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Letter of Transmittal

To: NYSDEC

Date: November 29, 2006

File No.: 442667

Subject: Evaluation of In Situ Treatment Technologies for the Former Carborundum Company, Hyde Park Facility (NYSDEC Site No. 932036)

Attn: Mr. Michael Hinton

We are sending you the following items: x Enclosed __ Under Separate Cover

1. Evaluation of In Situ Treatment Technologies as Remedial Alternatives for Groundwater, Former Carborundum Company, Electric Products Division, Hyde Park Facility (Site No. 932036), Town of Niagara, New York, November 2006 (PDF file sent via email).

These are transmitted as checked below:

__ For Your Information	X For Your Use	__ Approved as Noted
__ As Requested	X For Approval	__ For Review

Remarks: This report is submitted on behalf of the Atlantic Richfield Company. Submittal of this report constitutes completion of Task 1 – Literature Review and Identification and Assessment of Candidate Technologies, as stated in a January 31, 2006 letter from Intera to NYSDEC. If you have any questions, please contact William Barber of the Atlantic Richfield Company at (216) 271-8038.

Signed: Mark S. Raybuck

Mark S. Raybuck
Project Manager

Copy to: File (442667 No. 13d)

EVALUATION OF IN SITU TREATMENT TECHNOLOGIES AS REMEDIAL ALTERNATIVES FOR GROUNDWATER

Former Carborundum Company, Hyde Park Facility
(Site No. 932036)
Town of Niagara, Niagara County, NY

Submitted to:

New York State Department of Environmental Conservation
Division of Hazardous Waste Remediation

Submitted by:

Atlantic Richfield Company

A BP affiliated company

4850 East 49th Street
Cuyahoga Heights, Ohio 44125

Prepared by:

PARSONS

180 Lawrence Bell Drive, Suite 104
Williamsville, New York 14221
Phone: (716) 633-7074
Fax: (716) 633-7195

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1. OVERVIEW

The former Carborundum Hyde Park facility (Site) is located near the intersection of Hyde Park Boulevard and Rhode Island Avenue in the Town of Niagara, New York. BP America (BP), in cooperation with The New York State Department of Environmental Conservation (NYSDEC) and the New York State Department of Health (NYSDOH), has conducted soil and groundwater remediation activities. Trichloroethene was released into the soil and groundwater at the Site during its past operations. BP has performed an environmental investigation and removed contaminated soil, and continues to monitor groundwater.

Results of the recently completed 5-year groundwater monitoring program indicate some stabilization or decrease in concentrations of trichloroethene and its breakdown products in the groundwater. BP is in the process of evaluating methods to enhance the groundwater remediation using an *in situ* remediation treatment for chemicals of concern (COCs).

Analysis of groundwater samples suggests that natural bio-attenuation mechanisms are limited to adequate in groundwater (Intera, 2006a). The limiting factors are likely the presence of dissolved oxygen and the lack of organic carbon. Preliminary analysis indicates that enhanced bioremediation and/or chemical reduction could potentially accelerate the natural processes and reduce COCs below groundwater standards in a shorter time-frame than natural attenuation alone. Technologies such as injection of vegetable oil type substrates, construction of a "bio-reactor," or emplacement of controlled release carbon and zero-valent iron technology should be further evaluated.

Evaluation of selected remedial technologies would be continued with pilot-scale testing and hydrogeological analysis. Pilot testing may initially consist of injection of a carbon source in the overburden and bedrock, and further hydrogeological characterization of the bedrock, such as packer testing and borehole geophysics.

Details of a preliminary technology evaluation, and recommendations for the next phase in the selection process, are provided below.

2. PURPOSE

The purpose of this document is to evaluate *in situ* treatment technologies as potential remedial alternatives for groundwater. A site plan is provided as Figure 1. The goal of *in situ* treatment is to reduce the concentrations of COCs by enhanced reductive dechlorination. The COCs at the Site are: trichloroethene (TCE), cis and trans-1,2-dichloroethene (DCE), vinyl chloride (VC), and 1,1-dichloroethane (DCA).

This evaluation has been conducted using published literature, experience from environmental technical experts, and knowledge gained from the Ekonol Polyester Resins Site in Wheatfield, NY. The Ekonol Site (Voluntary Clean-up Program #V00653-9) is similar to the Hyde Park facility in hydrogeologic, geochemical and COC characteristics. The Ekonol Site is currently in the remedial selection phase. Bench-scale treatability testing for bioremediation and chemical reductive de-chlorination is under way, to assist in remedy selection. Due to the similarities, the information and results summarized in the Remedial Alternatives Report

(Parsons, 2006) from the ongoing Ekonol work have been used in the evaluation and selection of technologies as discussed for the Hyde Park facility.

In a January 31, 2006 letter from Intera to the NYSDEC, a list of treatment technologies was provided as potential alternatives. This list was expanded and re-categorized into the following:

- *In Situ* Bioremediation using injection of carbon substrates. Enhanced bioremediation using vegetable oil emulsion, sodium lactate, molasses, corn syrup, HRC®, or EOS®. These technologies use a similar biological reductive dechlorination process, and have similar costs. Thus, they are grouped together at this stage of the selection process. The specific commercial product and detailed emplacement strategy are more appropriately considered after any bench-scale or pilot tests, and as part of the remedial design phase.

- Construction of a bio-reactor and/or bio-wall to enhance bioremediation. This technology uses a similar dechlorination process as described above, yet the materials and design differ.

- Emulsified zero-valent iron (EZVI). This technology reduces the COCs using a combination of abiotic chemical reduction and enhanced biodegradation.

- EHC™ bioremediation technology. This emerging technology, similar to EZVI, integrates a controlled-release solid carbon with zero-valent iron (ZVI) particles to yield a material for stimulating reductive dechlorination.

3. SITE CHARACTERIZATION

The hydrogeologic setting consists of two water-bearing units: overburden soils and fractured bedrock. Due to the characteristic differences in each unit, this remedial alternatives discussion considers the overburden groundwater and treatment of the bedrock groundwater separately, when appropriate.

The overburden unit is a heterogeneous mixture of silt and clay, with minor proportions of sand and gravel. The coarse fractions exist as both embedded grains in the silt and clay, and as lenses. The estimated geometric mean hydraulic conductivity, based on slug test results is 4.3×10^{-6} ft/s (1.31×10^{-4} cm/sec) (Intera, 2006a). The bedrock was described as a dolostone (Intera, 2006a) and is presumably a member of the Lockport Group. Horizontal fractures varied from open and mineralized to closed. The geometric mean hydraulic conductivity of bedrock was estimated as 3.43×10^{-5} ft/s (1.05×10^{-3}cm/sec) (Intera, 2006a).

Groundwater generally flows northeast to southwest in both units. Differences in hydraulic head measurements at well clusters were observed, averaging approximately 1.8 feet. This indicates that the low permeability overburden acts as a confining layer to the bedrock in some areas.

As part of the ongoing groundwater monitoring program, natural attenuation parameters are sampled and evaluated using the USEPA 1998 protocol scoring methods. The results indicated that natural attenuation through biotransformation varies from limited to adequate in both the overburden and the bedrock groundwater. Supporting evidence for biotransformation included spatial and temporal reduction of TCE, presence and reduction of TCE degradation products, including ethene (spatially and temporally), nitrate concentrations lower than 1 mg/L, ferrous iron (Fe^{+2}) concentrations greater than 1 mg/L, and sufficient redox potential to sustain the biotransformation. Non-supporting evidence for biotransformation included TOC concentrations less than 10 mg/L, and dissolved oxygen greater than 0.5 mg/L. Also, the presence of sulfate may potentially be slowing the transformation of DCE to ethene.

While the evidence for biodegradation is limited to adequate, the USEPA scoring method does not include abiotic pathways. The abiotic reduction of chlorinated aliphatic hydrocarbons has been demonstrated to be effective at the similar and nearby Bell Aerospace Site (Madsen and Yager, 1996, Yager et al., 1997, Yager, 2000). Given the similarities between the Hyde Park and Bell Aerospace sites, there is a potential for natural abiotic processes to contribute to the degradation of COCs in groundwater.

Overall, the data appear to show that the rate of natural attenuation (biotic and abiotic) has been sufficiently rapid, in the overburden, relative to COC transport, to prevent downgradient transport of COCs across the eastern and southern property boundaries. The rate of natural attenuation appears more limited in the bedrock groundwater. In both zones, the rate of natural attenuation may not be sufficient to achieve onsite groundwater standards in a reasonable time. Enhancement of the natural degradation processes could be an effective technology to achieve the remedial goals in a shorter time period.

4. TECHNOLOGY EVALUATIONS

The goal of an *in situ* treatment at the Site is to accelerate natural dechlorination processes. The evaluation presented below summarizes selected *in situ* technologies, and suggests preferred options based on the evaluation. Additional details concerning these technologies are provided in the references cited, including the Ekonol Remedial Alternatives Report (Parsons, 2006).

4.1. *In Situ* Bioremediation Using Injection of Carbon Substrates

Technology: Enhancing the existing conditions by adding a source of carbon (substrate), such as vegetable oil, or sodium lactate, can increase the degradation rate, and therefore reduce the time to achieve goals in a cost-effective manner. Preliminary data evaluation suggests that enhanced bioremediation could be an effective remedial alternative for both overburden and bedrock groundwater.

The main considerations of an *in situ* injection for enhanced anaerobic bioremediation are (1) substrate loading and (2) distribution of the substrate in the area requiring treatment. Substrate loading can be estimated based on (1) existing data for native electron acceptors (e.g., dissolved oxygen, nitrate, sulfate), (2) the hydrogen content of potential substrates, and (3) comparison with substrate loadings at other sites with similar characteristics. Distribution of the substrate and treatment area will depend on the type of substrate (i.e., soluble, insoluble or emulsions.)

Applicability at Site: A preliminary review of the data suggests that injection of substrate is feasible in both the overburden and the bedrock. Evidence to support this includes the presence and reduction of TCE degradation products (spatially and temporally), nitrate and ferrous iron (Fe^{+2}) concentrations, and sufficient oxidation-reduction potential to sustain the biotransformation. This evidence, coupled with the lack of TOC, suggests that addition of a carbon source, to serve as an electron donor to the native bacteria, may effectively accelerate the biotransformation process and effectively reduce COCs.

Enhanced bioremediation in a source area could temporarily increase concentrations of intermediate degradation products of chlorinated VOCs, such as vinyl chloride (CL:AIRE, 2006). However, due to the relatively low concentrations of COCs, the temporary increase in intermediates is likely to be insignificant. Also, substrate emplacement should result in depletion of sulfate, such that intermediate degradation products are converted to ethene or ethane.

The success and implementability of this remedy for the overburden and bedrock groundwater will depend on such factors as the size of the desired treatment area, and the ability to inject the substrate in the soils or bedrock. Additional characterization and pilot studies would assist in determining if this technology should be implemented (DoD, 2006).

4.2 Construction of a Bio-reactor

Technology: An innovative approach to shortening the remediation time-frame is selective excavation to remove residual source materials from shallow soils (overburden groundwater system), and subsequently place a backfill material consisting of bark mulch, gravel, and vegetable oil into the excavated area (Parsons and AFCEE, 2004). Hematite may also be added to the mulch and gravel mixture to improve remedial performance (Wilson, 2006). This is similar to using carbon substrates discussed above to enhance the natural attenuation. The bio-reactor functions by (1) decreasing chemical loading to shallow groundwater by reducing the mass of residual chemical constituents in the subsurface; and (2) providing a long-term source of organic carbon that can be transported into the surrounding overburden groundwater, and possibly into bedrock.

This remedy is generally optimized through the injection of liquid substrates and/or the addition of bioaugmentation cultures to accelerate the complete reductive dechlorination process. As performance data for a bio-reactor becomes available, the need to accelerate the application of substrates is evaluated.

Applicability at Site: Previously, the majority of the source area soils were removed (DE&S, 1999). The installation of a mulch bio-reactor in the overburden groundwater may be technically-feasible for a reasonably low cost. The primary challenge is evaluating whether transport of carbon substrate from the bio-reactor will be substantial enough to treat downgradient groundwater. Post-installation performance monitoring would be used to determine if treatment was progressing. Specifically, the time-frame in which COC reduction will occur, and the effect on COC transport across downgradient property boundaries, would be evaluated. This is dependent upon the area being treated and expected treatment zone.

As with substrate injection, temporary increases in intermediate degradation products are possible, but intermediate products should be converted to ethene or ethane by sulfate depletion.

4.3 Emulsified Zero Valent Iron

Technology: This technology is injects an emulsion consisting of zero-valent iron particles, a surfactant, vegetable oil, and water into the subsurface. The zero valent iron, surfactant, and vegetable oil contribute to the dehalogenation of chlorinated, organic compounds and non-aqueous phase liquids (DNAPLs), such as trichloroethylene (TCE) (Gavaskar et. al., 2005). Typically, the particles consist of nanoscale and microscale zero-valent iron. The zero-valent iron is believed to degrade the DNAPL abiotically, whereas the vegetable oil and surfactant promote longer-term, anaerobic biodegradation. Note that DNAPL has not been observed at this Site.

Applicability at Site: Although EZVI is an innovative technology for remediation of chlorinated solvent sites, it is not a preferred technology for this Site for the following reasons:

- The primary application of EZVI is treatment of DNAPL source zones (O'Hara et. al 2006). Previous excavation of the source area has left only residual concentration of COCs.
- The relatively large treatment area would require a substantial volume of material to be injected COC concentrations are low enough that other more economical technologies are more appropriate.
- EZVI has not been demonstrated in fractured bedrock.

4.4 Controlled-Release Carbon and Microscale Zero Valent Iron - EHC™

Technology: A relatively new remedial product called EHC™, by Adventus Group attempts to combine the benefits of enhanced bioremediation and chemical reductive dechlorination. EHC™ is combination of controlled-release carbon and reduced metal (e.g. ZVI, aluminum or zinc). The organic component supports the growth of bacteria in groundwater, which consume dissolved oxygen and reduce the redox potential. Furthermore, the fermentation of the carbon releases electron donors for dehalogenating and halorespiring bacteria, which degrade the COCs. The micro-sized metal supports direct chemical dechlorination of COCs through abiotic pathways, while further reducing the redox potential.

The fundamentals of EHC™ reactions are based upon biological and chemical principals that have been shown to be effective at reducing concentrations of TCE and associated degradation products (AFCEE, 2004; Quinn et. al., 2005). However, the technology is relatively new and currently, there are few publications documenting its use. The technology is similar to EZVI, in that the reactive pathways are presumably anaerobic biodegradation and abiotic chemical reduction (Quinn, 2005). The most notable difference between EHC™ and EZVI, is the *in situ* longevity. EZVI has a maximum reactive life of approximately six months, whereas EHC can be designed to last up to five years, according to the developer.

Applicability at Site: A review of the Site data suggests that EHC™ may be an appropriate technology for application at the Site, for the same reasons specified in Section 4.1.1 for carbon substrate injection. This includes the presence and reduction of TCE degradation products (spatially and temporally), nitrate and ferrous iron (Fe^{+2}) concentrations, and sufficient oxidation-reduction potential to sustain the biotransformation. It will also provide chemical reductive dechlorination if bio-enhancement alone is not sufficient. Uncertainties associated with the evaluation of EHC™ include:

- Lack of documented field sites. EHC™ is an innovative technology which has been demonstrated at few field sites. Therefore, the effectiveness is unsubstantiated, but can be tested through pilot studies.
- As with other enhanced bioremediation techniques, the potential exists to temporarily increase the concentration of intermediate degradation products.
- There could be difficulties in distributing this product in a relatively low-permeability formation.

5. PREFERRED OPTIONS

Given the site conditions, it appears that emplacement of a carbon source will enhance biodegradation such that the dechlorination process will be accelerated, and concentrations of COCs may be reduced to levels that are below groundwater standards. The addition of zero-valent iron to the carbon substrate is likely to be cost-prohibitive due to the expense of the iron and the low concentration in groundwater. The primary factor requiring further evaluation is the methodology to distribute the carbon source in the subsurface.

The following options are recommended for further evaluation of groundwater remediation at the Site, in both the overburden and bedrock formations. Option 1 is preferred. If the pilot testing for Option 1 indicates limitations, then Options 2 (primarily for overburden groundwater) and Option 2A will be given consideration.

In addition to the pilot testing proposed below, results from the Ekonol Site treatability testing for bioremediation, EZVI, and EHC™ will be reviewed to assist in evaluating potential technologies. These results will used in part to make decisions on pilot testing, and will be integrated with pilot test results in the remedial selection process.

Preferred Remedial Options

Technology	General Comments	Applicability to Site	Limitations	Testing Requirements	Relative Cost
1. *In situ* bioremediation using substrate injection	Vegetable oil, sodium lactate, or similar materials.	Presence and reduction of TCE degradation products (spatially and temporally), nitrate and ferrous iron (Fe^{+2}) concentrations, and sufficient oxidation-reduction potential to sustain the biotransformation.	Potential temporary increases in intermediate degradation products of chlorinated VOCs. Ability to inject the substrate in the soils or bedrock.	Borehole geophysics: caliper, fluid temperature/conductivity, gamma, optical and acoustic televiewer logs. One or two injection well pilot tests using injectable carbon substrates in overburden and bedrock.	Low to moderate.
2. Bio-reactor (primarily for overburden groundwater)	Excavate/backfill with mulch, gravel, vegetable oil, in areas with highest overburden concentrations.	Same water quality evidence as listed for Option 1. Majority of the source area soils were previously removed, relatively simple technology.	Potential temporary increases in intermediate degradation products of chlorinated VOCs.	Due to construction area, pilot testing not necessary. Detailed locations and depths of the bio-reactor to be determined during design phase.	Low to moderate.
2a. *In situ* remediation using injection of an emulsified substrate with ZVI	Emulsified substrate containing ZVI, such as EHC™.	Same water quality evidence as listed for Option 1. Also provides chemical reductive dechlorination if bio-enhancement alone is not sufficient	Lack of documented field sites, potential temporary increases in intermediate degradation products, potential difficulties in distributing.	One or two-well pilot tests similar to those for Option 1.	Moderate to high.

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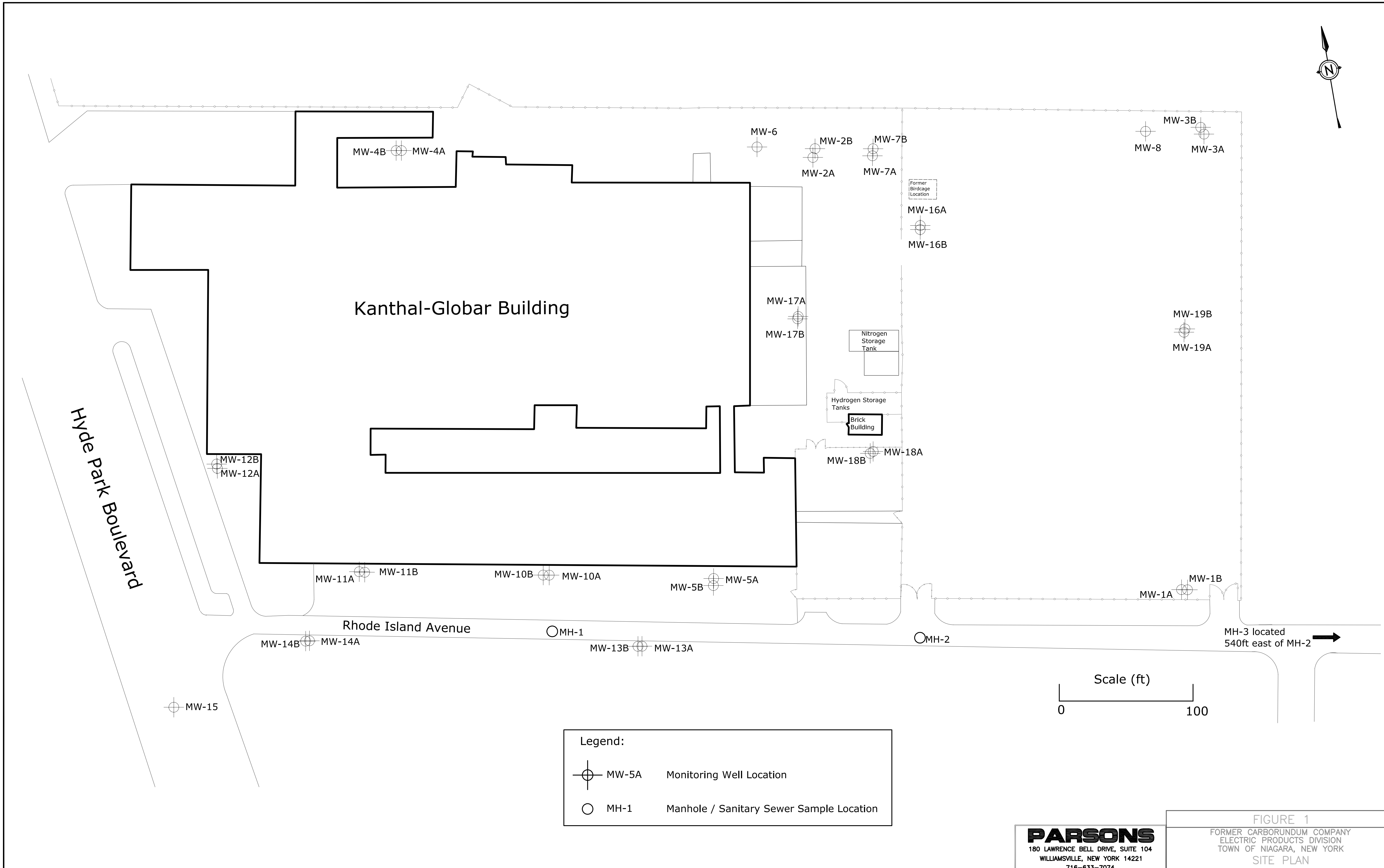

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180 LAWRENCE BELL DRIVE, SUITE 104
WILLIAMSVILLE, NEW YORK 14221
716-633-7074

FIGURE 1
FORMER CARBORUNDUM COMPANY
ELECTRIC PRODUCTS DIVISION
TOWN OF NIAGARA, NEW YORK
SITE PLAN