Cost and Performance Summary Report
In Situ Bioremediation and Soil Vapor Extraction at the Former Beaches Laundry & Cleaners
Jacksonville Beach, Florida
March 2010

Executive Summary

The former Beaches Laundry and Cleaners (Beaches) was a large drycleaning business located at 106 North 6th Street in Jacksonville Beach, Florida. Beaches used tetrachloroethene (PCE) to conduct dry cleaning activities from 1950 to 1990. Analytical results from a groundwater sample collected during an initial site screening assessment conducted in 1996 indicated the presence of PCE and vinyl chloride (VC). Additional site investigations indicated high concentrations of PCE, trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2 DCE), and VC in groundwater that exceeded the Florida Groundwater Cleanup Target Levels (FGCTLs). The contaminated groundwater plume extended southwesterly for a distance of approximately 700 feet from the northeast corner of the building. Analytical results of soil samples indicated the presence of PCE at or below the Florida Soil Cleanup Target Levels (FSCTLs).

Three pilot injection of Fenton's reagent (hydrogen peroxide and ferrous iron catalyst) were conducted from July 1999 to August 2000 and did not significantly reduce VOC concentrations in groundwater. Therefore, a revised remedial action plan consisting of phased approach was implemented. The phased approach included excavation of contaminated soil followed by the Soil Vapor Extraction (SVE) system to accelerate the removal of mass from the source area. A total of 244 tons of contaminated soil was excavated from the northeast corner of the Beaches building. Following soil excavation, the SVE system began operation on February 7, 2007 to address remaining soil contamination in the vadose zone of the site. Groundwater treatment consisted of in situ enhanced bioremediation to expedite the bioremediation process of the plume through the addition of nutrient amendments (potassium lactate and denatured ethanol). During the enhanced bioremediation, a series of six injection events were conducted every month from January to June 2008.

Baseline and post injection monitoring was conducted at the site for both the SVE and enhanced bioremediation system. The goals of the revised remedial action plan is to reduce PCE, TCE, cis-1,2 DCE, and VC contaminant concentrations in the soil to below FSCTLs, and to reduce the groundwater contaminant concentrations to below the Florida Natural Attenuation Default Criteria (FNADCs). Once the FNADC are achieved, it is anticipated that natural attenuation will reduce the contaminant concentrations to below FGCTLs. Samples collected from the influent of the SVE system indicated that PCE and methane concentrations were below the detection limit; therefore, the SVE system was shut down and converted to a passive system in March 2009. Groundwater concentrations of PCE and TCE continue to exceed the FNADCs at several locations within the aquifer based on sampling in July 2008. Analytical results indicate that the phased remedial action at the site resulted in significant reductions in contaminant concentrations and are continuing to decrease.

Summary Information [1, 4, 6, 9, 10, 14]

The former Beaches Laundry and Cleaners (Beaches) was a large drycleaning business that used tetrachloroethene (PCE) to conduct dry cleaning activities from 1950 to 1990 (Figure 1). Beaches operated in a building located at 106 North 6th Street in Jacksonville Beach, Florida in an area of mixed commercial and residential development. Since the end of drycleaning operations in 1990, the building has been used for a variety of commercial purposes such as a skating and skateboarding recreational center and a community theater. During a site screening assessment conducted in the fall of 1996 by Earth Systems Group, Inc., a temporary well was installed near the northeast corner of the building at a depth of approximately six feet below ground surface (bgs). Analytical results from a groundwater sample collected from the temporary well indicated the presence of PCE and vinyl chloride (VC).

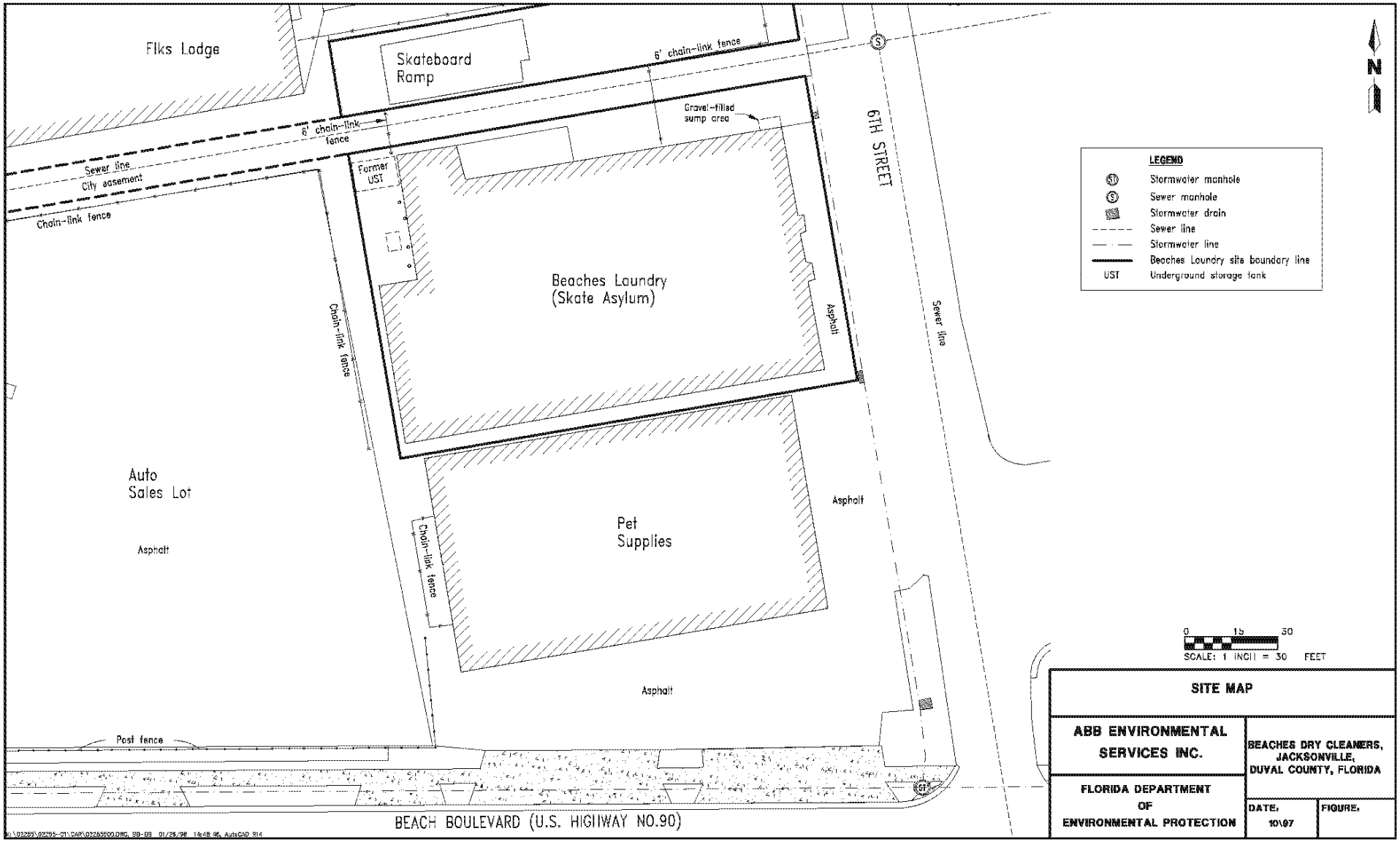
Cleanup Authority	FDEP State Cleanup
FDEP Facility ID:	169602467
Type of Action:	Drycleaning Solvent Cleanup Program
Lead:	Golder Associates
Oversight:	Florida Department of Environmental Protection (FDEP)

On January 13, 1997, Beaches was made eligible for cleanup under the Drycleaning Solvent Cleanup Program (DSCP). A contamination assessment was conducted in 1997 by ABB Environmental Services, Inc. (ABB-ES) for the Florida Department of Environmental Protection (FDEP), which involved soil sampling, groundwater sampling (collected from numerous direct-push technology [DPT] borings and 22 newly installed monitoring wells), and slug testing. Soil samples were generally collected in and around the likely primary source of contamination, which was a gravel-filled seepage bed used to receive PCE-laden condensate and rinse water that discharged to a pipe at the northeast corner of the building. Analytical results of soil samples indicated the presence of PCE. However, the concentrations in these samples were generally at or below the Florida Soil Cleanup Target Levels (FSCTLs) which are presented in Table 1.

Table 1: Florida Soil Cleanup Target Levels	
Tetrachloroethene (PCE):	30 µg/kg
Trichloroethene (TCE):	30 µg/kg
Cis-1,2 dichloroethene:	400 µg/kg

Analytical results from the groundwater sampling from the 1997 contamination assessment indicated extensive groundwater contamination in a large plume circumscribing concentrations of PCE, trichloroethene (TCE), cis-1,2 dichloroethene (cis-1,2 DCE), and VC that were found to exceed the Florida Groundwater Cleanup Target Levels (FGCTLs) shown in Table 2. The contaminated groundwater plume was 300 to 450 feet wide and extended southwesterly for a distance of approximately 700 feet from the northeast corner of the building. The plume was 20 to 40 feet thick, and the depth ranged from 5 to 45 feet bgs. Also, more than half of the total plume volume exceeded the Florida Natural Attenuation Default Criteria (FNADC) shown in Table 3, which are used to determine if groundwater contamination may be amenable to reaching the FGCTLs without active treatment of the plume.

Figure 1. Site Map [1]



PCE concentrations exceeded 1,500 µg/L at numerous locations throughout the plume and the highest concentration of PCE was 67,000 µg/l, detected in a DPT boring sample collected at a depth of 20 to 22 feet bgs, approximately 60 feet southwest of the building. These high concentrations of contaminants detected in the groundwater suggested the presence of Dense Non-Aqueous Phase Liquids (DNAPL) at the site.

Table 2: Florida Groundwater Cleanup Target Levels	
Tetrachloroethene (PCE):	3 µg/L
Trichloroethene (TCE):	3 µg/L
Cis-1,2 dichloroethene:	70 µg/L
Trans-1,2 dichloroethene:	100 µg/L
Vinyl Chloride:	1 µg/L

Table 3: Groundwater Natural Attenuation Default Criteria	
Tetrachloroethene (PCE):	300 µg/L
Trichloroethene (TCE):	300 µg/L
Cis-1,2 dichloroethene:	700 µg/L
Trans-1,2 dichloroethene:	1000 µg/L
Vinyl Chloride:	100 µg/L

Time Line	
1950 - 1990	Drycleaning operations
Fall, 1996	Site screening assessment
May – August 1997	Site contamination assessment
October 30, 1998	Initial remedial alternatives analysis recommended in-situ chemical oxidation for groundwater; no soil removal or treatment.
July, 1999; August, 1999; and May, 2000	Three pilot injection tests of different chemical oxidation agents were conducted, but did not significantly reduce VOC concentrations in groundwater.
September 13, 2001	Revised remedial alternatives analysis recommended a phased remediation approach, including excavation of contaminated soil in the source area above the plume, followed by co-solvent flushing within the plume, followed by enhanced bioremediation within the plume, followed by natural attenuation.
September – October 2002	Additional soil assessment conducted at the site.
April 28, 2004	FDEP approved soil excavation work plan, which recommended placing 11 horizontal SVE wells in the excavated area to allow subsequent treatment of soil containing less than 17 mg/kg of PCE to be left in place near building bearing walls.
August 3-25, 2004	Soil removal and SVE and injection well emplacement.
April 11, 2006	FDEP approves remedial action plan for operating the SVE system to remediate contaminated soil beneath the Beaches building, and for the design and operation of the enhanced bioremediation system to remediate contaminated groundwater beneath the building.
June 2006	SVE injection system connected to the SVE wells that were emplaced in 2004.
February 7, 2007	SVE system startup

Time Line	
January 21 – July 18, 2008	Enhanced bioremediation conducted by injecting a total of 77,400 gallons of potassium lactate and ethanol solution into the groundwater and flushing with 10,800 gallons of water over a six-month period, at depths ranging from 2 to 45 feet beneath an approximately 3,200 square-foot area on the northeast corner of the building that housed Beaches Drycleaner.
March 2009	SVE system shut-off and converted to a passive system.

Based on the results of the 1997 assessment, a remedial alternatives analysis was conducted in 1998 by Harding Lawson Associates (HLA). The remedial alternatives analysis recommended in situ chemical oxidation for groundwater, but contained no recommendation for the soil. Three separate injections of different chemical oxidation formulations were pilot tested at the site between July 19, 1999 and May 24, 2000. The chemical oxidation formulation used at the site was Fenton's reagent, which consisted of hydrogen peroxide and ferrous iron catalyst. The number of injection wells and percentage of hydrogen peroxide varied for each of the three injection tests. The injections were conducted in the area where the highest PCE concentrations were detected in the groundwater. The pilot test results indicated that in-situ chemical oxidation did not significantly reduce the concentrations of volatile organic chemicals (VOCs) in the groundwater, which may have been due to high buffering capacity found at the site. However, the likely reason for the failure of the chemical oxidation pilot tests to reduce contaminant concentrations in groundwater was that the injection wells were located hydraulically down gradient of the contaminant source area. A soil investigation conducted in the seepage sump area in 2001 had indicated the presence of more extensive soil contamination than had been found earlier. Therefore, later in 2001, HLA proposed a phased approach to remediation of the site; the approach involved excavation of contaminated soil, followed by co-solvent flushing (to sequentially dissolve and then extract DNAPLs) of the groundwater areas of highest concentrations, followed by enhanced in situ bioremediation of the groundwater to achieve the FNADC, which would allow active treatment to be discontinued and allow natural attenuation to achieve FGCTLs.

In 2002, during the first phase of the remediation plan which included soil excavation, additional sampling indicated the presence of PCE, TCE, and DCE soil concentrations with PCE as high as 258 mg/kg at depths of 2 to 5 feet bgs. A soil excavation target concentration of 17 mg/kg of PCE was used as an initial goal. However, this goal could not be achieved at various locations of the excavation areas due to close proximity of the water table (4 ft bgs) and the need to maintain the structural integrity of the buildings on site. Therefore, a soil vapor extraction system was planned to be installed and operated to achieve FSCTLs after excavation of contaminated areas. Approximately 174 cubic yards of contaminated soils were removed from the area beneath the facility floor slab in the northeast quadrant of the building that formerly housed the drycleaning operation.

In April 2004, as the draft remediation plan for soil was being refined, a membrane interface probe (MIP) investigation was conducted to better understand the extent of DNAPLs in the groundwater and additional groundwater monitoring was conducted to provide a better understanding of the shape and movement of the groundwater plume over time. Based on the results of these activities, it became evident that the size and concentrations of PCE and PCE

degradation products had declined significantly since the time of the soil removal action in September 2004. These changes were mainly attributed to the soil excavations, which had removed the main source of contamination, but it was also attributed to the dechlorination of the contaminants by naturally occurring biological agents. Based on this information, the remedial action plan for the groundwater phase of the cleanup approach was prepared in 2005 and was finalized in March of 2006. Enhanced bioremediation was selected as the treatment technology for groundwater; however it was recommended that it be applied only on a limited basis in the source area of the plume followed by an assessment to determine how it should be applied, as appropriate to the remainder of the plume.

After the remedial action plan was finalized in March 2006, the SVE system for soil remediation and the enhanced bioremediation injection system for groundwater remediation were installed by Golder Associates, Inc. Eleven horizontal SVE wells were installed following the 2004 excavation. However, these SVE wells were not operated until February 2007. The SVE system began operation on February 7, 2007. In March 2009, the SVE system was shut-off and converted to a passive system based on samples obtained in July 2008 and September 2008, which indicated non-detect levels of methane and PCE in the influent.

Implementation of the final 2006 remedial action plan for the enhanced bioremediation injection system was initiated by constructing six new injection wells spaced approximately 12 feet apart along the northern and eastern edges of the northeast corner of the building; each well contained screened injection points at three different depths. The 2006 remedial action plan also specified the use of three existing monitoring wells as additional injection points, and the use of the 11 SVE wells as surface-level injection points. A series of six injection events were implemented between January and June 2008 (one event per month). A total of 77,400 gallons of a solution containing 76,672 gallons of water, 193 gallons of 60% potassium lactate solution and 15.6 gallons of 90% ethanol solution was injected into the groundwater at depths ranging from 2 to 45 feet bgs beneath an approximately 3,200 square-foot area on the northeast corner of the building that housed Beaches. The injections were flushed with a total of 10,800 gallons of water to prevent biofouling of the injection wells. After the first four injections and one month following the fifth and sixth injection events, thirteen (13) groundwater samples were collected near the injection site and analyzed for PCE, TCE, cis-1,2 DCE, and VC. Figure 2 shows results for the four (4) samples collected in the shallow portion of the plume (approximately 8 to 20 feet bgs), and Figures 3, and 4 show the results for the six (6) and three (3) samples that were collected in the intermediate (approximately 20 to 30 feet bgs) and deep (approximately 30 to 45 feet bgs) portions of the plume, respectively. The figures also show samples that had been collected and analyzed prior to 2006 (baseline sampling event) thus illustrating the decrease in groundwater contamination that followed the soil removal phase of the cleanup in 2004.

Factors that Affected Cost or Performance [1, 2, 7]

The soil profile at the site consists of silty, fine to very fine-grained sand with shell fragments from surface to 40 - 50 feet bgs. Underlying the surficial sands is approximately 3 feet of clayey sand followed by 12 - 15 feet of clay overlying clayey sand. The maximum depth evaluated in the site investigation was 65 feet bgs. The shell fragments and carbonate sand grains found in the subsurface increased the buffering capacity of the soil. The increased buffering capacity appeared to have limited the effectiveness of the chemical oxidation pilot treatments.

The entire groundwater contaminated plume is contained within the surficial aquifer, which ranges in depth from 3 to 75 feet bgs across Duval County. This aquifer appears to reach depths of approximately 50 feet bgs at the site. As shown on Figures 2 through 4, groundwater contamination at the site is depicted in terms of three depth intervals because the surficial aquifer was subdivided into three similar, but slightly different zones, based on the initial and subsequent hydrogeological data collected at the Beaches site. The direction of groundwater flow within all three zones of this aquifer is to the east-southeast. Average hydraulic conductivities in the shallow, intermediate, and deep portions of the aquifer are 14, 5.87, and 18 feet per day (ft/day), respectively. The seepage velocities at the shallow, intermediate, and deep portions of the aquifer are 0.19, 0.06 and 0.036 ft/day, respectively.

Listed below are the key matrix characteristics employed at the site and the values measured for each during site characterization.

Matrix Characteristics [1,2,7,14]

Parameter	Value
Soil Classification	0-45 ft bgs: Sand 45-48 ft bgs: Clayey Sand 48-65 ft bgs: Clay
Hydraulic Conductivity	Shallow:14 feet per day Intermediate: 5.8 ft/day Deep: 1.8 ft/day
Seepage Velocity	Shallow:0.19 ft/day Intermediate: 0.06 ft/day Deep: 0.04 ft/day
pH	5.6 to 7.3
Temperature	24.5 to 28.5 degrees Celsius
Dissolved Oxygen	0.58 to 2.14 mg/l
Depth/Thickness of Zone of Interest	3 feet bgs or less

Figure 2. Pre- and Post-Treatment Groundwater Concentrations at the 8- to 20-foot Depth Interval [12]

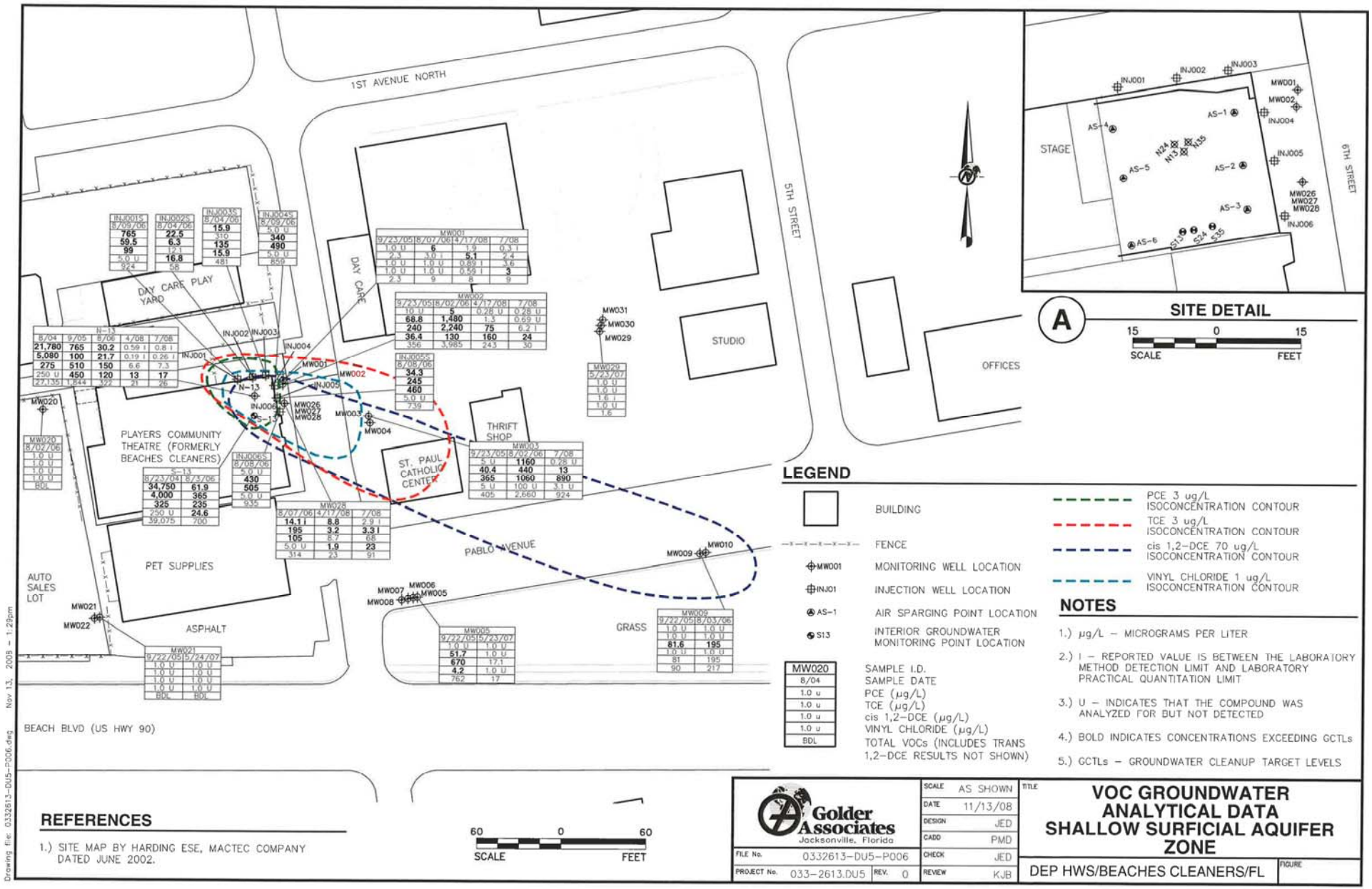


Figure 3. Pre- and Post-Treatment Groundwater Concentrations at the 20- to 30-foot Depth Interval [12]

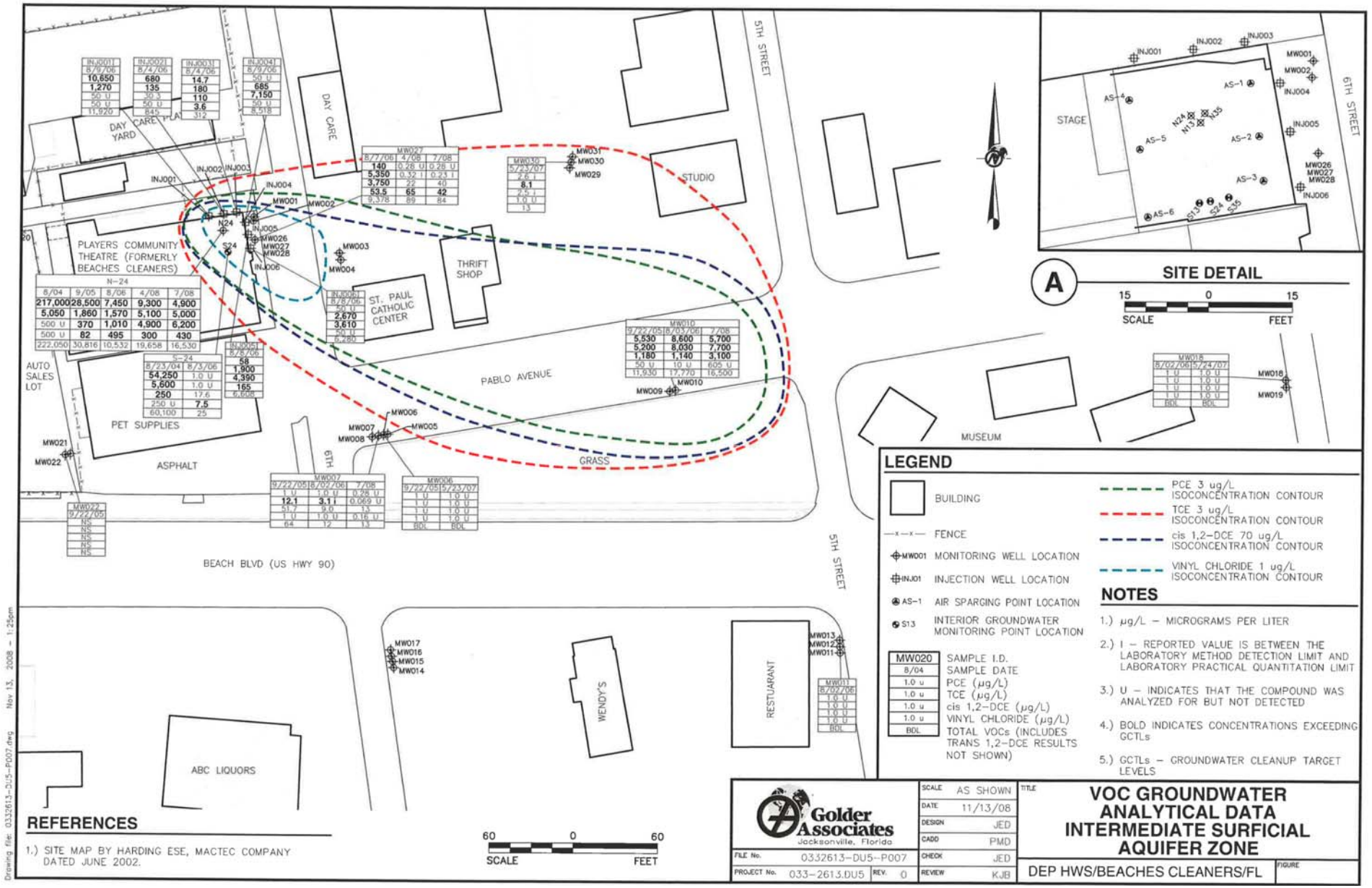
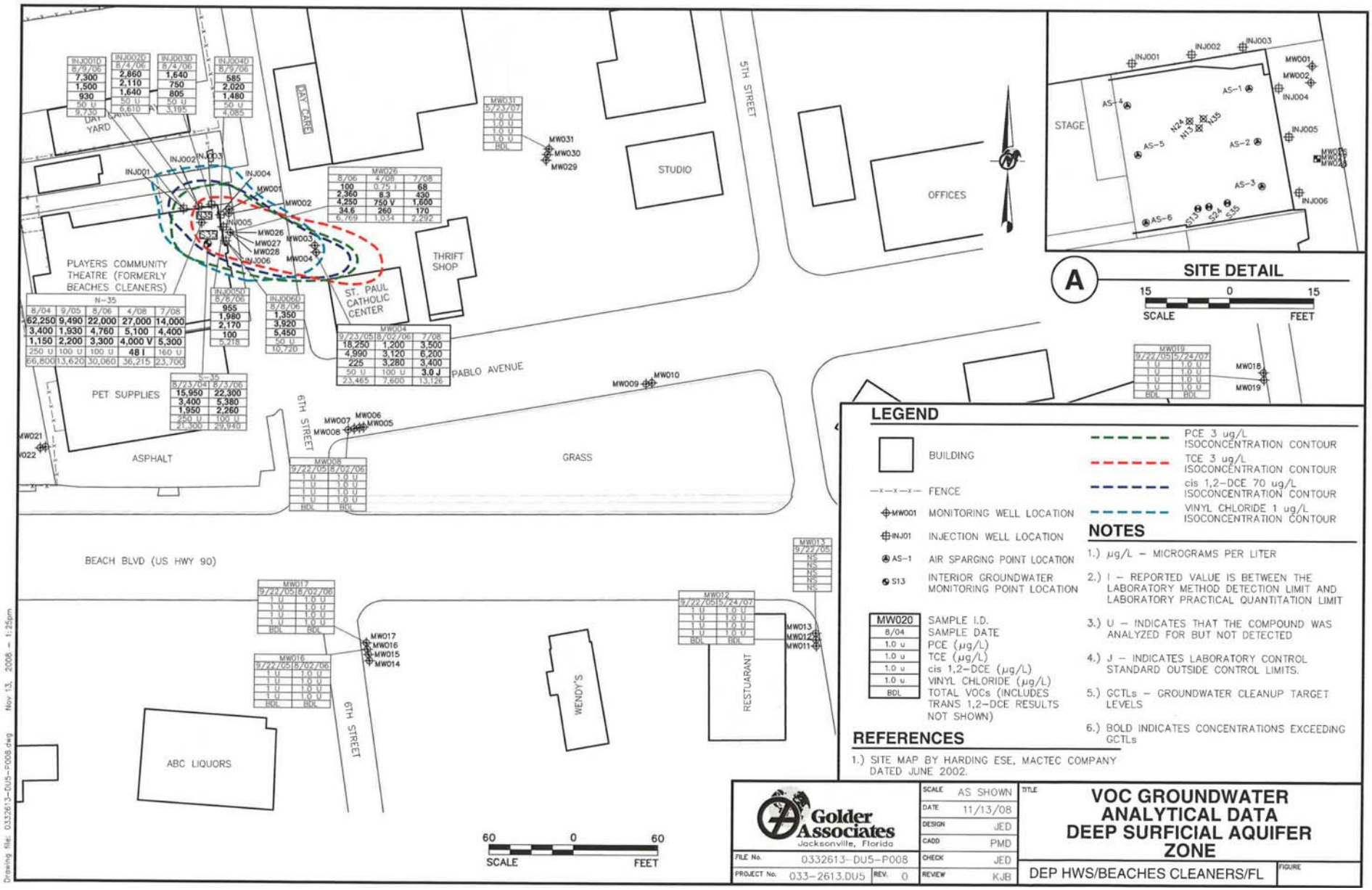


Figure 4. Pre- and Post-Treatment Groundwater Concentrations at the 30- to 45-foot Depth Interval [12]



Treatment Technology Description [6, 5, 9, 10, 13, 14]

As noted above, soil excavation and SVE were the technologies selected to address VOCs in the soil at the site, and enhanced bioremediation was the technology selected to address VOCs in the groundwater. The following subsections provide site specific details on the design and operation of the SVE system and the injection system used to implement the enhanced bioremediation technology.

Soil Vapor Extraction

The revised remedial approach recommended by HLA consisted of a phased approach consisting of soil excavation and in-situ enhanced bioremediation. The target area for the soil excavation was the area near the northeast corner of the site, where a soil sample exceeded the PCE FSCTL for leachibility (30 µg/kg). The soil excavation activities were completed in October 2004 and a total of 244 tons (174 yd^3) of contaminated soil and debris were removed from the northeast corner of the Beaches building. The excavated area was approximately 1,400 square feet. All materials with PCE concentrations above 17 mg/kg were removed from the southern and western portions of the site. The only remaining area where concentrations exceeded the removal goal was below the vadose zone in the upper surficial aquifer.

Following the 2004 source removal, a SVE system was designed to address soil contamination in the vadose zone of the site. The SVE system was installed to address portions of the site that could not be excavated due to building structural concerns and the shallow groundwater table. This system was used to facilitate the remediation of soil remaining at the site with PCE concentrations between the FSCTL (See Table 1) and 17 mg/kg. In addition, the SVE wells were designed such that they could quickly be converted into injection wells for injecting bioremediation enhancement agents (potassium lactate and denatured ethanol) as part of the enhanced bioremediation program, and then converted back to SVE wells after each injection event. Such conversions were successful, but required a one-week down period following each injection event to avoid fouling the SVE system due to biological growth.

The concentration of VOCs detected in the soil samples determined the placement of the horizontal SVE wells. A total of eleven four-inch diameter horizontal SVE wells were installed inside and adjacent to the soil excavation area, as shown in Figure 5. The SVE wells were installed approximately two feet bgs. The wells were constructed with a 4-inch inside diameter PVC piping with either 15 or 10 feet of screen. Further SVE well specifications are provided in Figure 6. Four wells were installed in close proximity to the south side of the interior excavation area and another four wells were installed directly within the excavation area, each measuring approximately 10 feet in screen length. Three wells with 10 feet in screen length were installed at the western wall of the final excavation area.

Due to the high hydraulic conductivity and high water table, the SVE system was designed to handle low vacuum pressure and low flow. The SVE system was powered by a 7.5 horsepower (HP) blower. The system consisted of vapor extraction wells and vacuum transmission lines to the SVE trailer that included control valves, a moisture separator, a surge tank, a vacuum blower, a particulate filter, and a carbon treatment unit. The moisture separator served to remove suspended water from the air stream. Wastes accumulated during this process were stored in a

moisture separator tank installed at the site. The air filtering system was installed to remove particulate matter from the air stream and the carbon adsorption unit helped keep the effluent discharge of target constituents to below 13.7 pounds per day. Each well was connected to a 2-inch conveyance pipe which includes a valve to allow adjustment of the vapor removal rate.

The key operating parameters for the SVE system applied at the site and the values measured for each of them are presented in Table 4.

Table 4: Soil Vapor Extraction	
Number of horizontal SVE wells	11
Well Screen Length.	10 or 15 feet
Depth of Installation	2 feet below ground surface
PVC diameter	4 inches
Screen Slot diameter	0.02 inches

The SVE system was monitored remotely and system maintenance visits were conducted 1 week after operation began and monthly thereafter. Due to water entrainment, there were a few occasions where the system was temporarily shut down until the water could be drained. As a result, the system operated approximately 76% of the time since the startup. Air samples were collected from the SVE system and analyzed for VOCs. During the operation of the SVE system, methane was detected in the system influent, most likely from the increased activity of methanogenic bacteria in response to the amendment injections. The SVE system was operated until samples collected in July 2008 and September 2008 indicated non-detect levels of methane in the influent vapor. The SVE system was then shut down and converted to a passive system in March 2009.

Figure 5. Soil Vapor Extraction System Well Locations [9]

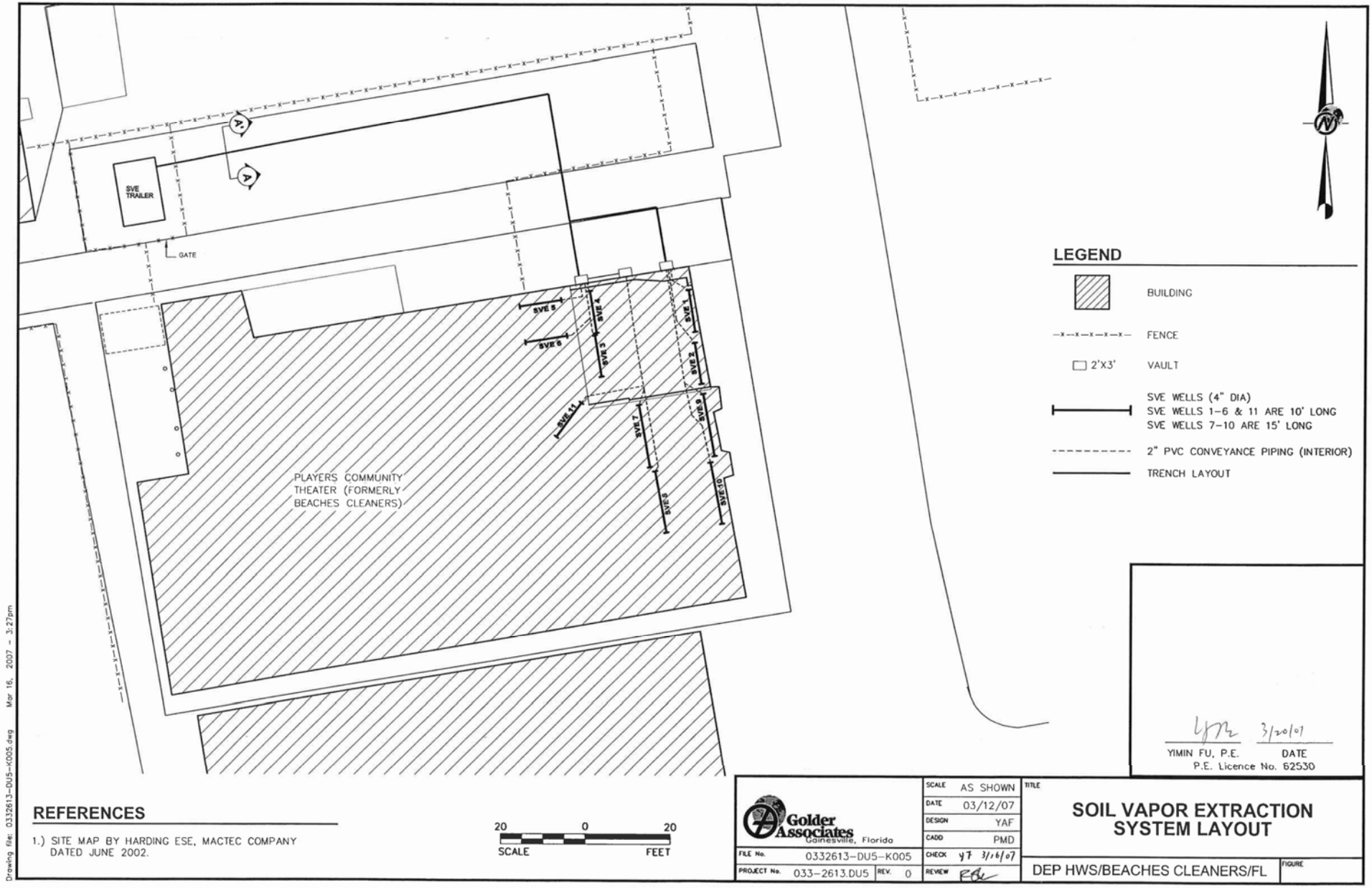
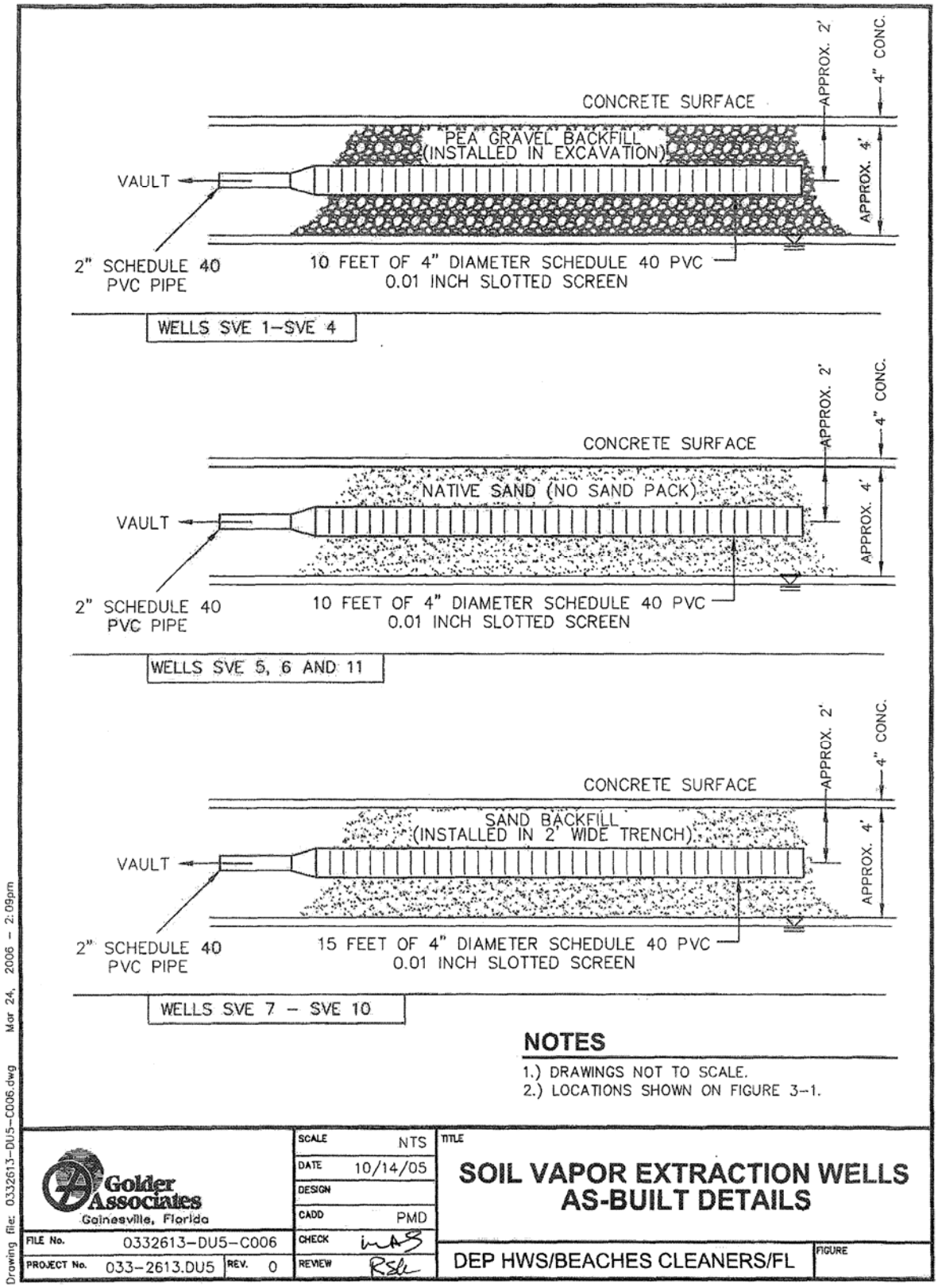


Figure 6. Soil Vapor Extraction System Well [8]



Enhanced Bioremediation

In situ enhanced bioremediation was recommended in order to expedite the bioremediation process in the dissolved phase (down gradient) portion of the plume through the addition of nutrient amendments. Excavation and SVE were included in the remedial design to accelerate the removal of mass from the source area. In-situ bioremediation was selected to address the dissolved PCE in groundwater.

Implementation of the final 2006 remedial action plan for the enhanced bioremediation injection system was initiated by constructing six new injection wells spaced approximately 12 feet apart along the northern and eastern edges of the northeast corner of the building; each well contained screened injection points at three different depths. The 2006 remedial action plan also specified the use of three existing monitoring wells as additional injection points, and the use of the 11 SVE wells as surface-level injection points. A total of 21 vertical injection points were used, including 7 well points between 10 to 20 feet bgs, 7 at 20 to 30 feet bgs, and 7 at 30 to 45 feet bgs. In addition the 11 SVE wells were utilized to inject into the first 3 feet of soil. Only five of the 11 SVE wells were used during the first and third injections, and the other 6 wells were used during the second and fourth events. All of the 11 SVE wells were used during the fifth and sixth events. The vertical injection well locations are depicted in site detail box, set in the upper right corner of Figure 2. There are three injection points each for well locations INJ-1 through INJ-6; Wells S-13, S-24, and S-35 each have one injection point.

A series of six injection events were conducted, one every month, from January to June 2008. The nutrient amendment consisted of potassium lactate and denatured ethanol to serve as a carbon and energy source to support the growth and activity of chlororespiratory microbes at the site. The stoichiometric requirement for the amendment design was calculated by determining the electron equivalents generated from the oxidation of potassium lactate and denatured ethanol in comparison to the electron equivalents required for complete reduction of VOCs and competing electron acceptors. An additional 80 percent factor of safety was included to compensate for the potential consumption of electron donor through methanogenesis. During each injection cycle, the amendment was mixed with 300 gallons of water for each injection well and flushed with water to clear the well screen. The amendment was injected on a monthly basis into each of the wells.

During the first four injection events, potassium lactate was mixed with groundwater into batches of 300 gallons (299 gallons of groundwater, 0.8 gallons of 60% potassium lactate solution, and 0.2 gallons of 90% ethanol solution). A total of 43 batches (each batch was 300 gallons) were injected for a total volume of 12,900 gallons during each of the first four events. During the first injection event, this mixture was injected into 26 injection points (21 vertical wells plus 5 of the SVE wells) at an average flow rate of 6 gallons per minute (gpm). The same process was used for the second injection event except 27 injection wells (21 vertical wells plus 6 of the SVE wells) were utilized instead of 26. The third injection event repeated the process used for the first injection event, and the fourth injection repeated the process used for the second injection event. During the first four injection events, a total of 51,600 gallons including 27 gallons of potassium lactate and 5.2 gallons of ethanol solution were injected into the wells at the site.

Based on the analytical results from the first four injections, the remedial action plan was modified to increase the amount of potassium lactate used in the injection. In addition, the injected volume was increased by an additional 300 gallons of water per well in order to distribute more carbon from the amendment in the intermediate and deep zones of the aquifer. For the fifth injection event, all thirty-two injection points (21 vertical wells and 11 SVE wells) were utilized at the site. Fifty-five batches of 300 gallons each were injected into each of these wells. The 300 gallon-solutions consisted of 298 gallons of groundwater, 1.5 gallons of potassium lactate and 0.2 gallons of denatured ethanol. A total of 18,600 gallons was injected at the site during the fifth injection event, and the same volume was injected again during the sixth event, which occurred from June 2 to 6, 2008. The total volume of groundwater and amendment solution injected during each of the six inject events is presented in Table 5. A total of 88,800 gallons of groundwater and nutrient amendments were injected during the six injection events.

Table 5: Enhanced Bioremediation Injection Amounts

Injection Event	Amount Injected (gallons)
1	12,900
2	12,900
3	12,900
4	12,900
Subtotal	**51,600**
5	18,300
6	18,300
Subtotal	**36,600**
Total	**88,200**

To decrease cost, the bioremediation process utilized the SVE wells along with injection wells and monitoring wells installed at the site. In order to inject the nutrient amendments into the SVE wells, the SVE system conveyance piping was modified. Ball valves were installed onto the piping for each SVE well to prevent the amendment slurry from entering the SVE system piping located inside the trailer. In addition, injection ports were installed near the ground surface for the amendment injection into the wells.

Performance Information [6,7, 8, 10, 11, 12, 13, 14]

The goals of the remedial action plan are to reduce PCE, TCE, cis-1,2 DCE, and VC contamination in the soil to the FSCTLs shown in Table 1, and in the groundwater to below the FNADCs shown in Table 3, which would eventually achieve the FGCTLs shown on Table 2 through natural attenuation. Neither of these goals have been met at the Beaches site; however, the phased approach, including excavation and SVE to address soil, and bioremediation to address groundwater appears to have resulted in significant reductions in the levels of contamination that were present at the site. The following paragraphs discuss monitoring results related to the implementation of the SVE and enhanced bioremediation technologies at the Beaches site.

SVE Monitoring Results

SVE influent air samples were collected monthly from April 2007 to September 2007. These air samples indicated PCE concentrations ranging from below detection limits (bdl) to 3.91 mg/m^3. The effluent SVE vapor indicated PCE concentrations ranging from bdl to 1.73 mg/m^3. The amount of VOCs within the effluent remained well below the maximum allowable limits of 2.8 pounds per day for individual Hazardous Air Pollutants (HAPS). Effluent air vapor was treated using an air filter system and activated carbon system.

From February 5, 2007 to September 30, 2007, the system removed a total mass of 4.63 lbs of VOCs. The average mass removal rate was 0.0005 lbs/day at an average air influent flow rate of 200 cubic feet per minute (cfm). Annual and cumulative mass recovery rates are shown in Figure 7.

Samples obtained in July 2008 and September 2008 indicated non-detect levels of methane. In addition, PCE levels were determined to be non-detect in the influent. As a result, the SVE system was shut off and converted to a passive system in March 2009.

Bioremediation Monitoring Results

Groundwater monitoring was conducted on July 1-2, 2008 about a month after the final injection at the site. A total of twenty-one monitoring wells were sampled. The samples were compared to baseline data collected prior to the injection process to determine the percent reduction. Table 6 summarizes the analytical results from the 2006 baseline monitoring event and post injection monitoring event in 2008.

Post injection monitoring results indicate that the bioremediation program has been effective in establishing reducing conditions and achieving reductive dechlorination of VOCs over most of the treated area. As of July 2008, PCE and TCE concentrations exceed the FNADCs at several locations within the intermediate and deep aquifer levels. However, results indicate that these concentrations are continuing to decrease.

Shallow zone

Samples were collected before and after treatment from well numbers MW001, MW002, MW003, MW009, MW028, and N-13. The analytical results for these shallow zone wells indicate that total VOC reduction ranged from 65 to 99% in the shallow zone wells. At MW002, there was a 99% reduction (3,985 µg/l to 30 µg/l) in total VOC compared to the baseline data. Overall, PCE, TCE, cis-1,2 DCE and VC concentrations have decreased in the shallow zone source area. The cis-1,2 DCE concentration of 890 ug/L located downgradient from the source area is the only shallow zone NADC exceedance among the wells sampled in July 2008. Over the course of the injections, PCE concentrations were reduced to levels below the GCTL. At MW003, PCE concentrations significantly declined from a baseline concentration of 1,160 µg/l to below the detection limit of 0.38 µg/l. TCE concentrations were also significantly reduced, ranging from bdl to approximately 21 µg/l. The most significant reduction occurred in MW002 with a reduction from 1,480 µg/l to bdl. The TCE GCTL was exceeded at only two locations. The cis-1,2 DCE concentrations after the injections ranged from 6.2 µg/l to 890 µg/l. The reductions in cis-1,2 DCE along with the TCE and PCE reductions indicate a significant mass transformation at the site. VC concentration increased from bdl to 23 µg/l at MW028 and from bdl to 3ug/L at MW001. These increases were expected based on the process of the biological reductive dechlorination of PCE and TCE.

Figure 7. Soil Vapor Extraction System Annual and Cumulative Mass Recovery [12]

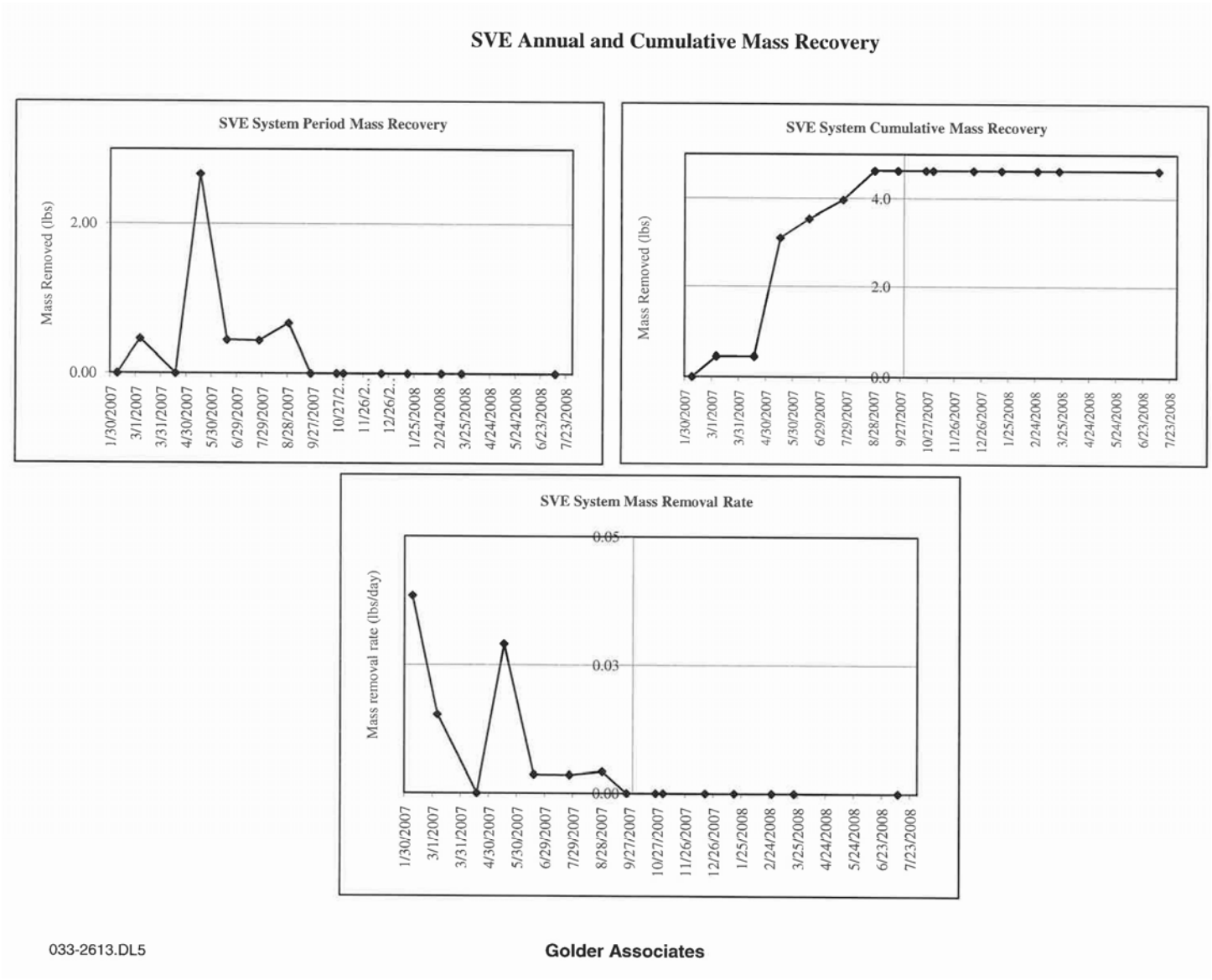


Table 6: Groundwater Monitoring Well Analytical Results			
		2006 Baseline (µg/L)	**2008 Sampling Results (µg/L)**
Shallow Zone Wells			
MW001	**PCE**	6	0.3
	TCE	3	2.4
	cis-1,2 DCE	bdl	3.6
	VC	bdl	3
MW002	**PCE**	5	bdl
	TCE	1, 480	bdl
	cis-1,2 DCE	2,240	6.2
	VC	VC: 130	24
MW003	**PCE**	1,160	bdl
	TCE	440	13
	cis-1,2 DCE	1,060	890
	VC	bdl	bdl
MW009	**PCE**	bdl	Not Sampled
	TCE	bdl	Not Sampled
	cis-1,2 DCE	195	Not Sampled
	VC	bdl	Not Sampled
MW028	**PCE**	14	2.9
	TCE	195	3.3
	cis-1,2 DCE	105	68
	VC	bdl	23
N-13	**PCE**	30.2	0.8
	TCE	21.7	0.26
	cis-1,2 DCE	150	7.3
	VC	120	17

Table 6: Groundwater Monitoring Well Analytical Results			
		2006 Baseline (µg/L)	**2008 Sampling Results (µg/L)**
Intermediate Zone Wells			
MW007	**PCE**	bdl	bdl
	TCE	12	bdl
	cis-1,2 DCE	9	13
	VC	bdl	bdl
MW010	**PCE**	8,600	5,700
	TCE	8,030	7,700
	cis-1,2 DCE	1,140	3,100
	VC	bdl	605
MW027	**PCE**	140	bdl
	TCE	5,350	0.23
	cis-1,2 DCE	3,750	40
	VC	53.5	42
N-24	**PCE**	7,450	4,900
	TCE	1,570	5,000
	cis-1,2 DCE	1,010	6,200
	VC	495	430
Deep Zone Wells			
MW004	**PCE**	1,200	3,500
	TCE	3,120	6,200
	cis-1,2 DCE	3,280	3,400
	VC	bdl	3
MW026	**PCE**	100	68
	TCE	2,360	430
	cis-1,2 DCE	4,250	1,600
	VC	35	170
N-35	**PCE**	22,000	14,000
	TCE	4,760	4,400
	cis-1,2 DCE	3,300	5,300
	VC	bdl	bdl

Intermediate Zone

Samples were collected before and after treatment from well numbers MW007, MW010, MW027, and N-24. The total VOC concentrations were reduced approximately 99% at MW027 from 9,378 to 84 µg/l. VC was the only VOC that exceeded the FGCTL at MW027. PCE, TCE, and cis-1,2 DCE were all reduced to below the FGCTL at this monitoring well. The PCE concentration in MW027 was reduced from 140 µg/l to bdl and TCE was reduced from a concentration of 5,350 µg/l to 0.23 µg/l. These data indicated that the area around MW027 has been effectively treated.

Deep Zone

Samples were collected before and after treatment from well numbers MW004, MW026, and N-35. At the down gradient well MW004, PCE concentrations increased slightly over the injection period from 1,200 to 3,500 ug/L. TCE concentrations also increased slightly at MW004 from 3,120 to 6,200 µg/L. Cis-1,2 DCE increased from 3,280 to 3,400 µg/L and VC remained at levels similar to the baseline at MW004. At MW026, PCE, TCE, and cis-1,2 DCE concentrations decreased while VC concentrations increased from 34.6 to 120 µg/L, indicating the occurrence of reductive dechlorination. At N-35, although PCE and TCE, concentrations decreased from 22,000 to 14,000 ug/L and 4,760 to 4,400 µg/L, respectively, significant PCE, TCE and cis-1,2 DCE mass remain. April 2008 sampling data indicated significant increases in PCE, TCE and cis-1,2 DCE concentration compared to the baseline, suggesting that additional contaminant mass may have been released from the aquifer.

Performance Data Quality [12, 13]

A quality assurance review was performed on all data/samples collected according to the Florida Standard Operating Procedures (SOPs). Samples were delivered under a chain of custody consistent with the SOPs and analyzed by National Environmental Laboratory Accreditation Conference (NELAC)-certified laboratory. The laboratory performed a surrogate analysis and accuracy and precision values were met.

Cost Information [5, 8]

The cost estimate for the phased remediation plan presented below. The cost includes capital costs, construction costs, O&M costs, and monitoring costs. Costs are based on the vendors selected and the operational life of the remedial system.

Soil Excavation

Soil excavation and source area well installation total	$299,000

SVE System

SVE capital costs	$40,000
SVE startup	$48,000
Well Installation/Baseline sampling	$73,700
One lactate injection	$2,700
Reporting	$9,220
O&M for one year	$39,000
TOTAL	**$212,620**

Phased Enhanced Bioremediation System

2007 Well installation	$8,000
Sampling	$6,000
Reporting	$2,500
2008 Six Monthly Lactate Injections/Monitoring	$138,000
Reporting	$5,400
2009 Well Installation	$43,000
Baseline groundwater sampling	$12,000
Four Quarterly Injections/Sampling	$78,000
Reporting	$10,600
TOTAL	**$303,500**

Observations and Lessons Learned [6, 12, 13, 14]

Soil Excavation

- The source removal goal of removing all materials with PCE concentrations above 17 mg/kg was accomplished in the southern and western portions of excavation.

Soil Vapor Extraction

- The SVE vapor influent concentrations were successfully reduced to below the detection limits.
- The SVE system was shut down during the injection and the SVE lateral wells were utilized for injection wells.
- Samples obtained in July 2008 and September 2008 indicated non-detect levels of methane. In addition, PCE levels were determined to be non-detect in the influent. As a result, the SVE system was shut off and converted to a passive system in March 2009.

Enhanced Bioremediation

- To decrease costs, the bioremediation injection system utilized the existing SVE wells along with injection wells and some monitoring wells to inject the amendment. Ball valves were installed on the SVE wells in order to prevent the amendment slurry from entering the SVE system piping inside the trailer.

- Based on the analytical results from the first four injections, the remedial action plan was modified to increase the amount of potassium lactate used in the injection. In addition, the injected volume was increased by an additional 300 gallons of water per well in order to distribute more carbon from the amendment in the intermediate and deep zones of the aquifer.
- Increasing the mass of electron donor in the bioremediation injection system increases the production of methane. The SVE system will provide the engineering control to address excessive methane generation.
- The potassium lactate and denatured ethanol amendments were effective in accelerating the biodegradation of PCE and PCE degradation products. The total VOC reduction ranged from 65 to 99% in the shallow zone wells.
- More targeted injections for the intermediate and deeper levels are needed to enhance the reductive dechlorination at the site.
- The addition of vertical injection wells upgradient of the site helped further enhance the capability to deliver electron donor to source areas with elevated VOC concentrations.
- Use of existing horizontal SVE wells for the bioremediation injections helped lower the cost to implement the series of injection.

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