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Feasibility Study Report

Lubricant Packaging and Supply Company Site

Middletown, Orange County, New York

NYSDEC SITE CODE # 3-36-034

November, 2002

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1.0 INTRODUCTION

In February 1999, the New York State Department of Environmental Conservation (NYSDEC) contacted representatives of the former Lubricant Packaging and Supply Company, Inc., (LPS) to begin negotiations for the implementation of a Remedial Investigation and Feasibility Study (RI/FS) for the LPS property ("Site") in Middletown, NewYork. These negotiations ended in an agreement between NYSDEC and George Saines, Inc. (GSI), owner of the LPS Site. The terms of the agreement are found in Consent Order #W3-0142-99-05, entered into on March 31, 2000, by NYSDEC and GSI. The RI Report was submitted to NYSDEC in June of 2002. NYSDEC and the New York State Department of Health (NYSDOH) reviewed the RI Report and responded with comments in a July 24, 2002, letter to Steven J. Saines, principal author of the RI Report and this FS. A complete response to all NYSDEC and NYSDOH comments and concerns was recorded in a response letter to NYSDEC dated July 30, 2002; the RI Report was edited accordingly. Work on the Feasibility Study began in August 2002 in accordance with a NYSDEC request to complete the FS by the end of October 2002.

Prior to the March 2000 Order between NYSDEC and LPS, an order between the same two parties was entered into 1991 and satisfied in 1994 with the completion of the LPS Phase II Investigation Report (Consent Order #W3-0142-86-09, dated February 20, 1991). The Phase II Investigation was conducted from 1992 to 1993 to identify the nature and extent of volatile organic compounds (VOC) in soil and ground water beneath the LPS Site. Since 1987, NYSDEC had classified the LPS parcel as an inactive hazardous waste site requiring additional study to determine its level of contamination (Classification: "2a"). The Phase II Investigation Report, submitted to NYSDEC in November 1994, documented the presence of 1,1,1-trichloroethane (TCA) in site soils and ground water above NYSDEC's permissible standards. Based on the Phase II Report information, NYSDEC reclassified the Site in June of 1995 from a "2a" Classification to a "2", defined as an inactive hazardous waste site requiring remedial action (due to the presence of significant threats to public health or the environment). In a December 29, 1995, letter to NYSDEC, LPS questioned the conclusions leading to the reclassification of the site, as well as noting minor factual errors in the Department's Inactive Hazardous Waste Disposal Report. NYSDEC responded in a February 6, 1996, letter stating that despite minor errors in its records, reclassification of the LPS property to a category 2 site was justified.

Although the Phase II report, submitted to NYSDEC in November 1994 describes the nature and extent of VOC contamination at the LPS Site, NYSDEC personnel, in accordance with New York's superfund regulations, required additional work to be performed which could *more fully* define the nature and extent of contamination at the LPS Site. The additional information required by NYSDEC was supplied in the June 2002 Remedial Investigation (RI) Report. United States Environmental Protection Agency (USEPA) and NYSDEC protocols (with respect to sample collection, handling and chemical analysis) were observed throughout the RI. A Health and Safety Plan, under which work was performed for the RI, was provided to NYSDEC prior to the submission of the RI Work Plan in April 2001.

The current, March 2000 RI/FS Order calls for: 1) The preparation of an RI/FS Work Plan; 2) The implementation and reporting of the Remedial Investigation; 3) The completion of a Feasibility Study; 4) If required, the implementation of Interim Remedial Measures; 5) Periodic Progress Reports, and 6) Departmental reviews of submittals by the Respondent (GSI) The Order also specifies penalties, site entrance requirements, payment of state costs, NYSDEC reservation of rights and indemnification, public notice, communication instructions and miscellaneous NYSDEC rights and Respondent responsibilities and requirements. GSI has thus far complied with the provisions of the March 2000 Order as specified in items 1, 2, 3 and 5 above. An RI Work Plan was last revised and approved by NYSDEC in April 2001; field work commenced shortly thereafter for the Remedial Investigation. Monthly Progress Reports have been submitted to NYSDEC documenting RI work. The LPS RI report was submitted to NYSDEC in June of 2002 and completed in July 2002 with the submission of a private water supply map of the area surrounding the LPS site. NYSDEC then required the submission of the FS report within three months of the RI completion. The original Feasibility Study was completed in November 2002. Following editorial comments and requests for additional information and data by NYSDEC and NYSDOH in a January 27, 2003 letter, LPS performed a sub-slab soil gas survey beneath the LPS building. LPS also responded to NYSDEC & NYSDOH requests for additional information, by researching a new remedial alternative for the site - Soil Vapor Extraction (SVE). Newly collected data and information along with revisions to the report text as per NYSDEC / NYSDOH requests are included in this revised Feasibility Study Report (May 2003, Revision 1).

The goal of this Feasability Study is to research, evaluate and compare appropriate remedial technologies which, when implemented at the LPS Site, will restore contaminated subsurface soil and ground water to levels which meet NYSDEC and NYSDOH health and environmental standards. The FS Report is arranged in six sections. Section 1.0 (this section) provides an introduction to the recent regulatory history of the site. Section 2.0 includes a description of the property, site history and operations, local geology / hydrogeology, the environmental state of soil, ground water & soil gas, and a summary of exposure pathways present at and near the site. Section 3.0 describes the remedial action objectives and goals for soil and ground water at the Site, as well as a brief description of the remedial technologies chosen to be analyzed in this FS. Section 4.0 presents a detailed analysis of the remedial action alternatives based on eight performance criteria initially developed by USEPA and adopted by NYSDEC. Section 5.0 presents a comparative evaluation of the remedial action. The evaluation uses a matrix scoring system to rate the relative merits of selecting one remedial technology over another based on each remedy's projected performance at the LPS Site. A preferred remedy is chosen at the end of this section. Section 6.0 and 7.0 discuss the FS Report's limitations and reference sources.

This FS Report incorporates the work enumerated above on behalf of GSI, owner of the LPS property. The FS satisfies the last technical requirements of the March 2000 RI/FS Consent Order agreement with NYSDEC. Supporting documents and information may be found in the LPS Phase II Investigation Report, the LPS RI Report or in the Appendices of this report.

2.0 BACKGROUND

2.1 SITE LOCATION AND DESCRIPTION

The Lubricant Packaging Site is located in an industrial park just off of Highland Avenue Extension, on a northern border between the City of Middletown and the Town of Wallkill. The industrial park is easily accessible to commercial traffic from State Route 17M/302 which crosses Highland Avenue Extension approximately one half mile from the park, (see Figure 1, LPS Site Location Map, Appendix A). Figure 2, an LPS Site Survey Map (Appendix A), illustrates the location of the LPS property along Industrial Place, the only road which services this portion of the Northern Middletown Industrial Park. Other companies using facilities within the industrial park are/were General Switch (now occupied by Zenith Auto Parts Corp.), Orange and Rockland Electric Utility (Electrical Substation), Guild Molders, Inc. (now called Risdon AMS, A Crown Cork & Seal Company), a former U.S. Army Storage Depot, Wallace Oil Company and Orange County Corrugated (now called the National Packaging Company - NPC). The location of these companies can be referenced on Figure 3, Industrial Place Parcels, also located in Appendix A of this report.

The LPS Site is approximately one acre in size. The original building, which was used for LPS business until 1987, is a one-story cinder block warehouse and office building. In 1978, a two-story metal fabrication warehouse building was added to the southwest side of the original facility. It is distinguished from the original building by the greater width dimension it displays on site maps. The total building occupies approximately seven thousand square feet of the total property.

The LPS property generally decreases in elevation from north to south (see Figure 4 for property contour information). The southern portion of the property is nearly flat; all adjacent areas to the west, south and east of this level ground also shares the same topography. This flat area was once part of a large railroad marshaling, repair and coal depot facility in Middletown. The operation has currently shrunk to one infrequently used track (note single track on Figure 1). The surface soil on the southern portion of the property and adjacent areas reflects past railroad activity by its black, cinder-rich appearance (see Figure 5 for an illustration of the LPS property formerly used for rail road activities). Additional site description information is presented in the 1994 Phase II Site Investigation Report, which includes regional, local and site specific maps.

2.2 SITE HISTORY

Prior to the establishment of an industrial park and a lubrication business at 17 Industrial Place, a significant portion of the Lubricant Packaging property was utilized as a railroad repair and supply yard as well as a coal depot. Proof of these past activities is supported by three lines of evidence: 1) The cinder composition of topsoil on the southern portion of the site (Figure 5, Appendix A) and adjoining properties along with the proximity of the property to an active railroad line; 2) Accounts of railroad activity by Middletown residents familiar with the area; 3) Photographs and maps available at the Middletown Historical Society. Additional evidence was discovered on The Bedrock Geology of the Goshen-Greenwood Lake Area, NY Map (Offield, 1967). This map also contains topographic and cultural features and is based on aerial photography from 1942, with cultural revisions by the Geologic Survey in 1954. A copy of a portion of this map is included as Figure 6 in Appendix A of this report.

From an examination of photographs, maps, and topsoil conditions on the northeastern corner of the property, it appears that this portion of the LPS parcel was *not* utilized in any significant fashion by railroad activities. The sharp topographic rise and presence of a bedrock ledge at ground surface in the northeastern corner of the property supports this conclusion. Industrial activity at this site prior to the railroad era was unlikely based on data at the Historical Society. The date of abandonment of the railroad yard and coal stockpile areas (located to the southwest of the site) is not exactly known, although it is estimated to have taken place between 1954 and 1962.

Discussion with various offices of the City of Middletown did not yield a date for the construction and development of a road into this portion of the Northern Middletown Industrial Park (i.e., Industrial Place). However, the establishment of manufacturing facilities along Industrial Place suggests modern industrial development of this land began in the late 1950's. The General Switch facility, built in 1958, was one of the first businesses established along Industrial Place. The Lubricant Packaging Site was developed in 1962 when Thomas Freeborn and his business partner established F&W Bearing Service.

The primary business activity of F&W Bearing, at that time, was the de-greasing and re-lubrication of metal ball bearings sent to the facility by a variety of industrial concerns. Most of the de-greasing was accomplished by tumbling bearings in a bath of mineral spirits. However, some limited use of the solvent TCA was necessary for specific greases. Fresh de-greasing solvents were received by either drum or offloaded from tanker trucks into bulk storage tanks located behind the LPS building (see Figure 7, Appendix A). Spent solvents were stored in drums and shipped to solvent recycling companies by truck. Solvent recycling companies also picked-up spent solvent with their own tanker trucks.

A secondary activity of the company was the packaging of lubricants for a variety of uses and clientele. With time, the packaging of lubricants grew in importance for the F&W Bearing Service. In 1972, the F&W Bearing Service was sold by Thomas Freeborn, who was then sole proprietor of the firm, and its name was changed to Lubricant Packaging and Supply Company, Inc., shortly after the purchase. The new name reflected the dominance of lubricant sales and packaging by the firm with respect to servicing bearings. Following the new ownership, the volume of business at Lubricant Packaging expanded to the point where additional warehouse space was added to the existing building in order to store lubricant products. From the late 1970's until early 1987, outdoor storage of drummed lubrication products became a common practice at the site. To accommodate a growing inventory, Lubricant Packaging bought a larger warehouse and storage facility on Wisner Avenue in Middletown in 1986.

In December of 1986, the sale of Lubricant Packaging and Supply Company, Inc., was completed to SOS Fuels, Inc., with its bearing, packaging, and lubricant supply business. At the time of the sale, Lubricant Packaging and Supply Company, Inc., was moving its principal place of operation from 17 Industrial Place to a facility at 75 Wisner Avenue in Middletown. Both properties served as warehousing facilities for Lubricant Packaging and Supply Company, Inc., before and after the ownership transfer of the company to SOS Fuels, Inc., in December 1986. SOS Fuels bought the Wisner Avenue LPS Property, but did not purchase the LPS property at 17 Industrial Place.

In February of 1987, while organizing sold and unsold inventory at the 17 Industrial Place property, a NYSDEC inspection of the Lubricant Packaging Site alleged that "several hundred drums of hazardous waste and some storage tanks of listed hazardous wastes were identified as being stored on-site without proper TSD permits . . . " The waste oil drums, among which contained spent de-greasing solvents, were removed from the site shortly after the inspection. This action met all the terms of a consent agreement between NYSDEC and Lubricant Packaging, dated February 20, 1991. The issue of oil and solvent spillage during the use and storage of these materials at the Lubricant Packaging Site was the topic of the Phase II Site Investigation between 1992 and 1993. In November 1994 a Phase II Site Investigation Report was submitted to NYSDEC.

Since 1987, the LPS Industrial Place building has been leased to several businesses, most of which have manufactured medical supplies and devices. No outside storage of supplies or chemicals has occurred since 1987. Currently, the building is being leased by TRI/BOR Medical, Inc., a manufacturer of medical supplies.

2.3 LOCAL GEOLOGY / HYDROGEOLOGY

According to regional bedrock maps and field work, the LPS property is underlain by the Austin Glen Grit and Shale member of the Normanskill Shale. The LPS Site is located in the middle/upper section of this unit, composed of massive dirty sandstones, siltstones or graywackes and thinly bedded shales. A bedrock outcrop approximately 200 feet northeast of the LPS property was studied to compare local lithology and structure with published reports: measurement and observation of the bedrock outcrop match these reports well. See Figures 3 through 18 in the November 1994 Phase II Site Investigation Report for reference.

Rock cores recovered from drilling activities on the General Switch Site, across the road from the LPS property on Industrial Place Extension, indicated that near-surface bedrock consists of alternating thin layers of shale and siltstone. A top of bedrock contour map for the LPS and General Switch Sites was included in the Phase II Site Investigation Report. The orientation of bedrock fracturing in the vicinity of LPS and the General Switch Site is consistent with local bedrock structure. Primary fracturing roughly parallel to strike was observed at the sandstone outcrop just northeast of the LPS property. However, a secondary set of fractures trending roughly southeast to northwest, perpendicular to strike, were also noted, again consistent with the structural history of the area. Bedrock fracture zones may influence, to a high degree, ground water flow characteristics in the vicinity of the LPS Site.

Above local bedrock at the LPS Site rests an assortment of surficial materials with a variety of sources. As noted in more detailed discussions of geology in the Phase II Site Investigation Report, the LPS Site at one time was covered with glacially re-worked materials derived from regional bedrock. All of the surficial materials on the LPS property, with the possible exception of its extreme northeastern corner, have been disturbed due to building construction and/or past railroad activities. Up to 8' of fill has been noted in borings and test pits on the southern and eastern portion of the site and shallow to nonexistent soil profiles exist on the northern portion of the property, closest to the bedrock outcrop. In general, once the fill has been penetrated or uncovered, the soil material or rocks generally match the description of regional till and/or bedrock. Fill materials on the site generally consist of crushed shale, re-worked glacial till, coal cinders and demolition/construction debris (i.e., broken brick, ceramic tile and concrete). The southern and eastern portions of the site appear to have been topographically lower (by several feet) in the recent past. Railroad activities may have required the systematic filling of low-lying or wet areas with cinders and construction debris. The LPS Site and surrounding industrial park may have once resembled the wetland area now present on the General Switch property or the seasonal wetland east of the railroad tracks and just north of the LPS parcel.

Surface water, in the form of natural perennial streams or ponds, is not present on or directly adjacent to the LPS Site. However, two minor hydrogeologic features do exist in relatively close proximity to LPS: (1) A small, seasonal wetland area across Industrial Place Extension from the LPS building on General Switch Property, and; (2) A modified, intermittent wetland and unnamed stream channel located east of the railroad track line; A fold-up Northern Middletown Industrial Park Map was included with the RI Report and illustrates this latter feature in yellow ink. All surface and ground water flow from the Northern Middletown Industrial Park eventually empties into this unnamed tributary to Monhagen Brook, which then empties into the Wallkill River, the region's major river. Former City of Middletown employees identified the unnamed stream as Draper Run; where necessary in the text of this report or on associated maps, the Draper Run name will be used to describe this surface water feature.

The headwaters of Draper Run start a few hundred feet to the north and east of the LPS Site. Along the eastern side of the Norfolk Southern Railroad line, a modified seasonal wetland area exists. Although dry most of the year, when the wetland contains sufficient standing water during the rainy season of the year, surface water flow has been observed to take place through a modified channel paralleling the railroad track. The channel extends to a subsurface culvert system behind the Risdon Corporation property. From that point to Wisner Avenue, approximately one-half mile southwest of the culvert, the subsurface course of Draper Run is hidden from view and is unmapped. City of Middletown employees indicated that Draper Run was channelized and buried as a result of railroad activities in the distant past. They state that several subsurface branches are likely to exist beneath the industrial park area. Draper Run briefly "daylights" as it passes under Wisner Avenue, where year round flow is normally observed. Up gradient sediment and down gradient stream water samples were obtained from Draper Run during the RI. Sample locations and results were reported on report maps.

Rapid infiltration of local runoff and rain water in the industrial park is commonly observed since the railroad yard soils are composed largely of highly porous coal slag, cinders and construction materials. The sloped terrain around the perimeter of the old railroad yard, which contributes surface runoff to the industrial park basin, is draped in low permeability soils derived from glacial till. Therefore, the central portion of the industrial park area is suspected to be an area of significant recharge to shallow ground water. Discharge of shallow ground water to Draper Run and its subsurface collection channels is thought to be the preferred flow route for local ground water. Since Draper Run appears to be a local discharge zone for ground water, deeper recharge to the underlying till and bedrock is less likely to take place.

Ground water and surface water flows from the northwest of the industrial park area to the south and east, roughly parallel to the existing railroad track line. Ground water flow direction was established during the Phase II Site Investigation and confirmed during the RI. Static ground water level contour maps for the General Switch Site also exhibit a flow direction which is consistently to the south. Careful analysis of topography down gradient of the General Switch and LPS Sites suggests that ground water elevations will continue to drop slowly in a southerly direction. Ground water flow direction should roughly parallel the south trending railroad track across Wisner Avenue, across State Route 211 to the vicinity of Houston Avenue in Middletown. This projected ground water flow analysis was illustrated in Figure 18 of the Phase II Report. A more detailed discussion of geology, Hydrology, and the hydraulic properties of local geologic materials are contained in chapters 3 and 4 of the 1994 Phase II Report.

2.4 SOIL ENVIRONMENTAL CONDITIONS

The following VOCs were detected in LPS soils exceeding method detection limits (MDLs) during the Phase II and Remedial Investigations. Those contaminants in bold italicized type were found at levels above NYSDEC's recommended soil cleanup levels.

- acetone;
- methylene chloride;
- chloroform;
- chloroethane (CA);
- benzene;
- toluene;
- ethyl benzene;
- xylenes;
- carbon disulfide;
- 1,1-dichloroethane (1,1-DCA);
- 1,1-dichloroethene (1,1-DCE);
- cis 1,2-dichloroethene (cis 1,2-DCE);
- ***1,1,1-trichloroethane (1,1,1-TCA)***;
- 1,1,2-trichloroethane (1,1,2-TCA);
- trichloroethene (TCE); and
- tetrachloroethene (PCE).

Soil analytical data from the Phase II and Remedial Investigations indicated that TCA had the greatest areal distribution and concentration across the Site. TCA was found in all eight of the test pit & monitoring well locations during the Phase II Investigation (these locations were chosen based on subsurface soil gas readings). TCA was also found in 3 of the 18 Geoprobe locations sampled during the RI. The Geoprobe locations were chosen based on achieving adequate areal coverage of the LPS property. PCE was detected at 3 of the original 8 Phase II Investigation locations and at five of the 18 Geoprobe locations. As indicated by the list of VOCs detected in LPS soils, other contaminants were detected, but at lower frequencies and concentration levels. Sample location depths varied, and contaminants were not found in any specific soil horizon.

The highest concentration of TCA in soil was determined to be 14,000 ppb, detected at test pit two during the Phase II Investigation. Excluding this high concentration, TCA soil levels ranged from 1.1 to 4200 ppb, with an average soil concentration of 718 ppb, when detected. The highest concentration of PCE in soil was determined to be 1100 ppb, also detected at test pit two during the Phase II Investigation. Excluding this high concentration, PCE soil levels ranged from 0.9 to 270 ppb, with an average soil concentration of 48 ppb, when detected. TCE was detected six times in LPS soils during both the Phase II and Remedial Investigations, ranging from 7.3 to 77 ppb. TCE soil concentrations, when detected, averaged 24 ppb. With the exception of TCA and PCE, no VOCs exceeded 100 μg/kg (ppb) in LPS soils. Therefore, only TCA and PCE will be considered contaminants of concern (COC) for this FS.

2.5 GROUND WATER ENVIRONMENTAL CONDITIONS

The following VOCs were detected in LPS ground water exceeding method detection limits (MDLs) during the Phase II and Remedial Investigations:

- vinyl chloride;
- chloroethane (CA);
- chlorobenzene;
- carbon tetrachloride
- dibromochloromethane;
- 1,1-dichloroethane (1,1-DCA);
- 1,1-dichloroethene (1,1-DCE);
- trans 1,2 dichloroethene (trans 1,2 - DCE);
- cis 1,2-dichloroethene (cis 1,2-DCE);
- 1,1,1-trichloroethane (1,1,1-TCA);
- 1,1,2-trichloroethane (1,1,2-TCA);
- trichloroethene (TCE); and
- tetrachloroethene (PCE).

Ground water analytical data from the Phase II and Remedial Investigations indicated that TCA had the greatest areal distribution and concentration across the Site. TCA was found in all (4) monitoring wells during the Phase II Investigation, ranging from 1300 to 2600 ppb. During the RI, all of the same Phase II monitoring wells detected TCA, at levels ranging from 46 to 420 ppb. In the new bedrock monitoring well, TCA was the only VOC detected at a level of 21 ppb.

PCE was also found in three of the four original Phase II monitoring wells at levels ranging from 11 to 1900 ppb. During the RI, the same three monitoring wells again detected PCE, this time at levels ranging from 4.6 to 53 ppb. Samples from monitoring well MW-1 have not detected PCE during the Phase II and Remedial Investigations. As noted above, new monitoring well MW-5 detected only TCA. Most of the remaining VOCs listed above are decomposition products from TCA, PCE and carbon tetrachloride. (Only TCA was known to have been used by LPS.) Through reductive dechlorination, TCA decomposes to 1,1-DCA, then CA, then ethane. PCE commonly decomposes through reductive dechlorination to TCE, then 1,2-DCE, then vinyl chloride, then ethene. Carbon tetrachloride decomposes through reductive dechlorination to chloroform, then dichloromethane, then chloromethane, then methane. Except for the detection of chlorobenzene at two LPS monitoring wells (levels below 10 ppb), all of the above compounds in ground water can be accounted for based on the release of three chlorinated solvents to the environment: TCA, PCE and Carbon Tetrachloride.

2.6 SOIL GAS ENVIRONMENTAL CONDITIONS

As part of the first revision to this FS report, sub-slab soil gas data was collected at six locations beneath the LPS building in March 2003. NYSDOH had requested that up to 10 soil gas samples be collected around the perimeter of the LPS building during the RI. This author argued that insufficient TCA concentrations exist in soil and ground water to produce soil gas levels which could pose a health threat to workers in the LPS building (OSHA permits levels up to 350 ppm of TCA over 8-hour periods). Nevertheless, the venting of possible harmful concentrations of TCA beneath the LPS building was evaluated in the original LPS FS report (November 2002). A sub-slab soil gas venting system was proposed within remedy #2, institutional controls.

Following the submittal of the original (November 2002) FS report, NYSDOH stated that OSHA regulations do not apply in buildings where the current occupant does not use the specific chemicals of concern (i.e. TCA). Therefore, in the case of the current occupant of the LPS building (TriBor) who does not employ TCA in their business processes, any level of TCA in indoor air above background is not permitted by NYSDOH rules. NYSDOH again requested that soil gas samples be collected around the LPS building for the FS. Following discussions with NYSDEC and NYSDOH, it was agreed that a smaller number of sub-slab soil gas samples would be required to evaluate soil gas conditions beneath the building than if perimeter soil gas samples were collected. Because of the technical difficulty of collecting the perimeter soil gas samples, 6 sub-slab soil gas samples were proposed and approved by NYSDEC. The sub-slab soil gas samples were collected on March 29, 2003 and analyzed by Lancaster Laboratory in Lancaster, PA. The results were sent to NYSDEC in a letter report on April 19, 2003.

TCA was detected in all sub-slab soil gas sampling locations, ranging from 21 ppb to 3000 ppb. Daughter compound 1,1 DCA was detected in three of the six samples (ranging from 6 to 200 ppb). TCE was also detected at all of the sampling locations (ranging from 2 to 110 ppb). Its common daughter product, 1,1 DCE, was detected at three of the six sampling locations (ranging from 1 to 19 ppb). One sampling location detected PCE at 3 ppb. A summary table of the results and sampling location map can be found in Appendix J, which contains the April 19, 2003 soil gas results letter report to NYSDEC.

2.7 CONTAMINANT SOURCES & FATE

It is clear that TCA contamination in both soils and ground water are derived from random on-site spills and leaks during the course of LPS business between 1962 and 1987. The presence of PCE, TCE and carbon tetrachloride in on-site soils and ground water is believed to be the result of up gradient trespass via ground water and soil gas transport from the former General Switch site. PCE, TCE and carbon tetrachloride were not used by, or sold from, the LPS Site. Therefore, the presence of cis 1,2-DCE, chloroform, dichloromethane, chloromethane and some vinyl chloride, for example, are also believed to be the result of up gradient trespass since these compounds are derived from the degradation of PCE, TCE and carbon tetrachloride. Despite the source of the secondary VOC contaminants at the LPS Site, the implementation of remedial technologies effective at reducing the concentration and extent of TCA in soil and ground water beneath the LPS property should also reduce secondary VOC contaminant levels.

The reduction of VOC concentrations in LPS soils via partitioning to air and water, and via biodegradation (i.e., reductive dechlorination), is expected to continue slowly under natural conditions. TCA levels in LPS soils and ground water have declined by approximately 30% annually, or 84 - 97% over the past eight years based on ground water concentration declines observed between the Phase II and Remedial Investigations. Some of the declines are the result of reductive dechlorination. This conclusion is based on the presence of TCA daughter products in ground water, such as 1,1-DCA and CA. Some of the TCA declines are also the result of advection off-site via ground water transport. Due to the low hydraulic gradient and low permeability of subsurface soils, it is expected that advection of VOC contaminants will also proceed slowly in the future. It is uncertain how much TCA was removed from soil and ground water via biodegradation, how much moved off-site via advection with ground water transport, and how much volatilized, but TCA concentrations in ground water have declined by approximately one order of magnitude during the eight years separating the Phase II sampling events in 1993 from the RI sampling in 2001. If environmental conditions remain the same as those experienced around the LPS Site during the past decade, another order of magnitude decline in ground water TCA concentrations would be expected by the year 2010.

2.8 IDENTIFICATION OF EXPOSURE PATHWAYS

An exposure pathway is the course a contaminant could take from a source to an organism. An exposure pathway describes a unique mechanism by which an individual or population may be exposed to chemicals at or originating from contaminated sites. Each exposure pathway includes a source, or release from a source, an exposure route, and an exposure point. If the exposure point is different from the source, a transport media must also be included. Without these three components, an exposure pathway is incomplete (i.e., no exposure can occur).

Current on-site exposure to contaminated near-surface soil is an incomplete pathway to organisms which live and/or work exclusively ***on*** the LPS soil surface. However, on-site exposure to subsurface soil is currently possible to burrowing animals and plants. Future exposure is also possible to construction workers who might be required to dig into the property's subsurface (i.e., buried utilities, future construction work). However, the construction worker's exposure pathway must be considered a remote possibility. Only one area on the LPS property near TP-1 has a soil TCA concentration level above the NYSDEC recommended soil cleanup level at a depth of 4 feet or less (the maximum depth one would expect a construction worker to be exposed). For this low probability case alone, the FS will consider a possible complete future exposure pathway for soil.

Current on-site soil gas exposure is also a possible complete pathway, especially to those who work in the LPS building. It is this possible pathway which prompted NYSDOH to direct LPS to sample for soil gas during the RI. However, in the past, this exposure pathway was considered to be low risk, like that of the hypothetical construction worker exposed to subsurface soils (discussed in the previous paragraph). Source areas of soil and ground water contaminated with TCA on the LPS site do not appear to be high enough to give rise to high concentrations of TCA in indoor air, as per OSHA indoor air standards. However, based on the discussion in section 2.6 of this report on soil gas conditions, NYSDOH does not consider OSHA health standards to be applicable at the LPS site. NYSDOH has indicated that TCA concentrations greater than background may exceed their indoor air standards. The original November 2002 FS considered remedial steps to remove the possibility of a significant soil gas pathway to workers inside the LPS building. This revision to the FS leaves the sub-slab soil gas remediation system unchanged in remedy 2 - institutional controls.

VOC soil gas exposure to organisms outside the LPS building, but still on the LPS property, is also a possible exposure pathway. However, this exposure pathway is not considered to be quantifiable nor significant at sites similar to LPS around the country. For this reason, current and future outdoor exposure pathways will not be considered in the FS.

Current on-site exposure to contaminated ground water is an incomplete pathway. Ground water is not currently used and the property is connected to a public water supply for potable and non-potable uses. Furthermore, there are no nearby ground water discharges to surface water where volatilization of VOCs off the water table can occur within a half mile of the site. However, in the absence of relevant institutional controls (i.e., deed restrictions on the installation of wells), future exposures to ground water could occur. Therefore, the potential exists for the future completion of a ground water exposure pathway.

Current off-site exposure to soil is an incomplete pathway. However, off-site exposure to soil gas is a possible complete pathway if ground water contaminant concentrations are very high and vadose zone soil gas is drawn to low pressure atmospheric areas inside buildings. Ground water concentrations on the site do not appear to be high enough to support exceedances of off-site soil gas standards according to OSHA standards. NYSDEC background standards would hold the exposure concentration to TCA at very low levels. Workers at the Risdon Corporation factory represent hypothetical receptors of TCA contaminated soil gas. Risdon is located directly down gradient of the known General Switch ground water plume and obliquely down gradient from contaminated soil and ground water at the LPS Site. Other off-site exposure pathways may exist further down gradient from the LPS and General Switch sites, but are not identifiable based on the current definition of ground water and soil gas contamination down gradient of the LPS Site.

Current off-site exposure to contaminated ground water is an incomplete pathway since no known wells or ground water uses exist within the Northern Middletown Industrial Park. Ground water flows to the south and east into the older section of the Industrial Park and into the city of Middletown. In the absence of relevant institutional controls (i.e., deed restrictions or ordinances controlling well installation), future exposures to contaminated ground water could occur.

In summary, the possibility exists for on site exposure pathways to TCA-laden soil gas for workers in the LPS and Risdon buildings, but no complete pathway currently exists for exposure to contaminated soil and/or ground water. In the absence of relevant institutional controls, future exposure pathways to on-site soil, and on-site and off-site ground water are also possible.

3.0 REMEDIAL ACTION OBJECTIVES

The objective of this Feasibility Study is to identify, compare and evaluate remedial alternatives that reduce, to the maximum extent practicable, health and environmental hazards (both existing and potential) relating to soil, soil gas and ground water contamination originating from the LPS Site. The alternatives take into account factors including contaminant fate and transport, exposure route, contaminant concentration and potential receptors.

As per NYSDEC instruction, the goal of the LPS remedial action is to restore the site to pre-release conditions to the extent feasible and authorized by law. New York State guidelines and standards will be used as cleanup objectives. Specifically, this refers to all bedrock and all unconsolidated overburden above bedrock (i.e., railroad soils, construction debris, native till and interstitial ground water) which have been contaminated by past Site activities. The following sections describe the identification of appropriate, New York State standards and guidelines that will demonstrate achievement of the remediation goals.

3.1 DEVELOPMENT OF REMEDIATION GOALS

As described in the RI Exposure Assessment Report, the LPS Site currently does not appear to pose significant exposure risks to human health or the environment. However, NYSDEC has scored this site as a Class 2 site, which requires restoration of the site to pre-release conditions because of potential risks to human health and the environment. As discussed previously in section 2.8, several complete contaminant exposure pathways may exist which could potentially pose a risk to current and future users of the LPS property or properties down gradient of the site. One possible exposure pathway relates to soil gas intrusion into the LPS building, or neighboring buildings, as a result of soil and/or ground water volatilization of TCA spilled at the site. TCA may also have been adsorbed by the concrete floor or cinder blocks due to past direct contact. Another possible exposure pathway identifies future persons (i.e., construction workers) who might be exposed to high soil and/or ground water contaminants as a result of excavation activities on or near the LPS Site. The last major complete exposure pathway references possible future users of contaminated ground water derived from the LPS Site.

Although these pathways are considered to be low risk, state and federal guidance suggests that soil and drinking water standards (or Maximum Contaminant Levels [MCLs]) should be used to guide remediation considerations by those cleaning up contaminated sites. As MCLs promulgated by New York State meet or exceed the MCLs set under the federal Safe Drinking Water Act, the state's MCLs would normally form a basis to set standards to which ground water at the Site should be remediated. The same analysis could be applied to the soil clean up standards promulgated by the state. However, VOCs originating from at least one other source located up gradient of the Site may be migrating onto the Site at concentrations exceeding natural "background" conditions in ground water and in some cases, the ground water MCLs. These same VOCs may also influence soil and soil gas data collected at the LPS Site. Some remedial alternatives, which are assessed in this Feasibility Study (e.g., ground water extraction and treatment), would likely capture additional contamination originating from off-site sources, resulting in increased contaminant concentrations on-site. For this reason, attainment of ground water MCLs for all VOC contaminants on site may not be technically practicable until contaminant sources up gradient of the Site are remediated.

Although LPS will utilize New York State soil and ground water standards as the ultimate measure of remedial success, LPS believes that a technically complete remediation at this site may still mean that some soil gas and/or ground water standards will be exceeded due to trespass from up gradient sources. Therefore, LPS proposes the establishment of secondary background concentrations for ground water and soil gas at this site. When the primary New York State standards are approached, but not yet attained, LPS would have the right to investigate background (up gradient) levels to determine if on-site cleanup is being hampered by off-site trespass. Although soil cleanup standards have not been exceeded for VOC contaminants other than TCA at the LPS Site, similar background soil concentrations would be proposed if exceedances were ever discovered for non-TCA compounds. The establishment of secondary background concentrations during future remedial actions is proposed because the selected remedy may not be capable of attaining clean up standards if additional VOCs are added to the LPS Site via soil gas or ground water transport. The establishment of secondary background concentrations are also necessary because it is conceivable that the selected remedy may increase the concentrations of contaminants entering the LPS property from off-site sources (i.e. the SVE remedy with ground water pumping and treatment). LPS cannot agree to New York State soil, soil gas and ground water cleanup standards if it can be demonstrated that these contaminants originated from an off-site source.

The VOC contaminants of concern and their corresponding state MCLs and state soil cleanup standards are listed below:

NYSDEC Ground Water Cleanup Standards
&
NYSDEC Recommended Soil Cleanup Objectives

Contaminant of Concern @ LPS	**Ground Water Standard (ppb)**	**Soil Cleanup Objective (ppb) ***
1,1,1 Trichloroethane (1,1,1 TCA)	***5***	***800***
1,1,2-Trichloroethane (1,1,2-TCA)	5	800
1,1-Dichloroethane (1,1-DCA)	***5***	200
1,1-Dichloroethene (1,1-DCE)	***5***	400
Chloroethane (CA)	***50***	1900
Tetrachloroethene (PCE)	***5***	1400
Trichloroethene (TCE)	***5***	700
Cis 1,2-Dichloroethene (cis 1,2-DCE)	***5***	300
Trans 1,2 dichloroethene (trans 1,2 - DCE)	5	300
Vinyl Chloride	***2***	200
Carbon Tetrachloride	***5***	600
Chloroform	7	300
Dibromochloromethane	***50***	N/A
Chlorobenzene	***5***	1700

* Taken from NYSDEC's TAGM #4046
Bold & Italicized numbers represent current exceedances of these standards at LPS.
NYSDOH soil gas standards have not been promulgated, but are based on unaffected background data.

3.2 REMEDIAL ACTION ALTERNATIVES

A preliminary list of remedial technologies was prepared, summarized and submitted to NYSDEC for review prior to the implementation of the RI program. It was included in the July 2002 RI Report as Appendix F. The technology review guided the RI by highlighting data collection needs during the RI field work. The technology review also narrowed the scope of remedial actions for the LPS Site by eliminating technologies which were technologically inappropriate and/or inefficient. The broad list of remedial technologies still thought to be worthy of consideration for the LPS Site fall into one of the response categories listed below:

1. **No Action** – No Action typically refers to an absence of efforts to reduce contaminant mass, treat contamination or contain contamination. No Action commonly includes limited actions such as periodic monitoring, and may be appropriate in areas where potential endangerment is negligible, or where an active response could cause unacceptable increases in endangerment to human health or the environment.

2. **Containment** – Structural or hydraulic barriers may be used to achieve remedial objectives by containing contaminants within an area where risk to human health and the environment is acceptable.

3. **Removal** – Removal and treatment or disposal would achieve remedial objectives by reducing the mass of contaminants in soil and ground water.

4. **In-Situ Treatment** – Achievement of remedial objectives may be accomplished through in-situ reduction of contaminant mass, toxicity, and/or mobility.

Except for the use of containment technologies which would capture or increase the mass of off-site contaminants, remedies from all the broad response categories have been retained for evaluation in this FS. The Remedial Technology Prioritization Report identified the following remedies as potentially applicable for reducing contaminant risk at the LPS Site:

No Action
Institutional Controls
Selected Soil Removal
Air Sparging
Enhanced Bioremediation
Groundwater Circulation Well
In-situ Enhanced Soil Mixing
In Well Air Stripping
Natural Attenuation
Permeable Reactive Barriers
Phytoremediation
Six-phase Soil Heating
Soil Vapor Extraction (SVE)
Thermal Enhanced Vapor Extraction System
Aeration
Air Stripping
Incineration
Liquid Phase GAC
Solar Detoxification
Sorption
Sprinkler Irrigation

This FS is incapable of evaluating in detail all of the technologies listed above which passed the primary screening evaluation. However, a secondary screening was performed using the following criteria to narrow the remedial actions evaluated in this report:

Effectiveness – The potential effectiveness of each technology in meeting contaminant reduction goals and in addressing estimated volumes or areas of contaminated media will be evaluated. Reliability of each technology with respect to the contaminants and conditions on the Site, and the effectiveness of the option in protecting human health and the environment during construction and implementation will be assessed. Both short-term effectiveness and long-term effectiveness will be evaluated.

Implementability – The technical and institutional feasibility of implementing each technology will be evaluated. Institutional feasibility includes availability of necessary equipment and skilled workers, and the ability to obtain any permits that may be necessary. The evaluation takes into consideration the reliability of the alternative, feasibility for location and conditions, and the applicability of the remedy to problems at the Site.

Cost – Relative capital and O&M costs of technology, rather than detailed cost estimates, will be used. Alternatives with significantly higher costs which provide results similar to those of less expensive alternatives may be screened out.

Table 1 summarizes the results of this Secondary Technology Screening Evaluation. Only the alternatives judged as the most promising on the basis of this evaluation are retained for further consideration in this FS. The remaining remedial technologies left for consideration in this FS are summarized in Table 2. Both Tables can be found in Appendix B of this report.

3.3 SELECTED REMEDIAL TECHNOLOGIES

LPS Remedy #1 – No Action is retained as an alternative. This remedy is retained to serve as a baseline for other alternatives and to evaluate whether it is necessary to implement specific soil or ground water remedial actions.

LPS Remedy #2 – Site Institutional Controls is retained as an alternative. Institutional Controls at the LPS Site are measures which restrict access to the LPS property or restrict exposure to LPS contaminated media, but they do not directly reduce soil or ground water contaminants. Among the Institutional Control measures proposed in this FS are: 1) Complete the fencing of all contaminated portions of the property; 2) Restrict future access to subsurface soils and ground water by implementing deed restrictions on the future development of water wells and subsurface excavations at the LPS Site as per NY law (exceptions can be allowed if environmental remedial work is performed and/or health and safety precautions are observed); 3) Remove potentially hazardous levels of soil gas from beneath the LPS building to prevent possible exposure to current and future workers in the LPS building.

LPS Remedy #3 – Selected Soil Excavation and Removal is retained as an alternative. This remedy will evaluate the removal of contaminated soil in areas where sampling has indicated that levels of TCA are at or above the soil cleanup standards stipulated in section 3.1 of this FS. The soils will be disposed at the nearest permitted landfill capable of accepting this specific contaminated soil.

LPS Remedy #4 – Enhanced Bioremediation is retained as an alternative. This remedy will evaluate the use of adding environmentally safe chemical compounds (polylactate esters) into the soil and ground water system to promote the rate of current microbial degradation of TCA.

LPS Remedy #5 – In-Situ Oxidation (Hydrogen Peroxide Injection) into soil hot spot areas is retained as an alternative. This remedy has the potential to significantly reduce toxicity, mobility and the volume of contaminants within a reasonable time frame (weeks to months) in hot spot soil areas.

LPS Remedy #6 – Phytoremediation of soils and ground water over the entire contaminated portion of the site is retained as an alternative. This remedy has the potential to slowly biodegrade soil contaminants while reducing the mass flux of TCA contaminated ground water from leaving the LPS Site.

LPS Remedy #7 – Permeable Reactive Barriers is also retained as an alternative. This remedy would place reactive substances in the subsurface along the down gradient sides of the LPS property to prevent TCA contaminated ground water from trespassing down gradient from the site. The reactive substances could be iron or an organic substrate like mulch, which would catalyze or provide needed electron donors to the TCA degradation process.

LPS Remedy #8 – Soil Vapor Extraction (SVE) was added as an alternative following NYSDEC's review of the original FS report. This remedy would place a network of horizontal and/or vertical vadose-zone wells into the four delineated soil contamination areas beneath the LPS site. The network of wells would be capable of removing soil gas from the subsurface via "vapor extraction", then direct the contaminated soil gas to a treatment cell (i.e. activated carbon) to remove volatile organic compounds prior to release into the atmosphere. In order to avoid atmospheric short-circuiting of the system, an impermeable cap may be required above the SVE areas. Also, in order to avoid subsurface flooding of the well/piping network, a staggered network of well depths and extraction pipes may be required in addition to the use of ground water depression pumps. (See Figures 13 & 14 for recent ground water elevation conditions which will necessitate hydrologic controls.)

4.0 DETAILED ANALYSIS OF REMEDIAL ACTION ALTERNATIVES

This section provides an evaluation and comparison of the remedial alternatives retained through the secondary screening conducted in section 3.2 and illustrated in Table 1. The following evaluations include a more detailed description of each alternative, assessments of each alternative with respect to the eight evaluation criteria described below, and a comparison of the alternatives.

The eight evaluation criteria developed by the USEPA and adopted by the state of New York for detailed analysis of remedial alternatives follow:

1. **Short-Term Effectiveness** – This criterion assesses the effects of the alternatives during construction and implementation up to 5 years after the beginning of the remedial action, or until remedial response objectives are met. The 0 - 5 year time frame is not stipulated by NYSDEC nor USEPA policy or guidance, but is recommended here by the author as an approximate reference interval for the assessment of cleanup times. Factors that are addressed include potential risks to workers and the community, potential adverse environmental impacts resulting from the implementation of the alternative, and estimated times for remedial response objectives to be achieved.

2. **Long-Term Effectiveness and Permanence** – Alternatives are assessed based on their long-term effectiveness and permanence as well as to the degree of certainty that the remedy will prove successful. This assessment also accounts for the adequacy and long-term reliability of controls, if any, that will be used to manage any untreated wastes that remain at the Site. Again, this author recommends the use of 5 - 25 years as an approximate reference interval to assess the cleanup time required by the proposed remedies.

3. **Reduction of Toxicity, Mobility or Volume** – The degree to which alternatives employ treatment that reduces toxicity, mobility or volume of contaminated media are assessed. The evaluation will focus on the relative amount of hazardous materials that will be destroyed or treated, the degree of expected reduction in toxicity, mobility of volume, the irreversibility of the treatment, and the type and quantity of residuals that will remain following treatment.

4. **Implementability** – The implementability of each alternative is to be assessed with respect to technical feasibility, administrative feasibility, and the availability of services and materials. The reliability and potential technical difficulties associated with each alternative will be accounted for as well as the ability to obtain necessary permits, equipment and personnel to implement the alternative.

5. **Cost** – General costs associated with each alternative are assessed. Costs include capital costs, annual operating and maintenance costs and present worth costs. Although the U.S. is currently experiencing low interest rates on capital investments, a 4% average return on capital

was assumed for the next 25 years. This is more in line with historic interest rates during the last quarter of the twentieth century. A cost analysis spreadsheet for each of the remedies evaluated in this FS are included in Appendix B as Tables 4 - 12. Table 13 summarizes all the remedy costs by components.

6. Compliance with ARARs – Alternatives are assessed as to whether they satisfy applicable or relevant and appropriate requirements of state and federal environmental and public health laws. A partial list of ARARs for this site are contained in Table 14 of Appendix B.

7. Overall Protection of Human Health and the Environment – The alternatives are assessed to determine whether they provide adequate protection of human health and the environment. The evaluation is based on factors assessed under other evaluation criteria, including short-term effectiveness, long-term effectiveness and permanence, and compliance with ARARs.

8. Community Acceptance – To the extent possible, community acceptance of each alternative is assessed. Community acceptance will be more fully evaluated following review and comment of this Feasibility Study.

A qualitative comparison of each of the criteria are presented in Tables 15, 16, 17 and 18 in Appendix B of this report. Table 15 evaluates the eight criteria with respect to their effectiveness at mitigating ***soils*** on the LPS site. Table 16 evaluates the eight criteria with respect to their effectiveness at mitigating ***soil gas*** on the LPS site. Table 17 evaluates the eight criteria with respect to their effectiveness at ***ground water cleanup*** beneath the LPS site. Table 18 evaluates the eight criteria with respect to their effectiveness at ***ground water cleanup*** beyond (down gradient of) the LPS site.

Short and long term effectiveness were qualitatively rated based on a four point scale with 0 representing no effectiveness, 1 representing low effectiveness, 2 representing moderate effectiveness and 3 representing high effectiveness. Likewise, the criteria concerned with the reduction of toxicity, mobility and volume of contaminants were rated. A value of 0 was assigned to remedies with no reduction, 1 was assigned to low reductions, 2 was assigned to moderate reductions and 3 was assigned to high reductions. The implementability criteria used the same four point scale, with 0 assigned to great effort required to implement the remedy, 1 assigned to moderate effort to implement the remedy, 2 assigned to little effort to implement the remedy and 3 assigned to no effort required to implement the remedy. Evaluation using the cost criteria came closest to a quantitative analysis of the remedies. An assigned value of 0 was given to those remedies with total costs exceeding 1 million dollars. An assigned value of 1 was given to those remedies with total costs between ½ to 1 million dollars. An assigned value of 2 was given to those remedies with total costs between 1/4 to ½ million dollars. An assigned value of 3 was given to those remedies with total costs less than 1/4million dollars. ARAR compliance was rated as follows: 0 was assigned to no compliance; 1 was assigned to low compliance; 2 was assigned to moderate compliance; 3 was assigned to high compliance. The Overall Protectiveness criteria was evaluated by assigning 0 to no protection gain, 1 to remedies with low gains in protection, 2 to remedies with moderate gains in protection, and 3 to remedies with large gains in protectiveness. Community Acceptance was qualitatively judged based on a value of 0 being assigned to no perceived community acceptance; 1 being assigned to low perceived community acceptance; 2 being assigned to moderate community acceptance; and 3 being assigned to high community acceptance. A tabulation of the mostly qualitative scores is illustrated in each the four tables (15 - 18) and total scores are compared in the final column. Those remedies with the highest scores are those which perform better than rival technologies. However, some caution should be exercised when viewing the data in this light. Assignment of values, although well reasoned by this author, are subject to biases and error. More importantly, although all eight criteria are evaluated as per USEPA guidance, some criteria will be more or less important depending on site specific conditions. In this case, weighting of the criteria should be considered. In the analysis presented in this FS, no weighting of any criteria was performed.

4.1 LPS Remedy #1 – No Action

Description: Under this alternative, no action would be taken to remediate contaminated soil, soil gas or ground water at the Site. The contaminated soils and ground water beneath the site would eventually attenuate naturally until all sources of TCA have been depleted. The current TCA level in ground water suggests that sources of TCA contributing to ground water contamination could be present for a long time, and that attainment of remedial action objective concentrations would not occur within what is generally considered a reasonable time frame.

Application: No discussion warranted for the No Action remedy.

4.1.1 Assessment

Short-Term Effectiveness [None]

Under the No Action Alternative there would be no action taken to remediate contaminated soil and ground water at or near the site. Contaminated soil and ground water will eventually attenuate as the source of TCA is depleted in site soils. However, natural attenuation would not likely occur within a reasonable period of time.

Long-Term Effectiveness and Permanence [Very Low]

The No Action Alternative would eventually provide a permanent solution to soil and ground water contamination. Following significant natural attenuation of TCA within and down gradient of contaminated LPS soils, risks would eventually diminish to acceptable levels. As noted above, the time required to achieve an environmentally acceptable permanent solution would likely be great (20 years or more).

Reduction of Toxicity, Mobility or Volume [Very Low]

Reduction in the toxicity and volume of TCA contaminated media would occur under a No Action Alternative, but at a relatively slow rate governed by the speed of natural decomposition reactions and microbial processes.

Implementability [No Effort]

No active remediation is undertaken for this alternative.

Compliance with ARARs [No Compliance]

As described in section 2.7, the presence of contamination up gradient of the LPS property may preclude meeting chemical-specific ARARs mandated by NYSDEC (i.e., contaminant concentrations in various media, as they relate to health or risk-based concentration limits or discharge limitations set by NY State). Nevertheless, primary remedial action goals will still consist of New York State mandated cleanup levels. The No Action Alternative is unlikely to meet New York State mandated cleanup levels within a reasonable period of time.

Cost [None]

Cost is not applicable to the No Action Alternative.

Overall Protection of Human Health and the Environment [Low - None]

As reduction in the mobility, toxicity or volume of contaminants proceeds very slowly and chemical-specific ARARs are not met, the No Action Alternative affords no additional protection to human health and the environment in the future. Until concentrations attenuate to New York State mandated cleanup levels, human health and environmental risk will remain or decline gradually.

Community Acceptance [Low]

The community would likely find the No Action alternative unacceptable as it does not conform to ARARs and does not provide any additional protection to human health for future soil, soil gas or ground water exposure (i.e., installation of new wells) within a reasonable period of time.

4.2 LPS Remedy #2 – Site Institutional Controls

Description: Under this alternative, no specific action would be taken to remediate contaminated soil or ground water at the LPS Site. However, efforts would be taken to further restrict access to the site so as to avoid receptor contact or exposure with contaminated soil, ground water or their byproducts. These site restrictions would be comprised of three major components: 1) Fencing in the entire LPS owned area which is considered contaminated; 2) To protect future contact with contaminated soil and ground water, deed restrictions would be sought to prevent any future owner or user of the site from developing a water production well (other than for environmental remediation purposes) or excavating into contaminated soils (without first taking health and environmental precautions); 3) Site Institutional Controls would involve the reduction or elimination of possible contact with harmful or hazardous levels of soil gas which might enter the LPS Building from subsurface soils. This would be achieved by constructing a soil gas mitigation system for the LPS building. This latter control would eliminate potential current and future exposure to workers in the LPS Building. Under the Site Institutional Control Alternative, the contaminated soils and ground water beneath the site would eventually attenuate naturally until all sources of TCA have been depleted.

Application: Site institutional controls could be easily implemented with the use of a local fencing contractor to add supplemental fencing to the perimeter of the site. Approximately 165' of additional fencing is required to completely enclose the LPS property from normal outside trespass. The fencing contractor could also repair and "tie-in" existing perimeter fencing. Deed restrictions can be crafted by one of the attorneys currently working on legal matters for the LPS site. These would be filed in Goshen, the county seat of Orange County. Lastly, if the site institutional control remedy is selected for the LPS site, a soil gas mitigation system will be installed beneath portions of the current LPS building. With sampling information from the sub-slab soil gas survey, the system will be engineered to capture and divert soil gases from areas where concentrations are deemed harmful to the occupants of the LPS building. Installation of the system will be completed by a contractor with experience in sub-slab soil gas remediation systems (similar to radon mitigation systems). The soil gas piping system will be installed by removing and replacing some of the current cement flooring in the LPS building. An active ventilation system will be connected to the sub-slab piping system, drawing ambient atmospheric air beneath the building and venting the potentially harmful soil gases above the roof line of the building outside.

4.2.1 Assessment

Short-Term Effectiveness [High for soil gas mitigation only]

Under the Site Institutional Control Alternative, there would be no action taken to remediate contaminated soil and ground water at the site. Contaminated soil and ground water would be left to attenuate naturally which would eventually deplete the sources of TCA contaminated soil.

However, natural attenuation would not likely result in contaminant levels meeting New York State standards within a short period of time. The soil gas mitigation system, however, could achieve NYSDOH standards shortly after its installation, thus protecting workers from potentially harmful exposures to airborne TCA.

Long-Term Effectiveness and Permanence [High for soil gas mitigation only]

The Site Institutional Control Alternative does not provide a permanent solution to soil and ground water contamination, but does minimize current and future exposure scenarios to on-site human and animal populations. Following the slow rate of natural TCA degradation within and down gradient of contaminated LPS soils, risks related to solvent spillage at LPS would eventually diminish to acceptable levels. As noted earlier, the time required to achieve an environmentally acceptable permanent solution would likely be great (up to two decades or more).

Reduction of Toxicity, Mobility or Volume [Low - None]

Reduction in the toxicity and volume of TCA tainted media would occur under an Institutional Controls Alternative, but at a slow rate governed by the speed of natural attenuation processes.

Implementability [Little Effort]

No active remediation is undertaken for this alternative. However, this alternative involves legal paperwork, fence construction and the design and construction of a soil gas remediation system for the LPS Building. None of these tasks have large impediments to implementation. Some additional soil and soil gas exposure risk exists during the installation of the fence posts and sub-slab soil remediation system.

Compliance with ARARs [Low Compliance except for soil gas]

As described in the No Action Alternative discussion, the presence of contamination up gradient of the LPS property may preclude meeting NYSDEC chemical-specific ARARs (i.e., contaminant concentrations in various media, as they relate to health or risk-based concentration limits set by NY state). Nevertheless, primary remedial action goals will still consist of New York State mandated cleanup levels. The Site Institutional Control Alternative is unlikely to meet cleanup levels within a short-term time frame.

Cost [Low]

The cost of the Site Institutional Control Alternative is low compared to most of the other Alternatives evaluated in this FS. The direct capital cost of all the institutional controls is estimated to be approximately $5,000, although the long term (25 year) present worth value of this remedy is approximately $200,000 .

Overall Protection of Human Health and the Environment [Variable Protection]

As reduction in the mobility, toxicity or volume of contaminants proceeds slowly and chemical-specific ARARs are not met, the Site Institutional Control Alternative affords moderate protection to human health and the environment by preventing current and future exposure to contaminants in LPS soils and ground water. Until concentrations attenuate over time, some potential human health risk will remain.

Community Acceptance [Variable]

The community would likely find the Site Institutional Control Alternative to be an acceptable component to cleaning up the LPS Site. However, the community may not agree that it should be the sole remedy implemented based on the time required to achieve the cleanup goals at the site. The Site Institutional Control Alternative does not meet ARARs and does not provide protection against off-site human exposure in the future to contaminated ground water.

4.3 LPS Remedy #3 – Selected Soil Excavation and Removal

Description: Under this alternative, selected areas of the LPS Site will be excavated and disposed off-site in a permitted waste disposal facility. The excavated areas will be backfilled with clean earthen materials. Soil samples will be taken along the side walls of the excavation to confirm that remaining soils do not exceed the state soil cleanup standards. Strict site control measures will be enforced while excavations are open at the LPS Site.

Application: The selected soil excavation and removal remedy will require the services of an experienced excavation contractor. Soils will be removed from the four areas delineated in Figure 9 of this FS report, which inscribes/contains soils with TCA concentrations at or above the NYSDEC recommended clean up standards (see section 3.1 for a table of these NYSDEC standards). Tables 5 and 6 in Appendix B quantify the soil volumes to be excavated and transported from each of the contaminated soil areas delineated at the site. A total of 50,000 ft3 or 1852 yd3 or 2438 tons may require removal from the LPS site due to exceedances of TCA soil cleanup levels. Removal of the soils will take place in stages and levels. Soil samples will be collected along the perimeter of each stage and level to ascertain whether each excavation removes soils contaminated with TCA above NYSDEC recommended levels. The soils will be disposed at a permitted waste disposal facility. If the soils are deemed to be hazardous, a facility permitted to accept hazardous materials will be chosen.

4.3.1 Assessment

Short-Term Effectiveness [Moderate - High]

Under the Selected Soil Excavation and Removal Alternative, a major source of TCA contamination on the LPS Site will be removed. This could result in short-term improvements to ground water quality. Even if some of the TCA contaminated soils are not removed due to being missed by the sampling grid in the Phase II and Remedial Investigations, less source material will likely result in improvements to ground water quality. This remedy would also result in decreased risks from soil gas migration into the LPS building. It is likely that this alternative will bring about the fastest compliance with soil cleanup standards, but ground water cleanup goals would likely trail by several months or years due to the fact that other smaller areas of TCA soil contamination may exist undetected.

Long-Term Effectiveness and Permanence [Moderate - High]

The Selected Soil Excavation and Removal Alternative would provide a permanent solution to most soil and some ground water contaminated by TCA. The use of this alternative alone would require that existing TCA ground water contamination attenuate naturally on and down gradient of the site. Ground water quality could eventually achieve cleanup goals, possibly within 5 years after soil removal. Insufficient data exists to predict when cleanup goals will be met.

Reduction of Toxicity, Mobility or Volume [None]

In this alternative, the contaminated soil material will be transferred to a controlled waste disposal facility. No reduction in the toxicity, mobility or volume of soil will take place under a Selected Soil Excavation and Removal Alternative. The toxicity and mobility of the TCA will remain unchanged after disposal in a landfill. However, TCA leachate from the soil will be controlled by landfill collection and treatment systems. At the LPS Site, TCA transfer to soil gas and ground water will be significantly curtailed.

Implementability [Moderate - High Effort]

The Selected Soil Excavation and Removal Alternative involves rather straightforward construction techniques to remove and transport the contaminated soils to a permitted landfill facility. However, excavation of contaminated soils may prove to be difficult due to maintaining the stability of excavation pit sidewalls. Those areas requiring excavation near a property boundary will also require a step back distance to preclude excavation danger / failures to neighbors. Therefore, the Selected Soil Excavation and Removal Alternative would, at best, be only partially successful at removing TCA contaminated soil near the LPS property boundary.

Compliance with ARARs [Moderate - High]

To the extent that the Selected Soil Excavation and Removal Alternative removes TCA contaminated soil, it will meet ARARs related to soil cleanup standards and the removal of future soil gas risk. However, it is expected that ground water cleanup standards will not be met immediately after the completion of this alternative. In this sense, ground water related ARARs, both on and off-site will not be met directly following soil removal activities.

Cost [Moderate - High]

The cost of the Selected Soil Excavation and Removal Alternative is moderate to very high compared to the other Alternatives evaluated in this FS. Much depends on the classification of TCA soil as hazardous or nonhazardous. The cost of excavating and disposing of all TCA contaminated soil currently above the soil cleanup standards at the LPS Site is estimated to be $268,125 for nonhazardous soils and $1,072,500 for TCA soils classified as hazardous. This does not include the cost of project management, contingencies and future ground water monitoring activities. With these additional costs, the Selected Soil Excavation and Removal Alternative has an estimated to present worth value between $415,000 - $1,219,000.

Overall Protection of Human Health and the Environment [Moderate - High]

Removal of a large percentage of TCA source material will have a significant beneficial effect on all impacted media in the vicinity of the LPS site - soil, soil gas and ground water. If it was certain that all TCA spillage occurred in the four areas designated for soil removal, this remedy would be among the strongest proposals evaluated in this FS. However, based on monitoring well and ground water TCA concentrations and the hydraulic gradient at the site, it appears that at least some of the TCA may have been spilled elsewhere on the site.

In addition to the positive overall improvements this remedy offers to human health and the environment, the excavation and disposal of contaminated soils from the site carries a significant, but manageable short-term risk to human health and the environment. Excavation work typically carries risk due to the instability of earthen pits and the aeration of contaminated soils to the atmosphere. Transport of the contaminated materials to the disposal site also carries risk for workers and those in close contact with the transported material and the communities through which truck traffic passes. Refiling and grading activities are generally less risky. Following the implementation of this alternative, an increase in the overall protection to human health and the environment will be realized, as stated above.

Community Acceptance [Moderate]

Community acceptance of this alternative is anticipated as it would permanently remove sources of contamination from the site and disposal of the contaminated material would take place at a controlled facility. However, some concern is also expected during the excavation and removal process as these types of activities may increase noise, odors and heavy equipment traffic through local neighborhoods.

4.4 LPS Remedy #4 – Enhanced Bioremediation

Description: Under this alternative, selected areas of the LPS Site will receive environmentally safe additives to the ground surface and/or subsurface (via injection points or pits) to promote the rate and extent of bioremediation currently taking place in the LPS subsurface. The additives are designed to supply chemical compounds which enhance a reducing environment in areas where TCA contamination exists. TCA bioremediation takes place best in a reducing environment where biologically controlled processes promote the reductive dehalogenation of TCA into simpler chlorinated hydrocarbon compounds.

Application: If remedy #4 is selected for the LPS site, the application of bioremediation additives (chemical agents capable of sustaining a reducing environment in the subsurface) to the LPS site will likely take place in stages, following a pilot study. Among the possible vendors of bioremediation additives is Regenesis, Inc. of Los Angeles, CA. They have recommended the use of 6600 pounds of hydrogen release compound (HRC) injected into the subsurface via geoprobe rigs. However, other bioremediation additives are being considered, such as molasses. Because contaminants entered the subsurface from spills on the surface, it is likely that surface application of HRC, molasses or other similar additives will be the most effective. Surface preparation of the soils, prior to bioremediation agent application, will be done using common agricultural scarification and furrowing techniques. This will promote the adsorption of the bioremediation agent to the affected soils and will reduce runoff and inadvertent migration of the agent from the site. If pilot studies indicate that injection or trench filling of the bioremediation agent is a more appropriate application, these methods will be used. Injection of the agent will be completed with the use of a geoprobe mounted rig at multiple points withing the area of concern. Injection depth will be dictated by soil sampling results and the depth to ground water at the time of injection. It is anticipated that target depths will range from 4 to 8 feet below the ground surface.

4.4.1 Assessment

Short-Term Effectiveness [Low - Moderate]

Under the Enhanced Bioremediation Alternative, the source of TCA contamination on the LPS Site will be actively treated with products designed to supply essential microbial nutrients and promote a reducing environment so that natural bioremediation rates are increased. As noted in section 2.7, under natural conditions, it appears that TCA reduction in ground water is taking place at an approximate annual rate of 30%. Enhanced bioremediation rates are expected to accelerate these degradation rates significantly. However, this alternative might not result in short term compliance (< 5 years) with soil and ground water cleanup standards as set forth in this FS.

Long-Term Effectiveness and Permanence [High]

Although short term compliance is not probable, long term effectiveness and permanence is expected. The Enhanced Bioremediation Alternative would probably provide a permanent solution to both soil and ground water contamination, and minimize future TCA exposure scenarios to human and animal populations. Land application of bioremediation additives would increase the likelihood that soil cleanup goals would be achieved. The use of this alternative alone would result in a moderate pace of cleanup, but would have the effect of "chasing" TCA ground water contamination off-site, as the bioremediation rate increase would not be confined solely to the LPS Site. Off-site ground water quality could also achieve cleanup goals, but would lag behind cleanup progress on site due to slower, natural rates of bioremediation taking place down gradient of LPS.

Reduction of Toxicity, Mobility or Volume [Moderate - High]

A reduction in the toxicity and volume of contaminated soils and ground water will occur under an Enhanced Bioremediation Alternative. TCA will eventually break down into DCA, CA and ethane or ethanol. The common daughter products of TCA are considered to be toxicologically similar to each other. Therefore, as the mass of TCA (and daughter products) is reduced, total site toxicity is reduced. As the mass of TCA is reduced, so too does the volume of contaminated media (soil and ground water). This alternative is expected to remove a greater amount of TCA in subsurface soils and ground water in the long term than through physical excavation, because excavation will not be able to remove all contaminated soils due to structural and safety limitations. The enhanced bioremediation additives can be targeted at all contaminated soils without regard to structural stability and safety issues.

Implementability [Little Effort]

Compared to the Soil Excavation and Removal Alternative, implementation of the Enhanced Bioremediation Alternative is simpler and less risky in terms of logistics and off-site safety. Surface mixing of the additives (i.e., with water) is required followed by application directly onto the ground surface, into a shallow ditch or through the use of Geoprobe holes or pre-drilled wells.

Compliance with ARARs [Low - Moderate]

The Enhanced Bioremediation Alternative will result in slower achievement of compliance with soil cleanup goals, and also perhaps ground water cleanup standards. This alternative will not, therefore, comply with all soil and ground water ARARs in the short term. This alternative is expected to achieve compliance with all ARARs in the long term.

Cost [Low - Moderate]

Except for the institutional control and phytoremediation alternatives, the cost of the Enhanced Bioremediation Alternative is the least expensive compared to the other alternatives evaluated in this FS. Regenesis, a major producer of enhanced bioremediation products, estimates initial product cost of approximately $40,000, with another $20,000 in application costs. Follow up contingencies, project management and ground water monitoring costs add another $200,000 to this remedy. The total present worth value of this alternative is expected to reach $243,000.

Overall Protection of Human Health and the Environment [Moderate]

Compared to the Soil Excavation and Removal Alternative, the Enhanced Bioremediation Alternative carries less risk to human health and the environment during remedial action implementation. However, the speed at which the Enhanced Bioremediation Alternative works cannot compete with the excavation and removal method. Protection of human health and the environment is achieved with the Enhanced Bioremediation Alternative, but long term risks of exposure to contaminated soils and ground water are greater than with quicker remedies.

Community Acceptance [Moderate]

Community acceptance of this alternative is expected as it would not be an unsightly, inconvenient or a dangerous remedial process. Some concern may occur with respect to the monitoring of TCA degradation progress and/or the time required to meet the New York State mandated cleanup standards.

4.5 LPS Remedy #5 – In-Situ Oxidation

Description: Under this alternative, selected areas of the LPS Site will receive one or more doses of a powerful oxidizing agent (i.e., hydrogen peroxide) applied to areas of highest soil contamination in the subsurface (via injection points or excavation pits) to induce the oxidation of TCA in LPS soil and ground water. The oxidizing agents are capable of and enhance the oxidizing environment in areas where TCA contamination exists. The technology involves the application of a Fenton-like chemistry to create and migrate hydroxyl radicals, which in turn degrade organic contamination into carbon dioxide and water. The in-situ oxidation process has demonstrated cleanup not only of VOCs dissolved in ground water and adsorbed to saturated soils, but also the destruction of DNAPL. This remedy would not be capable of addressing soil and groundwater TCA contamination which exists outside the areas where oxidation treatment occurs. Any remaining oxidizing agents would likely be consumed by subsurface carbon sources in the local soils or groundwater. It is anticipated that bench testing of contaminated soil and ground water would be required to identify appropriate reagent dosage amounts and confirm that the in-situ treatment technology will be capable of lowering the pH to a desired range that will allow effective oxidation of contamination. Following treatment of contaminated soil zones, periodic ground water monitoring would be required to evaluate the effectiveness of the in-situ treatment.

Application: The introduction of oxidants into the subsurface at the LPS site does not differ, fundamentally, from the introduction of bioremediation additives to the soil. The additive/oxidant must be applied to the contaminated soils such that close physical contact occurs between a solution containing the additive/oxidant and TCA contaminated soils. (It should be noted that two completely different chemical reactions are supported by bioremediation additives and oxidants.) The type and quantity of oxidant to be used are still not certain. However, hydrogen peroxide solution (12 - 25% strength) is a likely candidate believed to be capable of oxidizing TCA. Following a pilot test from one of the contaminated soil areas, oxidant volumes can be estimated. Because the oxidants proposed for use at the LPS site can be hazardous to human health and the environment, great care must be exercised in their application. Simple surface application of the oxidants (similar to the proposed delivery system for the bioremediation additives) is not proposed for the oxidizing agent. Instead, two shallow subsurface techniques are proposed: 1) Shallow horizontal trickling pipes and/or 2) Shallow vertical injection points.

The first delivery system requires minor excavation (1 - 2' deep) above the contaminated soil plots. A network of shallow ditches will be prepared allowing for uniform exposure to subsurface contaminated soils. Within the ditches, a series of perforated oxidant resistant piping will be laid and connected to solid riser pipes. The shallow network of piping will then be backfilled with clean sand & gravel backfill, then loosely covered with native soils. Liquid oxidant delivery can be introduced to the subsurface soils via the buried piping network.

The secondary delivery system would make use of a geoprobe rig equipped with a liquid delivery system. Shallow (4-8') probe penetrations would take place, then liquid oxidant would be injected into the subsurface under pressure. Depending on the radius of influence of these vertical injection holes (via pilot testing), a grid of injection point locations will be developed to address contaminated soil areas. Both of the oxidant delivery systems are capable of treating the contaminated soils in-situ. Both delivery systems limit human and environmental exposure to the potentially hazardous oxidants.

4.5.1 Assessment

Short-Term Effectiveness [High]

The In-Situ Oxidation Alternative meets the objectives of reducing contaminant concentrations within a reasonable period of time period. Once oxidant application begins, and is applied at all soil hot spot areas (source areas) achievement of New York State mandated soil cleanup standards is expected to be less than one year. The time required to achieve groundwater cleanup standards is less certain. Application of the oxidants does pose short-term risks to workers handling and applying the hydrogen peroxide to the LPS subsurface.

Long-Term Effectiveness and Permanence [High]

In-situ oxidation is effective over the long term as the treatment permanently removes contaminants from soil and ground water in the application area. Upon reduction of contaminant concentrations to below New York State mandated cleanup levels, the remedy will be permanent, assuming all major areas of soil contamination have been treated. However, as noted earlier in this report, potential sources of VOCs up gradient of the Site could influence establishment and achievement of New York State mandated cleanup levels. Off-site ground water quality would eventually achieve cleanup goals, but might lag behind cleanup progress on site due to slower, natural rates of bioremediation taking place down gradient of LPS.

Reduction of Toxicity, Mobility or Volume [High]

Treatment of contaminated soil and ground water using in-situ oxidation permanently reduces mobility, toxicity and volume of contaminants. Following completion of in-situ oxidation at all LPS soil hot spots, the mobility of contaminants in ground water down gradient of the LPS Site is not likely to increase. Due to a cessation of contaminants entering ground water at the LPS Site, all down gradient releases will probably decrease. During the period of natural attenuation down gradient of the LPS Site, TCA contaminant volume is likely to decrease through biodegradation.

Implementability [Moderate Effort]

In-situ oxidation is an innovative technology. Nevertheless, it has been used at more than 100 contaminated sites and has demonstrated effectiveness in destroying organic compounds in soils, ground water, and as DNAPL. Site conditions are moderately amenable to use this technology as the compacted fill material soils and till are not homogeneous, nor particularly permeable. If injection wells were used, it would be particularly important to determine the effective radius of treatment from each application well. Pit application may be more advantageous in terms of complete application of contaminated soils, but more difficult in terms of physical application and health and safety issues. The services and equipment for in-situ oxidation will most likely be provided by specialty contractors. These contractors would be on-site during injection activities.

Compliance with ARARs [High]

The In-Situ Oxidation Alternative will result in the quick achievement of compliance with the New York State mandated soil cleanup goals, and shortly thereafter, with ground water cleanup standards in the treatment areas. If other contaminant sources are not oxidized, groundwater cleanup standards will take longer to achieve. This alternative is, therefore, expected to comply with similar soil and ground water ARARs in the short term. However, the injection of potentially hazardous materials into the subsurface is not normally permitted under most existing environmental rules. A permit or variance may be required prior to implementation of this remedy.

Cost [Moderate]

The cost of the In-Situ Oxidation Alternative is comparable to the other alternatives evaluated in this FS. However, a specialized contractor will be required to implement this remedy and a number of additional safety issues will need to be addressed. The present worth value of this remedy is estimated to be $375,000.

Overall Protection of Human Health and the Environment [Moderate]

The In-Situ Oxidation Alternative would reduce risks to human health and the environment associated with future exposure pathways for contaminated soil exposure and ground water ingestion. The short-term effectiveness evaluation determined that there would likely be no adverse impacts to the community during implementation. Most adverse environmental impacts and risks to workers could be controlled by implementation of appropriate safety measures and control technologies. In-situ oxidation degrades contaminants into carbon dioxide and water, generates no waste streams requiring treatment or disposal, and therefore, in conjunction with natural attenuation down gradient of LPS, provides long-term effectiveness and permanence.

This alternative should be able to attain New York State mandated cleanup levels. In consideration of the above evaluation criteria, this alternative provides good overall protection of human health and the environment.

Community Acceptance [Moderate - High]

The community would likely find In-Situ Oxidation to be an acceptable alternative as it provides good overall protectiveness to human health and the environment, and is not considered to cause nuisance problems or endanger human health outside the application areas.

4.6 LPS Remedy #6 – Phytoremediation

Description: This Phytoremediation Alternative is a bioremediation and hydraulic control remedy that would use several different varieties of trees to remove, transfer, and/or destroy contaminants in LPS soils and ground water. There are several different types of phytoremediation mechanisms; all are described more fully in the RI Preliminary Screening Technology Report. Those mechanisms expected to be useful at the LPS Site are: Rhizospheric biodegradation (biodegradation enhanced by root activity); Phyto-volatilization (transpiration of contaminated ground water via the leaves - first absorbed through the roots); Phyto-degradation (degradation of contaminants via plant metabolism); Hydraulic Control (the varieties of trees chosen are selected partially for their fast growth rate and large water consumption - they act as natural pumps as they consume contaminated ground water).

The plants most used and studied at phytoremediation projects are poplar trees. However, Willow and naturally occurring Sumac trees will also be considered at the LPS Site. A tree planting density of approximately 1/100 ft^2 will be considered for the LPS Site.

Application: The phytoremediation remedy is easily implemented at the LPS site. Tree planting can take place using a small augering rig or portable augering too. Spacing density is initially proposed at approximately 10 foot centers, yielding approximately 240 trees. While a small area near the northeastern edge of the property may require some surface grading, most of the site is relatively flat and easily accessible. Once shallow holes (1-3') are augered, a tree wisp or seedling will be inserted into the hole along with some soil amendment and fertilizer. During the first year, a water program may be implemented to maximize the success rate and growth of the trees. Following the first year, typical horticultural maintenance will be required.

4.6.1 Assessment

Short-Term Effectiveness [Low]

Under the Phytoremediation Alternative, the sources of TCA contamination on the LPS Site (soil "hot spots") and those areas with only ground water contamination will be "treated" via the planting and nurturing of two or more varieties of fast growing, dense, root-producing, high water-consuming trees. Bioremediation of soils and ground water is not expected to be noticeable until the third year of growth. Therefore, this alternative may not result in short term compliance with soil and ground water New York State mandated cleanup standards as set forth in this FS.

Long-Term Effectiveness and Permanence [Moderate - High]

As noted above, phytoremediation is not expected to achieve short term compliance with soil and ground water New York State mandated cleanup standards, but long term effectiveness and permanence is expected. The Phytoremediation Alternative could provide a permanent solution to both soil and ground water contamination, and minimize future TCA exposure scenarios to human and animal populations. However, the use of this alternative alone would result in a slow pace of cleanup. Current natural attenuation rates would be expected to increase with the presence of numerous trees on LPS soils and both processes would eventually achieve New York State mandated cleanup goals. Off-site contaminated ground water might lag in the rate of cleanup progress due to slower, natural rates of bioremediation taking place down gradient of LPS.

Reduction of Toxicity, Mobility or Volume [Moderate]

A reduction in the toxicity and volume of contaminated soils and ground water will occur under a Phytoremediation Alternative. Under the influence of rhizospheric biodegradation, TCA degradation will be promoted, some through the route of reductive dechlorination, eventually breaking down into DCA, CA and ethane or ethanol. TCA contaminated ground water will also be degraded metabolically following plant uptake. However, some fraction of TCA currently in soil and ground water may be released as undegraded TCA via plant transpiration through its leaves. For this small fraction of TCA, no reduction in toxicity and an increase in mobility would have occurred. Atmospheric TCA, in small concentrations, is considered to be relatively short-lived and of little impact to human health and the environment.

Implementability [Low Effort]

The Phytoremediation Alternative can be implemented without difficulty and does not introduce additional risk to remedial activities on-site.

Compliance with ARARs [Low - Moderate]

The Phytoremediation Alternative will result in slower achievement of compliance with soil and ground water New York State mandated cleanup goals than the in-situ oxidation or soil removal alternatives. This alternative will not, therefore, comply with similar soil and ground water ARARs in the short term. This alternative is expected to achieve compliance with all ARARs in the long term.

Cost [Moderate]

The cost of the Phytoremediation Alternative is comparable to the other alternatives evaluated in this FS. The initial capital expenses are low, but because the remedy works slowly, project management and monitoring costs will be higher than for those remedies that are fast acting. The total cost of this alternative is expected to reach about $250,000.

Overall Protection of Human Health and the Environment [Low - Moderate]

The speed of the Phytoremediation Alternative cannot compete with the excavation and removal method, nor the in-situ oxidation alternative. These latter remedies will offer superior protection of human health and the environment for on-site exposure pathways. However, there is less difference between these faster acting remedies when considering off-site exposure scenarios.

Community Acceptance [Moderate - High]

Community acceptance of phytoremediation is expected as it has been well received elsewhere in the US where applied. Some concern may exist based on the length of time required to achieve New York State mandated cleanup standards for soil and ground water.

4.7 LPS Remedy #7 – Permeable Reactive Barrier Walls

Description: Permeable Reactive Barrier (treatment) Walls are installed in or down gradient from the flow path of a contaminant plume. The contaminants in the plume react with the media inside the barrier to either break the compound down into harmless products or immobilize contaminants by precipitation or sorption. At LPS, the permeable reactive barrier wall would be placed along the down gradient perimeter of the site and keyed into the siltstone bedrock. The wall would be comprised of either zero valent iron filings or mulch.

The zero-valent iron wall reduces chlorinated contaminants such as TCA, TCE and PCE. As the iron is oxidized, a chlorine atom is removed from the compound using electrons supplied by the oxidation of iron. The chlorinated compounds are reduced to nontoxic by-products. Under the mulch alternative (which is significantly cheaper), similar oxidation-reduction reactions are supported, but the reactions are less rapid.

Application: If selected, the placement of a permeable reactive barrier (PRB) wall along the down gradient perimeter of the LPS site would be among the most challenging engineering tasks of future remedial work at this site. PRB placement will require the physical trenching to bedrock of at least 500 linear feet along the property boundary (see Figure 12). Depth to bedrock along the 390 feet of the western perimeter of the property averages 20' or more, whereas the 100'+ southern property boundary begins at 20'+ at its easternmost corner, then gradually decreases to an estimated 7' below ground surface. The trench width will be selected based on the calculated volume and thickness of the specific PRB material required to successfully treat TCA contaminated ground water at the concentration levels observed at the LPS site (i.e. iron filings, mulch). Based on a 1 foot wide trench, 9225 ft3 of PRB material will be required. Trenching to the top of bedrock should allow PRB placement within the more permeable unconsolidated material and therefore, insure that most lateral ground water movement (which is believed to predominate at this site) will be treated by passing through the PRB. Trenching through or around boulders within the unconsolidated till may prove to be difficult, but only a few boulders were encountered during the Phase II and RI subsurface investigations.

4.7.1 Assessment

Short-Term Effectiveness [Low - High]

Under the Permeable Reactive Barrier Wall Alternative, the source of TCA contamination on the LPS Site (soil "hot spots") would not be actively treated, but would be allowed to slowly leach to ground water and undergo natural rates of biodegradation as per the past 40 years at the LPS Site. However, trespass of TCA via ground water down gradient of the site would be effectively limited due to the placement of the permeable reactive barrier wall along the down gradient perimeter of the property. Soil and ground water New York State mandated cleanup standards migrates off-site. It may also require permits and variances to existing rules since the placement of reactive materials in the subsurface may be prohibited by current law. It should comply with ARARs with respect to off-site contamination.

Cost [High]

The cost of the Permeable Reactive Barrier (PRB) Wall Alternative is high compared to most other alternatives evaluated in this FS. The estimated present worth value for the LPS Site ranges from $322,000 for a mulch-based PRB to $1,047,000 for an iron filing PRB.

Overall Protection of Human Health and the Environment [Low - High]

The construction of a permeable reactive barrier wall will carry similar levels of risk as compared with those discussed in the Soil Excavation and Disposal Alternative. Heavy equipment, soil removal, soil replacement and excavation safety all carry some level of risk to workers and those living and working close to the remedial activities. However, these risks are short term and generally manageable. The strength of this remedy rests in its ability to immediately reduce TCA ground water concentrations down gradient of the LPS property and thus improve the overall protection of human health and the environment off-site.

Community Acceptance [Moderate - High]

Community acceptance of this alternative is uncertain as it would not directly address the sources of contamination on site. However, long term reduction in off-site migration of TCA contaminated ground water would probably be supported. Some concern may be expected during the excavation due to increased noise, odor and heavy equipment activity on site.

4.8 LPS Remedy #8 – Soil Vapor Extraction (SVE)

Description: Under this alternative, selected areas of soil contamination on the LPS Site will be partially excavated and/or drilled to install piping in the subsurface. The horizontal piping network or vertical wells will be capable of conducting contaminated TCA soil gas from depth to the surface. The soil vapor extraction (SVE) piping network will be connected to vacuum equipment or a blower capable of exerting negative pressure on contaminated soils in the subsurface. Vacuum extraction of soil gasses adjacent to the contaminated soil will occur, thus removing TCA contaminants in the vapor phase. Relatively clean soil gas, flowing from uncontaminated areas adjacent to the affected areas, will replace the contaminated soil gas. In the process, liquid phase TCA (clinging to soil particles in the contaminated soil areas) will reestablish its old equilibrium between liquid and vapor phase, thus promoting mass reduction of the liquid phase in favor of vapor phase TCA. The contaminated soil gasses will be directed to a treatment cell (i.e. activated carbon) to remove volatile organic compounds prior to release into the atmosphere. In order to avoid atmospheric short-circuiting of the system, an impermeable cap may be required above the SVE areas. Also, in order to avoid subsurface flooding of the well/piping network, a staggered network of well depths and extraction pipes may be required in addition to the use of ground water depression pumps. Once favorable conditions are established, SVE is a proven and dependable technology.

Application: SVE was added as the last remedy of to this FS following NYSDEC's review of the original (November, 2000) FS report. SVE was originally rejected as an appropriate technology for the LPS site due to seasonally high ground water elevations, shallow soil contamination and less than average soil permeabilities. In order to manage these conditions, the proposed SVE system at the LPS site will be designed to operate during high ground water table conditions. The placement of ground water depression pumps within the SVE system will enable the remedy to operate during the wetter months of the year as well as the dry months. A horizontal network of SVE piping placed at two or more depths within the contaminated soil horizon will also allow the system to operate at different depth horizons in the case that ground water intrusion becomes a problem. To avoid atmospheric short-circuiting of the SVE system, the placement of an asphalt, plastic or rubber liner over the surface of the contaminated soil area and surrounding buffer perimeter. Conventional trenching and backfilling activities will be required to place the subsurface piping network and connecting riser pipes. Vacuum / blower equipment, as well as air and ground water treatment equipment will be required to be housed in utility buildings or within the current LPS warehouse. An estimated 50,000 ft3 of soils contaminated with TCA may be treated with the SVE system. Assuming a 20% pore space volume for soil gasses, 10,000 ft3 of soil gas will represent one pore volume of air removed from the system. See Appendix I for details of a generically engineered system for the LPS site.

4.8.1 Assessment

Short-Term Effectiveness [Moderate - High]

Under the SVE Alternative, the source of TCA contamination on the LPS Site will be actively targeted. As with pump and treat ground water technologies, the initial months or years of system operation removes the majority of contaminants within reach of the SVE piping system. Moderate to high short- term effectiveness is expected. However, success of the system will depend on keeping the targeted contaminated soils unsaturated (i.e. ground water depression pumps) and the system will also have to guard against atmospheric short-circuiting of soil gas vapors.

Long-Term Effectiveness and Permanence [High]

If the system is capable of minimizing atmospheric short circuiting and keeping contaminated soils unsaturated, the long term effectiveness and permanence of this remedy is high. Any soil contamination not delineated in the Phase II and FS investigations would likely not be remedied by this targeted remedial approach.

Reduction of Toxicity, Mobility or Volume [None]

Little to no reduction in the toxicity and volume of TCA will occur under an SVE Alternative. However, a reduction in the volume of TCA contaminated soil and ground water above recommended or prescribed levels will be achieved on and adjacent to the site. The TCA captured from contaminated soil gas and ground water will eventually be trapped by activated carbon and sent to a vendor capable of removing and or destroying the contaminants adsorbed to the carbon.

Implementability [Moderate]

Compared to the Soil Excavation and Removal Alternative or the PRB Alternative, implementation of the SVE Alternative is simpler and less risky in terms of logistics and off-site safety. However significant engineering and construction work will be required to construct the subsurface soil gas piping network and ground water depression pump system. In addition, the surface construction of the capping system on top of each of the contaminated soil areas will require careful and significant work loads.

Compliance with ARARs [Moderate - High]

The SVE Alternative will result in faster achievement of compliance with soil cleanup goals and ground water cleanup standards than in less active remedies. This alternative will therefore achieve a high level of compliance with most soil, soil gas and ground water ARARs in the short and long term. This alternative by itself may not achieve compliance with long term ARARs for ground water.

Cost [Moderate]

The present worth value of the SVE system with engineering controls is estimated at $509,000, making it one of the more costly remedies considered in this FS, but not nearly as costly as the iron filled treatment wall or the removal of contaminated soils under a hazardous waste designation. Targeted removal of TCA contaminated source material and short term management and ground water monitoring costs favor this remedy. This remedy is considered less favorable because it requires significant engineering tasks such as the construction of a cap and the necessity for ground water control and treatment.

Overall Protection of Human Health and the Environment [Moderate - High]

Compared to the most aggressive source control / removal remedy -- Soil Excavation and Removal -- the SVE Alternative carries less risk to human health and the environment during remedial action implementation. Faster removal of the contaminated soils will decrease TCA exposure risks from all media in the future. However, some risk to human health remains during the construction and operation of the system. The likelihood of TCA contaminated soil gas exposure is increased during the operation of the system.

Community Acceptance [Moderate]

Community acceptance of this alternative is expected, since it will reduce site contaminant levels in the short and long term. However, high acceptance is not expected since the operation may be noisy and to some degree unsightly.

5.0 COMPARATIVE EVALUATION OF REMEDIAL ALTERNATIVES

A semi-quantitative comparative evaluation of all FS remedial alternatives was completed in order to remove some of the subjectivity of this exercise for the author, regulator and lay reader. The Comparative Evaluation results are illustrated in Tables 15 - 18 found in Appendix B. Each contaminated media on the LPS Site was evaluated based on the original eight performance criteria set forth by the USEPA & NYSDEC for superfund sites. An unweighted scoring legend was prepared to help evaluate each remedy with respect to each performance criterion. For those remedies capable of achieving the maximum benefit with respect to each performance standard, a value of 3 was assigned. For projections of moderate to low achievement in meeting the performance standards, values of 2 and 1 were assigned, respectively. For those remedies which were judged to be incapable of achieving any benefit with respect to the performance criteria under evaluation, a 0 was assigned. This evaluation exercise was performed for each remedial alternative with each of the eight performance criteria specified for use in the superfund program. The results were added for each remedial alternative and a total score was assigned to each remedy for each contaminated medium. The highest total score indicates the most suitable remedy for the contaminated media under consideration. A combination of several remedies used together was also evaluated to broaden the use of this comparison tool. Contaminated media such as on-site soil, ground water and soil gas were evaluated in this fashion, as well as contaminated off-site ground water.

5.1 Short-Term Effectiveness

LPS #1 -- No Action – This alternative is evaluated throughout the Feasibility Study in compliance with the NCP to serve as a baseline for comparison with other alternatives. The alternative does not offer short-term protection to human health or the environment nor is it likely to attain New York State mandated cleanup levels within a reasonable period of time.

LPS #2 -- Site Institutional Controls – This remedy is very effective in limiting short term human and environmental exposure to on-site contamination. TCA contaminated soil, soil gas and contaminated ground water could all be controlled sufficiently to prevent harmful exposure to on-site contamination. However, LPS #2 does nothing to address off-site exposure. Both LPS #1 and #2 are not effective in achieving New York State mandated cleanup levels within a short period of time.

LPS #3 – Selected Soil Excavation and Removal – This alternative will achieve short term success with respect to the mitigation of on-site soil contamination, the ultimate source of all contaminated media on-site. It will also achieve short term reductions in soil gas levels while meeting New York State mandated soil clean up goals. This remedy will be moderately successful in achieving New York State mandated cleanup goals for ground water (both on-site and off-site) in the short term. This alternative also poses some risk to site workers and the nearby community during the implementation of this remedy.

LPS #4 – Enhanced Bioremediation – By itself, this alternative does not offer dramatic short-term reductions in soil, soil gas and ground water contaminant levels. Nor will this remedy attain New York State mandated cleanup levels within a short period of time. The achievement time frame for this alternative is considered to be moderate term. However, Enhanced Bioremediation will achieve New York State mandated cleanup levels faster than the LPS #1 and LPS #2.

LPS #5 – In-Situ Oxidation (Hydrogen Peroxide Injection) – This alternative is considered to be a very effective remedy in the short term for the reduction of on-site soil, ground water and soil gas contamination in the immediate area around injection points, but has similar considerations for risk to Site workers as mentioned for LPS #3. (A unique risk exists for workers handling hydrogen peroxide.) LPS#5 will not likely improve ground water contaminant levels at some distance from the injection area due to the changes oxidant injection will have on the subsurface oxidation/reduction environment.

LPS #6 – Phytoremediation – By itself, phytoremediation does not offer short-term reductions in contaminant levels for any of the LPS media considered in this comparative evaluation, nor is phytoremediation likely to attain New York State mandated cleanup levels within a short period of time. The achievement time frame for this alternative is considered to be moderate to long term. However, phytoremediaton will achieve New York State mandated cleanup levels faster than the LPS #1 and LPS #2.

LPS #7 – Permeable Reactive Barriers – This alternative could achieve significant short term improvements in contaminant levels with respect to off-site ground water. This claim is subject to some error as the concentration and extent of off-site TCA ground water contamination is not exactly known. However, LPS #7 would not achieve on-site soil, soil gas and ground water New York State mandated cleanup goals in the short term. In terms of short term effectiveness, LPS #7 is no more effective than the No Action alternative.

LPS#8 - Soil Vapor Extraction - This alternative can achieve short term success with respect to the mitigation of on-site soil contamination, the ultimate source of all contaminated media on-site. If properly engineered, it will also achieve short term reductions in soil gas levels while meeting New York State mandated soil clean up goals. This remedy will be moderately to highly successful in achieving New York State mandated cleanup goals for ground water (both on-site and off-site) in the short term if all areas of contamination are treated thoroughly. This alternative also poses some risk to site workers and the nearby community during the construction and implementation of this remedy.

5.2 Long -Term Effectiveness and Permanence

LPS #1 -- No Action – This alternative is evaluated throughout the Feasibility Study in compliance with the NCP to serve as a baseline for comparison with other alternatives. The No Action alternative does not offer good long-term prospects for the mitigation of soil, soil gas and ground water contamination, nor should it be considered a permanent solution.

LPS #2 -- Site Institutional Controls – This remedy is effective in limiting human and environmental exposure to on-site contamination in the short and long term. TCA contaminated soil, soil gas and ground water could all be controlled sufficiently to prevent harmful human exposures to on-site contamination. However, LPS #2 does nothing to reduce on-site contaminant levels nor does it address off-site exposure. LPS#2 could be considered an effective and permanent long term remedy with the addition of another remedial alternative which removed or accelerated VOC degradation both on and off-site.

LPS #3 – Selected Soil Excavation and Removal – This alternative is considered to be a highly effective and permanent remedy in the long term for all contaminated media and pathways present at the LPS Site. However, some soil contaminants will remain in the subsurface over the long term due to health & safety and engineering restrictions during excavation. Some soil contaminants are also believed to exist between Phase II and RI sampling location points and would therefore not be removed during excavation activities.

LPS #4 – Enhanced Bioremediation – This alternative offers very good long term prospects for improvements in all contaminated media and pathways present at the LPS Site. Enhanced Bioremediation should also be considered a good permanent remedy. As per the injection grid initially proposed by Regenesis, all soil contaminants would experience increased rates of VOC decomposition.

LPS #5 – In-Situ Oxidation (Hydrogen Peroxide Injection) – This alternative is also considered to be very effective in the long term for soil contaminants in the areas in which oxidant is injected. The remedy should also be considered permanent since complete VOC destruction is expected to take place in oxidant injection areas. This remedy may hinder or reverse the natural rate of VOC decomposition (reductive dechlorination) in soil and ground water further away and down gradient from the oxidant injection areas due to subsurface changes in the oxidation state of soil and ground water.

LPS #6 – Phytoremediation – This remedy offers moderately good long-term prospects for contaminant mitigation in soil and ground water. This remedy should also be considered permanent in the long term since most phytoremediation processes involve VOC contaminant removal to the atmosphere or destruction.

LPS #7 – Permeable Reactive Barriers – This alternative would achieve the long term removal of VOC contaminants for off-site ground water if the reactive barrier/wall is maintained or recharged. This remedy will not achieve on-site soil, soil gas or ground water New York State mandated cleanup goals in the short or long term.

LPS#8 -- Soil Vapor Extraction - This alternative is considered to be a moderately to highly effective and permanent remedy in the long term for all contaminated media and pathways present at the LPS Site. However, some soil contaminants will remain in the subsurface over the long term due to New York State mandated conditions which prevents significant soil gas flushing. Some soil contaminants are also believed to exist between Phase II and RI sampling location points and would therefore not be removed during excavation activities.

5.3 Reduction of Toxicity, Mobility or Volume

LPS #1: No Action – This alternative is evaluated throughout the Feasibility Study in compliance with the NCP to serve as a baseline for comparison with other alternatives. The No Action alternative will not reduce the toxicity, mobility or volume of VOC contamination in soil, soil gas and ground water.

LPS #2: Site Institutional Controls – This remedy does not reduce the toxicity, mobility or volume of the VOC contaminated media. However, it redirects TCA contaminated soil gas to areas where exposure risk are low.

LPS #3 – Selected Soil Excavation and Removal – This remedy does not reduce the toxicity, mobility or volume of the VOC contaminated media. However, the largest percentage of contaminated media (soil) is removed from the LPS Site and is placed in a controlled solid waste disposal facility where the toxicity, mobility and volume of the waste is controlled by a leachate collection system and landfill gas venting system.

LPS #4 – Enhanced Bioremediation – This alternative offers very good long term prospects for the reduction in toxicity, mobility and volume of the VOC contaminated media at the LPS Site. Through the bioremediation process, VOCs are generally decomposed into smaller, less complex and less toxic byproducts until they are reduced to water and carbon dioxide. (Vinyl chloride production is an exception to this general rule with respect to toxicity.)

LPS #5 – In-Situ Oxidation (Hydrogen Peroxide Injection) – This alternative is also considered to be a very effective remedy with respect to the reduction in toxicity, mobility and volume of VOC contaminated media at the LPS Site. LPS#5 may be considered better than the bioremediation alternative because it can achieve these results in the short term. Complete VOC destruction is expected within a short time frame, with short half-lives expected for intermediate daughter compounds prior to the production of water and carbon dioxide.

LPS #6 – Phytoremediation – This remedy offers similar prospects for the reduction of toxicity, mobility and volume as the Enhanced Bioremediation alternative. Similar processes and a longer time frame is expected for the phytoremediation alternative. Some additional untreated volatilization of VOC contaminants to the air may be expected with the phytoremediation alternative in comparison to the Enhanced Bioremediation alternative.

LPS #7 – Permeable Reactive Barriers – This alternative would not achieve any reduction of toxicity, mobility and volume of on-site VOC contaminants. However, for off-site ground water, the reactive barrier/wall is expected to yield significant reductions in all dissolved VOC contaminants.

LPS#8 - Soil Vapor Extraction - This remedy does not reduce the toxicity or volume of the TCA captured during SVE operations but rather transfers the contaminant from the uncontrolled soil media to a controlled carbon based media. However, reductions in the toxicity (directly related to TCA concentration) and volume of contaminated soil will take place. The TCA will remain as mobile as in the past.

5.4 Implementability

LPS #1: No Action – This alternative is evaluated throughout the Feasibility Study in compliance with the NCP to serve as a baseline for comparison with other alternatives. There are no impediments to implement the No Action alternative.

LPS #2: Site Institutional Controls – This remedy requires a minor amount of effort and financing to implement. It is considered to be easily implementable.

LPS #3 – Selected Soil Excavation and Removal – This alternative remedy requires a substantial investment in safety planning and engineering. Complete removal of contaminated soils on the LPS Site will be difficult due to the proximity (and depth) of some of the contamination near property boundaries which are not accessible. Selected Soil Excavation and Removal is considered to be moderately to very difficult to implement well.

LPS #4 – Enhanced Bioremediation – This alternative is significantly easier to implement than LPS#3. No excavation and removal activities are required. The construction of pits or delivery well points would be required, as well as an adequate delivery method for the bioremediation additives. This remedy is considered to be implementable with moderate to minor effort.

LPS #5 – In-Situ Oxidation (Hydrogen Peroxide Injection) – This alternative is also easier than LPS#3. It too requires no excavation and removal activities and the delivery of oxidants to the subsurface will require the construction of pits or delivery well points. LPS#5 is slightly more difficult to implement because the oxidants used to inject in the subsurface are hazardous materials (highly reactive) and must be used with great caution. This remedy is considered to be implementable with moderate effort.

LPS #6 – Phytoremediation – This remedy may require a greater time to implement than LPS#2, but it is no more difficult to implement. The property must be prepared for tree planting by grading some areas and trimming back existing foliage. But the placement of young saplings will not be more difficult than the installation of fence posts and a soil gas mitigation system. The phytoremediation remedy is considered to be easily implementable

LPS #7 – Permeable Reactive Barriers – This alternative would require the greatest amount of effort to install correctly (effectively). The irregular surface and depth of the foundation bedrock is one challenge to overcome. Another challenge is the installation and filling of an open trench (with reactive material) along the down gradient perimeter of the property where off-site access is not available due to the existing fence and parking lot on the Risdon property. The Permeable Reactive Barrier Alternative is considered to be implementable with great difficulty.

LPS#8 - Soil Vapor Extraction - This alternative remedy requires a substantial investment in engineering, detailed construction and careful operation. Removal of TCA from contaminated soils by SVE will be difficult due to the shallow depth of some of the soils, a shallow ground water table, and, in some areas, near surface bedrock. SVE is considered to be moderately difficult to implement well.

5.5 Cost

LPS #1: No Action – This alternative is evaluated throughout the Feasibility Study in compliance with the NCP to serve as a baseline for comparison with other alternatives. The No Action alternative will not result in any additional costs to an environmental cleanup project.

LPS #2: Site Institutional Controls – This remedy is considered to be the least costly (not including the No Action Remedy) in terms of capital expense ($5,000) and long term present worth value ($192,000) compared to all other remedial alternatives.

LPS #3 – Selected Soil Excavation and Removal – This alternative has the potential to be the most costly among the remedies considered in this FS if the excavated soil is characterized as hazardous. A hazardous classification of the soils would result in the present worth value of this alternative exceeding one million dollars (i.e., $1,219,000) whereas a nonhazardous classification may cost up to $415,000.

LPS #4 – Enhanced Bioremediation – This alternative offers a smaller price tag than most other remedies considered in this FS: $93,000 in capital expenses and $150,000 for long term operation and maintenance of the remedy. The total present worth value is therefore expected to approach $243,000.

LPS #5 – In-Situ Oxidation (Hydrogen Peroxide Injection) – This alternative is projected to be 30% more costly than LPS#4. Capital costs are much more expensive (@ $318,000), but long term maintenance is less costly (@ $58,000), yielding a total present worth value for this alternative of approximately $376,000.

LPS #6 – Phytoremediation – Although phytoremediation has a low initial capital cost requirement ($50,000), its slow cleanup pace requires a significant long term operation and maintenance cost ($195,000). A present worth value of $246,000 is expected for this remedy.

LPS #7 – Permeable Reactive Barriers – If iron filings are used as the reactant in the barrier wall, this alternative becomes the most expensive of the remedies (except for soil excavation of classified hazardous waste). An estimated $1,047,000 would be required for the completion of this remedial alternative. Significant savings can be gained by using mulch. A mulch wall has an estimated present worth value of $322,000.

LPS#8 - Soil Vapor Extraction - This alternative is projected to be moderately costly, but has the potential to be very costly if ground water yield is greater than expected and cleanup is slower than expected. If designed and constructed well, the system may not require a great deal of adjustments. However, frequent changes and modifications due to engineering control limitations will increase the cost. The projected present worth value of this remedy is calculated to be $509,000.

5.6 Compliance with ARARs [See Table 14 for ARAR references]

LPS #1: No Action – This alternative is evaluated throughout the Feasibility Study in compliance with the NCP to serve as a baseline for comparison with other alternatives. This remedy does not make any attempt to satisfy local, state or federal applicable or relevant rules and regulatory requirements.

LPS #2: Site Institutional Controls – This remedy does not address soil, ground water nor outdoor air regulations, but does address indoor air rules as they relate to the current LPS building. This alternative remedy calls for the installation of a soil gas mitigation system which would intercept potentially contaminated soil gas from beneath the LPS building and remove them to the outside atmosphere. The remedy was judged to be strongly supportive of indoor air ARARs, but unsupportive of all other ARARs.

LPS #3 – Selected Soil Excavation and Removal – This alternative remedy directly addresses recommended state soil cleanup levels and indirectly addresses air and ground water regulations for the chemicals of concern at the LPS Site. Removal of contaminated soils will have a direct impact on the future release of contaminants to ground water and air. The remedy was judged to be strongly supportive of most ARARs.

LPS #4 – Enhanced Bioremediation – This alternative addresses applicable and relevant rules for all contaminated media, but does so at a slower rate than the LPS#3 alternative. The decomposition of VOC contaminants in on-site soils and ground water will be accelerated under this remedy, which will in turn reduce VOC releases to the atmosphere. The remedy was judged to be moderately supportive of ARARs.

LPS #5 – In-Situ Oxidation (Hydrogen Peroxide Injection) – This alternative remedy directly addresses recommended state soil cleanup levels and indirectly addresses air and ground water regulations for the chemicals of concern at the LPS Site. The chemical destruction of contaminated soils will have a direct impact on future releases of contaminants to ground water and air. The remedy was judged to be strongly supportive of most ARARs.

LPS #6 – Phytoremediation – This alternative addresses applicable and relevant rules for all contaminated media, but does so at a slower rate than the LPS#3 or LPS#5 alternatives. Phytoremediation processes will speed the decomposition of VOC contaminants in on-site soils and ground water, which will in turn reduce VOC releases to the atmosphere. However, the pace at which this remedial alternative works is judged to be slower than the Enhanced Bioremediation - LPS#4. Therefore, this remedy is judged to be weakly supportive of most ARARs.

LPS #7 – Permeable Reactive Barriers – Except for strong compliance with off-site ground water cleanup standards, this alternative does not address on-site soil, ground water and air applicable or relevant rules. Therefore, this remedy is judged to be unsupportive of most ARARs.

LPS#8 - Soil Vapor Extraction - This alternative remedy directly addresses recommended state soil cleanup levels and indirectly addresses air and ground water standards for the chemicals of concern at the LPS Site. Removal of TCA from contaminated soils will have a direct impact on the future release of contaminants to ground water and air. This remedy is judged to be strongly supportive of most ARARs.

5.7 Overall Protection of Human Health and the Environment

LPS #1: No Action – This alternative is evaluated throughout the Feasibility Study in compliance with the NCP to serve as a baseline for comparison with other alternatives. The No Action alternative will not increase the overall protection of human health and the environment because it will not remove or reduce the toxicity, mobility or volume of VOC contamination at the LPS Site.

LPS #2: Site Institutional Controls – This remedy will significantly increase the overall protection of human health and the environment by limiting access to contaminated media on site. However, it does not address off-site exposure routes.

LPS #3 – Selected Soil Excavation and Removal – This remedy will also increase the overall protection of human health and the environment. However, this remedy calls for the removal of the largest source of contamination on-site -- VOC laden soils. By removing the most significant source of contamination, subsequent reductions in ground water and soil gas contamination will result. This remedy does pose some decrease in the overall protection of human health and the environment <u>during</u> the excavation and removal process due to the increased number and strength of exposure pathways to contaminated soil and soil gas.

LPS #4 – Enhanced Bioremediation – This alternative offers good (moderate to long term) prospects for the overall protection of human health and the environment with respect to all media, both on and off-site. However, compared to LPS#3 and LPS#5, this remedy does not succeed in supplying similar levels of on-site protection in the short term.

LPS #5 – In-Situ Oxidation (Hydrogen Peroxide Injection) – This remedy will increase the overall protection of human health and the environment by destroying, in-situ, the largest source of contamination on-site - VOC laden soils. By oxidizing the most significant source of contamination, subsequent reductions in ground water and soil gas contamination will result. The implementation of this remedy does not pose as much of a decrease in the overall protection of human health and the environment as LPS#3. Proper control and application of the oxidant should result only in minor decreases to the overall protection of human health and the environment <u>during</u> the implementation of this remedial alternative. The implementation of this remedy alone may also leave untouched smaller, minor pockets of VOC contamination which would be less likely to degrade in an oxidizing environment.

LPS #6 – Phytoremediation – Like LPS#4, this alternative offers good (moderate to long term) prospects for the overall protection of human health and the environment with respect to all media, both on and off-site. However, compared to LPS#3 and LPS#5, this remedy does not succeed in supplying similar levels of protection to human health or the environment in the short term.

LPS #7 – Permeable Reactive Barriers – This alternative would not achieve any on-site increase in the overall protection of human health and the environment, but would significantly increase off-site protection of human health and the environment. This would be achieved by significant reductions in VOC ground water concentrations leaving the LPS Site due barrier wall reactions with dissolved VOC contaminants.

LPS#8 - Soil Vapor Extraction - This remedy will increase the overall protection of human health and the environment. SVE removes TCA from contaminated soils by flushing the subsurface with relatively clean, VOC-free air and transferring the TCA to carbon media. By removing the most significant source of contamination on site, subsequent reductions in ground water and soil gas contamination will result. This remedy may temporarily decrease the overall protection of human health and the environment due to the increased area and strength of exposure pathways to contaminated soil and soil gas during the construction and operation of the SVE system.

5.8 Community Acceptance

LPS #1: No Action – This alternative is evaluated throughout the Feasibility Study in compliance with the NCP to serve as a baseline for comparison with other alternatives. The No Action alternative will not likely result in strong community acceptance, although weak support of this alternative must be acknowledged due to the lack of interest or involvement by neighboring property owners, etc., in the industrial park area during the Phase II and Remedial Investigations.

LPS #2: Site Institutional Controls – This remedy is considered to be more acceptable to the immediate community around the LPS Site than the No Action alternative since it offers effective protection against all on-site contaminant pathways. Because no off-site protection is achieved with this remedial alternative, community acceptance is not expected to be strong if this is the only remedy implemented.

LPS #3 – Selected Soil Excavation and Removal – Moderate to high acceptance of this alternative is expected from those members of the community which desire a speedy cleanup of the LPS Site. However, some disapproval of the excavation and removal operations may occur from neighboring businesses and more distant residents of the Washington Heights and other Middletown neighborhoods through which contaminated soils would be hauled to an accepting landfill. An overall moderate acceptance of this alternative is recorded in Tables 15-18.

LPS #4 – Enhanced Bioremediation – This alternative was also projected to receive moderate acceptance by the community. Those members of the community who desire a speedy cleanup at the LPS Site might favor LPS#3 or LPS#5, but those who would object to the removal and transport activities required in LPS#3, might favor this remedy.

LPS #5 – In-Situ Oxidation (Hydrogen Peroxide Injection) – This alternative is projected to garner the greatest amount of community support since it does not entail disruptive and potentially dangerous excavation and removal activities, while still achieving most cleanup goals established by state and federal regulations.

LPS #6 – Phytoremediation – This alternative is projected to receive moderate to high acceptance by the community. Those members of the community who desire a speedy cleanup at the LPS Site might favor LPS#3 or LPS#5, but phytoremediation projects around the country have seldom been opposed due to the aesthetic benefits they yield in otherwise dilapidated or unappealing urban / industrial settings.

LPS #7 – Permeable Reactive Barriers – Both types of reactive barriers are projected to receive moderate community acceptance. Difficulty in implementation may detract from overwhelming acceptance of this remedy, especially from neighboring property owners, such as the Risdon Corp. The fact that this remedy only addresses off-site exposure pathways may also reduce the overall acceptance of this remedy if it is the only alternative implemented.

LPS#8 - Soil Vapor Extraction - Moderate acceptance of this alternative is expected from those members of the community which desire a speedy cleanup of the LPS Site. However, some disapproval of the SVE operations may occur from neighboring businesses and their employees during the operation of the SVE system which may create some noise and rely on some unsightly plumbing or equipment sheds. An overall moderate acceptance of this alternative is recorded in Tables 15-18.

5.9 Identification of Preferred Alternatives

As noted in Tables 15 -18 in Appendix B, an identification of preferred alternatives can be drawn from the FS analysis:

1. For ***On-Site Soil Remediation***, **In-situ Chemical Oxidation (LPS#5)** is the preferred remedy with a Matrix Score of 20.5, 3.5 points higher than any other remedial alternative or combination thereof. Based on the matrix scoring comparisons, LPS#5 is favored over all other remedies because it achieves high scores in short and long term effectiveness, reduction of soil toxicity, mobility and volume, ARAR compliance, overall protectiveness and community acceptance. It scores moderately high in the cost and implementability categories. The Enhanced Bioremediation and SVE alternatives scored a distant second for on-site soil remediation.

2. For ***On-Site Soil Gas Remediation***, **Institutional Controls (LPS#2)** is the preferred remedy with a Matrix Score of 19.5. However, one other remedy scored one point less than LPS#2 (In-Situ Chemical Oxidation). These two remedies scored highly for most of the performance criteria. Institutional Controls received no performance points in the Reduction of toxicity, mobility and volume category whereas the In-Situ Chemical Oxidation alternative posted moderately weak scores in the implementability and Overall Protectiveness categories. The Matrix Scoring Table for Soil Gas Remediation also scored the combination of Institutional Controls, Enhanced Bioremediation and Phytoremediation together. This trio of remedies scored the highest with 20.5 points.

3. For ***On-Site Ground Water Remediation***, **In-situ Chemical Oxidation (LPS#5) and Soil Vapor Extraction System (LPS#8)** are the preferred remedies with a Matrix Score of 17.5. Again, these remedies were the clear favorites based on the scoring system established in the Matrix Scoring Table. Enhanced Bioremediation was the secondary choice with a score of 16. However, the Ground Water Remediation Scoring Table also evaluated the combination of Institutional Controls, Enhanced Bioremediation and Phytoremediation together, as noted in the above discussion. This trio of remedies scored the same as the In-Situ Chemical Oxidation and SVE alternatives.

4. For ***Off-Site Ground Water Remediation***, the **Iron-Filled Permeable Reactive Wall (LPS#7 and the Soil Vapor Extraction System (LPS#8)** are the preferred remedies with a Matrix Score of 18. The Mulch-filled Permeable Reactive Wall and Enhanced Bioremediation were secondarily favored with scores of 16.5 each. The iron-filled reactive wall scored a "3" (maximum) in every category but cost and implementability, where it was assigned the lowest score of 0. The Off-Site Ground Water Remediation Scoring Table also evaluated the combination of Institutional Controls, Enhanced Bioremediation and Phytoremediation together. This combination of remedies, along with the mulch PRB remedy and the Enhanced Bioremediation remedy, scored in the second place category.

5. In summary, the following remedies are preferred, based on the matrix scoring system discussed above:

Media	1st Preferred Remedy	2nd Preferred Remedy
Soil Gas	Institutional Controls	In-Situ Chemical Oxidation
Soil	In-Situ Chemical Oxidation	Enhanced Bioremediation
Ground Water (On-Site)	In-Situ Chemical Oxidation	Soil Vapor Extraction
Ground Water (Off-Site)	Iron-filled Permeable Reactive Wall	Soil Vapor Extraction

6. Because the initial implementation of institutional controls at the LPS Site is not costly and does not interfere with other remedies, it appears that this remedy should be selected as the first component of any remedial action plan for the LPS Site.

7. Because some of the remaining remedies are not compatible with each other, or have predicted negative consequences, one or more of the remedies must be eliminated in favor of those remedies which will work best together for all contaminated media at the LPS Site. For example, if in-situ chemical oxidation and enhanced bioremediation remedies were both employed on the LPS Site, the additives injected for each respective remedy would have the effect of reacting with one another instead of destroying the VOC contaminants, since each additive influences the redox potential of soil and ground water in the opposite direction. In the same way, if in-situ chemical oxidation and a permeable reactive wall were used together, excess chemical oxidants in ground water would likely react with the permeable reactive wall, thus reducing the barrier's effectiveness and longevity. Lastly, if the SVE system is selected, the ground water pump and treat component of this system will draw contaminants from neighboring properties onto the LPS property, increasing the time it will take to reach remedial action cleanup standards and increasing future remedial work, cost and liabilities.

8. For reasons of high cost and difficult implementability, the iron-filled permeable reactive wall is recommended for elimination as a possible remedy.

9. An objective analysis of the matrix scoring system, based on USEPA's eight evaluation criteria, suggests that In-situ chemical oxidation is the preferred remedy to be used in conjunction with institutional controls at the LPS Site. While the SVE system achieved very similar matrix scores, it requires active ground water pumping to operate efficiently. Ground water pumping will increase off-site contributions of contaminants to the LPS property and hinder future remedial progress.

10. It should be noted that in-situ oxidation will require significant testing and study at the LPS site prior to full application. It will be required to radically reverse the current slow progress of natural attenuation via reductive dechlorination in a reducing environment in favor of a highly oxidizing environment. In-situ oxidation may also be hampered as an effective remedy due to the high volume of lubricants which have been spilled on this site along with TCA. These petroleum hydrocarbon based lubricants will consume oxidant just like TCA, and excessive volumes of oxidant may be required to eliminate TCA from the LPS subsurface. If, during the remedial design phase of this cleanup project, in-situ chemical oxidation is abandoned as a site-wide remedy due to cost, effectiveness during a pilot study, overall protection concerns or difficulty in implementation, the backup site-wide remedy for the site should be a combination of Enhanced Bioremediation and Phytoremediation. These remedies will accelerate the destruction of TCA via reductive dechlorination, which is already taking place at the LPS site. In this sense, these two remedies are more conservative than oxidation and have a higher probability of achieving New York State cleanup goals in the long run. However, compared to in-situ oxidation, they will require significantly more time to reach remedial action goals for soil and ground water.

11. The scoring system created for this FS weighted each performance category equally. That is, each of the eight performance criteria (short term effectiveness; long term effectiveness and permanence; reduction of toxicity, mobility & volume; implementability; cost; ARAR compliance; overall protectiveness; and community acceptance) were considered to be equally important criteria by which to select the remedy (or remedies) most appropriate for the LPS Site. However, at each contaminated site, some criteria are more important than others, depending on site specific factors. If, during the review of this FS, NYSDEC believes that weighting one or more of the performance criteria is appropriate, based on site-specific factors, a re-analysis of LPS#1 - LPS# 8 using this matrix scoring system could again be performed.

6.0 REPORT LIMITATIONS AND OMISSIONS

The data and remedy selections presented in this FS Report are based on the information available to the author from August 2002 to May 2003. The projections of remedial alternative costs were largely determined by costs incurred at other environmental cleanup sites as reported by the USEPA sponsored Federal Remediation Technologies Roundtable Publications, or similar sources. Site-specific engineering designs and analyses were avoided due to time and cost limitations, although a generic SVE system was designed for the site as per NYSDEC's request. This author has conducted the Feasability Study in a manner consistent with sound geologic, engineering and project management practices. No other warranty or guarantee, expressed or implied, is made. This report does not attempt to evaluate past or present compliance with federal, state and local environmental or land use laws and regulations. Furthermore, this author makes no guarantees regarding the completeness or accuracy of any information obtained from public or private files or previous investigations conducted near the LPS Site.

7.0 REFERENCES

A variety of technical documents and publications were used during the course of this project. Some of the references consulted are presented below. Referenced documents and publications may or may not have been reviewed in their entirety.

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Title 6, Chapter IV, Subchapter B, Part 375 - Inactive Hazardous Waste Disposal Site Remedial Program, New York State Regulations.

8.0 APPENDICES

A. FS Figures
B. FS Tables
C. LPS Remedy #2 – Site Institutional Controls - Supporting Documentation
D. LPS Remedy #3 – Selected Soil Excavation & Removal - Supporting Documentation
E. LPS Remedy #4 – Enhanced Bioremediation - Supporting Documentation
F. LPS Remedy #5 – In-Situ Oxidation - Supporting Documentation
G. LPS Remedy #6 – Phytoremediation - Supporting Documentation
H. LPS Remedy #7 – Permeable Reactive Barrier Walls - Supporting Documentation
I. LPS Remedy #8 – Soil Vapor Extraction (SVE) - Supporting Documentation
J. Sub-Slab Soil Gas Survey of the LPS Building, March 2003 - Letter Report & Results
K. Key LPS & NYSDEC Correspondences

FS Appendices

A. FS Figures

B. FS Tables

C. LPS Remedy #2 – Site Institutional Controls - Supporting Documentation

- Site Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups, USEPA
- Mitigating Indoor Air Quality Problems - Problem #3: Contaminant Entering Building from Outdoors

D. LPS Remedy #3 – Selected Soil Excavation and Removal - Supporting Documentation

- Federal Remediation Technologies Roundtable Screening Matrix & Reference Guide, FRTR
- TAGM #4046 - VOCs Soil Cleanup Criteria Table, NYSDEC
- "Northeast Tipping Fees", by Chris Campman, Manager Solid Waste, Gannett Fleming, Inc.
- Typical Soil Excavation Remedies, FRTR Web Site

E. LPS Remedy #4 – Enhanced Bioremediation - Supporting Documentation

- A Citizen's Guide to Bioremediation, USEPA
- Technical and Regulatory Requirements for Enhanced In Situ Bioremediation of Chlorinated Solvents in Groundwater, ITRC
- Use of Bioremediation at Superfund Sites, USEPA
- In Situ Bioremediation Using Hydrogen Release Compound or Molasses at Six Drycleaner Site, Various Locations, FRTR
- Acceleration of Bioremediation Using HRC at the LPS Site - September 20, 2002 Regenesis Proposal
- Hydrogen Release Compound, HRC: Low Cost Chlorinated Contaminant Treatment, Regenesis
- HRC Technical Bulletin #1.1.1: The Nature of Chlorinated Aliphatic Hydrocarbons (CAHs), Regenesis
- HRC Technical Bulletin #1.1.2: Biological Reductive Dechlorination of CAHs, Regenesis
- HRC Technical Bulletin #1.1.3: Using Organic Substrates to Promote Biological Reductive Dechlorination of CAHs, Regenesis
- HRC Technical Bulletin #1.1.4: Competition for Hydrogen between Reductive Dechlorinators and other Microorganisms, Regenesis
- HRC Technical Bulletin #1.3.1: Environmentally Safe, Regenesis
- HRC Technical Bulletin #3.1.2: HRC Injection TCE Remediation in Glacial Till Aquifer in Brighton, New York, Regenesis
- HRC Technical Bulletin #4.1.2: HRC and Iron Wall Technology, Regenesis
- HRC Technical Bulletin #4.1.3: HRC and Application of Organic Substrates, Regenesis
- HRC Technical Bulletin #4.1.4: HRC Application and Chemical Oxidants, Regenesis

F. LPS Remedy #5 – In-Situ Oxidation - Supporting Documentation

- A Citizen's Guide to Chemical Oxidation, USEPA
- In Situ Chemical Oxidation at Six Drycleaner Sites, Various Locations, FRTR
- Butler Cleaners, Jacksonville FL, FRTR
- In Situ Chemical Treatment, GWRTAC Technology Evaluation Report
- Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater, ITRC
- Field Applications of In Situ Remediation Technologies: Chemical Oxidation, USEPA

G. LPS Remedy #6 – Phytoremediation - Supporting Documentation

- A Citizen's Guide to Phytoremediation, USEPA
- Phytotechnology Technical and Regulatory Guidance Document, ITRC
- Phytoremediation, GWRTAC Technology Evaluation Report
- Introduction to Phytoremediation, USEPA
- Phytoremediation at Aberdeen Proving Grounds, Edgewood Area J-Field Site, Edgewood MD, FRTR
- Phytoremediation at Carswell Air Force Base, Fort Worth TX, FRTR
- Green II Landfill Phytoremediation Components, Hocking County, OH
- DOE Piketon Uranium Enrichment Facility Phytoremediation Estimates for TCE Cleanup

H. LPS Remedy #7 – Permeable Reactive Barrier Walls - Supporting Documentation

- A Citizen's Guide to Permeable Reactive Barriers, USEPA
- Regulatory Guidance for Permeable Reactive Barriers Designed to Remediate Chlorinated Solvents, ITRC
- Permeable Reactive Barriers, Section 7.0, Remediation Technology Cost Compendium, USEPA RTDF
- Cost and Performance Report: Permeable Reactive Wall Remediation of Chlorinated Solvents in Ground Water, ESTCP, USDOD
- Permeable Reactive Barrier Technologies for Contaminant Remediation, USEPA
- Field Applications of In Situ Remediation Technologies: Permeable Reactive Barriers, USEPA
- Permeable Reactive Subsurface Barriers for the Interception and Remediation of Chlorinated Hydrocarbon and Chromium (VI) Plumes in Ground Water, USEPA Remedial Technology Fact Sheet

I. LPS Remedy #8 – Soil Vapor Extraction (SVE) - Supporting Documentation

- A Citizen's Guide to Soil Vapor Extraction, USEPA
- Harris Environmental Letter and Generic Design Drawings
- Soil Vapor Extraction (SVE) at Seven Drycleaner Sites, USEPA

J. Sub-Slab Soil Gas Survey of the LPS Building, March 2003 - Letter Report and Results

K. Key LPS & NYSDEC Correspondences

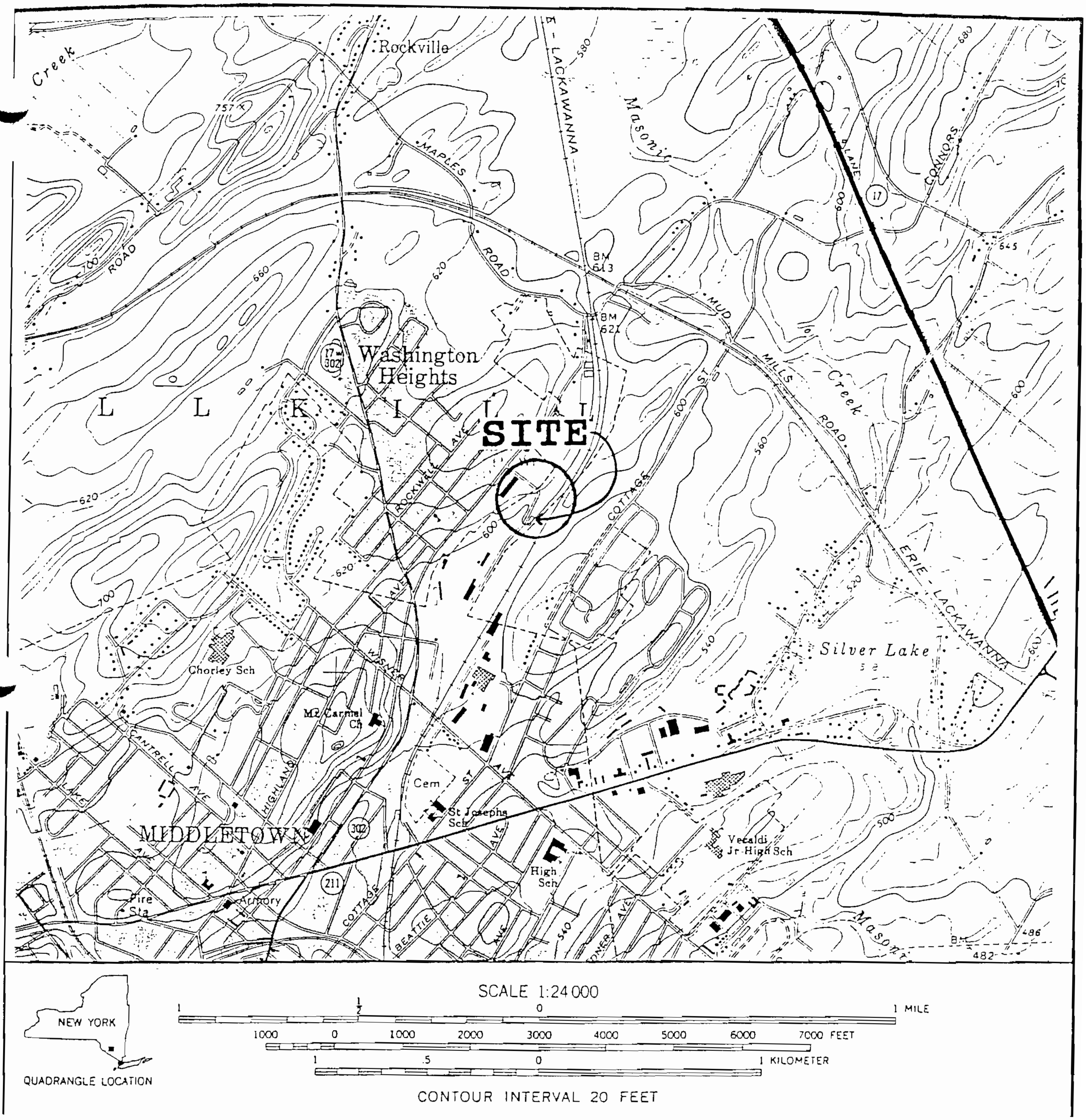


Figure 1
LPS Site Location Map
From Middletown, NY USGS Quad

SAINES ENVIRONMENTAL
SERVICES

S
Mr. Steven J. Saines
257 Midland Pl
Logan, OH 43138-1234

SES

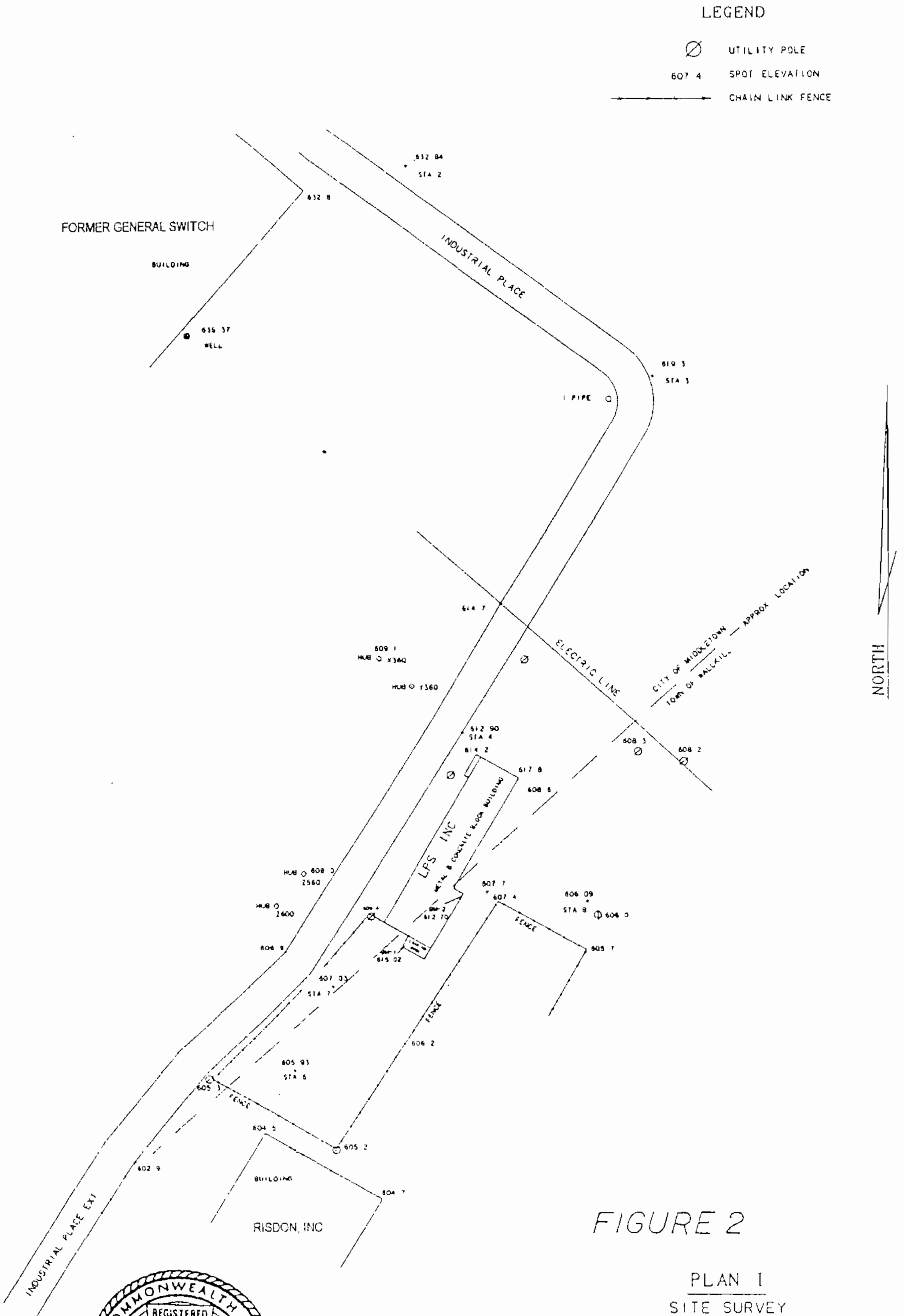


FIGURE 2

PLAN I

SITE SURVEY
VICINITY OF
LPS, INC.
SITUATE IN
CITY OF MIDDLETOWN & TOWN OF WALLKILL
ORANGE COUNTY, NEW YORK

SCALE 1 INCH = 155 FEET
DATE MARCH, 1993

GREGORY H. CLARK
LAND SURVEYOR
29248-E

SURVEY BY: Gregory H. Clark

GREGORY H CLARK, PE-PLS
PROFESSIONAL ENGINEER REG NO 36544-E
PROFESSIONAL LAND SURVEYOR NO 29248-E
P O BOX 461
CLARION, PA 16214

DATE OF SURVEY AUGUST 1992

[illegible] 3/29/93

Industrial Place Parcels
Middletown, NY

1, 14. Highland Park Village Apartments
2, 4, 5. Laurwal Holding Co. (Formerly General Switch)
3, 13. Orange & Rockland Utilities
6, 7. Wallace Oil Company
8. National Packaging Company
9, 10. Risdon Corporation
11. Lubricant Packaging, Inc.
12. Norfolk Southern RR

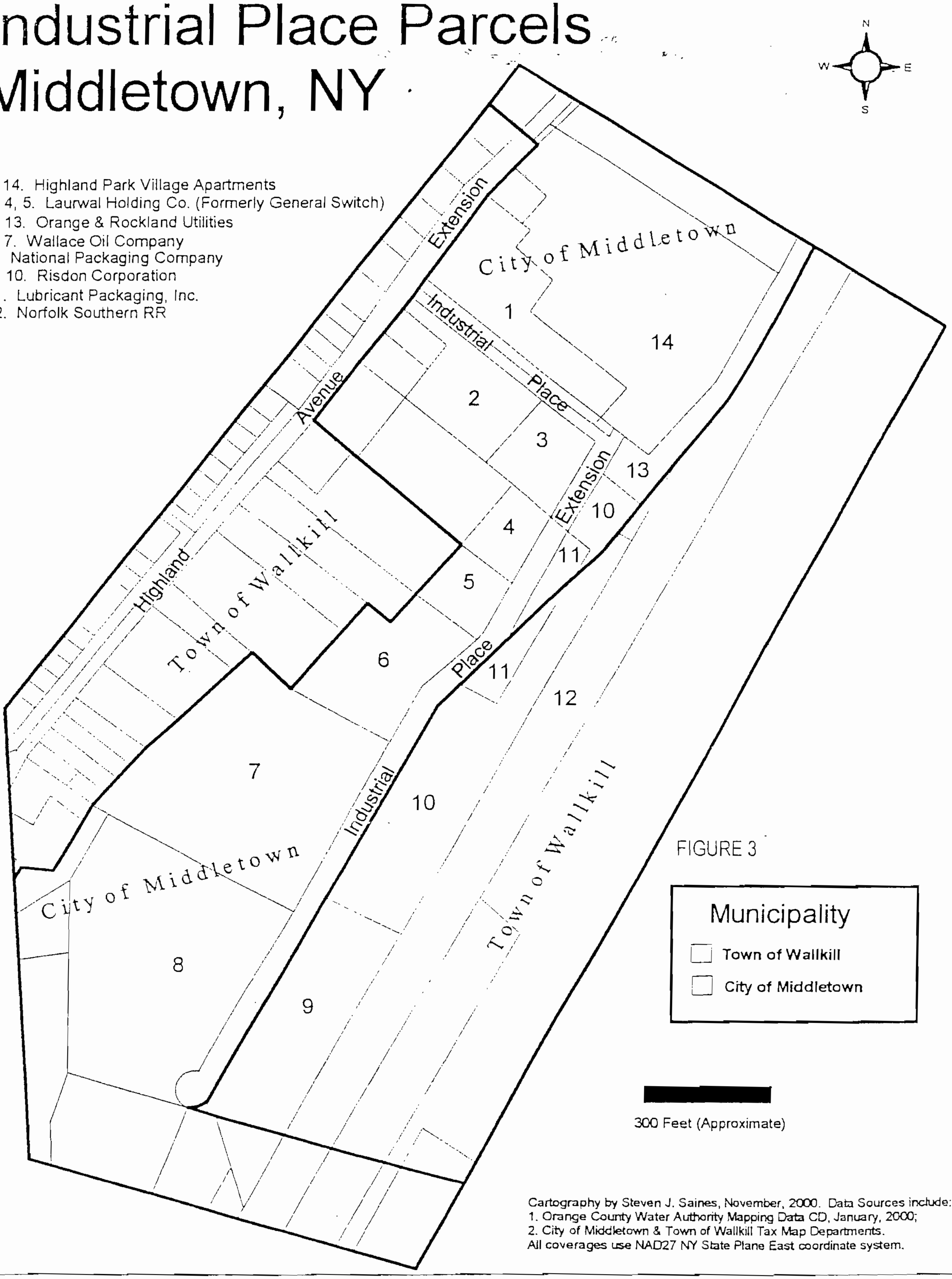
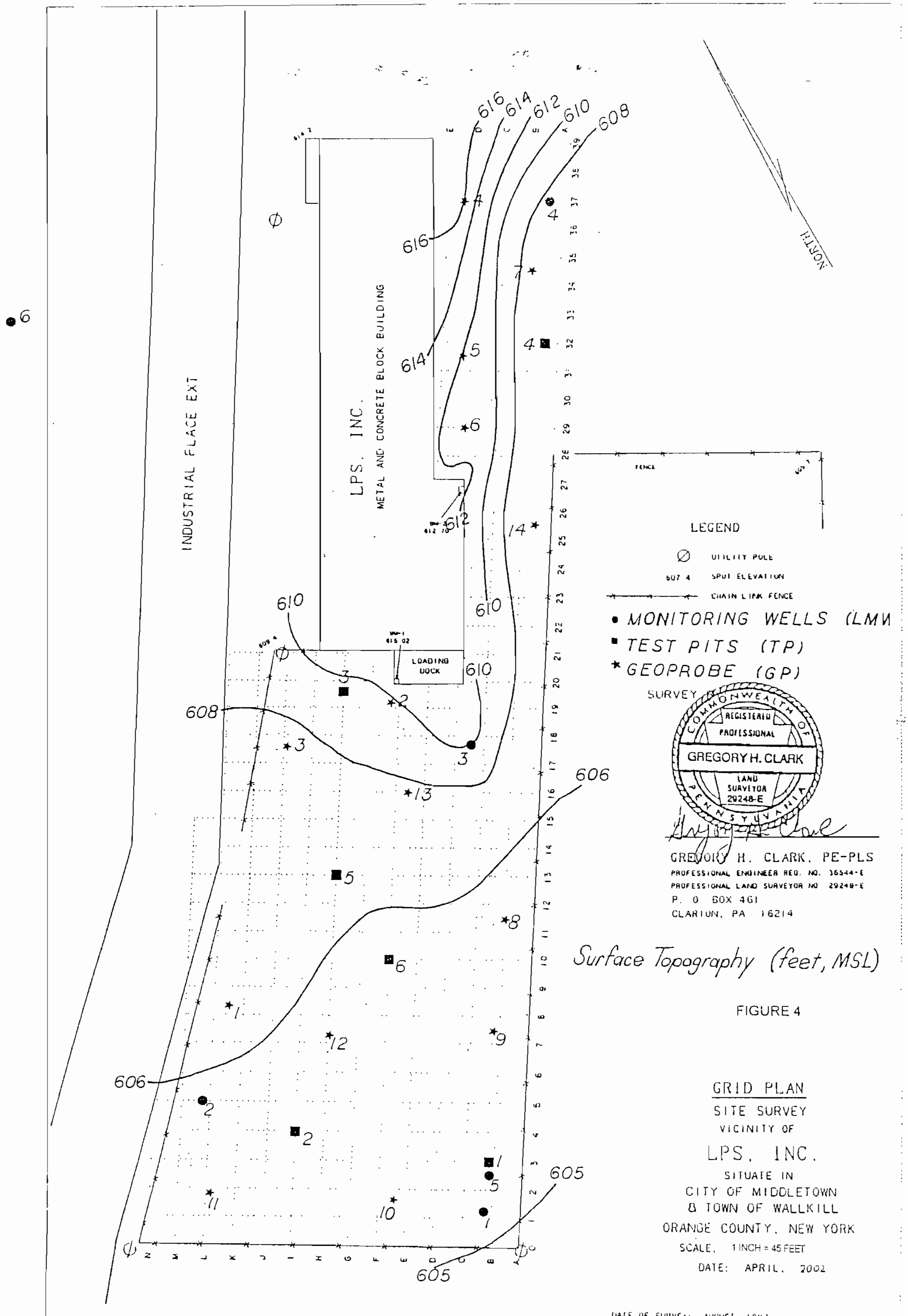


FIGURE 3

Cartography by Steven J. Saines, November, 2000. Data Sources include:
1. Orange County Water Authority Mapping Data CD, January, 2000;
2. City of Middletown & Town of Wallkill Tax Map Departments.
All coverages use NAD27 NY State Plane East coordinate system.



GREGORY H. CLARK
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29248-E

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PROFESSIONAL ENGINEER REG. NO. 36544-E
PROFESSIONAL LAND SURVEYOR NO 29248-E
P. O BOX 461
CLARION, PA 16214

Surface Topography (feet, MSL)

FIGURE 4

GRID PLAN
SITE SURVEY
VICINITY OF
LPS, INC.
SITUATE IN
CITY OF MIDDLETOWN
& TOWN OF WALLKILL
ORANGE COUNTY, NEW YORK
SCALE, 1 INCH = 45 FEET
DATE: APRIL, 2002

DATE OF SURVEY: AUGUST, 1992

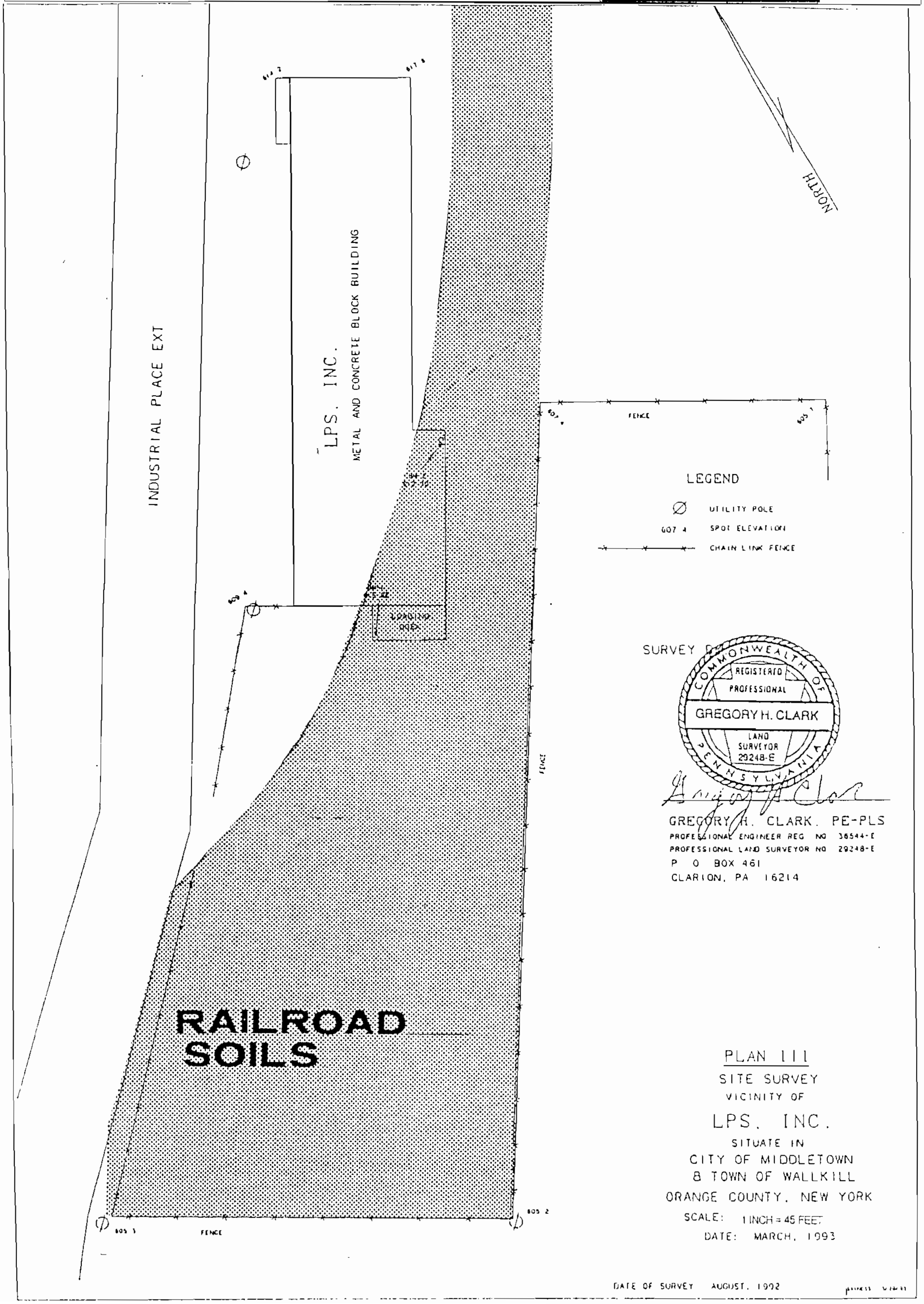
FIGURE 5

Surficial Materials Derived from Former Railroad Activities
LPS Site

SAINES ENVIRONMENTAL SERVICES

S Mr. Steven J. Saines
257 Midland Pl
Logan, OH 43138-1234

SES



SURVEY D

GREGORY H. CLARK
LAND SURVEYOR
29248-E

Gregory H Clark

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PLAN III
SITE SURVEY
VICINITY OF
LPS. INC.
SITUATE IN
CITY OF MIDDLETOWN
8 TOWN OF WALLKILL
ORANGE COUNTY. NEW YORK
SCALE: 1 INCH = 45 FEET
DATE: MARCH, 1993

DATE OF SURVEY AUGUST, 1992

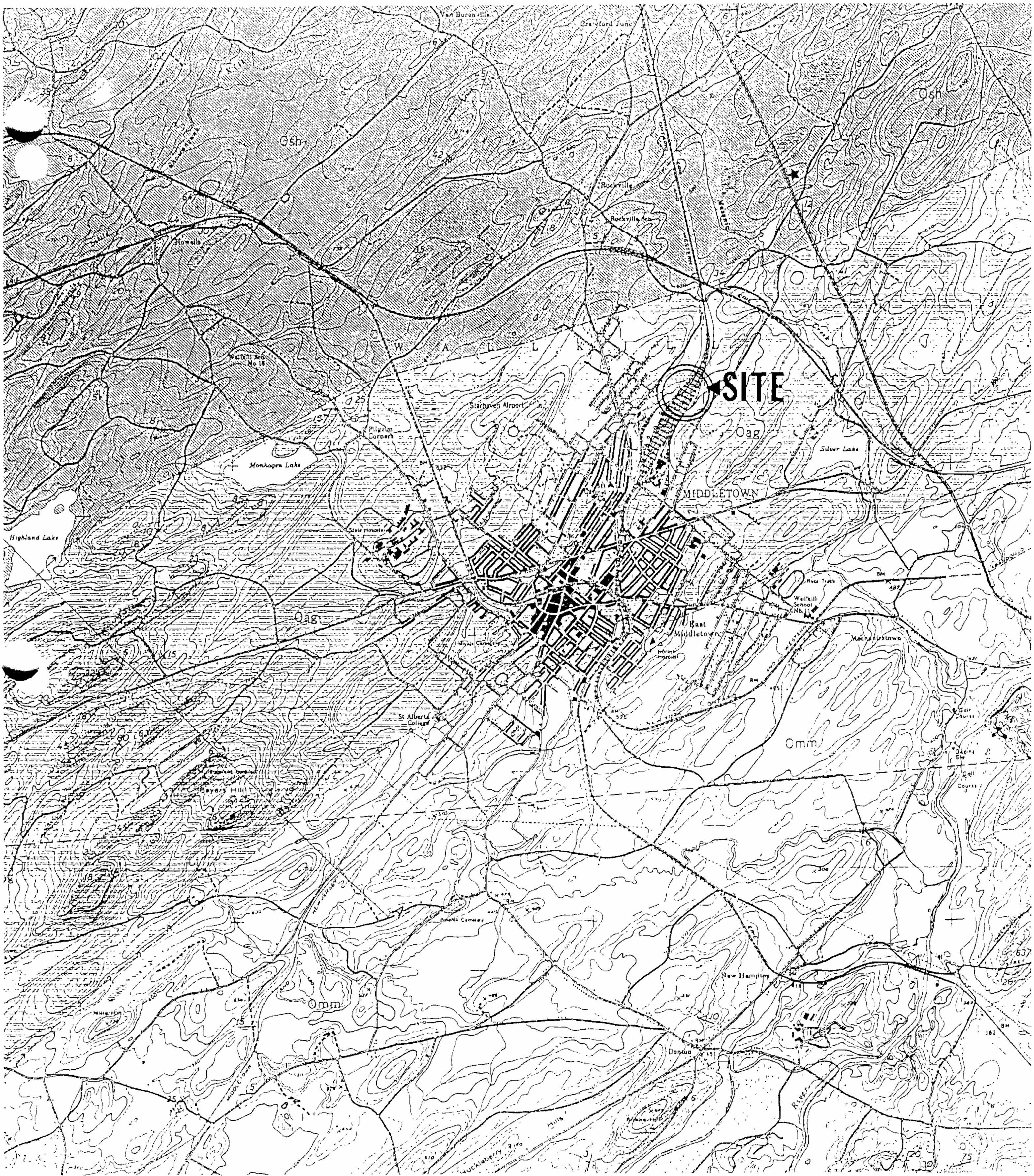

FIGURE 6

LPS Site, circa 1954
From Geology of the Goshen-
Greenwood Lake Area, NY,
Plate 1, (Offield, 1967)

SAINES ENVIRONMENTAL
SERVICES

S
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Logan, OH 43138-1234

SES

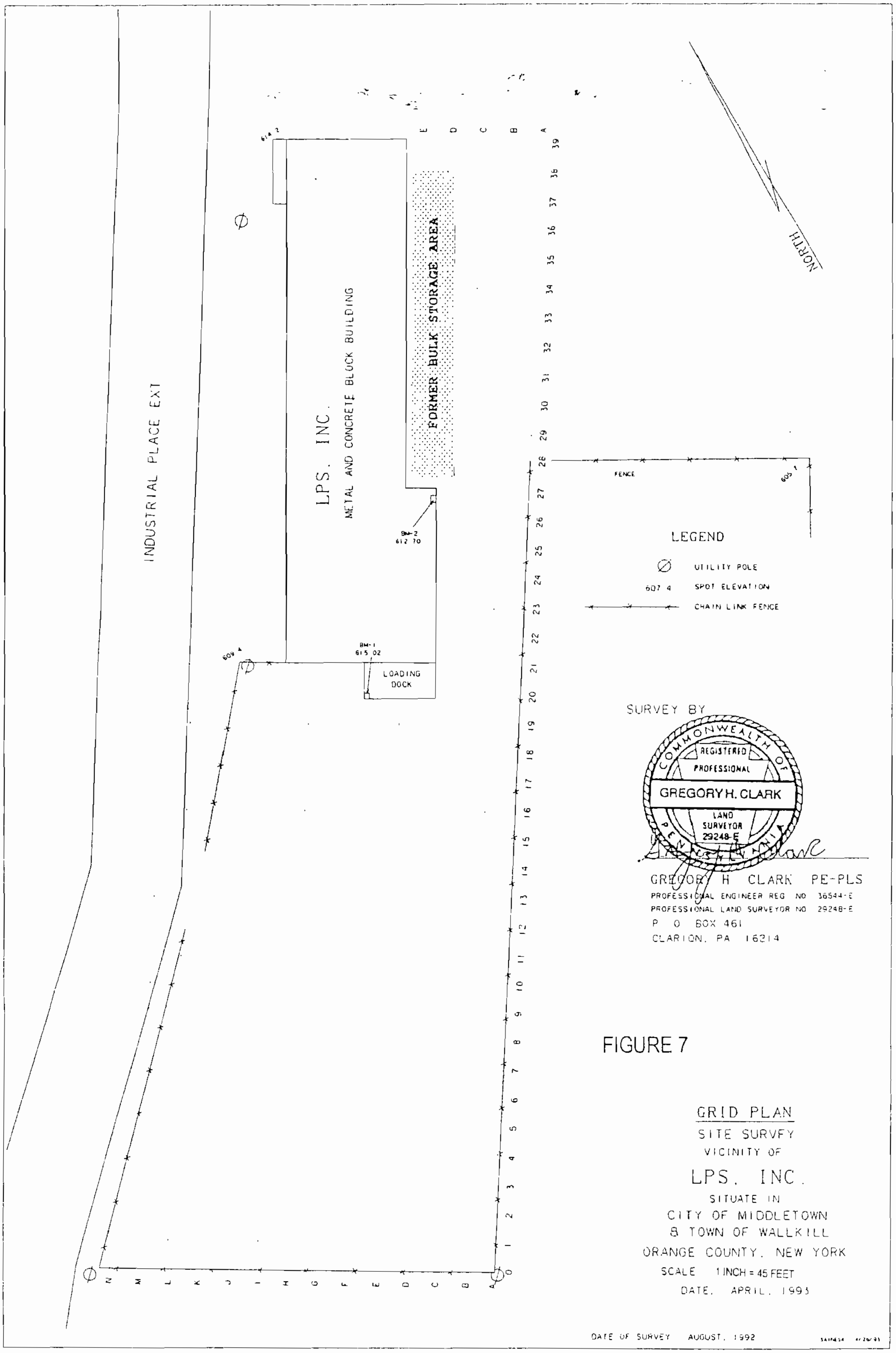

FIGURE 7

SURVEY BY

GREGORY H. CLARK
LAND SURVEYOR
29248-E

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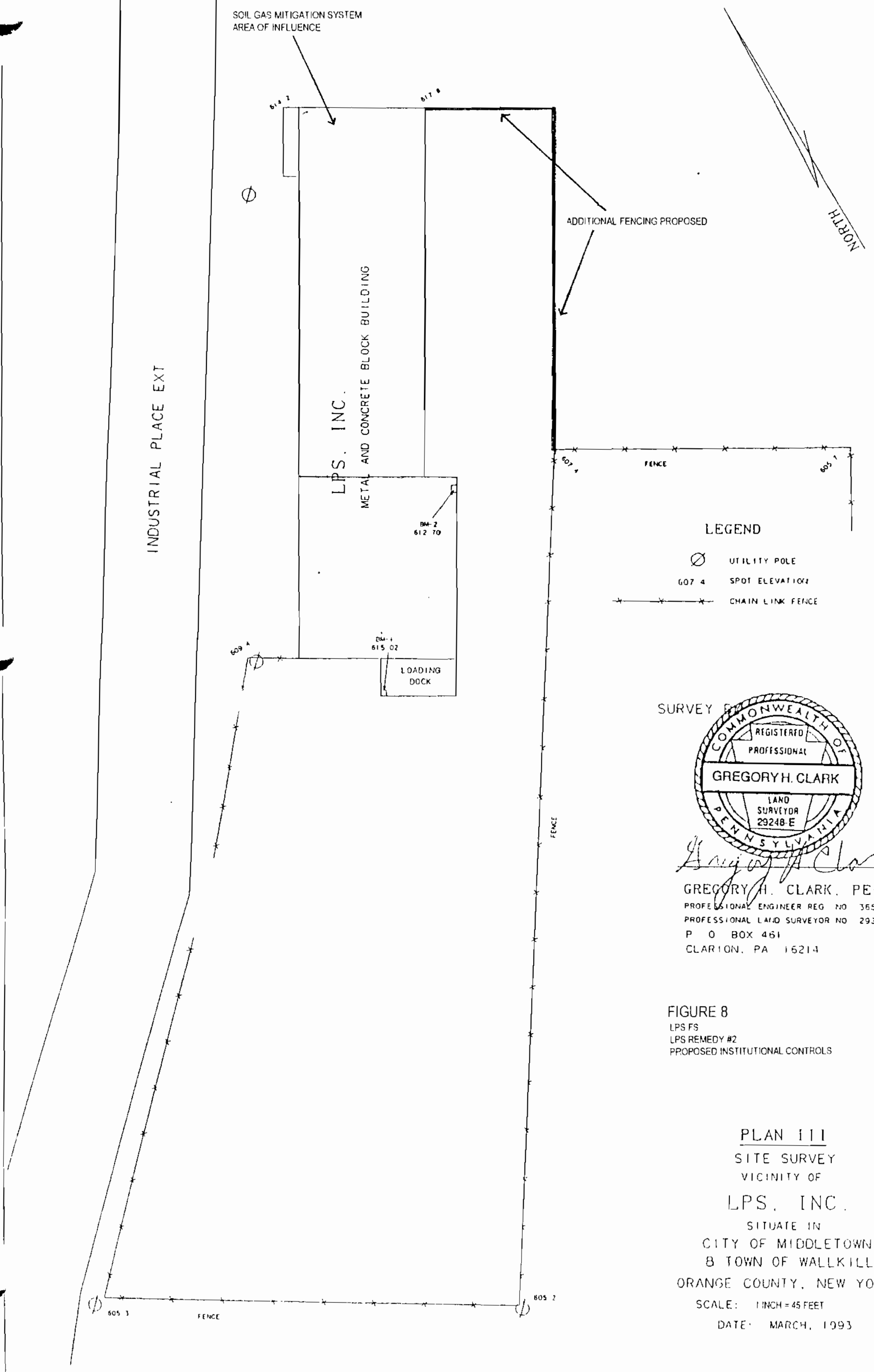
PROFESSIONAL ENGINEER REG. NO. 36544-E
PROFESSIONAL LAND SURVEYOR NO. 29248-E
P. O. BOX 461
CLARION, PA 16214

GRID PLAN
SITE SURVEY
VICINITY OF
LPS. INC.
SITUATE IN
CITY OF MIDDLETOWN
& TOWN OF WALLKILL
ORANGE COUNTY, NEW YORK
SCALE 1 INCH = 45 FEET
DATE: APRIL, 1993

DATE OF SURVEY AUGUST, 1992



SURVEY B

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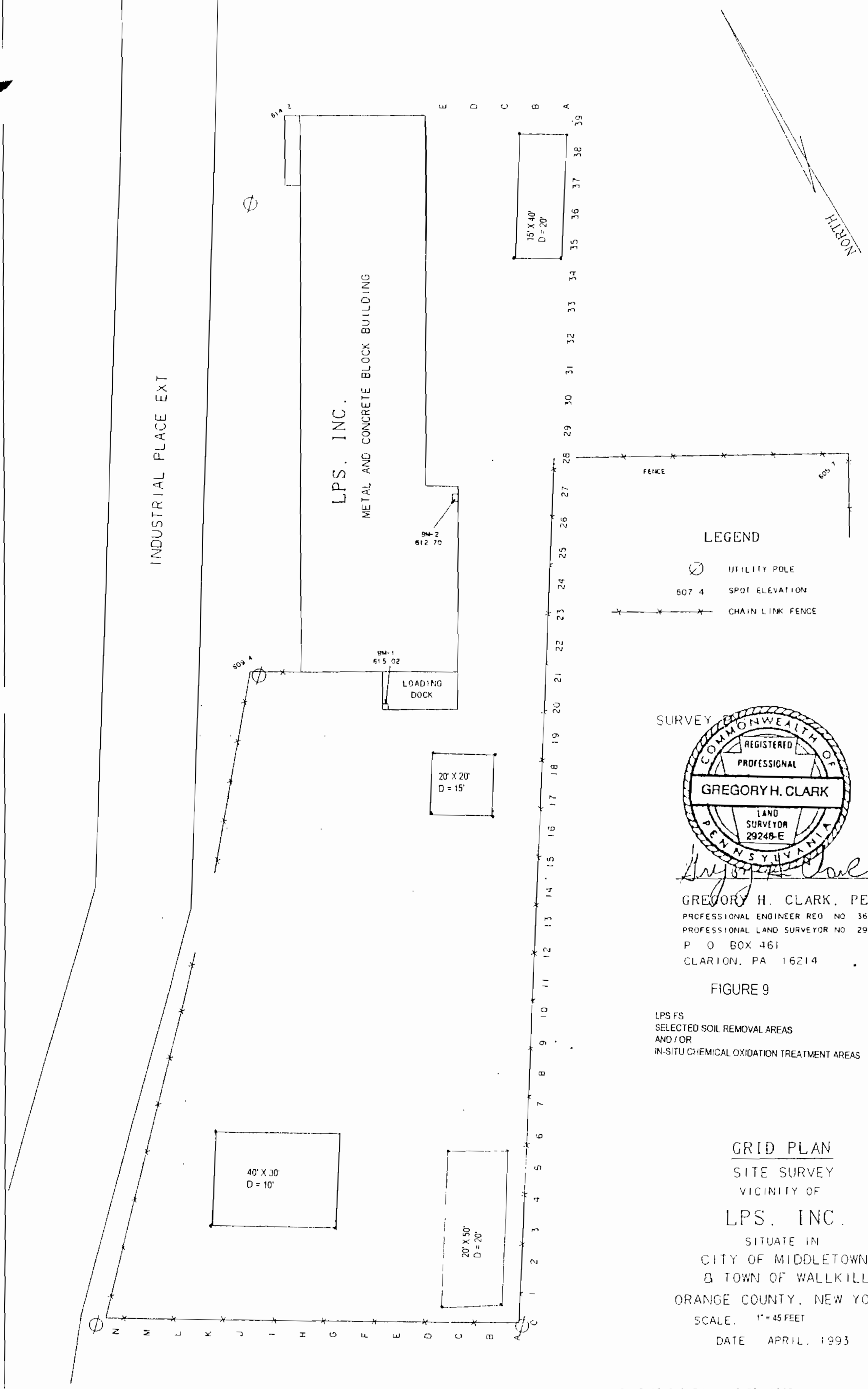
GREGORY H. CLARK, PE-PLS
PROFESSIONAL ENGINEER REG NO 35544-E
PROFESSIONAL LAND SURVEYOR NO 29248-E
P O BOX 461
CLARION, PA 16214

FIGURE 8
LPS FS
LPS REMEDY #2
PROPOSED INSTITUTIONAL CONTROLS

PLAN III
SITE SURVEY
VICINITY OF
LPS, INC.
SITUATE IN
CITY OF MIDDLETOWN
& TOWN OF WALLKILL
ORANGE COUNTY, NEW YORK
SCALE: 1 INCH = 45 FEET
DATE: MARCH, 1993

DATE OF SURVEY: AUGUST, 1992



SURVEY B

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FIGURE 9

LPS FS
SELECTED SOIL REMOVAL AREAS
AND / OR
IN-SITU CHEMICAL OXIDATION TREATMENT AREAS

GRID PLAN

SITE SURVEY
VICINITY OF
LPS, INC.
SITUATE IN
CITY OF MIDDLETOWN
& TOWN OF WALLKILL
ORANGE COUNTY, NEW YORK
SCALE. 1" = 45 FEET
DATE APRIL, 1993

DATE OF SURVEY, AUGUST, 1992

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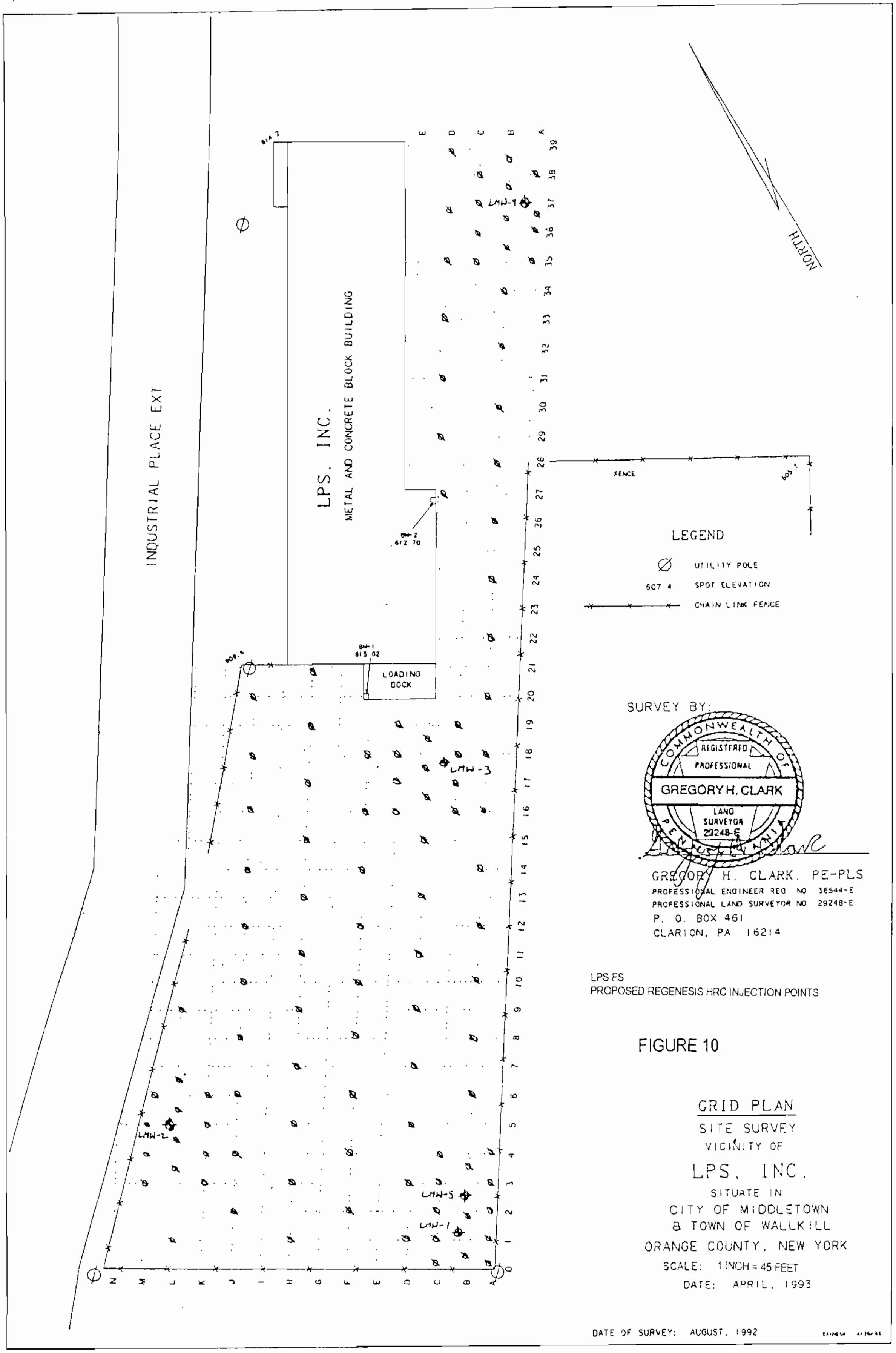


LEGEND

∅ UTILITY POLE

607.4 SPOT ELEVATION

—×—×— CHAIN LINK FENCE

SURVEY BY:

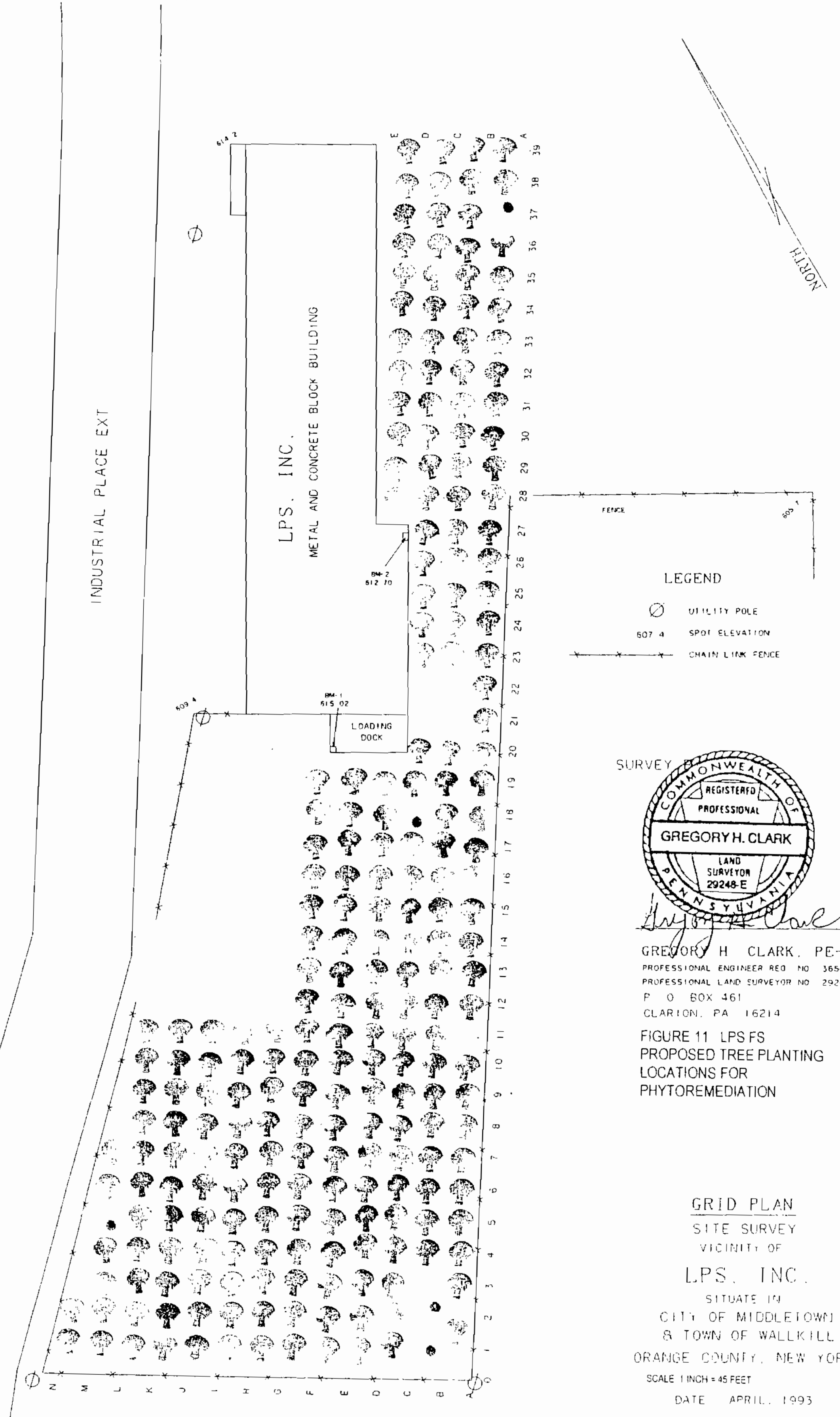
GREGORY H. CLARK. PE-PLS
PROFESSIONAL ENGINEER REG NO 36544-E
PROFESSIONAL LAND SURVEYOR NO 29248-E
P. O. BOX 461
CLARION, PA 16214

LPS FS
PROPOSED REGENESIS HRC INJECTION POINTS

FIGURE 10

GRID PLAN
SITE SURVEY
VICINITY OF
LPS, INC.
SITUATE IN
CITY OF MIDDLETOWN
& TOWN OF WALLKILL
ORANGE COUNTY, NEW YORK
SCALE: 1 INCH = 45 FEET
DATE: APRIL, 1993

DATE OF SURVEY: AUGUST, 1992



SURVEY

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Gregory H Clark

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CLARION, PA 16214

FIGURE 11 LPS FS
PROPOSED TREE PLANTING
LOCATIONS FOR
PHYTOREMEDIATION

GRID PLAN
SITE SURVEY
VICINITY OF
LPS. INC.
SITUATE IN
CITY OF MIDDLETOWN
& TOWN OF WALLKILL
ORANGE COUNTY, NEW YORK
SCALE 1 INCH = 45 FEET
DATE APRIL, 1993

DATE OF SURVEY AUGUST, 1992

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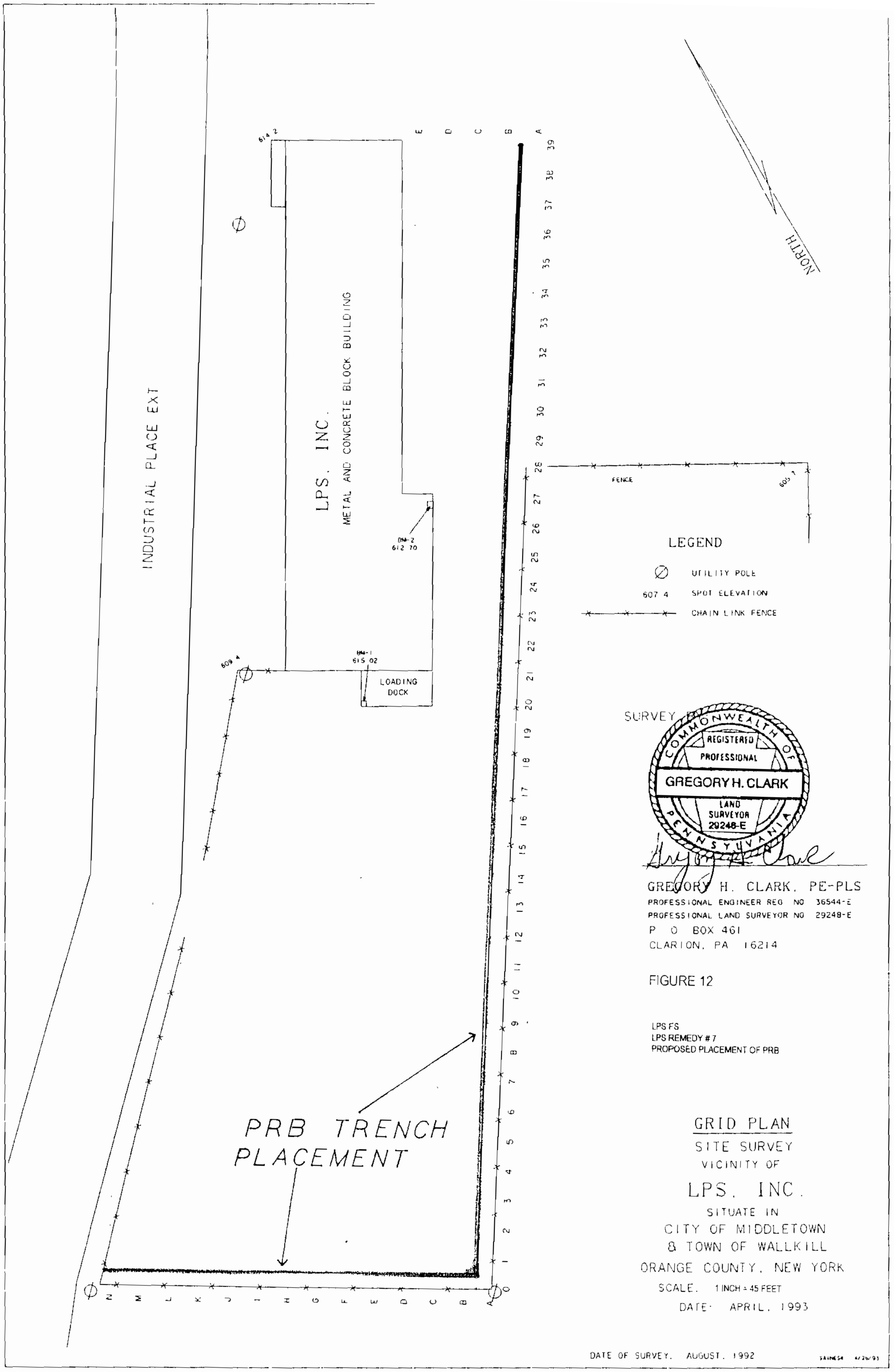

SURVEY BY

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PROFESSIONAL LAND SURVEYOR NO 29248-E
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CLARION, PA 16214

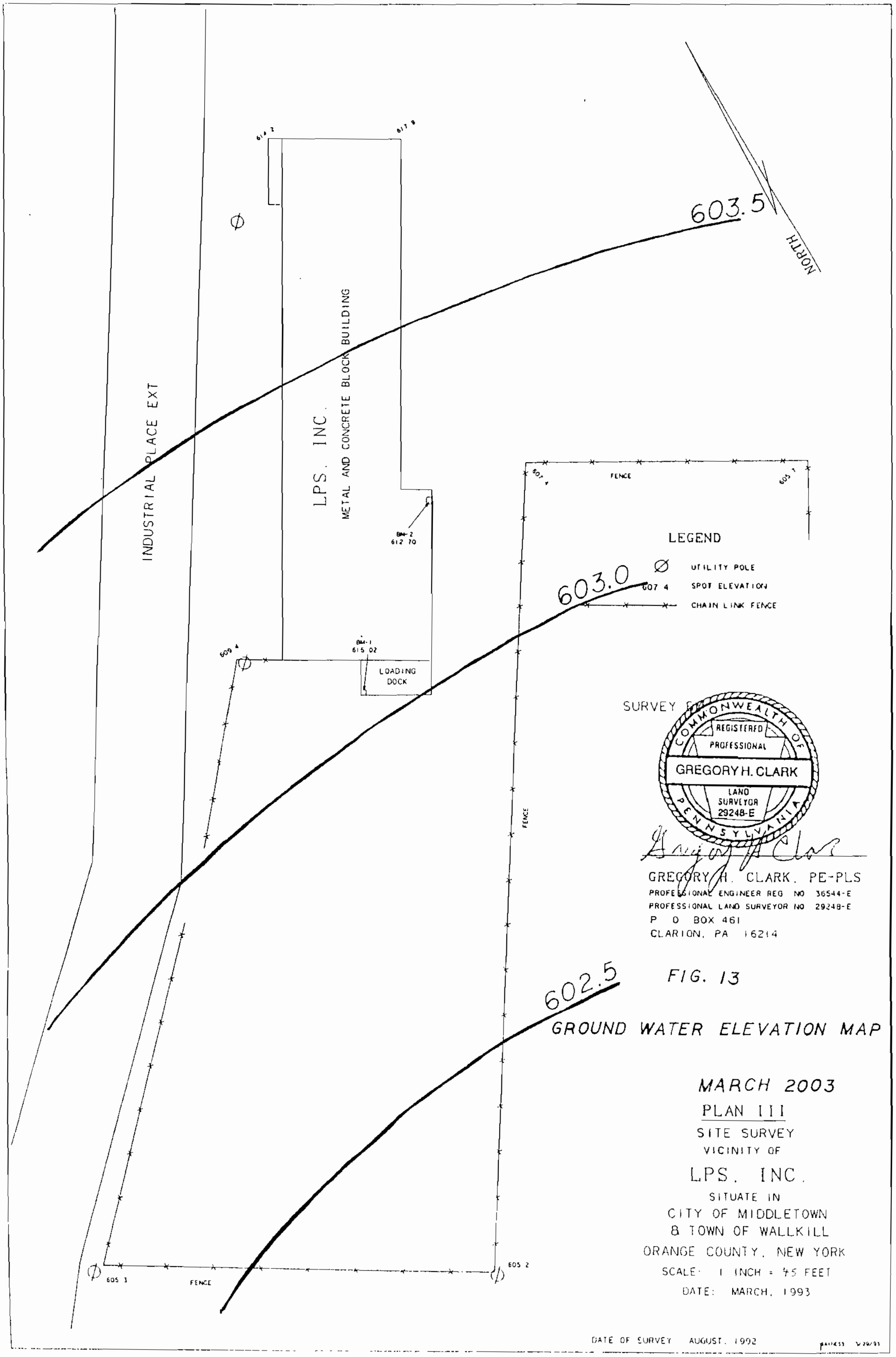
FIGURE 12

LPS FS
LPS REMEDY # 7
PROPOSED PLACEMENT OF PRB

GRID PLAN
SITE SURVEY
VICINITY OF
LPS. INC.
SITUATE IN
CITY OF MIDDLETOWN
& TOWN OF WALLKILL
ORANGE COUNTY, NEW YORK
SCALE. 1 INCH = 45 FEET
DATE: APRIL, 1993

DATE OF SURVEY. AUGUST, 1992

SAINES4 4/26/93



SURVEY S

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PROFESSIONAL LAND SURVEYOR NO 29248-E
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CLARION, PA 16214

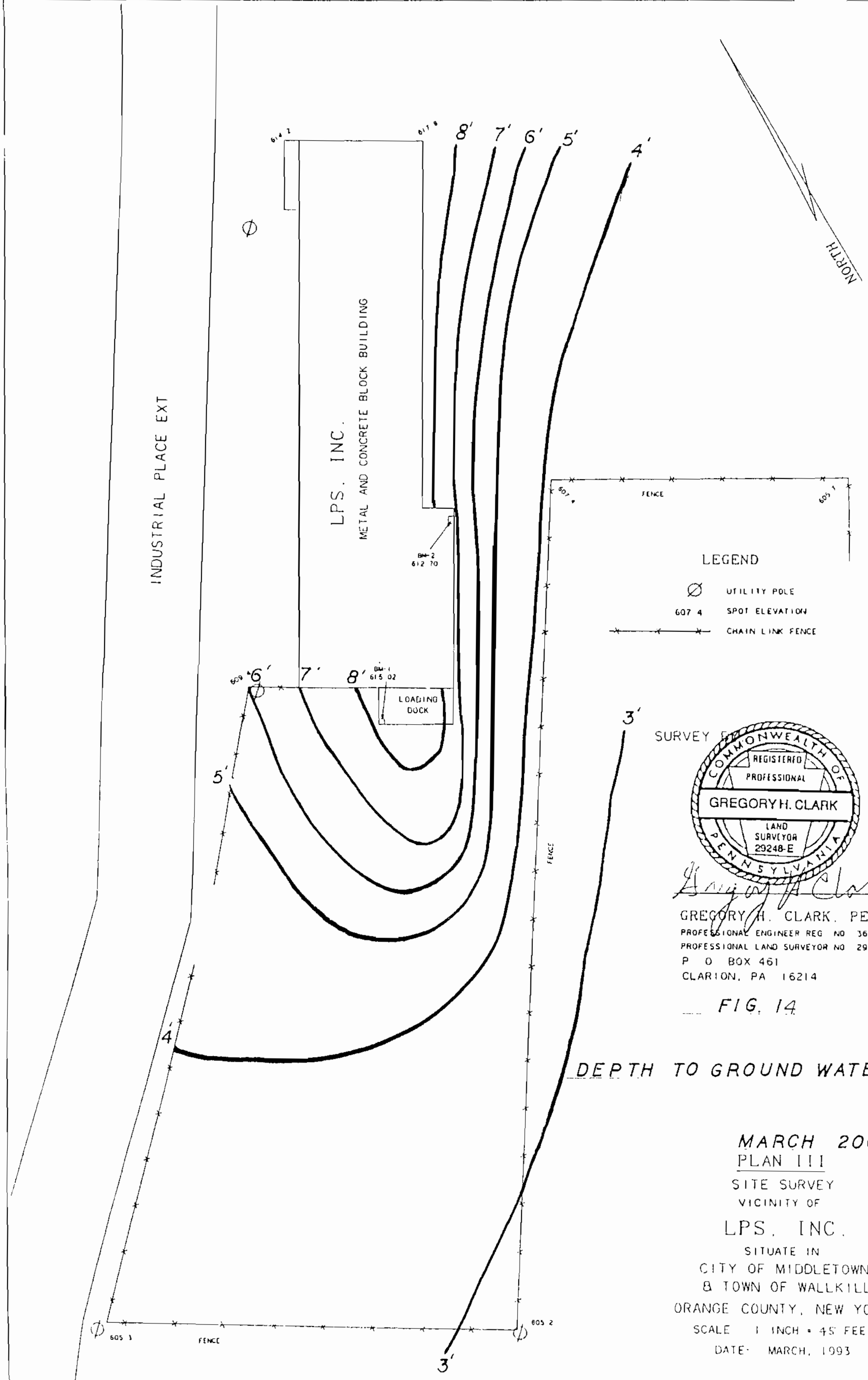
FIG. 13

GROUND WATER ELEVATION MAP

MARCH 2003

PLAN III
SITE SURVEY
VICINITY OF
LPS. INC.
SITUATE IN
CITY OF MIDDLETOWN
& TOWN OF WALLKILL
ORANGE COUNTY, NEW YORK
SCALE: 1 INCH = 45 FEET
DATE: MARCH, 1993

DATE OF SURVEY AUGUST, 1992



SURVEY

GREGORY H. CLARK
29248-E

Gregory H Clark

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PROFESSIONAL LAND SURVEYOR NO 29248-E
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CLARION, PA 16214

FIG. 14

DEPTH TO GROUND WATER

MARCH 2003
PLAN III
SITE SURVEY
VICINITY OF
LPS. INC.
SITUATE IN
CITY OF MIDDLETOWN
& TOWN OF WALLKILL
ORANGE COUNTY, NEW YORK
SCALE 1 INCH = 45 FEET
DATE: MARCH, 1993

DATE OF SURVEY AUGUST, 1992

TABLE 1
SECONDARY LPS TECHNOLOGY SCREENING

Technology	Screening Comment	Screening Conclusion
No Action No Action	Carried through the Feasibility Study as a Baseline.	Retained
Site Institutional Controls Fence in / Restrict all Contaminated Areas	May be Used Alone or in Conjunction with Other Technologies.	**Retained**
Remove Potential Soil Gases from Beneath the LPS Building	May be Used Alone or in Conjunction with Other Technologies.	**Retained**
Deed Restrict Drilling New Drinking Water Wells	May be Used Alone or in Conjunction with Other Technologies.	**Retained**
Monitoring	Ongoing Monitoring of Wells can Provide Information on Migration of Contamination and Level of Cleanup	**Retained**
Thermal Treatment Six Phase Soil Heating & Thermal Enhanced Vapor Extraction System & Incineration of Contaminated Soil	Technology may be inefficient for the concentrations of TCA expected. For that area in the capillary fringe and in the saturated zone, a large amount of energy will be used heating water. Incineration is more complicated and costly, less efficient than off-site disposal for this volume & type of cont.	Eliminated
Excavation Selected Soil Removal	Proven, Effective Technology for Removing Contaminated Soil in areas removed from structures or load bearing walls. Off-site disposal of soil in a permitted landfill will control future leaching of TCA. May be Used Alone or in Conjunction with other technologies	**Retained**
Aeration - Soil Soil Vapor Extraction & Air Sparging In-situ Enhanced Soil Mixing	Effective permeability of subsurface soils estimated to be low and variable, combined with relatively shallow contamination. These site properties make soil SVE inefficient / ineffective. Soil mixing will require some excavation & soil handling; treatment considered more difficult and costly than disposal.	Partially Retained (FS Revision 1)
Aeration - Ground Water Pumping & Aeration Pumping & Air Stripping Pumping & Liquid Phase GAC Pumping & Other Sorption Media	Subsurface permeability is limited. This technology is proven, but very slow at cont. mass removal. Continuous ground water removal will draw greater contaminant mass from upgradient and side gradient sources. Without participation of other PRPs, this remedy is deemed unsatisfactory.	Partially Retained (FS Revision 1)
In-situ Air Sparging In-Well Air Stripping Ground Water Recirculation Wells	Subsurface permeability is limited. These technologies may prove effective, but only with dense well spacing. Bio-fouling is expected with resulting maintenance. The ground water aeration technologies attack the secondary source of TCA contamination. Soil remediation attacks primary source of contamination. Soil treatment scenarios are considered more effective and direct.	Eliminated

Table Continues

TABLE 1 (continued)
SECONDARY LPS TECHNOLOGY SCREENING

Technology	Screening Comment	Screening Conclusion
In-Situ Chemical Treatment Oxidation (Hydrogen Peroxide Injection)	Innovative Technology with Limited Field Evaluation. Provides rapid in-situ destruction of contaminants. May reverse naturally occuring reductive dechlorination process in soil and ground water. May be Used Alone or in Conjunction with other technologies.	**Retained**
Passive Treatment Walls (Permeable Reactive Barrier Walls)	Difficulty in keying bottom of wall to bedrock. Limited working area around the down gradient property perimeter, although may consider emplacement technology other than trenching. Low maintenance.	**Retained**
In-Situ Biological Treatment Enhanced Bioremediation (includes Natural Attenuation Processes)	Innovative Technology with Limited Field Evaluation. Relatively easy treatment application. Treatment will occur both on-site and off-site. Uses a process which is already occuring at slower rates. Will address soil and ground water contamination. May be Used Alone or in Conjunction with other technologies	**Retained**
Phytoremediation (Hybrid Poplar, Willow, Sumac Tree Planting)	Innovative Technology with Limited Field Evaluation. Provides slow in-situ enhanced bioremediation of soil. Provides slow, low volume ground water treatment. May be Used Alone or in Conjunction with other technologies	**Retained**

TABLE 2
EVALUATION OF LPS REMEDIAL TECHNOLOGIES

General Response Action	Remedial Technology	Effectiveness	Implementability	Cost
No Action	Natural Attenuation	May not Achieve Remedial Action Goals.	Easily Implemented	None
Site Institutional Controls	Fencing - Restricts Site Access	Effective in Preventing Ingestion of Contaminated Soil On Site. May not Achieve Remedial Action Goals within a reasonable period of time.	Easily Implemented	Low Capital, Low O&M
	Soil Gas Remediation Beneath LPS Building.	Effective in Preventing Current & Future Exposure to Possible Harmful Levels of TCA in the LPS Building. May not Achieve Remedial Action Goals.	Possible to Construct Soil Gas Mitigation System, But May Require Future Refinement.	Low Capital, Low O&M
	Deed Restriction on New Wells Limit Aquifer Use Beneath LPS	Effective in Preventing Ingestion of Contaminated Ground Water On Site. May not Achieve Remedial Action Goals within a reasonable period of time.	Easily Implemented. Requires Local Ordinance Approval and Cooperation	Low Capital, Low O&M
	Ground-Water Monitoring	Useful for for Documenting Conditions. Does not Achieve Remedial Action Goals by Itself. Important Component of Most Remedial Actions	Easily Implemented With Existing Monitoring System. Additional wells possible.	Low Capital, Moderate-High O&M
Selected Soil Removal	Soil Excavation	Effective in Removing Known TCA Sources. Will Achieve Remedial Action Goals in LPS Soils. May not Immediately Clean Ground Water. Undiscovered TCA Hot Spots May Remain.	Readily Implemented with Traditional Construction Equipment. May be difficult to deliver to relatively impermeable soils.	Moderate-High Capital, Low-Moderate O&M
Enhanced Bioremediation	Accelerated Natural Attenuation Processes. (Innovative Technology)	Expected to Achieve Soil and Ground Water Cleanup Goals in the Moderate-Long Term.	Readily Implemented on the LPS Property. May be difficult to deliver to relatively impermeable soils.	Low-Moderate Capital, Moderate-High O&M
In-Situ Chemical Oxidation	Chemical Breakdown via Oxidation using Hydrogen Peroxide (Innovative Technology)	Will Achieve Soil Cleanup Goals in Areas where the Oxidant is Applied in Sufficient Doses, but will not Eliminate TCA in Soils where Oxidant is not Directly Applied. May not achieve Ground Water Cleanup Goals. May Reduce Natural Attenuation Rates.	Readily Implemented on LPS Property.	High Capital, Low-Moderate O&M
Phytoremediation	Rhizospheric Biodegradation Phytoremediaton-volatilization Phytoremediaton-degradation Hydraulic Control (Innovative Technology)	Effective in Containing & Removing Contaminants in the Long-Term. Therefore, may Achieve Cleanup Goals for Soil & Ground Water in the Long-Term. Will also Promote Natural Attenuation Processes.	Readily Implemented on LPS Property.	Low Capital, Moderate O&M
In-Situ Treatment Wall	Chemical Breakdown via Oxidation (Innovative Technology)	Will not Achieve Soil or Ground Water Cleanup Goals on LPS Property. Will Achieve Off-Site Ground Water	Challenging to Construct Properly.	High Capital, Low O&M
Soil Vapor Extraction (SVE)	Soil Gas Vacuuming	Will achieve soil cleanup goals in contaminated areas when groundwater table is depressed and piping network is sufficiently dense.	Moderately difficult to implement due to seasonally high ground water and the requirement to cap the surface to control atmospheric short-circuiting.	Moderate - High Capital Moderate - High O+M

Table 3
Ground Water Elevation Information, March 2003
LPS Site, Middletown, NY

Well Identification	Aquifer Material	Ground Surface Elevation (ft)	Top of NC Cosing Elevation (ft)	Ground Water Elevation (ft)	Depth to Ground Water (ft below ground surface)
LMW-1	Till	605.4	607.7	602.4	3.0
LMW-2	Till + Fractured Bedrock	606.2	607.9	602.6	3.6
LMW-3	Till	610.0	611.7	602.9	7.1
LMW-4	Till	608.5	610.7	603.6	4.9
LMW-5	Competent Bedrock	605.2	607.4	601.7	NA

Table 4: Selected Institutional Controls - LPS Site

	Initial Capital Costs
Deed Restriction	$1,000
Soil Gas Mitigation System Installation	$2,500
Complete Fencing Perimeter of Site	$1,500
Capital Cost for Institutional Control Components: Subtotal	**$5,000**

Additional Costs for an Institutional Control Remedy	Annual O+M	Present Worth
Long-Term Project Management ($3000 per year x 25 years)	$3,000	$46,866
Long-Term Ground Water Monitoring (2 semi-annual sampling events for 25 years)	$8,000	$124,976
Soil Gas Mitigation System - Maintenance	$1,000	$15,622
Institutional Control - Additional Costs Subtotal		**$187,464**

Institutional Control Remedy - Estimated Total Present Worth Value (Present worth calculated by assuming 4% average annual return on capital over the next 25 years.)	**$192,464**

Table 5: Hazardous Waste Soil Excavation Cost Estimates - LPS Site

Excavation Area	LMW-1,5 Area	TP-2 Area	LMW-3 Area	LMW-4 Area	Totals
Dimensions (LxWxH) (ft)	20' x 50' x 20'	30' x 40' x 10'	20' x 20' x 15'	15' x 40' x 20'	
Volume (ft3)	20000	12000	6000	12000	50000
Volume (yd3)	741	444	222	444	1852
Weight (Tons) [Assume 2632.5 lb/yd3]	975	585	293	585	2438
Excavation & Disposal Costs [Year 2004 Capital Costs]	$429,000	$257,400	$128,700	$257,400	**$1,072,500**
[Average Cost (Haz Waste) = $440 / ton] *					**Subtotal**
Includes excavation, transportation, disposal, analytical, labor					

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Additional Costs - Hazardous Waste Soil Removal Remedy	Initial Capital Costs	Annual O+M	Percent Worth
Replace 3-4 Monitoring Wells	$15,500	$0	$15,500
($3500 per shallow well, $5000 per deep bedrock well)			
Additional Down Gradient Monitoring Wells	$18,000	$0	$18,000
(as discussed in the Ground Water Monitoring Cost Worksheet)			
Short-Term Ground Water Monitoring	$0	$8,000	$35,616
(2 semi-annual sampling events for 5 years)			
Short-Term Project Managment	$0	$5,000	$22,260
($5000 per year x 5 years)			
Second Mobilization Contingency (Adjusted, assuming implementation in	$55,527	$0	$55,527
(Remove additional soils in areas of persistent contamination)			
Hazardous Waste Soil Removal - Additional Costs Subtotal			**$146,903**
			Subtotal

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Hazardous Waste Soil Removal - Estimated Total Costs	**$1,219,403**
(Present worth calculated by assuming 4% average annual return on capital over the next 25 years.)	

* USEPA and Federal Remediation Technologies Roundtable, June, 2002, [http://www.frtr.gov/matrix2/section4/4-29.html]

Hazardous waste disposal costs ranged nationally from $270 to $460 / ton. Highest costs in CA and Northeast US.

Using higher Northeast US averages, $440 was chosen ~ 4 times non-hazardous rates.

Table 6: Non-Hazardous Waste Soil Excavation Cost Estimates - LPS Site

Excavation Area	LMW-1,5 Area	TP-2 Area	LMW-3 Area	LMW-4 Area	Totals
Dimensions (LxWxH) (ft)	20' x 50' x 20'	30' x 40' x 10'	20' x 20' x 15'	15' x 40' x 20'	
Volume (ft3)	20000	12000	6000	12000	50000
Volume (yd3)	741	444	222	444	NA
Weight (Tons) [Assume 2632.5 lb/yd3]	975	585	293	585	2438
Excavation & Disposal Costs [Year 2004 Capital Costs]					
[Avg Cost (Non- Haz Waste) = $110 / ton] *					
Includes excavation, transportation, disposal, analytical, labor	$107,250	$64,350	$32,175	$64,350	**$268,125** **Subtotal**

Additional Costs - Non-Hazardous Waste Soil Removal Remedy	Initial Capital Costs	Annual O+M	Present Worth
Replace 3-4 Monitoring Wells ($3500 per shallow well, $5000 per deep bedrock well)	$15,500	$0	$15,500
Additional Down Gradient Monitoring Wells (as defined in the Ground Water Monitoring Cost Worksheet)	$18,000	$0	$18,000
Short-Term Ground Water Monitoring (2 semi-annual sampling events for 5 years)	$0	$8,000	$35,616
Short-Term Project Managment ($5000 per year x 5 years)	$0	$5,000	$22,260
Second Mobilization Contingency (Adjusted, assuming implementation in year 2006.) (Remove additional soils in areas of persistent contamination)	$55,527	$0	$55,527
Non-Hazardous Waste Soil Removal - Additional Costs Subtotal			**$146,903** **Subtotal**
Non-Hazardous Waste Soil Removal - Estimated Total Present Worth Value			**$415,028**

(Present worth calculated by assuming 4% average annual return on capital over the next 25 years.)

* Based on NY/NJ/PA Non-Hazardous rate assumptions (2002):

$60/ton disposal fee x 2500 tons	$150,000
12 days of excavation and backfilling work @ ~$1000/day	$12,000
$15/ton hauling fee	$37,500
25 samples, TCLP analytical for landfill @ $900	$22,500
20 samples, analytical for confirmation sampling @ $200	$4,000
14 days of oversight work @ $750/day	$10,500
$15/ton backfill material	$37,500
Total	$274,000
2500 tons of contaminated soil / $274,000 = $110/ton	$110

Table 7: Enhanced Bioremediation Cost Estimates - LPS Site *

	Initial Capital Cost	Annual O+M	Present Worth
Treatment Zone Volume*	122850 (ft3)		
Soil Bulk Density	1.76 (g/cm3)		
HRC Delivery Points	$110		
Amount of HRC / Point	60 (lb)		
Total Amount of HRC Required	6600 (lb)		
HRC Cost @ 5.75 / lb	$37,950	$0	$37,950
HRC Shipping Costs from CA	$6,250	$0	$6,250
Injection Costs (6 days @ $2000)	$12,000	$0	$12,000
Project Oversight @ $750/day	$4,500	$0	$4,500
Equipment Rental	$1,800	$0	$1,800
Cost of Bioremediation Components	**$62,500**		**$62,500**
		Subtotal	

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Additional Costs for the Enhanced Bioremediation Remedy

	Initial Capital Cost	Annual O+M	Present Worth
Mid-term Project Management ($4000 per year for 15 years)	$0	$4,000	$44,472
Second Mobilization Contingency: (Adjusted, assuming implementation in 2009) (Injection of HRC in areas of persistent contamination)	$12,359	$0	$12,359
Ground Water Monitoring (Mid-Term) (2 semi-annual sampling events for 15 years)	$0	$8,000	$88,944
Additional Down Gradient Monitoring Wells (as discussed in the Ground Water Monitoring Cost Worksheet)	$18,000	$0	$18,000
Additional Cost for Analysis of Natural Attenuation Parameters (15 years)	$0	$1,500	$16,677
Enhanced Bioremediation Additional Costs Subtotal			**$180,452**

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Enhanced Bioremediation Remedy - Estimated Total Present Worth Value			**$242,952**

(Present worth calculated by assuming 4% average return on capital over the next 25 years.)

* Based on Regenesis Evaluation & Quote, Appendix E

Table 8: In-Situ Chemical Oxidation Cost Estimates - LPS Site

Excavation Area	LMW-1,5 Area	TP-2 Area	LMW-3 Area	LMW-4 Area
Dimensions (LxWxH) (ft)	20' x 50' x 20'	30' x 40' x 10'	20' x 20' x 15'	15' x 40' x 20'
Volume (ft3)	20000	12000	6000	12000
Volume (yd3)	741	444	222	444
In-Situ Oxidation Costs (Year 2004 Capital Costs) [Average Cost = $110 / yd3] *	$81,481	$48,889	$24,444	$48,889
Includes design, implementation and initial monitoring of oxidant injections.			Subtotal	**$203,704**

Additional Costs for the Chemical Oxidation Remedy	Initial Capital Costs	Annual O+M	Present Worth
Pilot Test	$50,000	$0	$50,000
Short-Term Project Management ($5000 per year x 5 years)	$0	$5,000	$22,260
Short-term Ground Water Monitoring (2 semi-annual sampling events for 5 years)	$0	$8,000	$35,616
Additional Down Gradient Monitoring Wells (as discussed in the Ground Water Monitoring Cost Worksheet)	$18,000	$0	$18,000
Second Mobilization Contingency (Assume Implementation in 2006) (Re-inject oxidant in areas of persistent contamination)	$46,272	$0	$46,272
Chemical Oxidation - Additional Costs Subtotal			**$172,148**
Chemical Oxidation - Estimated Total Present Worth Value (Present worth calculated by assuming 4% average annual return capital over the next 25 years.)			**$411,468**

* Based on Comparable costs incurred at:
Butler Cleaners, Jacksonville, Fl & 6 Dry Cleaner Sites (KS - 1, WI - 1, Fl - 4)
USEPA and Federal Remediation Technologies Roundtable, June, 2002, [http://www.frtr.gov/matrix2/section4/4-29.html]

Table 9: Phytoremediation Cost Estimates - LPS Site *

Approximate surface area with potential contamination = 30,000 ft2
Proposed Tree density ~ 1/100 ft2
Less 20% (60 trees), to alllow for accessibility to the site.
Calculated # of Trees = 300 - 20% (60) = 240 Trees.
(Year 2004 Costs)

Site Preparation:	$5,000
Tree Planting Costs ($80/tree) x 240	$19,200
Estimated Cost for Phytoremediaton Components:	**$24,200**
	Subtotal

Additional Costs for a Phytoremediation Remedy	Initial Capital Costs	Annual O+M	Present Worth
Annual O&M (tree maintenance x 25 years)	$0	$1,500	$23,433
Long-Term Ground Water Monitoring (2 semi-annual sampling events for 25 years)	$0	$8,000	$124,976
Long-term Project Management ($3000 per year for 25 years.)	$0	$3,000	$46,866
Pest, drought or blight contingency (replacement/care) (Adjusted, assuming implementation in year 2009)	$8,239	$0	$8,239
Add Down Gradient Monitoring Wells	$18,000	$0	$18,000
Phytoremediation Additional Costs Subtotal			**$221,514**
Phytoremediation Remedy - Estimated Total Present Worth Value:			**$245,714**

(Present worth value calculated by assuming 4% average annual return on capital over the next 25 years.)

* Based on Costs incurred at the following remediation sites: (Appendix G)
Aberdeen Proving Grounds, MD (Federal Remediation Technologies Roundtable Case Studies, EPA-C-02-004, June 2002)
Carswell AFB, Texas (Federal Remediation Technologies Roundtable Case Studies, EPA-C-02-004, June 2002)
DOE Piketon Enrichment Facility, OH (Appendix G)
Green II Landfill, OH (Appendix G)

Table 10: Permeable Reactive Barrier Cost Estimates - LPS Site

	Linear Length (feet)	Depth to Bedrock (Average) (feet)	Width of Trench (Proposed)(feet)	Wall Volume (ft3)
Reactive Wall Segment A (from LMW-1 to LMW-4)	375	20	1	7500
Reactive Wall Segment B (from LMW-1 to SE fence corner)	115	15	1	1725
Total Volume				9225
Iron Filings Barrier Wall: Average Cost for Installation = $93/ft3. * Includes Trenching Costs & Iron Filings Purchase (Year 2004 Costs)				**$857,925** Subtotal
Mulch Barrier Wall: Average Cost for Installation. ** $1/ft3 for mulch fill + ($250/linear foot of trench). (Year 2004 Costs) (Costs include Design, Construction & Oversight of Construction)				**$131,722** Subtotal

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Additional Costs for the Permeable Reactive Barrier Remedy	Initial Capital Costs	Annual O+M	Present Worth
Long-term Project Management: ($4000 per year x 25 years)	$0	$3,000	$46,866
Long-term Ground Water Monitoring. (2 semi-annual sampling events for 25 years)	$0	$8,000	$124,976
Additional Down Gradient Monitoring Wells: (as discussed in the Ground Water Monitoring Cost Worksheet)	$18,000	$0	$18,000
Permeable Reactive Barrier Wall - Additional Costs Subtotal			**$189,842**

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Reactive Barrier Wall (Mulch) - Estimated Total Present Worth Value	**$321,564**
Reactive Barrier Wall (Iron Filings) - Estimated Total Present Worth Value (Present worth value calculated by assuming 4% average annual return on capital over the next 25 years.)	**$1,047,767**

* From USEPA Cost Analyses for Selected Ground Water Cleanup Projects: Pump and Treat Systems and Permeable Reactive Barriers. National Service Center for Environmental Publications, Cincinnati, OH. EPA 542-R-00-013, February 2001, and @ clu-in.org

** From "Mulch Biowall Used to Treat TCE-Contaminated Ground Water, USEPA Technology News and Trends, Ground Water Currents, Issue No. 1. National Service Center for Environmental Publications, Cincinnati, OH. , EPA 542—02-003, July 2002.

Table 11: Soil Vapor Extraction (SVE) Cost Estimates - LPS Site

Contaminated Soil Area	LMW-1,5 & TP-2 Area	LMW-3 Area	LMW-4 Area	Totals
Surface Dimensions (LxW) (ft x ft)	(20' x 50') & (20'x 20')	20' x 20'	15' x 40'	
Dimensions plus 20' per edge for capping (ft x ft)	One Area = 90' x 200'	60 x 60'	55 x 80'	
Minimum surface area to be capped (ft2)	18000	3600	4400	26000
Contaminated Soil Volume (ft3)	32000	6000	12000	50000
Capping Cost Estimate (assume $5/ft2)	$90,000	$18,000	$22,000	$130,000
SVE Equipment (Air & Ground Water)				
Pilot testing & design				$25,000
4 LRP Units (soil gas & ground water removal)	$30,000	$15,000	$15,000	$60,000
Materials, installation, housing	$15,000	$8,000	$10,000	$33,000
Estimated Capital Costs for SVE System			Subtotal	**$248,000**

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Additional Costs - SVE Remedy (with Engineering & Hydrologic Controls)	Initial Capital Costs	Annual O&M	Present Worth
Air & Ground Water Treatment Equipment Operation (5 Years)		$9,000	$40,068
GAC Air Treatment Costs ssuming $2/ft3 cont. soil x 50,000 ft3)		$20,000	$89,040
GAC Ground Water Treatment Costs (Assuming 2 gpm for 5 years > 5,250,000 gal @ $12/1000 gal)		$12,500	$55,650
Short Term Ground Water Monitoring Costs (2 semi-annual sampling events for 5 years)		$8,000	$35,616
Short Term Project Management ($5000 per year for 5 years)		$5,000	$22,260
Additional Down Gradient Monitoring Wells	$18,000		$18,000
SVE System Additional Costs Subtotal			**$260,634**

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SVE System Remedy - Estimated Total Present Worth Value **$508,634**

(Present worth calculated by assuming 4% average annual return on capital over the next 25 years.)

Cost Estimates based on comparable costs incurred at:

1. Soil Vapor Extraction (SVE) at Seven Drycleaner Sites, Various Locations (5 Florida, 1 WI, 1 OR)

USEPA and Federal Remediation Technologies Roundtable, June, 2002, [http://www.frtr.gov/matrix2/section4/4-29.html]

2. Also, cost estimates for treatment costs from: Cost Analyses for Selected Groundwater Cleanup Projects: Pump and Treat Systems and Permeable Reactive Barriers

USEPA Solid Wase and Emergency Response (EPA 542-R-00-013, February 2001)

Also, design criteria from Harris Environmental, Inc. (See Appendix I)

Table 12: Ground Water Monitoring Cost Estimates - LPS Site

	No. Wells	No. Sampling Events	Cost Per Unit	Cost (Year 2004)	Present Worth
Monitoring Wells					
Existing Site Wells:	5				
Up gradient Wells (General Switch: MW-6 +/or MW-9)	2				
Install down gradient wells * (Possible on Risdon or Middletown Industrial Development Property)	3		$6,000	$18,000	$18,000
Total Monitoring Wells	10				
Short-term Monitoring Requirements (Up to 5 years)** (5 years semi-annual monitoring)		10	$8,000	$16,000	$71,232
Mid-term Monitoring requirements (5 - 15 years)** (15 years semi-annual monitoring)		30	$8,000	$16,000	$177,888
Long-term Monitoring Requirements (15 - 25 years)** (25 years semi-annual monitoring)		50	$8,000	$16,000	$249,952
Natural Attenuation Parameters - Additional Analytical Cost					
($1500 per sampling event) - 15 years			$1,500	$1,500	$16,677
($1500 per sampling event) - 25 years			$1,500	$1,500	$23,433

(Present worth calculated assuming 4% average annual return on capital over the next 25 years.)

* Higher cost per unit well due to off-site status of wells.

** Assume sampling 12 wells per sampling event (10 wells + blank + duplicate).
(12 x $125 = $1500, lab) + ($2500 labor) = $4000)

Table 13: Remedy Cost Comparisons - LPS Site

Remedial Alternative	Capital Expenses (Including Contingencies)	Annual Operation & Maintenance (incl. monitoring & management)	Expected Duration of Remedial Action (years)	Present Worth Value O&M (2004 Dollars)	Present Worth Value of Remedy (2004 Dollars)
Site Institutional Controls	$5,000	$12,000	25	$187,464	$192,464
Soil Removal: Hazardous	$161,527	$13,000	5	$57,876	$1,219,403
Soil Removal: Non-Hazardous	$357,152	$13,000	5	$57,876	$415,028
Enhanced Bioremediation	$92,859	$13,500	15	$150,093	$242,952
In-Situ Chemical Oxidation	$317,976	$13,000	5	$57,876	$375,852
Phytoremediation	$50,439	$12,500	25	$145,275	$245,714
Treatment Wall: Iron Filings	$875,925	$11,000	25	$171,842	$1,047,767
Treatment Wall: Mulch	$149,722	$11,000	25	$171,842	$321,564
Soil Vapor Extraction with ground water Treatment	$266,000	$54,500	5	$242,634	$508,634
Site Institutional Controls & Enhanced Bioremediation & Phytoremediation	$130,298	$14,500	10	$117,610	$247,908
Soil Removal: Non-Hazardous & Treatment Wall: Mulch & Site Institutional Controls	$493,874	$14,000	5	$62,328	$556,202

(Present worth calculated by assuming 4% average annual return on capital over the next 25 years.)

TABLE 14
ARARs FOR LPS REMEDIAL ACTION PROGRAM

Medium	Requirement	Applicable or Relevant and Appropriate	Requirement Synopsis	Action to be Taken to Attain ARAR
	State Regulatory Requirements			
Ground Water, Surface Water	6 NYCRR 700-706 Classifications and Standards of Quality and Purity.	Relevant and Appropriate	Establishes ambient surface water and ground-water quality standards and ground-water effluent standards.	Standards will be considered in alternative evaluation
Ground Water	10 NYCRR 170 Drinking Water Standards	Relevant and Appropriate	Establishes drinking water standards for common organic and inorganic chemicals and action levels for lead and copper in public drinking water.	Standards will be considered in alternative evaluation
Air	6 NYCRR 256-260 Air Quality Classification System, Classifications and Standards	Relevant and Appropriate	Establishes an air quality classification system and air quality standards, and provides geographical classifications.	Standards will be considered in alternative evaluation
Soil	NYSDEC TAGM # 4046 Recommended Soil Cleanup Standards	Relevant and Appropriate	Establishes a recommended soil cleanup level for state lead remedial sites.	Standards will be considered in alternative evaluation
Indoor Air	NYSDOH Indoor Air Standards Based on background data.	Relevant and Appropriate	Establishes a proposed indoor air standard for businesses which do not use the contaminants of concern.	Standards will be considered in alternative evaluation
	Federal Regulatory Requirements			
Ground Water	40 CFR 141 Subparts B, G and I Federal Safe Drinking Water Maximum Contaminant Levels (MCLs) for Organic and Inorganic Chemicals	Relevant and Appropriate	Establishes MCLs for common organic and inorganic chemicals and action levels for lead and copper in public drinking water	Standards will be considered in alternative evaluation
Ground Water	40 CFR 141 Subpart F Federal Safe Drinking Water Maximum Contaminant Level Goals (MCLGs) for Organic and Inorganic Chemicals	Relevant and Appropriate	Establishes MCLGs for organic and inorganic contaminants	Standards will be considered in alternative evaluation
Ground Water	40 CFR 143.3 Federal Safe Drinking Water National Secondary Maximum Contaminant Levels	To be Considered	Establishes guidelines to control contaminants that affect aesthetic qualities of water	Standards will be considered in alternative evaluation
Ground Water	40 CFR 141 Federal Safe Drinking Water Proposed MCLs for Synthetic Inorganic and Organic Chemicals	To be Considered	Establishes MCLs for organic and inorganic contaminants	Standards will be considered in alternative evaluation
Water	Federal Drinking Water Health Advisories	To be Considered	Health advisories indicating non-carcinogenic effects of contaminants	Will be considered
Air	40 CFR 50 National Ambient Air Quality Standards	To be Considered	NAAQS are enforced through state regulations	Will be considered

Table 15: On-Site Soil Remedies1	Short-term Effectiveness (soil mitigation) [0 - 5 years]	Long-term Effectiveness (soil mitigation) [5 - 25 years]	Reduction of Soil Toxicity, Mobility Volume	Implementability (Ease of)	Cost	ARAR Compliance (for soil cleanup)	Overall Protectiveness (soil exposure)	Community Acceptance	Total Score
No Action	0	.5	0	3	3	0	0	1	7.5
Institutional Controls	0	.5	0	2.5	3	0	2.5	2.5	11
Selected Soil Removal-Hazardous	2.5	2.5	0	.5	0	2.5	2.5	2	12.5
Soil Removal Non-Hazardous	2.5	2.5	0	1	1.5	2.5	2.5	2	14.5
Enhanced Bioremediation	1.5	3	2.5	2	2.5	1.5	2	2	17
In-situ Chemical Oxidation	2.5	2.5	3	1.5	2	3	3	3	**20.5**
Phytoremediation	1	2.5	2	2.5	2	1.5	1.5	2.5	15.5
Permeable Reactive Wall - Iron Filings	0	0	0	0	0	0	0	2	2
Permeable Reactive Wall - Mulch	0	0	0	0	2	0	0	2	4
Soil Vapor Extraction with Hydrologic + Engineering Controls	2.5	3	2.5	1	1	2.5	2.5	2	17
Institutional Controls & Enhanced Bioremediation & Phytoremediation	1.5	3	2.5	2	2	1.5	2	2.5	17
Soil Removal & Mulch Reactive Wall & Inst. Controls	3	3	0	1	1	3	2.5	2	15.5
Matrix Scoring Legend for **On-Site Soil Remedies**	0 - none 1 - low 2- moderate 3 - high	0 - none 1 - low 2- moderate 3 - high	0 - none 1 - low 2- moderate 3 - high	0 - great effort 1 - mod.effort 2 - little effort 3 - no effort	> $ 1 m - 0 $.5 -1 m - 1 $1/4-.5 m - 2 < $ 1/4 m - 3	0 - no compl. 1 - low compl. 2- mod. compl. 3 - high compl.	0 - no protect 1 - low prot. 2- mod. prot. 3 - high prot..	0 - none 1 - low 2- moderate 3 - high	

Table 16: On-Site Soil Gas Remedies	Short-term Effectiveness **(soil gas exposure)** [0 - 5 years]	Long-term Effectiveness **(soil gas exposure)** [5 - 25 years]	Reduction of **Soil Gas** Toxicity, Mobility & Volume	Implementability (Ease of)	Cost	ARAR Compliance **(for soil gas cleanup)**	Overall Protectiveness **(soil gas exposure)**	Community Acceptance	Total Score
No Action	0	.5	0	3	3	0	0	1	7.5
Institutional Controls	3	3	0	2.5	3	2	3	3	**19.5**
Selected Soil Removal-Hazardous	2.5	2.5	0	.5	0	2	2	2	11.5
Soil Removal Non-Hazardous	2.5	2.5	0	1	1.5	2	2	2	13.5
Enhanced Bioremediation	1.5	3	2.5	2	2.5	1.5	1.5	2	16.5
In-situ Chemical Oxidation	2.5	2.5	2.5	1.5	2	2.5	2	3	18.5
Phytoremediation	.5	2	2	2.5	2	.5	1	2.5	13
Permeable Reactive Wall - Iron Filings	0	0	0	0	0	0	0	2	2
Permeable Reactive Wall - Mulch	0	0	0	0	2	0	0	2	4
Soil Vapor Extraction with Hydrologic + Engineering Controls	3	3	0	1	1	3	3	2.5	16.5
Institutional Controls & Enhanced Bioremediation & Phytoremediation	3	3	2.5	2	2	2	3	3	20.5
Soil Removal & Mulch Reactive Wall & Inst. Controls	2.5	2.5	0	.5	1	2	3	3	14.5
Matrix Scoring Legend for **On-Site Soil Gas Remedies**	0 - none 1 - low 2- moderate 3 - high	0 - none 1 - low 2- moderate 3 - high	0 - none 1 - low 2- moderate 3 - high	0 - great effort 1 - mod. effort 2 - little effort 3 - no effort	> $ 1 m - 0 $.5 -1 m - 1 $1/4-.5 m - 2 < $ 1/4 m - 3	0 - no compl. 1 - low compl. 2- mod. compl. 3 - high compl	0 - no protect 1 - low prot. 2- mod. prot. 3 - high prot.	0 - none 1 - low 2- moderate 3 - high.	

Table 17: LPS Ground Water Remedies	Short-term Effectiveness **(GW cleanup)** [0 - 5 years]	Long-term Effectiveness **(GW cleanup)** [5 - 25 years]	Reduction of **GW** Toxicity, Mobility & Volume	Implementability (Ease of)	Cost	ARAR Compliance **(for GW cleanup)**	Overall Protectiveness **(GW exposure)**	Community Acceptance	Total Score
No Action	0	0	0	3	3	0	0	1	7
Institutional Controls	0	.5	0	2.5	3	0	3	2.5	11.5
Selected Soil Removal-Hazardous	2	2.5	0	.5	0	2	2	2	11
Soil Removal Non-Hazardous	2	2.5	0	1	1	2	2	2	12.5
Enhanced Bioremediation	1	3	2.5	2	2.5	1.5	1.5	2	16
In-situ Chemical Oxidation	2	2.5	2.5	1.5	2	2	2	3	**17.5**
Phytoremediation	1	2	2	2.5	2	1	1.5	2.5	14.5
Permeable Reactive Wall - Iron Filings	0	0	0	0	0	0	0	2	2
Permeable Reactive Wall - Mulch	0	0	0	0	2	0	0	2	4
Soil Vapor Extraction with Hydrologic + Engineering Controls	2.5	3	3	1	1	2.5	2.5	2	17.5
Institutional Controls & Enhanced Bioremediation & Phytoremediation	1	3	2.5	2	2	1.5	3	2.5	17.5
Soil Removal & Mulch Reactive Wall & Inst. Controls	1.5	2.5	0	0	1	2	3	2	12
Matrix Scoring Legend for **LPS Ground Water Remedies**	0 - none 1 - low 2- moderate 3 - high	0 - none 1 - low 2- moderate 3 - high	0 - none 1 - low 2- moderate 3 - high	0 - great effort 1 - mod.effort 2 - little effort 3 - no effort	> $ 1 m - 0 $.5 -1 m - 1 $1/4-.5 m - 2 < $ 1/4 m - 3	0 - no compl. 1 - low compl. 2- mod. compl. 3 - high compl.	0 - no protect 1 - low prot. 2- mod. prot. 3 - high prot.	0 - none 1 - low 2- moderate 3 - high	

Table 18: Down Gradient Ground Water	Short-term Effectiveness (GW cleanup) [0 - 5 years]	Long-term Effectiveness (GW cleanup) [5 - 25 years]	Reduction of GW Toxicity, Mobility & Volume	Implementability (Ease of)	Cost	ARAR Compliance (for GW cleanup)	Overall Protectiveness (GW exposure)	Community Acceptance	Total Score
No Action	0	0	0	3	3	0	0	1	7
Institutional Controls	0	.5	0	2.5	3	0	0	1	7
Selected Soil Removal-Hazardous	1.5	2.5	0	.5	0	2	1.5	2	10
Soil Removal Non-Hazardous	1.5	2.5	0	1	1.5	2	1.5	2	12
Enhanced Bioremediation	1.5	3	2.5	2	2.5	1.5	1.5	2	16.5
In-situ Chemical Oxidation	1.5	2.5	2.5	1.5	2	2	1.5	2.5	16
Phytoremediation	.5	2	2	2.5	2	1	1.5	2.5	14
Permeable Reactive Wall - Iron Filings	3	3	3	0	0	3	3	3	**18**
Permeable Reactive Wall - Mulch	2.5	2.5	2.5	0	2	2.5	2.5	2	16.5
Soil Vapor Extraction with Hydrologic + Engineering Controls	2	3	3	1	1	3	3	2	18
Institutional Controls & Enhanced Bioremediation & Phytoremediation	1.5	3	2.5	2	2.5	1.5	1.5	2	16.5
Soil Removal & Mulch Reactive Wall & Inst. Controls	3	2.5	2.5	0	1	2.5	2.5	2	16
Matrix Scoring Legend for **Down Gradient Ground Water**	0 - none 1 - low 2- moderate 3 - high	0 - none 1 - low 2- moderate 3 - high	0 - none 1 - low 2- moderate 3 - high	0 - great effort 1 - mod.effort 2 - little effort 3 - no effort	> $ 1 m - 0 $.5 -1 m - 1 $1/4-.5 m - 2 < $ 1/4 m - 3	0 - no compl. 1 - low compl. 2- mod. compl. 3 - high compl.	0 - no protect 1 - low prot. 2- mod. prot. 3 - high prot.	0 - none 1 - low 2- moderate 3 - high	

Table 19 A
Proposed Time Schedule for Remedy Implementation
Feasibility Study, LPS Site, Middletown NY

Remedial Alternative	**Fourth Quarter 2003**	**First Quarter 2004**	**Second Quarter 2004**	**Third Quarter 2004**	**Fourth Quarter 2004**	**Expected time to Meet Remedial Action Objective (Years)**
Site Institutional Controls	PRAP	Prepare deed restriction	Install Soil Gas Mitigation System	Complete perimeter fencing	Begin Monitoring and Maintenance	Uncertain
Soil Removal: Hazardous	PRAP	Prepare bid documents + Retain Engineering Consultant + Construction Contractor	Prepare Remedial Design Documents	NYSDEC Review of Remedial Design and Remedial Action Plan	Begin remedial Action Plan as per approved design Specs.	<5
Soil Removal: Non-Hazardous	PRAP	Prepare bid documents + Retain Engineering Consultant + Construction Contractor	Prepare Remedial Design Documents	NYSDEC Review of Remedial Design and Remedial Action Plan	Begin remedial Action Plan as per approved design Specs.	<5
Enhanced Bioremediation	PRAP	Prepare bid documents + Retain Engineering Consultant + Construction Contractor	Prepare Remedial Design Documents	NYSDEC Review of Remedial Design and Remedial Action Plan	Begin remedial Action Plan as per approved design Specs.	<15
In-Situ Chemical Oxidation	PRAP	Prepare bid documents + Retain Engineering Consultant + Construction Contractor	Prepare Remedial Design Documents	NYSDEC Review of Remedial Design and Remedial Action Plan	Begin remedial Action Plan as per approved design Specs.	<5

Table 19 B
Proposed Time Schedule for Remedy Implementation
Feasibility Study, LPS Site, Middletown NY

Phytoremediation	PRAP	Prepare bid documents + Retain Engineering Consultant + Construction Contractor	Prepare Remedial Design Documents	NYSDEC Review of Remedial Design and Remedial Action Plan	Begin remedial Action Plan as per approved design Specs.	<25
Treatment Wall: Iron Filings	PRAP	Prepare bid documents + Retain Engineering Consultant + Construction Contractor	Prepare Remedial Design Documents	NYSDEC Review of Remedial Design and Remedial Action Plan	Begin remedial Action Plan as per approved design Specs.	<25
Treatment Wall: Mulch	PRAP	Prepare bid documents + Retain Engineering Consultant + Construction Contractor	Prepare Remedial Design Documents	NYSDEC Review of Remedial Design and Remedial Action Plan	Begin remedial Action Plan as per approved design Specs.	<25
Soil Vapor Extraction with Ground water Treatment	PRAP	Prepare bid documents + Retain Engineering Consultant + Construction Contractor	Prepare Remedial Design Documents	NYSDEC Review of Remedial Design and Remedial Action Plan	Begin remedial Action Plan as per approved design Specs.	5-10
Site Institutional Controls and Enhanced Bioremediation & Phytoremediation	PRAP	Prepare bid documents + Retain Engineering Consultant + Construction Contractor	Prepare Remedial Design Documents	NYSDEC Review of Remedial Design and Remedial Action Plan	Begin remedial Action Plan as per approved design Specs.	<15
Soil Removal: Non-Hazardous & Treatment Wall: Mulch & Site Institutional Controls	PRAP	Prepare bid documents + Retain Engineering Consultant + Construction Contractor	Prepare Remedial Design Documents	NYSDEC Review of Remedial Design and Remedial Action Plan	Begin remedial Action Plan as per approved design Specs.	<5

United States Environmental
Protection Agency

Office of Solid Waste and
Emergency Response

OSWER 9355.0-74FS-P
EPA 540-F-00-005
September, 2000

Office of Solid Waste and Emergency Response

Institutional Controls:

A Site Manager's[1] Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups

Table of Contents

Purpose

This fact sheet provides Superfund and RCRA Corrective Action site managers and decision-makers with an overview of the types of Institutional Controls (ICs) that are commonly used or implemented, and outlines the factors that should generally be considered when evaluating and selecting ICs as part of the remedy. For more detailed information on the different types of instruments available, site managers and attorneys should consult the document, "Institutional Controls: A Reference Manual (Workgroup Draft - March 1998)." EPA site managers should also work closely with Regional attorneys and Headquarters staff in the Office of Emergency and Remedial Response (OERR), the Office of Site Remediation Enforcement (OSRE), the Federal Facilities Restoration and Reuse Office (FFRRO), the Federal Facilities Enforcement Office (FFEO) and/or the Office of Solid Waste (OSW) on any site-specific issues that may arise while evaluating, implementing, enforcing, or monitoring ICs.[2]

Definition and Importance of ICs

Generally, EPA begins the remedy evaluation process with the expectation that treatment or engineering controls will be used to address principal threat wastes and that groundwater will be returned to its beneficial use. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) emphasizes that ICs, such as water use restrictions, are meant to supplement engineering controls during all phases of cleanup and may be a necessary component of the completed remedy. The NCP also cautions against the use of ICs as the sole remedy unless active response measures are determined to be impracticable. At the same time, ICs play an important role in site remedies. Often, ICs are a critical component of the cleanup process and are used by the site manager to ensure both the short- and long-term protection of human health and the environment. For this reason it is important to understand what constitutes an IC. Specifically for EPA, ICs:

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[1] Site Manager, as used in this fact sheet, refers to both CERCLA sites and RCRA facilities. In RCRA, project managers are the equivalent to site managers in CERCLA.

[2] This document provides guidance to EPA Regions and states involved in Superfund and RCRA corrective action cleanups. It also provides guidance to the public and the regulated community on how EPA intends to evaluate and implement institutional controls as part of a cleanup decision. The guidance is designed to implement national policy on these issues. The document does not, however, substitute for CERCLA, RCRA or EPA's regulations, nor is it a regulation itself. Thus, it does not impose legally-binding requirements on EPA, States, or the regulated community, and may not apply to a particular situation based upon the circumstances. EPA and State decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate. Any decisions regarding a particular facility will be made based on the applicable statutes and regulations. Therefore, interested parties are free to raise questions and objections about the appropriateness of the application of this guidance to a particular situation, and EPA will consider whether or not the recommendations or interpretations in the guidance are appropriate in that situation. EPA may change this guidance in the future.

- are non-engineered instruments such as administrative and/or legal controls that minimize the potential for human exposure to contamination by limiting land or resource use:
- are generally to be used in conjunction with, rather than in lieu of, engineering measures such as waste treatment or containment:
- can be used during all stages of the cleanup process to accomplish various cleanup-related objectives; and,
- should be "layered" (i.e., use multiple ICs) or implemented in a series to provide overlapping assurances of protection from contamination. These concepts are discussed in the text box below.

Some examples of ICs include easements, covenants, well drilling prohibitions, zoning restrictions, and special building permit requirements. Deed restriction is a phrase often used in remedy decision documents to describe easements or other forms of ICs; however, this is not a traditional property law term and should be avoided. Fences that restrict access to sites are often termed ICs; however, because fences are physical barriers instead of administrative or legal measures, EPA does not consider them to be ICs. ICs are among the tools allowable under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [as amended by the Superfund Amendments and Reauthorization Act (SARA)], the NCP, and the Resource Conservation and Recovery Act (RCRA). To read more about the regulatory framework for ICs, refer to the box on page 3 entitled, "A Look at ICs in CERCLA, the NCP and RCRA." Finally, where protectiveness depends on reducing exposure, ICs are a response action under CERCLA or a corrective action under RCRA. Accordingly, even in the unusual case where a CERCLA Record of Decision (ROD) only requires the implementation of ICs, it is considered to be a "limited action," not a "no action" ROD. Likewise, when a corrective action under RCRA includes an IC, whether it is part of an interim measure or occurs at the end of the cleanup as part of the final corrective measure, the IC is considered a part of the remedy.

Common Misnomers

"Deed restriction" is not a traditional property law term, but rather is a generic term used in the NCP and elsewhere as a shorthand way to refer to types of ICs. To avoid confusion, site managers should avoid the term and instead be specific about the types of ICs under consideration and their objectives. In addition, EPA does not consider physical barriers as ICs. Fences that restrict access to sites are often termed as ICs. However, fences are not considered by EPA to be ICs .

ICs are vital elements of response alternatives because they simultaneously influence and supplement the physical component of the remedy to be implemented. On the one hand, the right mix of ICs can help ensure the protectiveness of the remedy; on the other, limitations in ICs may lead to reevaluation and adjustment of the remedy components, including the proposed ICs. At some sites, remedy contingencies may protect against uncertainties in the ability of the ICs to provide the required long-term protectiveness. These points illustrate how important it is for site managers to evaluate ICs as thoroughly as the other remedy components in the Feasibility Study (FS) or Corrective Measures Study (CMS), when looking for the best ICs for addressing site-specific circumstances. Adding ICs on as an afterthought without carefully thinking about their objectives, how the ICs fit into the overall remedy, and whether the ICs can be realistically implemented in a reliable and enforceable manner, could jeopardize the effectiveness of the entire remedy.

Often ICs are more effective if they are layered or implemented in series. Layering means using different types of ICs at the same time to enhance the protectiveness of the remedy. For example, to restrict land use, the site manager may issue an enforcement tool [e.g., Unilateral Administrative Order (UAO)]; obtain an easement; initiate discussions with local governments about a potential zoning change: and enhance future awareness of the restrictions by recording them in a deed notice and in a state registry of contaminated sites. Also, the effectiveness of a remedy may be enhanced when ICs are used in conjunction with physical barriers, such as fences, to limit access to contaminated areas.

ICs may also be applied in series to ensure both the short- and long-term effectiveness of the remedy. For example, the site manager may use an enforcement tool to require the land owner to obtain an easement from an adjacent property owner in order to conduct ground water sampling or implement a portion of the active remedy. This easement may not be needed for the long-term effectiveness of the remedy and is terminated when the construction is complete. At another site, the site manager may use an Administrative Order on Consent (AOC) or permit condition to prohibit the land owner from developing the site during the investigation. Later, the site manager may add a provision to the Consent Decree (CD) or the permit requiring the land owner to notify EPA if the property is to be sold and to work with the local government to implement zoning restrictions on the property.

Layering and Implementing ICs in Series

ICs are more effective if they are layered or implemented in series.

Layering ICs means using different types of ICs at the same time to enhance the protectiveness of the remedy.

Using ICs in series is the use of ICs at different points in the investigation and remediation process to ensure the short- and long-term protection of human health and the environment.

Types of ICs

A Look at ICs in CERCLA, the NCP, and RCRA

CERCLA as amended by SARA, the NCP and RCRA support the use of ICs in remediation of a site:

CERCLA—Section 121(d)(2)(B)(ii)(III) refers to the use of enforceable measures (e.g., ICs) as part of the remedial alternative at sites. EPA can enforce the implementation of ICs, but not necessarily their long term maintenance. For example, the local government with zoning jurisdiction may agree to change the zoning of the site to prohibit residential land uses as part of the remedy, but the local government retains the authority to change the zoning designation in the future. EPA is authorized, under CERCLA section 104(j), to acquire (by purchase, lease or otherwise) real property interests, such as easements, needed to conduct a remedial action provided that the state in which the interest is to be acquired is willing to accept transfer of the interest following the remedial action. Transfers of contaminated Federal property are subject to special deed requirements under CERCLA sections 120(h)(3)(A)(iii) and 120(h)(3)(C)(ii)(I) and (II).

NCP—the NCP provides EPA's expectations for developing appropriate remedial alternatives, including ICs under CERCLA. In particular, it states that EPA expects to use treatment to address the principal threats posed by sites; engineering controls for wastes that pose relatively low risk or where treatment is impracticable; and a combination of the two to protect human health and the environment [40 CFR 300.430(a)(1)(iii)(A), (B), and (C)]. In appropriate situations, a combination of treatment, containment, and ICs may be necessary. The NCP also emphasizes the use of ICs to supplement engineering controls during all phases of cleanup and as a component of the completed remedy, but cautions against their use as the sole remedy unless active response measures are determined to be impracticable [40 CFR 300.430(a)(1)(iii)(D)]. In the case where ICs are the entire remedy, the response to comments section of the preamble to the NCP states that special precautions must be made to ensure the controls are reliable (55 Federal Register, March 8, 1990, page 8706). Recognizing that EPA may not have the authority to implement such controls, the NCP requires that (for fund financed sites) the state assure that the ICs implemented as part of the remedial action are in place, reliable, and will remain in place after the initiation of operation and maintenance [40 CFR 300.510(c)(1)]. Lastly, for Superfund financed and private sites, the NCP also requires the state to hold any interest in property that is acquired (once the site goes into O&M) to ensure the reliability of ICs [40 CFR 300.510(f)].

RCRA—RCRA requirements are imposed through legal mechanisms different from those used under CERCLA. In RCRA, authorized states are the primary decision makers, this results in a wide variety of state-specific mechanisms being available. This fact sheet does not attempt to list all of the state and local IC mechanisms, but to identify key principles for the use of ICs. If the IC is being imposed through a RCRA permit, steps should be taken to ensure that long-term enforcement is not lost through property transfer or permit expiration. Cleanups under RCRA are conducted in connection with the closure of regulated units and facility-wide corrective action either under a permit [RCRA sections 3004(u) and (v)], interim status order [RCRA section 3008(h)] or imminent hazard order [RCRA section 7003] or other authorities. It should also be noted that landfill closure requirements under 40 CFR 264.119 require deed notices that the land has been used to manage hazardous waste, although the notice itself does not restrict future use. EPA expects to use a combination of methods (e.g., treatment, engineering, and institutional controls) under RCRA, as appropriate, to achieve protection of human health and the environment. EPA also expects to use ICs, such as water and land use restrictions, primarily to supplement engineering controls, as appropriate, for short- and long-term management to prevent or limit exposure to hazardous wastes and constituents. ICs are not generally expected to be the sole remedial action.

General Categories

There are four categories of institutional controls: governmental controls; proprietary controls; enforcement and permit tools with IC components; and informational devices. Each of these categories is described below. In addition, a checklist that highlights steps in implementing ICs during the cleanup process and a matrix summarizing examples of ICs are included at the end of the fact sheet.

Governmental Controls—Governmental controls are usually implemented and enforced by a state or local government and can include zoning restrictions, ordinances, statutes, building permits, or other provisions that restrict land or resource use at a site. Local governments have a variety of land use control measures available from simple use restrictions to more sophisticated measures such as planned unit development zoning districts and overlay zones.

Development zoning districts allow for more flexible site planning and overlay zones impose additional requirements to those of the underlying zoning district. Regardless of which measures are relied on, the land use control should be carefully evaluated to make certain that there are no exceptions which could allow for improper use of the site (e.g., allowing a day care center use within an industrial district). Once implemented, local and state entities often use traditional police powers to regulate and enforce the controls. Since this category of ICs is put in place under local jurisdiction, they may be changed or terminated with little notice to EPA, and EPA generally has no authority to enforce such controls.

For active military bases, the local authority for regulating and enforcing ICs is the Commanding Officer. Therefore, EPA and the state should work with the installation personnel to incorporate restrictions into the base master plans, instructions, and orders used by the Commanding Officer to govern conduct, actions and activities on the base (in some cases these restrictions may be imposed as permit conditions if the base is subject to RCRA permit requirements).

Proprietary Controls—These controls, such as easements and covenants, have their basis in real property law and are unique in that they generally create legal property interests. In other words, proprietary controls involve legal instruments placed in the chain of title of the site or property. The instrument may include the conveyance of a property interest from the owner (grantor) to a second party (grantee) for the purpose of restricting land or resource use. An example of this type of control is an easement that provides access rights to a property so the Potentially Responsible Party (PRP), facility owner/operator, or regulatory agency may inspect and monitor a groundwater pump-and-treat system or cover system. The benefit of these types of controls is that they can be binding on subsequent purchasers of the property (successors in title) and transferable, which may make them more reliable in the long-term than other types of ICs.

However, proprietary controls also have their drawbacks. Property law can be complicated because a property owner has many individual rights with respect to his or her property. To illustrate this point, property rights can be thought of as a bundle of sticks, with each stick representing a single right (e.g., the right to collect rents). The terminology, enforceability, and effect of each of these rights is largely dependent upon real property common law and the state where the site is located. A property owner can convey certain rights to other entities (either voluntarily or involuntarily through condemnation) and keep other rights. For example, if it is determined that a long-term easement is required to ensure remedy protectiveness, this "right" would need to be transferred by the property owner to another entity. For the easement to bind subsequent purchasers, some states require that the entity be an adjacent property owner. This may complicate long-term monitoring and enforcement since the party receiving the right (the grantee) is often not an adjacent property owner. To eliminate this problem, a proprietary control may be established "in gross." This means that the holder of the control (the grantee) does not need to be the owner of the adjacent property. However, it should be noted that easements in gross may not be enforceable under the laws of some states. State property laws governing easements should therefore be researched before this type of IC is selected in order to determine its enforceability in that jurisdiction.

A distinction at Federal sites being transferred to the private sector is that CERCLA sections 120(h)(3)(A)(iii) and 120(h)(3)(c)(ii) and (iii) require that property interests be retained by the Federal government. At active Federal sites, proprietary controls may not be an option because a deed does not exist or the landholding Federal agency lacks the authority to encumber the property. However, the landholding Agency may be willing to enter a Memorandum of Understanding (MOU) with EPA and/or state regulators providing for specific IC implementation plans, periodic inspections and other activities which it will undertake (in lieu of deed restrictions) to assure that ICs for the active site will remain effective.

Enforcement and Permit Tools with IC Components—Under sections 104 and 106(a) of CERCLA, UAOs and AOCs can be issued or negotiated to compel the land owner (usually a PRP) to limit certain site activities at both Federal and private sites; CDS can also be negotiated at private sites under 122(d). Similarly, EPA can enforce permits, conditions and/or issue orders under RCRA sections 3004(a), 3004(u) and (v), 3008(h), or 7003. These tools are frequently used by site managers, but may also have significant shortcomings that should be thoroughly evaluated. For example, most enforcement agreements are only binding on the signatories, and the property restrictions are not transferred through a property transaction. For example, if a PRP under CERCLA signs a CD or receives a UAO and then sells his or her property, many types of ICs would not be enforceable against the next owner. This could jeopardize the protectiveness of the remedy. One possible solution to this problem is to ensure that the enforcement tool contains provisions requiring EPA or state notification and/or approval prior to a property transfer. In this instance, EPA could negotiate an agreement with the new owner. Another solution is to require signatories of an enforcement document to implement additional long-term institutional controls such as information devices or proprietary controls (*i.e.*, layering).

Informational Devices—Informational tools provide information or notification that residual or capped contamination may remain on site. Common examples include state registries of contaminated properties, deed notices, and advisories. Due to the nature of some informational devices (*e.g.*, deed or hazard notices) and their potential non-enforceability, it is important to carefully consider the objective of this category of ICs. Informational devices are most likely to be used as a secondary "layer" to help ensure the overall reliability of other ICs.

ICs at Federal Facilities

Because of Federal ownership, there are significant differences in the way ICs are applied at Federal facilities. Some proprietary or governmental controls cannot be applied on active Federal facilities. However, for properties being transferred as part of a base closure, the Department of Defense does have the authority to restrict property by retaining a property interest (i.e., an easement intended to assure the protectiveness of the remedy). For active bases, ICs are commonly addressed through remedy selection documents, base master plans, and separate MOUs. More detailed information on ICs and Federal facilities is contained in "Institutional Controls: A

Reference Manual (Workgroup Draft - March 1998)" and in the FFRRO IC guidance ("Institutional Controls and Transfer of Real Property under CERCLA Section 120(h)(3)(A), (B), or (C)," January, 2000).

Legal Mechanisms for Imposing ICs Under CERCLA and RCRA

CERCLA and RCRA employ the same types of ICs to reduce exposure to residual contamination. However, as explained below, EPA's legal authority to establish, monitor and enforce ICs varies significantly between the two programs. As a result, officials involved in cleanups need to appreciate the range of options available under each program before determining whether, and to what extent, ICs should be incorporated into a remedial decision.

At CERCLA sites, EPA often imposes ICs via enforcement tools (e.g., UAOs, AOCs, and CDs). Since these enforcement tools only bind the parties named in the enforcement document, it may be necessary to require the parties to implement ICs that "run with the land" (i.e., applied to the property itself) in order to bind subsequent land owners. For Fund-lead CERCLA sites, the lead agency has the responsibility for ensuring ICs are implemented. Legal mechanisms such as UAOs, AOCs and CDS should also require reporting to EPA and/or the state of any sale of the property.

Under RCRA, ICs are typically imposed through permit conditions or by orders issued under section 3008(h). In certain circumstances cleanup may also be required under the imminent hazard order authority of section 7003. In the case where an IC is meant to continue beyond the expiration of a permit, an order may be required to ensure the IC remains in effect for the long term RCRA permit writers should incorporate ICs as specific permit conditions, where appropriate. By doing so, such conditions would be enforceable through the permit. At the same time, permit writers should consider whether additional ICs are available (e.g., governmental and/or proprietary controls) to ensure that subsequent property owners will be aware of, and bound by, the same types of restrictions. Similar factors should be considered when preparing RCRA corrective action orders to ensure that both the current facility owner/operator and any subsequent property owners are subject to effective and enforceable ICs that will minimize exposure to any residual contamination.

One significant difference between RCRA and CERCLA is that RCRA generally does not authorize EPA to acquire any interests in property. Therefore, many proprietary controls (such as easements) will require the involvement of third parties (e.g., states or local governments) under RCRA.

ICs and Future Land Use

Land use and ICs are usually linked. As a site moves through the Superfund Remedial Investigation/Feasibility Study (RI/FS) or RCRA Facility Investigation/Corrective Measures Study (RFI/CMS), site managers should develop assumptions about reasonably anticipated future land uses and consider whether ICs will be needed to maintain these uses over time. EPA's land use guidance (Land Use in CERCLA Remedy Selection Process, OSWER Directive No. 9355.7-04, May 25, 1995) states that the site manager should discuss reasonably anticipated future uses of the site with local land use planning authorities, local officials, and the public, as appropriate, as early as possible during the scoping phase of the RI/FS or RFI/CMS. Where there is a possibility that the land will not be cleaned up to a level that supports unlimited use and unrestricted exposure, the site manager should also discuss potential ICs that may be appropriate, including legal implementation issues, jurisdictional questions, the impact of layering ICs and reliability and enforceability concerns. It is also important for the site manager to recognize that, in addition to land uses, ICs can be used to affect specific activities at sites (e.g., fishing prohibitions).

Screening ICs

The need for ICs can be driven by both the need to guard against potential exposure and to protect a remedy. If any remedial options being evaluated in the FS or CMS leave waste in place that would not result in unrestricted use and unlimited exposure, ICs should be considered to ensure that unacceptable exposure from residual contamination does not occur. However, ICs may not be necessary if the waste that is left at the site allows for unrestricted use and unlimited exposure. Remedy options that typically leave residual wastes on site and necessitate ICs include capping waste in place, construction of containment facilities, natural attenuation and long-term pumping-and-treatment of groundwater.

ICs should be evaluated in the same level of detail as other remedy components. ICs are considered response actions under CERCLA and RCRA. ICs must meet all statutory requirements, and are subject to the nine evaluation criteria outlined in the NCP (40 CFR 300.430 (e)(9)(i)) for CERCLA cleanups. The balancing criteria recommended for corrective actions should generally be used in evaluating ICs under RCRA. However, before applying these criteria, the site manager should first make several determinations:

☐ Objective—Clearly state what will be accomplished through the use of ICs.

> Example: Restrict the use of groundwater as a drinking water source until the Maximum Contaminant Levels are met.

☐ Mechanism—Determine the specific types of ICs that can be used to meet the various remedial objectives.

> Example: Work with the local jurisdiction to develop ordinances to restrict well drilling or prohibit groundwater access until cleanup goals are met; record the groundwater contamination in the land record to provide notice of the issue to the public; and record contaminated aquifers on state registry to maintain institutional tracking.

☐ Timing—Investigate when the IC needs to be implemented and/or secured and how long it must be in place. Since ICs are often implemented by parties other than EPA, the time required to secure an IC should be taken into consideration.

> Example: A deed notice may be required in the short-term, and a formal petition for a zoning change may be necessary in the long-term, both of which need to be in place prior to site deletion from the NPL.

☐ Responsibility—Research, discuss, and document any agreement with the proper entities on exactly who will be responsible for securing, maintaining and enforcing the control. It might be useful to secure a written statement of the appropriate entities' willingness to implement, monitor, and enforce the IC prior to the signature of the remedy decision document.

> Example: Work with the State to determine whether it is willing and able to hold an enforceable easement to ensure appropriate land use; in addition, determine whether the local government is willing and able to change and enforce the applicable zoning requirements. If assurances cannot be obtained, then ICs may not be a viable component of the remedy.

Typically, the site manager is faced with balancing the relative strengths of ICs in terms of enforceability, permanence, etc., with achieving remedial objectives. As discussed previously, one option is to "layer" different controls to ensure long-term reliability. For example, layered ICs may involve concurrent use of enforceable agreements, deed notices, and adoption of land use controls by a local government. ICs may also be used in series. For example, an enforcement order may prohibit the land owner from disturbing the cap on his/her property (i.e., a short-term control), until the local government goes through the process of restricting the future use of the land (i.e., the long-term control).

Determining the State Role

Where EPA is implementing a remedy, states often play a major role in implementing and enforcing ICs. As stated previously, some governmental controls may be established under state jurisdiction: the state may use its enforcement tools to compel the PRP or facility land owner to limit site activities; the state may provide the notification or information on the contamination that remains on-site; or the state may assume ownership of a property in order to implement, maintain, and enforce proprietary controls. Under RCRA, the state will typically be imposing and overseeing the remedial action.

When to Begin Coordinating with the State

No matter what role the state assumes with ICs, the EPA site manager should begin coordinating with the state early in the RI/FS (for CERCLA) or RFI/CMS (for RCRA) process or after sampling has been completed and the extent of the risk is known. Even if ICs are not required for the long-term maintenance of the selected remedy, they may be necessary during the response activities.

Factors to Consider in State Coordination

In evaluating the need for and the type of ICs that may be implemented at a site, the site manager should consult with their Regional attorney to determine who has the proper legal authority to implement and enforce the proposed controls. Certain states have enacted statutes that provide the state with the legal authority to restrict land use at contaminated properties. In addition, several states have adopted statutes providing for conservation easements. These easements override common law barriers to the enforcement of easements by parties who do not own adjacent property. For example, at many sites, the state, in cooperation with the PRPs or facility owner/operator, may use its own enforcement tools to restrict the use of the land and ensure that the selected remedy, including ICs, is implemented and maintained. At other sites, a property interest may be conveyed (either directly or, if necessary, through EPA at Superfund sites) from the owner of the land to the state which becomes the holder and enforcer of a proprietary control. Finally, the state is often responsible for issuing advisories or warnings of potential risks (e.g., fishing or swimming prohibitions), and providing registries of hazardous waste sites (i.e., informational controls).

If it appears that the state will be relied upon to establish the ICs, the site manager should immediately talk to state agency personnel to gauge their willingness to establish, maintain and enforce the control, if necessary. This discussion is encouraged regardless of the type of IC(s) that will be implemented. The site manager should work with his or her state counterpart to identify and contact the appropriate state agency and personnel for each proposed IC. In addition, if a property interest is conveyed by the land owner to EPA to perform a remedial action (e.g., to ensure the reliability of the ICs restricting the use of the land), CERCLA requires the state to accept transfer of the title from EPA following completion of the CERCLA remedial action. If the state does not agree to accept title to the property, the site manager must find another party to assume ownership (e.g., a local government, community group or trust) or another type of IC (e.g., local government control)[3] must be selected. State assurances for O&M or for transfer of property interest are formalized in a Superfund State Contract (SSC), cooperative agreement, or MOU that is negotiated between the state and EPA.

State Role at Fund-Financed CERCLA Cleanups

The state assumes other responsibilities for ICs if the remedial action, including the ICs, will be Fund-financed under CERCLA. CERCLA specifically requires that the state provide assurance that it will assume responsibility for operation and maintenance (O&M) of the selected remedy before a Fund-financed remedial action is implemented. The NCP requires the state to ensure that any ICs implemented as part of the remedial action at the site are in place, reliable, and will remain in place after the initiation of O&M. These assurances are also documented in a cooperative agreement, SSC or MOU.

State Role at RCRA Sites

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[3] Likewise, either the state or a third party must be willing to accept property interests at PRP-led sites.

Under RCRA, states will typically be the implementing and overseeing agency. Therefore the state, when authorized and overseeing corrective action, will be responsible for identifying appropriate institutional controls. Where EPA is overseeing the remedy there are no state assurance requirements in RCRA Corrective Action. However, because there is no Federal mechanism in RCRA allowing EPA to acquire interest in property, EPA may be forced to rely on third parties (typically state or local government) to establish, maintain and enforce most types of ICs.

State Role at Federal Facilities
At Federal facilities, the landholding agency is ultimately responsible for all response activities. The state is not required to provide assurance that it will assume responsibility for O&M. However, states may enter into an agreement with the landholding Federal agency to monitor and enforce ICs at Federal sites.

Determining the Role of Local Governments

CERCLA, RCRA, and the NCP do not specify a role for local governments in implementing the selected remedy. However, a local government is often the only entity that has the legal authority to implement, monitor and enforce certain types of ICs (e.g., zoning changes). While EPA and the states take the lead on CERCLA and RCRA response activities, local governments have an important role to play in at least three areas: (1) determining future land use; (2) helping engage the public and assisting in public involvement activities; and (3) implementation and long-term monitoring and enforcement of ICs. Therefore, it is critical that the site manager and his or her state counterpart involve the appropriate local government agency in discussions on the types of controls that are being considered. The capability and willingness of the local government to implement and ensure the short- or long-term effectiveness of the proposed ICs should be considered during the RI/FS or RFI/CMS. In certain cases, cooperative agreements may be considered to assist local governments in the implementation, monitoring and enforcement of required ICs.

Evaluating ICs

Once the site manager has considered the objectives, mechanism, timing, and entity responsible for implementing, monitoring and enforcing the ICs, the next phase is selecting the ICs. The following sections contain a discussion of the CERCLA and RCRA factors that site managers should generally consider when evaluating ICs during the FS or CMS. If the site manager proposes to layer or use the ICs in series, he or she should also characterize the likelihood that this approach can actually be achieved. It is important to note that at CERCLA sites, the statute requires the site manager to evaluate ICs, just like other remedy components, against the nine NCP criteria. The site manager must ensure that remedies are protective of human health and the environment. ICs may be an important element in this determination. RCRA sites managers have the latitude to use balancing criteria, but unlike CERCLA, RCRA regulations do not require this balancing step. The CERCLA and RCRA criteria are categorized below in three groups: threshold, balancing, and modifying.

~~**Threshold Criteria**~~

ICs in CERCLA Removal Actions

ICs will rarely be a component of true emergencies where a time critical action serves as the only response at a site. It is more likely that a site manager will choose ICs as a component of a non-time critical removal action or during a follow-up remedial action. A post-removal site control agreement must be completed before commencing a fund-financed removal action where ICs are included in post-removal site control (OSWER Directive No. 9360.22-02). As in the remedial process, begin considering ICs when conducting an analysis of land use assumptions during the removal decision-making process. Where a final, site-wide, non-time critical removal remedy decision will be made, ICs should be thoroughly and rigorously evaluated with all other response actions in the Engineering Evaluation/Cost Analysis (EE/CA). In short, because ICs are considered to be actions, apply the full criteria required by the NCP for EE/CA evaluations. It is anticipated that ICs would not be chosen as the sole action for a removal.

It is fundamental that a remedy under RCRA or CERCLA that includes ICs meet the following threshold criteria:

- protect human health and the environment; and

- for CERCLA sites, comply with Applicable or Relevant and Appropriate Requirements (ARARs).

The site manager for RCRA facilities should also consider whether remedies that include ICs:

- attain media cleanup standards or comply with applicable standards for waste management; and
- control the source(s) of releases so as to reduce or eliminate, to the extent practicable, further releases of hazardous waste that might cause threats to human health and the environment.

Balancing Criteria

The site manager evaluates the individual, layered or series of ICs to determine their respective strengths and weaknesses. ICs are also evaluated in combination with engineered controls to identify the key tradeoffs that should be balanced for the site. Following are balancing criteria required by CERCLA and the NCP and recommended by the RCRA program in guidance.

Long-term effectiveness and permanence (CERCLA) or reliability (RCRA)—Under both CERCLA and RCRA, this factor assesses the permanence/reliability and effectiveness of ICs that may be used to manage treatment residuals or untreated wastes that remain at the site over time. When evaluating whether an IC will be effective over the long-term, the site manager should consider factors such as: whether the property is a government-owned site or a privately-owned site that is likely to change hands; the applicability of ICs to multiple property owners; the size of the area to be managed: the number of parcels; the contaminated media to be addressed; the persistence of the contamination; whether site contamination is well-defined; and whether local governments or other governing bodies are willing and able to monitor and enforce long-term ICs. The site manager should also consider the contaminated media to be addressed by the ICs. Different ICs may be required for different media.

Where ICs must be effective for a long period, either proprietary or governmental controls should be considered because they generally run with the land and are enforceable. However, both proprietary and governmental controls have weaknesses in terms of long-term reliability. For example, with proprietary controls, common law doctrines may restrict enforcement by parties who do not own adjoining land. This can render proprietary controls ineffective if EPA or another party capable of enforcing the control is not the owner of the adjacent property. To eliminate this problem, proprietary controls may be established "in gross," signifying that the holder of the control does not need to be the owner of the adjacent property. However, some courts do not recognize in gross proprietary controls.

At some sites, governmental controls may be preferable to proprietary controls. For example, the site manager might work with a local government to pass an ordinance to restrict construction or invasive digging that might disturb or cause exposure to covered residual lead contamination in a large residential area. The implementation of government controls might be considered a beneficial addition to information tools that may be forgotten over the long term or an enforcement action that would be binding only on certain parties. Proprietary controls would likely be deemed impractical at such a site due to the complex and uncertain task of obtaining easements from multiple property owners.

Like proprietary controls, the use of governmental controls may not be effective over the long term. Of primary concern are the political and fiscal constraints that may affect the ability of a state or local government to enforce the controls. Similarly, governmental controls may be problematic when the local or state government is or may become the site owner or operator because of the appearance of a conflict of interest. Regardless of the control selected, its viability over the long term needs to be closely evaluated.

Reduction of toxicity, mobility, or volume through treatment—
This CERCLA and RCRA criterion does not apply since ICs are not treatment measures.

Short-term Effectiveness—Short-term effectiveness of ICs at CERCLA and RCRA sites should be evaluated with respect to potential effects on human health and the environment during construction and implementation of the remedy. In order to satisfy this criterion, the remedy might entail the use of an IC through an enforcement order to compel the PRP to restrict certain uses of the groundwater at or down gradient from the site during remediation. After remediation is complete, other ICs might be implemented if residual contamination remains on site (i.e., implementing ICs in series).

Implementability—This CERCLA and RCRA criterion evaluates the administrative feasibility of an action and/or the activities that need to be coordinated with other offices and agencies. Implementation factors that generally should be considered for ICs include whether the entity responsible for implementation possesses the jurisdiction, authority, willingness and capability to establish, monitor and enforce ICs. A proper analysis of implementability can be complex, considering such diverse factors as the extent to which land being restricted is owned by liable parties and the willingness and capability of the local government or other authority responsible for establishing controls for land or resource use.

Cost—This CERCLA and RCRA criterion includes estimated capital and O&M costs. In CERCLA, estimated costs for implementing, monitoring, and enforcing ICs should be developed. For example, cost estimates for ICs might include legal fees associated with obtaining easements restricting land use, the costs of purchasing property rights (e.g.., groundwater rights, easements), or the wages of the state or local government personnel that will regularly monitor the IC to ensure that it has not been violated. It is interesting to note that once the total life-cycle costs of implementing, monitoring and enforcing an IC – which may exceed 30 years – are fully calculated, it may actually be less costly in the long term to implement a remedy that requires treatment of the waste. For more information on estimating response costs, see "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study," EPA 540-R-00-002, OSWER 9355.0-075. In RCRA, costs historically have played a less prominent role in remediation selection. Typically cost estimates are expected to be developed at the discretion of the owner/operator, although implementors should take into account sites where ICs are inappropriately costly.

Modifying Criteria

Typically the site manager presents the proposed remedy, including ICs to the state, local government, and community for comment prior to implementation. The issues and concerns of these stakeholders may result in modifications to the remedy and are addressed by the site manager in the remedy decision document. Following is a discussion of these modifying criteria *(note: these criteria are only recommended in RCRA guidance).*

State Acceptance—The site manager should make the appropriate state authorities aware of the basis and scope of the ICs to be implemented under CERCLA or RCRA, and what role, if any, the state is expected to play to make ICs an effective part of the remedy. The state can formally express its concerns about the use of ICs, in general, and its role, in particular, or indicate its willingness to take on the responsibility for implementing and enforcing the proposed ICs.

If the state's position is uncertain at the time the remedy is selected (e.g., for CERCLA sites, when the ROD is signed or, for RCRA facilities, when the permit/order is issued or modified), it may be necessary to outline contingent remedial approaches in the decision documents. Specifically, remedies that require long-term ICs to remain protective may require alternative actions (e.g., additional soil removal) if the ICs are later determined to be unenforceable or cannot meet the remedial objectives. Alternatively, at a RCRA site, it may be necessary to leave a facility under a permit or other mechanism enforceable by the regulating agency. If the state's willingness or ability to implement or enforce an IC changes after remedy selection, the protectiveness of the remedy should generally be re-evaluated and, when necessary, remedial decisions revised. Under CERCLA, this may require an Explanation of Significant Differences (ESD), or even a ROD amendment. Under RCRA, a permit modification or change to a corrective action order may be necessary. It is important to note that under no circumstances can a Fund-financed CERCLA remedial action be initiated without receiving state assurances on ICs and property transfer.

Local Government and Community Acceptance—Involving the community and local government early during the remedy decision process will enable the site manager to more fully evaluate IC options. Discussions with the local government and community give the site manager the opportunity to:

- gather local government and community input on the proposed ICs;
- identify whether a particular stakeholder group may be harmed as a result of a proposed IC (for example, will a ban on fishing cause an economic hardship in the community);
- receive comment on the impacts of the potential ICs on religious or cultural customs and beliefs (e.g., preventing access to property which grows the plants that are used in a tribal ceremony); and
- determine if the community has special needs in regards to the IC (for example, will it be necessary to publish informational devices in multiple languages).

In addition, the local government and community's response to certain types of ICs and the willingness and capability of the local government to monitor ICs will help the site manager determine whether the ICs will be effective overall. This is especially important if nearby property owners will need to agree to implement proprietary controls or if other governmental ICs (e.g., zoning changes) will have an impact on the community. Early involvement will also enable the community to work with the local government to develop innovative approaches to using ICs, especially in light of any future land use plans.

As with other aspects of the proposed remedy, the community should have the opportunity to comment on the proposed IC component of the remedy during the public comment period. It may be necessary to educate the community about ICs so that its members understand how the different ICs may impact their property and activities. Under CERCLA, it may also be possible, as long as all appropriate requirements are met, to provide a Technical Assistance Grant to the community so they can hire a technical expert to assist them in evaluating ICs and the overall remedy.

In some cases, it may be appropriate not to identify the exact IC required at the time of the remedy decision. In these instances the critical evaluation of the available ICs should still be conducted and the specific objective(s) of the ICs should be clearly stated in the ROD or other decision document. Examples of when this flexibility may be appropriate are contingent remedies based on pilot studies or if a remedy would not be implemented for several years and the state is developing enabling language for Conservation Easements authority.

Site Manager Responsibilities After ICs are Selected

The site manager's responsibilities for ICs does not end once the ICs are selected. Site managers also should ensure that the ICs are actually implemented, are reliable, are enforced, and remain effective. It should be noted that NPL sites cannot be deleted until the entire remedy, including ICs, have been implemented. This may involve the following:

- working with state and local governmental entities to obtain commitments and resources for implementing and enforcing ICs, including negotiating a CERCLA SSC with the state to obtain assurances that the ICs will be put in place, are reliable and will remain in place after initiation of O&M activities;
- ensuring that the PRP or facility owner complies with the provisions in the enforcement tools to implement the ICs and provides notice of the ICs to potential future users/owners of the property;
- working with other Federal agencies to implement and enforce ICs;
- acquiring property for implementation of the CERCLA remedy; and
- checking the status of ICs during the CERCLA five-year review.

Conclusion

The ICs outlined in this fact sheet can be important elements of environmental cleanups. ICs play an important role in limiting risk and are often needed to ensure that engineered remedies are not affected by future site activities. When selecting ICs, the site manager needs to evaluate the situation at the site, define the needs that ICs are intended to address, identify the kinds of legal and other tools available to meet these needs, and ensure the ICs are implemented effectively. All of this requires up-front planning and working closely with the Regional office attorneys, the state, community, and PRPs or facility owner/operators. Key concepts to keep in mind when implementing ICs are provided in the text box below.

If you have questions regarding the material covered in this fact sheet, consult the draft document, "Institutional Controls: A Reference Manual" or contact your Regional Coordinator in the OERR Technical Regional Response Center. For information on model language for enforcement or legal documents used to implement ICs, consult your Regional Counsel, OSRE or the Office of General Counsel.

Key Concepts

☐ Under the NCP, the use of ICs should not substitute for active response measures (unless active measures are not practicable).

☐ If the site cannot accommodate unrestricted use and unlimited exposure, an IC will generally be required.

☐ Make sure the objective(s) of the IC are clear in the decision document.

☐ Coordinate early with state and local governments.

☐ Layer ICs and/or place them in series depending upon site circumstances.

☐ Evaluate ICs as rigorously as other remedial alternatives.

☐ Understand the life-cycle strengths, weaknesses and costs for the implementation, monitoring and enforcement of ICs.

☐ Get assurances, in writing, from entities that will implement, monitor, and enforce ICs.

☐ Remember that since all ICs have weaknesses, the role of the RCRA/CERCLA decision makers is to select the best ICs to protect human health and the environment.

Checklist for Implementing ICs

During the initial phase of cleanup (i.e., RI/FS or RFI/CMS), the site manager should:

- establish clear objectives (what are you trying to accomplish through the use of ICs?)
- discuss future land use plans with the community and local government to help in analyzing the appropriate ICs and other remedial alternatives
- evaluate ICs using the appropriate threshold, balancing, and modifying criteria
- coordinate with regional attorneys on legal matters and the State as appropriate
- be innovative/creative but realistic

During remedy selection, the site manager should:

- present information that helps the public understand the impacts of the specific ICs and their relationship with the overall remedy
- clearly describe the objectives to be attained by ICs
- specify performance standards (e.g., prevent exposure to contaminated ground water by prohibiting well drilling)
- consider layering ICs to enhance their overall effectiveness
- discussions with entities (e.g., local/state governments) involved in implementing ICs
- discuss the kinds of controls envisioned and include enough information to show that effective implementation of the ICs can reasonably be expected
- discuss plans for monitoring land use and other aspects of the remedy that depend on ICs
- discuss the enforcement mechanisms that are anticipated to ensure the long-term reliability of the ICs
- continue coordination with attorneys

During remedy implementation (i.e., RD/RA and CMI), the site manager should:

- ensure that appropriate measures are taken to implement the ICs (e.g., arrange discussions between PRPs, other property owners, and local government or state officials)
- be aware that ICs need to be fully implemented to obtain a RCRA permit termination, or for CERCLA sites, fully implemented to obtain RA completion, a site completion, and partial or full deletion
- prepare an ESD or ROD amendment for CERCLA sites or a permit modification or order revision for RCRA sites if the ICs will not result in the remedy being protective of human health and the environment; if this becomes necessary, also ensure that the public is provided an opportunity to comment on the proposed replacement ICs

During Post-Remediation activities (e.g., a CERCLA five-year review), the site manager should:

- Evaluate both the administrative/legal components as well as the physical evidence to ensure that ICs are both implemented and fully effective
- Document these results in the Five-Year Review Report (for CERCLA sites)

Problem #3:

Contaminant Entering Building From Outdoors

Examples

Soil gases
(e.g., radon, gasoline from tanks, methane from landfills)

Contaminants from nearby activities
(e.g., roofing, dumpster, construction)

Outdoor air intake near source
(e.g., parking, loading dock, building exhaust)

Outdoor air contains pollutants or excess moisture
(e.g., cooling tower mist entrained in outdoor air intake)

Solutions

Remove the source, if it can be moved easily

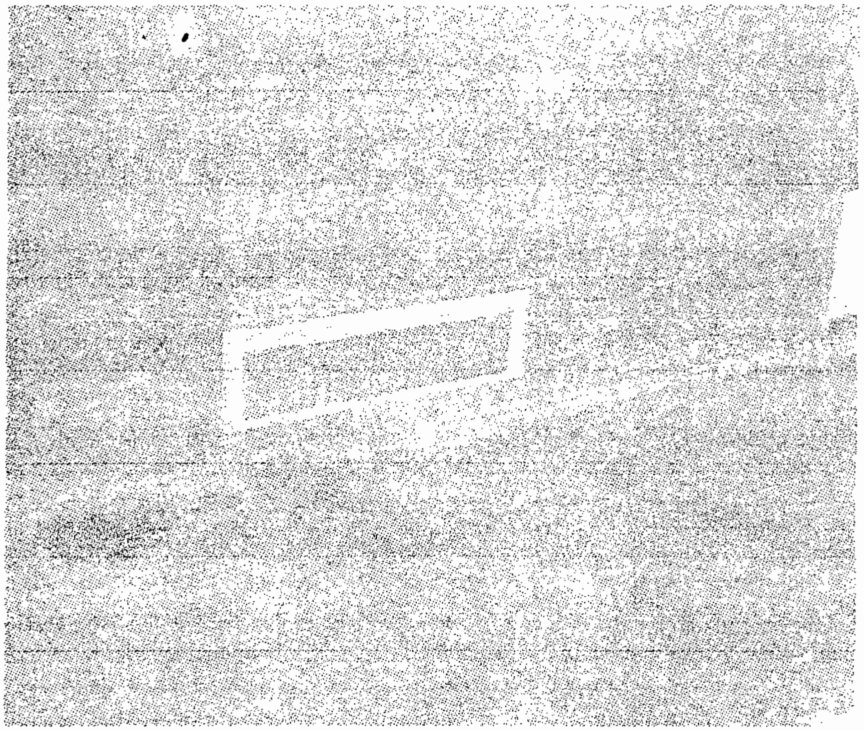
- remove debris around outdoor air intake
- relocate dumpster

Reduce source (for example, shift time of activity to avoid occupied periods)

- painting, roofing, demolition
- housekeeping, pest control

Relocate elements of the ventilation system that contribute to entry of outdoor air contaminants

- separate outdoor air intakes from sources of odors, contaminants
- separate exhaust fan outlets from operable windows, doors, air intakes
- make rooftop exhaust outlets taller than intakes



For cosmetic reasons, air intakes are frequently located on rooftops or near the ground. This air intake could become a means of drawing lawn cuttings, vehicle exhaust, and pesticides into the building.

Change air pressure relationships to control pollutant pathways

- install subslab depressurization to prevent entry of soil gas contaminants (radon, gases from landfills and underground tanks)
- pressurize the building interior relative to outdoors (this will not prevent contaminant entry at outdoor air intakes)
- close pollutant pathways (e.g., seal cracks and holes)

Add special equipment to HVAC system

- filtration equipment to remove pollutants (select to fit the situation)

Table 3-2: Treatment Technologies Screening Matrix

Rating Codes ■ - Better; ○ - Average; △ - Worse; ◆ - See definition Y - Yes; N - No. F - Full; P - Pilot. S - Solid; L - Liquid; V - Vapor. NA - Not Applicable I - Inadequate. O&M - Operation & Maintenance; Cap - Capital; B - Both	Development Status	Treatment Train (excludes off-gas treatment)	Residuals Produced	O&M or Capital Intensive	Availability	System Reliability/ Maintainability	Cleanup Time	Overall Cost	Nonhalogenated VOCs	Halogenated VOCs	Nonhalogenated SVOCs	Halogenated SVOCs	Fuels	Inorganics	Radionuclides	Explosives
Soil, Sediment, Bedrock, and Sludge																
3.1 In Situ Biological Treatment																
Bioventing	F	N	N	N	■	■	○	■	■	◆	■	△	■	△	◆	△
Enhanced Bioremediation ·· Aerobic ·· Anaerobic	F	N	N	O&M	■	○	○	■	■	■	■	◆	■	◆	◆	■
Phytoremediation ·· Enhanced Rhizosphere Biodegradation ·· Phyto-accumulation ·· Phyto-degradation ·· Phyto-stabilization	F	N	L,S	N	○	△	△	■	○	○	○	◆	○	○	△	△
3.2 In Situ Physical/Chemical Treatment																
Chemical Oxidation	F	N	N	O&M	■	○	■	○	○	○	△	○	△	◆	△	○
Electrokinetic Separation	F	Y	L	O&M	○	○	○	△	○	○	○	○	△	■	○	△
Fracturing (Enhancements) ·· Blast-Enhanced ·· Pneumatic Fracturing	F	Y	N	Cap	■	○	○	○	○	○	○	○	○	△	△	△
Soil Flushing ·· Cosolvents Enhancement	F	N	L	O&M	■	○	○	○	■	■	○	○	○	■	△	△
Soil Vapor Extraction	F	Y	L,V	O&M	■	■	○	■	■	■	△	△	■	△	△	△
Solidification /Stabilization ·· In Situ Vitrification ·· Chemical Fixation ·· Cement Based Processes	F	N	S	Cap	■	■	■	■	△	△	○	○	△	■	■	△
3.3 In Situ Thermal Treatment																
Thermal Treatment ·· Electrical Resistance Heating ·· Radio Frequency/ Electromagnetic Heating ·· Hot Air Injection ·· Steam Injection ·· Conductive Heating	F	Y	L,V	B	■	■	■	○	■	■	■	■	■	△	△	△
3.4 Ex Situ Biological Treatment (assuming excavation)																
Biopiles	F	N	V	N	■	■	○	■	■	■	○	◆	■	◆	△	△
Composting	F	N	N	N	■	■	○	■	○	○	○	◆	■	△	△	■

Landfarming	F	N	N	N	■	■	○	■	○	○	■	○	■	△	△	◆
Slurry Phase Biological Treatment	F	Y	S,L,V	B	■	○	○	○	○	■	■	◆	■	◆	△	■

3.5 Ex Situ Physical/Chemical Treatment (assuming excavation)

Chemical Extraction ·· Acid Extraction ·· Solvent Extraction	F	Y	L	B	■	○	○	○	○	○	■	■	○	■	○	△
Chemical Reduction /Oxidation	F	Y	S	Cap.	■	■	■	○	○	○	○	○	○	■	△	○
Dehalogenation ·· Base-Catalyzed Decomposition ·· Glycolate/Alkaline Polyethylene Glycol (A/PEG)	F	Y	V	B	○	△	○	△	△	■	△	■	△	△	△	○
Separation ·· Magnetic Separation ·· Sieving/Physical Separation	F	Y	S	O&M	■	■	■	○	○	○	○	○	△	○	△	△
Soil Washing	F	Y	S L	B	■	■	■	○	○	○	○	○	○	○	△	△
Solidification /Stabilization ·· Bituminization ·· Emulsified Asphalt ·· Modified Sulfur Cement ·· Polyethylene Extrusion ·· Pozzolan/Portland Cement ·· Radioactive Waste Solidification ·· Sludge Stabilization ·· Soluble Phosphates ·· Vitrification/Molten Glass	F	N	S	Cap.	■	■	■	■	△	△	○	○	△	■	■	△

3.6 Ex Situ Thermal Treatment (assuming excavation)

Hot Gas Decontamination	P	N	N	B	○	■	■	■	△	△	△	△	△	△	△	△
Incineration ·· Circulating Bed Combustor ·· Fluidized Bed ·· Infrared Combustion ·· Rotary Kiln	F	N	L S V	B	■	○	■	△	■	■	■	■	■	△	△	■
Open Burn/Open Detonation	F	N	S	B	■	■	■	■	△	△	△	△	△	△	△	■
Pyrolysis ·· Fluidized Bed ·· Molten Salt Destruction ·· Rotary Kiln	F	N	L S V	B	■	△	■	△	○	○	■	■	○	△	△	△
Thermal Desorption ·· High Temperature ·· Low Temperature	F	N	L S	B	■	○	■	○	■	■	■	■	■	△	△	■

3.7 Containment

Landfill Cap ·· Asphalt/Concrete Cap ·· RCRA Subtitle C Cap ·· RCRA Subtitle D Cap	F	N	L V	Cap	■	■	△	■	○	○	○	○	○	○	△	○
Landfill Cap Alternatives ·· Water Harvesting ·· Vegetative Cover	F	N	L V	Cap.	■	■	△	■	○	○	○	○	○	○	△	○

·· Evapotranspiration Cap																
3.8 Other Treatment																
Excavation, Retrieval, and Off-Site Disposal	F	N	NA	N	■	■	■	◆	○	○	○	○	○	○	△	○
Ground Water, Surface Water, and Leachate																
3.9 In Situ Biological Treatment																
Enhanced Biodegradation ·· Nitrate Enhancement ·· Oxygen Enhancement with Air Sparging ·· Oxygen Enhancement with Hydrogen Peroxide ·· Co-Metabolic Treatment	F	N	N	O&M	■	○	◆	■	■	◆	■	◆	■	◆	△	○
Natural Attenuation	F	N	N	O&M	■	○	◆	■	■	○	○	○	■	△	△	△
Phytoremediation ·· Enhanced Rhizosphere Biodegradation ·· Hydraulic Control ·· Phyto-Degradation ·· Phyto-Volatilization ·· Phyto-accumulation, ·· Phyto-stabilization ·· Aeration	F	N	L S	N	○	△	△	■	○	○	○	○	○	◆	△	△
3.10 In Situ Physical/Chemical Treatment																
Air Sparging	F	N	V	N	■	■	■	■	■	○	○	○	■	△	△	△
Bioslurping	F	Y	L V	N	■	○	○	■	○	○	■	■	■	○	△	△
Chemical Oxidation	F	N	N	O&M	■	○	■	○	○	○	△	○	△	◆	△	○
Directional Wells (enhancement)	F	N	N	Cap.	■	○	○	○	○	○	○	○	○	○	△	○
Dual Phase Extraction ·· Dual Phase Extraction ·· Fluid/Vapor Extraction	F	Y	L V	B	■	○	○	○	■	■	■	■	■	△	△	△
Thermal Treatment ·· Hot Water or Steam Flushing/Stripping ·· Steam Injection ·· Electrical Heating	F	Y	L V	B	■	○	■	○	○	■	■	■	■	△	△	△
Hydrofracturing Enhancements	F	Y	N	N	■	■	○	○	○	○	○	○	○	○	△	○
In-Well Air Stripping ·· Circulating Wells	F	Y	L V	Cap.	■	○	△	○	○	○	○	△	○	△	△	△
Passive /Reactive Treatment Walls ·· Funnel and Gate ·· Iron Treatment Wall	F	N	S	Cap.	■	■	△	○	■	■	■	■	○	◆	△	■
3.11 Ex Situ Biological Treatment																
Bioreactors	F	N	S	Cap.	■	○	○	■	■	■	■	◆	■	△	△	■
Constructed Wetlands	F	N	S	Cap.	△	◆	◆	○	○	○	○	◆	○	■	△	■
3.12 Ex Situ Physical/Chemical Treatment (assuming pumping)																
Adsorption/ Absorption ·· Activated Alumina ·· Forager Sponge	F	N	S	O&M	■	○	△	△	○	○	○	○	△	■	◆	△

·· Lignin Adsorption/ Sorptive Clays ·· Synthetic Resins															
Advanced Oxidation Processes ·· UV Photolysis ·· UV Oxidation	F	Y	V	B	■	○	△	○	■	■	■	■	■	◆	◆	■
Air Stripping	F	Y	V	O&M	■	■	△	■	■	■	△	△	△	△	△	△
Granulated Activated Carbon (GAC)/Liquid Phase Carbon Adsorption	F	Y	S	O&M	■	■	△	○	■	■	■	■	■	◆	△	◆
Ground Water Pumping ·· Surfactant Enhanced Recovery ·· Drawdown Pumping	F	Y	L	B	■	■	△	△	○	○	○	◆	○	○	△	○
Ion Exchange	F	Y	S	B	■	■	△	○	△	△	△	△	△	■	○	△
Precipitation/ Coagulation /Flocculation ·· Coagulants and Flocculation	F	Y	S	Cap.	■	■	△	○	△	△	△	△	△	■	○	△
Separation ·· Distillation ·· Filtration/ Ultrafiltration /Microfiltration ·· Freeze Crystallization ·· Membrane Pervaporation ·· Reverse Osmosis	F	Y	S	B	■	■	■	△	■	■	■	■	■	◆	◆	△
Sprinkler Irrigation ·· Trickling Filter	F	N	N	N	■	■	△	■	■	■	△	△	△	△	△	△
3.13 Containment															
Physical Barriers ·· Slurry Walls ·· Biobarrier ·· Sheet Piling	F	N	N	Cap.	■	■	△	■	■	■	■	■	■	■	△	■
Deep Well Injection	F	N	S L	N	■	○	NA	■	○	○	○	○	○	○	○	○
3.14 Air Emissions/Off-Gas Treatment															
Biofiltration	F	NA	S L	N	○	◆	■	■	■	◆	◆	◆	■	△	NA	◆
High Energy Destruction ·· High Energy Corona ·· Tunable Hybrid Plasma Reactor	P	NA	N	I	△	△	NA	○	■	■	■	■	■	○	NA	△
Membrane Separation	P	NA	N	I	△	△	NA	○	■	■	○	○	○	△	NA	○
Oxidation ·· Catalytic Oxidation ·· Internal Combustion Engine Oxidation ·· Thermal Oxidation ·· Ultraviolet Oxidation	F	NA	N	N	■	■	NA	■	■	■	■	■	■	△	NA	○
Scrubbers ·· Water or Caustic Scrubbers	F	NA	Y	Cap.	■	■	NA	■	△	△	△	△	△	■	NA	NA
Vapor Phase Carbon Adsorption ·· VOC Recovery and Recycle	F	NA	S	N	■	■	NA	■	■	■	■	■	■	○	NA	■

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FRTR

Remediation Technologies Screening Matrix and Reference Guide, Version 4.0

2.6.2 Common Treatment Technologies for Halogenated SVOCs in Soil, Sediment, Bedrock and Sludge

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Common treatment technologies for halogenated SVOCs in soil, sediment, and sludge include biodegradation, dehalogenation, incineration, and excavation with off-site disposal.

All types of biodegradation, in situ and ex situ, can be considered to remediate soils: in situ bioremediation, bioventing, composting, controlled solid phase, or landfarming. Slurry phase biological treatment is also applicable but is less widely used. Treatability studies should be conducted to evaluate design parameters, such as degradation rates, supplemental organism addition, cleanup levels achievable, degradation intermediates, and nutrient/oxygen addition.

Biodegradation uses a process in which indigenous or inoculated microorganisms (e.g., fungi, bacteria, and other microbes) degrade (i.e., metabolize) organic contaminants found in soil and/or . In the presence of sufficient oxygen (aerobic conditions), microorganisms will ultimately convert many organic contaminants to carbon dioxide, water, and microbial cell mass. In the absence of oxygen (anaerobic conditions), the contaminants will be ultimately metabolized to methane and carbon dioxide. Sometimes contaminants may not be completely degraded, but only transformed to intermediate products that may be less, equally, or more hazardous than the original contaminant.

The in situ bioremediation of soil typically involves the percolation or injection of ground water or uncontaminated water mixed with nutrients. Ex situ bioremediation typically uses tilling or continuously mixed slurries to apply oxygen and nutrients, and is performed in a prepared bed (liners and aeration) or reactor.

Dehalogenation adds reagents to soils contaminated with halogenated SVOCs. The dehalogenation process is achieved by either the replacement of the halogen molecules or the decomposition and partial volatilization of the contaminants.

Incineration uses high temperatures, 870° to 1,200° C (1,400° to 2,200° F), to volatilize and combust (in the presence of oxygen) organic constituents in hazardous wastes. The destruction and removal efficiency (DRE) for properly operated incinerators exceeds the 99.99% requirement for hazardous waste.

Distinct incinerator designs available for solids are rotary kiln, fluidized bed, and infrared units. All three types have been used successfully at full scale.

For incineration of halogenated SVOCs, off-gas treatment is needed to neutralize the acidic gas as the products of oxidation.

Excavation, retrieval, and off-site disposal of contaminated soil (with or without stabilization) to a landfill have been performed extensively at many sites. Landfilling of hazardous materials, especially hazardous wastes, is becoming increasingly difficult and expensive as a result of growing regulatory control, and may be cost-prohibitive for sites with large volumes, greater depths, or complex hydrogeologic environments. Determining the feasibility of off-site disposal requires knowledge of land disposal restrictions and other regulations developed by state governments.

FRTR

Remediation Technologies Screening Matrix and Reference Guide, Version 4.0

Section 3 Treatment Perspectives

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Three primary strategies used separately or in conjunction to remediate most sites are:

- Destruction or alteration of contaminants.
- Extraction or separation of contaminants from environmental media.
- Immobilization of contaminants.

Treatment technologies capable of contaminant destruction by altering their chemical structure are thermal, biological, and chemical treatment methods. These destruction technologies can be applied in situ or ex situ to contaminated media.

Treatment technologies commonly used for extraction and separation of contaminants from environmental media include soil treatment by thermal desorption, soil washing, solvent extraction, and soil vapor extraction (SVE) and ground water treatment by either phase separation, carbon adsorption, air stripping, ion exchange, or some combination of these technologies. Selection and integration of technologies should use the most effective contaminant transport mechanisms to arrive at the most effective treatment scheme. For example, more air than water can be moved through soil. Therefore, for a volatile contaminant in soil that is relatively insoluble in water, SVE would be a more efficient separation technology than soil flushing or washing.

Immobilization technologies include stabilization, solidification, and containment technologies, such as placement in a secure landfill or construction of slurry walls. No immobilization technology is permanently effective, so some type of maintenance is desired. Stabilization technologies are often proposed for remediating sites contaminated by metals or other inorganic species.

These concepts about site remediation strategies and representative technologies associated with them are summarized in Figure1: Classification of Remedial Technologies by Function. One feature obvious from the figure is that the choice of applied technologies is not extensive once a strategy is selected.

Generally, no single technology can remediate an entire site. Several treatment technologies are usually combined at a single site to form what is known as a treatment train. SVE can be integrated with ground water pumping and air stripping to simultaneously remove contaminants from both ground water and soil. The emissions from the SVE system and the air stripper can be treated in a single air treatment unit. An added benefit is that the air flow through the soil stimulates or enhances natural biological activity, and some biodegradation of contaminants occurs. In some cases, air is injected into either the saturated or the unsaturated zones to facilitate contaminant transport and to promote biological activity.

For the purpose of this document, the technologies are separated into 14 treatment groups as follows:

- Soil, sediment, and sludge:
  - In situ biological treatment.
  - In situ physical/chemical treatment.
  - In situ thermal treatment.
  - Ex situ biological treatment (assuming excavation).

  - Ex situ physical/chemical treatment (assuming excavation).
  - Ex situ thermal treatment (assuming excavation).
  - Containment.
  - Other treatment processes.
- Ground water, surface water, and leachate:
  - In situ biological treatment.
  - In situ physical/chemical treatment.
  - Ex situ biological treatment (assuming pumping).
  - Ex situ physical/chemical treatment (assuming pumping).
  - Containment.
- Air emissions/off-gas treatment.

These 14 treatment groups correspond to the following 14 subsections (3.1 through 3.14). The discussion of the broad application of each treatment group (e.g., in situ biological treatment for soil, sediment, bedrock and sludge) in this section is followed by a more detailed discussion of each treatment technology (e.g., bioventing) in that treatment group, in Section 4. Information on completed projects in these treatment process areas has been presented in tables extracted from the *Treatment Technologies for Site Cleanup: Annual Status Report Tenth Edition (February 2001)*, and the *Synopses of Federal Demonstrations of Innovative Site Remediation Technologies*, FRTR, 1993.

Tables 3-1 and 3-2 summarize pertinent information for each of the treatment technologies presented in Section 4. Information summarized includes the following:

- Technology Profile Number (refers to Section 4).
- Developmental Status (full scale vs. pilot scale).
- Typical Treatment Train.
- Residuals Produced.
- O&M or Capital Intensive.
- Availability.
- Contaminants Treated.
- System Reliability/Maintainability.
- Cleanup Time.
- Overall Cost.

Additionally, a brief description of each treatment technology is presented at the beginning of each process description.

TABLE 3-1a. DEFINITION OF LEGENDS USED IN THE TREATMENT TECHNOLOGIES SCREENING MATRIX

<table>
<tr><th>Factors</th><th colspan="4">Definitions</th></tr>
<tr><td>Development Status
Scale status of an available technology.</td><td colspan="2">F
Full scale: technology has been used in real site remediation.</td><td colspan="2">P
Pilot Scale: studies conducted in the field or the laboratory to fine-tune the design of the technology.</td></tr>
<tr><td>Treatment Train
Is the technology only effective as part of the treatment train?</td><td colspan="2">Y
Technology must be used with the combination of other technologies as a treatment train.</td><td colspan="2">N
Technology can be used as a stand alone one.</td></tr>
<tr><td>Residuals Produced
Residuals need to be treated.</td><td>S
Solid</td><td>L
Liquid</td><td>V
Vapor</td><td>N
None</td></tr>
</table>

O&M or Capital Intensive Main cost intensive parts.	**O&M** Operation and Maintenance Intensive	**Cap** Capital Intensive	**B** Both O&M and Capital Intensive	**N** Neither O&M or Capital Intensive

TABLE 3-1b. DEFINITION OF SYMBOLS USED IN THE TREATMENT TECHNOLOGIES SCREENING MATRIX

Factors and Definitions	Worse △	Average ○	Better ■	Other ◆
Availability Number of vendors that can design, construct, and maintain the technology.	Fewer than 2 vendors	2-4 vendors	More than 4 vendors	Data Not Available
Contaminants Treated Contaminants are classified into the following eight groups: - Nonhalogenated VOCs; - Halogenated VOCs; - Nonhalogenated SVOCs; - Halogenated SVOCs; - Fuels; - Inorganics; - Radionuclides; - Explosives.	No Demonstrated Effectiveness at Pilot or Full Scale	Limited Effectiveness Demonstrated at Pilot or Full Scale	Effectiveness Demonstrated at Pilot or Full Scale	Level of Effectiveness highly dependent upon specific contaminant and its application/design
System Reliability /Maintainability The expected range of demonstrated reliability maintenance relative to other effective technologies	Low reliability and high maintenance	Average reliability and average maintenance	High reliability and low maintenance	Not applicable
Cleanup Time provided that this technology is effective for this specific contaminant. Time required to clean up a "standard" site using the technology. The "standard" site is assumed to be 20,000 tons (18,200 metric tons) for soils and 1 million gallons (3,785,000 liters) for ground water.	More than 3 years for in situ soil	1-3 years	Less than 1 year	Contaminant specific
	More than 1 year for ex situ soil	0.5-1 year	Less than 0.5 year	Contaminant specific
	More than 10 years for water	3-10 years	Less than 3 years	Contaminant specific
Overall Cost Design, construction, and operations and maintenance (O&M) costs of the core process that defines each technology, exclusive of mobilization, demobilization, and pre-	More than $330/metric ton ($300/ton) for soils	$110-$330 /metric ton ($100-$300 /ton)	Less than $110/metric ton ($100/ton)	Contaminant specific
	More than $2.64/1,000 liters	$0.79-$2.64 /1,000 liters ($3.00-	Less than $0.79/1,000 liters	Contaminant specific

and post-treatment. For ex situ soil, sediment, and sludge technologies, it is assumed that excavation costs average $55.00/metric ton ($50/ton). For ex situ ground water technologies, it is assumed that pumping costs average $0.07/1,000	($10/1,000 gal.) for ground water	$10.00/ 1,000	($3.00/1,000 gallons)	
	More than $11.33/kg ($25/lb) for air emissions and off-gases	$3.17- $11.33 /kg ($7-$25/lb)	Less than $3.17/kg ($7/lb)	Contaminant specific

Source: Remediation Technologies Screening Matrix and Reference Guide, Version I (EPA, USAF, 1993).

NYS Department of Environmental Conservation - Home - Site Map - Search

APPENDIX A of TAGM #4046

TABLE 1
Recommended soil cleanup objectives (mg/kg or ppm)
Volatile Organic Contaminants

Shortcut to TAGM 4046 Tables for SVOCs | Pesticides/PCBs | Heavy Metals

Contaminant	Partition Coefficient, Koc	Groundwater Standards/ Criteria, Cw (ug/l or ppb)	a Allowable soil conc., Cs (ppm)	b ** Soil cleanup objectives to protect GW quality (ppm)	USEPA Health Based (ppm)		CRQL (ppb)	*** Rec. Soil Cleanup Objective (ppm)
					Carcin- ogens	Systemic Toxicants		
Acetone	2.2	50	0.0011	0.11	N/A	8,000	10	0.2
Benzene	83	0.7	0.0006	0.06	24	N/A	5	0.06
Benzoic Acid	54 *	50	0.027	2.7	N/A	300,000	5	2.7
2-Butanone	4.5 *	50	0.003	0.3	N/A	4,000	10	0.3
Carbon Disulfide	54 *	50	0.027	2.7	N/A	8,000	5	2.7
Carbon Tetrachloride	110 *	5	0.006	0.6	5.4	60	5	0.6
Chlorobenzene	330	5	0.017	1.7	N/A	2,000	5	1.7
Chloroethane	37 *	50	0.019	1.9	N/A	N/A	10	1.9
Chloroform	31	7	0.003	0.30	114	800	5	0.3
Dibromochloromethane	N/A	50	N/A	N/A	N/A	N/A	5	N/A
1,2-Dichlorobenzene	1,700	4.7	0.079	7.9	N/A	N/A	330	7.9
1,3-Dichlorobenzene	310 *	5	0.0155	1.55	N/A	N/A	330	1.6
1,4-Dichlorobenzene	1,700	5	0.085	8.5	N/A	N/A	330	8.5
1,1-Dichloroethane	30	5	0.002	0.2	N/A	N/A	5	0.2
1,2-Dichloroethane	14	5	0.001	0.1	7.7	N/A	5	0.1
1,1-Dichloroethene	65	5	0.004	0.4	12	700	5	0.4
1,2-Dichloroethene (trans)	59	5	0.003	0.3	N/A	2,000	5	0.3
1-3 dichloropropane	51	5	0.003	0.3	N/A	N/A	5	0.3
Ethylbenzene	1,100	5	0.055	5.5	N/A	8,000	5	5.5
113 Freon (1,1,2 Trichloro- 1,2,2 Trifluoroethane)	1,230 *	5	0.060	6.0	N/A	200,000	5	6.0

Methylene chloride	21	5	0.001	0.1	93	5,000	5	0.1
4-Methyl-2-Pentanone	19 *	50	0.01	1.0	N/A	N/A	10	1.0
Tetrachloroethene	277	5	0.014	1.4	14	800	5	1.4
1,1,1-Trichloroethane	152	5	0.0076	0.76	N/A	7,000	5	0.8
1,1,2,2-Tetrachloroethane	118	5	0.006	0.6	35	N/A	5	0.6
1,2,3-trichloropropane	68	5	0.0034	0.34	N/A	80	5	0.4
1,2,4-trichlorobenzene	670 *	5	0.034	3.4	N/A	N/A	330	3.4
Toluene	300	5	0.015	1.5	N/A	20,000	5	1.5
Trichloroethene	126	5	0.007	0.70	64	N/A	5	0.7
Vinyl chloride	57	2	0.0012	0.12	N/A	N/A	10	0.2
Xylenes	240	5	0.012	1.2	N/A	200,000	--	1.2

a. Allowable Soil Concentration Cs = f x Cw x Koc
b. Soil cleanup objective = Cs x Correction Factor (CF)
N/A is not available

* Partition coefficient is calculated by using the following equation:
log Koc = -0.55 log S + 3.64, where S is solubility in water in ppm.
All other Koc values are experimental values.

** Correction Factor (CF) of 100 is used as per TAGM #4046

*** As per TAGM #4046, Total VOCs < 10 ppm.

Note: Soil cleanup objectives are developed for soil organic carbon content (f) of 1%, and should be adjusted for the actual soil organic carbon content if it is known.

Federation of New York Solid Waste Associations

Spring 2001 Conference May 6-9, 2001 Bolton Landing, New York

Plenary Session: Industry Outlook

Northeast Tipping Fees presented by:

Chris Campman Manager Solid Waste Gannett Fleming, Inc.

This paper and presentation discuss the impact of tipping fees and solid waste capacity in the Mid-Atlantic and northeast regions. As state and local governments implement additional controls on solid waste facilities, potential volume issues loom on the horizon.

Local, state and federal regulations have impacted all solid waste facilities. Restrictions due to local host community benefits and concerns have impacted both tipping fees and daily capacities at the sites. Various state agencies have made attempts to exert pressure to restrict facility capacity through expansion and permit renewal reviews.

State Government/Waste Capacity

The Mid-Atlantic States have been working together (love/hate) in the recent past to develop a balanced approach for the management of solid waste in the region. This approach hopes to integrate environmentally sound waste disposal including landfills, waste-to-energy, recycling, re-use, and composting initiatives. This approach has a long road to go.

The nation continues to increase the amount of solid waste generated for disposal. In 1998 the nation generated approximately 340 million tons of municipal solid waste, an increase of over 36% from the decade before. This increase was due to many factors such as a robust economy, package modification, and increases in population.

During this time period the climate for disposal changed. More stringent regulations and requirements for solid waste facilities were enacted. This caused a decrease in the number and availability of waste disposal sites, all while an increase in material requiring disposal occurred. This has caused a major shift in waste markets and the industry itself.

Our robust economy caused the consolidation of the private side of the waste industry, which spilled over in the public side. As private companies internalize disposal options, the number of transfer stations increases, and long haul transportation options expand. This causes an imbalance in disposal sites that accept the wastes of certain companies. Additionally, a geographic imbalance exists in certain part of the region, which tends to complicate the matter.

As the landfill disposal business moves into the next decade, operational changes will occur. After the wave of consolation in private industry the reality of increased debt payments and lower margins have forced the major companies to cut costs.

Tipping Fees

In the last ten to fifteen years tipping fees have fluctuated downward. The fluctuation of rates and services offered has driven the market from high margins and profits to survival through economies of scale to reduced services and staffing. Site capacity has again become the major trump card for survival.

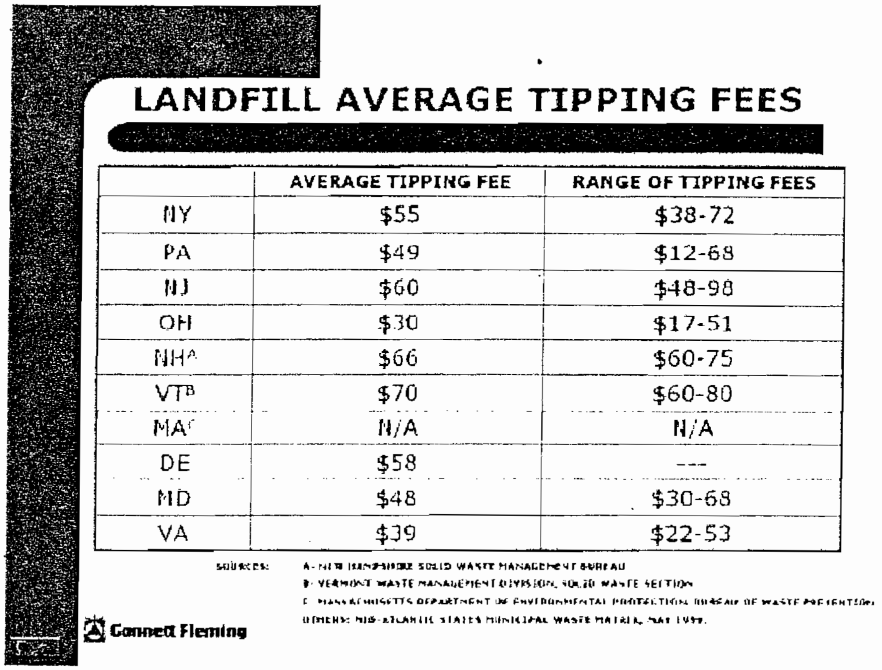
Public operations have experienced a similar life cycle. Years ago the regulators in many states encouraged the development of waste disposal systems to solve environmental concerns. These systems had a captured market and included initiatives for recycling and re-use. Tipping fees were high but the services offered were numerous and environmentally sound. Challenges in the courts changed the face of solid waste collection and disposal as well as recycling and other services offered.

Public operations had to compete with privates for the waste and a dual market developed. Many public operations continue today to struggle with traditional operations in the public setting versus the competitive market.

The larger private companies have the options to integrate their systems, which reduce cost, and with multiple disposal sites they can move waste to sites based on cost and volume capacity. Accounting measures and reporting regulations can provide firms with incentives that are not available to public operations.

Any discussion regarding tipping fees must be couched with the reality that pricing can fluctuate greatly at every site. Discounts for volume are routine as well as internal costs reductions. Every site has its own criteria to set pricing, which normally considers volume, market conditions and individual site conditions.

The graphics attached show the landfill average tipping fees for many states. The states of PA, OH and VA have a low end on the range, which explains why they import large volumes of waste. The top 10 import states provide a national trend in the northeast/Mid-Atlantic and in the Midwest.

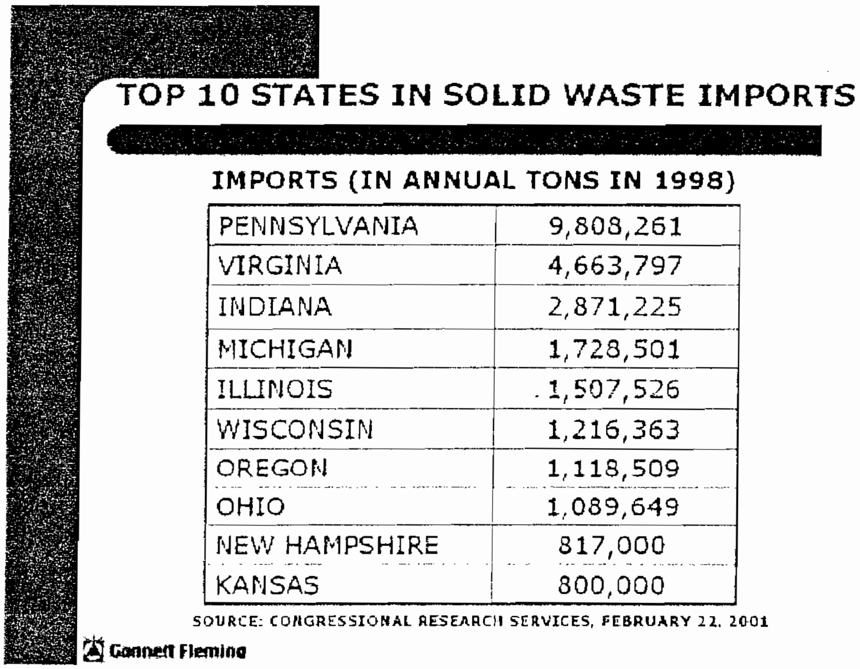


LANDFILL AVERAGE TIPPING FEES

	AVERAGE TIPPING FEE	RANGE OF TIPPING FEES
NY	$55	$38-72
PA	$49	$12-68
NJ	$60	$48-98
OH	$30	$17-51
NH[A]	$66	$60-75
VT[B]	$70	$60-80
MA[C]	N/A	N/A
DE	$58	---
MD	$48	$30-68
VA	$39	$22-53

SOURCES: A- NEW HAMPSHIRE SOLID WASTE MANAGEMENT BUREAU
B- VERMONT WASTE MANAGEMENT DIVISION, SOLID WASTE SECTION
C- MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION, BUREAU OF WASTE PREVENTION
OTHERS: MID-ATLANTIC STATES MUNICIPAL WASTE MATRIX, MAY 1999.

Gannett Fleming



TOP 10 STATES IN SOLID WASTE IMPORTS

IMPORTS (IN ANNUAL TONS IN 1998)

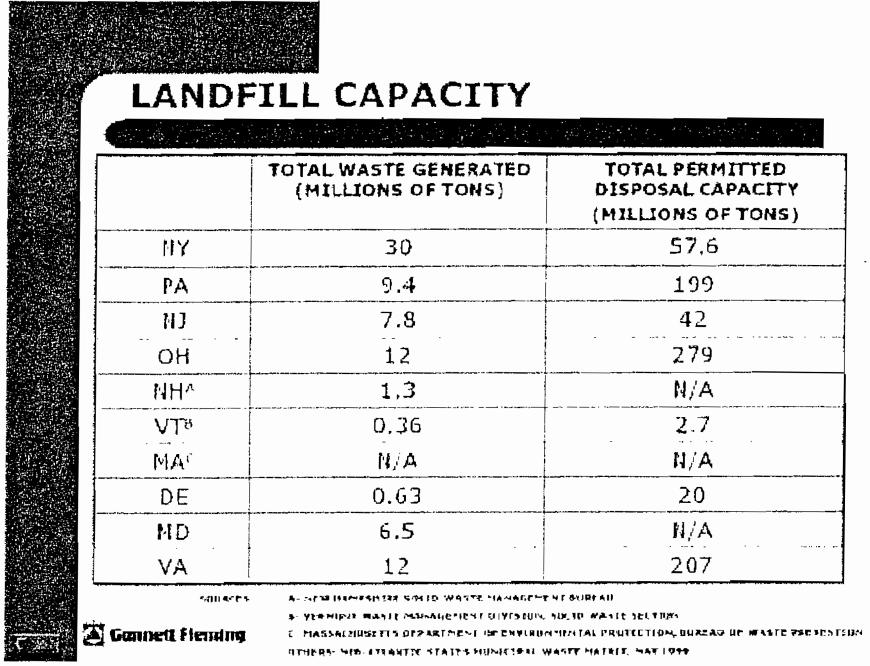
PENNSYLVANIA	9,808,261
VIRGINIA	4,663,797
INDIANA	2,871,225
MICHIGAN	1,728,501
ILLINOIS	1,507,526
WISCONSIN	1,216,363
OREGON	1,118,509
OHIO	1,089,649
NEW HAMPSHIRE	817,000
KANSAS	800,000

SOURCE: CONGRESSIONAL RESEARCH SERVICES, FEBRUARY 22, 2001

Gannett Fleming

The tipping fee issue will always be a topic of interest in maintaining services and profitability.

Waste capacity is a major factor in the graphic versus the amount of waste generated. Again the amount of capacity available is focused in PA, OH and VA. These states also have the low end of the range on tipping fees. With the capacity focused in only a few states, a major concern is transportation of the waste from the large generation areas to the disposal site.



LANDFILL CAPACITY

	TOTAL WASTE GENERATED (MILLIONS OF TONS)	TOTAL PERMITTED DISPOSAL CAPACITY (MILLIONS OF TONS)
NY	30	57.6
PA	9.4	199
NJ	7.8	42
OH	12	279
NH[A]	1.3	N/A
VT[B]	0.36	2.7
MA[C]	N/A	N/A
DE	0.63	20
MD	6.5	N/A
VA	12	207

SOURCES:
A- NEW HAMPSHIRE SOLID WASTE MANAGEMENT BUREAU
B- VERMONT WASTE MANAGEMENT DIVISION, SOLID WASTE SECTION
C- MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION, BUREAU OF WASTE PREVENTION
OTHERS: MID-ATLANTIC STATES MUNICIPAL WASTE MATRIX, MAY 1999

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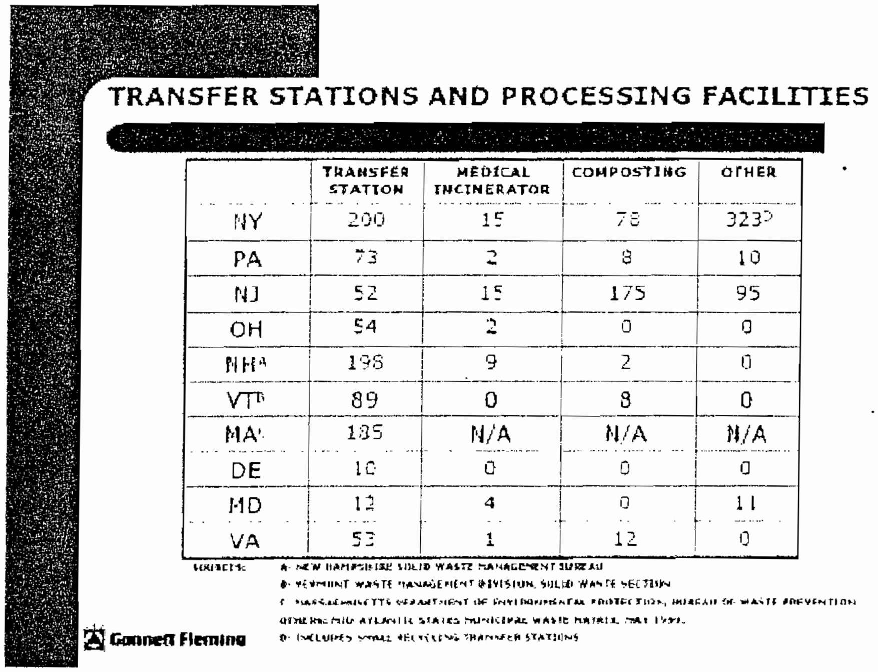
Transfer stations provide the loading option that is preferred. Long haul of solid waste to PA, OH and VA is from the New York City area, northern New Jersey, and other large metro areas in the northeast. The graphic shows the number of transfer stations. The numbers are high in many states because of the number of small transfer stations in rural areas.



TRANSFER STATIONS AND PROCESSING FACILITIES

	TRANSFER STATION	MEDICAL INCINERATOR	COMPOSTING	OTHER
NY	200	15	78	323[D]
PA	73	2	8	10
NJ	52	15	175	95
OH	54	2	0	0
NH[A]	196	9	2	0
VT[B]	89	0	8	0
MA[C]	135	N/A	N/A	N/A
DE	10	0	0	0
MD	12	4	0	11
VA	53	1	12	0

SOURCES: A- NEW HAMPSHIRE SOLID WASTE MANAGEMENT BUREAU
B- VERMONT WASTE MANAGEMENT DIVISION, SOLID WASTE SECTION
C- MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION, BUREAU OF WASTE PREVENTION
OTHERS: MID-ATLANTIC STATES MUNICIPAL WASTE MATRIX, MAY 1991.
D- INCLUDES SMALL RECYCLING TRANSFER STATIONS

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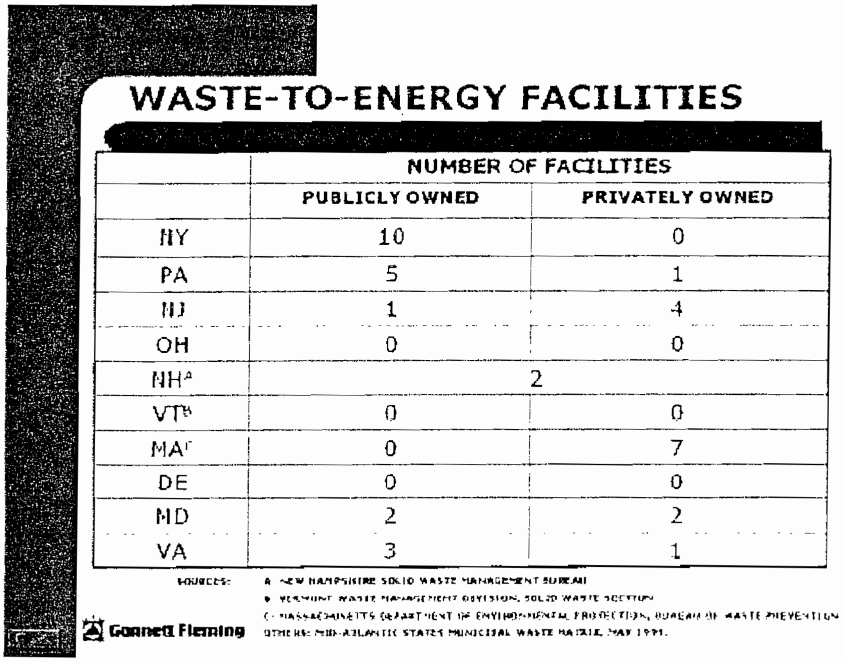

WASTE-TO-ENERGY FACILITIES

	NUMBER OF FACILITIES	
	PUBLICLY OWNED	PRIVATELY OWNED
NY	10	0
PA	5	1
NJ	1	4
OH	0	0
NH[A]	2	
VT[B]	0	0
MA[C]	0	7
DE	0	0
MD	2	2
VA	3	1

SOURCES: A- NEW HAMPSHIRE SOLID WASTE MANAGEMENT BUREAU
B- VERMONT WASTE MANAGEMENT DIVISION, SOLID WASTE SECTION
C- MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION, BUREAU OF WASTE PREVENTION
OTHERS: MID-ATLANTIC STATES MUNICIPAL WASTE MATRIX, MAY 1991.

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The impact of changing regulations and states giving citizens and host communities a much stronger voice in the permitting and operation of the sites has increased the permitting time line and increased operational costs. New, more stringent requirements are being thrust upon the sites.

Host community agreements with the landfill are required in many states before the site can receive a permit to operate. The registration of trucks and traffic flow patterns are additional methods to control waste flows. Harm-versus-benefits analysis and public hearings are also required.

The combination of new state and local controls, which benefit the environment, have begun to slow down the pipeline of new facilities, permit renewals and available capacity. States are also imposing statewide volume caps regardless of individual site capacity issues.

Future

- New Greenfield landfill sites?
- So what's going to happen with tipping fees up down or level?
- Capacity to remain status quo or increase/decrease?
- Private consolidation renewed?
- Public operations continue to privatize?
- Recycling and re-use to increase/decrease?
- Waste-to-energy increase in plants?

What will happen is uncertain, but change is inevitable.

The number of landfills should remain relativity constant. The number of Greenfield sites in the mill has not been increasing. Therefore, the existing landfills will increase in value based on capacity and transportation availability. This should have a direct relation to an increase in tipping fees. Depending upon the areas within the region, individual sites will still have tipping fee and capacity concerns.

With capacity such an issue, methods to improve compaction or density have become a priority. Improved heavy equipment utilization, equipment for compaction only, GIS systems and changes to wheels and blades have vastly improved compaction rates. Mixing various types of waste material on the operating face has increased compaction. The use of alternative daily cover materials has reduced the volume consumed by traditional cover soils. The use of improved technologies such as leachate re-circulation and bio-reactor technologies (aerobic and anaerobic) have shown dramatic increases in settlement. All of these improvements will produce an increase in volume, which means increased revenue from the same landfill footprint.

Conclusions

- Tipping fee increases are needed in the market to cover operations including labor, fuel and equipment costs.
- Tipping fees will increase due to volume constraints
- Tipping fees will increase due to state and local regulation tightening
- Regional imbalance regarding disposal sites will continue.

Typical Soil Excavation Remedies*

Description:

Typical Contaminated Soil Excavation Remedies require the removal and transport of contaminated materials to permitted off-site treatment and/or disposal facilities. Some pretreatment of the contaminated media may be required in order to meet state and local disposal restrictions.

Applicability:

Excavation and off-site disposal is applicable to the complete range of contaminant groups with no particular target group. Excavation and off-site disposal by relocating the waste to a different site may be considered safer than leaving or treating the contaminated materials on site.

Limitations:

Factors that may limit the applicability and effectiveness of the process include:

- Generation of fugitive emissions may be a problem during operations.
- The distance from the contaminated site to the nearest disposal facility with the required permit(s) will affect cost.
- Depth and composition of the media requiring excavation must be considered.
- Transportation of the soil through populated areas may affect community acceptability.
- Disposal options for certain waste (e.g., mixed waste) may be limited. There is currently only one licensed disposal facility for radioactive and mixed waste in the United States.
- Contaminants can potentially migrate from disposal facilities via effluent discharges to surface water, leachate into ground water, volatilization to the atmosphere, etc.
- Disposal facilities can develop odor problems as well as mosquito and insect problems without proper design and maintenance.

Data Needs:

- The type of contaminant and its concentration will impact off-site disposal requirements.
- Soil characterization as dictated by land disposal restrictions are required.
- Most hazardous wastes must be treated to meet either RCRA or non-RCRA treatment standards prior to land disposal. Radioactive wastes would have to meet disposal facility waste form requirements based on waste classification.

Performance Data:

Excavation and off-site disposal is a well proven and readily implementable technology. Prior to 1984, excavation and off-site disposal was the most common method for cleaning up hazardous waste sites. Excavation is the initial component in all ex situ treatments.

The rate of excavation depends on a number of factors, including the number of loaders and trucks operating. The excavation of 18,200 metric tons (20,000 tons) of contaminated soil would typically require about 2 months. Disposal of the contaminated media is dependent upon the availability of adequate containers to transport the hazardous waste to a permitted facility.

CERCLA includes a statutory preference for treatment of contaminants, and excavation and off-site disposal is now less acceptable than in the past. The disposal of hazardous wastes is governed by RCRA (40 CFR Parts 261-265), and the U.S. Department of Transportation (DOT) regulates the transport of hazardous materials (49 CFR Parts 172-179, 49 CFR Part 1387, and DOT-E 8876).

DOE has demonstrated a cryogenic retrieval of buried waste system, which uses liquid nitrogen (LN2) to freeze soil and buried waste to reduce the spread of contamination while the buried material is retrieved with a series of remotely operated tools. Other excavation/retrieval systems that DOE is currently developing include a remote excavation system, a hydraulic impact end effector, and a high pressure waterjet dislodging and conveyance end effector using confined sluicing.

Cost:

Cost estimates for excavation and disposal range from $300 to $510 per metric ton ($270 to $460 per ton) depending on the nature of hazardous materials and methods of excavation. These estimates include excavation/removal, transportation, and disposal at a RCRA permitted facility. Additional cost of treatment at disposal facility may also be required. Excavation and off-site disposal is a relatively simple process, with proven procedures. It is a labor-intensive practice with little potential for further automation. Additional costs may include soil characterization and treatment to meet land ban requirements.

Additional cost information can be found in the Hazardous, Toxic, and Radioactive Wastes (HTRW) Historical Cost Analysis System (HCAS) developed by Environmental Historical Cost Committee of Interagency Cost Estimation Group.

****

* From: **http://www.frtr.gov/matrix2/section4/4-29.html**
October, 2002

United States
Environmental Protection
Agency

Office of Solid Waste and
Emergency Response
(5102G)

EPA 542-F-01-001
April 2001
www.epa.gov/superfund/sites
www.cluin.org

EPA

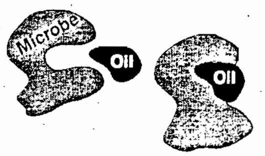
A Citizen's Guide to Bioremediation

The Citizen's Guide Series

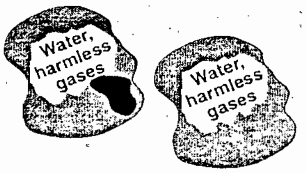
EPA uses many methods to clean up pollution at Superfund and other sites. Some, like bioremediation, are considered new or *innovative*. Such methods can be quicker and cheaper than more common methods. If you live, work, or go to school near a Superfund site, you may want to learn more about cleanup methods. Perhaps they are being used or are proposed for use at your site. How do they work? Are they safe? This Citizen's Guide is one in a series to help answer your questions.

What is bioremediation?

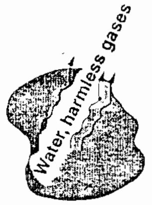
Bioremediation allows natural processes to clean up harmful chemicals in the environment. Microscopic "bugs" or *microbes* that live in soil and groundwater like to eat certain harmful chemicals, such as those found in gasoline and oil spills. When microbes completely digest these chemicals, they change them into water and harmless gases such as carbon dioxide.



Microbe eats oil



Microbe digests oil and changes it to water and harmless gases



Microbe releases water and harmless gases into soil or groundwater

How does it work?

In order for microbes to clean up harmful chemicals, the right temperature, nutrients (fertilizers), and amount of oxygen must be present in the soil and groundwater. These conditions allow the microbes to grow and multiply—and eat more chemicals. When conditions are not right, microbes grow too slowly or die. Or they can create more harmful chemicals. If conditions are not right at a site, EPA works to improve them. One way they improve conditions is to pump air, nutrients, or other substances (such as molasses) underground. Sometimes microbes are added if enough aren't already there.

The right conditions for bioremediation cannot always be achieved underground. At some sites, the weather is too cold or the soil is too dense. At such sites, EPA might dig up the soil to clean it above ground where heaters and soil mixing help improve conditions. After the soil is dug up, the proper nutrients are added. Oxygen also may be added by stirring the mixture or by forcing air through it. However, some microbes work better without oxygen. With the right temperature and amount of oxygen and nutrients, microbes can do their work to "bioremediate" the harmful chemicals.

Sometimes mixing soil can cause harmful chemicals to evaporate before the microbes can eat them. To prevent these chemicals from polluting the air, EPA mixes the soil inside a special tank or building where chemicals that evaporate can be collected and treated.

Microbes can help clean polluted groundwater as well as soil. To do this, EPA drills wells and pumps some of the groundwater into tanks. Here, the water is mixed with nutrients and air before it is pumped back into the ground. The added nutrients and air help the microbes bioremediate the groundwater. Groundwater can also be mixed underground by pumping nutrients and air into the wells.

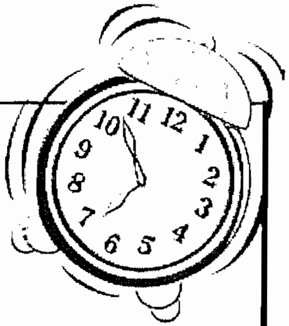
Once harmful chemicals are cleaned up and microbes have eaten their available "food," the microbes die.

Is bioremediation safe?

Bioremediation is very safe because it relies on microbes that naturally occur in soil. These microbes are helpful and pose no threat to people at the site or in the community. Microbes themselves won't hurt you, but never touch the polluted soil or groundwater—especially before eating.

No dangerous chemicals are used in bioremediation. The nutrients added to make microbes grow are fertilizers commonly used on lawns and gardens. Because bioremediation changes the harmful chemicals into water and harmless gases, the harmful chemicals are completely destroyed. To ensure that bioremediation is working, EPA tests samples of soil and groundwater.

How long will it take ?



The time it takes to bioremediate a site depends on several factors:

- types and amounts of harmful chemicals present
- size and depth of the polluted area
- type of soil and the conditions present
- whether cleanup occurs above ground or underground

These factors vary from site to site. It can take a few months or even several years for microbes to eat enough of the harmful chemicals to clean up the site.

Why use bioremediation?

EPA uses bioremediation because it takes advantage of natural processes. Polluted soil and groundwater can be cleaned at the site without having to move them somewhere else. If the right conditions exist or can be created underground, soil and groundwater can be cleaned without having to dig or pump it up at all. This allows cleanup workers to avoid contact with polluted soil and groundwater. It also prevents the release of harmful gases into the air. Because microbes change the harmful chemicals into water and harmless gases, few if any wastes are created.

Often bioremediation does not require as much equipment or labor as most other methods. Therefore, it is usually cheaper. Bioremediation has successfully cleaned up many polluted sites and is being used at 50 Superfund sites across the country.

For more information

write the Technology Innovation Office at:

U.S. EPA (5102G)
1200 Pennsylvania Ave., NW
Washington, DC 20460

or call them at
(703) 603-9910.

Further information also can be obtained at **www.cluin.org** or **www.epa.gov/superfund/sites**.

TECHNICAL & REGULATORY GUIDANCE

TECHNICAL AND REGULATORY REQUIREMENTS FOR ENHANCED IN SITU BIOREMEDIATION OF CHLORINATED SOLVENTS IN GROUNDWATER

-FINAL-

December 23, 1998

Prepared by the Interstate Technology and Regulatory Cooperation
Workgroup
In Situ Bioremediation Subgroup

EXECUTIVE SUMMARY

Enhanced *in situ* bioremediation (EISB) of chlorinated solvents in groundwater involves the input of an organic carbon source, nutrients, electron acceptors, and/or microbial cultures to stimulate degradation. EISB systems may be used to remediate high concentration areas within plumes or source areas, to help provide containment of a chlorinated solvent plume, or as part of a treatment train downgradient from a primary cleanup or containment system.

The major biological processes by which chlorinated solvent compounds degrade include anaerobic reductive dechlorination, aerobic cometabolism, and oxidation. Anaerobic reductive dechlorination involves the replacement of chlorine atoms in the chlorinated compound by hydrogen. An electron donor, either hydrogen gas or a precursor carbon compound, is necessary for the reduction to occur. Aerobic cometabolism involves the fortuitous degradation of chlorinated solvents by enzymes intended to metabolize compounds such as toluene, phenol, or methane. The organisms gain no benefit from the degradation, and may be harmed. Direct degradation of certain lesser chlorinated solvents can occur in either anaerobic or aerobic environments.

A key factor in the design of EISB systems is the mechanism of delivery of the various amendments to the targeted portion of the groundwater plume. Various types of delivery mechanisms have been used, including dual vertical well recirculation, horizontal well recirculation, combinations of well-infiltration trench recirculation, direct liquid amendment injection, gas amendment injection, and pass-through or reactive cell designs. Each of these may have advantages or disadvantages depending upon the major objective of the project and site conditions. For sites in which treatment of high concentration portions of a plume is the goal, systems with either dual wells or other arrangements may provide semi-closed loops which reduce downgradient flow of contaminants while providing biotreatment. For systems which are designed to reduce concentrations in portions of plumes downgradient from other remediation systems, some sort of pass-through system may be needed. These may include recirculation systems oriented at an angle to the natural hydraulic gradient, single-well recirculation systems, direct injection systems, or passive systems.

A variety of amendments may be added to EISB systems. Common carbon sources for anaerobic sites include lactic acid, sodium benzoate, methanol, and yeast extract. Common carbon sources for aerobic cometabolism sites are toluene, phenol, and methane. Most sites require nutrients, such as phosphate, nitrate, or potassium. Electron acceptors are added at some sites to promote cometabolism or direct oxidation of lesser chlorinated compounds, such as vinyl chloride. These can be added by gas injection or as a solid, such as magnesium peroxide. Naturally occurring or engineered microorganisms with specific biodegradation capabilities can be added to promote aerobic cometabolism or (less commonly) anaerobic reductive dechlorination.

EISB systems may face significant regulatory issues that require careful attention. ITRC is seeking help from regulatory agencies to help resolve some of these issues. Multiple regulatory authorities may become involved in oversight and permitting. In particular, federal and state regulations regarding the movement, treatment, and reinjection of contaminated groundwater are confusing and subject to multiple interpretations. Recirculation and reinjection of contaminated groundwater in recirculation systems may be subject to RCRA hazardous waste and land disposal regulations. Class IV injections (hazardous waste injections into useable aquifers) for non-CERCLA and non-RCRA sites are prohibited by underground injection control (UIC) regulations.

There are potential solutions to these obstacles, including the use of Area of Contamination (AOC) and Corrective Action Management Units (CAMUs), CERCLA and RCRA permit waivers, and treatability variances. At present, there is no consensus on the best regulatory mechanism to allow reinjection to occur. It is therefore important to begin identifying permitting and other regulatory requirements and to communicate effectively with the public and stakeholder groups early in the process.

An EISB project should include a thorough initial site assessment, a laboratory treatability test, field pilot design, field pilot test, and scale-up design. The initial site assessment should accurately characterize the contaminant distribution in the area of the proposed system in both groundwater and source (if applicable). Natural attenuation parameters should be analyzed in both soil and groundwater. If necessary, the site assessment should include additional hydrogeologic study.

A laboratory treatability test should be employed at most sites. It should include either microcosm or column studies designed to show specific biodegradation mechanisms through mass determinations of parent and daughter products, and other metabolic products. The treatability test may also include direct microbial population information.

Based on the results of a successful laboratory treatability test, the field pilot should be designed to deliver amendments to the intended portion of the contaminated aquifer. All permitting and regulatory requirements should be identified and the permitting process should begin as soon as possible. The engineering design should incorporate a thorough understanding of the hydrogeology of the system. This normally includes modeling of groundwater flow, as well as transport and degradation of targeted compounds. A suitable field pilot site should be selected where the hydrogeology is fairly simple and well characterized.

Common problems encountered during operation of the field pilot include biofouling, and insufficient nutrient delivery. Biofouling can be reduced by well surging, pulsing of nutrients, and addition of high concentrations of certain electron donors or acceptors. A gradual startup of the system is recommended to determine the effective delivery rate and to reduce biofouling.

The ultimate success of the field pilot should be judged by a clearly defined loss of contaminant mass in the system, the laboratory and field evidence for specific appropriate microbial activity, and the correlation of contaminant loss with degradation parameters. Field evidence for cometabolism is more difficult than for anaerobic reductive dechlorination, and therefore cometabolism sites rely heavily on laboratory treatability studies.

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Environmental Protection
Agency

Solid Waste and
Emergency Response
(5102G)

EPA 542-R-01-019
September 2001
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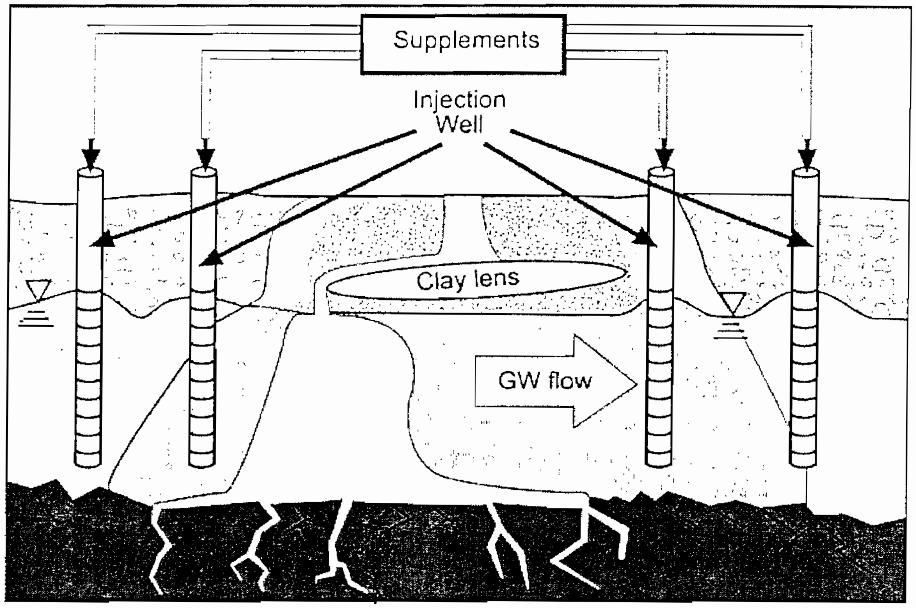
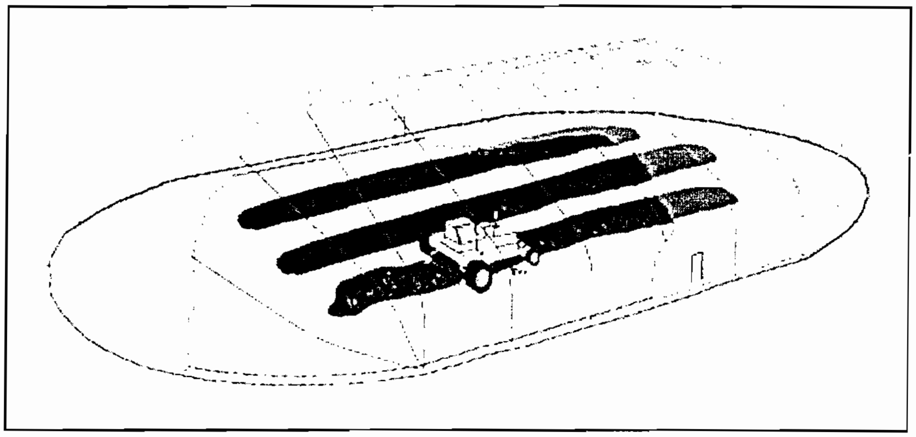
EPA

Use of Bioremediation at Superfund Sites





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1.0 SUMMARY

Bioremediation is a technology that uses microorganisms to treat contaminants through natural biodegradation mechanisms (intrinsic bioremediation) or by enhancing natural biodegradation mechanisms through the addition of microbes, nutrients, electron donors, and/or electron acceptors (enhanced bioremediation). This technology, performed *in situ* (below ground or in place) or *ex situ* (above ground), is capable of degrading organic compounds to less toxic materials such as carbon dioxide (CO_2), methane, and water through aerobic or anaerobic processes. Bioremediation is being used with increasing frequency to remediate contaminated media at hazardous waste sites because, compared with other remediation technologies, it often is less expensive and more acceptable to the public.

This report focuses on the use of enhanced bioremediation technologies at 104 Superfund remedial action sites and other contaminated sites. It provides a snapshot of current applications of bioremediation and presents trends over time concerning selection and use of the technology, contaminants and site types treated by the technology, and cost and performance of the technology. This information will help inform site managers, technology users, developers, and other interested parties about the capabilities and current applications of bioremediation.

Highlights of this report are listed below:

- **Technology Types** - Since 1991, the percentage of bioremediation projects performed *ex situ* has decreased while the percentage of projects performed *in situ* has increased. In 1991, only 35 percent of the Superfund remedial action bioremediation projects were *in situ* versus 53 percent in 1999. Bioventing is the most commonly implemented *in situ* treatment technology for source treatment[1]. Land treatment is the most commonly used *ex situ* source treatment technology.

- **Site Types** - The most common type of Superfund remedial action site where bioremediation is used is wood preserving (31 percent), followed by petroleum sites (21 percent). The most common types of contaminants at these sites are polycyclic aromatic hydrocarbons (PAHs) (40 percent); benzene, toluene, ethylbenzene, and xylenes (BTEX) (37 percent); and pesticides and herbicides (27 percent).

- **Project Status** - Over half of bioremediation projects at Superfund remedial action sites (57 percent) are in the operational phase, while 26 percent are in the predesign, design, or installation phases, and 17 percent have been completed. Of the 18 completed projects, 14 are *ex situ* source treatment projects, and 4 are *in situ* projects for source treatment and groundwater treatment.

- **Trends in Use** - Few bioremediation Records of Decision (RODs) were signed in the early- to mid-1980s. Beginning in fiscal year (FY) 1988, the number of bioremediation RODs has increased. In general, 8 to 12 bioremediation RODs have been signed per year.

- **Performance** - Available performance data shows that bioremediation is capable of reducing contaminant concentrations in contaminated media. Bioremediation is being used to treat recalcitrant organic compounds, including chlorinated volatile organic compounds (VOCs), PAHs, pesticides and herbicides, and explosives. For ten projects treating chlorinated VOCs, concentrations of VOCs in treated groundwater ranged from below detect limit (<5 µg/L for tetrachloroethene [PCE], trichloroethene [TCE], and dichloroethene [DCE]) to 1,200 µg/L (for carbon tetrachloride).

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[1] The term source treatment includes treatment of soil, sludge, sediment, or other solid waste.

For seven projects treating PAHs, concentrations of PAHs in treated soil and sludges ranged from 3.3 mg/kg to 795 mg/kg, with some projects showing more than 90% removal. For four projects treating pesticides and herbicides, concentrations of specific pesticides and herbicides in treated soil were less than 10 mg/kg at two projects and less than 200 mg/kg at the other two projects, with some projects showing more than 90% removal. For six projects treating explosives, three showed removals of more than 75% and the others showed removals ranging from little or none to as much as 64%.

- **Cost** - Information about the cost of using bioremediation to treat contaminated media was available for 67 sites. Unit costs for bioventing projects ranged from approximately $2 per cubic yard (cy) to more than $300/cy, with most sites less than $40/cy. Unit costs for *ex situ* bioremediation of soil, such as land treatment or composting systems, ranged from $13/cy to more than $500/cy, with most projects costing less than $300/cy.

Information sources used for this report included Superfund RODs, ROD amendments, and Explanations of Significant Differences (ESDs) issued by EPA through fiscal year 1999 (EPA 2001); and cost and performance reports prepared by the Federal Remediation Technologies Roundtable (FRTR 2001). Specific references are identified at the end of this report.

Section 2 of the report provides an overview of bioremediation technologies, including *in situ* and *ex situ* technologies, and provides examples of field use for three types of bioremediation technologies. The characteristics of bioremediation projects at Superfund and other sites are described in Section 3, including the types of bioremediation projects that have been conducted and the selection of bioremediation as a remedy. Section 4 provides a summary of the performance of bioremediation technologies, with a summary of bioremediation costs in Section 5. Information about vendors of bioremediation technologies is provided in Section 6. References used in preparation of this report are in Section 7, and additional information about selected information sources is in Section 8.

Appendix A to the report provides selected information about 104 bioremediation projects, including site name, location, ROD year, contaminants treated, project status, and contact name. Appendix B provides additional information related to the development of the cost curves for bioventing projects.

In Situ B emediation Using Hydrogen Release Compound or Molasses at Six Drycleaner Sites, Various Locations

Federal
Remediation
Technologies
Roundtable

Site Name:	Contemporary Cleaners; Decorah Shopping Center Drycleaners; Dixie Cleaners; Hayden Island Cleaners; Springdale Cleaners; Washington Square Mall Dry Cleaners
Location:	Contemporary Cleaners, FL; Decorah Shopping Center Drycleaners, WI; Dixie Cleaners, FL; Hayden Island Cleaners, OR; Springdale Cleaners, OR; Washington Square Mall Dry Cleaners, WI
Period of Operation:	Contemporary Cleaners - 154 days, dates not specified Decorah Shopping Center Drycleaners - not specified Dixie Cleaners - June, 2000 to June, 2001 Hayden Island Cleaners - 15 months, dates not specified Springdale Cleaners - not specified Washington Square Mall Dry Cleaners - 20 months, dates not specified
Cleanup Type:	Full-scale remediations and field demonstrations

Technology:
In Situ Bioremediation

- Injection of hydrogen release compound was performed at 4 sites at depths from 12 to 40 feet. Treatment areas ranged from 200 to 14,600 square feet and total HRC® injected ranged from 2,300 to 22,000 pounds of HRC®. Injection wells were installed using direct push techniques, usually in a grid based on 10-foot centers. HRC® was applied in a single injection.
- Injection of molasses was performed at one site at depths from 12 to 17 feet. The treatment area was not specified. Injection wells were installed using direct push techniques. Six injections were performed over a period of 6 months, with 15-25 gallons of molasses and 25 gallons of water injected during each injection.

Cleanup Authority: State

Contacts:
Varied by site

Contaminants:
Chlorinated Solvents

- All of the sites were contaminated with PCE or TCE
- Concentrations varied by site ranging from 0.025 to 1,230 mg/L for PCE and 0.00039 to 8.3 mg/L for TCE
- Two sites reported that DNAPLs were present

Waste Source: Waste and wastewater from drycleaning operations

Type/Quantity of Media Treated:
Groundwater

- Groundwater conditions varied by site
- Plume sizes ranged from 15,000 to 140,000 square feet; treatment areas ranged from 200 to 18,000 square feet.

Purpose/Significance of Application:
Use of in situ bioremediation to treat chlorinated solvents in groundwater at drycleaner facilities

Regulatory Requirements/Cleanup Goals:

- Cleanup goals were based on state regulatory goals or EPA MCLs.
- Specified cleanup goals included 0.003 mg/L for PCE and 0.003 to 0.005 mg/L for TCE

Results:

In situ bioremediation with HRC® (5 sites):

- All of the sites reported reductions in PCE and TCE, and evidence of biodegradation, including increases in the concentrations of PCE and TCE degradation products
- Information about progress towards specific cleanup goals was not provided

In situ bioremediation with molasses (1 site):

- Sampling results from a 20-month period following bioremediation indicated that PCE was reduced from 2 mg/L to below analytical detection limits (detection limits were not specified). TCE concentrations were reduced from 0.9 to 0.015 mg/L

Costs:

- Total project costs ranged from $79,000 to treat a 200 square foot area to depths from 25 to 40 feet; to $300,000 to treat an 18,400 square foot area to from 25 to 30 feet
- Costs included well installation, application of the technology, and post-treatment monitoring but do not include site assessment

Description:

In situ bioremediation was conducted at six drycleaner sites contaminated with chlorinated solvents from drycleaning operations with TCE and PCE as the primary contaminants in groundwater. The concentrations of TCE and PCE contamination varied by site with levels of PCE in groundwater as high as 1,230 mg/L and TCE in groundwater as high as 8.3 mg/L. The remediations, including full-scale and demonstration-scale projects, involved the subsurface injection of substances to promote bioremediation.

In situ bioremediation was performed using HRC® at five sites and molasses at one site. The injection wells were installed using direct push techniques, and the concentrations of TCE and PCE were monitored after the application of the technology. A single injection of HRC® was performed at the five sites. Reductions in PCE and TCE concentrations and increases in PCE and TCE biodegradation products were reported for all five sites. At one site, molasses was injected 6 times over a period of 20 months. PCE concentrations in groundwater decreased to below analytical detection limits and the site was closed.

View the Complete Document

September 20, 2002 0KL0203-32h

Steven Saines
Ohio EPA
2195 Front Street
Logan, OH 43138
Fax: (740) 385-6490

Subject: Acceleration of Bioremediation Using HRC® at the LPS Site

Dear Mr. Saines:

We have reviewed the information that you provided for the above-referenced site. In the following sections, we provide design and cost information for a potential site remediation approach. This information should be considered preliminary since a number of assumptions have been made concerning site conditions and the extent of the contaminant plume requiring remediation. We look forward to working with you to develop a specific strategy that meets your objectives.

Use of HRC to Accelerate Bioremediation

Hydrogen Release Compound (HRC) is used to enhance in situ biodegradation rates for chlorinated hydrocarbons (CHs) by supporting anaerobic reductive dechlorination processes. Reductive dechlorination is now recognized as one of the primary attenuation mechanisms by which chlorinated solvent groundwater plumes can be contained and/or remediated.

HRC is a proprietary polylactate ester that, upon being deposited into the subsurface, slowly releases lactate. Lactate is metabolized by naturally occurring microorganisms, resulting in the creation of anaerobic aquifer conditions and the production of hydrogen. Naturally occurring microorganisms capable of reductive dechlorination then use the hydrogen to progressively remove chlorine atoms from chlorinated hydrocarbon contaminants (i.e. convert tetrachloroethene [PCE] to trichloroethene [TCE] to dichloroethene [DCE] to vinyl chloride [VC] to ethene).

HRC is manufactured as a viscous gel that can be injected into the saturated zone in a grid or barrier configurations for either localized area or cutoff-based treatment approaches. The use of HRC for groundwater remediation offers a comparatively simple and cost effective remediation alternative for sites that would otherwise require unacceptably long periods of time for natural attenuation or the high levels of capital investment and operating expense associated with active remediation technologies.

Design/Proposal Assumptions

Using the information you provided, we have made the following assumptions to estimate system design variables and dose amounts.

- Plume area requiring treatment: approximately 390 ft x 70 ft
- Representative contaminant concentration: 400 ug/L 1,1,1-TCA, 430 mg/L carbon tetrachloride, 450 ug/L cis-1,2-DCE, 150 ug/L 1,1-DCA
- Contaminated saturated zone thickness requiring treatment: 15 feet
- Estimated groundwater velocity: up to 10 feet/year. Note that groundwater velocity controls the extent to which new contaminant is brought into the treatment zone. This contaminant loading must be considered when specifying time release compound dosing requirements.
- Current groundwater geochemistry: unknown. For the purposes of this proposal, we assume oxygen <10 mg/L, nitrate <5 mg/L, potential manganese reduction demand <5 mg/L, potential ferric iron reduction demand <25 mg/L, and potential sulfate reduction demand <25 mg/L. Higher competing electron acceptor-based electron donor demand may require increased amounts of HRC to achieve remedial goals.

The design specifications and costs provided below represent a preliminary design for an accelerated bioremediation project. This design may need to be adjusted as detailed design and regulatory oversight issues are finalized. For instance, the following design variables may need to be adjusted prior to the implementation:

- Treatment areas may need to be increased or decreased depending on the overall site remediation strategy.
- Exact HRC delivery locations should be selected in the final design process. HRC injection locations may need to be adjusted to take into account site features such as underground utilities and other site structures.

Regenesis' Applications engineering staff is available to assist in the selection of an appropriate final design.

Preliminary Design and Cost Information for Full Scale Remediation

It is assumed that the full-scale remediation approach for the site would consist of a grid-based application to reduce contaminant levels in the source area.

As discussed, we recommend applying HRC via a grid application across the entire contaminated area (see attached figure). Application details are as follows:

HRC Grid Treatment

Design Feature	Specification
Saturated thickness requiring treatment	15 feet
Treatment Area	Approximately 390 feet x 70 feet
Delivery Pt. Spacing and Configuration	Around monitoring wells: 10 ft-on-center Across remainder of site: 20 ft-on-center 110 total points
HRC dose rate in lbs/vertical foot of injection	4 lbs/foot (60 lbs/point)
Material requirement	110 pts x 15 feet x 4 lbs/ft = 6,600 lbs
Material cost at $5.75/lb*	$37,950 plus shipping and applicable sales tax

*Based on the above-proposed HRC application, the total amount of HRC proposed for this injection is 6,600 pounds. If all of the HRC is purchased in the same order, the cost will be $5.75/pound. Therefore, the total cost of 6,600 pounds of HRC is $37,950 plus applicable sales tax and shipping. If less or more HRC is purchased than the total amount proposed, the cost per pound may be greater or less than the $5.75 per pound quoted above. Please see the attached price sheet for HRC volume pricing structure.

Total Project Cost

The total cost of an accelerated bioremediation project can be estimated as the sum of the following items:

- HRC material and shipping costs.
- HRC injection fieldwork costs. Customers are responsible for selecting a local injection subcontractor.
- Groundwater monitoring well construction (if necessary to monitor project performance).
- Periodic groundwater sampling and analysis.
- Consultant oversight and reporting. Regenesis data evaluation and technical support are provided free of charge.

The costs provided in this letter apply to HRC material costs for one application. The need for re-applications will depend on your plume management strategy, site specific biodegradation performance, remedial goals for the site, and other technical or regulatory considerations. For plume area treatments, one to two re-applications could be necessary over the course of the project, although each re-application would most likely be done over a reduced area and dose amount compared to the initial application. For barrier-based designs, re-applications will be necessary every one to two years as long as there is a need to prevent contaminant migration.

HRC Delivery to Contaminated Zone

Typically, HRC is applied using direct push hydraulic equipment. Drive rods are pushed to the bottom of the contaminated saturated zone and then HRC is injected as the rods are withdrawn. The minimum recommended rod size is a 0.625-inch inner diameter. For sites where direct push is not feasible, auger-based equipment can be used to deliver HRC. Also, the use of permanent, small diameter re-injection wells may be a more cost-effective approach for sites requiring repeated applications of HRC. Technical support personnel at Regenesis are available to discuss the suitability of alternate HRC delivery methods.

Costs for HRC injection should be obtained from local subcontractors. If necessary, Regenesis can assist in locating qualified HRC injection subcontractors. Budgetary cost estimates for direct push-based injection range from $1,000 to $2,000 per day. Typically, one to two HRC injection points can be completed per hour and up to 20 points can be completed per day, depending on soil type, depths of injection, and subcontractor experience.

HRC should be injected using an appropriate pump capable of processing a material with a viscosity of 20,000 centipoise at flow rates of 3 to 10 gallons per minute at pressures ranging from 200 psig to 1,500 psig. Failure to use appropriate equipment could increase field time and result in improper application of the HRC. Regenesis can provide a suitable pump for a cost of $150 per day plus shipping.

Recommended Groundwater Monitoring Program for Pilot/Full Scale Treatment

Monitoring of selected wells should be conducted to validate the HRC-based enhancement of reductive dechlorination processes. Also, an initial or "baseline" round of sampling should be performed to identify pre-HRC installation groundwater conditions. After delivery of the HRC to the subsurface, samples can be collected on a monthly or bi-monthly frequency. After the initial biodegradation and geochemical trends have been identified, the monitoring frequency can be decreased to a quarterly, semiannual, or annual program.

The monitoring program should employ low flow groundwater sampling techniques and include the measurement of the following field/chemical parameters:

- all relevant contaminants
- field parameters: dissolved oxygen, ORP, pH, temperature, and ferrous iron (optional field measurement)
- natural attenuation/inorganic parameters: total and dissolved iron, total and dissolved manganese, nitrate, sulfate, sulfide, and chloride
- HRC-based electron donor: total organic carbon and metabolic acids (lactic, pyruvic, acetic, propionic, and butyric)
- End-product dissolved gases: carbon dioxide, methane, ethane and ethene

A specially qualified laboratory should do the analytical testing for the metabolic acids, otherwise most laboratories can provide testing for the remaining parameters. A typical cost for the above testing program is approximately $300 per sample.

Regenesis appreciates the opportunity to provide this information for your project. Please feel free to contact Todd Balzer, Regenesis' Ohio Valley District Manager, at 513.934.0567 (e-mail at todd@regenesis.com) or me at 949.366.8000 (e-mail at kevin@regenesis.com).

Sincerely,

Kevin Lapus
Applications Engineer

REGENESIS

Hydrogen Release Compound, HRC®

Price Sheet: Effective September 1, 2000

Cost Effective Treatment of Chlorinated Solvents

Hydrogen Release Compound (HRC) offers a passive, low-cost approach to rapid remediation of chlorinated solvent impacted sites. HRC is a proprietary, environmentally safe polylactate ester specially formulated for slow release of lactic acid upon hydration. When placed within a contaminated aquifer, HRC stimulates a multi-step process resulting in the degradation of chlorinated solvent compounds such as PCE, TCE and their derivatives as well as other groundwater contaminants. ***The use of HRC results in the cost-effective and rapid restoration of property values.***

HRC* Pricing

Regenesis offers a volume discount structure for the purchase of HRC as follows:

Quantity (lbs.)	HRC Price/lb. (US $)	Quantity (lbs.)	HRC Price/lb. (US $)
150	$8.00	6,000	$5.75
500	$7.50	10,000	$5.50
1,500	$7.00	20,000	$5.25
3,000	$6.00	40,000	$5.00

* HRC is shipped in four-and-a-quarter gallon containers weighing approximately 30 pounds. Material Safety Data Sheet is included with each shipment.

Freight – All freight is FOB San Clemente, CA unless otherwise specified when order is placed.

Minimum Order – 150 lbs. ($1,200.00)

Bench-Scale Laboratory Testing

Laboratory testing of soil and groundwater is available to confirm the ability of HRC to stimulate dechlorination. However, such testing is generally not required. Testing cost is $2,500 per groundwater/soil slurry sample.

Payment Terms – Net 30 days. Accounts outstanding after 30 days will be assessed 1.5% interest per month. Accounts outstanding over 90 days will be re-invoiced at the undiscounted price of $8.00 per pound.

Return Policy – A 15% restocking fee will be charged for all returned product. Return freight must be prepaid. All requests to return product must be pre-approved by Regenesis. Returned product must be in original condition and no product will be accepted for return after a period of 90 days from time of delivery.

Terms & Conditions – Other terms and conditions are on reverse side.

Order From – **REGENESIS**----- *1011 Calle Sombra• San Clemente, CA 92673-6244*
Tel: 949.366.8000 • Fax: 949.366.8090 • www.regenesis.com • orc@regenesis.com

Remittance Address: Department 8873
Los Angeles, CA 90084-8873

REGENESIS

Hydrogen Release Compound, HRC®

TERMS AND CONDITIONS

1. **CASUALTY AND AVAILABILITY OF RAW MATERIALS.** REGENESIS Bioremediation Products ("Seller") shall not be liable for delays in delivery or failure to manufacture or deliver due to causes beyond its reasonable control, including but not limited to acts of God, acts of buyer, acts of military or civil authorities, fires, strikes, flood, epidemic, war, riot, delays in transportation or car shortages, or inability to obtain necessary labor, materials, components or services through seller's usual and regular sources at usual and regular prices. In any such event seller may, without notice to buyer, at any time and from time to time, postpone the delivery dates under this contract or make partial delivery or cancel all or any portion of this and any other contract with buyer without further liability to buyer. Cancellation of any part of this order shall not affect seller's right to payment for any product delivered hereunder.

2. **LIMITED WARRANTY.** Seller warrants that the product sold hereunder is made with HRC as specified on face of invoice. Seller makes no other warranty of any kind respecting the product, and expressly DISCLAIMS ALL OTHER WARRANTIES OF WHATEVER KIND RESPECTING THE PRODUCT, INCLUDING ALL WARRANTIES OF MERCHANTABILITY AND FITNESS FOR PARTICULAR PURPOSE. BUYER'S SOLE REMEDY FOR BREACH OF THIS LIMITED WARRANTY SHALL BE REFUND OF THE PURCHASE PRICE, PROVIDED THAT ANY UNUSED PORTION OF THE PRODUCT IS PROMPTLY RETURNED TO SELLER. UNDER NO CIRCUMSTANCES WILL SELLER BE LIABLE FOR ANY CONSEQUENTIAL OR OTHER DAMAGES.

3. **DISCLAIMER.** Seller disclaims to the full extent permitted by law all warranties, expressed or implied, including any implied warranty of merchantability, fitness for any particular purpose or against infringement, to any person other than buyer. Where warranties to a person other than buyer may not be disclaimed under law, seller extends to such a person the same warranty seller makes to buyer or lessee as set forth herein, subject to all disclaimers, exclusions and limitations of warranties, all limitations of liability and all other provisions set forth in the Terms and Conditions herein. Buyer agrees to transmit a copy of the Terms and Conditions set forth herein to any and all persons to whom buyer sells, or otherwise furnishes the products and/or services provided buyer by seller and buyer agrees to indemnify seller for any liability, loss, costs and attorneys' fees which seller may incur by reason, in whole or in part, of failure by buyer to transmit the Terms and Conditions as provided herein.

4. **LIMITATION OF SELLER'S LIABILITY AND LIMITATION OF BUYER'S REMEDY.** Seller's liability on any claim of any kind, including negligence, for any loss or damage arising out of, connected with, or resulting from the manufacture, sale, delivery, resale, repair or use of any goods or services covered by or furnished hereunder, shall in no case exceed the lesser of the cost of repairing or replacing goods failing to conform to the forgoing warranty or the price of the goods or services or part thereof which gives rise to the claim. IN NO EVENT SHALL SELLER BE LIABLE FOR SPECIAL INCIDENTAL OR CONSEQUENTIAL DAMAGES, OR FOR DAMAGES IN THE NATURE OF PENALTIES.

5. **INDEMNIFICATION.** Buyer agrees to defend and indemnify seller of and from any and all claims or liabilities asserted against seller in connection with the manufacture, sale, delivery, resale or repair or use of any goods covered by or furnished hereunder arising in whole or in part out of or by reason of the failure of buyer, its agents, servants, employees or customers to follow instructions, warnings or recommendations furnished by seller in connection with such goods, by reason of the failure of buyer, its agents, servants, employees or customers to comply with all federal, state and local laws applicable to such goods, or the use thereof, including the Occupational Safety and Health Act of 1970, or by reason of the negligence of buyer, its agents, servants, employees or customers.

6. **EXPENSES OF ENFORCEMENT.** In the event Seller undertakes any action to collect amounts due from Buyer, or otherwise enforce its rights hereunder, Buyer agrees to pay and reimburse Seller for all such expenses, including, without limitation, all attorneys and collection fees.

7. **TAXES.** Liability for all taxes and import or export duties, imposed by any city, state, federal or other governmental authority, shall be assumed and paid by buyer. Buyer further agrees to defend and indemnify seller against any and all liabilities for such taxes or duties and legal fees or costs incurred by seller in connection therewith.

8. **ASSISTANCE AND ADVICE.** Upon request, seller in its discretion will furnish as an accommodation to buyer such technical advice or assistance as is available in reference to the goods. Seller assumes no obligation or liability for the advice or assistance given or results obtained, all such advice or assistance being given and accepted at buyer's risk.

9. **ENTIRE AGREEMENT.** This agreement constitutes the entire contract between buyer and seller relating to the goods or services identified herein. No modifications hereof shall be binding upon the seller unless in writing and signed by seller's duly authorized representative, and no modification shall be effected by seller's acknowledgment or acceptance of buyer's purchase order forms containing different provisions. Trade usage shall neither be applicable nor relevant to this agreement, nor be used in any manner whatsoever to explain, qualify or supplement any of the provisions hereof. No waiver by either party of default shall be deemed a waiver of any subsequent default.

® Registered Trademark of **REGENESIS** *Bioremediation Products*

HRC Design Software for Plume Area/Grid Treatment

Regenesis Technical Support: USA (949) 366-8000, www.regenesis.com

Site Name: LPS Site
Location: Middletown, NY
Consultant: Ohio EPA

Site Conceptual Model/Extent of Plume Requiring Remediation

Width of plume (intersecting gw flow direction)	390	ft		
Length of plume (parallel to gw flow direction)	70	ft	=	27,300
Depth to contaminated zone	20	ft		
Thickness of contaminated saturated zone	15	ft		
Nominal aquifer soil (gravel, sand, silty sand, silt, clay)	silt			
Total porosity	0.3		Eff. porosity:	0.3
Hydraulic conductivity	0.26	ft/day	=	9.2E-05
Hydraulic gradient	0.02	ft/ft		
Seepage velocity	6.3	ft/yr	=	0.017
Treatment Zone Pore Volume	122,850	ft^3	=	919,041

Dissolved Phase Electron Donor Demand	Contaminant		Stoich. (wt/wt)
	Conc (mg/L)	Mass (lb)	contam/H_2
Tetrachloroethene (PCE)	0.06	0.5	20.7
Trichloroethene (TCE)	0.09	0.7	21.9
cis-1,2-dichloroethene (DCE)	0.45	3.4	24.2
Vinyl Chloride (VC)	0.02	0.2	31.2
Carbon tetrachloride	0.43	3.3	19.2
Chloroform	0.00	0.0	19.9
1,1,1-Trichloroethane (TCA)	0.40	3.1	22.2
1,1-Dichlorochloroethane (DCA)	0.15	1.1	24.7
Hexavalent Chromium	0.00	0.0	17.3
User added, also add stoichiometric demand	0.00	0.0	0.0
User added, also add stoichiometric demand	0.00	0.0	0.0

Sorbed Phase Electron Donor Demand

Soil bulk density	1.76	g/cm^3	=	110
Fraction of organic carbon: foc	0.005	range: 0.0001 to 0.01		

(Values are estimated using Soil Conc=foc*Koc*Cgw)	Koc	Contaminant		Stoich. (wt/wt)
(Adjust Koc as nec. to provide realistic estimates)	(L/kg)	Conc (mg/kg)	Mass (lb)	contam/H_2
Tetrachloroethene (PCE)	263	0.08	3.5	20.7
Trichloroethene (TCE)	107	0.05	2.2	21.9
cis-1,2-dichloroethene (DCE)	80	0.18	8.1	24.2
Vinyl Chloride (VC)	2.5	0.00	0.0	31.2
Carbon tetrachloride	110	0.24	10.6	19.2
Chloroform	34	0.00	0.0	19.9
1,1,1-Trichloroethane (TCA)	183	0.37	16.5	22.2
1,1-Dichlorochloroethane (DCA)	183	0.14	6.2	24.7
User added, also add stoichiometric demand	0	0.00	0.0	0.0
User added, also add stoichiometric demand	0	0.00	0.0	0.0

Competing Electron Acceptors	Electron Acceptor		Stoich. (wt/wt)
	Conc (mg/L)	Mass (lb)	elec acceptor/H_2
Oxygen	10.00	77	8.0
Nitrate	5.00	38	12.4
Est. Mn reduction demand (potential amt of Mn2+ formed)	5.00	38	27.5
Est. Fe reduction demand (potential amt of Fe2+ formed)	25.00	192	55.9
Estimated sulfate reduction demand	25.00	192	12.0

Not realistic DO value, try 8 or less

Microbial Demand Factor	3	Recommend 1-4x
Safety Factor	2	Recommend 1-4x

Injection Point Spacing and Dose:

Injection spacing within rows (ft)	10.0	# points per row:	39

Injection spacing between rows (ft)	10.0	# of rows:	7
Advective travel time bet. rows (days)	577	Total # of points:	273
		Minimum req. HRC dose per foot (lb/ft)	4.0

Project Summary				
Number of HRC delivery points (adjust as nec. for site)			110	
HRC Dose in lb/foot (adjust as nec. for site)			4.0	<-Minumum Dose Override
Corresponding amount of HRC per point (lb)			60	
Number of 30 lb HRC Buckets per injection point			2.0	
Total Number of 30 lb Buckets			220	
Total Amt of HRC (lb)			6,600	
HRC Cost		$	5.75	
Total Material Cost		**$**	**37,950**	
Shipping and Tax Estimates in US Dollars				
Sales Tax	rate: 0%	$	-	
Total Matl. Cost		$	37,950	
Shipping of HRC (call for amount)		$	-	
Total Regenesis Material Cost		**$**	**37,950**	

Hydrogen Release Compound, HRC®
Chlorinated Contaminant Remediation

HRC®: Low Cost Chlorinated Contaminant Treatment

Hydrogen Release Compound (HRC®) offers a passive, low-cost, approach to rapid remediation of chlorinated solvent impacted sites. HRC is a proprietary, environmentally safe polylactate ester specially formulated for slow release of lactic acid upon hydration. When placed within a contaminated aquifer, HRC stimulates a multi-step process resulting in the degradation of chlorinated solvent compounds such as PCE, TCE, TCA and their derivatives, as well as other chlorinated compounds. *The use of HRC results in the cost-effective and rapid restoration of property values.*

Advantages of HRC & Its Time Release Feature

1. Low cost:

   Since HRC is a passive, *in-situ* approach, the large capital and operations/maintenance (O&M) costs associated with active engineered systems are avoided, such as those associated with pump and treat, air sparging with soil vapor extraction, and continuous injection systems. Treatment with HRC is a fraction of the cost of expensive and inflexible "iron wall" technology.

2. Rapid:

   HRC produces a continuous, slow release of hydrogen into the contaminated aquifer. This hydrogen serves as an electron donor increasing rates of contaminant degradation by an order of magnitude or more over that of natural attenuation alone.

3. Degrades PCE and TCE to non-toxic end products:

   Because of its consistent slow release of hydrogen, HRC stimulates rapid and complete dechlorination resulting in non-toxic end products such as ethene. HRC has also been proven effective in treating a range of other halogenated compounds, perchlorates, pesticides, nitrate and chromium.

4. Simple and safe to install:

   HRC is simply added to the bottom of excavations or applied directly into the aquifer through push-points or borings. HRC is a non-toxic, food-grade compound that is safe to install and is environmentally sound.

5. Cuts off plume migration and eliminates future liability:

   HRC can be strategically applied to degrade contaminants around the plume's perimeter to avoid further migration. This effective form of "barrier" technology is applied at a fraction of the cost of iron wall technologies or active pumping or sparging systems.

6. Desorbs and degrades residual DNAPL:

   Residual DNAPL which is difficult to locate and treat is desorbed and degraded in place by a combination of HRC's stimulation of biosurfactant activity and its continuous production of highly diffusible hydrogen.

7. Time-release eliminates continuous substrate additions:

   By providing a constant hydrogen source, HRC dramatically reduces O&M costs compared to the repeated or continuous injections required when attempting a treatment with solutions of common organic substrates.

8. Optimizes dechlorination activity.

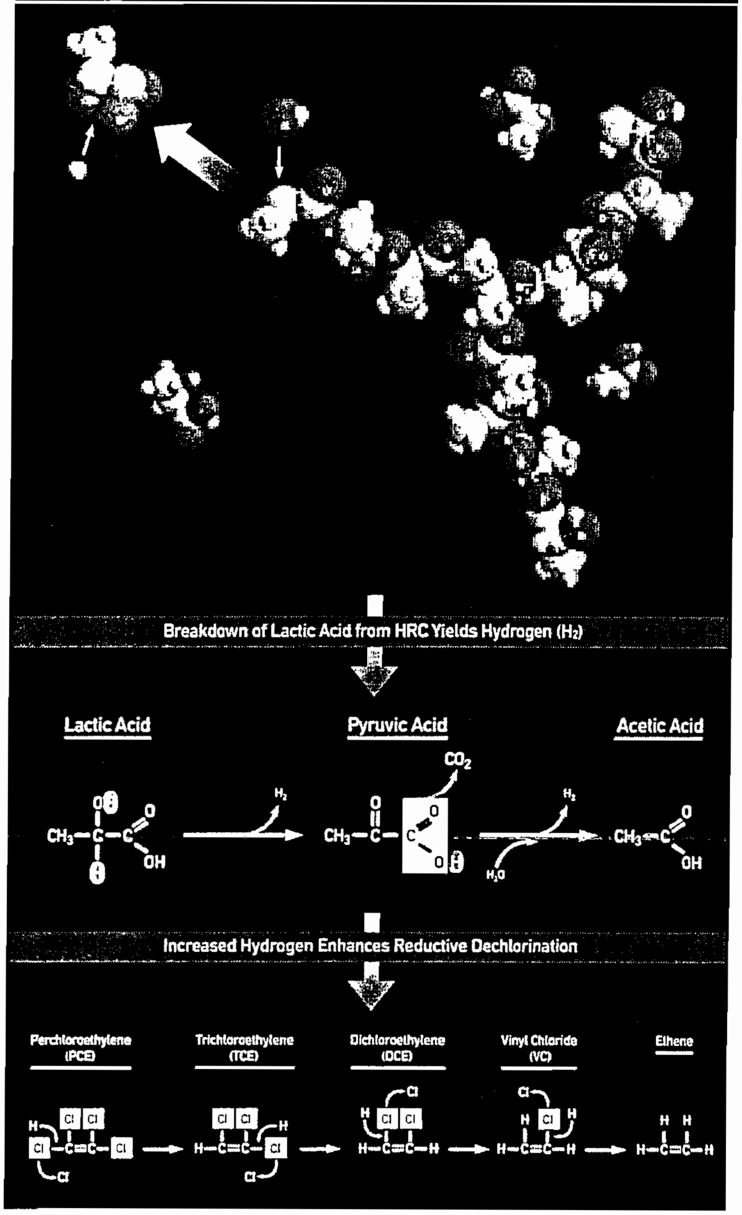
   By maintaining a constant low concentration of hydrogen within the contaminated aquifer, HRC can optimize dechlorination activity. Rapid releases of hydrogen associated with common organic substrate applications result in the wasteful and potentially dangerous generation of methane, interfering with dechlorination activity.

HRC and Reductive Dechlorination

Reductive dechlorination is a term used to describe the mechanism by which chlorinated hydrocarbons are biologically degraded under anaerobic conditions. In this natural process, anaerobic microbes substitute hydrogen (H) for chlorine on chlorinated contaminant molecules thus dechlorinating the compound. While this is a natural process, it usually proceeds in the groundwater environment at slow rates that are not sustainable. ***HRC increases the rate of dechlorination an order of magnitude or more, rapidly taking the contaminant through a step-wise dechlorination process that ultimately results in non-toxic compounds such as ethene and ethane.***

HRC is a proprietary, environmentally safe polylactate ester specially formulated for slow release of lactic acid upon contact with water in the subsurface environment. Once in place, the HRC slowly and continuously releases lactic acid. Indigenous anaerobic microbes then metabolize the lactic acid generated by HRC and produce hydrogen. The resulting continuous, low concentration of hydrogen is then used by reductive dechlorinating microbes to rapidly dechlorinate the contaminant for over a year's time.

Figure 4: **HYDROGEN RELEASE COMPOUND, HRC**
Role in Enhanced Reductive Dechlorination



HRC may favor reductive dechlorination over competing methanogenic activity

Within the subsurface anaerobic microbial consortium, there exists microbes that use hydrogen primarily for the production of methane (methanogens), and those that use hydrogen primarily for dechlorination (reductive dechlorinators). Results from university studies suggest that there is competition for hydrogen between the reductive dechlorinators and methanogens (Fennell, et al., 1997; Yang and McCarty, 1999). High hydrogen concentrations may favor methanogenic activity, whereas reductive dechlorinators are best supported in conditions of moderate hydrogen concentrations (2-10 nM). Thus, since HRC's long-lasting time-release feature facilitates moderate hydrogen concentrations, it may be an ideal approach for optimizing reductive dechlorination over competing methanogenic activity.

Plume Treatment

HRC is injected directly into the plume area through multiple push-points or boreholes. Once in place the HRC stimulates the rapid degradation of target contaminants in the subsurface.

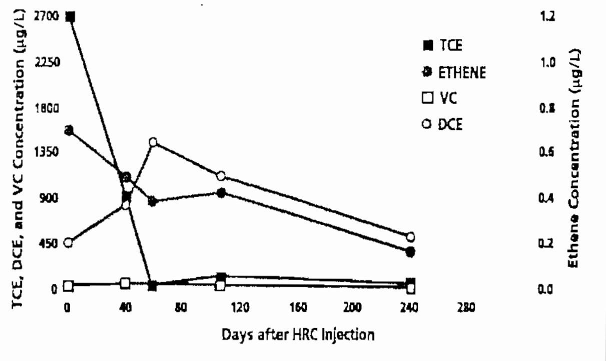
Benefits:

- Low cost treatment
- Simple to apply with minimal disruption
- No safety concerns as with oxidizing chemicals
- No operations and maintenance

Case History:

HRC was selected as the technology to treat a TCE plume within a sandy aquifer at a military base in Florida. A total of a 6000 pounds of HRC was injected into the core of a plume within 25 push-points across a 30' interval. An estimated 4000 sq. ft. area was treated. Results collected over a 240 day period indicated excellent performance with the HRC completely dechlorinating the TCE through to ethene. This project was accomplished for $36,000 in HRC cost and an estimated $3,000 in push-point subcontractor costs.

Figure 1: **CHANGE IN TCE, DCE, VC & ETHENE**
Upon HRC Application in Florida



Plume Cut-Off

HRC is injected directly across the migrating plume in push-points or boreholes. Once in place, the HRC stimulates the rapid degradation of the migrating target compounds, effectively cutting-off the plume in the form of a permeable reactive barrier.

Benefits:

- Effectively contains plume
- No wells or trenching required
- Low cost treatment
- No safety concerns as with oxidizing chemicals
- No operations and maintenance

Case History:

At a former manufacturing facility in Ohio, DCE and vinyl chloride (VC) groundwater contaminants in a bedrock aquifer were migrating off-site generating considerable potential liability. A line of open-rock HRC filled borings were installed to cut-off the plume. Results of the application were excellent with >99% reduction in DCE and >99% reduction in VC. This application was performed at a fraction of the cost of competing technologies such as the construction of iron walls or inefficient pump and treat systems.

Figure 2: **PLUME CUT-OFF**

Anaerobic Test		DCE			VC		
Well	Location	Baseline Jul-99	180 Days Jan-00	Percent Reduction	Baseline Jul-99	180 Days Jan-00	Percent Reduction
H-1	20' upgradient	5,700	2,000	65%	450	200	56%
H-2	5' downgradiant	2,600	1,100	58%	1,200	240	72%
H-3	25' downgradiant	590	3	99.6%	210	1	99.5%

Cost-Effective Site Remediation

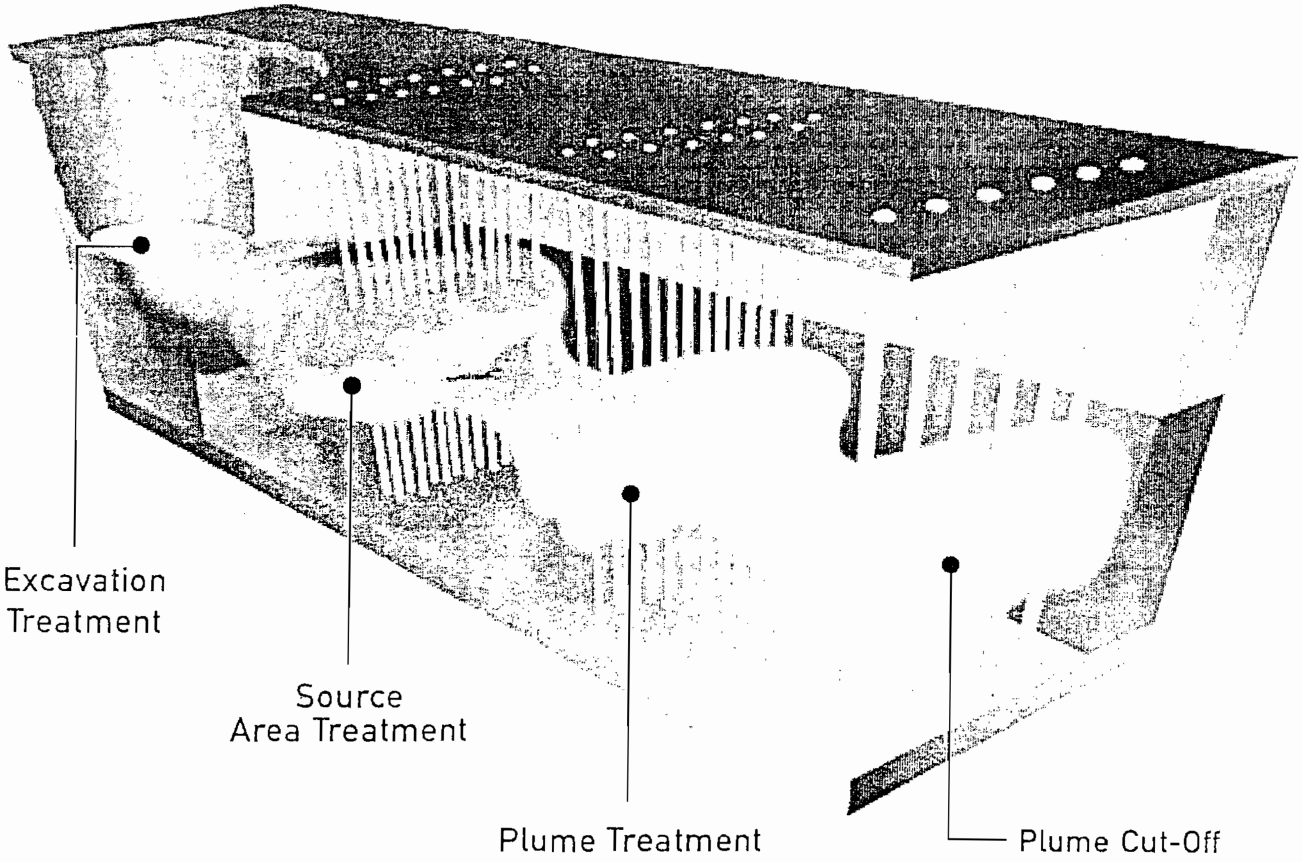
Simple and Inexpensive to Apply

HRC is manufactured as a viscous liquid that is pumped into the contaminated aquifer via direct-push equipment or augered boreholes. HRC can also be placed directly into open excavations prior to backfilling.

Treats a Range of Contaminants

HRC is widely applied for the cost-effective treatment of chlorinated solvent contaminants such as PCE, TCE, TCA, carbon tetrachloride and their derivatives. HRC has also been shown to effectively treat chlorinated pesticides, PCP, perchlorate, nitrate and chromium.

HRC Applications are Flexible and Can Be Designed to Meet a Variety of Objectives:



HRC® Applications

Excavation Treatment

HRC is placed into the bottom of open excavations prior to backfilling. Once in place the HRC stimulates the rapid degradation of the target compounds directly at the source of the contamination.

Benefits:

- Low cost source area treatment
- Easily applied along with planned excavations
- No operations or maintenance
- No safety concerns as with oxidizing chemicals

Case History:

At a commercial dry cleaning facility in Washington, a pipe leak caused PCE to contaminate groundwater at very high concentrations. HRC was injected in a plume treatment. The source area soils were excavated to groundwater surface, and HRC was placed within the excavation prior to backfilling with clean soil. After 328 days of HRC release activity, the PCE concentration had dropped by 99% (from a high of 67,400 ppb to 259 ppb).

Source Area Treatment

HRC is injected directly into the source area through multiple push-points or boreholes. Once in place the HRC stimulates the desorption and degradation of the contaminants within the source zone.

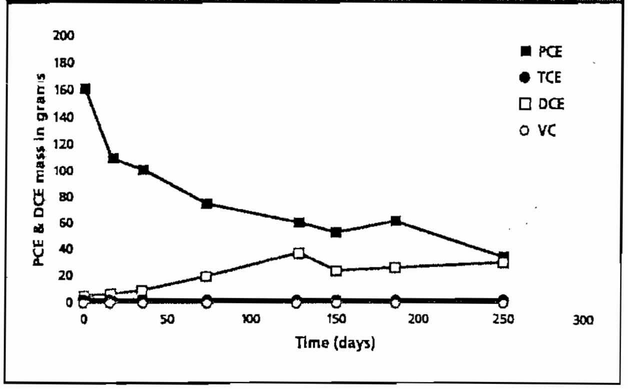
Benefits:

- Low cost source area treatment
- Desorbs and degrades residual DNAPL
- No safety concerns as with oxidizing chemicals
- No operations and maintenance

Case History:

At a dry cleaning facility in Wisconsin, HRC was applied to treat groundwater contamination in the source area of a PCE spill. Dissolved PCE concentrations were in excess of 22,000 ppb indicating the presence of nearby residual DNAPL. Within 250 days of a single HRC application, dissolved PCE mass had decreased 80% with concentrations averaging less than 3,000 ppm across the treated source area.

Figure 3: **CHANGE IN PCE, TCE, DCE & VC MASS**
Upon HRC Application in Wisconsin



HRC® - Cost-Effective Remediation

HRC offers a cost-effective, *in situ* method of treating chlorinated compounds. The material is applied very inexpensively using push-point or borehole delivery methods, and once in place a single HRC application continues to treat the contaminant plume for a year's time. It is this low cost of application and the elimination of operation and maintenance costs that gives HRC technology its dramatic cost advantage over other treatment options.

Plume Treatment

Figure 5 displays a cost comparison of HRC to other viable options for treating four typical plume scenarios assuming a TCE contaminant concentration of 10 ppm.

Figure 5: PLUME-WIDE REMEDIATION COST COMPARISON TECHNOLOGY COST COMPARISON ($)*

	Smaller Site (50' x 75')		Larger Site (200' x 200')	
	Shallow Aquifer (20' bgs)	Deeper Aquifer (50' bgs)	Shallow Aquifer (20' bgs)	Deeper Aquifer (50' bgs)
HRC Treatment	130,000	134,000	316,000	324,000
Pump and Treat	595,000	633,000	778,000	876,000
Air Sparging w/SVE	334,000	358,000	639,000	760,000
Chemical Oxidation	320,000	343,00	1,495,000	1,636,000

** Comparison costs were generated by an independent environmental consulting firm and include costs through project completion, e.g. sampling, monitoring, reporting, etc. All costs are reported in today's dollars. A net present value analysis would make HRC treatment appear considerably more favorable.*

Plume Cut-Off

Figure 6 displays a cost comparison of HRC to other viable options for cutting-off a migrating plume under four typical plume scenarios assuming a TCE contaminant concentration of 10 ppm.

Figure 6: PLUME CUT-OFF BARRIER TECHNOLOGY COST COMPARISON ($)*

	Smaller Plume (50' wide)		Larger Plume (200' wide)	
	Shallow Aquifer (20' bgs)	Deeper Aquifer (50' bgs)	Shallow Aquifer (20' bgs)	Deeper Aquifer (50' bgs)
HRC Treatment	145,000	145,500	175,000	176,000
Iron Wall Permeable Barrier	336,914	394,514	632,586	776,586
Pump and Treat	578,945	615,265	685,893	757,443
Air Sparging w/SVE	350,825	356,525	641,767	675,017

** Comparison costs were generated by an independent environmental consulting firm and include all project costs for operating a plume cut-off for a five year period. All costs are reported in today's dollars. A net present value analysis would make HRC treatment appear considerably more favorable.*

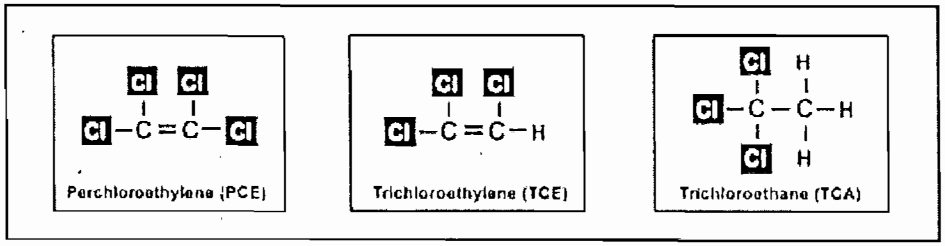
HRC is a sensible, cost-effective solution for treating
chlorinated contaminants in groundwater and for restoring property values.

HRC TECHNICAL BULLETIN # 1.1.1

Hydrogen Release Compound HRC®

The Nature of the Chlorinated Aliphatic Hydrocarbons (CAHs)

Chlorinated Aliphatic Hydrocarbons (CAHs), a family of compounds that are commonly used as chlorinated organic solvents, are increasingly being detected in soil and groundwater. The most prevalent of these CAHs are perchlorethylene (PCE), trichloroethylene (TCE), and trichloroethane (TCA), as illustrated in Figure 1. Beginning in the 1960s, these solvents have been used primarily for degreasing in the dry cleaning, electronics, industrial manufacturing and machine maintenance industries. Due to leakage of these CAHs from storage tanks and machinery, dissolved phase PCE , TCE, and TCA are now appearing in groundwater at concentrations which have been proven unhealthful and even carcinogenic.



Perchloroethylene (PCE)

Trichloroethylene (TCE)

Trichloroethane (TCA)

Figure 1

Unlike petroleum products, CAHs are more dense than water and can exist as Dense Non-Aqueous Phase Liquids (DNAPLs) which are not stopped at the water table and flow through the saturated zone to the aquitard. Obviously, this DNAPL property of CAHs makes them much more difficult to clean up compared to petroleum hydrocarbons. This is mainly due to the fact that CAHs, once in the saturated zone, form "fingers" which can lead to the collection of large amounts of solvent in one or more pools on top of less permeable layers (see Figure 2). It was earlier thought that their high volatilities would lead to the vaporazation of CAHs before entering the saturated zone, thus eliminating the concern over groundwater contamination. Unfortunately, any CAHs that do not vaporize are transported into the saturated zone and form fingers that become too difficult to locate for conventional mechanical remediation methods to be effective.

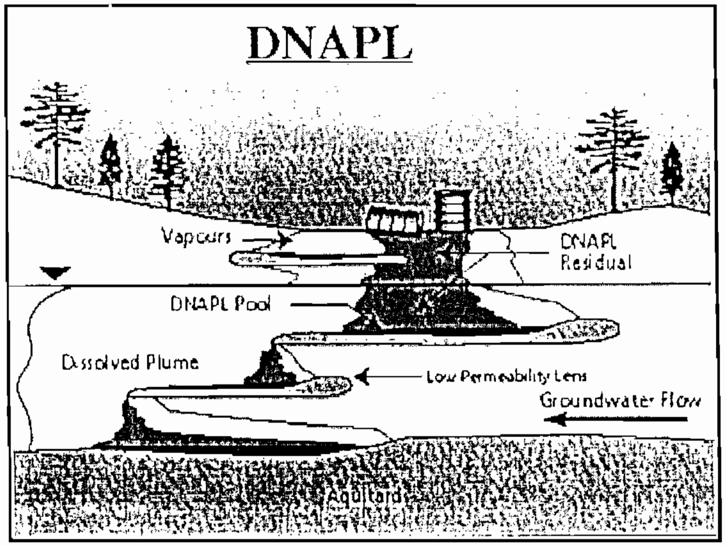


Figure 2

There are several other important factors which have helped lead to extensive groundwater contamination by CAHs and difficulty in contaminant removal by mechanical methods (1):

- The relatively low viscosity of CAHs allow rapid downward movement in the subsurface.

- The low interfacial tension between liquid CAHs and water allows the CAHs to enter easily into small fractures and pore spaces, which can lead to deep penetration in to the subsurface.

- The high relative solubilities of CAHs mean that a spill can cause groundwater contamination to reach levels that are harmful to human health.

- The low partitioning of CAHs to soil materials means that they will bind weakly to soil and rock materials, in both the unsaturated and saturated zones. Due to this poor sorption, soils will not significantly retard the movement of a chlorinated solvents, and contaminant plumes can advance much further than petroleum hydrocarbon contaminated plumes.

As mechanical methods commonly used for the clean up of petroleum hydrocarbons are costly and can be ineffective in CAH remediation, the focus has turned to bioremediation. Through a biological process called reductive dechlorination, anaerobic microorganisms indigenous to the aquifer can use hydrogen to remove the chlorine atoms from CAHs resulting in non-toxic end products such as ethene (see HRC technical bulletin #1.1.2 for detailed information on reductive dechlorination). The fact that hydrogen is a limiting factor in the process of reductive dechlorination is the basis for the application of Hydrogen Release Compound, HRC. HRC is an environmentally safe, food quality, high viscosity, polylactate ester specially formulated for the slow release of lactic acid upon hydration. The lactic acid released from HRC is metabolized by indigenous microbes to produce the hydrogen necessary for reductive dechlorination to occur. Given the insidious nature of CAH/DNAPL contamination, bioremedial solutions based on these principles hold great promise.

References

1. Pankow, J.F. and J.A. Cherry. 1996. Dense Chorinated Solvents and Other DNAPLs in Groundwater. Waterloo Press.

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HRC TECHNICAL BULLETIN # 1.1.2

Hydrogen Release Compound HRC®

Biological Reductive Dechlorination of CAHs

Reductive dechlorination is the most prominent mechanism by which chlorinated aliphatic hydrocarbons (CAHs) are biologically degraded under anaerobic conditions. CAHs, commonly used as degreasing solvents (see TB 1.1.1), are hydrocarbons whose hydrogen atoms have been replaced, or substituted, with chlorine atoms. It is in this chlorinated state that these hydrocarbons are considered toxic in groundwater. In order to remedy this problem the chlorine atoms must be removed.

Reductive dechlorination is the process by which anaerobic microorganisms substitute hydrogen (H+) for chlorine on CAHs. Hydrogen, resulting from the breakdown of HRC, acts as a source of electrons which provide the reducing conditions necessary for dechlorination of CAHs, as shown in the Figure 1.

$$\boxed{RCl + H^+ + 2e^- \longrightarrow RH + Cl}$$

Figure 1

Through this process, CAHs can be degraded to form vinyl chloride, and even ethene, as depicted in Figure 2.

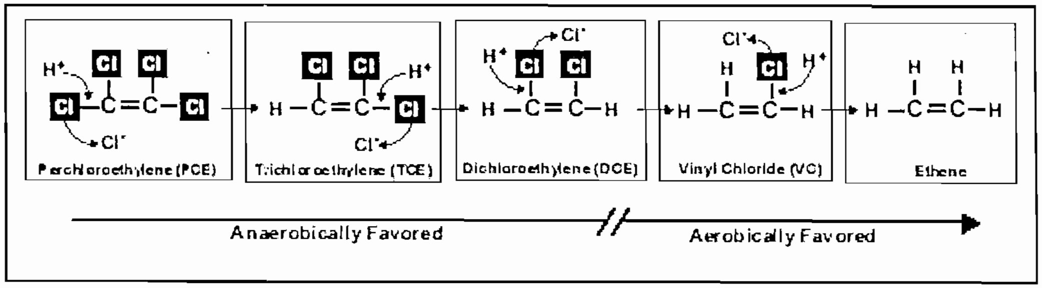

Figure 2

While the degradation rates of PCE and TCE are highest under anaerobic conditions, vinyl chloride will degrade up to four times faster under aerobic conditions (Figure 2). Therefore, optimal results for CAH remediation with HRC may be achieved by combined treatment with Oxygen Release Compound (ORC®) to enhance aerobic bioremediation of vinyl choride.

NOTE: For a complete discussion on reductive dechlorination of CAHs, see the RABITT document (1).

References:

1. Morse, J.M. and B.C. Alleman; Gossett, J.M. and S.H. Zinder; Sewell, G.W.; Vogel, C.M. 1997. A Treatability Test for Evaluating the Potential Applicability of the Reductive Anaerobic Biological In Situ Treatment Technology (RABITT) to Remediate Chloroethenes. ESTCP Technical Protocol.

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HRC TECHNICAL BULLETIN # 1.1.3

Hydrogen Release Compound HRC®

Using Organic Substrates to Promote Biological Reductive Dechlorination of CAHs

The use of organic substrates has been proven to enhance the bioremediation of Chlorinated Aliphatic Hydrocarbons (CAHs). The effect of the addition of organic acids and alcohols on the reductive dechlorination of tetrachloroethylene (PCE) is described by Gibson and Sewell (1). In this process, the acids and alcohols are metabolized by one group of organisms to yield hydrogen which in turn is used by another group of organisms to effect reductive dechlorination.

HRC, once deposited into the subsurface, slowly releases lactic acid. The resulting lactic acid acts as a nutrient source for anaerobic bacteria which metabolize the lactic acid as illustrated in Figure 1.

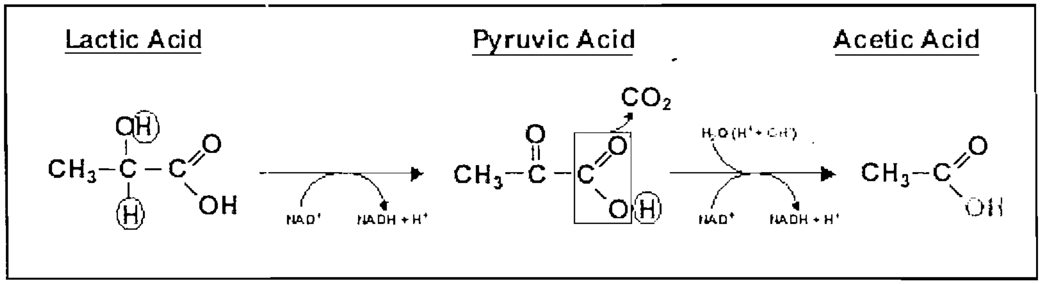

Figure 1

During the process, in which hydrogen atoms are taken up by NAD+ to form NADH , lactic acid is first degraded to pyruvic acid, which is in turn degraded to acetic acid. The driving force for fermentation of lactic acid to acetic acid is the generation of ATP during glycolysis. To make this possible, the microbe must first regenerate NAD+ by releasing the hydrogen from NADH. This is facilitated through the use of an enzyme called hydrogenase via the following reaction:

$$\mathrm{NADH} + \mathrm{H}^+ \xrightarrow[\text{Hydrogenase}]{} \mathrm{NAD}^+ + \mathrm{H}_2$$

Typically, in the conversion of lactic acid to acetic acid by acetogens, one mole of lactic acid produces two moles of hydrogen as H2. The hydrogen is then available for conversion of CAHs to dechlorinated aliphatic hydrocarbons (see TB 1.1.2).

References:

1. Gibson, S.A. and G.W. Sewell. April 1992. Applied and Environmental Microbiology. 58(4): 1392-1393.

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HRC TECHNICAL BULLETIN # 1.1.4

Hydrogen Release Compound HRC®

Competition for Hydrogen Between Reductive Dechlorinators and Other Microorganisms

The microbial population that inhabits the subsurface under conditions of low redox potential is sometimes referred to as the "anaerobic web". This is a revealing term which reflects the lack of knowledge we face when dealing with the microbial dynamics of the subsurface. One of the major challenges for some microbiologists is to better define this microcosm - but it is not an easy task. The anaerobic web is an ecosystem every bit as complex as those we experience at our sensory scale.

Among the complexities of the entire problem we want to focus in on a few relevant issues as they pertain to the dynamics of HRC and reductive dechlorination. A series of microbially mediated events can be set forth as follows:

1. First, the aquifer has to be driven anaerobic if it is not already in that condition. Obviously, this has to be achieved to support the growth and development of anaerobic microorganisms. To achieve this state, all the oxygen and the other electron acceptors such as nitrate and sulfate have to be consumed. As detailed in Technical Bulletin 2.6.1, this condition can be achieved by providing substrates such as lactic acid to the aquifer. HRC is a source of this lactic acid and its metabolism by anaerobic microorganisms to carbon dioxide and water "burns up" all of the electron acceptors.

2. Now the stage is set for the important reactions that remove chlorinated hydrocarbons. Recognize that the redox potential goes from positive to negative as electron acceptors are consumed. As soon as electron acceptors are gone the dynamics of the microbial web shift; as redox potential shifts so do the dominant species of microoganisms in the aquifer. As low to moderate negative redox conditions form, certain kinds of fermentative microorganisms can thrive that will attack the HRC derived lactic acid and turn it first into pyruvic acid and then acetic acid. It is through this process that the hydrogen is formed; one mole of H_2 is derived in the conversion of lactic acid to pyruvic acid and another mole of H_2 is derived from the conversion of pyruvic acid to acetic acid. Further details can be found in Technical Bulletin 1.1.3.

3. The hydrogen formed by fermentative microorganisms is now available for reductive dechlorination - however, there are other competing microbial processes that also demand hydrogen. The most common of these is methanogenesis. As the name implies this is a methane generating reaction that involves the combination of CO_2 with hydrogen.

Recently, some of the experts in the field of reductive dechlorination, including laboratory groups at Cornell and Stanford as represented in the references given, have offered the hypothesis that there is competition for hydrogen between reductive dehalogenators and methanogens. They believe that a low concentration of hydrogen favors the reductive dehalogenators and starves out the methanogens that have a larger appetite for hydrogen.

With an excess of hydrogen in the system the methanogens are favored and crowd out the reductive dehalogenators. The objective would then be to keep hydrogen concentrations low. This can be accomplished with the use of slow release organic acid materials such as HRC.

Returning to the subject of anaerobic web complexity, we have to remind the reader that the rules are not so standardized. In fact, some of the organisms that generate the hydrogen may also perform reductive dechlorination. Also, both reductive dechlorinators and methanogens may co-exist in some systems so that "everyone is satisfied". Lastly, not everyone accepts the hydrogen competition theory and there are dissenting opinions which have not yet reached the literature, but will in the near future.

HRC provides a basis for designing a low-cost passive system for plume control. When designing as HRC remediation system one must consider all competing uses for the hydrogen generated. If in a given aquifer system the dynamics of hydrogen competition are present, and if HRC hydrogen generation is minimal enough given hydrogeological and microbial conditions, then there is a basis for expecting an additional benefit from using the HRC.

References

1. Fennel, D.E., J.M Gossett and S.H. Zinder. 1997. Environmental Science & Technology. 31: 918-926.

2. Yang, Y. and L. McCarty. 1998. The First International Conference on Remediation of Chlorinated and Recalcitrant Compounds. Platform Presentation. Monterey, California, May 19, 1998.

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HRC TECHNICAL BULLETIN # 1.3.1

Hydrogen Release Compound HRC®

Environmentally Safe

Hydrogen Release Compound, HRC, is a polylactate ester that is a food-grade substance. Lactic acid occurs naturally in milk and foods (such as sauerkraut), and is also formed in muscles during exercise. In the subsurface environment, lactic acid products are eventually completely removed either as methane or CO2 and water, leaving no residue.

The only other ingredient in HRC is food grade magnesium phosphate (MgPO4). Magnesium phosphate is a naturally occurring mineral and is used in fertilizers. Magnesium phosphate has even been used medically as a laxative. In the function of the product phosphorous from the phosphate helps the metabolism of the lactic acid to produce the hydrogen used in reductive dechlorination.

In a review of all of 40CFR141 there is no reference to MCLs for lactic acid or its derivatives pyruvic acid, propionic acid, and acetic acid (see HRC technical bulletin #1.3.2). As with all chemicals, safe handling practices should be used to avoid any excess exposure to skin and any exposure to eyes. A full MSDS is provided with the product. As indicated in the MSDS, there is the potential for skin irritation with large scale exposure or with sensitive individuals. It is recommended that vinyl or rubber protective gloves be worn during handling of the product. Contact with eyes will cause irritation and the use of splash goggles or some other form of eye protection should be considered mandatory.

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HRC TECHNICAL BULLETIN # 3.1.2

Hydrogen Release Compound HRC®

HRC Injection TCE Remediation in Glacial Till Aquifer in Brighton, New York

A site in Brighton, New York was contaminated with trichloroethylene (TCE) at concentrations reaching 26,000 ppb in a very tight glacial till and clay aquifer with very low velocity (hydraulic conductivity 0.01 ft/day). Depth to groundwater was recorded at approximately five feet bgs. Approximately 500 pounds of HRC were injected into borings spaced five feet on center in a 560 square foot grid (see Figure 1).

Following 166 days of treatment with HRC, total TCE mass was reduced by 66%. TCE daughter products cis-1,2-DCE and vinyl chloride mass increased and decreased. In addition to a 69% reduction in overall sulfate mass dissolved iron levels also increased. These results strongly support the occurrence of enhanced biological reductive dechlorination of TCE. The detection of ethene also indicates that degradation was being stimulated beyond vinyl chloride to non-toxic substances. TCE, cis-1,2-DCE, and VC overall mass changes are graphically presented in Figure 2. Concentration contour plots depicting changes in TCE, cis-1,2-DCE, VC, sulfate, and dissolved iron are presented in Figures 3 to7. Treatment and monitoring are ongoing.

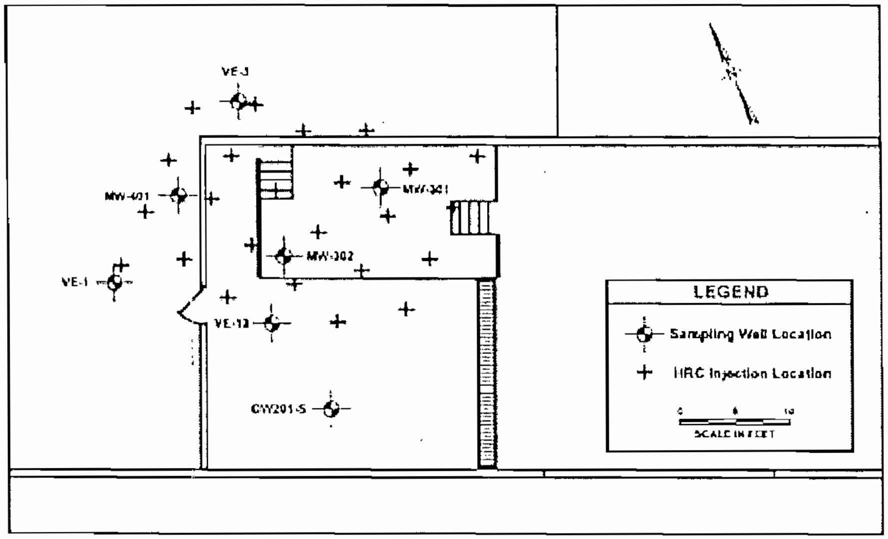

Figure 1

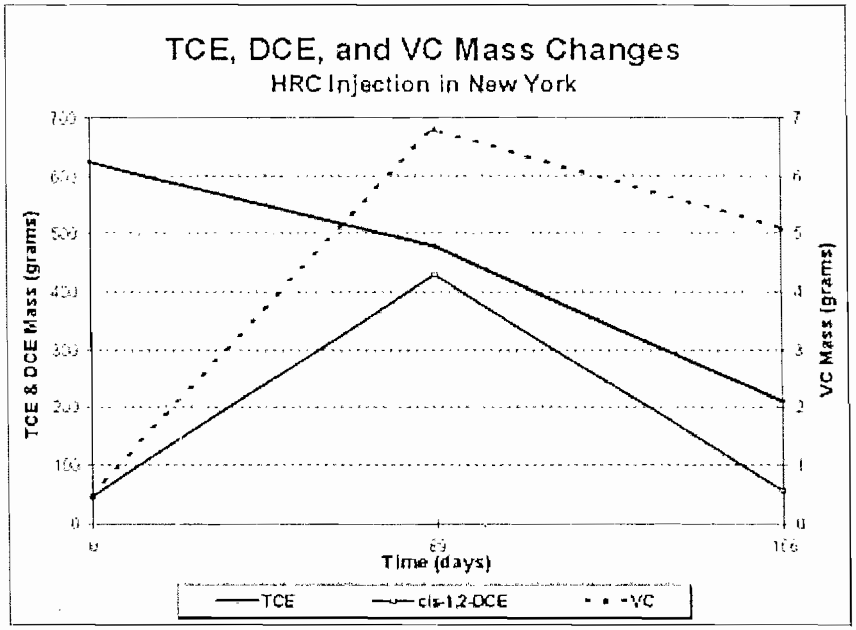
TCE, DCE, and VC Mass Changes
HRC Injection in New York
TCE & DCE Mass (grams)
0
100
200
300
400
500
600
700
VC Mass (grams)
0
1
2
3
4
5
6
7
Time (days)
0
69
106
TCE
cis-1,2-DCE
VC

Figure 2

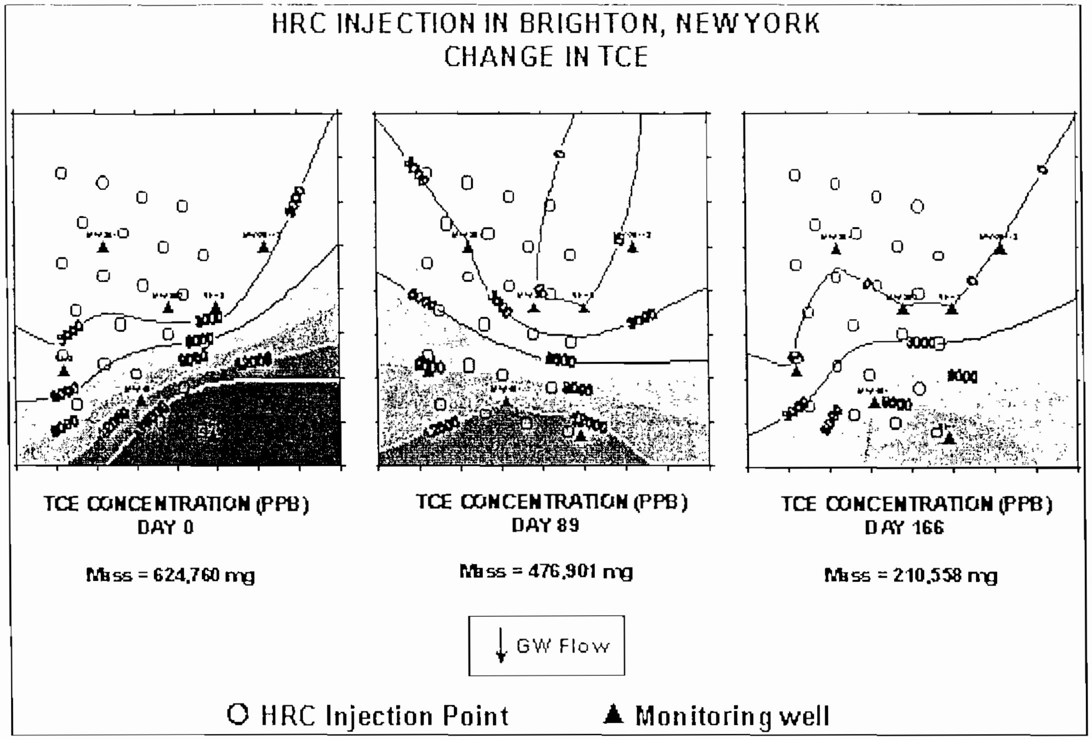
HRC INJECTION IN BRIGHTON, NEWYORK
CHANGE IN TCE
TCE CONCENTRATION (PPB)
DAY 0
Mass = 624,760 mg
TCE CONCENTRATION (PPB)
DAY 89
Mass = 476,901 mg
TCE CONCENTRATION (PPB)
DAY 166
Mass = 210,558 mg
GW Flow
O HRC Injection Point
▲ Monitoring well

Figure 3

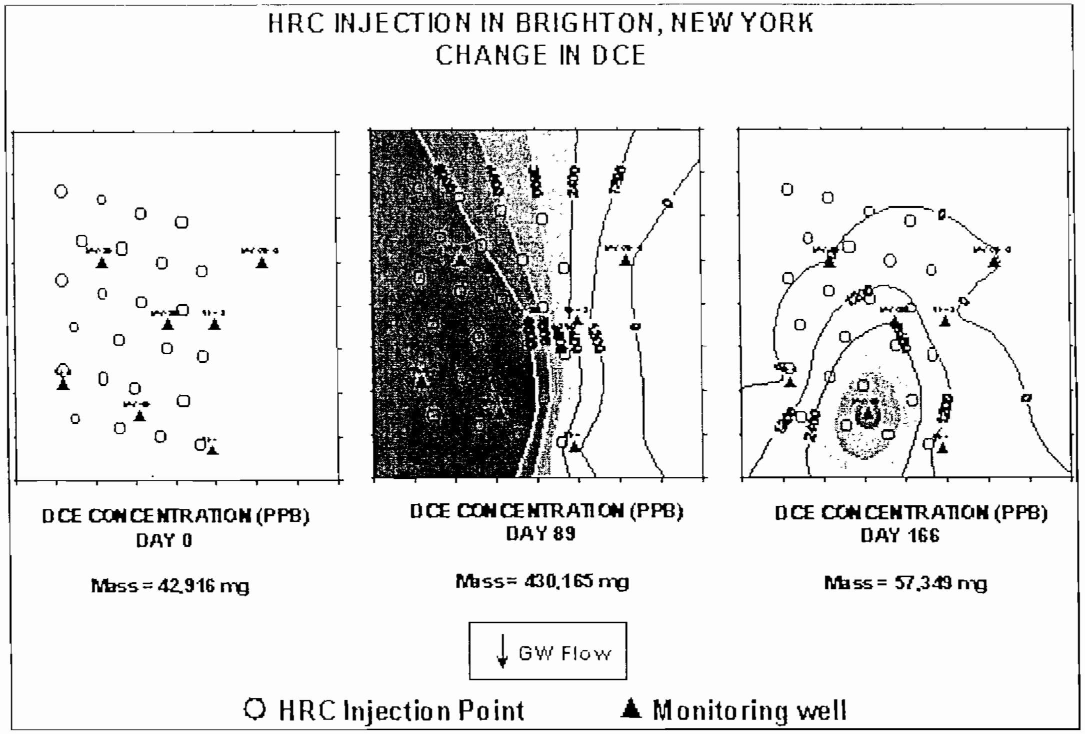
HRC INJECTION IN BRIGHTON, NEW YORK
CHANGE IN DCE
DCE CONCENTRATION (PPB)
DAY 0
Mass = 42,916 mg
DCE CONCENTRATION (PPB)
DAY 89
Mass= 430,165 mg
DCE CONCENTRATION (PPB)
DAY 166
Mass = 57,349 mg
GW Flow
HRC Injection Point
Monitoring well

Figure 4

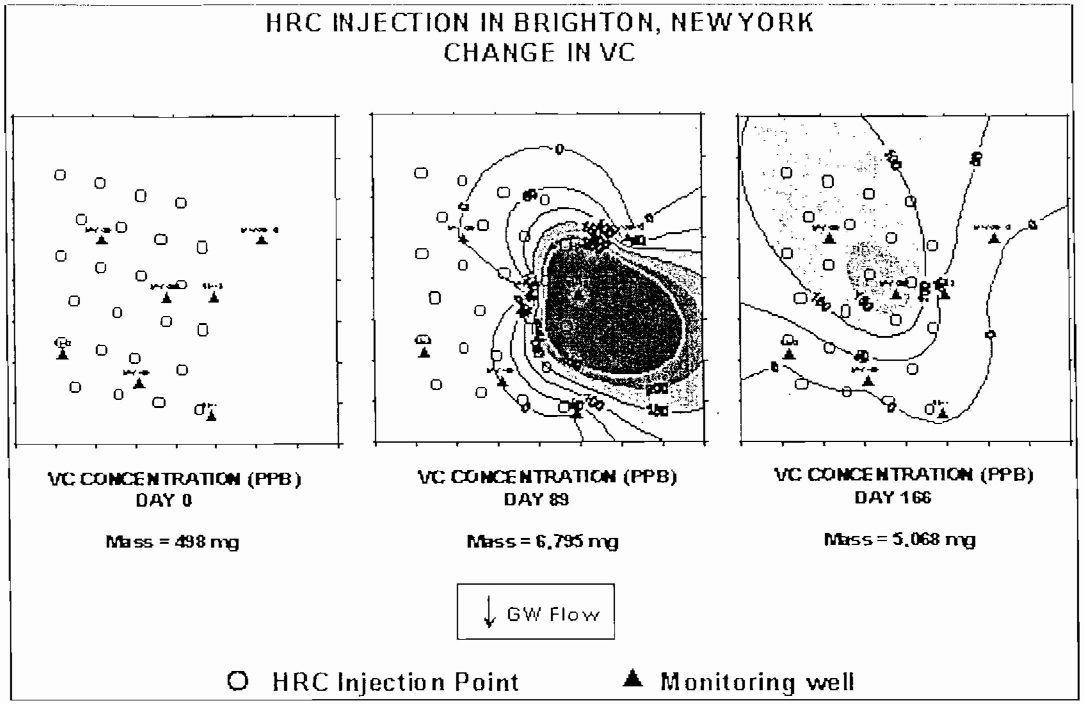
HRC INJECTION IN BRIGHTON, NEW YORK
CHANGE IN VC
VC CONCENTRATION (PPB)
DAY 0
Mass = 498 mg
VC CONCENTRATION (PPB)
DAY 89
Mass = 6,795 mg
VC CONCENTRATION (PPB)
DAY 166
Mass = 5,068 mg
GW Flow
HRC Injection Point
Monitoring well

Figure 5

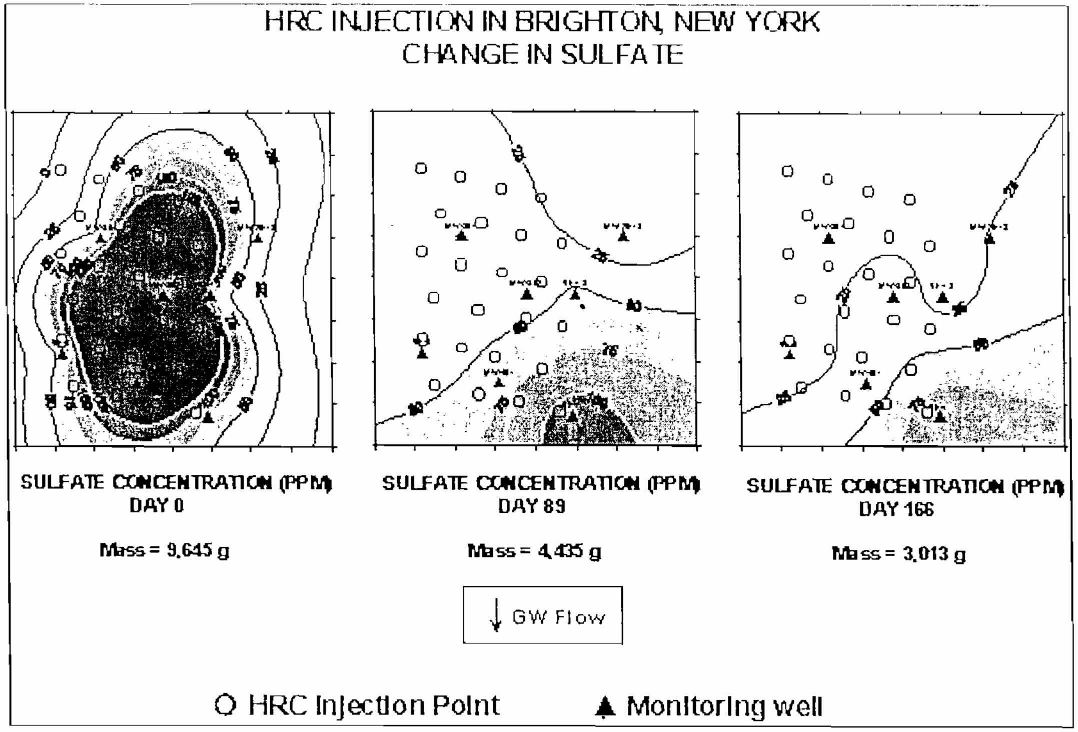
HRC INJECTION IN BRIGHTON, NEW YORK
CHANGE IN SULFATE
SULFATE CONCENTRATION (PPM)
DAY 0
Mass = 9,645 g
SULFATE CONCENTRATION (PPM)
DAY 89
Mass = 4,435 g
SULFATE CONCENTRATION (PPM)
DAY 166
Mass = 3,013 g
GW Flow
HRC Injection Point
Monitoring well

Figure 6

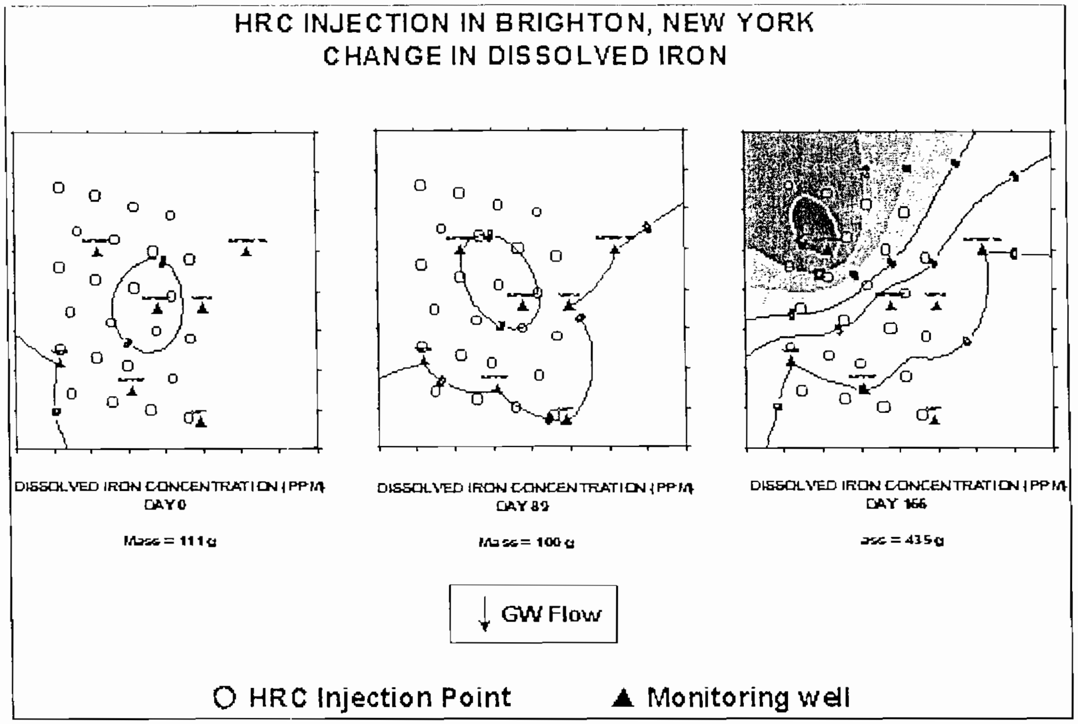

Figure 7

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HRC TECHNICAL BULLETIN #4.1.2

Hydrogen Release Compound HRC™

HRC and Iron Wall Technology (ZVI)

HRC technology is a passive approach for the accelerated bioremediation of chlorinated hydrocarbons such as perchloroethene (PCE), trichloroethene (TCE) and other compounds. How then do these methods contrast with passive mechanical operations that are currently in use such as iron walls (zero valent iron)?

Zero Valent Iron

Passive mechanical systems are essentially a reference to zero valent iron technology (ZVI), more commonly known as the "Iron Wall". ZVI technology is a patented technology that carries significant royalty payments on the order of 15% of the cost of the project. The technology has received significant attention in recent years as people search for effective ways treat chlorinated solvent plumes. However, the conclusion often reached by those who have researched the topic is that ZVI technology is often viewed as an "expensive Band-Aid" insofar as it is expensive to install and simply cuts off the plume and does not address the source of contamination nor the upgradient plume area.

ZVI/HRC Barrier Cost Comparison

In comparison to the use of a line of HRC application points (in for form of an "HRC Barrier") to achieve the same plume cut-off as an iron wall, the HRC option is usually a fraction of the cost (e.g. 1/30th the cost) of a comparable "iron wall" application. For example, the plume treatment accomplished by an iron wall installation costing $800,000 could very well be accomplished by an HRC application costing $26,000.

Performance Problems with Iron Walls

To give credit where credit is due, ZVI technology is a valid technology for specific instances however, it must be properly designed. While iron wall applications have been successful at reducing target contaminant concentrations moving through the iron wall on several sites, these designs are susceptible to failure in every dimension – length, depth, and thickness.

With respect to depth the issue is simply as follows. Depending on the specific design water can in fact breach the barrier and can flow underneath the iron wall. With respect to length it is the same issue -- if improperly designed water will flow around. In either case, the costly iron wall installation is deemed a failure by allowing untreated water to circumvent the treatment zone.

HRC TECHNICAL BULLETIN H-4.1.2 – pg. 2

Hybrid Iron Wall with HRC Application

In terms of iron wall failure, thickness is the least worrisome dimension of failure. The track record has been good in terms of limiting the breakthrough of parent or daughter compounds. However, the thicker the wall the more costly it is as tremendous volumes of iron are required and excavation/disposal costs increase dramatically with thickness . An interesting feature related to thickness also emerges in that the extinction of the contaminant is governed by a logarithmic function such that a full 90% of the thickness is required to remediate the last 10% of the contamination. This raises an intriguing option – a hybrid ZVI and HRC system. The key to making this work is to have a very low cost trenching installation of the iron wall -- on the order of six inches rather than six feet. This would then allow a limited breakthrough such that a very low cost HRC injection down gradient can do the polishing. In very general terms a $500,000 wall that is several feet thick can be scaled back to $100,000 and supplemented with a down gradient HRC barrier that would typically run less than $20,000.

In summary, there are various limitations to ZVI technology for *in situ* remediation, the most obvious is the tremendous cost and inflexibility of the constructed installation, not to mention their unproven long-term viability. Given that bioremediation is a viable option for the accelerated natural attenuation of contaminated sites, the following are some advantages of using an HRC slow release hydrogen strategy.

1. Low Capital, Design, and O&M Costs:

HRC is a passive, in situ approach and avoids substantial design, capital, and operations/maintenance (O&M) costs. These features are not a given for iron walls which is technically passive – but involves substantial design and capital costs for these large-scale construction projects. Sometimes even the design costs alone of a ZVI system will approach or exceed the costs of an HRC treatment.

2. Minimal Site Disturbance:

HRC offers the potential for in situ treatment without the requirement for aboveground equipment after initial injection, thereby allowing remediation without disrupting normal business or commercial activities. Applying these slow-releasing substrates to the subsurface is fast and easy. An iron wall operates invisibly but the installation is a major undertaking.

3. Applicability at Deeply Contaminated Silts

Iron walls have depth limitations as a function of trenching. However, HRC can be easily placed at depth through the use of injection or auger backfilling. Because HRC releases lactic acid and hydrogen out into the contaminated aquifer, an in situ treatment area is formed. Thus, treatment occurs over a large area, without rely on capturing and funneling all of the contaminated groundwater through a small trench to contact immobile iron particles as in the iron wall technology.

HRC TECHNICAL BULLETIN #4.1.3

Hydrogen Release Compound HRC™

HRC and Application of Organic Substrates

In this technical bulletin, HRC technology is compared to the use of common organic substrates to promote degradation of chlorinated solvent compounds *in situ.*

In order to understand the advantages of HRC technology, one must recognize that HRC is a passive method. Once installed it then stimulates the continuous release of low dissolved hydrogen concentrations for over a year's time, without the need for active infiltration, batch dosing of wells, etc. Engineers and scientists in the field have attempted to use other common substrates (such as sugars). In each case however, the organic substrate application required costly mechanical design and infrastructure to allow for continuous or semi-continuous substrate, and costly O&M associated with routine applications. HRC technology completely eliminates these design, installation and maintenance tasks, and all of the associated costs.

In addition to the dramatic cost advantage of HRC technology compared to the use of other substrates, there is also a distinct technical advantage- the consistent release of low dissolved hydrogen concentrations from HRC does not promote the formation of methane, as other substrates do.

The following discussion gives greater details to these benefits of HRC over the use of other organic substrates.

Organic Substrate Injection is Costly

The use of common organic substrates to stimulate chlorinated solvent degradation in groundwater requires mechanical design and construction of continuous or semi-continuous injection systems. There are a number of concerns with these approaches:

1) Organic compound delivery systems are costly. To continuously inject a soluble substrate like sugar or molasses, one must install multiple substrate application wells. Piping and trenching are required to continuously feed these wells. An electronically activated solenoid system to control the substrate dosing is generally required as well. In the event the substrate is injected directly into

the subsurface without a well (e.g. push-points) then reapplication will be required at regular intervals (e.g. every 7 to 14 days with molasses). This comes at a very high labor/ subcontractor cost. Thus, while the common organic substrate is cheap on a per pound basis, the actual treatment will be very costly. HRC on the other hand does not require continuous or semi-continuous feeding. HRC is simply injected once into the subsurface through push-points or borings (or placed in excavations prior to backfilling) and left to do its work-continuously releasing low concentrations of dissolved hydrogen.

2) Organic compound delivery systems all plug. Due to the very nature of substrates such as molasses or corn syrup, biodegradation of the material results in biomass buildup (slime). This rapidly plugs the injection system requiring labor costs associated with well cleaning (with either hydrogen peroxide or acid-both are compounds which are very detrimental to the process which

the system is installed to stimulate). With HRC technology, this problem is completely avoided, as HRC requires only a one-time injection into the subsurface through a boring resulting in the production of hydrogen for year's time.

3) Injection Introduces Oxygen. The continuous or semi-continuous injection of substrate inherently introduces oxygen and increases the redox of the subsurface environment. This tends to stop the dechlorination process, until redox potential is re-established in the proper range. This slows the overall remediation as the subsurface micro-flora adjust to the every shifting redox.

HRC Technology- Minimizes Methane Production

Common Substrates Produce Methane. The application of large amounts of dissolved organic substrates to the subsurface stimulates methane production. This is the result of too much hydrogen produced when a "slug" of substrate is added to the subsurface all at once. This is an almost unavoidable phenomenon with the use of common substrates such as molasses, corn syrup, lactate, etc. This methane production dramatically reduces the efficiency of the substrate addition, stealing hydrogen from the desired dechlorination reaction. Generating this condition in the aquifer can result in the buildup of dangerous gases. HRC release hydrogen at a slow controlled rate, thereby keeping dissolved hydrogen concentrations low, avoiding the creation of methanogenic conditions.

HRC Maximizes Dechlorination. HRC releases hydrogen at a continuous slow rate. The result is the maintenance of low concentrations of hydrogen in the contaminated groundwater. Sites where HRC has been applied have been shown to contain dissolved hydrogen concentrations in the range of 2-8 nM. In a recent publication (Yang and McCarty, 1998), it was shown that maintaining a concentration of hydrogen below 10nmolar produced efficient dechlorination while concentrations in excess of 10 nM (as produced by common substrate application) stimulated methanogenesis. Other research has indicated that the production of methanogenic conditions often inhibits the dechlorination process altogether.

3) HRC is More Efficient. Common substrates, which have been tested for stimulating the cleanup of chlorinated solvents from groundwater, include molasses, corn syrup, alcohols, etc. Each of these substrates, in addition to stimulating methane production as they are dosed into the subsurface, are inherently less efficient at stimulating dechlorination compared to HRC. In most cases this is the result of lower hydrogen production on a molar basis (i.e., more of the other substrates is required to produce the same amount of reducing power). In addition, many organic mixes such as molasses contain detrimental salts such as sulfates. Sulfates reduce the efficiency of the dechlorination process by accepting electrons that otherwise would have resulted in dechlorination. Thus the presence of impurities such as sulfates have an interfering effect on the dechlorination process, extending the time and cost of the remediation process in comparison to the use of HRC.

The Advantages of Using HRC

Given that bioremediation is a viable option for the accelerated natural attenuation of contaminated sites, the following are some advantages of using slow-release compounds.

1. Low Capital, Design, and O&M Costs:

Since the slow-release compounds are part of a passive, *in situ* approach, substantial design, capital, and operations/maintenance (O&M) costs are avoided. Actively engineered systems such as injection well patterns, solenoids dosing systems, etc. are expensive, time-consuming, and often burdened with costly and extensive design considerations. Sometimes even the design costs alone of mechanical systems will approach or exceed the costs of an ORC or HRC treatment.

2. Minimal Site Disturbance:

HRC offers the potential for *in situ* treatment without the requirement for aboveground equipment after initial injection, thereby allowing remediation without disrupting normal business or commercial activities. Applying these slow-releasing substrates to the subsurface is fast and easy. After application, there are no aboveground indications that the product has been applied because it works silently below ground.

3. Applicability at Difficult to Manage Sites:

HRC is ideal for sites where geological or physical conditions make active systems inappropriate. Particularly in clay soils, where pumping is difficult and sparging promotes channeling, the slow release of diffusible lactic acid and hydrogen has distinct advantages.

4. Limited Disturbance of the Contaminant Plume:

Any mechanical action in the aquifer has the potential to distort the dynamics of a contaminant plume—usually not to the benefit of the project. The very small volume of HRC injected has minimal if any impact on plume dimensions, and the slow release of lactate and hydrogen simply disperse passively without any potential for plume disruption.

5. Usefulness at Remote Sites:

HRC is ideal at geographically remote sites, particularly in regions that are difficult to access. The HRC process, being passive in nature, requires no utilities such as power or water. This represents a great advantage over mechanical delivery systems required in the use of other organic substrates which utilities and constant attention for batch dosing or operation and maintenance.

6. Constant and Persistent Source of Electron Acceptor/Donor:

HRC will remain where emplaced and generate diffusible active agents slowly over time. Particularly in the case of chlorinated hydrocarbons, where plumes are difficult to locate, a continuous source of diffusible materials increases the effectiveness of contact, containment, and remediation.

HRC TECHNICAL BULLETIN #4.1.4

Hydrogen Release Compound HRC™

HRC Application and Chemical Oxidants

The use of chemical oxidation in groundwater remediation is characterized by the use of two main strategies. The first is the use of Fenton's Reagent that involves that catalysis of hydrogen peroxide by an iron salt – typically iron sulfate. This generates highly reactive free radicals that chemically oxidize contaminants. The second approach involves the use of permanganate – typically potassium permanganate that also oxidizes the contaminants.

Chemical oxidation is an active process that requires the handling of hazardous chemicals on-site. The following points describe other basic differences between active chemical oxidation and the gentler HRC stimulated biological reductive dechlorination.

1) *HRC is More Cost Effective in Treating Dissolved Plumes*. Chemical oxidation requires contact between the short-lived free radical generated and the target compound. This requires that the chemical oxidant be injected into many points at very close spacing. It also requires very large quantities of chemical reagents. These characteristics make chemical oxidation approaches much more costly than a simple installation of passive releasing HRC. In comparison to HRC, chemical oxidation of a dissolved phase plume may cost three to four times that of a similar HRC plume treatment.

2) *HRC is Safe*. Both the permanganate and Fenton's Reagent technologies are dangerous to handle (both the reagents and the reactions are dangerous). Patents which have strong safety considerations are held by many of the companies offering these services which focus on methods of application that revolve around these safety and efficacy issues. HRC, on the other hand, is safe to handle when following the instructions and does not produce excessive heat or explosive conditions.

3) *Chemical Oxidation Prohibits Natural Attenuation*. Chemical oxidation disrupts the anaerobic condition of the aquifer. As a result, once chemical oxidation is applied in an area, natural dechlorination activity is inhibited. Thus, one cannot make the argument that chemical oxidation will treat the majority of the contamination, leaving the remaining contamination to natural attenuation. Due to the resulting oxidized environment, natural attenuation of the chlorinated solvent contaminant simply will not occur. At several sites where chemical oxidation has been applied, HRC has been proposed as a follow-on process to restore the natural attenuation processes to ensure continued contaminant degradation.

4) *Chemical Oxidation may Produce Undesirable By-Products*. In the chemical oxidation of chlorinated hydrocarbons it is not completely clear what by-products are generated. The exposure of contaminants and even background organic matter to high-energy free radicals is not a straightforward proposition. Some reports on the formation of chlorinated derivatives of a questionable nature such as chloramines have appeared in relation to Fenton's Reagent, and the

use of potassium permanganate has been shown to produce hexavalent chrome contamination plumes from naturally occurring chrome deposits. HRC produces none of these negative effects.

The Advantages of Using Slow-Release Compounds

Given that bioremediation is a viable option for the accelerated natural attenuation of contaminated sites, the following are some advantages of using slow-release compounds over active chemical oxidation systems.

1. Low Capital, Design, and O&M Costs:

Since the slow-release compounds are part of a passive, *in situ* approach, substantial design, capital, and operations/maintenance (O&M) costs are avoided. Actively engineered systems such as a chemical injection well arrays are expensive, time-consuming, and often burdened with costly and extensive design considerations.

2. Environmental Safety:

With respect to HRC, the ester simply degrades into two naturally occurring, safe compounds—glycerol and lactic acid, from which very low concentrations of dissolved hydrogen is derived biologically. Chemical oxidation on the other hand has been shown to cause secondary groundwater pollution in the form of hexavalent chrome contamination.

4. Safe Application and Treatment:

The use of HRC avoids the stated hazards of using permanganate or Fenton's Reagent. Chemical oxidation systems on the other hand have been shown to be very dangerous to apply, and require highly skilled delivery personnel with emergency/ health and safety personnel on standby.

5. Applicability at Difficult to Manage Sites

Slow-release compounds are ideal for sites where geological or physical conditions make active systems inappropriate. Particularly in clay soils, where transport of the transient hydroxyl radical generated in chemical oxidation is difficult, the slow release of diffusible lactate and hydrogen from HRC has advantages.

United States
Environmental Protection
Agency

Office of Solid Waste and
Emergency Response
(5102G)

EPA 542-F-01-013
April 2001
www.epa.gov/superfund/sites
www.cluin.org

A Citizen's Guide to Chemical Oxidation

The Citizen's Guide Series

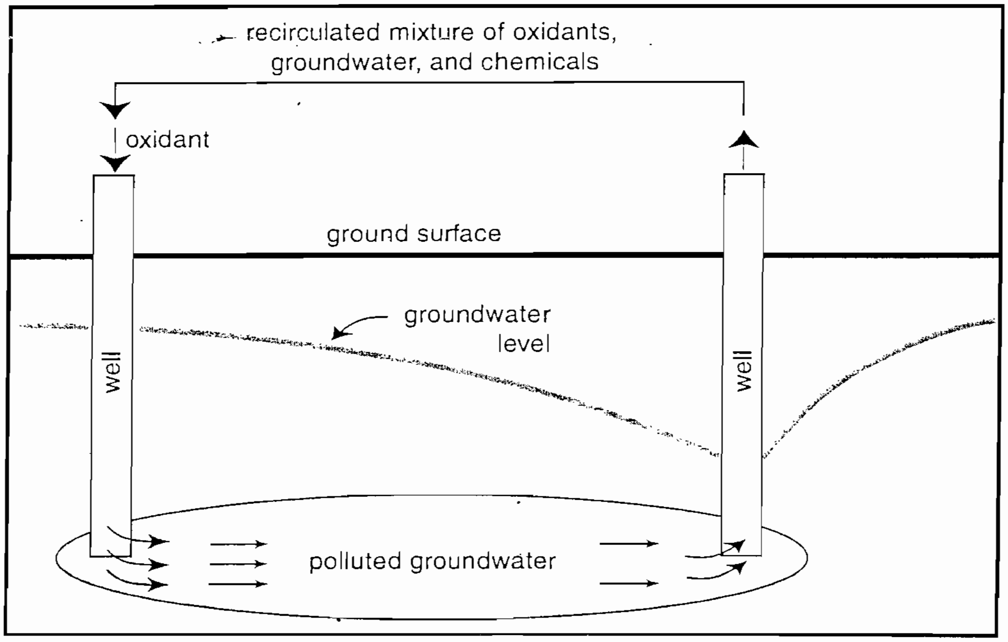
EPA uses many methods to clean up pollution at Superfund and other sites. Some, like chemical oxidation, are considered new or *innovative*. Such methods can be quicker and cheaper than more common methods. If you live, work, or go to school near a Superfund site, you may want to learn more about cleanup methods. Perhaps they are being used or are proposed for use at your site. How do they work? Are they safe? This Citizen's Guide is one in a series to help answer your questions.

What is chemical oxidation?

Chemical oxidation uses chemicals called *oxidants* to destroy pollution in soil and groundwater. Oxidants help change harmful chemicals into harmless ones, like water and carbon dioxide. Chemical oxidation can destroy many types of chemicals like fuels, solvents, and pesticides.

How does it work?

Chemical oxidation does not involve digging up polluted soil or groundwater. Instead, wells are drilled at different depths in the polluted area. The wells pump the oxidant into the ground. The oxidant mixes with the harmful chemicals and causes them to break down. When the process is complete, only water and other harmless chemicals are left behind.



To clean up a site faster, oxidants can be pumped in one well and out another well. This approach helps mix the oxidant with the harmful chemicals in the groundwater and soil. After the mixture is pumped out, it is pumped back (*recirculated*) down the first well. As pumping and mixing continues, more polluted soil and groundwater are cleaned up.

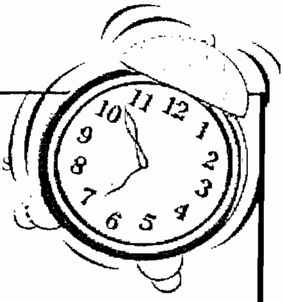
It can be hard to pump oxidants to the right spots in the ground. So before drilling starts, EPA must study the conditions underground by testing the soil and groundwater. Where is the pollution? How will the oxidant spread through the soil and groundwater to reach it?

The most common oxidant to clean up pollution is *hydrogen peroxide*. Another is *potassium permanganate*, which is cheaper. Both oxidants are pumped as liquids. And both have advantages depending on the site. Ozone is another strong oxidant, but because it is a gas, it can be difficult to use.

At some sites, a *catalyst* is used with the oxidant. A catalyst is a chemical that increases the strength or speed of a process. For instance, if hydrogen peroxide is mixed with an iron catalyst, it produces a strong chemical called a *free radical*. Free radicals can destroy more harmful chemicals than hydrogen peroxide alone.

Chemical oxidation can create enough heat to boil water. The heat can cause the chemicals underground to *evaporate*, or change into gases. The gases rise through the soil to the ground surface where they are captured and cleaned up.

How long will it take ?



The time it takes for chemical oxidation to clean up a site depends on several factors:

- size and depth of the polluted area
- type of soil and conditions present
- how groundwater flows through the soil (How fast? Along what path?)

In general, chemical oxidation offers rapid cleanup times compared to other methods. Cleanup times can be measured in months, rather than years.

Is chemical oxidation safe?

Chemical oxidation can be quite safe to use, but there are potential hazards. Oxidants are *corrosive*, which means they can wear away certain materials and can burn the skin. People who work with oxidants must wear protective clothing. Some oxidants can explode if used under the wrong conditions. Explosions can be prevented, however, through proper design of the chemical oxidation system. EPA makes sure that the system is properly designed. Workers also test the soil, groundwater, and air after chemical oxidation to make sure the site is cleaned up.

Why use chemical oxidation?

Chemical oxidation is being used at hundreds of sites across the country. It destroys pollution underground without having to dig it up or pump it out for transport to a treatment system. This saves time and money. Often chemical oxidation is used to clean up pollution that other methods can't reach, like pollution deep within the groundwater. Chemical oxidiation can be used to clean up the source of pollution. Most other methods that are used to remove the source are very slow and more expensive.

For more information

write the Technology Innovation Office at:

U.S. EPA (5102G)
1200 Pennsylvania
Ave., NW
Washington, DC 20460

or call them at
(703) 603-9910.

Further information also can be obtained at **www.cluin.org** or **www.epa.gov/superfund/sites**.

In Situ nical Oxidation at Six Drycleaner Sites, Variou ocations

Federal
Remediation
Technologies
Roundtable

Site Name:	Butler Cleaners #1; Butler Cleaners #2; Former Quick-N-Easy Wash-O-Mat and Former Artistic Cleaners (these two facilities contributed to the same groundwater plume); Hanner's Cleaners; Paul's Classic Dry Cleaners; Swift Cleaners
Location:	Butler Cleaners #1, Jacksonville, FL; Butler Cleaners #2, Jacksonville, FL; Former Quick-N-Easy Wash-O-Mat and Former Artistic Cleaners, Wichita, KS; Hanner's Cleaners, Pompano Beach, FL; Paul's Classic Dry Cleaners, WI; Swift Cleaners, Jacksonville, FL
Period of Operation:	Butler Cleaners #1 - ongoing (dates not specified) Butler Cleaners #2 - October, 1999 Former Quick-N-Easy Wash-O-Mat and Former Artistic Cleaners - 1999 Hanner's Cleaners - June to September, 2000 Paul's Classic Dry Cleaners - Not specified Swift Cleaners - July 1999
Cleanup Type:	Field demonstration

Technology:

In situ chemical oxidation:

- At the Butler Cleaners #1, Butler Cleaners #2, and Former Quick-N-Easy Wash-O-Mat and Former Artistic Cleaners sites, solutions of potassium permanganate were injected into the subsurface to oxidize contaminants. At two sites the solutions were mixtures of potassium permanganate with water, with potassium permanganate making up 8% to 15% of the solution. At one site, the solution was heated and tertiary butyl alcohol was added to help mobilize the contaminants. The solutions were injected through from one to 45 wells, and injection volumes ranged from 1,000 to 2,200 gallons. At two of the sites SVE was also used to remove contaminants from the soil.
- At the Hanner's Cleaners and Swift Cleaners sites, solutions of water, hydrogen peroxide (12 to 25%), and an unspecified catalyst were injected into the subsurface to oxidize contaminants. The solutions were injected through from 6 to 12 wells, and volumes ranged from 1,700 to 20,000 gallons. SVE was also used at both sites to remove contaminants from the soil.
- At the Paul's Classic Dry Cleaners site, a field demonstration of an ozone in-well air sparging system was conducted. The treatment system consisted of a single well where sequential sparging and groundwater recirculation functions were performed in the sparge well. The system delivered an air and ozone gas mixture (the composition of the mixture was not specified) at a rate of 1.7 to 2.2 cfm first to the lower sparge point, then the in-well sparge point, each for a specified period of time. In-well pumping was then performed. This process was repeated in a cycle over a period of 16-18 hours/day. Multi-phase extraction was also conducted at the site.

Cleanup Authority: State

Contacts:
Varied by site

Contaminants:

Chlorinated Solvents

- All of the sites were contaminated with PCE and TCE
- Concentrations varied by site ranging with concentrations ranging from 1 to 42 mg/L for PCE and 0.02 to 012 mg/L for TCE
- Five sites reported that DNAPLs were present or likely to be present.

Waste Source: Waste and wastewater from drycleaning operations

Type/Qu of Media Treated:
Groundwate
- Reported plume areas ranged from 130,000 to 1.3 million square feet, and reported plume depths ranged from 25 to 75 feet bgs. Reported actual treatment areas ranged from 400 to 7,900 square feet, and reported actual treatment depths ranged from 30 to 45 feet.

Purpose/Significance of Application:
Demonstration of in situ oxidation technologies for remediation of chlorinated solvents in groundwater at drycleaner facilities

Regulatory Requirements/Cleanup Goals:
- Cleanup goals were based on state regulatory goals or EPA MCLs.
- Specified cleanup goals included 0.005 to 0.014 mg/L for PCE and 0.012 mg/L for TCE

Results:
Only one site (Swift Cleaners) reported achieving remediation goals. Other sites reported that contaminant concentrations were not significantly reduced or that cleanup goals were not met.

Costs:
Reported design and implementation costs:
- Potassium permanganate systems - $105,000 to $230,000
- Hydrogen peroxide - $110,000 to $170,000
- Ozone sparging - Not specified

Description:
In situ chemical oxidation was conducted at six drycleaner sites contaminated with chlorinated solvents from drycleaning operations with TCE and PCE as the primary contaminants in groundwater. At three sites solutions of potassium permanganate were injected into the subsurface, at two sites solutions of hydrogen peroxide and catalyst were injected into the subsurface, and at one site an ozone in-well air sparging system was installed. Only one site (Swift Cleaners) reporting achieving remediation goals. Other sites reported that contaminant concentrations were not significantly reduced or that cleanup goals were not met.

View the Complete Document

Butler Cleaners, Jacksonville, FL

Remediation Technology

In-Situ Chemical Oxidation - Potassium Permanganate ($KmnO_4$)

Site Description

This is an active PCE drycleaning site that has been in operation since 1972. The adjacent property was occupied by a gasoline station from the 1920s to the 1950s. Three USTs were removed from this site in 1992. The site is located in a residential/commercial setting.

Site Hydrogeology

Depth to Water: 6 ft below land surface (bls)
Unconfined Aquifer
Lithology:
  Surface - 28 ft bls: very fine - fine-grained sand
  28 - 34 ft bls: sandy clay

Hydraulic Gradient: 0.0036 ft/ft
Hydraulic Conductivity: 8.7 ft/day
Seepage Velocity: 0.1 ft/day

Groundwater Contamination

Contaminants Present: PCE, TCE, cis 1,2-DCE, trans 1,2-DCE, vinyl chloride, toluene, ethylbenzene, xylenes, naphthalene

Highest Contaminant Concentrations: 17,000 µg/l PCE, 830 µg/l TCE, 120 µg/l cis 1,2-DCE, 1170 µg/l vinyl chloride

Deepest Groundwater Contamination: 27 ft bls

Contaminant Plume Size: delineation not yet completed

Remediation Scenario

Treatment Area: approximately 10 ft x 40 ft to a depth of 30 ft

Quantity/Concentration: 3 initial injection events of 5,000 gallons at a concentration of 7.7 g/L $KmnO_4$ (Carus Free Flowing grade) per injection event.

Injection: 9 well clusters with 5 1-inch diameter monitoring/injection wells screened at 5-10 ft, 10-15 ft, 15-20 ft, 20-25 ft, and 25-30 ft depth intervals. Two clusters initially utilized as injection wells with other wells converted to injection wells based upon $KmnO_4$ and contaminant distribution. Periodic injections are ongoing.

Results

Post-pilot test monitoring indicates that, following initial injection of $KmnO_4$, contaminant concentrations decreased [illegible] areas of $KmnO_4$ distribution. However, periodic monitoring indicates that rebound of elevated PCE concentrations is occurring upon reduction of $KmnO_4$ concentrations within the formation. Rebound of PCE concentrations is likely due to the existence of residual DNAPL PCE that continues to act as an ongoing source of dissolved phase PCE contamination.

Costs

Approximately $230,000 for design and implementation of the pilot test system and approximately $30,000 per event for quarterly monitoring and $KmnO_4$ injection (not including reporting costs).

Lessons Learned

1. $KmnO_4$ is effective for the oxidation of dissolved phase PCE contamination

2. Effective remediation of chlorinated solvent contamination using $KmnO_4$ may be confounded by the presence of DNAPL contamination due to mass transfer limitations of contaminant mass from the DNAPL to dissolved phase. Determination of the presence of residual DNAPL PCE is integral to the successful application of in-situ chemical oxidation technologies.

Contacts

Florida Department of Environmental Protection: Douglas Fitton
(850) 488-0190
LFR Levine-Fricke: Kevin Warner, P.E. (850) 422-2555

This profile last updated: November 15, 2000

Technology
Evaluation Report

TE-99-01

GWRTAC
E
SERIES

In Situ Chemical Treatment

Prepared By:

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July 1999

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1.0 SUMMARY

In situ chemical treatments have been demonstrated to be promising alternatives to conventional pump-and-treat practice for contaminated soils and groundwater. Depending on site and contamination characteristics, *in situ* chemical treatment can be achieved by either injection of liquid, gaseous, and colloidal reactive chemicals into subsurface soils and/or aquifers, or by installation of a permeable chemical treatment wall across the ground-water flow path. Both conventional well injection techniques and innovative technologies, such as deep soil mixing and hydraulic fracturing, have been field demonstrated for injection of chemicals into the subsurface. The innovative injection technologies are especially useful in injecting chemical reagents into a low permeability area. Chemical treatment walls can be installed either as a simple reactive cell or in the funnel-and-gate configuration. Several technologies, including conventional trench excavation, caisson-based and mandrel-based techniques, and jet grouting, have been commercially used for construction of treatment walls.

In situ chemical treatment techniques are particularly useful for (1) treatment of source areas to reduce mass of contaminants, such as NAPLs, and (2) interception of plumes to remove mobile organics and metals. In many cases chemical treatment methods are chosen where biological methods won't function effectively with respect to rate or extent either due to contaminant characteristics and/or site conditions. Treatment via chemical injection can be oxidative, reductive/precipitative, or desorptive/dissolvable depending on chemicals injected. *In situ* oxidation offers the advantages of being rapid, aggressive, and insensitive to contaminant characteristics and concentrations. The most extensively tested oxidants include hydrogen peroxide (Fentonís or Fenton-like reagents), potassium permanganate, and ozone. *In situ* redox (reductive) manipulation is particularly useful for immobilization of redox-sensitive contaminants and reductive degradation of chlorinated solvents dispersed over large areas deep below the surface. Dithionite, hydrogen sulfide, and colloidal Fe^0 have been tested for this purpose. *In situ* chemical flushing (desorptive/dissoluble) is very effective in removal of strongly sorbed or very low solubility compounds, such as DNAPL, from soils. *In situ* treatment walls are ideal for treatment of shallow groundwater contaminated with inorganics and organics. The treatment wall as a passive treatment technology has the least effect on the ecosystem.

Selection of a technology for *in situ* chemical treatment of contaminants at a specific site relies on careful site characterization and screening tests. Both laboratory treatability studies and field pilot tests are typically required. The successful application of a particular *in situ* chemical treatment technique requires (1) effective chemical reaction of the introduced chemical with contaminants at a proper rate and extent, and (2) effective delivery of the reagents throughout the zone to be treated.

A primary obstacle for *in situ* chemical treatment techniques involves delivery, distribution and mass transfer of chemicals in subsurface environments. A major concern for *in situ* chemical flushing is the uncertainty of the fate and effects of washing reagents in the subsurface environment. Effort is also needed to prevent mobilized contaminants from migrating into the surrounding environment. Concerns about immobilization and reductive degradation arise from the fact that some lightly chlorinated degradation products are persistent and very toxic, and that immobilized contaminants could be re-mobilized once local environmental conditions change. In addition, caution needs to be taken in handling chemicals because these chemical treatment techniques inherently involve use of potentially hazardous chemicals, sometimes in large quantities. Details on the potential application of each *in situ* chemical treatment technology, influencing factors, and possible process-induced detrimental effects are summarized in Tables 1-4.

Despite the fact that *in situ* chemical technologies offer significant benefits over conventional pump-and-treat technology, their use is still very limited because of technical uncertainties and regulatory or procedural barriers. The U. S. EPA has taken a series of measures to encourage and promote the development and application of these technologies. In addition, the U. S. DOE and the U. S. DOD, along with private industries, are also investing *in situ* chemical treatment methods and trying to accelerate their effective development across the U. S.

Table 1. Summary of *In Situ* Chemical Treatment Technologies by Chemical Injection of Oxidants[1]

Technology	**Chemical Injection - Oxidation**		
	Hydrogen Peroxide	**Permanganate**	**Ozone**
Treatable Compounds	Chlorinated solvents, polyaromatic hydrocarbons, and petroleum products. Not effective for chlorinated alkanes and saturated aliphatic hydrocarbons.		
Suitable Matrices	Soils and groundwater		
Influencing Factors			
pH	Prefer low pH of 2 to 4, but feasible up to near neutral pH.	Prefer neutral pH of 7 to 8, but effective over a wide range.	Effective at natural soil pH.
Natural Organic Matter (NOM) and Other Reduced Species	Any reduced species in the system can exert a demand for oxidant. Of particular importance are NOM, anthropogenic organic matter and reduced inorganics.		
Permeability	Prefer high permeability, but feasible for low permeability with use of advanced oxidant delivery techniques, such as deep soil mixing and soil fracturing. Fenton's reagent and ozone rely on free radical generation and thus transport away from point of injection is constrained.		
Temperature	All oxidants are affected by temperature to varying degrees.		
Depth	With use of the advanced delivery techniques, depth is generally not a limitation.		
Oxidant Degradation	Easily degraded in contact with soil/groundwater.	The oxidant is very stable.	Ozone degradation in soils is limited.
Other factors	May need to supply iron ($FeSO_4$) to form Fentonís reagent.		
Potential Detrimental Effects	Particulates can be generated and permeability loss is possible. Potential side effects include gas evolution with peroxide and ozone and generation of fugitive emissions, potentially toxic byproducts, potential effects on/of metals and reduction of biomass.		
References	Siegrist (1998); and U. S. EPA (1998a)	Siegrist (1998); and U. S. EPA (1998a)	U. S. EPA (1998a); and Masten and Davies (1997)

[1] This table provides some features for application of oxidation for *in situ* treatment. Site-specific information is needed for field application.

Table 2. Summary of *In Situ* Chemical Treatment Technologies by Chemical Injection of Reductants

Technology	Chemical Injection - Reduction		
	Dithionite	**Gaseous Hydrogen Sulfide**	**Colloidal Zero Valent Iron**
Treatable Compounds	Redox sensitive elements (Cr, U, Th) and chlorinated solvents dispersed over a large area.	Redox sensitive metals, such as Cr.	Redox sensitive elements (Cr, U, Th) and chlorinated solvents.
Suitable Matrices	Generally groundwater system		
Influencing Factors			
pH	Prefer alkaline condition.	No pH adjustment is required.	High pH prohibits reactions due to formation of surface coating on iron.
Natural Organic Matter (NOM)	Unknown		Potential coating on iron surface.
Permeability	High permeability.	High and low permeability.	Depends on colloidal iron delivery technique.
Depth		No field trial available	
Other factors	Effective in water saturated zone.	N_2 gas carrier is desired.	Require high soil water content and low oxygen content.
Potential Detrimental Effects	Handling difficulties and potential generation of toxic gases.		Possible generation of toxic intermediates.
References	Fruchter et al. (1997)	Thornton and Jackson (1994)	Kaplan et al. (1994) Cantrell and Kaplan (1997); and Siegrist et al. (1999)

Table 3. Summary of *In Situ* Chemical Treatment Technologies by Chemical Flushing

Technology	Chemical Injection - *In situ* Chemical Flushing		
	Surfactants and Cosolvents	**Surfactants and Cosolvent Foams**	**Acidic and Chelating Solution**
Treatable Compounds	Effective for treating many compounds, particularly dense non-aqueous phase liquids (DNAPLs).		Metal contaminants.
Suitable Matrices	Soils		
Influencing Factors			
pH	Effective over a wide pH range, but a high pH can enhance surfactant solubility and increase extraction for contaminants.		pH around 3 is good for acid solutions; a wide pH range is good for chelating solutions.
Natural Organic Matter (NOM)	NOM tends to tightly bind contaminants and decrease extraction efficiency.		
Permeability	High permeability.	High and low permeability.	High permeability.
Potential Detrimental Effects	The mobilized contaminants may escape into the surrounding environment.		
References	Jafvert (1996); and Roote (1998)	Peters et al. (1994)	Evanko and Dzombak (1997); and Smith et al. (1995)

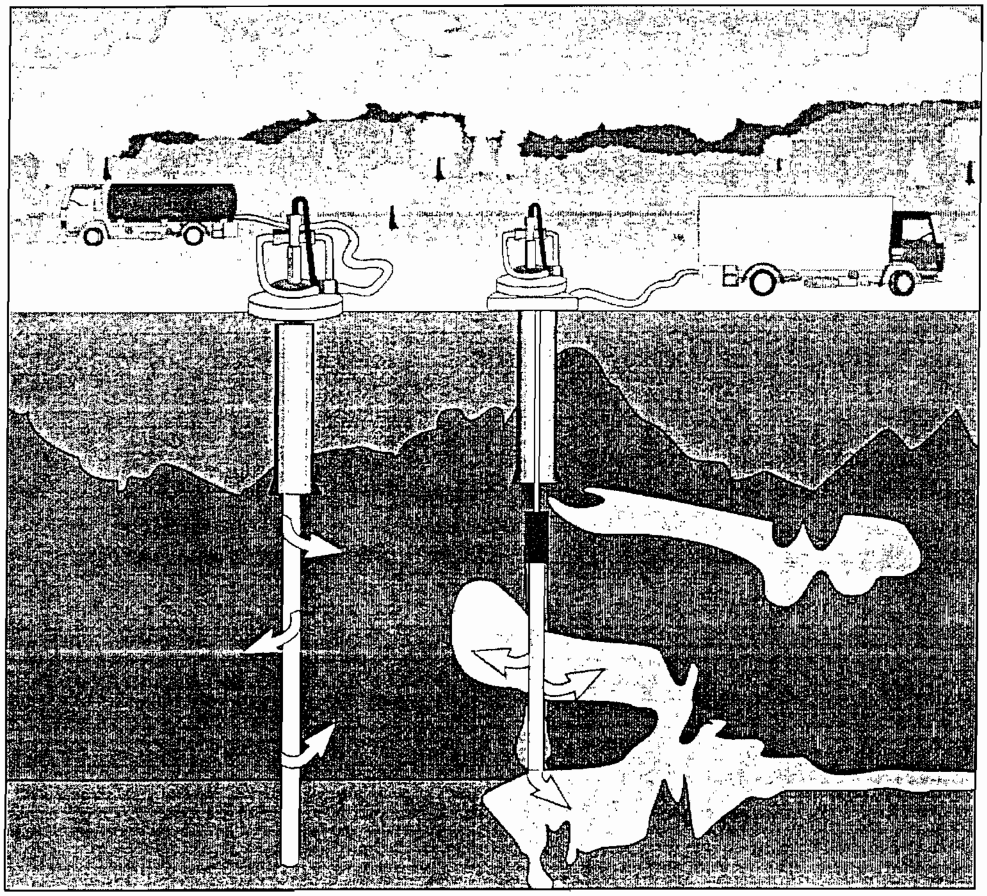
Table 4. Summary of *In Situ* Chemical Treatment Technologies by Permeable Chemical Treatment Walls[1]

Technology	**Permeable Chemical Treatment Wall**		
	Sorption	**Precipitation**	**Degradation**
Treatable Compounds	A wide variety of inorganic and organic contaminants.	Heavy metals and radioactives.	Metal anions and organic contaminants.
Suitable Matrices	Groundwater		
Influencing Factors			
pH	Depend on contaminants to be treated and the sorbents used.	Generally require high pH.	Depend on particular degradation reactions.
Natural Organic Matter (NOM)	Dissolved organic matter can remobilize contaminants.		
Depth	Typically used at shallower depths (3 to 12 m)		
Potential Detrimental Effects	The immobilized (sorbed or precipitated) contaminants may be re-mobilized upon environmental condition changes. Toxic degradation intermediates can also be generated.		
References	Vidic and Pohland (1996); http://www.rtdf.org/barrdocs.htm		

[1] In this report, permeable chemical treatment wall refers to a physical wall built by excavation followed by re-emplacement with reactive materials as filling.

Technical/Regulatory Guidelines

Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater



June 2001

Prepared by
Interstate Technology and Regulatory Cooperation Work Group
In Situ Chemical Oxidation Work Team

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EXECUTIVE SUMMARY

The contamination of groundwater and subsurface soil in the United States is a challenging problem. There are estimated to be 217,083 sites requiring some form of remediation (U.S. EPA, 1997). All of these sites potentially threaten groundwater resources. They are frequently impediments to the reuse of "brownfield" sites. Conventional treatment methods, such as pump-and-treat technology, are often costly and less than effective. Emerging in situ groundwater and subsurface soil treatment technologies may provide effective, lower-cost alternatives. It is important to fully understand all aspects of any innovative technology. This guidance document was developed to outline the technical and regulatory requirements of In Situ Chemical Oxidation (ISCO). ISCO refers to a general group of specific technologies, with each technology representing specific combinations of oxidants and delivery techniques. Specific primary oxidants addressed in this document are hydrogen peroxide, potassium and sodium permanganate, and ozone. Additionally this document is intended to expedite movement to a consensus on regulatory requirements through the ITRC concurrence process. It should prove useful to regulators, stakeholders, consultants, and technology implementers.

The document is divided into sections consisting of technology overview, remedial investigations, safety concerns, regulatory concerns, applicability, injection design, monitoring, and stakeholder concerns. From a regulatory perspective, the most important sections of the document are identification of injection restrictions, implementation and post closure monitoring. Appendix B provides case studies of ISCO implementations, and the reference list includes documents with additional case study data.

Site characterization is a critical step in effectively applying ISCO or any other remedial technology. A complete understanding of the site geology, hydrogeology, and geochemistry, as well as the contaminant profile, is necessary. Specifics on field and laboratory analytical parameters are provided in Section 2. Once a complete understanding of the site has been accomplished, it is important to develop a conceptual site model in order to relate the data in three-dimensions. Numerous hydrogeological and geochemical models are available to further evaluate site conditions.

Regulatory issues associated with ISCO include the state or federal programs associated with Underground Injection Control (UIC), and Air Quality. Permitting will typically not be an extensive process in ISCO deployment, as required permits may be limited to UIC concerns. Air Quality concerns are limited to controlling fugitive vapors that may be produced by the heat of reaction. Monitoring issues are discussed in this document.

Health and safety issues for ISCO include the following: (1) safely handling the oxidants, as hydrogen peroxide, potassium permanganate, and sodium permanganate solutions are strong nonspecific oxidants; (2) permanganate dust is hazardous; (3) the presence of ozone will increase the flammability of many materials; and (4) the generation of ozone usually includes high-voltage equipment concerns.

Tribal and stakeholder concerns should be addressed in detail. This requires frank public discussion about the potential risks and benefits of the technology and about site-specific issues. This document provides detail on tribal and stakeholder concerns in Section 7.

TECHNOLOGY STATUS REVIEW

IN SITU OXIDATION

ESTCP

Environmental Security
Technology Certification
Program

November 1999

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United States
Environmental Protection
Agency

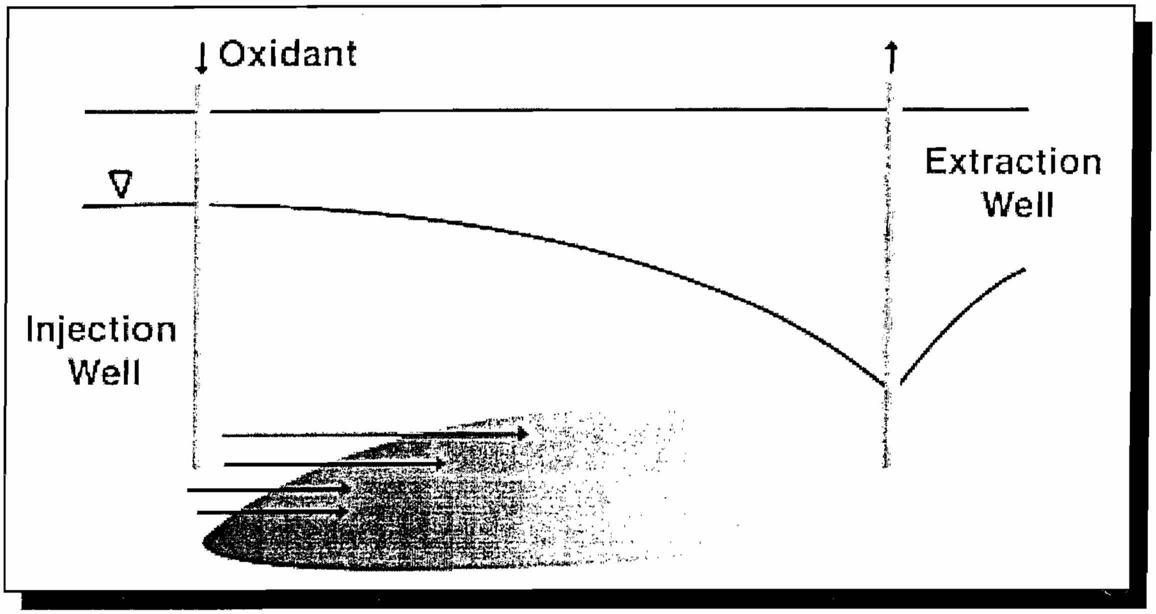
Solid Waste and
Emergency Response
(5102G)

EPA 542-R-98-008
September 1998
http://www.epa.gov/swertio1
http://clu-in.org

EPA

Field Applications of *In Situ* Remediation Technologies:

Chemical Oxidation



EPA 542-R-98-008
September 1998

Field Applications of *In Situ* Remediation Technologies:

Chemical Oxidation

**U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office
Washington, DC 20460**

Foreword

Some 80 percent of the hazardous waste sites in the United States have contaminated ground water. Conventionally, the treatment of contaminated ground water has been done by extracting the contaminated water, treating it above ground, and reinjecting or discharging the clean water ("pump-and-treat"). The extracted contaminants must be disposed of separately. It is becoming increasingly apparent that pump-and-treat technologies require considerable investment (between $14-17 million) over a long time (30 years or longer), and may not actually clean up the source of the contamination. Current policies and law stress "permanent" remedies over containment. Consequently, there is considerable interest and effort being expended on alternative, innovative treatment technologies for contaminated ground water.

This report is one in a series that document recent pilot demonstrations and full-scale applications that either treat soil and ground water in place or increase the solubility and mobility of contaminants to improve their removal by other remediation technologies. It is hoped that this information will allow more regular consideration of new, less costly, and more effective technologies to address the problems associated with hazardous waste sites and petroleum contamination. This and the other reports listed below are available to the public from the Technology Innovation Office website: http://clu-in.org/pubitech.htm.

Surfactant Enhancements
Treatment Walls
Hydrofracturing/Pneumatic Fracturing
Cosolvents
Electrokinetics
Thermal Enhancements
In Situ Chemical Oxidation
Ground-Water Circulation Wells

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Introduction

Purpose and Process

The purpose of this document is to describe completed and ongoing pilot demonstrations and full-scale applications of *in situ* chemical oxidation technologies for the remediation of soil and ground water at waste disposal and spill sites.

Information for this report came from commercial and government databases, such as the Dialog Information Services and the Environmental Protection Agency's (EPA) Vendor Information System for Innovative Treatment Technologies (VISITT). Additional materials were obtained from EPA Regional Offices, Department of Energy staff at the Oak Ridge National Laboratory and Westinghouse Savannah River, Department of Defense site staff, and Battelle Laboratories. Personal interviews and discussions with representatives of EPA and other federal agencies, state environmental quality offices, academic research centers, hazardous waste remediation consulting firms, and technology vendors provided supplementary information.

Technology Needs

In situ chemical oxidation is one of several innovative technologies that show promise in destroying or degrading an extensive variety of hazardous wastes in ground water, sediment, and soil. The oxidants used are readily available, and treatment time is usually measured in months rather than years, making the process economically feasible.

Enrichment with dissolved oxygen has been shown to stimulate *in situ* biological processes, but also is used at at least one site to oxidize arsenic. Potassium permanganate is a stable and easily handled oxidant in both solid and solution form. Hydrogen peroxide can be costly, and because of its volatility requires protective measures. Nevertheless, the shorter process may save on labor and operating costs.

In situ chemical oxidation can be applied in conjunction with other treatments such as pump-and-treat and soil vapor extraction to break down remaining compounds. It is less costly and disruptive then other traditional soil treatments such as excavation and incineration. *In situ* chemical oxidation may be used in applications where the effectiveness of bioremediation is limited by the range of contaminants and/or climate conditions.

Technology Description

In situ chemical oxidation is based on the delivery of chemical oxidants to contaminated media in order to either destroy the contaminants by converting them to innocuous compounds commonly found in nature. The oxidants applied in this process are typically hydrogen peroxide (H_2O_2), potassium permanganate ($KMnO_4$), ozone, or, to a lesser extent, dissolved oxygen (DO).

The most common field applications thus far have been based on Fenton's Reagent whereby hydrogen peroxide is applied with an iron catalyst creating a hydroxyl free radical. This hydroxyl free radical is capable of oxidizing complex organic compounds. Residual hydrogen peroxide decomposes into water and oxygen in the subsurface and any remaining iron precipitates out. This process has a history of application in waste treatment fields.

The volume and chemical composition of individual treatments are based on the contaminant levels and volume, subsurface characteristics, and pre-application laboratory test results. The methods for delivery of the chemical may vary. The oxidant can be injected through a well or injector head directly into the subsurface, mixed with a catalyst and injected, or combined with an extract from the site and then injected and recirculated. In the case of hydrogen peroxide, stabilizers may be needed because of the compound's volatility.

In situ chemical oxidation is being used for ground water, sediment, and soil remediation. It can be applied to a variety of soil types and sizes (silt and clay). It is used to treat volatile organic chemicals (VOCs) including dichloroethene (DCE), trichloroethene (TCE), tetrachloroethene (PCE), and benzene, toluene, ethylbenzene, and xylene (BTEX) as well as semi-volatile organic chemicals (SVOCs) including pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs).

Hydrogen Peroxide (H_2O_2)

Anniston Army Depot, Anniston, AL

Installation Date:
1997

Media:
Soil

Contaminants:
TCE

Oxidant:
H_2O_2

Soil Type:
Clay backfill

Points of Contact:
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Anniston Army Depot (SIOAN-RK)
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Full-scale soil remediation using *in situ* chemical oxidation for the removal of dense non-aqueous phase liquids (DNAPLs) such as chlorinated solvents, and hydrocarbons, was begun in 1997 at Anniston Army Depot, Anniston, Alabama.

Site Background

The site consists of three industrial waste lagoons backfilled with clay in 1978. It is approximately 2 acres with over 43,125 yd^3 of contaminated soil containing up to 31% trichloroethene (TCE), dichloroethene (DCE), methylene chloride, and benzene, toluene, ethylbenzene, and xylene (BTEX). TCE accounts for approximately 85% of the 72,000 lbs of volatile organic chemicals. The majority of contaminants were found at depths of 8 ft and greater. The highest concentrations of TCE occur at depths between 8 and 10 ft (maximum 20,100 mg/kg). The water table fluctuates from 25-30 ft below the surface.

Technology Application

Three differently sized injector wells were installed to target three distinct depth intervals. Single shallow injectors screened from 8-14 ft were installed in areas where contamination is shallower than 15 ft, single intermediate injectors were installed where contamination was found from 15-20 ft, and paired shallow and deep injectors screened from 20-26 ft were installed in areas where contamination was found at both deep and shallow depths. In addition, 25 deep ground-water injector wells were used for monitoring, and a vent flow balance system was installed to aid in maintaining an effective radial dispersion of catalyst and H_2O_2. The Geo-Cleanse® patented injection process was employed to deliver H_2O_2 and trace quantities of ferrous sulfate and acid (to control pH) into the contaminated soil. Chemical oxidation of the soil took place over a 120-day period during which 109,000 gallons of 50% H_2O_2 were injected through a total of 255 injectors. Post-treatment sampling began while the full-scale treatment was still in progress. In cases where contaminant concentrations remained above Soil Screening Levels (SSLs), the location was re-treated for polishing treatment.

The total cost to complete this project is estimated to be $5.7M. Project completion originally anticipated for the end of fiscal year 1998 is now contingent upon funding a final $500K and final sampling. Funding for this project was made available in increments. Therefore, the actual expenditures breakdown by cost categories are not available. Project managers estimate that approximately two-thirds of the funds have been allocated for capital costs including chemicals and the injection process and one-third for monitoring and support. Oversight by the Army Corps of Engineers is not included in this funding.

Results

This full-scale treatment was initiated in July 1997. For those areas where sampling and polishing has been completed, results indicate that this process was effective in reducing contaminant concentrations in clays to below SSLs. Soil concentrations of up to 1,760 mg/kg of TCE have been reduced to below detection. Additional polishing treatment may still be warranted depending upon the results of final sampling in the remaining blocks. As noted above, additional funding has been requested to complete this process. Operating data indicate no adverse migration of organics to surrounding soils or ground water.

Site-specific References

Levin, R. S; Wilson, J.; Ware, L.; Findley, J.; and Baehr, J. "Full-Scale Soil Remediation of Chlorinated Solvents in Clay Soils by *In Situ* Chemical Oxidation," Battelle, First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California May 1998

Bryant, J. Daniel and Wilson, J. "Rapid Delivery System Completes Oxidation Picture," *Soil & Groundwater Cleanup,* pp 6-11, August/September 1998

Former Sign Manufacturing Facility, Denver, CO

Installation Date:
1996

Media:
Ground water

Contaminants:
BTEX

A pilot followed by a full-scale treatment of *in situ* chemical oxidation (ISOTEC℠) for remediation of ground water contaminated with benzene, toluene, ethylbenzene, and xylene (BTEX) was conducted at a former sign manufacturing facility in Denver, Colorado, from 1996-1997.

Site Background

The approximate 100 x 100-ft site contained leaking gasoline and fuel oil underground storage tanks. A contaminant plume was found within a thin sandy gravel lens, with a clay layer above and bedrock below. The depth to ground water was 5 ft. Pre-treatment samples indicated BTEX in the ground water at a

Oxidant:
H_2O_2

Soil Type:
Sandy gravel

Point of Contact:
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EWMA of Colorado
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Englewood, CO 80112
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E-mail: ewmadenver@aol.com

maximum concentration of 24,595 µg/L.

Technology Application

The pilot program involved three treatment cycles, with 4 days per cycle. Each cycle involved injection of hydrogen peroxide and chelated iron through each of eight injection points. Full-scale remediation was ordered based on the results of this pilot application. The final application involved one six-day cycle using 14 injection points and 7 injection trenches.

The total cost of this demonstration, including pilot and full-scale programs, was approximately $200K. This included the cost of materials, injections, and sampling. The monitoring wells were pre-existing.

Results

The pilot program began in August 1996, and analyses of post-treatment samples from the full-scale operation were completed in March 1997. BTEX was not detected in the post-treatment samples from nine of the monitoring wells. The total BTEX concentration in the remaining four wells was 89 µg/L. As a result, the state issued an unrestricted "no further action letter" for the site. Based on this action, the property was sold.

Site-specific References

"Remediate Contaminated Property," *Construction Design & Engineering Journal*, March 4-13, 1998, p 2B

Warehousing Facility, Union County, NJ

Installation Date:
1995

Media:
Ground water

Contaminants:
MTBE, BTEX

A pilot test and full-scale treatment of *in situ* chemical oxidation for remediation of ground water contaminated with methyl tert-butyl ether (MTBE) and benzene, toluene, ethylbenzene, and xylene (BTEX) were conducted at a warehouse in Union County, New Jersey, from 1995-1996.

Site Background

The approximately 100 x 80 ft site contained gasoline, waste oil, and fuel oil underground storage tanks that had leaked. The site soils were unsorted and unstratified pebbles, cobbles, and boulders in a matrix of sand, silt, and clay. The depth to ground water was approximately 18 ft. Pre-treatment samples from the well with highest concentrations of contaminants indicated total BTEX levels in excess of 25,000 µg/L and MTBE levels in excess of 6,000 µg/L.

Oxidant:
H_2O_2

Soil Type:
Unsorted rocks in sand

Point of Contact:
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Washington State University
College of Engineering and
Architecture
Pullman, WA 99164
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Fax: 509-335-7632
E-mail: rjwatts@wsu.edu

Technology Application

A pilot application was performed using one injection point in the area of highest contamination and one injection point 18 ft away. A single treatment of reagent was completed over a 3-day period. Injections were performed in cycles with catalysts followed by the oxidizer. A site engineered injection apparatus was used to control the flow of hydrogen peroxide (H_2O_2) and the proprietary ISOTEC℠ catalyst (iron complex) into the capillary fringe of the vadose zone. Based on the results of this pilot, full-scale remediation was ordered. Six injection points were installed and three treatment cycles were performed over several days within a 3-month period.

The total cost of this demonstration, including pilot and full-scale programs, was approximately $220K. This included chemicals, injections, and sampling. Pre-existing monitoring wells were used for sampling, so installation costs are not included.

Results

The field pilot program began in December 1995, and analyses of post-treatment samples from the full-scale operation were completed in October 1996. Post-treatment samples taken 4 months after the final treatment application indicated that most of the contaminants, including MTBE, were below detection limits. Total BTEX concentrations were less than 25 µg/L in the same well that had registered in excess of 25,000 µg/L in pre-test samples. As a result, the case was closed in November 1996.

Site-specific References

Greenberg, R. S.; Andrews, T.; Kakarla, P.K.C.; and Watts, R.J. "In-Situ Fenton-Like Oxidation of Volatile Organics: Laboratory, Pilot, and Full-Scale Demonstrations," *Remediation*, Spring 1998, pp 29-42

Former News Publisher Facility, Framingham, MA

Installation Date:
1996

Media:
Ground water

Contaminants:
TCA, DCE, VC

Oxidant:
H_2O_2

Soil Type:
Fine-grained silty sand

Point of Contact:
Carl Shapiro
TGG Environmental, Inc.
100 Crescent Road
Needham, MA 02494
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E-mail: cshapiro@tgge.com

A pilot and full-scale application of *in situ* chemical oxidation (CleanOX®) for the remediation of 1,1-dichloroethene (DCE), 1,1,1-trichloroethane (TCA), and vinyl chloride (VC) in ground water was performed at a former news publisher facility in Framingham, Massachusetts, in 1996.

Site Background

A dry well discovered during a site assessment contained chlorinated solvents and petroleum hydrocarbons from disposal of ink and degreaser wastes. The site includes a plant, which is approximately 100 x 100 ft, and adjacent land of approximately the same dimensions. The area of cleanup consisted of crushed stone and soil surrounding the former dry well. Soil surrounding the dry well was a fine-grained silty sand. Depth to ground water averages approximately 2½ ft below ground surface. The contaminant plume is approximately 80 x 80 ft. Prior to CleanOX® treatment, remedial actions at the site included disposal of over 6,000 gallons of hazardous liquids and fifteen 55-gallon drums of hazardous sludge. Pre-treatment concentrations of TCA in the two monitoring wells were measured at 40,600 and 4,800 µg/L, and VC concentrations were 440 and 110 µg/L.

Technology Application

The pilot-scale application was conducted to evaluate site-specific geochemistry. Two CleanOX® application points were used over a 3-day period for treatment within the 30 ft diameter dry well area. The application involved a solution of H_2O_2, an iron catalyst, and an acid to control pH. Two 4-in diameter PVC wells and five surrounding monitoring wells were sampled prior to application and resampled 3 weeks after treatment.

The total cost of this application was $45K. This included the chemicals, the application, and the expertise required to apply and report on the treatment. It did not include the cost of monitoring wells.

Results

Samples collected 3 weeks after the treatment indicated that TCA at the two contaminated wells dropped from 40,600 to 440 µg/L and from 4,800 to 2,300 µg/L. Concentrations of VC dropped to levels ranging from below detection to 85 µg/L in nearby wells.

The reduction of chlorinated hydrocarbon contaminants achieved with the CleanOX® application, coupled with the quantity of source contaminants removed during the original remediation tasks, allowed the site owner to successfully close the site with state approval without additional treatment. No specific restrictions on the use of the site were necessary, and the site remains closed.

Site-specific References

Not available.

Active Industrial Facility, Clifton, NJ

Installation Date:
1995

Media:
Ground water

Contaminants:
VOCs, TCA

Oxidant:
H_2O_2

Soil Type:
Fill

Point of Contact:
Michael Tumulty
H2M
555 Preakness Ave.
Totowa, NJ 07512
Tel: 973-942-0700
Fax: 973-942-1333
E-mail: tumulty@h2m.com

A pilot and initial injection for full-scale application of *in situ* chemical oxidation (CleanOX®) for the remediation of trichloroethane (TCA) and other volatile organic compounds (VOCs) in ground water were performed at an active industrial facility in Clifton, New Jersey, from 1995-1996.

Site Background

Releases from an underground storage tank resulted in a ground-water plume. An existing ground-water pump-and-treat system was located outside the building and had operated for five years prior to this application with moderate reduction in contaminant concentrations. The high level of iron-metabolizing bacteria at the site caused frequent operations and maintenance problems for the pump-and-treat system. The aquifer is heterogeneous and highly stratified. Site soils are low in permeability (about 1 millidarcy) and conductivity (about 10^{-5} cm/sec), and the ground water has high organic carbon concentrations. Depth to ground water is approximately 16 ft. Pretreatment sampling indicated average total VOC concentrations at 44 mg/L. Maximum TCA concentration was measured at 101 mg/L in one monitoring well.

Technology Application

The pilot-scale application, using H_2O_2, an iron catalyst, and an acid for pH balance, was performed at an existing well. The chemicals were applied over a 3-week period. The full-scale application involved the installation of an additional eleven 4-in diameter PVC wells into the fractured bedrock underneath the facility building. The application wells were screened 10 - 30 ft below ground surface. Samples were taken following this application and repeated a couple of months later.

The cost of the pilot and full-scale applications was approximately $235K. This included drilling the wells, applying chemicals, sampling, testing, and engineering oversight.

Results

Average total VOC concentrations dropped from the original 44 mg/L to 15 mg/L. The post-treatment average level is assumed to be skewed since the project uncovered the fracture system containing most of the contaminant. Results of this application indicated a 98% reduction in TCA concentrations in the most contaminated well, from 101 mg/L to 2 mg/L. Another full-scale application probably would be required to achieve MCLs for drinking water. The water standard required for industrial application is 1 mg/L.

Site-specific References

Not available

Westinghouse Savannah River Site, Aiken, SC

Installation Date:
1997

Media:
Ground water, soil

Contaninants:
TCE, PCE

Oxidant:
H_2O_2

Soil Type:
Sand, clay

Point of Contact:
Karen M. Jerome
Westinghouse Savannah River Company
Tel: 803-725-5223
Fax: 803-725-7673
E-mail: karen.jerome@srs.gov

A field demonstration of *in situ* chemical oxidation to treat dense non-aqueous phase liquids (DNAPLs)—primarily tetrachloroethylene (PCE) and trichloroethene (TCE)—was conducted in 1997 at the Savannah River Site in Aiken, South Carolina.

Site Background

The site selected for this demonstration was a 50 x 50 ft area adjacent to a seepage basin. The treatment zone consisted of 64,000 ft^3 of soil containing approximately 600 lbs of DNAPL. The soils consist of sand and clayey sands. DNAPL is present at approximately 140 ft below ground surface and about 20 ft below the top of the water table. The average ground-water contaminant concentrations in the treatment area were approximately 119 mg/L PCE and 21 mg/L TCE. The soil contained PCE concentrations of 10-150 μg/kg. The highest concentrations were found at approximately 140 ft below ground surface. This area of the Savannah River site was once a fuel and target fabrication facility where uranium, lithium, aluminum, and other materials were processed into fuel elements and targets for use in the nuclear production reactors.

Technology Application

Four injector wells, three monitoring wells, and three vadose zone lysimeters were installed. Holes were drilled to depths of approximately 155 ft, and samples were collected at various levels to determine the soil concentration of TCE and PCE in soil. The treatment zone was approximately 30 ft deep. The Geo-Cleanse® patented injection process was then employed to inject H_2O_2 and a catalyst (ferrous sulfate) over a 6-day period in a circular area with a radius of 27 ft. Injection was conducted in batch mode with one batch injected per day. The volume of the injection varied from 500-1000 gallons per batch. Three days after the last injection, post-test drilling was initiated to verify destruction of DNAPL. In addition, post-test sampling of monitoring wells was conducted weekly for a 3-month period.

The total cost of the demonstration was approximately $511K. This included approximately $60K for site preparation, $151K for pre-test drilling and characterization, $184K for a technology test, $49K for post-test drilling and characterization, $7K for demobilization, and $60K for documentation and project management.

Results

The demonstration, from pre-test characterization of the site through post-test activities, took place between January and July 1997. A comparison of pre- and post-test soil borings indicated a 94% destruction of DNAPL in the treatment zone. The estimated pre-test DNAPL mass was 593 lbs, and the estimated post-test mass was 36 lbs. Total destruction was not achieved and can be attributed to the process not contacting all DNAPL globules in the fine-grained sediments. Average contaminant concentrations in the ground water were reduced to 0.65 mg/L PCE and 0.07 mg/L TCE at the completion of treatment.

Follow-up work was conducted in the summer of 1998 to determine the effects of the chemical reactions on the geochemistry and microbiology of the test zone and surrounding areas.

Site-specific References

Jerome, K.M.; Riha, B.; Looney, B.B. *Final Report for Demonstration of In Situ Oxidation of DNAPL Using the Geo-Cleanse® Technology*, U.S. Department of Energy, Westinghouse Savannah River Company, Aiken, South Carolina, September 1997

Jerome, K.; Looney, B.B.; and Wilson, J. "Field Demonstration of *In Situ* Fenton's Destruction of DNAPLs," Battelle, First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California, May 1998

"Field Demonstration of *In Situ* Fenton's Destruction of DNAPLs," in Wickramanayake, G.B. and Hinchee, R.E. (eds.), *Physical, Chemical, and Thermal Technologies, Remediation of Chlorinated and Recalcitrant Compounds*, Battelle Press, Columbus, Ohio, 1998

Bryant, J. Daniel and Wilson, J. "Rapid Delivery System Completes Oxidation Picture," *Soil & Groundwater Cleanup*, pp 6-11, August/September 1998

United States
Environmental Protection
Agency

Office of Solid Waste and
Emergency Response
(5102G)

EPA 542-F-01-002
April 2001
www.epa.gov/superfund/sites
www.cluin.org

A Citizen's Guide to Phytoremediation

The Citizen's Guide Series

EPA uses many methods to clean up pollution at Superfund and other sites. Some, like phytoremediation, are considered new or *innovative*. Such methods can be quicker and cheaper than more common methods. If you live, work, or go to school near a Superfund site, you may want to learn more about cleanup methods. Perhaps they are being used or are proposed for use at your site. How do they work? Are they safe? This Citizen's Guide is one in a series to help answer your questions.

What is phytoremediation?

Phytoremediation uses plants to clean up pollution in the environment. Plants can help clean up many kinds of pollution including metals, pesticides, explosives, and oil. The plants also help prevent wind, rain, and groundwater from carrying pollution away from sites to other areas.

How does it work?

Phytoremediation works best at sites with low to medium amounts of pollution. Plants remove harmful chemicals from the ground when their roots take in water and nutrients from polluted soil, streams, and groundwater. Plants can clean up chemicals as deep as their roots can grow. Tree roots grow deeper than smaller plants, so they are used to reach pollution deeper in the ground.

Once inside the plant, chemicals can be:

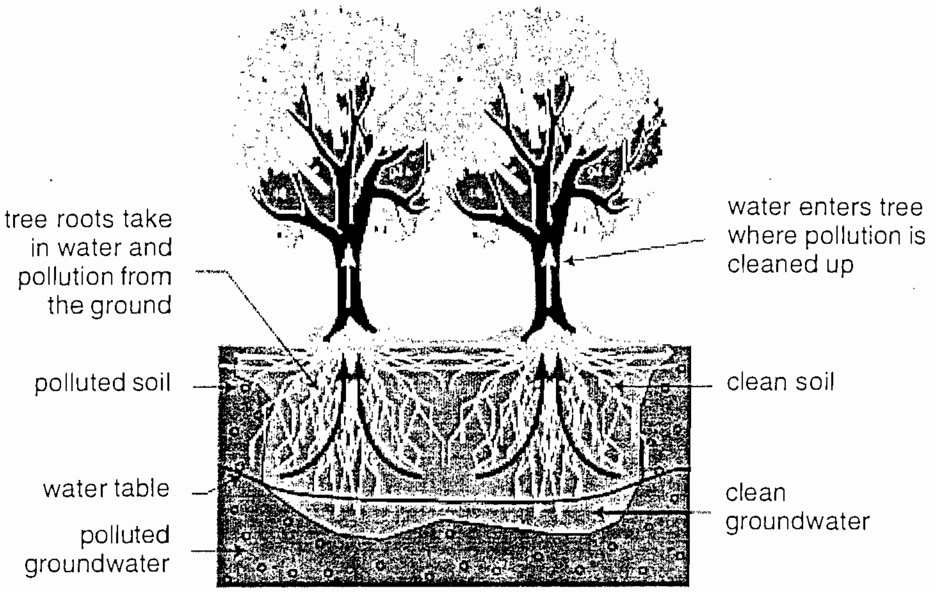
- stored in the roots, stems, or leaves
- changed into less harmful chemicals within the plant
- changed into gases that are released into the air as the plant transpires (breathes).

Phytoremediation can occur even if the chemicals are not taken into the plant by the roots. For example, chemicals can stick or *sorb* to plant roots. Or they can be changed into less harmful chemicals by bugs or *microbes* that live near plant roots. (Please see *A Citizen's Guide to Bioremediation [EPA 542-F-01-001].)* The plants are allowed to grow and take in or sorb chemicals. Afterward, they are harvested and destroyed, or recycled if metals stored in the plants can be reused. Usually, trees are left to grow and are not harvested.

Plants grown for phytoremediation also can help keep harmful chemicals from moving from a polluted site to other areas. The plants limit the amount of chemicals that can be carried away by the wind or by rain that soaks into the soil or flows off the site.

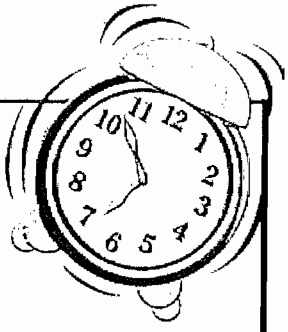
Is phytoremediation safe?

Before phytoremediation begins, EPA studies whether plants grown to clean up pollution can be harmful to people. EPA tests the plants and air to make sure that the plants do not release harmful gases into the air.



Some insects and small animals may eat the plants used for phytoremediation. Scientists are studying these animals to see whether the plants can harm them. Scientists also are studying whether these animals pose harm to the larger animals that eat them. In general, as long as plants are not eaten, they are not harmful to people.

How long will it take ?



The time it takes to clean up a site using phytoremediation depends on several factors:

- type and number of plants being used
- type and amounts of harmful chemicals present
- size and depth of the polluted area
- type of soil and conditions present

These factors vary from site to site. Plants may have to be replaced if they are destroyed by bad weather or animals. This adds time to the cleanup. Often it takes many years to clean up a site with phytoremediation.

Why use phytoremediation?

EPA uses phytoremediation because it takes advantage of natural plant processes. It requires less equipment and labor than other methods since plants do most of the work. Trees and plants can make a site more attractive as well. The site can be cleaned up without removing polluted soil or pumping polluted groundwater. This allows workers to avoid contact with harmful chemicals. Phytoremediation has been successfully tested in many locations, and is being used at several Superfund sites.

For more information
write the Technology Innovation Office at:

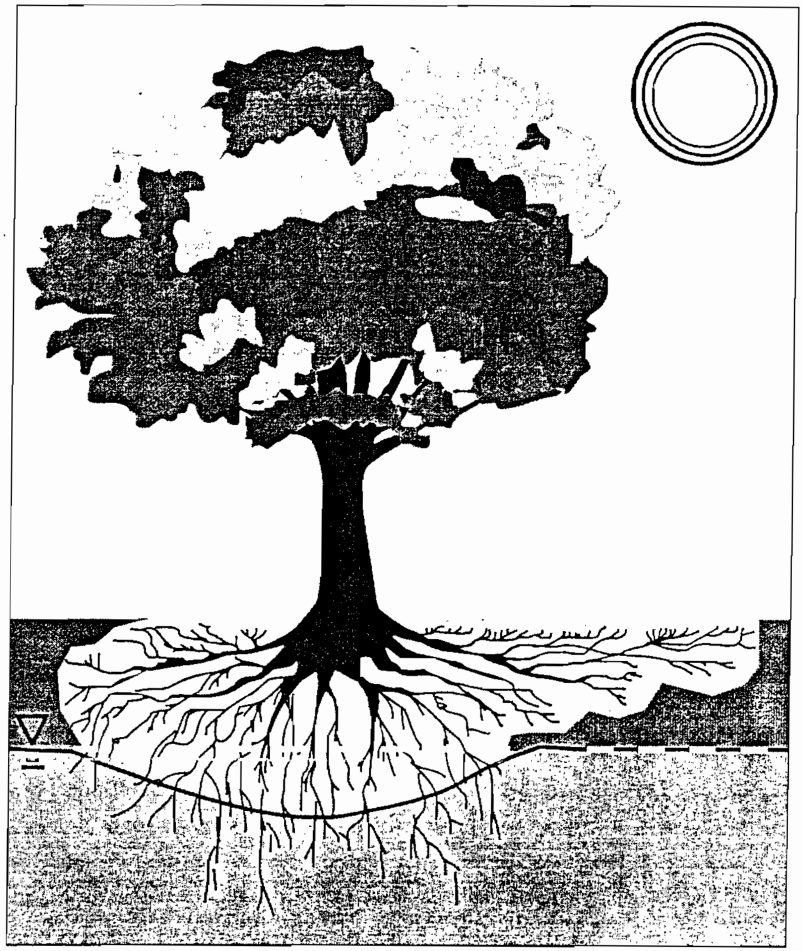
U.S. EPA (5102G)
1200 Pennsylvania Ave., NW
Washington, DC 20460

or call them at
(703) 603-9910.

Further information also can be obtained at **www.cluin.org** or **www.epa.gov/superfund/sites.**

Technical/Regulatory Guidelines

Phytotechnology Technical and Regulatory Guidance Document



April 2001

Prepared by
Interstate Technology and Regulatory Cooperation Work Group
Phytotechnologies Work Team

EXECUTIVE SUMMARY

> *Terminology in this field of using plants to remediate, treat, stabilize, and control contaminated media is rather new. Throughout the development process of this document, we referred to the science as "phytoremediation." Recently realizing that we are actually discussing a variety of technologies and techniques in various applications to manage a contaminant, a contaminated plume, or the media containing contaminants, we now refer to "phytotechnologies" as the overarching terminology, while using "phytoremediation" more precisely to describe contaminant removal or destruction.*

Phytotechnologies are a set of technologies using plants to remediate or contain contaminants in soil, groundwater, surface water, or sediments. Some of these technologies have become attractive alternatives to conventional cleanup technologies due to relatively low costs and the inherently aesthetic nature of planted sites.

This attention on phytotechnologies led to the December 1999 publication of the ITRC document, *Phytoremediation Decision Tree*. The decision tree was designed to allow potential users to take basic information from a specific site and, through a flowchart layout, decide if phytotechnologies are feasible at that site.

The purpose of this document is to provide technical and regulatory guidance to help regulators understand, evaluate, and make informed decisions on phytotechnology proposals. This document includes a description of phytotechnologies, regulatory and policy issues, technical requirements for phytotechnologies, stakeholder concerns, case studies, and technical references.

The technical descriptions of phytotechnologies within this document concentrate on the functioning mechanisms. For example, the application of phytotechnology as a hydraulic control for groundwater is described as phytostabilization. This approach was selected to provide both scientific accuracy and a basic understanding of these mechanisms to the reader.

Phytotechnologies remain an emerging technology, and a section detailing current research efforts along with potential applications is also included. The case studies, which are included, were selected to cover the various phytotechnology mechanisms described in this document.

There are general regulatory issues regarding any application of remedial technologies—phytotechnologies are no exception. There are currently few, if any, specific regulations pertaining to the application of phytotechnologies. However, this document outlines the regulatory considerations and offers recommendations on issues that may be unique to phytotechnologies.

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Evaluation Report

TE-98-01

GWRTAC
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SERIES

Phytoremediation

Prepared By:

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October 1997

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1.0 SUMMARY

Phytoremediation is the use of vegetation for *in situ* treatment of contaminated soils, sediments, and water. It is best applied at sites with shallow contamination of organic, nutrient, or metal pollutants that are amenable to one of five applications: Phytotransformation, Rhizosphere Bioremediation, Phytostabilization, Phytoextraction, or Rhizofiltration. In this Technology Evaluation report, it is shown that phytoremediation has been utilized at a number of pilot and full-scale field demonstration tests. It is an emerging technology that should be considered for remediation of contaminated sites because of its cost effectiveness, aesthetic advantages, and long-term applicability. Phytoremediation is well-suited for use at very large field sites where other methods of remediation are not cost-effective or practicable; at sites with low concentrations of contaminants where only "polishing treatment" is required over long periods of time; and in conjunction with other technologies where vegetation is used as a final cap and closure of the site. There are limitations to the technology that need to be considered carefully before it is selected for site remediation. These include limited regulatory acceptance, long duration of time sometimes required for clean-up to below action levels, potential contamination of the vegetation and food chain, and difficulty establishing and maintaining vegetation at some toxic waste sites.

Plants have shown the capacity to withstand relatively high concentrations of organic chemicals without toxic effects, and they can uptake and convert chemicals quickly to less toxic metabolites in some cases. In addition, they stimulate the degradation of organic chemicals in the rhizosphere by the release of root exudates, enzymes, and the build-up of organic carbon in the soil. For metal contaminants, plants show the potential for phytoextraction (uptake and recovery of contaminants into above-ground biomass), filtering metals from water onto root systems (rhizofiltration), or stabilizing waste sites by erosion control and evapotranspiration of large quantities of water (phytostabilization).

In this technology evaluation, recent field tests of phytoremediation are reported on wastes containing petroleum hydrocarbons such as benzene, toluene, ethylbenzene, and xylenes (BTEX) and polycyclic aromatic hydrocarbons (PAHs), pentachlorophenol, polychlorinated biphenyls (PCBs), chlorinated aliphatics (trichloroethylene, tetrachloroethylene, and 1,1,2,2-tetrachloroethane), ammunition wastes (2,4,6-trinitrotoluene or TNT, and RDX), metals (lead, cadmium, zinc, arsenic, chromium, selenium), pesticide wastes and runoff (atrazine, cyanazine, alachlor), radionuclides (cesium-137, strontium-90, and uranium), and nutrient wastes (ammonia, phosphate, and nitrate). Different species of plants have been used in various applications including: Salix spp. (hybrid poplars, cottonwoods, and willow), grasses (rye, Bermuda grass, sorghum, fescue, bullrush), legumes (clover, alfalfa, and cowpeas), aquatic plants (parrot feather, duckweed, arrowroot, cattail, pondweed), and hyperaccumulators for metals (sunflowers, Indian mustard, and *Thlaspi* spp.).

Key findings of this technology evaluation show that phytoremediation has successfully been applied at a brownfields site for remediation of soil contaminated with lead; a small pond at Chernobyl with uranium contamination; a riparian zone buffer strip at Amana, Iowa for nitrate and atrazine removal from agricultural runoff; and at an engineered wetland at Milan, Tennessee for TNT removal. In addition, many successful applications have involved remediation actions at small sites, such as agricultural cooperatives with pesticide and ammonia spills where state agencies have jurisdiction. At these sites, few funds are available for long-term compliance monitoring, and it is not to the advantage of the owners to pay for monitoring voluntarily. Therefore, long-term monitoring and evaluation of phytoremediation technology is still needed to demonstrate efficacy, to further define suitable plants and applications, and to gain acceptance from regulatory agencies.

EPA/600/R-99/107
February 2000

Introduction to Phytoremediation

National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Abstract

Phytoremediation is the name given to a set of technologies that use different plants as a containment, destruction, or an extraction technique. Phytoremediation as a remediation technology that has been receiving attention lately as the results from field trials indicate a cost savings compared to conventional treatments.

The U.S. EPA has a dual role in which it seeks to protect human health and the environment associated with hazardous waste sites, while encouraging development of innovative technologies that might more efficiently clean up these sites.

This Introduction is intended to provide a tool for site regulators, owners, neighbors, and managers to evaluate the applicability of phytoremediation to a site. This document defines terms and provides a framework to understand phytoremediation applications. It is a compilation of research and remediation work that has been done to date. The format is intended to be accessible to EPA RPMs, state regulators, and others who need to choose between alternate technologies, as well for site owners, consultants, contractors, and students who are interested in basic information. It is not a design manual, and is not intended to provide enough information to choose, engineer, and install a phytoremediation application.

This work may also be used to help guide research, development, and regulation. Areas of needed research have been identified. By compiling the published and unpublished work, research repetition can be avoided, and areas of opportunity that need attention should be clear.

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Figures

Tables

Phytoremediation at Aberdeen Proving Grounds, Edgewood Area J-Field Site, Edgewood, MD

Site Name:	Aberdeen Proving Grounds, Edgewood Area J-Field Site
Location:	Edgewood, MD
Period of Operation:	Spring 1996 - Ongoing (data available through 1998)
Cleanup Type:	Field demonstration

Technol
Phytoremediation

Demonstration area is approximately 2,034 m^2 and contains 156 viable poplars
Two-year-old hybrid poplars were planted 5 to 6 ft in Spring 1996; surficial drainage was installed to remove precipitation quickly and allowed trees to reach groundwater
New trees were planted in October 1998 to increase the phytoremediation area and assess the usefulness of native species for phytoremediation

Cleanup Authority: Not identified

Contacts:
Technical Contacts
Harry Compton
U.S. EPA, ERT (MS101)
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Steve Hirsh
U.S. EPA, Region 3 (3HS50)
1650 Arch Street
Philadelphia, PA 19103-2029
Tel: 215-814-3352
E-mail: hirsh.steven@epa.gov

Contaminants:
Chlorinated Solvents
- 1,1,2,2-TCA, TCE, DCE at levels up to 260 ppm

Waste Source: Open burning/detonation of munitions

Type/Quantity of Media Treated:
Groundwater
Contamination is 5 to 40 ft bgs
plume is slow-moving due to tight soils and silty sand

Purpose/Significance of Application:
Long-term field demonstration of phytoremediation for treatment of chlorinated solvents in groundwater

Regulatory Requirements/Cleanup Goals:
Provide hydraulic influence of the groundwater plume and mass removal of contaminants; no quantitative cleanup goals were identified

Results:
Sampling was performed for groundwater; sap flow monitoring; tree transpiration gas and condensate sampling; and exposure pathway assessments
Groundwater level data indicated that hydraulic influence is occurring, with the trees currently removing 1,091 gpd and at the end of 30 years expected to remove 1,999 gpd
Contaminated plume has not migrated off-site during the growing seasons
Contaminant uptake is minimal at this time but expected to improve as the trees mature

Costs:
Capital costs of $80/tree including $5,000 for initial site preparation, additional $80,000 for UXO clearance of soil during planting; O&M costs: $30,000

Description

Aberdeen Proving Grounds is located at the tip of the Gunpowder Neck Peninsula in Edgewood Maryland. At APG, the Army practiced open trench (toxic pits) open burning/detonation of munitions containing chemical agents and dunnage from the 1940s to the 1970s. Large quantities of decontaminating agents containing solvents were used during the operation, and the surficial groundwater table was contaminated with solvents (1,1,2,2-TCA, TCE, DCE) at levels up to 260 ppm. A demonstration of phytoremediation to clean up shallow groundwater was performed at the site was performed by the U.S. Air Force (USAF) as part of the Department of Defense's (DOD's) Environmental Security Technology Certification Program (ESTCP), and the SITE Program.

At the APG site, a process called deep rooting was used to achieve hydraulic influence. Hybrid poplar trees were planted in the spring of 1996 at five to six feet bgs to maximize groundwater uptake. The field demonstration and evaluation will be for a five year period. The U.S. Geological Survey has estimated that hydraulic influence will occur when 7,000 gallons of water per day are removed from the site. The latest field data indicates that hydraulic influence is occurring. Current tree uptake is 1,091 gpd and is expected to increase to 1,999 gpd at the end of 30 years. Contaminant uptake is minimal at this time but is expected to improve as the trees mature. Groundwater sampling indicates that the contaminated plume has not migrated off-site during the growing season and sampling data showed non-detectable emissions from transpiration gas. There are several on-going studies to determine if deleterious compounds retained in the leaves and soil could pose risks to environmental receptors. Cost for site preparation included additional costs for UXO clearance, for a total of $80/tree, with O&M costs of $30,000 per year.

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Phytoremediation at Carswell Air Force Base, Fort Worth, TX

Federal
Remediation
Technologies
Roundtable

Site Name: Carswell Air Force Base

Location: Fort Worth, Texas

Period of Operation: Spring 1996 - Ongoing (data available through 2001)

Cleanup Type: Field demonstration

Technol

Phytoremediation

- In April 1996, 660 eastern cottonwoods were planted in a one acre area
- Two sizes of trees were planted - whips and 5-gallon buckets

Cleanup Authority: Not identified

Contacts:

Greg Harvey
U.S. Air Force, ASC/EMR
1801 10th Street - Area B
Wright Patterson AFB, OH
Tel: 937-255-7716 ext. 302
Fax: 937-255-4155
E-mail: Gregory.Harvey@wpafb.af.mil

Contaminants:

Chlorinated Solvents

- TCE

Waste Source: Manufacture and assembly of military aircraft

Type/Quantity of Media Treated:

Groundwater

- Shallow (under 12 ft) aerobic aquifer

Purpose/Significance of Application:

Long-term field demonstration of phytoremediation for treatment of chlorinated solvents in groundwater

Regulatory Requirements/Cleanup Goals:

- Provide hydraulic containment and removal of contaminants
- Reduce mass of TCE in the aquifer transported across the downgradient end of the site by 30 % during the second growing season and by 50 % during the third growing season, as compared to baseline TCE mass flux calculations

Results:

- Root biomass and extent were examined in September of 1997 (the second growing season)
- In September 1997, the roots of both the whips and caliper trees had reached the water table and the depth distribution of the roots was similar
- The maximum reduction in the outflow of contaminated groundwater that could be attributed to the trees was approximately 11 %, and was observed at the peak of the third growing season
- Preliminary field data collected during the fifth dormant season (January 2001) indicate that the trees were beginning to have a widespread effect on groundwater geochemistry, reducing dissolved oxygen content beneath the trees to less than 1 mg/L

Costs:

The total cost for site preparation was $22,000, site work $171,200, and annual O&M $2,000, in addition to costs for research level monitoring.

Description

Groundwater at the U.S. Air Force Plant 4 (AFP4) and adjacent Naval Air Station, Fort Worth, Texas, has been contaminated with chlorinated solvents from operations associated with the manufacture and assembly of military aircraft. . A demonstration of phytoremediation to clean up shallow groundwater was performed at the site was performed by the U.S. Air Force (USAF) as part of the Department of Defense's (DOD's) Environmental Security Technology Certification Program (ESTCP), and the SITE Program.

The first three growing seasons at Carswell resulted in a remediation system that reduced the mass of contaminants moving through the site. The maximum observed reduction in the mass flux of TCE across the downgradient end of the site during the demonstration period was 11 percent. Increases in hydraulic influence and reductive dechlorination of the dissolved TCE plume are expected in out years, and may significantly reduce the mass of contaminants. Modeling results indicate that hydraulic influence alone may reduce the volume of contaminated groundwater that moves offsite by up to 30 percent. The decrease in mass flux that can be attributed to in situ reductive dechlorination has yet to be quantified. The total cost for site preparation was $22,000, site work $171,200, and annual O&M $2,000, in addition to costs for research level monitoring.

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Closure Scenario	Details	Estimated Capital Construction Cost
Modified BAT Cap	- Same as BAT except omits GCL	$1,400,000
Phytoremediation Cap	- plant high density of select trees on existing cap	$278,000
Complete Leachate Collection System	- install extraction wells - install collection tank, lift station, piping - install toe drain	$510,000
Leachate Toe Drain only	- install toe drain - install collection tank, lift station, piping	$499,000
Perimeter Fencing	- 6' chain-link fence	$65,000

4.6 Landfill Improvements Beyond Capping

There are several capital items and operational tasks which are recommended no matter which capping scenario is chosen. A perimeter fence is recommended. Its design should be to prevent trespassers from directly contacting waste constituents, keep motorized vehicles off of the cap, and prevent illegal dumping activities. Secondly, a subsurface leachate collection system is recommended to maximize removal of the landfill's existing leachate inventory and thereafter remove leachate as it accumulates. This will greatly reduce or eliminate the formation of leachate seeps and will help ensure long term stability of the landfill's outslopes. Lastly, the cost of disposing of the collected leachate must be considered.

5.0 HYDROLOGIC MODELING

To assess the predicted effectiveness of each landfill cap improvement scenario in terms of leachate prevention, USEPA's Hydrologic Evaluation of Landfill Performance (HELP) model, version 3.07, was used. Version 3.07 was completed this past November and was made available to SHARP by the author, Dr. Paul Schroeder of the U.S. Army Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi. The HELP model is a complex two-dimensional water balance program incorporating many different algorithms and equations to account for surficial and subsurface runoff, evapotranspiration, and percolation across the different components of a landfill cap. Its primary purpose is to assist in the comparison of landfill design alternatives as judged by their water balances. All simulation periods for this report were over a 20 year period. Climatic input was derived using the U.S. Department of Agriculture's synthetic weather generator program, WGEN, using site-specific data for growing season, average temperatures, and average precipitation. All actual HELP model runs are included in Appendix C. A summary of HELP model output is provided in the following table.

Green II Landfill, Hocking County, OH

GREEN II LANDFILL - PHYTOREMEDIATION						
Tree Planting Specifications		spacing (ft)	trees/acre	acres	Total # trees	
		12	302.5	8.5	2571	
Average Rainfall	May-96	Jun-96	Jul-96	Aug-96	Sep-96	Oct-96
	4.61	3.62	4.37	3.92	3.14	2.67
	Nov-96	Dec-96	Jan-96	Feb-96	Mar-96	Apr-96
	3.17	2.98	2.52	2.37	3.63	3.82
						Annual
						40.82

BS .... 3.0.1.3 CONSTRUCTION
articipant ... FP01 FIXED PRICE SUB #1
ost Code ..... 6100 REMEDIAL ACTION
/M Attribute . DIRECT
iscipline .... F OTHER
/M Title ..... PHYTOREMEDIATION
race Number .. F.2.5 0
stimate File . G:\ESTIMATE\65-30\ESTSRIF2\Q3CMS.Est 9-24-97 12:17a

Contracting Type ..... G General Contractor
Funding Type .... E-EXPENSE
Level of Estimate .... P Planning/Feasibility Estimate
Discipline Estimator . ALT 3
Cross Cut ....
Standard Value File .. SRIFS_2.Val

Building/Area ....
Plant Site .... S
Source Site .... PORTS
Receiving Site .... PORTS
Quantity Take-Off By ...

Expiration Date 12/15/1997

ITEM	DESCRIPTION	MATERIAL				LABOR				TOTAL COST M + L
		Qty.	Unit	Unit Pr.	Total	Hours	Cft.	Rate	Total	
1 -A	PLANT 1-YEAR OLD POPLAR TREES, VENDOR QUOTE	2.00	ACRES	15,000.00	30,000	0		0.00	0	30,000
2 -A	DESIGN	1.00	LS	15,000.00	15,000	0		0.00	0	15,000
3 -A	SITE VISIT DURING DESIGN	1.00	LS	3,000.00	3,000	0		0.00	0	3,000
****	SUBTOTAL ****				48,000	0			0	48,000
	TOTAL DIRECT				48,000				0	48,000
	SALES TAX				2,880					2,880
	SUBTOTAL				50,880				0	50,880
	TOTAL INDIRECT			20.00%	10,176			20.00%	0	10,176
	TOTAL				61,056	0			0	61,056

USDOE Piketon Enrichment Uranium Facility
Piketon, Ohio

United States
Environmental Protection
Agency

Office of Solid Waste and
Emergency Response
(5102G)

EPA 542-F-01-005
April 2001
www.epa.gov/superfund/sites
www.cluin.org

EPA

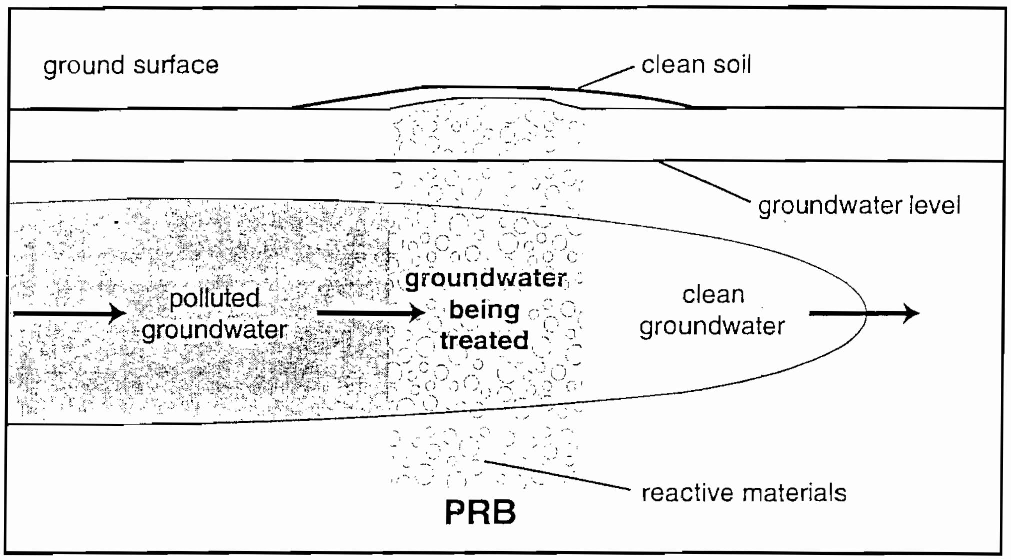
A Citizen's Guide to Permeable Reactive Barriers

The Citizen's Guide Series

EPA uses many methods to clean up pollution at Superfund and other sites. Some, like permeable reactive barriers, are considered new or *innovative*. Such methods can be quicker and cheaper than more common methods. If you live, work, or go to school near a Superfund site, you may want to learn more about cleanup methods. Perhaps they are being used or are proposed for use at your site. How do they work? Are they safe? This Citizen's Guide is one in a series to help answer your questions.

What are permeable reactive barriers?

A permeable reactive barrier or *PRB* is a wall built below ground to clean up polluted groundwater. The wall is *permeable,* which means it has tiny holes that allow groundwater to flow through it. *Reactive* materials in the wall trap harmful chemicals or change the chemicals into harmless ones. Clean groundwater flows out the other side of the wall.



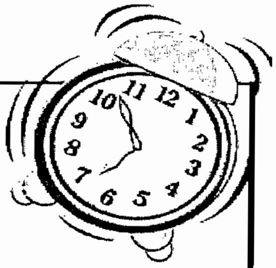
How do they work?

A PRB is built by digging a long, narrow trench in the path of the polluted groundwater. The trench is filled with a reactive material that can clean up the harmful chemicals. Iron, limestone, and carbon are common types of reactive materials that can be used. The reactive materials may be mixed with sand to make it easier for water to flow through the wall, rather than around it. At some sites, the wall is part of a funnel that directs the polluted groundwater to the reactive part of the wall. The filled trench or funnel is covered with soil, so it usually cannot be seen above ground.

The material used to fill the trench depends on the types of harmful chemicals in the groundwater. Different materials clean up pollution through different methods by:

- Trapping or *sorbing* chemicals on their surface. For example, carbon has a surface that chemicals sorb to as groundwater passes through.
- *Precipitating* chemicals that are dissolved in water. This means the chemicals settle out of the groundwater as solid materials, which get trapped in the wall. For example, limestone can cause dissolved metals to precipitate.
- Changing the chemicals into harmless ones. For example, iron can change some types of solvents into harmless chemicals.
- Encouraging tiny bugs or *microbes* in the soil to eat the chemicals. For example, nutrients and oxygen in a PRB help the microbes grow and eat more chemicals. When microbes completely digest the chemicals, they can change them into water and harmless gases such as carbon dioxide. (*A Citizen's Guide to Bioremediation* [EPA 542-F-01-001] describes how microbes work.)

How long will it take ?



Cleaning groundwater with a PRB may take many years. The time it takes depends on two major factors that vary from site to site:

- type and amount of pollution present in the groundwater
- how fast the groundwater moves through the PRB

Groundwater may move a few inches to hundreds of feet per year. Its speed varies from site to site.

Are PRBs safe?

PRBs have a good safety record. Once built, they have no moving parts, equipment, or noise. The reactive materials placed in the PRB trench are not harmful to the groundwater or to people. The polluted groundwater is cleaned underground so cleanup workers can avoid contact with it. Some soil, which may be polluted, must be removed when digging the trench. EPA makes sure that the polluted soils are handled safely. For example, they cover loose soil to keep dust and harmful gases out of the air.

EPA tests the air to make sure that dust and gases are not released. If the soil is polluted, it may be cleaned using another cleanup method. Or the soil is disposed of properly in a landfill. The groundwater is tested regularly to make sure the PRB is working.

Why use PRBs?

PRBs work best at sites with loose, sandy soil and a steady flow of groundwater. The pollution should be no deeper than 50 feet. PRBs clean up many types of pollution underground. Since there is no need to pump polluted groundwater above ground, PRBs can be cheaper and faster than other methods. Very little waste needs to be disposed of in a landfill, which also saves money. There are no parts to break, and there is no equipment above ground so the property can be used while it is being cleaned up. There are no energy costs to operate a PRB because it works with the natural flow of groundwater. PRBs have been installed at more than 40 sites in the United States and Canada.

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For more information

write the Technology Innovation Office at:

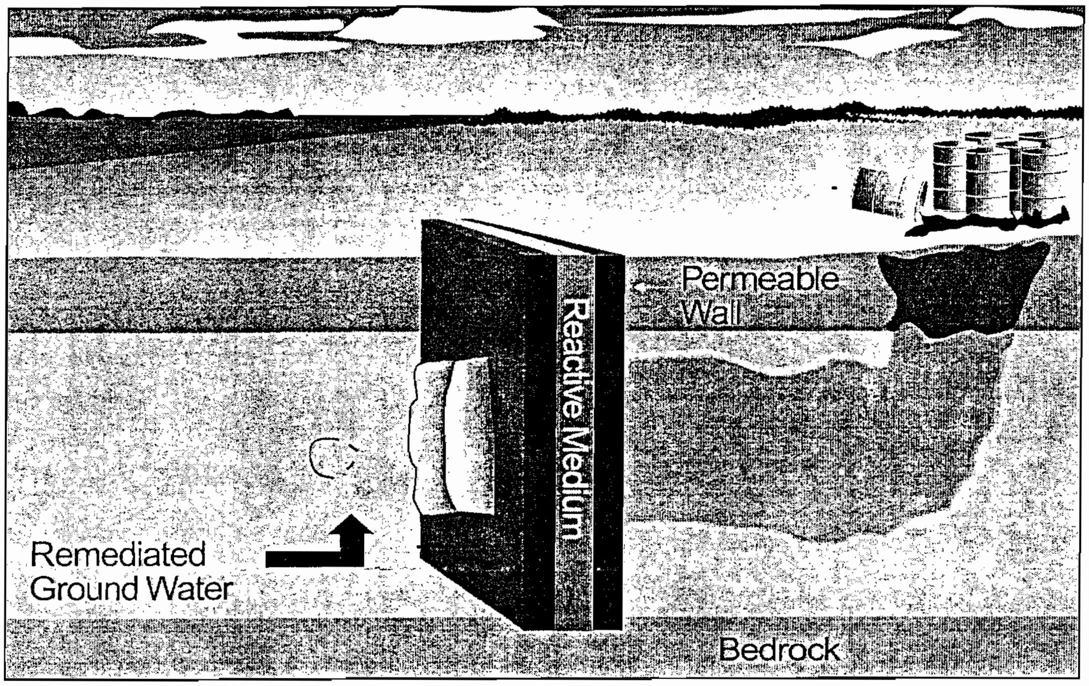
U.S. EPA (5102G)
1200 Pennsylvania Ave., NW
Washington, DC 20460

or call them at
(703) 603-9910.

Further information also can be obtained at **www.cluin.org** or **www.epa.gov/superfund/sites**.

Technical/Regulatory Guidelines

Regulatory Guidance for Permeable Reactive Barriers Designed to Remediate Chlorinated Solvents



2nd Edition
December 1999

Prepared by
Interstate Technology and Regulatory Cooperation Work Group
Permeable Reactive Barriers Work Group

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7.0 PERMEABLE REACTIVE BARRIERS

A permeable reactive barrier (PRB) is an *in situ* treatment zone of reactive material that degrades or immobilizes contaminants as groundwater flows through it. PRBs are installed as permanent, semi-permanent, or replaceable units across the flow path of a contaminant plume. The type of reactive material used for the PRB is determined based on the specific contaminants and the conditions of the aquifer. Examples of reactive materials used in PRBs include zero-valent iron, organic carbon, and limestone. Most PRBs are installed in one of two basic configurations - funnel and gate or continuous trench. This section presents a summary of data obtained from case studies of PRB projects and the results of the analysis of those data.

Methodology for Cost Analysis for PRB Projects

As Exhibit 7-1 shows, 16 PRB case studies addressing 16 individual projects were identified from the available information sources. The case studies, prepared by the FRTR and the Remediation Technology Development Forum (RTDF)[6], were obtained from the report *Cost Analyses for Selected Groundwater Cleanup Projects: Pump and Treat and Permeable Reactive Barriers*, February 2001. PRB projects were identified using the criteria discussed in Section 1 and the following two technology-specific criteria:

- The PRB system was operated on a full-scale basis (as opposed to a pilot-scale or field demonstration project).
- Information was available about the capital cost of the PRB system.

Capital and operating cost data were obtained from the case studies. A review of the information showed that, while capital costs were available for all 16 projects, annual operating costs were available for only two projects. Further, none of the case studies provided information about unit costs or information needed to calculate unit costs such as the quantity of groundwater treated or the mass of contaminant removed. Therefore, it was determined that fully defined cost data, as described in Section 1, were not available for any of the PRB projects. Exhibit 7-1 summarizes available information about the sites, including site name and location, PRB design, and cost data.

Exhibit 7-2 summarizes available capital cost information for the 16 PRB projects by the 25th percentile, 50th percentile (median), 75th percentile, and average to illustrate the range of costs. The median total capital cost of the 16 PRB projects was $680,000.

Results

As discussed in Section 1, fully defined cost data must be available for at least five sites to identify a potential correlation between unit cost and quantity treated. Fully defined cost data were not available for any of the PRB projects because no information about the quantity treated was available. Therefore, no quantitative analyses of unit cost versus quantity treated was performed.

Potential correlations between unit cost and other factors, such as type of contaminant, were considered, but no correlations were evident. While no quantitative correlations for those factors were evident, the following qualitative information about potential factors affecting the design and operation of PRB systems was provided in the case studies; in the EPA report *Cost Analyses for Selected Groundwater Cleanup Projects: Pump and Treat and Permeable Reactive Barriers*, February, 2001; and in the report *Permeable Reactive Barriers Notebook*. The specific effects of those and other factors on the cost of a PRB system are highly site-specific.

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[6] The RTDF includes members representing industry, government, and academia who have an interest in identifying steps government and industry can take together to develop and improve the environmental technologies needed to address their mutual cleanup problems in the safest, most cost-effective manner possible. Information about the RTDF is available through the organization's web site at <*www.rtdf.org*>. Case studies are available in *Field Applications of In Situ Remediation Technologies: Permeable Reactive Barriers*, EPA 542-R-99-002, 1999.

Exhibit 7-1. Summary Information for PRB Sites (Page 1 of 4)

Site Name and Location	Contaminants [1]	Capital Cost ($) [2]	Cost Components						Installation Date	Installation Method [3]	Number of PRBs/Gates	PRB Location or Function	Reactive Medium Material [4]	Dimensions of Reactive Medium			
			Design	Construction	Materials	Reactive Media	Engineering	Unspecified						Total Mass	Width	Length	Depth
CHLORINATED SOLVENTS																	
Kansas City Plant, MO	1,2-DCE, VC	1,600,000 Design = 200,000 Other = 1,300,000	●	●	●	●			Apr. 1998	CT	1	Top half of trench	2 ft Fe°, 4 ft sand	370 tons of iron	6 ft	130 ft	13-27 ft
												Bottom half of trench	100% Fe°				27-33 ft
Caldwell Trucking, NJ	TCE	1,400,000	●	●	●	●			Apr. 1998	HF	2	Permeation infill	Fe°	250 tons	3 in	150 ft	15-50 ft
												Hydrofrace	Fe°		3 in	90 ft	15-50 ft
Former Manufacturing Site, NJ	1,1,1-TCA; PCE; TCE; DNAPL	1,100,000 Design = 180,000 Iron = 360,000 Other = 560,000	●	●	●	●			Sept. 1998	DE, CT, SPC	1	DNAPL excavation	1:1 Fe°/sand	720 tons of iron	5 ft	127 ft	25 ft
												Top 4 to 7 ft of CT	3:2 Fe°/sand				
												Bottom 7 to 21 ft of CT	4:1 Fe°/sand				
FHA Facility, CO	TCA; 1,1-DCE; TCE; cis-1,2-DCE	1,100,000 Iron = 210,000 Other = 890,000	●	●	●	●			Oct. 1996	F&G	4	All 4 PRBs	Fe°	476 tons of iron	varies	Each gate is 40 ft wide	25 ft
Industrial Site, NY	TCE, cis-1,2-DCE, VC	1,000,000 Iron = 360,000 Other = 640,000		●	●	●			Dec. 1997	CT	2	Main trench	Fe°	742 tons	1 ft	370 ft	18 ft
												Upgradient trench			1 ft	10 ft	NR

Exhibit 7-1. Summary of Information for PRB Sites
(Page 2 of 4)

Site Name and Location	Contaminants[1]	Capital Cost ($)[2]	Cost Components						Installation Date	Installation Method[3]	Number of PRBs/Gates	PRB Location or Function	Reactive Medium Material[4]	Dimensions of Reactive Medium			
			Design	Construction	Materials	Reactive Media	Engineering	Unspecified						Total Mass	Width	Length	Depth
Intersil, CA[5]	TCE, cis-1,2-DCE, VC, Freon 113®	760,000 Iron = 170,000 Other = 590,000		●	●	●			Feb. 1995	F&G	1	NA	Fe^o	220 tons	4 ft	36 ft	11-31 ft
Aircraft Facility, OR	TCE	710,000						●	Mar. 1998	F&G	2	Gate 1	Fe^o	324 tons of iron*	Two 9-in thick layers	50 ft	to 24-34 ft
												Gate 2	Fe^o, sand		3 ft	60 ft	to 24-34 ft
Lowry Air Force Base, CO	TCE	600,000	●	●	●	●			Dec. 1995	F&G	1	NA	Fe^o	NR	5 ft	10 ft	0-17 ft
Industrial Site, N. Ireland	TCE; cis-1,2-DCE	580,000		● *	●	●	●		Dec. 1995	F&R	1	NA	Fe^o	NR	Vessel has 4-ft diam.	Vessel has 4-ft diam.	33-49 ft
Industrial Site, KS	TCE; 1,1,1-TCA	400,000 Iron = 50,000 Other = 350,000		● *	●	●			Jan. 1996	F&G	1	NA	Fe^o	70 tons	3 ft	20 ft	0-30 ft
Industrial Site, SC	TCE, cis-1,2-DCE, VC	360,000 Design = 45,000 Iron = 130,000 Other = 180,000	●	●	●	●			Nov. 1997	CT	1	NA	Fe^o, sand (1:1 ratio)	400 tons of iron	1 ft	375 ft*	0-29 ft

Exhibit 7-1. Summary of Information for PRB Sites
(Page 3 of 4)

Site Name and Location	Contaminants[1]	Capital Cost ($)[2]	Cost Components						Installation Date	Installation Method[3]	Number of PRBs/Gates	PRB Location or Function	Reactive Medium Material[4]	Dimensions of Reactive Medium			
			Design	Construction	Materials	Reactive Media	Engineering	Unspecified						Total Mass	Width	Length	Depth
Former Dryclean Site, Germany	PCE; 1,2-DCE	160,000 Design = 39,000 Other = 120,000	●	●		●			June 1998	CW	1	NS	1:1 mass ratio Fe^0/ gravel	69 tons	2-3 ft	33 ft	10 - 33 ft[6]
												NS	IS	85 tons		41 ft	
METALS AND INORGANICS																	
Nickel Rim Mine Site, Canada	Ni, Fe, Sulfate	43,000	●	●	●	●			Aug. 1995	C&F	1	NA	OC/ pea gravel	NR	12 ft	50 ft	14 ft deep
COMBINATION OF CONTAMINANTS																	
Y-12 Site, Oak Ridge National Lab, TN	U, Tc, HNO3	1,900,000	●	●	●	●			Nov. 1997	CT	1	NS	100% iron	80 tons iron	2 ft	26 ft	22-30 ft
												NS	100% gravel	NR		199 ft	
									Dec. 1997	F&R	5	All 5 reactors	iron	NR	NR	NR	NR
Marzone Inc., GA	alpha-HCB, beta-HCB, DDD, DDT, xylene, EB, lindane, methyl parathion	650,000 Design = 200,000 Other = 450,000	●	●	●	●			Aug. 1998	F&G	1	NA	AC	0.9 tons	NR	NR	NR

Exhibit 7-1. Summary of Information for PRB Sites
(Page 4 of 4)

Site Name and Location	Contaminants [1]	Capital Cost ($) [2]	Cost Components						Installation Date	Installation Method [3]	Number of PRBs/Gates	PRB Location or Function	Reactive Medium Material [4]	Dimensions of Reactive Medium			
			Design	Construction	Materials	Reactive Media	Engineering	Unspecified						Total Mass	Width	Length	Depth
U.S. Coast Guard Support Center, NC[7]	Cr^{+6}, TCE	460,000 Design = 160,000 Iron = 150,000 Other = 150,000	●	●	●	●			June 1996	CT	1	NA	Fe^{0}	450 tons	2 ft	150 ft	3-24 ft

Source: EPA, Office of Solid Waste and Emergency Response, *Cost Analyses for Selected Groundwater Cleanup Projects: Pump and Treat and Permeable Reactive Barriers*, EPA 542-R-00-013, December 2000.

Notes:

[1] Contaminant Key: As = arsenic, HCB = hexachlorobenzene, Cd = cadmium, Cu = copper, Cr^{-6} = hexavalent chromium, DCE = dichloroethene, DDD = dichlorodiphenyldichloroethane, DDT = dichlorodiphenyltrichloroethane, DNAPL = dense non-aqueous-phase liquid, EB = ethylbenzene, Fe = Iron, HNO3 = nitric acid, Ni = Nickel, Pb = lead, PCE = tetrachloroethene, Tc = technetium, TCA = trichloroethane, TCE = trichloroethene, U = uranium, VC = vinyl chloride, Zn = zinc.

[2] All reported capital costs were adjusted for site locations and years when costs were incurred, as described in the text. All unadjusted (reported) costs are presented in parentheses. Adjusted costs are not presented in parentheses.

[3] Installation Method Key: C&F = cut and fill, CT = continuous trencher, CW = continuous wall, DE = dense nonaqueous-phase liquid (DNAPL) extraction, F&G = funnel and gate, F&R = funnel and reaction vessel, HF = hydraulic fracturing, SPC = Sheet piling construction.

[4] Reactive Media Material Key: AC = activated carbon, AFO = amorphous ferric oxyhydroxide, Fe^{0} = zero-valent iron, IS = iron sponge (wood shavings or chips impregnated with hydrated iron oxide), LM = limestone, OC = organic carbon (municipal/leaf compost and wood chips), PO_4 = bone char phosphate.

NA = Not applicable, NR = Not reported, NS = Not specified

Exhibit 7-2. Summary of Remedial Cost Data for 16 PRB Sites

Cost Category	PRB Sites (16 Sites)			
	25th Percentile ($)	Median ($)	75th Percentile ($)	Average ($)
Total Capital Cost ($)[1]	440,000	680,000	1,000,000	730,000

Source: FRTR and RTDF - Refer to Exhibit 7-1 for a list of sites.

Notes:

[1] All reported costs were adjusted for location and years during which costs were incurred, as described in Section 1.

Hydrogeologic setting: Because a PRB relies on the natural gradient of the groundwater to allow the plume to move through the reactive zone, the groundwater flow patterns and distribution of the contaminants in the plume (location and extent) are important considerations in the installation of a PRB. Those conditions are influenced by such parameters as the piezeometric surfaces and gradient, hydraulic conductivity, permeability, and porosity (which may vary stratigraphically), and seasonal variation in groundwater flow direction and flux. The depth of the aquifer and of the contamination, whether the aquifer is unconfined or confined, and the chemistry of the aquifer also influence the design of the PRB, including location and configuration (funnel and gate or continuous trench), size, and whether and how the PRB is keyed into the subsurface (for example, keyed into a low-permeability clay layer to prevent underflow of the contaminant).

Geochemistry: Geochemical parameters of the aquifer or plume, such as pH, oxygen content, presence of reducing agents (for example, sulfates), affect the type of reactive media used and the life expectancy of the media. Potential reactions of the specific reactive media with the geochemical properties of the groundwater also may affect the ability of the reactive media to degrade, sorb, precipitate, or otherwise remove contaminants from the groundwater. For example, as groundwater containing carbonate passes through a PRB containing zero-valent iron, calcite ($CaCO_3$) precipitates. Should carbonate levels in the groundwater be high, the resultant precipitate may build up on the reactant surface and reduce the effectiveness of the PRB .

Properties of the contaminant and extent of contamination: Properties of the contaminants, their concentrations, and degradation rates in the presence of the reactive media affect the type of reactive media used, the thickness of the reactive zone and the residence time, the effectiveness of the reactive media, and the life of the reactive media. In addition, the extent of the plume (including variations in types and concentrations of contaminants throughout the plume) affects the placement and orientation of the PRB to capture and treat the entire plume.

Source control: The presence of NAPLs in groundwater can serve as a continuing source of contamination, extending the length of time during which it is necessary to operate a system to reach cleanup levels. Source controls may be implemented at site to address the NAPLs, with the type and extent of the NAPL contamination determining the complexity and potential effectiveness of the source control.

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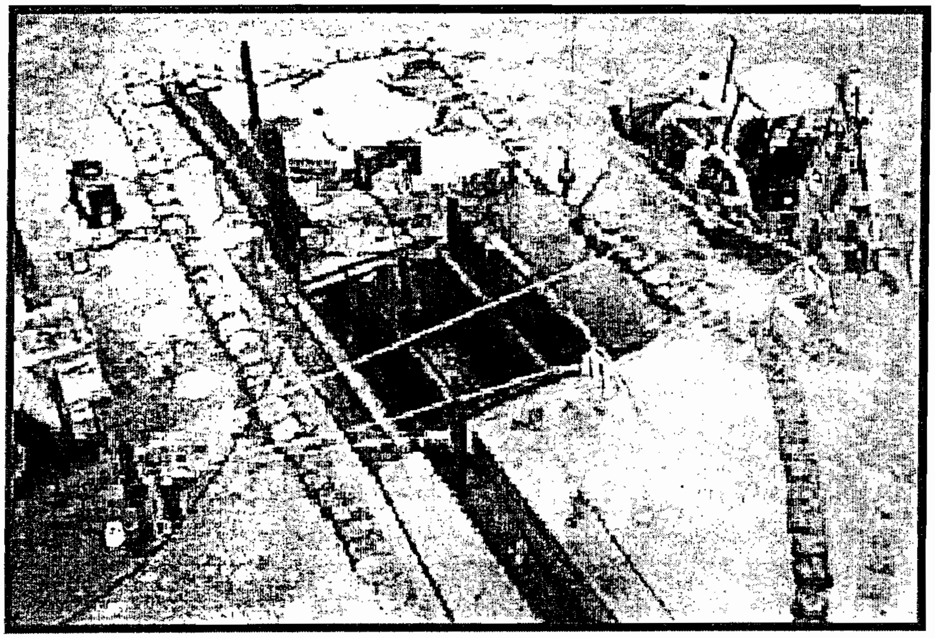
Cost and Performance Report



Permeable Reactive Wall Remediation of Chlorinated Hydrocarbons in Groundwater

July 1999

ENVIRONMENTAL SECURITY
TECHNOLOGY CERTIFICATION PROGRAM

U.S. Department of Defense

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United States
Environmental
Protection Agency

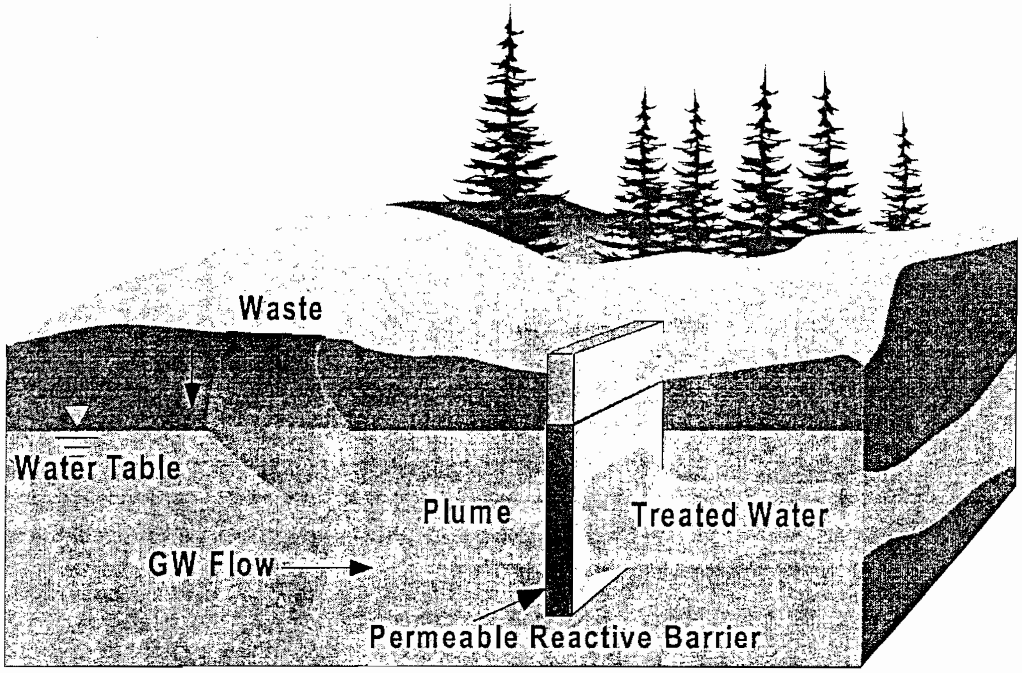
Office of Research and
Development
Washington DC 20460

Office of Solid Waste and
Emergency Response
Washington DC 20460

EPA/600/R-98/125
September 1998

RTDF

Permeable Reactive Barrier Technologies for Contaminant Remediation



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1.0 Executive Summary

Perhaps no recent remedial technology has generated as much interest as the use of subsurface permeable reactive barriers (PRBs). This is due to the perceived PRB cost/benefit ratio and the potential of PRBs to mitigate the spread of contaminants that have proven difficult and expensive to manage with other cleanup methods. The concept of a PRB is relatively simple. Reactive material is placed in the subsurface where a plume of contaminated ground water must move through it as it flows, typically under its natural gradient (creating a passive treatment system) and treated water comes out the other side (Figure 1). The PRB is not a barrier to the water, but it is a barrier to the contaminant. When properly designed and implemented, PRBs are capable of remediating a number of contaminants to regulatory concentration goals. It is currently believed that these systems, once installed, will have extremely low, if any, maintenance costs for at least five to ten years. There should be no operational costs other than routine compliance and performance monitoring.

The majority of installed PRBs use iron metal, Fe(0), as the reactive media for converting contaminants to non-toxic or immobile species. Iron metal has the ability to reductively dehalogenate hydrocarbons, such as converting trichloroethene (TCE) to ethene. It can also reductively precipitate anions and oxyanions, such as converting soluble Cr(VI) oxides to insoluble Cr(III) hydroxides. Organic materials are being used as reactive media in some PRBs to biologically remediate certain other contaminants, such as nitrate and sulfate. Both laboratory and field results have shown that the rate of transformation of these and many other contaminants is sufficiently rapid for PRBs to be successfully used as full-scale remediation systems. Numerous other reactive materials are being investigated, as are means to enhance both the iron and biological reactions. Many of the references for these investigations are listed and described in Appendix A.

Commercial PRBs are currently built in two basic configurations (although others are being evaluated), the funnel-and-gate and the continuous PRB. Both have required some degree of excavation and been limited to fairly shallow depths of fifty to seventy feet or less. Newer techniques for emplacing reactive media, such as the injection of slurries, hydrofracturing, driving mandrels, etc., may serve to overcome some of these emplacement limitations. The funnel-and-gate design PRB uses impermeable walls (sheet pilings, slurry walls, etc.) as a "funnel" to direct the contaminant plume to a "gate(s)" containing the reactive media, whereas the continuous PRB completely transects the plume flow path with reactive media. Due to the funnels, the funnel-and-gate design has a greater impact on altering the ground-water flow than does the continuous PRB. In both designs it is necessary to keep the reactive zone permeability equal to or greater than the permeability of the aquifer to avoid diversion of the flowing waters around the reactive zone.

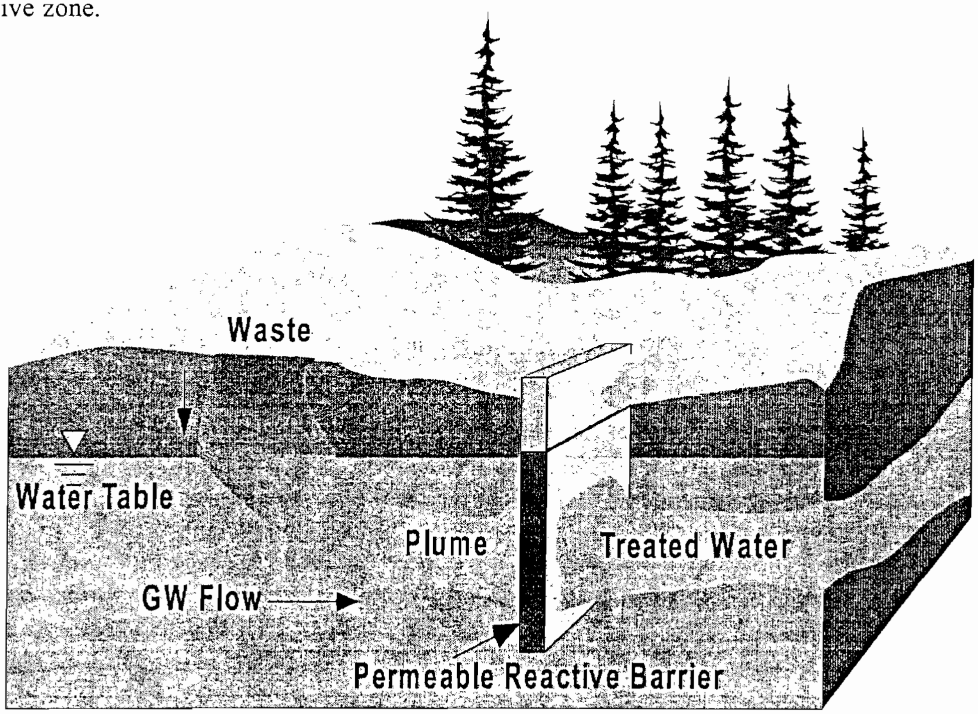


Figure 1. Example of plume being treated by a permeable reactive barrier wall.

Several important issues must be addressed when considering contaminant remediation through the use of PRB technology. These include the nature of the contaminant and the availability of reactive media that can transform the contaminant yet remain reactive, in situ, for relatively long time periods. For contaminants of unknown treatability or media of unknown reactivity, addressing these issues will require laboratory studies using both batch and column techniques. The mobility, toxicity and stability of the transformation products resulting from the contaminant and media interactions must also be assessed. If these transformation products are regulated compounds, they must not exit the reactive zone of the PRB without themselves being immobilized or transformed to innocuous compounds.

A thorough understanding of system hydrogeology and plume boundaries is needed prior to implementing a PRB, due to the need for the plume to passively flow through the reactive zone of the PRB. The hydrogeologic characterization must also yield information suitable for determining the rate of ground-water flow through the reactive zone of the PRB. This is necessary to establish the ground-water/contaminant residence time per unit thickness of reactive media which, when combined with the contaminant transformation rate as it passes through the media, determines the total thickness of reactive media that is required. During PRB installation the reactive media must be made accessible to the contaminant by some emplacement method and, as with most remedial technologies, this becomes increasingly difficult at greater contaminant depth or for contaminants in fractured rock. Once installed, the PRB should be carefully monitored for both compliance and performance; compliance to ascertain that regulatory contamination goals are being met, and performance to assess whether the PRB emplacement is meeting its design criteria and longevity expectations.

As for any remedial technology, it is important to fully understand the factors that can result in either successful implementation and remediation or failure to achieve the remedial design goals. This document addresses the factors, such as those mentioned above, that have been found to be relevant for successfully implementing PRBs for contaminant remediation. Additionally, it provides sufficient background in the science of PRB technology to allow a basic understanding of the chemical reactions proposed for the contaminant transformations that have been witnessed both in the laboratory and in field settings. It contains sections on PRB-treatable contaminants and the treatment reaction mechanisms, feasibility studies for PRB implementation, site characterization for PRBs, PRB design, PRB emplacement, monitoring for both compliance and performance, and summaries of several field installations. The appendices supplement this information with a detailed table of information available in the literature through 1997, summarizing the significant findings of PRB research and field studies (Appendix A), a further examination of the physical and chemical processes important to PRBs, such as corrosion, adsorption, and precipitation (Appendix B), and a set of scoping calculations that can be used to estimate the amount of reactive media required and facilitate choosing among the possible means of emplacing the required amount of media (Appendix C). Appendix D provides a list of acronyms and Appendix E a glossary of terms that are used within this document.

The goal of this Issue Paper is to provide the most recent information available on PRB technologies and to do so in a format that is useful to stakeholders such as implementors, state and federal regulators, Native American tribes, consultants, contractors, and all other interested parties. Other documents are also available which address PRB topics that are not discussed in detail in this report to avoid duplicative effort, such as regulatory issues related to PRB technology and cost information. For example, the Interstate Technology and Regulatory Cooperation (ITRC) Workgroup (Permeable Barrier Wall Subgroup) has prepared a document titled "Regulatory Guidance for Permeable Barrier Walls Designed to Remediate Chlorinated Solvents" (ITRC, 1997) and the Environics Directorate, U.S. Air Force, has published "Design Guidance for Application of Permeable Barriers to Remediate Dissolved Chlorinated Solvents" (Battelle, 1997). Documents on the costs of PRB technology are being prepared by U.S. EPA's Technology Innovation Office (TIO) and by its Office of Research and Development, National Risk Management Research Laboratory (ORD-NRMRL). Several web sites also provide information about PRB technology. Among these are:

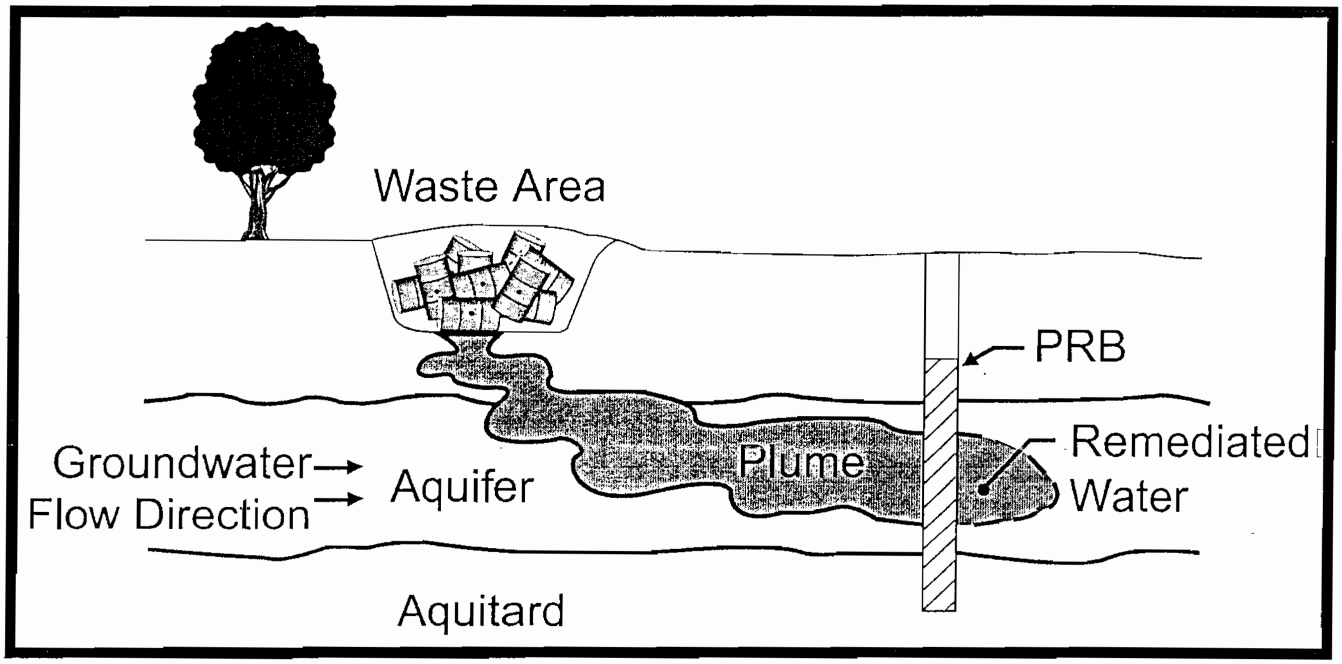
RemedialTechnologies Development Forum
- http://www.rtdf.org

Ground-Water Remediation Technologies Analysis Center
- http://www.gwrtac.org

United States
Environmental Protection
Agency

Field Applications of *In Situ* Remediation Technologies:

Permeable Reactive Barriers



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Introduction

A permeable reactive barrier (PRB) contains or creates a reactive treatment zone oriented to intercept and remediate a contaminant plume. It removes contaminants from the groundwater flow system in a passive manner by physical, chemical or biological processes. Some PRBs are installed as permanent or semi-permanent units across the flow path of a contaminant plume. Some PRBs are installed as *in situ* reactors that are readily accessible to facilitate the removal and replacement of reactive media. Most have the reactive media installed or created in intimate contact with the surrounding aquifer material.

This report summarizes information about the use of PRBs for groundwater remediation at 47 sites in the United States, Canada, and selected locations abroad. PRB sites included were identified by the Remediation Technologies Development Forum (RTDF) Permeable Reactive Barriers Action Team members, and information was provided by the points-of-contact listed. The U.S. Environmental Protection Agency's (EPA) Technology Innovation Office has prepared this document to assist potential PRB users in making more informed decisions related to their respective sites.

Complete profiles of these sites are available on the Remediation Technologies Development Forum/Permeable Reactive Barriers Action Team's Internet site (*www.rtdf.org/public/permbarr/prbsumms/default.cfm*).

In addition to the site-by-site information included (pages 9-23), charts and graphs at the end of this section of the report summarize overall statistics concerning the sites profiled. For example, Figure 1 (page 4) shows that PRBs were used for full-scale cleanup at most of the sites profiled and provides a breakdown of these sites by the category of contaminants treated. Figure 2 (page 4) shows the breakdown of U.S., Canadian, and European sites profiled by contaminant groups. Figure 3 (page 5) illustrates that the profiles are almost evenly divided between Federal and private-sector sites, and Figure 4 (page 5) shows the types of barriers used at these sites. Figure 5 (page 6) illustrates that, while zero-valent iron (Fe^0) was the most frequently used reactive medium, a variety of other media or media mixtures are available and have been used in PRBs.

Internet versions of the PRB profiles are updated periodically as new information is received. Profile information for PRB sites that are currently not in the database may be submitted on-line at *www.rtdf.org/public/permbarr/prbsumms/default.cfm* by clicking on the "Submit New Profile" button at the top of the page.

The RTDF/PRB Action Team was established in 1995. Its members include representatives from government, academia, and the private sector working as partners to further public and regulatory acceptance of PRBs for remediating chlorinated solvents, metals, radionuclides, and other groundwater pollutants.

United States
Environmental Protection
Agency

National Risk Management
Research Laboratory
Ada, OK 74820

EPA/600/F-97/008
July 1997

Permeable Reactive Subsurface Barriers for the Interception and Remediation of Chlorinated Hydrocarbon and Chromium(VI) Plumes in Ground Water

Office of Research and Development

U.S. EPA REMEDIAL TECHNOLOGY FACT SHEET

Scope of this fact sheet:

This document concerns the use of permeable reactive subsurface barriers for the remediation of plumes of chlorinated hydrocarbons and Cr(VI) species in ground water, using zero-valent iron (Fe^0) as the reactive substrate. Such systems have undergone thorough laboratory research, pilot-testing, and are now being installed as full-scale remedial technologies at field sites. Although research is progressing for other contaminants and different reactive substrates, these technologies are not as mature and will not be considered in this document.

Chemistry of TCE and chromate remediation by Fe^0:

Chlorinated hydrocarbons such as trichloroethylene (TCE) have been widely used as commercial solvents and are commonly found as ground water contaminants. As chlorinated hydrocarbons contact iron metal, they react at the iron surface. Figure 1 illustrates the reductive dechlorination of TCE to ethene and ethane which are easily biodegraded. Electrons are provided by the corrosion (or oxidation) of the iron metal. Two competing pathways, sequential hydrogenolysis (A) and reductive β–elimination (B), each lead to ethene and ethane as final products. A reactive subsurface barrier is designed to provide sufficient contaminant residence time for intermediate products, such as cis- 1,2-DCE and vinyl chloride (VC), to fully degrade to ethene and ethane.

Chromium is also a very common contaminant, typically having been released to the environment as a result of plating and other industrial operations. It occurs in the subsurface in either the Cr(VI) or Cr(III) valence states. The higher oxidation-state Cr(VI) forms, e.g. chromate (Figure 2), are far more toxic, carcinogenic, and mobile in the ground water than the reduced Cr(III) species. At typical ground water pH of 6 to 9, Cr(III) tends to precipitate from the ground water as chromium hydroxide, $Cr(OH)_3$ (Figure 2). When iron is present, the Cr(III) can precipitate as a mixed chromium-iron hydroxide solid solution, which has a lower solution equilibrium activity than either pure solid-phase hydroxide (2). Hence both the toxicity and mobility of chromium are greatly decreased when it is reduced from Cr(VI) to Cr(III).

Both TCE and chromate (as well as many other chemicals) have been shown to be reduced by Fe^0, resulting in the dechlorination of the TCE and the precipitation and immobilization of Cr. The Fe^0 donates the electrons necessary to reduce the contaminants and becomes oxidized to Fe^{2+} or Fe^{3+}. A variety of Fe precipitates and other chemical species can occur, dependant upon the system geochemistry.

Concept and definition of reactive barriers:

Environmental scientists are generally familiar with the concept of barriers for restricting the movement of contaminant plumes in ground water. Such barriers are typically constructed of highly impermeable emplacements of materials such as grouts, slurries, or sheet pilings to form a subsurface *wall*. The goal of such constructions is to eliminate the possibility that a contaminant plume can move toward and endanger sensitive receptors such as drinking water wells or discharge into surface waters. Permeable reactive barrier walls reverse this concept of subsurface barriers. Rather than serving to constrain plume migration, permeable reactive barriers are designed as preferential conduits for the contaminated ground water flow. When the contaminated water passes through the reactive zone of the barrier, (for example, a zone comprised of granular iron), the contaminants are either immobilized or chemically transformed to a more desirable (e.g., less toxic, more readily biodegradable, etc.) state. A permeable reactive subsurface barrier can be defined as:

> *an emplacement of reactive materials in the subsurface designed to intercept a contaminant plume, provide a preferential flow path through the reactive media, and transform the contaminant(s) into environmentally acceptable forms to attain remediation concentration goals at points of compliance.*

Barrier configurations:

Currently, two basic designs are being used in full-scale implementations of reactive barriers: (1) the funnel and gate and (2) the continuous trench. Other designs are being researched and evaluated.

The design of a funnel and gate system is shown in Figure 3a. Basically, an impermeable *funnel*, typically consisting of interlocking sheet pilings or slurry walls, is emplaced to enclose and direct the flow of contaminated water to a *gate* or *gates* containing the permeable zone of reactive Fe metal. The design must prevent the contaminant plume from flowing around the barrier. Due to directing large amounts of water through a much smaller cross-sectional area of the aquifer, ground water velocities within the barrier will be higher than those resulting from the natural gradient. The continuous trench (Figure 3b) is simply a trench that has been excavated and simultaneously backfilled with reactive Fe, allowing the water to pass through the barrier under its natural gradient.

Both configurations require that information on contaminant concentration, contaminant degradation rate in the presence of the reactive substrate, and ground water flow rate through the barrier be known. This allows determination of the required residence time in the zone needed to achieve remedial goals, hence allowing calculation of the required thickness of the reactive zone.

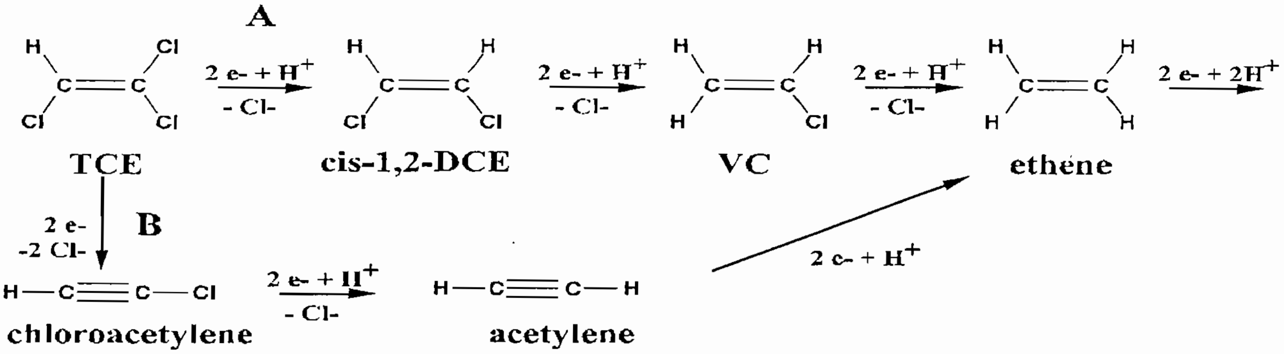


Figure 1. *Reductive dechlorination of TCE to ethene and ethane.*

Site characterization:

A complete site characterization is of critical importance for the successful installation of a reactive barrier. The entire plume must be directed through and remediated within the reactive zone of the barrier. The plume must not be able to pass over, under, or around the barrier and the reactive zone must be capable of reducing the contaminant to concentration goals without rapidly plugging with precipitates or losing its reactivity. To achieve the required performance requires knowledge of:

- plume location
- plume direction
- contaminant concentrations
- hydrologic changes with time
- concentration attenuation over time and distance
- stratigraphic variations in permeability
- confining layers
- fracturing, and
- aqueous geochemistry

The barrier design, location, emplacement methodology, and estimated life expectancy are based on the site characterization information, therefore faulty information could jeopardize the entire remedial scenario. A complete discussion of site characterization is beyond the scope of this document, but guidance documents are in preparation that will contain extensive discussions of characterization requirements.

Compliance and performance monitoring:

Monitoring for regulatory compliance and treatment performance are both necessary when using reactive barrier technology. When locating the wells, selecting the screen lengths, and designing other aspects of the monitoring well system, the sampling program objectives and site conditions should be carefully considered.

Compliance monitoring determines whether regulatory contaminant concentration requirements are being met. Typically the compliance monitoring criteria will be set by the State where the site is located. Normal compliance monitoring parameters include:

- the contaminants of interest
- potential contaminant daughter (degradation) products
- general water quality parameters

In general, several monitoring wells should be installed to determine:

- are regulatory goals being achieved?
- does contaminant breakthrough occur (immediately or over time)?
- is the contaminant flowing around the wall?

Typical well locations would include:

- upgradient of the wall
- within the reactive zone of the wall
- immediately downgradient of the reactive zone discharge
- at each end of the wall
- below the wall, and
- above the reactive zone (if possible)

In addition to the contaminants, their products, and the routine water quality parameters listed above, performance monitoring of permeable reactive barriers should include:

- hydrologic parameters (baseline and changes over time)
- precipitates on the iron surfaces (and rate of buildup)
- Eh
- dissolved oxygen, and
- ferrous iron

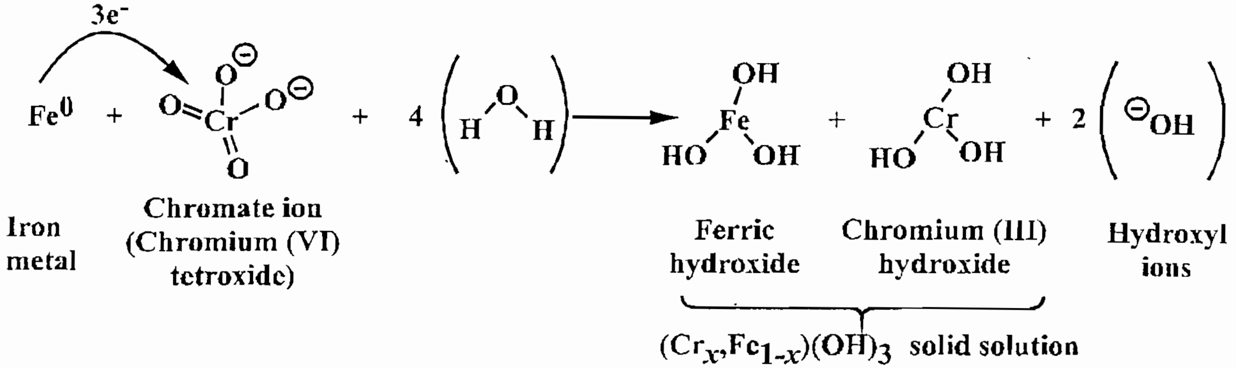


Figure 2. *Reduction of Cr(VI) to Cr(III) and precipitation of hydroxide phases.*

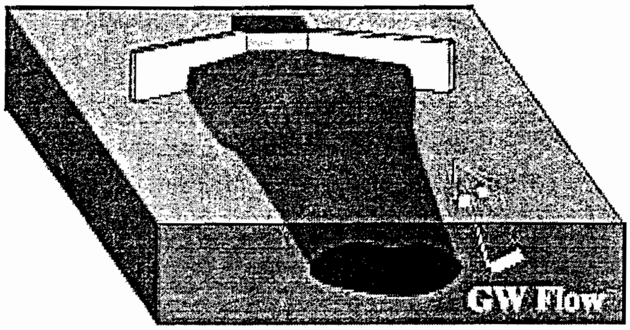


Figure 3a. *Plume capture by a funnel & gate system. Sheet piling funnels direct the plume through the reactive gate.*

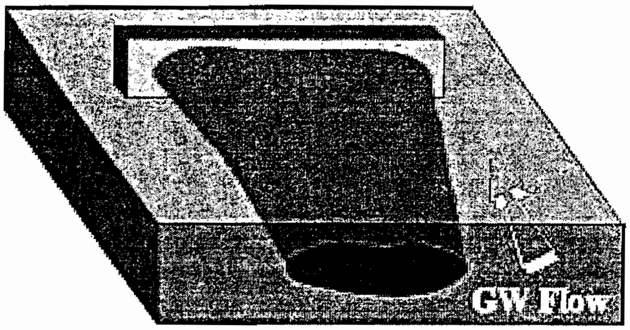


Figure 3b. *Plume capture by a continuous trench system. The plume moves unimpeded through the reactive gate.*

Knowledge of these parameters helps confirm emplacement as well as address and detect possible:

- loss of reactivity
- decrease in permeability
- decrease in reaction zone residence time
- short circuiting of the reactive zone (i.e., preferential pathways), and
- funnel wall leakage

Some advantages and disadvantages of reactive barrier technology:

Advantages--

- actual in situ contaminant remediation, rather than simple migration control as with impermeable barriers
- passive remediation, no ongoing energy input and limited maintenance following installation
- no required surface structures other than monitoring wells following installation
- can remediate plumes even when the source term of the plume cannot be located
- should not alter the overall ground water flow pattern as much as high-volume pumping
- contaminants are not brought to the surface; i.e., no potential cross-media contamination
- no disposal requirements or disposal costs for treated wastes
- avoids the mixing of contaminated and uncontaminated waters that occurs with pumping

Disadvantages--

- currently restricted to shallow plumes, approximately 50 feet or less below ground surface
- plume must be very well characterized and delineated
- limited long-term field testing data is available and field monitoring is in its infancy
- limited field data concerning longevity of wall reactivity or loss of permeability due to precipitation
- currently no field-tested applications to remediation of contaminant source terms

Current applications of reactive barriers to contaminant plumes:

Permeable reactive subsurface barriers are currently being used in full-scale field applications for the treatment of plumes of chlorinated hydrocarbons and chromate. As of this writing, six full-scale reactive barriers have been installed in the field. Information on five of these installations is provided in Table 1.

Regulatory acceptance of permeable reactive barriers for subsurface contaminant remediation:

The U.S. Environmental Protection Agency has supported the development of this innovative in-situ technology through active collaboration on research involving the National Risk Management Research Laboratory and the National Exposure Research Laboratory of U.S. EPA's Office of Research and Development, through the Remediation Technologies Development Forum (RTDF) Permeable Barriers Action Team, and from support provided by U.S. EPA's Technology Innovation Office (TIO). In addition, support has been provided from several regional offices where sites are testing the technology at pilot scale. The U.S. EPA recognizes this technology as having potential to more effectively remediate subsurface contamination at many types of sites at significant cost savings compared to other more traditional approaches. The U.S. EPA is actively involved in the evaluation and monitoring of this new technology to answer questions regarding long-term system performance, and in providing guidance to various stakeholder groups.

As with any remedial technology, adequate site characterization is necessary to demonstrate that the technology is suitable for application at a particular site. There are site characteristics, such as excessive depth to contaminant plume, fractured rock, etc., which would argue against permeable reactive barriers as a remedy selection. These situations are currently topics of research and/or pilot testing. More definitive information regarding the application of the technology will be included in a forthcoming EPA Issue Paper.

The Interstate Technology and Regulatory Cooperation (ITRC) Workgroup (Permeable Barrier Wall Subgroup) is also actively involved in defining the regulatory implications associated with the installation of permeable reactive barriers in the subsurface and in providing guidance on regulatory issues where possible.

Additional sources of information on reactive barriers:

Remedial Technologies Development Forum, Permeable Barriers Work Group

http://www.rtdf.org

Ground-Water Remediation Technologies Analyis Center (GWRTAC)

http://www.gwrtac.org:80/

EnviroMetal Technologies Inc.

http://www.beak.com:80/Technologies/ETI/eti.html

Table 1. Specifications for selected permeable reactive barrier installations.

Site	Industrial facility, Mountain View, California	Industrial facility, Belfast, Northern Ireland	Industrial facility, Coffeyville, Kansas	USCG facility, Elizabeth City, North Carolina	Government facility, Lakewood, Colorado
Installation Date	*Sept. 1995*	*Dec. 1995*	*Jan. 1996*	*June 1995*	*Oct. 1996*
Contaminant & high conc. Design	2 mg L^{-1} cDCE	300 mg L^{-1} TCE	400 µg L^{-1} TCE	10 mg L^{-1} TCE 10 mgL^{-1} Cr(VI)	700 µg L^{-1} each TCE & DCE 15 µg L^{-1} VC
Reactive Wall Type	*Excavate & fill*	*Reaction Vessel*	*Funnel & Gate*	*Continuous Trench*	*Funnel & Multiple Gate*
Funnel Material	*Not Applicable*	*Slurry Walls*	*Soil-Bentonite Slurry*	*Not Applicable*	*Sealable Joint Sheet Pilings*
Funnel Length	*Not Applicable*	*100 ft + 100 ft*	*490 ft + 490 ft*	*Not Applicable*	*1040 ft total*
No. of Gates	*Not Applicable*	*1 Reaction vessel*	*1*	*Not Applicable*	*4*
Reactive Material	Fe^0	Fe^0	Fe^0	Fe^0	Fe^0
Reactive Zone Height	*5 ft*	*16 ft in vessel*	*11 ft*	*Approx. 23 ft*	*10-15 ft*
Reactive Zone Length	*44 ft*	*NA*	*20 ft*	*150 ft*	*40 ft each (4 x 40 = 160)*
Reactive Zone Thickness	*4.5 ft*	*16 ft in vessel*	*3 ft*	*2 ft*	*Gates differed,* *low = 2 ft* *high = 6 ft*
Total Mass of Reactant	*90 tons*	*15 tons*	*70 tons*	*450 tons*	*No Information*
Treatment Wall Depth	*15 to 20 ft bgs*	*18 to 40 ft bgs*	*17 to 28 ft bgs*	*3 to 26 ft bgs*	*10-15 to 20-25 ft bgs*
Total System Length	*44 ft*	*Approx. 200 ft*	*1000 ft*	*150 ft*	*1200 ft*
Special Features & Misc.	*HDPE atop Fe to surface upgradient directs* H_2O *through Fe*	*Walls direct* H_2O *to vessel inlet, gravity flow to outlet downgradient*		*Two contam. treated. Chain trencher with immediate Fe placement*	*Largest of its kind. Gates installed using sheet pile box.*
Cost	*No Information*	*$375 K*	*$400 K*	*$500 K*	*No Information*

For more information, contact:

Dr. Robert W. Puls (RTDF co-chair)
U.S. Environmental Protection Agency
National Risk Management Research Laboratory
P.O. Box 1198
Ada, OK 74820
Tel: (405) 436-8543
Email: puls@epamail.epa.gov

Authors:

Robert W. Puls, Subsurface Protection and Remediation Division, NRMRL, ORD, U.S. EPA

Robert M. Powell, Powell & Associates Science Services, Las Vegas, NV (*under subcontract to ManTech Environmental Research Services Corp.*)

References for the chemical reactions and mechanisms:

(1) Roberts, L. A.; Totten, L. A.; Arnold, W. A.; Burris, D. R.; Campbell, T. J. *Environmental Science & Technology* **1996**, *30*, 2654-2659.

(2) Powell, R. M.; Puls, R. W.; Hightower, S. K.; Sabatini, D. A. *Environmental Science & Technology* **1995**, *29*, 1913-1922.

Appendix I

LPS Remedy #8– Soil Vapor Extraction

Supporting Documentation

- A Citizen's Guide to Soil Vapor Extraction, USEPA
- Harris Environmental Letter and Generic Design Drawings
- Soil Vapor Extraction (SVE) at Seven Drycleaner Sites, USEPA

United States
Environmental Protection
Agency

Office of Solid Waste and
Emergency Response
(5102G)

EPA 542-F-01-006
April 2001
www.epa.gov/superfund/sites
www.cluin.org

EPA

A Citizen's Guide to Soil Vapor Extraction and Air Sparging

The Citizen's Guide Series

EPA uses many methods to clean up pollution at Superfund and other sites. If you live, work, or go to school near a Superfund site, you may want to learn more about cleanup methods. Perhaps they are being used or are proposed for use at your site. How do they work? Are they safe? This Citizen's Guide is one in a series to help answer your questions.

What are soil vapor extraction and air sparging?

Soil vapor extraction or *SVE* removes harmful chemicals, in the form of *vapors*, from the soil above the water table. Vapors are the gases that form when chemicals evaporate. The vapors are extracted (removed) from the ground by applying a vacuum to pull the vapors out.

Air sparging uses air to help remove harmful vapors from polluted soil and groundwater below the water table. When air is pumped underground, the chemicals evaporate faster, which makes them easier to remove. Like SVE, a vacuum then extracts the vapors. Certain chemicals—like solvents and fuel—evaporate easily. SVE and air sparging work best on these types of chemicals. SVE and air sparging are often used at the same time to clean up both soil and groundwater.

What is the Water Table?

The water table is the level of groundwater below the ground surface.

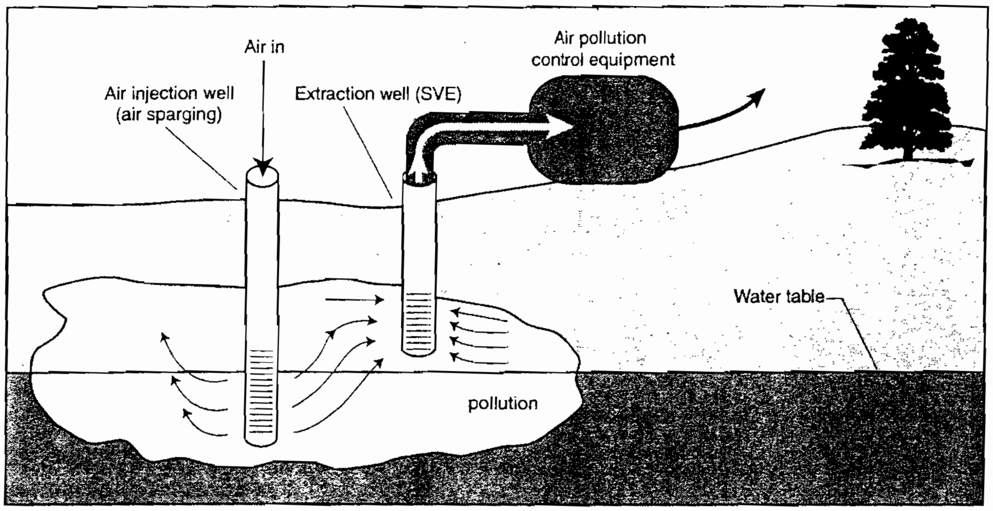
How do they work?

SVE requires drilling *extraction wells* within the polluted area. These wells are drilled into the soil, but not the groundwater. Attached to the wells is equipment that creates a vacuum, which pulls air and vapors through the soil and up to the surface.

Air injection wells can be drilled to help the cleanup. Air injection wells pump air into the ground. The air causes the pollution to evaporate faster. Sometimes air vents are used instead of air injection wells. Air vents don't pump air, but provide a passage for fresh air to enter the ground. The number of air injection and extraction wells can range from one to hundreds, depending on the size of the polluted area.

Once the extraction wells pull the air and vapors out of the ground, special air pollution control equipment collects them. The equipment separates the harmful vapors from the clean air. Then, the vapors *sorb* or stick to solid materials. Or they are condensed to liquids. These polluted solids and liquids are disposed of safely.

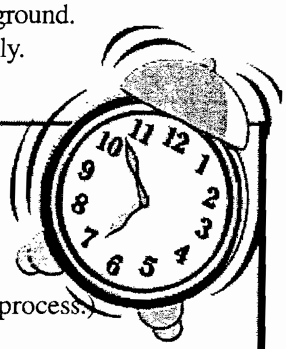
Air sparging works very much like SVE. However, the wells that pump air into the ground are drilled into water-soaked soil below the water table. Air pumped into the wells disturbs the groundwater. This helps the pollution change into vapors. The vapors rise into the drier soil above the groundwater and are pulled out of the ground by extraction wells. The harmful vapors are removed in the same way as SVE.



The air used in SVE and air sparging also helps clean up pollution by encouraging the growth of *microbes*. These tiny bugs are found naturally in soil and can use pollution for food. When microbes completely digest pollution, they can change it into water and harmless vapors. (*A Citizen's Guide to Bioremediation* [EPA 542-F-01-001] describes how microbes work.)

Are soil vapor extraction and air sparging safe?

When properly designed and operated, SVE and air sparging are safe cleanup methods. No one has to dig up the pollution, and no chemicals—just air—are added to the ground. EPA makes sure that harmful vapors are collected and disposed of properly.



How long will it take ?

Cleaning up a site using SVE and air sparging can take years. The time depends on several factors:

- size and depth of the polluted area
- type of soil and conditions present (wet or dense soil can slow the process.)
- type and amounts of harmful chemicals present

The air injected into the ground can be heated to speed up the process. The heated soil helps evaporate the chemicals faster. Also, other sources of heat, like steam or hot water can be pumped into the injection wells to heat up the soil. (See *A Citizen's Guide to In Situ Thermal Treatment* [EPA 542-F-01-012].)

Why use soil vapor extraction and air sparging?

SVE and air sparging are quicker than cleanup methods that rely on natural processes to do the work. In general, the wells and equipment are simple to install and maintain. And they can reach greater depths than methods that involve digging up soil. SVE and air sparging are effective at removing many types of pollution that can evaporate. Both methods can be used with other methods to clean up other types of pollution as well. Both methods work best in loose soils—like sand and gravel. But they both work well under many types of conditions.

SVE and air sparging are often chosen to clean up Superfund sites. EPA has selected SVE for use at approximately196 sites and air sparging for use at roughly 48 sites.

For more information
write the Technology Innovation Office at:

U.S. EPA (5102G)
1200 Pennsylvania Ave., NW
Washington, DC 20460

or call them at
(703) 603-9910.

Further information also can be obtained at **www.cluin.org** or **www.epa.gov/superfund/sites**.

Harris Environmental, Inc.

Stan Sowl, CES
600 Stone House Road
Clarion, PA 16214
Phone: (814) 764-5316
Fax: (814) 764-5311

-Environmental Consulting
-Environmental Investigation
-UST & AST Facility Inspections
-Certified UST/AST Work
-Radon Testing

May 17, 2003

Mr. Steve Saines
Saines Environmental Services
257 Midland Place
Logan, OH 43138

RE: LPS Facility, City of Middletown, Borough and Town of Wallkill, Orange County, State of New York

Dear Steve:

I have reviewed the files of your work completed at LPS. As we discussed, you were looking to provide a variation of a Soil Vapor Extraction (SVE) system to provide soil and groundwater remediation at the above referenced facility. Due to the relatively high water table and high bedrock interface, SVE in of itself may not be practical. A Liquid Ring Pump (LRP) unit, which removes groundwater and also provides vacuum to promote soil gas vapor extraction may be the combination of technologies you seek. The LRP unit derives its suction from a centrifugal impeller, the seal of which is provided by water. Newer versions of the LRP also utilize a vegetable/oil base fluid to provide a seal to generate vacuum. The water based LRP unit requires a potable water supply source that feeds a small holding tank on the LRP base. Groundwater is also used to provide a seal in the pump, but in the event of low water, the potable supply enhances or supplements the groundwater. Drawdown within the well is achieved and the soil is now open to the screened interval of the well casing. The vacuum created by the LRP then draws soil vapors through the well screen. From the wellhead, the groundwater/soil gas is directed through a small knockout tank. The liquids settle to the bottom of the knockout tank and are transferred to the groundwater treatment bed. The vapors are drawn from the top of the knockout tank, through the LRP, and exhausted to the vapor phase carbon treatment bed. Air Quality and groundwater discharge permits would be required.

Because of the high groundwater table and shallow vadose zone operation as described above, the system and remediation would be limited in efficiency unless multiple wells were installed. There are four (4) major areas of concern you have identified for the soil contaminate issue. One 15' by 40' area is located at the northeast corner of the property. A second area, approximately 20 feet square is located south of the LPS building, in the vicinity of the former loading dock. The remaining two (2) areas of concern are located near the south property boundary. One (1) area is approximately 20' by 50', at the southeast corner, the second is approximately 40' by 30' immediately west of the southeast contaminate area. An SVE system requires good communication with the vadose zone and little impact from the groundwater table. Due to the elevated water table, approximately three (3) to five (5) feet below grade, and the gravel consistency of the existing parking area wherein the contaminates lie, capping of the area would be required to assure that no short circuiting of the system would occur (i.e. no drawing of atmospheric vapors, but solely soil vapors). Asphalt capping of the entire area could be done, but would be impractical. It is proposed to place a rubberized lining/capping material over the areas of soil contamination to eliminate short-circuiting of the SVE system. Excavation to bury this capping material is impractical, as this would reduce the vadose zone even further. Therefore, it is suggested that a rubber/impervious material (hereafter rubber) capping material be placed directed on the existing soil and a 12" soil layer be placed on top of the cap material. This capping would extend approximately 15 to 20 feet beyond the projected areal soil contaminate extent. The two (2) areas in the southern section of the parcel can be placed under the same cap material.

A single extraction well in the middle of the northern and middle parcel capped contaminate area and two (2) distinct extraction wells in the southern parcel contaminated areas should provide communication with both the soil gas and groundwater, however in lieu of a single well, a trenched system within each contaminate area manifolded to an extraction point would provide viable communication in the subsurface matrices. A generic design of this system is attaché dto this letter fro your review. Of course, the LRP system design is based on pilot study data that would show vacuum readings from observation wells and the amount of drawdown and yield of groundwater. Prior to installation of the LRP system, pilot tests can be done to determine equipment sizing.

Because of the shallow groundwater table, periods of SVE inundation would occur. To eliminate the problems associated with this phenomenon, the LRP will remove the soil vapors and also remove the contaminated groundwater for treatment as well. This scenario would be a dual phase remediation activity for each media.

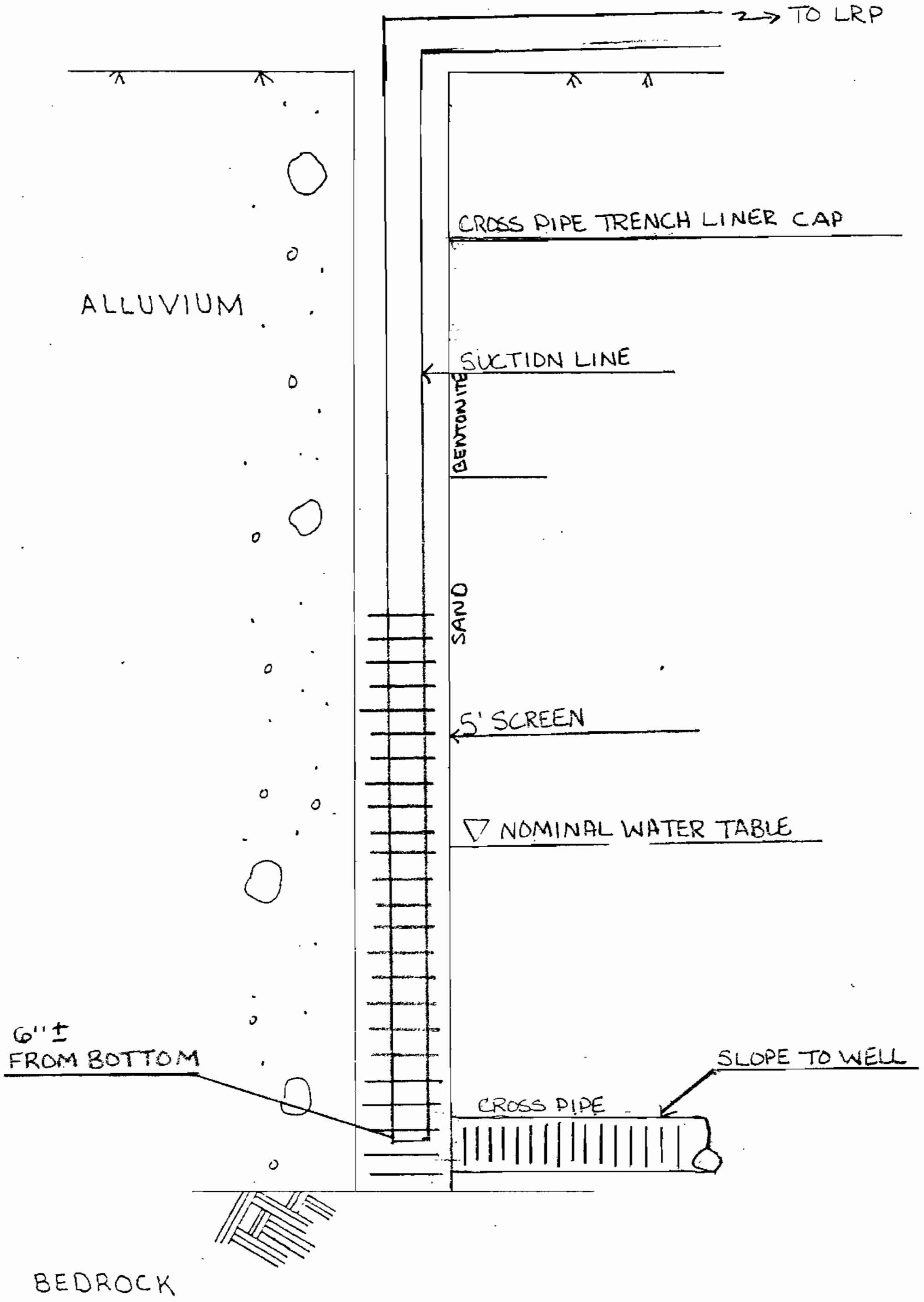
Soil vapors will be treated through an activate carbon canister treatment bed. A minimum of two (2) canisters in series can be placed at the LRP vapor discharge. The canisters would be monitored periodically for breakthrough and replaced or rotated from secondary to primary as breakthrough occurs. Groundwater will be treated through a treatment bed compromising of an bag filter for sediments, an iron filter, and multiple custom carbon compound filtration media for the groundwater contaminates. Groundwater samples analyzed for iron and total suspended solids and dissolved solids are requested to determine the degree of filtration needed to eliminate these remediation filtration media blinding agents. A polish liquid phase carbon canister scenario as used with the vapor phase effluent will provide for acceptable groundwater discharge. Groundwater discharge can be to the existing sanitary sewer system, with permission form the governing authority, or an NPDES permit can be obtained from NYSDEC. A waiver for air quality discharge permit would need approved from NYSDEC for the vapor phase discharge.

The activities described herein are based on soil, groundwater and delineation information provided by your office in the Remedial Investigation Report dated June 2002 and the November 2002 LPS Feasibility Study. The results of any pilot studies may be cause for revision of the system or general design of the system described here.

If you have any questions, please feel free to call anytime.

Harris Environmental, Inc.

Stan H. Sowl, CES

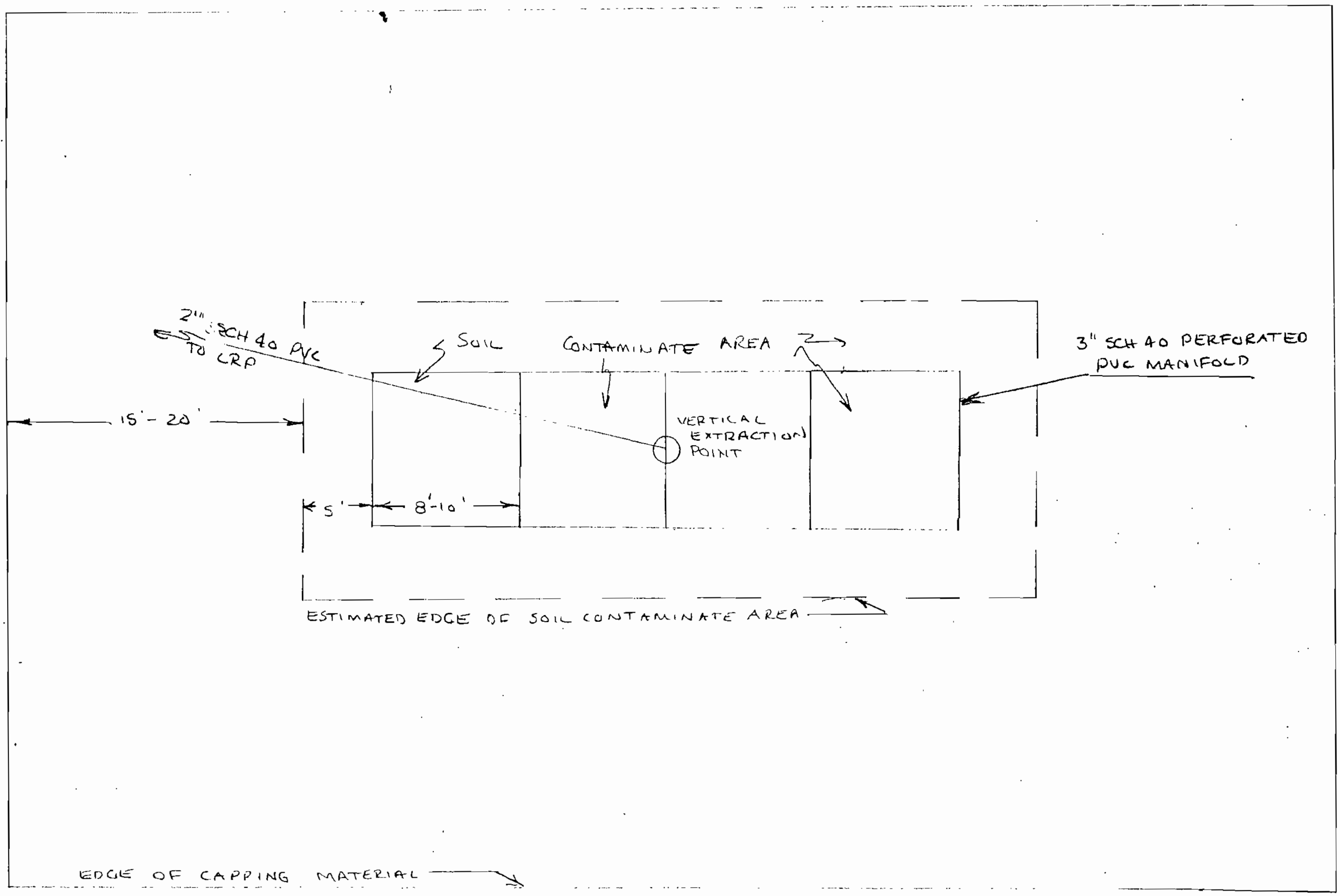


Not to Scale

Typical Recovery Well Detail
for
LPS

City of Middletown Orange Co., NY

Harris Environmental, Inc.
ENVIRONMENTAL CONSULTING
600 Stonehouse Road
Clarion, PA 16214
(814) 764-5316



SCALE: 1" = 20' ±

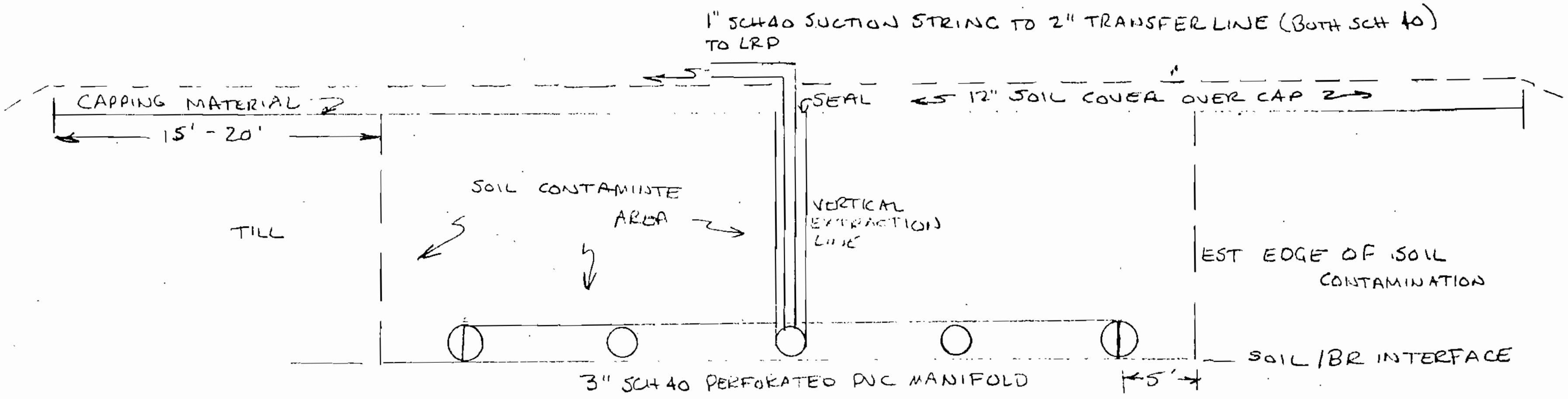
Harris Environmental, Inc.
ENVIRONMENTAL CONSULTING

600 Stonehouse Road
Clarion, PA 16214

(814) 764-5316

TYPICAL SVE TRENCH SCHEMATIC
FOR
LPS FACILITY
Borough/Town of Wallkill
Orange County, NY

Sheet 1 of 2



SCALE: 1" = 20'±

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ENVIRONMENTAL CONSULTING

600 Stonehouse Road
Clarion, PA 16214

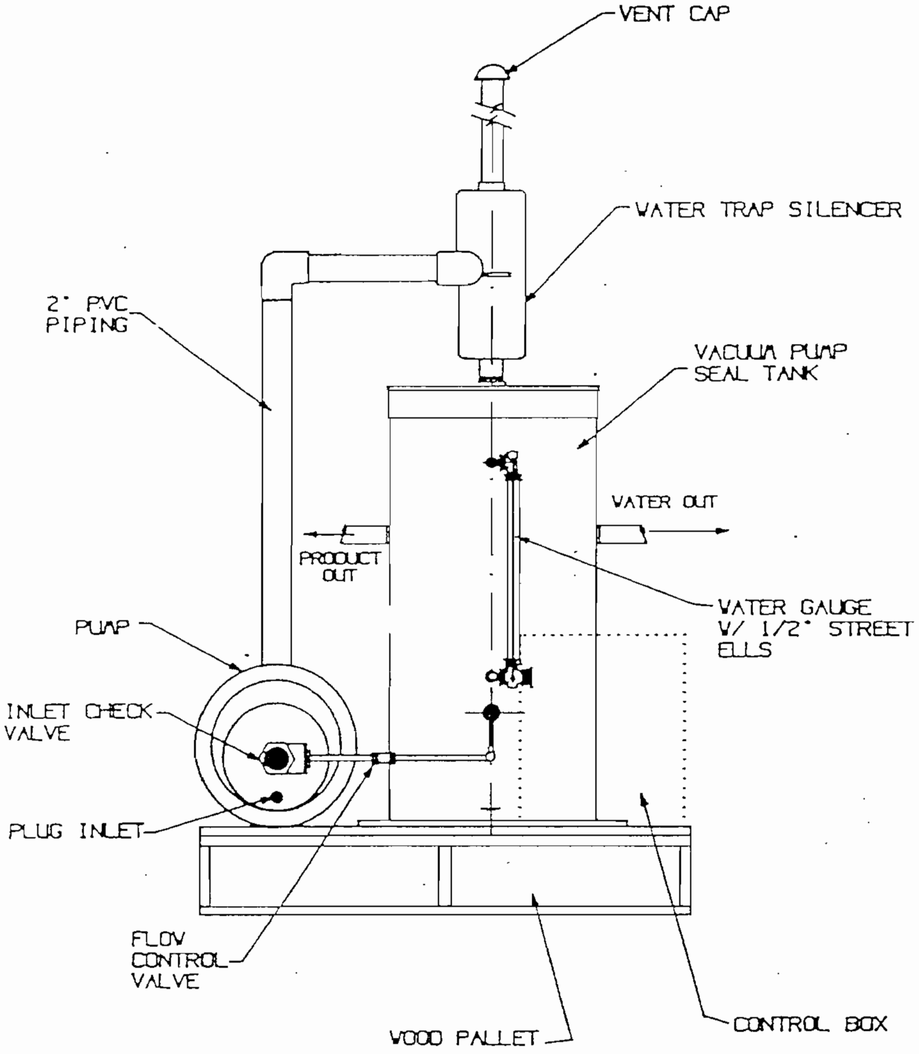
(814) 764-5316

TYPICAL SVE TRENCH SCHEMATIC
FOR
LPS FACILITY
Borough/Town of Wallkill

Orange County, NY

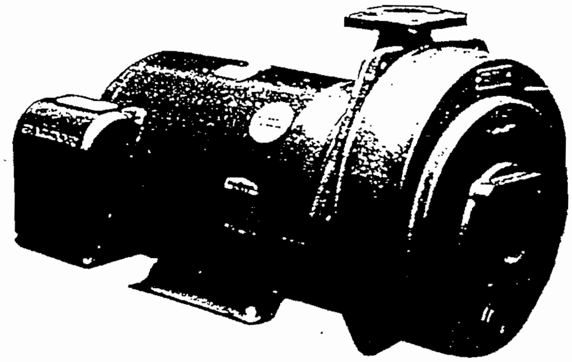
Sheet 2 of 2

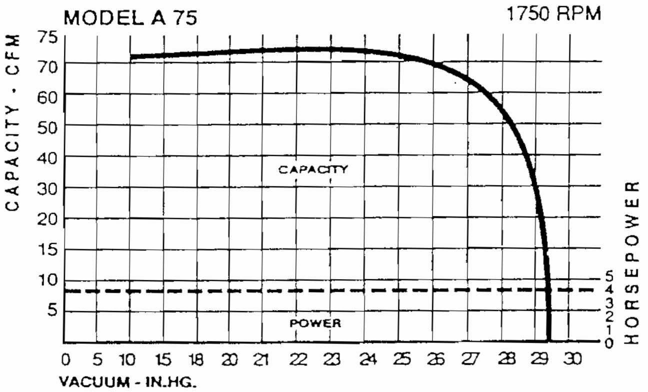
LIQUID RING PUMP SPECIFICATIONS

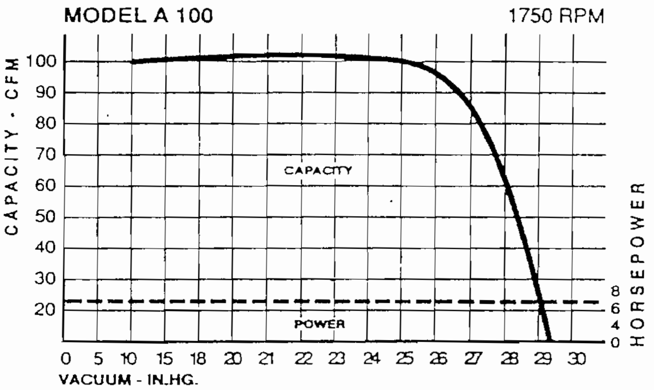


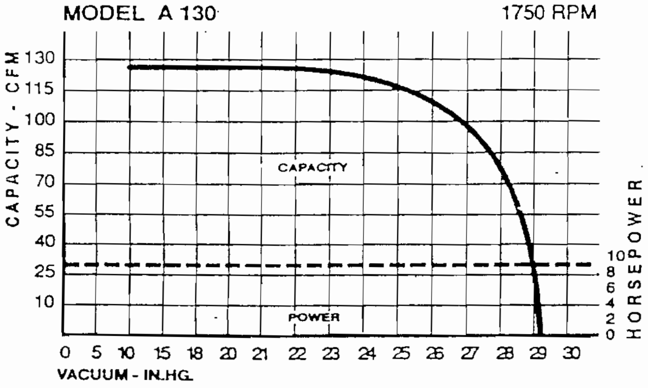
LIQUID RING PUMP

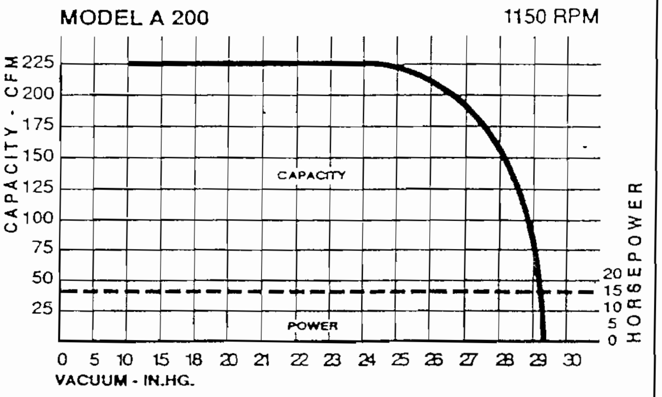
QUALITY AMERICAN PUMPS





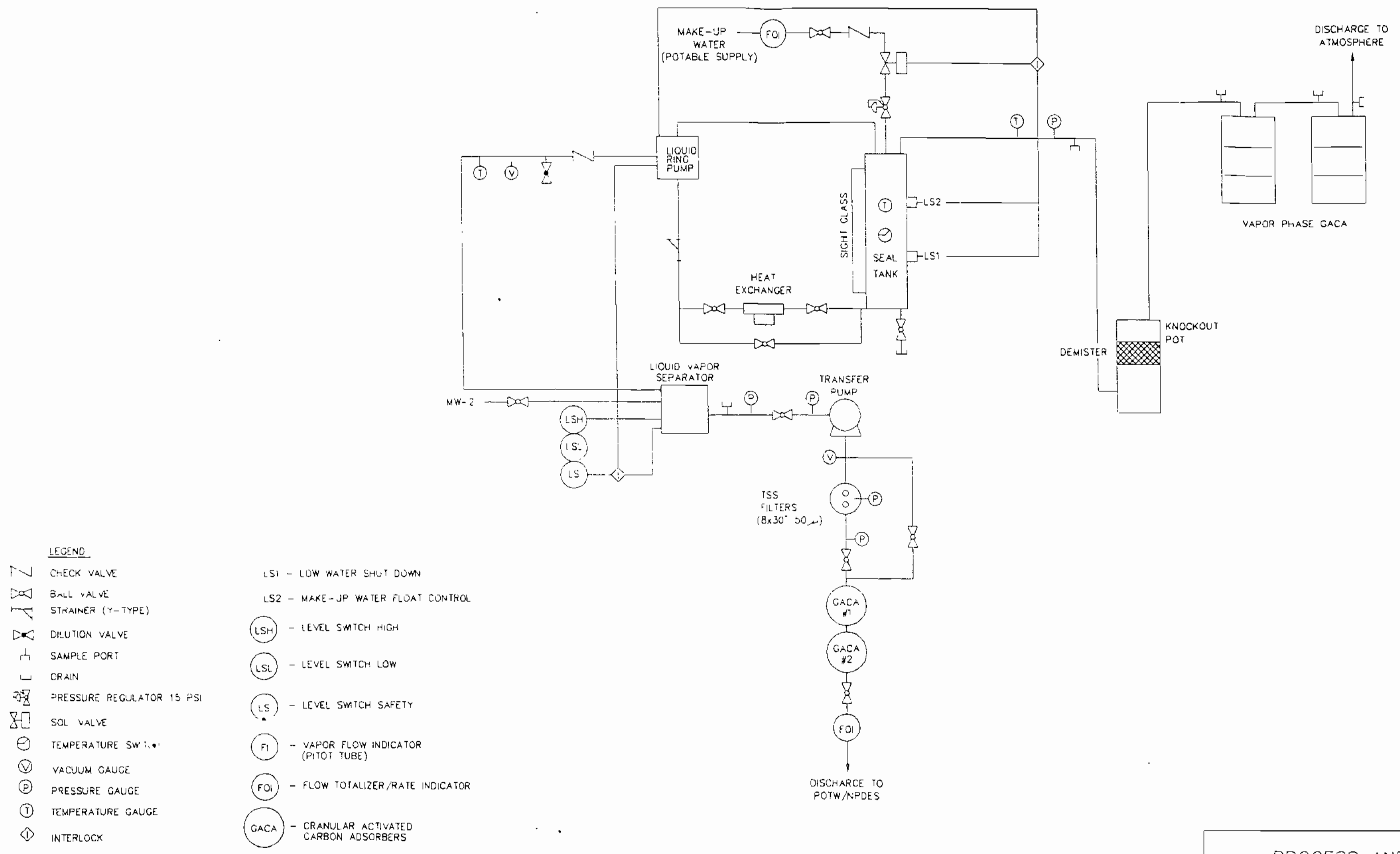






atlantic fluidics, inc.

atlantic fluidics, inc.
21 South Street
South Norwalk, CT 06854
(203) 853-7315



PROCESS AND INSTRUMENTATION DIAGRAM

DRAWN BY. L. STRUM
DATE 3/27/00
REVISED
HWPA #120172.001
DWG. NO. 120172PD

Soil Vapor Extraction (SVE) at Seven Drycleaner Sites, Various Locations

Federal Remediation Technologies Roundtable

Site Name:	Abe's Main Street Cleaners; Donaldson's Drycleaners; Dry Clean USA; One Price Drycleaners; Sir Galloway Dry Cleaners; Stuart Cleaners & Tailors; The Dry Cleaner
Location:	Abe's Main Street Cleaners, Portland, OR; Donaldson's Drycleaners, WI; Dry Clean USA, Orlando, FL; One Price Drycleaners, Sunrise, FL; Sir Galloway Dry Cleaners, Miami, FL; Stuart Cleaners & Tailors, Stuart, FL; The Dry Cleaner, Alamonte Springs, FL
Period of Operation:	Abe's Main Street Cleaners - 1998 (dates not specified) Donaldson's Drycleaners - Not specified Dry Clean USA - April, 1999 to December, 2000 One Price Drycleaners - February, 2000 to August, 2000 Sir Galloway Dry Cleaners - January, 2000 to July, 2000 Stuart Cleaners & Tailors - January, 2000 to July, 2000 The Dry Cleaner - March, 1999 to September, 1999
Cleanup Type:	Full scale

Technology:
SVE

- SVE systems consisted of from 1 to 14 vapor extraction wells applying a vacuum of 19 to 70 inches of water and drawing 80 to 290 scfm of soil vapor at depths from 0.5 to 40 feet bgs.. Two system also had air injection wells.
- At three sites pump and treat of contaminated groundwater was also conducted. The groundwater pump and treat continued operation for an unspecified period of time after the SVE system was shut down.
- At two sites, prior to SVE, excavation of hot spots was performed. At one of those sites the excavation was followed by backfilling and capping with asphalt to minimize infiltration of surface water into the contaminated areas.

Cleanup Authority: State

Contacts:
Varied by site

Contaminants:
Chlorinated Solvents

- Concentrations of PCE in soil varied among the sites and ranged from 1 to 1,000 mg/kg. Some sites reported other chlorinated organics in the soil such as TCE, cis-1,2-DCE and VC
- Concentrations of PCE on groundwater varied among the sites and ranged from 0.003 to 55 mg/L. Some sites reported other chlorinated organics in the soil such as TCE, cis-1,2-DCE and VC. Two site reported that DNAPLs were present or likely to be present.

Waste Source: Waste and wastewater from drycleaning operations

Type/Quantity of Media Treated:
Soil

Purpose/Significance of Application:
Use of soil vapor extraction to remediate soil contaminated with chlorinated solvents at drycleaning sites

Regulatory Requirements/Cleanup Goals:

- Soil cleanup goals were based on state regulatory goals
- Five sites had a soil cleanup goal of 30 mg/kg leachable PCE; one site had a soil cleanup goal 0.3 mg/kg for PCE.

Results:

- All of the sites reported that SVE effectively removed PCE from soils
- The amounts of VOCs removed by the SVE systems ranged from 2 to7 pounds

Costs:

Design and implementation costs for SVE systems ranged from $30,000 to $160,000; annual O&M costs for SVE systems ranged from $26,000 to $67,000

Description:

SVE was conducted at six drycleaner sites contaminated with chlorinated organic compounds from drycleaning operations. All of the sites reported that SVE effectively removed PCE from soils, with the amount of VOCs removed ranging from 2 to 7 pounds. Reported design and implementation costs for the SVE systems ranged from $30,000 to $160,000 and reported annual O&M costs ranged from $26,000 to $67,000.

View the Complete Document

United States
Environmental Protection
Agency

Solid Waste and
Emergency Response
(5102G)

EPA 542-R-00-013
February 2001
clu-in.org

Cost Analyses for Selected Groundwater Cleanup Projects:
Pump and Treat Systems and Permeable Reactive Barriers

SUMMARY

Groundwater contamination is present at many Superfund and RCRA corrective action sites. Groundwater cleanup technologies, such as pump-and-treat (P&T) systems and permeable reactive barriers (PRBs), are being used at a number of those sites. Information about the costs of groundwater cleanup technologies and factors that affect those costs may be valuable to site managers, technology developers and users, and others involved in groundwater remediation efforts to identify and evaluate those technologies for new and ongoing projects. This report presents the results of an analysis, performed by the U.S. Environmental Protection Agency (EPA), of costs for groundwater cleanup incurred at 48 sites (the 32 P&T sites and 16 PRB sites listed in Exhibit 1). The report is based on data in case studies prepared by EPA and other members of the Federal Remediation Technologies Roundtable (FRTR) and by the Remediation Technologies Development Forum (RTDF), and supplements EPA's analysis of 28 groundwater remediation projects (*Groundwater Cleanup: Overview of Operating Experience at 28 Sites, September 1999, EPA 542-R-99-006*).

The analysis of the 48 sites found that there is a significant amount of variability in the costs of groundwater cleanups and that many of the factors that affect costs are site-specific. However, the following overall conclusions can be drawn:

- The types of contaminant groups in the groundwater affect the capital costs of a P&T system. In general, capital costs and annual operating costs were lower for sites at which chlorinated solvents are present, alone or with other volatile organic compounds (VOCs), than for sites at which other combinations of contaminants (such as VOCs with metals) are present. For sites at which complex combinations are present, it generally was necessary to use more complex aboveground treatment systems.
- The types of above-ground treatment affect the annual operating costs of a P&T system. For P&T sites at which chlorinated solvents are present, alone or with other VOCs, and at which air stripping or granular activated carbon (GAC) treatment only are used, annual operating costs were lower than for sites at which the same contaminants are present but a wider variety of treatment technologies are used. The additional treatment technologies sometimes require additional labor and use of both chemicals and energy.
- For the sites in this analysis, the capital costs for PRBs generally were lower than those for P&T systems. Decisions about whether a PRB or P&T system would be less expensive for a given site generally are based on total life-cycle costs for each type of system (including total capital and operating costs); such site-specific factors as hydrogeology, contaminant type, extent of contamination, and remedial goals often are considered in making such decisions. In addition, PRBs may not be technically feasible at all sites.

The FRTR includes senior executives of eight agencies that have an interest in exchanging information about remediation technologies. Primary members include the U.S. Departments of Defense, Energy, and the Interior, and EPA. Other participants include the Nuclear Regulatory Commission, the National Aeronautics and Space Administration, the Tennessee Valley Authority, and the U.S. Coast Guard. Information about the Roundtable is available through the FRTR's web site at <*www.frtr.gov*>. Information about the P&T sites was obtained from FRTR case studies.

The RTDF includes members representing industry, government, and academia who have an interest in identifying steps government and industry can take together to develop and improve the environmental technologies needed to address their mutual cleanup problems in the safest, most cost-effective manner possible. Information about the RTDF is available through the RTDF's web site at <*www.rtdf.org*>. Information about PRB sites was obtained primarily from an RTDF report; limited information was obtained from FRTR and other sources.

- Economies of scale were observed when the P&T system treats relatively large volumes of groundwater. For systems treating more than 20 million gallons of groundwater per year, capital and annual operating costs per volume of groundwater treated per year appear to be lower than those costs for systems treating less than 20 million gallons per year.

CRITERIA FOR SELECTING SITES FOR ANALYSIS

Exhibit 2 provides a description of P&T and PRB technologies. In selecting sites for this analysis, the available FRTR and RTDF case studies were screened using the following criteria:

- The P&T or PRB system was operated on a full-scale basis (rather than as a pilot-scale or field demonstration).
- For P&T sites, information was available about the capital cost, the annual average operating cost, and the amount of groundwater treated per year of system operation; for PRB sites, information was available about the capital cost.
- For P&T sites, aquifer cleanup goals (not containment-only goals) had been established.

For the analysis, 48 sites were identified (32 P&T sites and 16 PRB sites, including one site at which a PRB replaced a P&T system), as shown in Exhibit 1.

EXHIBIT 1. ALPHABETICAL LIST OF SELECTED SITES

Site Name	
P&T Sites (32)	
Amoco Petroleum Pipeline, Michigan	Mystery Bridge at Highway 20 Superfund Site, DOW/DSI,
Baird and McGuire Superfund Site, Massachusetts	Odessa Chromium I Superfund Site, OU 2, Texas
Bofors Nobel Superfund Site, OU 1, Michigan	Odessa Chromium IIS Superfund Site, OU 2, Texas
City Industries Superfund Site, Florida	Old Mill Superfund Site, Ohio
Des Moines TCE Superfund Site, OU 1, Iowa	SCRDI Dixiana Superfund Site, South Carolina
Former Firestone Facility Superfund Site, California	Site A (confidential Superfund site), New York
Former Intersil, Inc. Site, California*	Sol Lynn/Industrial Transformers Superfund Site, Texas
French Limited Superfund Site, Texas	Solid State Circuits Superfund Site, Missouri
Gold Coast Superfund Site, Florida	Solvent Recovery Services of New England, Inc. Superfund Site,
JMT Facility RCRA Site (formerly Black & Decker), New York	Sylvester/Gilson Road Superfund Site, New Hampshire
Keefe Environmental Services Superfund Site, New Hampshire	Twin Cities Army Ammunition Plant Superfund Site (TCAAP),
King of Prussia Technical Corporation Superfund Site, New	United Chrome Superfund Site, Oregon
LaSalle Electrical Superfund Site, Illinois	U.S. Aviex Superfund Site, Michigan
Libby Groundwater Superfund Site, Montana	U.S. Department of Energy (DOE) Kansas City Plant, Missouri
McClellan Air Force Base Superfund Site, OU B/C California	U.S. DOE, Savannah River site, A/M Area, South Carolina
Mid-South Wood Products Superfund Site, Arkansas	Western Processing Superfund Site, Washington
PRB Sites (16)	
Aircraft Maintenance Facility, Oregon	Industrial Site, Northern Ireland
Caldwell Trucking, New Jersey	Industrial Site, South Carolina
Federal Highway Administration Facility, Colorado	Kansas City Plant, Missouri
Former Drycleaning Site, Germany	Lowry Air Force Base, Colorado
Former Intersil, Inc. Site, California*	Marzone Inc./Chevron Chemical Company, Georgia
Former Manufacturing Site, New Jersey	Nickel Rim Mine Site, Ontario, Canada
Industrial Site, Kansas	U.S. Coast Guard Support Center, North Carolina
Industrial Site, New York	Y-12 Site, Oak Ridge National Laboratory, Tennessee

*Both a PRB and a P&T system were operated at the former Intersil site.

EXHIBIT 2. SELECT GROUNDWATER TREATMENT TECHNOLOGIES

Pump and Treat (P&T)

P&T involves extracting contaminated groundwater through recovery wells or trenches and treating the groundwater by *ex situ* (aboveground) processes, such as air stripping, carbon adsorption, biological reactors, or chemical precipitation. Variables in the design of a typical P&T system include:

- The number and pumping rate of groundwater extraction points (determined by such factors as the extent of contamination and the productivity of the contaminated aquifer)
- The *ex situ* treatment processes employed (determined by such factors as system throughput and the contaminants that require remediation)
- The discharge location for the effluent from the treatment plant (determined by such factors as location of the site and regulatory requirements)

Additional information about the fundamentals of P&T technology can be found in *Design Guidelines for Conventional Pump-and-Treat Systems*.

Permeable Reactive Barriers (PRBs)

A PRB is an *in situ* (below-ground) treatment zone of reactive material that degrades or immobilizes contaminants as groundwater flows through it. PRBs are installed as permanent, semi-permanent, or replaceable units across the flow path of a contaminated plume. Natural gradients transport contaminants through strategically placed media. The media degrade, sorb, precipitate, or otherwise remove groundwater contaminants. The choice of the reactive media for a PRB is based on the specific organic or inorganic contaminant to be remediated. Most PRBs installed to date use zero-valent iron (Fe^0) as the reactive medium for converting contaminants to nontoxic or immobile species. Other applications under development use limestone, organic carbon, or bone char phosphate. The hydrogeologic setting at the site also is crucial; PRBs are best applied to shallow, unconfined aquifer systems in unconsolidated deposits, as long as the reactive material is more conductive than the aquifer.

Most PRBs are installed in one of two basic configurations: funnel-and-gate or continuous trench, although other techniques such as hydrofracturing also are used. The funnel-and-gate system employs impermeable walls to direct the contaminated plume through a gate, or treatment zone, that contains the reactive media. In a continuous trench configuration, a trench is installed across the entire path of the plume and is filled with reactive media. Most PRBs installed to date have had depths of 50 feet (ft) or less. PRBs having depths of 30 ft or less can be installed with a continuous trencher, while those installed at depths between 30 and 70 ft require a more innovative installation method, such as biopolymers. Installation of PRBs at depths greater than 70 ft is more challenging.

IMPORTANT DATA CONSIDERATIONS

Several important considerations related to the data and results presented in this report are listed below:

- The sites selected are not a statistically representative sample of groundwater remediation projects; rather, they present a range of the types of systems that are used to clean up groundwater at Superfund and RCRA corrective action sites.
- Cost data were provided by EPA remedial project managers (RPMs), site owners, or vendors; include both actual and estimated costs of groundwater cleanup; and were not verified independently by EPA.
- Groundwater cleanup has been completed at only two of the 32 P&T sites and is ongoing at the other P&T sites. For the 30 P&T sites where remediation is ongoing, the costs presented in this report do not necessarily represent the total cost of cleaning up groundwater at the site.
- Because groundwater cleanup is ongoing at most of the sites and the total time necessary to complete cleanup is not known, this report presents the average annual operating costs rather than the total operating costs incurred during site remediation. Likewise, no net present value (NPV) was calculated for the remedial costs because additional costs will be incurred at sites at which remediation is ongoing, and the length of time each system will operate in the future is not known. Rather, costs are presented as unit costs (cost per year or cost per 1,000 gallons). The unit costs are described in more detail later in this report.
- The costs for PRB and P&T systems presented in this report may include costs for source control remedies (such as slurry walls) employed at the sites, when the source control was an integrated part of the groundwater cleanup. Exhibits 10 and 11 present the components included in the costs for each of the sites included in this analysis.

METHODOLOGY FOR EVALUATING THE COSTS OF P&T AND PRB TECHNOLOGIES

Total capital and total annual operating costs were provided in the individual case studies by EPA RPMs, site owners, and vendors. For this analysis, the following methodology was used to calculate unit costs and adjusted costs for the 48 sites.

Unit Costs

There are several ways in which unit costs can be calculated for groundwater remediation systems. The following three types of unit costs were used in this analysis:

- ***Average operating cost per year of operation:*** This value was calculated by dividing the total operating cost to date by the number of years represented by that cost. Several factors affect the average operating cost per year, including throughput of the system, the treatment processes required to treat the extracted groundwater, and the operating efficiency of the system. Because a breakdown of annual operating costs by year was not available for most of the sites, the change in operating costs over the life of a site's remediation system could not be evaluated.
- ***Capital cost per 1,000 gallons of groundwater treated per year:*** This value represents the relative costs of installing remedial systems of various capacities, and is influenced by such factors as:
  - the complexity of the aquifer (which affect the size and complexity of the system needed to extract the contaminated groundwater)
  - the types of contaminants targeted for treatment at the site (which affect the components of the treatment plant needed to remove the contaminants)
  - the water and air discharge limits for the particular site (which affect the treatment plant components needed)
  - restoration goals (which affect the time frame for cleanup)
- ***Average annual operating cost per 1,000 gallons of groundwater treated per year:*** This value represents the relative costs of operating systems of various capacities and complexities. Similar to the capital cost per 1,000 gallons of groundwater treated per year, this unit cost is highly dependent on such site-specific factors as the complexity of the aquifer, the types of contaminants targeted for treatment, the water and air discharge limits, and the restoration goals.

Adjusted Costs

Remediation costs for the selected sites were adjusted for the location of the site (location adjustment) and for the years in which costs were incurred (inflation adjustment). Those adjustments are described below and in Appendix A to this report. Appendix A presents the equations used to adjust the total capital and total annual operating costs; gives equations used to calculate the average annual operating costs; and shows example calculations for one of the sites.

- ***Location adjustment:*** Costs were adjusted for location by multiplying the costs provided for each site by an Area Cost Factor (ACF) Index published by the U.S. Army Corps of Engineers in PAX Newsletter No. 3.2.1, dated March 31, 1999 and available at <*http://www.hq.usace.army.mil/cemp/e/es/pax/paxtoc.htm*>.
- ***Inflation adjustment:*** The inflation factor used for this analysis was based on the Construction Cost Index published by Engineering News Record. The most current year that had an annual average inflation adjustment factor available at the time of preparing this report was for 1999. Costs were adjusted to year 1999 dollars by multiplying the costs provided for each site by an inflation adjustment factor for the year in which the costs were incurred. For capital cost time adjustment, the inflation adjustment factor for the actual year that the costs were incurred was used. For annual operating cost time adjustment, the inflation adjustment factor for the median year of all years over which the costs were incurred was used. The Construction Cost Index is available at *http://www.enr.com/cost/costcci.asp.*

RESULTS AND CONCLUSIONS

This analysis considered six main factors that affect the cost of P&T and PRB technology applications (discussed in reference 1): (1) characteristics or properties of contaminants present, (2) system design and operation, (3) source control, (4) hydrogeologic setting, (5) extent of contamination, and (6) remedial goals. The analysis found that the costs varied significantly between sites and that many of the factors that affect costs are site-specific. In addition, the amount of information available about each of the factors varied by site. For the analysis, general conclusions were identified about the effect of a factor when information related to that factor was available for five or more sites.

Exhibits 3 through 9 present the results of the cost analysis for the 48 sites, with detailed data for each site summarized in Exhibits 10 and 11 for P&T and PRB sites, respectively. Exhibit 3 provides an overall summary of the remedial cost and unit cost data for the 48 sites included in the analysis, while Exhibits 4 through 9 present 25th percentile, 50th percentile (median), 75th percentile, and average costs, based on the types of contaminants present, the technologies used, and the volume of groundwater treated each year. General conclusions about the effect of contaminant property factors and system design and operation factors are presented below.

EXHIBIT 3. SUMMARY OF REMEDIAL COST AND UNIT COST DATA FOR 48 SITES

Cost Category	P&T Sites (32 Sites)				PRB Sites (16 Sites)			
	25th Percent.	Median	75th Percent.	Average	25th Percent.	Median	75th Percent.	Average
Years of system operation (with data available)	4	5	8	6	NC	NC	NC	NC
Average volume of groundwater treated per year (1,000 gallons per year)	7,000	30,000	100,000	120,000	NC	NC	NC	NC
Total capital cost ($)[1]	1,700,000	2,000,000	5,900,000	4,900,000	440,000	680,000	1,000,000	730,000
Average operating cost per year ($ per year)[1]	180,000	260,000	730,000	770,000	NC[2]	NC[2]	NC[2]	NC[2]
Capital cost per volume of groundwater treated per year ($/1,000 gallons per year)[1]	23	78	350	280	NC	NC	NC	NC
Average annual operating cost per volume of groundwater treated per year ($/1,000 gallons per year)[1]	5	16	41	32	NC	NC	NC	NC

Source: FRTR and RTDF; refer to Exhibit 1 for a list of sites.

[1] All reported costs were adjusted for site locations and years in which costs were incurred, as described in the text.

[2] Two of the case studies at PRB sites (Intersil and USCG) included annual operating costs for the PRB systems. Those costs are presented in Exhibit 11.

NC = Not calculated; insufficient data available.

Contaminant property factors:

Contaminant properties affect the cost of groundwater remediation systems. These properties define (1) the relative ease with which contaminants can be removed from the extracted groundwater (by *ex situ* treatment technologies), (2) the steps that are required to treat the groundwater, and (3) the complexity of the mixture of contaminants. Sites analyzed on the basis of contaminant property factors included sites contaminated with chlorinated solvents, alone or with other VOCs, and sites at which other combinations of contaminants were present. On the basis of site-specific data, the following conclusions can be made about contaminant property factors:

- The type of contaminant groups in the groundwater affects both the capital and the annual operating cost of a P&T system, as shown in Exhibit 4. For sites with chlorinated solvents alone or with other VOCs (such as ethers or ketones), capital costs were lower than those for sites with other combinations of contaminants (such as chlorinated solvents, BTEX, metals, PCBs, or PAHs). The median capital cost for P&T systems removing chlorinated solvents, alone or with other VOCs, is $1,900,000, as compared with a median capital cost of $7,400,000 for P&T systems removing other combinations of contaminants. The type of contaminant groups in the groundwater has similar effects on the annual operating cost of a P&T system. Sites at which chlorinated solvents, alone or with other VOCs, were present had lower annual operating costs than sites at which other combinations of contaminants were present. The median annual operating cost for P&T systems removing chlorinated solvents alone, or with other VOCs, is $12 per 1,000 gallons treated, as compared with a median annual operating cost of $39 per 1,000 gallons treated for P&T systems removing other combinations of contaminants.

EXHIBIT 4. COST COMPARISON OF P&T SYSTEMS THAT TREAT VARIOUS CONTAMINANT GROUPS

Contaminant Group	Cost Range			Average Cost	Number of Sites
	25th Percentile	Median	75th Percentile		
Total Capital Cost[2]					
Chlorinated solvents, alone or with other VOCs	$1,200,000	$1,900,000	$4,400,000	$3,600,000	18
Other combinations of contaminants (solvents, BTEX, metals, PCBs or PAHs)[1]	$4,300,000	$7,400,000	$15,000,000	$8,900,000	9
Average Annual Operating Cost per 1,000 Gallons Treated[2,3]					
Chlorinated solvents, alone or with other VOCs	$3	$12	$40	$26	18
Other combinations of contaminants (solvents, BTEX, metals, PCBs or PAHs)[1]	$10	$39	$61	$53	9

[1] The costs of P&T systems that treat only metals or only BTEX are not included in this exhibit because data were available for only three such systems. General conclusions were developed about the effect of a factor when information about that factor was available for five or more sites.

[2] All reported costs were adjusted for site locations and years in which costs were incurred, as described in the text.

[3] The average volume of groundwater treated per year for the 18 sites at which chlorinated solvents, alone or with other VOCs, were present and the nine sites at which a combination of contaminants were present are 160,000,000 and 65,000,000 gallons, respectively.

- The type of above-ground treatment affects the annual operating cost of a P&T system. For sites contaminated with chlorinated solvents, alone or with other VOCs, Exhibit 5 compares the annual operating costs of treatment systems using air stripping or GAC only with annual operating costs of treatment systems using a wider variety of treatment technologies. For P&T sites for which remedial cleanup goals had been established for chlorinated solvents, alone or with other VOCs, and using air stripping or GAC treatment only, annual operating costs were lower than those for sites for which remedial cleanup goals had been established for the same contaminants but at which other combinations of treatment technologies, such as biological treatment or filtration, were used. The median average annual operating cost for P&T systems removing chlorinated solvents with air stripping or GAC only is $3 per 1,000 gallons treated. The median average annual operating cost for P&T systems removing the same contaminants with other combinations of treatment technologies is $40 per 1,000 gallons treated. At sites for which remedial cleanup goals had been established for chlorinated solvents, alone or with other VOCs, treatment technologies besides air stripping or GAC may be necessary because other substances present in the groundwater may inhibit the effectiveness of the air stripping or GAC units. For example, at Sol Lynn, the initial treatment system included an air stripper and GAC unit only. However, an iron filter was added to the treatment train to minimize fouling of the packing of the air stripper. Such additional treatment technologies may require additional labor and use of chemicals or electricity.

EXHIBIT 5. ANNUAL OPERATING COST COMPARISON OF VARIOUS P&T TECHNOLOGIES AT SITES CONTAMINATED WITH CHLORINATED SOLVENTS, ALONE OR WITH OTHER VOCs

Treatment Technology	Average Annual Operating Cost per 1,000 Gallons Treated[1,2]			Number of Sites
	25th Percentile ($)	Median ($)	75th Percentile ($)	
AS and/or GAC treatment only	2	3	12	11
Other combination of treatment technologies (see Exhibit 10)	28	40	41	7
All sites with chlorinated solvents, alone or with other VOCs	3	12	40	18

[1] All reported costs were adjusted for site locations and years when costs were incurred, as described in the text.

[2] The average volume of groundwater treated per year for the 11 sites at which air stripping (AS) or granular activated carbon (GAC) was used, the 7 sites at which other combinations of treatment technologies were used, and the 18 sites at which chlorinated solvents alone or with other VOCs, were present are 260,000,000; 19,000,000; and 160,000,000 gallons, respectively.

System design and operation factors:

The cost of a groundwater remediation system is affected by a number of factors including the type of treatment technologies used to remediate the site, the adequacy of a system design to remediate the site, system downtime, system optimization efforts, the amount and type of monitoring performed, and the use of multiple primary treatment technologies (for example, P&T and an *in situ* technology). On the basis of site-specific data, the following conclusions can be made about system design and operation factors:

- For the sites included in the analysis, the total capital costs for PRBs generally were lower than those for P&T systems. As demonstrated in Exhibit 6, the 75th percentile of total capital costs for the 16 PRB projects ($1,000,000) was less than the 25th percentile of total capital costs for the 32 P&T projects ($1,700,000). The data included in the analysis show that the total capital cost of a very large PRB may approach the total capital cost of a small P&T system. In addition, the median total capital cost for the 32 P&T projects is $2,000,000; the median total capital cost for the 16 PRB projects is $680,000. Decisions about whether a PRB or P&T system would be less expensive for a given site generally are based on total life-cycle costs for each type of system; such site-specific factors as hydrogeology, contaminant type, extent of contamination, and remedial goals should be considered in making those decisions. Further, PRBs may not be feasible at every site; therefore, a comparison of P&T and PRB systems may not be appropriate for a given site.

EXHIBIT 6. CAPITAL COST COMPARISON OF P&T AND PRB SYSTEMS

Technology	Capital Cost Range[1]			Average Capital Cost[1] ($)	Number of Sites
	25th Percentile ($)	Median ($)	75th Percentile ($)		
P&T	1,700,000	2,000,000	5,900,000	4,900,000	32
PRBs	440,000	680,000	1,000,000	730,000	16

[1] All reported costs were adjusted for site locations and years when costs were incurred, as described in the text

- Two of the case studies at PRB sites included annual operating costs for the PRB systems. The adjusted annual operating costs for the PRBs at those sites are $75,000 at the U.S. Coast Guard site and $120,000 at the Intersil site. The annual operating costs included in the analysis are those for relatively new PRB systems, and operating costs included monitoring costs only; maintenance was not required during the period of operation for which data were available. As a PRB system ages, maintenance of the system may be required, including replacement of the exhausted reactive medium and other repairs of the PRB system. Decisions about whether a PRB or a P&T system would be less expensive would include an analysis of total life-cycle costs for each type of system. Again, such site-specific factors as hydrogeology, contaminant type, extent of contamination, and remedial goals should be considered in making those decisions.

- Economies of scale were observed when relatively large volumes of groundwater were treated annually by a P&T system. For sites at which more than 20 million gallons of groundwater per year are treated, the capital and annual operating costs per volume of groundwater treated per year appear to be lower than at sites where 20 million gallons or less are treated per year. As Exhibit 7 shows, the median capital costs per volume of groundwater treated per year for P&T sites at which 20 million gallons or less are treated per year and for those at which more than 20 million gallons are treated per year are $440 per 1,000 gallons per year and $24 per 1,000 gallons per year, respectively. The data show a similar trend in annual operating costs per volume of groundwater treated per year. The median average annual operating costs per volume of groundwater treated per year for P&T sites at which 20 million gallons or less are treated per year and for those at which more than 20 million gallons are treated per year are $42 per 1,000 gallons per year and $5 per 1,000 gallons per year, respectively.

  Exhibits 8 and 9 show the distribution of the unit capital costs and the average annual operating costs for the P&T sites included in the analysis, respectively, as a function of volume of groundwater treated per year. For sites at which more than 20 million gallons per year are treated, operating and capital costs are lower than costs for sites at which 20 million gallons or less per year are treated. Unit costs vary more for sites at which 20 million gallons or less per year are treated than for sites at which 20 million or more gallons per year are treated. Because of the variability in the costs, these data are not intended for use in making estimates of costs for other sites.

EXHIBIT 7. COMPARISON OF UNIT TREATMENT COST FOR P&T SITES WITH VOLUME TREATED PER YEAR

Size of Treatment System Size (1,000 gallons/year)	Cost Range			Average Cost	Number of Sites
	25th Percentile	Median	75th Percentile		
Capital Cost Per Volume of Groundwater Treated Per Year ($/1,000 gallons/year)[1]					
≤ 20,000	$200	$440	$730	$580	14
> 20,000	$14	$24	$62	$49	18
Average Annual Operating Cost Per Volume of Groundwater Treated Per Year ($/1,000 gallons)[1,2]					
≤ 20,000	$33	$42	$64	$62	14
> 20,000	$3	$5	$7	$10	18

[1] All reported costs were adjusted for site locations and years when costs were incurred, as described in the text.

[2] The average volume of groundwater treated per year for the 14 sites treating 20 million gallons or less of groundwater annually and the 18 sites treating more than 20 million gallons of groundwater annually are 7,800,000 and 200,000,000 gallons, respectively.

Other Factors - Source control, hydrogeology, extent of contamination, and remedial goals also can have a significant effect on remediation costs; however, insufficient data were available to develop quantitative conclusions about the effects of those factors on the costs for the sites included in the analysis.[1] Several site-specific examples are presented below to demonstrate how each of those factors increase or decrease costs for a particular site. The examples listed below compare remediation costs for P&T sites at which the groundwater is contaminated with chlorinated solvents, alone or with other VOCs. The examples also are presented in Exhibits 10 and 11, which include costs and information about the factors that affect the costs for all 48 sites included in the analysis.

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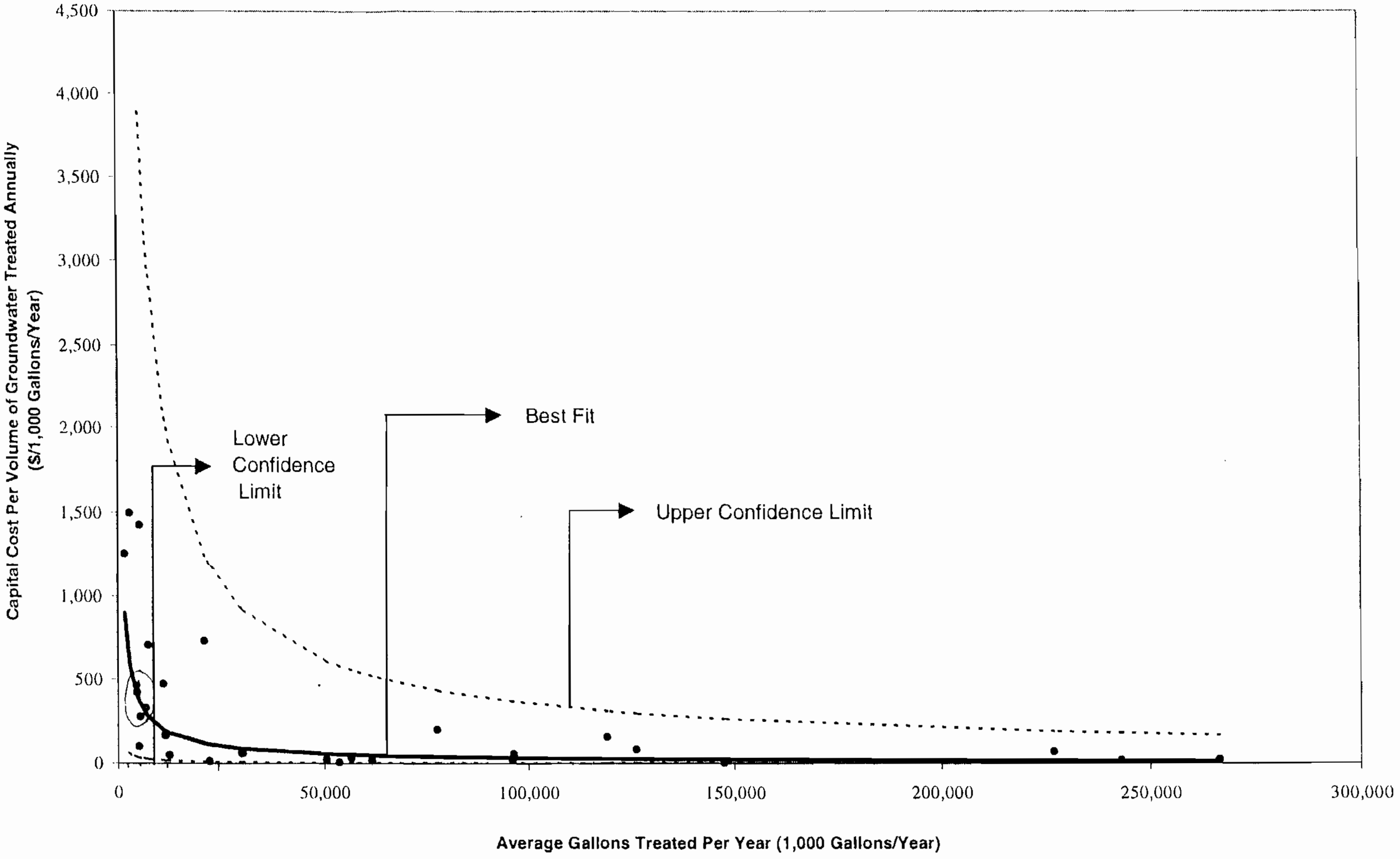
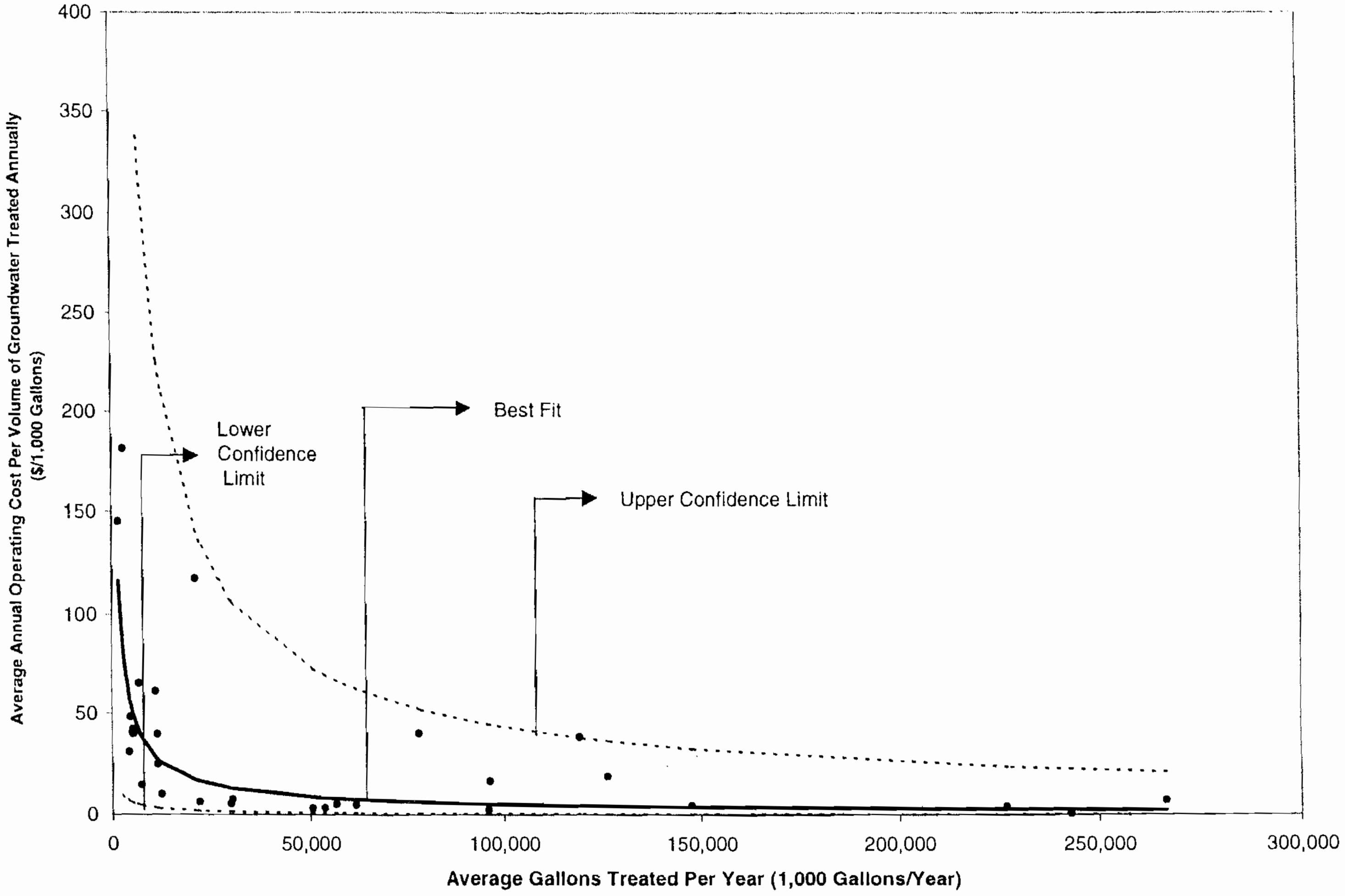
[1] *There are several tools available that are used to estimate the costs for use of groundwater (and other) cleanup technologies, and that address these types of factors. Tools include products such as RACER and RS Means®. Additional information on these products is available through the RACER and RS Means® web sites, at <www.talpart.com/products/racer/racerabout.html> and <www.rsmeans.com>, respectively.*

EXHIBIT 8. CAPITAL COST FOR PUMP AND TREAT SYSTEMS AS A FUNCTION OF QUANTITY TREATED PER YEAR



1. All reported costs were adjusted for site locations and years when costs were incurred, as described in the text.
2. This chart shows a solid line based on a best fit of the available data for the 32 P&T sites, and dashed lines for the upper and lower confidence intervals using a 95% degree of confidence. The lines were drawn based on the results from a statistical analysis of the available data, using SAS JMP software; the specific methodology used to draw the lines is described more fully in the EPA report titled "Year 2000 Remediation Technology Cost Compendium" (under preparation by EPA's Technology Innovation Office). This chart shows an expanded view of the data points within the ranges shown, and does not include several sites that are treating more than 300,000 gallons per year.

EXHIBIT 9. ANNUAL OPERATING COST FOR PUMP AND TREAT SYSTEMS AS A FUNCTION OF QUANTITY TREATED PER YEAR



1. All reported costs were adjusted for site locations and years when costs were incurred, as described in the text.
2. This chart shows a solid line based on a best fit of the available data for the 32 P&T sites, and dashed lines for the upper and lower confidence intervals using a 95% degree of confidence. The lines were drawn based on the results from a statistical analysis of the available data, using SAS JMP software; the specific methodology used to draw the lines is described more fully in the EPA report titled "Year 2000 Remediation Technology Cost Compendium" (under preparation by EPA's Technology Innovation Office). This chart shows an expanded view of the data points within the ranges shown, and does not include several sites that are treating more than 300,000 gallons per year.

Source control factors:

The method, timing of application, and success of source controls in mitigating contact of non-aqueous phase liquids (NAPLs) or other sources of contaminants, such as highly contaminated soil, with groundwater affect the cost of groundwater remediation systems. At several sites, efforts were made to remove NAPL or isolate the NAPL from contact with the groundwater. Such efforts often involved significant capital expenditures. For example, at Western Processing, both dense non-aqueous phase liquids (DNAPLs) and light non-aqueous phase liquids (LNAPLs) were observed in the groundwater. A slurry wall was constructed around the site to contain the plume and NAPLs and help achieve the cleanup goals in a limited amount of time. Capital costs for construction of the slurry wall were approximately $1.8 million.

Hydrogeologic factors:

The cost of groundwater remediation systems is affected by the properties of the aquifer. These properties include hydraulic connection of aquifers that allows for contamination of more than one aquifer, aquifer flow parameters, influences of adjacent surface water bodies on the aquifer system, and influences of adjacent groundwater production wells on the aquifer system. The following example illustrates a specific case in which hydrogeological factors affected the cost of the groundwater remediation technology implemented at the site. At JMT, the hydraulic conductivity in the contaminated bedrock aquifer was relatively low (0.65 feet per day). To increase the hydraulic conductivity, controlled blasting was carried out to create an artificial fracture zone, which served as an interceptor drain in the bedrock around the extraction well. While that approach increased the capital cost of the system, it allowed effective extraction of the groundwater from the bedrock aquifer by one well screened in the new fracture zone.

Extent of contamination factors:

The magnitude of the contaminated groundwater plume, including the area and depth of the plume and the concentration of contaminants within the plume, affect the cost of groundwater remediation systems. Typically, groundwater contamination that is limited in area and depth is easier and cheaper to remediate than the same mass of contaminant when it extends deeper and spreads out over a larger area. This factor affects the size of the extraction and treatment system and the complexity of the system in terms of the quantity of groundwater to be extracted from the aquifer and treated *ex situ*. For example, at Gold Coast, the initial areal extent of the contaminated plume was estimated to be 0.87 acre, and the initial volume of the plume was estimated to be less than 3 million gallons. The site was remediated at a total cost of less than $800,000.

Remedial goal factors:

Regulatory factors affect the design of a remedial system or the period of time it must be operated. These factors include aquifer restoration or treatment system performance goals, and specific system design requirements (such as disallowing reinjection of treated groundwater or specifying the treatment technology to be used). For example, at Western Processing, a P&T system, consisting of more than 200 groundwater extraction points pumping approximately 265 gpm, was installed. After approximately seven years of operation, an ESD was issued to change the focus of remediation efforts from restoration to containment. Because of that change, the system was modified to a system pumping approximately 80 gpm, which significantly reduced operating costs for the system.

NOTICE AND DISCLAIMER

This report was prepared by EPA's Technology Innovation Office with support provided under Contract Number 68-W-99-003. Information in this report is derived from a variety of references (including personal communications with experts in the field), some of which have been peer-reviewed. This report has undergone EPA and external review by experts in the field. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. For more information about this report, please contact: Linda Fiedler, U.S. EPA, Technology Innovation Office, Ariel Rios Building, 1200 Pennsylvania Ave., N.W. (MS 5102G), Washington, D.C., 20460; (703) 603-7194; e-mail: *fiedler.linda@epa.gov.*

United States
Environmental Protection
Agency

Office of
Solid Waste and
Emergency Response

Publication 9200.5-223FS
EPA 540/F-95/030
PB95-963315
April 1996

EPA

Engineering Forum Issue Paper:
Soil Vapor Extraction Implementation Experiences

Office of Emergency and Remedial Response

Quick Reference Fact Sheet

This fact sheet identifies issues and summarizes experiences with soil vapor extraction (SVE) as a remedy for volatile organic compounds (VOCs) in soils. The issues presented here reflect discussions with over 30 Remedial Project Managers (RPMs) and technical experts. This fact sheet has been developed jointly by the the Engineering Forum and Office of Emergency and Remedial Response, with assistance from the Office of Research and Development. Special thanks are due to Robert Stamnes (Engineering Forum Co-Chair), John Blanchard (OERR), David Becker (USACE), and Dom DiGiulio (ORD). EPA's Engineering Forum is a group of professionals, representing EPA's Regional Offices, who are committed to identifying and resolving the engineering issues related to remediation of Superfund and hazardous waste sites. The Forum is sponsored by the Technical Support Project. The information presented here is advisory in nature, should be verified for its applicability to a given site, and is not intended to establish Agency policy. RPMs should consult their regional management before applying the recommendations cited in this paper for appropriateness at their site.

Soil vapor extraction (SVE) is a commonly used technology for VOCs in soils that EPA has selected as a "presumptive remedy" (see bibliography at the end of this paper). SVE is an *in situ* treatment technology that uses vacuum blowers and extraction wells to strip volatile compounds from unsaturated soil. The extracted vapors are treated at the surface and released to the atmosphere or reinjected into the subsurface. The extraction wells typically are constructed of polyvinyl chloride (PVC) pipe, which is screened through the area of contamination. Emissions from the SVE process often are filtered by activated carbon, or treated either by thermal destruction or condensation refrigeration, before being released into the air. Consult the bibliography at the end of this fact sheet for additional details.

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Site Characterization

Before remedial technologies for soil treatment can be evaluated, a site investigation should be conducted to characterize the soils and other site features.

Two major factors determine SVE's effectiveness: soil permeability and constituent volatility. Pertinent soil measures include hydraulic conductivity, soil vapor components, gas permeability, and soil moisture content. SVE is generally less practical in moist, silty or clayey soils. Pertinent measures of volatility include vapor pressure, water solubility, boiling point, and Henry's Law constant (chemicals with a dimensionless vapor pressure of greater than 0.5 mm Hg and a Henry's Law constant greater than 0.01 generally are expected to respond to SVE). Other important factors are depth to the water table, potential for water table upwelling, site structures, subsurface obstructions, and the presence of dense nonaqueous phase liquids (DNAPLs).

Site investigation should begin with geophysical methods (electromagnetic survey or ground-penetrating radar) to determine the presence and location of non-aqueous phase liquids, follow with soil-gas monitoring to locate hot spots, and conclude with soil-matrix sampling to determine the full extent of contamination and establish cleanup levels. Bench- and field-scale studies may be needed to determine treatability. The cost of sampling the soil matrix can be reduced by using a hydropunch or cone penetrometer equipped with sensing devices.

One example illustrates the importance of adequate site characterization in heterogeneous soil conditions. At the site, a continuous rock layer was discovered several years after SVE had been implemented. The rock layer prevented the vacuum from reaching the deep soils. The system was modified by adding horizontal wells, and has reached asymptotic contaminant levels after six years of operation.

At another site, the hydraulic conductivity of soils was low, and varied by an order of magnitude. In the vadose zone, air permeability (which characterizes a soil's resistance to gas flow) was higher than hydaulic conductivity (resistance to liquid flow) and varied by only 30 percent. This information allowed the selection of SVE. Without the air permeability data, SVE would have been ruled out due to the low and widely varying hydraulic conductivity of the site soils.

When a shallow water table is present, it is particularly important to investigate the potential for groundwater upwelling (which can result in removal of less vapor and more water) and its effects on SVE (see the discussion on the effects of moisture on contaminant removal by granular activated carbon (GAC) systems in the *Implementation and Air Emissions Control* section of this fact sheet).

At a wetlands site that had been capped since the early 1980s, a treatability test had to be cut short because of high concentrations of methane in the extracted air. The methane was believed to result from the decomposition of organic matter under the cap. The final design must include appropriate treatment based upon the predicted level of methane. Note that a buildup of methane in a SVE system can pose a serious explosion risk; another remedy may be more appropriate.

A cap covering another site had been in place for some time prior to the SVE system installation. The contaminants initially present at the site were trichloroethane (TCE) and perchloroethane (PCE). Subsequent sampling beneath and along the edges of the cap revealed that anaerobic conditions under the cap had reduced the initial compounds to vinyl chloride. For this reason, the potential for biodegradation of contaminants should be considered when evaluating the use of caps to enhance SVE systems. Vinyl chloride is a very toxic compound that can be released into the air or groundwater.

Determination of Cleanup Levels

Soil criteria and air quality regulations applicable to SVE operations may vary substantially among states, and sometimes between localities within the same state. Accordingly, specific cleanup criteria should be established before SVE or any cleanup technology is chosen.

Some RPMs caution that because SVE is implemented easily and initially may yield good results, it may be selected without adequate attention to setting achievable soil cleanup levels. In many cases, it may be difficult to reach cleanup levels close to background using SVE, because of unsuspected subsurface variability or other limiting factors.

Pilot Testing

Pre-design pilot testing is highly recommended to "fine tune the system" and identify potential problems before final design. Pilot tests may reveal contaminants or areas of contamination that were not identified previously, even at sites where comprehensive remedial investigations have been conducted. Currently, most pilot testing is conducted after the record of decision (ROD) has been signed, at the pre-design stage. Several RPMs believe that advancing the initial pilot test to the remedial investigation stage would be beneficial, and would accord better with the concepts of the Superfund Accelerated Cleanup Model (SACM) and the presumptive remedies initiatives.

Soil-column testing may be useful for SVE implemenation. This laboratory test uses representative soils from a prospective site to determine the minimum time to reduce the concentrations of VOCs in the soil matrix. It measures the number of soil pore volumes of air that must be passed through a column of contaminated soil to achieve the desired contaminant level. That number is divided by the number of soil pore volumes of air that can be extracted from the site in one year, yielding the number of years to clean up the site. The estimated cleanup time is an important factor in determining the cost and effectiveness of any cleanup technology. Column testing can underestimate the time for remediation if the site is heterogenious, and may overestimate the time for remediation due to faster air flow through the column. This can make it difficult to transfer the information from column tests to field situations.

Because the air pollution control system was not pilot-tested at one site at the same time as soil-air permeability, the VOC concentration in the discharge was higher than expected once the system began operations. Due to the higher concentrations, the system could operate at only 10 percent of its design flow capacity and still meet emission standards. Adequate pilot testing would have revealed this design flaw.

System Design

Models can be used during the design stage to predict a system's performance under varying conditions. There are many models available; Air 3D is a commonly used numeric air flow model. Many other models are available, but there is no consistent pattern of use for these models. Several RPMs also suggest modeling be used to troubleshoot an operating SVE system. For example, when actual results did not match the projections at one site, a model was used to locate the source of contaminant loss in the system.

Some models are conservative and may not reflect true site conditions (such as adjacent or overlying buildings or pavement). For example, one commonly used model assumes no cover, thereby overestimating the amount of infiltration that will percolate through the soil for a given rainfall, thus overestimating contaminant migration.

Several RPMs agreed that when models are used to design an SVE system, *the input parameters (air permeability; soil grain size) should reflect site-specific field conditions*. Otherwise, there is a potential for costly errors in the number and placement of wells. At one site, for example, a model programmed with default assumptions resulted in twice as many required wells than when the model was run using field measurements. This information should be collected initially in order to avoid delays later.

Properly designed pilot tests can provide data to optimize SVE system design. A pilot test at one site provided measurements to estimate the radius of influence of an extraction well and the preferential air flow paths. The setup included one vertical extraction well and several soil vapor probe nests. Measurements at some probes indicated that the vacuum was greater farther away from the extraction well than at other probes. These data were helpful in identifying preferential flow paths, which were used to design the layout of the extraction wells. Nests of probes also provided data on the vertical variability of the subsurface, which helped to determine the screening intervals for the extraction wells. Another RPM observed that in certain soils, a small radius of influence for vapor extraction requires the installation of several nested wells for SVE to perform adequately. These wells should be installed with permeable packing materials.

Several RPMs recommend horizontal extraction trenches for SVE at sites with a shallow water table. A larger area is cleaned if the air flow is primarily horizontal. Surface seals are used to avoid drawing air from the atmosphere into the trenches. The potential for vertical short-circuiting is increased, however, by the greater permeability in the trenches after disturbing the soil. "Short-circuiting" is a phenomenon where injection air or extracted gasses follow geological fractures or other highly permeable zones instead of dispersing evenly throughout the target zone.

Depending on the characteristics of the site, different materials can be used to seal the surface. A flexible membrane liner (FML) can be rolled over the site and easily removed when the SVE treatment is complete. FMLs are readily available in a variety of materials, with high density polyethylene (HDPE) being the most common. The life of FMLs can be very short if exposed to sunlight. Alternatives to a synthetic membrane are clay or bentonite, which can be applied in any thickness. Clay liners are not as easily removed as the FMLs, and both types are susceptible to damage from personnel and equipment. A third alternative—the most common at commercial or industrial sites—is the use of a concrete or asphalt cap. This alternative works well at sites that have been paved or will be paved (for example, a gas station).

Air inlet wells, in conjunction with the extraction wells, prevent stagnant zones and improve air flow. At one site, valves on the inlet wells were used to control the air drawn into the soil. At another site, the soil to be treated was not very thick and horizontal extraction wells were used instead of vertical extraction wells. A ground surface seal prevented short-circuiting by ambient air, and air inlet wells were placed in areas of potential stagnation. A surface seal was necessary to eliminate preferential flow paths. To prevent stagnation, one RPM recommend-ed that the SVE system not be shut down for extended periods when a surface seal is installed. Stagnation may lead to anaerobic conditions, which may promote reduction of saturated chlorinated hydrocarbons to vinyl chloride.

SVE systems designed "from the ground up" may be more expensive to design and construct than "packaged" systems. Using a "packaged" system or reusing a successful system may reduce design and construction costs.

It may be beneficial to use a single company, whenever possible, for both the design and operation of the SVE system, because close collaboration is necessary before and during pilot testing. If this is not possible, you might have the designer prepare performance specificiations for the SVE system. The construction company then would be responsible to design and implement the system to meet specific output parameters. Communication and coordination especially are important when the design engineers and the operation engineers work under different contracts. The design engineers must retain responsibility for the system until it is operating smoothly.

System Enhancements

Air sparging injects clean air into the saturated zone, increasing aerobic biodegradation and promoting the physical removal of organics by direct volatilization. Air sparging should be considered when there are high concentrations of VOCs in, or immediately below, the capillary fringe area. Experts caution that air sparging can induce migration of vapors into nearby confined spaces or may cause nearby groundwater monitoring wells to show low levels of dissolved contaminants because of the volatilization of gas immediately around the well. SVE is used sometimes in conjunction with air sparging to remove contaminants from the vadose zone.

At one site, where air sparging was used to supplement SVE, its effectiveness depended upon the depth at which the aquifer was sparged. The results suggested that sparging was effective in the upper few feet of the saturated zone. The test also indicated that spreading of contaminants was not an issue, since the sparged zone was shallow. Pulsed SVE operation was used in conjunction with some of the sparging activities.

Sparging has appeared to be most effective in the mid-range permeability soils. Air sparging is less effective in soils with very high or very low permeability for two reasons: (1) air tends to move around low permeability regions (clay lenses) and (2) sandy soils or sand lenses can short-circuit the sparge influence zone.

Experts have identified several developing technologies that show potential for improving the effectiveness of SVE. These include thermal enhancement, dual phase extraction, pneumatic or hydraulic fracturing for tight soils, and co-metabolic processes. Experiences with system enhancements can be found in the EPA publication, *Soil Vapor Extraction Enhancement Technology Resource Guide* (see bibliography).

Implementation a nd Air Emissions Control

Implementation

At one site, a "phased" approach was used to implement SVE as an interim measure. Wells were first placed in areas in which the highest levels of contaminants were expected. Additional wells were added over time as the system's behavior became known. This remedial approach also involved using a skid-mounted system that was moved to different extraction locations. This maximized removal by permitting operators to adjust to variations in contamination and hydrogeologic conditions.

RPMs described several actual and potential site-specific problems experienced during SVE implementation. The SVE system at one site was shut down for two weeks during the winter due to unexpected freezing of above-ground piping. The problem was alleviated by installing insulation and explosion-proof heating cable around the piping.

Also, for systems over landfills, heat from subsurface decomposition could increase the potential for landfill fires.

Air Emissions Control

Vapor contaminants from SVE wells or trenches are captured by air pollution control equipment. Granular activated carbon (GAC) units are often used to remove the VOCs. At sites where high removal rates are needed due to high concentration, high flow rate, or both, the carbon absorbers may become saturated quickly; this must be considered during design. Many SVE systems initially exhibit high VOC removal rates due to flushing and evaporation. The VOC removal rate then drops to a constant level in which the mass transfer of the VOC contamination is controlled by diffusion.

The estimated mass of contaminant will influence the size and type of air pollution control system selected for an SVE system. Loadings to the air treatment system are sometimes estimated incorrectly because original concentrations of contaminants are not sustained over time. On the other hand, gross underestimates of the loading rates of contaminants on air pollution control systems may lead to health and safety problems. Excess heat buildup occurs in the GAC if the rate of contaminant accumulation is too great. At one site, carbon adsorption was initially installed as an emission control measure, but, due to a greater contaminant load than originally expected, the frequency of carbon replacement was greater than expected. The carbon adsorption unit had to be replaced by catalytic oxidation. After removal of the sources and the immediately surrounding contaminated soils, VOC concentrations in the remaining soils dropped to lower levels, and the system was switched back to carbon adsorption.

The adsorption capacity of GAC depends on several factors, including the VOC type, concentration, vapor temperature, and relative humidity. Isotherms, which show the mass of contaminants that can be adsorbed per unit mass of carbon at specified temperature intervals, are available from carbon vendors and may be used to predict contaminant-specific adsorption capacity for a specific charcoal-based carbon. GAC generally has a high affinity for volatile molecules, such as lighter hydrocarbons or chlorinated compounds. However, some hydrocarbons such as isopentane have relatively low adsorption capacities.

The relative humidity of the incoming vapor stream may limit the effectiveness of contaminant removal by GAC. Water vapor will occupy adsorption sites preferentially, thereby decreasing the capacity of the carbon to remove contaminants from the air stream. The heat generated by pumping and by the compression of vapors often results in an exhaust stream of elevated temperature. The off-gases from some vacuum systems must be cooled for efficient treatment prior to entering the carbon adsorption units.

Systems using a resin to adsorb VOCs have been reported to attain removal efficiencies similar to GAC. This type of system can be rented, thereby lowering capital costs. Vendors of air pollution technologies that compete with carbon adsorption may provide free technical assistance to ensure that their systems remain operational throughout the cleanup.

For one system that uses a resin, the VOCs are purged from the medium by an inert gas, such as nitrogen, and the contaminant is recovered as a condensate. At one site where this type of system was used, a recycler picked up the condensate for reuse. Storage of the condensate, which in some cases may be concentrated petroleum product, may introduce additional design considerations. For example, air monitoring or explosion-proof facilities in the storage area may be required.

Other technologies that have been used for SVE off-gas treatment are condensation, catalytic oxidation, incineration, cavitation, photo-oxidation, ultraviolet (UV) oxidation, titanium dioxide (TiO_2), internal combustion engines, packed-bed thermal processors, biofilters, reduction processes, and direct discharge.

Monitoring Extracted Vapor

RPMs and experts have recommended monitoring at the emission source by an electron capture device, continuous flame ionization detector, or photo-ionization detector. Periodically, source monitoring should be supplemented with perimeter monitoring. Involving the state's air permit group early in the process will expedite the permit process.

Special attention should be paid to the concentrations of oxygen in the extracted vapor. High levels of oxygen may indicate short-circuiting of the intended air flow through the system. Conversely, high levels of carbon dioxide may stem from biological degradation, which can be exploited by design changes in the SVE system. However, one specialist has stated that in alkaline soils, it may be inadvisable to use changes in concentrations of CO_2 to estimate biodegradation. Alkaline soils can absorb CO_2, and as a result, CO_2 formed as a byproduct of biological activity would not be measured in the vapor extracted from alkaline soils.

One potential source of error in sampling extracted vapors occurs when the sampling syringes used upstream from the air treatment system are diluted with ambient air due to the vacuum inside the SVE. The air entering the syringe can be reduced by capping the syringe immediately after it is withdrawn from the SVE sampling port or by using a stopcock. An alternative is to bring the sample to ambient pressure with filtered air and account for the dilution; this should be done before the syringe is capped. Still another approach is to use canister sampling, which allows the sample to be maintained at the initial pressure until analyzed.

Overall Performance of the SVE System

The growing interest in this *in situ* technology is due in part to its demonstrated effectiveness for removing volatile compounds, relatively low cost, low space requirements, and the apparent "simplicity" of the system's design and operation. However, its success may be limited by overlying structures or heterogeneous soils. Even if the SVE system quickly attains cleanup goals, post-performance monitoring may be required in case the system needs to be reactivated.

At one site, the SVE treatment system reportedly performed better than expected, taking less than one year to achieve cleanup goals rather than the expected two to five years. The initial concentration of PCE in a sandy soil at the site was as high as 1,300 ppm. In less than one year, soil samples demonstrated that the state's interim cleanup standards were reached. The negotiations between the PRP and the state were simplified because the state's interim soil cleanup standards provided a clear endpoint.

The ease with which SVE systems can be installed and operated obscures the complexity of vapor behavior in site-specific subsurface settings. At one site, analyses of SVE air effluent, and analyses of groundwater from wells in the vicinity of the SVE system, indicated that the radius of influence increased over time. The system was designed to extract carbon tetrachloride from the soil. Initially, only carbon tetrachloride was detected in effluent from the SVE system. However, after the system had been in operation for a while, trichloroethane (TCA), dichloroethene (DCE), and trichloroethylene (TCE) were detected in air and groundwater samples. The closest source of TCA, DCE, or TCE was more than 2,000 feet away, well beyond the previously determined radius of influences for the wells. Although the reasons for this phenomenon are not known, one explanation is that the SVE operation desiccated the soil over time, creating a preferential pathway to the second contamination source.

At some sites, there are indications that SVE may be remediating groundwater indirectly. During the time the SVE has operated at one site, for example, the concentrations of contaminants detected in groundwater have dropped significantly. It is uncertain whether this reduction is linked to the SVE or attributable to natural attenuation. At another site, the extent of a contaminated groundwater plume was reduced during SVE operation. The SVE may have contributed to the removal of contaminants from the groundwater by enhancing both partitioning and biodegradation of contaminants.

SVE has not achieved cleanup goals at all sites. The use of other technologies, such as the excavation of hot spots or technological enhancements (see page 4), in conjunction with SVE, may assist in achieving the desired cleanup goals.

Shutting Down the SVE System

Cleanup is usually considered complete when sampling indicates that residual contaminant levels in the soil are at or below those required. Confirmatory soil borings and soil gas samples usually are required prior to closure. Additional criteria for determining when an SVE system should be shut down include: the cumulative amount of contaminant removed, extraction well vapor concentrations, and soil gas contaminant concentration and composition.

When setting cleanup standards for SVE sites, it should be noted that immobile, high-molecular-weight compounds will not be removed by SVE and will remain in the soil.

Measuring extracted vapor concentrations gives an idea of the effectiveness of the system; however, a decrease is not necessarily strong evidence that soil concentrations have decreased. Decreases in vapor concentrations can be attributed also to such other phenomena as water table upwelling and short-circuiting. Monitoring extraction well vapor composition and concentration gives more insight into the effectiveness of the system. If the total vapor concentration decreases without a change in composition, then the decrease is most likely due to one of the phenomena listed above. If the decrease in concentration is accompanied by a shift to less volatile compounds, then there is probably a change in the residual contaminant concentration.

It is sometimes difficult to persuade state agencies to commit to shutting off SVE systems once acceptable levels of cleanup have been reached, because without long-term monitoring it is difficult to determine whether cleanup levels have been achieved permanently. Experts recommend that VOC measurements in the soil matrix be taken again after soil gas measurements have indicated that the SVE system has reached steady-state. If later measurements show that the target risk levels have not been achieved, it may be necessary to reconfigure the system or enhance it with other technologies such as biodegradation or capping.

The SVE system at another site was shut down when VOC levels in the soil gas met the air emission standards, and the groundwater concentrations met the maximum contaminant levels established for drinking water. However, after several months, the concentrations of contaminants rose above standards and the system was reactivated. Such a circumstance may occur because contaminants can diffuse slowly from less permeable soils and interact with soil gas and groundwater.

The operating life of one SVE system was based on its efficiency of removing contaminants relative to groundwater pumping and treatment. An analysis of this SVE system revealed that it was more cost-effective than pump-and-treat systems if it could remove more than 0.001 pounds per hour of the target contaminant. Therefore the decision was made to operate the SVE system until it could no longer exceed this rate of contaminant removal. When this occurred, the system was shut down.

At one site, monitoring of soil vapor indicated that the constant levels of removal of contaminant mass had been met, although pockets of tightly bound contaminant remained in the vadose zone and groundwater. Eventually the state consented to shut down the system, but required that two extraction wells be left in place as a contingency.

Community Involvement

RPMs suggest that cleanup levels should be defined as "goals" for the community early in the process. The community needs to be told that the "law of diminishing returns" may ultimately limit the amount of contamination that can be removed. As more and more contamination is removed from the soil, and as the remaining amounts of concentration of contaminants are lowered, the cost and time necessary to remove additional contaminants increases. For example, the time or cost to remove the last 10 percent of the original mass of contaminants could equal that required to remove the initial 80 to 90 percent of contaminants.

Community involvement at one SVE site was particularly active and innovative. At this site Regional staff provided a hazardous waste health and safety training course to anyone in the community who was interested. This training was attended by approximately 30 people. People from the community were also trained and hired to operate and maintain the SVE system and to collect environmental samples. EPA also established an analytical laboratory in the town for analysis of samples collected at the site. The community involvement effort associated with this site resulted in local acceptance of the system.

While designing SVE pilot studies or SVE systems, care must be taken to determine the effect of the SVE systems on the surrounding communities. For instance, at one site located in a residential area, noise from the blower and its effect on the surrounding residences had to be taken into consideration during the SVE pilot study. To address community concerns at another residential site, the system's air stripper was housed in a colonial-style building that blended in with the local architecture.

Selected Bibliograpy

Innovative Site Remediation Technology, Vacuum Vapor Extraction
U.S. EPA, OSWER, Technology Innovation Office, April 1995
EPA/542-B-94-002, 222 pp.

This monograph is one of a series of eight on innovative site and waste remediation technologies. It is the cumulation of a multi-organizational effort involving over 100 experts over a two-year period. It provides experienced, practical, professional guidance on the application of this technology.

Abstracts of Remediation Case Studies
Prepared by member Agencies of the Federal Remediation Treatment Technologies Roundtable: U.S. EPA, DOD, DOE, DOI, NASA, TVA, USCG, March 1995
NTIS/PB95/182903,101 pp.

This report is a collection of abstracts summarizing 37 case studies of site remediation projects prepared by federal agencies. The case studies document the results and lessons learned from early technology applications. They help establish benchmark data on cost and performance, which can lead to greater confidence in the selection and use of cleanup technologies.

Soil Vapor Extraction and Bioventing
U.S. Army Corps of Engineers, November 1995. Engineering Manual EM 1110-1-4001.

This manual provides practical guidance for the design and operation of soil vapor extraction and bioventing systems. The manual describes current practices for site characterization, system design, and system startup and operations.

Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds in Soils
Directive 9355.0-48FS, September 1993.
EPA 540-F-93-048, PB 93-963346, 26 pp.

Presumptive remedies are preferred technologies for common categories of sites, based on historical patterns of remedy selection and EPA's scientific and engineering evaluation of performance data. Soil vapor extraction (SVE), thermal desorption, and incineration are the presumptive remedies for Superfund sites with VOC contaminated soil assuming the site characteristics meet certain criteria.

Soil Vapor Extraction Enhancement Technology Resource Guide: Air Sparging, Bioventing, Fracturing, Thermal Enhancements
U.S. EPA, OSWER, Technology Innovation Office, October 1995.
EPA/542-B-95-003, 35 pp.

This reports contains an extensive bibliography of EPA and other agencies' information resources on air sparging, bioventing, fracturing, and thermal enhancements for SVE.

Evaluation for Unsaturated/Vadose Zone Models for Superfund Sites
U.S. EPA, ORD, Robert S. Kerr Environmental Research Laboratory
Ada, OK, March 1994
EPA/600/R-93/184,188 pp.

This manual evaluates several transport models for unsaturated soils and quantifies the sensitivity and uncertainty of model outputs to changes in input parameters.

A Citizen's Guide to Soil Vapor Extraction and Air Sparging
U.S. EPA, OSWER, Technology Innovation Office, Washington, DC, March 1996
EPA/542-F-96-008, 4 pp.

This fact sheet presents in lay terms the technologies, processes, and limitations of soil vapor extraction (SVE) remediation. It may be a very useful handout to communities associated with possible SVE systems.

Soil Vapor Extraction (SVE) Treatment Technology Resource Guide
U.S. EPA, OSWER, Technology Innovation Office, Washington, DC, September 1994
EPA/542/B-94/007, 27 pp.

This report lists an extensive bibliography of EPA and other agencies' information resources focusing solely on soil vapor extraction.

Air Sparging for Site Remediation
Hinchee, R.E., International Symposium on *In Situ* and On Site Bioreclamation, 2nd Ed: 1993
San Diego, CA, Lewis Publishing. 1994, 142 pp.

This book is a collection of papers focusing on air sparging as a useful *in situ* tool for hydrocarbon contamination.

Engineering Forum Issue: Considerations in Deciding to Treat Contaminated Unsaturated Soils *in Situ*
U.S. EPA, OSWER, December 1993
EPA/540/S-94/500, 27 pp.

This issue paper assists in deciding if *in situ* treatment of contaminated soil is a potentially feasible remedial alternative. It also presents reviews of *in situ* technologies. The document contains tables of generic and technology specific critical factors and conditions for the use of *in situ* treatment technologies and addresses soil vapor extraction.

Engineering Bulletin: Technology Preselection Data Requirements
U.S. EPA, OSWER, Office of Emergency and Remedial Response, Washington, DC, October 1992
EPA/540/S-92/009, 9 pp.

This bulletin lists soil, water, and contaminant data elements needed to evaluate the potential applicability of technologies for treating contaminated soil and water. It emphasizes the physical, chemical, soil, and water characteristics for which observations and measurements should be compiled.

Technology Assessment of Soil Vapor Extraction and Air Sparging
U.S. EPA, ORD, Risk Reduction Engineering Laboratory, Cincinnati, OH, September 1992
EPA/600/R-92/173

This document summarizes a substantial body of available information that describes the effectiveness and characteristics of air sparging systems and case studies of practical air sparging applications.

Air/Superfund National Technical Guidance Study Series: Estimation of Air Impacts for Soil Vapor Extraction (SVE) Systems
U.S. EPA, OAR, Office of Air Quality Planning and Standards, RTP, NC, January 1992
EPA/450/1-92/001, 91 pp.

This report provides procedures for estimating the ambient air concentrations associated with soil vapor extraction (SVE). Procedures are given to evaluate the effect of the concentration of the contaminants in the soil-gas and the extraction rate on the emission rates and on the ambient air concentrations at selected distances from the SVE system.

In Situ Soil Vapor Extraction Treatment, Engineering Bulletin
U.S. EPA, OSWER, Office of Emergency and Remedial Response, Washington, DC, May 1991
EPA/540/2-91/006, 12 pp.

This bulletin provides information on the technology applicability, the limitations of the technology, the technology description, the types of residuals produced, the site requirements, the latest performance data, the status of the technology, and sources for further information.

Soil Vapor Extraction Technology: Reference Handbook, Final Report
U.S. EPA, ORD, Risk Reduction Engineering Laboratory, Cincinnati, OH, February 1991
EPA/540/2-91/003, 316 pp.

This report discusses the basic science of the subsurface environmental and subsurface monitoring, emission control, and costs. The report also discusses state-of-the-art technology, the best approach to optimize systems application, and process efficiency and limitations.

How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites
U.S. EPA, OSWER, May 1995
EPA 510-B-95-007

This manual provides technical guidance to state and local regulators in evaluating corrective action plans for remediating underground storage tank releases (and other hazardous waste sites) using "alternative technologies." The manual describes eight cleanup technologies, including SVE and air sparging, and provides engineering related considerations and parameters for evaluating the feasibility of a given technology.

Acknowledgements

The assistance of the Engineering Forum members is greatly appreciated:

Ken Erickson, Region 9
Rich Ho, Region 2
Chet Janowski, Region 1
Paul Leonard, Region 3
Robert Stamnes, Region 10

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Soil Vapor Extraction Sites

Soil vapor extraction is the remedy for VOCs in soils at the sites listed below. At some sites, the treatment is already complete. Some sites are currently operating, and some are in the design phase. This list has been adapted from the *Innovative Treatment Technologies: Annual Status Report (Sixth Edition)*, September 1994 (EPA 542-R-94-005). This list is not comprehensive.

Hamilton-Standard Division, CT
Kellogg-Deering Well Field, CT
Linemaster Switch Corporation, CT
United Technologies Corp., CT
Groveland Wells, MA
Industri-Plex, MA
Silresim, MA
Silresim, MA
Wells G&H OU 1, MA
Union Chemical Co., ME
Mottolo Pig Farm, NH
South Municipal Water Supply Well, NH
Tibbetts Road, NH
Tinkham Garage, NH
Peterson/Puritan Inc., RI
Picillo Farm Site, RI
Stamina Mills, RI
A. O. Polymer, NJ
FAA Technical Center, NJ
Garden State Cleaners, NJ
Naval Air Engineering Center, NJ
South Jersey Clothing, NJ
Swope Oil & Chem. Co., NJ
Applied Environmental Services, NY
Circuitron Corporation, NY
Genzale Plating Company, NY
Mettiace Petrochemicals Company, Inc., NY
Pasley Solvents and Chemicals, Inc., NY
Sinclair Refinery, NY
SMS Instruments, NY
Vestal Water Supply, NY
Janssen Inc., PR
Upjohn Manufacturing Co., PR
Delaware Sand and Gravel, DE
Bendix, PA
Cryochem, PA
Letterkenny Army Depot, PA
Lord-Shope Landfill, PA
Raymark, PA
Saergertown Industrial Area Site, PA
Tyson's Dump, PA
Arrowhead Associates/Scovill, VA
U.S. Defense General Supply, VA
Hollingsworth Solderless, FL
Robins AFB, GA
ABC Dry Cleaners, NC
Charles Macon Lagoon, NC
JADCO-Hughes, NC
USMC Camp Lejeune Military Base, NC
Medley Farm, SC
SCRDI Bluff Road, SC
Carrier Air Conditioning, TN
Acme Solvent Reclaiming, Inc., IL
American Chemical Services, IN
Enviro. Conservation and Chemical, IN
Fisher Calo Chem, IN
Main Street Well Field, IN
MIDCO, IN
Seymour Recycling, IN
Wayne Waste Reclaimation, IN
Chem Central, MI
Clare Water Supply, MI
Electro-Voice, MI
Kysor of Cadillac Industrial, MI
Peerless Plating, MI
Springfield Township Dump, MI
Sturgis Municipal Well Field, MI
ThermoChem, Inc., MI
Verona Well Field, MI
Long Prairie Groundwater Contamination, MN
Miami County Incinerator, OH
Pristine, Inc., OH
Skinner Landfill, OH
Zanesville Well Field, OH
City Disposal Corporation Landfill, WI
Hagen Farm Source Control, WI
Muskego Sanitary Landfill, WI
Wausau Groundwater Contamination, WI
Prewitt Abandoned Refinery, NM
Petro-Chemical Systems, Inc., TX
Chemplex, IA
McGraw Edision, IA
Coleman Operable Unit, KS
Cleburn Street, NE
Hastings GW Contamination, NE
Lindsay Manufacturing, NE

Waverly Groundwater Contamination, NE
Chemical Sales Company, CO
Martin Marietta, CO
Rocky Flats, CO
Rocky Mountain Arsenal, CO
Sand Creek Industrial, CO
Utah Power and Light/American Barrel, UT
Hassayampa Landfill, AZ
Motorola 52nd Street, AZ
Phoenix-Goodyear Airport Area, AZ
Tucson International Airport, AZ
Williams AFB, AZ
Barstow Marine Corps Logistics Base, CA
Fairchild Semiconductor, CA
Hexcel, CA
IBM, CA
Intel, CA
Intersil/Siemens, CA
Lawrence Livermore Natl. Laboratory, CA
Lorentz Barrel and Drum, CA
Moffett Air Field, CA
Monolithic Memories/AMD, CA
National Semiconductor, CA
Pacific Coast Pipeline, CA
Purity Oil Sales, CA
Raytheon, CA
Signetics, CA
Solvent Service, CA
Spectra Physics, CA
Van Waters and Rogers, CA
Watkins-Johnson, CA
Eielson Air Force Base, AK
Commencement Bay, WA
Fairchild AFB, WA
Fort Lewis Military Res., WA
Hanford, WA
Pondrers Corner (Lakewood), WA

Appendix J

Sub-Slab Soil Gas Survey of the LPS Building

March 2003

Letter Report & Results

257 Midland Place
Logan, OH 43138-1234
April 19, 2003

Ms. Gianna Aiezza
New York State Department of Environmental Conservation
Division of Environmental Remediation, Region 3
21 South Putt Corners Road
New Paltz, NY 12561-1696

RE: LPS, Site No. 3-36-034, Orange Co., NY — Sub-Slab Soil Gas Sampling & Results.

Dear Ms. Aiezza:

As per my email and telephone calls with you last month, I was able to perform a sub-slab soil gas survey at the LPS site as per NYSDOH guidance. As I discussed with you briefly, I had trouble locating a certified ELAP laboratory in New York State that was capable of meeting all the requirements of the general guidance and the low detection limits requested by NYSDOH. I was able to speak with Jerry McDonald of NYSDOH about my project a few days before I was scheduled to sample. He indicated that the lab I had chosen had detection limits which were too high (5ppb), and recommended I subcontract with one of several California laboratories (Performance Analytical or Air Toxics Limited) who were able to report 1ppb or less. He was not aware of any New York State labs capable of doing this work, but did suggest Lancaster Laboratories, in Lancaster, PA, if immediate delivery of summa canisters was an issue. Having worked with Lancaster Labs in the past, I was able to arrange a stop by their facility on my trip to New York on March 28, 2003. Sub-slab sampling was performed on March 29, 2003 at the LPS site as per the description in my Sampling Proposal submitted to your office on February 13, 2003.

The six evacuated summa canisters were calibrated at Lancaster Labs with valve settings capable of collecting full canister samples over the course of one hour. After the valves were fitted to the summa canisters on the morning of March 29th, six pieces (30" long by 1/4" diameter) of new polyethylene tubing were cut and attached to each summa canister. The canisters were left isolated in an office room while six ½" inch holes were drilled into the LPS cement floor with a rotary hammer drill. The location of the holes are similar to the locations marked on the sampling proposal sent to your office in February. An exact location is indicated on the diagram accompanying this letter report. The average thickness of the cement was 5", and loose materials were encountered directly beneath the slab (gravel suspected) . Each hole was drilled to approximately 7 ½" in depth from the top of the cement floor, allowing a small cavity to remain below the bottom of the slab. The holes were swept clean with an electric vacuum cleaner, allowing some of the soil gas immediately below the cement floor hole to be purged. Each hole was temporarily plugged with clean paper towels until each of the six summa canisters were positioned next to each hole. The end of each piece of polyethylene tubing was placed approximately 3" into the floor hole. The tubing was held in place by friction with taped, compressed paper toweling, just below the floor surface. Wet Quickrete was then mounded on top of the paper towel wadding and around the tube to a height of approximately 1" above the floor surface to prevent any short circuiting of indoor air with the sub-slab soil gas. The valve for the summa canister was then opened and allowed to collect sub-slab soil gas for a minimum of one hour. This procedure was repeated at each of the six sub-slab soil gas holes. After one hour, each of the summa canister valves were shut and the tubing was removed from the floor hole. The holes were stuffed with rags and, at locations #1 and #2, re-covered with the existing carpeting. The valves from the canisters were then removed. The summa canisters were labeled and packed into the fitted boxes supplied by the laboratory. They were shipped to Lancaster Laboratories on March 31, 2003 and received by the lab on April 1, 2003.

The results from the soil gas investigation are shown on the attached summary table. In every soil gas hole, the chemical of concern at the LPS site (TCA) was detected, with levels ranging from 21 to 3000 ppb. Several daughter products of TCA were also detected. In addition to TCA related detections, TCE was also found at lower concentrations (ranging from 2 to 110 ppb). As stated in past reports to NYSDEC, TCE was never used by LPS, but has been used by neighboring companies in the industrial park.

This letter report should satisfy the NYSDEC requirement to conduct a sub-slab soil gas investigation as part of the LPS Feasibility Study. It will appear in the revised FS, which I am currently preparing for submission to your office in the near future. The report will be accompanied by laboratory data sheets documenting the analytical results. Please call or email me if you have any questions related to this investigation. If NYSDEC and NYSDOH are satisfied with work, I will re-cement the soil gas holes in the LPS building on my next trip to New York this summer. The holes are currently plugged with rags.

Sincerely,

Steven J. Saines

Steven J. Saines

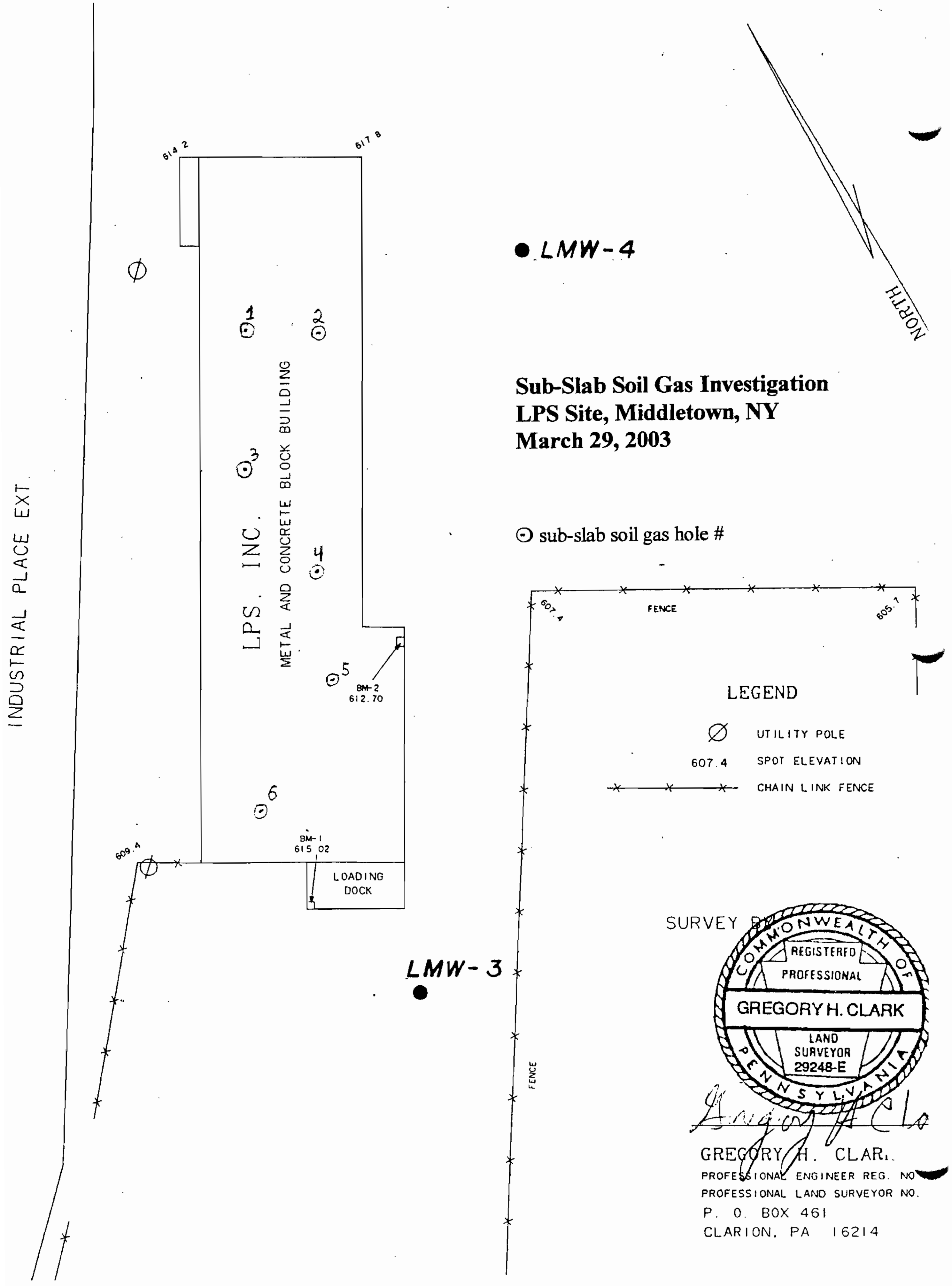
cc:
Michael Sandor, MJS Engineering
Douglas Zamelis, Green & Seifert, PLLC
George Saines, LPS

stevesaines@yahoo.com
740-385-7810 (H)
740-385-5445 (W)

Sub-Slab Soil Gas Sampling Results - LPS Site, Middletown, NY: March 29, 2003.
Concentration reported in parts per billion - volume: [ppb (v)] by Lancaster Laboratories, Lancaster, PA.

Soil Gas Compound Name	*Hole 1*	*Hole 2**	*Hole 3*	*Hole 4*	*Hole 5*	*Hole 6*
Vinyl Chloride	<1	<10	<1	<1	<1	<1
Chloroethane	<1	<10	<1	<1	<1	<1
1,1-Dichloroethene	1	19	<1	<1	8	<1
trans-1,2-Dichloroethene	<1	<10	<1	<1	<1	<1
1,1-Dichloroethane	6	200	<1	<1	12	<1
cis-1,2-Dichloroethene	<1	<10	<1	<1	2	<1
1,1,1-Trichloroethane	670	3000	230	400	88	21
1,2-Dichloroethane	<1	<10	<1	<1	<1	<1
Trichloroethene	2	110	2	7	61	44
1,1,2-Trichloroethane	<1	<10	<1	<1	<1	<1
Tetrachloroethene	<1	<10	<1	<1	<1	3

* Dilution factor for sample collected at Hole 2 = 10 X



Sub-Slab Soil Gas Investigation
LPS Site, Middletown, NY
March 29, 2003

⊙ sub-slab soil gas hole #

LEGEND

∅	UTILITY POLE
607.4	SPOT ELEVATION
—×—×—×—	CHAIN LINK FENCE

SURVEY B

GREGORY H. CLARK
29248-E

GREGORY H. CLAR
PROFESSIONAL ENGINEER REG. NO
PROFESSIONAL LAND SURVEYOR NO.
P. O. BOX 461
CLARION, PA 16214

NYSDOH

General Guidance for Soil Gas Sampling

- Samples collected from within a structure should be situated within the sub-floor aggregate or approximately six inches below the slab. The point should be sealed to prevent infiltration of ambient air.
- Outdoor samples should be taken from a minimum of 5 feet below grade (generally 6 fbg). However, if this sample depth is not achievable due to shallow groundwater elevation, the sample should be taken from one foot above the water table.
- A minimum of one well volume must be purged prior to sampling. This purge time is a function of the tube diameter. For example, assuming a tube diameter of 0.25 inches, the duration of purging should be no longer than 12 seconds at a rate of 1 liter per minute (L/min) or no longer than 3 seconds at a rate of 4 L/min to evacuate one well volume.
- The NYSDOH preferred flow rate for sampling is 0.1 liter per minute. ASTM recommends that flow rate not exceed 0.2 liter per minute. Any faster than this increases the possibility of pulling in ambient air.
- Holding time of samples should not exceed 24 hours.
- Samples should be collected using SUMMA canisters or Tedlar bags.
- Samples collected in Tedlar bags should be kept out of contact with direct light and heat. An easy way to do this is to place samples into a cooler that is at room temperature. DO NOT add ice or refrigerate the cooler in any way.
- Samples should be analyzed using EPA TO-14 or TO-15 methods.

*Please note that this guidance is not site specific and may not be appropriate for some sites.

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Where quality is a science.

FAX Cover Page

If received in error, please notify sender at once.

Facsimile Communication
Fax Number: (717) 656-6766

TO: Steven Saines

COMPANY: Ohio EPA

FROM: Richard Entz Ext. 1559

Date: 3/26/03

Number of pages: ~~4~~ 5 (including this cover sheet)

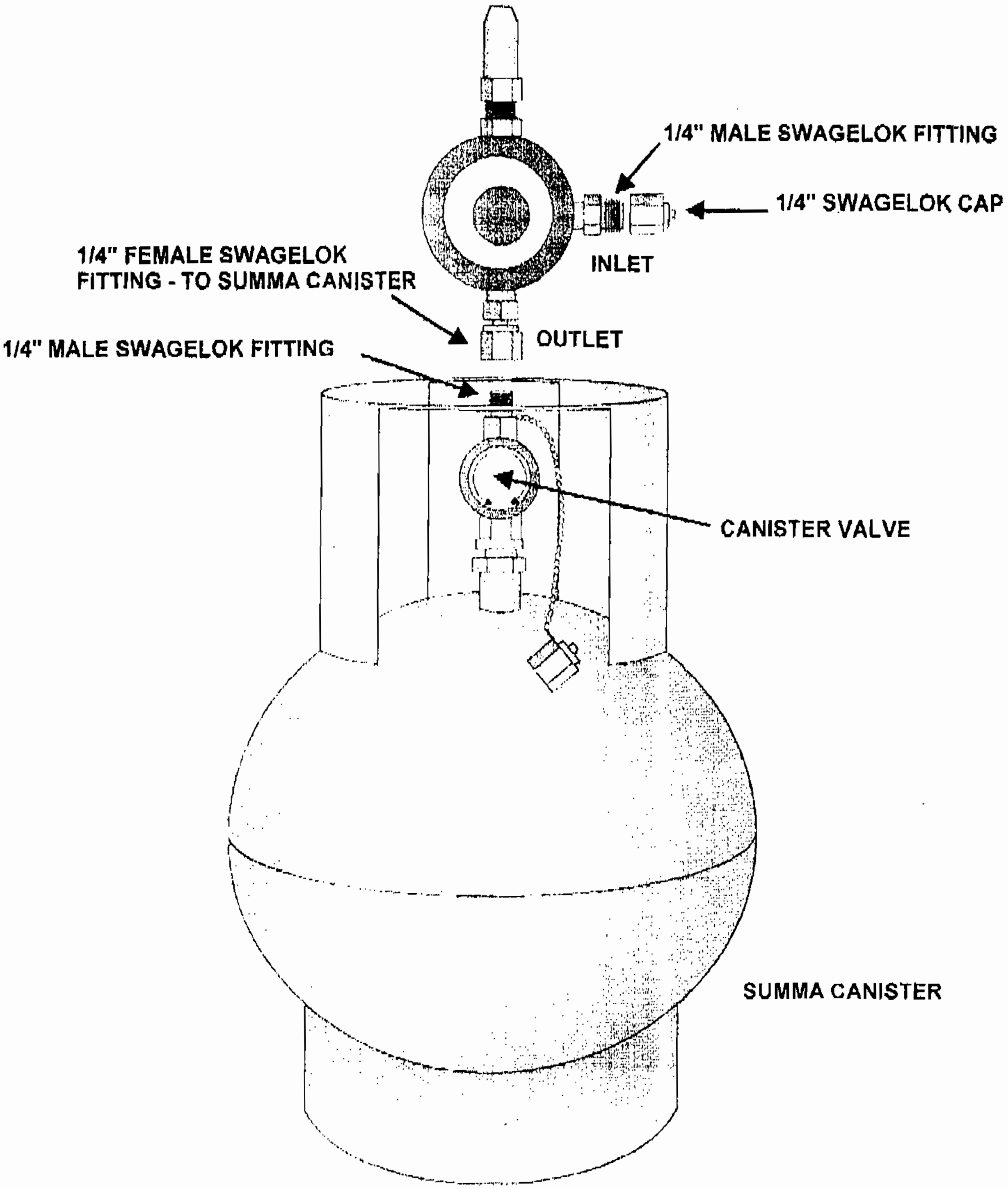
Comments: Here are the Instructions for collecting a sample using the SUMMA canister and flow controller. I've also included a description of the fitting on the end of the flow controller. You will need to be able to connect the 1/4inch OD tubing to that point.

If you have problems with this transmission, please call me at (717) 656-2308 ext 1559 as soon as possible.

Dept. # 39 Fax # (740) 385-6490

LANCASTER LABORATORIES • 2425 NEW HOLLAND PIKE, PO BOX 12425, LANCASTER, PA 17605-2425
TEL 717-656-2300 • FAX 717-656-2681

Diagram for Connecting Passive Flow Controller to Summa Canister



Lancaster Laboratories
Where quality is a science.

Instructions for collection of samples in SUMMA® canisters using a passive flow controller.

1. Remove the canister and passive flow controller from the shipping box. It has been evacuated by the laboratory. Note the identification on the tag attached to the canister. Some assembly will be required before the sample can be collected.

2. Remove the Swagelok™ cap (brass or stainless steel) on the top of the SUMMA® canister. This will require a small adjustable or 9/16 inch wrench to fit the cap.

3. Remove the Swagelok™ cap (brass) and the stainless steel Swagelok™ plug on the passive flow controller assembly if this is in place. This will also require a 9/16 inch wrench. If no cap or plug are on the passive flow controller go to step 4.

4. Attach the passive flow controller to the canister as indicated in the drawing. The connector at the bottom of the flow controller (identified as the outlet in the drawing) is attached to the SUMMA® canister. Tighten the Swagelok™ fitting to the canister.

5. If probes are to be attached to the passive flow controller, these should be attached to the connector as indicated in the drawing of the flow controller assembly.

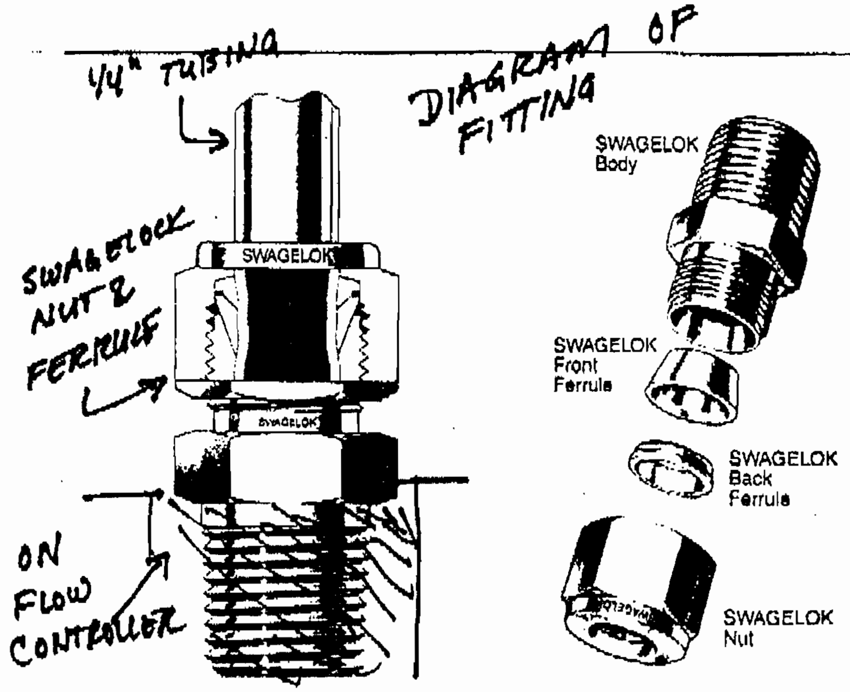
6. Once the passive flow controller is attached the sampling can begin. To start the sampler, open the valve on the canister at least one turn. The flow controller has been calibrated in the laboratory to deliver a flow so that the correct volume is collected in the sampling time period.

7. At the end of the sampling period close the valve to the SUMMA® canister. Do not overtighten the valve. Record the sampling time on the chain of custody along with the identification number for the canister. Do not place a sticker on the canister. If the canister must be labeled, please place the label or write on the card attached to the canister.

8. After the valve is closed, remove the passive flow controller. Replace the Swagelok™ cap on the canister and tighten it with a wrench. The controller can be fitted on another canister or packed up for return to the laboratory. If the flow controller is returned to the laboratory, replace the Swagelok™ cap and plug on the controller.

9. Pack the canister and flow controller in the shipping box, making sure that the flow controller is padded using the bubble wrap which was used as the canister was sent to the site.

Specific questions on sampling should be addressed to Richard Entz of Lancaster Laboratories by calling (717) 656-2308 ext 1559.



SWAGELOK Tube Fittings provide a leak-proof, torque-free seal at all tubing connections and eliminate costly, hazardous leaks in instrumentation and process tubing.

All the action in the fitting moves along the tube axially instead of with a rotary motion. Since no torque is transmitted from the fitting to the tubing, there is no initial strain which might weaken the tubing.

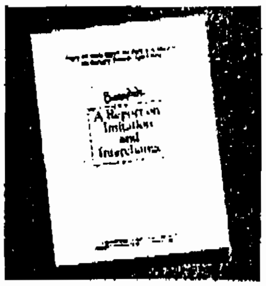
Total system design must be considered to ensure safe, trouble-free performance. Material compatibility, adequate ratings, proper installation, operation and maintenance are the responsibility of the system designer and user.

To ensure reliable performance, SWAGELOK Tube Fittings are composed of four precision made components, all manufactured to very stringent tolerances under rigid quality control procedures. The consistency and quality of these matched components has permitted their use in many difficult and severe services.

Although the fitting consists of four components – Nut, Back Ferrule, Front Ferrule and Body – it becomes a five-piece connection when affixed to the tubing. The two-ferrule design and sequential action of the fitting overcome variations in tube materials, wall thicknesses and hardness to ensure safe, reliable, leak-free connections. SWAGELOK Tube Fittings are easily installed with no special tools required. See page 53.

CAUTION

Do Not mix or interchange parts with those of other manufacturers. See page 56



Ask your Authorized SWAGELOK Sales & Service Representative for a copy of the Report on Imitation and Interchange.

Only Authorized SWAGELOK Tube Fitting Sales & Service Representatives sell and service SWAGELOK Tube Fittings. Suppliers of look-alike fittings and components simply cannot guarantee SWAGELOK Tube Fitting components' gageability, performance, availability and service.

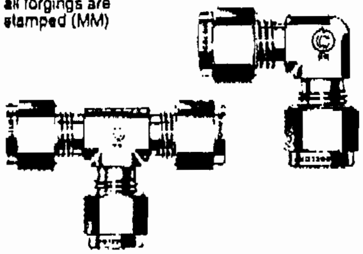
Metrication

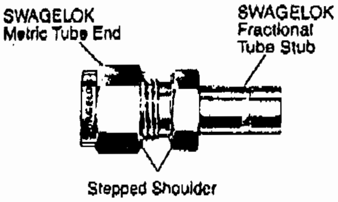
SWAGELOK Metric Tube Fittings are similar in appearance to SWAGELOK Tube Fittings in fractional sizes. The significant difference is in the internal diameter of the tube fitting components. Due to the external similarity between metric and fractional sizes, a stepped shoulder has been machined into the body hex of barstock fittings and the nut hex for easy identification of SWAGELOK Metric Tube fittings. Shaped fittings are stamped *MM* for metric tubing.

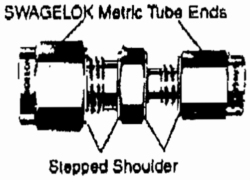
Crawford Fitting Company makes a wide range of Metric Tube Fittings in sizes from 2mm to 38mm. Many fittings are available with ISO pipe threads for connecting to equipment ports using British BSPP, DIN and JIS straight pipe threads and DIN, British BSPT and JIS tapered pipe threads.

For an explanation of these threads, see page 51. Standard sizes, shapes and materials available worldwide.

Elbows and Tees have no step on forging – all forgings are stamped (MM)



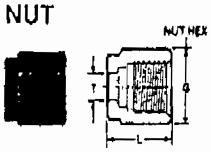




Hydraulic Swaging Unit

A Hydraulic Swaging Unit must be used when installing 1-1/4", 1-1/2", 2", 28mm, 32mm, and 38mm SWAGELOK Tube Fittings. The unit is designed to swage the ferrules on the tubing prior to the final assembly into a fitting. It ensures a safe and reliable, torque-free, leak-proof seal on large size carbon steel and stainless steel tubing. See page 55 for complete information.

NUT



T Tube O.D.	Ordering Number	G	L
1/4	PFA-422-1	5/8	.65
3/8	PFA-622-1	13/16	.68
1/2	PFA-822-1	1	.79

BACK FERRULE

T Tube O.D.	Ordering Number
1/4	PFA-424-1
3/8	PFA-624-1
1/2	PFA-824-1

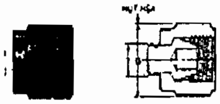
FRONT FERRULE

T Tube O.D.	Ordering Number
1/4	PFA-423-1
3/8	PFA-623-1
1/2	PFA-823-1

PLUG

Plugs Unused Port of SWAGELOK Tube Fitting

Dimensions – G is across hex flats.

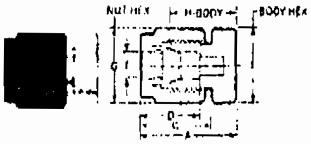


T Tube O.D.	Ordering Number	G
1/4	PFA-420-P	5/8
3/8	PFA-620-P	13/16
1/2	PFA-820-P	1

CAP

Caps End of Tubing

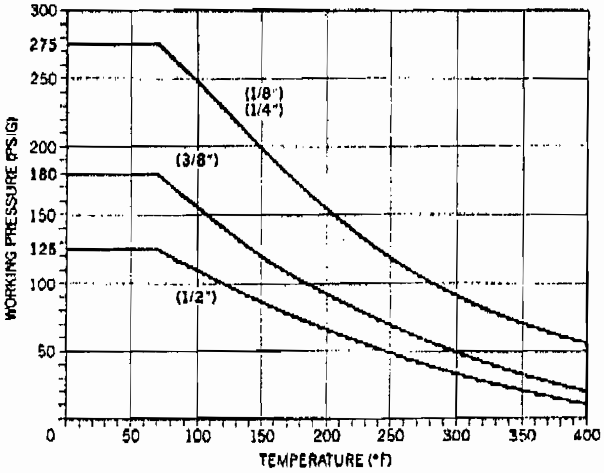
Dimensions – A-C-D are typical finger-tight. F-G are across hex flats.



T Tube O.D.	Ordering Number	A	C	D	F	G	H
1/4	PFA-420-C	.98	.73	.60	5/8	5/8	.69
3/8	PFA-620-C	1.04	.76	.67	13/16	13/16	.75
1/2	PFA-820-C	1.18	.87	.90	1	1	.78

Dimensions are in inches – for reference only, subject to change

SWAGELOK *PFA* Tube Fitting and Tubing Pressure/Temperature Curves

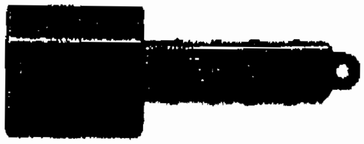


Size	Pressure Rating @70° F (20° C)		Temperature Range	
	psig	bar	°F	°C
1/8	275	19	400	200
1/4	275	19	400	200
3/8	180	12.5	400	200
1/2	125	8.5	400	200

To determine kPa, multiply psig by 6.89. Working Pressure of SWAGELOK PFA Tube Fittings used on metal or glass tubing is 25 psig (1.7 bar). They may also be used in moderate vacuum systems.

SWAGELOK Groove Cutter

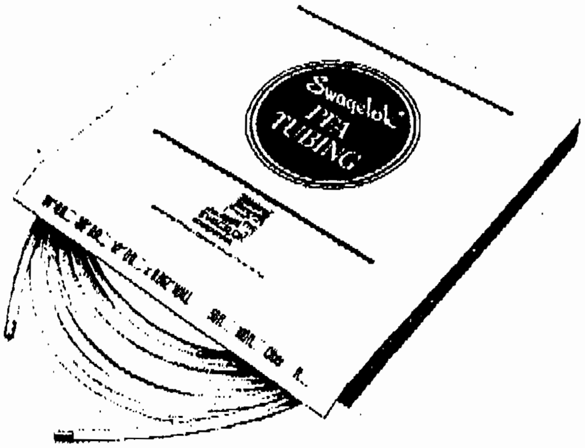
Designed to groove PFA Tubing used in SWAGELOK PFA Tube Fittings.



Size	Ordering Number
1/4	MS-GC-4
3/8	MS-GC-6
1/2	MS-GC-8

SWAGELOK *PFA* TUBING

TUBING MATERIAL: PFA 350



Ordering Number	Nominal Size O.D. (Inches)	Nominal Wall Thickness (Inches)	Length (Feet)
PFA-T2-030-500	1/8	0.030	500
PFA-T4-062-100	1/4	0.062	100
PFA-T6-062-50	3/8	0.062	50
PFA-T8-062-50	1/2	0.062	50

Other lengths of tubing are available from your Authorized SWAGELOK Sales & Service Representative. Tubing made of PFA 450 material for high purity applications is also available upon request.

Analysis Request / vironmental Services Chain of ody

Lancaster Laboratories
Where quality is a science.

For Lancaster Laboratories use only
Acct. # 1907 Group# 846876 Sample # 402083 2-37

COC # 0012199

Please print. Instructions on reverse side correspond with circled numbers.

① Client: Steven J. Saines Acct. #:
Project Name/#: 740-380-5445 PWSID #:
Project Manager: Steven J. Saines P.O.#:
Sampler: Quote #:
Name of state where samples were collected: New York

② Sample Identification	Date Collected	Begin Time Collected	③ Grab	Composite	Matrix ④ Soil	Water (Check if Applicable ☐ Potable ☐ NPDES)	Other Subslab Soil Gas	Total # of Containers	⑤ Analyses Requested: EPA TO-14 or TO-15 Chlorinated Solvents only	Remarks End Time	⑥ Temperature of samples upon receipt (if requested)
Lancaster Summa 159 (LPS-1)	3/29/03	11:26		✓			✓	1	✓	12:31	
Lancaster Summa 75 (LPS-2)	↓	12:17		✓			✓	1	✓	13:21	
" " " 26 (LPS-3)		12:28		✓			✓	1	✓	13:37	
" " " 40 (LPS-4)		12:42		✓			✓	1	✓	13:44	
" " " 172 (LPS-5)		12:57		✓			✓	1	✓	14:04	
" " " 110 (LPS-6)		13:00		✓			✓	1	✓	14:05	

For Lab Use Only
FSC:
SCR #:

⑦ **Turnaround Time Requested** (TAT) (please circle): [✓ Normal] Rush
(Rush TAT is subject to Lancaster Laboratories approval and surcharge.)
Date results are needed: April 14, 2003
Rush results requested by (please circle): Phone Fax E-mail
Phone #: Fax #:
E-mail address:

⑧ **Data Package Options** (please circle if required)
QC Summary Type VI (Raw Data)
Type I (Tier I) GLP
Type II (Tier II) Other
Type III (NJ Red. Del.)
Type IV (CLP)

SDG Complete? Yes No
Site-specific QC required? Yes No
(If yes, indicate QC sample and submit triplicate volume.)
Internal Chain of Custody required? Yes No

Relinquished by	Date	Time	Received by	Date	Time ⑨
Steven J. Saines	3/30/03	17:00	George Saines	3/30/03	1700
				4/1/03	0922

Lancaster Laboratories, Inc., 2425 New Holland Pike, PO Box 12425, Lancaster, PA 17605-2425 (717) 656-2300
Copies: White and yellow should accompany samples to Lancaster Laboratories. The pink copy should be retained by the client.

2102 Rev. 10/27/02

Analysis Report

Lancaster Laboratories

ANALYTICAL RESULTS

Prepared for:

Steven Saines
257 Midland Place

Logan OH 43138-1234
740-380-5445

Prepared by:

Lancaster Laboratories
2425 New Holland Pike
Lancaster, PA 17605-2425

SAMPLE GROUP

The sample group for this submittal is 846876. Samples arrived at the laboratory on Tuesday, April 01, 2003.

Client Description	Lancaster Labs Number
LPS-1 Summa Canister 159 Composite Air Sample	4020832
LPS-2 Summa Canister 75 Composite Air Sample	4020833
LPS-3 Summa Canister 26 Composite Air Sample	4020834
LPS-4 Summa Canister 40 Composite Air Sample	4020835
LPS-5 Summa Canister 172 Composite Air Sample	4020836
LPS-6 Summa Canister 110 Composite Air Sample	4020837

1 COPY TO Steven Saines Attn: Mr. Steven Saines

Questions? Contact your Client Services Representative
Richard C Entz at (717) 656-2300.

Respectfully Submitted,

Robert E. Mellinger
Sr. Chemist/Coordinator

Lancaster Laboratories Sample No. AQ 4020832

Collected:03/29/2003 11:26

Submitted: 04/01/2003 09:20
Reported: 04/14/2003 at 14:24
Discard: 04/22/2003
LPS-1 Summa Canister 159 Composite Air Sample

Account Number: 01907

Steven Saines
257 Midland Place

Logan OH 43138-1234

CAT No.	Analysis Name	CAS Number	As Received Result	As Received Limit of Quantitation	Units	Dilution Factor

Laboratory Chronicle

CAT No.	Analysis Name	Method	Trial#	Analysis Date and Time	Analyst	Dilution Factor
07199	TO 14 VOA Extended List	EPA Method TO14A	1	04/01/2003 21:26	Douglas Graham	10
07199	TO 14 VOA Extended List	EPA Method TO14A	1	04/01/2003 22:10	Douglas Graham	1
07200	TO 14 VOA Extended List cont.	EPA Method TO14A	1	04/01/2003 22:10	Douglas Graham	1

VOLATILE ORGANICS IN AIR
SUMMA CANISTER SAMPLE
ANALYSIS DATA SHEET

Sample No.: LPS-1
Date Collected: 03/29/03
Date Received: 04/01/03
Lab Sample ID: 4020832
Date Analyzed: 04/01/03
Time Analyzed: 22:10
Canister ID: SUMMA0159
Pressure Rec'd: 14.6 psia
Final Pressure: 29.2 psia
Injection Volume: 500 cc
Nominal Volume: 250 cc
Dilution Factor: 1.0
Instrument ID: HP4224
Lab File ID: C:\HPCHEM\1\DATA\APR01\0901010.D

CAS RN	COMPOUND NAME	CONCENTRATION UNITS: ppb(v)	Q
75-01-4	Vinyl Chloride	1	U
75-00-3	Chloroethane	1	U
75-35-4	1,1-Dichloroethene	1	
156-60-5	trans-1,2-Dichloroethene	1	U
75-34-3	1,1-Dichloroethane	6	
156-59-2	cis-1,2-Dichloroethene	1	U
71-55-6	1,1,1-Trichloroethane	670	D
107-06-2	1,2-Dichloroethane	1	U
79-01-6	Trichloroethene	2	
79-00-5	1,1,2-Trichloroethane	1	U
127-18-4	Tetrachloroethene	1	U

U = Compound was undetected at the specified limit of quantitation.
B = Compound was found in method blank.   D = analysis of diluted sample.

Lancaster Laboratories Sample No. AQ 4020833

Collected:03/29/2003 12:17

Submitted: 04/01/2003 09:20
Reported: 04/14/2003 at 14:24
Discard: 04/22/2003
LPS-2 Summa Canister 75 Composite Air Sample

Account Number: 01907

Steven Saines
257 Midland Place
Logan OH 43138-1234

CAT No.	Analysis Name	CAS Number	As Received Result	As Received Limit of Quantitation	Units	Dilution Factor

Laboratory Chronicle

CAT No.	Analysis Name	Method	Trial#	Analysis Date and Time	Analyst	Dilution Factor
07199	TO 14 VOA Extended List	EPA Method TO14A	1	04/01/2003 22:53	Douglas Graham	100
07199	TO 14 VOA Extended List	EPA Method TO14A	1	04/01/2003 23:37	Douglas Graham	10
07200	TO 14 VOA Extended List cont.	EPA Method TO14A	1	04/01/2003 23:37	Douglas Graham	10

VOLATILE ORGANICS IN AIR
SUMMA CANISTER SAMPLE
ANALYSIS DATA SHEET

Sample No.: LPS-2	Date Collected: 03/29/03	Date Received: 04/01/03
Lab Sample ID: 4020833	Date Analyzed: 04/01/03	Time Analyzed: 23:37
Canister ID: SUMMA0075	Pressure Rec'd: 10.3 psia	Final Pressure: 20.7 psia
Injection Volume: 500 cc	Nominal Volume: 250 cc	Dilution Factor: 10.0
Instrument ID: HP4224	Lab File ID: C:\HPCHEM\1\DATA\APR01\1101012.D	

CAS RN	COMPOUND NAME	CONCENTRATION UNITS: ppb(v)	Q
75-01-4	Vinyl Chloride	10	U
75-00-3	Chloroethane	10	U
75-35-4	1,1-Dichloroethene	19	D
156-60-5	trans-1,2-Dichloroethene	10	U
75-34-3	1,1-Dichloroethane	200	D
156-59-2	cis-1,2-Dichloroethene	10	U
71-55-6	1,1,1-Trichloroethane	3000	D
107-06-2	1,2-Dichloroethane	10	U
79-01-6	Trichloroethene	110	D
79-00-5	1,1,2-Trichloroethane	10	U
127-18-4	Tetrachloroethene	10	U

U = Compound was undetected at the specified limit of quantitation.
B = Compound was found in method blank. D = analysis of diluted sample.
NOTE: Limits of quantitation were raised due to the high concentration of volatile organic compounds in this sample.

Lancaster Laboratories Sample No. AQ 4020834

Collected:03/29/2003 12:28

Submitted: 04/01/2003 09:20
Reported: 04/14/2003 at 14:24
Discard: 04/22/2003
LPS-3 Summa Canister 26 Composite Air Sample

Account Number: 01907

Steven Saines
257 Midland Place

Logan OH 43138-1234

CAT No.	Analysis Name	CAS Number	As Received Result	As Received Limit of Quantitation	Units	Dilution Factor

Laboratory Chronicle

CAT No.	Analysis Name	Method	Trial#	Analysis Date and Time	Analyst	Dilution Factor
07199	TO 14 VOA Extended List	EPA Method TO14A	1	04/02/2003 00:19	Douglas Graham	10
07199	TO 14 VOA Extended List	EPA Method TO14A	1	04/02/2003 01:03	Douglas Graham	1
07200	TO 14 VOA Extended List cont.	EPA Method TO14A	1	04/02/2003 01:03	Douglas Graham	1

VOLATILE ORGANICS IN AIR
SUMMA CANISTER SAMPLE
ANALYSIS DATA SHEET

Sample No.: LPS-3
Lab Sample ID: 4020834
Canister ID: SUMMA0026
Injection Volume: 500 cc
Instrument ID: HP4224

Date Collected: 03/29/03
Date Analyzed: 04/02/03
Pressure Rec'd: 11.4 psia
Nominal Volume: 250 cc
Lab File ID: C:\HPCHEM\1\DATA\APR01\1301014.D

Date Received: 04/01/03
Time Analyzed: 01:03
Final Pressure: 22.8 psia
Dilution Factor: 1.0

CAS RN	COMPOUND NAME	CONCENTRATION UNITS: ppb(v)	Q
75-01-4	Vinyl Chloride	1	U
75-00-3	Chloroethane	1	U
75-35-4	1,1-Dichloroethene	1	U
156-60-5	trans-1,2-Dichloroethene	1	U
75-34-3	1,1-Dichloroethane	1	U
156-59-2	cis-1,2-Dichloroethene	1	U
71-55-6	1,1,1-Trichloroethane	230	D
107-06-2	1,2-Dichloroethane	1	U
79-01-6	Trichloroethene	2	
79-00-5	1,1,2-Trichloroethane	1	U
127-18-4	Tetrachloroethene	1	U

U = Compound was undetected at the specified limit of quantitation.
B = Compound was found in method blank. D = analysis of diluted sample.

Lancaster Laboratories Sample No. AQ 4020835

Collected:03/29/2003 12:42

Submitted: 04/01/2003 09:20
Reported: 04/14/2003 at 14:24
Discard: 04/22/2003
LPS-4 Summa Canister 40 Composite Air Sample

Account Number: 01907

Steven Saines
257 Midland Place

Logan OH 43138-1234

CAT No.	Analysis Name	CAS Number	As Received Result	As Received Limit of Quantitation	Units	Dilution Factor

Laboratory Chronicle

CAT No.	Analysis Name	Method	Trial#	Analysis Date and Time	Analyst	Dilution Factor
07199	TO 14 VOA Extended List	EPA Method TO14A	1	04/02/2003 01:46	Douglas Graham	10
07199	TO 14 VOA Extended List	EPA Method TO14A	1	04/02/2003 02:30	Douglas Graham	1
07200	TO 14 VOA Extended List cont.	EPA Method TO14A	1	04/02/2003 02:30	Douglas Graham	1

VOLATILE ORGANICS IN AIR
SUMMA CANISTER SAMPLE
ANALYSIS DATA SHEET

Sample No.: LPS-4	Date Collected: 03/29/03	Date Received: 04/01/03
Lab Sample ID: 4020835	Date Analyzed: 04/02/03	Time Analyzed: 02:30
Canister ID: SUMMA0040	Pressure Rec'd: 14.1 psia	Final Pressure: 28.1 psia
Injection Volume: 500 cc	Nominal Volume: 250 cc	Dilution Factor: 1.0
Instrument ID: HP4224	Lab File ID: C:\HPCHEM\1\DATA\APR01\1501016.D	

CAS RN	COMPOUND NAME	CONCENTRATION UNITS: ppb(v)	Q
75-01-4	Vinyl Chloride	1	U
75-00-3	Chloroethane	1	U
75-35-4	1,1-Dichloroethene	1	U
156-60-5	trans-1,2-Dichloroethene	1	U
75-34-3	1,1-Dichloroethane	1	U
156-59-2	cis-1,2-Dichloroethene	1	U
71-55-6	1,1,1-Trichloroethane	400	D
107-06-2	1,2-Dichloroethane	1	U
79-01-6	Trichloroethene	7	
79-00-5	1,1,2-Trichloroethane	1	U
127-18-4	Tetrachloroethene	1	U

U = Compound was undetected at the specified limit of quantitation.
B = Compound was found in method blank.   D = analysis of diluted sample.

Lancaster Laboratories

Lancaster Laboratories Sample No. AQ 4020836

Collected:03/29/2003 12:57

Submitted: 04/01/2003 09:20
Reported: 04/14/2003 at 14:24
Discard: 04/22/2003
LPS-5 Summa Canister 172 Composite Air Sample

Account Number: 01907

Steven Saines
257 Midland Place
Logan OH 43138-1234

CAT No.	Analysis Name	CAS Number	As Received Result	As Received Limit of Quantitation	Units	Dilution Factor

Laboratory Chronicle

CAT No.	Analysis Name	Method	Trial#	Analysis Date and Time	Analyst	Dilution Factor
07199	TO 14 VOA Extended List	EPA Method TO14A	1	04/02/2003 03:56	Douglas Graham	1
07200	TO 14 VOA Extended List cont.	EPA Method TO14A	1	04/02/2003 03:56	Douglas Graham	1

VOLATILE ORGANICS IN AIR
SUMMA CANISTER SAMPLE
ANALYSIS DATA SHEET

Sample No.: LPS-5 Date Collected: 03/29/03 Date Received: 04/01/03
Lab Sample ID: 4020836 Date Analyzed: 04/02/03 Time Analyzed: 03:56
Canister ID: SUMMA0172 Pressure Rec'd: 11.8 psia Final Pressure: 23.6 psia
Injection Volume: 500 cc Nominal Volume: 250 cc Dilution Factor: 1.0
Instrument ID: HP4224 Lab File ID: C:\HPCHEM\1\DATA\APR01\1701018.D

CAS RN	COMPOUND NAME	CONCENTRATION UNITS: ppb(v)	Q
75-01-4	Vinyl Chloride	1	U
75-00-3	Chloroethane	1	U
75-35-4	1,1-Dichloroethene	8	
156-60-5	trans-1,2-Dichloroethene	1	U
75-34-3	1,1-Dichloroethane	12	
156-59-2	cis-1,2-Dichloroethene	2	
71-55-6	1,1,1-Trichloroethane	88	
107-06-2	1,2-Dichloroethane	1	U
79-01-6	Trichloroethene	61	
79-00-5	1,1,2-Trichloroethane	1	U
127-18-4	Tetrachloroethene	1	U

U = Compound was undetected at the specified limit of quantitation.
B = Compound was found in method blank. D = analysis of diluted sample.

Lancaster Laboratories

Lancaster Laboratories Sample No. AQ 4020837

Collected:03/29/2003 13:00

Account Number: 01907

Submitted: 04/01/2003 09:20
Reported: 04/14/2003 at 14:24
Discard: 04/22/2003
LPS-6 Summa Canister 110 Composite Air Sample

Steven Saines
257 Midland Place

Logan OH 43138-1234

CAT No.	Analysis Name	CAS Number	As Received Result	As Received Limit of Quantitation	Units	Dilution Factor

Laboratory Chronicle

CAT No.	Analysis Name	Method	Trial#	Analysis Date and Time	Analyst	Dilution Factor
07199	TO 14 VOA Extended List	EPA Method TO14A	1	04/02/2003 05:24	Douglas Graham	1
07200	TO 14 VOA Extended List cont.	EPA Method TO14A	1	04/02/2003 05:24	Douglas Graham	1

VOLATILE ORGANICS IN AIR
SUMMA CANISTER SAMPLE
ANALYSIS DATA SHEET

Sample No.: LPS-6
Lab Sample ID: 4020837
Canister ID: SUMMA0110
Injection Volume: 500 cc
Instrument ID: HP4224

Date Collected: 03/29/03
Date Analyzed: 04/02/03
Pressure Rec'd: 11.4 psia
Nominal Volume: 250 cc
Lab File ID: C:\HPCHEM\1\DATA\APR01\1901020.D

Date Received: 04/01/03
Time Analyzed: 05:24
Final Pressure: 22.9 psia
Dilution Factor: 1.0

CAS RN	COMPOUND NAME	CONCENTRATION UNITS: ppb(v)	Q
75-01-4	Vinyl Chloride	1	U
75-00-3	Chloroethane	1	U
75-35-4	1,1-Dichloroethene	1	U
156-60-5	trans-1,2-Dichloroethene	1	U
75-34-3	1,1-Dichloroethane	1	
156-59-2	cis-1,2-Dichloroethene	1	U
71-55-6	1,1,1-Trichloroethane	21	
107-06-2	1,2-Dichloroethane	1	U
79-01-6	Trichloroethene	44	
79-00-5	1,1,2-Trichloroethane	1	U
127-18-4	Tetrachloroethene	3	

U = Compound was undetected at the specified limit of quantitation.
B = Compound was found in method blank. D = analysis of diluted sample.

Quality Control Summary

Client Name: Steven Saines Group Number: 846876
Reported: 04/14/03 at 02:25 PM

Laboratory Compliance Quality Control

Analysis Name	Blank Result	Blank LOQ	Report Units	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Max
Batch number: A030911AA	Sample number(s): 4020832-4020837							
Vinyl Chloride	N.D.	1.	ppb(v)	88		45-167		
Chloroethane	N.D.	1.	ppb(v)					
1,1-Dichloroethene	N.D.	1.	ppb(v)					
trans-1,2-Dichloroethene	N.D.	1.	ppb(v)					
1,1-Dichloroethane	N.D.	1.	ppb(v)					
cis-1,2-Dichloroethene	N.D.	1.	ppb(v)					
1,1,1-Trichloroethane	N.D.	1.	ppb(v)	88		69-152		
1,2-Dichloroethane	N.D.	1.	ppb(v)					
Trichloroethene	N.D.	1.	ppb(v)	86		63-141		
1,1,2-Trichloroethane	N.D.	1.	ppb(v)					
Tetrachloroethene	N.D.	1.	ppb(v)					

*- Outside of specification
(1) The result for one or both determinations was less than five times the LOQ.
(2) The background result was more than four times the spike added.

Sub-Slab Soil Gas Sampling Results - LPS Site, Middletown, NY: March, 2003.
Concentration reported in parts per billion - volume: [ppb (v)]

Soil Gas Compound Name	*Hole 1*	*Hole 2**	*Hole 3*	*Hole 4*	*Hole 5*	*Hole 6*
Vinyl Chloride	<1	<10	<1	<1	<1	<1
Chloroethane	<1	<10	<1	<1	<1	<1
1,1-Dichloroethene	1	19	<1	<1	8	<1
trans-1,2-Dichloroethene	<1	<10	<1	<1	<1	<1
1,1-Dichloroethane	6	200	<1	<1	12	<1
cis-1,2-Dichloroethene	<1	<10	<1	<1	2	<1
1,1,1-Trichloroethane	670	3000	230	400	88	21
1,2-Dichloroethane	<1	<10	<1	<1	<1	<1
Trichloroethene	2	110	2	7	61	44
1,1,2-Trichloroethane	<1	<10	<1	<1	<1	<1
Tetrachloroethene	<1	<10	<1	<1	<1	3

* Dilution factor for sample collected at Hole 2 = 10 X

Appendix K

Key LPS & NYSDEC Correspondence

257 Midland Place
Logan, OH 43138-1234
February 28, 2003

Ms. Laura Zeppetelli
New York State Department of Environmental Conservation
Division of Environmental Remediation
Bureau of Program Management, Room 1224
625 Broadway
Albany, NY 12233-7012

RE: LPS, Site No. 3-36-034, Orange Co., NY — Cost Recovery Bill No. 1

Dear Ms. Zeppetelli:

I received your phone message last week indicating that attorney Rusinko believes the latest date for paying the LPS cost recovery bill (without violating the RI/FS order between NYSDEC and George Saines, Inc.) is March 8, 2003. As I have discussed with you this past month, your legal department is not willing to negotiate a payment schedule with George Saines, Inc. unless we complete a financial disclosure questionnaire supplying all personal information about George Saines, not just George Saines, Inc. Our attorney advises us that the contractual obligation to pay is that of the corporation, and not George Saines individually, and therefore we respectfully decline this option.

Last week I also spoke with site coordinator Gianna Aiezza about the possibility of selling the LPS building and property, but having George Saines, Inc. retain the environmental liability. Ms. Aiezza stated that this was a possibility that George Saines, Inc. could pursue independently of NYSDEC. However, she cautioned that New York State Law allows for the state to hold the new property owner liable for environmental restoration if the previous landowner defaults on its obligations with the state. We concluded that this avenue of funding cost recovery bills would not be fruitful in the near future.

Earlier this week (2/24/03), I held a conference call (telephone) meeting with the technical regulators at your New Paltz office, requesting guidance and advice concerning the impending violation of the RI/FS Order due to non-payment of the first cost recovery bill. Just prior to that meeting, I supplied the LPS site coordinator (Gianna Aiezza) with a computer slide show which presented key LPS business transactions in the past, our environmental strategy over the past 10 years of site investigation work at the site and the financial status of George Saines, Inc., including yearly gross and net income for the corporation. (I copied your email address with this slide show.) Unfortunately, the technical staff would not discuss financial or legal information, deferring all discussions of this nature to your office or with the enforcement attorneys at NYSDEC.

Based on the efforts enumerated above, George Saines, Inc. believes it has made all reasonable efforts to avoid violating its RI/FS Orders with NYSDEC. George Saines, Inc. is financially unable to pay the cost recovery bill in one payment. While the corporation believes it is capable of paying the bill over an extended period of time, it has been unable to discuss a payment schedule with NYSDEC without disclosing the personal assets of its principals.

In order to demonstrate a good faith effort in working towards a cleanup at the LPS site, George Saines, Inc. is taking the following actions: 1) Submission of a partial payment of $1420.33 (5%) towards the first cost recovery bill. This payment is enclosed as a check, made out to the New York State Department of Environmental Conservation. A second payment is planned following the completion of all technical requirements for the RI/FS Order. 2) Completion of a revised Feasibility Study, which was originally submitted to NYSDEC in November 2002. Following a review by your New Paltz staff, additional items have been requested to make the FS complete. These items will be obtained over the next three months and submitted to your New Paltz office for review.

Because I have spent the last month working with you and others in an effort to satisfy RI/FS cost recovery obligations, I have not had the time to carefully review the invoice you submitted to George Saines, Inc. Although we do not dispute the fact that NYSDEC has incurred some costs related to the regulation of the LPS site, my cursory review of the invoice and its billing dates suggests that a fair amount of billing on this project was incurred during time periods when no document preparation nor document review was taking place. During the next three months, while I am working on satisfying the remaining technical requirements for the FS, would you please request that appropriate NYSDEC staff make copies of the work products they produced (i.e. review notes, meeting notes, telephone memos, comment letters, interoffice reports, etc.) which would substantiate the hours billed. Thank you for your assistance in this matter.

If you have any questions relating to this letter, the actions presented herein, or my request for additional information, please call or email me at your earliest convenience. Thank you for your assistance during this critical period of our cleanup project.

Sincerely,

Steven J Saines

Steven J. Saines

cc:
Michael Sandor, MJS Engineering
Douglas Zamelis, Green & Seifter, PLLC
George Saines, LPS
Gianna Aiezza, NYSDEC
Rosalie Rusinko, NYSDEC

✓ stevesaines@yahoo.com
740-385-7810 (H)
740-385-5445 (W)

257 Midland Place
Logan, OH 43138-1234
February 13, 2003

Ms. Gianna Aiezza
New York State Department of Environmental Conservation
Division of Environmental Remediation, Region 3
21 South Putt Corners Road
New Paltz, NY 12561-1696

RE: LPS, Site No. 3-36-034, Orange Co., NY – Soil Gas Sampling

Dear Ms. Aiezza:

As per my letter of February 8, 2003, I am submitting a sub-slab soil gas sampling plan for the LPS building. I have been in communication with the current occupants of the LPS building this week; they have provided me with at least 6 locations where floor holes can be drilled without seriously disrupting their current manufacturing activities. These six locations are marked on the accompanying floor plan for the LPS building. Please indicate if these locations are satisfactory to NYSDEC/NYSDOH. A few alternative locations may be available, and we probably will have some discretion in the choice of sampling locations in the southern portion of the building.

The holes will be made with a masonry rotary drill to a depth sufficient to breach the current concrete floor. I propose to drill a hole with sufficient diameter to install a small length of PVC casing (3/4" - 2"); the annular space will be filled with a small volume of bentonite and hydrated to insure the purging and sampling of sub slab soil gas from beneath the LPS building and not indoor air. I still require some guidance from your office concerning New York's technical specifications for installing and sampling the sub-slab ports. While I have conducted soil gas and stack gas sampling in the past, I would like to defer to NYSDEC and/or NYSDOH guidance. Please call or email me with your thoughts, comments or reference.

Accounting for my work and school schedule, I anticipate performing the sub slab soil gas survey in April, 2003. As I noted in last week's letter, I am also currently working with your Bureau of Program Management in Albany to arrange a schedule of payment on NYSDEC's first cost recovery bill to LPS.

Sincerely,

Steven J. Saines

Steven J. Saines

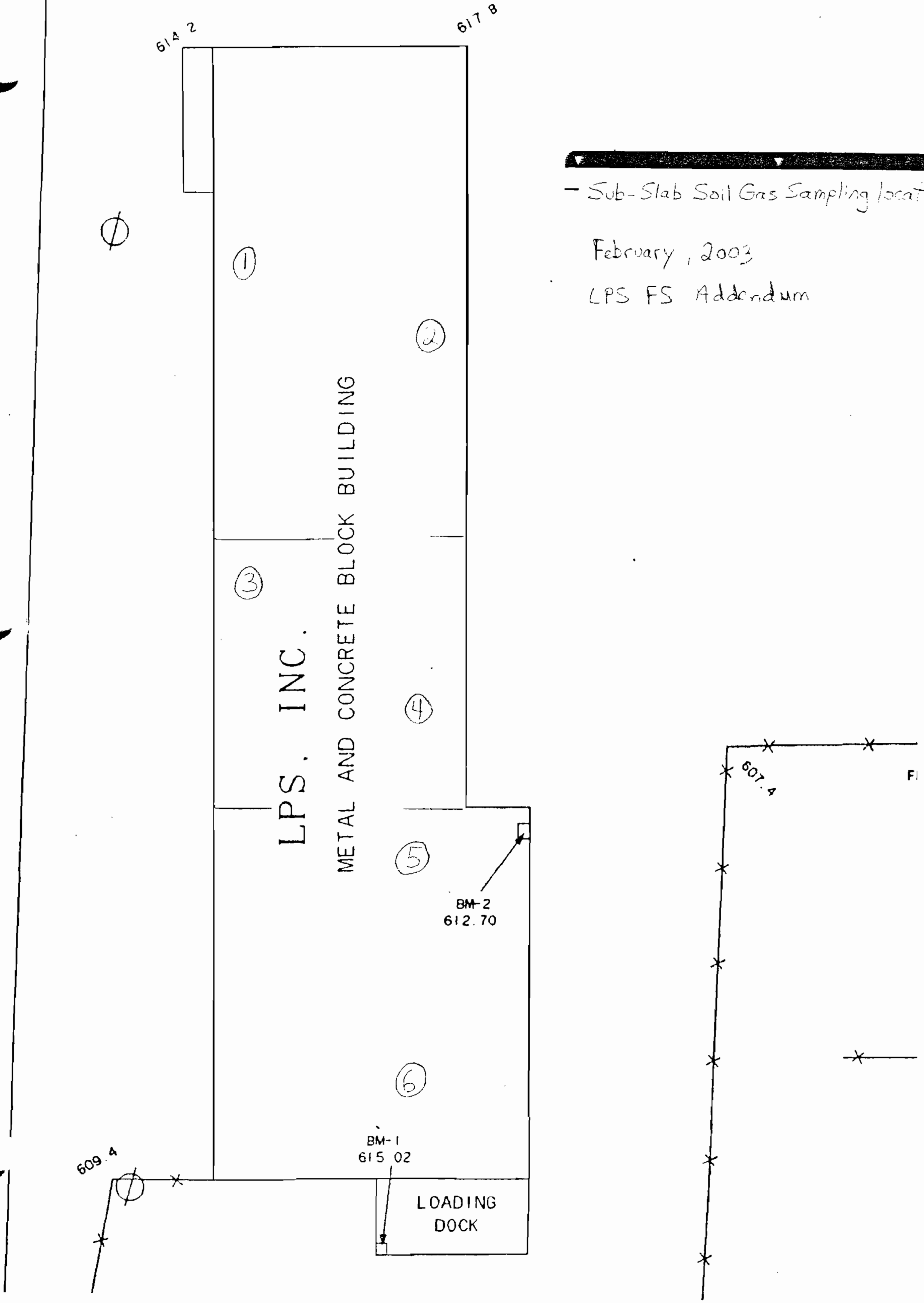
cc
Michael Sandor, MJS Engineering
Douglas Zamelis, Green & Seifter
George Saines, LPS

stevesaines@yahoo.com
740-385-7810 (H)
740-385-5445 (W)

- Sub-Slab Soil Gas Sampling locations -

February, 2003

LPS FS Addendum



257 Midland Place
Logan, OH 43138-1234
February 8, 2003

Ms. Gianna Aiezza
New York State Department of Environmental Conservation
Division of Environmental Remediation, Region 3
21 South Putt Corners Road
New Paltz, NY 12561-1696

RE: LPS, Site No. 3-36-034, Orange Co., NY — FS Comments Letter.

Dear Ms. Aiezza:

I received your Feasibility Study Report comment letter of January 27, 2003 one week ago (January 31, 2003). Thank you for enumerating the LPS FS deficiencies as judged by NYSDEC, and for including the December 3, 2002 NYSDOH comments concerning the same FS report.

I hope to address your comments and those of NYSDOH in the near future, starting with a proposal to conduct a sub slab soil gas survey of the LPS building. Even though LPS is willing to conduct a sub slab soil gas survey in the interests of finalizing its FS obligations, we would like to state our opposition to this plan, especially since LPS already evaluated a sub slab soil vapor extraction system in the FS report to mitigate any hypothetical atmospheric TCA exposure to current and future occupants of the building. After speaking with you on the telephone earlier this week, you indicated that NYSDEC is not only interested in worker health issues, but in delineating additional contamination underneath the building. We also oppose the survey on these grounds, because we believe sub-slab contamination to be a remote possibility given that the LPS concrete floor is in good shape and no floor drains exist. As we prepare for the survey, our biggest obstacle to collecting samples (besides added costs to the FS project) may be finding appropriate places to drill into the floor. The current occupant of the building (TriBor Corp.), manufactures medical supplies and requires dust free "clean rooms" to assemble its products. I will contact TriBor in the coming week to discuss possible locations for floor sampling ports. Following a discussion with TriBor, I will call you to discuss the possible number and location of sub slab sampling ports inside the LPS building. I will also require some guidance from your office concerning the technical specifications for installing and sampling the sub-slab ports. If you have NYDEC or NYSDOH guidance on this type of work, I will be requesting a copy.

LPS will proceed with the sub slab soil gas proposal as required by your FS comment letter. However, I may require an extension to your February 17, 2003 deadline for proposal submission since I am concurrently working on fulfilling another NYSDEC submission deadline. On January 24, 2003, Donna Weigel of your Bureau of Program Management in Albany, NY submitted to LPS a partial cost recovery bill for $28,406. LPS is not sufficiently capitalized to make this payment and is requesting an extended schedule of payments from NYSDEC. Any expenditure of funds to NYSDEC for cost recovery purposes at this time will also make it more difficult for me to complete the FS in a time frame considered acceptable by your office. We are currently completing a NYSDEC financial disclosure questionnaire and will submit this to your Albany office in the near future. Please take these issues into consideration prior to taking any enforcement action against LPS. It is the intent of LPS to comply with its RI/FS obligations as outlined in the consent order governing this site. However, we can only achieve this outcome by efficiently conducting all RI/FS tasks within the bounds of our financial resources.

Sincerely,

Steven J. Saines

cc:
Michael Sandor, MJS Engineering
Douglas Zamelis, Hancock & Estabrook
George Saines, LPS
Laura Zeppetelli, NYSDEC

stevesaines@yahoo.com
740-385-7810 (H)
740-385-5445 (W)

257 Midland Place
Logan, OH 43138-1234
February 8, 2003

Ms. Laura Zeppetelli
New York State Department of Environmental Conservation
Division of Environmental Remediation
Bureau of Program Management, Room 1224
625 Broadway
Albany, NY 12233-7012

RE: LPS, Site No. 3-36-034, Orange Co., NY — Cost Recovery Bill No. 1

Dear Ms. Zeppetelli:

Thank you for taking my phone calls and emails this past week concerning the above referenced cost recovery bill for $28,406.69. LPS/George Saines, Inc. is not sufficiently capitalized to make a payment of this magnitude within the 30 day time frame required by NYSDEC. We are therefore requesting that New York consider a yearly payment schedule which will allow LPS/George Saines, Inc. to make payments to the state while it also pays past debts and ongoing expenses related to the RI/FS work being conducted at the LPS site. A specific proposal will be included when we submit the financial disclosure questionnaire you sent me earlier this week.

I received the electronic version of the financial disclosure questionnaire and was able to send this to my father, George Saines, for review. As per our most recent email exchanges, my father is in the process of completing the form as George Saines, Inc., respondent in the order on consent at the LPS site. I will be submitting his responses to you following a brief review by our attorney, Douglas Zamelis. However, as I stated in our email correspondence, the questionnaire appears to ask individual questions which do not supply meaningful responses for a corporation. Please advise.

As per our telephone discussion, I want to record NYSDEC's willingness to suspend the deadline for submitting payment to New York State (March 2, 2003) until we resolve the issue described above. Please call or email me if you have any questions or feel I am misrepresenting our discussions. Thank you for your assistance thus far.

Sincerely,

Steven J. Saines

cc
Michael Sandor, MJS Engineering
Douglas Zamelis, Hancock & Estabrook
George Saines, LPS
Gianna Aiezza, NYSDEC

stevesaines@yahoo.com
740-385-7810 (H)
740-385-5445 (W)

New York State Department of Environmental Conservation
Division of Environmental Remediation, Region 3
21 South Putt Corners Road, New Paltz, New York 12561-1696
Phone: (845) 256-3153 • **FAX:** (845) 255-3414
Website: www.dec.state.ny.us

Erin M. Crotty
Commissioner

January 27, 2003

Steven J. Saines
257 Midland Place
Logan, Ohio 43138-1234

Re: Feasibility Study Report
Lubricant Packaging Inc.
Inactive Hazardous Waste Disposal Site No. 3-36-034

Dear Mr. Saines,

The NYSDEC and NYSDOH have reviewed the Feasibility Study Report dated November 2002 and provide the comments outlined below. Specific NYSDOH comments can be found attached.

1. Remedial Goals for this site, since it is a Class 2 site, is the restoration of the site to pre-disposal/pre-release conditions, to the extent feasible and authorized by law. Furthermore, New York State guidelines and standards are to be used as cleanup objectives. Revise the Report to reflect this.

2. A detailed discussion of the remedial alternatives need to be included in the report. This should include discussion of volume to be removed off site, pilot testing as necessary, volume of oxidants to be used, etc.

3. Costs need to be present as capital costs, annual operation and maintenance costs and present worth values.

4. Time frames need to be provided for time to implement the remedy and expected length of time to meet remedial action objectives.

5. Include Soil Vapor Extraction as an alternative for soil remediation.

6. Refer to applicable figures and tables in the appendices throughout the FS Report.

As discussed with you by telephone, soil gas sampling should be performed under the building prior to revising the Feasibility Study Report. Submit a proposal for soil gas sampling by February 17, 2002. If you have any questions, please feel free to contact me at (845) 256-3153.

Sincerely,

Gianna Aiezza

Gianna Aiezza
Project Manager

DOH STATE OF NEW YORK
DEPARTMENT OF HEALTH

Flanigan Square, 547 River Street, Troy, New York 12180-2216

Antonia C. Novello, M.D., M.P.H., Dr.P.H.
Commissioner

Dennis P. Whalen
Executive Deputy Commissioner

RECEIVED
DEC 6 2002
NYS-DEC
REGION 3-NEW PALTZ

December 3, 2002

Ms. Gianna Aiezza
NYS Department of Environmental Conservation
Division of Environmental Remediation, Reg. 3
21 South Putt Corners Road
New Paltz, New York 12561-1696

Re: Feasibility Study Report
Lubricant Packaging and Supply
Middletown, Orange County
Site # 366034

Dear Ms. Aiezza:

I have reviewed the *Feasibility Study* for the above referenced project and offer the following comments:

- The data does not support the conclusion that the levels of volatile organic compounds (VOCs) found in on-site soil and groundwater are not sufficiently elevated to create a discernable impact to soil gas and subsequently to indoor air. Please refer to the soil gas survey completed in 1993. The levels of soil gas found during that investigation were significantly elevated when compared to NYS DOH background air concentration database.
- Please be advised that OSHA standards pertain to those facilities actively using specific chemicals and whose employees are using these chemicals in the current process. They will have been advised of the toxicity and possible side effects of the chemicals of concern. OSHA standards do not apply to employees who may be inhaling VOC impacted indoor air that is not due to current production processes. It is more appropriate to compare indoor air concentrations to expected background concentrations.
- The General Switch property (NYS HWS Registry Site # 336025) has had documented disposal of VOCs resulting in impacts to soil and groundwater. Therefore, it is inappropriate to use background samples collected from General Switch property to develop site specific cleanup criteria for the LPS property. The New York State guidelines and standards should be used as cleanup objectives—keeping in mind that the feasibility of achieving these objectives can be reevaluated, as necessary, during the remedial process.
- Indicate the location of GMW-9 and supply the data collected from its' last monitoring event.
- Please provide clarification of the following statement found on Table 12: "NYSDOH Blah Blah Indoor Air Standards".

I thank you for the opportunity to comment on this project and look forward to its' progress. If you have any questions, I can be reached at (518) 402-7880.

Sincerely,

Bridget K Callag

Bridget K. Callaghan
Environmental Specialist
Bureau of Environmental Exposure Investigation

cc: Mr. G. Litwin / Mr. G. Laccetti / file
Mr. K. Mundy – OCDH
Mr. R. Pergadia – NYSDEC, Reg.3

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257 Midland Place
Logan, OH 43138-1234
July 30, 2002

Ms. Gianna Aiezza
New York State Department of Environmental Conservation
Division of Environmental Remediation, Region 3
21 South Putt Corners Road
New Paltz, NY 12561-1696

RE: LPS, Site No. 3-36-034, Orange CO., NY - July 2002 RI Report Editions.

Dear Ms. Aiezza:

I received your July 24, 2002 letter this past weekend, which contains NYSDEC and NYSDOH comments on the June 2002 RI Report submitted on behalf of LPS / George Saines, Inc. Thank you for your timely review. I have prepared the following responses to your comments:

NYSDEC Comment 1: "It is the Department's understanding, based on telephone conversations with you, that a current well survey is being completed and will be submitted by the end of July, 2002."

LPS Response: This understanding is correct. A well survey map (Appendix M) is included with this letter along with edited segments of text from section 3.4 and Appendix F of the RI Report describing the well survey. All edited pages to the RI Report included with this letter are noted by the footer title and date; edited text appears in italics and/or strikeouts.

NYSDEC Comment 2: "It is the Department's understanding that a radon mitigation system will be included in the Feasibility Study per the NYSDOH's request. This is as an alternative to the soil gas sampling that was originally agreed upon as part of the Remedial Investigation, but was not completed."

LPS Response: I am in agreement with this arrangement, and George Saines has verbally consented to this course of action.

NYSDEC Comment 3: "The Department disagrees with your conclusion that soil contamination near the back door of the LPS building is from the adjacent property, located a good distance away and on the opposite side of Industrial Park Road."

LPS Response: The conclusion that General Switch could be responsible for the low levels of PCE and TCE found in soils on the far side of the LPS building is a difficult judgement to support. An early draft of the RI report also discussed the possibility that this contamination was due to LPS activity. The most honest conclusion I can make is that there is little evidence to support either conclusion. I have not found any evidence showing that LPS ever used PCE or TCE in the past. On the other hand, General Switch used PCE regularly. If LPS had received PCE or TCE tainted trichloroethane (TCA) from a solvent supplier, one would expect to find relatively greater amounts of TCA contamination in the soil along with traces of TCE and PCE. But in several of the soil samples collected, no TCA contamination was present. It is also not plausible to believe that PCE and TCE could be the result of TCA decomposition, since the former two compounds contain double bounded carbon atoms and/or one additional chlorine atom in their molecular structure. Nature does not support PCE or TCE production from TCA thermodynamically. Therefore, the only two likely possibilities for the presence of PCE and TCE in LPS soils and ground water is: 1) water and/or soil gas transport from an adjacent property to the LPS site, or; 2) the undocumented past use of PCE and TCE by LPS personnel. Since it appears quite reasonable that up gradient PCE and TCE contamination is responsible for the presence of these compounds at other locations on the LPS property, I did not believe it is unreasonable to suspect that releases on the General Switch Site might also be responsible for the presence of PCE and TCE at these locations on the LPS property. I am not sure the assignment of the source of these compounds will materially change the RI process at the LPS site, nor the clean up strategies considered in the FS. If NYSDEC is willing to live with this uncertainty for the time being, LPS is also willing to set this issue aside.

NYSDEC Comment 4: "As discussed with you, a Feasibility Study is being developed and will be submitted by the end of October, 2002."

LPS Response: I will diligently work on the FS, following this submission, in an effort to meet your October deadline. I would, however, like the department to make at least one or two recommendations (not requirements) concerning the type of remedial technologies they feel would best be suited for use at the LPS site. For financial reasons, LPS is not prepared to submit multiple FS reports in the future if the Department judges the clean-up technologies reviewed in the first FS to be inappropriate. Currently, I am entertaining the evaluation of the following two clean-up strategies: 1) physical removal of contaminated soils to a landfill, and; 2) phytoremediation. Please let me know what your thoughts are concerning clean up strategies.

Included with your July 24, 2002 letter was a June 25, 2002 comment letter from Bridget Callaghan of the NYSDOH. Her comments and my responses are listed below:

NYSDOH Comment 1: "Section 2.3 - Groundwater flow is to the southeast not the southwest."

LPS Response: Agreed. The reference to ground water flow direction has been corrected in section 2.3 and a revised page is included with this letter.

NYSDOH Comment 2: "Section 3.4 - Please clarify whether an additional well survey will be performed."

LPS Response: A well survey was performed earlier this month and a map illustrating the results is included with this submission (Appendix M)

NYSDOH Comment 3: "Section 3.5 - Monitoring well LMW-5 was installed next to monitoring well LMW-1, not monitoring well LMW-2."

LPS Response: The error in describing the new bedrock well (LMW-5) location has been corrected and a revised page from Section 3.5 is included with this letter.

NYSDOH Comment 4: "Section 5.0 - It is important to note that while no off-site contamination was found during this investigation, previous investigations have indicated off-site migration of the contaminants."

LPS Response: Agreed. This point has been added to conclusion 5 using similar language; a revised page from Section 5.0 is included with this letter.

NYSDOH Comment 5: "Elevated levels of carbon tetrachloride are found in three of the on-site wells (LMW-2, LMW-3 and LMW-4). Since this chemical is found downgradient and not upgradient, in monitoring well GW-6, the source may be on-site. Indicate whether it is known if this chemical, or any others, were used on-site."

LPS Response: No use of carbon tetrachloride has been documented at the LPS site; in fact, the use of carbon tet in the U.S. after 1970 was widely curtailed due to health and safety issues. There is no easy explanation for its presence in the above referenced monitoring wells. During the Phase II Investigation at LPS, carbon tetrachloride was not detected in soil or ground water. The source of carbon tetrachloride is currently not known; I am not certain if General Switch ever used this compound.

NYSDOH Comment 6: "Additional monitoring wells should be installed to the southwest and south to delineate the plume of volatile hydrocarbons in ground water."

LPS Response: Additional monitoring wells down gradient of LPS could better define the extent of volatile organic compounds in the ground water system. However, adjacent (down gradient) property owner Risdon Corp. did not respond to letters and phone calls, except to say it would study the matter. The RI proceeded without a formal response by Risdon. Although testing sediments in Draper Run did not detect any volatile organic contamination, the down gradient Draper Run (surface water) sampling point detected TCA at a level of 1.6 ppb. It is possible that this detection is from releases at LPS.

NYSDOH Comment 7: "Please indicate if the historic well located on the Risdon Property is still viable. This well would provide additional data for plume delineation."

LPS Response: Consultants for the General Switch site indicated the well no longer exists. A long time employee of Risdon indicated the same. As noted above, Risdon did not formally communicate with me during the RI.

NYSDOH Comment 8: "Please conduct an interior survey of on-site buildings to identify any sumps or floor drains."

LPS Response: This was done during the Phase II Investigation and during the RI. No sumps or floor drains exist in the old or new section of the LPS building. Reference to past surveys of the building are noted in the first paragraph on page 2 of the Exposure Assessment Report, found in Appendix F of the RI Report.

NYSDOH Comment 9: "Remove the following statement: ' TCA is not classifiable as a human carcinogen. It is therefore thought that exposure to levels of TCA found near hazardous waste sites in the U.S. do not cause significant health effects.' EPA classification of human carcinogen does not represent all possible health effects. Non-carcinogenic effects must also be considered."

LPS Response: The above noted statement has been removed; a revised page to Appendix F accompanies this letter.

I trust you will find the above responses to be satisfactory to NYSDEC and NYSDOH. If you object to any of the responses, please feel free to contact me again. With the completion of the well survey and RI editions, I am now able to concentrate my efforts on the completion of the FS. If you are aware of other contaminated sites with similar characteristics to the LPS site, and where an FS has already been completed to the satisfaction of NYSDEC and NYSDOH, please let me know. I would like to use other successful FS reports as models to guide me in the creation of the upcoming LPS FS. Thank you for your time and consideration in reviewing this submission.

Sincerely,

Steven J. Saines

Steven J. Saines

cc w/out enclosures: MJS Engineering
Douglas Zamelis
George Saines

stevesaines@yahoo.com
(740) 385-7810 (H)
(740) 380-5445 (W)

New York State Department of Environmental Conservation
Division of Environmental Remediation, Region 3
21 South Putt Corners Road, New Paltz, New York 12561-1696
Phone: (914) 256-3153 • **FAX:** (914) 255-3414
Website: www.dec.state.ny.us

Erin M. Crotty
Commissioner

July 24, 2002

Steven J. Saines
257 Midland Place
Logan, Ohio 43138-1234

Re: Remedial Investigation Report
Lubricant Packaging Inc.
Inactive Hazardous Waste Disposal Site No. 3-36-034

Dear Mr. Saines,

The NYSDEC and NYSDOH have reviewed the Remedial Investigation Report dated June 2002 and provide the comments outlined below. Specific NYSDOH comments can be found attached.

1. It is the Department's understanding, based on telephone conversations with you, that a current well survey is being completed and will be submitted by the end of July 2002.

2. It is the Department's understanding that a radon mitigation system will be included in the Feasibility Study per the NYSDOH's request. This is as an alternative to the soil gas sampling that was originally agreed upon as part of the Remedial Investigation, but was not completed.

3. The Department disagrees with your conclusion that soil contamination near the back door of the LPS building is from the adjacent property, located a good distance away and on the opposite side of Industrial Park Road.

4. As discussed with you, a Feasibility Study is being developed and will be submitted by the end of October 2002.

Provide responses and a revised pages of the RI Report by August 12, 2002. If you have any questions, please feel free to contact me at (845) 256-3153.

Sincerely,

Gianna Aiezza

Gianna Aiezza
Project Manager

cc: R. Pergadia
R. Rusinko, Esq
B. Callaghan (NYSDOH)

STATE OF NEW YORK
DEPARTMENT OF HEALTH

Flanigan Square, 547 River Street, Troy, New York 12180-2216

Antonia C. Novello, M.D., M.P.H., Dr.P.H.
Commissioner

Dennis P. Whalen
Executive Deputy Commissioner

RECEIVED
NYS-DEC
REGION 3-NEW PALTZ

June 25, 2002

Ms. Gianna Aiezza
NYS Department of Environmental Conservation
Division of Environmental Remediation, Reg. 3
21 South Putt Corners Road
New Paltz, New York 12561-1696

Re: Remedial Investigation Report
Lubricant Packaging and Supply
Middletown, Orange County
Site # 366034

Dear Ms. Aiezza:

I have reviewed the Remedial Investigation Report for the above referenced project and offer the following comments:

Specific Comments

- Section 2.3 - Groundwater flow is to the southeast not the southwest.
- Section 3.4 - Please clarify whether an additional well survey will be performed.
- Section 3.5 - Monitoring well LMW-5 was installed next to monitoring well LMW-1, not monitoring well LMW-2.
- Section 5.0 - It is important to note that while no off-site contamination was found during this investigation, previous investigations have indicated off-site migration of the contaminants.

General Comments

- Elevated levels of carbon tetrachloride are found in three of the on-site wells (LMW-2, LMW-3 and LMW-4). Since this chemical is found downgradient and not upgradient, in monitoring well GW-6, the source may be on-site. Indicate whether it is known if this chemical, or any others, were used on–site.
- Additional monitoring wells should be installed to the southwest and south to delineate the plume of volatile hydrocarbons in groundwater.
- Please indicate if the historic well located on the Ridson Property is still viable. This well would provide additional data for plume delineation.
- Please conduct an interior survey of on-site buildings to identify any sumps or floor drains.

Appendix F: Exposure Assessment

- Remove the following statement: " TCA is not classifiable as a human carcinogen. It is therefore thought that exposure to levels of TCA found near hazardous waste sites in the U.S. do not cause significant health effects." EPA classification of human carcinogen does not represent all possible health effects. Non-carcinogenic effects must also be considered.

Soil gas sampling that was requested by NYS DOH and proposed in the scope of work has not been conducted. Please provide me with a sampling plan for review prior to sample collection. The sampling plan and data may be submitted as an addendum under a separate cover.

The Remedial Investigation has not provided sufficient information to fully assess public exposures. I reserve further comment pending resolution of this matter. I thank you for the opportunity to comment on this project and look forward to its' progress. If you have any questions please contact me at (518) 402-7880.

Sincerely,
Bridget K Callagh
Bridget K. Callaghan
Environmental Specialist
Bureau of Environmental Exposure Investigation

cc: Mr. G. Litwin / Mr. G. Laccetti / file
Mr. K. Mundy – OCHD
Mr. R. Pergadia – NYSDEC, Reg.3

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A Brief History of Lubricant Packaging & Supply Co. Inc.

February, 2003

Steven J. Saines

A Brief History of LPS
An Outline

- Site History
- Clean Up Strategy
- Investigation Results
- LPS Finances
- Personal Limitations
- Future Course of Action

LPS Site History: Prior to 1962

- Prior to the industrial revolution, the area consisted of wooded seasonal wetlands, similar to the undeveloped parcels of property west of the LPS site
- During the late 1800s, the LPS property was located along the northern edge of a large railroad marshaling facility developed on the northern edge of the city of Middletown

LPS Site History: 1962 - 1972

- The City of Middletown developed Industrial Place for new and expanding companies in the Middletown area
- Thomas Freeborn and partner constructed and operated F&W Bearing Service at 17 Industrial Place
- The original building was constructed with a solid concrete slab as floor. No floor drains exist
- Six oil storage tanks were placed along the eastern (back) portion of the building.
- One storage tank dedicated to solvents (usually mineral spirits, infrequently 1,1,1 TCA)

LPS Site History: 1962 - 1972 (cont.)

- Bearings most often degreased by tumbling in mineral spirits, TCA used to remove specialty greases. (F&W regreased/oiled bearings and returned to owner.)
- TCA also packaged as pure solvent to customers
- Some TCA soil and water contamination probable during Freeborn's management of F&W Bearing
- TCA contamination not believed to be widespread, but concentrated on the eastern edge of the property

LPS Site History: 1972 - 73

- F&W Bearing Service sold to George Saines
- George Saines re-names business Lubricant Packaging & Supply Co., Inc., as the direct sale and re-packaging of lubricants dominate business activities

LPS Site History: 1973 - 86

- Business expands and products (mostly drums of grease & oil) are stored outside
- Truck trailers also parked in yard to store unused containers, cases of oil, transmission fluids, etc
- Extension to the building added, doubling storage area.
- Building extension also has poured concrete floor
- Outside storage of products still common practice as business & stock continue to expand

LPS Site History: 1973 - 86 (cont.)

- *Personal experience*: spillage commonly caused when truck or fork lift transport damages drums or containers.
- Spillage also occured below the tank farm during tanker unloading of oils and solvents
- *Personal estimate*: 95 - 99% of fluids spilled on site were lubricating oils or mineral spirits.
- *Personal estimate*: Less than 5% of spillage was TCA
- 1985-6, purchase of wharehouse property on 75 Wisner Ave, ½ mile from LPS site

LPS Site History: 1986

- Sale of business stock, machinery & customers to SOS Fuels, Inc
- Sale of wharehouse property on Wisner Ave. also to SOS Fuels, Inc.

LPS Site History: 1987

- Inspection of LPS property at 17 Industrial Place by NYSDEC -Discovery of drums containing TCA and soils contaminated with TCA
- NYSDEC classifies site as a category "2a" hazardous facility

LPS Site History: 1991-1995

- LPS enters Phase I and Phase II consent agreement with NYSDEC, 1991
- ERM-Northeast completes Phase I Investigation, 1991
- Preliminary Investigation completed (grid established, geophysics & soil gas surveys conducted), 1993
- Phase II investigation completed, 1994
- NYSDEC reclassifies LPS site from "2a" to "2", 1995

LPS Site History: 1999-2003

- NYSDEC solicits LPS to enter RI/FS order, 1999.
- Steve Saines meets / discusses RI/FS options with NYSDEC legal & technical staff prior to order signing
- NYSDEC verbally expresses a willingness to "work with" LPS as best it can during the RI/FS process and during the remedy selection
- LPS submits RI Work Plan prior to RI/FS Order, then signs order with Work Plan attached, April 2000
- RI work completed, July 2002
- FS work and report are submitted, November 2002
- NYSDEC requests additional FS work, January 2003.
- First past cost recovery bill submitted to LPS, January 2003

LPS Clean Up Strategy

- Protect human health and the environment with respect to past releases of TCA at the LPS site.
- Comply with NYSDEC requirements to the maximum extent possible
- Remain a responsible landowner in Middletown's Northern Industrial Park

LPS Clean Up Strategy (cont.)

- Avoid litigation / attorney services as much as possible.
- Utilize Steve Saines as much as possible (to reduce professional service costs).
- When using Steve Saines, request sufficient time for task completion from NYSDEC.
- In the RI, use innovative technologies to increase site characterization cost efficiency
- In the FS, evaluate newer, less expensive technologies capable of cleaning up the site

LPS Investigation Results

- Phase II investigation discovered release spill areas with a soil gas survey
- Analytical results from 8 soil sampling locations and 4 monitoring well locations defined site conditions.
- The RI confirmed the Phase II findings with 20 new soil sample locations. No new TCA source areas were delineated
- The RI also sampled the 4 existing Phase II monitoring wells, 1 new bedrock well (constructed for the RI), 1 existing up gradient monitoring well (General Switch) and 1 down gradient stream location (Draper Run)

LPS Investigation Results (cont.)

- On-site ground water TCA concentrations have fallen significantly between 1993 and 2002.
- TCA contamination continues to comingle with chlorinated VOCs from the General Switch Site.
- General Switch is currently evaluating the rate & extent of its ground water contamination via orders with the USEPA

LPS Finances: 1972

- Lubricant Packaging & Supply, Inc. becomes the corporate structure by which LPS is operated.
- George Saines, Inc. is formed to purchase and maintain the LPS building at 17 Industrial Place

LPS Finances: 1972 - 1986

- LPS purchased an additional wharehouse on Wisner Avenue to accommodate storage needs

LPS Finances: December 1986

- Sale of LPS materials, customers and the Wisner Avenue wharehouse & property to SOS Fuels, Inc.
- Proceeds pay off outstanding loans (referenced earlier).
- George Saines continues to be employed by SOS Fuels until 1991.

LPS Finances: 1987 - Present

- In 1987, Lubricant Packaging & Supply Co. Inc. ceases to be a profit making company. It continues to exist as a corporation with expenses (losses).
- George Saines, Inc. rents the building & property @ 17 Industrial Place, starting in the late 1980s.
- The LPS building has hosted several tenants and experienced a few vacancy periods up to the present.
- Current occupant, TriBor, Inc., manufactures medical devices.

LPS Finances: 1987 - Present (cont.)

- Current gross property income @ 17 Industrial Place ~ **$24,000** / year.
- Current yearly expenses @ 17 Industrial Place ~ **$13,000** (> $9000 in taxes).
- Current net income @ 17 Industrial Place ~ **$11,000** (average for last 3 years).
- Studies, fines, prof. services @ 17 Industrial Place ~ **$160,000** since 1987
- Net Income from rental @ 17 Industrial Place ~ **$140,000** since 1987

LPS Finances: 1987 - Present (cont.)

- First cost recovery bill from NYSDEC for $28,500 due early March, 2003.
- FS still ongoing, all costs not yet submitted to George Saines, Inc
- Steven Saines only partially compensated for environmental services rendered over the past 10 years

LPS Finances: Present

LPS, Inc. & George Saines, Inc. cannot meet current & future financial obligations <u>with the pace of work and cost recovery currently required by NYSDEC</u>.

Personal Limitations

- Age Issues: George Saines (74) is dealing with memory limitations
- Health issues: George Saines is currently being treated for prostate cancer. Steve Saines has several ruptured discs making work at and travel to LPS more difficult
- Geographic Issues: Steve Saines is the principle consultant for the site, but lives and works in Ohio

LPS: Future Course of Action?

- Negotiate an extended project timeline?
- Implement an inexpensive remedy?
- Complete the FS?
- Begin payment on the first cost recovery bill?
- File for bankruptcy?

Presentation Limitations

The previous presentation, "A Brief History of Lubricant Packaging & Supply Co. Inc." was composed by Steven J. Sanes solely for the purposes of discussing with NYSDEC the limitations hindering LPS from complying with NYSDEC schedules for work completion and bill payments as per the RI FS Order governing the LPS site in Orange County, NY. The facts presented in this presentation are based on the author's knowledge of the site and its history, as experienced by him during his employment with the company during its operation as a for profit lubricant packaging business and during the period since 1987, in which he has acted as the principle environmental investigator for delineating the extent of TCA contaminant sources on this property. Steven Sanes has composed this presentation in manner consistent with sound engineering practices and with commonly practiced professional judgement. No other warranty or guarantee of its accuracy, expressed or implied, is made. This presentation does not attempt to evaluate past or present compliance with federal, state and local regulations. Furthermore, Steven Sanes makes no guarantees regarding the completeness of this information for any legal purposes.