Cosolvent Flushing Pilot Test Report
Former Sages Dry Cleaner

5800 Fort Caroline Road
Jacksonville, Florida 32211

FDEP Facility Identification Number:
169600614

December 4, 1998
LFR Project Number: 6006.10-08
FDEP Module Number: D006

Prepared for
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CERTIFICATION

All engineering information, conclusions, and recommendations in this document have been prepared under the supervision of and reviewed by a LFR Levine·Fricke Professional Engineer.

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1.0 INTRODUCTION

This report summarizes the results of the Cosolvent Flushing Pilot Test conducted at the former Sages Dry Cleaner Facility located at 5800 Fort Caroline Road, Jacksonville, Florida (Figure 1). The pilot test was conducted in general accordance with the February 1998 Pilot Test Work Plan (LFR Levine·Fricke [LFR] 1998a) for the Former Sages Dry Cleaner. Section 2.0 of this report summarizes modifications made to the pilot test after the plan was approved. The purpose of the pilot test was to evaluate the potential effectiveness and feasibility of utilizing this technology at this and other Florida Department of Environmental Protection (FDEP) Dry Cleaner Site Program facilities. The FDEP Hazardous Waste Cleanup Section and the FDEP Underground Injection Control section approved the pilot test plan in March 1998.

The alcohol flushing pilot test began on August 9, 1998, and ended on August 15, 1998. Posttest hydraulic containment began on August 15, 1998. The posttest hydraulic containment was discontinued on August 25, 1998, after the ethanol concentration in the treatment system influent dropped below the 10,000-milligram per liter (mg/l) termination criterion.

The objectives of the pilot test as outlined in the February 1998 work plan were as follows:

- Evaluate the feasibility and effectiveness of cosolvent flushing remedial technology at the Site for other FDEP Drycleaning Solvent Cleanup Program (DSCP) sites.

- Demonstrate implementability of the cosolvent flushing technology.

- Successfully demonstrate that the proposed system configuration can achieve and maintain hydraulic containment while satisfying long-term injection permit requirements.

- Collect sufficient data necessary for estimating the full-scale remedial technology design parameters (e.g., well spacing, alcohol injection volume, injection rates, and extraction rates).

- Evaluate the effectiveness of the Akzo Nobel Coatings Inc. (“Akzo”) Macro Porous Polymer® (MPP®) system in removing tetrachloroethene (PCE) from the extracted ternary alcohol/water/PCE mixture.

Based on the objectives stated in the pilot test work plan, the Sages site cosolvent flushing pilot test was successful. Improvements to the flushing procedure presented below can make this technology feasible for use at other FDEP DSCP facilities.

Pilot testing activities were completed on September 10, 1998, with the collection of posttest groundwater samples. The U.S. EPA laboratory in Ada, Oklahoma, is currently analyzing these samples. Results of these analyses will be presented in the first periodic monitoring report. Additional soil borings and multi-level samplers (MLSs) were installed by the U.S. Environmental Protection Agency (U.S. EPA) during the period from September 10 through September 15, 1998. The University of Florida (UF) is evaluating data collected from MLSs before, during, and after the pilot test. The data and evaluation will be presented by the UF in their final report to the Florida Center for Solid and Hazardous Waste Management. This report is due by December 31, 1998. The U.S. EPA and UF are currently studying enhanced biodegradation of PCE in the presence of ethanol. The results of this study should be available by July 1999.

2.0 PLAN MODIFICATIONS

Leading researchers from UF and U.S. EPA National Risk Management Laboratory, Ada, Oklahoma, joined LFR and the FDEP to design and implement the pilot test. A supplemental source area investigation was conducted by LFR, UF, and the U.S. EPA using equipment provided by the U.S. EPA (LFR 1998b). The maximum depth of this investigation was limited to 35 feet below ground surface (bgs). This investigation showed that a dense nonaqueous phase liquid (DNAPL) PCE source area was primarily between 26 and 31 feet bgs. Figure 2 presents the estimated horizontal extent of DNAPL PCE source area in the 26- to 31-foot interval.

Because the depth and areal extent of the DNAPL PCE source area were different than expected, the scope of the pilot test was modified. Because of additional funding provided by the U.S. EPA Technology Innovation Office, the scope of the pilot test was expanded to cover an area approximately twice the size of the area proposed in the original pilot test plan. The following are specific pilot test plan items that were changed:

1. The number of recovery wells was increased from three to six. The number of injection wells was increased from one to three. These changes were made to increase the coverage area of the cosolvent flushing test to include the volume of DNAPL zone between 26 and 31 feet bgs. The DNAPL PCE zone is identified in the June 11, 1998 letter report on Oversight of Cone Penetrometer Activities.

2. The total injection rate was increased from 2 to 4 gallons per minute (gpm) and the volume of alcohol was increased from 4,500 to 9,000 gallons. Because of the increase in the number of injection wells and volume of the DNAPL zone covered by the pilot test, the total injection flow rate was increased and the volume of alcohol required was increased. The individual flow rates to each of the injection wells were as follows: IW-1 0.8 gpm, IW-2 1.4 gpm, and IW-3 0.8 gpm.

3. The total extraction rate was increased from 4 to 8 gpm. This change was a result of the increased injection rate and the increased volume of the test area.

This change is in accordance with the 2 to 1 extraction to injection ratio recommended in the original pilot test plan.

4. The cosolvent was changed from 95 percent ethanol/5 percent isopropanol (IPA) to 95 percent ethanol/5 percent water (volume/volume). We believe that eliminating IPA from the ethanol mixture used in the pilot test reduced the overall project cost by eliminating the need for additional posttest hydraulic containment to reduce the IPA concentration to an acceptable level. It is projected that an additional one to two weeks of hydraulic containment would have been necessary to reduce IPA (the denaturing agent for ethanol) to the FDEP guidance concentration of 3.5 ppm.

5. The number of MLSs was changed from three to seven. This increase was necessary due to the increase in the number of injection and recovery wells.

6. The number of monitoring wells was increased from eight to ten. The February 1998 Pilot Test Work Plan called for installing seven shallow monitoring wells and one deep monitoring well. Initially, the deep monitoring well was proposed to be a slanted monitoring well installed approximately 15 feet beneath the clay layer. Because of the source area characterization conducted by LFR, UF, Tufts University, and the U.S. EPA (LFR 1998b), it was determined that a deep vertical well could be installed just down-gradient of the test area. Three of the shallow monitoring wells were proposed to be installed in the test area. However, because of the increase in the number of injection and recovery wells and the additional MLS installed in the test area, these three monitoring wells were eliminated. The data collected from the injection wells, recovery wells and the MLSs provide sufficient data for evaluation of the pilot test.

7. Five 0.5-inch diameter monitoring wells were installed by the U.S. EPA cone penetrometer drill rig. These wells are being used to provide additional data for the proposed biodegradation study at the Site.

3.0 WELL INSTALLATION AND PRELIMINARY SAMPLING

The monitoring wells, recovery wells, and injection wells were installed between June 23 and July 3 1998. The seven multilevel samplers were installed July 10 through July 13, 1998. Table 1 presents well construction data for the wells installed for the pilot test program. Figure 2 presents a Site map showing the locations of the monitoring, injection, and recovery wells. Also presented on Figure 2 is the estimated limit of DNAPL PCE in the 26- to 31-foot depth interval. Soil samples were also collected during installation of the injection wells and recovery wells. These samples were analyzed by UF using the American Society for Testing and Materials (ASTM) Method D422 (grain size distribution analysis) and ASTM Method E1195 (organic sorption coefficient). Figure C-1 presents a plot of the grain size distribution (Appendix C). Table C-1 presents the results of the organic sorption coefficient analysis (Appendix C).

Groundwater samples were collected from monitoring, recovery, and injection wells on July 13 and 14, 1998. The samples were collected in accordance with our FDEP-approved Comprehensive Quality Assurance Plan (CompQAP; LFR 1997) and shipped to Savannah Laboratories in Tallahassee, Florida, for analysis using EPA Method 8021 (purgeable halocarbons). Table 2 presents the pretest analytical results. Figure 3 presents a plot of the Savannah Laboratories analysis of PCE concentrations in groundwater at a depth of 26 feet to 31 feet bgs. Also, this figure presents the approximate limits of the DNAPL PCE source area based on soil borings, laser induced fluorescence borings, and resistivity borings.

Bassett and Associates of Jacksonville, Florida, surveyed the locations and elevations of the monitoring, recovery and injection wells. Appendix D contains a sealed copy of the site survey.

4.0 PRETEST AND POSTTEST TRACER STUDIES

As discussed in the Pilot Test Work Plan, UF conducted a pre-pilot test partition interwell tracer test (PITT) and an interfacial tracer test. Funding for this study was provided by the State University System of Florida Center for Solid and Hazardous Waste Management and the U.S. EPA Technology Innovation Office. The purpose of the tracer study was to: provide an estimate of the mass of DNAPL PCE present in the swept volume of the injection and extraction system; estimate the swept volume of the injection and recovery wells; and estimate the arrival time of alcohol to the recovery system. Sample analysis and data evaluation is ongoing at this time.

The tracers used in the pretest tracer study include potassium bromide, potassium iodide, sodium dodecyl benzene sulfonate (SDBS), methanol, n-hexanol, 2,4-dimethyl-3-pentanol (DMP), 2-ethyl-1-hexanol, ethanol, n-octanol, 2-methyl-2-propanol (TBA), 2-methyl-2-propanol (IBA), 2-octanol, 2-propanol (IPA), and 2,6-dimethyl-2-heptanol. The maximum concentration of a tracer was 2,000 milligrams per liter (mg/l) at the injection wells. Over the four-day period of the pretest tracer study, the tracer concentrations were reduced by approximately 3 orders of magnitude.

After completion of alcohol injection, a flushing test commenced. The recovery wells were pumped at a rate of 8 gpm for 8 days. Once the flushing test was completed, the posttest tracer study began. The tracers used in the posttest tracer study included SDBS, TBA, DMP, ethyl-hexanol, and hexanol. The maximum injection concentration of the posttest tracers was 2,000 mg/l. The final concentrations of these tracers were approximately 1 mg/l. Samples were collected from selected wells and will be analyzed for the posttest tracer compounds. A final report for the pretest tracer study and posttest tracer study is due to the Center for Solid and Hazardous Waste by December 31, 1998. A preliminary evaluation of the data was performed by the UF. Preliminary data from the tracer studies is presented in Table 3.

5.0 ALCOHOL FLUSHING PILOT TEST

As indicated above, several modifications to the pilot test plan were incorporated into pilot test injection and extraction system. Figure 4 presents a process flow diagram of the pilot test system. To optimize the pilot test, in-situ multiphase contaminant transport modeling studies were conducted by UF and LFR. The results of the modeling study provided simulation data useful during the layout of the injection and extraction system and the screened interval of the injection and recovery wells. Based on DNAPL estimates and other data obtained during the pretest tracer study, injection and recovery well flow rates were adjusted in an effort to optimize the DNAPL PCE mass recovery. We believe that the modifications to the system design based on the modeling studies and the pretest tracer study significantly increased the mass recovery and resulted in more effective hydraulic containment. The modeling study results and pretest tracer study also identified a need to modify the injection procedure as discussed below.

5.1 Injection System

Nine thousand gallons of ethanol were injected in the flushing zone over a four-day period. As stated in Section 2, the injection rates were 0.8 gpm for IW-1, 1.4 gpm for IW-2, and 0.8 gpm for IW-3. Alcohol was initially injected only into the bottom 2 feet of the screened interval of the wells, with potable water injected above the alcohol to keep the alcohol restricted to the lower portion of the formation as it flowed out from the well. A neoprene rubber well packer was used to separate the two fluid streams inside the well. The alcohol was injected in the lower zone of the injection wells while potable water was injected in the upper zone as discussed above. The concentration of alcohol was systematically increased as proposed in the pilot test work plan to minimize viscous fingering effects. After approximately one pore volume of alcohol was flushed in the lower zone (approximately 1,000 gallons of ethanol), the packers in the wells were raised at a rate of approximately six inches per hour to allow the alcohol to begin moving into the areas with greater quantities of DNAPL. At approximately 70 hours into the injection period, the packers were lowered at the same rate, until they reached the initial set point. Since alcohol was only injected into the formation in the region below the packer, this procedure placed more of the alcohol in the lower portion of the DNAPL-affected area. Appendix B (Figures B-1 through B-3) presents the injection flow rates in each of the injection wells and the depth of the packers with time.

5.2 Mass Recovery

The pilot test began on Sunday August 9, 1998, at approximately 14:55 PM Groundwater elevations were measured prior to and during the test to estimate the capture zone of the flushing system. After approximately 2 hours of flushing with only water, it was determined that a capture zone sufficient for the pilot test had been established. At approximately 17:25 PM, alcohol injection began. Groundwater extraction was maintained during the entire pilot test. Figures B-4 through B-9 show the recovery well flow rates versus time.

Table 3 presents aquifer parameters measured in the pretest and posttest PITT along with the estimated mass recovery from individual recovery wells. The PITT test results can be considered as estimates of these parameters accurate to within plus or minus 30 percent. Based on a preliminary evaluation of the data from the pretest tracer study, it is believed that approximately 75 percent of the mass of DNAPL in the test zone was located within the swept volumes of RW-3, RW-6 and RW-7. Appendix A contains plots of concentration of PCE and ethanol in samples collected from each of the recovery wells versus extracted fluid volume. These plots present data measured over an 8-day period from August 9 through August 17, 1998.

The following is a discussion of these data for each recovery well:

RW-2. As shown in Table 3, prior to alcohol flushing, the amount of DNAPL in the swept volume from the IWs to RW-2 is estimated to be 3.2 liters. This is 7 percent of the estimated total mass in the swept volume of the test area. Because of the lower percentage of DNAPL in the swept volume of this recovery well, it was decided that the extraction rate for this well would be less than the average. Appendix A (Figure A-1) shows the PCE concentration and ethanol volume percentage versus volume of fluids extracted. Initially, the PCE concentration was approximately 70 mg/l. After a jump from 70 mg/l to 160 mg/l, the PCE concentration decreased to approximately 30 mg/l prior to ethanol breakthrough. After ethanol breakthrough, the PCE concentration increased to approximately 80 to 100 mg/l. The maximum ethanol concentration measured in this well was 18 percent. When the ethanol concentration began to decrease after about 72 hours, the PCE concentration also decreased. This decrease and the posttest PITT indicate that some PCE DNAPL remains in the swept volume of recovery well RW-2. The concentration of PCE dropped to the pre-breakthrough PCE concentration at a pumped volume of approximately 20,000 liters of fluids (approximately 122.4 hours after startup).

RW-3. The estimated volume of PCE in this zone is 11.6 liters. Appendix A (Figure A-2) presents the PCE concentration in mg/l and the ethanol concentration in percent versus volume of fluids extracted from RW-3. Prior to ethanol breakthrough at RW-3, the PCE concentration was approximately 40 to 50 mg/l. Ethanol breakthrough occurred after extracting approximately 8,000 to 10,000 liters of groundwater from RW-3 (23 to 26 hours after beginning the test). After breakthrough, the PCE concentration increased rapidly to 1,000 to 1,200 mg/l range. The PCE concentration plateau lasted for approximately 5,000 liters of groundwater extraction (approximately 17 hours).

While the ethanol concentration remained high, the PCE concentration began to decrease after a total volume pumped of 15,000 liters. The PCE concentration did not decrease rapidly, indicating that heterogeneities exist in the aquifer. In a homogenous aquifer, the PCE concentration can be expected to decrease rapidly after the depletion of the PCE. By extrapolating the tailing portion of PCE concentration curve, it appears that the vast majority of PCE in the swept volume of RW-3 would be removed over a 4 to 6 day flushing time frame, rather than the 2 to 3 day time frame expected for a homogeneous formation. After extracting approximately 40,000 liters of groundwater from this recovery well, the PCE concentration returned to the pre-breakthrough concentration of approximately 40 to 50 mg/l.

RW-4. The estimated volume of DNAPL PCE in the swept zone of RW-4 prior to the test is approximately 4.6 liters. Appendix A (Figure A-3) presents the ethanol and PCE concentration versus extracted volume. The PCE concentration prior to breakthrough was approximately 15 mg/l. This plot shows that ethanol had a stair-step breakthrough curve. The PCE concentration versus extracted volume followed the stepwise increase and stabilized at approximately 400 mg/l. This plateau corresponded to a ethanol concentration, which stabilized at approximately 40 percent. When the ethanol concentration began to decrease, the PCE concentration also decreased. This indicates that additional ethanol would be necessary to recover the majority of the DNAPL PCE. At approximately 45,000 liters of extracted fluids, the PCE concentration dropped to the pre-breakthrough value.

RW-5. The pretest tracer study showed that very little DNAPL PCE was located in the swept volume of RW-5. Also, the arrival time of tracers was longer than the other recovery wells. Because of the low percentage of DNAPL in the swept volume of this recovery well, it was decided that the extraction rate would be much less than the average. Figure A-4 presents the PCE and ethanol concentration versus extracted volume. At this time, the relationship between ethanol concentration and PCE concentration over time is unclear. Other data collected during the pilot test and PITT studies from the adjacent MLSs and monitoring wells were also difficult to interpret. After a complete evaluation of the data collected from the tracer studies and the pilot test is completed, the relationship between these parameters may become better understood. However, because of the lower quantity of PCE in the swept volume of this well, the future evaluations of data from the area of this well are not likely to provide an understanding of the effectiveness of flushing in this zone.

RW-6. The pretest tracer study indicated that approximately 7.2 liters of DNAPL PCE were present in the swept volume of this recovery well. The ethanol and PCE concentrations versus extracted fluids volume is presented in Appendix A (Figure A-5). The PCE concentration prior to ethanol breakthrough was approximately 25 mg/l. The plots of the PCE and ethanol concentrations do not display a discernable plateau. Both compounds appear to peak after the extracted fluid volume reaches 35,000 liters. The maximum PCE concentration was over 630 mg/l, indicating that enhanced solubility occurred in the swept volume of this recovery well. The maximum ethanol concentration was approximately 17 percent. This travel distance for the swept volume from this recovery well is long in comparison to other recovery wells. This may account for the lower ethanol concentration seen in this recovery well. The shape of the PCE concentration curve is very similar to the shape of the ethanol concentration curve. The PCE versus extracted fluid curve decreased with the decreasing concentration of ethanol. This indicates that there is additional DNAPL PCE within the swept volume of this well.

RW-7. The estimated mass of DNAPL PCE in the swept volume around RW-7 was approximately 14 liters, based on the results of the pretest PITT study. The ethanol and PCE concentration versus extracted fluids volume is presented in Appendix A (Figure A-6). The pre-breakthrough PCE concentration was approximately 15 mg/l. The PCE concentration in RW-7 peaked at approximately 1,300-mg/l. Ethanol concentration reached a plateau at approximately 25 percent. The ethanol plateau lasted for approximately 26 hours. As with RW-6, it is believed that volume of alcohol flushed through this zone was not sufficient to remove all the accessible DNAPL PCE.

5.3 Hydraulic Containment

Table 4 includes measurements of the groundwater elevations measured during the pilot test. Static groundwater level elevations measured prior to the test are plotted on Figure 5. Figures 6 through 8 present groundwater elevations measured at three time intervals. The groundwater capture zone appears to encompass the entire test zone at each of the measuring events. Groundwater screening samples were collected from monitoring wells MW505 through MW509 during the pilot test. These samples were analyzed by UF for PCE and ethanol. Verbal reports were provided to LFR during pilot testing activities. The ethanol concentration measured in these monitoring wells was below 82 mg/l, indicating that effective capture was indeed established. The PCE concentrations in the monitoring wells were either near the pretest values or declined during the test. This indicates that PCE was not mobilized horizontally in the aquifer during the pilot tests. Ethanol is a highly mobile compound in groundwater. Ethanol was not detected in the groundwater monitoring wells during the pilot test. This also indicates that the extraction system was effectively capturing the volume to the test zone.

DNAPL PCE has repeatedly been observed in MW010 (previously referred to as SAG-1) and has been periodically removed during contamination assessment activities over the past 18 months. We estimate that approximately 10 to 20 milliliters (ml) of PCE accumulates in this well over a one-month period. There appears to be a preferential pathway from the source area to this well. This well is believed to be screened to the clay layer that is approximately 35 feet bgs. During the posttest hydraulic containment phase, this well was periodically purged from the bottom with a peristaltic pump. DNAPL PCE was not observed in the purge water collected from this well. This also suggests that significant DNAPL PCE vertical mobilization does not appear to have occurred.

6.0 WASTE MANAGEMENT

Approximately 200,000 gallons of non-hazardous wastewater was disposed of at a licensed wastewater treatment facility. Twenty-six 55-gallon drums of solids were disposed of as a hazardous waste by a licensed treatment facility. Approximately 50 liters of fluids including the PCE recovered during the pilot test were disposed of by a licensed hazardous waste facility.

6.1 Well Installation Waste Disposal

Solids collected from the well installation activities were placed in twenty-five 55-gallon drums prior to disposal. The solids were disposed of as hazardous waste (D039) by City Environmental, Inc. Water generated from the well installation activities was placed in a 5,000-gallon aboveground storage tank. This IDW water remained at the Site until just prior to the start of pilot testing activities. This water was cycled through the air-stripping tower approximately 12 times. Table 5 presents treatment system PCE and ethanol concentrations during pilot testing activities. After the analytical data from a sample collected from the effluent of the air stripper indicated that the concentration of PCE was below detection limits, the air stripper effluent was discharged into the infiltration gallery installed in the southwest corner of the Site. This sample was collected on July 30, 1998, and is denoted DEVT-EFF in Table 5. Laboratory analysis is presented in Appendix C. The total volume of IDW water treated was approximately 4,000 gallons.

6.2 Pretest Hydraulic Containment Waste Disposal

Water extracted from the recovery wells during the pretest tracer study was routed through the air-stripping tower for primary removal of PCE. Based on analysis of samples collected from the influent and effluent of the air-stripping unit (ASU), the air-stripping tower removed 99.5 percent of the PCE in a single pass. Since the groundwater concentration of PCE was approximately 70 mg/l prior to treatment, and the allowable PCE concentration for disposal as a nonhazardous waste is 56 ug/l, the extracted groundwater was cycled through the air stripping tower a second time. The effluent PCE concentration from the air-stripping tower was below detection limit after the second pass. The treated water was routed to 20,000-gallon Baker tanks for temporary storage. These samples were collected on August 3 and August 5. The results are present in Table 5.

Because of the presence of tracer compounds in the treated water, the water was disposed of as a non-hazardous waste. Upon receipt of confirmatory analytical results, the water was transported by Clarke Environmental to the Industrial Waste of Jacksonville facility for disposal as a nonhazardous waste. The total volume of groundwater disposed for the pretest tracer study was approximately 40,000 gallons.

6.3 Flushing and Posttest Treatment and Disposal

After completion of the pretest tracer study, the entire flushing system was modified. The Akzo Nobel MPP® effluent system was inserted into the treatment train as the primary water treatment unit. The air-stripping tower became the secondary treatment unit to polish the MPP® effluent stream. Table 5 presents the laboratory results of samples collected from the MPP® influent and effluent and the ASU effluent during and after the pilot test. One of the MPP® effluent samples analyzed by Savannah Laboratories had PCE above disposal limits. This sample was collected in conjunction with MPP® influent samples and may reflect cross-contamination. One of the samples collected from the MPP® effluent and submitted to Advanced Environmental Laboratories also had a concentration above discharge limits. This sample was also packaged with the influent sample. In addition, the effluent sample was analyzed after the influent, which may have resulted in the higher concentration. The effluent stream was continuously monitored between August 9 and August 12 with an SRI model 8610 gas chromatograph (GC-2). Appendix C contains a printout of the MPP® effluent PCE analysis from this GC. PCE was not detected with this GC during this period. After PCE concentration peaked in the influent stream, analysis of the effluent of the MPP® stream by GC-2 was discontinued.

After the treatment process, the groundwater was pumped to one of five 20,000-gallon Baker tanks for temporary storage. Clarke Environmental, Inc., transported the treated groundwater to the Industrial Waste facility for disposal. The total volume of water disposed of for the flushing test and the posttest tracer study was approximately 160,000 gallons. PCE and water collected from the MPP® system condensate tank was disposed of by Clarke Environmental, Inc., on October 22, 1998. The total fluid volume was approximately 50 liters, which included the recovered PCE and water.

7.0 CONCLUSIONS

The following conclusions are based on the data collected and analyzed to date, as well as evaluation of observations made during the pilot test.

1) Enhanced dissolution and solubilization was demonstrated as a result of cosolvent flushing. Analytical data from RW-7 indicates that peak PCE concentration was 80 to 90 times larger than the initial PCE concentration. In other recovery wells, the ratio of peak PCE concentration to initial PCE concentration was on the order of 30 to 40. It should be pointed out that the initial PCE concentration was collected after only four days of pumping. We believe that a better comparison of the effect of enhanced solubility of DNAPL PCE would be to consider the ratio of the peak PCE concentration during the cosolvent pilot test to the PCE concentration in groundwater after a year of groundwater extraction and treatment operation. The MPP® influent PCE concentration was approximately 7 mg/l at the end of posttest hydraulic containment. For samples collected after one year of groundwater extraction and treatment operation, the anticipated PCE concentration would be between 100 ug/l and 1 mg/l. Under these conditions, a flow rate of 8 gpm and an average PCE concentration of 500 ug/l would produce a PCE mass recovery rate of 8 kg/year. The mass recovered in this pilot test is greater than 65 kg, which is greater than the mass recovery achievable from 8 years of groundwater extraction and treatment operation.

2) Based on the data available, it appears that the hydraulic containment system was adequate to maintain capture within the testing zone. Groundwater elevations measured during the course of the pilot test showed an inward gradient from the outer monitoring wells (MW505, MW506, MW507, and

MW509) toward the recovery wells. Significant DNAPL PCE migration was not observed during the test. When complete MLS data and boring data are available, a more complete discussion of PCE mobilization will be possible.

3) The MPP® system is very effective for removal of PCE from a ternary mixture. Using this system in future applications of cosolvent flushing will significantly reduce the waste disposal costs. We believe that primary treatment of the ternary mixture with the MPP® system prior to re-injection could have eliminated $100,000 to $150,000 from the project cost. Incorporation of re-use of ethanol may require a distillation column to re-concentrate the alcohol.

4) Overall, this pilot test was very successful at the Sages facility. With the field data obtained, experience gained in the study, and the design improvements discussed below, LFR believes that this technology can be applied to other FDEP DSCP facilities. Given favorable site conditions and an appropriate source area investigation, cosolvent flushing (and surfactant flushing) can be applied in a cost-effective manner to other FDEP DSCP facilities.

8.0 RECOMMENDATIONS

The following recommendations are proposed for further remediation at the former Sages Dry Cleaner facility:

1. Additional Source Assessment. Additional source assessment at the Site is recommended to delineate the extent of remaining DNAPL PCE, both in the test area and beneath it. A deep soil boring performed during the initial assessment at the Site showed high concentration of PCE, and groundwater from MW508 (screened from 45 to 50 feet bgs) contained PCE at up to 4.8 mg/l.

2. Full-Scale Cosolvent Flushing. Given the success of the pilot test, it is recommended that full-scale cosolvent flushing be used at the Site to remove remaining DNAPL PCE in the original test area, as well as DNAPL PCE that may be discovered in the soil beneath a depth of 35 feet bgs. It is further recommended that the issue of injection and recovery well layout be revisited. The original layout was designed conservatively, with primary focus placed upon minimizing the potential for off-site migration of mobilized PCE. This design led to inefficiencies in PCE extraction because of stagnation zones in the test area, and led to an increase in the swept volume in the test area.

3. Alcohol Re-Use. The success of the Akzo MPP® system in removing PCE from the ternary mixture will allow the incorporation of a process step that will re-concentrate the alcohol from the treated fluid stream for re-injection.

4. Continued Monitoring of Groundwater Wells. As discussed in comment number 3 of the March 11, 1998 FDEP Underground Injection Control section comments memorandum, groundwater monitoring is recommended monthly for the first

quarter and at least quarterly thereafter for one year. LFR recommends that this monitoring schedule be followed. These data should be evaluated to determine the risk of off-site PCE migration. Further Risk-Based Corrective Action evaluation should be based on these data.

9.0 PILOT TEST DESIGN IMPROVEMENTS

This section presents an outline of design improvements recommended for future pilot tests:

1) Pilot test flushing activities should not be started until evaluation of tracer test data has been completed. This will allow sufficient time to optimize the injection, extraction, and re-injection system.

2) The volume of alcohol injected should be based on the swept volume of the injection and extraction system and not the pore volume of the treated area. In this pilot test, the injection volume was based on the pore volume of the DNAPL contaminated zone. This resulted in an under-estimate of the volume of alcohol needed for this pilot test by a factor of 2.

3) If re-use of alcohol can be incorporated into the study design, sufficient alcohol flooding of the contaminated zone may be achieved at substantial cost savings. Savings can be realized in two areas. Clearly, the total volume of alcohol required will be reduced, if alcohol from the treated fluids stream can be re-concentrated and re-injected. A second area of savings comes from reducing the volume of wastewater containing a high concentration of alcohol. Re-use of alcohol provides a gallon-for-gallon savings in disposal costs.

4) We believe that alcohol and surfactant flushing would be more cost effective if the injection and extraction system and the treatment system were trailer mounted. The injection and extraction system trailer would be fully equipped with pumps, hoses, connections, meters, and other appurtenances for fast setup at a site. The treatment system would be setup similar to the MPP® system trailer but would include re-use processing equipment as necessary. These trailers could be used at numerous sites.

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Table 1
Monitoring Well Construction Data
Former Sages Dry Cleaner, Jacksonville, Florida

Well ID	Total Depth (feet bgs)	Screened Interval (feet bgs)	Well Diameter (inches)	Casing Material	TOC Elevation (feet NGVD)	Ground Elevation (feet NGVD)	Date Installed	Installed By
MW505	31	26-31	2	PVC	43.96	44.17	6/24/98	LFR
MW506	31	26-31	2	PVC	42.86	43.00	6/25/98	LFR
MW507	31	26-31	2	PVC	42.48	42.70	7/1/98	LFR
MW508a	50	45-50	2	PVC	44.19	44.35	6/25/98	LFR
MW509	31	26-31	2	PVC	43.80	43.80	6/24/98	LFR
MW510	31	26-31	2	PVC	44.09	44.31	6/30/98	LFR
MW511	31	26-31	2	PVC	44.16	44.34	6/30/98	LFR
MW512	31	26-31	2	PVC	44.05	44.20	7/1/98	LFR
MW513	31	26-31	2	PVC	44.05	44.11	6/30/98	LFR
MW514	31	26-31	2	PVC	43.85	44.08	7/1/98	LFR
RW002	31	26-31	4	PVC	43.87	44.00	6/25/98	LFR
RW003	31	26-31	4	PVC	44.03	44.10	6/25/98	LFR
RW004	31	26-31	4	PVC	44.04	44.00	6/26/98	LFR
RW005	31	26-31	4	PVC	42.13	43.20	6/29/98	LFR
RW006	31	26-31	4	PVC	43.31	4.20	6/29/98	LFR
RW007	31	26-31	4	PVC	44.10	43.20	6/29/98	LFR
IW001	32.5	25-32.5	4	PVC	43.80	44.00	6/30/98	LFR
IW002	32.5	25-32.5	4	PVC	44.12	44.10	6/30/98	LFR
IW003	32.5	25-32.5	4	PVC	43.53	43.70	6/30/98	LFR

Notes

[a]MW-508 is a deep monitoring well.
bgs = below ground surface
TOC = top of casing
NGVD = National Geodetic Vertical Datum
PVC = polyvinyl chloride
LFR = Levine-Fricke-Recon Inc.

Table 2
Pretest Analytical Results for Groundwater Samples
Former Sages Dry Cleaner, Jacksonville, Florida

Parameter	RW002	RW003	RW004	RW005	RW006	RW007	IW001	IW002	IW003	MW505
1,1,1-Trichloroethane	1000 U	2500 U	25 U	1 U	25 U	1000 U	2500 U	2500 U	2500 U	2.5 U
1,1,2,2-Tetrachloroethane	1000 U	2500 U	25 U	1 U	25 U	1000 U	2500 U	2500 U	2500 U	2.5 U
1,1,2-Trichloroethane	1000 U	2500 U	25 U	1 U	25 U	1000 U	2500 U	2500 U	2500 U	2.5 U
1,1-Dichloroethane	1000 U	2500 U	25 U	1 U	25 U	1000 U	2500 U	2500 U	2500 U	2.5 U
1,1-Dichloroethene	1000 U	2500 U	25 U	1 U	25 U	1000 U	2500 U	2500 U	2500 U	2.5 U
1,2-Dichlorobenzene	1000 U	2500 U	25 U	1 U	25 U	1000 U	2500 U	2500 U	2500 U	2.5 U
1,2-Dichloroethane	1000 U	2500 U	25 U	1 U	25 U	1000 U	2500 U	2500 U	2500 U	2.5 U
1,2-Dichloropropane	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
1,3-Dichlorobenzene	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
1,4-Dichlorobenzene	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
2-Chloroethylvinyl ether	10,000 U	25,000 U	250 U	10 U	250 U	10,000 U	25,000 U	25,000 U	25,000 U	25 U
Bromodichloromethane	1,000 U	2,500 U	25 U	2	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
Bromoform	5,000 U	12,000 U	120 U	5 U	120 U	5,000 U	12,000 U	12,000 U	12,000 U	12 U
Bromomethane	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
Carbon tetrachloride	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
Chlorobenzene	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
Chloroethane	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
Chloroform	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
Chloromethane	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
Dibromochloromethane	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
Dichlorodifluoromethane	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
Methylene chloride (Dichloromethane)	5,000 U	12,000 U	120 U	5 U	120 U	5,000 U	12,000 U	12,000 U	12,000 U	12 U
Tetrachloroethene	44,000	68,000	750	62	970	43,000	90,000	96,000	81,000	88
Trichloroethylene	1,000 U	2,500 U	25 U	1	85	1,000 U	2,500 U	2,500 U	2,500 U	3 U
Trichlorofluoromethane	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
Vinyl chloride	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
cis-1,2-Dichloroethylene	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
cis-1,3-Dichloropropene	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
trans-1,2-Dichloroethylene	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U
trans-1,3-Dichloropropene	1,000 U	2,500 U	25 U	1 U	25 U	1,000 U	2,500 U	2,500 U	2,500 U	3 U

Note

U = not detected above the reported

Table 2
Pretest Analytical Results for Groundwater Samples
Former Sages Dry Cleaner, Jacksonville, Florida

Parameter	MW506	MW507	MW508	MW509	MW510	MW511	MW512	MW513	MW514
1,1,1-Trichloroethane	1 U	2.5 U	100 U	1000 U	100 U	25 U	5 U	50 U	100 U
1,1,2,2-Tetrachloroethane	1 U	2.5 U	100 U	1000 U	100 U	25 U	5 U	50 U	100 U
1,1,2-Trichloroethane	1 U	2.5 U	100 U	1000 U	100 U	25 U	5 U	50 U	100 U
1,1-Dichloroethane	1 U	2.5 U	100 U	1000 U	100 U	25 U	5 U	50 U	100 U
1,1-Dichloroethene	1 U	2.5 U	100 U	1000 U	100 U	25 U	5 U	50 U	100 U
1,2-Dichlorobenzene	1 U	2.5 U	100 U	1000 U	100 U	25 U	5 U	50 U	100 U
1,2-Dichloroethane	1 U	2.5 U	100 U	1000 U	100 U	25 U	5 U	50 U	100 U
1,2-Dichloropropane	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
1,3-Dichlorobenzene	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
1,4-Dichlorobenzene	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
2-Chloroethylvinyl ether	10 U	25 U	1,000 U	10,000 U	1,000 U	250 U	50 U	500 U	1,000 U
Bromodichloromethane	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
Bromoform	5 U	12 U	500 U	5,000 U	500 U	120 U	25 U	250 U	500 U
Bromomethane	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
Carbon tetrachloride	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
Chlorobenzene	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
Chloroethane	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
Chloroform	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
Chloromethane	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
Dibromochloromethane	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
Dichlorodifluoromethane	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
Methylene chloride (Dichloromethane)	5 U	12 U	500 U	5,000 U	500 U	120 U	25 U	250 U	500 U
Tetrachloroethene	47	140	4,600	52,000	5,100	250	260	2,100	6,000
Trichloroethylene	1 U	3 U	160	2,300	2,700	940	78	1,500	1,800
Trichlorofluoromethane	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
Vinyl chloride	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
cis-1,2-Dichloroethylene	1 U	3 U	100 U	1,000 U	100 U	220	5 U	50 U	100 U
cis-1,3-Dichloropropene	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
trans-1,2-Dichloroethylene	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U
trans-1,3-Dichloropropene	1 U	3 U	100 U	1,000 U	100 U	25 U	5 U	50 U	100 U

Note

U = not detected above the reported

Table 3
Pretest and Posttest Partition Interwell Tracer Test Summary
Former Sages Dry Cleaner, Jacksonville, Florida

Parameter	Recovery Well						
	RW002	RW003	RW004	RW005	RW006	RW007	Total
Pre-Cosolvent Flushing PITT							
Conservative Tracer Travel Time (hrs)	22.4	14.5	14.1	39.1	33.5	23.0	
Well Swept Volume (gallons)	445	951	883	329	1,381	1,062	**5,051**
NAPL Saturation (percent)	0.19	0.32	0.14	0.33	0.14	0.34	
NAPL Volume (L)	3.2	11.6	4.6	4.1	7.2	13.7	**44.3**
Percent of Total NAPL	7.1	26.2	10.3	9.3	16.3	30.8	**100.0**
Post-Cosolvent Flushing PITT							
NAPL Saturation (percent)	0.07	0.06	0.08	0.13	0.06	0.08	
NAPL Volume (L)	1.5	2.2	2.6	1.9	2.5	3.2	**13.9**
Percent of Total NAPL	11.0	15.7	19.0	13.9	17.7	22.7	**100.0**
Calculated Mass Recovery Based on PCE Concentrations (L)	1.0	10.5	3.7	0.0	12.0	14.3	**41.5**

Note

PITT = Partition Interwell Tracer Test
hrs = hours
NAPL = nonaqueous phase liquid
L = liter

Table 4
Groundwater Elevations During Pilot Testing
Former Sages Dry Cleaner, Jacksonville, Florida

Date	Time		Monitoring Well and TOC Elevation (feet NGVD))									
			MW505 43.96	MW506 42.86	MW507 42.48	MW508 44.19	MW509 43.80	MW510 44.09	MW511 44.16	MW512 44.05	MW513 44.05	MW514 43.85
4-Aug-98	11:15	**Depth to Groundwater**	7.07	5.61	5.52	NR	6.78	NR	NR	NR	NR	NR
		Groundwater Elevation	36.89	37.25	36.96	-	37.02	-	-	-	-	-
4-Aug-98	15:30	**Depth to Groundwater**	7.02	5.65	5.56	6.47	6.80	7.03	7.11	6.97	6.99	6.81
		Groundwater Elevation	36.94	37.21	36.92	37.72	37.00	37.06	37.05	37.08	37.06	37.04
9-Aug-98	10:30	**Depth to Groundwater**	5.66	4.34	4.16	5.62	5.68	6.11	6.31	5.98	6.18	6.10
		Groundwater Elevation	38.30	38.52	38.32	38.57	38.12	37.98	37.85	38.07	37.87	37.75
9-Aug-98	16:00	**Depth to Groundwater**	6.20	4.74	4.65	5.66	5.97	6.27	6.42	6.22	6.31	6.20
		Groundwater Elevation	37.76	38.12	37.83	38.53	37.83	37.82	37.74	37.83	37.74	37.65
9-Aug-98	17:00	**Depth to Groundwater**	6.26	4.76	4.71	5.66	6.06	6.29	6.43	6.23	6.31	6.20
		Groundwater Elevation	37.70	38.10	37.77	38.53	37.74	37.80	37.73	37.82	37.74	37.65
9-Aug-98	22:30	**Depth to Groundwater**	6.35	4.87	4.79	5.71	6.10	6.36	6.50	6.31	6.40	6.28
		Groundwater Elevation	37.61	37.99	37.69	38.48	37.70	37.73	37.66	37.74	37.65	37.57
10-Aug-98	13:30	**Depth to Groundwater**	6.59	5.06	5.00	5.84	6.29	6.52	6.62	6.49	6.53	6.39
		Groundwater Elevation	37.37	37.80	37.48	38.35	37.51	37.57	37.54	37.56	37.52	37.46
11-Aug-98	12:30	**Depth to Groundwater**	6.94	5.39	5.34	6.04	6.51	6.71	6.79	6.69	6.70	6.54
		Groundwater Elevation	37.02	37.47	37.14	38.15	37.29	37.38	37.37	37.36	37.35	37.31
13-Aug-98	18:00	**Depth to Groundwater**	5.95	4.61	4.55	5.53	5.75	5.99	6.09	5.97	6.06	5.91
		Groundwater Elevation	38.01	38.25	37.93	38.66	38.05	38.10	38.07	38.08	37.99	37.94
14-Aug-98	2:30	**Depth to Groundwater**	6.00	4.63	4.66	5.50	5.84	6.17	6.30	6.09	6.20	6.09
		Groundwater Elevation	37.96	38.23	37.82	38.69	37.96	37.92	37.86	37.96	37.85	37.76

Note

TOC = top of casing

Table 5
Treatment System Analytical Results
Former Sages Dry Cleaner, Jacksonville, Florida

Sample Identification	Sample Date	Sample Time	Concentration of PCE (in µg/l) EPA Method 8021	Concentration of Ethanol (in mg/l) EPA Method 8260	Laboratory
DEVT-EFF	7/30/98	17:30	< 1	N/A	SL
Baker Tank	8/3/98	13:30	230	N/A	SL
ASU Inf	8/3/98	8:30	70,000	N/A	SL
ASU Eff	8/3/98	8:30	1,500	N/A	SL
ASU Inf	8/5/98	9:20	590	N/A	AEL
ASU Eff	8/5/98	9:30	1.2	N/A	AEL
ASU-EFF	8/10/98	7:00	< 1	< 1	AEL
MPP Influent	8/11/98	13:35	220,000	N/A	SL
MPP Effluent	8/11/98	13:40	< 5	65,000	SL
MW508	8/11/98	15:05	730	< 120	SL
RW002	8/12/98	16:15	120,000	130,000	SL
RW003	8/12/98	16:15	70,000	200,000	SL
RW004	8/12/98	16:15	40,000	170,000	SL
RW005	8/12/98	16:15	2,500	21,000	SL
RW006	8/12/98	16:15	220,000	100,000	SL
RW007	8/12/98	16:15	380,000	150,000	SL
MW508	8/13/98	5:15	4,800	< 1	AEL
MPP-Influent	8/13/98	8:00	233,200	94,482	AEL
MPP-Effluent	8/13/98	8:00	195	N/A	AEL
RW002	8/13/98	15:05	100,000	100,000	SL
RW003	8/13/98	15:05	410,000	190,000	SL
RW004	8/13/98	15:05	250,000	110,000	SL
RW005	8/13/98	15:05	4,500	25,000	SL
RW006	8/13/98	15:05	250,000	100,000	SL
RW007	8/13/98	15:05	350,000	110,000	SL
DUP-1 (RW003)	8/13/98	15:05	400,000	180,000	SL
ASU-EFF	8/13/98	14:00	< 5	N/A	SL
MPP INF	8/14/98	15:00	120,000	30,000	SL
MPP EFF	8/14/98	15:15	< 5	N/A	SL
DUP-1	8/14/98	15:20	< 5	N/A	SL
A/S EFF	8/14/98	15:30	< 5	N/A	SL
MPP-EFF-0815	8/15/98	16:15	< 5	N/A	SL
A/S-EFF-0815	8/15/98	16:20	< 5	N/A	SL
DUP-1	8/15/98	16:15	< 5	N/A	SL
MPP-EFF-0816	8/16/98	16:10	< 5	N/A	SL
A/S-EFF-0816	8/16/98	16:20	< 5	N/A	SL
MPP-EFF-0817	8/17/98	15:10	36	N/A	SL
A/S-EFF-0817	8/17/98	15:20	< 5	N/A	SL
MPP-INF-0815	8/15/98	16:10	73,000	16,000	SL
MPP-INF-0816	8/16/98	16:00	41,000	12,000	SL
MPP-INF-0817	8/17/98	15:00	19,000	8,400	SL
ASU (Effluent)	8/18/98	12:00	< 2.5	11,000	SL
MPP INF	8/24/98	10:35	7,600	2,500	SL
MPP EFF	8/24/98	10:05	2.5	2,700	SL
ASU EFF	8/24/98	11:00	2.5	2,600	SL
DUP (ASU-Effluent)	8/24/98	11:00	2.5	2,500	SL

Notes

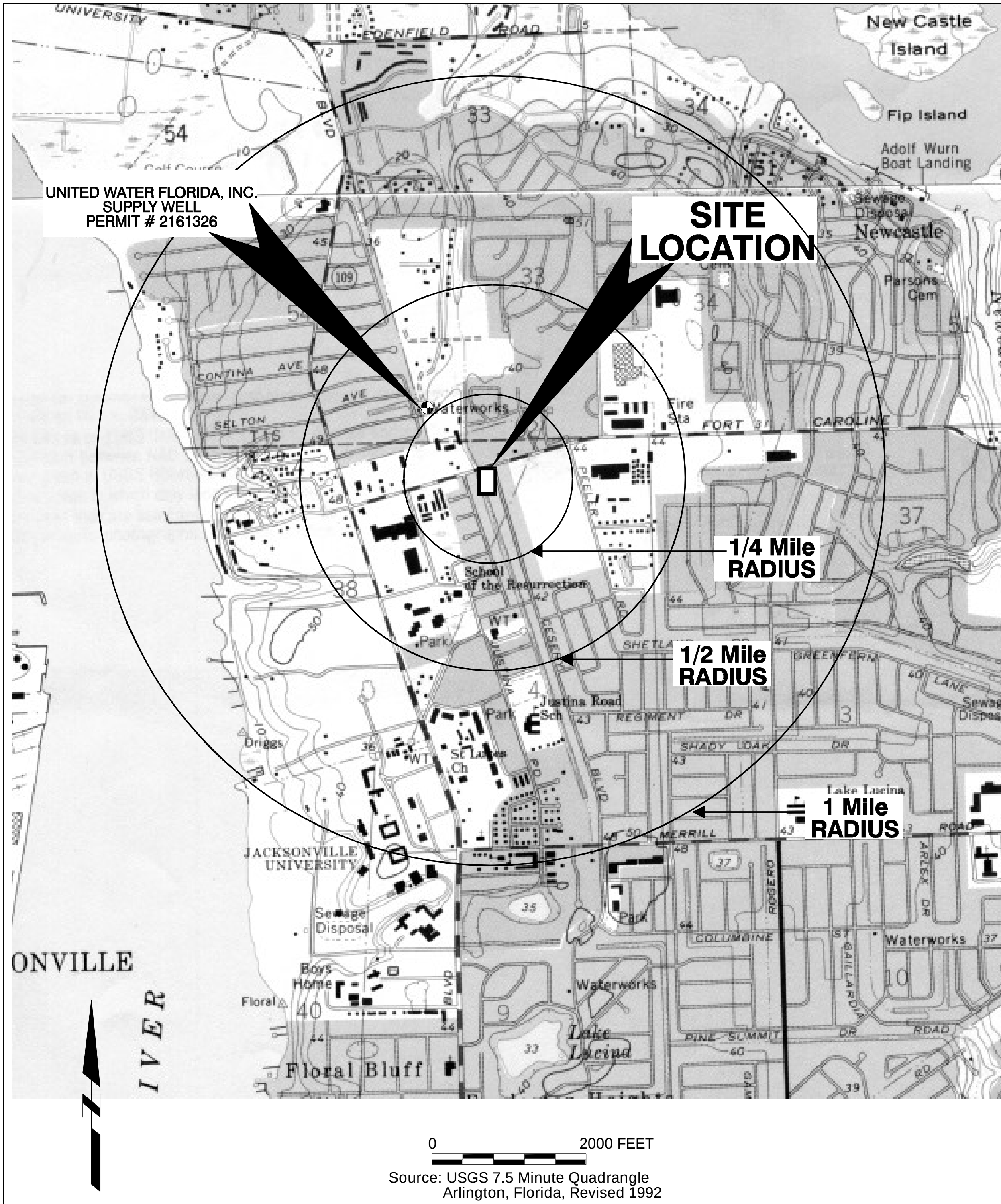
EPA = U.S. Environmental Protection Agency
µg/l = micrograms per liter
mg/l = milligrams per liter
DEVT = development water
ASU = air stripping unit
Eff = effluent
MPP = Macro Porous Polymer®
DUP = duplicate
SL = Savannah Laboratories
AEL = Advanced Environmental Laboratories

Table 6
Daily Groundwater Concentration Data
Former Sages Dry Cleaner, Jacksonville, Florida

Sample Date	Compound	Monitoring Well				
		MW505	MW506	MW507	MW508	MW509
8/11/98	PCE	< 0.46	< 0.46	< 0.46	0.91	4.5
	Ethanol	< 82	< 82	< 82	< 82	< 82
8/12/98	PCE	< 0.46	< 0.46	< 0.46	1	2.7
	Ethanol	< 82	< 82	< 82	< 82	< 82
8/14/98	PCE	< 0.46	1.32	< 0.46	0.87	0.7
	Ethanol	< 82	< 82	< 82	< 82	< 82
8/16/98	PCE	< 0.46	< 0.46	< 0.46	1.7	1.7
	Ethanol	< 82	< 82	< 82	< 82	< 82
8/17/98	PCE	< 0.46	< 0.46	1.7	3.7	< 0.46
	Ethanol	< 82	< 82	< 82	< 82	< 82
8/18/98	PCE	< 0.46	< 0.46	< 0.46	1.6	5.4
	Ethanol	< 82	< 82	< 82	< 82	< 82

Notes:

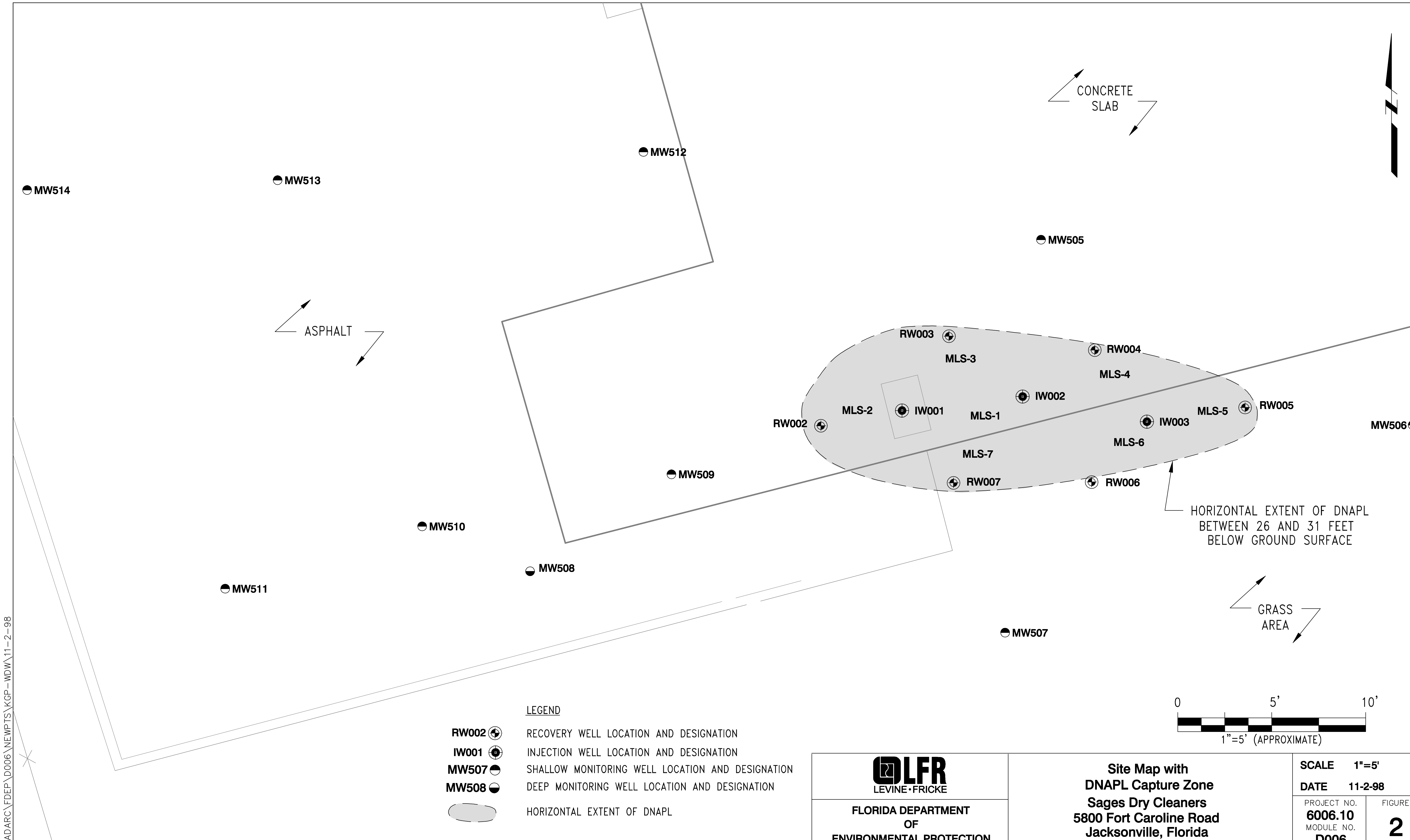
Values are presented in milligrams per liter (mg/l).
Detection limits are 1 mg/l for PCE and 1 mg/l for ethanol.
82 mg/l of ethanol is approximately 0.01 percent by volume.
PCE = tetrachloroethene
mg/l = milligrams per liter



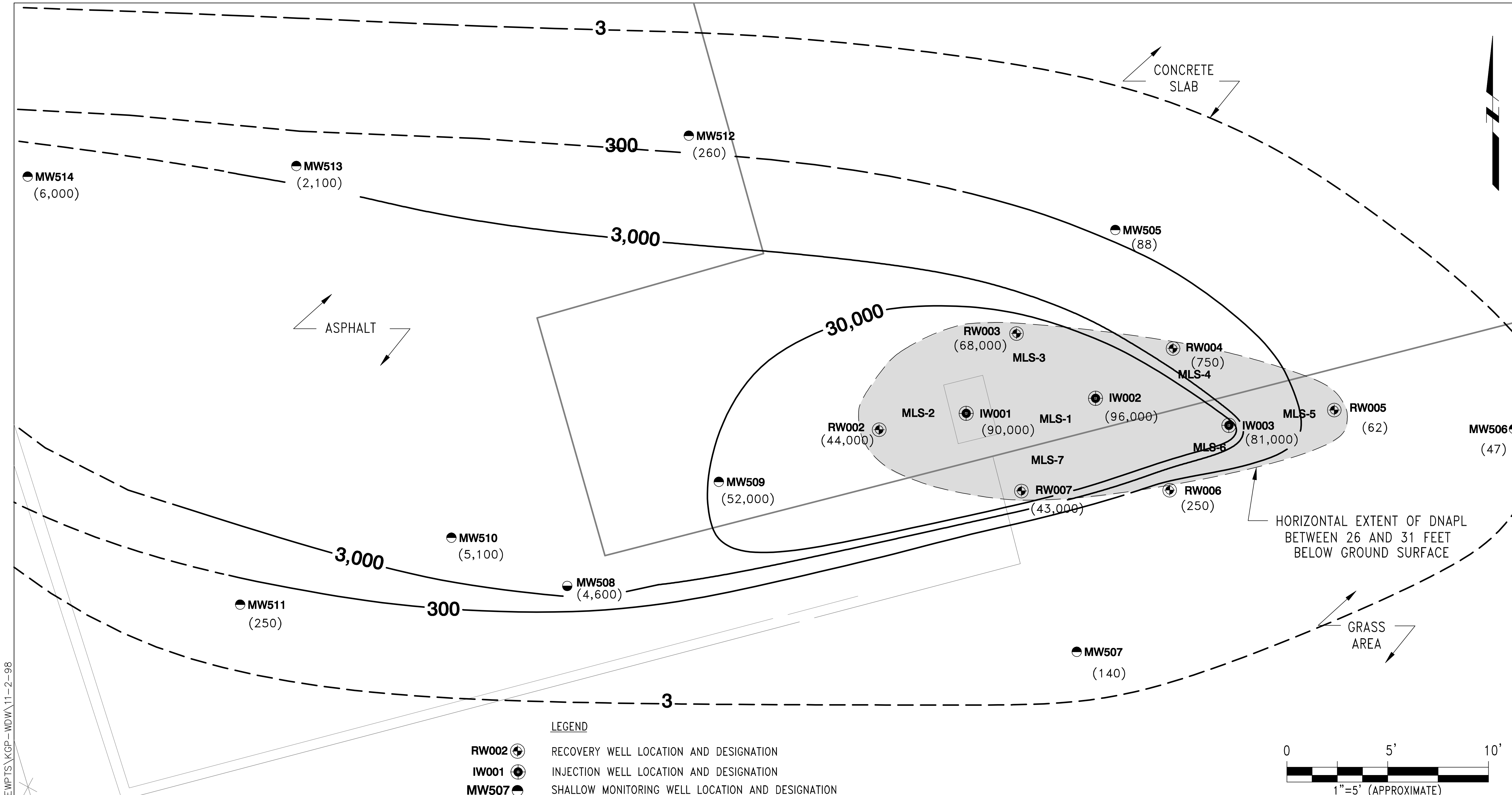
Source: USGS 7.5 Minute Quadrangle
Arlington, Florida, Revised 1992

ARCGRACH\FDEP\D0D6\SAGES2\WDW\10-26-98

LFR LEVINE • FRICKE	**Site Location Map** **Former Sages Dry Cleaner** **5800 Ft. Caroline Road** **Jacksonville, Florida**	SCALE 1"=2,000' DATE 10-26-98	
FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION		PROJECT NO. **6006.00** MODULE NO. **D006**	FIGURE **1**



CADARC\FDEP\D006\NEWPTS\KGP-WDW\11-2-98



LEGEND

RW002	RECOVERY WELL LOCATION AND DESIGNATION
IW001	INJECTION WELL LOCATION AND DESIGNATION
MW507	SHALLOW MONITORING WELL LOCATION AND DESIGNATION
MW508	DEEP MONITORING WELL LOCATION AND DESIGNATION
	HORIZONTAL EXTENT OF DNAPL
(250)	PCE CONCENTRATION VALUE (ppm)
3	PCE ISOCONCENTRATION CONTOUR
ppm	PARTS PER MILLION

LFR LEVINE·FRICKE

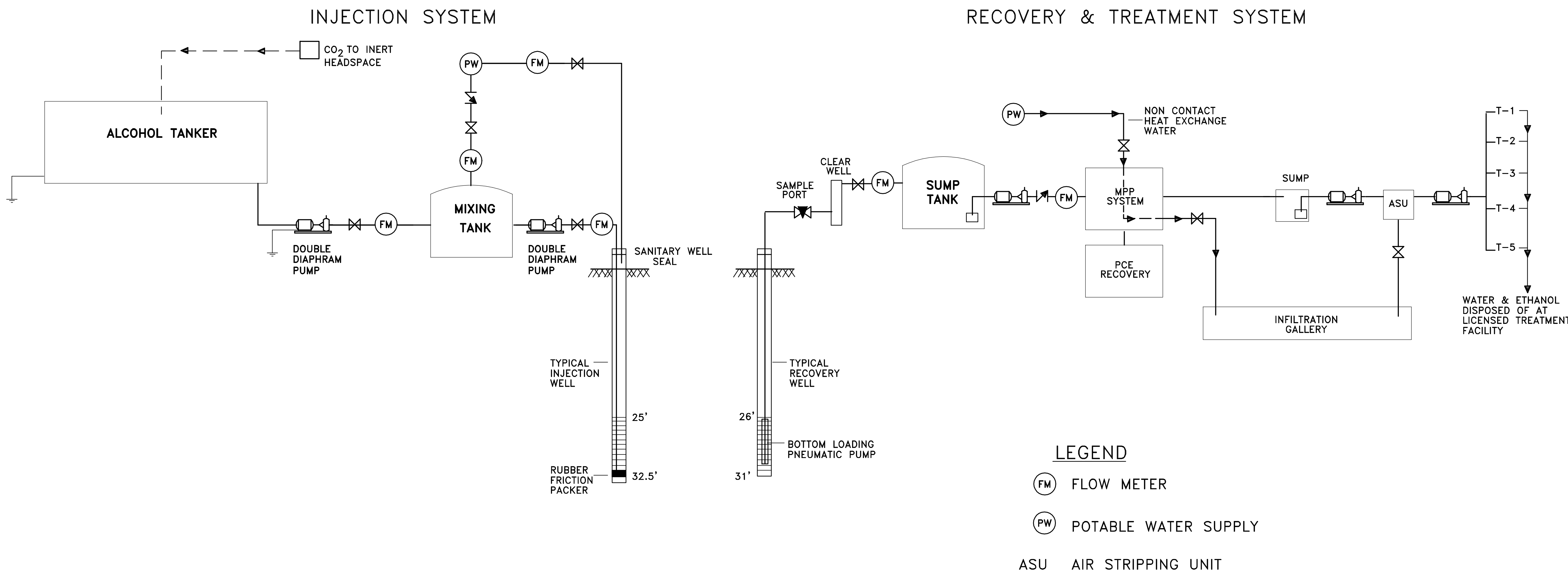
FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

PCE Concentration Contour and DNAPL Capture Zone, July 1998

Sages Dry Cleaners
5800 Fort Caroline Road
Jacksonville, Florida

SCALE	1"=5'
DATE	11-2-98
PROJECT NO.	6006.10
MODULE NO.	D006
FIGURE	3

CADARC\FDEP\D006\NEWPTS\KGP-WDW\11-2-98



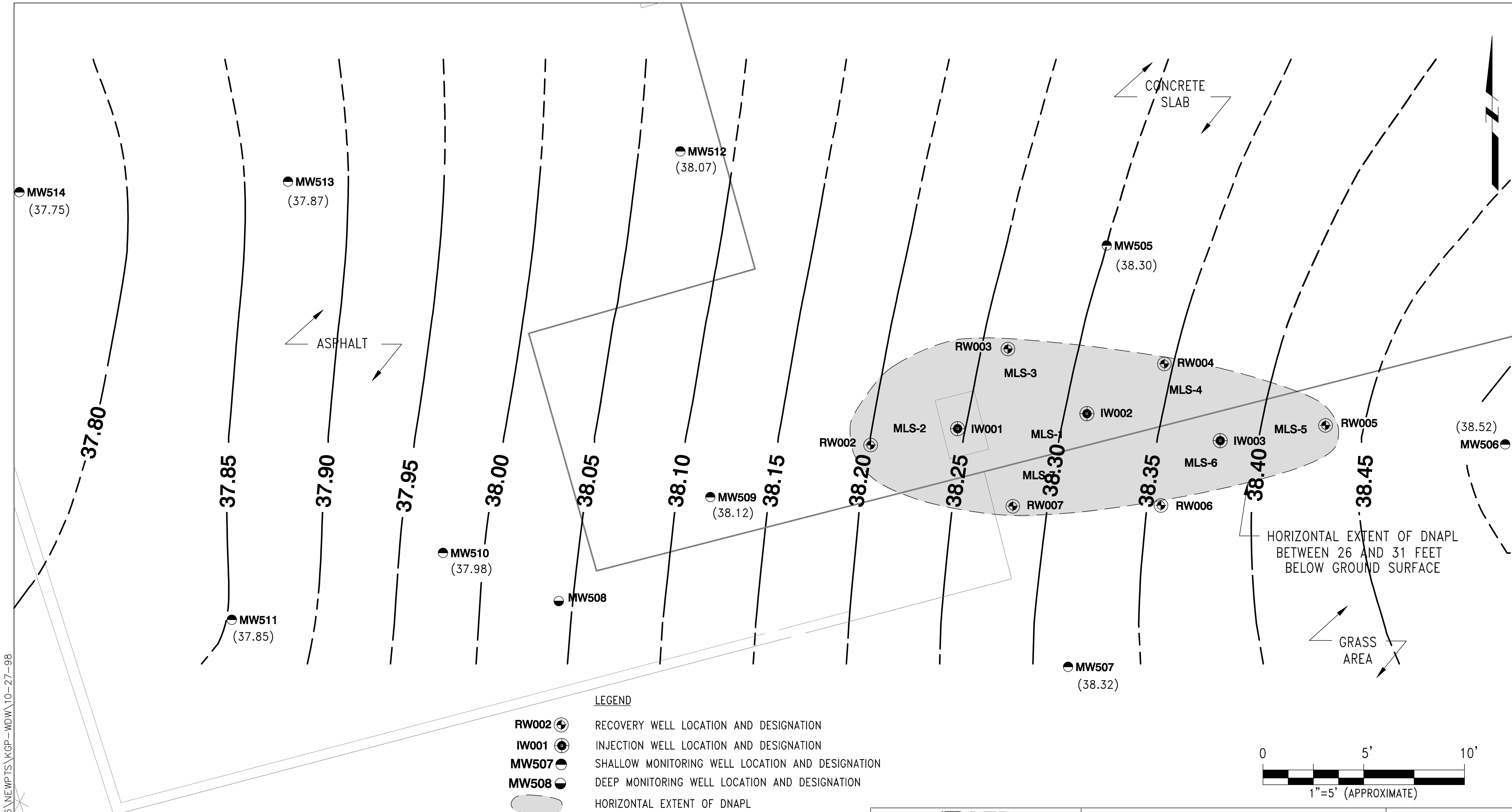
LFR LEVINE•FRICKE

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Process Flow Diagram
Former Sages Dry Cleaner
5800 Ft. Caroline Road
Jacksonville, Florida

SCALE NTS	
DATE 2-25-98	
PROJECT NO. 6006.01	FIGURE 4
MODULE NO. D006	

FDEP\D006\D006PFD\KGP-WDW\2-25-98



LEGEND

RW002	RECOVERY WELL LOCATION AND DESIGNATION
IW001	INJECTION WELL LOCATION AND DESIGNATION
MW507	SHALLOW MONITORING WELL LOCATION AND DESIGNATION
MW508	DEEP MONITORING WELL LOCATION AND DESIGNATION
	HORIZONTAL EXTENT OF DNAPL
(37.98)	GROUNDWATER ELEVATION (FT NAVD88)
—37.85—	GROUNDWATER ISOCONTOUR (FT NAVD88) CONTOUR INTERVAL= 0.05 FT
NAVD88	NORTH AMERICAN VERTICAL DATUM 1988

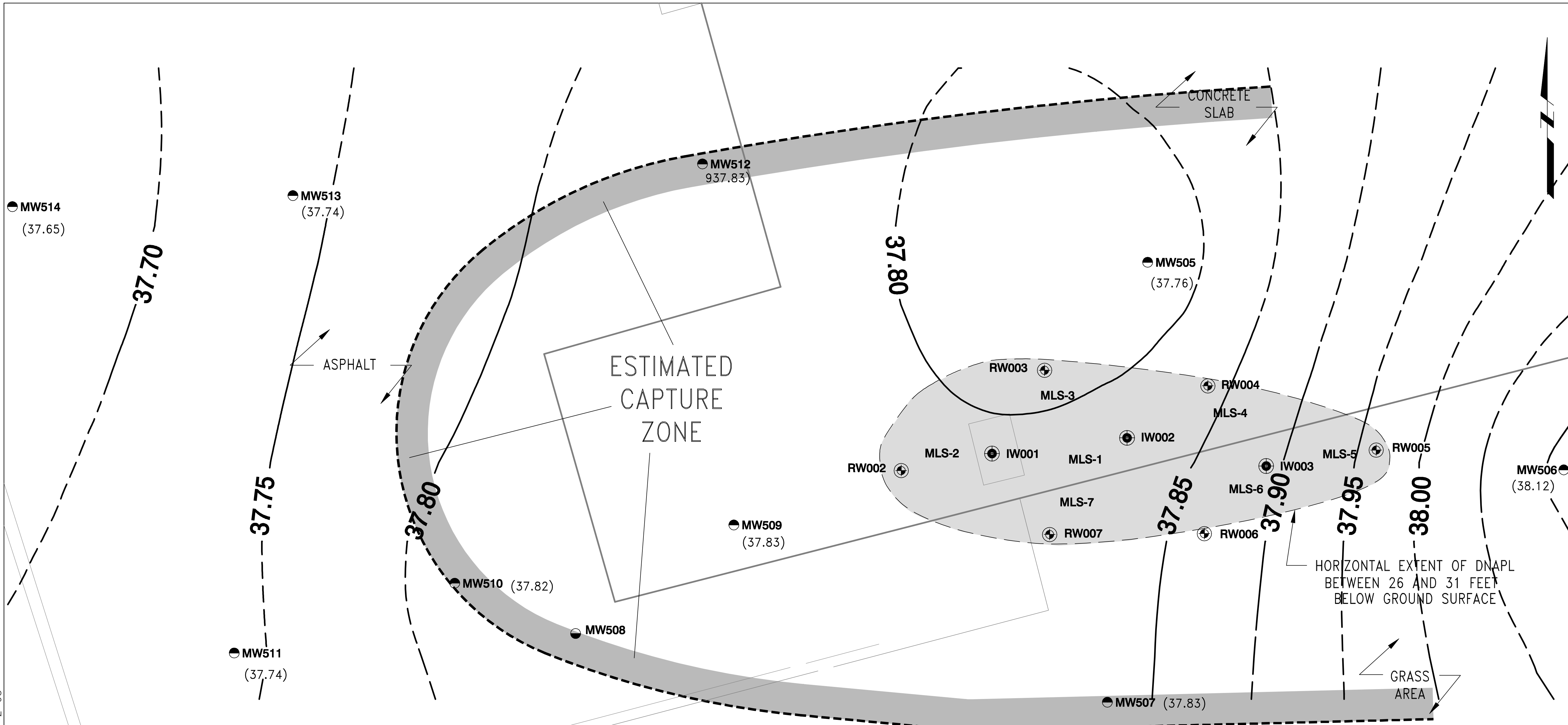
LFR
LEVINE·FRICKE

FLORIDA DEPARTMENT
OF
ENVIRONMENTAL PROTECTION

Static Groundwater Contour Elevations & DNAPL Capture Zone 08/9/98 10:30
Sages Dry Cleaners
5800 Fort Caroline Road
Jacksonville, Florida

SCALE 1"=5'	
DATE 10-27-98	
PROJECT NO. 6006.10	FIGURE
MODULE NO. D006	5

CADARC\FDEP\D006\NEWPTS\KGP-WDW\10-27-98



LEGEND

RW002	RECOVERY WELL LOCATION AND DESIGNATION
IW001	INJECTION WELL LOCATION AND DESIGNATION
MW507	SHALLOW MONITORING WELL LOCATION AND DESIGNATION
MW508	DEEP MONITORING WELL LOCATION AND DESIGNATION
	HORIZONTAL EXTENT OF DNAPL
(37.82)	GROUNDWATER ELEVATION (FT NAVD88)
—37.75—	GROUNDWATER ISOCONTOUR (FT NAVD88) CONTOUR INTERVAL= 0.05 FT
NAVD88	NORTH AMERICAN VERTICAL DATUM 1988

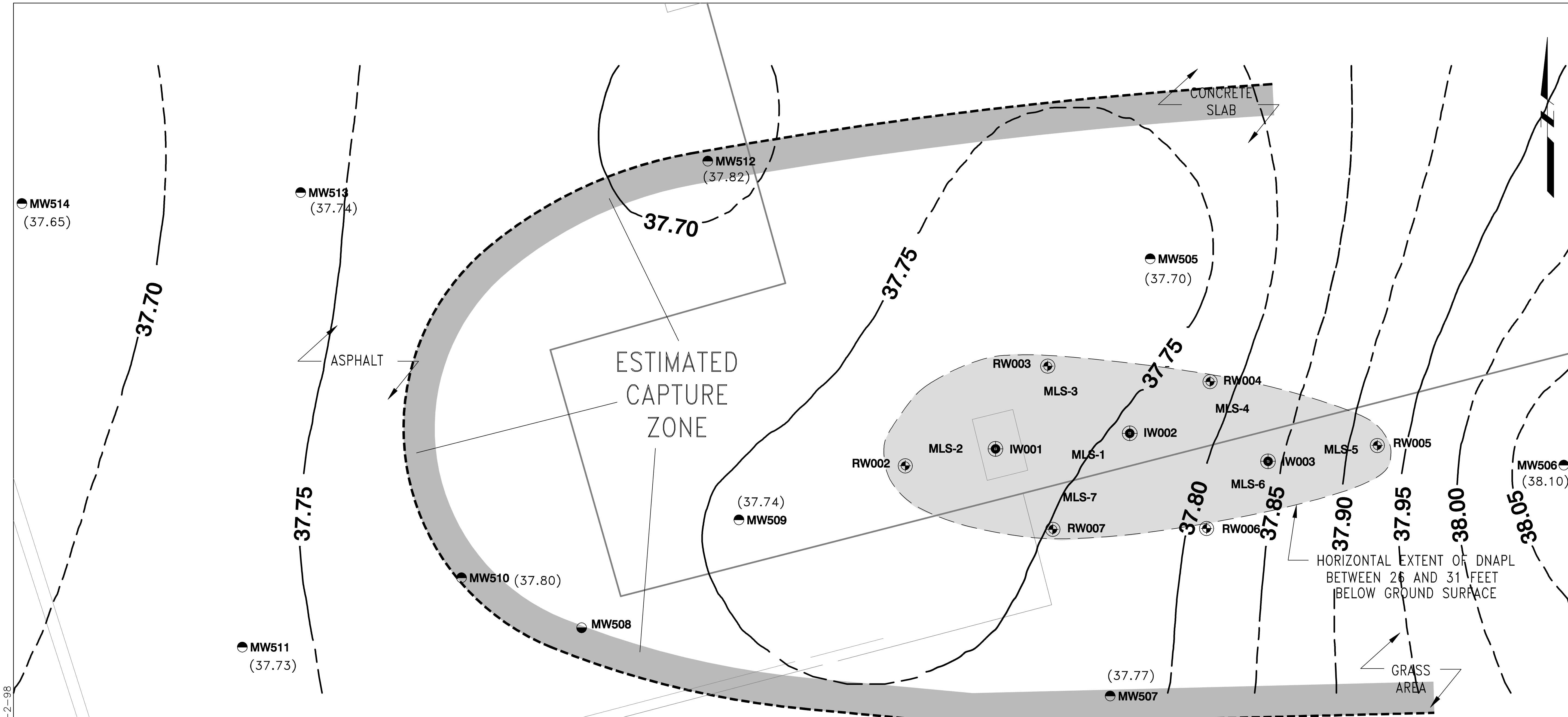
LFR
LEVINE•FRICKE

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Groundwater Contour Elevations & DNAPL Capture Zone 08/9/98 15:59
Sages Dry Cleaners
5800 Fort Caroline Road
Jacksonville, Florida

SCALE 1"=5'
DATE 11-2-98
PROJECT NO. 6006.10
MODULE NO. D006
FIGURE 6

CADARC\FDEP\D006\NEWPTS\KGP-WDW\11-2-98



LEGEND

RW002	RECOVERY WELL LOCATION AND DESIGNATION
IW001	INJECTION WELL LOCATION AND DESIGNATION
MW507	SHALLOW MONITORING WELL LOCATION AND DESIGNATION
MW508	DEEP MONITORING WELL LOCATION AND DESIGNATION
	HORIZONTAL EXTENT OF DNAPL
(37.80)	GROUNDWATER ELEVATION (FT NAVD88)
—37.75—	GROUNDWATER ISOCONTOUR (FT NAVD88) CONTOUR INTERVAL= 0.05 FT
NAVD88	NORTH AMERICAN VERTICAL DATUM 1988

0 5' 10'

1"=5' (APPROXIMATE)

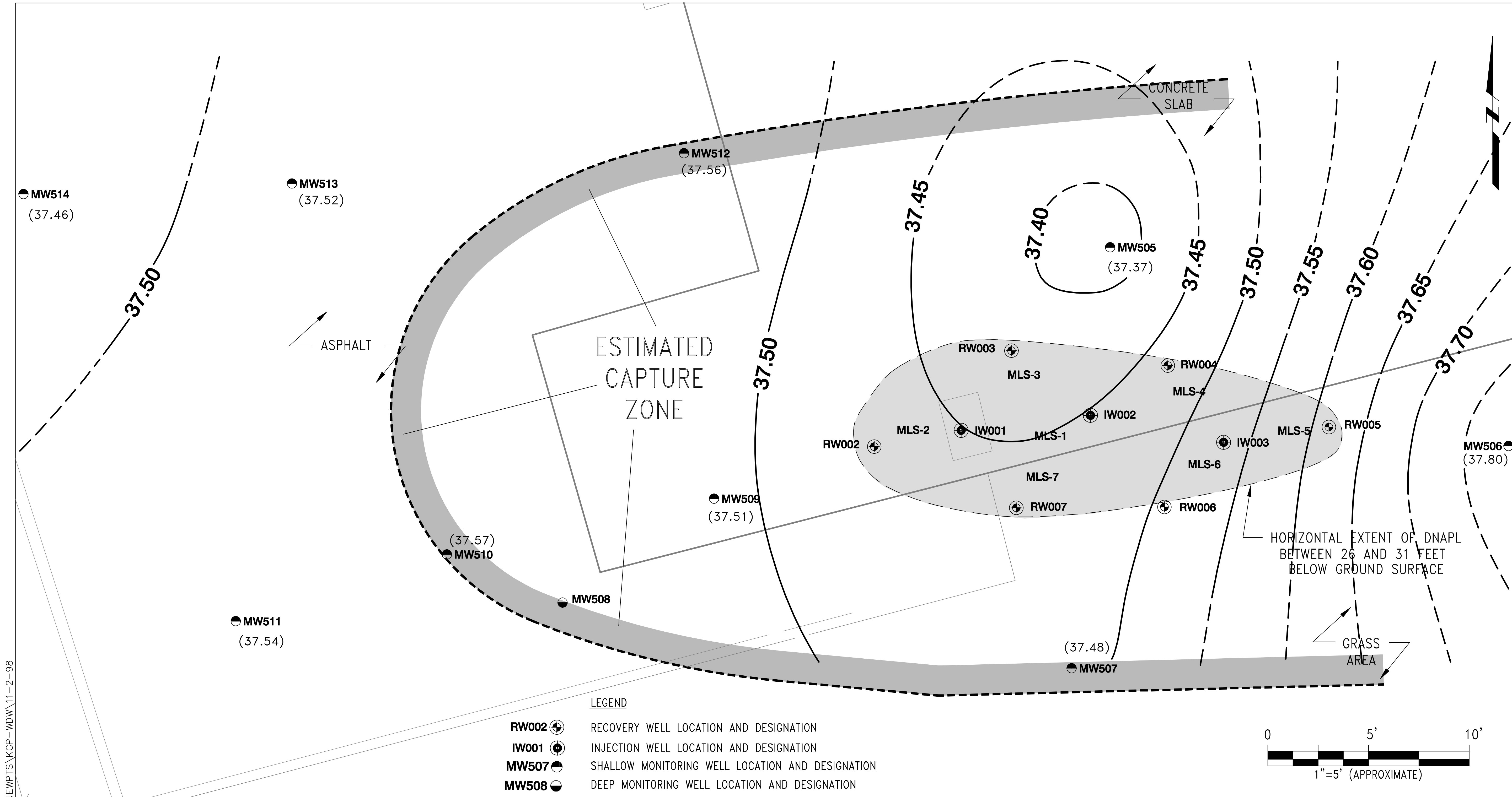
LFR LEVINE·FRICKE

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Groundwater Contour Elevations & DNAPL Capture Zone 08/9/98 17:00

Sages Dry Cleaners
5800 Fort Caroline Road
Jacksonville, Florida

SCALE 1"=5'
DATE 11-2-98
PROJECT NO. 6006.10
MODULE NO. D006
FIGURE 7



LEGEND

RW002	RECOVERY WELL LOCATION AND DESIGNATION
IW001	INJECTION WELL LOCATION AND DESIGNATION
MW507	SHALLOW MONITORING WELL LOCATION AND DESIGNATION
MW508	DEEP MONITORING WELL LOCATION AND DESIGNATION
	HORIZONTAL EXTENT OF DNAPL
(37.57)	GROUNDWATER ELEVATION (FT NAVD88)
—37.55—	GROUNDWATER ISOCONTOUR (FT NAVD88) CONTOUR INTERVAL= 0.05 FT
NAVD88	NORTH AMERICAN VERTICAL DATUM 1988

LFR
LEVINE•FRICKE

FLORIDA DEPARTMENT
OF
ENVIRONMENTAL PROTECTION

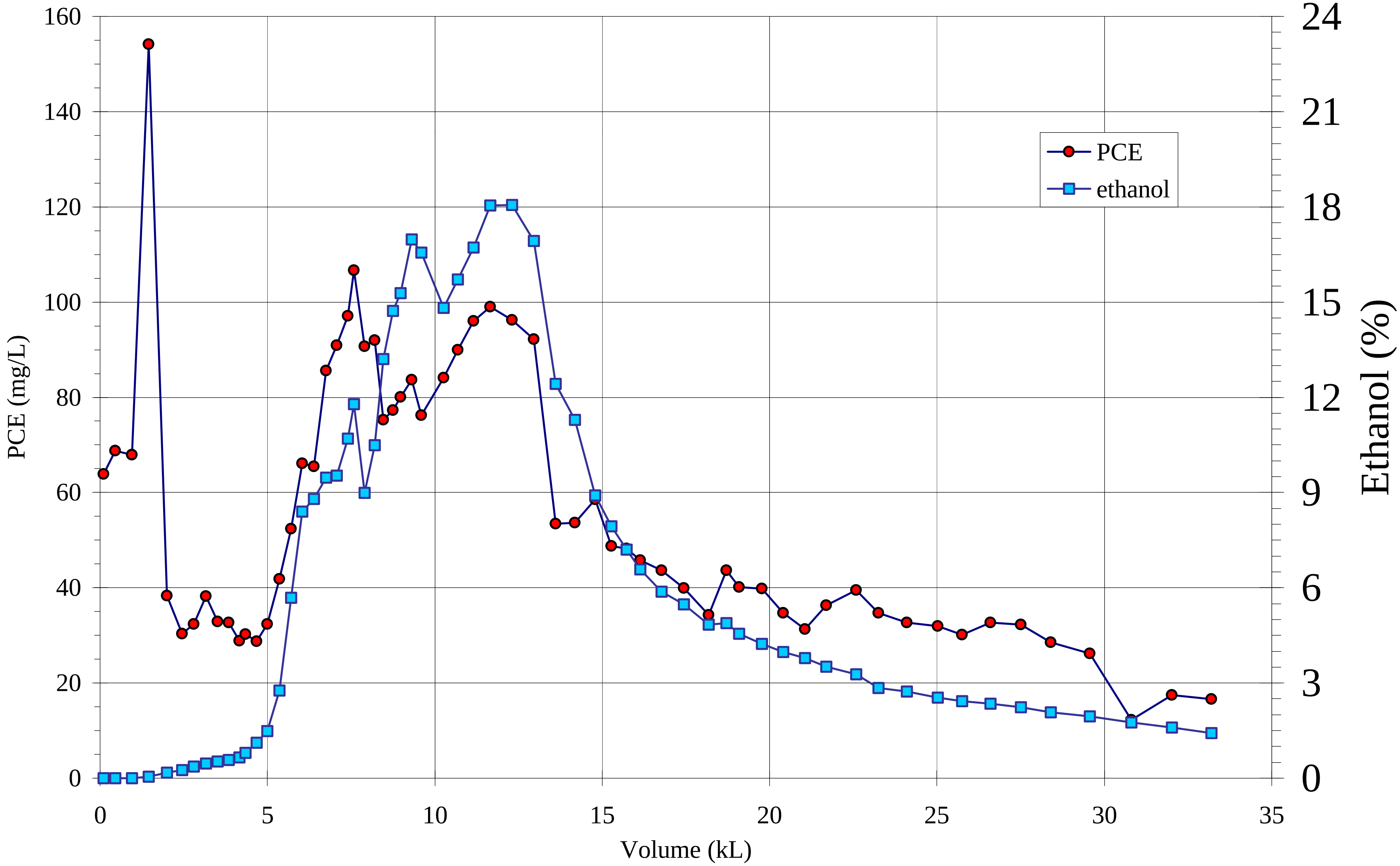
Groundwater Contour Elevations
& DNAPL Capture Zone 08/10/98 13:00
Sages Dry Cleaners
5800 Fort Caroline Road
Jacksonville, Florida

SCALE 1"=5'
DATE 11-2-98
PROJECT NO. 6006.10
MODULE NO. D006
FIGURE 8

APPENDIX A

PCE AND ETHANOL CONCENTRATIONS VERSUS EXTRACTED VOLUME OF FLUIDS

FIGURE A-1
PCE and Ethanol Concentations in RW002



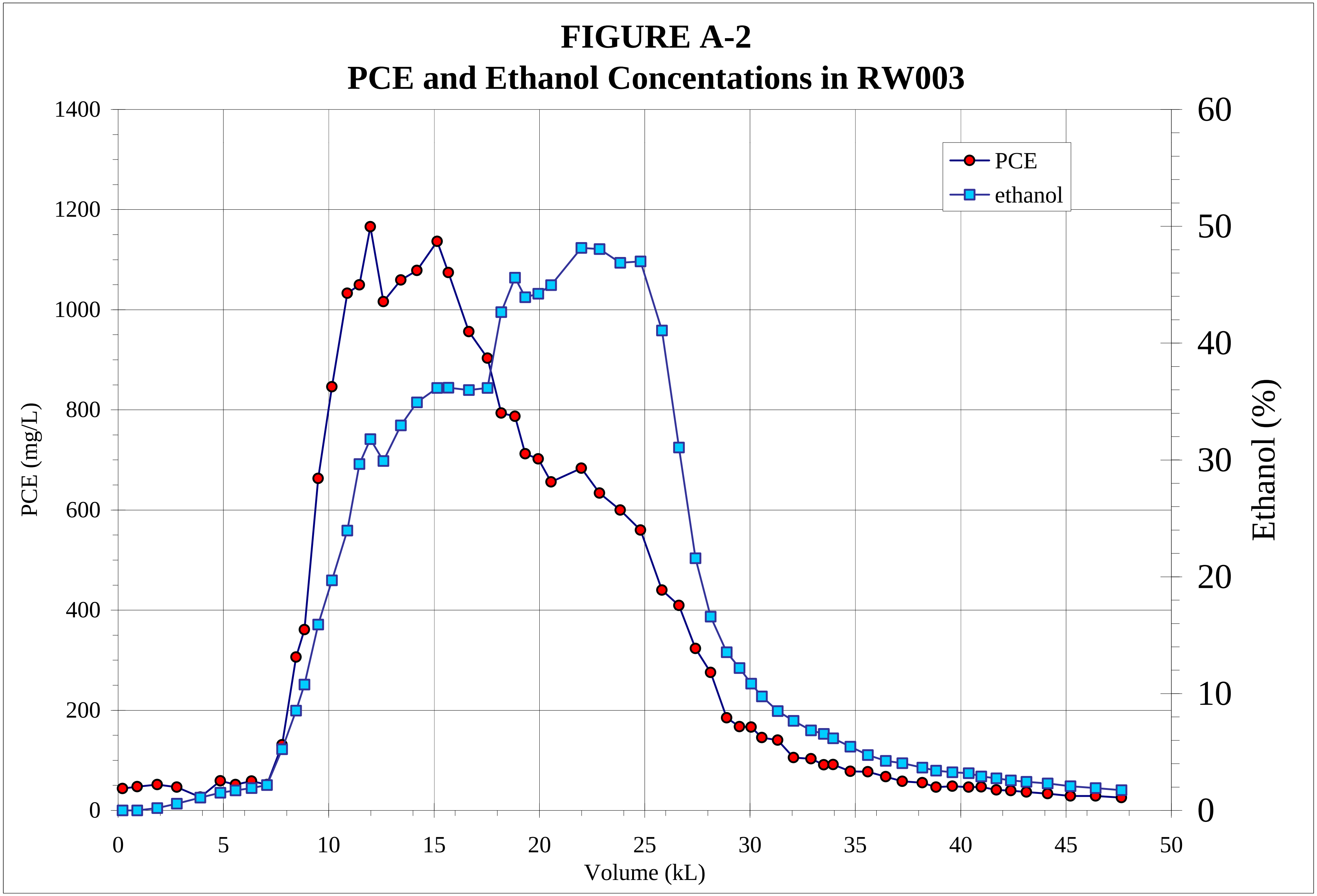
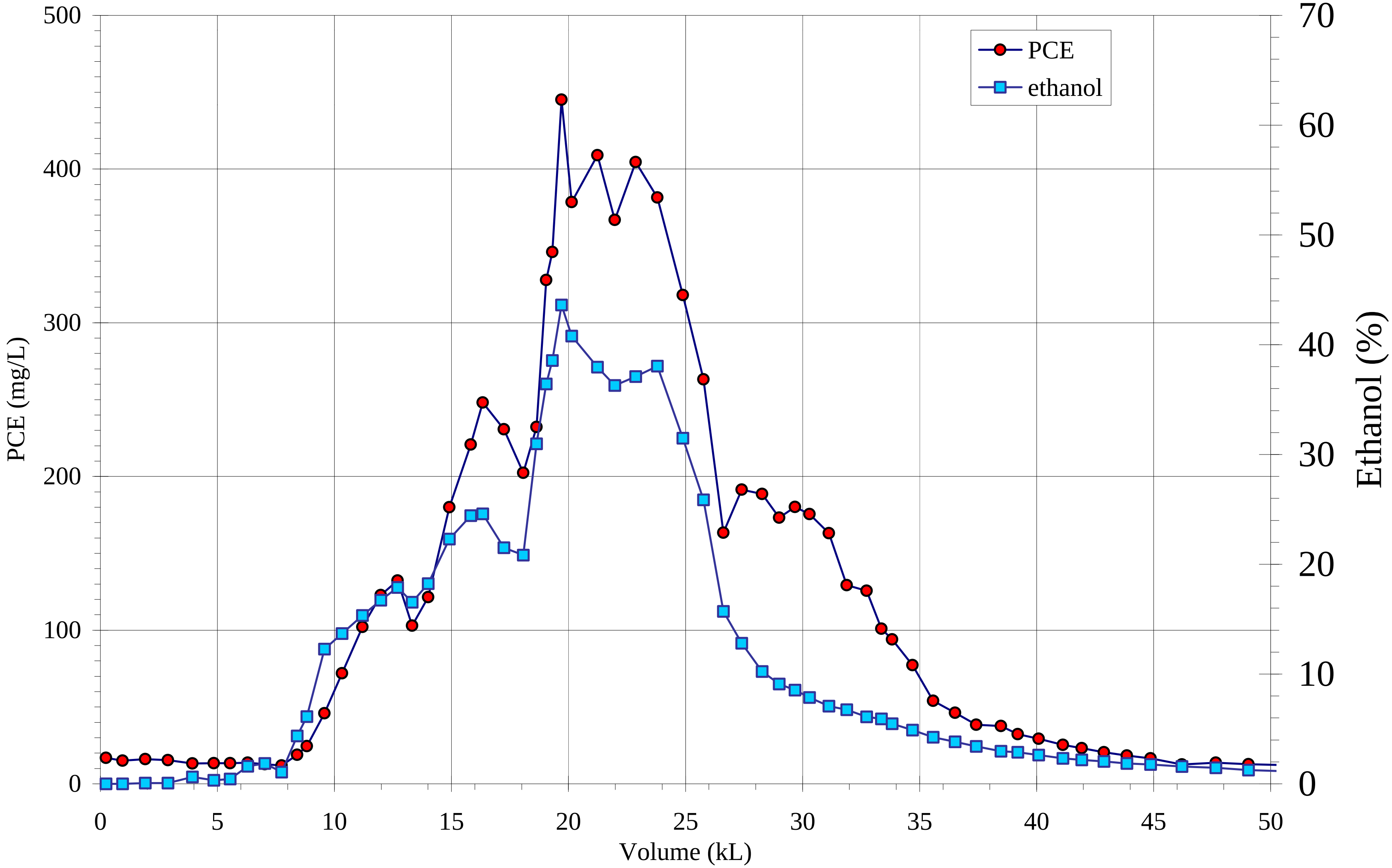


FIGURE A-2
PCE and Ethanol Concentations in RW003
PCE
ethanol
PCE (mg/L)
Ethanol (%)
Volume (kL)
0
200
400
600
800
1000
1200
1400
0
10
20
30
40
50
60
0
5
10
15
20
25
30
35
40
45
50

FIGURE A-3
PCE and Ethanol Concentations in RW004



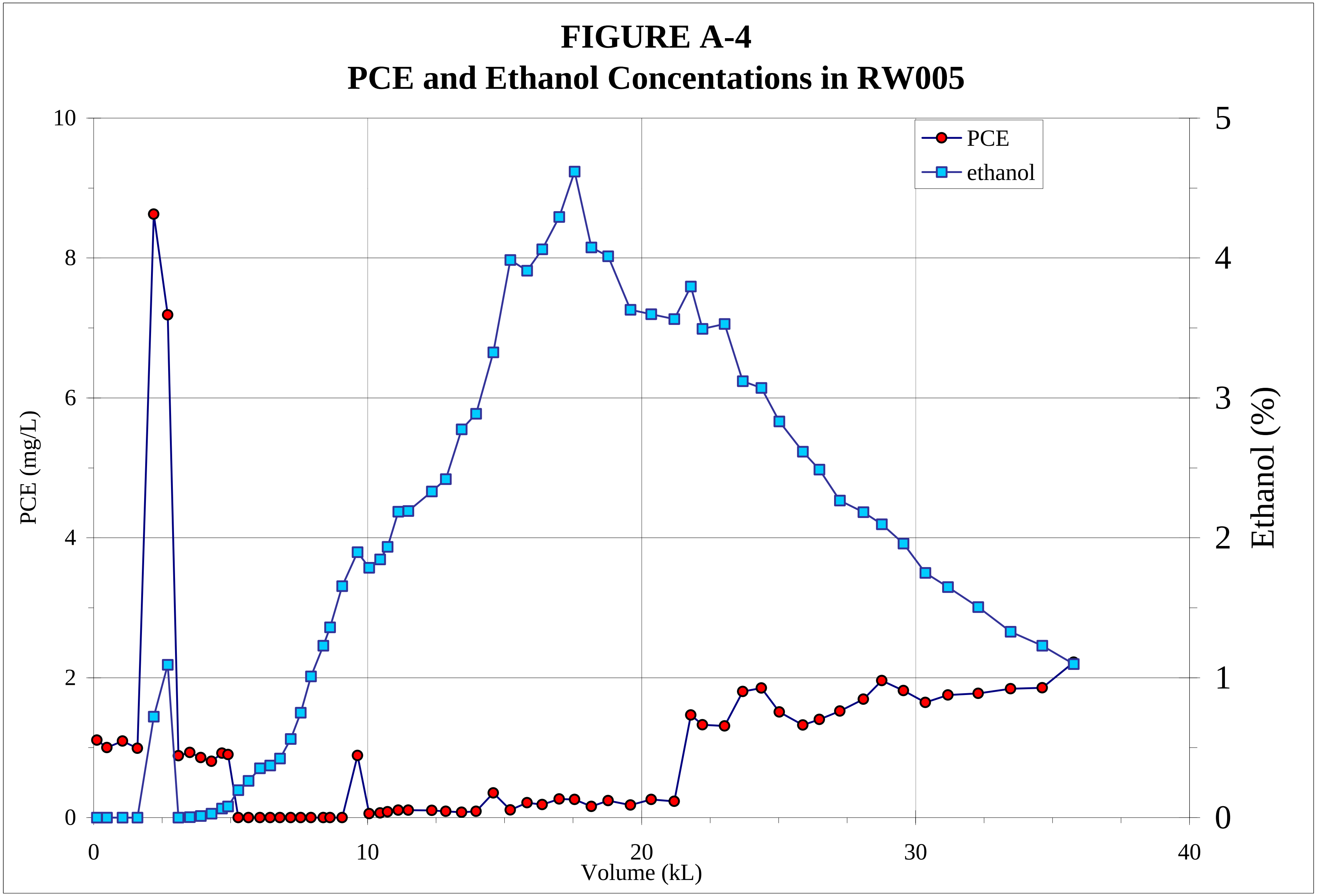


FIGURE A-4
PCE and Ethanol Concentations in RW005
PCE
ethanol
PCE (mg/L)
Ethanol (%)
Volume (kL)
0
2
4
6
8
10
0
1
2
3
4
5
0
10
20
30
40

FIGURE A-5
PCE and Ethanol Concentations in RW006

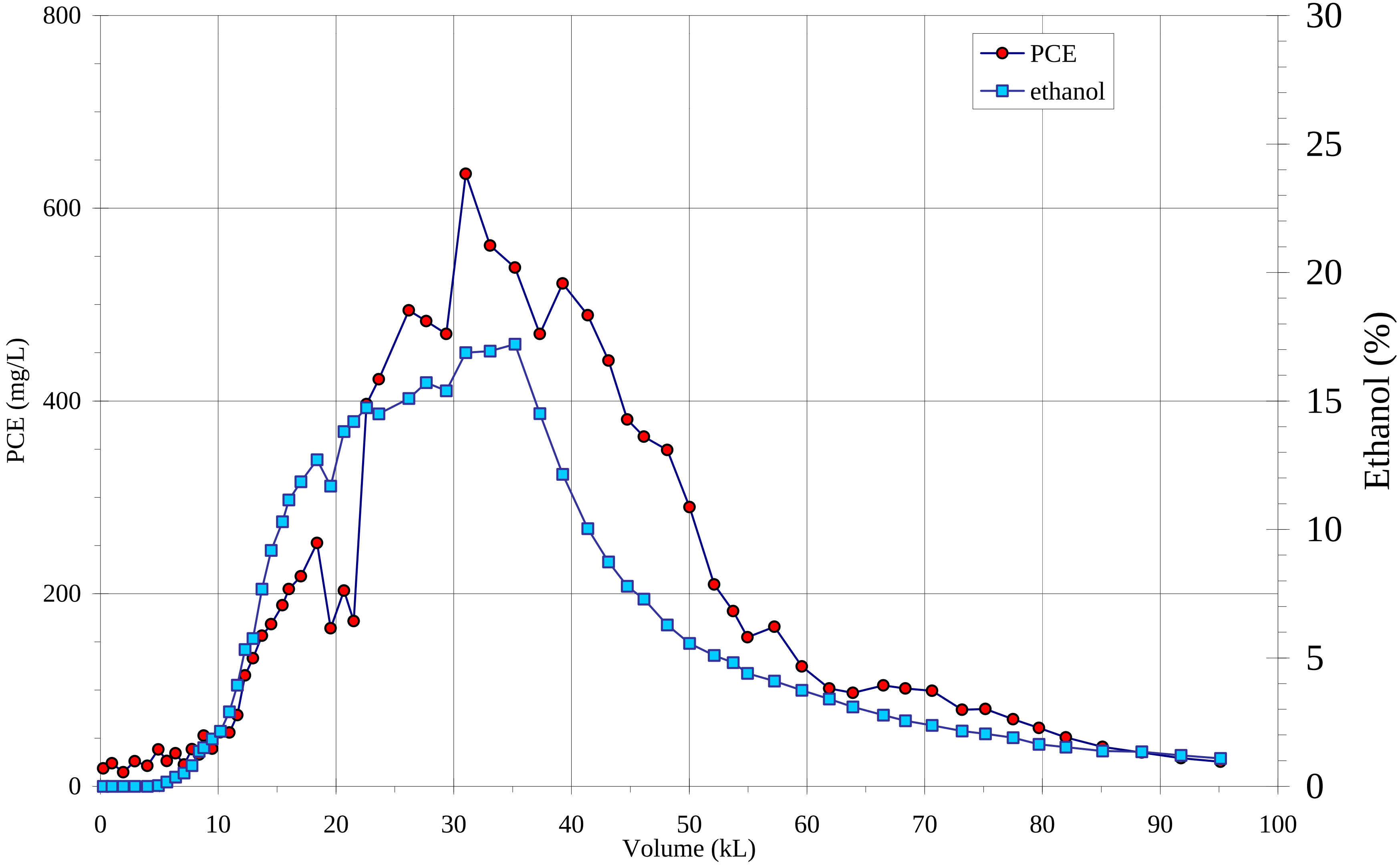
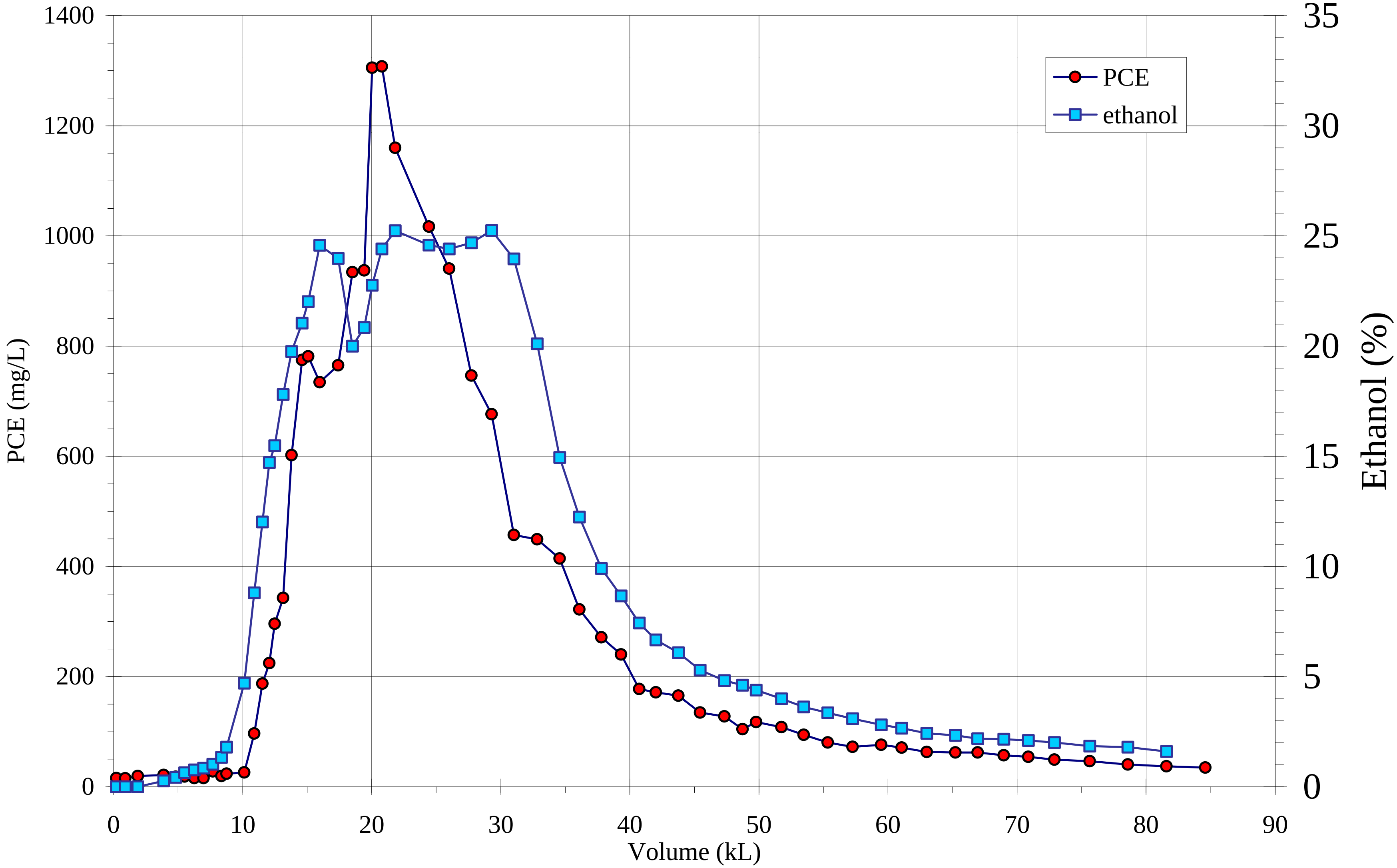


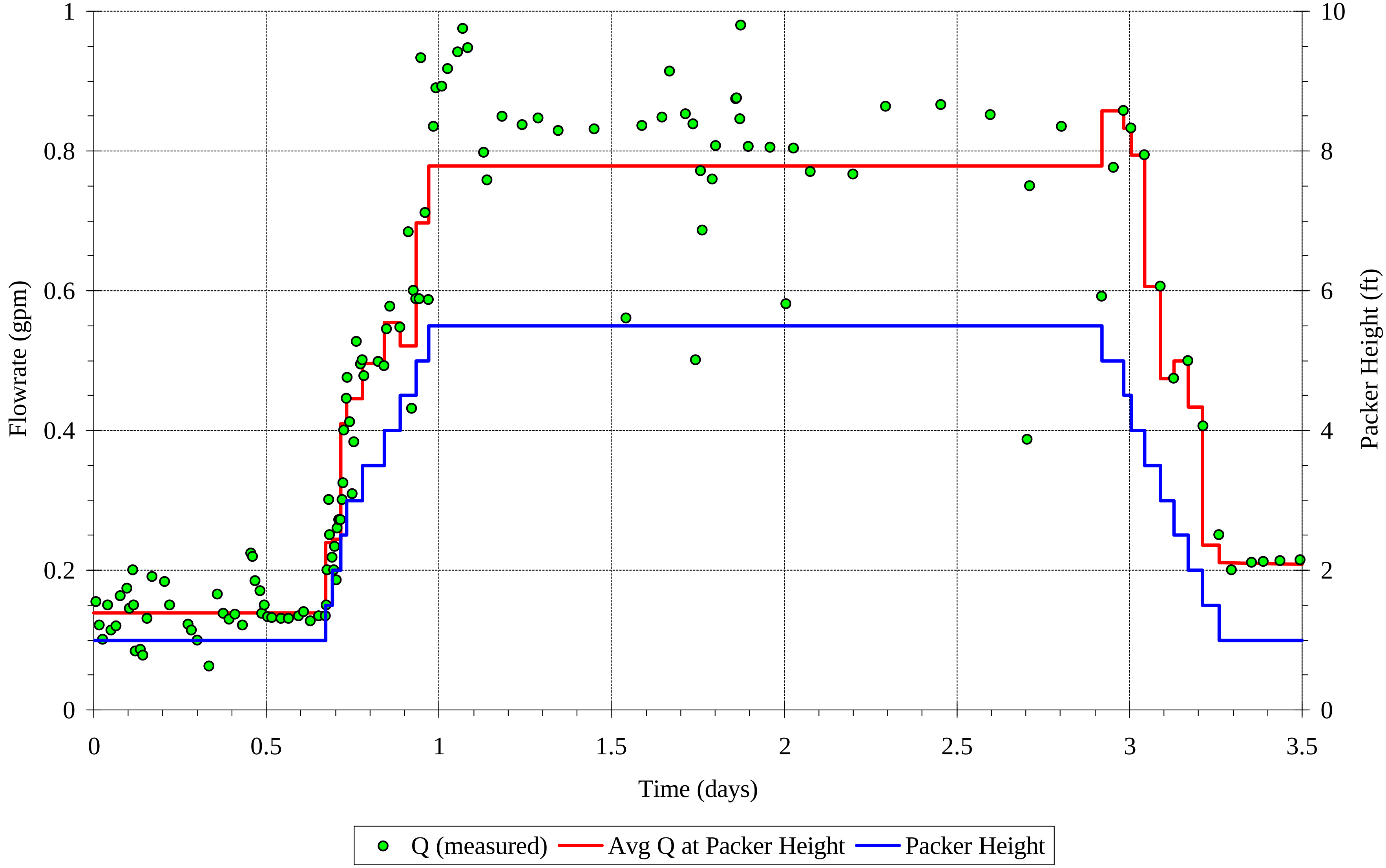
FIGURE A-6
PCE and Ethanol Concentations in RW007



APPENDIX B

INJECTION AND EXTRACTION RATE VERSUS TIME

Figure B-1
IW001 Injection Information



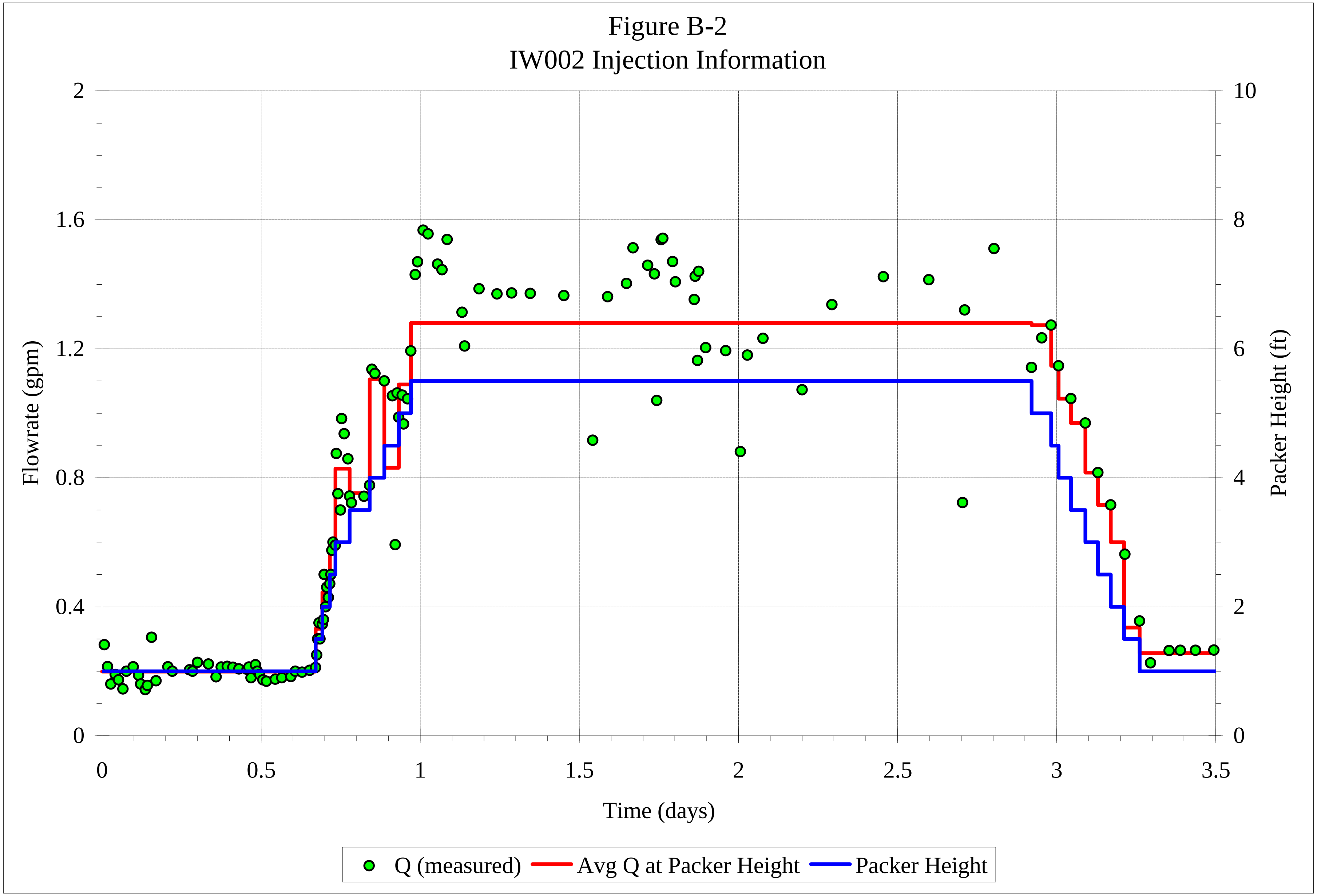


Figure B-2
IW002 Injection Information
Flowrate (gpm)
Packer Height (ft)
Time (days)
2
1.6
1.2
0.8
0.4
0
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
Q (measured)
Avg Q at Packer Height
Packer Height

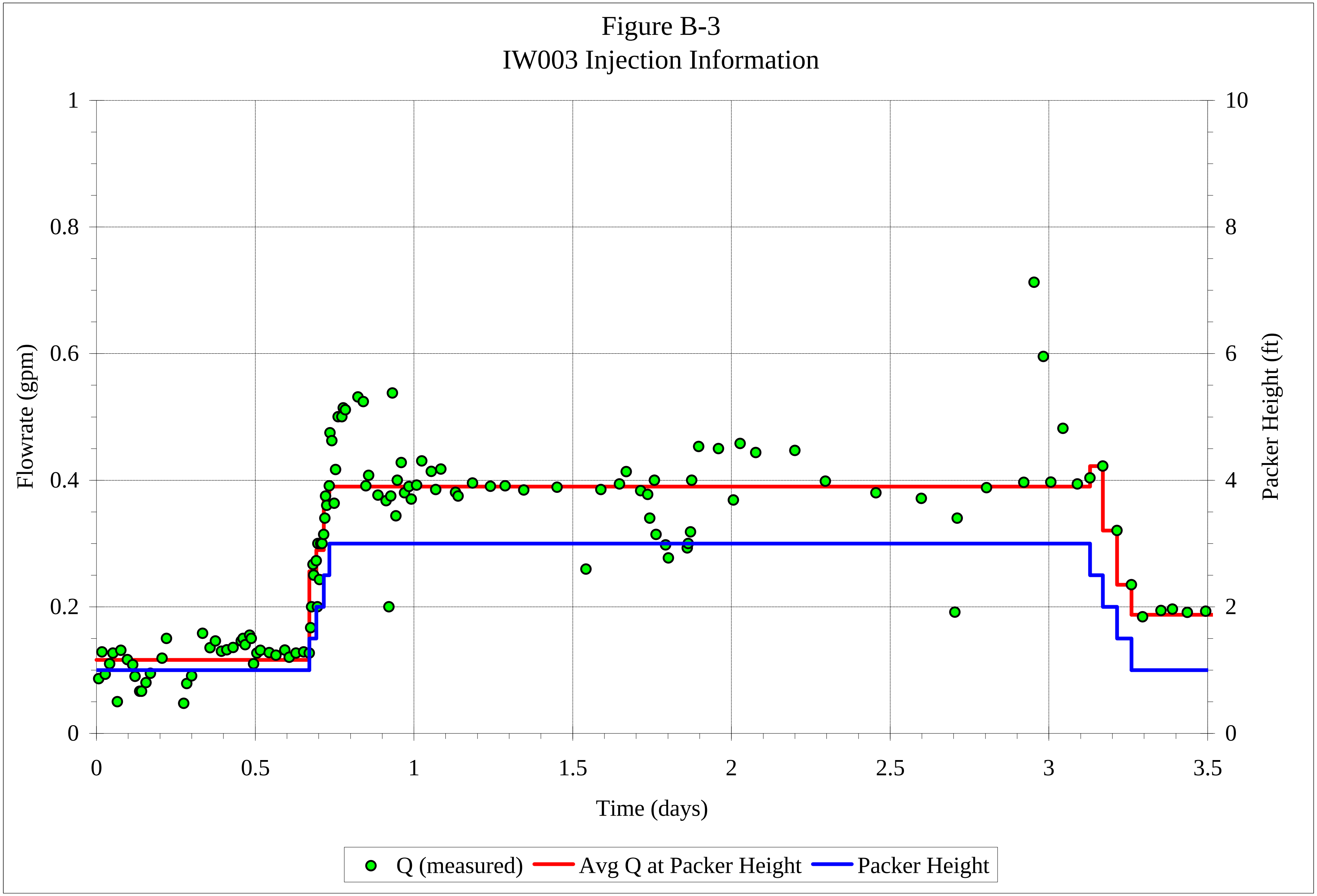


Figure B-3
IW003 Injection Information
Flowrate (gpm)
Packer Height (ft)
Time (days)
0
0.2
0.4
0.6
0.8
1
0
2
4
6
8
10
0
0.5
1
1.5
2
2.5
3
3.5
Q (measured)
Avg Q at Packer Height
Packer Height

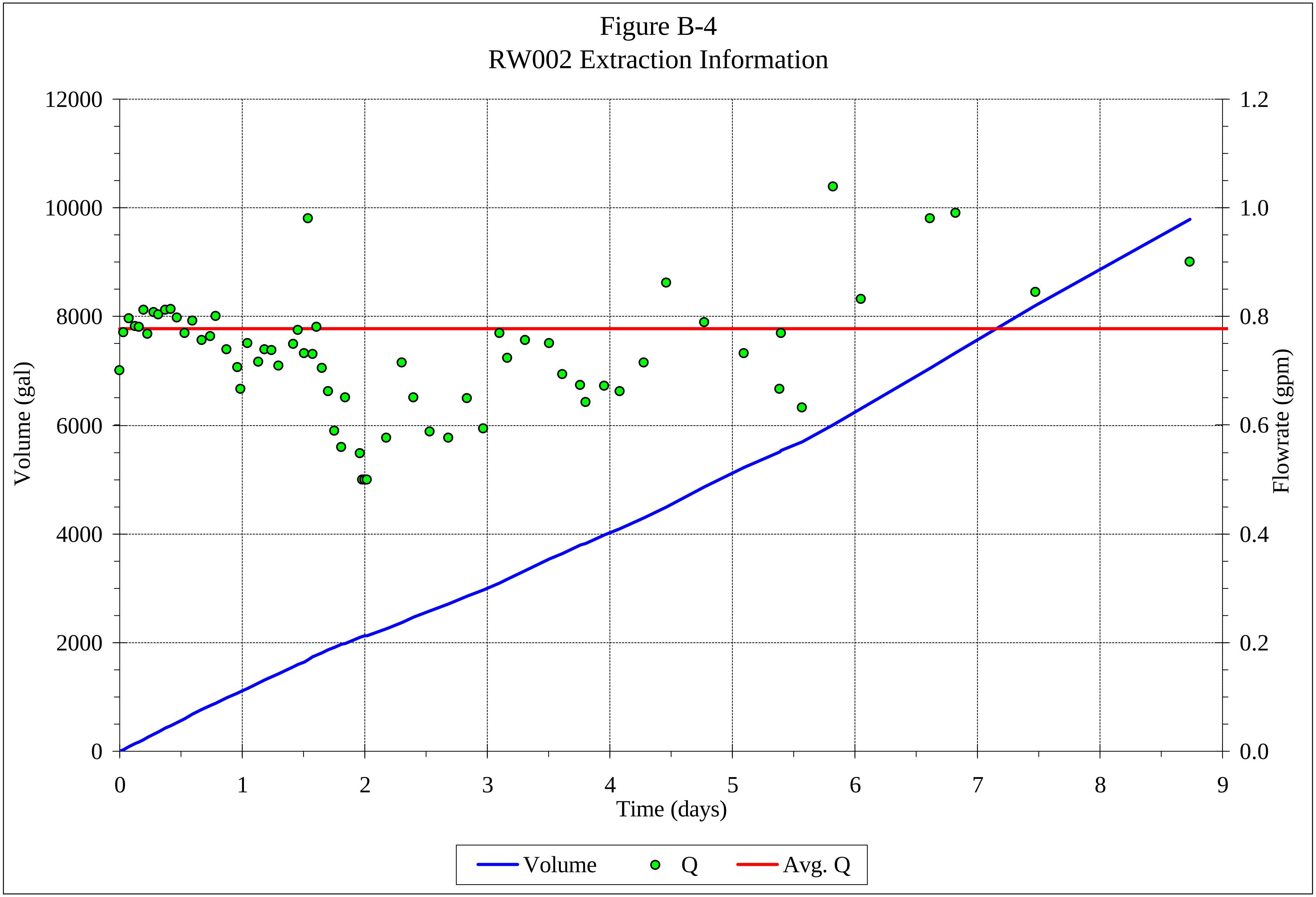


Figure B-4
RW002 Extraction Information
Volume (gal)
Flowrate (gpm)
Time (days)
12000
10000
8000
6000
4000
2000
0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
Volume
Q
Avg. Q

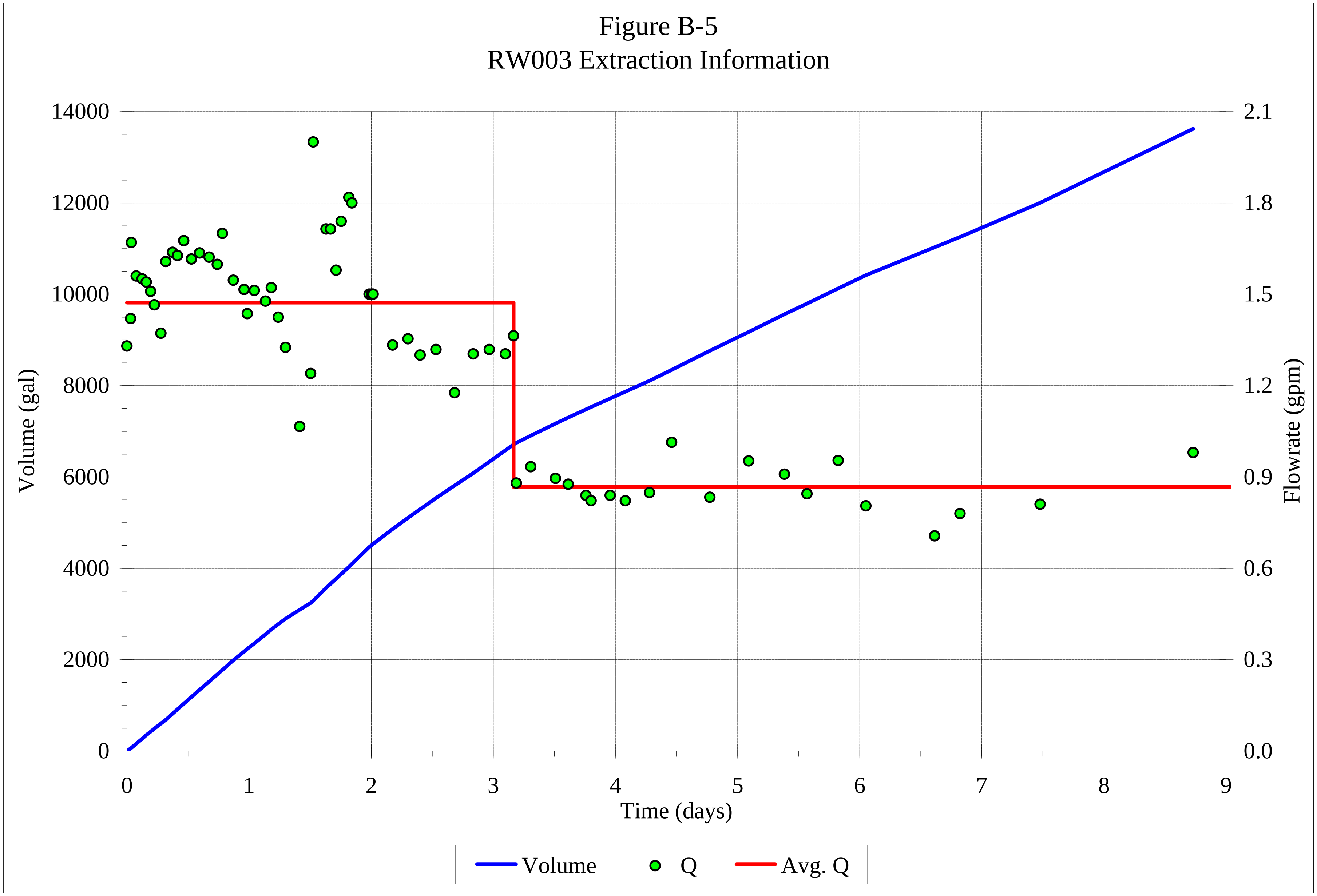


Figure B-5
RW003 Extraction Information
Volume (gal)
Flowrate (gpm)
Time (days)
14000
12000
10000
8000
6000
4000
2000
0
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0
0
1
2
3
4
5
6
7
8
9
Volume
Q
Avg. Q

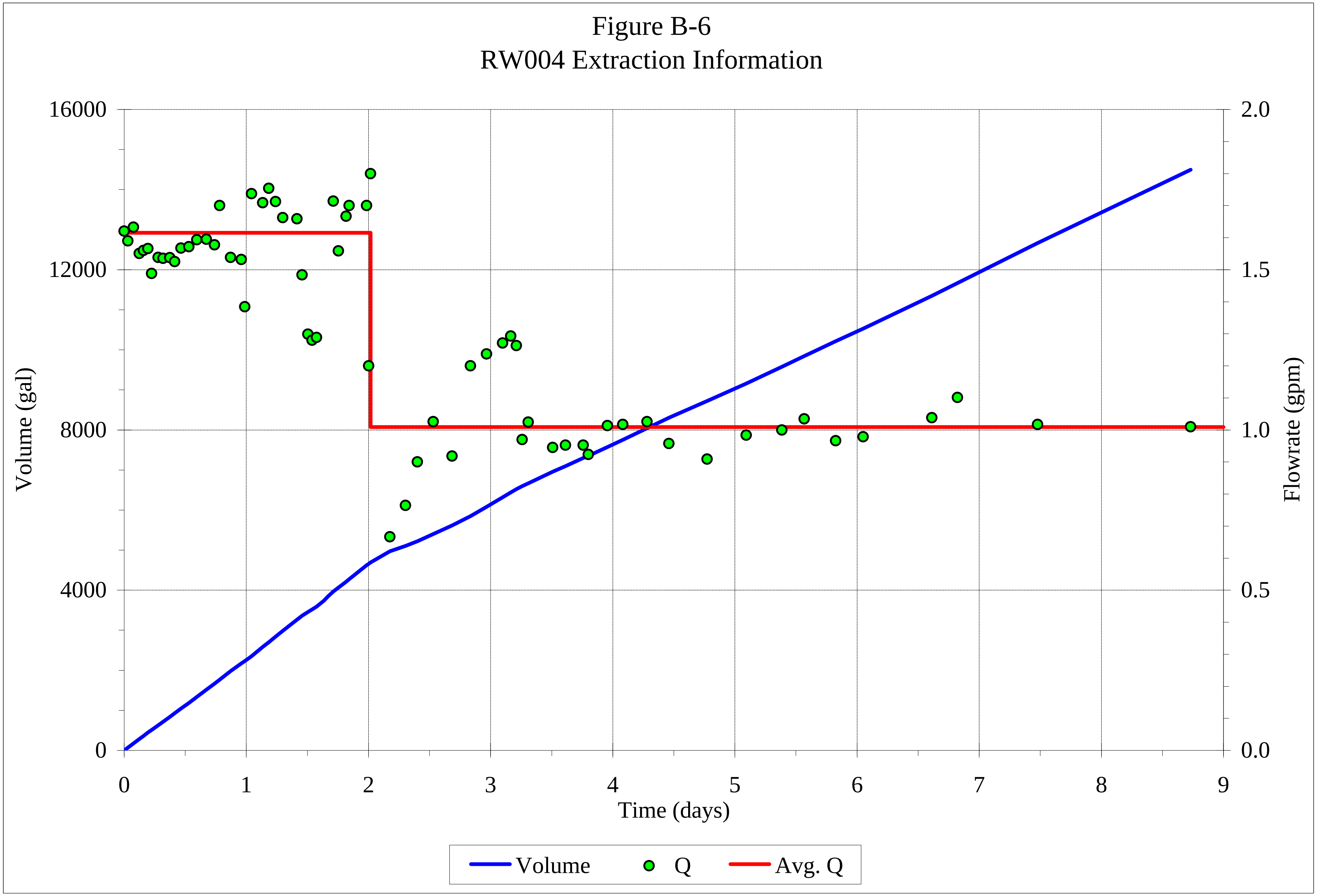


Figure B-6
RW004 Extraction Information
16000
12000
8000
4000
0
2.0
1.5
1.0
0.5
0.0
Volume (gal)
Flowrate (gpm)
0
1
2
3
4
5
6
7
8
9
Time (days)
Volume
Q
Avg. Q

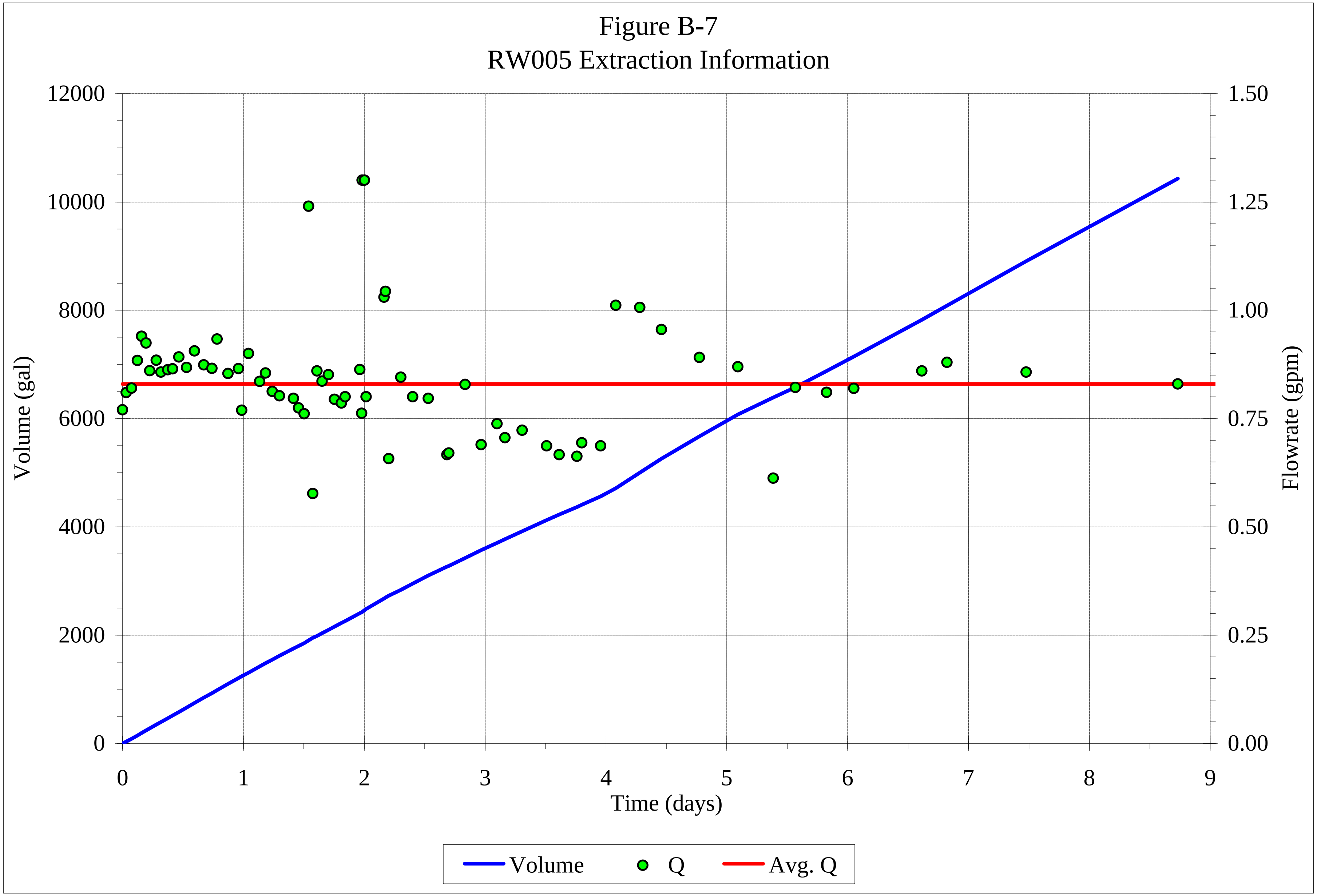


Figure B-7
RW005 Extraction Information
Volume (gal)
Flowrate (gpm)
Time (days)
12000
10000
8000
6000
4000
2000
0
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
1
2
3
4
5
6
7
8
9
Volume
Q
Avg. Q

APPENDIX C

PARTITION COEFFICIENT AND GRAIN-SIZED DISTRIBUTION DATA

Table C-1
Partition Coefficients Analysis
Sages Dry Cleaner, Jacksonville, Florida

Vial #	ID	Tare (g)	+ Soil (g)	+ Soln (g)	Estimated Dry Weight of Soil (g)	PCE Soln. Added (ml)	Total Water Present (ml)	Equilibrium PCE Conc. (ppm)	Mass of PCE in Water (µg/l)	Mass of PCE in Solids (µg/l)	Fraction Sorbed (percent)	Sorption Coefficient, Kd	Koc
2	MLS-7, 26-28, 0.2	4.6665	9.2227	12.11	3.638	2.894	3.814	53.265	203.17	87.66	43.1	0.45	38.5
3	MLS-7, 26-28, 0.5	4.6332	9.1557	12.039	3.714	2.890	3.701	56.986	210.90	79.53	37.7	0.38	12.1
4	MLS-7, 26-28, 0.5	4.622	9.1038	12.0296	3.680	2.933	3.736	58.030	216.81	77.90	35.9	0.36	11.8
5	MLS-7, 26-28, 0.8	4.1656	9.0975	11.9382	3.891	2.847	3.891	62.832	244.48	41.65	17.0	0.17	5.5
6	MLS-7, 26-28, 0.8	4.6621	9.1499	12.0234	3.540	2.880	3.830	53.041	203.14	86.29	42.5	0.46	15.0
7	MLS-7, 26-28, 1.1	4.6441	9.1555	12.0616	3.638	2.913	3.788	56.999	215.94	76.79	35.6	0.37	15.7
8	MLS-7, 26-28, 1.1	4.6442	9.1335	12.0418	3.620	2.915	3.786	60.897	230.58	62.37	27.0	0.28	12.0
9	MLS-6, 26.2-28, 0.2	4.627	9.1493	12.0387	3.640	2.896	3.781	59.842	226.25	64.79	28.6	0.30	22.8
10	MLS-6, 26.2-28, 0.2	4.6673	9.1418	12.1157	3.601	2.981	3.856	64.812	249.93	49.62	19.9	0.21	16.3
11	MLS-6, 26.2-28, 0.5	4.6293	9.2204	12.0393	3.685	2.825	3.734	67.059	250.41	33.53	13.4	0.14	15.2
12	MLS-6, 26.2-28, 0.5	4.6129	9.0707	11.9364	3.578	2.872	3.755	64.214	241.10	47.55	19.7	0.21	23.2
13	MLS-5, 26.2-28, 0.5	4.6295	9.1129	11.9699	3.564	2.864	3.786	64.638	244.69	43.08	17.6	0.19	14.3
14	MLS-5, 26.2-28, 0.5	4.617	9.1199	11.9714	3.579	2.858	3.784	69.007	261.13	26.09	10.0	0.11	8.1
15	MLS-5, 26.2-28, 0.8	4.6516	9.164	12.0087	3.614	2.851	3.752	53.697	201.46	85.08	42.2	0.44	11.7
16	MLS-5, 26.2-28, 0.8	4.6196	9.1047	11.9871	3.592	2.889	3.784	53.821	203.66	86.67	42.6	0.45	12.0
17	MLS-5, 26.2-28, 1.1	4.6322	9.1243	11.9764	3.543	2.859	3.811	57.542	219.26	68.02	31.0	0.33	17.9
18	MLS-5, 26.2-28, 1.1	4.6724	9.1435	12.0336	3.526	2.897	3.844	55.565	213.60	77.51	36.3	0.40	21.2
19	MLS-5, 28.7-30.5, 0.2	4.6705	9.1291	12.0448	3.598	2.922	3.785	59.091	223.65	70.04	31.3	0.33	15.1
20	MLS-5, 28.7-30.5, 0.2	4.6503	9.1329	12.0574	3.618	2.931	3.798	56.578	214.90	79.67	37.1	0.39	17.8
21	MLS-5, 28.7-30.5, 0.5	4.6456	9.2252	12.0169	3.591	2.798	3.789	54.040	204.74	76.46	37.3	0.39	11.7
22	MLS-5, 28.7-30.5, 0.5	4.6392	9.1505	12.0496	3.538	2.906	3.882	55.760	216.44	75.58	34.9	0.38	11.4
23	MLS-5, 28.7-30.5, 0.8	4.6526	9.141	12.0675	3.545	2.933	3.879	52.455	203.45	91.32	44.9	0.49	NA
24	MLS-5, 28.7-30.5, 0.8	4.6194	9.1165	11.958	3.552	2.848	3.795	56.914	216.00	70.21	32.5	0.35	NA

	Kd	Koc
Mean =	**0.33**	**15.67**
Standard Deviation =	**0.11**	**6.84**
Coefficient of Variation =	**33.6%**	**43.6%**

Notes:

ID = identification
g = gram
ml = milliliter
ppm = parts per million
µg/l = micrograms per liter
NA = not analyzed

Table C-2
On-Site GC-2 Results
Effluent Concentration of PCE
Sages Dry Cleaner, Jacksonville, Florida

Date	Time	PCE concentration (micrograms per liter)
8/9/98	16:29:59	< 1
8/9/98	16:42:41	< 1
8/9/98	17:02:39	< 1
8/9/98	17:36:08	< 1
8/9/98	17:54:57	< 1
8/9/98	18:13:06	< 1
8/9/98	18:24:51	< 1
8/9/98	18:38:07	< 1
8/9/98	19:00:01	< 1
8/9/98	19:14:21	< 1
8/9/98	20:05:41	< 1
8/9/98	20:29:28	< 1
8/9/98	21:00:57	< 1
8/9/98	21:19:34	< 1
8/9/98	22:13:12	< 1
8/9/98	22:30:32	< 1
8/9/98	22:48:04	< 1
8/9/98	23:09:28	< 1
8/9/98	23:34:47	< 1
8/10/98	0:04:15	< 1
8/10/98	0:38:34	< 1
8/10/98	0:59:13	< 1
8/10/98	1:37:40	< 1
8/10/98	2:22:21	< 1
8/10/98	2:48:18	< 1
8/10/98	3:10:10	< 1
8/10/98	3:31:31	< 1
8/10/98	10:52:46	< 1
8/10/98	17:59:50	< 1
8/10/98	19:27:25	< 1
8/10/98	20:02:41	< 1
8/10/98	22:14:13	< 1
8/10/98	22:41:24	< 1
8/10/98	23:08:16	< 1
8/10/98	23:35:16	< 1
8/11/98	0:02:23	< 1
8/11/98	0:29:16	< 1
8/11/98	1:13:09	< 1
8/11/98	1:40:13	< 1
8/11/98	2:28:12	< 1
8/11/98	2:55:18	< 1
8/11/98	3:22:14	< 1

Table C-2
On-Site GC-2 Results
Effluent Concentration of PCE
Sages Dry Cleaner, Jacksonville, Florida

Date	Time	PCE concentration (micrograms per liter)
8/11/98	3:49:18	< 1
8/11/98	4:16:17	< 1
8/11/98	4:43:17	< 1
8/11/98	5:10:14	< 1
8/11/98	5:37:13	< 1
8/11/98	6:04:17	< 1
8/11/98	6:31:16	< 1
8/11/98	6:58:16	< 1
8/11/98	7:25:16	< 1
8/11/98	7:52:13	< 1
8/11/98	8:19:16	< 1
8/11/98	8:46:13	< 1
8/11/98	9:13:15	< 1
8/11/98	9:40:15	< 1
8/11/98	11:04:23	< 1
8/11/98	11:31:38	< 1
8/11/98	11:58:52	< 1
8/11/98	12:26:07	< 1
8/11/98	12:53:22	< 1
8/11/98	13:20:37	< 1
8/11/98	13:47:51	< 1
8/11/98	14:15:06	< 1
8/11/98	14:42:21	< 1
8/11/98	15:09:37	< 1
8/11/98	15:36:51	< 1
8/11/98	16:04:06	< 1
8/11/98	16:31:21	< 1
8/11/98	16:58:36	< 1
8/11/98	17:25:51	< 1
8/11/98	17:53:06	< 1
8/11/98	18:20:22	< 1
8/11/98	18:47:36	< 1
8/11/98	19:14:51	< 1
8/11/98	19:42:06	< 1
8/11/98	20:09:20	< 1
8/11/98	20:36:35	< 1
8/11/98	21:03:50	< 1
8/11/98	21:31:05	< 1
8/11/98	21:58:20	< 1
8/11/98	22:25:35	< 1
8/11/98	22:52:49	< 1
8/11/98	23:20:04	< 1

Table C-2
On-Site GC-2 Results
Effluent Concentration of PCE
Sages Dry Cleaner, Jacksonville, Florida

Date	Time	PCE concentration (micrograms per liter)
8/11/98	23:47:20	< 1
8/12/98	0:14:35	< 1
8/12/98	0:41:50	< 1
8/12/98	1:09:04	< 1
8/12/98	1:36:19	< 1
8/12/98	2:03:34	< 1
8/12/98	2:30:49	< 1
8/12/98	2:58:03	< 1
8/12/98	3:25:18	< 1
8/12/98	3:52:33	< 1
8/12/98	4:19:48	< 1
8/12/98	4:47:03	< 1
8/12/98	5:14:18	< 1
8/12/98	5:41:32	< 1
8/12/98	6:08:47	< 1
8/12/98	6:36:02	< 1
8/12/98	7:03:17	< 1
8/12/98	7:30:32	< 1
8/12/98	9:31:31	< 1
8/12/98	9:58:46	< 1
8/12/98	10:26:01	< 1
8/12/98	11:29:52	< 1
8/12/98	11:57:08	< 1
8/12/98	12:24:23	< 1
8/12/98	12:51:37	< 1
8/12/98	13:18:53	< 1
8/12/98	13:48:00	< 1
8/12/98	14:15:14	< 1
8/12/98	14:46:25	< 1
8/12/98	15:19:47	< 1
8/12/98	15:31:56	< 1

Note:

PCE = tetrachloroethene

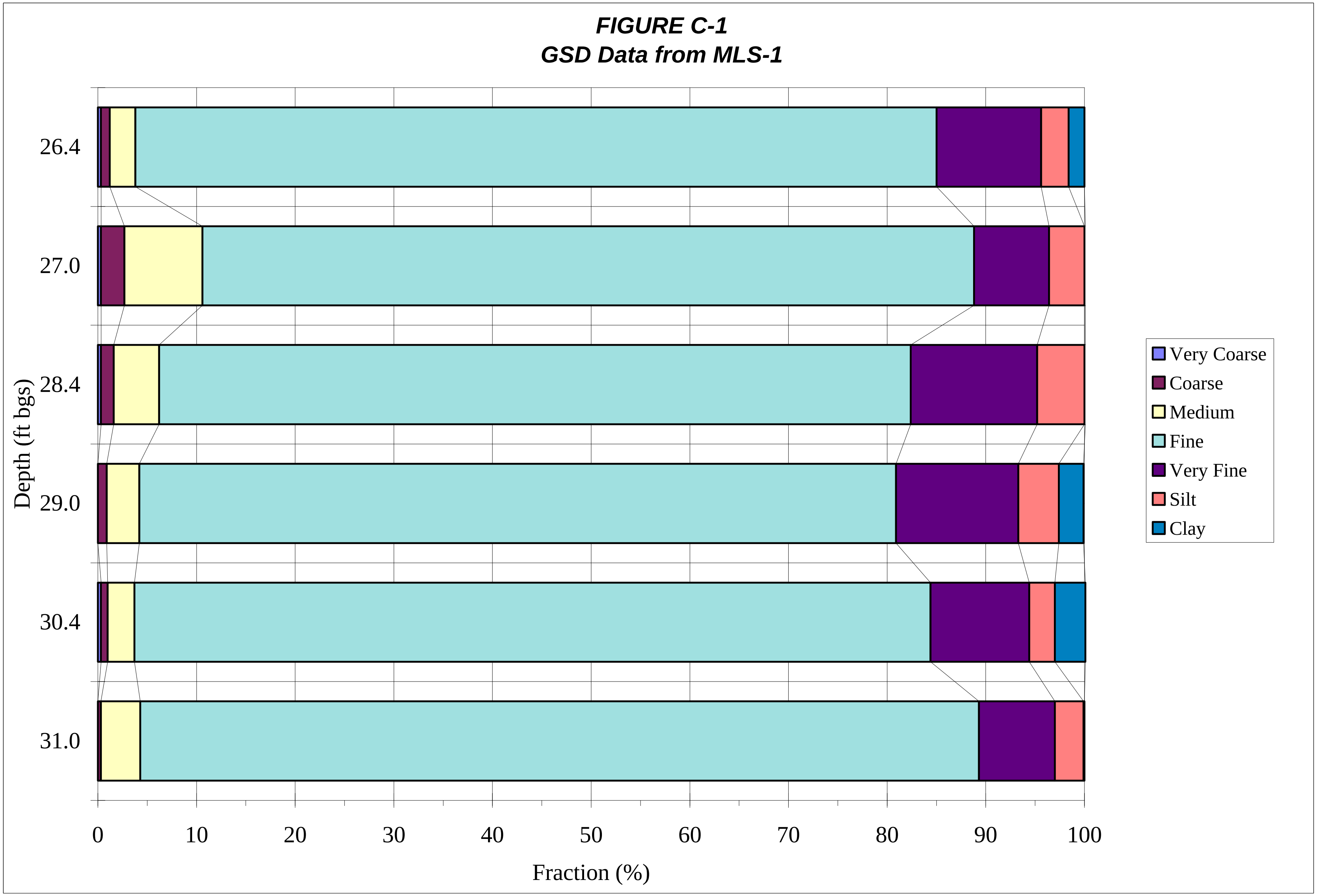


FIGURE C-1
GSD Data from MLS-1
Depth (ft bgs)
26.4
27.0
28.4
29.0
30.4
31.0
0
10
20
30
40
50
60
70
80
90
100
Fraction (%)
Very Coarse
Coarse
Medium
Fine
Very Fine
Silt
Clay

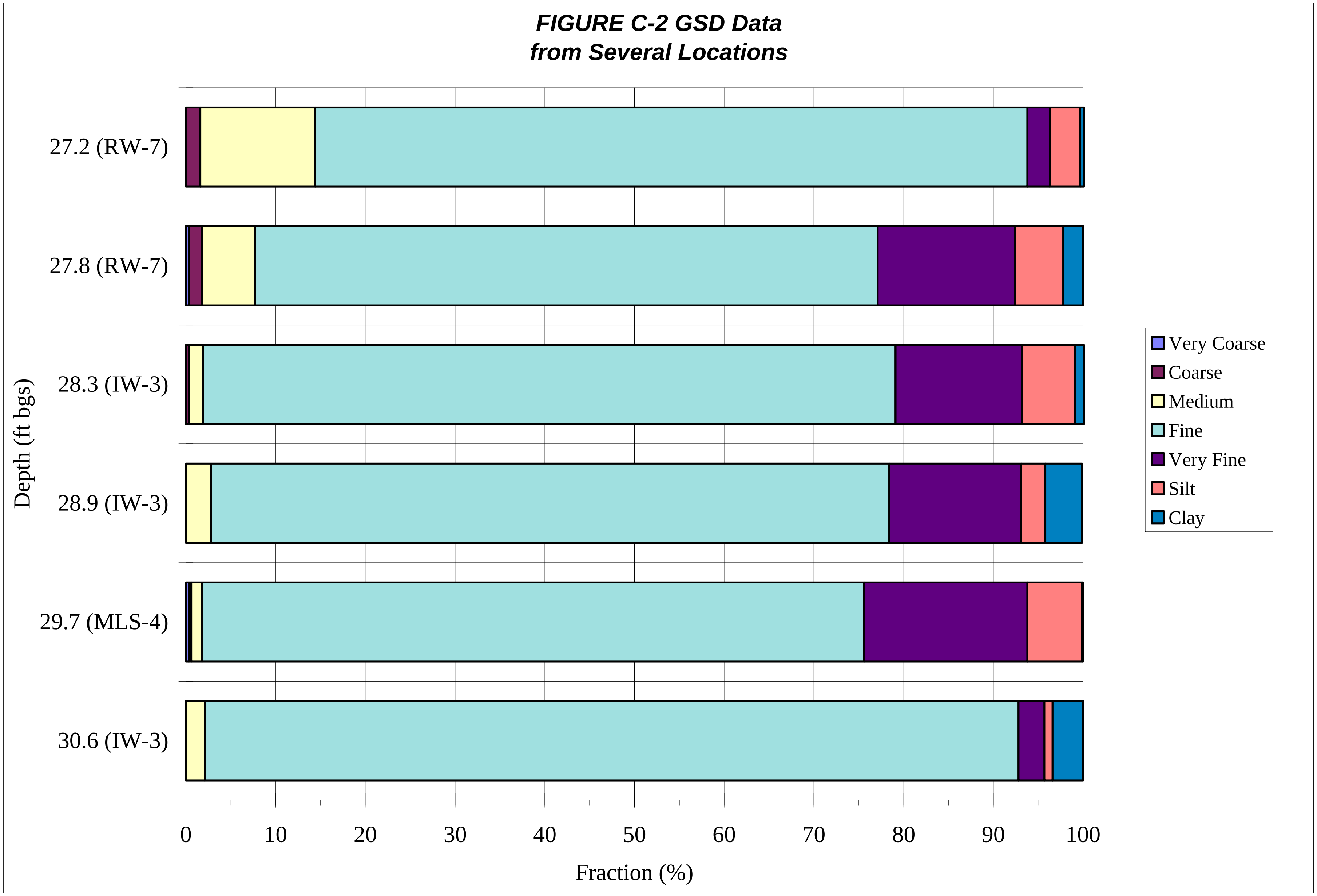


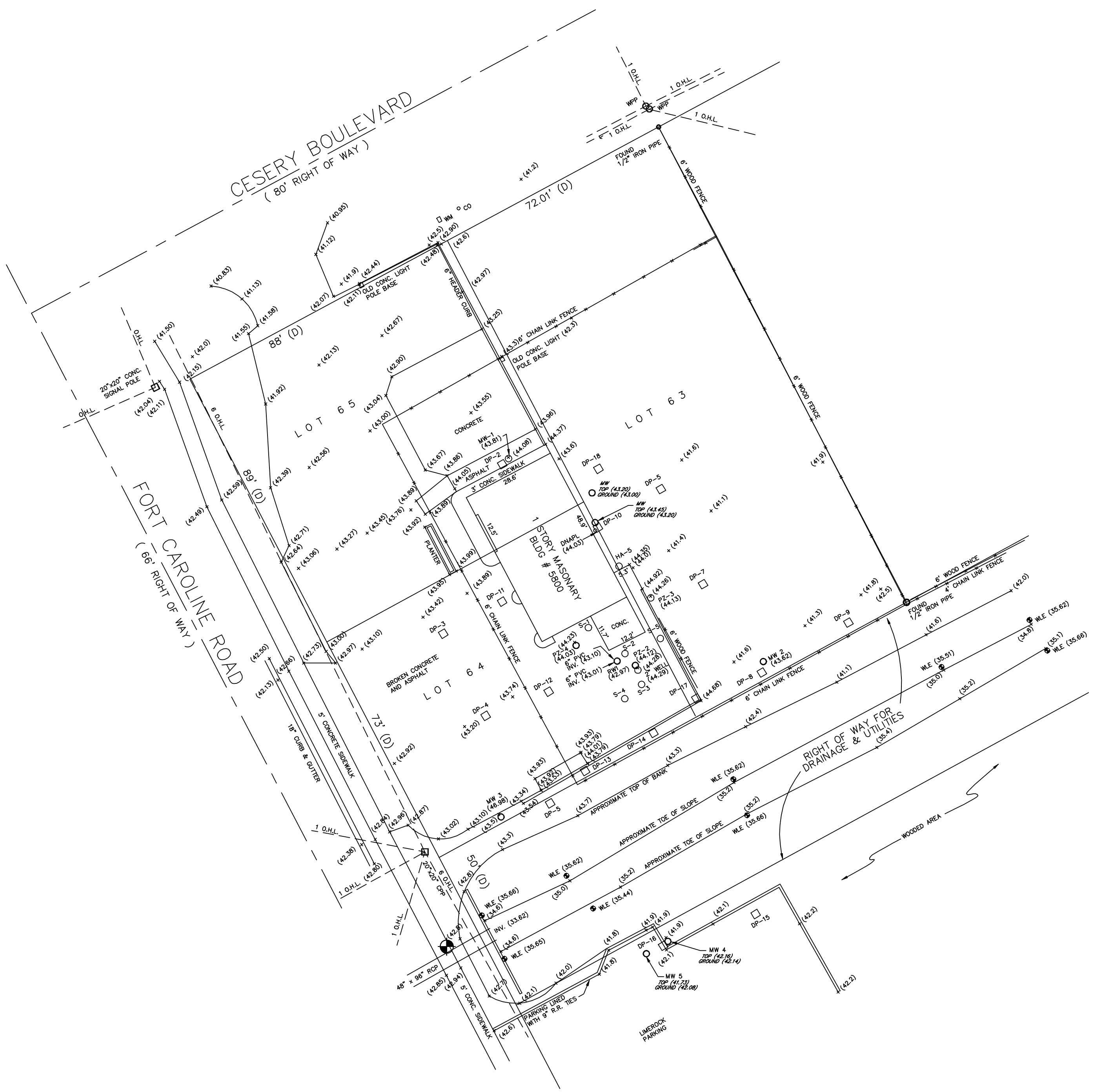
FIGURE C-2 GSD Data
from Several Locations
27.2 (RW-7)
27.8 (RW-7)
28.3 (IW-3)
28.9 (IW-3)
29.7 (MLS-4)
30.6 (IW-3)
Depth (ft bgs)
0
10
20
30
40
50
60
70
80
90
100
Fraction (%)
Very Coarse
Coarse
Medium
Fine
Very Fine
Silt
Clay

APPENDIX D

SEALED SITE SURVEY MAP

MAP SHOWING SPECIFIC PURPOSE SURVEY OF

LOTS 63, 64 AND 65, BLOCK 1, ARLINGTON HILLS UNIT 7A REPLAT, AS RECORDED IN PLAT BOOK, 28, PAGES 77–77A
CURRENT PUBLIC RECORDS, DUVAL COUNTY, FLORIDA.



ABBREVIATION	DEFINITION
BLDG.	BUILDING
CONC.	CONCRETE
CPP	CONCRETE POWER POLE
INV.	INVERT
MW	MONITORING WELL
PVC	POLYVINYLCHLORIDE PIPE
RCP	REINFORCED CONCRETE PIPE
WLE	WATER LEVEL ELEVATION
OHL	OVERHEAD ELECTRIC LINE

THE SPECIFIC PURPOSE OF THIS MAP IS TO SHOW A LIMITED TOPOGRAPHIC SURVEY

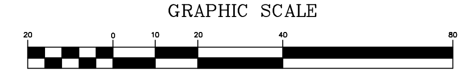
REFERENCE BENCH MARK: X–CUT ON TOP BACK OF CURB AT S.E. CORNER OF FT. CAROLINE RD. & CESERY BLVD. APPROXIMATELY ON THE S.LY RIGHT OF WAY OF FT. CAROLINE RD. ELEV. (41.54)

THIS MAP DOES NOT PURPORT TO BE A BOUNDARY SURVEY.

BOUNDARY LINE & RIGHT OF WAY LINES SHOWN HEREON ARE APPROXIMATE.

ELEVATIONS SHOWN THUS +(41.54) REFER TO NATIONAL GEODETIC VERTICAL DATUM. (N.G.V.D.)

GRAPHIC SCALE



(IN FEET)
1 inch = 20 ft.

RECHECKED: DEC. 17, 1997 TO SHOW ADDITIONAL MONITORING WELLS ONLY; W.O. #12–97–18.

CHARLES BASSETT & ASSOC., INC.

SURVEYORS – ENGINEERS – LAND PLANNERS
9 NORTH ACME STREET – JACKSONVILLE, FLORIDA – 32211 – PHONE (904) 724–9433

I HEREBY CERTIFY THAT THIS SPECIFIC PURPOSE SURVEY, PERFORMED UNDER MY RESPONSIBLE DIRECTION, MEETS THE MINIMUM TECHNICAL STANDARDS FOR LAND SURVEYORS IN ACCORDANCE WITH CHAPTER 61G17–6, FLA. ADMINISTRATIVE CODE (PURSUANT TO SECTION 472.027, FLORIDA STATUTES), ~~AND FURTHER CERTIFY THAT THERE ARE NO VISIBLE ENCROACHMENTS UPON THE SUBJECT PROPERTY EXCEPT AS SHOWN ON THIS SURVEY.~~

SURVEYED APRIL 1, 19 97

CHARLES R. BASSETT, REGISTERED LAND SURVEYOR FLA. NO. 1576

~~BEARING DATUM BASED ON~~

~~FLOOD ZONE AS BEST ASCERTAINED FROM THE FLOOD INSURANCE RATE MAP, COMMUNITY PANEL NO.~~ ~~DATED~~

FIELD BOOK NO.: 685	PAGE: 45–46	LEGAL: N/A	ORDER NO.: 2–97–29
COMPUTER FILE: CLEANRB.DWG		SCALE: 1" = 20'	FILE NO.: S–4982