SECOR
International Incorporated

Remedial Action Plan
Barg French Dry Cleaners
1923 Third Avenue
Seattle, Washington

SECOR PN: 001.01214.001

Submitted by
SECOR International Incorporated
12034 - 134th Court NE, Suite 102
Redmond, Washington 98052-2442
(425) 372-1600

Prepared For
Union Bank of California
Environmental Risk Management
500 South Main Street, Suite 370
Orange, California 92868

June 1, 2001

Prepared by:

Marc Sauze, P.E.
Associate Engineer

Reviewed by:

Todd Tiffany
Principal-in-Charge

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1.0 INTRODUCTION

SECOR International Incorporated (SECOR) is pleased to submit this Draft Remedial Action Plan (RAP) for the former Barg French Dry Cleaning facility located at 1923 Third Avenue in Seattle, Washington (Site). SECOR was authorized to proceed with the project by the Union Bank of California (UBOC) as stipulated in a Letter of Authorization (Log # E01-1165-T) dated April 11, 2001.

UBOC as Trustee of the Havers Trust has entered the Washington State Department of Ecology (Ecology) Voluntary Clean up Program (VCP) and has initiated an Independent Remedial Action for the Site. Informal Ecology consultation is herein requested regarding the proposed RAP and periodically during the remediation. The remedial action has been designed to achieve remediation of the soil and groundwater at the Site to cleanup levels that will satisfy Ecology's requirements to issue a no further action (NFA) opinion letter that contains no restrictions for the Site.

This document is based on a review of the reports summarizing assessment work completed by others and provides a Site description, a summary of the Site background, the remediation objectives, the remedial approach, a scope of work and the Site project schedule. Assessment work at the Site has been ongoing since 1999.

1.1 Site Location and Description

The Site is located at 1929 Third Avenue in a commercial/retail area located immediately north of the downtown core of Seattle, Washington. The Site covers approximately 6,480 square feet and has been legally owned by the Henrietta Havers Trust ('Trust') since 1955. The UBOC is the trustee of the Havers Trust. The Site is currently occupied by a three-story commercial/retail building (the Heiden Building) that was constructed in 1914. The Barg French Dry-Cleaners was reportedly a tenant on the first floor of the building from 1951 to 2000. The former location of the dry cleaning operation is currently vacant and a bookstore occupies the remaining portion of first floor. The second floor of the building is currently occupied by a photographer. The Site location is shown on Figure 1 and the site layout is presented on Figure 2.

Surrounding land use consists of densely packed commercial/retail buildings with associated parking structures that include restaurants, shops, hotels and a theater.

1.1.1 Regional Geology

The Site is located within the Puget Lowland physiographic province, a broad, low-lying region situated between the Cascade Range to the east and the Olympic Mountains to the west. The Puget Sound Region is underlain by Quaternary sediments deposited by a number of glacial episodes. Deposition occurred during a number of glacial advances and retreats that created the existing subsurface conditions. The regional sediments consist primarily of interlayered and/or sequential deposits of alluvial clays, silts, and sands that are typically situated over deposits of glacial till. Outwash sediments consisting of sand, silt, and clay were deposited by rivers, streams, and post-glacial lakes during the glacial retreats. With the exception of the most recent recessional deposits, the outwash sediments have been over-consolidated by the overriding ice sheets. The resulting lithology is characterized by a thin, uncompacted till layer overlying a densely compacted till layer.

The geologic stratum mapped in the Site vicinity is classified as Vashon Till (Waldron *et al*, 1962). This formation typically consists of a compact concrete-like mixture of silt, sand, gravel, and clay. This formation can occur at depths up to 150 feet thick, but generally less than 50 feet thick. The upper 2 to 5 feet generally consists of loose silty sand and gravel. Documented laboratory testing has shown that the permeability of glacial till ranges from 10^{-5} to 10^{-7} centimeters per second. Over consolidated clays have a similar range, but sands and gravels have higher permeabilities.

1.1.2 Site Geology

Based on boring logs for monitoring wells and soil vapor extraction wells installed at the Site, the near-surface lithology beneath the Site consists of medium to fine gray sand grading into gray sandy silt at 15 to 20 feet below ground surface (bgs). The medium to fine gray sand was slightly moist and loosely consolidated and the sandy silt was very wet and dense.

1.1.3. Hydrogeology

The principal aquifers in the Puget Sound Region are in glacial drift that, along with finer grained interglacial sediments, underlies the basin lowland to depths of more than 1,000 feet, and in alluvial deposits that underlie the major lowland and mountain river valleys.

The glacial drift is comprised of unconsolidated sand, gravel, silt, and clay, and partially consolidated glacial till. The sand and gravel units in the drift form the principal aquifers. These aquifers typically receive ample recharge from the heavy precipitation characteristic of western Washington. The drift in the Puget Sound region varies greatly in composition, and accordingly, in water-yielding capability. Typically, wells in glacial drift that tap silt, clay or till in the Puget Sound region (i.e., approximately 75 to 100 feet bgs) may have yields on the order of 100 gallons per minute (gpm). Deeper wells tapping thick, saturated layers of highly permeable gravel and coarse sand (typically at depths greater than 250 feet bgs) can yield more than 1,000 gpm.

The primary aquifers are typically overlain, by relatively impermeable glacial till deposits that are present at or near the ground surface over much of the Puget Sound region. Within these till deposits are localized areas or lenses of water-bearing sands and gravels that may result in a shallow, perched water table. Lateral and vertical migration of shallow groundwater may be impeded by the relatively impermeable nature of the till and by the sometimes discontinuous nature of the perched water-bearing sands and gravel. Perched and discontinuous zones of shallow groundwater may be seasonally or perennially present, depending on Site-specific conditions.

In the Puget Sound region, shallow groundwater flow direction often mimics the surface topography. Groundwater typically flows from areas of high elevation to areas of low elevation. In addition, shallow groundwater flow usually parallels or migrates toward nearby surface water bodies. However, surface features such as streets, utility trenches, and paved areas can locally alter the flow direction of shallow groundwater.

A shallow, perched water table is present at the Site and occurs between approximately 11 and 12 feet bgs. Attempts were made to drill a boring at the site to determine whether an aquitard is present at the site between the perched groundwater and regional groundwater that is believed to occur at approximately 50 feet bgs. Due to limitations posed by utility corridors and the dense development of the area, a limited access drill rig had to be used and could only penetrate the soil to approximately 30 feet bgs before refusal. However, based on boring logs recorded at a property approximately four blocks from the Site, regional groundwater in the vicinity of the Site occurs at a depth of approximately 50 to 70 feet bgs. The regional groundwater unit was overlain at this location by 18 feet of dry sandy silt (till) and is believed to act as an aquitard between areas of localized perched water and the deeper regional aquifer. Therefore, the shallow, perched water table at the Site is significantly separated from the regional groundwater. A cumulative summary of the groundwater elevations measured at the Site is presented in Table 1.

The groundwater flow direction has not been established for the perched groundwater at the Site. Based on local topography in the vicinity of the Site, the direction of the regional groundwater flow and the flow direction of uncontrolled surface water are expected to follow local topography, toward the southwest (toward Puget Sound).

Washington Administrative Code (WAC) 173-340-720 (a)(ii) states that groundwater is not a potential future source of drinking water if it is present in insufficient quantity to have a sustainable yield greater than 0.5 gpm or contains greater than 10,000 mg/L of total dissolved solids. During a drawdown test conducted on May 22-23, 2001, the average yield of two wells at the Site were well below this threshold (approximately 0.1 gpm). Based on such a low potential yield, there is no apparent beneficial use for the perched groundwater at the Site given that it could not be extracted in sufficient volume to satisfy uses other than drinking water (i.e., not sufficient for irrigation or industrial use). The nearest surface water body to the Site is Elliot Bay, which is located over ¼-mile from the Site.

1.2 Background

SECOR conducted a review of available files pertinent to the Site at Ecology's Northwest Regional Office in Bellevue, Washington. The series of reports included background historical information and results of intrusive soil and groundwater quality assessment work completed at the Site since 1999. A list of reports reviewed is provided in Appendix A.

Three phases of subsurface soil sampling were completed in the dry cleaning portion of the building and the bookstore area to assess the potential impact of the dry cleaning operation on the Site. The initial investigation conducted by Webster, Inc. (Webster) in June 1999 included collection of a near-surface soil sample adjacent to the dry cleaning unit. Results indicated that the soil sample contained PCE at a concentration of 2,200 ug/kg.

Two additional phases of subsurface soil sampling were subsequently completed in August and September 1999 by Kleinfelder Inc. (Kleinfelder) at twelve boring locations within a radius of approximately 20 feet of the dry cleaning unit. Soil samples were collected from depths ranging from 2.5 feet to 16.5 feet bgs. During these investigations, PCE was identified as the primary contaminant of concern for the Site. Analytical results indicated the presence of PCE in soil samples collected from each of the borings. PCE concentrations were typically greater at depths ranging from 3 feet to 11 feet bgs and trended to lower concentrations at depths greater than 12 feet. The maximum concentration of PCE detected at the Site was 8.9 milligrams per kilogram (mg/kg) in boring SP-2 at a depth of 7-feet bgs. SP-2 is located approximately 10-feet northeast of the former dry-cleaning unit. Soil samples collected along the perimeter of the investigation area typically contain PCE at concentrations of 1 mg/kg or less. The locations of the borings and the concentrations of PCE detected in soil samples collected during the Kleinfelder investigation are presented on Figure 2, and the soil sample analytical results are presented in tabular form on Tables 2 and 3. No impacts to groundwater were identified during the Webster and Kleinfelder investigations.

To assess the potential release of PCE to the subsurface via the underground floor drain and sewer line, a remote video camera system was used to observe the condition of the underground lines for direct evidence of leakage (i.e., broken lines or corrosion points). The approximate location of the sewer line is shown on Figure 2. The line was inferred to be located at approximately 1.5 bgs. Results of the video investigation indicated the sewer line was constructed of cast iron and was in good condition with no evidence of cracks or leaks.

In October 1999, a Kleinfelder representative met with representatives of Ecology's Toxics Cleanup Program to discuss the subsurface findings and the applicability of MTCA Method A versus Method B Cleanup levels. Ecology requested additional soil and/or groundwater information to determine if shallow groundwater beneath the Site had been impacted. Ecology representatives indicated that if groundwater is not encountered within 15 feet of the greatest depth of soil contamination, an assumption can be made that groundwater has not been affected and the MTCA Method B Soil Cleanup level of 19,600 ug/kg are applicable.

On November 19, 1999, two additional soil borings were completed at the Site to a depth of approximately 30 feet bgs. Fill material was encountered in the upper 8 to 9 feet followed by dense native till. Soil samples were collected at approximate 5 foot intervals throughout the borings, analytical results indicated PCE concentrations ranged from less than 50 ug/kg to 600 ug/kg (below the MTCA Method B Cleanup level). Soil samples collected at the 25 to 30 foot intervals indicated that low PCE concentrations detected in shallow soil decrease to non-detectable concentrations at depths greater than 20 feet bgs. Groundwater was not encountered during drilling except for minor amounts of localized perched water at approximately 8 to 9 feet bgs.

Based on these results, Ecology issued an opinion letter dated February 17, 2000 indicating that they were unable to identify an issue appropriate for review under the VCP. UBOC as Trustee of the Havers Trust viewed the letter as equivalent to an NFA determination.

In September 2000, in accordance with the request of a prospective purchaser of the Site, UBOC as Trustee of the Havers Trust contracted Clayton Group Services, Inc. (Clayton) for the remediation of the shallow PCE-impacted soils to meet the Model Toxics Control Act (MTCA) Method A soil cleanup level of 0.5 mg/kg. Soil vapor extraction wells were installed in the impacted areas identified during the previous investigations. Soil samples collected and submitted for analysis during the installation of soil vapor extraction (SVE) wells confirmed the horizontal extent of PCE-impacted soil identified during previous investigations and the trend towards lower PCE concentrations in soils with increasing depth. The soils in the borings were saturated during drilling below approximately 11 to 12 feet bgs, but no water was standing in the wells after installation. A week following the installation of the SVE wells, shallow perched water was present at approximately 11 to 12 feet bgs in the SVE wells and groundwater samples were collected for PCE analysis. Groundwater sample results indicated that the concentrations of PCE in groundwater were greater than both the MTCA Method A and Method B groundwater cleanup levels. PCE concentrations ranged from less than the laboratory reporting limit in the well located at northeast limit of the groundwater investigation area to a maximum concentration of 4,200 micrograms per liter (μg/L) in the well located in the vicinity of the former dry-cleaning unit. Table 4 presents the analytical results for groundwater samples collected to date.

In January 2001, drilling was conducted to further delineate the extent of PCE-impacted soil and groundwater. The additional investigation confirmed that PCE concentrations in the soil were greatest at the former location of the dry cleaning machine and assumed release point. A reduction of concentrations was also observed in soil samples collected at greater lateral distances from the former dry-cleaning machine. The distribution of PCE-impacted groundwater exhibited the same pattern as in the distribution of PCE-impacted soils (i.e., greater concentrations in samples collected nearest the former dry-cleaning machine, and decreasing concentrations with increasing distance from the former dry-cleaning machine). Depth to groundwater ranged from approximately 11 to 12 feet bgs. There was no clearly defined direction of perched groundwater flow beneath the Site. These results were consistent with the several sites in the vicinity of the Site which have perched zones of groundwater in the subsurface. The perched groundwater results from the presence of a dry silt layer from 20 to 60 feet bgs. The silt layer acts as a confining layer between the perched groundwater and the regional water table which is reported at approximately 50 to 70 feet bgs. The presence of dense glacial till and access limitations prevented attempts to drill to the reported depth of regional groundwater.

Results of the investigations indicate that PCE and TCE impacts in the soils and perched groundwater have been adequately defined laterally and vertically.

2.0 REMEDIATION OBJECTIVES

To facilitate securing the NFA, the UBOC as Trustee of the Havers Trust has entered Ecology's VCP and is seeking formal guidance and input from Ecology during remediation of the Site. The remedial action has been designed to achieve remediation of the soil and groundwater at the Site to cleanup levels that will satisfy Ecology's requirements to issue an NFA opinion letter that contains no restrictions for the Site. The following remedial objectives have been identified for the Site:

- MTCA Method A Soil Cleanup Levels for unrestrictive land use, and;
- MTCA Method B Groundwater Cleanup levels for the perched groundwater.

UBOC as Trustee of the Havers Trust understands that Ecology has adopted changes to the MTCA standards and cleanup levels and that the changes will take effect August 15, 2001. Ecology has elected to implement the revisions six months after adoption in order to develop the guidance necessary for effective use of the new rules. MTCA Method A can be used at sites where all the identified contaminants have established Method A cleanup levels. The existing MTCA Method A soil cleanup level for PCE is 0.5 mg/kg, and the new MTCA Method A soil cleanup level is 0.05 mg/kg. The Ecology Site Manager for the Site has indicated that for sites where the final remedial plan is issued prior to the August 15, 2001 effective date, the existing rules will apply. Because this RAP was finalized prior to August 15, 2000 and the RAP will be implemented immediately after Ecology VCP concurrence with the RAP, the existing MTCA cleanup levels will apply to remediation of the Site.

2.1 Development of Site-Specific Method B Groundwater Cleanup Levels

Site-specific MTCA Method B groundwater cleanup levels were calculated. The following sections describe the methods used to determine appropriate Method B perched groundwater cleanup levels.

2.1.1 Data Evaluation and Identification of Constituents of Concern

Data generated during the investigations conducted from 1999 to the present indicate that the constituents of concern in perched groundwater at the Site are PCE and TCE. As noted above, PCE and TCE in soil will be remediated to MTCA Method A residential soil cleanup levels.

2.1.2 Exposure Assessment

As previously discussed, WAC 173-340-720 (a)(ii) states that groundwater is not a potential future source of drinking water if it is present in insufficient quantity to have a sustainable yield greater than 0.5 gpm. Drawdown tests conducted at the Site indicate the average yield is well below this threshold, and therefore, no apparent beneficial use for the perched groundwater at the Site. The nearest surface water body to the Site is Elliot Bay, located over ¼-mile from the Site, and the perched groundwater is therefore not an apparent threat to surface water bodies. A regional groundwater in the vicinity of the Site occurs at a depth of approximately 50 to 70 feet bgs. The regional groundwater unit in the vicinity of the Site is overlain by approximately 18 feet of dry sandy silt (till) and is believed to be an aquitard between areas of localized perched water and the deeper regional aquifer. Therefore, the shallow, perched water table at the Site is significantly separated from the regional groundwater.

Because perched groundwater has no apparent beneficial use, and is not a threat to regional groundwater or surface water, Method B cleanup levels have been calculated based on the following potential exposure pathways:

- Exposure to PCE and TCE in indoor and outdoor air due to volatilization of PCE and TCE from the perched groundwater. Calculations were made to account for vapor transport from the perched groundwater to indoor and outdoor air. Because groundwater cannot be extracted at a usable yield, the dermal contact and ingestion pathways do not apply to perched groundwater at the Site. Note that the soil will be cleaned up to Method A cleanup levels, and should not result in residual exposure through the indoor and outdoor air pathway.

- Potential future exposure to PCE and TCE during possible future construction at the Site. This pathway is retained for consideration because UBOC as Trustee of the Havers Trust wants no restrictions on future use of the Site. Although renovation is likely at the Site, only the uppermost two feet of soil will be affected during renovation. The groundwater to indoor air calculations described below take this change into account (i.e., a 10-foot thick vadose zone). Because groundwater would continue to have no apparent beneficial use if the Site were to undergo a more intensive re-construction, the only additional potential exposure would be construction worker exposure during de-watering of a deep excavation. The exposure scenario would revert to exposure from the groundwater to indoor air pathway after completion of construction. Note that the soil will be cleaned up to Method A cleanup levels, and would result in no residual exposure to construction workers under this Exposure Assessment.

2.1.3 Calculation of Method B Groundwater Cleanup Levels Protective of Human Health

Site-specific Method B Groundwater cleanup levels were calculated for PCE and TCE for each exposure pathway (i.e., groundwater to outdoor air, groundwater to indoor air, and construction worker). Ecology has not published a guidance for calculating site-specific Method B cleanup levels. Because Ecology has not published a guidance for calculating site specific Method B cleanup levels, the Oregon Department of Environmental Quality (ODEQ) *Risk-Based Decision Making for the Remediation of Petroleum Contaminated Sites* (ODEQ, 1999) was reviewed and used to calculate cleanup levels. The ODEQ guidance is based on, and concisely summarizes, the following technical guidances:

- *Standard Guide for Risk-Based Corrective Action at Petroleum Release Sites* published by the American Society for Testing and Materials (ASTM, 1995b);
- *Soil Screening Guidance: Technical Background Document* (EPA, 1996b); and,
- *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals)* (EPA, 1991a).

To calculate a groundwater cleanup level protective of ambient air, ambient air concentrations were calculated according to the formulas presented in WAC 173-340-750(3)(A) to provide a carcinogenic risk of 1 in 1,000,000 and a hazard quotient (HQ) of 1. The lower of the two numbers calculated using the equations presented in WAC 173-340-750(3)(A) (The 1 in 1,000,000 carcinogenic result was lower for both PCE and TCE) was then selected as the ambient air concentration that would be used to calculate the appropriate perched groundwater cleanup level. These calculations include inputs to address all uses and receptors. These ambient air concentrations were then used to calculate groundwater cleanup levels protective of the indoor air pathway using the Johnson and Ettinger vapor transport model (1991) as provided in the ODEQ guidance. Use of the Johnson and Ettinger transport model (1991) to calculate groundwater levels protective of indoor air is also consistent with the ASTM *Standard Guide for Risk-Based Corrective Action at Petroleum Release Sites.* A similar vapor diffusion model provided in the ODEQ guidance was used to determine a groundwater cleanup level that is protective of the outdoor air exposure pathway.

The ODEQ guidance was also used because it provides a model for calculating a groundwater cleanup level protective of excavation workers, which the ASTM Standard Guide does not. The groundwater cleanup level for protection of excavation workers was calculated using the equations presented in the ODEQ guidance.

Once all the calculations were made, the lowest cleanup level generated by all the pathway calculations was selected for each PCE and TCE as the Method B perched groundwater cleanup level for the Site. These levels are 196 µg/L for PCE for potential exposure to the excavation worker and 247 µg/L for TCE for protection of indoor ambient air. A summary of calculated groundwater cleanup levels is presented in Table 5.

WAC 173-340-708(5)(d) states that the cancer risks resulting from exposure to multiple hazardous substances may be apportioned between hazardous substances in any combination as long as the total excess cancer risk does not exceed 1 in 100,000. Because perched groundwater cleanup levels for TCE and PCE were calculated based on risks of 1 in 1,000,000, the maximum potential risk for the presence of two hazardous substances is 2 in 1,000,000 when the perched groundwater cleanup levels are achieved. Therefore, the excess risk of these compounds at the calculated cleanup levels would be well below the 1 in 100,000 threshold set by MTCA Method B.

WAC 173-340-708(6)(d) states that that the cancer risks resulting from exposure via multiple exposure pathways may be apportioned between hazardous substances in any combination as long as the total excess cancer risk does not exceed 1 in 100,000. However, because the excavation worker exposure pathway is not additive with the indoor air exposure pathway (i.e., it is extremely unlikely that the person that comes in contact with contaminated groundwater during construction will also choose to live in the same building), the additive effect of multiple pathways should not be of concern. In addition, indoor and outdoor air pathway calculation resulted in cleanup levels that were two and 100 times greater than the excavation worker cleanup levels, respectively. Therefore, excess cancer risk resulting from the indoor and outdoor exposure pathways after cleanup to the perched groundwater cleanup levels calculated for the excavation worker will likely be well below 1 in 1,000,000.

The calculations performed to determine the Method B perched groundwater cleanup levels for PCE and TCE are presented in Appendix B, and the groundwater levels protective for each migration pathway are presented in Table 5.

3.0 REMEDIAL APPROACH

Based on the available Site information, the remediation method most likely to effectively remediate the soil and groundwater at the Site is dual phase vacuum extraction (DPVE). Based on SECOR's experience with remediation of PCE-impacted sites, DPVE has been highly effective in removing VOCs including PCE and trichloroethylene (TCE), which is also present at the Site at lesser concentrations, in low to medium permeability environments. Removal of volatile contaminants through the extraction of soil vapor is one of the most effective techniques to remediate PCE impacted sites. This is primarily due to the volatility of PCE and the relatively high rate of transport that can be achieved in the vapor phase. By extracting groundwater in conjunction with the soil vapor, the PCE remaining in the dewatered soils will volatilize and be removed with the extracted vapor, greatly increasing the overall removal rates. By applying a high vacuum, the flow rates of air and water will induce the transfer of VOCs into the vapor phase.

The applicability of DPVE at the Site is dependent on the recharge rate of the perched groundwater, because DPVE is more efficient in the vadose zone. A slow recharge rate is optimal because it causes the water table to drop, which exposes soil to a greater vacuum and increases the efficiency of the remediation. Should the perched groundwater recharge at a high rate, groundwater pumping will be required to continually expose and more effectively remove VOCs from the vadose zone.

The remedial action planned is designed to achieve cleanup of soil and groundwater to targeted levels within eighteen months of start-up of the system. The scope of work and implementation schedule to complete the Site remediation is presented in the following subsections.

3.1 Pre-Remediation Planning and Data Collection

Prior to implementation of the remediation system, a detailed Site reconnaissance and a thorough review of additional Site-specific information will be conducted. Also included in this phase will be a groundwater monitoring and sampling event to provide baseline information on groundwater quality. In addition, a groundwater response test (drawdown test) has been completed to provide an estimate of anticipated groundwater recharge rates during system operation.

A Site-specific health and safety plan to cover all anticipated phases of work will be prepared.

3.2 Permitting and Waste Streams

The remediation system will generate two waste streams; air and water. Regulatory agency permits will be required for each waste stream. An air permit will be required from the Puget Sound Clean Air Agency (PSCAA). PSCAA is the lead regulatory agency for air discharge permitting. An air permit application was previously submitted for this Site. The remaining permit requirements include filing a Notice of Construction (NOC) permit modification to proceed with system installation and start-up. The entire process, from application to approval, is anticipated to take three to four weeks.

Disposal of treated groundwater to sanitary sewer will require a permit from King County METRO (METRO). It is anticipated that a METRO Discharge Authorization for less than 25,000 gallons per day will be adequate for this Site. According to METRO representatives and King County Code – Title 28, the permitting process includes submittal of a fully completed application packet, posting the public notice portion of the permit application in the newspaper, issuing a draft permit for regulatory agency and public review, and, upon approval, issuance of a final permit. This process is estimated to take 30 to 45 days to complete.

A City of Seattle electrical work permit will be required for the installation of the electrical components of the remedial system. This work will be performed by a state-licensed electrician, who will be required to obtain the necessary permit.

Based on the temporary nature of the system configuration and SECOR's experience with installation of these types of systems, it is anticipated that a City of Seattle construction permit will not be required.

3.3 Installation and Start-up of Remediation System

The remediation system will be configured to include extraction from all wells. Higher extraction rates will be focused on areas exceeding cleanup levels. During the start-up phase, SECOR will monitor surrounding well points and system extraction rates to determine the radius of influence and removal efficiency of the system. The results will allow SECOR to refine the configuration of the system to effectively treat areas containing the highest contaminant concentrations. Depending on the groundwater recharge rate, groundwater pumping may required to supplement vapor phase extraction.

The DPVE system will be situated in the former location of the dry cleaning facility. Above ground PVC piping will connect all wells in the former location of the dry cleaning facility and the bookstore to the DPVE extraction system. Should the perched groundwater recharge at a low rate, groundwater removal may be more effective by focusing extraction from a subset of the wells containing groundwater recharging at a higher rate. Given a low overall recharge rate, the system will extract primarily vapors with a focused higher vacuum on the higher groundwater producing wells. Higher volume extraction will be achieved at selected well points through the use of portable equipment such as suction pumps, venturis and downhole DC pumps. A schematic diagram of the system design is shown in Figure 5.

During start-up and regular operation of the system, recovered vapors will be treated by activated carbon and discharged under permit to the atmosphere. Groundwater recovered will be treated using the existing system and will be discharged under permit to the sanitary sewer.

Given that the system will be located inside a walled area, noise control for the system is not currently anticipated. Should noise control be required, sound proofing consisting of an insulated enclosure surrounding the blowers will be constructed.

3.4 Operation of Remediation System

Data from monthly monitoring of the soil vapor extraction system off-gasses and quarterly monitoring of the groundwater wells will be used to optimize the operation of the system and to assess the effectiveness of the system in reaching the Site cleanup goals. It is assumed, based on a SECOR's experience with similar projects, that approximately eighteen months will be required to achieve remediation targets.

3.5 Groundwater Monitoring and Sampling During System Operation

SECOR will conduct groundwater monitoring and sampling events on a quarterly basis following start-up of the remediation system. Prior to sample collection, the remediation system will be shut down for approximately one week to allow groundwater levels to recover so that sufficient water is available for sampling. One set of groundwater elevation measurements will be collected while the system is operating. Another set of groundwater elevation measurements will be collected while the system is off. This data may be helpful in determining areas of recharge to the perched water table.

Groundwater samples will be collected using a peristaltic pump, and will be placed into 40 milliliter vials preserved with hydrochloric acid and submitted to On-Site Environmental, Inc. (OSE) of Redmond, Washington for analysis of PCE and TCE using EPA Method 8260.

Based on the anticipated period of operation of the system (eighteen months), a minimum of six quarterly groundwater monitoring/sampling events will be conducted. It is understood that perched groundwater at the Site will be considered remediated following two consecutive sampling events indicating that PCE concentrations are below the MTCA Method B Cleanup Levels.

3.6 Follow-up Soil Sampling and Closure Report Preparation

Following the completion of the perched groundwater remediation, SECOR will complete confirmation soil sampling by drilling borings in the impacted areas and submitting soil samples from those borings for analysis. Results of soil sampling will be used to document the performance of the remediation efforts. Due to access restrictions, all soil sampling will be performed using a hand-operated direct push technology. Soil samples will be collected at 5-foot intervals during drilling and will be field-screened for indications of contamination. All of the soil samples will be screened for volatile organic vapors using a photoionization detector (PID), checked for visual and olfactory evidence of contamination, and logged according to the United Soil Classification System (USCS).

Following confirmation of the successful completion of remediation, the system will be shut down and all existing wells will be decommissioned as required by State of Washington regulations. SECOR will document all the remediation activities and the follow-up sampling results in a report for submittal to the Ecology under the VCP with a request for an NFA finding with no restrictions.

4.0 ESTIMATED PROJECT SCHEDULE

SECOR proposes the following schedule to remediation and close the Site:

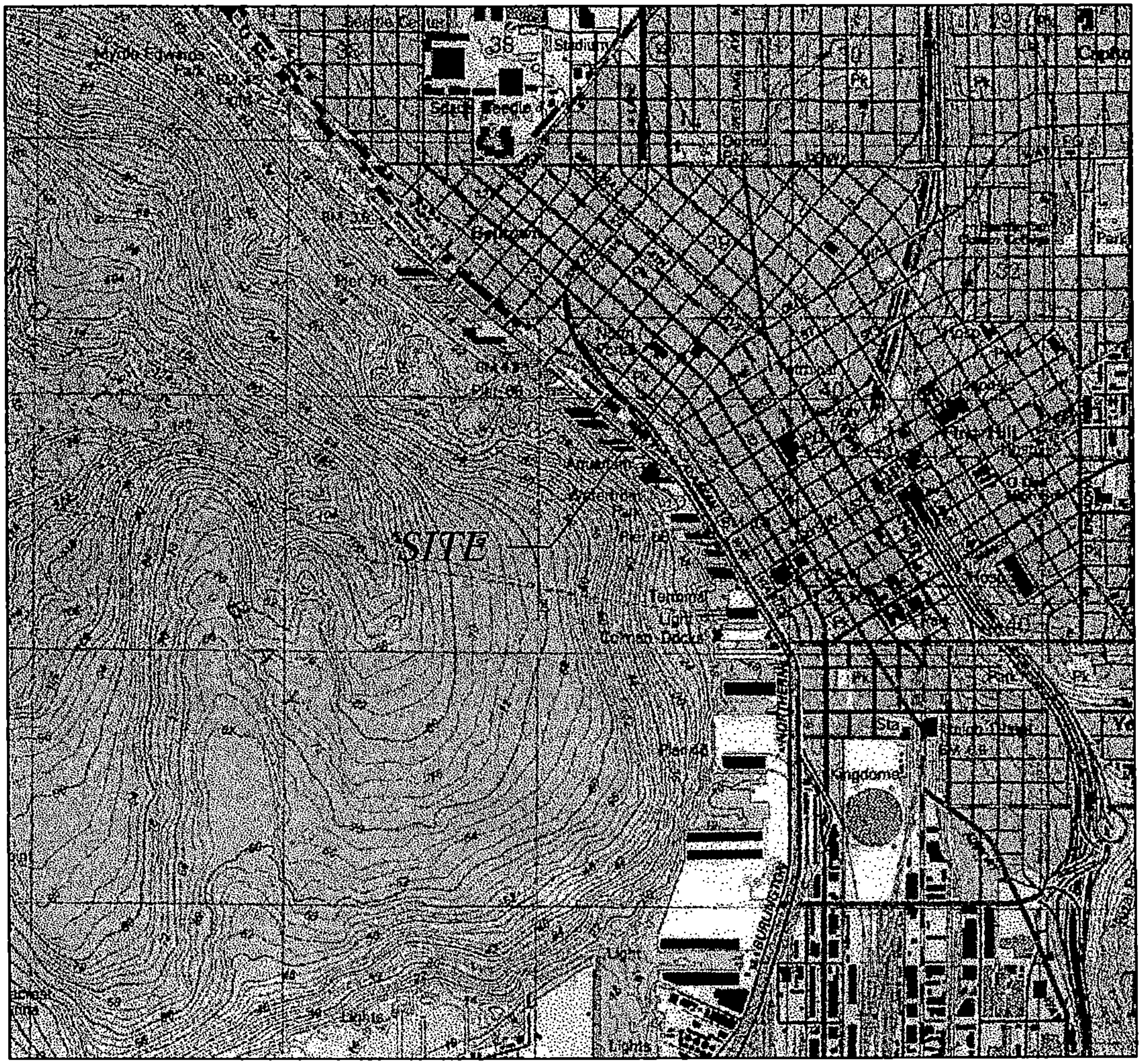
Task	Estimated Date
Submit RAP to Ecology	July 2001
Installation and Start-up of System	August 2001 (Following Permit Approvals and Ecology Review)
Operation of Remediation System	September 2001 - February 2003 (18 months)
Initiate Closure Monitoring	September 2002
Follow-up Soil Sampling	February 2003 – March 2003
Final Report to Ecology	April 2003
Decommission Wells/Dismantle System	May 2003 to July 2003

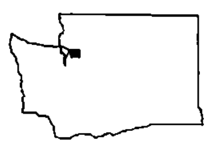
The above schedule is an estimate only and is based on 18 months of system operation to remediate the Site. Project initiation will follow permit approvals and Ecology's review of the RAP. The estimated time required to remediate the Site may be less than 18 months if analytical results indicate that remediation is occurring at a rate greater than anticipated.

5.0 CLOSURE

The discussion contained in this RAP represents our professional opinion. These opinions are based on currently available information and are arrived at in accordance with currently accepted hydrogeologic and engineering practices at this time and location. Other than this, no warranty is implied or intended.

FIGURES





North

0 1/2 1

SCALE (METRIC)

REFERENCE: USGS 7.5x15 MINUTE QUADRANGLE; SEATTLE SOUTH, WASHINGTON; 1983

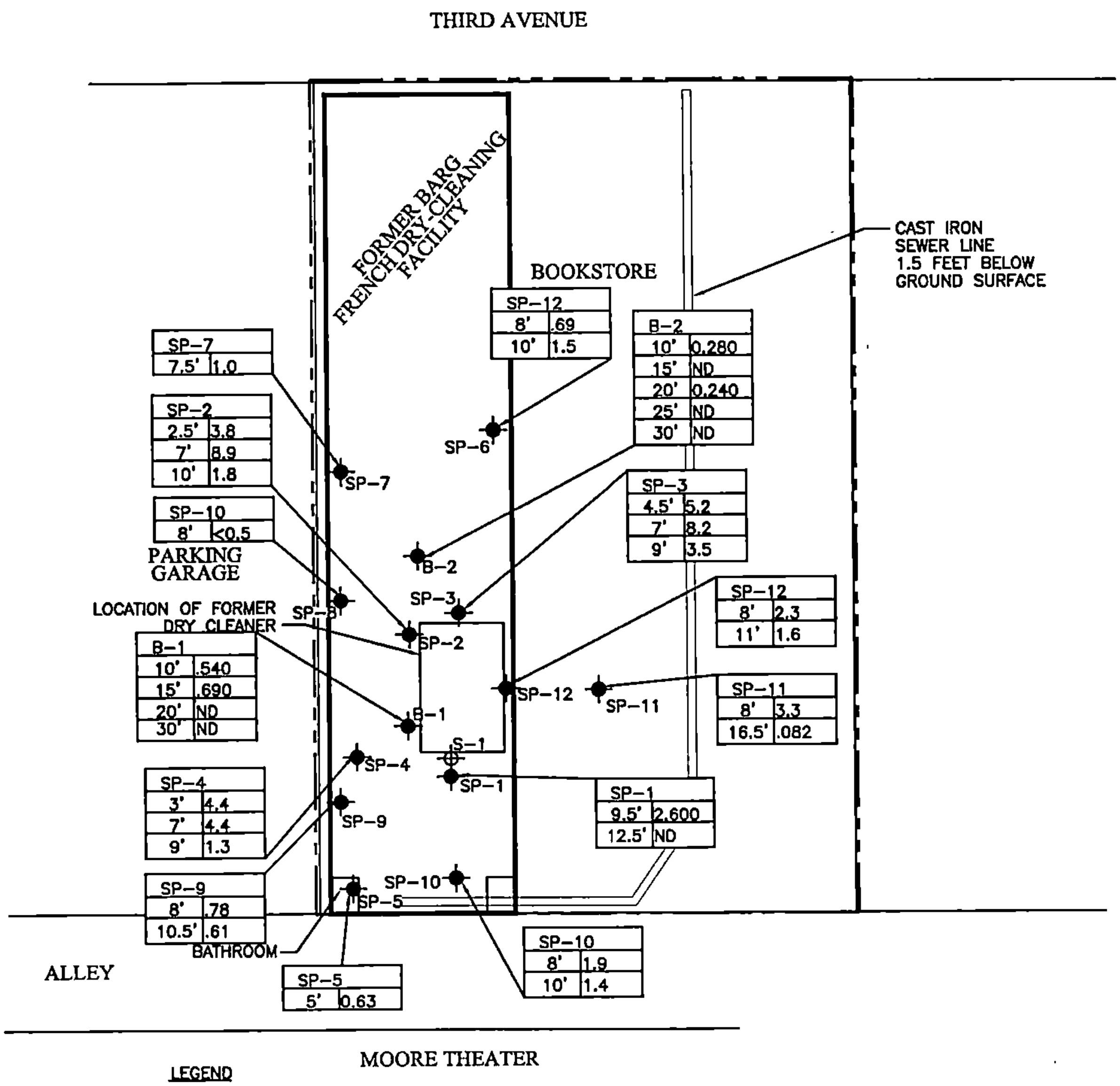
SECOR
International Incorporated
12034 134th COURT NE, SUITE 102
REDMOND, WASHINGTON 98052
(425) 372-1600

SITE LOCATION MAP

FORMER BARG FRENCH DRY CLEANING FACILITY
1929 THIRD AVENUE
SEATTLE, WASHINGTON

FIGURE: 1

JOB#: 001.01214.001 APPR: DWN: SES DATE: 5/22/01



LEGEND

— — — — SITE BOUNDARY

APPROXIMATE SOIL BORING LOCATION (KLEINEFELDER, INC.)

APPROXIMATE SOIL BORING LOCATION (WEBSTER, INC.)

1.4 PCE CONCENTRATIONS IN mg/kg

ANALYTICAL RESULTS BOX

WELL I.D.	
DEPTH	RESULT

SAMPLE COLLECTION DATES

6/1999 = S-1 COLLECTED BY WEBSTER, INC.

8/1999 = SP-1, SP-2, SP-3, SP-4, & SP-5 COLLECTED BY KLEINFELDER, INC.

9/1999 = SP-6, SP-7, SP-8, SP-9, SP-10, SP-11, & SP12 COLLECTED BY KLEIFELDER, INC.

11/1999 = B-1, B-2 COLLECTED BY KLEINFELDER INC.

NOTE:

1. ALL SAMPLES COLLECTED BY KLEINFELDER, INC. & WEBSTER, INC.

SOURCE: BASE MAP FROM CLAYTON ENVIRONMENTAL SERVICES, NAMED FIGURE 2, SITE PLAN.

North

0 20 40

SCALE (FEET)

SECOR
International Incorporated
12034 134th COURT NE, SUITE 102
REDMOND, WASHINGTON 98052
(425) 372-1600

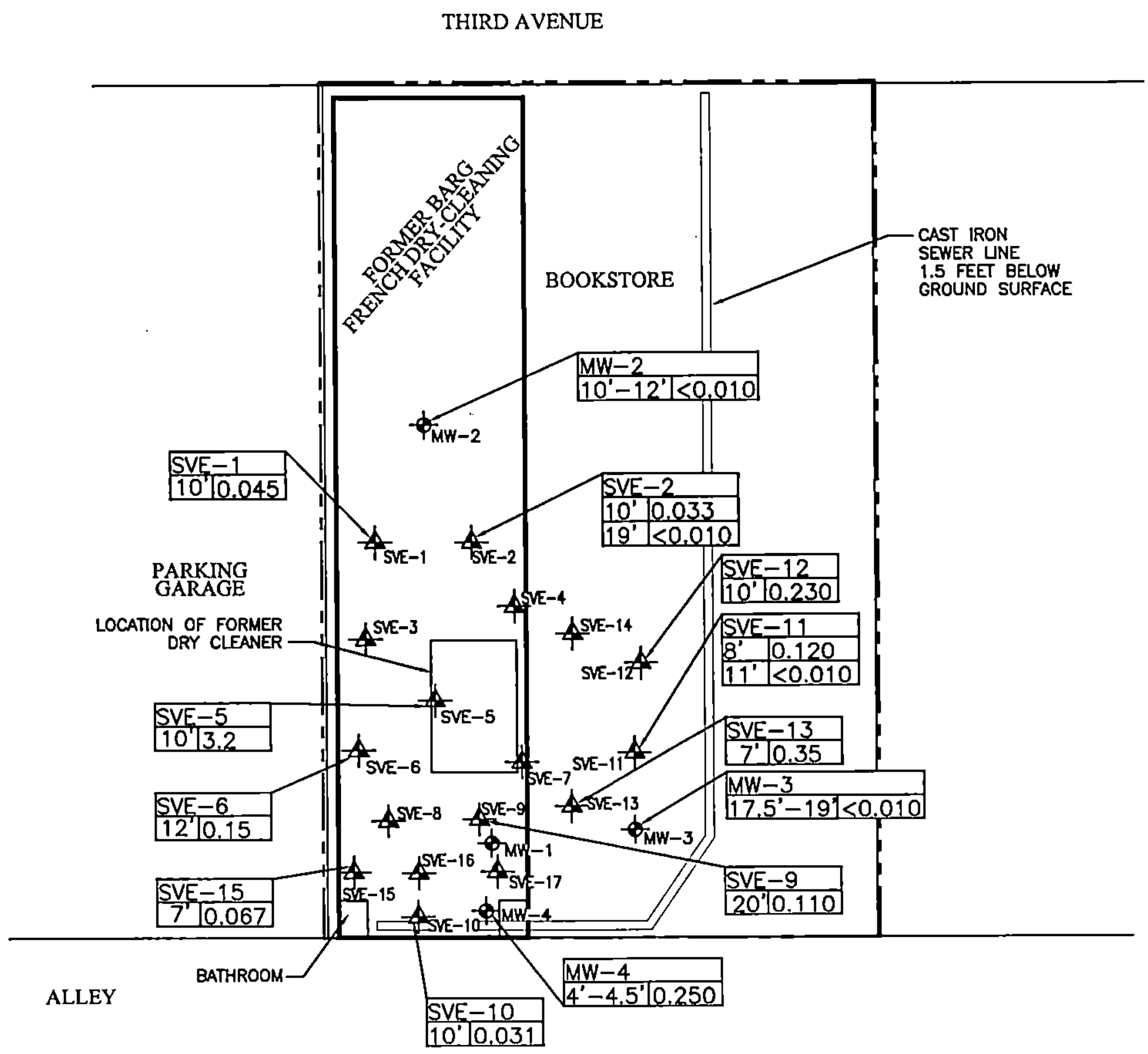
SITE PLAN WITH SOIL SAMPLE LOCATIONS WITH ANALYTICAL RESULTS (JUNE 1999-NOV. 1999)
FORMER BARG FRENCH DRY CLEANING FACILITY
1929 THIRD AVENUE
SEATTLE, WASHINGTON

FIGURE: 2

JOB#: 001.01214.001 APPR: DWN: SES DATE: 5/21/01

(001)R:CAD\CAD_FILES\PROJECTS\OFFICE\001\01214\001\01012141.DWG-FIGURE 3 TAB

DWG: 01012141



LEGEND

— — — — SITE BOUNDARY

MW-4 GROUNDWATER MONITORING WELL LOCATION

SVE-14 SOIL VAPOR EXTRACTION POINT

0.035 PCE CONCENTRATIONS IN mg/kg

ANALYTICAL RESULTS BOX

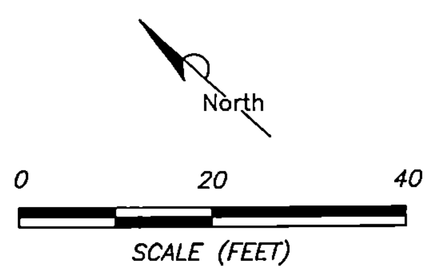
WELL I.D.	
DEPTH	RESULT

SAMPLE COLLECTION DATES

09/13/00 = SVE-1, SVE-2, SVE-5, SVE-10, SVE-11, SVE-12, & SVE -13

09/14/00 = SVE-6, & SVE-15

01/19/01 = MW-2, MW-3, & MW-4



NOTE:

1. ALL SAMPLES COLLECTED BY CLAYTON ENVIRONMENTAL SERVICES.

SOURCE: BASE MAP FROM CLAYTON ENVIRONMENTAL SERVICES, NAMED FIGURE 2, SITE PLAN.

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REDMOND, WASHINGTON 98052
(425) 372-1600

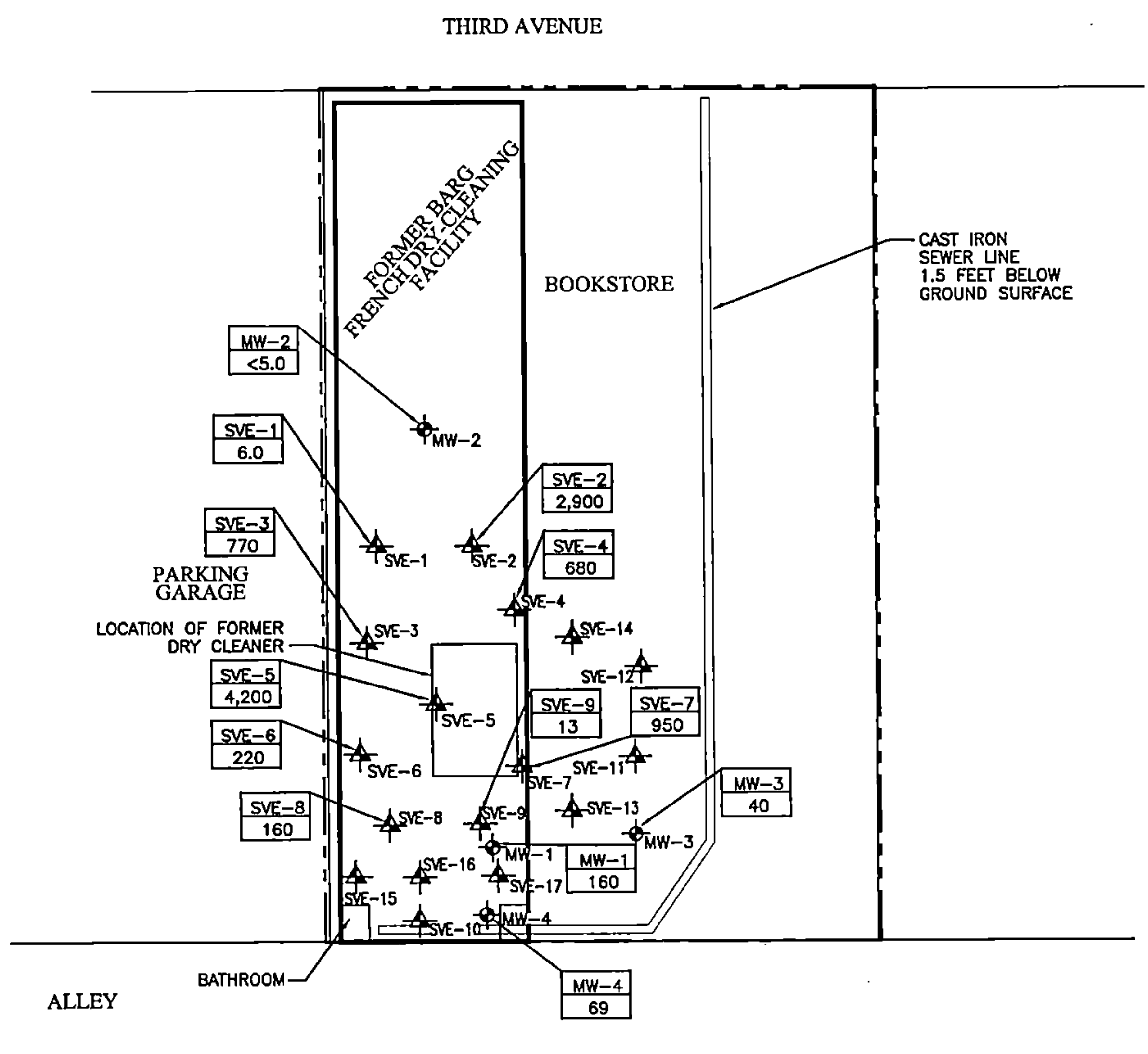
SITE PLAN SOIL SAMPLE LOCATIONS WITH ANALYTICAL RESULTS PCE (SEPT. 2000 & JAN. 2001)
FORMER BARG FRENCH DRY CLEANING FACILITY
1929 THIRD AVENUE
SEATTLE, WASHINGTON

FIGURE: *3*

JOB#: 001.01214.001 *APPR:* *DWN: SES* *DATE: 5/21/01*

(001)R:CAD\CAD_FILES\PROJECTS\OFFICE\001\01214\001\01012141.DWG-FIGURE 3 TAB

DWG: 01012141



LEGEND

— — — — SITE BOUNDARY

MW-4 GROUNDWATER MONITORING WELL LOCATION

SVE-14 SOIL VAPOR EXTRACTION POINT

2,900 PCE CONCENTRATION IN GROUNDWATER (µg/l)

SAMPLE COLLECTION DATES

09/19/00 = SVE-1, SVE-4, SVE-5, SVE-6, SVE-7, & SVE-9

01/24/00 = MW-1, MW-2, MW-3, MW-4, SVE-2, SVE-3, SVE-8

ANALYTICAL RESULTS BOX

WELL I.D.
RESULT

North

0 20 40

SCALE (FEET)

NOTE:

1. ALL SAMPLES COLLECTED BY CLAYTON ENVIRONMENTAL SERVICES.

SOURCE: BASE MAP FROM CLAYTON ENVIRONMENTAL SERVICES, NAMED FIGURE 2, SITE PLAN.

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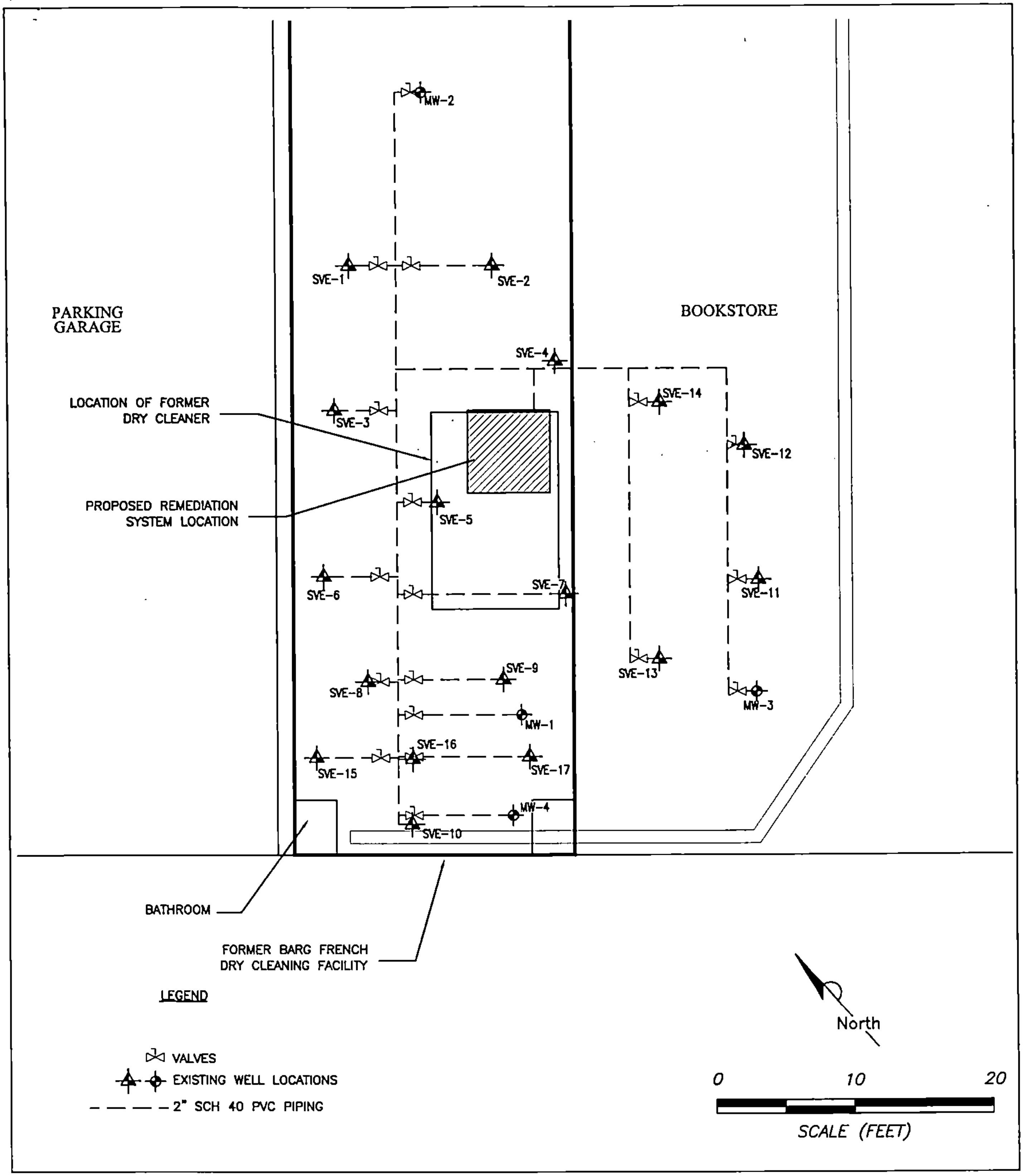
SITE PLAN WITH GROUNDWATER ANALYTICAL RESULTS - PCE (SEPT. 2000 & JAN. 2001)
FORMER BARG FRENCH DRY CLEANING FACILITY
1929 THIRD AVENUE
SEATTLE, WASHINGTON

FIGURE: 4

JOB#: 001.01214.001 APPR: DWN: SES DATE: 5/21/01

(001)R:CAD\CAD_FILES\PROJECTS\OFFICE\001\01214\001\01012141.DWG--FIGURE 3 TAB

DWG: 01012141



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CONCEPTUAL PIPING LAYOUT FOR DUAL PHASE EXTRACTION SYSTEM
FORMER BARG FRENCH FACILITY
1929 THIRD AVENUE
SEATTLE, WASHINGTON

FIGURE: 5

JOB#: 001.01214.001 APPR: [signature] DWN: SES DATE: 7/27/01

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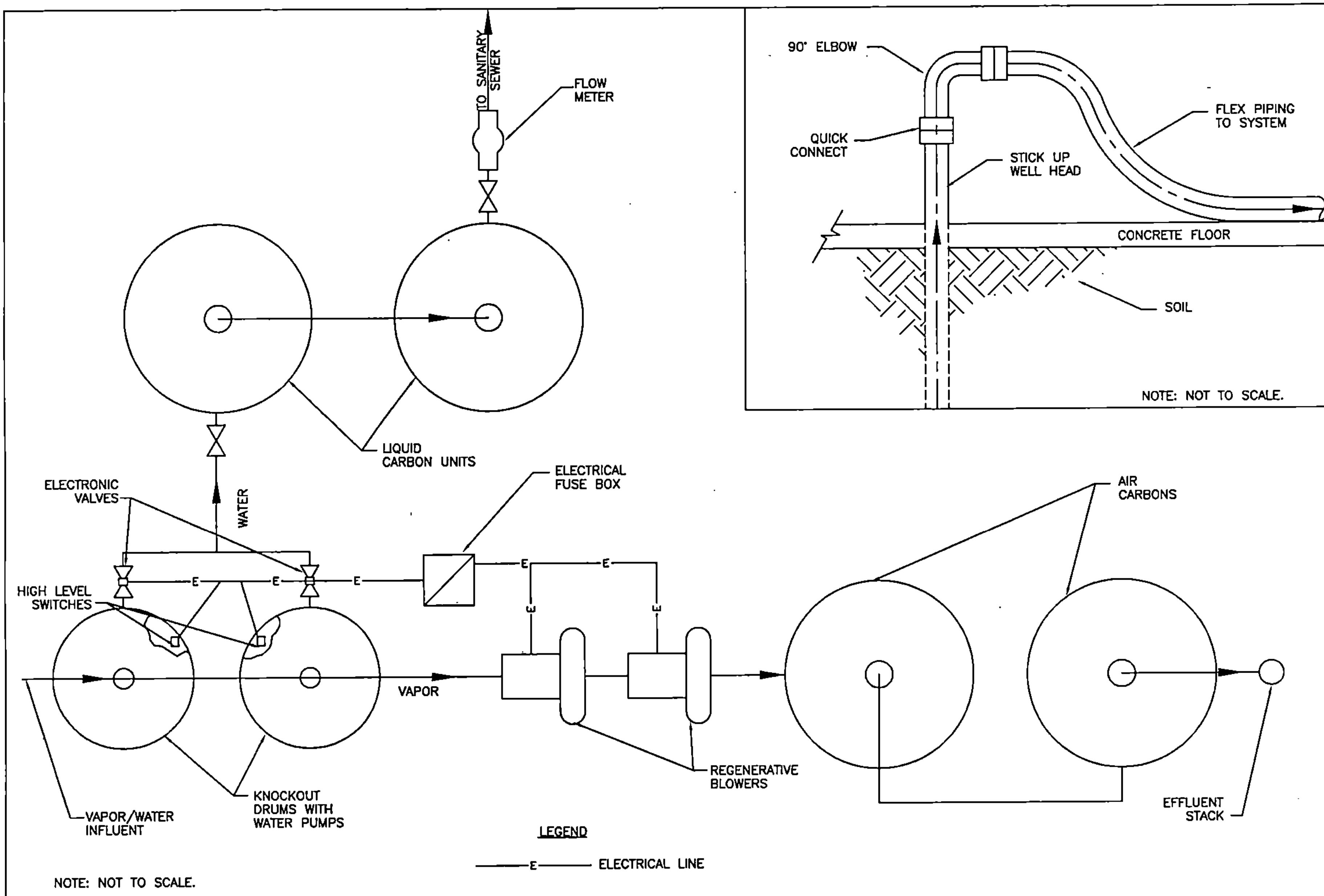

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CONCEPTUAL REMEDIATION SYSTEM LAYOUT

FORMER BARG FRENCH FACILITY
1929 THIRD AVENUE
SEATTLE, WASHINGTON

FIGURE: 6

JOB#: 001.01214.001 APPR: DWN: SES DATE: 7/27/01

(001)R:CAD\CAD_FILES\PROJECTS\OFFICE\001\01214\001\SYSTEM\01012141SYS.DWG

DWG: 01012141SYS

TABLES

Table 1. Cumulative Summary of Groundwater Elevations
Former Location of Barg French Dry Cleaning Facility
1929 3rd Avenue, Seattle, Washington

Well Number/ TOC Elevation	Casing Height AGS	Date of Measurement	DTW (feet btoc)	DTW (feet bgs)	Total Depth (feet bgs)	SWL (feet)	Change in SWL (feet)
SVE-1 109.59	2.48	9/19/00 1/24/01	14.21 14.19	11.73 11.71	20	95.38 95.40	– 0.02
SVE-2 109.34	2.16	9/19/00 1/24/01	13.98 13.91	11.82 11.75	20	95.36 95.43	– 0.07
SVE-3 109.27	2.09	9/19/00 1/24/01	13.90 13.85	11.81 11.76	17	95.37 95.42	– 0.05
SVE-4 109.34	2.10	9/19/00 1/24/01	13.94 13.88	11.84 11.78	15	95.40 95.46	– 0.06
SVE-5 108.50	1.30	9/19/00 1/24/01	13.08 13.08	11.78 11.78	17	95.42 95.42	– 0.00
SVE-6 109.31	2.18	9/19/00 1/24/01	13.89 13.92	11.71 11.74	18	95.42 95.39	– -0.03

Table 1. Cumulative Summary of Groundwater Elevations
Former Location of Barg French Dry Cleaning Facility
1929 3rd Avenue, Seattle, Washington

Well Number/ TOC Elevation	Casing Height AGS	Date of Measurement	DTW (feet btoc)	DTW (feet bgs)	Total Depth (feet bgs)	SWL (feet)	Change in SWL (feet)
SVE-7 109.90	2.72	9/19/00 1/24/01	14.58 14.51	11.86 11.79	19.5	95.32 95.39	– 0.07
SVE-8 109.11	1.93	9/19/00 1/24/01	14.06 13.42	12.13 11.49	15	95.05 95.69	– 0.64
SVE-9 109.67	2.42	9/19/00 1/24/01	14.51 14.31	12.09 11.89	19	95.16 95.36	– 0.20
SVE-10	N/A	9/19/00 1/24/01	–	–	10	– –	– –
SVE-11	N/A	9/19/00 1/24/01	–	–	10	– –	– –
SVE-12	N/A	9/19/00 1/24/01	–	–	10	– –	– –

Table 1. Cumulative Summary of Groundwater Elevations
Former Location of Barg French Dry Cleaning Facility
1929 3rd Avenue, Seattle, Washington

Well Number/ TOC Elevation	Casing Height AGS	Date of Measurement	DTW (feet btoc)	DTW (feet bgs)	Total Depth (feet bgs)	SWL (feet)	Change in SWL (feet)
SVE-13	N/A	9/19/00	–	–	10	–	–
		1/24/01				–	–
SVE-14	N/A	9/19/00	–	–	10	–	–
		1/24/01				–	–
SVE-15	N/A	9/19/00	–	–	12	–	–
		1/24/01				–	–
SVE-16	N/A	9/19/00	–	–	10	–	–
		1/24/01				–	–
SVE-17	N/A	9/19/00	–	–	10	–	–
		1/24/01				–	–
MW-1 107.90	0.70	9/19/00	–	–	14	–	–
		1/24/01	12.63	11.93		95.27	–

Table 1. Cumulative Summary of Groundwater Elevations
Former Location of Barg French Dry Cleaning Facility
1929 3rd Avenue, Seattle, Washington

Well Number/ TOC Elevation	Casing Height AGS	Date of Measurement	DTW (feet btoc)	DTW (feet bgs)	Total Depth (feet bgs)	SWL (feet)	Change in SWL (feet)
MW-2 109.08	1.89	9/19/00	–	–	17.5	–	–
		1/24/01	14.28	12.39		94.80	–
MW-3	1.89	9/19/00	–	–	20.5	–	–
		1/24/01	13.60	11.71		–	–
MW-4 110.00	2.95	9/19/00	–	–	17	–	–
		1/24/01	14.15	11.20		95.85	–

All Measurements as reported in February 27, 2001, report by Clayton Group Services Inc. (Clayton)
NOTES:
AGS = Above Ground Surface (feet)
TOC = Top of casing (feet)
DTW = Depth to water.
btoc = Below top of casing
bgs = below ground surface
SWL = Static water level.
– = Not monitored.
bgs = below ground surface
N/A - Not applicable

Table 2. Summary of Soil Sampling Analytical Results
June 1999 to November 1999
Barg French Dry Cleaners
1929 3rd Avenue, Seattle, WA

Sample Identification	Sample Date	Depth of Sample (feet)	PID Reading (ppm)	PCE (mg/kg)
S-1	Jun-99	9.5	NA	2.6
		12.5	NA	ND
SP-1	Aug-99	9.5	ND	2.6
		12.5	ND	<0.05
SP-2	Aug-99	2.5	ND	3.8
		7	500	8.9
		10	TRACE	1.8
SP-3	Aug-99	4.5	ND	5.2
		9	ND	3.5
SP-4	Aug-99	3	300	4.4
		7	80.000	4.4
		9	ND	1.3
SP-5	Aug-99	5	ND	0.6
SP-6	Sep-99	8	200	0.7
		10	ND	1.5
SP-7	Sep-99	7.5	36	1.0
SP-8	Sep-99	8	15	<0.05
SP-9	Sep-99	8	38	0.8
SP-10	Sep-99	8	10	1.9
		10	6	1.4
SP-11	Sep-99	8	80	3.3
		16.5	ND	0.1
SP-12	Sep-99	8	97	2.3
		11	ND	1.6
B-1-1	Nov-99	5	56	NA
B-1-2	Nov-99	10	45	0.5
B-1-3	Nov-99	15	47	0.7
B-1-4	Nov-99	20	ND	<0.05
B-1-5	Nov-99	25	NA	NA
B-1-6	Nov-99	30	ND	<0.05
B-2-1	Nov-99	5	5	NA
B-2-2	Nov-99	10	7	0.3
B-2-3	Nov-99	15	3	<0.05
B-2-4	Nov-99	20	ND	0.2

Table 2. Summary of Soil Sampling Analytical Results
June 1999 to November 1999
Barg French Dry Cleaners
1929 3rd Avenue, Seattle, WA

Sample Identification	Sample Date	Depth of Sample (feet)	PID Reading (ppm)	PCE (mg/kg)
B-2-5	Nov-99	25	ND	<0.05
B-2-6	Nov-99	30	ND	<0.05

All Measurements as reported in December 20, 2000, report by Clayton Group Services Inc. (Clayton)

NOTES:

PID = Photoionization detector

ppm = parts per million

PCE = Perchloroethylene (aka tetrachloroethylene)

mg/kg = milligrams per kilogram

NA = Not applicable/Not performed

ND = Not Detected

Table 3. Summary of Soil Sampling Analytical Results
September 2000 to January 2001
Barg French Dry Cleaners
1929 3rd Avenue, Seattle, WA

Sample Point	Sample Date	Sample Identification	Depth of Sample (feet)	Trichloroethene (mg/kg)	Tetrachloroethylene (mg/kg)	Methylene Chloride (mg/kg)
SVE-1	9/12/00	VP1-091200-S1	10	<0.010	0.045	<0.050
SVE-2	9/12/00	VP2-091200-S1	10	<0.010	0.033	<0.050
	9/12/00	VP2-091200-S2	19	<0.010	<0.010	<0.050
SVE-5	9/12/00	VP5-091200-S1	10	<0.010	3.2	<0.050
SVE-6	9/13/00	VP6-091300-S1	12	<0.010	0.150	<0.020
SVE-9	9/14/00	VP9-091400-S1	20	<0.010	0.110	0.06*
SVE-10	9/12/00	VP10-091200-S1	10	<0.010	0.031	<0.050
SVE-11	9/12/00	VP11-091200-S1	8	<0.010	0.120	0.07*
	9/12/00	VP11-091200-S2	11	<0.010	<0.010	0.025*
SVE-12	9/12/00	VP12-091200-S1	10	<0.010	0.230	0.02*
SVE-13	9/12/00	VP13-091200-S1	7	<0.010	0.035	<0.020

Table 3. Summary of Soil Sampling Analytical Results
September 2000 to January 2001
Barg French Dry Cleaners
1929 3rd Avenue, Seattle, WA

Sample Point	Sample Date	Sample Identification	Depth of Sample (feet)	Trichloroethene (mg/kg)	Tetrachloroethylene (mg/kg)	Methylene Chloride (mg/kg)
SVE-15	9/13/00	VP15-091300-S1	7	<0.010	0.067	<0.020
MW-2	1/19/01	011901-S1	10 to 12	<0.010	<0.010	0.042*
MW-3	1/19/01	011901-S2	17.5 to 19	<0.010	<0.010	0.032*
MW-4	1/19/01	011901-S3	4 to 4.5	<0.010	0.250	<0.020

All Measurements as reported in February 27, 2001, report by Clayton Group Services Inc. (Clayton)

NOTES:

SVE = Soil Vapor Extraction Point

MW = Monitoring Well

mg/kg = Milligrams per kilogram

* = result likely due to laboratory contamination (as per Clayton report)

**Table 4. Summary of Groundwater Sampling Analytical Results
Former Location of Barg French Dry Cleaning Facility
1929 3rd Avenue, Seattle, WA**

Sample Point	Sample Date	Trichloroethene (µg/l)	Tetrachloroethylene (µg/l)	Methylene Chloride (µg/l)
SVE-1	9/19/00	<5	6	<5
SVE-2	1/24/01	20	2,900	<5
SVE-3	1/24/01	<5	770	<5
SVE-4	9/19/00	29	680	<5
SVE-5	9/19/00	5	4,200	<5
SVE-6	9/19/00	<5	220	<5
SVE-7	9/19/00	<5	950	<5
SVE-8	1/24/01	<5	160	<5
SVE-9	9/19/00	<5	13	<5

Table 4. Summary of Groundwater Sampling Analytical Results
Former Location of Barg French Dry Cleaning Facility
1929 3rd Avenue, Seattle, WA

Sample Point	Sample Date	Trichloroethene (µg/l)	Tetrachloroethylene (µg/l)	Methylene Chloride (µg/l)
MW-1	1/24/01	<5	160	<5
MW-2	1/24/01	<5	<5	<5
MW-3	1/24/01	<5	40	<5
MW-4	1/24/01	<5	69	<5

All Measurements as reported in February 27, 2001, report by Clayton Group Services Inc. (Clayton)
NOTES:
SVE = Soil Vapor Extraction Point
MW = Monitoring Well
µg/L = Micrograms per liter; approximate parts per billion.
– = Not sampled or not analyzed.

Table 5. Summary of Calculated Groundwater Cleanup Levels (mg/L)

Protection Type	Perchloroethylene (PCE)	Trichloroethylene (TCE)
Protective of Indoor Ambient Air (RBC_{wi})	0.485	0.247
Protective of Outdoor Air (RBC_{wo})	19.469	9.468
Protective of Excavation Workers (RBC_{const})	0.196	1.277

Notes:

-All equations presented in Appendix B

- RBC_{wi}: Risk-Based Calculation for the groundwater to indoor air pathway protective of indoor air (mg/L)
- RBC_{wo}: Risk-Based Calculation for the groundwater to outdoor air pathway protective of outdoor air (mg/L)
- RBC_{const}: Risk-Based Calculation protective of excavation workers (mg/L) for dermal contact and inhalation pathways

-Ambient air concentrations were calculatated according to formulas presented in WAC 173-340-750(3)(A) to provide a carcinogenic risk of 1 in 1,000,000 and a hazard quotient of 1 to be used to calculate groundwater Cleanup Levels

-The calculated ambient air concentrations were then used to calculate groundwater clean-up levels protective of indoor and outdoor air using the Johnson and Ettinger vapor transport model (1991) and the Oregon Department of Environmental Quality (ODEQ) model for protection of excavation workers. These models are provided in *Risk-Based Decision Making for the Remediation of Petroleum Contaminated Sites* (ODEQ, 1999)

- All inputs selected from default ODEQ Exposure Factors with the exception of Foundation Crack Fraction (Default = 0.0010, adjusted to 0.010 to account for actual floor condition) and Indoor Air Mixing Zone (Default = 200 cm, adjusted to 400 cm to accurately reflect actual mixing zone)

APPENDIX A

REPORTS REVIEWED

SUMMARY OF REPORTS REVIEWED BY SECOR

Reviewed by SECOR at Washington Department of Ecology (Ecology) on February 28, 2001

Phase I; Limited Phase II; Asbestos Report
Websters, Inc. – 6/1/99

Final Report – Environmental Assessment and Phase II Soil and Shallow Groundwater Characterization; Kleinfelder, Inc. – 9/7/99

Final Report Addendum Phase II Subsurface Soil Characterization Havers Trust
Kleinfelder, Inc. – 11/2/99

Additional Phase II Subsurface Soil Characterization
Kleinfelder, Inc. – 12/20/99

Additional Depth to Water Information
Kleinfelder, Inc. – 2/10/00

Report of Soil and Groundwater Sampling Results
Clayton Group Services, Inc.– 11/14/00

Not Available at Time of SECOR File Review

Remediation Alternatives
Clayton Group Services, Inc. – 10/13/00

Radius Map with Geocheck
Environmental Data Resources, inc. (EDR) – 10/19/00

Ecology File Review
Clayton Group Services, Inc.– 11/10/00

Report of Monitoring Well Installations and Soil and Groundwater Sampling Results
Clayton Group Services, Inc. 2/27/01

APPENDIX B

METHOD B LIST OF EQUATIONS AND VARIABLE INPUTS

LIST OF EQUATIONS
Former Barg-French Drycleaning Facility
Risk-Based Cleanup Level Calculations

$$\text{RBC}_{\text{air}}\ (\mu\text{g/l}) = \frac{RISK \times ABW \times LIFE \times UCF}{CPF \times DWIR \times DUR \times INH} \qquad \text{(Equation 1)}$$

Where:

RBCair = Risk-Based Calculation for air

RISK = Acceptable cancer risk level (1 in 1,000,000)

ABW = Average body weight during the period of exposure (70 kg)

LIFE = Lifetime (75 years)

UCF = Unit conversion factor (1,000 μg/mg)

CPF = Carcinogenic potency factor as specified in WAC 173-340-708(8) (kg-day/mg)

DWIR = Drinking water ingestion rate (2.0 liters/day)

DUR = Duration of exposure (30 years)

INH = Inhalation correction factor as defined in WAC 173-340-720(7)

$$RBC_{wi}(mg/L) = \frac{RBC_{air}(\mu g/m^3) \cdot 10^{-3}\, mg/\mu g}{VF_{wi}(L/m^3)} \qquad \text{(Equation 2)}$$

Where:

RBC_{wi} = Risk-Based Calculation for groundwater effects on indoor air quality

RBC_{air} = Risk-Based Calculation for air

VF_{wi} = Volatilization factor for water and indoor air quality (See Equation 4)

10^{-3} mg/μg = Unit correction factor (UCF)

$$RBC_{wo}(mg/L) = \frac{RBC_{air}(\mu g/m^3) \cdot 10^{-3}\, mg/\mu g}{VF_{wo}(L/m^3)} \qquad \text{(Equation 3)}$$

Where:

RBC_{wo} = Risk-Based Calculation for groundwater effects on outdoor air quality

RBC_{air} = Risk-Based Calculation for air

VF_{wo} = Volatilization factor for water and outdoor air quality

10^{-3} mg/µg = Unit correction factor (UCF)

$$VF_{wi}\left(L/m^3\right) = \frac{H \cdot \left(\dfrac{D_{Teff} \cdot 86{,}400 s/day}{L_B \cdot ER \cdot L_w}\right)}{1 + \left(\dfrac{D_{Teff} \cdot 86{,}400 s/day}{L_B \cdot ER \cdot L_w}\right) + \left(\dfrac{D_{Teff} \cdot L_{crk}}{D_{veff} \cdot L_w \cdot f_{crk}}\right)} \cdot 10^3 \frac{L}{m^3} \qquad \text{(Equation 4)}$$

Where:

VF_{wi} = Volatilization factor for water and indoor air quality

D_{Teff} = Total effective diffusion coefficient (cm^2/s)

L_w = Total distance from groundwater to surface (cm)

L_B = Building height (indoor air mixing zone) (cm)

L_{crk} = Thickness of crack (building slab) (cm)

F_{crk} = Foundation crack fraction (cm)

ER = Building air exchange rate (1/day)

D_{veff} = Effective diffusion coefficient in the vadose zone (cm^2/s)

86,400 s/day = Unit conversion factor for time

10^n n/n = Unit correction factor (UCF)

$$VF_{wo}\left(L/m^3\right) = \frac{D_{Teff} \cdot H \cdot 10^3 g/kg \cdot 10^3 L/m^3}{(Q/C) \cdot L_w \cdot 10^2 cm/m} \qquad \text{(Equation 5)}$$

VF_{wo} = Volatilization factor for water and outdoor air quality

D_{Teff} = Total effective diffusion coefficient (cm^2/s)

H = Henry's Law Constant (unitless)

Q/C = Average flux from contaminated soil/Air concentration at the center of the site

L_w = Total distance from groundwater to surface (cm)

10^n n/n = Unit correction factor (UCF)

$$D_{Teff} = \frac{L_w}{\left(\frac{L_v}{D_{veff}}\right) + \left(\frac{L_{cap}}{D_{capeff}}\right)} \quad \text{(Equation 6)}$$

Where:

D_{Teff} = Total effective diffusion coefficient (cm^2/s)

D_{veff} = Effective diffusion coefficient in the vadose zone (cm^2/s)

D_{capeff} = Effective diffusion coefficient in the capillary fringe zone (cm^2/s)

L_{cap} = Thickness of the capillary fringe (cm)

L_v = Thickness of the vadoze zone (cm)

L_w = Total distance from groundwater to surface (cm) ($L_w = L_v + L_{cap}$)

$$D_{capeff} = \frac{D_{air} \cdot n_{acap}^{10/3} \cdot H + D_w \cdot n_{wcap}^{10/3}}{H \cdot n^2} \quad \text{(Equation 7)}$$

Where:

D_{capeff} = Effective diffusion coefficient in the capillary fringe zone (cm^2/s)

H = Henry's Law Constant (unitless)

n = Total soil porosity (unitless)

n_{acap} = Air-filled porosity in the capillary fringe (unitless)

n_{wcap} = Water-filled porosity in the capillary fringe (unitless)

D_{air} = Diffusion coefficient in air (cm^2/s)

D_w = Diffusion coefficient in water (cm^2/s)

$$D_{veff} = \frac{D_{air} \cdot n_a^{10/3} \cdot H + D_w \cdot n_w^{10/3}}{H \cdot n^2} \quad \text{(Equation 8)}$$

Where:

D_{veff} = Effective diffusion coefficient in the vadose zone (cm^2/s)

D_{air} = Diffusion coefficient in air (cm^2/s)

n_a = Air-filled porosity in the vadose zone (unitless)

H = Henry's Law Constant (unitless)

D_w = Diffusion coefficient in water (cm^2/s)

n_w = Water-filled porosity in the vadose zone (unitless)

n = Total soil porosity (unitless)

$$RBC_{we} = \frac{ARL_c \cdot AT_c \cdot 365d/yr \cdot BW}{ED_e \cdot EF_e \cdot [(IRA_e \cdot VF_{we} \cdot SF_i) + (DA_{we} \cdot EvF_{we} \cdot SA_{we} \cdot SF_o)]} \quad \text{(Equation 9)}$$

Where:

ARL_c = Acceptable risk level (carcinogens) (same as RISK)

AT_c = Averaging time (yr)

BW = Body weight (kg)

DA_{we} = Dermal absorbtion factor for groundwater – construction worker (yr)

ED_e = Exposure duration – construction worker (yr)

EF_e = Exposure frequency – construction worker (d/yr)

EvF_{we} = Event frequency – construction worker groundwater contact (event/d)

IRA_e = Inhalation rate – construction worker (m^3/d)

SA_{we} = Skin surface contact area – construction worker to groundwater (cm^2)

SF_i = Cancer slope factor inhaled $(mg/kg\text{-}day)^{-1}$

SF_o = Cancer slope factor oral $(mg/kg\text{-}day)^{-1}$

VF_{we} = Volatilization factor for water – construction worker (L/m^3)

$$DA_{we} = 2 \cdot K_p \cdot \sqrt{\frac{6 \cdot \tau \cdot t_{event}}{\pi}} \cdot \left(\frac{10^{-3} L}{cm^3}\right) \text{ for } t_{event} < t^* \qquad \text{(Equation 10)}$$

Where:

DA_{we} = Dermal absorbtion factor for groundwater – construction worker (yr)

K_p = Dermal permeability coefficient (cm/hr)

t_{event} = Duration of exposure (hr/event)

τ = Lag time (hr/event)

t* = Time to reach steady state (hr)

$$DA_{we} = K_p \cdot \left[\frac{t_{event}}{1+B} + 2 \cdot \tau \cdot \left(\frac{1+3B}{1+B}\right)\right] \cdot \left(\frac{10^{-3L}}{cm^3}\right) \text{ for } t_{event} > t^* \qquad \text{(Equation 11)}$$

DA_{we} = Dermal absorbtion factor for groundwater – construction worker (yr)

K_p = Dermal permeability coefficient (cm/hr)

t_{event} = Duration of exposure (hr/event)

τ = Lag time (hr/event)

t* = Time to reach steady state (hr)

B = Relative hydrophobicity (unitless)

VARIABLE INPUTS

PCE Variable List	
RISK	0.000001
BW	70
LIFE	75
UCF	1000
CPF	0.00203
BR	20
ABS	1
DUR	30
D_{air}	0.072
D_w	8.2E-06
H	0.754
n	0.38
n_a	0.26
n_w	0.12
n_{acap}	0.038
n_{wcap}	0.342
L_{cap}	5
L_v	295
L_B	400
L_{crk}	15
f_{crk}	0.01000
ER	24
UCF_2	0.00100
Q/C	68.8
K_p	0.37
t_{event}	2
τ	0.9
t*	4.3
B	0.25
ARL_c	0.000001
AT_c	70
BW_a	70
ED_e	1
EF_e	9
EvF_{we}	2
IRA_e	15.2
SA_{we}	7000
SF_i	0.00203
SF_o	0.052
VF_{we}	0.5

TCE Variable List	
RISK	0.000001
BW	70
LIFE	75
UCF	1000
CPF	0.006
BR	20
ABS	1
DUR	30
D_{air}	0.079
D_w	0.0000091
H	0.4223
n	0.38
n_a	0.26
n_w	0.12
n_{acap}	0.038
n_{wcap}	0.342
L_{cap}	5
L_v	295
L_B	400
L_{crk}	15
f_{crk}	0.01000
ER	24
UCF_2	0.00100
Q/C	68.8
K_p	0.23
t_{event}	2
τ	0.55
t*	1.3
B	0.026
ARL_c	0.000001
AT_c	70
BW_a	70
ED_e	1
EF_e	9
EvF_{we}	2
IRA_e	15.2
SA_{we}	7000
SF_i	0.006
SF_o	0.011
VF_{we}	0.5