCATION
MW-97-5S	⌖	1997 MONITORING WELL LOCATION
MW-98-9D	⌖	1998 MONITORING WELL LOCATION
MW-00-11A	☒	2000 MONITORING WELL LOCATION
SD-1	▣	STORM DRAIN
	⊠	2005 OFFSITE MONITORING WELL LOCATION

NOTES:

U	COMPOUND NOT DETECTED AT STATED METHOD DETECTION LIMIT
J	ESTIMATED CONCENTRATION
NS	NOT SAMPLE

NOTE:
BASE MAP PROVIDED BY DELAWARE ENGINEERING, P.C.

Atlantic Richfield Company
(A BP Affiliated Company)

URS
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CRANFORD, NJ 07016
PHONE: (908) 272-8300
FAX: (908) 272-3940

Issue Date:	04/20/05	
	Revisions	
No.	Date	Description

Project Description

Former Columbia Cement Company, Inc.
159 Hanse Avenue
Freeport, New York

Sheet Title:

GROUNDWATER GEOCHEMICAL DATA

Drawn By:	J.T.	12/18/06
Checked By:	M.B.	12/18/06
Scale:	AS SHOWN	
Project Number:	38546433	
Sheet Number:	FIGURE 9	

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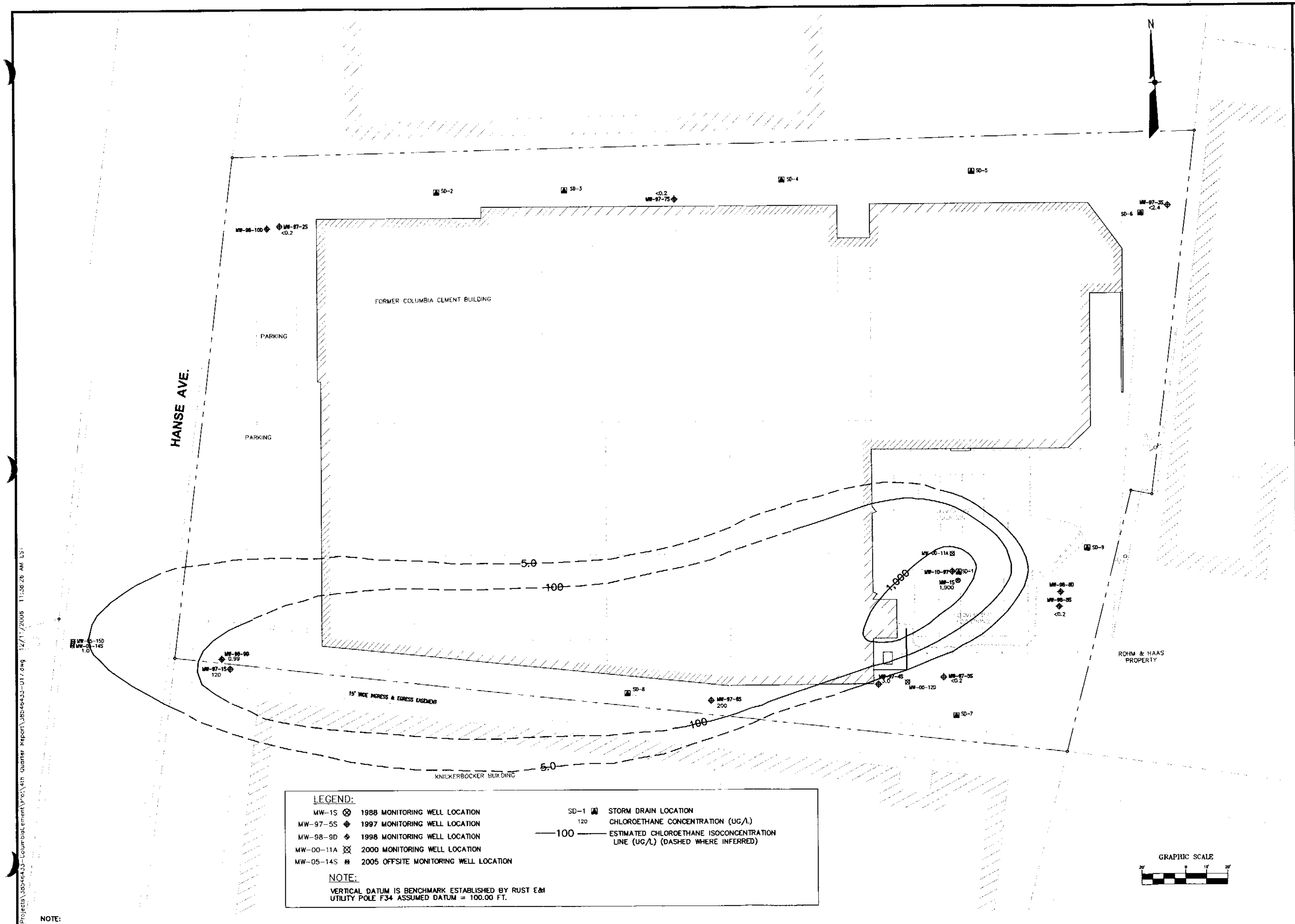

NOTE:
BASE MAP PROVIDED BY DELAWARE ENGINEERING, P.C.

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Issue Date: 04/20/05

Revisions		
No.	Date	Description

Project Description

Former Columbia Cement Company. Inc.
159 Hanse Avenue
Freeport, New York

Sheet Title:

GROUNDWATER ISOCONCENTRATION MAP CHLOROETHANE IN SHALLOW WELLS JUNE, 2006

Drawn By:	J.T.	12/18/06
Checked By:	M.B.	12/18/06
Scale:	AS SHOWN	
Project Number:	38546433	
Sheet Number:	FIGURE 10	

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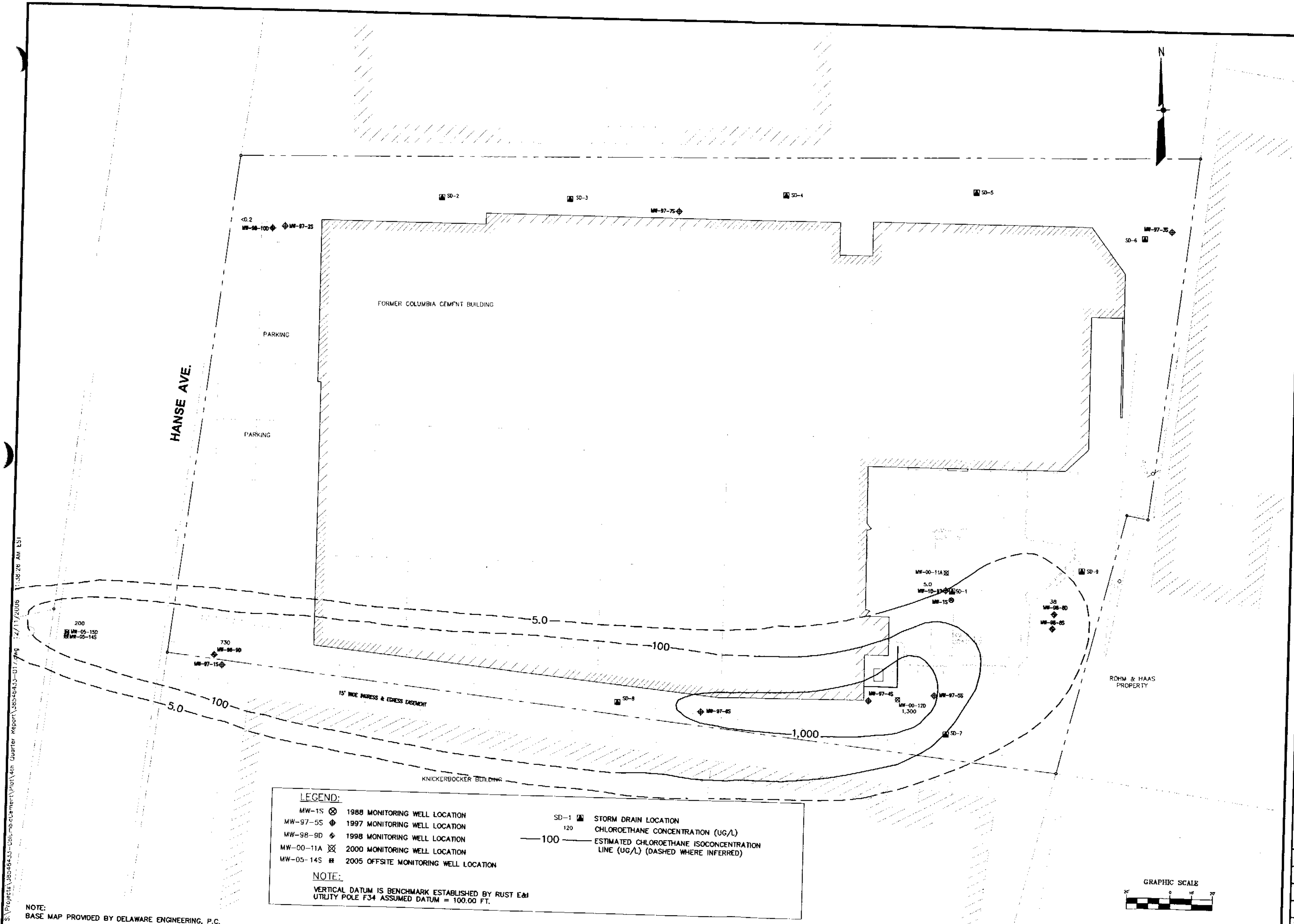

NOTE:
BASE MAP PROVIDED BY DELAWARE ENGINEERING, P.C.

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Issue Date:	04/20/05	
	Revisions	
No.	Date	Description

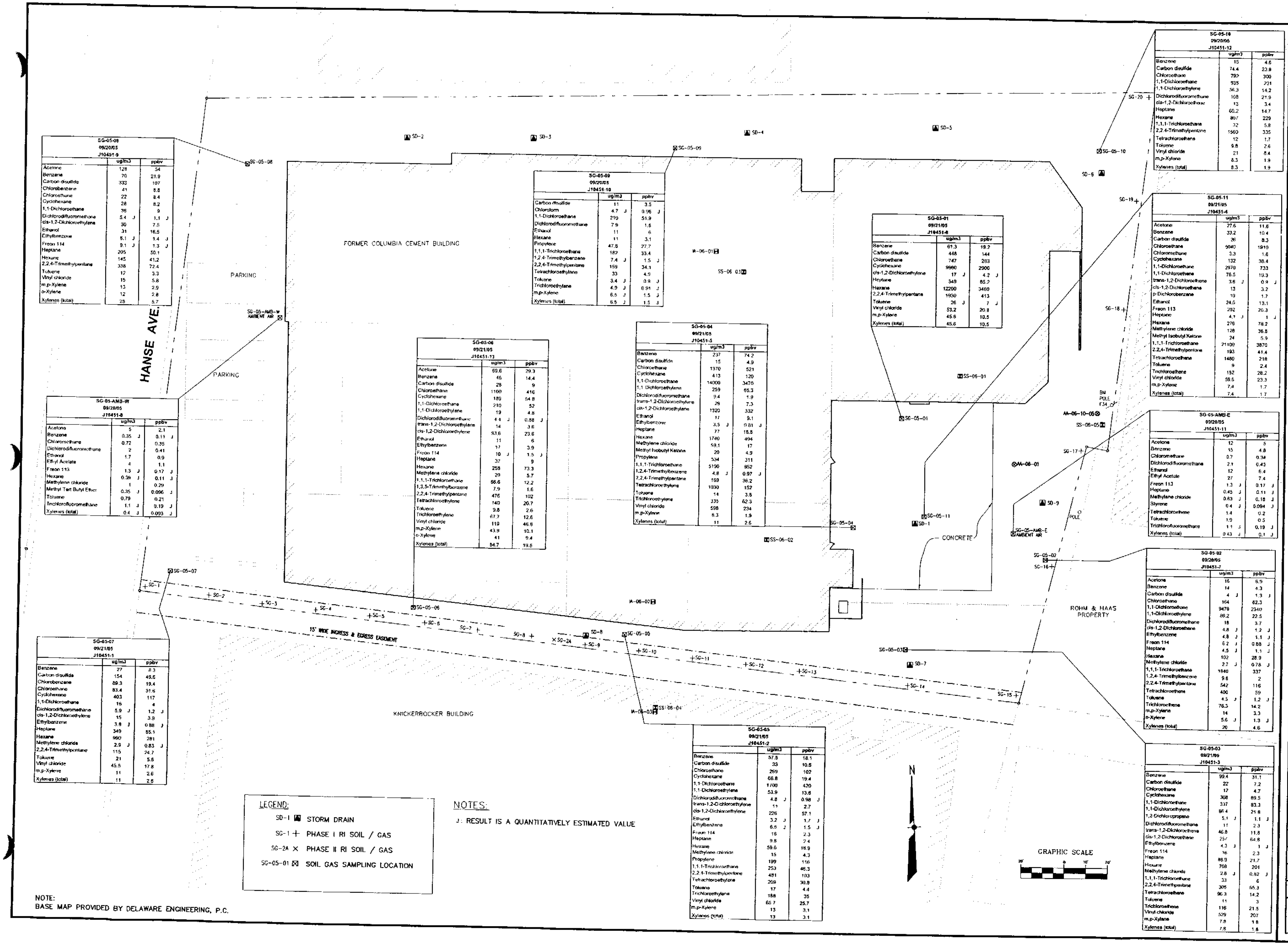
Project Description

Former Columbia
Cement Company. Inc.
159 Hanse Avenue
Freeport, New York

Sheet Title:

**GROUNDWATER
ISOCONCENTRATION
MAP CHLOROETHANE
IN DEEP WELLS
JUNE, 2006**

Drawn By:	J.T.	12/18/06
Checked By:	M.B.	12/18/06
Scale:	AS SHOWN	
Project Number:	38546433	
Sheet Number:	FIGURE 11	



SG-05-08 09/20/05 J10451-9	ug/m3	ppbv
Acetone	128	54
Benzene	70	21.9
Carbon disulfide	333	107
Chlorobenzene	41	8.8
Chloroethane	22	8.4
Cyclohexane	28	8.2
1,1-Dichloroethane	36	9
Dichlorodifluoromethane	5.4 J	1.1 J
cis-1,2-Dichloroethylene	30	7.5
Ethanol	31	16.5
Ethylbenzene	6.1 J	1.4 J
Freon 114	9.1 J	1.3 J
Heptane	205	50.1
Hexane	145	41.2
2,2,4-Trimethylpentane	338	72.4
Toluene	12	3.3
Vinyl chloride	15	5.8
m,p-Xylene	13	2.9
o-Xylene	12	2.8
Xylenes (total)	25	5.7

SG-05-AMB-W 09/20/05 J10451-8	ug/m3	ppbv
Acetone	5	2.1
Benzene	0.35 J	0.11 J
Chloromethane	0.72	0.35
Dichlorodifluoromethane	2	0.41
Ethanol	1.7	0.9
Ethyl Acetate	4	1.1
Freon 113	1.3 J	0.17 J
Hexane	0.39 J	0.11 J
Methylene chloride	1	0.29
Methyl Tert Butyl Ether	0.35 J	0.096 J
Toluene	0.79	0.21
Trichlorofluoromethane	1.1 J	0.19 J
Xylenes (total)	0.4 J	0.093 J

SG-05-07 09/21/05 J10451-1	ug/m3	ppbv
Benzene	27	8.3
Carbon disulfide	154	49.6
Chlorobenzene	89.3	19.4
Chloroethane	83.4	31.6
Cyclohexane	403	117
1,1-Dichloroethane	16	4
Dichlorodifluoromethane	5.9 J	1.2 J
cis-1,2-Dichloroethylene	15	3.9
Ethylbenzene	3.8 J	0.88 J
Heptane	349	85.1
Hexane	990	281
Methylene chloride	2.9 J	0.83 J
2,2,4-Trimethylpentane	115	24.7
Toluene	21	5.6
Vinyl chloride	45.5	17.8
m,p-Xylene	11	2.6
Xylenes (total)	11	2.6

SG-05-06 09/21/05 J10451-13	ug/m3	ppbv
Acetone	69.6	29.3
Benzene	46	14.4
Carbon disulfide	28	9
Chloroethane	1100	416
Cyclohexane	189	54.8
1,1-Dichloroethane	210	52
1,1-Dichloroethylene	19	4.8
Dichlorodifluoromethane	4.4 J	0.88 J
trans-1,2-Dichloroethylene	14	3.6
cis-1,2-Dichloroethylene	93.6	23.6
Ethanol	11	6
Ethylbenzene	17	3.9
Freon 114	10 J	1.5 J
Heptane	37	9
Hexane	258	73.3
Methylene chloride	20	5.7
1,1,1-Trichloroethane	66.6	12.2
1,3,5-Trimethylbenzene	7.9	1.6
2,2,4-Trimethylpentane	476	102
Tetrachloroethylene	140	20.7
Toluene	9.8	2.6
Trichloroethylene	67.7	12.6
Vinyl chloride	119	46.6
m,p-Xylene	43.9	10.1
o-Xylene	41	9.4
Xylenes (total)	84.7	19.5

SG-05-09 09/20/05 J10451-10	ug/m3	ppbv
Carbon disulfide	11	3.5
Chloroform	4.7 J	0.96 J
1,1-Dichloroethane	210	51.9
Dichlorodifluoromethane	7.9	1.6
Ethanol	11	6
Hexane	11	3.1
Propylene	47.6	27.7
1,1,1-Trichloroethane	182	33.4
1,2,4-Trimethylbenzene	7.4 J	1.5 J
2,2,4-Trimethylpentane	159	34.1
Tetrachloroethylene	33	4.9
Toluene	3.4 J	0.9 J
Trichloroethylene	4.9 J	0.91 J
m,p-Xylene	6.5 J	1.5 J
Xylenes (total)	6.5 J	1.5 J

SG-05-04 09/21/05 J10451-5	ug/m3	ppbv
Benzene	237	74.2
Carbon disulfide	15	4.9
Chloroethane	1370	521
Cyclohexane	413	120
1,1-Dichloroethane	14000	3470
1,1 Dichloroethylene	259	65.3
Dichlorodifluoromethane	9.4	1.9
trans-1,2-Dichloroethylene	29	7.3
cis-1,2-Dichloroethylene	1320	332
Ethanol	17	9.1
Ethylbenzene	3.5 J	0.81 J
Heptane	77	18.8
Hexane	1740	494
Methylene chloride	59.1	17
Methyl Isobutyl Ketone	20	4.9
Propylene	534	311
1,1,1-Trichloroethane	5190	952
1,2,4-Trimethylbenzene	4.8 J	0.97 J
2,2,4-Trimethylpentane	169	36.2
Tetrachloroethylene	1030	152
Toluene	14	3.8
Trichloroethylene	335	62.3
Vinyl chloride	598	234
m,p-Xylene	8.3	1.9
Xylenes (total)	11	2.6

SG-05-05 09/21/05 J10451-2	ug/m3	ppbv
Benzene	57.8	18.1
Carbon disulfide	33	10.6
Chloroethane	269	102
Cyclohexane	66.8	19.4
1,1-Dichloroethane	1700	420
1,1-Dichloroethylene	53.9	13.6
Dichlorodifluoromethane	4.8 J	0.98 J
trans-1,2-Dichloroethylene	11	2.7
cis-1,2-Dichloroethylene	226	57.1
Ethanol	3.2 J	1.7 J
Ethylbenzene	6.5 J	1.5 J
Freon 114	16	2.3
Heptane	9.8	2.4
Hexane	59.6	16.9
Methylene chloride	15	4.3
Propylene	199	116
1,1,1-Trichloroethane	253	46.3
2,2,4-Trimethylpentane	481	103
Tetrachloroethylene	209	30.8
Toluene	17	4.4
Trichloroethylene	188	35
Vinyl chloride	65.7	25.7
m,p-Xylene	13	3.1
Xylenes (total)	13	3.1

SG-05-01 09/21/05 J10451-6	ug/m3	ppbv
Benzene	61.3	19.2
Carbon disulfide	448	144
Chloroethane	747	283
Cyclohexane	9980	2900
cis-1,2-Dichloroethylene	17 J	4.2 J
Heptane	349	85.2
Hexane	12200	3460
2,2,4-Trimethylpentane	1930	413
Toluene	26 J	7 J
Vinyl chloride	53.2	20.8
m,p-Xylene	45.6	10.5
Xylenes (total)	45.6	10.5

SG-05-10 09/20/05 J10451-12	ug/m3	ppbv
Benzene	15	4.6
Carbon disulfide	74.4	23.9
Chloroethane	792	300
1,1-Dichloroethane	935	231
1,1-Dichloroethylene	56.3	14.2
Dichlorodifluoromethane	108	21.9
cis-1,2-Dichloroethene	13	3.4
Heptane	60.2	14.7
Hexane	807	229
1,1,1-Trichloroethane	32	5.8
2,2,4-Trimethylpentane	1560	335
Tetrachloroethene	12	1.7
Toluene	9.8	2.6
Vinyl chloride	21	8.4
m,p-Xylene	8.3	1.9
Xylenes (total)	8.3	1.9

SG-05-11 09/21/05 J10451-4	ug/m3	ppbv
Acetone	27.6	11.6
Benzene	33.2	10.4
Carbon disulfide	26	8.3
Chloroethane	5040	1910
Chloromethane	3.3	1.6
Cyclohexane	132	38.4
1,1-Dichloroethane	2970	733
1,1-Dichloroethene	76.5	19.3
trans-1,2-Dichloroethene	3.6 J	0.9 J
cis-1,2-Dichloroethene	13	3.2
p-Dichlorobenzene	10	1.7
Ethanol	24.6	13.1
Freon 113	202	26.3
Heptane	4.1 J	1 J
Hexane	276	78.2
Methylene chloride	128	36.8
Methyl Isobutyl Ketone	24	5.9
1,1,1-Trichloroethane	21100	3870
2,2,4-Trimethylpentane	193	41.4
Tetrachloroethene	1480	218
Toluene	9	2.4
Trichloroethene	152	28.2
Vinyl chloride	59.6	23.3
m,p-Xylene	7.4	1.7
Xylenes (total)	7.4	1.7

SG-05-AMB-E 09/20/05 J10451-11	ug/m3	ppbv
Acetone	12	5
Benzene	15	4.8
Chloromethane	0.7	0.34
Dichlorodifluoromethane	2.1	0.43
Ethanol	12	6.4
Ethyl Acetate	27	7.4
Freon 113	1.3 J	0.17 J
Heptane	0.45 J	0.11 J
Methylene chloride	0.63 J	0.18 J
Styrene	0.4 J	0.094 J
Tetrachloroethene	1.4	0.2
Toluene	1.9	0.5
Trichlorofluoromethane	1.1 J	0.19 J
Xylenes (total)	0.43 J	0.1 J

SG-05-02 09/20/05 J10451-7	ug/m3	ppbv
Acetone	16	6.9
Benzene	14	4.3
Carbon disulfide	4 J	1.3 J
Chloroethane	164	62.3
1,1-Dichloroethane	9470	2340
1,1-Dichloroethylene	89.2	22.5
Dichlorodifluoromethane	18	3.7
cis-1,2-Dichloroethene	4.8 J	1.2 J
Ethylbenzene	4.8 J	1.1 J
Freon 114	6.2 J	0.88 J
Heptane	4.5 J	1.1 J
Hexane	102	28.9
Methylene chloride	2.7 J	0.78 J
1,1,1-Trichloroethane	1840	337
1,2,4-Trimethylbenzene	9.8	2
2,2,4-Trimethylpentane	542	116
Tetrachloroethene	400	59
Toluene	4.5 J	1.2 J
Trichloroethene	76.3	14.2
m,p-Xylene	14	3.3
o-Xylene	5.6 J	1.3 J
Xylenes (total)	20	4.6

SG-05-03 09/21/05 J10451-3	ug/m3	ppbv
Benzene	99.4	31.1
Carbon disulfide	22	7.2
Chloroethane	12	4.7
Cyclohexane	308	89.5
1,1-Dichloroethane	337	83.3
1,1-Dichloroethylene	86.4	21.8
1,2-Dichloropropane	5.1 J	1.1 J
Dichlorodifluoromethane	11	2.3
trans-1,2-Dichloroethene	46.8	11.8
cis-1,2-Dichloroethene	257	64.8
Ethylbenzene	4.3 J	1 J
Freon 114	16	2.3
Heptane	88.9	21.7
Hexane	708	201
Methylene chloride	2.8 J	0.82 J
1,1,1-Trichloroethane	33	6
2,2,4-Trimethpentane	305	65.3
Tetrachloroethene	96.3	14.2
Toluene	11	3
Trichloroethene	116	21.5
Vinyl chloride	529	207
m,p-Xylene	7.8	1.8
Xylenes (total)	7.8	1.8

LEGEND:

SD-1 ▣ STORM DRAIN
SG-1 + PHASE I RI SOIL / GAS
SG-2A × PHASE II RI SOIL / GAS
SG-05-01 ☒ SOIL GAS SAMPLING LOCATION

NOTES:

J: RESULT IS A QUANTITATIVELY ESTIMATED VALUE

NOTE:
BASE MAP PROVIDED BY DELAWARE ENGINEERING, P.C.

Atlantic Richfield Company
(A BP Affiliated Company)

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Issue Date: 04/20/05

No.	Date	Revisions Description

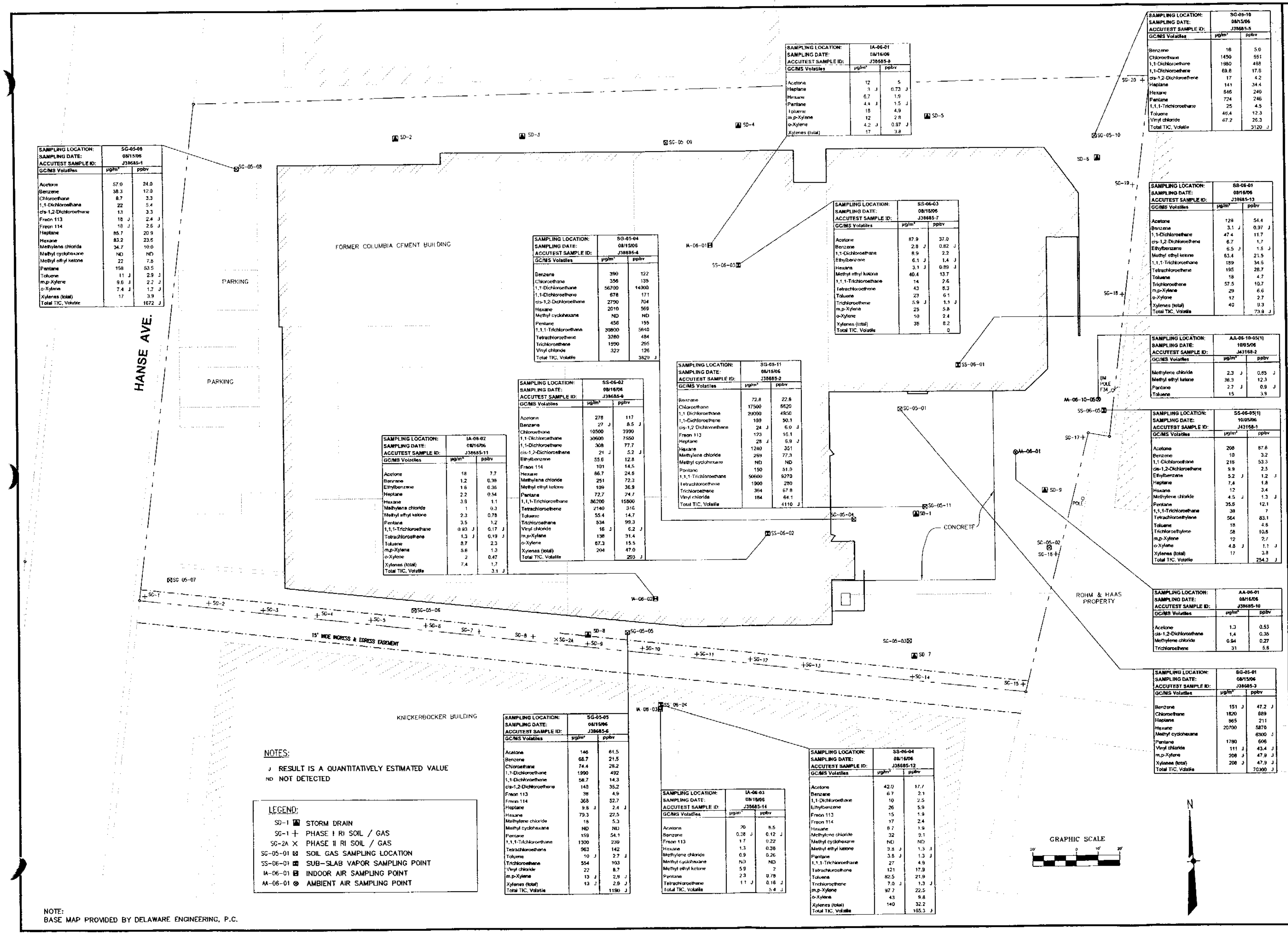
Project Description

Former Columbia Cement Company. Inc.
159 Hanse Avenue
Freeport, New York

Sheet Title:

2005 SOIL VAPOR INTRUSION SAMPLING LOCATIONS AND RESULTS

Drawn By:	J.T.	12/18/06
Checked By:	M.B.	12/18/06
Scale:	AS SHOWN	
Project Number:	38546433	
Sheet Number:	FIGURE 12	



SAMPLING LOCATION:	SG-05-08	
SAMPLING DATE:	08/15/06	
ACCUTEST SAMPLE ID:	J38685-1	
GC/MS Volatiles	µg/m³	ppbv
Acetone	57.0	24.0
Benzene	38.3	12.0
Chloroethane	8.7	3.3
1,1-Dichloroethane	22	5.4
cis-1,2-Dichloroethene	13	3.3
Freon 113	18 J	2.4 J
Freon 114	18 J	2.6 J
Heptane	85.7	20.9
Hexane	83.2	23.6
Methylene chloride	34.7	10.0
Methyl cyclohexane	ND	ND
Methyl ethyl ketone	22	7.8
Pentane	158	53.5
Toluene	11 J	2.9 J
m,p-Xylene	9.6 J	2.2 J
o-Xylene	7.4 J	1.7 J
Xylenes (total)	17	3.9
Total TIC, Volatile		1672 J

SAMPLING LOCATION:	SG-05-04	
SAMPLING DATE:	08/15/06	
ACCUTEST SAMPLE ID:	J38685-4	
GC/MS Volatiles	µg/m³	ppbv
Benzene	390	122
Chloroethane	356	135
1,1-Dichloroethane	56700	14000
1,1-Dichloroethene	678	171
cis-1,2-Dichloroethene	2790	704
Hexane	2010	569
Methyl cyclohexane	ND	ND
Pentane	456	155
1,1,1-Trichloroethane	30800	5640
Tetrachloroethene	3280	484
Trichloroethene	1590	295
Vinyl chloride	322	126
Total TIC, Volatile		3820 J

SAMPLING LOCATION:	IA-06-02	
SAMPLING DATE:	08/16/06	
ACCUTEST SAMPLE ID:	J38685-11	
GC/MS Volatiles	µg/m³	ppbv
Acetone	18	7.7
Benzene	1.2	0.38
Ethylbenzene	1.6	0.36
Heptane	2.2	0.54
Hexane	3.9	1.1
Methylene chloride	1	0.3
Methyl ethyl ketone	2.3	0.78
Pentane	3.5	1.2
1,1,1-Trichloroethane	0.93 J	0.17 J
Tetrachloroethene	1.3 J	0.19 J
Toluene	8.7	2.3
m,p-Xylene	5.6	1.3
o-Xylene	2	0.47
Xylenes (total)	7.4	1.7
Total TIC, Volatile		3.1 J

SAMPLING LOCATION:	SS-06-02	
SAMPLING DATE:	08/16/06	
ACCUTEST SAMPLE ID:	J38685-9	
GC/MS Volatiles	µg/m³	ppbv
Acetone	278	117
Benzene	27 J	8.5 J
Chloroethane	10500	3990
1,1-Dichloroethane	30600	7550
1,1-Dichloroethene	308	77.7
cis-1,2-Dichloroethene	21 J	5.2 J
Ethylbenzene	55.6	12.8
Freon 114	101	14.5
Hexane	86.7	24.6
Methylene chloride	251	72.3
Methyl ethyl ketone	109	36.9
Pentane	72.7	24.7
1,1,1-Trichloroethane	86200	15800
Tetrachloroethene	2140	316
Toluene	55.4	14.7
Trichloroethene	534	99.3
Vinyl chloride	16 J	6.2 J
m,p-Xylene	138	31.4
o-Xylene	67.3	15.5
Xylenes (total)	204	47.0
Total TIC, Volatile		203 J

SAMPLING LOCATION:	SG-05-11	
SAMPLING DATE:	08/15/06	
ACCUTEST SAMPLE ID:	J38685-2	
GC/MS Volatiles	µg/m³	ppbv
Benzene	72.8	22.8
Chloroethane	17500	6620
1,1-Dichloroethane	20000	4950
1,1-Dichloroethene	199	50.1
cis-1,2-Dichloroethene	24 J	6.0 J
Freon 113	123	16.1
Heptane	28 J	6.9 J
Hexane	1240	351
Methylene chloride	269	77.3
Methyl cyclohexane	ND	ND
Pentane	150	51.0
1,1,1-Trichloroethane	50600	9270
Tetrachloroethene	1900	280
Trichloroethene	364	67.8
Vinyl chloride	164	64.1
Total TIC, Volatile		4110 J

SAMPLING LOCATION:	SS-06-03	
SAMPLING DATE:	08/15/06	
ACCUTEST SAMPLE ID:	J38685-7	
GC/MS Volatiles	µg/m³	ppbv
Acetone	87.9	37.0
Benzene	2.6 J	0.82 J
1,1-Dichloroethane	8.9	2.2
Ethylbenzene	6.1 J	1.4 J
Hexane	3.1 J	0.89 J
Methyl ethyl ketone	40.4	13.7
1,1,1-Trichloroethane	14	2.6
Tetrachloroethene	43	6.3
Toluene	23	6.1
Trichloroethene	5.9 J	1.1 J
m,p-Xylene	25	5.8
o-Xylene	10	2.4
Xylenes (total)	35	8.2
Total TIC, Volatile		0

SAMPLING LOCATION:	IA-06-01	
SAMPLING DATE:	08/16/06	
ACCUTEST SAMPLE ID:	J38685-8	
GC/MS Volatiles	µg/m³	ppbv
Acetone	12	5
Heptane	3 J	0.73 J
Hexane	6.7	1.9
Pentane	4.4 J	1.5 J
Toluene	18	4.9
m,p-Xylene	12	2.8
o-Xylene	4.2 J	0.97 J
Xylenes (total)	17	3.8

SAMPLING LOCATION:	SG-05-10	
SAMPLING DATE:	08/15/06	
ACCUTEST SAMPLE ID:	J38685-5	
GC/MS Volatiles	µg/m³	ppbv
Benzene	16	5.0
Chloroethane	1450	551
1,1-Dichloroethane	1980	488
1,1-Dichloroethene	69.8	17.6
cis-1,2-Dichloroethene	17	4.2
Heptane	141	34.4
Hexane	846	240
Pentane	724	246
1,1,1-Trichloroethane	25	4.5
Toluene	46.4	12.3
Vinyl chloride	67.2	26.3
Total TIC, Volatile		3120 J

SAMPLING LOCATION:	SS-06-01	
SAMPLING DATE:	08/16/06	
ACCUTEST SAMPLE ID:	J38685-13	
GC/MS Volatiles	µg/m³	ppbv
Acetone	129	54.4
Benzene	3.1 J	0.97 J
1,1-Dichloroethene	47.4	11.7
cis-1,2-Dichloroethene	6.7	1.7
Ethylbenzene	6.5 J	1.5 J
Methyl ethyl ketone	63.4	21.5
1,1,1-Trichloroethane	189	34.6
Tetrachloroethene	195	28.7
Toluene	18	4.7
Trichloroethene	57.5	10.7
m,p-Xylene	29	6.6
o-Xylene	12	2.7
Xylenes (total)	40	9.3
Total TIC, Volatile		73.9 J

SAMPLING LOCATION:	AA-06-10-05(1)	
SAMPLING DATE:	10/05/06	
ACCUTEST SAMPLE ID:	J43168-2	
GC/MS Volatiles	µg/m³	ppbv
Methylene chloride	2.3 J	0.65 J
Methyl ethyl ketone	36.3	12.3
Pentene	2.7 J	0.9 J
Toluene	15	3.9

SAMPLING LOCATION:	SS-06-05(1)	
SAMPLING DATE:	10/05/06	
ACCUTEST SAMPLE ID:	J43168-1	
GC/MS Volatiles	µg/m³	ppbv
Acetone	208	87.6
Benzene	10	3.2
1,1-Dichloroethane	216	53.3
cis-1,2-Dichloroethene	9.9	2.5
Ethylbenzene	5.2 J	1.2 J
Heptane	7.4	1.8
Hexane	12	3.4
Methylene chloride	4.5 J	1.3 J
Pentane	35.6	12.1
1,1,1-Trichloroethane	38	7
Tetrachloroethylene	564	83.1
Toluene	18	4.8
Trichloroethylene	58	10.8
m,p-Xylene	12	2.7
o-Xylene	4.8 J	1.1 J
Xylenes (total)	17	3.8
Total TIC, Volatile		254.3 J

SAMPLING LOCATION:	AA-06-01	
SAMPLING DATE:	08/16/06	
ACCUTEST SAMPLE ID:	J38685-10	
GC/MS Volatiles	µg/m³	ppbv
Acetone	1.3	0.53
cis-1,2-Dichloroethene	1.4	0.35
Methylene chloride	0.94	0.27
Trichloroethene	31	5.8

SAMPLING LOCATION:	SG-05-01	
SAMPLING DATE:	08/15/06	
ACCUTEST SAMPLE ID:	J38685-3	
GC/MS Volatiles	µg/m³	ppbv
Benzene	151 J	47.2 J
Chloroethane	1820	689
Heptane	865	211
Hexane	20700	5870
Methyl cyclohexane		6300 J
Pentane	1780	606
Vinyl chloride	111 J	43.4 J
m,p-Xylene	208 J	47.9 J
Xylenes (total)	208 J	47.9 J
Total TIC, Volatile		70300 J

SAMPLING LOCATION:	SG-05-05	
SAMPLING DATE:	08/15/06	
ACCUTEST SAMPLE ID:	J38685-6	
GC/MS Volatiles	µg/m³	ppbv
Acetone	146	61.5
Benzene	68.7	21.5
Chloroethane	74.4	28.2
1,1-Dichloroethane	1990	492
1,1-Dichloroethene	56.7	14.3
cis-1,2-Dichloroethene	140	35.2
Freon 113	38	4.9
Freon 114	368	52.7
Heptane	9.8 J	2.4 J
Hexane	79.3	22.5
Methylene chloride	18	5.3
Methyl cyclohexane	ND	ND
Pentane	159	54.1
1,1,1-Trichloroethane	1300	239
Tetrachloroethene	963	142
Toluene	10 J	2.7 J
Trichloroethene	554	103
Vinyl chloride	22	8.7
m,p-Xylene	13 J	2.9 J
Xylenes (total)	13 J	2.9 J
Total TIC, Volatile		1190 J

SAMPLING LOCATION:	IA-06-03	
SAMPLING DATE:	08/16/06	
ACCUTEST SAMPLE ID:	J38685-14	
GC/MS Volatiles	µg/m³	ppbv
Acetone	20	8.5
Benzene	0.38 J	0.12 J
Freon 113	1.7	0.22
Hexane	1.3	0.38
Methylene chloride	0.9	0.26
Methyl cyclohexane	ND	ND
Methyl ethyl ketone	5.9	2
Pentane	2.3	0.78
Tetrachloroethene	1.1 J	0.16 J
Total TIC, Volatile		5.4 J

SAMPLING LOCATION:	SS-06-04	
SAMPLING DATE:	08/16/06	
ACCUTEST SAMPLE ID:	J38685-12	
GC/MS Volatiles	µg/m³	ppbv
Acetone	42.0	17.7
Benzene	6.7	2.1
1,1-Dichloroethane	10	2.5
Ethylbenzene	26	5.9
Freon 113	15	1.9
Freon 114	17	2.4
Hexane	6.7	1.9
Methylene chloride	32	9.1
Methyl cyclohexane	ND	ND
Methyl ethyl ketone	3.9 J	1.3 J
Pentane	3.8 J	1.3 J
1,1,1-Trichloroethane	27	4.9
Tetrachloroethene	121	17.9
Toluene	82.5	21.9
Trichloroethene	7.0 J	1.3 J
m,p-Xylene	97.7	22.5
o-Xylene	43	9.8
Xylenes (total)	140	32.2
Total TIC, Volatile		165.3 J

NOTES:

J RESULT IS A QUANTITATIVELY ESTIMATED VALUE
ND NOT DETECTED

LEGEND:

SD-1 ▣ STORM DRAIN
SG-1 + PHASE I RI SOIL / GAS
SG-2A × PHASE II RI SOIL / GAS
SG-05-01 ⊠ SOIL GAS SAMPLING LOCATION
SS-06-01 ▣ SUB-SLAB VAPOR SAMPLING POINT
IA-06-01 ▣ INDOOR AIR SAMPLING POINT
AA-06-01 ⊗ AMBIENT AIR SAMPLING POINT

NOTE:
BASE MAP PROVIDED BY DELAWARE ENGINEERING, P.C.

Atlantic Richfield Company
(A BP Affiliated Company)

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Issue Date: 04/20/05

Revisions		
No.	Date	Description

Project Description

Former Columbia Cement Company, Inc.
159 Hanse Avenue
Freeport, New York

Sheet Title:

2006 SOIL SOIL VAPOR INTRUSION SAMPLING LOCATIONS AND RESULTS

Drawn By:	J.T.	12/18/06
Checked By:	M.B.	12/18/06
Scale:	AS SHOWN	
Project Number:	38546433	
Sheet Number:	FIGURE 13	

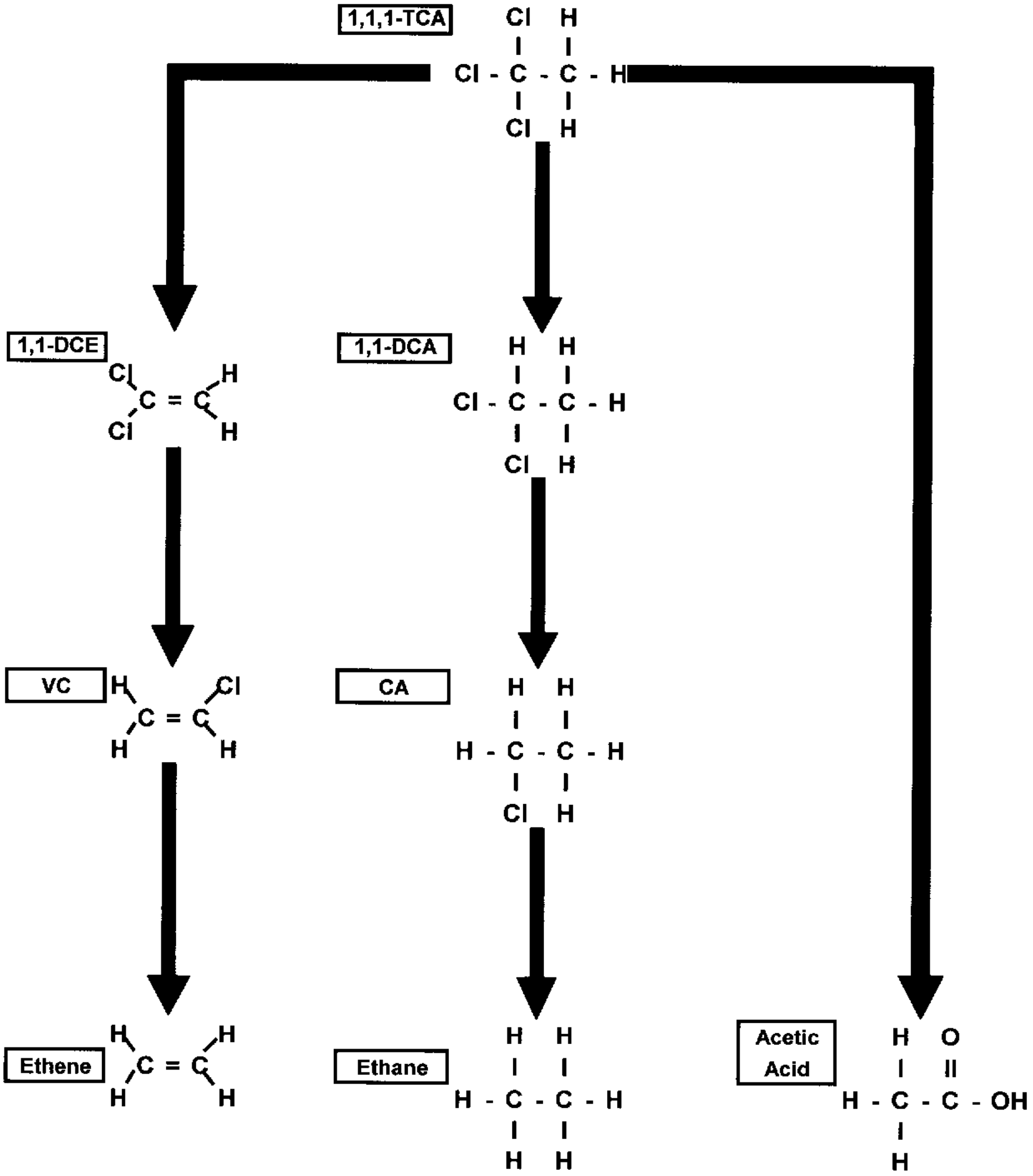
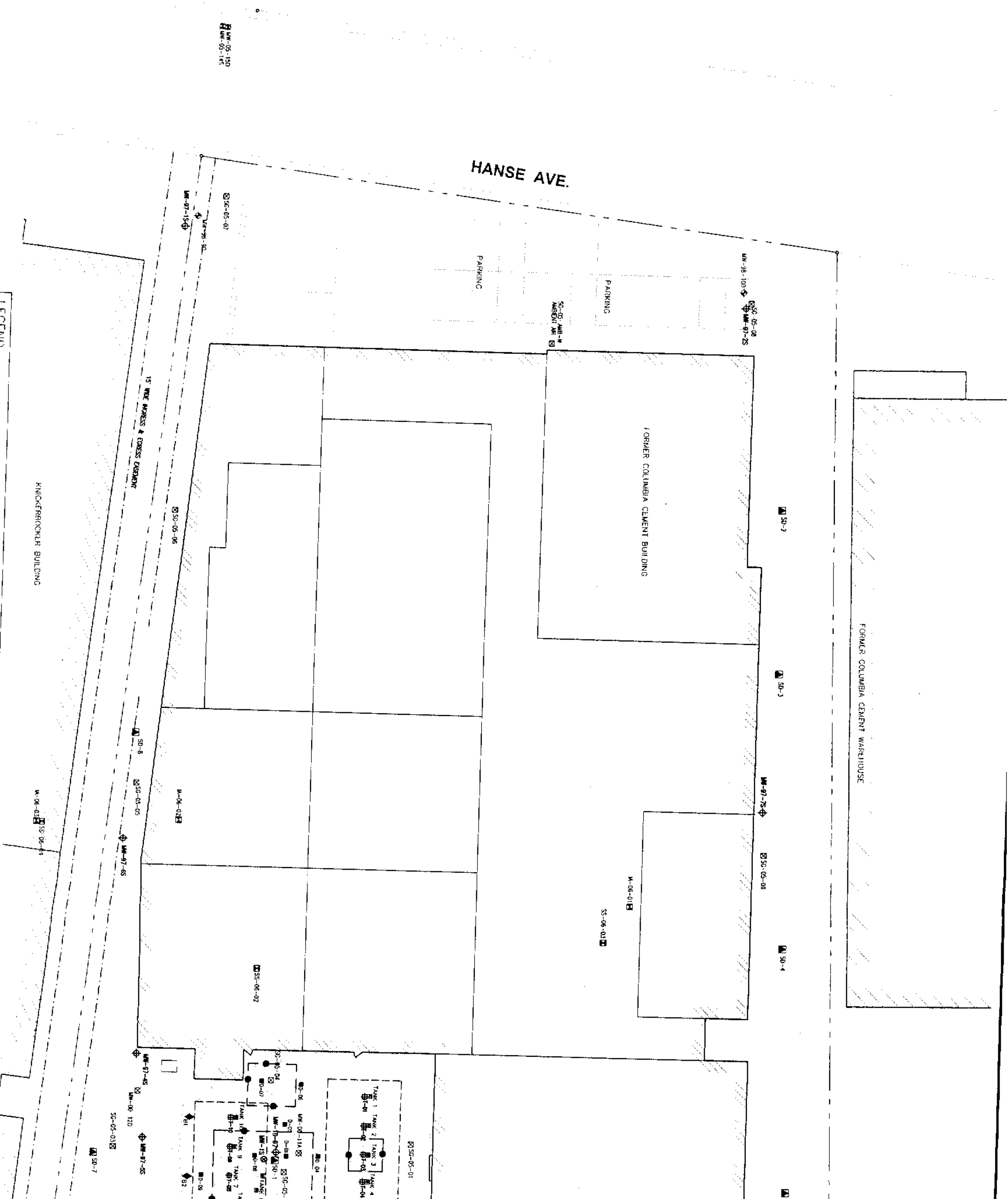


FIGURE 14
Pathways of 1,1,1-TCA transformations. Green arrows indicate abiotic reactions. Blue arows indicate biotic transformations (after Vogel and McCarty, 1987a).

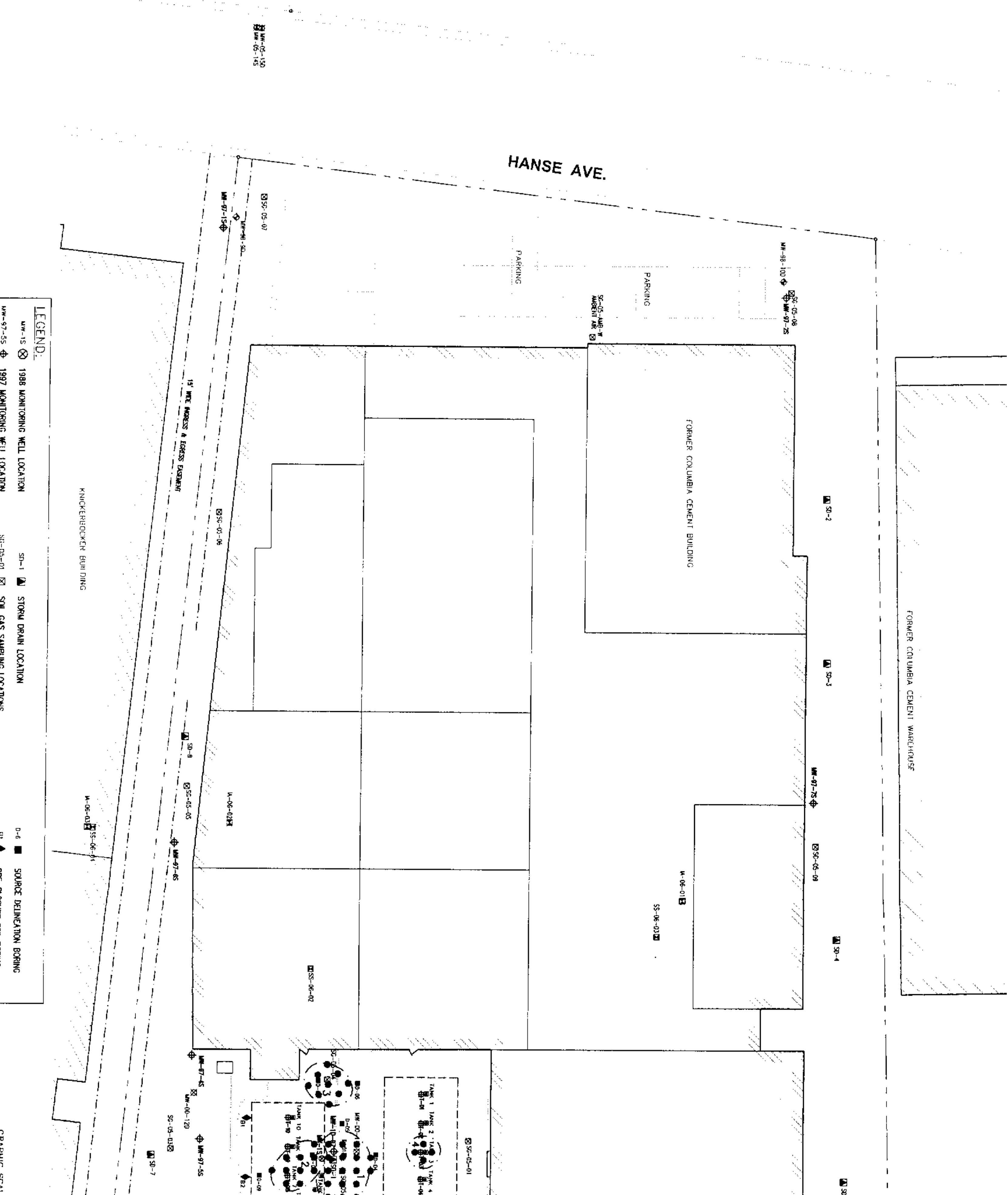
ENT)\FS\FIGURE-15.dwg 12/29/2005 1:48:28 PM EST

S(COLUMBIA CEMENT)\FS\FIGURE--15.dwg, 12/28/2006 2:51:29 PM



CEMENT)\FS\FIGURE-16.dwg 12/28/2006 1:49:52 PM EST

6433(COLUMBIA CEMENT)\FS\FIGURE-16.dwg, 12/28/2006 2:53:17 PM



CEMENT)\FS\FIGURE-17.dwg 12/28/2006 1:54:13 PM EST

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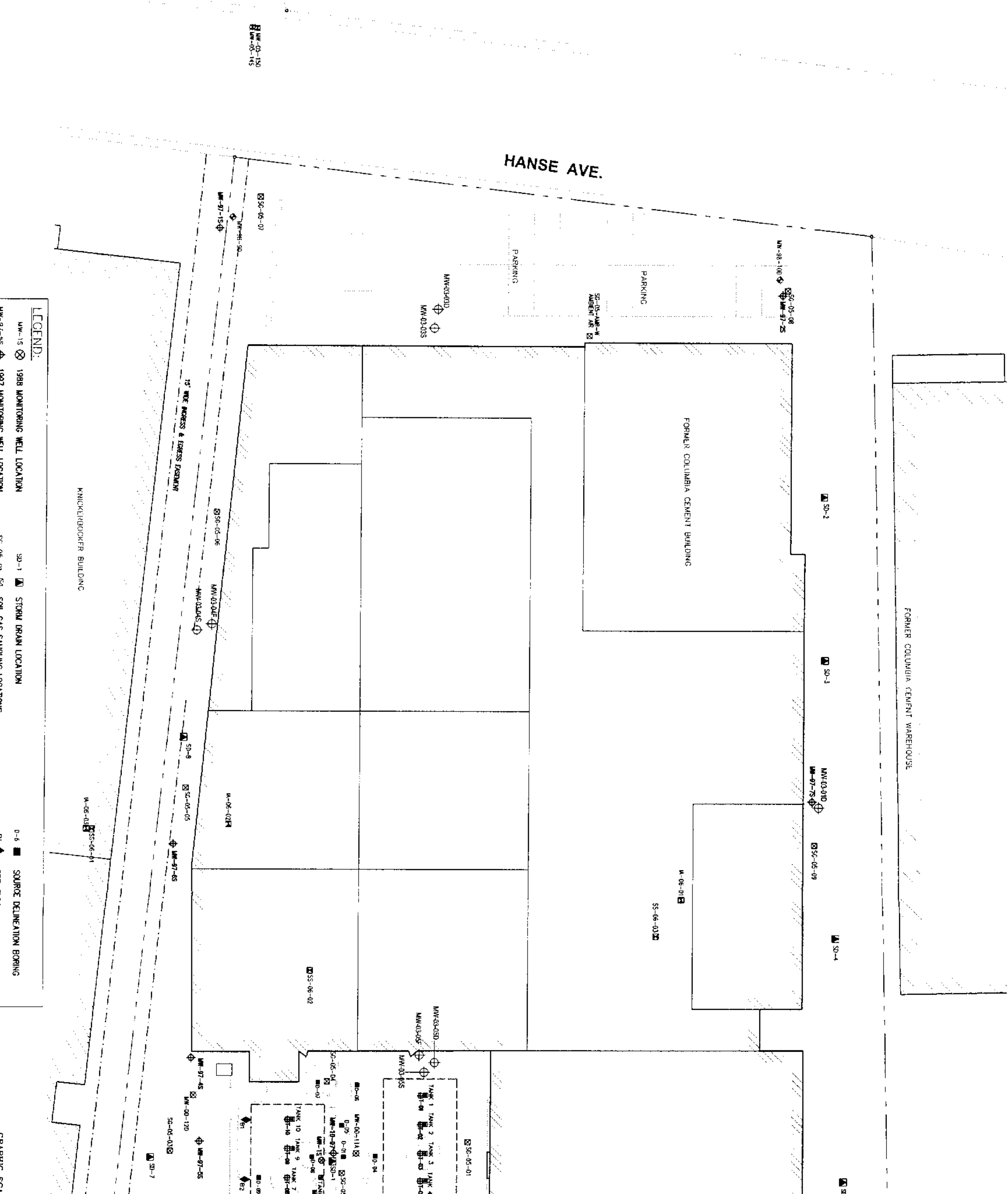
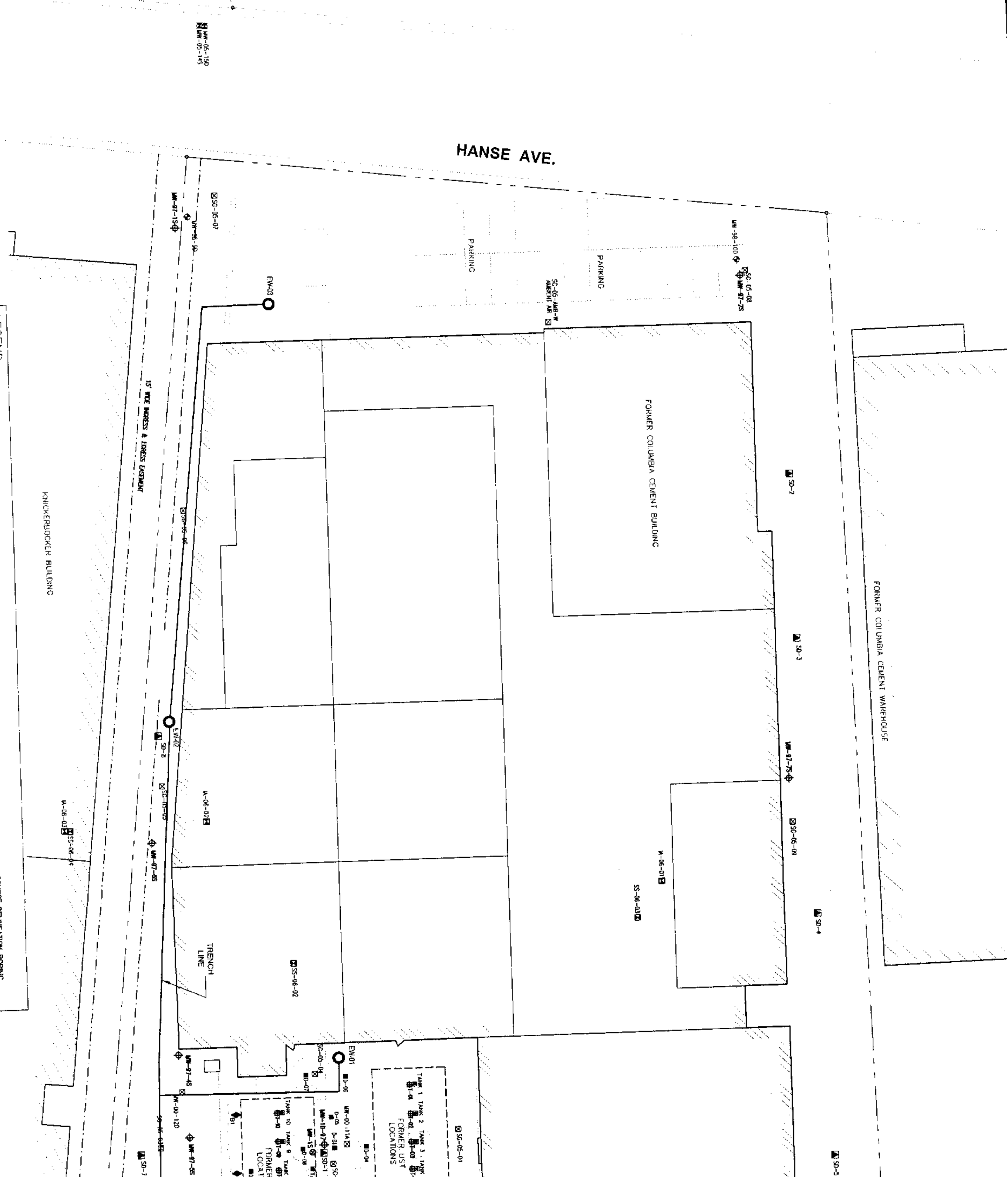
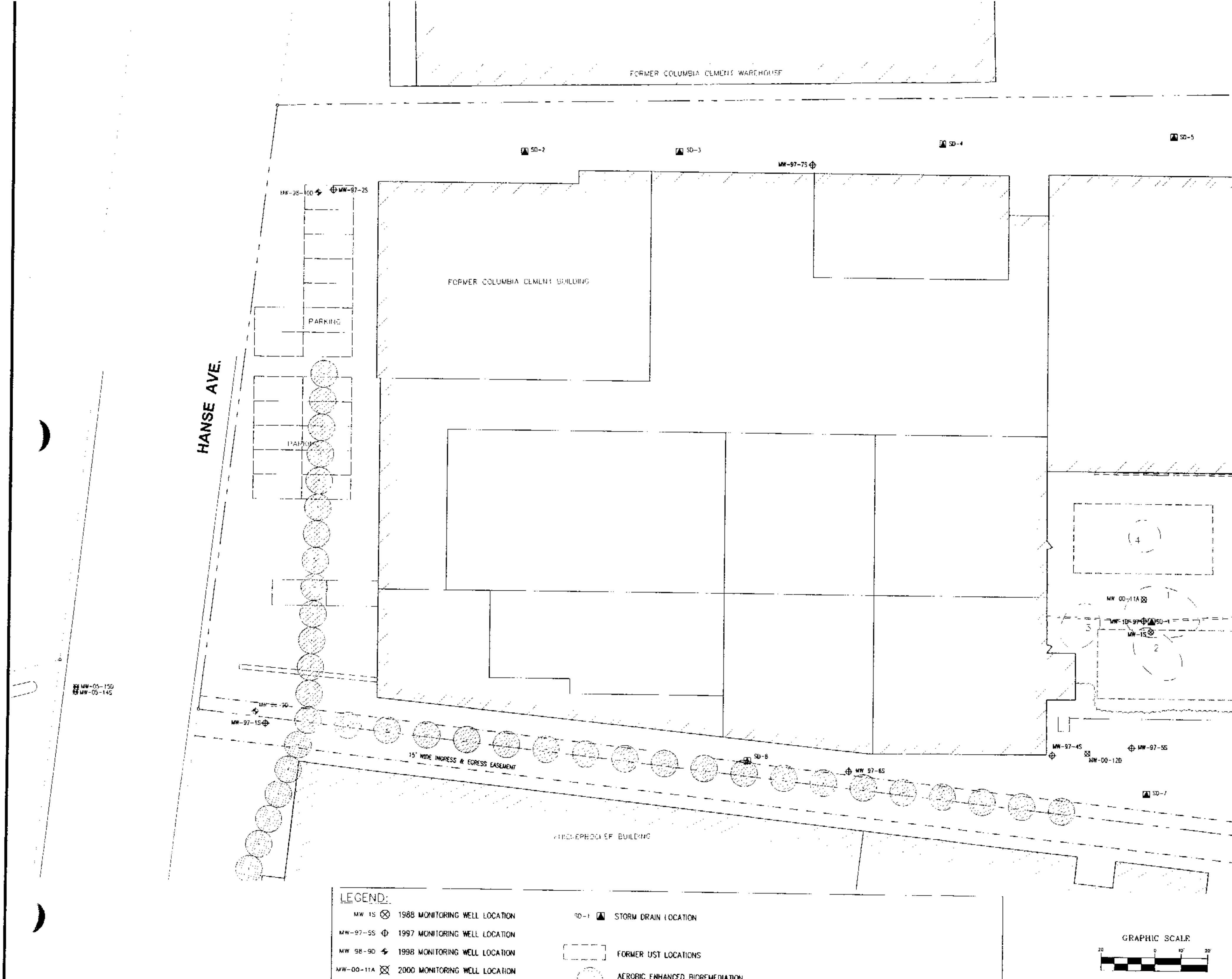


S\FIGURE-18.dwg 12/28/2006 2:10:56 PM EST

LUMBIA CEMENT)\FS\FIGURE-18.dwg, 12/28/2006 2:56:44 PM




FORMER COLUMBIA CEMENT WAREHOUSE
SD-2
SD-3
SD-4
SD-5
MW-97-7S
MW-98-10D
MW-97-2S
FORMER COLUMBIA CEMENT BUILDING
PARKING
PARKING
HANSE AVE.
MW-05-15D
MW-05-14S
MW-98-9D
MW-97-1S
15' WIDE INGRESS & EGRESS EASEMENT
SD-8
MW 97-6S
BUILDING
4
MW 00-11A
1
3
MW-1D-97
SD-1
MW-1S
2
MW-97-4S
MW-00-12D
MW-97-5S
SD-7
LEGEND:
MW 1S ⊗ 1988 MONITORING WELL LOCATION
MW-97-5S 1997 MONITORING WELL LOCATION
MW 98-9D 1998 MONITORING WELL LOCATION
MW-00-11A ⊠ 2000 MONITORING WELL LOCATION
SD-1 STORM DRAIN LOCATION
FORMER UST LOCATIONS
AEROBIC ENHANCED BIOREMEDIATION
GRAPHIC SCALE
20
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10'
20'

APPENDIX A
BENCH-SCALE TREATABILITY STUDY REPORTS

IN-SITU CHEMICAL OXIDATION
BENCH SCALE STUDY

ADVENTUS
AMERICAS

VIA E-MAIL: mark_becker@urscorp.com

August 03, 2005

Mr. Mark Becker
Project Manager
URS Corp.
12 Commerce Drive
Cranford, NJ 07016

SUBJECT: Final Report – Bench Scale Test For Chemical Oxidation Treatment of Chlorinated Solvent Impacted Soils
Adventus Project No. AAI5-031

Dear Mr. Becker,

This document constitutes the final report for the chemical oxidation treatment of chlorinated solvent impacted soils from the Former Columbia Cement, Inc., Freeport, NY (the Site). This report presents the results of the initial characterization of the Site soil and water, and the results of the activated persulfate testing.

Sample Reception

On April 27, 2005 Adventus received one (five gallon) pail of soil (SB-042005) and one (five-gallon) pail of water (MW-ID-97) from the Site. Both pails were placed into cold room storage upon receipt.

On April 28, 2005 the soil was homogenized by hand and duplicate samples were collected for volatile organic compounds (VOC), total organic carbon (TOC), and chemical oxygen demand (COD) analyses. A composite sample of water was also collected and submitted for VOC, TOC, and COD analyses. All samples were shipped via overnight courier to Severn Trent Laboratories (STL) – Chicago for analysis.

A natural oxidant demand (NOD) test was also conducted on a sample of the Site soil using a standard NOD protocol (**Appendix A**).

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Initial Soil and Groundwater Characterization Results

The initial VOC, TOC, and COD concentrations in the Site soil and water samples are presented in **Table 1**. The main VOC present in the Site soil was 1,1,1-trichloroethane (TCA) (135,500 μg/kg). Nine other VOCs were detected in the soil at much lower concentrations (**Table 1**). The TOC and COD concentrations were 5,250 mg/kg and 18,000 mg/kg, respectively.

The Site water contained trace concentrations of chloroethane (4.8 μg/L) and 1,1-dichloroethane (1 μg/L). TOC and COD concentrations were 11μg/L and 33μg/L, respectively.

The calculated soil Natural Oxidant Demand (NOD) was 42 mg $KMnO_4$ per gram of soil.

Table 1: Initial VOC and COD concentrations in the Site soil and water samples

Parameter	Soil[1]	Units	Water	Units
Chloroethane	ND (120)	μg/kg	4.8	μg/L
1,1-Dichloroethane	525	μg/kg	1.0	μg/L
1,1,1-Trichloroethane	135,500	μg/kg	ND (1)	μg/L
Trichloroethene	60	μg/kg	ND (1)	μg/L
Toluene	825	μg/kg	ND (1)	μg/L
Tetrachloroethene	80	μg/kg	ND (1)	μg/L
Ethylbenzene	60	μg/kg	ND (1)	μg/L
m&p-Xylene	265	μg/kg	ND (2)	μg/L
o-Xylene	114	μg/kg	ND (1)	μg/L
p-Isopropyltoluene	80	μg/kg	ND (1)	μg/L
Naphthalene	60	μg/kg	ND (1)	μg/L
Total VOCs	**137,569**	**μg/g**	**5.8**	**μg/L**
TOC	5,250	mg/kg	11	mg/L
COD	18,000	mg/kg	33	mg/L

[1]Average of duplicate samples
ND = non detect (detection limit)

Experimental Procedure

Based on the mix of target compounds, activated persulfate was selected as the oxidant of choice. Two activation methods (hydrogen peroxide and chelated iron) were tested. Treatment was conducted on combined soil and groundwater samples from the site.

Approximately 300 g of the homogenized site soil was weighed out into 12 – 1L glass jars with Teflon lined lids. The initial characterization revealed that the VOCs concentrations in the Site water were much lower than the concentrations present at the site, thus the Site water was spiked with seven constituents of interest (COI) as outlined in **Table 2**.

Table 2: Initial and Target COI concentrations in the Site water

Parameter	Site Water Received April 27th	Target Concentration	Units
Vinyl Chloride	ND (1)	15	μg/L
Chloroethane	4.8	10,000	μg/L
Methylene Chloride	ND (1)	10	μg/L
1,1-Dichloroethane	1.0	660	μg/L
1,1,1-Trichloroethane	ND (1)	150	μg/L
Benzene	ND (1)	15	μg/L
Toluene	ND (1)	4	μg/L

Table 3 summarizes the persulfate treatments and sampling schedule for each jar. Jars 1, 4, 7, and 10 were controls and thus were filled with spiked Site water. Jars 2, 3, 5, and 6 were filled with a solution of spiked Site water containing 6.3 g/L persulfate ($Na_2S_2O_8$) and 30 g/L 30% hydrogen peroxide (H_2O_2). Jars 8, 9, 11 and 12 were filled with a solution of spiked Site water containing 6.3 g/L sodium persulfate ($Na_2S_2O_8$) and 0.5 g/L ethylenediaminetetraacetic acid iron (III) sodium salt (NaFe(III)EDTA). The jars were inverted several times to mix the soil and water and were placed into an insulated box.

On day 2 (48 hrs after the first application of sodium persulfate), the water and soil in jars 1, 2, 3, 7, 8 and 9 were sampled for VOC, and COD at STL-Chicago. The water was also sampled for persulfate and analyzed by Adventus.

Jars 5, 6, 11, and 12 were re-amended with persulfate and the appropriate activator on day 2. For jars 5 and 6 the 6.3 g of persulfate was dissolved in 30 g of 30% H_2O_2 and then added to the treatment jar. For jars 11 and 12 approximately 40 mL of water was removed from the treatment jar and the 6.3 g of persulfate and 0.5 g of NaFe(III)EDTA were dissolved in this solution and then returned to the treatment jar.

On day 6 (96 hours after the second application of sodium persulfate) the water and soil for the remaining jars were sampled as outlined above for day 2.

Table 3: Summary of Treatments

Jars	Persulfate Addition	Persulfate Activator	Sampling
1,4,7,10	None	None	Jars 1 and7 sampled on Day 2 Jars 4 and 10 sampled on Day 4
2,3	6.3 g on Day 0	H_2O_2	Sampled on Day 2
5,6	6.3 g on Days 0 & 6	H_2O_2	Sampled on Day 6
8,9	6.3 g on Day 0	NaFe(III)EDTA	Sampled on Day 2
11,12	6.3 g on Days 0 & 6	NaFe(III)EDTA	Sampled on Day 6

Results

This section presents the total VOC, COD, and persulfate results of the sodium persulfate batch tests. With the exception of the controls, all other results reported in this section are the average of duplicate treatment jars. The complete analytical data set is included in Appendices B, C, D, and E.

The soil VOC concentrations in all four-control jars were much lower than the initial characterization result. The lower concentrations in the controls may be attributed to partitioning of COIs into the aqueous phase or a hot spot may have been sampled during the initial characterization.

Hydrogen Peroxide Activated Persulfate Treatment

The soil and water results from the persulfate treatment jars activated with hydrogen peroxide are presented in **Tables 4** and **5**. On day 2 the soil VOC concentrations decreased from 2,779 μg/kg in the control to 1,439 μg/kg in response to 6.3 g/L persulfate and 30 g/L of H_2O_2. After an additional 6.3 g/L of persulfate, 30 g/L of 30% H_2O_2 (equivalent to 9 g of H_2O_2) and a four day incubation period, the soil VOC concentrations decreased from 2,275 μg/kg in the control to 502 μg/kg. This corresponded to 48% and 78% removals of total VOC after 2 and 6 days of hydrogen peroxide activated persulfate treatment, respectively.

The COD concentrations were reduced by 57% and 47%, on days 2 and 6 respectively, in response to the persulfate treatment.

Table 4: VOC and COD concentrations in soil following H_2O_2 activated persulfate treatment

Parameter	Day 2			Day 6		
	Control	6.3 g $Na_2S_2O_8$	% Removal After 2 Days	Control	12.6 g $Na_2S_2O_8$	% Removal After 6 Days
Total VOC (μg/kg)	2,779	1,439	48%	2,275	502	78%
COD (mg/kg)	20,000	8,550	57%	9,100	4,850	47%

The water persulfate concentrations revealed that persulfate was fully consumed on day 2 and day 6.

On day 2 the water VOC concentrations decreased from 14,806 μg/L in the control to 1,430 μg/L in response to 6.3 g/L persulfate and 30 g/L of 30% H_2O_2. After the second application of persulfate and H_2O_2 and four additional days of incubation, the water VOC concentrations decreased from 13,952 μg/L in the control to 782 μg/L. This corresponded to 90% and 94% removals of total VOC after 2 and 6 days of hydrogen peroxide activated persulfate treatment, respectively.

Despite the substantial removal of VOCs, only a small decrease in the COD concentration was observed on day 2 and no reduction in the COD concentration was observed on day 6. This is consistent with other studies (Brown et.al), which have shown that sodium persulfate works well on organics and is not consumed in satisfying the general oxidant demand of a soil (i.e. reduced metals etc.).

Table 5: VOC, COD, and persulfate concentrations in water following H_2O_2 activated persulfate treatment

Parameter	Day 2			Day 6		
	Control	6.3 g $Na_2S_2O_8$	% Removal After 2 Days	Control	12.6 g $Na_2S_2O_8$	% Removal After 6 Days
Total VOC (µg/L)	14,806	1,430	90%	13,952	782	94%
COD (mg/L)	310	305	2%	300	360	0%
Persulfate (g/L)	0	0	---	0	0	---

NaFe(III)EDTA Activated Persulfate Treatment

The soil and water analytical results from the persulfate treatment jars activated with NaFe(III)EDTA are presented in **Tables 6** and 7.

On day 2 the soil VOC concentrations decreased from 2,590 µg/kg in the control to 2,516 µg/kg in response to 6.3 g/L persulfate and 0.5 g/L of NaFe(III)EDTA. After an additional 6.3 g/L of persulfate, 0.5 g/L of NaFe(III)EDTA and a four day incubation period, the soil VOC concentrations decreased from 2,530 µg/kg in the control to 2,321 µg/kg. This corresponded to 3% and 8% removals of total VOC after 2 and 6 days of NaFe(III)EDTA activated persulfate treatment, respectively.

On day 2 the soil COD concentration was reduced by 57%. The COD concentration on day 6 was greater than the control. The COD concentrations in the persulfate treated jars on days 2 and 6 were similar, but the concentration in the control was much lower than the initial COD concentration and the value on day 2, thus is appears that control value may have been incorrect.

Table 6: VOC and COD concentrations in soil following NaFe(III)EDTA activated persulfate treatment

Parameter	Day 2			Day 6		
	Control	6.3 g $Na_2S_2O_8$	% Removal After 2 Days	Control	12.6 g $Na_2S_2O_8$	% Removal After 6 Days
Total VOC (µg/kg)	2,590	2,516	3%	2,530	2,321	8%
COD (mg/kg)	26,000	11,100	57%	6,500	11,000	0

The persulfate concentrations in the water were 5.1 g/L and 10.4 g/L on days 2 and 6, respectively. This corresponded to a consumption of 1.2 g and 2.2 g of persulfate on days 2 and 6, respectively. This shows that persulfate radicals were not generated using chelated iron as an activator.

The water VOC concentrations on days 2 and 6 were 11,758 µg/L and 7,843 µg/L, respectively. The COD concentrations were greater in the jars amended with sodium persulfate and NaFe(III)EDTA than in the controls.

Table 7: VOC, COD, and persulfate concentrations in water following NaFe(III)EDTA activated persulfate treatment

Parameter	Day 2			Day 6		
	Control	6.3 g $Na_2S_2O_8$	% Removal After 2 Days	Control	12.6 g $Na_2S_2O_8$	% Removal After 6 Days
Total VOC (µg/L)	14,890	11,758	21%	9,879	7,843	21%
COD (mg/L)	270	715	0	290	1,050	0
Persulfate (g/L)	0	5.1	---	0	10.4	---

When accounting for the total mass of VOCs in the soil (300 g) and water (approximately 835 mL), the oxidation results (**Table 8**) show that persulfate activated with hydrogen peroxide was more effective in oxidizing the VOCs than persulfate activated with NaFe(III)EDTA.

Table 8: Mass balance of VOCs in water and soil following H_2O_2 and NaFe(III)EDTA activated persulfate treatments

Parameter	Treatment	Media	Control	After Day 2	% Removal after Day 2	Control	After Day 6	% Removal after Day 6
Total VOCs (µg)	H_2O_2	Soil	834	432	**48%**	683	151	**78%**
	H_2O_2	Water	13,234	1,577	**88%**	12,348	803	**94%**
	NaFe(III) EDTA	Soil	777	755	**3%**	759	696	**8%**
	NaFe(III) EDTA	Water	13,199	10,565	**20%**	9,021	7,262	**19%**

Removal of TCA and CA

Table 9 below summarizes the concentrations of key COI in groundwater and soil after Day 2 and Day 6, for each control and treatment jar. The TCA and CA concentrations indicate that there is some variability in the results for the duplicate control and treatment jars.

Table 9: Concentrations of target COI in water and soil following H_2O_2 and NaFe(III)EDTA activated persulfate treatments

Parameter	Media	Treatment	Day 2		Day 6		Units
			1st Jar	Duplicate Jar	1st Jar	Duplicate Jar	
TCA	Soil	Control	1,300	1,600	1,000	1,300	µg/kg
	Water	Control	440	510	700	680	µg/L
	Soil	H_2O_2	120	1,500	13	680	µg/kg
	Water	H_2O_2	300	770	430	140	µg/L
	Soil	NaFe(III)EDTA	1,700	1,900	390	3,300	µg/kg
	Water	NaFe(III)EDTA	400	410	850	1100	µg/L
CA	Soil	Control	1,400	880	1,200	1,000	µg/kg
	Water	Control	14,000	14,000	13,000	8,800	µg/L
	Soil	H_2O_2	55	170	ND (5.9)	ND (6.1)	µg/kg
	Water	H_2O_2	89	87	7.8	7.2	µg/L
	Soil	NaFe(III)EDTA	980	150	210	500	µg/kg
	Water	NaFe(III)EDTA	11,000	11,000	5,700	7,500	µg/L

ND = non detect (detection limit)

Table 10 below summarizes the percent removal of key COI for both tests in groundwater and soil after Day 2 and Day 6. High and low percent removals for TCA and CA are shown for each case.

Table 10: Percent removal of target COI in water and soil following H_2O_2 and NaFe(III)EDTA activated persulfate treatments

Parameter	Media	Treatment	% Removal after Day 2		% Removal after Day 6	
			High	Low	High	Low
TCA	Soil	H_2O_2	90.77	-15.38	98.70	32.00
	Water	H_2O_2	31.82	-75.00	80.00	38.57
	Soil	NaFe(III)EDTA	-6.25	-11.76	70	-746.15
	Water	NaFe(III)EDTA	21.57	19.61	1.16	-27.91
CA	Soil	H_2O_2	96.07	87.86	99.51	99.49
	Water	H_2O_2	99.38	99.36	99.94	99.94
	Soil	NaFe(III)EDTA	82.95	-11.36	79.00	50.00
	Water	NaFe(III)EDTA	21.43	21.43	35.23	14.77

The highest removal efficiency was seen with hydrogen peroxide activated persulfate. The results show that with two applications (after 6 days) of hydrogen peroxide activated persulfate, the highest removal efficiency for TCA ranged from 80% to 98.70%, and that for CA it ranged from 99.51 to 99.94%. On the other hand, the lowest removal efficiency for TCA ranged from 32.00% to 38.57%, and that for CA it ranged from 99.49 to 99.94%. This indicates that the hydrogen peroxide activated persulfate was very effective in treating the target COI in both groundwater and soil after two applications of the oxidant. This shows that oxidant demand is close to 42g sodium persulfate per Kg of soil and 60 g hydrogen peroxide per Kg of soil.

Conclusions

The following conclusions can be drawn from these tests:

1. The site-specific COI can be oxidized by sodium persulfate activated with hydrogen peroxide.
2. Iron activated sodium persulfate was not efficient in treating the site-specific COI.
3. The estimated oxidant demand for the soil is 42 g sodium persulfate per Kg of soil and 60 g hydrogen peroxide per Kg of soil.

Please feel free to call the undersigned if there are any questions or if we can be of any further assistance.

Yours truly,

Adventus Americas, Inc.

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Director, Remedial Design and Engineering Services

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Appendix A

Natural Oxidant Demand (NOD)Test Procedure (Modified from REMLAB-01 VER 1.3)

Purpose: To determine the amount of potassium permanganate required to meet the NOD of the soil

Procedure:

1) Homogenize soil sample using a stainless steel spoon. Minimize handling time to minimize volatile losses.
2) Prepare a 1N potassium permanganate solution (=0.2M, 31.61 g $KmnO_4$ in 1L).
3) Label seven 125-mL glass jars with the date, project number, amount and concentration of potassium permanganate and sequence number. Place a 100-mL graduated cylinder in front of each jar.

Summary of NOD jars

Jar Number	Volume 1N $KMnO_4$ (mL)	Volume Water (mL)	Dosage (mg $KMnO_4$/g soil)	Concentration (mg/L)
1	0.0	75.0	0.00	0
2	0.5	74.5	0.32	211
3	1.5	73.5	0.95	632
4	5.0	70.0	3.16	2,107
5	15.0	60.0	9.50	6,323
6	50.0	25.0	31.61	21,073
7	75.0	0.0	47.42	31,610

4) Weigh out 50 g of soil into each of the seven jars. Record weight of soil in each jar.
5) Pipette the appropriate volume of 1N potassium permanganate solution into each of six graduated cylinders. Note that the first cylinder is for the control and thus does not receive any potassium permanganate. Top up each graduated cylinder, except for number seven, with de-ionized water to a final volume of 75-mL.
6) Add the contents of each graduated cylinder to the corresponding jar. Seal each jar and invert several times to mix the soil and liquid. Record date and time the experiment was started.
7) Invert the jars daily several times to mix the soil and liquid for the duration of the experiment (48 hours or 7 days). Prior to inverting the jars, record any changes in colour of the samples.
8) After 7 days, record the colour in the jars.

9) Sample the supernatant from the control, the jar that has the lowest potassium permanganate concentration (lightest purple colour) and the jar with the next lowest concentration
10) Measure the absorbance of the samples with a spectrophotometer (wavelength set at 525 nm).
11) Prepare a calibration curve in the concentration range of the samples and quantify the permanganate concentrations in the samples.

Appendix B - Initial Characterization Results

Parameter	Soil Initial		Soil Initial Dup		Water Initial	
	39287	units	39288	units	39289	units
Dichlorodifluoromethane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Chloromethane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Vinyl chloride	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Bromomethane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Chloroethane	ND (120)	ug/kg	ND (120)	ug/kg	4.8	ug/L
Trichlorofluoromethane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,1-Dichloroethene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Carbon disulfide	ND (120)	ug/kg	ND (120)	ug/kg	ND (5)	ug/L
Acetone	ND (230)	ug/kg	ND (240)	ug/kg	ND (5)	ug/L
Methylene chloride	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
trans-1,2-Dichloroethene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Methyl-tert-butyl-ether (MTBE)	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,1-Dichloroethane	170	ug/kg	880	ug/kg	1.0	ug/L
2,2-Dichloropropane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
cis-1,2-Dichloroethene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
2-Butanone (MEK)	ND (120)	ug/kg	ND (120)	ug/kg	ND (2)	ug/L
Bromochloromethane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Chloroform	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,1,1-Trichloroethane	41,000	ug/kg	230,000	ug/kg	ND (1)	ug/L
1,1-Dichloropropene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Carbon tetrachloride	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Benzene	ND (29)	ug/kg	ND (29)	ug/kg	ND (1)	ug/L
1,2-Dichloroethane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Trichloroethene	ND (29)	ug/kg	120	ug/kg	ND (1)	ug/L
1,2-Dichloropropane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Dibromomethane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Bromodichloromethane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
cis-1,3-Dichloropropene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
4-Methyl-2-pentanone (MIBK)	ND (120)	ug/kg	ND (120)	ug/kg	ND (5)	ug/L
Toluene	550	ug/kg	1,100	ug/kg	ND (1)	ug/L
trans-1,3-Dichloropropene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,1,2-Trichloroethane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Tetrachloroethene	ND (120)	ug/kg	160	ug/kg	ND (1)	ug/L
1,3-Dichloropropane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
2-Hexanone	ND (120)	ug/kg	ND (120)	ug/kg	ND (5)	ug/L
Dibromochloromethane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,2-Dibromoethane (EDB)	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Chlorobenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,1,1,2-Tetrachloroethane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Ethylbenzene	49	ug/kg	71	ug/kg	ND (1)	ug/L
m&p-Xylenes	220	ug/kg	310	ug/kg	ND (2)	ug/L
o-Xylene	97	ug/kg	130	ug/kg	ND (1)	ug/L
Styrene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Bromoform	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Isopropylbenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Bromobenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,1,2,2-Tetrachloroethane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,2,3-Trichloropropane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
n-Propylbenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
2-Chlorotoluene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,3,5-Trimethylbenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
4-Chlorotoluene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
tert-Butylbenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,2,4-Trimethylbenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
sec-Butylbenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,3-Dichlorobenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
p-Isopropyltoluene	ND (120)	ug/kg	160	ug/kg	ND (1)	ug/L
1,4-Dichlorobenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
n-Butylbenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,2-Dichlorobenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,2-Dibromo-3-chloropropane	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,2,4-Trichlorobenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Hexachlorobutadiene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
Naphthalene	120	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,2,3-Trichlorobenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
1,3,5-Trichlorobenzene	ND (120)	ug/kg	ND (120)	ug/kg	ND (1)	ug/L
% Solids, solid	86.2	%	84.8	%	n/a	
% Moisture, Solids	13.8	%	15.2	%	n/a	
COD	19,000	mg/kg	17,000	mg/kg	33	mg/L
TOC	4,500	mg/kg	6,000	mg/kg	11	mg/L

Appendix C - Day 2 Analytical Data (Water)

		Jar 1			Jar 2			Jar 3			Jar 7			
		Control			6.3 g Na2S2O8 + H2O2 (Day 2)			6.3 g Na2S2O8 + H2O2 (Day 2)			Control			6.3 NaFe(I
Analyte	**Units**	**39713**	**Qualifier**	**DL**	**39714**	**Qualifier**	**DL**	**39715**	**Qualifier**	**DL**	**39716**	**Qualifier**	**DL**	**39717**
Chemical Oxygen Demand (COD)	mg/L	***310***		50	***350***		50	***260***		50	***270***		50	***710***
Dichlorodifluoromethane	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Chloromethane	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Vinyl chloride	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Bromomethane	ug/L	***20***	U*	20	***1.0***	U*	1.0	***1.0***	U*	1.0	***20***	U*	20	***20***
Chloroethane	ug/L	***14000***		200	***89***		1.0	***87***		1.0	***14000***		200	***11000***
Trichlorofluoromethane	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,1-Dichloroethene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Carbon disulfide	ug/L	100	U	100	1.8	J	5.0	2.0	JH	5.0	100	U	100	100
Acetone	ug/L	100	U	100	***770***	A	50	***750***		500	100	U	100	100
Methylene chloride	ug/L	***30***		20	***7.7***		1.0	***10***	H	1.0	***30***	H	20	***27***
trans-1,2-Dichloroethene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Methyl-tert-butyl-ether (MTBE)	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,1-Dichloroethane	ug/L	***180***		20	21		1.0	***27***	H	1.0	***190***		20	***170***
2,2-Dichloropropane	ug/L	20	U*	20	***1.0***	U*	1.0	***1.0***	U*	1.0	***20***	U*	20	***20***
cis-1,2-Dichloroethene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
2-Butanone (MEK)	ug/	100	U	100	5.0	U	5.0	***8.9***	H	5.0	100	U	100	100
Bromochloromethane	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Chloroform	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,1,1-Trichloroethane	ug/	***440***		20	***300***		10	***770***		100	***510***		20	***400***
1,1-Dichloropropene	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Carbon tetrachloride	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Benzene	ug/	***16***	J	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,2-Dichloroethane	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
richloroethene	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,2-Dichloropropane	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Dibromomethane	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Bromodichloromethane	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
cis-1,3-Dichloropropene	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
4-Methyl-2-pentanone (MIBK)	ug/	***100***	U*	100	***5.0***	U*	5.0	***5.0***	U*	5.0	***100***	U*	100	***100***
oluene	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
trans-1,3-Dichloropropene	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,1,2-Trichloroethane	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
etrachloroethene	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,3-Dichloropropane	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
2-Hexanone	ug/	100	U	100	5.0	U	5.0	5.0	U	5.0	100	U	100	100
Dibromochloromethane	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20

Appendix C - Day 2 Analytical Data (Water)

		Jar 1			Jar 2			Jar 3			Jar 7			
		Control			6.3 *g* Na2S2O8 + H2O2 (Day 2)			6.3 *g* Na2S2O8 + H2O2 (Day 2)			Control			6.3 NaFe(
Analyte	**Units**	**39713**	**Qualifier**	**DL**	**39714**	**Qualifier**	**DL**	**39715**	**Qualifier**	**DL**	**39716**	**Qualifier**	**DL**	**39717**
Ethylbenzene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
m&p-Xylenes	ug/L	40	U	40	2.0	U	2.0	2.0	U	2.0	40	U	40	40
o-Xylene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Styrene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Bromoform	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Isopropylbenzene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Bromobenzene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,1,2,2-Tetrachloroethane	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,2,3-Trichloropropane	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
n-Propylbenzene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
2-Chlorotoluene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,3,5-Trimethylbenzene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
4-Chlorotoluene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
tert-Butylbenzene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,2,4-Trimethylbenzene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
sec-Butylbenzene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,3-Dichlorobenzene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
p-Isopropyltoluene	ug/L	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,4-Dichlorobenzene	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
n-Butylbenzene	ug/	***20***	U*	20	***1.0***	U*	1.0	***1.0***	U*	1.0	***20***	U*	20	***20***
1,2-Dichlorobenzene	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,2-Dibromo-3-chloropropane	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,3,5-Trichlorobenzene	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
1,2,4-Trichlorobenzene	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Hexachlorobutadiene	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
Naphthalene	ug/	20	U	20	1.0	U	1.0	1.0	U	1.0	20	U	20	20
, , - r c oro enzene	ug	20		20	.0		.0	.0		.0	20		20	20

Appendix C - Day 2 Analytical Data (Soil)

		Jar 1			Jar 2			Jar 3			Jar 7			
		Control			6.3 g Na2S2O8 + H2O2 (Day 2)			6.3 g Na2S2O8 + H2O2 (Day 2)			Control			6.3 NaFe
Analyte	**Units**	**39719**	**Qualifier**	**DL**	**39720**	**Qualifier**	**DL**	**39721**	**Qualifier**	**DL**	**39722**	**Qualifier**	**DL**	**3972**
Chemical Oxygen Demand (COD)	mg/Kg	***20000***		690	***7500***		370	***9600***		390	***26000***		810	***14000***
% Solids	%	***75.7***		0.10	***78.7***		0.10	***77.5***		0.10	***77.2***		0.10	***78.0***
Dichlorodifluoromethane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Chloromethane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Vinyl chloride	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Bromomethane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Chloroethane	ug/Kg	***1400***		130	***55***		6.4	***170***		6.5	***880***	H	130	***980***
Trichlorofluoromethane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,1-Dichloroethene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Carbon disulfide	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	***5.8***
Acetone	ug/Kg	***21***	*	6.6	***440***		250	***390***		260	***79***	*	6.5	***79***
Methylene chloride	ug/Kg	6.6	U	6.6	***9.9***		6.4	***16***		6.5	***12***	M	6.5	6.4
trans-1,2-Dichloroethene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Methyl-tert-butyl-ether (MTBE)	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,1-Dichloroethane	ug/Kg	***48***		6.6	***3.9***	Ja	6.4	***15***		6.5	***19***		6.5	***34***
2,2-Dichloropropane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
2-Butanone (MEK)	ug/Kg	6.6	U	6.6	***24***		6.4	***51***		6.5	6.5	U	6.5	6.4
Bromochloromethane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Chloroform	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,1,1-Trichloroethane	ug/Kg	***1300***		66	***120***		6.4	***1500***		65	***1600***		65	***1700***
1,1-Dichloropropene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Carbon tetrachloride	ug/Kg	6.6	U	6.6	6.4	U	6.4	***84***		6.5	6.5	U	6.5	6.4
Benzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,2-Dichloroethane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
richloroethene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,2-Dichloropropane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Dibromomethane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Bromodichloromethane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
cis-1,3-Dichloropropene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
4-Methyl-2-pentanone (MIBK)	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
oluene	ug/Kg	***6.1***	a	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	***4.0***
trans-1,3-Dichloropropene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,1,2-Trichloroethane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
etrachloroethene	ug/Kg	***3.5***	a	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,3-Dichloropropane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
2-Hexanone	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Dibromochloromethane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,2-Dibromoethane (EDB)	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4

Appendix C - Day 2 Analytical Data (Soil)

		Jar 1			Jar 2			Jar 3			Jar 7			
		Control			6.3 g Na2S2O8 + H2O2 (Day 2)			6.3 g Na2S2O8 + H2O2 (Day 2)			Control			Nal
Analyte	**Units**	**39719**	**Qualifier**	**DL**	**39720**	**Qualifier**	**DL**	**39721**	**Qualifier**	**DL**	**39722**	**Qualifier**	**DL**	**397**
1,1,1,2-Tetrachloroethane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.
Ethylbenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.
m&p-Xylenes	ug/Kg	13	U	13	13	U	13	13	U	13	13	U	13	1
o-Xylene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	***3.***
Styrene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Bromoform	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Isopropylbenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Bromobenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,1,2,2-Tetrachloroethane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,2,3-Trichloropropane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
n-Propylbenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
2-Chlorotoluene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,3,5-Trimethylbenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
4-Chlorotoluene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
tert-Butylbenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,2,4-Trimethylbenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
sec-Butylbenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,3-Dichlorobenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
														6.9
1,4-Dichlorobenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
n-Butylbenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,2-Dichlorobenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,2-Dibromo-3-chloropropane	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,3,5-Trichlorobenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
1,2,4-Trichlorobenzene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Hexachlorobutadiene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
Naphthalene	ug/Kg	6.6	U	6.6	6.4	U	6.4	6.5	U	6.5	6.5	U	6.5	6.4
, , - r c oro enzene	ug g	6.6	U	6.6	.4		.4	6.5	U	6.5	.5		.5	6.4

U	analyte was not detected at or above the stated limit
H	Alternate peak selection upon analytical review
M	manually integrated compound
J	result is an estimated value below the reporting limit or a tentatively identified compound (TIC)
*	Batch QC is greater than reporting limit

Appendix D - Day 6 Analytical Data (Water)

		Jar 4			Jar 5			Jar 6			Jar 10			Ja	
		Control			12.6 g Na2S2O8 + H2O2 (Day 6)			12.6 g Na2S2O8 + H2O2 (Day 6)			Control			12.6 g N NaFe(III)E	
Analyte	**Units**	**39725**	**Qualifier**	**DL**	**39726**	**Qualifier**	**DL**	**39727**	**Qualifier**	**DL**	**39728**	**Qualifier**	**DL**	**39729**	**Q**
Chemical Oxygen Demand (COD)	mg/L	*300*		50	*350*		50	*370*		50	*290*		50	1100	
Dichlorodifluoromethane	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
Chloromethane	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	2.7	
Vinyl chloride	ug/L	10		10	1.0	U	1.0	1.0	U	1.0	9.3	J	10	1.0	
Bromomethane	ug/L	10	U	10	1.0	U	1.0	*2.5*		1.0	10	U	10	1.0	
Chloroethane	ug/L	*13000*	*H*	200	*7.8*		1.0	*7.2*		1.0	*8800*		500	*5700*	
Trichlorofluoromethane	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
1,1-Dichloroethene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
Carbon disulfide	ug/L	50	U	50	*7.9*		5.0	*8.6*		5.0	50	U	50	*13*	
Acetone	ug/L	50	U	50	*390*	M	50	*520*	*M*	100	50	U	50	*40*	
Methylene chloride	ug/L	*20*		10	*6.1*		1.0	*6.9*		1.0	*20*		10	*25*	
trans-1,2-Dichloroethene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
Methyl-tert-butyl-ether (MTBE)	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
1,1-Dichloroethane	ug/L	*170*		10	*4.2*		1.0	*3.9*		1.0	*170*		10	*140*	
2,2-Dichloropropane	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
cis-1,2-Dichloroethene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
2-Butanone (MEK)	ug/	50	U	50	*15*		5.0	*17*		5.0	50	U	50	*27*	
Bromochloromethane	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
Chloroform	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
1,1,1-Trichloroethane	ug/	*700*		10	*430*		10	*140*	H	20	*860*		10	*850*	
1,1-Dichloropropene	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
Carbon tetrachloride	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
Benzene	ug/	*12*		10	1.0	U	1.0	1.0	U	1.0	*11*		10	*3.8*	
1,2-Dichloroethane	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
richloroethene	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
1,2-Dichloropropane	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
Dibromomethane	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
Bromodichloromethane	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
cis-1,3-Dichloropropene	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
4-Methyl-2-pentanone (MIBK)	ug/	50	U	50	5.0	U	5.0	5.0	U	5.0	50	U	50	5.0	
oluene	ug/	*8.1*	*Ja*	10	*0.98*	a	1.0	*0.93*	*Ja*	1.0	*8.6*	*Ja*	10	*1.3*	
trans-1,3-Dichloropropene	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
1,1,2-Trichloroethane	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
etrachloroethene	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	*1.6*	
1,3-Dichloropropane	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
2-Hexanone	ug/	50	U	50	5.0	U	5.0	5.0	U	5.0	50	U	50	5.0	
Dibromochloromethane	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
1,2-Dibromoethane (EDB)	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	
Chlorobenzene															

Appendix D - Day 6 Analytical Data (Water)

		Jar 4			Jar 5			Jar 6			Jar 10			Jar 11			Jar 12		
		Control			12.6 g Na2S2O8 + H2O2 (Day 6)			12.6 g Na2S2O8 + H2O2 (Day 6)			Control			12.6 g Na2S2O8 + NaFe(III)EDTA (Day 6)			12.6 g Na2S2O8 + NaFe(III)EDTA (Day 6)		
Ethylbenzene	ug/L	***19***		10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
m&p-Xylenes	ug/L	***9.8***	***J***	20	2.0	U	2.0	2.0	U	2.0	20	U	20	2.0	U	2.0	2.0	U	2.0
o-Xylene	ug/L	***3.0***	***Ja***	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
Styrene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
Bromoform	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
Isopropylbenzene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
Bromobenzene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
1,1,2,2-Tetrachloroethane	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
1,2,3-Trichloropropane	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
n-Propylbenzene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
2-Chlorotoluene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
1,3,5-Trimethylbenzene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
4-Chlorotoluene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
tert-Butylbenzene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
1,2,4-Trimethylbenzene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
sec-Butylbenzene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
1,3-Dichlorobenzene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
p-Isopropyltoluene	ug/L	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
1,4-Dichlorobenzene	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
n-Butylbenzene	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
1,2-Dichlorobenzene	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
1,2-Dibromo-3-chloropropane	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
1,3,5-Trichlorobenzene	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
1,2,4-Trichlorobenzene	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
Hexachlorobutadiene	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
Naphthalene	ug/	10	U	10	1.0	U	1.0	1.0	U	1.0	10	U	10	1.0	U	1.0	1.0	U	1.0
, , - r c oro enzene	ug	10		10	.0		.0	.0		.0	10		10	.0		.0	.0		.0

Appendix D - Day 6 Analytical Data (Soil)

		Jar 4			Jar 5			Jar 6			Jar 10			Jar 11			Jar 12		
		Control			12.6 g Na2S2O8 + H2O2 (Day 6)			12.6 g Na2S2O8 + H2O2 (Day 6)			Control			12.6 g Na2S2O8 + NaFe(III)EDTA (Day 6)			12.6 g Na2S2O8 + NaFe(III)EDTA (Day 6)		
Analyte	**Units**	**39731**	**Qualifier**	**DL**	**39732**	**Qualifier**	**DL**	**39733**	**Qualifier**	**DL**	**39734**	**Qualifier**	**DL**	**39735**	**Qualifier**	**DL**	**39736**	**Qualifier**	**DL**
Chemical Oxygen Demand (COD)	mg/Kg	***9100***		680	4500		730	5200		450	6500		330	15000		460	7000		300
% Solids	%	***77.8***		0.10	***84.9***		0.10	***82.3***		0.10	***80.2***		0.10	80.3		0.10	***83.0***		0.10
Dichlorodifluoromethane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Chloromethane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Vinyl chloride	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Bromomethane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Chloroethane	ug/Kg	***1200***		64	5.9	U	5.9	6.1	U	6.1	***1000***		62	***210***		6.2	***500***		120
Trichlorofluoromethane	ug/Kg	***6.4***	***U****	6.4	5.9	U*	5.9	***6.1***	***U****	6.1	***6.2***	***U****	6.2	***6.2***	***U****	6.2	6.0	U*	6.0
1,1-Dichloroethene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Carbon disulfide	ug/Kg	6.4	U	6.4	5.9	U	5.9	***7.1***		6.1	6.2	U	6.2	6.2	U	6.2	***9.8***		6.0
Acetone	ug/Kg	6.6		6.4	***150***		5.9	***130***		6.1	***150***		6.2	***91***		6.2	***43***		6.0
Methylene chloride	ug/Kg	***5.5***	***Ja***	6.4	5.9	U	5.9	***12***		6.1	***19***		6.2	***7.3***		6.2	***6.9***		6.0
trans-1,2-Dichloroethene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Methyl-tert-butyl-ether (MTBE)	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,1-Dichloroethane	ug/Kg	***53***		6.4	5.9	U	5.9	6.1	U	6.1	***42***		6.2	***8.1***		6.2	***30***		6.0
2,2-Dichloropropane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
cis-1,2-Dichloroethene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
2-Butanone (MEK)	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	***12***		6.2	***21***		6.0
Bromochloromethane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Chloroform	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,1,1-Trichloroethane	ug/Kg	***1000***		64	***13***		5.9	***680***		61	***1300***		62	***390***		62	***3300***		60
1,1-Dichloropropene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Carbon tetrachloride	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Benzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,2-Dichloroethane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Trichloroethene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,2-Dichloropropane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Dibromomethane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Bromodichloromethane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
cis-1,3-Dichloropropene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
4-Methyl-2-pentanone (MIBK)	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Toluene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	***8.8***		6.2	6.2	U	6.2	6.0	U	6.0
trans-1,3-Dichloropropene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0

Appendix D - Day 6 Analytical Data (Soil)

		Jar 4			Jar 5			Jar 6			Jar 10			Jar 11			Jar 12		
		Control			12.6 g Na2S2O8 + H2O2 (Day 6)			12.6 g Na2S2O8 + H2O2 (Day 6)			Control			12.6 g Na2S2O8 + NaFe(III)EDTA (Day 6)			12.6 g Na2S2O8 + NaFe(III)EDTA (Day 6)		
Analyte	**Units**	**39731**	**Qualifier**	**DL**	**39732**	**Qualifier**	**DL**	**39733**	**Qualifier**	**DL**	**39734**	**Qualifier**	**DL**	**39735**	**Qualifier**	**DL**	**39736**	**Qualifier**	**DL**
1,1,2-Trichloroethane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Tetrachloroethene	ug/Kg	***3.7***	***Ja***	6.4	5.9	U	5.9	6.1	U	6.1	***3.5***	Ja	6.2	6.2	U	6.2	6.0	U	6.0
1,3-Dichloropropane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
2-Hexanone	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Dibromochloromethane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,2-Dibromoethane (EDB)	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Chlorobenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,1,1,2-Tetrachloroethane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Ethylbenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
m&p-Xylenes	ug/Kg	13	U	13	12	U	12	12	U	12	12	U	12	12	U	12	12	U	12
o-Xylene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Styrene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Bromoform	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Isopropylbenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Bromobenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,1,2,2-Tetrachloroethane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,2,3-Trichloropropane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
n-Propylbenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
2-Chlorotoluene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,3,5-Trimethylbenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
4-Chlorotoluene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
tert-Butylbenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,2,4-Trimethylbenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
sec-Butylbenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,3-Dichlorobenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
p-Isopropyltoluene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,4-Dichlorobenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
n-Butylbenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,2-Dichlorobenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,2-Dibromo-3-chloropropane	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,3,5-Trichlorobenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
1,2,4-Trichlorobenzene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Hexachlorobutadiene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0
Naphthalene	ug/Kg	6.4	U	6.4	5.9	U	5.9	6.1	U	6.1	6.2	U	6.2	6.2	U	6.2	6.0	U	6.0

U	analyte was not detected at or above the stated limit
H	Alternate peak selection upon analytical review
M	manually integrated compound
J	result is an estimated value below the reporting limit or a tentatively identified compound (TIC)
*	Batch QC is greater than reporting limit

Appendix E: Sodium Persulfate Titrations

June 23/05 - Sampling #1 (Day 2)

Sample ID	Burette Start (mL)	Burette End (mL)	mL of KMnO4 used to titrate the blank	mL of KMnO4 used to titrate the sample	Normality of KMnO4 solution used	Volume of sample (mL)	g/L sodium persulfate	g/L sodium persulfate consumed
Blank	**0**	**19.7**	**19.7**					
Control (Jar 1)	0	19.9	19.7	19.9	0.5	20	**-0.6**	control
6.3 g Na2S2O8 + H2O2 (Jar 2)	0	19.9	19.7	19.9	0.5	20	**-0.6**	0
6.3 g Na2S2O8 + H2O2 (Jar 3)	19.9	39.6	19.7	19.7	0.5	20	**0.0**	0
Control (Jar 7)	0	19.9	19.7	19.9	0.5	20	**-0.6**	control
6.3 g Na2S2O8 + NaFe(III)EDTA (Jar 8)	19.9	37.9	19.7	18	0.5	20	**5.1**	1.2
6.3 g Na2S2O8 + NaFe(III)EDTA (Jar 9)	0	18	19.7	18	0.5	20	**5.1**	1.2

June 27/05 - Sampling #2 (Day 6 from start of expt., Day 4 from 2nd persulfate application)

Sample ID	Burette Start (mL)	Burette End (mL)	mL of KMnO4 used to titrate the blank	mL of KMnO4 used to titrate the sample	Normality of KMnO4 solution used	Volume of sample (mL)	g/L sodium persulfate	g/L sodium persulfate
Blank	**0**	**19.5**	**19.5**					
Control (Jar 4)	20	39.5	19.5	19.5	0.5	20	**0.0**	control
12.6 g Na2S2O8 + H2O2 (Jar 5)	0	19.8	19.5	19.8	0.5	20	**-0.9**	0
12.6 g Na2S2O8 + H2O2 (Jar 6)	21	41.4	19.5	20.4	0.5	20	**-2.7**	0
Control (Jar 10)	1	20.5	19.5	19.5	0.5	20	**0.0**	control
12.6 g Na2S2O8 + NaFe(III)EDTA (Jar 11)	20.5	36.2	19.5	15.7	0.5	20	**11.3**	1.3
12.6 g Na2S2O8 + NaFe(III)EDTA (Jar 12)	28.3	44.5	19.5	16.2	0.5	20	**9.8**	2.8
12.6 g Na2S2O8 + NaFe(III)EDTA (Jar 11) Repeated	0	16	19.5	16.0	0.5	20	**10.4**	2.2
12.6 g Na2S2O8 + NaFe(III)EDTA (Jar 12) Repeated	16.1	32.2	19.5	16.1	0.5	20	**10.1**	2.5

ENHANCED REDUCTIVE DECHLORINATION
BENCH SCALE STUDY

ADVENTUS
AMERICAS

EHC AND HRC FEASIBILITY STUDY FOR THE TREATMENT OF CHLORINATED SOLVENTS IN GROUNDWATER FROM THE FORMER COLUMBIA CEMENT INC. FACILITY, FREEPORT, NY (THE SITE): BENCH SCALE TREATABILITY INVESTIGATION

FINAL REPORT

Prepared for:

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Cranford, NJ 07016

***Submitted by*:**
ADVENTUS AMERICAS
ADVENTUS Project No.: AAI5-032

October 21, 2005

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EXECUTIVE SUMMARY

A bench-scale treatability was completed at Adventus Remediation Technologies' facility in Mississauga, Ontario, for the treatment of groundwater impacted with chlorinated volatile organic compounds from the former Columbia Cement, Inc. facility in Freeport, NY (the Site). The purpose of the project was to determine the capability of EHC and HRC to treat chloroethane (1,500 ug/L), the primary contaminant in groundwater.

A review of the scientific literature indicated that degradation of chloroethane could occur both via biotic as well as abiotic pathways under reducing conditions. HRC supports biological degradation while EHC supports both biological and chemical reduction.

A set of six flow-through column systems was set up, which included two control columns, two EHC columns and two HRC columns. Two application rates (0.1% and 0.5%) of EHC and HRC were tested. The effectiveness of these treatment systems was assessed using data collected in six sampling events over a period of 107 days.

Overall the treatment systems have demonstrated some reduction in chloroethane over time. However, during the initial three sampling events, it was difficult to assess the effectiveness of the treatments due to the decrease in chloroethane concentrations in the feed and control systems. Both systems showed a significant lag time of between 42 and 71 days, before degradation of chloroethane was truly observed.

Only one of the six sampling events indicated that there was an added benefit of using enhancements such as EHC and HRC to degrade chloroethane. Significant removal was observed in the non-sterile and sterile control columns indicating that the added enhancements did not significantly improve the biotic removal of chloroethane. Removal of chloroethane was primarily from combined abiotic methods and biotic methods without the enhancements. This indicates that chloroethane has a potential to attenuate naturally.

The experiments were conducted at a pore volume flush rate three times the rate observed in the field. Within the limited enhancement that was observed, the data shows that in the short term, HRC performed better than EHC. However, it is likely that the slow release feature of EHC coupled with zero valent iron would perform better in the long run. The study concludes that it is not feasible to enhance the reductive dechlorination of chloroethane in groundwater at the Site.

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Appendix A – Methodology for Headspace SPME GC/ECD determination of VOCs in water samples

Appendix B – Summary of pH and Oxidation Reduction Potentials Readings

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1.0 INTRODUCTION

1.1. Project Background

This report was prepared for URS Corp. to determine the ability of EHC and HRC to treat the COI present in groundwater at the former Columbia Cement Inc. facility in Freeport, New York (Site). This report presents the results and interpretation of data collected from a bench-scale feasibility study completed between April 2005 and September 2005 at Adventus Remediation Technologies' facility in Mississauga, Ontario.

1.2. EHC and HRC Technology Background

EHC is a patented combination of controlled-release solid carbon and zero-valent iron (ZVI) to stimulate reductive dechlorination of persistent organic solvents in groundwater and source zones. The organic component of EHC (fibrous organic material) is nutrient rich, hydrophilic, and has high surface area; thus, it is an ideal support for growth of bacteria in the groundwater environment. As they grow on EHC particle surfaces, indigenous heterotrophic bacteria consume dissolved oxygen and thereby reduce the redox potential in groundwater. In addition, as the bacteria grow on the organic particles they ferment the carbon and release volatile fatty acids (VFAs) such as acetic, propionic, butyric, and lactic acids, which diffuse from the site of fermentation into the groundwater plume and serve as electron donors for other bacteria including dehalogenators and halorespiring species. Finally, the small ZVI particles provide substantial reactive surface area that stimulates direct chemical dechlorination and an additional drop in the redox potential of the groundwater. These physical, chemical, and biological processes combine to create an environment that stimulates chemical and microbiological dechlorination of solvents.

On the other hand, HRC is an ester of polylactic acid, which slowly releases lactic acid and other VFAs in groundwater. The VFAs serve as electron donor and promote the reductive dechlorination of chlorinated solvents.

Groundwater at the Site is predominantly contaminated with CA (CA), which is a degradation product of 1,1,1-TCA, a compound that was released at the Site. A review of the scientific literature indicated that degradation of CA could occur both via biotic as well as abiotic pathways. HRC supports biological degradation while EHC supports both biological and chemical reduction.

2.0 PROJECT OBJECTIVES AND METHODS

1.3. Project Objectives

The aim of this bench-scale feasibility study was to determine the ability of EHC and HRC to treat chlorinated volatile organic compounds in impacted groundwater collected at the Site. Specific objectives included:

- chemical characterization of the groundwater and soil samples;
- evaluation of the performance of EHC and HRC applied at two application rates;
- identification of the most effective product and determination of its optimal application rate for full-scale treatment;
- providing a comprehensive final report, including recommendations for potential full-scale implementation.

1.4. Initial Groundwater and Soil Characterization

On April 27, 2005 Adventus received one five-gallon pail of groundwater (MW-05-15D) and one five-gallon pail of soil (MW-98-9D) from the Site. Both pails were placed into cold room storage upon receipt.

On April 28, 2005 a sample of the groundwater was submitted for volatile organic compounds (VOC), total organic carbon (TOC), chloride, alkalinity, pH, nitrate, sulfate, total iron, and dissolved iron analyses. The soil was homogenized by hand and samples were collected for VOC, TOC, chloride, alkalinity, pH, nitrate, sulfate, and total iron analyses. All samples were shipped via overnight courier to Severn Trent Laboratories (STL) – Chicago for analysis.

The initial groundwater and soil characterization results are presented in **Tables 1 and 2**. The main VOC present in the groundwater was CA (730 ug/L) and a trace amount of chlorobenzene (CB) was also detected at 4 ug/L. Analysis of the Site soil revealed a low concentration of m&p-Xylene (12 ug/kg). All other VOCs were below the analytical detection limit (i.e., non-detect). This indicates that the soil itself is not from a highly contaminated area or that losses have occurred during the collection and/or shipment of the samples.

The TOC concentration was much greater in the soil (9,300 mg/kg) than in the groundwater sample (8 mg/L).

Table 1: Initial VOC and TOC results in the Site soil and groundwater samples

Parameter	Soil	Units	Water	Units
Chloroethane	ND (6.1)	ug/kg	730	ug/L
Chlorobenzene	ND (6.1)	ug/kg	4	ug/L
m&p-Xylene	12	ug/kg	ND (2)	ug/L
Total VOCs	**12**	**ug/kg**	**734**	**ug/L**
TOC	9,300	mg/kg	8	mg/L

ND = non detect (detection limit)

The inorganic constituents are summarized in **Table 2**. The Site soil and groundwater were both neutral and had pH values of 6.9 and 6.3, respectively. The inorganic chemistry of the groundwater was dominated by chloride (75 mg/L) and trace amounts of sulfate (0.29 mg/L), total iron (8 mg/L) and dissolved iron (0.065 mg/L) were detected. The carbonate alkalinity was 380 mg/L in the groundwater and was below the detection limit in the soil. The inorganic chemistry of the soil was dominated by total iron (9,700 mg/kg) and lower concentrations of chloride (3.3 mg/kg) and sulfate (3 mg/kg) were also detected.

Table 2: Inorganic constituents in the Site soil and groundwater samples

Parameter	Soil	Units	Water	Units
Chloride	3.3	mg/kg	75	mg/L
Total Alkalinity (as $CaCO_3$)	ND (500)	mg/kg	380	mg/L
pH	6.9	pH units	6.3	pH units
Nitrate-N	ND (1.2)	mg/kg	ND (0.1)	mg/L
Sulfate	3	mg/kg	0.29	mg/L
Total Iron	9,700	mg/kg	8	mg/L
Total Dissolved Iron	NA	---	0.065	mg/L

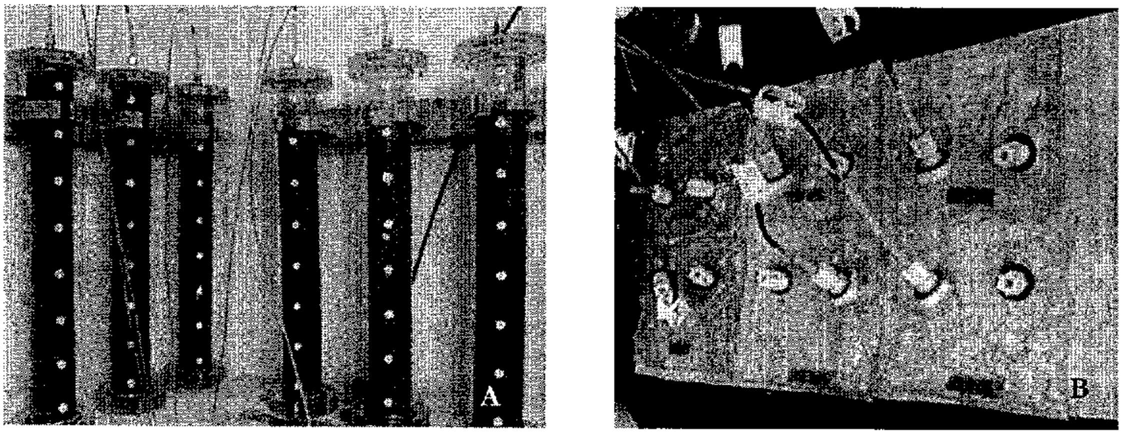
ND = non detect (detection limit)
NA = not applicable

2.3 Column Test Set Up

On June 21, 2005, six column systems were set up with Plexiglas columns (Table 3, Photographs 1A and 1B). Two of the columns were amended with EHC, two columns received HRC and the remaining two were control columns. The EHC columns were filled with a 0.1% and 0.5% (by mass) mixtures of EHC with Site soil. The same application rates were tested for the HRC columns. The first control column was filled with Site soil "as received" and the second control column was filled with Site soil that was autoclaved at 250°F for 20 minutes. One gram of mercuric chloride, a microbial inhibitor, was also added to the autoclaved soil.

Table 3: Summary of the Column Testing

System #	Description	Application Rate (%)
1	EHC2007Fe50	0.1
2	EHC2007Fe50	0.5
3	HRC	0.1
4	HRC	0.5
5	Control	0
6	Sterile Control	0



Photograph 1A and 1B. Laboratory set up of the EHC columns. Each system consists of a column (A) followed by Tedlar bag to collect the effluent (B). Columns 1 – 6 (Left to Right).

The concentrations of CA and CB in the Site groundwater sample were below the typical Site concentrations and thus the feed water was spiked with these two constituents of interest. A separate feed was prepared for the sterile control column as described above except mercuric chloride was also added to the feed bag. Spiked groundwater was continuously being pumped into the bottom of each column. The effluent line from each column was connected to a separate Tedlar bag, which collected the effluent from the column over time. Initially, the feed flow rate was set at 150 mL/day to fill the columns and then was reduced to 70 mL/day. This corresponded to a pore volume flush rate that was three times that calculated from field observations/measurements. This was the slowest flow rate that could be tested to collect sufficient water for analysis at each sampling event.

Oxidation-reduction potential (ORP) and pH were initially monitored daily and then weekly. On July 11th (Day 14), July 26th (Day 29), August 8th (Day 42) September 6th (Day 71), 2005 influent and effluent samples were collected from each system. The influents were sampled for VOC and the column effluents were sampled for VOC, ethane, alkalinity, chloride, and TOC analyses. All samples from the first four sampling events were submitted to Severn Trent Laboratories.

Two additional sampling events were completed on September 29th (Day 94) and October 12th (Day 107). During the final two sampling events, effluent samples were collected directly from the column and were analyzed by Adventus using the solid phase microextraction (SPME) method (**Appendix A**).

3.0 COLUMN RESULTS

3.1 pH and ORP Data

The pH and ORP data is presented in **Appendix B**. The Site groundwater pH ranged between 6.5 and 7.3. The pH values of the control column effluents were similar to the feed and ranged between 6.5 and 7.0. The effluents from both the EHC and HRC treatment columns initially showed a decrease in the pH and then the pH increased into the neutral range with time. The pH of the EHC columns ranged between 5.8 and 7.1, while the pH of the HRC columns ranged between 5.0 and 6.9.

During the initial 30 days of the study the EHC columns produced the best reductive conditions. After day 30, the EHC, HRC, and control columns all showed slightly positive ORP values. The last reading showed that the treatment columns, control columns, and feeds all had negative ORP values. Neither, EHC or HRC were not able to sustain low ORP levels (-150 mV or less) considered optimum to support reductive dechlorination until Day 107.

3.2 First Sampling Event (Day 14)

Appendix C shows all the analytical data collected during this study. **Table 4** shows the data for Day 14 sampling event. On Day 14, the CA concentrations in the two feeds were found to be below the targeted concentrations of 1,500 ug/L and 20 ug/L for CA and CB, respectively.

Table 4: Influence of EHC and HRC on VOC concentrations after 14 days

Parameter	Concentration (ug/L)							
	0.1% EHC	0.5% EHC	0.1% HRC	0.5% HRC	Control	Sterile Control	Feed	Sterile Feed
CA	490	500	510	430	540	480	800	720
CB	2.3	3.7	2.3	9.5	7.4	16	7	10

ND = non detect (detection limit)

Both controls showed reductions in the CA concentration when compared to their respective feeds. The sterile control system showed 33% reduction in CA while the non-sterile control showed 32.5% reduction in CA. This indicates that some abiotic removal as well as removal by indigenous microorganisms was occurring in both columns.

Removal of CA was 39% in the 0.1% EHC column, and was 38% in the 0.5% EHC column. Consequently, the enhanced biotic removal of CA in the EHC columns was only 5.5 to 6.5% more than that in the non-sterile control.

Removal of CA in the 0.1% HRC column was 36%, indicating that the biotic removal in this column was 3.5% more than that in the non-sterile column. Removal of CA in the 0.5% HRC column was 46%, indicating that the biotic removal in this column was 13.5% more than that in the non-sterile column.

The results indicate that significant enhancement in biotic removal from addition of EHC or HRC was not achieved on Day 14. This is probably due to a lag time associated with establishing the microbial colonies. The native anaerobic bacteria were most likely exposed to oxygen during sample collection and mixing of the soils in the laboratory for baseline testing. Consequently, the microorganisms responsible for reductive dechlorination were most likely inhibited during the early periods of the test.

The TOC results were higher in the columns amended with EHC and HRC than the controls (**Table 5**). As expected, the TOC concentration was greater in the EHC column with the higher application rate. The 0.5% HRC column was not sampled for TOC since there was not enough volume on Day 14.

Table 5: Influence of EHC and HRC on TOC and Ethane concentrations after 14 days

Parameter	Concentration					
	0.1% EHC	0.5% EHC	0.1% HRC	0.5% HRC	Control	Sterile Control
TOC (mg/L)	70	630	220	NA	13	53
Ethane (ug/L)	ND (4)	ND (4)	ND (4)	ND (4)	ND (4)	ND (4)

ND = non detect (detection limit)
NA = Not analyzed; due to insufficient volume of effluent

Please note that alkalinity and chloride results are not available for the Day 14 sampling event since the wrong preservative was added to these sample jars.

3.3 Second Sampling Event (Day 29)

Table 6 shows data from Day 29 sampling event. The VOC concentrations in the sterile feed were similar to the Day 14 results while the non-sterile feed showed an additional reduction in the CA concentration. Both feeds were below the targeted CA concentration of 1,500 ug/L. Losses in the headspace of the feed bag were most likely the reason for the drop in feed concentration.

Table 6: Influence of EHC and HRC on VOC concentrations after 29 days

Parameter	Concentration (ug/L)							
	0.1% EHC	0.5% EHC	0.1% HRC	0.5% HRC	Control	Sterile Control	Feed	Sterile Feed
CA	700	430	530	590	640	600	210	750
CB	ND (1)	5.1	ND (1)	ND (1)	ND (1)	ND (1)	ND (1)	ND (1)

ND = non detect (detection limit)

The sterile control system showed 20% reduction in CA which indicates that significant abiotic removal was occurring in the columns.

Since the non-sterile feed concentration dropped significantly (210 ppb), the results are compared to the sterile feed. Removal of CA was 7% in the 0.1% EHC column, and was 43% in the 0.5% EHC column. At best, the biotic removal of CA in the EHC columns was only 23% more than that in the sterile control.

Removal of CA in the 0.1% HRC column was 29%, indicating that the biotic removal in this column was 9% more than that in the sterile column. Removal of CA in the 0.5% HRC column was 21%, indicating that the biotic removal in this column was 1% more than that in the sterile column.

The results indicate that significant enhancement in biotic removal from addition of EHC or HRC was not achieved after 29 days.

The alkalinity of site groundwater did not change as a result of either treatment. The chloride concentrations of the effluents were between 5 and 25 mg/L greater than the background chloride concentration (75 mg/L). The sterile control had the highest chloride concentration since mercuric chloride was used as the microbial inhibitor. TOC concentrations in the EHC and HRC treatment columns decreased since Day 14 (**Table 7**). Ethane was not detected in any column effluent on Day 29.

Table 7: Influence of EHC and HRC on Alkalinity, Chloride, TOC and Ethane concentrations after 29 days

Parameter	Concentration					
	0.1% EHC	**0.05% EHC**	**0.1% HRC**	**0.05% HRC**	**Control**	**Sterile Control**
Alkalinity (mg/L)	370	380	420	330	420	370
Chloride (mg/L)	80	80	80	84	86	100
TOC (mg/L)	14	100	16	120	13	16
Ethane (ug/L)	ND (8)	ND (40)	ND (4)	ND (4)	ND (4)	ND (4)

ND = non detect (detection limit)

3.4 Third Sampling Event (Day 42)

Table 8 shows data for Day 42 sampling event. The total VOC concentration in both feeds continued to decrease from the previous sampling events and the CA concentrations were significantly lower than the targeted concentration of 1,500 ug/L. Possible explanation for the decrease in the feed concentration is that CA stock standard (50 mg CA per mL methanol) that was used to spike the Site groundwater showed a decreased in the CA concentration over time and thus the feed was being spiked to a concentration lower than the targeted (1,500 ug/L) value.

Table 8: Influence of EHC and HRC on VOC concentrations after 42 days

Parameter	Concentration (ug/L)							
	0.1% EHC	0.5% EHC	0.1% HRC	0.5% HRC	Control	Sterile Control	Feed	Sterile Feed
CA	230	200	350	290	400	510	310	280
CB	ND (1)	2.7	ND (1)	ND (1)	ND (1)	ND (1)	1.4	1.5

ND = non detect (detection limit)

Effluent CA concentrations from both controls were higher than the feed indicating 100% removal in both control columns.

Removal of CA was 26% in the 0.1% EHC column, and was 35% in the 0.5% EHC column. There was no removal of CA in the 0.1% HRC column and only 6.5% removal in the 0.5% HRC column. Due to a low CA feed concentration, it was difficult to determine to what extent EHC or HRC were able to enhance the biotic removal. At best the enhancement may have been 35% for EHC and 6.5% for HRC. The results indicate that significant enhancement in biotic removal from addition of EHC or HRC was not achieved.

Table 9 shows supporting analytical data for Day 42. The alkalinity of Site groundwater did not change as a result of either treatment. The chloride concentrations of the effluents were between 9 and 17 mg/L greater than the background chloride concentration (75 mg/L). Once again the sterile control column had the highest chloride concentration since mercuric chloride was used as a microbial inhibitor. TOC concentrations in the treatment (EHC and HRC) and control columns were very similar and, the TOC concentrations in the treatment columns decreased greatly from the values on Day 29. After 42 days of column operation, ethane was not detected in any column effluent.

Table 9: Influence of EHC and HRC on Alkalinity, Chloride, TOC and Ethane concentrations after 42 days

Parameter	Concentration					
	0.1% EHC	0.05% EHC	0.1% HRC	0.05% HRC	Control	Sterile Control
Alkalinity (mg/L)	330	300	370	330	380	350
Chloride (mg/L)	90	84	84	91	84	92
TOC (mg/L)	9.6	12	9.9	11	9.5	11
Ethane (ug/L)	ND (4)	ND (4)	ND (4)	ND (4)	ND (4)	ND (4)

ND = non detect (detection limit)

3.5 Fourth Sampling Event (Day 71)

Table 10 shows the data for Day 71 sampling event. On Day 71, the CA concentrations in the two feeds were greater than those reported during the first three sampling events since a new CA stock standard was used for spiking the feeds.

Both controls showed reductions in the CA concentration when compared to their respective feeds. The sterile control system showed 82% reduction in CA while the non-sterile control showed 89% reduction in CA. This indicates that significant abiotic removal was occurring in both columns.

Removal of CA was 92% in the 0.1% EHC column, and was 91% in the 0.5% EHC column. Consequently, the biotic removal of CA in the EHC columns was only 2 to 4% more than that in the non-sterile control.

Removal of CA in the 0.1% HRC column was 98.5%, indicating that the biotic removal in this column was 10% more than that in the non-sterile column. Removal of CA in the 0.5% HRC column was 100%, indicating that the biotic removal in this column was 11% more than that in the non-sterile column.

The results indicate that the addition of EHC or HRC did not achieve significant enhancement in the biotic removal of VOCs.

Table 10: Influence of EHC and HRC on VOC concentrations after 71 days

Parameter	Concentration (ug/L)							
	0.1% EHC	0.5% EHC	0.1% HRC	0.5% HRC	Control	Sterile Control	Feed	Sterile Feed
CA	180	190	33	4.8	230	390	2,200	2,200
CB	ND (1)	0.9	ND (1)	0.56	ND (1)	ND (1)	ND (5)	ND (5)

ND = non detect (detection limit)

The alkalinity of the Site groundwater increased in both the treatment and control columns (**Table 11**). The initial Site groundwater characterization revealed an alkalinity concentration of 380 mg/L and the column effluents had alkalinity values between 410 and 490 mg/L on Day 71.

The chloride concentrations of the column effluents also showed an increase between 15 and 24 mg/L greater than the background chloride concentration (75 mg/L). The sterile control continued to have the highest chloride concentration and as previously noted this was due to the addition of mercuric chloride.

The TOC concentrations in the treatment and control columns were similar to those from the third sampling event. The values were less than optimal to support reductive dechlorination. The steep drop in TOC from Day 29 was surprising as sufficient quantities of HRC and EHC were injected in the systems.

Ethane was not detected in any column effluent on Day 71.

Table 11: Influence of EHC and HRC on Alkalinity, Chloride, TOC and Ethane concentrations after 71 days

Parameter	Concentration					
	0.1% EHC	0.05% EHC	0.1% HRC	0.05% HRC	Control	Sterile Control
Alkalinity (mg/L)	440	410	420	450	470	490
Chloride (mg/L)	90	90	97	92	95	99
TOC (mg/L)	10	11	11	11	10	16
Ethane (ug/L)	ND (4)	ND (4)	ND (4)	ND (4)	ND (4)	ND (4)

ND = non detect (detection limit)

3.6 Additional Sampling Event #1 (Day 94)

Table 12 shows data from Day 94 sampling. The CA concentrations in the two feeds were slightly below the targeted concentration on Day 94. The slightly lower CA concentration in the non-sterile feed is likely due to the activity of indigenous microbes in the Site groundwater. Both controls showed reductions in the CA concentration when compared to their respective feeds. The sterile control system showed 5% reduction in CA while the non-sterile control showed 20% reduction in CA.

Removal of CA was 52% in the 0.1% EHC column, and was 50% in the 0.5% EHC column. Consequently, the biotic removal of CA in the EHC columns was about 30 to 30% more than that in the non-sterile control.

Removal of CA in the 0.1% HRC column was 62%, indicating that the biotic removal in this column was 42% more than that in the non-sterile column. Removal of CA in the 0.5% HRC column was 99%, indicating that the biotic removal in this column was 79% more than that in the non-sterile column. This was the only case where appreciable enhancements in biotic removal of CA were seen from among all the data sets.

Table 12: Influence of EHC and HRC on VOC concentrations after 94 days

Parameter	Concentration (ug/L)							
	0.1% EHC	0.5% EHC	0.1% HRC	0.5% HRC	Control	Sterile Control	Feed	Sterile Feed
CA	485	500	380	ND (10)	810	1,280	1,005	1,345
DCM	230	260	185	ND (10)	415	345	ND (10)	ND (10)
TCE	20	20	20	15	20	ND (10)	25	18
PCE	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	20	135	68

ND = non detect (detection limit)

The original feed water from the site was exhausted so the experiments were continued with a second batch of groundwater collected from the site. Lower concentrations of other VOCs (methylene chloride (DCM), tetrachloroethylene (PCE), trichloroethylene (TCE)) were also detected in the feed bags and/or column effluents (**Table 12**). This may be related to the use of a second batch of groundwater from the Site. DCM was not detected in the feed bags but was detected in the effluent of both controls. Trace concentrations of trichloroethylene (TCE) and tetrachloroethylene (PCE) were detected in the feeds and in some of the column effluents.

3.7 Additional Sampling Event #2 (Day 107)

The results from Day 107 sampling are shown in **Table 13.** Both controls showed reductions in the CA concentration when compared to their respective feeds. The sterile control system showed 51% reduction in CA while the non-sterile control showed 88% reduction in CA.

There was no enhancement in the biotic removal of CA in both EHC columns as the non-sterile effluent concentration of CA was essentially the same as the effluent from the treatment columns.

There was 96% removal of CA in the 0.1% HRC column and 99.5% removal of CA in the 0.5% HRC column. Consequently, the biotic removal of CA in HRC columns was only 8% to 12% more than that in the non-sterile column.

As observed in the previous sampling, DCM was produced in all the column effluents. Trace concentrations of TCE and PCE were also detected in the effluent columns.

Table 13: Influence of EHC and HRC on VOC concentrations after 107 days

Parameter	Concentration (ug/L)							
	0.1% EHC	0.5% EHC	0.1% HRC	0.5% HRC	Control	Sterile Control	Feed	Sterile Feed
CA	305	250	80	ND (10)	270	960	2,245	1,448
DCM	145	120	100	185	220	185	ND (10)	ND (10)
TCE	10	10	15	ND (10)	10	ND (10)	40	20
PCE	ND (10)	45	ND (10)	ND (10)	15	65	45	18

ND = non detect (detection limit)

4.0 CONCLUSIONS

The purpose of this bench-scale feasibility study was to determine the ability of EHC and HRC to treat chlorinated volatile organic compounds in impacted groundwater collected from the Site. The following conclusions are provided based on the results of the testing:

- The initial characterization of the Site groundwater revealed that it had lower than expected concentrations of the COI (CA and CB), thus the Site groundwater was spiked with these COI to better represent the Site conditions.
- Due to VOC reductions in the feed during the first three sampling event, it was difficult to assess the effectiveness of the treatments. Both the EHC and HRC treatments showed reductions in the total VOC concentrations, but the control systems also showed reductions in total VOCs.
- A lag time of approximately 70 days was observed in both systems for the microorganisms to get established. The ORP in both systems stayed in the positive range until after Day 94
- The fifth sampling (Day 94) showed that both EHC and HRC treatments were capable of treating CA. This was the only time the data indicated that biotic removal of CA was significantly enhanced by HRC and EHC.
- A consistently high biotic removal of CA was not seen with either EHC or HRC.
- The data shows that significant amounts of CA were being removed by abiotic means as well as biotic means without enhancements in the control columns. Consequently, there was no added value from using enhancements like HRC and EHC.
- The lack of enhanced biotic removal may have been from the lack of appropriate microorgansims capable of degrading CA in the soil from the downgradient area.

APPENDICIES

FINAL REPORT: EHC AND HRC FEASIBILITY STUDY FOR THE TREATMENT OF CHLORINATED SOLVENTS IN GROUNDWATER FROM THE FORMER COLUMBIA CEMENT INC., FREEPORT, NY (THE SITE)

Appendix A: Methodology for Headspace SPME GC/ECD determination of VOCs in water samples

In-house method of VOC analysis for Adventus Remediation Technologies
Method developed by Michael Gibson, PhD.

Introduction:

Solid phase microextraction (SPME) followed by GC desorption and analysis has been demonstrated to be an effective and reliable method of monitoring volatile contaminants in water samples. SPME fibers can be desorbed in the manual injection ports of most gas chromatographs (GC), not requiring the specialized hardware necessary for purge and trap or headspace systems typically used for VOC analysis (Santos F.J. *et al.*, 1996).

The SPME fiber is a fused-silica fiber coated with a stationary phase, housed in a specialized syringe-type holder for protection and for inserting through septa. The fiber can either be immersed in an aqueous sample or be exposed to the headspace above an aqueous sample. The absorption of analytes is based on equilibrium partitioning between the coating and the sample. Where samples are contaminated with oils or other components, which may damage or reduce the life of the fibers headspace analysis may be preferable. James and Stack (1997) compared headspace and immersion SPME for VOC analysis of wastewaters and found headspace SPME to be preferable.

The in-house method of analysis of VOCs in water samples was developed on the basis of headspace SPME followed by direct GC analysis.

Method:

The fibers used were Carboxen™/Polydimethylsiloxane with a 75μm thick stationary phase (Supelco No. 57318). Two (2) ml aqueous samples were placed in 4ml amber glass headspace vials with Teflon lined septa (Supelco No. 27006) with a 4 mm Teflon coated magnetic stir bar. Samples were stirred for 10 minutes prior to insertion of the fiber, the fiber was inserted (ensuring that it did not come in contact with the aqueous phase) for and additional 10 minutes. Fibers were removed from the samples and immediately (within 30 seconds) placed into the injection port of the GC for desorption and analysis.

Chromatographic analysis was performed using a SRI 8610C Gas Chromatograph coupled with a flame ionization detector (FID) and dry electrolytic conductivity detector (DELCD). The injection port was lined with a small bore, 0.75 mm ID, glass liner (Supelco No. 26375-05). Both the injector and detector were maintained at 200 °C. The analytical column was a VOCOL capillary column (30 m x 0.25 mm, 1.5 μm film thickness, Supelco No. 24205-U). Helium was used as the carrier gas; column flow rate was 10 ml/min. The column oven temperature program started at 40 °C for 2 min, increased at 10 °C/min to 150 °C for 2 min, then increased at 30 °C to 200 °C for a final 1 min.

References.

James K J, Stack M A (1997) Fresenius J Anal Chem 358: 833-837.
Santos F J, Galceran M T, Fraisse D (1996) J. Chromatogr. A, 742: 181-189.

Appendix B – Summary of pH and Oxidation Reduction Potential Readings

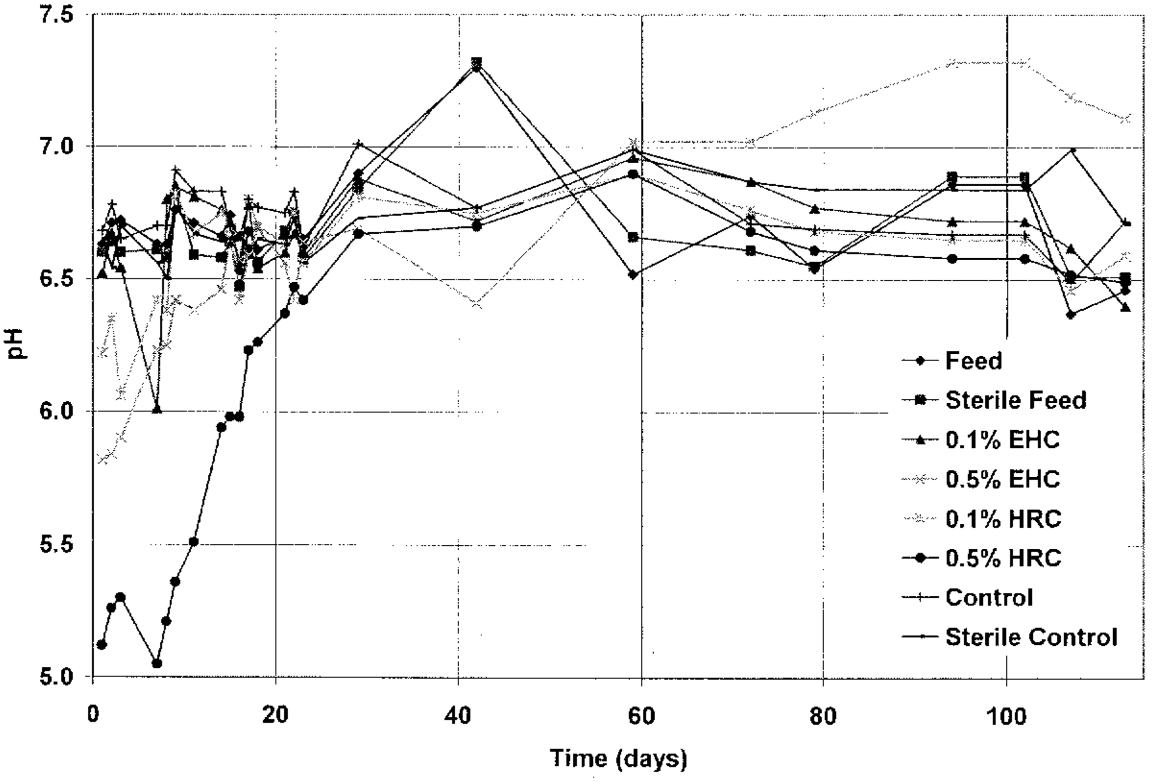


Figure A: pH readings of feeds and column effluents over time

Appendix B – Summary of pH and Oxidation Reduction Potential Readings

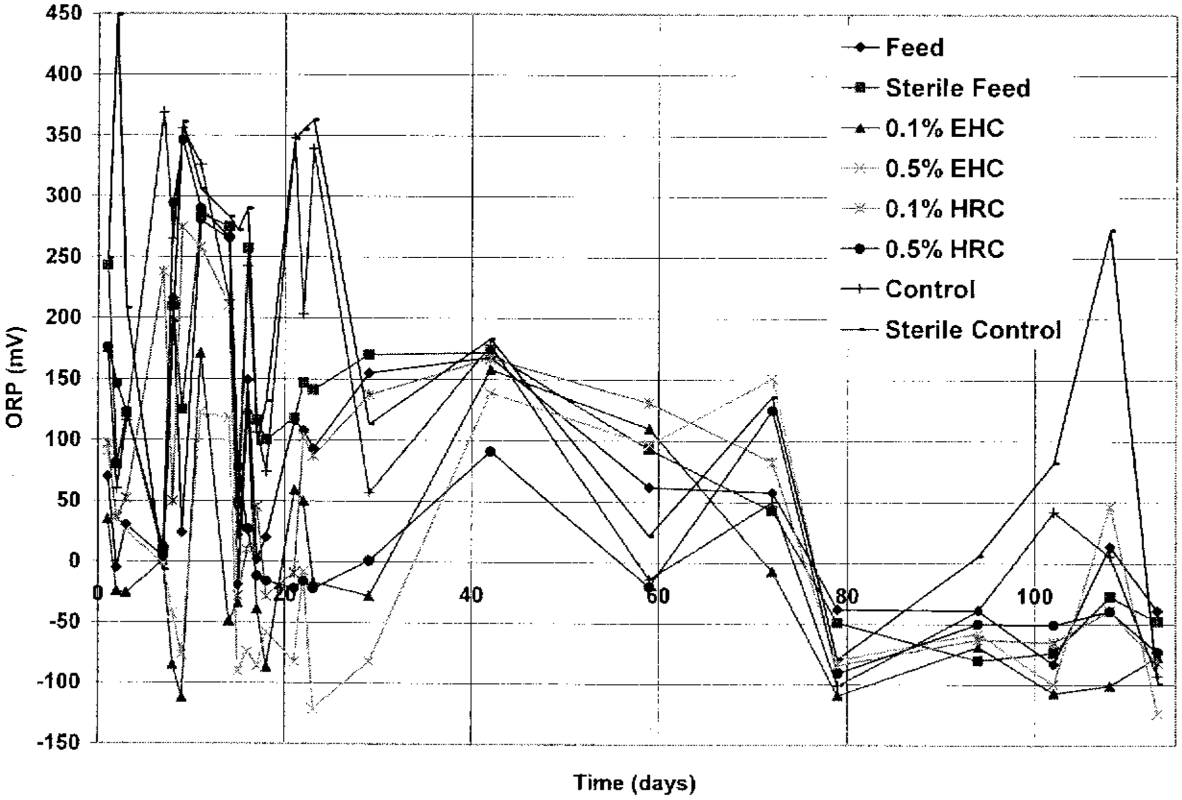


Figure B: ORP readings of feeds and column effluents over time

Appendix C – Analytical Data

AAI5-032 Sampling #6 t = 107 days

Analyte		**DL**	**0.1% EHC2007Fe50 41015**	**0.5% EHC2007Fe50 41016**	**0.1% HRC 41017**	**0.5% HRC 41018**	**Control 41019**	**Sterile Control 41020**	**Feed #1 41021**	**Feed #2 - Sterile 41022**	**Feed #2 - Sterile 41022D**	**Feed #2 - Sterile 41022Avg**
Vinyl Chloride	VC	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloromathane	DCM	10.0	145	120	100	185	220	185	ND	0	0	0
Cis-1,2-Dichloroethene	cis-DCE	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	CF	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	CT	14.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	1,2DCA	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	TCE	10.0	10	10	15	ND	10	ND	40	20	20	20
Tetrachloroethene	PCE	20.0	0	45	0	0	15	65	45	15	20	18
Chloroethane	CA	10.0	305	250	80	5	270	960	2245	1540	1355	1448
Total VOCs			**460**	**425**	**195**	**190**	**515**	**1,210**	**2,330**	**1,575**	**1,395**	**1,485**

AAI5-032 Initial Results

Baseline Sampling 28-Apr

	Soil Initial 39285	UNITS	Water Initial 39286	UNITS	
Dichlorodifluoromethane	ND (6.1)	ug/kg	ND (1)	ug/L	
Chloromethane	ND (6.1)	ug/kg	ND (1)	ug/L	
Vinyl chloride	ND (6.1)	ug/kg	ND (1)	ug/L	
Bromomethane	ND (6.1)	ug/kg	ND (1)	ug/L	
Chloroethane	ND (6.1)	ug/kg	730	ug/L	
Trichlorofluoromethane	ND (6.1)	ug/kg	ND (1)	ug/L	
1,1-Dichloroethene	ND (6.1)	ug/kg	ND (1)	ug/L	
Carbon disulfide	ND (6.1)	ug/kg	ND (5)	ug/L	
Acetone	ND (6.1)	ug/kg	ND (5)	ug/L	
Methylene chloride	ND (6.1)	ug/kg	ND (1)	ug/L	
trans-1,2-Dichloroethene	ND (6.1)	ug/kg	ND (1)	ug/L	
Methyl-tert-butyl-ether (MTBE)	ND (6.1)	ug/kg	ND (1)	ug/L	
1,1-Dichloroethane	ND (6.1)	ug/kg	ND (1)	ug/L	
2,2-Dichloropropane	ND (6.1)	ug/kg	ND (1)	ug/L	
cis-1,2-Dichloroethene	ND (6.1)	ug/kg	ND (1)	ug/L	
2-Butanone (MEK)	ND (6.1)	ug/kg	ND (5)	ug/L	
Bromochloromethane	ND (6.1)	ug/kg	ND (1)	ug/L	
Chloroform	ND (6.1)	ug/kg	ND (1)	ug/L	
1,1,1-Trichloroethane	ND (6.1)	ug/kg	ND (1)	ug/L	
1,1-Dichloropropene	ND (6.1)	ug/kg	ND (1)	ug/L	
Carbon tetrachloride	ND (6.1)	ug/kg	ND (1)	ug/L	
Benzene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,2-Dichloroethane	ND (6.1)	ug/kg	ND (1)	ug/L	
Trichloroethene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,2-Dichloropropane	ND (6.1)	ug/kg	ND (1)	ug/L	
Dibromomethane	ND (6.1)	ug/kg	ND (1)	ug/L	
Bromodichloromethane	ND (6.1)	ug/kg	ND (1)	ug/L	
cis-1,3-Dichloropropene	ND (6.1)	ug/kg	ND (1)	ug/L	
4-Methyl-2-pentanone (MIBK)	ND (6.1)	ug/kg	ND (5)	ug/L	
Toluene	ND (6.1)	ug/kg	ND (1)	ug/L	
trans-1,3-Dichloropropene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,1,2-Trichloroethane	ND (6.1)	ug/kg	ND (1)	ug/L	
Tetrachloroethene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,3-Dichloropropane	ND (6.1)	ug/kg	ND (1)	ug/L	
2-Hexanone	ND (6.1)	ug/kg	ND (5)	ug/L	
Dibromochloromethane	ND (6.1)	ug/kg	ND (1)	ug/L	
1,2-Dibromoethane (EDB)	ND (6.1)	ug/kg	ND (1)	ug/L	
Chlorobenzene	ND (6.1)	ug/kg	4	ug/L	
1,1,1,2-Tetrachloroethane	ND (6.1)	ug/kg	ND (1)	ug/L	
Ethylbenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
m&p-Xylenes	12	ug/kg	ND (2)	ug/L	
o-Xylene	ND (6.1)	ug/kg	ND (1)	ug/L	
Styrene	ND (6.1)	ug/kg	ND (1)	ug/L	
Bromoform	ND (6.1)	ug/kg	ND (1)	ug/L	
Isopropylbenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
Bromobenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,1,2,2-Tetrachloroethane	ND (6.1)	ug/kg	ND (1)	ug/L	
1,2,3-Trichloropropane	ND (6.1)	ug/kg	ND (1)	ug/L	
n-Propylbenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
2-Chlorotoluene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,3,5-Trimethylbenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
4-Chlorotoluene	ND (6.1)	ug/kg	ND (1)	ug/L	
tert-Butylbenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,2,4-Trimethylbenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
sec-Butylbenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,3-Dichlorobenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
p-Isopropyltoluene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,4-Dichlorobenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
n-Butylbenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,2-Dichlorobenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,2-Dibromo-3-chloropropane	ND (6.1)	ug/kg	ND (1)	ug/L	
1,2,4-Trichlorobenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
Hexachlorobutadiene	ND (6.1)	ug/kg	ND (1)	ug/L	
Naphthalene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,2,3-Trichlorobenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
1,3,5-Trichlorobenzene	ND (6.1)	ug/kg	ND (1)	ug/L	
% Solids, solid	82.6	%	n/a		
% Moisture, Solids	17.4	%	n/a		
Alkalinity, Total as CaCO3	ND (500)	mg/kg	380	mg/L	
Chloride	3.3	mg/kg	75	mg/L	
Nitrate as N	ND (1.2)	mg/kg	ND (0.1)	mg/L	
Sulfate	3	mg/kg	0.29	mg/L	
TOC	9,300	mg/kg	8	mg/L	
pH	6.9	pH units	6.3	pH units	
Total Iron	9,700	mg/kg	8	mg/L	
Dissolved Iron	n/a		0.065	mg/L	*the dissolved Fe result was below the RL but above the MDL.*

AAI5-032 Sampling #1 t=14 days

	Column 1 Effluent			Column 2 Effluent			
Analyte	**38927**	**Qualifier**	**DL**	**38928**	**Qualifier**	**DL**	**Units**
TOC Average Duplicates	70		10	630		40	mg/L
Dichlorodifluoromethane	1	U	1	1	U	1	ug/L
Chloromethane	1	U	1	1	U	1	ug/L
Vinyl chloride	1	U	1	1	U	1	ug/L
Bromomethane	1	U*	1	1	U*	1	ug/L
Chloroethane	490		10	500		10	ug/L
Trichlorofluoromethane	1	U	1	1	U	1	ug/L
1,1-Dichloroethene	1	U	1	1	U	1	ug/L
Carbon disulfide	5	U	5	2.4	J	5	ug/L
Acetone	52		5	96		5	ug/L
Methylene chloride	58		1	69		1	ug/L
trans-1,2-Dichloroethene	1	U	1	1	U	1	ug/L
Methyl-tert-butyl-ether (MTBE)	1	U	1	1	U	1	ug/L
1,1-Dichloroethane	1	U	1	1	U	1	ug/L
2,2-Dichloropropane	1	U	1	1	U	1	ug/L
cis-1,2-Dichloroethene	1	U	1	1	U	1	ug/L
2-Butanone (MEK)	5	U	5	47		5	ug/L
Bromochloromethane	1	U	1	1	U	1	ug/L
Chloroform	1	U	1	1	U	1	ug/L
1,1,1-Trichloroethane	1	U	1	1	U	1	ug/L
1,1-Dichloropropene	1	U	1	1	U	1	ug/L
Carbon tetrachloride	1	U	1	1	U	1	ug/L
Benzene	1	U	1	1	U	1	ug/L
1,2-Dichloroethane	1	U	1	1.3		1	ug/L
Trichloroethene	1	U	1	6		1	ug/L
1,2-Dichloropropane	1	U	1	1	U	1	ug/L
Dibromomethane	1	U	1	1	U	1	ug/L
Bromodichloromethane	1	U*	1	1	U*	1	ug/L
cis-1,3-Dichloropropene	1	U	1	1	U	1	ug/L
4-Methyl-2-pentanone (MIBK)	5	U	5	5	U	5	ug/L
Toluene	1	U	1	1	U	1	ug/L
trans-1,3-Dichloropropene	1	U	1	1	U	1	ug/L
1,1,2-Trichloroethane	1	U	1	1	U	1	ug/L
Tetrachloroethene	1	U	1	1	U	1	ug/L
1,3-Dichloropropane	1	U	1	1	U	1	ug/L
2-Hexanone	5	U	5	5	U	5	ug/L
Dibromochloromethane	1	U*	1	1	U*	1	ug/L
1,2-Dibromoethane (EDB)	1	U	1	1	U	1	ug/L
Chlorobenzene	2.3		1	3.7		1	ug/L
1,1,1,2-Tetrachloroethane	1	U	1	1	U	1	ug/L
Ethylbenzene	1	U	1	2.6		1	ug/L
m&p-Xylenes	2	U	2	2	U	2	ug/L
o-Xylene	1	U	1	1	U	1	ug/L
Styrene	1	U	1	1	U	1	ug/L
Bromoform	1	U*	1	1	U*	1	ug/L

AAI5-032 Sampling #1   t=14 days

	Column 1 Effluent			Column 2 Effluent			
Analyte	**38927**	**Qualifier**	**DL**	**38928**	**Qualifier**	**DL**	**Units**
Isopropylbenzene	1	U	1	1	U	1	ug/L
Bromobenzene	1	U	1	1	U	1	ug/L
1,1,2,2-Tetrachloroethane	1	U	1	1	U	1	ug/L
1,2,3-Trichloropropane	1	U	1	1	U	1	ug/L
n-Propylbenzene	1	U	1	1	U	1	ug/L
2-Chlorotoluene	1	U	1	1	U	1	ug/L
1,3,5-Trimethylbenzene	1	U	1	1	U	1	ug/L
4-Chlorotoluene	1	U	1	1	U	1	ug/L
tert-Butylbenzene	1	U	1	1	U	1	ug/L
1,2,4-Trimethylbenzene	1	U	1	1	U	1	ug/L
sec-Butylbenzene	1	U	1	1	U	1	ug/L
1,3-Dichlorobenzene	1	U	1	1	U	1	ug/L
p-Isopropyltoluene	1	U	1	1	U	1	ug/L
1,4-Dichlorobenzene	1	U	1	1	U	1	ug/L
n-Butylbenzene	1	U	1	1	U	1	ug/L
1,2-Dichlorobenzene	1	U	1	1	U	1	ug/L
1,2-Dibromo-3-chloropropane	1	U	1	1	U	1	ug/L
1,3,5-Trichlorobenzene	1	U	1	1	U	1	ug/L
1,2,4-Trichlorobenzene	1	U	1	1	U	1	ug/L
Hexachlorobutadiene	1	U	1	1	U	1	ug/L
Naphthalene	1	U	1	1	U	1	ug/L
1,2,3-Trichlorobenzene	1	U	1	1	U	1	ug/L

Analyte	38927	Qualifier	DL	38928	Qualifier	DL	Units
Ethane	4	U	4	4	U	4	ug/L

U = compound analyzed but not detected at a concentration above the reporting limit.

AAI5-032 Sampling #1 t=14 days

	Column 3 Effluent			Column 4 Effluent			
Analyte	**38929**	**Qualifier**	**DL**	**38930**	**Qualifier**	**DL**	**Units**
TOC Average Duplicates	220		40	---	---	---	---
Dichlorodifluoromethane	1	U	1	1	U	1	ug/L
Chloromethane	1	U	1	1	U	1	ug/L
Vinyl chloride	1	U	1	1	U	1	ug/L
Bromomethane	1	U*	1	1	U*	1	ug/L
Chloroethane	510		10	430		10	ug/L
Trichlorofluoromethane	1	U	1	1	U	1	ug/L
1,1-Dichloroethene	1	U	1	1	U	1	ug/L
Carbon disulfide	1.3	J	5	1.9	J	5	ug/L
Acetone	49		5	220		50	ug/L
Methylene chloride	56		1	62		1	ug/L
trans-1,2-Dichloroethene	1	U	1	1	U	1	ug/L
Methyl-tert-butyl-ether (MTBE)	1	U	1	1	U	1	ug/L
1,1-Dichloroethane	1	U	1	1	U	1	ug/L
2,2-Dichloropropane	1	U	1	1	U	1	ug/L
cis-1,2-Dichloroethene	1	U	1	1	U	1	ug/L
2-Butanone (MEK)	84		5	160		50	ug/L
Bromochloromethane	1	U	1	1	U	1	ug/L
Chloroform	1	U	1	1	U	1	ug/L
1,1,1-Trichloroethane	1	U	1	1	U	1	ug/L
1,1-Dichloropropene	1	U	1	1	U	1	ug/L
Carbon tetrachloride	1	U	1	1	U	1	ug/L
Benzene	1	U	1	1	U	1	ug/L
1,2-Dichloroethane	1	U	1	2.3		1	ug/L
Trichloroethene	1	U	1	1	U	1	ug/L
1,2-Dichloropropane	1	U	1	1	U	1	ug/L
Dibromomethane	1	U	1	1	U	1	ug/L
Bromodichloromethane	1	U*	1	1	U*	1	ug/L
cis-1,3-Dichloropropene	1	U	1	1	U	1	ug/L
4-Methyl-2-pentanone (MIBK)	5	U	5	5	U	5	ug/L
Toluene	1	U	1	1	U	1	ug/L
trans-1,3-Dichloropropene	1	U	1	1	U	1	ug/L
1,1,2-Trichloroethane	1	U	1	1	U	1	ug/L
Tetrachloroethene	1	U	1	1	U	1	ug/L
1,3-Dichloropropane	1	U	1	1	U	1	ug/L
2-Hexanone	5	U	5	5	U	5	ug/L
Dibromochloromethane	1	U*	1	1	U*	1	ug/L
1,2-Dibromoethane (EDB)	1	U	1	1	U	1	ug/L
Chlorobenzene	2.3		1	9.5		1	ug/L
1,1,1,2-Tetrachloroethane	1	U	1	1	U	1	ug/L
Ethylbenzene	1	U	1	1	U	1	ug/L
m&p-Xylenes	2	U	2	2	U	2	ug/L
o-Xylene	1	U	1	1	U	1	ug/L
Styrene	1	U	1	1	U	1	ug/L
Bromoform	1	U*	1	1	U*	1	ug/L

AAI5-032 Sampling #1 t=14 days

	Column 3 Effluent			Column 4 Effluent			
Analyte	**38929**	**Qualifier**	**DL**	**38930**	**Qualifier**	**DL**	**Units**
Isopropylbenzene	1	U	1	1	U	1	ug/L
Bromobenzene	1	U	1	1	U	1	ug/L
1,1,2,2-Tetrachloroethane	1	U	1	1	U	1	ug/L
1,2,3-Trichloropropane	1	U	1	1	U	1	ug/L
n-Propylbenzene	1	U	1	1	U	1	ug/L
2-Chlorotoluene	1	U	1	1	U	1	ug/L
1,3,5-Trimethylbenzene	1	U	1	1	U	1	ug/L
4-Chlorotoluene	1	U	1	1	U	1	ug/L
tert-Butylbenzene	1	U	1	1	U	1	ug/L
1,2,4-Trimethylbenzene	1	U	1	1	U	1	ug/L
sec-Butylbenzene	1	U	1	1	U	1	ug/L
1,3-Dichlorobenzene	1	U	1	1	U	1	ug/L
p-Isopropyltoluene	1	U	1	1	U	1	ug/L
1,4-Dichlorobenzene	1	U	1	1	U	1	ug/L
n-Butylbenzene	1	U	1	1	U	1	ug/L
1,2-Dichlorobenzene	1	U	1	1	U	1	ug/L
1,2-Dibromo-3-chloropropane	1	U	1	1	U	1	ug/L
1,3,5-Trichlorobenzene	1	U	1	1	U	1	ug/L
1,2,4-Trichlorobenzene	1	U	1	1	U	1	ug/L
Hexachlorobutadiene	1	U	1	1	U	1	ug/L
Naphthalene	1	U	1	1	U	1	ug/L
1,2,3-Trichlorobenzene	1	U	1	1	U	1	ug/L

Analyte	38929	Qualifier	DL	38930	Qualifier	DL	Units
Ethane	4	U	4	4	U	4	ug/L

U = compound analyzed but not detected at a concentration above the reporting limit.

AAI5-032 Sampling #1 t=14 days

	Column 5 Effluent			Column 6 Effluent			
Analyte	38931	Qualifier	DL	38932	Qualifier	DL	Units
TOC Average Duplicates	13		2	53		10	mg/L
Dichlorodifluoromethane	1	U	1	1	U	1	ug/L
Chloromethane	1	U	1	1	U	1	ug/L
Vinyl chloride	1	U	1	1	U	1	ug/L
Bromomethane	1	U*	1	1	U*	1	ug/L
Chloroethane	540		10	480		10	ug/L
Trichlorofluoromethane	1	U	1	1	U	1	ug/L
1,1-Dichloroethene	1	U	1	1	U	1	ug/L
Carbon disulfide	5	U	5	5	U	5	ug/L
Acetone	5	U	5	58		5	ug/L
Methylene chloride	90		1	51		1	ug/L
trans-1,2-Dichloroethene	1	U	1	1	U	1	ug/L
Methyl-tert-butyl-ether (MTBE)	1	U	1	1	U	1	ug/L
1,1-Dichloroethane	1	U	1	1	U	1	ug/L
2,2-Dichloropropane	1	U	1	1	U	1	ug/L
cis-1,2-Dichloroethene	1	U	1	1	U	1	ug/L
2-Butanone (MEK)	5	U	5	12		5	ug/L
Bromochloromethane	1	U	1	1	U	1	ug/L
Chloroform	1	U	1	1	U	1	ug/L
1,1,1-Trichloroethane	1	U	1	1	U	1	ug/L
1,1-Dichloropropene	1	U	1	1	U	1	ug/L
Carbon tetrachloride	1	U	1	1	U	1	ug/L
Benzene	1	U	1	1	U	1	ug/L
1,2-Dichloroethane	1	U	1	1	U	1	ug/L
Trichloroethene	1	U	1	1	U	1	ug/L
1,2-Dichloropropane	1	U	1	1	U	1	ug/L
Dibromomethane	1	U	1	1	U	1	ug/L
Bromodichloromethane	1	U*	1	1	U*	1	ug/L
cis-1,3-Dichloropropene	1	U	1	1	U	1	ug/L
4-Methyl-2-pentanone (MIBK)	5	U	5	5	U	5	ug/L
Toluene	1	U	1	1	U	1	ug/L
trans-1,3-Dichloropropene	1	U	1	1	U	1	ug/L
1,1,2-Trichloroethane	1	U	1	1	U	1	ug/L
Tetrachloroethene	1	U	1	1	U	1	ug/L
1,3-Dichloropropane	1	U	1	1	U	1	ug/L
2-Hexanone	5	U	5	5	U	5	ug/L
Dibromochloromethane	1	U*	1	1	U*	1	ug/L
1,2-Dibromoethane (EDB)	1	U	1	1	U	1	ug/L
Chlorobenzene	7.4		1	16		1	ug/L
1,1,1,2-Tetrachloroethane	1	U	1	1	U	1	ug/L
Ethylbenzene	1	U	1	1	U	1	ug/L
m&p-Xylenes	2	U	2	2	U	2	ug/L
o-Xylene	1	U	1	1	U	1	ug/L
Styrene	1	U	1	1	U	1	ug/L
Bromoform	1	U*	1	1	U*	1	ug/L

AAI5-032 Sampling #1 t=14 days

	Column 5 Effluent			Column 6 Effluent			
Analyte	**38931**	**Qualifier**	**DL**	**38932**	**Qualifier**	**DL**	**Units**
Isopropylbenzene	1	U	1	1	U	1	ug/L
Bromobenzene	1	U	1	1	U	1	ug/L
1,1,2,2-Tetrachloroethane	1	U	1	1	U	1	ug/L
1,2,3-Trichloropropane	1	U	1	1	U	1	ug/L
n-Propylbenzene	1	U	1	1	U	1	ug/L
2-Chlorotoluene	1	U	1	1	U	1	ug/L
1,3,5-Trimethylbenzene	1	U	1	1	U	1	ug/L
4-Chlorotoluene	1	U	1	1	U	1	ug/L
tert-Butylbenzene	1	U	1	1	U	1	ug/L
1,2,4-Trimethylbenzene	1	U	1	1	U	1	ug/L
sec-Butylbenzene	1	U	1	1	U	1	ug/L
1,3-Dichlorobenzene	1	U	1	1	U	1	ug/L
p-Isopropyltoluene	1	U	1	1	U	1	ug/L
1,4-Dichlorobenzene	5		1	1	U	1	ug/L
n-Butylbenzene	1	U	1	1	U	1	ug/L
1,2-Dichlorobenzene	1	U	1	1	U	1	ug/L
1,2-Dibromo-3-chloropropane	1	U	1	1	U	1	ug/L
1,3,5-Trichlorobenzene	1	U	1	1	U	1	ug/L
1,2,4-Trichlorobenzene	1	U	1	1	U	1	ug/L
Hexachlorobutadiene	1	U	1	1	U	1	ug/L
Naphthalene	1	U	1	1	U	1	ug/L
1,2,3-Trichlorobenzene	1	U	1	1	U	1	ug/L

Analyte	38931	Qualifier	DL	38932	Qualifier	DL	Units
Ethane	4	U	4	4	U	4	ug/L

U = compound analyzed but not detected at a concentration above the reporting limit.

AAI5-032 Sampling #1 t=14 days

	Feed #1			Feed #2			
Analyte	**38933**	**Qualifier**	**DL**	**38934**	**Qualifier**	**DL**	**Units**
TOC Average Duplicates	---	---	---	---	---	---	---
Dichlorodifluoromethane	1	U	1	1	U	1	ug/L
Chloromethane	1	U	1	1	U	1	ug/L
Vinyl chloride	1	U	1	1	U	1	ug/L
Bromomethane	1	U*	1	1	U*	1	ug/L
Chloroethane	800		10	720		10	ug/L
Trichlorofluoromethane	1	U	1	1	U	1	ug/L
1,1-Dichloroethene	1	U	1	1	U	1	ug/L
Carbon disulfide	5	U	5	5	U	5	ug/L
Acetone	5	U	5	5	U	5	ug/L
Methylene chloride	1	U	1	1	U	1	ug/L
trans-1,2-Dichloroethene	1	U	1	1	U	1	ug/L
Methyl-tert-butyl-ether (MTBE)	1	U	1	1	U	1	ug/L
1,1-Dichloroethane	1	U	1	1	U	1	ug/L
2,2-Dichloropropane	1	U	1	1	U	1	ug/L
cis-1,2-Dichloroethene	1	U	1	1	U	1	ug/L
2-Butanone (MEK)	5	U	5	5	U	5	ug/L
Bromochloromethane	1	U	1	1	U	1	ug/L
Chloroform	1	U	1	1	U	1	ug/L
1,1,1-Trichloroethane	1	U	1	1	U	1	ug/L
1,1-Dichloropropene	1	U	1	1	U	1	ug/L
Carbon tetrachloride	1	U	1	1	U	1	ug/L
Benzene	1	U	1	1	U	1	ug/L
1,2-Dichloroethane	1	U	1	1	U	1	ug/L
Trichloroethene	1	U	1	1	U	1	ug/L
1,2-Dichloropropane	1	U	1	1	U	1	ug/L
Dibromomethane	1	U	1	1	U	1	ug/L
Bromodichloromethane	1	U*	1	1	U*	1	ug/L
cis-1,3-Dichloropropene	1	U	1	1	U	1	ug/L
4-Methyl-2-pentanone (MIBK)	5	U	5	5	U	5	ug/L
Toluene	1	U	1	1	U	1	ug/L
trans-1,3-Dichloropropene	1	U	1	1	U	1	ug/L
1,1,2-Trichloroethane	1	U	1	1	U	1	ug/L
Tetrachloroethene	1	U	1	1	U	1	ug/L
1,3-Dichloropropane	1	U	1	1	U	1	ug/L
2-Hexanone	5	U	5	5	U	5	ug/L
Dibromochloromethane	1	U*	1	1	U*	1	ug/L
1,2-Dibromoethane (EDB)	1	U	1	1	U	1	ug/L
Chlorobenzene	7		1	10		1	ug/L
1,1,1,2-Tetrachloroethane	1	U	1	1	U	1	ug/L
Ethylbenzene	1	U	1	1	U	1	ug/L
m&p-Xylenes	2	U	2	2	U	2	ug/L
o-Xylene	1	U	1	1	U	1	ug/L
Styrene	1	U	1	1	U	1	ug/L
Bromoform	1	U*	1	1	U*	1	ug/L

AAI5-032 Sampling #1   t=14 days

	Feed #1			Feed #2			
Analyte	**38933**	**Qualifier**	**DL**	**38934**	**Qualifier**	**DL**	**Units**
Isopropylbenzene	1	U	1	1	U	1	ug/L
Bromobenzene	1	U	1	1	U	1	ug/L
1,1,2,2-Tetrachloroethane	1	U	1	1	U	1	ug/L
1,2,3-Trichloropropane	1	U	1	1	U	1	ug/L
n-Propylbenzene	1	U	1	1	U	1	ug/L
2-Chlorotoluene	1	U	1	1	U	1	ug/L
1,3,5-Trimethylbenzene	1	U	1	1	U	1	ug/L
4-Chlorotoluene	1	U	1	1	U	1	ug/L
tert-Butylbenzene	1	U	1	1	U	1	ug/L
1,2,4-Trimethylbenzene	1	U	1	1	U	1	ug/L
sec-Butylbenzene	1	U	1	1	U	1	ug/L
1,3-Dichlorobenzene	1	U	1	1	U	1	ug/L
p-Isopropyltoluene	1	U	1	1	U	1	ug/L
1,4-Dichlorobenzene	1	U	1	1	U	1	ug/L
n-Butylbenzene	1	U	1	1	U	1	ug/L
1,2-Dichlorobenzene	1	U	1	1	U	1	ug/L
1,2-Dibromo-3-chloropropane	1	U	1	1	U	1	ug/L
1,3,5-Trichlorobenzene	1	U	1	1	U	1	ug/L
1,2,4-Trichlorobenzene	1	U	1	1	U	1	ug/L
Hexachlorobutadiene	1	U	1	1	U	1	ug/L
Naphthalene	1	U	1	1	U	1	ug/L
1,2,3-Trichlorobenzene	1	U	1	1	U	1	ug/L

Analyte
Ethane

U = compound analyzed but not detected at a concentration above the reporting limit.

AAI5-032 Sampling #2 t=29 days

	Column 1 Effluent		Column 2 Effluent		Column 3 Effluent		
Analyte	**40030**	**Qualifie**	**40031**	**Qualifie**	**40032**	**Qualifie**	**Units**
Alkalinity, Total as CaCO3	370		380		420		mg/L
Chloride	80		80		80		mg/L
TOC Average Duplicates	14		100		16		mg/L
Dichlorodifluoromethane	1.0	U	1.0	U	1.0	U	ug/L
Chloromethane	1.0	U	1.0	U	1.0	U	ug/L
Vinyl chloride	1.0	U	1.0	U	1.0	U	ug/L
Bromomethane	1.0	U	1.0	U	1.0	U	ug/L
Chloroethane	700		430		530		ug/L
Trichlorofluoromethane	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
Carbon disulfide	5.0	U	5.0	U	5.0	U	ug/L
Acetone	5.0	U	20		5.0	U	ug/L
Methylene chloride	45		39		53		ug/L
trans-1,2-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
Methyl-tert-butyl-ether (MTBE)	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloroethane	1.0	U	1.0	U	1.0	U	ug/L
2,2-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
cis-1,2-Dichloroethene	1.0	U	1.1		1.0	U	ug/L
2-Butanone (MEK)	5.0	U	6.1		5.0	U	ug/L
Bromochloromethane	1.0	U	1.0	U	1.0	U	ug/L
Chloroform	1.0	U	1.0	U	1.0	U	ug/L
1,1,1-Trichloroethane	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloropropene	1.0	U*	1.0	U*	1.0	U*	ug/L
Carbon tetrachloride	1.0	U	1.0	U	1.0	U	ug/L
Benzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichloroethane	1.0	U	1.2		1.0	U	ug/L
Trichloroethene	1.0	U	5.1		1.0	U	ug/L
1,2-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
Dibromomethane	1.0	U	1.0	U	1.0	U	ug/L
Bromodichloromethane	1.0	U	1.0	U	1.0	U	ug/L
cis-1,3-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
4-Methyl-2-pentanone (MIBK)	5.0	U	5.0	U	5.0	U	ug/L
Toluene	1.0	U	1.0	U	1.0	U	ug/L
trans-1,3-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
1,1,2-Trichloroethane	1.0	U	1.0	U	1.0	U	ug/L
Tetrachloroethene	1.0	U	1.0	U	1.0	U	ug/L
1,3-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
2-Hexanone	5.0	U	5.0	U	5.0	U	ug/L
Dibromochloromethane	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dibromoethane (EDB)	1.0	U	1.0	U	1.0	U	ug/L
Chlorobenzene	1.0	U	4.1		1.0	U	ug/L
1,1,1,2-Tetrachloroethane	1.0	U	1.0	U	1.0	U	ug/L
Ethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
m&p-Xylenes	2.0	U	2.0	U	2.0	U	ug/L

AAI5-032 Sampling #2 t=29 days

	Column 1 Effluent		Column 2 Effluent		Column 3 Effluent		
Analyte	40030	Qualifier	40031	Qualifier	40032	Qualifier	Units
o-Xylene	1.0	U	1.0	U	1.0	U	ug/L
Styrene	1.0	U	1.0	U	1.0	U	ug/L
Bromoform	1.0	U	1.0	U	1.0	U	ug/L
Isopropylbenzene	1.0	U	1.0	U	1.0	U	ug/L
Bromobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,1,2,2-Tetrachloroethane	1.0	U	1.0	U	1.0	U	ug/L
1,2,3-Trichloropropane	1.0	U	1.0	U	1.0	U	ug/L
n-Propylbenzene	1.0	U	1.0	U	1.0	U	ug/L
2-Chlorotoluene	1.0	U	1.0	U	1.0	U	ug/L
1,3,5-Trimethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
4-Chlorotoluene	1.0	U	1.0	U	1.0	U	ug/L
tert-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2,4-Trimethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
sec-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,3-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
p-Isopropyltoluene	1.0	U	1.0	U	1.0	U	ug/L
1,4-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
n-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dibromo-3-chloropropane	1.0	U	1.0	U	1.0	U	ug/L
1,3,5-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2,4-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
Hexachlorobutadiene	1.0	U	1.0	U	1.0	U	ug/L
Naphthalene	1.0	U	1.0	U	1.0	U	ug/L
1,2,3-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L

AAI5-032 Sampling #2 t=29 days

Analyte	Column 4 Effluent 40033	Qualifie	Column 5 Effluent 40034	Qualifie	Column 6 Effluent 40035	Qualifie	Units
Alkalinity, Total as CaCO3	330		420		370		mg/L
Chloride	84		86		100		mg/L
TOC Average Duplicates	120		13		16		mg/L
Dichlorodifluoromethane	1.0	U	1.0	U	1.0	U	ug/L
Chloromethane	1.0	U	1.0	U	1.0	U	ug/L
Vinyl chloride	1.0	U	1.0	U	1.0	U	ug/L
Bromomethane	1.0	U	1.0	U	1.0	U	ug/L
Chloroethane	590		640		600		ug/L
Trichlorofluoromethane	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
Carbon disulfide	5.0	U	5.0	U	5.0	U	ug/L
Acetone	17		5.0	U	11		ug/L
Methylene chloride	140		88		47		ug/L
trans-1,2-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
Methyl-tert-butyl-ether (MTBE)	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloroethane	1.0	U	1.0	U	1.0	U	ug/L
2,2-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
cis-1,2-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
2-Butanone (MEK)	23		5.0	U	5.0	U	ug/L
Bromochloromethane	1.0	U	1.0	U	1.0	U	ug/L
Chloroform	1.0	U	1.0	U	1.0	U	ug/L
1,1,1-Trichloroethane	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloropropene	1.0	U*	1.0	U*	1.0	U*	ug/L
Carbon tetrachloride	1.0	U	1.0	U	1.0	U	ug/L
Benzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichloroethane	3.1		1.0	U	1.0	U	ug/L
Trichloroethene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
Dibromomethane	1.0	U	1.0	U	1.0	U	ug/L
Bromodichloromethane	1.0	U	1.0	U	1.0	U	ug/L
cis-1,3-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
4-Methyl-2-pentanone (MIBK)	5.0	U	5.0	U	5.0	U	ug/L
Toluene	1.0	U	1.0	U	1.0	U	ug/L
trans-1,3-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
1,1,2-Trichloroethane	1.0	U	1.0	U	1.0	U	ug/L
Tetrachloroethene	1.0	U	1.0	U	1.0	U	ug/L
1,3-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
2-Hexanone	5.0	U	5.0	U	5.0	U	ug/L
Dibromochloromethane	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dibromoethane (EDB)	1.0	U	1.0	U	1.0	U	ug/L
Chlorobenzene	10		2.1		21		ug/L
1,1,1,2-Tetrachloroethane	1.0	U	1.0	U	1.0	U	ug/L
Ethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
m&p-Xylenes	2.0	U	2.0	U	2.0	U	ug/L

AAI5-032 Sampling #2 t=29 days

Analyte	Column 4 Effluent 40033	Qualifier	Column 5 Effluent 40034	Qualifier	Column 6 Effluent 40035	Qualifier	Units
o-Xylene	1.0	U	1.0	U	1.0	U	ug/L
Styrene	1.0	U	1.0	U	1.0	U	ug/L
Bromoform	1.0	U	1.0	U	1.0	U	ug/L
Isopropylbenzene	1.0	U	1.0	U	1.0	U	ug/L
Bromobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,1,2,2-Tetrachloroethane	1.0	U	1.0	U	1.0	U	ug/L
1,2,3-Trichloropropane	1.0	U	1.0	U	1.0	U	ug/L
n-Propylbenzene	1.0	U	1.0	U	1.0	U	ug/L
2-Chlorotoluene	1.0	U	1.0	U	1.0	U	ug/L
1,3,5-Trimethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
4-Chlorotoluene	1.0	U	1.0	U	1.0	U	ug/L
tert-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2,4-Trimethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
sec-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,3-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
p-Isopropyltoluene	1.0	U	1.0	U	1.0	U	ug/L
1,4-Dichlorobenzene	1.3		3.1		1.0	U	ug/L
n-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dibromo-3-chloropropane	1.0	U	1.0	U	1.0	U	ug/L
1,3,5-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2,4-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
Hexachlorobutadiene	1.0	U	1.0	U	1.0	U	ug/L
Naphthalene	1.0	U	1.0	U	1.0	U	ug/L
1,2,3-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L

AAI5-032 Sampling #2 t=29 days

Analyte	Feed #1 40036	Qualifie	Feed #2 40037	Qualifie	Units
Alkalinity, Total as CaCO3					
Chloride					
TOC Average Duplicates					
Dichlorodifluoromethane	1.0	U	1.0	U	ug/L
Chloromethane	1.0	U	1.0	U	ug/L
Vinyl chloride	1.0	U	1.0	U	ug/L
Bromomethane	1.0	U	1.0	U	ug/L
Chloroethane	210		750		ug/L
Trichlorofluoromethane	1.0	U	1.0	U	ug/L
1,1-Dichloroethene	1.0	U	1.0	U	ug/L
Carbon disulfide	5.0	U	5.0	U	ug/L
Acetone	5.0	U	5.0	U	ug/L
Methylene chloride	6.1		1.0	U	ug/L
trans-1,2-Dichloroethene	1.0	U	1.0	U	ug/L
Methyl-tert-butyl-ether (MTBE)	1.0	U	1.0	U	ug/L
1,1-Dichloroethane	1.0	U	1.0	U	ug/L
2,2-Dichloropropane	1.0	U	1.0	U	ug/L
cis-1,2-Dichloroethene	1.0	U	1.0	U	ug/L
2-Butanone (MEK)	5.0	U	5.0	U	ug/L
Bromochloromethane	1.0	U	1.0	U	ug/L
Chloroform	1.0	U	1.0	U	ug/L
1,1,1-Trichloroethane	1.0	U	1.0	U	ug/L
1,1-Dichloropropene	1.0	U*	1.0	U*	ug/L
Carbon tetrachloride	1.0	U	1.0	U	ug/L
Benzene	1.0	U	1.0	U	ug/L
1,2-Dichloroethane	1.0	U	1.0	U	ug/L
Trichloroethene	1.0	U	1.0	U	ug/L
1,2-Dichloropropane	1.0	U	1.0	U	ug/L
Dibromomethane	1.0	U	1.0	U	ug/L
Bromodichloromethane	1.0	U	1.0	U	ug/L
cis-1,3-Dichloropropene	1.0	U	1.0	U	ug/L
4-Methyl-2-pentanone (MIBK)	5.0	U	5.0	U	ug/L
Toluene	1.0	U	1.0	U	ug/L
trans-1,3-Dichloropropene	1.0	U	1.0	U	ug/L
1,1,2-Trichloroethane	1.0	U	1.0	U	ug/L
Tetrachloroethene	1.0	U	1.0	U	ug/L
1,3-Dichloropropane	1.0	U	1.0	U	ug/L
2-Hexanone	5.0	U	5.0	U	ug/L
Dibromochloromethane	1.0	U	1.0	U	ug/L
1,2-Dibromoethane (EDB)	1.0	U	1.0	U	ug/L
Chlorobenzene	160		4.8		ug/L
1,1,1,2-Tetrachloroethane	1.0	U	1.0	U	ug/L
Ethylbenzene	1.0	U	1.0	U	ug/L
m&p-Xylenes	2.0	U	2.0	U	ug/L

AAI5-032 Sampling #2 t=29 days

	Feed #1		Feed #2		
Analyte	40036	Qualifie	40037	Qualifie	Units
o-Xylene	1.0	U	1.0	U	ug/L
Styrene	1.0	U	1.0	U	ug/L
Bromoform	1.0	U	1.0	U	ug/L
Isopropylbenzene	1.0	U	1.0	U	ug/L
Bromobenzene	1.0	U	1.0	U	ug/L
1,1,2,2-Tetrachloroethane	1.0	U	1.0	U	ug/L
1,2,3-Trichloropropane	1.0	U	1.0	U	ug/L
n-Propylbenzene	1.0	U	1.0	U	ug/L
2-Chlorotoluene	1.0	U	1.0	U	ug/L
1,3,5-Trimethylbenzene	1.0	U	1.0	U	ug/L
4-Chlorotoluene	1.0	U	1.0	U	ug/L
tert-Butylbenzene	1.0	U	1.0	U	ug/L
1,2,4-Trimethylbenzene	1.0	U	1.0	U	ug/L
sec-Butylbenzene	1.0	U	1.0	U	ug/L
1,3-Dichlorobenzene	1.0	U	1.0	U	ug/L
p-Isopropyltoluene	1.0	U	1.0	U	ug/L
1,4-Dichlorobenzene	1.0	U	1.0	U	ug/L
n-Butylbenzene	1.0	U	1.0	U	ug/L
1,2-Dichlorobenzene	1.0	U	1.0	U	ug/L
1,2-Dibromo-3-chloropropane	1.0	U	1.0	U	ug/L
1,3,5-Trichlorobenzene	1.0	U	1.0	U	ug/L
1,2,4-Trichlorobenzene	1.0	U	1.0	U	ug/L
Hexachlorobutadiene	1.0	U	1.0	U	ug/L
Naphthalene	1.0	U	1.0	U	ug/L
1,2,3-Trichlorobenzene	1.0	U	1.0	U	ug/L

AAI5-032 Sampling #2 t=29 days

	Column 1 Effluent		Column 2 Effluent		Column 3 Effluent		
Analyte	**40030**	**Qualifie**	**40031**	**Qualific**	**40032**	**Qualifie**	**Units**
Alkalinity, Total as CaCO3	370		380		420		mg/L
Chloride	80		80		80		mg/L
TOC Average Duplicates	14		100		16		mg/L
Dichlorodifluoromethane	1.0	U	1.0	U	1.0	U	ug/L
Chloromethane	1.0	U	1.0	U	1.0	U	ug/L
Vinyl chloride	1.0	U	1.0	U	1.0	U	ug/L
Bromomethane	1.0	U	1.0	U	1.0	U	ug/L
Chloroethane	700		430		530		ug/L
Trichlorofluoromethane	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
Carbon disulfide	5.0	U	5.0	U	5.0	U	ug/L
Acetone	5.0	U	20		5.0	U	ug/L
Methylene chloride	45		39		53		ug/L
trans-1,2-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
Methyl-tert-butyl-ether (MTBE)	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloroethane	1.0	U	1.0	U	1.0	U	ug/L
2,2-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
cis-1,2-Dichloroethene	1.0	U	1.1		1.0	U	ug/L
2-Butanone (MEK)	5.0	U	6.1		5.0	U	ug/L
Bromochloromethane	1.0	U	1.0	U	1.0	U	ug/L
Chloroform	1.0	U	1.0	U	1.0	U	ug/L
1,1,1-Trichloroethane	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloropropene	1.0	U*	1.0	U*	1.0	U*	ug/L
Carbon tetrachloride	1.0	U	1.0	U	1.0	U	ug/L
Benzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichloroethane	1.0	U	1.2		1.0	U	ug/L
Trichloroethene	1.0	U	5.1		1.0	U	ug/L
1,2-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
Dibromomethane	1.0	U	1.0	U	1.0	U	ug/L
Bromodichloromethane	1.0	U	1.0	U	1.0	U	ug/L
cis-1,3-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
4-Methyl-2-pentanone (MIBK)	5.0	U	5.0	U	5.0	U	ug/L
Toluene	1.0	U	1.0	U	1.0	U	ug/L
trans-1,3-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
1,1,2-Trichloroethane	1.0	U	1.0	U	1.0	U	ug/L
Tetrachloroethene	1.0	U	1.0	U	1.0	U	ug/L
1,3-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
2-Hexanone	5.0	U	5.0	U	5.0	U	ug/L
Dibromochloromethane	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dibromoethane (EDB)	1.0	U	1.0	U	1.0	U	ug/L
Chlorobenzene	1.0	U	4.1		1.0	U	ug/L
1,1,1,2-Tetrachloroethane	1.0	U	1.0	U	1.0	U	ug/L
Ethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
m&p-Xylenes	2.0	U	2.0	U	2.0	U	ug/L

AAI5-032 Sampling #2 t=29 days

	Column 1 Effluent			Column 2 Effluent	Column 3 Effluent		
Analyte	40030	Qualifiei	40031	Qualifiei	40032	Qualifiei	Units
o-Xylene	1.0	U	1.0	U	1.0	U	ug/L
Styrene	1.0	U	1.0	U	1.0	U	ug/L
Bromoform	1.0	U	1.0	U	1.0	U	ug/L
Isopropylbenzene	1.0	U	1.0	U	1.0	U	ug/L
Bromobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,1,2,2-Tetrachloroethane	1.0	U	1.0	U	1.0	U	ug/L
1,2,3-Trichloropropane	1.0	U	1.0	U	1.0	U	ug/L
n-Propylbenzene	1.0	U	1.0	U	1.0	U	ug/L
2-Chlorotoluene	1.0	U	1.0	U	1.0	U	ug/L
1,3,5-Trimethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
4-Chlorotoluene	1.0	U	1.0	U	1.0	U	ug/L
tert-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2,4-Trimethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
sec-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,3-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
p-Isopropyltoluene	1.0	U	1.0	U	1.0	U	ug/L
1,4-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
n-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dibromo-3-chloropropane	1.0	U	1.0	U	1.0	U	ug/L
1,3,5-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2,4-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
Hexachlorobutadiene	1.0	U	1.0	U	1.0	U	ug/L
Naphthalene	1.0	U	1.0	U	1.0	U	ug/L
1,2,3-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L

AAI5-032 Sampling #2 t=29 days

Analyte	Column 4 Effluent 40033	Qualifie	Column 5 Effluent 40034	Qualifie	Column 6 Effluent 40035	Qualifie	Units
Alkalinity, Total as CaCO3	330		420		370		mg/L
Chloride	84		86		100		mg/L
TOC Average Duplicates	120		13		16		mg/L
Dichlorodifluoromethane	1.0	U	1.0	U	1.0	U	ug/L
Chloromethane	1.0	U	1.0	U	1.0	U	ug/L
Vinyl chloride	1.0	U	1.0	U	1.0	U	ug/L
Bromomethane	1.0	U	1.0	U	1.0	U	ug/L
Chloroethane	590		640		600		ug/L
Trichlorofluoromethane	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
Carbon disulfide	5.0	U	5.0	U	5.0	U	ug/L
Acetone	17		5.0	U	11		ug/L
Methylene chloride	140		88		47		ug/L
trans-1,2-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
Methyl-tert-butyl-ether (MTBE)	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloroethane	1.0	U	1.0	U	1.0	U	ug/L
2,2-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
cis-1,2-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
2-Butanone (MEK)	23		5.0	U	5.0	U	ug/L
Bromochloromethane	1.0	U	1.0	U	1.0	U	ug/L
Chloroform	1.0	U	1.0	U	1.0	U	ug/L
1,1,1-Trichloroethane	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloropropene	1.0	U*	1.0	U*	1.0	U*	ug/L
Carbon tetrachloride	1.0	U	1.0	U	1.0	U	ug/L
Benzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichloroethane	3.1		1.0	U	1.0	U	ug/L
Trichloroethene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
Dibromomethane	1.0	U	1.0	U	1.0	U	ug/L
Bromodichloromethane	1.0	U	1.0	U	1.0	U	ug/L
cis-1,3-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
4-Methyl-2-pentanone (MIBK)	5.0	U	5.0	U	5.0	U	ug/L
Toluene	1.0	U	1.0	U	1.0	U	ug/L
trans-1,3-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
1,1,2-Trichloroethane	1.0	U	1.0	U	1.0	U	ug/L
Tetrachloroethene	1.0	U	1.0	U	1.0	U	ug/L
1,3-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
2-Hexanone	5.0	U	5.0	U	5.0	U	ug/L
Dibromochloromethane	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dibromoethane (EDB)	1.0	U	1.0	U	1.0	U	ug/L
Chlorobenzene	10		2.1		21		ug/L
1,1,1,2-Tetrachloroethane	1.0	U	1.0	U	1.0	U	ug/L
Ethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
m&p-Xylenes	2.0	U	2.0	U	2.0	U	ug/L

AAI5-032 Sampling #2 t=29 days

	Column 4 Effluent		Column 5 Effluent		Column 6 Effluent		
Analyte	40033	Qualifie	40034	Qualifie	40035	Qualifie	Units
o-Xylene	1.0	U	1.0	U	1.0	U	ug/L
Styrene	1.0	U	1.0	U	1.0	U	ug/L
Bromoform	1.0	U	1.0	U	1.0	U	ug/L
Isopropylbenzene	1.0	U	1.0	U	1.0	U	ug/L
Bromobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,1,2,2-Tetrachloroethane	1.0	U	1.0	U	1.0	U	ug/L
1,2,3-Trichloropropane	1.0	U	1.0	U	1.0	U	ug/L
n-Propylbenzene	1.0	U	1.0	U	1.0	U	ug/L
2-Chlorotoluene	1.0	U	1.0	U	1.0	U	ug/L
1,3,5-Trimethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
4-Chlorotoluene	1.0	U	1.0	U	1.0	U	ug/L
tert-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2,4-Trimethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
sec-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,3-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
p-Isopropyltoluene	1.0	U	1.0	U	1.0	U	ug/L
1,4-Dichlorobenzene	1.3		3.1		1.0	U	ug/L
n-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dibromo-3-chloropropane	1.0	U	1.0	U	1.0	U	ug/L
1,3,5-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2,4-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
Hexachlorobutadiene	1.0	U	1.0	U	1.0	U	ug/L
Naphthalene	1.0	U	1.0	U	1.0	U	ug/L
1,2,3-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L

AAI5-032 Sampling #2 t=29 days

Analyte	Feed #1 40036	Qualifie	Feed #2 40037	Qualifie	Units
Alkalinity, Total as CaCO3					
Chloride					
TOC Average Duplicates					
Dichlorodifluoromethane	1.0	U	1.0	U	ug/L
Chloromethane	1.0	U	1.0	U	ug/L
Vinyl chloride	1.0	U	1.0	U	ug/L
Bromomethane	1.0	U	1.0	U	ug/L
Chloroethane	210		750		ug/L
Trichlorofluoromethane	1.0	U	1.0	U	ug/L
1,1-Dichloroethene	1.0	U	1.0	U	ug/L
Carbon disulfide	5.0	U	5.0	U	ug/L
Acetone	5.0	U	5.0	U	ug/L
Methylene chloride	6.1		1.0	U	ug/L
trans-1,2-Dichloroethene	1.0	U	1.0	U	ug/L
Methyl-tert-butyl-ether (MTBE)	1.0	U	1.0	U	ug/L
1,1-Dichloroethane	1.0	U	1.0	U	ug/L
2,2-Dichloropropane	1.0	U	1.0	U	ug/L
cis-1,2-Dichloroethene	1.0	U	1.0	U	ug/L
2-Butanone (MEK)	5.0	U	5.0	U	ug/L
Bromochloromethane	1.0	U	1.0	U	ug/L
Chloroform	1.0	U	1.0	U	ug/L
1,1,1-Trichloroethane	1.0	U	1.0	U	ug/L
1,1-Dichloropropene	1.0	U*	1.0	U*	ug/L
Carbon tetrachloride	1.0	U	1.0	U	ug/L
Benzene	1.0	U	1.0	U	ug/L
1,2-Dichloroethane	1.0	U	1.0	U	ug/L
Trichloroethene	1.0	U	1.0	U	ug/L
1,2-Dichloropropane	1.0	U	1.0	U	ug/L
Dibromomethane	1.0	U	1.0	U	ug/L
Bromodichloromethane	1.0	U	1.0	U	ug/L
cis-1,3-Dichloropropene	1.0	U	1.0	U	ug/L
4-Methyl-2-pentanone (MIBK)	5.0	U	5.0	U	ug/L
Toluene	1.0	U	1.0	U	ug/L
trans-1,3-Dichloropropene	1.0	U	1.0	U	ug/L
1,1,2-Trichloroethane	1.0	U	1.0	U	ug/L
Tetrachloroethene	1.0	U	1.0	U	ug/L
1,3-Dichloropropane	1.0	U	1.0	U	ug/L
2-Hexanone	5.0	U	5.0	U	ug/L
Dibromochloromethane	1.0	U	1.0	U	ug/L
1,2-Dibromoethane (EDB)	1.0	U	1.0	U	ug/L
Chlorobenzene	160		4.8		ug/L
1,1,1,2-Tetrachloroethane	1.0	U	1.0	U	ug/L
Ethylbenzene	1.0	U	1.0	U	ug/L
m&p-Xylenes	2.0	U	2.0	U	ug/L

AAI5-032 Sampling #2 t=29 days

	Feed #1		Feed #2		
Analyte	40036	Qualifiei	40037	Qualifiei	Units
o-Xylene	1.0	U	1.0	U	ug/L
Styrene	1.0	U	1.0	U	ug/L
Bromoform	1.0	U	1.0	U	ug/L
Isopropylbenzene	1.0	U	1.0	U	ug/L
Bromobenzene	1.0	U	1.0	U	ug/L
1,1,2,2-Tetrachloroethane	1.0	U	1.0	U	ug/L
1,2,3-Trichloropropane	1.0	U	1.0	U	ug/L
n-Propylbenzene	1.0	U	1.0	U	ug/L
2-Chlorotoluene	1.0	U	1.0	U	ug/L
1,3,5-Trimethylbenzene	1.0	U	1.0	U	ug/L
4-Chlorotoluene	1.0	U	1.0	U	ug/L
tert-Butylbenzene	1.0	U	1.0	U	ug/L
1,2,4-Trimethylbenzene	1.0	U	1.0	U	ug/L
sec-Butylbenzene	1.0	U	1.0	U	ug/L
1,3-Dichlorobenzene	1.0	U	1.0	U	ug/L
p-Isopropyltoluene	1.0	U	1.0	U	ug/L
1,4-Dichlorobenzene	1.0	U	1.0	U	ug/L
n-Butylbenzene	1.0	U	1.0	U	ug/L
1,2-Dichlorobenzene	1.0	U	1.0	U	ug/L
1,2-Dibromo-3-chloropropane	1.0	U	1.0	U	ug/L
1,3,5-Trichlorobenzene	1.0	U	1.0	U	ug/L
1,2,4-Trichlorobenzene	1.0	U	1.0	U	ug/L
Hexachlorobutadiene	1.0	U	1.0	U	ug/L
Naphthalene	1.0	U	1.0	U	ug/L
1,2,3-Trichlorobenzene	1.0	U	1.0	U	ug/L

AAI5-032 Sampling #3 t= 42 days

	Column 1 Effluent		Column 2 Effluent		Column 3 Effluent		
Analyte	**40168**	**Qualifie**	**40169**	**Qualific**	**40170**	**Qualifie**	**Units**
Alkalinity, Total as CaCO3	330		300		370		mg/L
Chloride	90		84		84		mg/L
TOC Average Duplicates	9.6		12		9.9		mg/L
Dichlorodifluoromethane	1.0	U*	1.0	U*	1.0	U*	ug/L
Chloromethane	1.0	U*	1.0	U*	1.0	U*	ug/L
Vinyl chloride	1.0	U*	1.0	U*	1.0	U*	ug/L
Bromomethane	1.0	U*	1.0	U*	1.0	U*	ug/L
Chloroethane	230		200		350	H	ug/L
Trichlorofluoromethane	1.0	U*	1.0	U*	1.0	U*	ug/L
1,1-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
Carbon disulfide	5.0	U	5.0	U	5.0	U	ug/L
Acetone	5.0	U*	5.0	U*	5.0	U*	ug/L
Methylene chloride	16		25		44		ug/L
trans-1,2-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
Methyl-tert-butyl-ether (MTBE)	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloroethane	1.0	U	1.0	U	1.0	U	ug/L
2,2-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
cis-1,2-Dichloroethene	1.0	U	1.3		1.0	U	ug/L
2-Butanone (MEK)	5.0	U	5.0	U	5.0	U	ug/L
Bromochloromethane	1.0	U	1.0	U	1.0	U	ug/L
Chloroform	1.0	U	1.0	U	1.0	U	ug/L
1,1,1-Trichloroethane	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
Carbon tetrachloride	1.0	U	1.0	U	1.0	U	ug/L
Benzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichloroethane	1.0	U	1.0	U	1.0	U	ug/L
Trichloroethene	1.0	U	2.7		1.0	U	ug/L
1,2-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
Dibromomethane	1.0	U	1.0	U	1.0	U	ug/L
Bromodichloromethane	1.0	U	1.0	U	1.0	U	ug/L
cis-1,3-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
4-Methyl-2-pentanone (MIBK)	5.0	U	5.0	U	5.0	U	ug/L
Toluene	1.0	U	1.0	U	1.0	U	ug/L
trans-1,3-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
1,1,2-Trichloroethane	1.0	U	1.0	U	1.0	U	ug/L
Tetrachloroethene	1.0	U	1.0	U	1.0	U	ug/L
1,3-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
2-Hexanone	5.0	U	5.0	U	5.0	U	ug/L
Dibromochloromethane	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dibromoethane (EDB)	1.0	U	1.0	U	1.0	U	ug/L
Chlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,1,1,2-Tetrachloroethane	1.0	U	1.0	U	1.0	U	ug/L
Ethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
m&p-Xylenes	2.0	U	2.0	U	2.0	U	ug/L

AAI5-032 Sampling #3   t= 42 days

	Column 1 Effluent		Column 2 Effluent		Column 3 Effluent		
Analyte	40168	Qualifie	40169	Qualific	40170	Qualific	Units
o-Xylene	1.0	U	1.0	U	1.0	U	ug/L
Styrene	1.0	U	1.0	U	1.0	U	ug/L
Bromoform	1.0	U	1.0	U	1.0	U	ug/L
Isopropylbenzene	1.0	U	1.0	U	1.0	U	ug/L
Bromobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,1,2,2-Tetrachloroethane	1.0	U	1.0	U	1.0	U	ug/L
1,2,3-Trichloropropane	1.0	U	1.0	U	1.0	U	ug/L
n-Propylbenzene	1.0	U	1.0	U	1.0	U	ug/L
2-Chlorotoluene	1.0	U	1.0	U	1.0	U	ug/L
1,3,5-Trimethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
4-Chlorotoluene	1.0	U	1.0	U	1.0	U	ug/L
tert-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2,4-Trimethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
sec-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,3-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
p-Isopropyltoluene	1.0	U	1.0	U	1.0	U	ug/L
1,4-Dichlorobenzene	1.0	U	1.1		1.0	U	ug/L
n-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dibromo-3-chloropropane	1.0	U	1.0	U	1.0	U	ug/L
1,3,5-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2,4-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
Hexachlorobutadiene	1.0	U	1.0	U	1.0	U	ug/L
Naphthalene	1.0	U	1.0	U	1.0	U	ug/L
1,2,3-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L

AAI5-032 Sampling #3 t= 42 days

Analyte	Column 4 Effluent 40171	Qualifie	Column 5 Effluent 40172	Qualifie	Column 6 Effluent 40173	Qualifie	Units
Alkalinity, Total as CaCO3	330		380		350		mg/L
Chloride	91		84		92		mg/L
TOC Average Duplicates	11		9.5		11		mg/L
Dichlorodifluoromethane	1.0	U*	1.0	U*	1.0	U*	ug/L
Chloromethane	1.0	U*	1.0	U*	1.0	U*	ug/L
Vinyl chloride	1.0	U*	1.0	U*	1.0	U*	ug/L
Bromomethane	1.0	U*	1.0	U*	1.0	U*	ug/L
Chloroethane	290		400		510		ug/L
Trichlorofluoromethane	1.0	U*	1.0	U*	1.0	U*	ug/L
1,1-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
Carbon disulfide	5.0	U	5.0	U	5.0	U	ug/L
Acetone	5.0	U*	5.0	U*	5.0	U*	ug/L
Methylene chloride	60		73		41		ug/L
trans-1,2-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
Methyl-tert-butyl-ether (MTBE)	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloroethane	1.0	U	1.0	U	1.0	U	ug/L
2,2-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
cis-1,2-Dichloroethene	1.0	U	1.0	U	1.0	U	ug/L
2-Butanone (MEK)	5.0	U	5.0	U	5.0	U	ug/L
Bromochloromethane	1.0	U	1.0	U	1.0	U	ug/L
Chloroform	1.0	U	1.0	U	1.0	U	ug/L
1,1,1-Trichloroethane	1.0	U	1.0	U	1.0	U	ug/L
1,1-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
Carbon tetrachloride	1.0	U	1.0	U	1.0	U	ug/L
Benzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichloroethane	1.5	H	1.0	U	1.0	U	ug/L
Trichloroethene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
Dibromomethane	1.0	U	1.0	U	1.0	U	ug/L
Bromodichloromethane	1.0	U	1.0	U	1.0	U	ug/L
cis-1,3-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
4-Methyl-2-pentanone (MIBK)	5.0	U	5.0	U	5.0	U	ug/L
Toluene	1.0	U	1.0	U	1.0	U	ug/L
trans-1,3-Dichloropropene	1.0	U	1.0	U	1.0	U	ug/L
1,1,2-Trichloroethane	1.0	U	1.0	U	1.0	U	ug/L
Tetrachloroethene	1.0	U	1.0	U	1.0	U	ug/L
1,3-Dichloropropane	1.0	U	1.0	U	1.0	U	ug/L
2-Hexanone	5.0	U	5.0	U	5.0	U	ug/L
Dibromochloromethane	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dibromoethane (EDB)	1.0	U	1.0	U	1.0	U	ug/L
Chlorobenzene	1.0	U	1.0	U	26	H	ug/L
1,1,1,2-Tetrachloroethane	1.0	U	1.0	U	1.0	U	ug/L
Ethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
m&p-Xylenes	2.0	U	2.0	U	2.0	U	ug/L

AAI5-032 Sampling #3 t= 42 days

Analyte	Column 4 Effluent 40171	Qualifie	Column 5 Effluent 40172	Qualifie	Column 6 Effluent 40173	Qualific	Units
o-Xylene	1.0	U	1.0	U	1.0	U	ug/L
Styrene	1.0	U	1.0	U	1.0	U	ug/L
Bromoform	1.0	U	1.0	U	1.0	U	ug/L
Isopropylbenzene	1.0	U	1.0	U	1.0	U	ug/L
Bromobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,1,2,2-Tetrachloroethane	1.0	U	1.0	U	1.0	U	ug/L
1,2,3-Trichloropropane	1.0	U	1.0	U	1.0	U	ug/L
n-Propylbenzene	1.0	U	1.0	U	1.0	U	ug/L
2-Chlorotoluene	1.0	U	1.0	U	1.0	U	ug/L
1,3,5-Trimethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
4-Chlorotoluene	1.0	U	1.0	U	1.0	U	ug/L
tert-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2,4-Trimethylbenzene	1.0	U	1.0	U	1.0	U	ug/L
sec-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,3-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
p-Isopropyltoluene	1.0	U	1.0	U	1.0	U	ug/L
1,4-Dichlorobenzene	1.8		1.0	U	1.0	U	ug/L
n-Butylbenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2-Dibromo-3-chloropropane	1.0	U	1.0	U	1.0	U	ug/L
1,3,5-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
1,2,4-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L
Hexachlorobutadiene	1.0	U	1.0	U	1.0	U	ug/L
Naphthalene	1.0	U	1.0	U	1.0	U	ug/L
1,2,3-Trichlorobenzene	1.0	U	1.0	U	1.0	U	ug/L

AAI5-032 Sampling #3 t= 42 days

	Feed #1		Feed #2		
Analyte	**40174**	**Qualifie**	**40175**	**Qualifie**	**Units**
Alkalinity, Total as CaCO3					
Chloride					
TOC Average Duplicates					
Dichlorodifluoromethane	1.0	U*	1.0	U*	ug/L
Chloromethane	1.0	U*	1.0	U*	ug/L
Vinyl chloride	1.0	U*	1.0	U*	ug/L
Bromomethane	1.0	U*	1.0	U*	ug/L
Chloroethane	310		280		ug/L
Trichlorofluoromethane	1.0	U*	1.0	U*	ug/L
1,1-Dichloroethene	1.0	U	1.0	U	ug/L
Carbon disulfide	5.0	U	5.0	U	ug/L
Acetone	5.0	U*	5.0	U*	ug/L
Methylene chloride	1.0	U	1.0	U	ug/L
trans-1,2-Dichloroethene	1.0	U	1.0	U	ug/L
Methyl-tert-butyl-ether (MTBE)	1.0	U	1.0	U	ug/L
1,1-Dichloroethane	1.0	U	1.0	U	ug/L
2,2-Dichloropropane	1.0	U	1.0	U	ug/L
cis-1,2-Dichloroethene	1.0	U	1.0	U	ug/L
2-Butanone (MEK)	5.0	U	5.0	U	ug/L
Bromochloromethane	1.0	U	1.0	U	ug/L
Chloroform	1.0	U	1.0	U	ug/L
1,1,1-Trichloroethane	1.0	U	1.0	U	ug/L
1,1-Dichloropropene	1.0	U	1.0	U	ug/L
Carbon tetrachloride	1.0	U	1.0	U	ug/L
Benzene	1.0	U	1.0	U	ug/L
1,2-Dichloroethane	1.0	U	1.0	U	ug/L
Trichloroethene	1.4		1.5		ug/L
1,2-Dichloropropane	1.0	U	1.0	U	ug/L
Dibromomethane	1.0	U	1.0	U	ug/L
Bromodichloromethane	1.0	U	1.0	U	ug/L
cis-1,3-Dichloropropene	1.0	U	1.0	U	ug/L
4-Methyl-2-pentanone (MIBK)	5.0	U	5.0	U	ug/L
Toluene	1.0	U	1.0	U	ug/L
trans-1,3-Dichloropropene	1.0	U	1.0	U	ug/L
1,1,2-Trichloroethane	1.0	U	1.0	U	ug/L
Tetrachloroethene	1.0	U	1.0	U	ug/L
1,3-Dichloropropane	1.0	U	1.0	U	ug/L
2-Hexanone	5.0	U	5.0	U	ug/L
Dibromochloromethane	1.0	U	1.0	U	ug/L
1,2-Dibromoethane (EDB)	1.0	U	1.0	U	ug/L
Chlorobenzene	11	H	8.7		ug/L
1,1,1,2-Tetrachloroethane	1.0	U	1.0	U	ug/L
Ethylbenzene	1.0	U	1.0	U	ug/L
m&p-Xylenes	2.0	U	2.0	U	ug/L

AAI5-032 Sampling #3 t= 42 days

	Feed #1		Feed #2		
Analyte	40174	Qualifie	40175	Qualifie	Units
o-Xylene	1.0	U	1.0	U	ug/L
Styrene	1.0	U	1.0	U	ug/L
Bromoform	1.0	U	1.0	U	ug/L
Isopropylbenzene	1.0	U	1.0	U	ug/L
Bromobenzene	1.0	U	1.0	U	ug/L
1,1,2,2-Tetrachloroethane	1.0	U	1.0	U	ug/L
1,2,3-Trichloropropane	1.0	U	1.0	U	ug/L
n-Propylbenzene	1.0	U	1.0	U	ug/L
2-Chlorotoluene	1.0	U	1.0	U	ug/L
1,3,5-Trimethylbenzene	1.0	U	1.0	U	ug/L
4-Chlorotoluene	1.0	U	1.0	U	ug/L
tert-Butylbenzene	1.0	U	1.0	U	ug/L
1,2,4-Trimethylbenzene	1.0	U	1.0	U	ug/L
sec-Butylbenzene	1.0	U	1.0	U	ug/L
1,3-Dichlorobenzene	1.0	U	1.0	U	ug/L
p-Isopropyltoluene	1.0	U	1.0	U	ug/L
1,4-Dichlorobenzene	1.0	U	1.0	U	ug/L
n-Butylbenzene	1.0	U	1.0	U	ug/L
1,2-Dichlorobenzene	1.0	U	1.0	U	ug/L
1,2-Dibromo-3-chloropropane	1.0	U	1.0	U	ug/L
1,3,5-Trichlorobenzene	1.0	U	1.0	U	ug/L
1,2,4-Trichlorobenzene	1.0	U	1.0	U	ug/L
Hexachlorobutadiene	1.0	U	1.0	U	ug/L
Naphthalene	1.0	U	1.0	U	ug/L
1,2,3-Trichlorobenzene	1.0	U	1.0	U	ug/L

AAI5-032 Sampling #5 1 = 94 days

Analyte		DL	0.1% EHC2007Fe50 40838	0.5% EHC2007Fe50 40839	0.1% HRC 40840	0.5% HRC 40841	Control 40842	Sterile Control 40843	Feed #1 40844	Feed #2 - Sterile 40845	Feed #2 - Sterile 40846 D	Feed #2 - Sterile 40845 Avg
Vinyl Chloride	VC	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloromathane	DCM	10.0	230	260	185	ND	415	345	ND	ND	ND	ND
Cis-1,2-Dichloroethene	cis-DCE	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	CF	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	CT	14.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	1,2DCA	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	TCE	10.0	20	20	20	15	20	ND	25	15	20	17.5
Tetrachloroethene	PCE	20.0	ND	ND	ND	ND	ND	20	135	135	0	67.5
Chloroethane	CA	10.0	485	500	380	0	810	1280	1005	1330	1360	1345
Total VOCs			735	780	585	15	1,245	1,645	1,165	1,480	1,380	1,430

AAI5-032 Sampling #6 t = 107 days

Analyte		DL	0.1% EHC2007Fe50 41016	0.5% EHC2007Fe50 41016	0.1% HRC 41017	0.5% HRC 41018	Control 41019	Sterile Control 41020	Feed #1 41021	Feed #2 - Sterile 41022	Feed #2 - Sterile 41022D	Feed #2 - Sterile 41022Avg
Vinyl Chloride	VC	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloromathane	DCM	10.0	145	120	100	185	220	185	ND	0	0	0
Cis-1,2-Dichloroethene	cis-DCE	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	CF	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	CT	14.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	1,2DCA	10.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	TCE	10.0	10	10	15	ND	10	ND	40	20	20	20
Tetrachloroethene	PCE	20.0	0	45	0	0	15	65	45	15	20	18
Chloroethane	CA	10.0	305	250	80	5	270	960	2245	1540	1355	1448
Total VOCs			**460**	**425**	**195**	**190**	**515**	**1,210**	**2,330**	**1,575**	**1,395**	**1,485**

IN-SITU BIOREMEDIATION
BENCH SCALE STUDY

Terra Systems
INCORPORATED

REVISED DRAFT REPORT

IN SITU BIOREMEDIATION TREATABILITY STUDIES
COLUMBIA CEMENT
FREEPORT, NY

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DECEMBER 14, 2006

1.0 INTRODUCTION

Terra Systems, Inc. (TSI) has completed a treatability study for British Petroleum (BP) to evaluate enhanced anaerobic bioremediation to remediate chlorinated ethanes in groundwater underlying the former Columbia Cement facility (the Site) in Freeport, New York. A spill of 1,1,1-trichloroethane (1TCA) had occurred in April 1988 from a ruptured tanker truck. 1TCA and its daughter products 1,1-dichloroethane (1DCA), 1,1-dichloroethene (1DCE), and chloroethane (CA) have been detected in groundwater at the Site above their respective NYS Groundwater Standards. In addition to the chlorinated ethanes, benzene, toluene, ethylbenzene, xylenes, and methylene chloride have also been detected at the Site.

Anaerobic biodegradation is a well-established methodology for the treatment of tetrachloroethene, trichloroethene, and their daughter products cis-1,2-dichloroethylene (cis-1,2-DCE) and vinyl chloride (VC). These chlorinated volatile organic compounds (CVOC) can be degraded to carbon dioxide (CO_2), methane (CH_4) and other innocuous products such as ethene or ethane via reductive dechlorination and other biological processes. Similarly, 1TCA undergoes anaerobic biotransformation to 1DCA and CA. There is also an abiotic, dehydroelimination reaction that can transform 1TCA to 1,1-1DCE, VC, ethene, and potentially onto acetate.

The treatability studies were performed to determine:

- If biodegradation of 1TCA and 1DCA can be stimulated in Site soil and groundwater by the addition of carbon substrates;
- If the optimal biological microorganisms are present to facilitate biodegradation;
- If the addition of amendments (substrate and nutrients) will enhance the biodegradation; and
- If aerobic biodegradation could be used to biodegrade the residual daughter products

2.0 *SOIL AND GROUND WATER CHARACTERIZATION*

Soil samples were collected from the Site on July 6, 2005 by URS personnel. Soil samples were collected from the following locations and depths:

- SB-06-01 14-20 feet below ground surface (bgs) in the source area near MW-1S
- SB-06-02 12-18 feet bgs in the downgradient plume area near MW-97-1S

The samples were collected in brass liners. The soil samples were shipped on June 6, 2006 and received at TSI on June 7, 2006. After receipt at the laboratory, the soil samples were transferred from the brass liners, sieved through a 4.5 mm screen, and composited under anaerobic conditions.

Groundwater samples were collected from MW-1S and MW-97-1S and shipped from the Site on June 8, 2006 and received at TSI on June 9, 2006.

Portions of the soil and groundwater composites were then submitted for initial characterization. Table 1 summarizes the ground water and soil analytical results at the time of the June 2006 sampling event.

Low concentrations of tetrachloroethene (PCE), 1,1,2-trichloroethane, and VC with higher concentrations of CA were detected in the groundwater samples. Other volatile chlorinated ethenes and ethanes were not detected and only a trace of ethene. Relatively low levels of ethane and moderate to high levels of methane were detected. The 1TCA concentration in the SB-06-01 soil sample was quite high, 7,500 µg/kg, with detectable, but much lower levels of CA, 1DCE, 1DCA, TCE, and PCE. The methane level in the soil sample from SB-06-01 was low, 7.6 µg/L, and there was detectable ethene and ethane. The SB-06-02 soil contained 1,1,2-TCA, 1TCA, 1DCE, and 1DCA. Only a trace of methane was detected, with no detectable ethene or ethane.

The results of the initial soil/ground water analyses indicate that:

- The analytical data for CVOCs and natural attenuation parameters provide evidence of naturally occurring reductive dechlorination; and

Sections 2 and 3 present the test conditions for the anaerobic bioremediation and aerobic bioremediation studies, respectively. The results for both studies are presented in Section 4.

Table 1. Concentrations of CVOCs, Dissolved Hydrocarbon Gases, and Electron Acceptors in Site Groundwater and Soil

Parameter	Units	MW-1S Groundwater	SB 06-01 Soil	MW-97-1S	SB 06-02 Soil Groundwater
Alkalinity	mg/L as CaCO3	520	61	550	22
Ferrous Iron	mg/L	<1.0		4.0	
Nitrate	mg/L	1.0		1.0	
Sulfate	mg/L	1.2		1.2	
Total Organic Carbon	mg/L	6.3	4600	10	8700
Total Iron	mg/L or mg/kg	21	3700	23	3100
Percent Solids	%		88		87
Vinyl Chloride	µg/L or µg/kg	7.2	13	<1.1	<2.0
Chloroethane	µg/L or µg/kg	440	31	36	<2.0
1,1-Dichloroethene	µg/L or µg/kg	<1.1	210	<1.1	6.7
1,1-Dichloroethane	µg/L or µg/kg	<1.1	270	<1.1	6.4
cis-1,2-Dichloroethene	µg/L or µg/kg	<1.1	<2.0	<1.1	<2.0
1,1,1-Trichloroethane	µg/L or µg/kg	<1.1	7500	<1.1	29
Trichloroethene	µg/L or µg/kg	<1.1	16	<1.1	<2.0
1,1,2-Trichloroethane	µg/L or µg/kg	3.2	<2.0	3.3	40
Tetrachloroethene	µg/L or µg/kg	13	13	<1.1	<2.0
Methane	µg/L or µg/kg	410	7.6	23000	6.6
Ethene	µg/L or µg/kg	trace	12	<1.3	<2.4
Ethane	µg/L or µg/kg	37	12	37	<2.4

µg/L = micrograms per liter; µg/kg = micrograms per kilogram

3.0 *ANAEROBIC MICROCOSM STUDY*

TSI completed the laboratory portion of the Anaerobic Microcosm Study at its Wilmington, Delaware facility between July 11 and October 31, 2006. The study evaluated the potential for the addition of a soluble carbon substrate (lactate) and a slow-release substrate (SRS™, TSI's emulsified soy bean oil) to stimulate reductive dechlorination of 1TCA to CA and ethene/ethane. Based upon existing data, reductive dechlorination at the Site is likely limited by the availability of carbon to support anaerobic microbial growth and complete dechlorination of the 1TCA to CA and further to ethene and ethane. The study procedures and results are presented in this section of the report.

3.1 *MICROCOSM PREPARATION*

Two sets of Killed Controls, one Ambient treatment to determine if the native microbial could biodegrade the CVOCs under existing conditions, and two sets of with carbon-amended treatment microcosms were prepared on July 11, 2006 using 260-milliliter (mL) amber bottles and were incubated for up to 16 weeks. Each treatment was prepared in triplicate. The microcosms were prepared with 200 g soil and 160 mL of groundwater and amendments. Table 2 summarizes the individual microcosms that were prepared for this study and the quantities of groundwater, soil and amendments added to each microcosm. The microcosms were prepared and sampled in an anaerobic chamber containing 3% hydrogen, 5% carbon dioxide and 92% nitrogen to ensure anaerobic conditions were maintained. The microcosms were sealed with Mininert Valves. The microcosms were incubated at 21°C in the dark throughout the study.

The sterile poisoned controls were prepared using autoclaved groundwater and composited soil to account for potential abiotic losses of 1TCA from the microcosm. The sterile control soils were autoclaved for 30 minutes at 120 °C and 15 pounds per square inch of steam on two successive days. This control microcosm was also amended with 1,000 mg/L of mercuric chloride to further reduce the potential for microorganism survival. A second poisoned control was prepared in the same manner except it was also amended with 10,000 mg/L of sodium dithionite. Sodium dithionite will reduce iron and may produce ferric sulfide or ferric disulfide precipitates that could react with the 1TCA. The sterile control treatments were amended with 1 to 3 milligrams per liter (mg/L) of 1TCA in methanol. Approximately 14 mg/L of TOC was added with the methanol spike.

Table 2. Anaerobic Microcosm Amendments

No.	Treatment	Soil (g)	Liquid (mL)	Amendments
1	Poisoned Control	200 SB-06-01	160 MW-15 sterile groundwater	1,000 mg/L mercuric chloride, 1 mg/L resazurin
2	Poisoned Control with Sodium Dithionite	200 SB-06-01	160 MW-15 sterile groundwater	1,000 mg/L mercuric chloride, 1 mg/L resazurin, 10,000 mg/L sodium dithionite
3	Unamended	200 SB-06-01	160 MW-15 groundwater	1 mg/L resazurin
4	Lactate	200 SB-06-01	160 MW-15 groundwater	500 mg C/L lactate, 1 mg/L resazurin, 50 mg/L N, 5 mg/L P, and 50 mg/L yeast extract
5	SRS with Lactate	200 SB-06-01	160 MW-15 groundwater	500 mg C/L SRS, 1 mg/L resazurin

mg/L = milligrams per liter

The treatment microcosms were amended with either sodium lactate or SRS™ (emulsified soybean oil) as the carbon substrates. Sodium lactate was added at a dosage of 500 mg carbon per liter of groundwater (mg C/L) as an electron donor and fermentable substrate to support the generation of hydrogen. The SRS™ was added at 500 mg/L also. The SRS™ also contains sodium lactate as a fast-acting substrate to rapidly generate anaerobic conditions and well as yeast extract, nitrogen, and phosphorus. Yeast extract was added to the lactate-amended treatments as a source of trace elements. The lactate-amended treatments received 50 mg/L nitrogen and 5 mg/L phosphorus from ammonium chloride and disodium phosphate as nutrients. A solution of 1 mg/L resazurin was added to each microcosm as a visual indicator of oxidation-reduction potential (ORP). The microcosms remained clear when conditions are anaerobic and reducing, which are necessary for reductive dechlorination to occur. A pink color was observed when the microcosm are under aerobic, oxidizing conditions. Resazurin does not affect the biodegradation process and would not be added as part of a full-scale implementation. All of the microcosms became clear soon after they were set up indicating that there was sufficient organic matter in the soil and groundwater to support anaerobic conditions.

3.2 *ANAEROBIC MICROCOSM SAMPLING AND ANALYSIS*

Samples were collected from each microcosm in for analysis after 0, 4, 8, and 12 weeks of incubation. In addition, aqueous and soil samples were collected on Week 16 from treatment 1A (Sterile); 3A (Ambient); 4A, 4B, 4C (Lactate + Nutrients); and 5A, 5B, and 5C (SRS). Samples were collected from the microcosms within an anaerobic glove box to maintain anaerobic conditions. Samples were collected for CVOC and light hydrocarbon analyses. Aliquots (0.2 to 9 mL) of the samples to be analyzed by TSI for CVOCs in general accordance with SW-846 Method 8021B and for light hydrocarbons (ethene, ethane, and methane) in general accordance with a modified SW 846 Method 8015 were transferred directly into a 20-mL headspace vial containing 1 mL of a 25% sodium chloride solution adjusted to pH 2.0 with phosphoric acid and enough distilled water to bring the entire volume of sample and sodium chloride solution to 10 mL. After sampling, the withdrawn liquid was replaced with sterile glass beads.

4.0 *AEROBIC MICROCOSM STUDIES*

A separate aerobic microcosm study was conducted with the downgradient SB-06-02 soil and MW-97-1S groundwater. The following conditions were prepared in triplicate:

- Killed control
- Unamended
- Nutrient amended

Table 3 shows the amendments for each treatment. The studies were carried out in 260 mL bottles with 125 g soil, 130 mL groundwater, and about 62 mL headspace. The headspaces of the bottles were flushed with oxygen. The initial spiking solution for the aerobic treatments was mistakenly prepared with a mixture of cis-1,2-DCE and trans-1,2-DCE rather than 1DCE and the concentration of chloroethane to be added was not calculated correctly. Approximately 14 mg/L of TOC was added with the methanol in the spiking solutions. Therefore, on week 2, an additional spike of 5 mg/L 1DCE and 0.5 mg/L CA in methanol was added to each of the bottles in aerobic treatments. This resulted in an additional 201 mg/L of carbon from the methanol.

Table 3. Amendments for Aerobic Microcosm Studies

6	Poisoned Control with Oxygen	125 SB-06-02	130 MW-97-1S sterile groundwater	1,000 mg/L mercuric chloride, 1 mg/L resazurin, 62.5 mL oxygen
7	Unamended with Oxygen	125 SB-06-02	130 MW-97-1S groundwater	1 mg/L resazurin, 62.5 mL oxygen
8	Nutrients with Oxygen	125 SB-06-02	130 MW-97-1S groundwater	1 mg/L resazurin, 50 mg/L N, and 5 mg/L P,

4.2 *AEROBIC MICROCOSM SAMPLING AND ANALYSIS*

Samples were collected from each microcosm in for analysis after 0, 2, 4, 8, and 12 weeks of incubation. In addition, aqueous and soil samples were collected on Week 16 from treatment 6A (Sterile Aerobic); 7A (Ambient Aerobic); and 8A (Aerobic + Nutrients); and 5A, 5B, and 5C (SRS). Samples were collected for CVOC and light hydrocarbon analyses, pH, and ORP. Aliquots (1.0 to 9 mL) of the sample to be analyzed by TSI for CVOCs in general accordance with SW-846 Method 8021B and for light hydrocarbons (ethene, ethane, and methane) in general accordance with a modified SW 846 Method 8015 was transferred directly into a 20-mL headspace vial containing 1 mL of a 25% sodium chloride solution adjusted to pH 2.0 with phosphoric acid and enough distilled water to bring the entire volume of sample and sodium chloride solution to 10 mL. After sampling, the headspace was replaced with oxygen and the Mininert caps tightened.

5.0 RESULTS AND DISCUSSION

5.1 METABOLIC ACTIVITY IN ANAEROBIC MICROCOSMS

Metabolic activity refers to the level of anaerobic biological degradation that is occurring and has been evaluated in this study by measuring dissolved methane concentrations. The presence of methane in a microcosm was an indication that anaerobic microorganisms are present and actively biodegrading the organic substrate. Increases in methane concentrations following addition of an organic substrate to a microcosm indicate that the growth of anaerobic microorganisms can be stimulated. Methane was produced when other electron acceptors (e.g., oxygen, nitrate, sulfate, iron) have been depleted, and reductive dechlorination occurs most readily under these methanogenic conditions.

Figure 1 and Appendix I present the average dissolved methane concentrations for each microcosm set constructed with MW-1S groundwater and SB-06-01 soil. Average methane concentrations in the microcosms at the beginning of the study ranged from <6.6 to 172 µg/L. In the substrate-amended microcosms, maximum methane levels reached 62,667 µg/L in the microcosm amended with SRS™ at Week 12. Somewhat lower levels of methane were found in the lactate -amended treatment with a maximum average of 27,000 µg/L. Very little methane was not detected in the sterile control, sterile control + dithionite, or unamended microcosms sets.

The results of the microcosm study indicate:

- As expected, the sterile microcosms did not produce appreciable methane;
- Growth of indigenous microorganisms can be stimulated through the addition of an organic substrate. This conclusion is based on increases in methane concentrations observed in substrate-amended microcosms relative to the control microcosms; and
- Increased methane concentrations in each substrate-amended microcosm occurred by Week 8.

5.2 *pH AND ORP IN ANAEROBIC MICROCOSMS*

Samples were collected from the all five microcosms throughout the study to be analyzed for pH and oxidation-reduction potential (ORP). Figures 2 and 3 show the average pH and ORP for each treatment. Appendix I provides the results of all of the pH and ORP analyses.

The average initial pH ranged between 6.7 and 7.3. The average pH dropped to 6.3 to 6.5 in the sterile control amended with sodium dithionite. The average pH remained neutral (6.7 to 7.4) for the remaining treatments.

Oxidizing conditions (192 to 216 millivolts or mV) were found initially. Negative ORPs were found at Week 4 with the sodium dithionite, ambient, and lactate + nutrients treatments. Sodium dithionite acts as a reductant. The average ORP continued to drop with SRS, but increased between weeks 12 and 16 in the lactate + nutrients treatment.

5.3 *CVOC BIODEGRADATION IN ANAEROBIC MICROCOSMS*

Appendix I presents the analytical results for the anaerobic microcosms containing the MW-1S groundwater and SB-06-01 soil. Figures presenting the results for the various microcosms are summarized as follows:

Figure	Microcosm	Amendments
4	1	Sterile Control
5	2	Sterile Control + Dithionite
6	3	Ambient Control
7	4	Lactate
8	5	SRS™

CVOC concentrations presented on the figures are expressed in total micromoles (µMoles) units. Molar units were used so that each CVOC is expressed on an equivalent mass basis for comparison purposes. The micromolar concentrations are calculated by dividing the concentration in µg/L by the molecular weight of the CVOC (1TCA = 133.4 grams per mole [g/mol]; 1,1-DCE = 96.9 g/mol; 1DCA = 99 g/mol; CA = 64.5 g/mol; VC = 62.5 g/mol; ethene = 28 g/mol; and ethane = 30 g/mol).

The following summarizes the results for anaerobic microcosms containing Columbia Cement MW-1S groundwater and SB-06-01 soil:

- Initial average 1TCA concentrations in the microcosms ranged from 850 µg/L (SRS) to 3,650 µg/L (Ambient). 1DCE, 1DCA, CA, and ethane were also detected in the initial samples.
- Over the 12-16 week incubation period for the sterile control microcosms, there appeared to limited reductive dechlorination of the 1TCA to 1DCA, but no evidence for microbial activity based upon accumulation of methane was observed. Average losses of 88.8 % of the 1TCA was observed which might be attributed to 1TCA partitioning into the headspace in the microcosm or adsorption onto the glass bottle, soil, or glass beads. Treatment 1B showed

almost complete transformation of 1TCA to 1DCA suggesting that some microorganisms were not killed by the autoclaving or mercuric chloride. CA, methane, and ethane were detected in the initial Time 0 samples, but were not detected at the final sampling points. However, average concentrations of 1DCE and 1DCA increased slightly indicating the potential for abiotic transformation of the 1TCA. At week 16, relatively low levels of CA and VC were found in the soil phase indicating some potential adsorption onto the soil organic fraction.

- There appeared to be limited conversion of 1TCA to 1DCA in the sterile control amended with dithionite, but no further biodegradation to CA, ethene, or ethane. An average loss of 72.5% of the 1TCA was observed. No conversion of 1TCA to 1DCE was observed. Reduction of the iron with sodium dithionite did not promote the abiotic transformation of the 1TCA above the limited abiotic transformation observed in the sterile control.
- The concentration of 1TCA increased in all three replicates of the ambient control between weeks 0 and 4 suggesting that there was some free phase 1TCA in the soils that came to equilibrium with the groundwater. No increase in the 1TCA concentrations were observed in the sterile or sterile-dithionite amended treatments as most of the 1TCA would have been removed during the autoclaving process. From weeks 4 to 16, average 1TCA concentrations decreased as 1DCA concentrations increased. CA was found throughout the study and its concentration did not appear to change appreciably. 1DCE concentrations were highest at Week 8 with a small increase in Ethene levels at week 16. VC was not detected in the groundwater for the ambient treatment, but VC was detected in the soil sample from bottle 3A at 24 μg/kg.
- The microcosms amended initially with Lactate and nutrients showed almost complete conversion of the 1TCA to 1DCA by Week 4. 1DCA and CA concentrations greatly exceeded that of the parent 1TCA found at week 0 suggesting transformation of some adsorbed phase 1TCA. Further conversion of 1DCA to CA and VC was seen in all three replicates. CA levels increased slightly between weeks 12 and 16. Ethane and ethene represented at most 16% of the total chlorinated ethanes. Some 1TCA and 1DCA were found in the soil fraction at week 16 indicating adsorption to the soil organic fraction or potentially that low concentrations of these compounds persisted; a lower dilution was run for the soil samples than the groundwater samples.
- The microcosms amended with SRS™ achieved almost complete reduction of 1TCA to 1DCA within 4 weeks with further transformation to CA within the next four weeks. CA concentrations declined between weeks 12 and 16. However, ethene and ethane represented at most 10.3% of the chlorinated ethanes. Once again, 1TCA, 1DCA, and 1DCE were detected at relatively low levels in the soil phase due to adsorption to the soil organics or the lowered detection limits.

- Both sodium lactate and SRS^{TM} are potential organic substrate candidate for ground water based upon the almost complete conversion of 1TCA to CA. Lactate would have to be applied more frequently (monthly to quarterly) by either batch addition or via a recirculation system. SRS^{TM} would last longer in the subsurface requiring less frequent application and would not require a recirculation system.

5.4 *AEROBIC MICROCOSMS*

Methane concentrations initially ranged between 200 and 16,000 µg/L in treatments 7 and 8 prepared with the SB-06-02 soil and MW-97-1S groundwater. All of the methane was lost during the autoclaving process for the sterile control treatment 6. Under the aerobic conditions, methane was rapidly reduced in the aqueous phase of the treatments 7 and 8 bottles due to a combination of biodegradation, volatilization, and losses during sampling. No methane was detected at Week 16 in any of the three bottles analyzed.

The average pH of the aerobic treatments ranged between 6.4 and 7.6 with no discernible pattern. The initial ORP levels in the aerobic treatments ranged between 208 and 233 mV. ORP measurements were not made at Week 2. From weeks 4 to 12, the ORP of the sterile control remained oxidizing. At week 16, bottle 6A had a negative ORP of -41 mV. The average ORP of the ambient and nutrient amended treatments became reducing or slightly oxidizing from weeks 4 to 16. At week 12, the dissolved oxygen contents of the bottles were measured and found to be aerobic (7.7 to 11.7 mg/L).

All of the CVOCs were reduced under aerobic conditions. It is not certain how much of the removal was due to biodegradation and much was due to volatilization into the aerobic headspace or losses during sampling and replenishment of the oxygen. For all compounds including cDCE, tDCE, 1DCE, 1DCA, and CA, loss of the CVOCs was generally slower in the poisoned controls than the ambient or nutrient amended aerobic treatments. For some unknown reason, sterile control 6B showed faster losses than the other replicates for this treatment. The aerobic treatment 7 without nutrients generally showed faster degradation rates than the treatment 8 with nutrients.

The soil fraction for all three treatments retained some of the cDCE, tDCE, 1DCE, 1DCA, and VC. The combination of aerobic treatment and volatilization was able to remove over 96% of the contaminants in the aqueous phase. Stimulation of aerobic biodegradation by oxygen addition to the groundwater, dual phase vacuum extraction, or soil venting should be able to aerobically biodegrade the CA generated from the anaerobic biodegradation of the 1TCA.

5.0 *CONCLUSIONS AND RECOMMENDATIONS*

Conclusions of the bioremediation evaluation based on the results presented in this report are as follows:

- The growth of indigenous microorganisms at the Columbia Cement site can be stimulated through the addition of an organic substrate. This conclusion is supported by the observed increase in metabolic activity including production of methane and conversion of 1TCA to CA, ethene, and ethane through the addition of SRS™ or lactate. The native dechlorinators were able to completely dechlorinate the 1TCA to during the first eight weeks of the study;
- Based upon this study, sodium lactate and SRS™ are potential organic substrates to be considered for full-scale implementation. Due to its high solubility and rapid biodegradation, lactate will require frequent replenishment or continuous addition and may necessitate a groundwater recirculation system. The SRS™ is less soluble and more persistent. This substrate would require much less frequent injection and will not require groundwater recirculation but would likely require delivery through multiple injection points;
- Aerobic treatment by addition of oxygen to the groundwater, dual phase vacuum extraction, or venting will be able to remove the CA generated from the anaerobic biodegradation of the 1TCA.

The results of this study indicate that enhanced anaerobic bioremediation is a viable remedial alternative for the Columbia Cement Facility to address the chlorinated VOC plumes. Remedial performance can be evaluated and modified as part of the field-scale pilot test. It is recommended that injection of the lactate or SRS™ be conducted and monitored for at least three months to determine if the substrate can be effectively distributed.

FIGURES

Figure 1. Methane Anaerobic Average

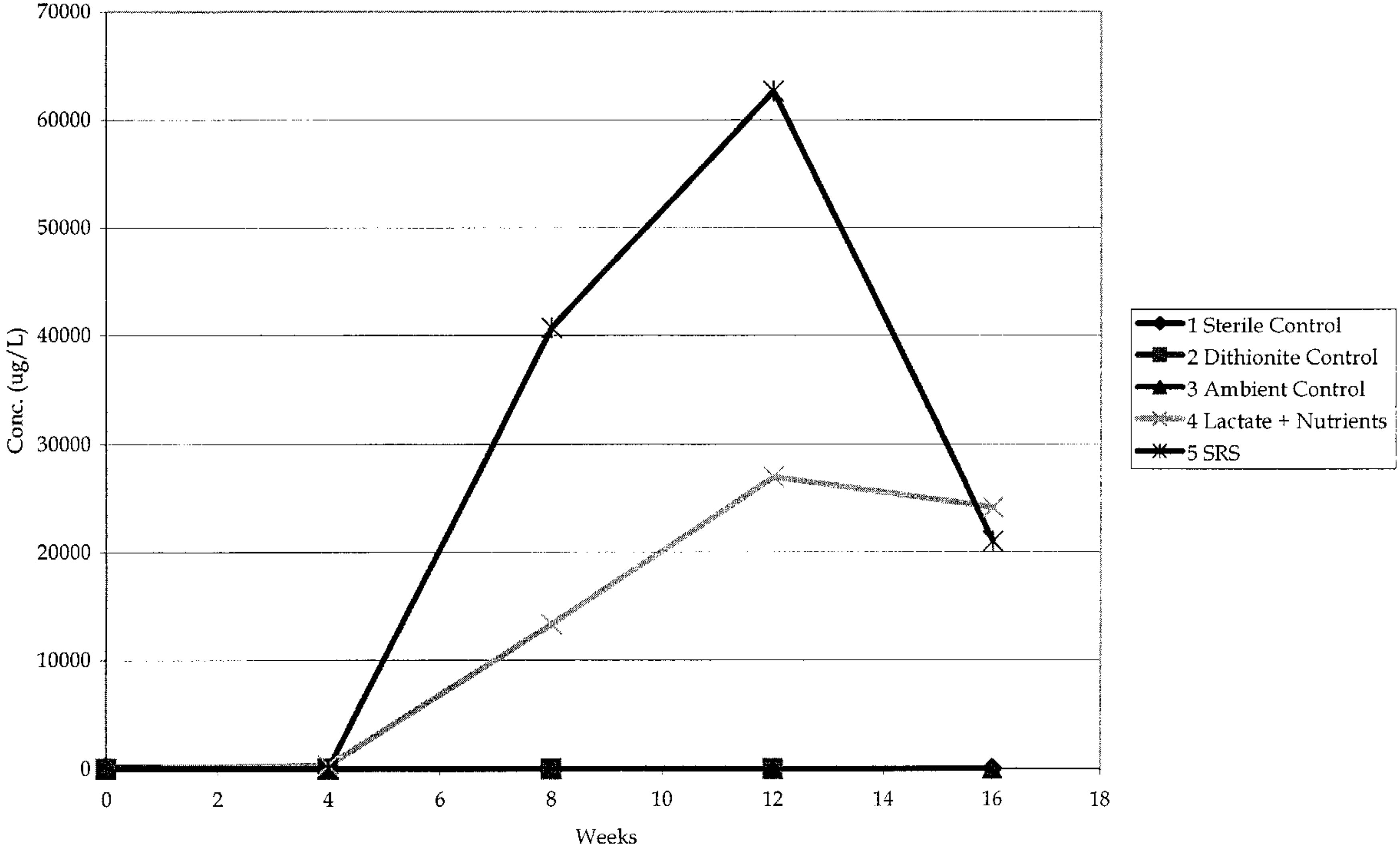


Figure 2. pH Anaerobic Average

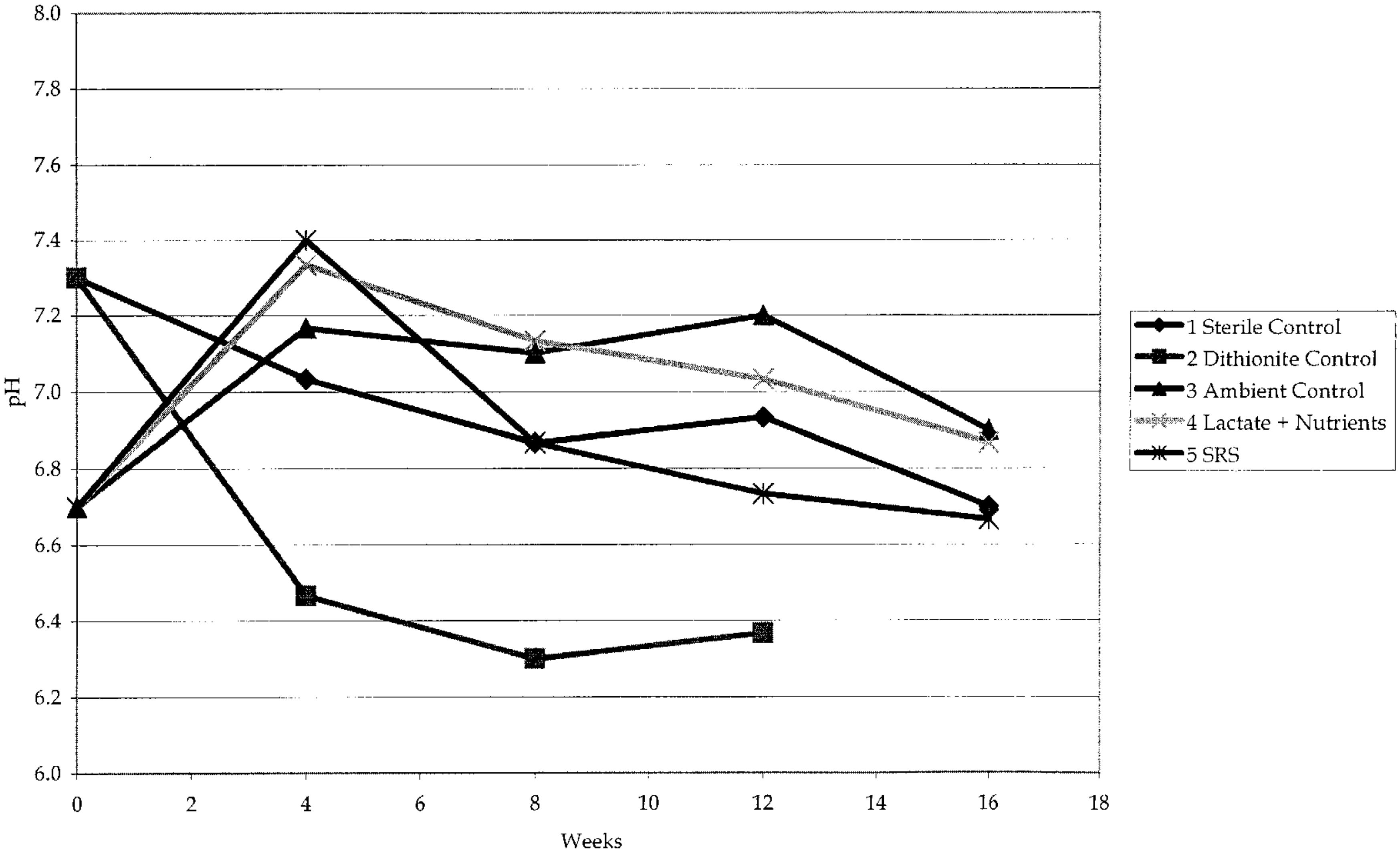


Figure 3. ORP Anaerobic Average

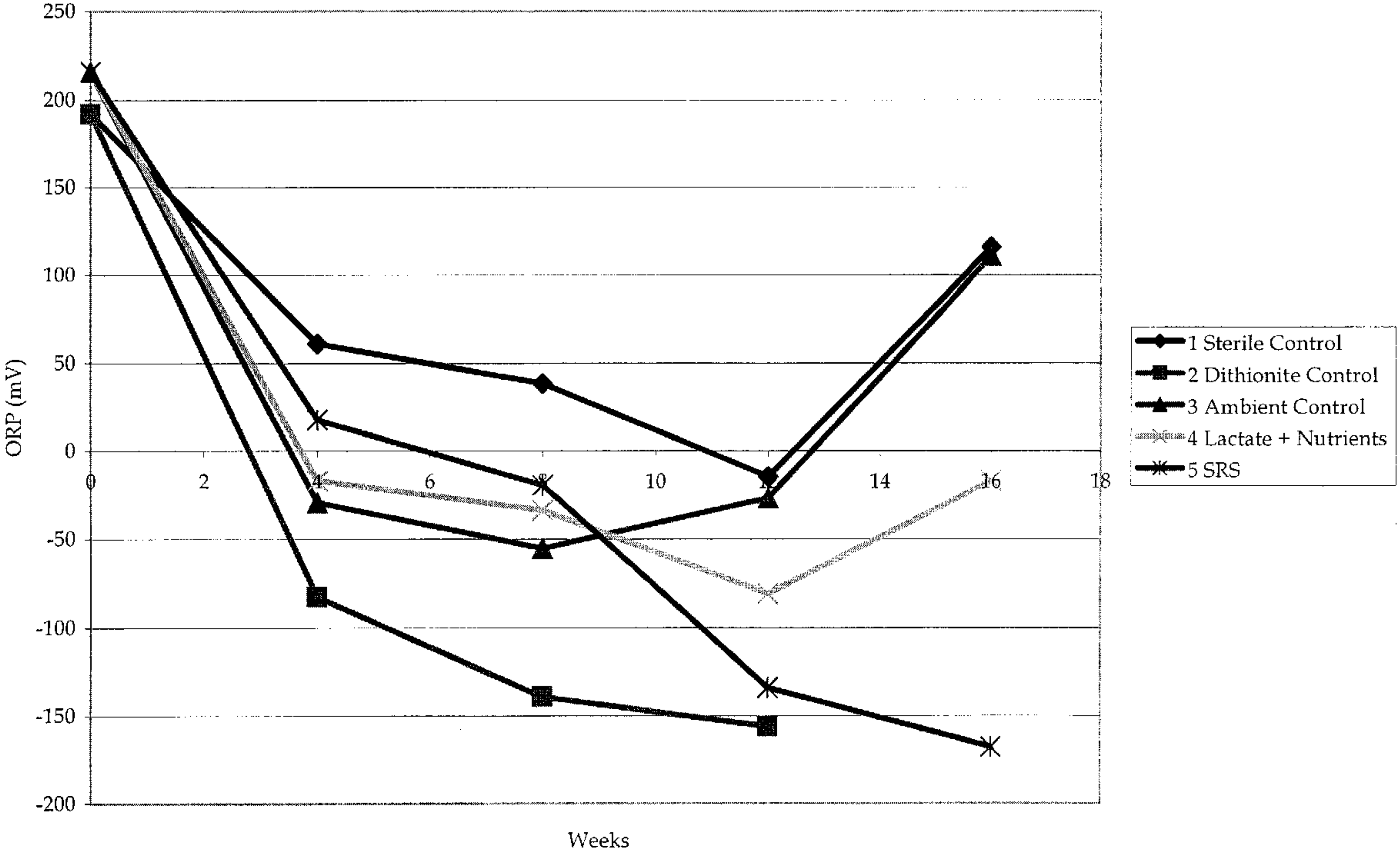


Figure 4. Treatment 1 Sterile Control Average

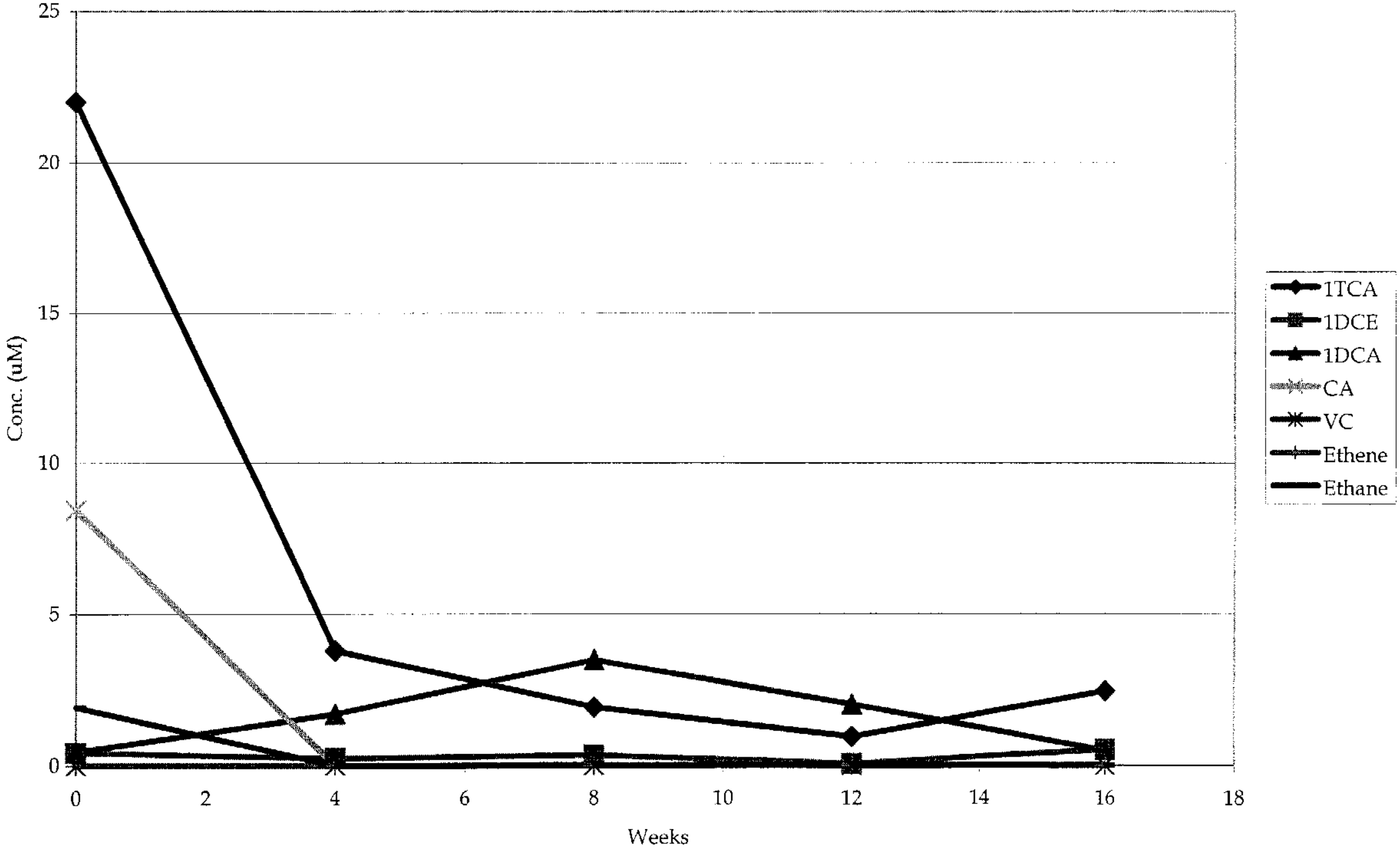


Figure 5. Treatment 2 Sterile Control with Dithionite Average

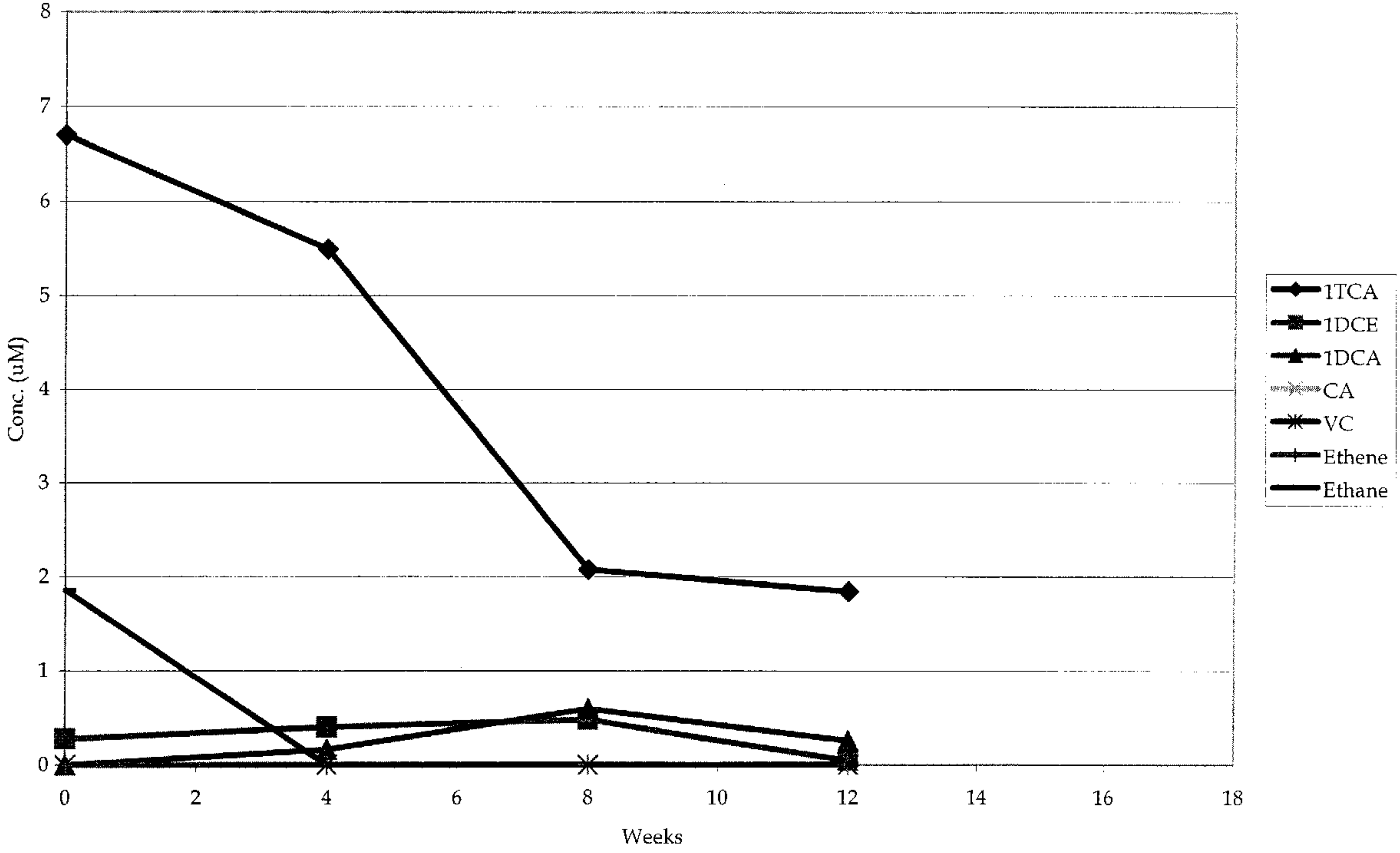


Figure 6. Treatment 3 Ambient Average

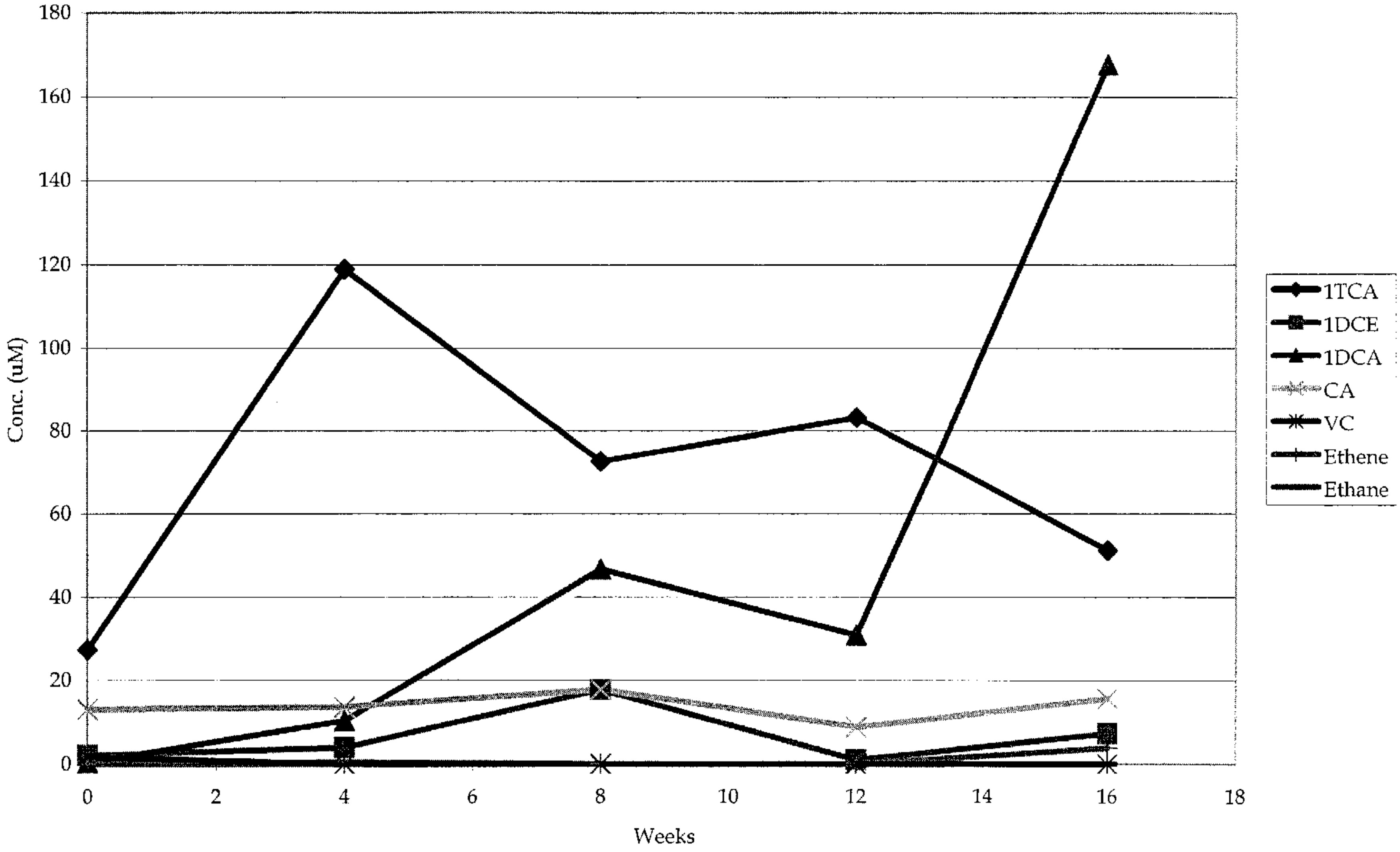


Figure 7. Treatment 4 Lactate Anaerobic Average

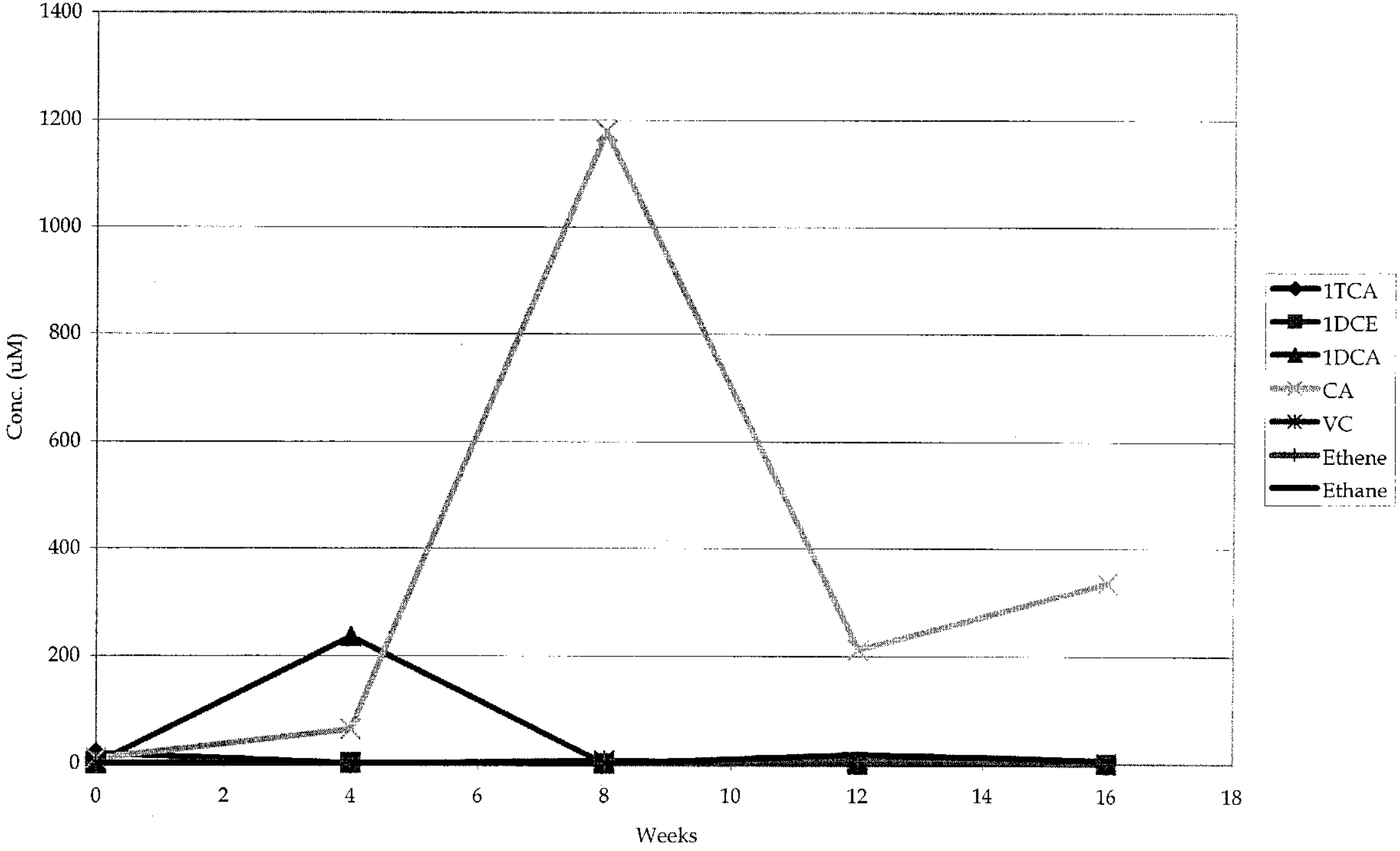


Figure 8. Treatment 4 Lactate Anaerobic Average

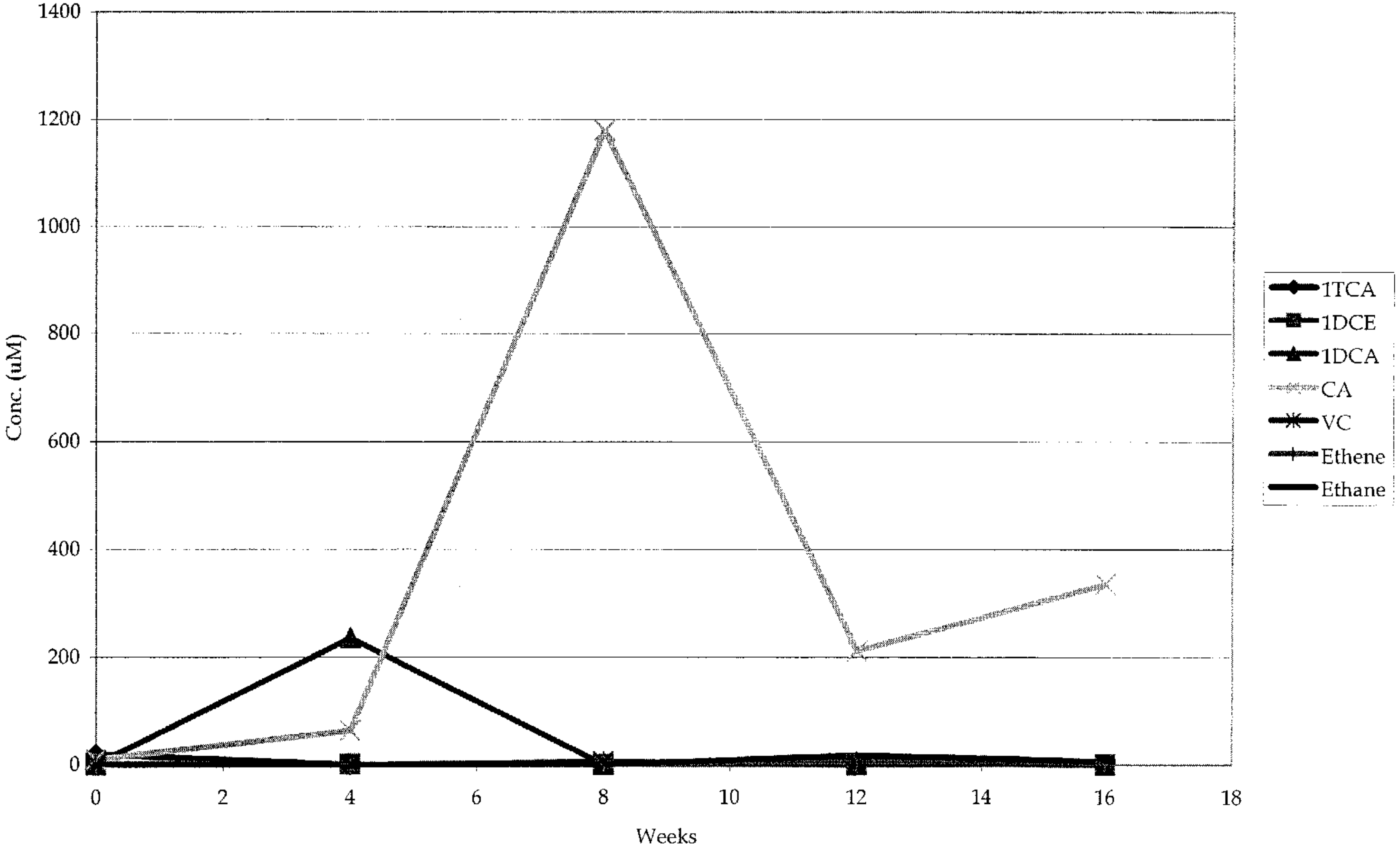


Figure 9. Treatment 6 Aerobic Control Average

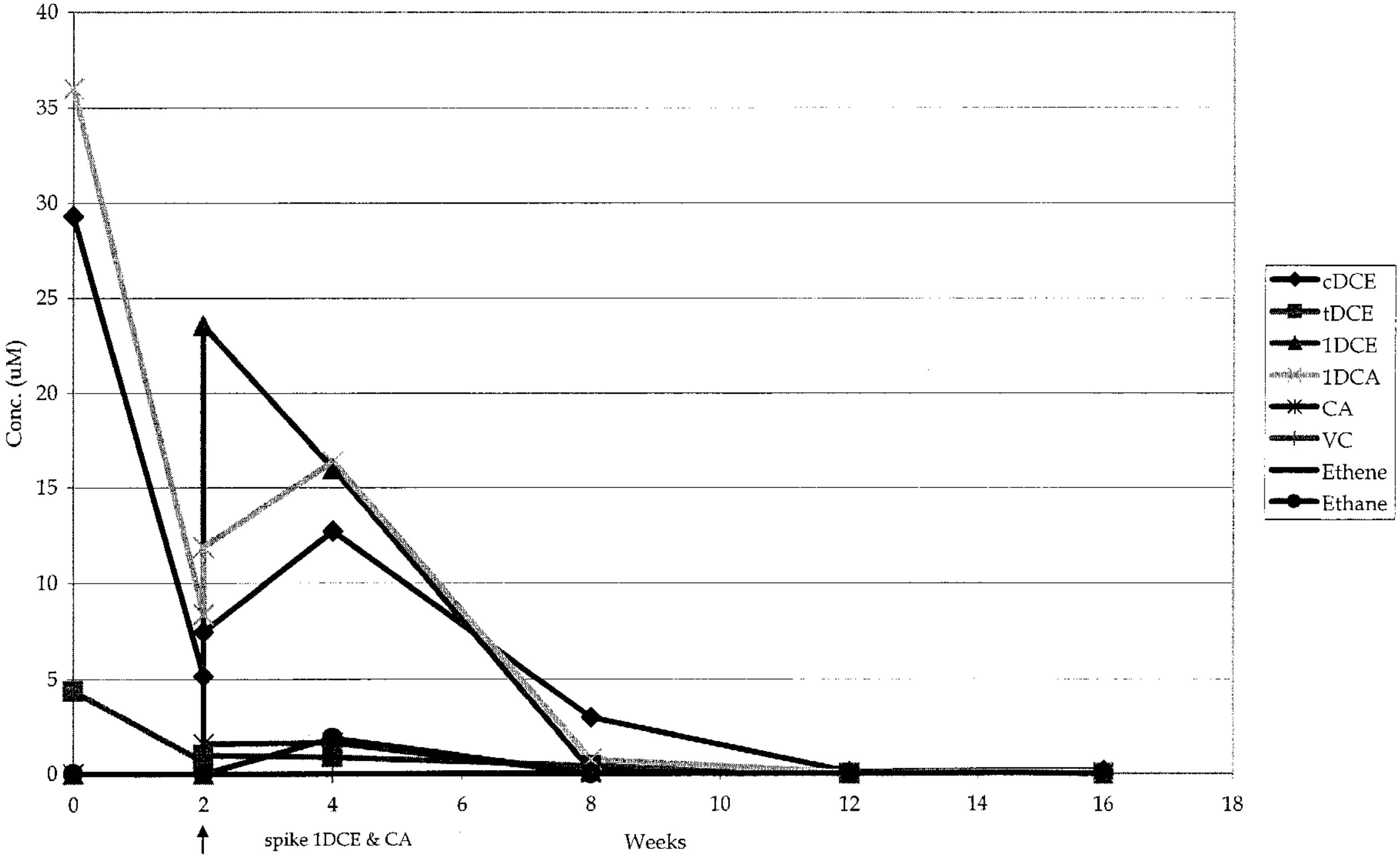


Figure 10. Treatment 7 Aerobic Ambient Average

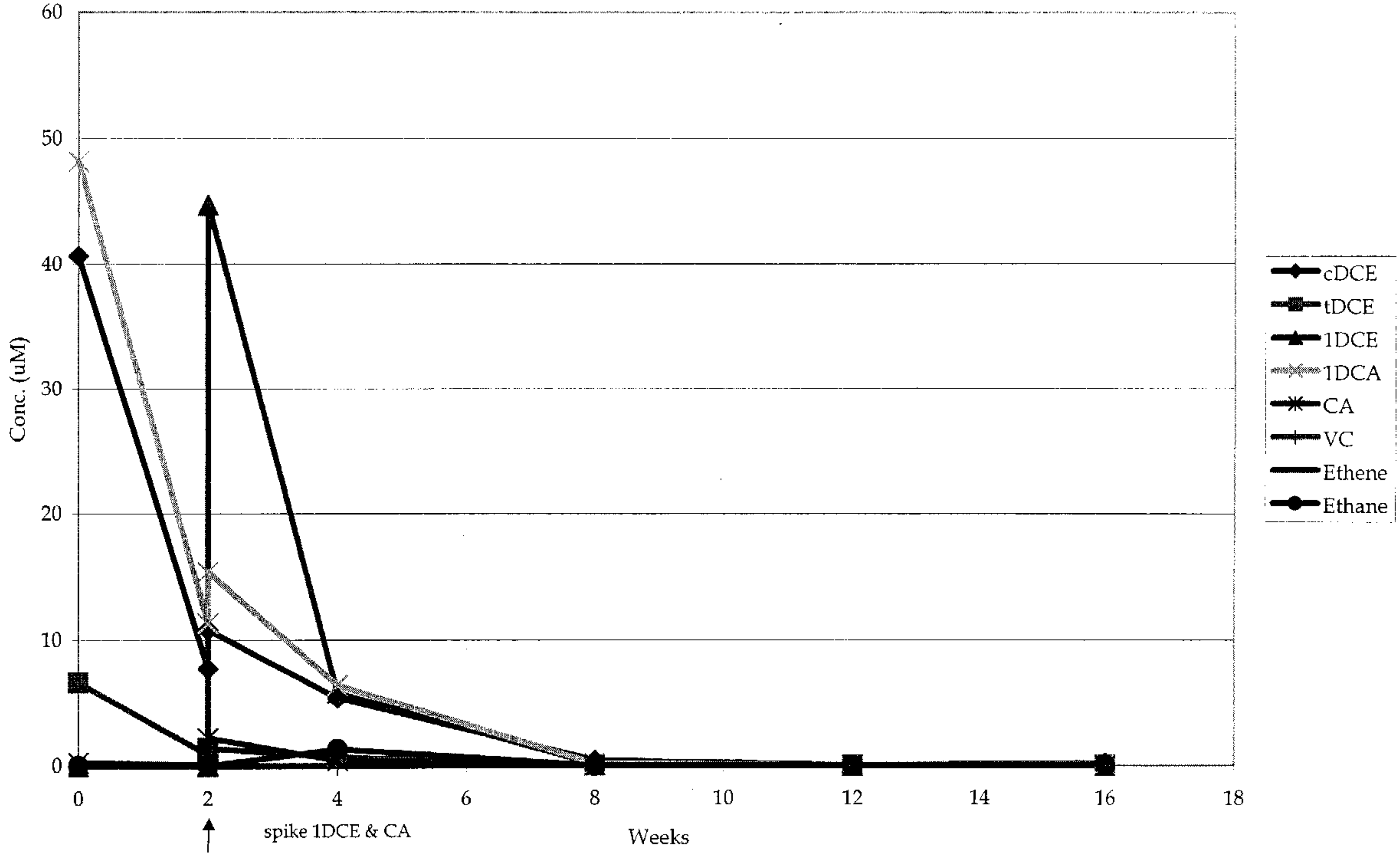
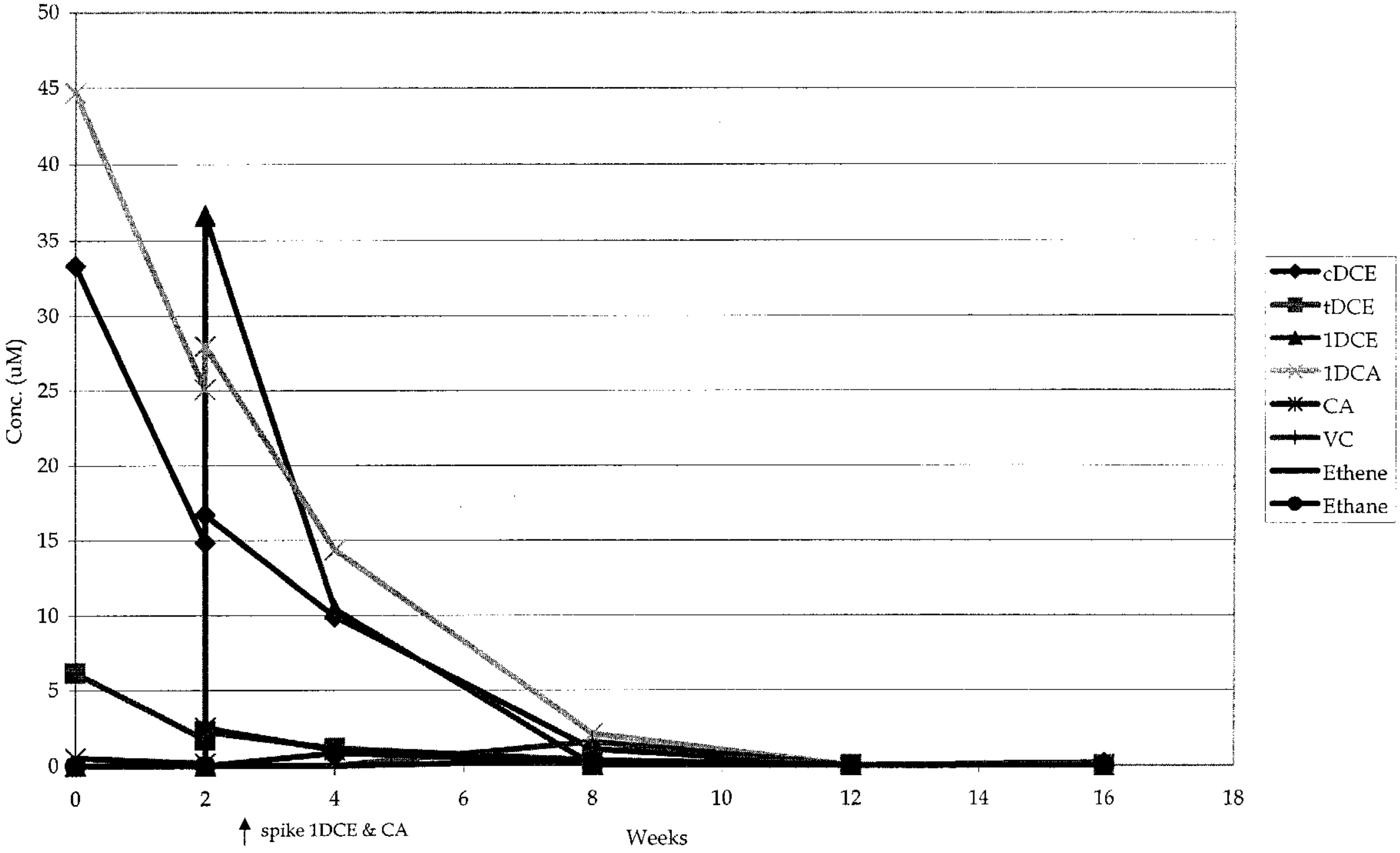


Figure 11. Treatment 8 Aerobic Nutrients Average



APPENDIX I

CONCENTRATIONS OF CHLORINATED ETHENES, LIGHT HYDROCARBON GASES, pH, AND ORP

1-A Sterile Control MW-1S Groundwater and SB-06-01 Soil

Compound	Week	0	4	8	12	16	16 Soil
1TCA	μg/L	2490	670	380	380	330	120
1DCE	μg/L	<10	<10	30	18	52	45
1DCA	μg/L	40	<10	40	38	50	20
CA	μg/L	620	<10	<2.0	<1.1	<1.1	11
VC	μg/L	<10	<10	<2.0	<1.1	<1.1	8.0
Methane	μg/L	170	<6.7	<1.3	<0.7	<0.7	11
Acetylene	μg/L	<10	<10	<2.0	<1.1	<1.1	<2.0
Ethene	μg/L	<12	<12	<2.4	<1.3	<1.3	9.0
Ethane	μg/L	55	<12	<2.4	<1.3	<1.3	15
1TCA	μM	18.7	5.0	2.8	2.8	2.5	0.90
1DCE	μM	<0.10	<0.10	0.31	0.19	0.54	0.46
1DCA	μM	0.40	<0.10	0.40	0.38	0.51	0.20
CA	μM	9.6	<0.16	<0.031	<0.018	<0.018	0.17
VC	μM	<0.16	<0.16	<0.032	<0.17	<0.17	0.13
Acetylene	μM	<0.38	<0.38	<0.076	<0.038	<0.038	<0.076
Ethene	μM	<0.43	<0.43	<0.086	<0.046	<0.046	0.32
Ethane	μM	1.8	<0.40	<0.080	<0.043	<0.043	0.50
pH		7.3	7.1	6.7	6.8	6.7	
ORP	mV	192	104	18	-15	116	

1-B Sterile Control MW-1S Groundwater and SB-06-01 Soil

Compound	Week	0	4	8	12
1TCA	μg/L	2880	160	16	8.2
1DCE	μg/L	48	<10	22	<2.0
1DCA	μg/L	35	450	840	520
CA	μg/L	270	<10	<2.0	<2.0
VC	μg/L	<10	<10	<2.0	<2.0
Methane	μg/L	270	<6.7	<1.3	<1.3
Acetylene	μg/L	<10	<10	<2.0	<2.0
Ethene	μg/L	<12	<12	<2.4	<2.4
Ethane	μg/L	57	<12	<2.4	<2.4
1TCA	μM	21.6	1.2	0.12	0.06
1DCE	μM	0.50	<0.10	0.23	<0.020
1DCA	μM	0.35	4.5	8.5	5.3
CA	μM	4.2	<0.16	<0.031	<0.031
VC	μM	<0.16	<0.16	<0.032	<0.032
Acetylene	μM	<0.38	<0.38	<0.076	<0.076
Ethene	μM	<0.43	<0.43	<0.086	<0.086
Ethane	μM	1.9	<0.40	<0.080	<0.080
pH		7.3	7.1	7.0	7.0
ORP	mV	192	117	79	-15

1-C Sterile Control MW-1S Groundwater and SB-06-01 Soil

Compound	Week	0	4	8	12
1TCA	μg/L	3440	690	380	<1.1
1DCE	μg/L	79	70	50	<1.1
1DCA	μg/L	61	61	160	45
CA	μg/L	740	<10	<2.0	<1.1
VC	μg/L	<10	<10	<2.0	<1.1
Methane	μg/L	75	<6.7	<1.3	<0.7
Acetylene	μg/L	<10	<10	<2.0	<1.1
Ethene	μg/L	<12	<12	<2.4	<1.3
Ethane	μg/L	62	<12	<2.4	<1.3
1TCA	μM	25.8	5.2	2.8	<0.0082
1DCE	μM	0.82	0.72	0.52	<0.011
1DCA	μM	0.62	0.62	1.6	0.45
CA	μM	11.5	<0.16	<0.031	<0.018
VC	μM	<0.16	<0.16	<0.032	<0.17
Acetylene	μM	<0.38	<0.38	<0.076	<0.038
Ethene	μM	<0.43	<0.43	<0.086	<0.046
Ethane	μM	2.1	<0.40	<0.080	<0.043
pH		7.3	6.9	6.9	7.0
ORP	mV	192	-38	19	-13

2-A Sterile Control MW-1S Groundwater and SB-06-01 Soil Amended with Sodium Dithionite

Compound	Week	0	4	8	12
1TCA	µg/L	1160	700	300	330
1DCE	µg/L	44	59	40	7.8
1DCA	µg/L	<10	<10	39	25
CA	µg/L	<10	<10	<2.0	<1.1
VC	µg/L	<10	<10	<2.0	<1.1
Methane	µg/L	<6.6	<6.7	<1.3	1.9
Acetylene	µg/L	<10	<10	<2.0	<1.1
Ethene	µg/L	<12	<12	<2.4	<1.3
Ethane	µg/L	67	<12	<2.4	<1.3
1TCA	µM	8.7	5.2	2.2	2.5
1DCE	µM	0.45	0.61	0.41	0.080
1DCA	µM	<0.10	<0.10	0.39	0.25
CA	µM	<0.10	<0.16	<0.031	<0.018
VC	µM	<0.16	<0.16	<0.032	<0.17
Acetylene	µM	<0.38	<0.38	<0.076	<0.038
Ethene	µM	<0.43	<0.43	<0.086	<0.046
Ethane	µM	2.2	<0.40	<0.080	<0.043
pH		7.3	6.9	6.3	6.4
ORP	mV	192	-38	-138	-150

2-B Sterile Control MW-1S Groundwater and SB-06-01 Soil Amended with Sodium Dithionite

Compound	Week	0	4	8	12
1TCA	µg/L	910	440	210	98
1DCE	µg/L	37	58	41	3.9
1DCA	µg/L	<10	49	90	27
CA	µg/L	<10	<10	<2.0	<1.1
VC	µg/L	<10	<10	<2.0	<1.1
Methane	µg/L	<6.6	<6.7	<1.3	3.2
Acetylene	µg/L	<10	<10	<2.0	<1.1
Ethene	µg/L	<12	<12	<2.4	<1.3
Ethane	µg/L	100	<12	<2.4	<1.3
1TCA	µM	6.8	3.3	1.6	0.7
1DCE	µM	0.38	0.60	0.42	0.040
1DCA	µM	<0.10	0.49	0.91	0.27
CA	µM	<0.10	<0.16	<0.031	<0.018
VC	µM	<0.16	<0.16	<0.032	<0.17
Acetylene	µM	<0.38	<0.38	<0.076	<0.038
Ethene	µM	<0.43	<0.43	<0.086	<0.046
Ethane	µM	3.3	<0.40	<0.080	<0.043
pH		7.3	6.3	6.3	6.4
ORP	mV	192	-119	-147	-169

2-C Sterile Control MW-1S Groundwater and SB-06-01 Soil Amended with Sodium Dithionite

Compound	Week	0	4	8	12
1TCA	µg/L	610	1060	320	310
1DCE	µg/L	<10	<10	59	1.8
1DCA	µg/L	<10	<10	48	25
CA	µg/L	<10	<10	<2.0	<1.1
VC	µg/L	<10	<10	<2.0	<1.1
Methane	µg/L	<6.6	<6.7	<1.3	3.8
Acetylene	µg/L	<10	<10	<2.0	<1.1
Ethene	µg/L	<12	<12	<2.4	<1.3
Ethane	µg/L	<12	<12	<2.4	<1.3
1TCA	µM	4.6	7.9	2.4	2.3
1DCE	µM	<0.10	<0.10	0.61	0.019
1DCA	µM	<0.10	<0.10	0.48	0.25
CA	µM	<0.10	<0.16	<0.031	<0.018
VC	µM	<0.16	<0.16	<0.032	<0.17
Acetylene	µM	<0.38	<0.38	<0.076	<0.038
Ethene	µM	<0.43	<0.43	<0.086	<0.046
Ethane	µM	<0.40	<0.40	<0.080	<0.043
pH		7.3	6.2	6.3	6.3
ORP	mV	192	-91	-132	-149

3-A Ambient Control MW-1S Groundwater and SB-06-01 Soil

Compound	Week	0	4	8	12	16	16 Soil
1TCA	µg/L	4180	11600	8600	12000	6820	1540
1DCE	µg/L	220	180	2130	120	710	89
1DCA	µg/L	46	630	5200	4610	16600	3310
CA	µg/L	940	520	960	570	1010	96
VC	µg/L	<10	<10	<40	<40	<25	24
Methane	µg/L	56	<6.7	<26	<26	<17	8.5
Acetylene	µg/L	<10	<10	<40	<40	<25	<2.0
Ethene	µg/L	<12	<12	<48	<48	110	12
Ethane	µg/L	60	<12	<48	<48	<30	18
1TCA	µM	31.3	87.0	64.5	90.0	51.1	11.5
1DCE	µM	2.3	1.9	22.0	1.2	7.3	0.92
1DCA	µM	0.46	6.4	52.5	46.6	167.7	33.4
CA	µM	14.6	8.1	14.9	8.8	15.7	1.5
VC	µM	<0.16	<0.16	<0.64	<0.64	<0.40	0.38
Acetylene	µM	<0.38	<0.38	<1.5	<1.5	<1.5	<0.076
Ethene	µM	<0.43	<0.43	<1.7	<1.7	3.9	0.43
Ethane	µM	2.0	<0.40	<1.6	<1.6	<1.6	0.60
pH		6.7	7.2	7.1	7.2	6.9	
ORP	mV	216	-48	-53	-28	111	

3-B Ambient Control MW-1S Groundwater and SB-06-01 Soil

Compound	Week	0	4	8	12
1TCA	µg/L	3660	20200	8990	10900
1DCE	µg/L	200	500	2160	<40
1DCA	µg/L	46	1300	4920	2280
CA	µg/L	840	1260	1210	570
VC	µg/L	<10	<10	<40	<40
Methane	µg/L	160	33	<26	<26
Acetylene	µg/L	<10	<10	<40	<40
Ethene	µg/L	<12	48	<48	<48
Ethane	µg/L	95	<12	<48	<48
1TCA	µM	27.4	151.4	67.4	81.7
1DCE	µM	2.1	5.2	22.3	<0.41
1DCA	µM	0.46	13.1	49.7	23.0
CA	µM	13.0	19.5	18.8	8.8
VC	µM	<0.16	<0.16	<0.64	<0.64
Acetylene	µM	<0.38	<0.38	<1.5	<1.5
Ethene	µM	<0.43	1.7	<1.7	<1.7
Ethane	µM	3.2	<0.40	<1.6	<1.6
pH		6.7	7.2	7.1	7.2
ORP	mV	216	-24	-71	-26

3-C Ambient Control MW-1S Groundwater and SB-06-01 Soil

Compound	Week	0	4	8	12
1TCA	µg/L	3110	15800	11500	10400
1DCE	µg/L	200	470	870	180
1DCA	µg/L	34	1150	3720	2280
CA	µg/L	740	850	1280	570
VC	µg/L	<10	<10	<40	<40
Methane	µg/L	110	22	<26	<26
Acetylene	µg/L	<10	<10	<40	<40
Ethene	µg/L	<12	<12	<48	<48
Ethane	µg/L	<12	<12	<48	<48
1TCA	µM	23.3	118.4	86.2	78.0
1DCE	µM	2.1	4.9	9.0	1.9
1DCA	µM	0.34	11.6	37.6	23.0
CA	µM	11.5	13.2	19.8	8.8
VC	µM	<0.16	<0.16	<0.64	<0.64
Acetylene	µM	<0.38	<0.38	<1.5	<1.5
Ethene	µM	<0.43	<0.43	<1.7	<1.7
Ethane	µM	<0.40	<0.40	<1.6	<1.6
pH		6.7	7.1	7.1	7.2
ORP	mV	216	-16	-42	-26

4-A Lactate + Nutrients MW-1S Groundwater and SB-06-01 Soil

Compound	Week	0	4	8	12	16	16 Soil
1TCA	µg/L	2940	9.6	<50	<20	<10	79
1DCE	µg/L	220	89	<50	<20	<10	65
1DCA	µg/L	30	24800	<50	<20	72	34
CA	µg/L	690	3020	76700	17500	32300	5670
VC	µg/L	<10	<10	250	110	190	5.3
Methane	µg/L	100	180	12000	31000	24500	1400
Acetylene	µg/L	<10	<10	<50	<20	<10	<2.0
Ethene	µg/L	<12	44	<60	170	62	18
Ethane	µg/L	<12	<12	<60	550	230	100
1TCA	µM	22.0	0.072	<0.52	<0.15	<0.075	0.59
1DCE	µM	2.3	0.92	<0.52	<0.21	<0.10	0.67
1DCA	µM	0.30	250.5	<0.51	<0.20	0.73	0.34
CA	µM	10.7	46.8	1189	271	501	87.9
VC	µM	<0.16	<0.16	4.0	1.8	3.0	0.085
Acetylene	µM	<0.38	<0.38	<1.9	<0.77	<0.38	<0.077
Ethene	µM	<0.43	1.6	<2.1	6.1	2.2	0.64
Ethane	µM	<0.40	<0.40	<2.0	18.3	7.7	3.3
pH		6.7	7.1	7.2	7.0	6.9	
ORP	mV	216	-69	-51	-68	73	

4-B Lactate + Nutrients MW-1S Groundwater and SB-06-01 Soil

Compound	Week	0	4	8	12	16	16 Soil
1TCA	µg/L	2230	<10	<50	<20	<10	110
1DCE	µg/L	120	82	<50	<20	<10	67
1DCA	µg/L	29	23100	<50	<20	85	34
CA	µg/L	510	4510	71700	17400	20000	5540
VC	µg/L	<10	<10	410	<20	39	9.3
Methane	µg/L	38	230	14000	29000	18000	1200
Acetylene	µg/L	<10	<10	<50	<20	<10	<2.0
Ethene	µg/L	<12	38	<60	270	52	22
Ethane	µg/L	<12	<12	<60	450	140	86
1TCA	µM	16.7	<0.075	<0.52	<0.15	<0.075	0.82
1DCE	µM	1.2	0.85	<0.52	<0.21	<0.10	0.69
1DCA	µM	0.29	233.3	<0.51	<0.20	0.86	0.34
CA	µM	7.9	69.9	1112	270	310	85.9
VC	µM	<0.16	<0.16	6.6	<0.32	0.62	0.149
Acetylene	µM	<0.38	<0.38	<1.9	<0.77	<0.38	<0.077
Ethene	µM	<0.43	1.4	<2.1	9.6	1.9	0.79
Ethane	µM	<0.40	<0.40	<2.0	15	4.7	2.9
pH		6.7	7.3	7.1	7.1	6.9	
ORP	mV	216	-14	2	-69	40	

4-C Lactate + Nutrients MW-1S Groundwater and SB-06-01 Soil

Compound	Week	0	4	8	12	16	16 Soil
1TCA	µg/L	2530	240	<50	<20	<5.0	18
1DCE	µg/L	170	100	<50	<20	<5.0	<2.0
1DCA	µg/L	34	22100	<50	<20	<5.0	17
CA	µg/L	670	4780	79900	6080	12700	3610
VC	µg/L	<10	<10	310	<20	<5.0	11
Methane	µg/L	21	600	14000	21000	30000	4700
Acetylene	µg/L	<10	<10	<50	<20	<5.0	<2.0
Ethene	µg/L	<12	<12	<60	<24	<6.0	9.0
Ethane	µg/L	<12	<12	<60	540	170	190
1TCA	µM	19.0	1.8	<0.52	<0.15	<0.037	0.13
1DCE	µM	1.8	1.03	<0.52	<0.21	<0.052	<0.021
1DCA	µM	0.34	223.2	<0.51	<0.20	<0.051	0.17
CA	µM	10.4	74.1	1239	94	197	56.0
VC	µM	<0.16	<0.16	5.0	<0.32	<0.080	0.18
Acetylene	µM	<0.38	<0.38	<1.9	<0.77	<0.19	<0.077
Ethene	µM	<0.43	<0.43	<2.1	<0.86	<0.21	0.32
Ethane	µM	<0.40	<0.40	<2.0	18	5.7	6.3
pH		6.7	7.6	7.1	7.0	6.8	
ORP	mV	216	33	-52	-106	-163	

5-A SRS MW-1S Groundwater and SB-06-01 Soil

Compound	Week	0	4	8	12	16	16 Soil
1TCA	µg/L	1340	7.6	<50	<20	<10	32
1DCE	µg/L	40	110	<50	<20	<10	32
1DCA	µg/L	<10	25400	<50	<20	<10	18
CA	µg/L	<10	2400	67600	10600	4650	1820
VC	µg/L	<10	<10	140	<20	37	6.6
Methane	µg/L	<6.6	55	34000	46000	14000	3800
Acetylene	µg/L	<10	<10	<50	<20	<10	<2.0
Ethene	µg/L	<12	44	<60	<24	57	11
Ethane	µg/L	<12	<12	<60	240	190	45
1TCA	µM	10.0	0.057	<0.52	<0.15	<0.075	0.24
1DCE	µM	0.41	1.1	<0.52	<0.21	<0.10	0.33
1DCA	µM	<0.10	256.6	<0.51	<0.20	<0.10	0.18
CA	µM	<0.16	37.2	1048	164	72	28.2
VC	µM	<0.16	<0.16	2.2	<0.32	0.59	0.11
Acetylene	µM	<0.38	<0.38	<1.9	<0.77	<0.38	<0.077
Ethene	µM	<0.43	1.6	<2.1	<0.86	2.0	0.39
Ethane	µM	<0.40	<0.40	<2.0	8.0	6.3	1.5
pH		6.7	7.3	7.0	6.7	6.6	
ORP	mV	216	13	-11	-213	-185	

5-B SRS MW-1S Groundwater and SB-06-01 Soil

Compound	Week	0	4	8	12	16	16 Soil
1TCA	µg/L	390	<10	<50	<20	<10	55
1DCE	µg/L	53	77	<50	<20	<10	47
1DCA	µg/L	31	14500	<50	<20	<10	27
CA	µg/L	<10	4030	49900	11700	6970	2570
VC	µg/L	<10	<10	<50	100	140	8.7
Methane	µg/L	<6.6	42	44000	71000	20000	1400
Acetylene	µg/L	<10	<10	<50	<20	<10	<2.0
Ethene	µg/L	<12	44	<60	<24	54	11
Ethane	µg/L	<12	<12	<60	140	110	47
1TCA	µM	2.9	<0.075	<0.52	<0.15	<0.075	0.41
1DCE	µM	0.55	0.8	<0.52	<0.21	<0.10	0.49
1DCA	µM	0.31	146.5	<0.51	<0.20	<0.10	0.27
CA	µM	<0.16	62.5	774	181	108	39.8
VC	µM	<0.16	<0.16	<0.80	1.6	2.2	0.14
Acetylene	µM	<0.38	<0.38	<1.9	<0.77	<0.38	<0.077
Ethene	µM	<0.43	1.6	<2.1	<0.86	1.9	0.39
Ethane	µM	<0.40	<0.40	<2.0	4.7	3.7	1.6
pH		6.7	7.7	6.8	6.7	6.7	
ORP	mV	216	-2	-24	-108	-161	

5-C SRS MW-1S Groundwater and SB-06-01 Soil

Compound	Week	0	4	8	12	16	16 Soil
1TCA	µg/L	820	<10	<50	<20	64	56
1DCE	µg/L	48	80	<50	<20	<10	49
1DCA	µg/L	<10	12300	<50	<20	<10	37
CA	µg/L	<10	8320	81800	14400	14500	2760
VC	µg/L	<10	<10	250	<20	66	5.7
Methane	µg/L	60	91	44000	71000	29000	1100
Acetylene	µg/L	<10	<10	<50	<20	<10	<2.0
Ethene	µg/L	<12	43	<60	<24	46	12
Ethane	µg/L	<12	67	<60	110	68	26
1TCA	µM	6.1	<0.075	<0.52	<0.15	0.48	0.42
1DCE	µM	0.50	0.8	<0.52	<0.21	<0.10	0.51
1DCA	µM	<0.10	124.2	<0.51	<0.20	<0.10	0.37
CA	µM	<0.16	129.0	1268	223	225	42.8
VC	µM	<0.16	<0.16	4.0	<0.32	1.1	0.09
Acetylene	µM	<0.38	<0.38	<1.9	<0.77	<0.38	<0.077
Ethene	µM	<0.43	1.5	<2.1	<0.86	1.6	0.43
Ethane	µM	<0.40	2.2	<2.0	3.7	2.3	0.87
pH		6.7	7.2	6.8	6.8	6.7	
ORP	mV	216	43	-23	-81	-157	

6-A Abiotic Aerobic MW-97-1S Groundwater and SB-06-02 Soil

Compound	Week	0	2	2	4	8	12	16	16 Soil
cDCE	µg/L	2610	360	540	1270	290	2.8	16	30
tDCE	µg/L	390	42	57	130	40	1.8	<1.1	34
1DCE	µg/L	<10	<10	1630	2410	50	<1.1	<1.1	44
1DCA	µg/L	3250	540	660	1760	76	2.5	7.9	14
CA	µg/L	<10	<10	79	160	<5.0	<1.1	<1.1	<2.0
VC	µg/L	<10	<10	<10	<10	<5.0	<1.1	4.2	7.9
Methane	µg/L	<6.6	<6.6	<6.6	<6.6	<3.3	<0.7	<0.7	<1.3
Acetylene	µg/L	<10	<10	<10	<10	<5.0	<1.0	<1.0	<2.0
Ethene	µg/L	<12	<12	<12	<12	<6.0	<1.3	<1.3	<2.4
Ethane	µg/L	<12	<12	<12	49	<6.0	<1.3	<1.3	<2.4
cDCE	µM	26.9	3.7	5.6	13.1	3.0	0.029	0.17	0.31
tDCE	µM	4.0	0.43	0.59	1.3	0.41	0.019	<0.011	0.35
1DCE	µM	<0.10	<0.10	16.8	24.9	0.52	<0.011	<0.011	0.45
1DCA	µM	32.8	5.5	6.7	17.8	0.77	0.025	0.080	0.14
CA	µM	<0.16	<0.16	1.2	2.5	<0.078	<0.017	<0.017	<0.031
VC	µM	<0.16	<0.16	<0.16	<0.16	<0.080	<0.018	<0.018	0.13
Acetylene	µM	<0.38	<0.38	<0.38	<0.38	<0.19	<0.042	<0.042	<0.077
Ethene	µM	<0.43	<0.43	<0.43	<0.43	<0.21	<0.046	<0.046	<0.086
Ethane	µM	<0.40	<0.40	<0.40	1.6	<0.20	<0.043	<0.043	<0.080
pH		6.7			6.8	6.9	7.4	7.0	
ORP	mV	208			92	46	27	-41	
DO	mg/L						10.1		

6-B Abiotic Aerobic MW-97-1S Groundwater and SB-06-02 Soil

Compound	Week	0	2	2	4	8	12
cDCE	µg/L	3450	160	500	140	19	1.5
tDCE	µg/L	520	30	63	36	<2.0	<1.1
1DCE	µg/L	<10	<10	3140	57	<2.0	<1.1
1DCA	µg/L	4250	280	860	59	11	<1.1
CA	µg/L	<10	<10	130	<10	<2.0	<1.1
VC	µg/L	<10	<10	<10	<10	<2.0	<1.1
Methane	µg/L	<6.6	<6.6	<6.6	<6.6	<1.3	<0.7
Acetylene	µg/L	<10	<10	<10	<10	<2.0	<1.0
Ethene	µg/L	<12	<12	<12	<12	<2.4	<1.3
Ethane	µg/L	<12	<12	<12	66	<2.4	<1.3
cDCE	µM	35.6	1.7	5.2	1.4	0.20	0.015
tDCE	µM	5.4	0.31	0.65	<0.10	<0.021	<0.011
1DCE	µM	<0.10	<0.10	32.4	0.6	<0.021	<0.011
1DCA	µM	42.9	2.8	8.7	0.6	0.11	<0.011
CA	µM	<0.16	<0.16	2.0	<0.16	<0.031	<0.017
VC	µM	<0.16	<0.16	<0.16	<0.16	<0.032	<0.018
Acetylene	µM	<0.38	<0.38	<0.38	<0.38	<0.077	<0.042
Ethene	µM	<0.43	<0.43	<0.43	<0.43	<0.086	<0.046
Ethane	µM	<0.40	<0.40	<0.40	2.2	<0.080	<0.043
pH		6.7			7.1	6.8	7.2
ORP	mV	208			83	69	48
DO	mg/L						11.0

6-C Abiotic Aerobic MW-97-1S Groundwater and SB-06-02 Soil

Compound	Week	0	2	2	4	8	12
cDCE	µg/L	2460	980	1130	2290	550	20
tDCE	µg/L	360	120	170	130	76	2.0
1DCE	µg/L	<10	<10	2080	2180	<10	<1.1
1DCA	µg/L	3200	1670	2010	3040	140	8.9
CA	µg/L	<10	<10	99	160	<10	<1.1
VC	µg/L	<10	<10	<10	<10	<10	<1.1
Methane	µg/L	<6.6	<6.6	<6.6	<6.6	<6.6	<0.7
Acetylene	µg/L	<10	<10	<10	<10	<10	<1.0
Ethene	µg/L	<12	<12	<12	<12	<12	<1.3
Ethane	µg/L	<12	<12	<12	54	<12	<1.3
cDCE	µM	25.4	10.1	11.7	23.6	5.7	0.21
tDCE	µM	3.7	1.2	1.8	1.3	0.78	0.021
1DCE	µM	<0.10	<0.10	21.5	22.5	<0.10	<0.011
1DCA	µM	32.3	16.9	20.3	30.7	1.4	0.090
CA	µM	<0.16	<0.16	1.5	2.5	<0.16	<0.017
VC	µM	<0.16	<0.16	<0.16	<0.16	<0.16	<0.018
Acetylene	µM	<0.38	<0.38	<0.38	<0.38	<0.38	<0.042
Ethene	µM	<0.43	<0.43	<0.43	<0.43	<0.43	<0.046
Ethane	µM	<0.40	<0.40	<0.40	1.8	<0.40	<0.043
pH		6.7			6.8	6.6	6.9
ORP	mV	208			98	72	65
DO	mg/L						7.7

7-A Ambient Aerobic MW-97-1S Groundwater and SB-06-02 Soil

Compound	Week	0	2	2	4	8	12	16	16 Soil
cDCE	µg/L	4720	960	1090	460	33	2.1	17	32
tDCE	µg/L	790	110	150	71	<2.0	<1.1	<1.1	34
1DCE	µg/L	<10	<10	2940	570	<2.0	<1.1	<1.1	45
1DCA	µg/L	5840	1450	1860	570	14	1.7	7.9	15
CA	µg/L	47	20	110	<10	<2.0	<1.1	<1.1	<2.0
VC	µg/L	<10	<10	<10	<10	<2.0	<1.1	4.2	9.5
Methane	µg/L	11000	<6.6	170	<6.6	<1.3	<0.7	<0.7	<1.3
Acetylene	µg/L	<10	<10	<10	<10	<2.0	<1.0	<1.0	<2.0
Ethene	µg/L	<12	<12	<12	<12	<2.4	<1.3	<1.3	<2.4
Ethane	µg/L	<12	<12	<12	54	<2.4	<1.3	<1.3	<2.4
cDCE	µM	48.7	9.9	11.2	4.7	0.34	0.022	0.18	0.33
tDCE	µM	8.2	1.1	1.5	0.73	<0.021	<0.011	<0.011	0.35
1DCE	µM	<0.10	<0.10	30.3	5.9	<0.021	<0.011	<0.011	0.46
1DCA	µM	59.0	14.6	18.8	5.8	0.14	0.017	0.080	0.15
CA	µM	0.73	0.31	1.7	<0.16	<0.031	<0.017	<0.017	<0.031
VC	µM	<0.16	<0.16	<0.16	<0.16	<0.032	<0.018	<0.018	0.15
Acetylene	µM	<0.38	<0.38	<0.38	<0.38	<0.077	<0.042	<0.042	<0.077
Ethene	µM	<0.43	<0.43	<0.43	<0.43	<0.086	<0.046	<0.046	<0.086
Ethane	µM	<0.40	<0.40	<0.40	1.8	<0.080	<0.043	<0.043	<0.080
pH		6.4			7.8	7.7	7.1	7.1	
ORP	mV	233			22	16	38	-6	
DO	mg/L						8.5		

7-B Ambient Aerobic MW-97-1S Groundwater and SB-06-02 Soil

Compound	Week	0	2	2	4	8	12
cDCE	µg/L	4780	460	1000	610	42	2.3
tDCE	µg/L	820	43	120	56	<2.0	<1.1
1DCE	µg/L	<10	<10	4780	650	16	<1.1
1DCA	µg/L	5740	570	1490	720	17	1.4
CA	µg/L	<10	<10	160	44	<2.0	<1.1
VC	µg/L	<10	<10	<10	<10	<2.0	<1.1
Methane	µg/L	5900	<6.6	150	75	<1.3	<0.7
Acetylene	µg/L	<10	<10	<10	<10	<2.0	<1.0
Ethene	µg/L	<12	<12	<12	<12	<2.4	<1.3
Ethane	µg/L	<12	<12	<12	<12	<2.4	<1.3
cDCE	µM	49.3	4.7	10.3	6.3	0.43	0.024
tDCE	µM	8.5	0.44	1.24	0.58	<0.021	<0.011
1DCE	µM	<0.10	<0.10	49.3	6.7	0.17	<0.011
1DCA	µM	58.0	5.8	15.1	7.3	0.17	0.014
CA	µM	<0.16	<0.16	2.5	0.68	<0.031	<0.017
VC	µM	<0.16	<0.16	<0.16	<0.16	<0.032	<0.018
Acetylene	µM	<0.38	<0.38	<0.38	<0.38	<0.077	<0.042
Ethene	µM	<0.43	<0.43	<0.43	<0.43	<0.086	<0.046
Ethane	µM	<0.40	<0.40	<0.40	<0.40	<0.080	<0.043
pH		6.4			7.4	7.6	7.6
ORP	mV	233			41	18	22
DO	mg/L						11.3

7-C Ambient Aerobic MW-97-1S Groundwater and SB-06-02 Soil

Compound	Week	0	2	2	4	8	12
cDCE	µg/L	2320	830	1050	500	42	1.4
tDCE	µg/L	320	100	140	71	8.6	1.8
1DCE	µg/L	<10	<10	5290	470	15	<1.1
1DCA	µg/L	2740	1340	1220	620	20	2.1
CA	µg/L	<10	<10	160	40	7.7	<1.1
VC	µg/L	<10	<10	<10	<10	<2.0	<1.1
Methane	µg/L	200	200	310	20	6.8	3.5
Acetylene	µg/L	<10	<10	<10	<10	<2.0	<1.0
Ethene	µg/L	<12	<12	<12	<12	<2.4	<1.3
Ethane	µg/L	<12	<12	<12	66	<2.4	<1.3
cDCE	µM	23.9	8.6	10.8	5.2	0.43	0.014
tDCE	µM	3.3	1.03	1.44	0.73	0.089	0.019
1DCE	µM	<0.10	<0.10	54.6	4.9	0.15	<0.011
1DCA	µM	27.7	13.5	12.3	6.3	0.20	0.021
CA	µM	<0.16	<0.16	2.5	0.62	0.12	<0.017
VC	µM	<0.16	<0.16	<0.16	<0.16	<0.032	<0.018
Acetylene	µM	<0.38	<0.38	<0.38	<0.38	<0.077	<0.042
Ethene	µM	<0.43	<0.43	<0.43	<0.43	<0.086	<0.046
Ethane	µM	<0.40	<0.40	<0.40	2.2	<0.080	<0.043
pH		6.4			7.7	7.5	7.3
ORP	mV	233			-52	13	34
DO	mg/L						11.7

8-A Nutrient Amended Aerobic MW-97-1S Groundwater and SB-06-02 Soil

Compound	Week	0	2	2	4	8	12	16	16 Soil
cDCE	µg/L	3980	1270	1660	1140	130	2.1	17	36
tDCE	µg/L	630	120	170	110	19	1.8	19	36
1DCE	µg/L	<10	<10	3730	920	16	<1.1	<1.1	46
1DCA	µg/L	4940	1890	2510	1460	28	1.9	8.0	16
CA	µg/L	25	<10	180	84	<2.0	<1.1	<1.1	<2.0
VC	µg/L	<10	<10	<10	<10	<2.0	<1.1	5.3	8.6
Methane	µg/L	1600	23	110	<6.6	<1.3	<0.7	<0.7	<1.3
Acetylene	µg/L	<10	<10	<10	<10	<2.0	<1.0	<1.0	<2.0
Ethene	µg/L	<12	<12	<12	<12	<2.4	<1.3	<1.3	<2.4
Ethane	µg/L	<12	<12	<12	<12	<2.4	<1.3	<1.3	<2.4
cDCE	µM	41.1	13.1	17.1	11.8	1.3	0.022	0.18	0.37
tDCE	µM	6.5	1.24	1.75	1.14	0.20	0.019	<0.011	0.37
1DCE	µM	<0.10	<0.10	38.5	9.5	0.17	<0.011	<0.011	0.47
1DCA	µM	49.9	19.1	25.4	14.7	0.28	0.019	0.081	0.16
CA	µM	0.39	<0.16	2.8	1.30	<0.031	<0.017	<0.017	<0.031
VC	µM	<0.16	<0.16	<0.16	<0.16	<0.032	<0.018	<0.018	0.14
Acetylene	µM	<0.38	<0.38	<0.38	<0.38	<0.077	<0.042	<0.042	<0.077
Ethene	µM	<0.43	<0.43	<0.43	<0.43	<0.086	<0.046	<0.046	<0.086
Ethane	µM	<0.40	<0.40	<0.40	<0.40	<0.080	<0.043	<0.043	<0.080
pH		6.4			7.5	7.6	7.1	6.4	
ORP	mV	233			-81	1	57	22	
DO	mg/L						11.6		

8-B Nutrient Amended Aerobic MW-97-1S Groundwater and SB-06-02 Soil

Compound	Week	0	2	2	4	8	12
cDCE	µg/L	2610	740	1080	460	30	<1.1
tDCE	µg/L	510	110	180	89	16	<1.1
1DCE	µg/L	<10	<10	3350	1140	<2.0	<1.1
1DCA	µg/L	3670	1300	1830	760	14	<1.1
CA	µg/L	39	<10	160	63	<2.0	<1.1
VC	µg/L	<10	<10	<10	<10	<2.0	<1.1
Methane	µg/L	7100	380	480	100	<1.3	<0.7
Acetylene	µg/L	<10	<10	<10	<10	<2.0	<1.0
Ethene	µg/L	<12	<12	<12	<12	<2.4	<1.3
Ethane	µg/L	<12	<12	<12	<12	<2.4	<1.3
cDCE	µM	26.9	7.6	11.1	4.7	0.31	<0.011
tDCE	µM	5.3	1.14	1.9	0.92	0.17	<0.011
1DCE	µM	<0.10	<0.10	34.6	11.8	<0.021	<0.011
1DCA	µM	37.1	13.1	18.5	7.7	0.14	<0.011
CA	µM	0.60	<0.16	2.5	0.98	<0.031	<0.017
VC	µM	<0.16	<0.16	<0.16	<0.16	<0.032	<0.018
Acetylene	µM	<0.38	<0.38	<0.38	<0.38	<0.077	<0.042
Ethene	µM	<0.43	<0.43	<0.43	<0.43	<0.086	<0.046
Ethane	µM	<0.40	<0.40	<0.40	<0.40	<0.080	<0.043
pH		6.4			7.6	7.7	7.6
ORP	mV	233			-31	8	25
DO	mg/L						8.6

8-C Nutrient Amended Aerobic MW-97-1S Groundwater and SB-06-02 Soil

Compound	Week	0	2	2	4	8	12
cDCE	µg/L	3100	2310	2120	1280	160	<1.1
tDCE	µg/L	650	280	310	140	62	1.8
1DCE	µg/L	<10	<10	3570	970	<2.0	<1.1
1DCA	µg/L	4660	4260	3970	2050	590	<1.1
CA	µg/L	39	32	150	56	33	<1.1
VC	µg/L	<10	<10	<10	<10	300	<1.1
Methane	µg/L	16000	89	220	<6.6	320	3.8
Acetylene	µg/L	<10	<10	<10	<10	<2.0	<1.0
Ethene	µg/L	<12	<12	<12	<12	28	<1.3
Ethane	µg/L	<12	<12	<12	76	24	<1.3
cDCE	µM	32.0	23.8	21.9	13.2	1.7	<0.011
tDCE	µM	6.7	2.89	3.20	1.44	0.64	0.019
1DCE	µM	<0.10	<0.10	36.8	10.0	<0.021	<0.011
1DCA	µM	47.1	43.0	40.1	20.7	6.0	<0.011
CA	µM	0.60	0.50	2.3	0.87	0.51	<0.017
VC	µM	<0.16	<0.16	<0.16	<0.16	4.8	<0.018
Acetylene	µM	<0.38	<0.38	<0.38	<0.38	<0.077	<0.042
Ethene	µM	<0.43	<0.43	<0.43	<0.43	1.0	<0.046
Ethane	µM	<0.40	<0.40	<0.40	2.5	0.80	<0.043
pH		6.4			7.7	7.3	7.8
ORP	mV	233			-25	-20	11
DO	mg/L						11.7

APPENDIX B
COST BACKUP

Former Columbia Cement Site, Freeport New York
Cost Estimate

Alternative 2
Excavation and Off-Site Disposal of Soil

Assumptions

1. All costs include labor, materials, and equipment unless otherwise stated.
2. The excavation area consists of four impacted areas (Residual Source Area 1, 2, 3 and 4) as shown in Figure 4.
3. Contaminated soil volume is 620 cubic yards.
4. 10 % of the contaminated soil (62 cubic yards) will be classified as hazardous waste.
5. Uncontaminated soil volume is 535 cubic yards.
6. Transportation & disposal is to R3 Technologies, PA.
7. Sheet piling will be used to protect the building foundation as well as protection from side wall sloughing.

Direct Capital Costs	**Qty**	**Units**	**Unit Rate**	**Cost**	***Reference***
1. Mobilization and Demobilization					
excavator					
compactor					
front end loader					
dozer					
pile driver					
dump trucks					
roll off containers and frac tanks					
miscellaneous construction equipment	1.00	LS	$25,000	**$25,000**	*Lump sum*
2. Construction of Soil Staging Area	1.00	LS	$1,500	**$1,500**	*Lump sum*
poly sheeting and soil berms					
3. Sheet piling					
total square footage is based on embedded area					
Area 1 & 2: 30'X38' embedment X 2 sheet piles = 2280 sf					
Area 3: 15'x15' embedment X 2 sheet piles = 450 sf					
Area 4: 15'X15' embedment X 2 sheet piles = 450 sf	3180.00	sf	$35	**$111,300**	*Means*
4. Dewatering During Excavation Operations					
Equipment and one man crew, 10 days	10.00	day	$800	**$8,000**	*Estimate*
5. Carbon Treatment and Disposal	1.00	LS	$15,000	**$15,000**	*Estimate*
6. Frac Tanks					
$3000 per month, 1 month	1.00	month	$3,000	**$3,000**	*Estimate*
7. Excavation of Soil					
Areas 1, 2, 3 & 4 (1,155 cu. yd.)	1155.00	cu.yd.	$10	**$11,550**	*Means*
8. Transportation and Disposal of Contaminated Soils					
Non-hazardous Soils (90% = 558 cu.yd.)					
558 cu.yd. X 1.5 ton/cu. Yd.= 837 tons	837.00	tons	$56	**$46,872**	*Means*
Hazardous (10% = 62 cu.yd)					
62 cu.yd. X 1.5 ton/cu. Yd.= 93 tons	93.00	tons	$150	**$13,950**	*Means*
9. Imported Backfill, Placement, Compaction & Paving					
assumes overburden soil will be reused, 20% contingency soil included					
material cost $18 per cy X (610 cy x 1.2)	732.00	cu.yd.	$18	**$13,176**	*Means*
placement and compaction $15 per cy X 610 cy	732.00	cu.yd.	$15	**$10,980**	*Means*
sub-grade 40 cy X $29 per cy	40.00	cu.yd.	$29	**$1,160**	*Experience*
concrete pavement 3,180 sf X $9 per sf	3180.00	sf	$9	**$27,030**	*Experience*

10. Decontamination and Health & Safety Facility						
truck/equipment decon pad (bermed)		1.00	LS	$5,000	**$5,000**	*Lump sum*
11. Site restoration and close storm drain sd-1		1.00	LS	$15,000	**$15,000**	*Lump Sum*
misc. repairs						
pressure wash inside drain and abandon in place						
Total Direct Capital Costs					**$308,518**	
Direct Expenses						
1. Design/Planning sampling						
10 geotechnical samples		10.00	each	$300	**$3,000**	*Estimate*
2. Confirmatory Soil Sampling						
eight post excavation borings to 23 ft bgs, 1 day geoprobe		1.00	day	$1,400	**$1,400**	*Estimate*
48 samples (six per boring)		48.00	each	$200	**$9,600**	*Estimate*
5 confirmatory samples for reuse of soil as backfill		5.00	each	$200	**$1,000**	*Estimate*
2. Re-install three wells in excavation		3 each		$2,000	**$6,000**	*Experience*
3. Field Oversight						
Confirmatory Soil Sampling	1 day	10.00	hours	$75	**$750**	*Estimate*
Installation of 3 wells	2 days	20.00	hours	$75	**$1,500**	*Estimate*
Well development	1 days	10.00	hours	$75	**$750**	*Estimate*
Source area excavation	8 days	80.00	hours	$90	**$7,200**	*Estimate*
Site restoration	1 day	10.00	hours	$75	**$750**	*Estimate*
Mob/demob	4 days	40.00	hours	$75	**$3,000**	*Estimate*
6. Field Oversight Expenses						
19 days X $100/day		19.00	days	$100	**$1,900**	*Estimate*
7. SPDES permit monitoring						
1 sample per day for 10 days		10.00	each	$200	**$2,000**	*Estimate*
contractor labor 8hrs/day, 10 days		80.00	hours	$55	**$4,400**	*Estimate*
Total Direct Expenses					**$43,250**	
Indirect Capital Costs						
1. Engineering (25% of total direct and capital costs)					**$87,942**	
2. Project Management (10% of total direct and capital costs)					**$35,177**	
3. Contingency (20% of total direct and capital costs)					**$70,354**	
Total Indirect Capital Costs					***$193,472***	
Total Capital Cost					***$545,240***	

Former Columbia Cement Site, Freeport New York
Cost Estimate

Alternative 3
In Situ Chemical Oxidation of Soil

Assumptions

1. All costs include labor, materials, and equipment unless otherwise stated.
2. In Situ Chemical Oxidation with Sodium Permanganate activated with Hydrogen Peroxide
3. The treatment area consists of four impacted areas (Residual Source Area 1, 2, 3 and 4) as shown in Figure 4 .
4. Chemical costs obtained from FMC, Chemical Products Groups
5. Chemical dosing rate based on bench-scale testing conducted by Adventus Americas in April 2005
6. Assumes two injection events spaced 3 months apart

Direct Capital Costs		Qty	Units	Unit Rate	Cost	*Reference*
1. Rental Equipment						
Geoprobe - injection and point installation						
Injection pumps and equipment		2	LS	25000	**$50,000**	*Lump sum*
2. Chemical Costs						
Sodium permanganate		87600	LBS	1.1	**$96,360**	*Vendor Quote*
Hydrogen peroxide		357200	LBS	0.245	**$87,514**	*Vendor Quote*
Freight costs for chemicals		10286	EACH	1	**$10,286**	*Vendor Quote*
3. Equipment charges						
Tanker truck for peroxide		2	/MONTH	1200	**$2,400**	*Vendor Quote*
Mixing pump with tanker truck		2	/MONTH	600	**$1,200**	*Vendor Quote*
Shipping		2	LS	1000	**$2,000**	*Vendor Quote*
Total Direct Capital Costs					**$249,760**	
[illegible]ect Expenses						
1. Confirmatory Soil Sampling						
eight post treatment borings per event (2 events total) to 24 ft bgs, 1 day geoprobe/event		2.00	day	$1,400	**$2,800**	*Estimate*
48 samples (average of six per boring)		96.00	each	$400	**$38,400**	*Estimate*
2. ISCO Supplies						
Equipment (pumps, mixers)		2.00	LS	$5,000	**$10,000**	*Estimate*
Consumables (PPE, sampling equipment, etc)		2.00	LS	$1,000	**$2,000**	*Estimate*
4. Field Oversight (total for two events)						
mob/demob/chemical storage area (2 days/event)	4 day	40	hours	55	**$2,200**	*Estimate*
ISCO injection oversight (10 days/event)	20 days	200	hours	75	**$15,000**	*Estimate*
Post-injection soil sampling (2 days/event)	4 days	40	hours	90	**$3,600**	*Estimate*
site restoration (1 day/event)	2 day	30	hours	55	**$1,650**	*Estimate*
	30 days					
5. Field Oversight Expenses						
30 days X $100/day		30	days	100	**$3,000**	*Estimate*
Total Direct Expenses					***$78,650***	
Indirect Capital Costs						
1. Engineering (15% of total direct capital costs)					**$49,261**	
2. Project Management (10% of total direct and capital costs)					**$32,841**	
3. Contingency (20% of total direct capital costs)					**$65,682**	
Total Indirect Capital Costs					***$147,784***	
Total Capital Cost					***$476,194***	

Former Columbia Cement Site, Freeport New York
Cost Estimate

Alternative 5
Monitored Natural Attenuation of Groundwater

Assumptions

1. All costs include labor, materials, equipment and O&M unless otherwise stated.
2. MNA is for 22 years based on preliminary modeling using Biochlor software program.

Direct Capital Costs		**Qty**	**Units**	**Unit Rate**	**Cost**	*Reference*
1. Additional Wells for MNA						
Two deep wells (30 ft bgs)		2.00	each	$3,000	**$6,000**	*Experience*
Two nested wells (shallow/intermediate/deep)		3.00	each	$5,000	**$15,000**	*Experience*
Two well clusters (shallow/deep)		2.00	each	$4,000	**$8,000**	*Experience*
Well development		12.00	each	$1,000	**$12,000**	*Experience*
Total Direct Capital Costs					**$41,000**	
Direct Expenses						
1. Field Oversight						
Well Installation	16 days	160.00	hours	$75	**$12,000**	*Estimate*
Well development	5 days	50.00	hours	$75	**$3,750**	*Estimate*
Groundwater model development	90 days	720.00	hours	$95	**$68,400**	*Estimate*
2. Field Oversight Expenses						
21 days X $100/day		21.00	days	$100	**$2,100**	*Estimate*
[illegible]al Direct Expenses					**$86,250**	
Indirect Capital Costs						
1. Engineering (15% of total direct and capital costs)					**$19,088**	
2. Project Management (10% of total direct and capital costs)					**$12,725**	
3. Contingency (20% of total direct and capital costs)					**$25,450**	
Total Indirect Capital Costs					***$57,263***	
Total Capital Cost					***$184,513***	
Operations And Maintenance Costs						
1. MNA sampling of 15 wells for five years						
2 samples per well per year for 5 years. 20 QA samples per year		250.00	samples	$500	**$125,000**	*Experience*
MNA sampling of 15 wells for seventeen years						
1 sample per well per year for 17 years, 6 QA samples per year		357.00	samples	$500	**$178,500**	*Experience*
2. Consumables and Expenses for sampling						
$ 1000 per event, 27 events		27.00	events	$1,000	**$27,000**	*Estimate*
3. Sampling Labor 120 hr/event, 27 events		3240.00	hours	$70	**$226,800**	*Experience*
4. Progress reports 20 hr/event, 27 events		540.00	hours	$95	**$51,300**	*Experience*
Total Operations And Maintenance Costs					***$608,600***	

Direct Expenses

1. Field Oversight						
Mob/demob	4 days	40.00	hours	$75	**$3,000**	*Estimate*
Installation of P&T extraction wells	4 days	40.00	hours	$75	**$3,000**	*Estimate*
Oversee installation of treatment systems	15	200.00	hours	$90	**$18,000**	*Estimate*
P&T aboveground piping and system hookup	5 days	50	hours	$90	**$4,500**	*Estimate*
P&T system start up	5 days	50	hours	$90	**$4,500**	*Estimate*
2. Field Oversight Expenses						
33 days X $100/day		33.00	days	$100	**$3,300**	*Estimate*
Total Direct Expenses					**$36,300**	

Indirect Capital Costs

1. Engineering (25% of total direct and capital costs)	**$163,475**
2. Project Management (10% of total direct and capital costs)	**$65,390**
3. Contingency (20% of total direct and capital costs)	**$130,780**
Total Indirect Capital Costs	***$359,645***
Total Direct Capital Costs	**$1,013,545**

Operations And Maintenance Costs

1. GW sampling of 15 wells					
4 samples per well per year for 7 years (includes 8 QA samples for each event)	644.00		$100	**$64,400**	*Experience*
2. Consumables and Expenses for sampling					
$ 1000 per event, 28 events	28.00	events	$1,000	**$28,000**	*Estimate*
3. Sampling Labor 60 hr/event, 28 events	1680.00	hours	$75	**$126,000**	*Experience*
4. Treatment System Supervision and Maintenance					
24 hr/wk field labor, 364 wks	8736.00	hours	$60	**$524,160**	*Experience*
8 hr/wk PM labor, 56 wks	448.00	hours	$120	**$53,760**	*Experience*
6. Treatment system consumables and maintenance					
liquid-phase carbon change out, 8 events per year	56	events	$4,000	**$224,000**	*Estimate*
vapor-phase carbon change out, 8 events per year	56	events	$2,000	**$112,000**	*Estimate*
chemicals, bag filters etc.	56	months	$1,000	**$56,000**	*Estimate*
sludge disposal	56	months	$600	**$33,600**	*Estimate*
7. Air sampling and monitoring					
monthly influent and effluent sample for VOCs	84	samples	$250	**$21,000**	*Estimate*
8. SPDES permit monitoring					
1 sample collection & analysis per day for 1st wk	10	samples	$150	**$1,500**	*Estimate*
1 sample per month	84	samples	$150	**$12,600**	*Estimate*
VOCs, TSS, pH					
2 VOCs samples per month for system performance	168	samples	$95	**$15,960**	*Estimate*
9. Post-treatment of of 10 wells					
2 samples per well per year for 5 years (includes 4 QA samples for each event)	110.00	samples	$100	**$11,000**	*Experience*
10. Consumables and Expenses for sampling					
$ 750 per event, 20 events	20.00	events	$750	**$15,000**	*Estimate*
11. Sampling Labor 40 hr/event, 20events	1680.00	hours	$75	**$126,000**	*Experience*
Total Operations And Maintenance Costs				***$1,424,980***	

Former Columbia Cement Site, Freeport New York
Cost Estimate

Alternative 7
In Situ Aerobic Biodegradation - Groundwater

Assumptions

1. All costs include labor, materials, and equipment unless otherwise stated.
2. In Situ Aerobic Biodegradation uses EHC-O
3. The treatment area consists of 200 ft long stretch of area at the west end of the property boundary along Hanse Ave with injection points on 10-ft centers and a 300 ft long stretch along the south side of the property with injection points on 15-ft centers.
4. Chemical costs obtained from Adventus
5. Required EHC-O amount based on a BOD of 11 mg/L
6. Assumes two injection events spaced 9 months apart

Direct Capital Costs		**Qty**	**Units**	**Unit Rate**	**Cost**	***Reference***
1. Rental Equipment						
Geoprobe						
Injection pumps and mixing equipment		20	LS	3000	**$60,000**	*Lump sum*
2. Chemical Costs						
EHC-O		8200	LBS	4.5	**$36,900**	*Vendor Quote*
Freight		2	LS	1000	**$2,000**	*Vendor Quote*
Total Direct Capital Costs					**$98,900**	
Direct Expenses						
1. Field Oversight (total for two events)						
mob/demob/chemical storage area (4 days/event)	8 days	80	hours	55	**$4,400**	*Estimate*
EHC-O injection oversight (10 days/event)	20 days	200	hours	75	**$15,000**	*Estimate*
Post-injection sampling (2 days/event)	4 days	40	hours	90	**$3,600**	*Estimate*
2. Field Oversight Expenses						
32 days X $100/day		32	days	100	**$3,200**	*Estimate*
Total Direct Expenses					***$26,200***	
Indirect Capital Costs						
1. Engineering (15% of total direct capital costs)					**$18,765**	
2. Project Management (10% of total direct and capital costs)					**$12,510**	
3. Contingency (20% of total direct capital costs)					**$25,020**	
Total Indirect Capital Costs					***$56,295***	
Total Direct Capital Cost					***$181,395***	
Operations And Maintenance Costs						
1. GW sampling of 12 wells						
4 samples per well per year for 3 years;		180.00	samples	$250	**$45,000**	*Experience*
2 samples per year for 4 years (MNA sampling) (includes 3 QA samples for each event)		120.00	samples	$250	**$30,000**	*Experience*
2. Consumables and Expenses for sampling						
$ 750 per event, 20 events		20.00	events	$750	**$15,000**	*Estimate*
3. Sampling Labor 30 hr/event, 20 events		600.00	hours	$75	**$45,000**	*Experience*
Total Operations And Maintenance Costs					***$135,000***	

Former Columbia Cement Site, Freeport New York
Cost Estimate

Alternative 9
Storm Drain Soil Removal

Assumptions

1. All costs include labor, materials, and equipment unless otherwise stated.
2. The excavation area consists of four impacted storm drains (SD-1, SD-5 and SD-8).
3. Contaminated soil volume is 6 cubic yards.
3. Contaminated soil will be removed with a vac-truck.
4. Transportation & disposal is to R3 Technologies, PA.
6. Soil in each storm drain will be removed to the water table, then replaced with clean sand fill.

Direct Capital Costs		**Qty**	**Units**	**Unit Rate**	**Cost**	***Reference***
1. Mobilization and Demobilization						
vac truck		1.00	LS	$500	**$500**	*Lump sum*
2. Vac-truck removal of sediment						
SD-1, SD-5 & SD-8 (6 cu. yd.)		1.00	day	$1,500	**$1,500**	*Means*
3. Transportation and Disposal of Contaminated Soils						
6 cu.yd. X 1.5 ton/cu. Yd.= 9 tons		9.00	tons	$56	**$504**	*Means*
4. Imported Backfill, Placement & Compaction						
material cost $18 per cy X (6 cy x 1.2)		6.00	cu.yd.	$18	**$108**	*Means*
placement and compaction $15 per cy X 6 cy		6.00	cu.yd.	$15	**$90**	*Means*
Total Direct Capital Costs					**$2,702**	
Direct Expenses						
3. Field Oversight						
Vac-truck sediment removal	1 day	10.00	hours	$75	**$750**	*Estimate*
Backfill	1 day	10.00	hours	$75	**$750**	*Estimate*
6. Field Oversight Expenses						
2 days X $100/day		2.00	days	$100	**$200**	*Estimate*
Total Direct Expenses					**$1,700**	
Total Capital Cost					***$4,402***	