

SITE EVALUATION REPORT

**National Heatset Printing
One Adams Boulevard
East Farmingdale
Suffolk County, New York**

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1.0 INTRODUCTION

Roux Associates, Inc. (Roux Associates) was retained by Robinson & Associates, P.C. (Robinson) to provide opinions regarding the timing of chemical releases at the property located at One Adams Boulevard in the Hamlet of East Farmingdale, Town of Babylon, Suffolk County, New York (the "Site"). The Site is sometimes referred to as the National Heatset Printing Site, or the NHS Site. This report supplements the report prepared by Dr. Ram on October 28, 2005. The opinions set forth within this report have been formulated by Dr. Neil M. Ram, who has been Vice President and National Client Manager for Roux Associates, Inc. (Roux Associates) since 1999. Prior to this position, Dr. Ram was the General Manager for Gradient Corporation, a risk assessment company located in Cambridge, Massachusetts; Manager of the New England District for Fluor Daniel GTI, Inc; and a Senior Project Manager at ICF Kaiser Engineers, Boston, Massachusetts, and Stone and Webster Engineering Corporation, Boston, Massachusetts. Dr. Ram was also an Assistant Professor of Environmental Engineering for four years at the University of Massachusetts.

In 1973, Dr. Ram graduated from Rutgers University with a Bachelor of Science in Environmental Science. In 1975, he obtained a Masters of Science in Environmental Science from Rutgers University. Dr. Ram earned a Masters of Science and a Ph.D. in Environmental Engineering from Harvard University in 1977 and 1979, respectively. He has also completed post doctorate research at the Technion Israel Institute of Science. Dr. Ram has close to 30 years of environmental engineering and hazardous waste assessment and remediation experience. He is a Certified Hazardous Materials Manager (CHMM) and a Licensed Site Professional (LSP) in the Commonwealth of Massachusetts.

A substantial part of Dr. Ram's experience includes Site investigation and feasibility studies; risk assessment; environmental compliance and permitting; hazardous waste assessment, Site assessment and Site remediation, engineering and design; modeling; water and wastewater engineering, sampling and analysis; regulatory policy development and support; hazardous waste training and teaching; compliance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and the Massachusetts Contingency Plan (MCP); fate and transport of contaminants in the environment; water treatment; bioassays; and remediation technology selection and implementation.

Dr. Ram has directed projects at hundreds of Underground Storage Tank (UST) sites and at properties contaminated with organic solvents, petroleum constituents, metals, PCBs, mercury, asbestos and acidic and mixed waste in all environmental matrices including several Superfund sites. His curriculum vitae is included as **Appendix A**.

Dr. Ram has provided testimony in court, at public meetings and in sworn depositions. In several cases he has also submitted affidavits containing extensive technical analysis of data and expert opinions. His testimony experience is included as **Appendix B**.

Dr. Ram was retained as an employee of Roux Associates by Robinson to provide professional services, including review of the documents, technical evaluations, and preparation of expert opinion reports summarizing the findings and opinions of this review and evaluation. More specifically, Dr. Ram was retained to evaluate the source(s) and timing of contaminant releases that have been observed in soil, groundwater and other media collected from the Site [chemicals detected at the Site include but are not limited to: volatile organic compounds (VOCs) such as tetrachloroethylene (PCE), other chlorinated VOCs (CVOCs), including trichloroethylene (TCE), 1,2-dichloroethylene (1,2-DCE), 1,1,1-trichloroethane (1,1,1-TCA), and non-halogenated organic chemicals including but not limited to methylbenzenes and petroleum distillates].

Opinions on this and related subjects are set forth herein. These opinions are based upon information received and considered by Roux Associates as of December 12, 2005. Any new information provided after December 12, 2005 is not included in this report. Roux Associates reserves the right to amend or supplement its opinions in consideration of any new information received.

In formulating these opinions, the following tasks were conducted:

- a) Review of documents pertaining to the subject Site provided by Robinson and by P.W. Grosser Consulting, Inc. (Grosser), including but not limited to reports prepared by Donnelly Engineering (Donnelly), H2M Group (H2M), Lawler, Matusky & Skelly Engineers (LMS), IT Engineering of New York, P.C. (IT), The Shaw Group Inc. (Shaw), Records of Decision (RODs) for the National Heatset Printing Site and the Fairchild Republic Main Site, expert reports prepared by Charles McLane, Charles Sosik and Hilton Hudnell, deposition testimony or summaries thereof of Charles McLane, Lawrence Donnelly, Eugene Leff and Charles Sosik, water quality results from the Miller Study, correspondence from the Suffolk County Department of Health Services

(SCDHS) and the Center for the Environment Cornell Laboratory for Environmental Applications of Remote Sensing;

- b) Review of pertinent technical literature related to contaminant fate and transport;
- c) Technical evaluations and calculations of Site data in rendering the opinions set forth herein; and
- d) Site inspection on December 7, 2005.

Dr. Ram's billing rate for this project is \$235 per hour.

1.1 Limitations

This report, including the exhibits attached hereto, describes the results of Roux Associates' review of information pertaining to the subject Site. The conclusions stated herein represent the application of a variety of engineering and technical disciplines to material facts and conditions associated with the Site and to existing and/or historical regulations and laws. The conclusions set forth in this report are based upon the facts, information, and data that have been provided to Roux Associates. Should any of these facts, information, and data changed or be amended, then Roux Associates reserves the right to amend its conclusions and opinions based upon such new information. Roux Associates has conducted this work in a professional manner using the degree of skill and care exercised for similar projects under similar conditions by reputable and competent environmental consultants. This report is not intended to satisfy the requirements of the National Contingency Plan or those under applicable New York State Department of Environmental Conservation (NYSDEC) laws or regulations.

2.0 SITE OVERVIEW

The National Heatset Printing Site is located at One Adams Boulevard in the Hamlet of East Farmingdale, Suffolk County, New York. The Site contains one multi-tenant industrial building and is approximately 4.5 acres in size. The Site was first developed in 1971. The building consists of about 90,000 square feet of commercial space that was first occupied in 1972. NHS occupied a portion of the on Site building (about 34,000 square feet) from July 1983 to April 1989. NHS operations consisted of lithographic tri-color printing of newspaper and periodical advertisements and manufacture of lithographic printing plates¹. Other tenants included Bitex Corporation (1972 to 1974) that conducted knitting and finishing operations and Babtex Corporation (1975 to 1982) that also conducted knitting and finishing operations². McLane reported that, according to the Bitex lease, Bitex operations included the use of “one Cleanex 250-280 lb. solvent washer extractor including dual solvent tank 58” X 40” cylinder, 30” door,” “one clean solvent storage tank with controls and pump,” “one dirty solvent still feed with controls and pump,” and “seven solvent reclaimers 80 lb. capacity with automatic re-cycling.” (Equipment list attached to lease 6/13/72, Seyfarth deposition, exhibit 28)³.

A summary of inspection reports from the Suffolk County Department of Health Services (SCDHS) is provided in **Table 1**. The earliest inspection report is an October 12, 1983 report (Bates number 0006672) that states, “inspection of your plant was conducted by a representative of this department on 6 October 1983. This inspection revealed that you will be discharging photo plate making waste to your sanitary system.” NHS was instructed to either cease this discharge or to connect the discharge to the Southwest Sewer District. Additional inspections, conducted in 1985 through 1987, indicated various staining, unregistered drums and tanks on the property. The contents of some of the unregistered drums was determined in March 1986 to include: developer, polychrome, ink, water, buffer, press wash, waste fountain solution, water and water/oil fountain solution. None of these reports indicate the presence of PCE or other solvents at the NHS Site during this time frame. As discussed below, the first mention of a chemical solvent at the NHS Site occurs in a February 2, 1988 Notice of Violation for discharge of waste oil to the leaching pool in the rear of the building that was found to contain certain solvents.

¹ June 11, 2001, IT, source Area Delineation Report and Oxidation Pilot Test Work Plan

² January 2005, Expert Report of Charles McLane regarding the National Heatset Printing Company

³ May 2005, Rebuttal Report, Charles McLane

According to the Record of Decision for the Site⁴, after National Heatset Printing Company filed for bankruptcy in 1987, the SCDHS discovered that National Heatset's chemical inventory was dumped onto the soils and into a leaching pool located off the rear of the building in the northeast side of the property. The chemicals that were allegedly disposed at this location included PCE and TCE. The April 26, 2005 Amended Complaint by the State of New York also alleges that the Heatset Corporations disposed of their chemical inventory by dumping chemicals onto soils and into a leaching pool on the Site. This is supported by a December 14, 1987 letter from SCDHS (0006829) referencing a December 11, 1987 telephone conversation regarding the bankruptcy of National Heatset (Case No. 877-71670-20). Shortly thereafter, a Notice of Violation (NOV) was issued by SCDHS to NHS for "Discharge of waste oil to open leaching pools." A sample taken from the leaching pool on February 2, 1988 was found to contain petroleum constituents (xylenes, ethyltoluene and trimethylbenzens) as well as 1,2-DCE and 1,1,2-trichloroethylene (1,1,2-TCE). PCE was not detected in this sample at a detection limit of 40 ppb. A later inspection report (Bates number S020508) clarified that the discharge to the leaching pool was, "an oily substance or possibly ink."

The finding of petroleum constituents, 1,2-DCE and 1,1,2-TCE prompted the SCDHS to issue NHS a February 11, 1988 letter directing NHS to immediately pump out all liquids and sludge from the leaching pool. Re-inspection of the leaching pool in April 1988 concluded that it had not been cleaned as of that time (Bates number 0006802). The leaching pool was subsequently pumped out sometime on or before May 25, 1988 (S020677). During this period, several drums were sampled and were found to contain petroleum constituents. 1,1,1-TCA (13,000 ppb) was identified in only one drum and PCE was not identified in any of the drums for which lab reports were provided (Bates numbers 0006780, S020518, S020519, 0006782, S020517).

The first detection of PCE within the leaching pool occurred during sample collection in November 1988. According to a November 2, 1988 Suffolk County memorandum, the liquid portion of the leaching pool was pumped on May 24, 1988 but the sludge had not been removed. The accompanying SCDHS notes indicate that, "the sludge was never pumped out and now the pool has the same amount of liquid as it originally did (Bates number 0006778)."

⁴ Record of Decision, National Heatset Printing Site, Site Number 1-54-140, June 1990.

A sample presumably of this liquid was collected on November 15, 1988 (the sample identification indicates, 'storm drain') was found to contain 79,000 ppb 1,1,2-TCE and 13,000,000 ppb PCE⁵ along with some ethyltoluene and 1,2,4-trimethylbenzene. The sample was collected from the bottom of a storm drain on the north side of the building after Chemical Management had completed the removal of an estimated 1,125 gallons of liquid and approximately seven yards of sludge from the leaching pool⁶. It is interesting to note that PCE was not detected in a sample of the original liquid in the leaching pool collected on February 2, 1988. Based on the finding of 1,1,2-TCE, PCE, p-ethyltoluene and 1,2,4-trimethylbenzene, SCDHS determined that it was necessary "for a Site evaluation to be performed to determine the extent of contamination left in the ground, as well as whether Site contamination, proposed remedial activities and extent of groundwater contamination, if it exists..."⁷ Various additional Site cleanup activities followed including Lionetti Oil Recovery Company pumping waste oil from various drums (Bates number S020504) and drum removal by Chemical Management (Bates number 0006750).

Site investigations were subsequently conducted by Donnelly Engineering between 1989 and 1995⁸. The Site was listed on the New York State Registry of Inactive Hazardous Waste Disposal Sites as a Class 2 Site in April 1993. Subsequent Site investigations were conducted from 1997 through 2002 by Donnelly, H2M, LMS Engineers, IT and Shaw. Significant findings from these reports are noted in the sections that follow:

February 3, 1989, Donnelly, Closure Plan

Materials used by NHS during manufacturing included inks, press cleaning compounds, photographic developers and photographic fixers. These materials contain halogenated and non-halogenated organic solvents, organic acids, alkalines and inorganic reducing agents.

⁵ 13,000,000 ppb PCE is equivalent to 13,000 ppm PCE.

⁶ December 23, 1988, SCDHS letter to Michael Adams

⁷ December 23, 1988, SCDHS letter to Michael Adams

⁸ August 1989, Site Contamination Investigation Report, Level II Report and April 1996 Report on August 1995 Soil Sampling Activities.

An inventory of material left behind by NHS was performed on January 25, 1989. Materials being stored on Site at that time included:

- Waste inks;
- Wastewater;
- Waste alcohol;
- Drums of synthetic hydraulic oil;
- Unopened ink; and
- Photographic chemicals (developers, fixers and wastewaters).

**August 1989, Site Contamination Investigation Report,
Level II Report, Donnelly Engineering**

Several soil borings and groundwater monitoring wells were installed at the Site.

April 1996, Report on August 1995 Soil Sampling Activities, Donnelly Engineering

According to this report, Donnelly installed a closed loop soil vapor extraction system at the Site in the spring of 1990 that was manufactured by Wastemizer Corp. (termed, "Cyclo Purge") in the vicinity of a contaminated storm drain (also referred to as the leaching pool). The drain and overflow leaching pool were pumped, washed and dredged of liquid and solid contents down to the water table. The top concrete covers were permanently removed from the storm drain. The empty concrete rings were lined with impervious, 20-millimeter thick PVC material. The linings were backfilled with certified clean sand and the tops of the PVC bags were folded over to deter storm water infiltration. The Cyclo Purge system consisted of 15 well points. As of September 1995, the system reportedly removed 2,000 pounds of PCE from the immediate vicinity of the storm drain from the vadose zone⁹.

⁹ The vadose zone is the unsaturated soil horizon located above the groundwater table.

August 1997, Remedial Investigation/Feasibility Study (RI/FS) Work Plan, H2M and LMS

The RI/FS Work Plan proposed installing additional monitoring wells, geoprobe points (14 at storm water drywells; 10 at former sanitary wastewater leaching pools and 15 at 'background' locations); and sampling drainage structures. The Work Plan also included advancing 60 soil borings and collecting 90 samples in the vicinity of the leaching pool, and on Site out-of-service sanitary waste disposal systems.

February 1999 Remedial Investigation and Feasibility Study (RI/FS), H2M

According to the RI/FS prepared by the H2M Group and LMS Engineers, NHP filed for bankruptcy in 1987 at which time the SCDHS discovered that NHP's chemical inventory had been disposed of by dumping the materials onto the soils and into a leaching pool located on the northeast side of the building.

The RI discussed the findings from samples collected during the field investigation including:

- 82 soil samples;
- 85 groundwater samples collected and analyzed on the Site and both upgradient and downgradient of the Site;
- 7 additional groundwater monitoring wells were installed and 4 existing wells sampled; and
- groundwater samples from four private homes.

The RI concluded that (1) there were no Site-related CVOCs present upgradient of the Site, (2) groundwater beneath the Site is significantly impacted by Site-related contaminants, and (3) the Site-related contaminated plume extends over 7,100 feet downgradient of the Site with the highest concentrations centered about 4,000 feet from the Site. The RI also described the presence of a clay unit at depths ranging from 70 to 85 feet below grade surface (fbgs); with the highest PCE found just above the clay unit¹⁰. PCE concentrations were highest directly below the leaching pool and the center of the PCE plume was reportedly located just east of the Columbus Boulevard, north of the North Amityville Town pool. (see Fig. 1.1 of the RIFS). The highest concentrations were reportedly centered about 4,000 feet downgradient of the Site¹¹.

¹⁰ The RIFS notes that unsaturated soils from the source area did not contain PCE or other VOCs approaching concentrations of concern. PCE was detected at 7,700,000 µg/kg at the 80 to 82 feet bgs level just above the clay layer at monitoring wells MW-7.

¹¹ This value is consistent with the distance to the mid-point center of mass estimated by Roux Associates to be located approximately 3,850 ft downgradient of the Site (see Section 3.1.2).

The RI also concluded that the only continuing source of VOC contamination at the NHP Site was present in the saturated zone beneath the previously identified source area north of the building. The RI further concluded that there was no evidence that any of the other on-Site drainage structures were contributing to VOC contaminant plume in groundwater.

June 1999, Record of Decision, National Heatset Printing Site, Town of Babylon, Suffolk County, Site Number 1-52-140

The remedy selected in the Record of Decision (ROD) is in-situ density driven convection type in-well stripping. The estimated construction cost as reported in the ROD is \$1.109M with an average annual operation and maintenance for 15 years of \$150,000.

The ROD reviews the Site history described in previous sections of this report.

According to the ROD, VOC contaminated groundwater is migrating off Site in a south-southeast direction. A cross section presented in the ROD indicates that the PCE concentration is greatest directly above the clay layer. The highest PCE concentrations were found at M-4 (11,900 ppb) approximately 2,200 feet downgradient of the Site.

September 29, 2000, the IT Group, Remedial Design

This is a Work Plan that proposed to define remedial design activities, the technical components of the design and associated costs. NYSDEC was unable to obtain bids at a reasonable cost at another inactive hazardous waste site and, therefore, an alternate remedy was recommended. Consequently, an Explanation of Significant Difference was issued in June 2000 adding groundwater extraction and treatment as an alternate remedy for downgradient groundwater contamination. The Work Plan describes additional source area delineation including advancement of soil borings inside and outside the warehouse building. Bench scale tests to determine the specific chemical oxidant type and dosage requirements for chemical oxidation treatment using sodium or potassium permanganate are also described as well as aquifer testing to determine hydraulic flow parameters of the Upper Glacial aquifer.

June 11, 2001 IT, Source Area Delineation Report and Oxidation Pilot Test Work Plan

The IT report re-iterates the Site history and discusses additional source area investigations including advancement of soil borings¹², installation and sampling of groundwater monitoring wells¹³, and completion of an aquifer pump test performed from April 23, 2001 to April 27, 2001. A plan for a permanganate injection pilot test was also described. Soil sample results identified PCE at the water table and at the sand/clay interface. None of the soil samples collected outside the warehouse contained PCE above the soil NYSDEC cleanup objective of 1,400 µg/kg. However elevated PCE levels were observed in soil boring samples collected from inside the warehouse.

September 2001, IT Extraction and Treatment and In Well Stripping System 65% Engineering Design Report

This report includes information about groundwater hydraulic conductivity based upon the pump test conducted in April 2001.

September 2001, Soil Vapor Extraction Pilot Test Work Plan, IT

This is a Work Plan to determine the effectiveness of soil vapor extraction (SVE) technology for the Site.

August 13, 2002, Shaw, Potassium Permanganate Injection 95% Design Report

Based upon bids for the recirculation wells being higher than expected, an Explanation of Significant Difference (ESD) was reportedly issued for the Site in June 2000 adding groundwater extraction and treatment as an alternate remedy for the downgradient groundwater contamination¹⁴. In June 2001, NYSDEC also approved an in situ chemical oxidation treatment using potassium permanganate to chemically oxidize the chlorinated ethenes. This report discusses the results of a potassium permanganate pilot test that was conducted at the Site.

¹² Three soil borings (labeled A, B & H) were completed outside the warehouse building and four soil borings (labeled C, E, F, & G) were completed inside the warehouse.

¹³ Well screens were 30 feet in length starting from the bottom of each soil boring.

¹⁴ Roux Associates was not provided with a copy of the ESD.

3.0 OPINIONS

Based upon review of project documents, Site information and technical publications, it can be concluded, within a reasonable degree of scientific certainty that,

- (1) Assuming that the conclusions of the RIFS are correct [namely that (a) the hydraulic conductivity at the Site is 270 feet per day with a gradient of approximately 0.00147 feet per foot and (b) Site-related contaminants extend over 7,100 feet downgradient of the Site with the highest concentrations centered about 4,000 feet from the Site], then the configuration of the contaminant plume is consistent with a slug of PCE released sometime between 1987 to 1989. These dates are consistent with information presented in the ROD indicating that after NHS filed for bankruptcy in 1987, the SCDHS discovered that NHS had disposed of its chemical inventory by dumping the materials onto the soils and into a leaching pool located off the rear of the building in the northeast side of the property.
- (2) Using the more Site-specific hydraulic conductivity value of 139 ft/day (median value) determined from a pump test conducted at the Site in April 2001 and incorporating the affects of dispersion, plume length calculations indicate that the length of the PCE plume reasonably attributable to a release during NHS' occupancy is shorter than what has been observed downgradient of the NHS Site. As result, PCE contamination observed in 1987 in a private well on Miller Avenue and the 5,700-foot long PCE plume that was identified in the 1999 RI/FS can not be attributed to PCE released from the Site when NHS occupied the on-Site building.

These opinions are discussed in further detail in the sections that follow.

3.1 Release Timing Assuming Parameters used in the 1999 RIFS

This section provides the basis for Roux Associates opinion regarding the timing of the PCE release at the subject Site based on parameters presented in the 1999 RIFS.

3.1.1 Overview of Chemical Time of Travel

Chemical constituents dissolved in groundwater will migrate in the direction of groundwater flow due predominantly to advective contaminant transport and, to a lesser extent, dispersion. As contaminants migrate, a 'plume' is formed in which the contaminant is distributed between the location of the release (sometimes termed the 'source' or 'source area') and downgradient locations where contaminants have come to be located as a result of contaminant migration along the groundwater flow path.

There are two generalized types of plumes:

Continuously formed plumes

Continuously formed plumes can be formed from single or multiple releases that occur over many years. Such releases result in sufficient contaminant mass that become adsorbed to soils in the source area such that contaminants are continuously desorbed from the contaminated soil into groundwater at a rate that results in high dissolved contaminant concentrations in the source area. Contaminants then migrate in the direction of groundwater flow and are attenuated and diluted as they move further from the source area. The generalized configuration of such plumes is typically represented by higher concentrations near the source area with diminishing contaminant concentrations further downgradient.

There are three types of continuously formed plumes: expanding, steady state (or stable) and shrinking. These are defined in ASTM E 1943-98 as follows:

Expanding Plume- Configuration where the solute plume margin is continuing to move outward or downgradient from the source area. This occurs when the rate of natural attenuation is slower than the rate that contaminant mass is entering the plume from a continuing source area.

Stable Plume-When a residual contaminant source exists, contaminants will migrate until they reach steady state condition, a point at which the rate of contaminant addition (i.e., source) is equal to the rate of attenuation (i.e., degradation) and the maximum plume length is achieved. This is referred to as a 'stable plume' where the solute plume margin is stationary over time and concentrations at points within the plume are relatively uniform over time. This occurs when the rate of natural attenuation in the plume is equal to the rate that contaminant mass is entering the plume from a continuing source area.

Shrinking Plume- Configuration where the solute plume margin is receding back toward the source area over time and the concentrations at points within the plume are decreasing over time. This occurs when the rate of natural attenuation is faster than the rate that contaminant mass is entering the plume. This typically occurs when the plume source is old, has been removed or is undergoing remediation.

Slug or Pulse formation plumes

Slug or pulse formation plumes are formed when a single or short-term release occurs such that residual contamination in the source area following the release event adds less contaminant mass to the groundwater as compared to that added during the initial release event. Slug or pulse plumes typically have either a low residual source or the source is sufficiently adsorbed to the soil matrix (bound) such that contaminants do not dissolve into groundwater to a significant extent. The generalized plume configuration for a slug plume is represented by higher downgradient contaminant concentrations as compared to near the source area. This configuration can also be true for plumes remaining after source area remediation has been completed or older receding plumes where the source area has exhausted itself before downgradient impacts can degrade. Over time, the contaminant slug moves in the direction of groundwater flow and spreads out. Although some residual mass remains in the area where the release occurred, the mass is small compared to the amount originally released.

Time of Travel Considerations

The length of a plume can often be used to estimate the time that contaminant transport has occurred (Ram, 1999) as follows:

- | | |
|--------------------------------------|---|
| Continuously Formed Expanding Plume: | Plume length is directly related to time since the end of the plume represents the first contaminant arrival time. |
| Continuously Formed Stable Plume: | Time is related to the plume length plus the time that the plume has been stable. |
| Continuously Formed Shrinking Plume: | Time cannot be related to plume length unless the full extent of the historical plume is known. |
| Slug Plume: | Distance from the source area to the center of mass or mid-level concentration is representative of the advective component of migration without the effects of dispersion (Baca, 1999 and 2000). |

Simple one-dimensional advective models (i.e. equations) can be used as a first estimate of plume age based on the length of an expanding, steady state, or slug plume. This approach relies upon groundwater monitoring data to estimate the status of the plume (i.e. steady-state, expanding or slug) and Darcy's Law to estimate the groundwater seepage velocity (V_s) using

Site specific or literature-derived hydraulic conductivity (K), hydraulic gradient (I), and effective porosity (n_e) values.

Roux Associates completed simple advective flow calculations to estimate the groundwater seepage velocities at the Site. Roux Associates used the distance from the source area to the plume's 'mid-level' concentration or center of mass to estimate the advective component of migration without the effects of dispersion.

Advection is defined by the groundwater seepage velocity, V_s , as:

$$V_s = \frac{KI}{n_e}$$

Where: K = hydraulic conductivity

I = hydraulic gradient

n_e = effective porosity

The rate of contaminant transport in groundwater is slowed (retarded) due to adsorption of the chemicals onto soil. Therefore, the contaminant flow rate is slower than the groundwater seepage velocity. The relative velocity between contaminant flow and groundwater flow can be derived by calculating a "retardation factor." Incorporating retardation or adsorption of the compound requires that a retardation factor (R_f) be calculated. To calculate a retardation factor, a contaminant-specific partitioning coefficient (K_d) must be calculated. The percentage of organic carbon (f_{oc}) present in the aquifer sediments and a contaminant-specific organic carbon partitioning coefficient (K_{oc}) are used in the following manner to compute a K_d :

$$K_d = (f_{oc})(K_{oc})$$

Where: K_d = partitioning coefficient

f_{oc} = aquifer organic carbon content

K_{oc} = contaminant organic carbon partitioning coefficient

Contaminant specific retardation factors, R_f , are then calculated according to:

$$R_f = 1 + \left[\frac{(K_d)(\rho)}{n_e} \right]$$

Where: R_f = retardation factor
 K_d = distribution coefficient
 ρ = soil bulk density
 n_e = effective soil porosity

Contaminant retardation factors are then incorporated into time of travel calculations by adjusting the seepage velocity to account for retarded flow. Contaminant velocity (V_c) is calculated as follows:

$$V_c = \frac{V_s}{R_f}$$

Where: V_c = retarded contaminant velocity
 V_s = groundwater seepage velocity
 R_f = retardation factor

Finally, the contaminant travel time is calculated according to the equation:

$$\text{Contaminant travel time} = \text{Plume length}/V_c$$

3.1.2 Steps Used to Complete Time of Travel Calculation Using Parameters Specified in the 1999 RI/FS

Roux Associates completed the following steps to determine the timing of the PCE release at the subject Site using the time-of-travel approach described in section 3.1.1.

Step 1: Determine the type of plume

Figures 4.1 through 4.4 of the RIFS indicate that the total halogenated VOC plume is consistent with a slug or pulse plume. The maximum concentrations of total halogenated VOCs at all three depth intervals (50 feet bgs, 65 to 70 feet bgs and 75 to 85 feet bgs as represented in figures 4.1 through 4.3) are located downgradient of the NHS Site with lower VOC concentrations observed nearer to the NHS Site. This configuration is also apparent in Figure 4.4 of the RIFS which depicts more elevated halogenated VOCs at depth (immediately above the clay layer) and at downgradient locations (wells M-4 and Autumn Lane). These same figures are provided in the ROD as figures 9 through 12. According to these figures and the accompanying text, the ROD concluded that:

1. The maximum concentration of halogenated VOCs in groundwater at 50 feet bgs was observed at the Silver Pine location (equal to 26.3 $\mu\text{g/L}$) located approximately 7,500 feet from the Site¹⁵;
2. The maximum concentration of halogenated VOCs in groundwater at 65 to 70 foot bgs was observed at the Autumn Lane location (2,750 $\mu\text{g/L}$) located approximately 4,300 feet from the Site¹⁶;
3. The maximum concentration of halogenated VOCs in groundwater at 75 to 85 foot bgs was observed at well M-4 (equal to 12,021 $\mu\text{g/L}$) located approximately 2,200 feet from the Site; halogenated VOC levels greater than 1,000 $\mu\text{g/L}$ extended about 4,500 feet to location M-28;
4. The highest PCE concentration in groundwater was found at location M-4 (11,900 $\mu\text{g/L}$), approximately 2,200 feet downgradient of the Site at an 85-foot depth.

Although residual contamination continues to be present in the source area, it is likely less elevated now than during the release event that caused the slug plume to form. PCE concentrations in Geoprobe groundwater samples collected as part of the RIFS (GP-1 through GP-5) in the vicinity of the leaching pool from approximately 5-feet below the water table (i.e., 17 feet bgs) ranged from 496 $\mu\text{g/L}$ in GP-3 to 7,690 $\mu\text{g/L}$ in GP-4. The RIFS also reported that PCE was present in October 1997 in source area monitoring wells MW-6 and MW-7 at concentrations of 1,900 J and 1,000 J $\mu\text{g/L}$ ¹⁷, respectively. PCE was also detected in three on-Site downgradient wells (MW-2A, 3A and 4A which are all screened at the groundwater table) at concentrations equal to 11,000 J $\mu\text{g/L}$; 3,100 J $\mu\text{g/L}$ and 350 J $\mu\text{g/L}$, respectively¹⁸. Additional sampling conducted about one year later (October 1, 1998), revealed that PCE concentrations in the two source area wells MW-6 and MW-7 had decreased to 210 and 330 $\mu\text{g/L}$, respectively. PCE in the three on-Site downgradient wells (MW-2A, 3A and 4A) had also decreased to 9,600 $\mu\text{g/L}$, 1,200 $\mu\text{g/L}$ and 120 $\mu\text{g/L}$, respectively. PCE was also detected in the two newly installed deep on-Site downgradient wells (MW-9 and MW-10 that are screened on top of the underlying

¹⁵ According to a December 1991 "Inventory of Potential Hazardous Disposal Sites," prepared by the Center for the Environment, Cornell Laboratory for Environmental Applications of Remote Sensing, several dumps are located between Southern State and Sunrise Highways in the vicinity of the Site. Two of these that appeared in a 1977 and 1984 air photo, are characterized as, "neighborhood dump on vacant land behind houses," and "neighborhood dumps increased to 2 acres; access detectable." Another dump that appears on 1947 and 1962 air photos is characterized as an open dump with large mounds of refuse and along trench.

¹⁶ The RIFS states that the highest concentrations of total halogenated solvents were detected in the 65 to 70 foot bgs sampling interval approximately 3,500 feet downgradient of the NHP Site; however according to the scale provided in Figure 4.2 (1,000 feet per inch), the Autumn lane well is located approximately 4,300 feet from the Site.

¹⁷ A "J" flag indicates an estimated value.

located approximately 82 feet bgs) at concentrations of 470 $\mu\text{g/L}$ and 250 $\mu\text{g/L}$, respectively. PCE concentrations observed in groundwater collected from borings A and B (located on either side of the former leaching pool) during the 2001 source area delineation conducted by IT, were equal to 6,200 $\mu\text{g/L}$ and 1,300 $\mu\text{g/L}$, respectively. PCE concentrations observed in groundwater collected from borings C, E, F, and G (located inside the building approximately 50 feet to 70 feet south of the former leaching pool) during the same 2001 investigation were equal to 440 $\mu\text{g/L}$, 410 $\mu\text{g/L}$, 340 $\mu\text{g/L}$, and non-detect, respectively. These concentrations are significantly lower than 13,000,000 $\mu\text{g/L}$ PCE¹⁹ that was observed in a sample collected in November 1988 from the leaching pool north of the building (Sample IRA 11-15).

Residual soil contamination in the source area is also insufficient to provide appreciable mass via desorption from soil to groundwater to form a continuous plume from the Site to downgradient locations. PCE soil data were provided in Table 4.1 (mobile lab) and Table 4.2 (analytical lab) of the RIFS. According to Table 4.2, PCE was observed in MW-6 at the 20' to 22' depth interval (equal to 210,000 J $\mu\text{g/kg}$ or ppb) and at 7,700,000 J $\mu\text{g/kg}$ at the 80' to 82' depth interval in MW-7²⁰ during installation of these two borings in September 1997.

The associated geologic log for MW-7 (noted as MW-7A in the lithographic log as this designation was used as a blind duplicate sample sent to the analytical laboratory) indicates the presence of clay beginning at the 78-foot bgs depth interval. Despite the high soil PCE concentration in MW-7, the groundwater samples collected from this well²¹ were very low, equal to 1,000J $\mu\text{g/L}$ in October 1997²² decreasing to 330 $\mu\text{g/L}$ in October 1998. The high soil PCE concentration at the 80' to 82' bgs depth interval in MW-7 compared to the low groundwater PCE concentrations observed within the 10-foot well screen immediately above this location is explained by the high affinity of PCE within the clay where the elevated PCE adsorbed to soil was observed. Calculations conducted by Roux Associates indicate that the observed PCE groundwater concentrations at MW-7 are approximately 100,000-times or more lower than those predicted by equilibrium partitioning between soil and groundwater. This clearly indicates that

¹⁸ Data provided in Table 4.23 of the RIFS. Text on page 4-13 of the RIFS indicates that data are from October 16, 1997.

¹⁹ This value exceeds the reported water solubility of PCE, equals to 200,000 $\mu\text{g/L}$ (USEPA, 1996)

²⁰ The lithographic log provided in Appendix A to the RIFS denotes this location as MW-7A.

²¹ According to Table 2.2 of the RIFS, MW-7 is a 2-inch diameter well that is screened from 70 to 80 feet bgs.

²² PCE in a blind duplicate sample from this well, designated as MW-7A, was equal to 880 J $\mu\text{g/L}$.

PCE is bound to the clay at location MW-7 and is not a continuing source to groundwater at this location²³.

PCE concentrations in soil samples collected inside the building during IT's source area delineation that was conducted in 2001 at borings C, E, F and G located approximately 50' to 75' feet south of the former leaching pool, contained PCE at depths ranging from 5' to 82' bgs. The greatest PCE concentration (equal to 1,800 ppm) was observed at location C at the 5' depth interval²⁴. According to the IT report, "No indications of DNAPL were detected in any of the soil samples."

Step 2: Define the plume length

In order to estimate plume length, the distance between the following two locations needs to be evaluated: (1) the source area of the release and (2) the distance to which the center of mass has migrated.

The administrative record clearly indicates that the former leaching pool was the primary source of PCE contamination at the NHS Site. The June 1999 ROD concluded that, "With the exception of SDW-12N (0 – 2 feet bgs), which exceeded the NYSDEC soil cleanup level of 50 ppm for zinc (105 ppm), none of the unsaturated subsurface soil samples taken beneath and downgradient of the on-Site drywells and sanitary systems exhibited any contaminants exceeding NYSDEC soil cleanup objectives." The ROD also indicated that no soil contaminants were found in the unsaturated soils. However, PCE was detected in the saturated soils located directly below the leaching pool at concentrations exceeding the NYSDEC soil cleanup objective of 1.4 ppm. According to the ROD, "These results indicate that the leaching pool was the primary source area of PCE contamination."

Therefore, the center of the northern side of the Site building where the leaching pool was located was used as the source area of the release in estimating the plume length.

²³ The theoretical Kd for PCE is equal to 0.0816 L/Kg (272 L/Kg * 0.0003) compared to the calculated Kd value of approximately 7,700 L/Kg using the method of Feenstra et.al (1991). The ratio of Kd calculated to Kd (equilibrium) is 94,362. A groundwater concentration of 330 µg/L results in a calculated Kd value of 23,333 L/Kg and a ratio of Kd calculated to Kd equilibrium of 285,944.

²⁴ Soil at this 5 foot depth interval is above the water table which is located at approximately 15 feet to 20 feet bgs.

Roux Associates relied upon data collected from the middle and deep horizons to estimate the distance to which the center of mass of the PCE slug migrated based upon an initial off site groundwater investigation that was conducted in March 1998 and four additional geoprobe sampling locations (Autumn Lane, Miller Avenue, Susan Lane and Debbie Lane) that were completed along Schleigel Boulevard²⁵. Roux Associates did not rely upon groundwater data from the 50-foot bgs depth interval since the RIFS and ROD conceptual Site model shows Site contamination migrating vertically downward and then traveling in a downgradient direction to the top of the clay surface. Further, localized dumping was noted between Southern State and Sunrise Highway and drums were observed in a 1972 at multiple locations between the Site and Southern State Highway. Therefore, shallow contamination may not have originated from the subject Site.

Since both advection and dispersion contribute to the length of a plume, Roux Associates considered both the location of the maximum downgradient PCE location as well as the range in the observed center of mass to estimate plume length that existed as of March 1998 when off-Site groundwater samples were collected during the RI. As noted previously, the effects of dispersion tend to lengthen a plume migrating through an aquifer and need to be considered when evaluating travel time based on plume length. In advective-dispersive transport, the distance from the source area to the downgradient edge of the plume is the result of both advection and dispersion. As a result, dividing the entire length of a groundwater plume by the advection rate alone, results in erroneously long travel time estimates. Unfortunately, dispersion coefficients (i.e., dispersivity) are difficult parameters to quantify and are typically used as calibration tools in predictive modeling due to their variability and uncertainty. However, as noted by Baca (1999 & 2000), the distance from the source area to a plume's 'mid-level' concentration or center of mass is representative of the advective component of migration without the affects of dispersion. As a result, time-of-travel calculations based upon advection and the estimated distance to the middle of a plume can provide reasonable estimates of release dates for expanding, stable, or slug plumes. Using this approach, the following plume lengths were determined to complete the time-of-travel calculations.

- Using total VOC groundwater data from the 65 foot to the 70 foot depth interval (Figure 4.2):

²⁵ The RIFS does not state the dates that the four additional groundwater geoprobe locations were sampled. Roux Associates has assumed that these additional samples were also collected in calendar year 1998.

- Distance from north side of Site to Autumn Lane (where maximum total VOCs were observed) = ~4,300 feet.
- Range in distance from the north side of the on-site building to the beginning and end of the 100 µg/L contour depicted in Figure 4.2 of the RIFS = ~2,300 feet to **5,500** feet.
- Using total VOC groundwater data from the 75 foot to the 85 foot interval (Figure 4.3):
 - Distance from north side of Site to M-4 (where maximum total VOCs and maximum PCE were observed) = **~2,200** feet.
 - The distance from the north side of the on-Site building to the end of the 1,000 µg/L contour depicted in Figure 4.3 of the RIFS = ~4,500' (at the Susan Lane well).

These distances are also depicted in Figure 4.4 (Conceptual off-site cross section NHS) of the RIFS.

The values noted above range from 2,200 feet to 5,500. The midpoint between these two values is 3,850 feet.

Step 3: Identify contaminant transport parameters provided in the RI/FS

As discussed earlier, the PCE transport rate is dependent upon a number of hydrogeologic parameters that affect both the groundwater velocity and the chemical retardation which results in slower PCE transport as compared to groundwater velocity. Various values for these parameters have been provided by contractors conducting investigations at the Site (i.e. IT, and H2M) as well as in expert reports prepared by Charles McLane III and Charles Sosik. K_{oc} values have also been published by the USEPA²⁶. These values are summarized in **Table 2**.

Values of these parameters determined by contractors for the NYSDEC and presented in the RIFS are provided below:

- $I =$ 0.0014 to 0.00147
- $V_s =$ 1.323 to 1.34 ft/day (based upon a total porosity value of 0.3)

²⁶ EPA Soil Screening Guidance: Technical Background Document, EPA/540/R95/128, May 1996 and EPA Basics of Pump-and-Treat Groundwater Remediation Technology, PB90-274549, EPA-600/8-90/003.

- $K = 270 \text{ ft/day}^{27}$
- $n = 0.3$ (The RI states this as the 'porosity' rather than as the 'effective porosity').

The RIFS did not include values for K_{oc} or f_{oc} ; however, K_{oc} values are provided by USEPA (see previous footnote) and f_{oc} values are provided by Boguslavsky²⁸:

- $K_{oc} = 265 \text{ L/Kg}$ (geometric mean of values provided by USEPA) to 364 L/Kg
- $F_{oc} = 0.0003$

Step 4: Apply the selected contaminant transport parameters to the time-of-travel equations to determine PCE time-of-travel

The resulting calculated PCE migration rate will vary based upon the hydrogeologic parameters that are selected in the transport equations previously described. A groundwater seepage velocity of 1.59 ft/day was calculated using the hydraulic conductivity and gradient reported in table 6.1 of the RIFS (equal to 270 ft/day and 0.00147 ft/ft , respectively), and an effective porosity of 0.25^{29} . The following range in PCE retarded transport times was then calculated using the range in K_{oc} values published by the USEPA:

- $R_f = 1.52$ ($K_{oc} = 265 \text{ L/Kg}$ and $n_e = 0.25$) to 1.72 ($K_{oc} = 364 \text{ L/Kg}$ and $n_e = 0.25$)
- $V_c = 337 \text{ ft/year}$ ($R_f = 1.72$) to 382 ft/year ($R_f = 1.52$)

The PCE travel time can then be calculated according to the equation:

$$\text{Contaminant travel time} = \text{Plume length}/V_c$$

The text box below provides the ranges in contaminant travel times (rounding to eliminate fractional years) using the ranges in plume length and PCE velocity:

²⁷ The RIFS states that the hydraulic conductivity value of 270 feet/day is a standard value taken from the U.S. Geologic Survey for the Upper Glacial aquifer.

²⁸ Boguslavsky, S.; 2000, "Organic Sorption and Cation Exchange Capacity of Glacial Sand, Long Island; <http://pbisotopes.ess.sunysb.edu/reports/boguslavsky/>

²⁹ Since the RI only reported a value for total porosity, a value for effective porosity was required to complete the seepage velocity calculation. An effective porosity of 0.25 was selected based upon a March 2003 Final Report on the Long Island Source Water Assessment Program prepared by CDM for the NY State Department of Health and a November 1990 report by CDM on Nassau County Regional Groundwater Model Development and Calibration.

The text box below provides the ranges in contaminant travel times (rounding to eliminate fractional years) using the ranges in plume length and PCE velocity:

Time of Travel Calculations Using Range of Values				
Plume length vs. V_c		Minimum Center of Mass Plume Length	Mid Point Center of Mass Plume Length	Maximum Center of Mass Plume Length
		2200 feet	3850 feet	5500 feet
Low End V_c	337 ft/year	7 years	11 years	16 years
High End V_c	382 ft/year	6 years	10 years	14 years

As noted above, the range in time of travel for the midpoint center of mass is 10 to 11 years. This value is approximately equal to the midpoint of the travel times (equal to 9 years) that can be calculated using the hydrogeologic parameters presented by C. McLane³⁰:

Time of Travel Calculations using Hydrogeologic Values Assumed by C. McLane				
Plume length vs. V_c		Minimum Plume Length	Mid Point Center of Mass	Maximum Plume Length
		2200 feet	3850 feet	5500 feet
McLane V_r	440 ft/year	5 years	9 years	12 years

In summary, the time of travel for a slug of PCE to migrate from the northern side of the on-site building to the observed center of mass located downgradient of the Site is:

Time of Travel of PCE Slug Observed in 1998	
Mid point of range in values	10 to 11 years
Mid point using C. McLane values	9 years

³⁰ McLane used the following parameters in Section 4.4 of his January 2005 report: $K = 285$ ft/day; effective porosity = 0.23; horizontal hydraulic gradient = 0.0017; and a PCE retardation = 1.75. The resulting seepage velocity is 2.11 ft/day with a retarded PCE velocity of 1.21 ft/day = 440 ft/year.

Step 5: Calculate release date

Using the PCE time of travel discussed above, the PCE release date is calculated (rounding to eliminate fractional years) based upon the year in which the data were collected (1998) that formed the basis of the plume length using the equation below.

$$\text{Release Date} = (1998) - (\text{Time of Travel})$$

Using this equation, the release dates are:

Release Date of PCE Slug Observed in 1998	
Mid point of range in values based upon parameters provided in the RIFS (10 to 11 years)	1987 to 1988
Mid point using C. McLane values (9 years)	1989

Step 6: Sensitivity analysis

Sensitivity analysis is the process used to quantify the uncertainty in the time of travel results caused by uncertainty in the estimates of aquifer parameters. Sensitivity analysis is typically performed by changing one parameter value at a time to determine the associated effect on the output. The effects of changing two or more parameters also may be examined to determine a wider range of potential solutions.

The time of travel calculations presented earlier included a sensitivity analysis on hydraulic conductivity (and hence groundwater velocity) and plume length. As concluded earlier, using the hydraulic conductivity value of 270 feet/day as presented in the RIFS, it can be concluded that a slug release could have occurred from the NHS Site sometime between 1987 to 1988.

Using a somewhat different seepage velocity, as presented by C. McLane, Roux Associates calculated that a PCE release from the NHS Site would have occurred in 1989. However as presented in the section that follows (section 3.2), using the median Site specific hydraulic conductivity value determined during an on-Site pumping test (equal to 139 ft/day), it can be concluded that PCE observed downgradient of the Site can not be solely attributed to a PCE release from the NHS Site.

A range in retarded PCE migration rates were also determined based upon different assumed plume lengths (minimum, midpoint and maximum plume lengths to the center of mass of the

plume). However, it is Roux Associates' opinion that the midpoint to center of mass for the plume length best represents actual advective travel time as discussed earlier.

Step 7: Assess whether time-of-travel results are consistent with Site history

According to the ROD for the Site³⁰, after NHS filed for bankruptcy in 1987, the SCDHS discovered that NHS' chemical inventory had been dumped onto the soils and into a leaching pool located off the rear of the building in the northeast side of the property. The chemicals that were allegedly disposed at this location included PCE and TCE. This history is consistent with the release dates of 1987 through 1989 presented above.

3.2 PCE Travel Time Using Hydraulic Conductivity Values Determined During On-Site Pumping Test

Notwithstanding the previous discussions, Roux Associates evaluated groundwater and contaminant plume migration rates using information gathered during the Site-related aquifer pumping test conducted by IT Corporation during April 2001. As presented in IT Corporation's September 2001 report titled, "Extraction and treatment and In-Well Stripping System 65% Engineering Design report", a 67-hour pumping test was completed to determine Site specific transmissivity³¹ and specific yield³² values for the upper glacial aquifer. The test was completed by pumping groundwater from monitoring well MW-10 at rates ranging from 30 gallons per minute (gpm) to 50 gpm while monitoring groundwater elevation responses in several nearby monitoring wells with electronic pressure transducers. A step-drawdown test was completed during the initial 2.5 hours of the 67-hour test during which the pumping rate was systematically increased from 30 gpm to 50 gpm. The remaining 64.5 hours of the test was conducted at a pumping rate of 50 gpm. Extracted groundwater was discharged to the local municipal treatment facility through a nearby sanitary sewer. Data collected during the test was analyzed using industry standard methods and tools. Results of the analyses revealed three reliable hydraulic conductivities (based upon a reasonable 70-foot thick saturated thickness assumption):

- 125 ft/day at monitoring well MW-3A;
- 139 ft/day at MW-4A; and

³⁰ Record of Decision, National Heatset Printing Site, Site Number 1-54-140, June 1990.

³¹ Transmissivity is the rate at which an aquifer transmits water through a unit thickness of aquifer under a unit hydraulic gradient. It is related to hydraulic conductivity by the saturated thickness of the aquifer.

- 147 ft/day at MW-2A.

The median hydraulic conductivity was equal to 139 ft/day³³. Data analysis also revealed specific yield values of 23% at MW-2A and MW-3A and 8% at MW-4A. IT discounted the results based on data collected from MW-9 as being unreliable as groundwater elevation responses at this location were not consistently detected until almost 3,000 minutes or about 50 hours into the test. Although Roux Associates did not independently analyze the aquifer pumping test data, a review of IT Corporation's curve matching analyses did not reveal any issues that would discredit the values presented in their report.

3.2.1 Site-Specific Groundwater and PCE Migrations Rates Based on Pumping Test Results

Using the parameters determined from the pumping test results, Roux Associates calculated Site-specific migration rates. As noted earlier, the groundwater seepage velocity, V_s , describes groundwater velocity or advection rate and is defined as:

$$V_s = \frac{KI}{n_e}$$

where: K = hydraulic conductivity

I = hydraulic gradient

n_e = effective porosity.

Based upon the median Site-specific hydraulic conductivity value of 139 ft/day and median effective porosity value of 23%, and the Site-specific hydraulic gradient of 0.0014, the groundwater seepage velocity at the Site is approximately 0.846 feet/day or 309 feet/year. As previously described, the rate of dissolved-phase PCE migration is retarded or is slowed due to adsorption of the chemicals onto aquifer material and is related to the groundwater seepage velocity. The retardation factor, which relates the contaminant migration rate to the groundwater advection rate was calculated to range from 1.52 to 1.72, and as a result, the Site-specific PCE advective migration rate ranges from 180 ft/year to 203 ft/year.

³² Specific yield is the amount of water that can drain, under the forces of gravity, from saturated aquifer material. Specific yield and effective porosity are roughly equivalent.

³³ The 139 ft/day value differs from the 253 ft/day value stated in sections 4.4 and 5.3 of the June 2001 IT Source Area Delineation Report.

3.2.2 Migration Potential Based upon Site-Specific Parameters – Advective Transport

PCE plume lengths based upon advective transport³⁵ resulting from PCE releases during NHS' occupancy of the Site were calculated using aquifer pumping test-based Site-specific transport rates. If PCE were released to the on-Site leaching pool, located on the north side of the on-site building, in 1983 or immediately upon NHS' occupancy, the advective front of the PCE plume would have migrated approximately 720 feet to 810 feet by the time PCE was detected in the private well on Miller Avenue in 1987³⁶. However, the Miller Avenue well is located approximately 4,000 feet from the north side of the NHS Site. Further, the advective front of a PCE release to the on-site leaching pool in 1983 would have migrated 2,700 to 3,045 feet as of 1998 when samples were collected as part of the Site RI/FS. However, the RI/FS concluded that the PCE plume was longer than this distance (approximately 5,900 feet long) in 1998 (distance from the source area north of the NHS building to the 'non-detect' level). Alternatively, if PCE were released in 1987 when NHS filed for bankruptcy, the advective front of the PCE plume would have migrated approximately 1,980 feet to 2,230 feet by the time that the 1998 Site investigation reported PCE concentrations of 100 µg/L approximately 5,700 feet downgradient of the Site (p 4-13 of RI/FS). Based on these calculations it can be concluded that neither the 32 mg/L PCE concentration observed in a private well on Miller Avenue or a 5,700-foot long PCE plume that was identified in the 1999 RI/FS can be attributed to PCE released from the NHS Site.

3.2.3 Migration Potential Based upon Site-Specific Parameters – Advective and Dispersive Transport

To assess the effects of dispersion upon migration distances, Roux Associates used the one-dimensional transport model BioScreen 1.4 (US EPA, 1996). Dispersivity, or the dispersion coefficient, was estimated by using the relationship presented by Xu and Eckstein (Xu and Eckstein, 1995) as implemented in BioScreen. Using the Site-specific advective groundwater seepage velocity of 309 ft/year, the low end of retardation factors equal to 1.52, an assumed constant PCE source strength of 200 mg/L (theoretical saturation), and no degradation, the distances to 1 µg/L (an assumed detection limit), 100 µg/L and to 1,000 µg/L were calculated for travel times associated with NHS occupancy and PCE detections. The results of the dispersion-based migration distance are summarized below.

³⁵ These results do not include the effects of dispersion.

³⁶ The 1999 RIFS reported that 32 mg/L of PCE was detected in the private well on Miller Avenue in 1987.

Summary of Dissolved PCE Plume Lengths Incorporating the Effects of Dispersion ³⁷				
Migration Period	Dispersivity (ft) Based on Xu and Eckstein as calculated by BioScreen			
	Dispersivity (ft)	Plume Length (ft) to 1 $\mu\text{g/L}$	Plume Length (ft) to 100 $\mu\text{g/L}$	Plume Length (ft) to 1,000 $\mu\text{g/L}$
1983 to 1987 (4 yrs)	22.4	~1,600	~1,300	~1,100
1987 to 1998 (11 yrs)	33.6	~3,600	~3,200	~2,800
1983 to 1998 (15 yrs)	37.6	~4,800	~4,200	~3,700

As summarized above, a PCE release from the NHS Site in 1983 could not have resulted in the 32 ppm (32,000 $\mu\text{g/L}$) of PCE observed in the Miller Avenue private wells (located approximately 4,000 feet from the NHS source area) sampled by the SCDHS during 1987. Further, the length of the leading edge of a PCE plume at the concentrations noted in the text box above resulting from a release either at the beginning of NHS' Site occupancy in 1983 or at the time NHS filed for bankruptcy in 1987, could not have extended to distances reported in the RIFS based on data collected in 1998 (i.e. 5,700 feet to the 100 $\mu\text{g/L}$ contour level). Additionally, if PCE were released in 1983, plume length calculations that include dispersion also predict a plume shorter than that observed in 1998. As summarized above, when the effects of dispersion are incorporated into plume length calculations, the length of the plume reasonably attributable to a release during NHS' occupancy is shorter than what has been observed in the general vicinity of the NHS Site. It can, therefore be concluded that neither the 32 $\mu\text{g/L}$ PCE observed in a private well on Miller Avenue or a 5,700-foot long PCE plume that was identified in the 1999 RI/FS can be attributed to PCE released from the NHS Site.

³⁷ A retardation factor of 1.72 would result in shorter plume lengths. Note that values shown in this table represent the distance to the leading edge of the plume at the stated concentration contour line with dispersion effects included.

4.0 REFERENCES

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TABLES

Table 1: Summary of Suffolk County Inspection Reports Reviewed	
October 12, 1983	October 6, 1983 inspection 'revealed that you will be discharging photo plate making waste to your sanitary system.' (0006672)
March 14, 1985	Rust red in numerous locations on south side of the building (S020482)
April 2, 1985	Observed one, 2700 G oil UST; unbermed chemical storage areas; fiber drum with yellow and red material; one 30-G plastic container with a thin, red liquid containing rinse water for printing (S020659).
April 10, 1985	Need to register 2700-G oil tank and indoor/outdoor drum storage (S020661)
April 17, 1985	In violation of Article 12 regarding storage and handling of raw and waste toxic materials.
March 28, 1986	Thirty-eight unregistered drums being stored; no receipts for toxic waste disposal and "strong evidence of dumping from staining of inks and oils on ground check outside drums (14)." (S020821). Chemicals noted include: developer, polychrome, ink, water, buffer, press wash, waste fountain solution, water water/oil fountain solution; blackish stain outside garage door on north side
April 2, 1986	Seyfarth Exhibit 7: Black stain with runoff from under the door
February 2, 1988	Notice of Violation for "Discharge of waste oil to open leaching pools at rear of building; IRM-2-2- sample taken for organic and metals parameters). Compounds included 1,2-DCE (24,000 ppb); 1,1,2-TCE (88 ppb); xylenes (270 ppb); p-ethyl toluene (1,000 ppb); 1,3,5-TMB (290 ppb) and 1,2,4-TMB (850 ppb). PCE < 40 ppb (S020509)
February 9, 1988	Nine, 55-G drums with unknown contents on west site of building (S020511).
April 27, 1988	Leaching pool at rear of building obviously has not been cleaned out. Several pipes coming from the north side of this building exiting the rear wall about 1 foot above ground that then turned downward in the ground to an unknown discharge point. These pipes do not appear to be roof drain pipes and there purpose and discharge points should be further investigated." (0006802)
May 4, 1988	Observed waste oil leaking from a 55-G drum and spillage on floor inside building. (0006798)
June 2, 1988	Photos of various drums around building. Several sample from drum #1, 2, 4 and 5; results showed toluene, ethylbenzene, xylenes, and trimethylbenzenes but no PCE (0006780; S020518; S020519; 0006782; S020517) (S020469 to 484)

Table 2: Hydrogeologic Parameters

Parameter	Value	Units	Comment	Source
Koc - PCE	265	L/Kg	Geo Mean	1
Koc - PCE	272	L/Kg	Average	1
Koc - PCE	177	L/Kg	Minimum	1
Koc - PCE	373	L/Kg	Maximum	1
Koc - PCE	364	ml/g	Value	2
l	0.0017			3
l	0.00147			5
l	0.0018			7
ne	0.23			3
ne	0.25			6,9
foc	0.0003			8
bulk density	1.65	g/cm ³		3
n	0.3			3
Longitudinal dispersivity	1/20 of plume length			3
K	270	ft/day	USGS standard	5
K	285	ft/day		3
K	253	ft/day		4,7
K	137	ft/day	Average in Table 3-1	6
K	139	ft/day	median	6
K	164	ft/day	Value used in Table 3-2. Note, this value appears to be a transcription error of the highest value from the pumping test (146.6 ft/day)	6
K	172	ft/day	Used by Shaw in time of travel	9
Sp. Yield	0.18		Average shown in Table 3-1	6
Sp. Yield	.08 to 0.20		range	6
Sp. Yield	.09 to .24		range	7
Sp. Yield	0.19		average	7
R	1.5		lower end estimate	3
R	1.75		conservative factor	3
R	1.52		using Koc = 265 and ne = 0.25	Ram
R	1.72		using Koc = 364 and ne = 0.25	Ram

Vs (ft/day)	Values used			Comment
	K (ft/day)	l	n	
0.846	139	0.0014	0.23	site-specific mean K
1.59	270	0.00147	0.25	RI adjusted for ne = 0.25

Vs	R	Vr	ft/year	10 year plume (ft)
0.846	1.52	0.56	203	2,032
0.846	1.72	0.49	180	1,795
1.59	1.52	1.05	382	3,818
1.59	1.72	0.92	337	3,374

References	
1	EPA, Soil Screening Guidance: Technical Background Document, EPA/540/R95/128, May 1996
2	EPA, Basics of Pump-and-Treat Ground Water Remediation Technology, PB90-274549, EPA-600/8-90/003
3	Expert Report of Charles F. McLane III, January 2005
4	2001 pump test data by IT as reported in Sosik report
5	RIFS, National Heatset Printing, February 1999, H2M
6	IT Corporation, September 2001, Extraction and Treatment and In-Well Stripping System 65% Engineering Design Report
7	June 11, 2001, IT Corp., Source Area Delineation Report Pilot Test Work Plan
8	Boguslavsky, S., 2000, "Organic Sorption and Cation Exchange Capacity of Glacial Sand, Lond Island; http://pbisotopes.ess.sunysb.edu/reports/bogusalvsky/
9	January 20, 2005, Downgradient Treatment Systems Project Final Engineering Design Report, Tab 1: Plume Migration Calculations

APPENDICES

APPENDIX A

Curriculum Vitae of Dr. Neil Ram

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Credentials:

Post Doctorate, Environmental Engineering, Technion Institute of Science, Haifa, Israel, 1980;
Ph.D., Environmental Engineering, Harvard University, Cambridge, MA, 1979
M.S., Environmental Engineering, Harvard University, Cambridge, MA, 1977
M.S., Environmental Science, Rutgers University, New Brunswick, NJ, 1975
B.S., Environmental Science, Rutgers University, New Brunswick, NJ (with honors), 1973.

Technical Specialties:

Contaminant fate and transport, environmental forensics, litigation support, Federal and State Superfund programs; environmental liability assessment, environmental chemistry, site assessment, risk assessment, Remedial Investigation Feasibility Studies (RI/FS), and remediation technology. Expertise in hydrogeology, water and corrosion chemistry and microbial ecology. Additional expertise in the screening, selection, design, implementation, operation and costing of remedial systems; selection and evaluation of sampling and analysis programs; data quality and data interpretation, environmental audits and water and wastewater treatment engineering. Projects have included, Federal and State Superfund sites, large industrial sites, abandoned sites, mining operations, gasoline service stations, and former manufactured gas plant and coal tar processing sites. Expertise in compliance with the National Contingency Plan (NCP), cost recovery and cost allocation, fate and transport of chemical contaminants and engineering design of unit operations. Worked on hazardous waste sites contaminated with organic solvents, non-aqueous phase liquids (both light [LNAPL] and dense [DNAPL]), gasoline constituents (BTEX and MTBE), PCBs, chlorobenzenes, mercury, chromium, lead and other metals, and acidic and mixed waste in all environmental matrices. Designed and developed treatability studies, written guidance for EPA's RCRA program and has helped the Massachusetts Department of Environmental Protection develop new regulations under the Massachusetts Contingency Plan (the MCP) and the State's Underground Storage Tank (UST) reimbursement program (21J). Expert in drinking water programs and treatment systems including extensive work with water disinfection and carbon adsorption systems with particular focus on the formation and removal of trihalomethanes (THMs) and MTBE from water.

Experience Summary:

Over 25 years experience in environmental engineering, hazardous waste assessment, and remediation: Vice President and National Client Manager of Roux Associates (1999 – present), General Manager, Gradient Corporation (a wholly-owned subsidiary of IT Corporation - 1999), Vice President and Manager of the New England District for Fluor Daniel GTI, Inc. (1991 – 1999), Senior Project Manager at ICF Kaiser Engineers (1989 – 1991), Senior Program Manager at Stone & Webster Engineering Corporation (1987 – 1989), Chemistry Division Manager at Alliance Technologies, Inc. (1984 – 1987), Assistant Professor of Civil Engineering at the University of Massachusetts at Amherst (1980 – 1984), and Post Doctoral Research Fellow at the Technion Institute of Science (1979 – 1980).

Testifying Expert

- Compliance with the National Contingency Plan: Provided expert opinions about whether response actions have been in substantial compliance with the NCP in order to determine eligibility for cost recovery under the NCP. Reviewed technical reports and other documentation to determine their compliance with requirements and EPA and State response actions under the NCP in the following areas: (1) worker health and safety, (2) documentation of costs, (3) appropriateness of response, (4) site evaluation, (5) RI/FS, (6) Remedial Design/Remedial Action, and (7) Public information and community relations. Clients have included several industrial companies, major oil companies, a mining company, and a municipal sewerage authority. Projects have included sites contaminated with solvents, PCBs, petroleum, heavy metals and VOCs. Also evaluated areas where alternative technologies could have been employed to provide more cost effective cleanup. Dr. Ram has also managed several Remedial Investigation Feasibility Studies and Human Health Risk Evaluations at federal Superfund sites (see "Additional areas of technical expertise").
- Hydrogeology/Chemical Fate and Transport: Expert opinions on timing of contaminant release using groundwater fate and transport models including simple advective flow models (Darcy's Law) to more complex computer models including MODFLOW and MT3D.
- Landfills: Expert opinions regarding historical operations at municipal landfills and cost allocation among multiple parties that transported or disposed of wastes and operated at landfills. Also provided opinions on the source and impact of various landfill constituents on downgradient receptors. Landfill sites have included: the Agriculture Street Landfill in New Orleans, LA; North Carver Landfill, North Carver, Massachusetts; Charles George Landfill, Massachusetts; Municipal Waste Transfer Station, Abington, Massachusetts; and the University of Maine Mixed Waste Landfill in Orno Maine.
- Environmental Chemistry (Environmental Forensics): Provided opinions regarding the timing of chemical releases using environmental forensic tools. Technical approaches have included chemical markers and additives, chemical component ratios, degradation analysis, chemical "fingerprinting," isotope analysis, groundwater modeling (time-of-travel) and factual information about historical site operations. Has opined about release dates of petroleum constituents at gasoline service stations, polychlorinated biphenyls (PCBs) and chlorinated solvents at industrial facilities, PAHs at former manufactured gas plant sites and fuel oil at industrial and residential properties. Also opined on data quality and validity of analytical methods and reported results. Has also opined about the causes of corrosion. Authored featured article (1999) in the Journal of Environmental Science and Technology on Environmental Forensics.
- Remediation: Provided opinions on the selection, design, implementation and associated costs of remediation systems to address soil and groundwater contamination using both state and federal technology selection criteria. Reviewed the design

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of municipal water supply wells and private water supply point-of-use treatment systems.

- Cost Allocation: Has allocated costs amongst potential responsible parties (PRPs) based upon equitable factors including toxicity, mass, distinguishability, degradability and facilitated transport of chemical contaminants. Has rendered opinions regarding the necessity and appropriateness of costs expended pursuant to the quality and type of data collected, response actions taken and adherence to pertinent federal and state environmental regulations. Authored feature article (2005) in the Journal of Environmental Science and Technology on cost allocation at hazardous waste sites.
- MTBE Migration and Treatment
Prepared expert reports and given courtroom testimony on the source, impact and treatment of MTBE for both private and public water supply systems. Have also modeled MTBE Subsurface transport to estimate release date(s). Reviewed MTBE treatment system design, treatment duration and costs. Conducted forensic analysis to distinguish MTBE gasoline formulations from pre-MTBE gasoline releases. Allocated costs between differential gasoline releases at service stations.
- Natural Resource Damage Claims: Retained by a paint manufacturer to formulate an allocation approach for funding an integrated multi-year study of the Lower Passaic River in connection with a Natural Resource Damages claim filed against about three dozen parties by the New Jersey Department of Environmental Protection for damage to this river. Designed an allocation based upon the available documentation and institutional knowledge about each parties' historical practices and discharge occurrences and the associated frequency and severity of these historical discharges. Also, retained as an expert witness on behalf of a chemical manufacturing company against a claim filed by the Department of Justice alleging fraudulent reporting of reasonably estimateable financial reserves for environmental liabilities. Provided opinions as to whether potential NRD claims should have been included in annual financial statements of this publicly-traded company.
- Former Coke Manufacturing and Coal Tar Processing Site: Technical expert on allocating past and future costs between past owner/operators of the largest coke manufacturing facility in the United States. Used GIS to map historical site features and operating parameters to identify source, timing and pathways of chemical releases (mostly polyaromatic hydrocarbon (PAH) and metals) from past operations. Assessed relative production rates and changes in site operations to allocate responsibility. Evaluated contaminant distribution as a tool in determining source and timing.
- Bankruptcy: As part of bankruptcy proceedings, provided sworn affidavit as to whether site abandonment would result in an imminent and substantial harm to the environment.
- Storm water flow
Provided opinions on the impacts of land development on surface water flow to down stream properties. Identified parameters effecting surface water runoff including: soil type, slope, cover, percent impervious cover, climate and season. Also described erosion mechanisms and storm water management to reduce erosion. Modeled surface water infiltration to groundwater and overland flow onto down stream property.
- Corrosion Failure
Provided expert opinions on the causes and timing of corrosion of underground storage tanks (USTs) and other steel structures based on site-specific information and the general industry knowledge about the causes of metal failure from corrosion. Has taught graduate level courses on the environmental chemistry of corrosion.
- UST systems
Formulated opinions regarding the cause for UST failures associated with various UST system components including tanks, product piping, dispenser drip pan and pumps, spill buckets, test boots, leak detectors and other system components. Knowledgeable about industry standard of care for testing and maintenance of UST systems. Patent in progress for testing the interstitial chamber of thermoplastic flexible product piping.
- Alleged Fraudulent Conveyance During Bankruptcy: Formulated opinions as to whether future environmental reserves were reasonably estimable according to Generally Accepted Accounting Principles (GAAP) and industry guidance. Provided sworn deposition at deposition to support claim filed by the U.S. Department of Justice.
- Mining Sites: Formulated opinions regarding liability, damages, cost allocation, environmental compliance, and remediation costs for several large mining operations contaminated with hazardous constituents including the Libby Mine in Libby, MT; Pinal Creek Mines near Phoenix Arizona and the Leadville mines in Leadville Colorado.
- Mediator: Provided binding opinion in dispute between two major oil companies regarding cause of historical releases and associated cost allocation to each of the two parties.

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Additional Areas of Expertise and Experience

- Federal Superfund Site Investigations and Feasibility Studies:** Dr. has managed or assisted in overseeing Superfund Remedial Investigation/Feasibility Studies and applications for Technical Impracticability, including the U.S. Titanium in Virginia (acidic wastes), MGM Brakes in Cloverdale, CA (PCBs), the Groveland NPL site in Groveland, MA (VOCs), the Picillo Farm NPL site in Picillo, Rhode Island (solvents and metals), Charles George landfill in Massachusetts (solvents and metals), the Morses Pond time critical removal action in Wellesley, MA (chromium), the Hows Corner NPL site in Maine (solvents), the Henderson Road NPL Site in Upper Merion Township, Pennsylvania (VOCs) and the Union Chemical NPL site in Maine (solvents).
- Massachusetts Hazardous Waste Sites:** Dr. Ram is and has been the Licensed Site Profession (LSP) of record for both Tier I (high priority sites) and Tier II (lower priority sites) Disposal sites contaminated with petroleum, metals, VOCs, and semi volatile organics for both industrial and major oil customers. Sites include a former specialty gas manufacturer (metals), a former electroplating company (metals and VOCs), a former chemical manufacturing company (chlorobenzenes), gasoline service stations and other industrial sites (VOCs and metals). As LSP, Dr. Ram has overseen the assessment and cleanup of these sites as required under the Massachusetts Contingency Plan (the 'MCP').
- Risk Assessment:** Managed risk assessments to evaluate the extent of contamination and its impact to human health and the environment. Primary editor for two books on the risks associated with drinking water contaminated with organic chemicals. Former manager of Enviroligic Data, Inc.; and Gradient Corporation.
- Environmental Compliance Audits and Permitting:** Conducted dozens of environmental compliance and liability audits at industrial facilities throughout the United States and in the United Kingdom to determine potential liabilities associated with site contamination and regulatory compliance. Regulatory compliance audits included air pollution control; water pollution control; hazardous waste management; solid waste management; underground storage tanks; materials, products and pesticide storage; PCB management; asbestos; past disposal practices; and occupational health and safety.
- Site Remediation, Engineering, and Design:** Project Director for large number of industrial and UST sites to identify and implement remediation technologies to achieve desired cleanup goals. Remediation technologies have included: groundwater recovery and treatment, in-situ and ex-situ bioremediation, air and ozone sparging, soil vapor extraction (SVE), thermally enhanced, SVE, excavation with off-site treatment, recovery of Non Aqueous Phase Product (NAPL), steam injection, monitored natural attenuation (MNA), and oxidation technologies such as permanganate injection.
- Chemical Fate and Transport Modeling:** Conducted analyses using a variety of industry-accepted models including MODFLOW, MT3D, VLEACH, and SESOIL. Determined plume migration and impacts, timing of plume arrival at receptors, and cleanup time frames based on calibrated input parameters.
- Water and Wastewater Engineering:** Taught graduate courses on water and wastewater treatment unit operations.

Conducted disinfection research projects for USEPA and the National Science Foundation. Conducted doctoral research on precursors to the formation of trihalomethanes (THM's). Also performed both algal assay and fish toxicity studies.

- Sampling and Analysis:** Managed an environmental laboratory of over 20 chemists involved in the analysis of complex matrices for chemical contaminants. Designed sampling for assessing the nature and extent of site contamination in environmental matrices.
- Regulatory Support:** Evaluated the Massachusetts Department of Environmental Protection's (DEP) waiver program under the MCP. Worked with the MADEP staff in establishing criteria for audit selection, identifying audit points in the MCP, and formulating audit activities. Assisted the MADEP in implementing several elements of the 1993 MCP. Assisted the MADEP and the Massachusetts Underground Storage Tank (UST) Board in writing regulations to implement the 21J UST reimbursement program.
- Training:** Has given many short courses and seminars to both private sector and regulatory agency personnel on various environmental technical topics.

Publications:

Books

"Proposed Compliance Audit, Compliance Assistance and Enforcement Program for the Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup Program," Chapter 39 in Hydrocarbon Contaminated Soils, Volume 3, Lewis Publishers, Inc., 1993 (co-authored with Anne Heffron and Brian Moran).

"Massachusetts Waiver Program Audit," Chapter 8 in Hydrocarbon Contaminated Soils, Volume II, Lewis Publishers Inc. 1992. (co-authored with Read, E., Mark Wert, and Sarah Weinstein).

"Significance and Treatment of Volatile Organic Compounds in Water Supplies," Lewis Publishers, Inc., ISBN-0-87371-123-8, 1990, (co-authored with R. Christman, and K. Cantor).

"Organic Carcinogens in Drinking Water: Detection, Treatment, and Risk Assessment," John Wiley & Sons, Inc., ISBN-471-80959-4. 1986, (co-authored with E. Calabrese and R.F. Christman).

Patents

Patent for Collecting Liquid and Vapor Samples from the Interstitial Chamber of Thermoplastic Flexible Product Delivery Piping, in progress

Journal Publications and Recent Proceedings

Ram, N.M. with N. Epler and M. Wiest, "Use of Graphics for Environmental Litigation Support: Examples from Real Cases," 2005 National Groundwater Association Ground Water and Environmental Law Conference, July 21-22, 2005; Baltimore, MD.

Ram, N. M. Wiest, and C. Davis, "Allocating Cleanup Costs at Hazardous Waste Sites," Journal of Environmental Science and Technology, March 2005.

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- Ram, N., "The Tools of Environmental Litigation Support: How Environmental Litigation Support Teams Employ a Unique Set of Skills and Tools to Improve the Outcome and Reduce the Cost of Legal Disputes," Environmental Forensics, 1, 25-30. 2000.
- Ram, N.; Leahy, M; Carey, E.; and Cawley, J. - "The Environmental Sleuth: Technical Approaches and Forensic Tools Can Determine Historic Causes, Timing and Impacts of Site Contamination"; Environmental Science & Technology, November 1, 1999.
- Ram, N.; "The Tools of Environmental Litigation Support: How Environmental Litigation Support Teams Employ a Unique Set of Skills and Tools to Improve the Outcome and Reduce the Cost of Legal Disputes"; International Journal of Environmental Forensics, 1 (1), March 1999.
- "Variation in the Use of Risk Based Groundwater cleanup Levels at Petroleum Release sites in the United States," Human and Ecological Risk Assessment, August 1997, (co-authored with B. Hoskins, P. Patrick, J. M. Cawley, Jr.
- Technology Effectiveness: A Response to Robert D. Fox, "Physical/Chemical Treatment of Organically Contaminated Soils and Sediments," Air and Waste Management, autumn 1996, (co-authored with W. Barber, D. Bass, R. Brown).
- "In-Situ Sparging: Mass Transfer Mechanisms"; John Wiley and Sons, Inc., September 1996, (co-authored with W. Clayton, D. Bass, C. Nelson), Remediation.
- Ram, N. *et al.*, "A Decision Framework for Selecting Remediation Technologies at Hydrocarbon-Contaminated Sites," Journal of Soil Contamination, 2(2): 167-189, 1993 (co-authored with D. Bass, R. Falotico, and M. Leahy).
- Ram, N. "Response Strategies Can Reduce Compliance Costs for Soil, Groundwater Contamination Problems," Manufacturers' Mart, New England, April 1992. Vol 13 No. 4, page 15.
- "Total Trihalomethane Formation During Targeted versus Conventional Chlorination of Seawater for Biofouling Control," Journal of Water Pollution Control Federation, September 1990, (co-authored with Yusaf Mussalli and Winston Chow).
- "Preoxidant Effects on Organic Halide Formation and Removal of Organic Halide Precursors," Environmental Technical Letters, published by Science and Technology, England, Volume 9, pp. 1089-1104, 1988, (co-authored with J.K. Edzwald and J. Malley).
- "Review of the Significance and Formation of Chlorinated N-Organic Compounds in Water Supplies Including Preliminary Studies on the Chlorination of Alanine, Tryptophan, Tyrosine, Cytosine, and Syringic Acid," Environment International, Vol. 11, 441-451. 1985.
- "Validity of Chlorine Residual Monitoring in the Presence of N-Organic Compounds in Water Supplies," Journal of American Water Works Association, 76:9, 74-81. 1984, (co-authored with J.P. Malley, Jr.).
- "Disinfection," Journal of Water Pollution Control Association, 76:9, 74-81. 1984, (co-authored with A. Venosa).
- "Multiple Bioassays to Assess the Toxicity of a Sanitary Landfill Leachate," Archives of Environ. Contam. and Tox., 13:2, 197-206. 1984, (co-authored with S. Plotkin).
- "Algal Assay Methods for Assessing the Impact of Wastewater Effluent on Receiving Waters," New England Water Pollution Control Journal, 17:1, 10-27. 1983.
- "Predicting Algal Stimulatory Properties of Wastewater Effluent," Journal of Env. Eng. Div. ASCE, 109:5, 1099-1110. October, 1983, (co-authored with P. Austin).
- "Selective Passage of Hydrophilic Nitrogenous Organic Materials Through Macroporous Resins," Environmental Science and Technology, 16:3, 174-174. 1982, (co-authored with J.C. Morris).
- "Microbial and Chemical Changes Occurring at the Mud-Water Interface in an Experimental Fish Pond," 33(3):71-76. Bamidgeh, Bulletin for Fish Culture in Israel. 1981, (co-authored with S. Utilizur and Y. Avnimelech).
- "Microbial Changes Occurring at the Sediment-Water Interface in an Intensively Stocked and Fed Fish Pond," Aquaculture, 27, 63-72. 1982, (co-authored with O. Zur and Y. Avnimelech).
- "Identification of Nitrogenous Organic Compounds in Aquatic Sources by Stopped-Flow Spectral Scanning Technique," Journal of Liquid Chromatography, 4(5), 791-811. 1981, (co-authored with J.C. Morris).
- "Environmental Significance of Nitrogenous Organic Compounds in Aquatic Sources," Environment International, 4:5/6, 397-405. 1981, (co-authored with J.C. Morris).
- "Nitrification in Four Acidic Streams in Southern New Jersey," Water Resources Investigations, pp 22-121. U.S. Geological Survey Publication. January 1978, (co-authored with J. Schornick).

Certifications:

- Certified Hazardous Materials Manager, December 1991
- Massachusetts Licensed Site Professional (License #6799)
- 30-Hour Total Quality Management & Quality Action Team Training, 1992 and 1993
- 40-Hour OSHA Training, 1989
- 8-Hour OSHA Supervisory Training, 199
- Annual OSHA Refresher Courses

Professional Affiliations and Activities

- Completed 16-hour training on "Negotiating Environmental Agreements," Massachusetts Institute of Technology, December 1997.
- Editor, "TechnoFlash," Fluor Daniel GTI, Inc.; 1991 – 1999
- Licensed Site Professional Association, 1993 – present
- Institute of Hazardous Materials Management, 1991 – present
- Hazardous Materials Control Research Institute, 1987 – 2000
- American Chemical Society, 1989 – present (Member # 00459672)
- American Water Works Association, 2003 (Member # 00066314)
- American Water Works Association, Project Advisory Committee, VOC Off-Gas Control, 1987 – 1989
- Standard Methods Committee (SMC), 17th Edition, 1987 – 2000
- National Groundwater Association, 2003 (Member # 3128931)
- Water Environment Federation, 1993 – present (Member # 01757759)

APPENDIX B

Testimony Experience of Dr. Neil Ram

NEIL M. RAM, PhD, LSP

Roux Associates, Inc.

nram@rouxinc.com

Testimony Experience [court testimony indicated by asterisk (*)]

Dr. Ram has provided testimony in court, at public meetings and in sworn depositions. In several cases Dr. Ram also submitted affidavits containing extensive technical analysis of data and expert opinions. Dr. Ram's testimony experience includes:

1. Gloria King *et al.* vs. Amerada Hess Corporation, Circuit Court for Baltimore County, 88CG 3637 60/27, June 5, 1991.
2. Westfarm Associates Limited Partnership vs. Washington Suburban Sanitary Commission, No. 94-1425, United States District Court for the District of Maryland, No. HM-92-9, July 1, 1993.*
3. Robershaw Controls Company vs. Watts Regulator Company *et al.*, (D. Me. C.A. No. 91-0382-PC), Civil Action File No. 91-0382-PC, United States District Court for the District of Maine, October 2, 1992 and October 14, 1992.
4. The Southland Corporation and Ewing Oil Company vs. The Marley Corporation, in the United States District Court for the District of Maryland, Civil Action No. L91-339, August 6, 1992.*
5. Charles Edison and Rosella Edison vs. Hyman Bluestein, the Estate of Bertha Bluestein, Joyce D. Weiner, Dr. Ruth E. Wolfe, Gulf of Maine Research Center, Inc. and Hugh F. Mulligan, Commonwealth of Massachusetts, Essex, SS, Salem Superior Court, C.A. No. 91-791., April 1994.
6. Suffolk County Water Authority vs. Fermenta ASC Corporation and SDS Biotech Corporation, Supreme Court of the State of New York, Index No. 89-2040, January 19, 1996 and March 14, 1996.*
7. Federal Insurance Company by and through Aviation Underwriters vs. Purex Industries, Inc., and Purex Industries, Inc., vs. Federal Insurance Company by and through Associated Aviation Underwriters, Houston Fire and Casualty Company by and through Houston General Insurance Company; and Liberty Mutual Insurance Company, United States District Court for the District of New Jersey, Civil Action Number 93-CV-393 (JBS), March 18-20, 1997.
8. Village of Ridgewood vs. Shell Oil Company, *et al.*, Superior Court of New Jersey, Law Division, Bergen County, Docket No. BER-L-780-92, January 7 and 8, 1997.
9. Ray Doino vs. Bruce Smith, *et. al.*, United States District Court Eastern District of New York, Civil Action No. 95-3942, September 5, 1997.
10. Weyerhaeuser Company vs. Commercial Union Ins. Co., Superior Court of the State of Washington for King County, No. 92-2-05214-8-SEA, February 10, 1997.
11. Iowa Comprehensive Petroleum Underground Tank Fund Board vs. Shell Oil Co., Case No. LACC027677 (Caseys, Springville) Iowa District Court for Linn County, November 25, 1997.

12. Iowa Comprehensive Petroleum Underground Tank Fund Board vs. Shell Oil Co., Case No. LA23137 (Caseys DeWitt). Iowa District Court for Clinton County, March 24, 1998.
13. Iowa Comprehensive Petroleum Underground Tank Fund Board vs. Shell Oil Co., Case No. LACE90388 (Dittmer Davenport). Iowa District Court for Scott County, March 24, 1998.
14. A. Kanavos vs. Bayer Corporation, Civil Action No. 96-07232D. Commonwealth of Massachusetts, Middlesex County Superior Court, January 26, 1998, February 6, 1998, and February 10, 1998 (deposition) and August 9, 2000 (trial).*
15. USA vs. J. Lightman, Civil Action No. 92-4710. In the U.S. District Court for the District of New Jersey, deposition: April 28-29, 1998; direct: *December 14-15, 1999; rebuttal: *January 19-20, 2000.
16. Iowa Comprehensive Petroleum Underground Tank Fund Board vs. Shell Oil Company, Law No. LACV71297 (Bavarian Inn). Iowa District Court for Polk County, January 15, 1999.*
17. Iowa Comprehensive Petroleum Underground Tank Fund Board vs. Shell Oil Company, Law No. LACV71298 (Southtown Unocal). Iowa District Court for Polk County, March 10, 1999.*
18. W. R. Grace & Co. and Ecarg, Inc., vs. Weja, Inc. d/b/a Clean Machine Car Wash, et al., Superior Court of New Jersey, Law Division, Hudson County, Docket No. HUD-L-7908-95. Jersey City, New Jersey. December 1, 1999.
19. Carolyn Enterprises, Inc., etc., et al. vs. Shell Oil Company, etc., et al., Docket No. MRS-L-2378-96, May 9, 2000, and July 11, 2000.
20. Laura Dunne, et al. vs. Shell Oil Corporation; Supreme Court of the State of New York, County of Westchester. June 2, 2000.*
21. Anamet, Inc., etc., et al. and Service Stations Specialists, Inc. vs. Shell Oil Company, etc., et al.; United States District Court for the District of New Jersey; Docket No. Civil Action No. 97-3985 (FSH), July 7, 2000.
22. Buell Industries, Inc. vs. Greater New York Mutual Insurance Company, et al.; Superior Court of Connecticut; Docket No. X04-CV-98-0116309-S. July 14, 2000.
23. Sherwin-Williams vs. Artra, et al.; United States District Court for the District of Maryland; Docket No. Civil Action S-91-2744. July 26 - 27, and August 2, 2000 (deposition), and November 12 and 13, 2001 and December 3, 2001 (trial).*
24. Commonwealth of Massachusetts, Abington Board of Health, in the matter of the Abington Transfer Station, LLC, before Hearing Officer Edward H. Masterson, January 22, 25, and February 8, 2001.*
25. Commonwealth of Massachusetts, Swan. Vs. Planning Board of East Bridgewater and Russell S. Graban & Company, Superior Court Civil Action No. 97-1080, July 16, 2001*
26. Home Insurance Company vs. Cornell-Dubilier Electronics et. al., Superior Court of New Jersey Law Division, Mercer County, Docket No. MER-L-5192-96, October 15 and 16, 2001

* Denotes trial testimony

27. The Fishbein Family Partnership vs. PPG Industries and Public Service, Electric, and Gas Co., (Garfield Avenue Site) Civil Action No. 93-653 (DMC), December 12, 2001
28. The Fishbein Family Partnership, PPG v. Lawrence Construction Company, Docket No. HUD-L-195-93 (Settles Site), December 12, 2001.
29. Mediator in binding mediation between Phillips Petroleum Company and Exxon Mobil Corporation for two service stations in Brookhaven and Norriton, PA, March 6, 2002
30. Albert Baccari Jr., and V. Baccari v. Shell Oil Products Company and Shell Oil Company, U.S. District Court for the District of Rhode Island, June 27, 2002
31. Official Committee of Asbestos Personal Injury Claimants and Official Committee of Asbestos Property Damage Claimants of W.R. Grace & Co. v. Sealed Air Corporation and Cryovac, Inc. vs Fresenius Medical Care Holdings, Inc. and National Medical Care, Inc., Case Number 01-1139, September 19, 2002.
32. The Fishbein Family Partnership vs. PPG Industries and Public Service, Electric, and Gas Co., (Garfield Avenue Site) Civil Action No. 93-653 (DMC), September 27, 2002.
33. Lakeside Swimming Pool and Supply Co., Frank D'Andrea and Elsriba D'Andrea vs. DB Companies, Inc., State of Rhode Island Superior Court Case No. PC-95-1558, Deposition on November 6, 2002, trial testimony on December 11, 2002.*
34. Gary Irby, et al. vs. United States Department of the Navy, et al., Case No. AW 003151, United States District Court of Maryland, August 18, 2003 (deposition), August 9 2004 (trial) and July 11, 2005 (trial).*
35. Hudson Transit Lines, Inc., vs. Transport Insurance Company, Liberty Mutual Insurance Company, and Fidelity & Casualty Company, Superior Court of New Jersey, Law Division: Bergen County Docket No. BER-L-8173-01, June 2, 2004.
36. John Lennox v. Mark-One, Inc., Middlesex Superior Court C.A. No.:01-03917-E; November 24, 2004.

* Denotes trial testimony