TECHNICAL REPORT

Remedial Investigation Report

Volume I of II

Solvents Recovery Service of New England, Inc.
Superfund Site
Southington, Connecticut

Prepared For:
SRSNE PRP Group

June 1998

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Executive Summary

This Remedial Investigation (RI) Report presents the results of RI data acquisition and evaluations completed by Blasland, Bouck & Lee, Inc. (BBL), on behalf of the Solvents Recovery Service of New England, Inc. (SRSNE) Site Potentially Responsible Parties (PRP) Group, regarding the SRSNE Superfund Site in Southington, Connecticut. This document serves as a supplement to the extensive RI Report prepared by HNUS Corporation (HNUS, May 1994) on behalf of the United States Environmental Protection Agency (USEPA), which summarized three phases of RI completed by HNUS between approximately May 1990 and December 1992. HNUS (May 1994) characterized the geology, hydrogeology, soil and ground-water quality, and completed a risk assessment for the SRSNE Site. These data and a considerable quantity of background information and data evaluations were presented in the previous, four-volume RI Report (HNUS, May 1994).

This Executive Summary provides a synopsis of each section of this RI Report.

Section 1. Introduction

- The information presented in this document fills specific data gaps that remained following twenty previous subsurface investigations, removal actions, and/or investigatory reports regarding the RI Study Area, including three phases of RI performed by HNUS on behalf of the USEPA. This report completes the characterization of the SRSNE Site, and supports the Feasibility Study, which will develop and analyze appropriate remedial alternatives for the site.

- Data gaps that remained following the three previous RI phases led to the following five objectives, which were identified in the RI Work Plan (BBL, November 1995), and filled during the completion of the RI:

  1) Further characterize the non-aqueous-phase liquid (NAPL) zone associated with the SRSNE Site and assess its restoration potential.

  2) Delineate and define the nature and extent of the off-site volatile organic compound (VOC) plume associated with the SRSNE Site.

  3) Assess whether the off-site VOC plume impacts or could potentially impact private water-supply wells.

  4) Delineate recoverable light NAPL (LNAPL).

  5) Assess vadose zone VOC contribution to the ground-water plume.

- To meet the above-listed objectives, and provide sufficient data to support a Technical Impracticability (TI) Evaluation as part of the forthcoming FS, several types of specialized data acquisition and evaluation techniques, and substantial field investigation activities were performed between June 1996 and July 1997.

Section 2. Site Background and Physical Setting

- The SRSNE Site RI Study Area is situated within the Quinnipiac River Valley, approximately 15 miles southwest of the city of Hartford, Connecticut.

- Subsurface investigations in the RI Study Area began with the development of the Town of Southington Well Field in the 1960s. Environmental investigations were initiated in the late 1970s due to the detection of VOCs at Production Wells No. 4 (which operated from 1966 to 1977) and No. 6 (which operated from 1978 through

1979). The subsequent evaluation of VOC sources in the vicinity of Production Wells No. 4 and 6 by the Connecticut Department of Environmental Protection (CT DEP, April 1978; October 1978) and a USEPA subcontractor (Warzyn, November 1980) identified five potential VOC sources, including the SRSNE Site. Ground-water sampling and hydraulic head measurements performed during this RI confirmed the presence of VOC plumes unrelated to the SRSNE Site in closer proximity to Town Wells No. 4 and 6. CT DEP enforcement orders have been issued to some of the property owners in the vicinity of Town Wells No. 4 and 6.

- For the purposes of this RI Report, the terms "SRSNE site" and "site" refer to the SRSNE Operations Area and the immediately downgradient Containment Area, which was established as part of Non-Time Critical Removal Action No. 1 (NTCRA 1).

- The key components of the RI Study Area include the SRSNE Operations Area, the adjoining former Cianci Property (including the NTCRA 1 Containment Area), the Town of Southington Well Field Property, and surrounding areas.

- Between 1955 and 1991, SRSNE processed in excess of 41 million gallons of waste solvents, fuels, paints, and similar liquid materials. A small fraction of these materials is believed to have entered the subsurface due to placement of distillation sludge in two unlined lagoons on site, occasional overflow of materials from these lagoons to ditches adjacent to the site, and incidental spills and leaks from drums, hoses, tanks, trucks, etc.

- The geology of the RI Study Area includes unconsolidated deposits composed of Pleistocene glacial outwash and till, with isolated deposits of fill and alluvium, overlying fractured, Triassic New Haven Arkose bedrock.

- The 216 monitoring wells, extraction wells, wetland drive points, and piezometers that comprise the ground-water monitoring network in the RI Study Area have been sorted into the following five hydrostratigraphic zones based on stratigraphy and for ease in data interpretation:

  - *Shallow, middle and deep overburden*, which represent the upper, middle, and lower thirds of the saturated overburden deposits, respectively; and

  - *Shallow and deep bedrock*, which represent approximately the upper 30 feet of bedrock and a zone between 60 and 90 feet below the top of bedrock, respectively.

- Seven previous remedial actions have been performed at the SRSNE Site.

  - Lagoon closure (1967);
  - 1983 Consent Decree remedial measures (installation of spill control and fire prevention measures, and surface pavement) (1983 to 1991);
  - On-site interceptor system installation and use for ground-water extraction and treatment (1985 through 1992);
  - SRSNE Site post shutdown cleanup of tanks and containment structures (1991);
  - Ditch sediment excavation and removal action (1992);
  - USEPA, Time Critical Removal Action, with removal and off-site disposal of laboratory chemicals, laboratory equipment, and processing equipment (1994); and
  - NTCRA 1, including the design, installation, and operation of a downgradient overburden ground-water containment and treatment system (1994 through present).

Section 3. Study Area Physical Characteristics

- The ground water within the monitored geologic section in the RI Study Area (to a depth of approximately 270 feet below grade) discharges to the Quinnipiac River and its tributaries. This inference is based on the observed hydraulic gradients, surface-water elevations, surface-water flow rates in the Quinnipiac River, and fundamental hydrogeologic principles.

- Ground-water flow converges toward the Quinnipiac River from both sides of the river throughout the monitored geologic section. This finding is consistent with the historical data measured during the previous investigations in the RI Study Area. Overburden hydraulic gradients also demonstrate flow into the NTCRA 1 overburden ground-water containment system. A potentiometric depression in the shallow bedrock in the vicinity of the NTCRA 1 overburden ground-water containment system indicates partial containment of shallow bedrock ground water due to the NTCRA 1 system.

- Vertical hydraulic gradients throughout the monitored section of overburden and bedrock in the study area are generally upward in the vicinity of the Quinnipiac River, downward within localized areas further from the river, and upward or neutral in the central portion of the Town of Southington Well Field Property. This finding is consistent with the historical data measured during the previous investigations in the RI Study Area.

- The overburden geologic formations include several glacially-derived soil units that range in texture from silty, fine sand to clean sand and gravel, with occasional cobbles and boulders. The horizontal hydraulic conductivity of the overburden is relatively low on site, but it increases by up to three orders of magnitude toward the south within the Town of Southington Well Field Property. This increase corresponds with a gradation from relatively silty outwash and till on site, to coarser outwash and gravelly drift in the Town Well Field Property. The overburden has been characterized as heterogenous and anisotropic in horizontal and vertical perspectives.

- Fractures within the New Haven Arkose bedrock were characterized in terms of dip angle, dip direction, aperture, and spacing. Bedrock fractures are primarily parallel to the gently east-southeastward dipping bedding.

- The hydraulic properties of the fractured New Haven Arkose bedrock are interpreted as highly heterogeneous on a small scale due to the variable spacing and connectedness of bedrock fractures; however, on a regional scale, the bedrock is believed to be relatively homogeneous and anisotropic. The bulk bedrock hydraulic conductivity in the plane of bedding is consistent with data reported in the literature.

Section 4. Nature, Extent, and Fate of Chemical Constituents

- The VOC plumes associated with the SRSNE Site extend into the Town of Southington Well Field Property, but do not extend to the locations of Town Production Wells No. 4 or 6, which are inactive. Several other VOC sources (unrelated to the SRSNE Site) are evident in the RI Study Area, some of which are situated closer to dormant Production Wells No. 4 and 6. The ground-water VOC plume associated with the SRSNE Site has been delineated in the shallow, middle, and deep overburden, and the shallow and deep bedrock. To simplify the analysis of VOC plumes related to the site, which processed numerous types of organic liquid wastes, plumes have been delineated on the basis of applicable ground-water regulatory criteria (rather than concentration contours for specific compounds), the potential extent of NAPL sources, and fundamental ground-water hydraulics and solute-transport principles. The ground-water quality database was used to identify wells that exhibited one or more exceedences of ground-water regulatory criteria. The locations of these wells were used to define a "regulatory plume" in each of the five monitored zones.

- Two private water-supply wells are located immediately upgradient (north) of the site, near at the edge of the VOC plumes associated with the SRSNE Site. One of the two private wells in question has contained VOCs in excess of ground-water regulatory criteria, and the CT DEP supplies that property owner with bottled water. The other well in question has historically indicated low concentrations of VOCs below applicable ground-water regulatory criteria (HNUS, July 1994). However, as an additional precaution, the SRSNE PRP Group is taking action to provide municipal water to these two properties. All other water-supply wells in the area around the site, including Town of Southington Production Wells No. 4 and 6, are outside of the regulatory VOC plumes attributable to the SRSNE Site.

- The Baseline Risk Assessment completed by HNUS (May 1994) identified that the potential risks associated with the ingestion of the study area ground water exceed USEPA target levels. The highest calculated ground-water ingestion risks relate to the Operations Area/former Cianci Property and the area immediately east of the Quinnipiac River downgradient of the Operations Area. As described by HNUS (May 1994), no current ground-water receptors exist in the areas downgradient and cross-gradient (immediately north) of the SRSNE Site, where the calculated ground-water ingestion risks exceeded target levels. Long-term risks relating to off-site ground-water quality will be managed through a final remedy for the portion of the regulatory VOC plume that extends beyond the TI zone.

- The probable and potential NAPL zones have been delineated in the overburden and bedrock in consort with Bernard Kueper, Ph.D., P.Eng. The potential overburden and bedrock NAPL zones cover approximately 12.4 and 14.2 acres, respectively, and were delineated on the basis of VOC effective solubility calculations for soil and ground-water matrices, site history and usage, and the relationships between the configuration of the VOC plumes and hydraulic gradients at the site.

- NAPL thickness measurements at wells and piezometers indicated measurable LNAPL at only one overburden well, signifying a limited distribution of potentially recoverable LNAPL. Free-phase, dense NAPL (DNAPL) was observed at four overburden and three bedrock wells and piezometers in the Operations Area and the (downgradient) former Cianci Property. Approximately 20 liters of DNAPL were collected as part of the NTCRA 1 activities, but the current DNAPL collection rate by the NTCRA 1 system is negligible. The exact distribution of NAPLs in the heterogeneous overburden and the fractured bedrock is sporadic and unpredictable. The NAPL is present as both disconnected blobs and ganglia of organic liquid referred to as residual, and in larger (potentially-mobile) accumulations referred to as pools.

- Vadose-zone solute transport (VLEACH modeling) results and VOC mass estimates indicate that vadose-zone soil remediation would not significantly reduce the dissolved VOC mass flux from the Operations Area. The overall contribution of VOCs to the saturated zone from the vadose zone in the Operations Area is negligible. The contribution of VOC leaching from the vadose zone accounts for approximately 7.4 percent of the total trichloroethene (TCE) mass flux within the saturated zone in the Operations Area. The net flux for ethylbenzene was from the saturated zone to the vadose zone due to diffusion from the water table. The remainder of the mass flux in the saturated zone in the Operations Area is attributed to NAPL solubilization and, potentially, VOC desorption from saturated soil. The total VOC mass in the vadose zone represents only 0.15 percent of the total combined subsurface VOC mass associated with the SRSNE Site.

- The distribution of VOCs in the vadose zone correlates closely with the Operations Area infrastructure where NAPL was stored and handled, including the primary and secondary solvent sludge storage lagoons, open-pit incinerator, leach field, and drum storage areas.

- The Baseline Risk Assessment (HNUS, May 1994) evaluated potential soil exposure risks based on the following assumed exposure pathways: 1) incidental ingestion; 2) dermal contact; and/or 3) inhalation of fugitive dusts. The only calculated Human Health Risk that exceeded USEPA acceptable levels for dermal contact with soil was related to the Operations Area and former Cianci Property surface soils. The existing pavement within the Operations Area prevents direct exposure to soil. The SRSNE PRP Group will also cap the Operations Area to further limit exposure to surface soils at the site under NTCRA 2.

- Natural attenuation of chlorinated organics in ground water was assessed based using the United States (US) Air Force method (Wiedemeier et al., September 1996; November 1996). The geochemical parameters indicate "adequate evidence" (rank between 15 and 20) to "strong evidence" (rank greater than 20) for biodegradation of chlorinated organics at the majority of the locations within the ground-water regulatory plume(s) where natural attenuation parameters were characterized. A detailed review of biologic and geochemical ground-water parameters and VOC degradation products confirms robust, active biodegradation within the probable NAPL zones and within the majority of the off-site, regulatory VOC plumes in overburden and bedrock. In general, VOC concentrations decline by approximately three orders of magnitude within a distance of 500 feet downgradient of the site. Nevertheless, temporal VOC concentration trends suggest concentrations may be increasing in the northern portion of the Town Well Field Property, immediately downgradient of the NAPL zones.

- The VOC plumes related to the SRSNE Site have resulted in little or no impact to surface-water quality in the Quinnipiac River. Surface-water analytical data indicate detectible VOCs at the inlet and outlet of the underground, 30-inch culvert that crosses beneath the former Cianci Property. Surface water samples from the Quinnipiac River indicated no detectible VOCs upstream of the culvert on December 30, 1997. Low concentrations of VOCs were detected upstream of the culvert on July 8, 1997. Immediately downstream of the culvert outlet, low concentrations of VOCs were detected in the river during both of these sampling events, with concentrations decreasing to non-detectible within approximately 500 feet downstream from the culvert.

- A graphical comparison between low-flow and traditional ground-water purging and sampling results for VOCs indicated similar results from both two methods. The majority of the data indicated slightly higher VOC concentrations detected in the traditional samples, and lower VOC concentrations detected in the low-flow samples, suggesting that traditional sampling is more conservative with respect to VOC plume delineation.

Section 5. Technical Impracticability Data Summary

- A TI Evaluation is appropriate for the SRSNE Site due to the presence of large quantities of NAPL in the subsurface, the highly heterogeneous nature of the geologic formations in the RI Study Area, and the influence of bedrock matrix diffusion.

- VOC mass calculations were performed by BBL in consort with Dr. Kueper. These calculations indicate that approximately 97.7 percent of the total subsurface VOC mass [2.20 million kilograms (kg), equivalent to 529,000 gallons of NAPL] associated with the SRSNE Site is in the form of NAPLs, and the remainder of the mass is in dissolved, sorbed, or vapor phase. Approximately 96.6 percent of the total subsurface VOC mass (2.18 million kg, equivalent to 520,000 gallons of NAPL) is in the saturated overburden, 3.2 percent (72,000 kg, equivalent to 17,000 gallons of NAPL) is in the bedrock, and 0.15 percent (3,500 kg, equivalent to 830 gallons of NAPL) is in the vadose zone. Given that more than 41 million gallons of waste liquids were processed at the SRSNE Site, the total estimated subsurface VOC mass associated with the site represents no more than 0.2 to 2.4 percent of the total materials processed by SRSNE.

- Detailed hydrogeologic characterization of the overburden and bedrock units, including their structure and hydraulic conductivity, indicate that these units are highly heterogeneous and complex at a small scale. Overburden strata observed in two test pits were discontinuous on a scale of a few feet, and exhibited cross-bedding, and varying dip directions along the contacts between layers. The overburden hydraulic conductivity was found to range by more than two orders of magnitude within a distance of a few feet based on soil samples collected at the test pits. The hydraulic conductivity of the bedrock matrix is approximately six orders of magnitude less than the hydraulic conductivity of the bedrock fractures.

- The bedrock matrix porosity represents a significant storage capacity for VOCs that diffuse into the matrix from the fractures, as confirmed by bedrock matrix VOC analysis. Matrix diffusion reduces the migration rate of the bedrock VOC plumes by a factor of 900 to 1,100. However, matrix diffusion will also significantly hinder efforts to restore bedrock ground-water quality. Preliminary matrix diffusion calculations performed by Dr. Kueper indicate that diffusion of VOCs back out of the bedrock matrix after the dissolution of NAPL will take hundreds of years.

- The TI zone, which will be delineated as part of the FS, will include

  - The potential NAPL zones in overburden and bedrock;

  - The zone where VOCs have diffused into the bedrock matrix to the degree that removal from the matrix can not be achieved within an acceptable time frame; and

  - The portion of the VOC plume downgradient of the two above-listed zones and upgradient of the capture zone that will be achieved by a permanent ground-water remedy, which will be specified in the ROD to address the off-site regulatory VOC plume.

Section 6. Interim Monitoring and Sampling

- Additional ground-water sampling will be performed at the edges of the interpreted VOC plumes as detailed in the proposed Interim Monitoring and Sampling Plan (presented as an appendix to in this RI Report). This work will be performed prior to the issuance of the Record of Decision (ROD) and, based on the results discussed above, should employ traditional purging and sampling methods. Additional surface-water sampling is also proposed along the Quinnipiac River as part of the interim monitoring and sampling program.

Section 7. Treatability and Pilot Studies

- Two potential uses for treatability and pilot studies within the RI Study Area include:

  - The evaluation of phytoremediation (treatment of contaminated soil, sediment, and ground water using plants) as a potential technology to naturally remove and treat VOC-impacted ground water; and

  - The pilot-scale assessment of ground-water collection and treatment using a constructed wetland, which is among the remedial alternatives (Alternatives GW-3A and GW-3B) currently being considered to address the off-site VOC plume.

- A phytotoxicity greenhouse study will be performed to assess whether poplar trees can grow in the overburden ground water from the NTCRA 1 Containment Area.

- A pilot study may also be appropriate to evaluate whether a constructed wetland would effectively treat dissolved VOCs in ground water that would discharge into the wetland from the shallow overburden zone. Wetlands have been used effectively to treat municipal waste water and landfill leachate, and may represent a promising technology to cost-effectively collect and treat VOC-impacted ground water within the off-site regulatory VOC plume.

Section 8. Summary and Conclusions

- The data gathered during the completion of the RI, which are discussed in detail in this RI Report, have achieved the following objectives described in the RI Work Plan (BBL, November 1995):
  - Delineated the overburden and bedrock zones containing NAPLs in terms of a probable NAPL zone where NAPL presence is known or highly suspected, and a potential NAPL zone, which serves as a safety factor due to the complexity of NAPL delineation in heterogeneous and fractured geologic media;
  - Characterized the nature and extent of the off-site VOC plume using pertinent ground-water regulatory criteria, the possible dimensions of the NAPL zone, regional ground-water hydraulics, solute-transport characteristics, and other potential VOC source areas. The VOC regulatory plumes associated with the SRSNE Site have been distinguished from several other, unrelated plumes associated with other VOC sources;
  - Characterized the potential impact of the SRSNE-related plumes on private water-supply wells;
  - Delineated the extent of LNAPLs in the overburden; and
  - Characterized the potential VOC loading to site ground water from the vadose zone. Vadose zone mass loading rate to overburden ground water was estimated using a vadose zone leaching model (VLEACH). The model was applied to two representative VOCs, including TCE and ethylbenzene.
- The NAPL zones in overburden and bedrock cover approximately 12.4 and 14.2 acres, respectively.
- The regulatory VOC plumes related to the SRSNE Site have been delineated in the shallow, middle and deep overburden and the shallow and deep bedrock. The plumes in the middle overburden and shallow bedrock extend the furthest downgradient of the site. Several other plumes, which are unrelated to the SRSNE Site, are also evident based on historical and new ground-water quality data. The SRSNE plumes have negligible impact on surface-water quality in the adjacent Quinnipiac River.
- Two private wells are situated near the upgradient edges of the VOC plumes associated with the SRSNE Site. Only one of these wells has historically indicated VOC concentrations above regulatory criteria, and this property is currently supplied with bottled drinking water by CT DEP. However, as an additional precaution, the SRSNE PRP Group will provide municipal water to these two properties. No other water-supply wells are within the regulatory VOC plumes attributed to the SRSNE Site, including Town of Southington Production Wells No. 4 and 6.
- LNAPL was observed at one only overburden monitoring well (0.01 foot thickness) near the center of the former SRSNE Site Operations Area, indicating a limited extent and quantity of potentially recoverable LNAPL.
- Leaching calculations for TCE in the vadose zone indicate that the simulated vadose-zone TCE flux to ground water within the Operations Area represented 7.4 percent of the total flux leaving the Operations Area through

overburden ground water. For ethylbenzene, the total flux to ground water from the vadose zone was negative due to rapid volatilization and diffusion from the ground water to the vadose zone.

- The Baseline Risk Assessment completed by HNUS (May 1994) identified that the potential risks associated with the ingestion of the study area ground water exceed USEPA target levels. However, as noted by HNUS, no current ground-water receptors exist in the areas downgradient and cross-gradient (immediately north) of the SRSNE Site, where the calculated ground-water ingestion risks exceeded target levels.

- The Baseline Risk Assessment (HNUS, May 1994) also evaluated potential soil exposure risks related to the Operations Area and former Cianci Property surface soils. The existing pavement within the Operations Area prevents direct exposure to soil. The SRSNE PRP Group will also cap the Operations Area to further limit exposure to surface soils at the site under NTCRA 2.

- The Quinnipiac River is interpreted as the discharge location for the ground water within the monitored geologic section of the RI Study Area, which extends to a depth of approximately 270 feet below grade.

- Approximately 96 percent of the total subsurface VOC mass associated with the SRSNE Site is in the form of NAPL in the saturated overburden, 3.2 percent is in the bedrock (approximately half of which is NAPL), and 0.15 percent is in the vadose zone. The total subsurface mass of VOCs is estimated as approximately 383,000 to 4.1 million kilograms. Converted to an equivalent volume of NAPL (assuming a mean NAPL density of 1.15 g/mL), this range of total VOC mass corresponds to 92,000 to 990,000 gallons of NAPL, which represents no more than 0.2 to 2.4 percent of the waste materials processed at the site.

- A TI Evaluation is appropriate for the SRSNE Site because of the presence of large quantities of slowly dissolving NAPLs in the saturated zone, heterogeneous nature and low permeability of the geologic media underlying the site, and the influence of matrix diffusion into bedrock. Collectively, these factors are expected to render aquifer remediation technically impracticable.

- The following RAOs have been developed for vadose-zone soil and ground water, in consideration of the potential human health risks associated with exposure to surface soils at the Operations Area and Cianci Property, the human health risks associated with exposure to ground water, the technical impracticability of remediating the NAPL-zone (i.e., the contaminant source), and alternative remedial strategies.

  Vadose-Zone Soil: Continue to limit potential human exposure to vadose-zone soils and mitigate the migration of constituents to ground water.

  Dissolved Phase Ground Water: Limit potential future human exposure through ingestion, direct contact and inhalation, and restore ground-water beyond the TI zone to the extent practicable.

1. Introduction

1.1 General

This Remedial Investigation (RI) Report describes the field investigations, data acquisition, and evaluations that were performed to complete the Remedial Investigation (RI) for the Solvents Recovery Service of New England, Inc. (SRSNE) Superfund Site located in Southington, Connecticut (Figures 1 and 2). This document was prepared by Blasland, Bouck & Lee, Inc. (BBL), in accordance with the Statement of Work (SOW) issued by the United States Environmental Protection Agency (USEPA) as part of the second Administrative Order on Consent (AOC, USEPA Region I CERCLA Docket No. I-97-1000) between USEPA and the SRSNE Potentially Responsible Party (PRP) Group, which was signed on February 6, 1997. This RI Report describes the data collection and interpretation associated with the completion of the RI for the SRSNE Superfund Site. In conjunction with the information presented in the previous RI Report, which was prepared by Halliburton NUS (HNUS) Environmental Corporation (HNUS, May 1994), this report satisfies the requirements of an RI as specified in the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) as amended, 42 U.S.C. 960 *et. seq.*; and the USEPA guidance document entitled *"Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA"* (USEPA, 1989). This report also complies with the National Contingency Plan (NCP) (40 CFR Part 300). This report was prepared based on an RI Report Outline that was submitted to USEPA and CT DEP on August 26, 1997, and discussed with USEPA and CT DEP at a meeting in Boston on September 11, 1997.

Numerous subsurface investigations were completed in the RI Study Area (Figure 2) prior to the current RI, beginning with investigations in support of the Town of Southington Well Field development in the 1960s. Later, the USEPA conducted three RI phases between approximately May 1990 and December 1992 that characterized the geology, hydrogeology, and soil and ground-water quality at the SRSNE Site (defined in Section 2.1) and surrounding area. These data and a considerable quantity of background information and data evaluations were presented in the previous, four-volume RI Report (HNUS, May 1994) which, in combination with this document, comprises the RI Report for the SRSNE Site. During subsequent development of the Feasibility Study (FS), however, USEPA determined that significant data gaps remained, which precluded completion of the FS and selection of a final remedy for the site. Subsequently, USEPA requested that the SRSNE PRP Group perform additional investigations and pilot studies to fill the data gaps and support the design and implementation of a Non-Time Critical Removal Action (NTCRA 1) to contain overburden ground water [characterized by high concentrations of solvent-related volatile organic compounds (VOCs) in both dissolved and non-aqueous phases] at, and immediately downgradient of the site. The NTCRA 1 Ground-Water Containment and Treatment System was constructed between February and July 1995, and began operation in July 1995. In June 1995, USEPA issued an Action Memorandum for a second NTCRA (NTCRA 2) to hydraulically contain VOC-impacted bedrock ground-water downgradient of the site. In June 1995, USEPA also initiated negotiations for the second AOC, which included the NTCRA 2 SOW and the RI/FS SOW. Pursuant to the NTCRA 2 SOW, the SRSNE PRP Group has initiated bedrock ground-water modeling activities, and has used the model to select an appropriate location to install a bedrock pumping well. (An Interim Technical Memorandum summarizing the set-up and preliminary simulation results from the NTCRA 2 model is presented as Appendix J of this document). The NTCRA 2 Design Investigation began in October 1997 and will provide necessary data to complete the NTCRA 2 Containment System design.

Recognizing that certain data gaps precluded the completion of an FS and selection of a remedy for the site, the SRSNE PRP Group agreed to perform the additional focused investigations described in the RI Work Plan (BBL, November 1995) to fill the data gaps, complete the RI, and support the remedy evaluation in the FS. To address USEPA and Connecticut Department of Environmental Protection (CT DEP) comments regarding the Draft RI Work Plan and Draft Project Operations Plan (POP) (BBL, January 1996), BBL prepared an RI Work Plan Addendum (BBL, February 13, 1996), RI Work Plan Addendum No. 2 (BBL, June 7, 1996), and RI Work Plan

Addendum No. 3 (BBL, June 18, 1996). On August 14, 1996, USEPA conditionally approved the following documents:

- RI Work Plan (BBL, November 1995);
- Draft POP (BBL, January 1996);
- RI Work Plan Addendum (BBL, February 13, 1996);
- RI Work Plan Addendum No. 2 (BBL, June 7, 1996); and
- RI Work Plan Addendum No. 3 (BBL, June 18, 1996).

BBL addressed USEPA's comments through the submittal of a Final POP (BBL, August 1996). Beyond the scope of work described in the above-listed USEPA-approved documents, several additional modifications were made to the scope of work, as described in RI Work Plan Addenda Nos. 4 through 7 and communicated via meetings, telephone discussions, or letters. Appendix A describes in detail the modifications to the USEPA-approved RI Work Plan.

Based on the identification of free-phase, pooled, non-aqueous phase liquids (NAPLs) during the NTCRA 1 construction activities, the PRP Group will also prepare a Technical Impracticability (TI) Evaluation for the site as part of the FS. The data gathered to complete the RI, discussed in this RI Report, have:

- Delineated the overburden and bedrock zones potentially containing NAPLs, which were encountered at six locations during the implementation of NTCRA 1 and five locations during this RI. The NAPL zone delineated during the completion of the RI will be the focus of a TI Evaluation with respect to ground-water restoration, based on the USEPA document *"Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration"* (USEPA, September 1993; CT DEP, January 1996). The NAPL zone includes dense and light NAPLs (i.e., DNAPL and LNAPL).

- Characterized the nature and extent of the off-site VOC plume, considering pertinent ground-water regulatory criteria, the possible dimensions of the NAPL zone, regional ground-water hydraulics, solute-transport characteristics, and other potential VOC source areas.

- Characterized the potential impact of the SRSNE-related VOC plumes on private water-supply wells.

- Delineated the extent of potentially recoverable LNAPL.

- Characterized the potential VOC loading to site ground water from the vadose zone.

HNUS previously compiled, evaluated, and summarized a considerable quantity of data in their four-volume RI Report, including the historical data generated prior to the first three phases of the RI (HNUS, May 1994). The primary purpose of this final RI Report is to enhance the site information presented by HNUS (May 1994), present the new information obtained by BBL to fill the data gaps discussed in the RI Work Plan (BBL, November 1995), and to provide a sufficient basis to proceed with the FS for the site. While this final RI Report does not re-package all of the data that have been obtained historically at the site, the results of previous investigations are summarized to provide background for the new information. This final RI Report also discusses aspects of regional hydrogeology and aqueous-phase, regulatory VOC plume extent that warrant reinterpretation based on newly acquired, comprehensive rounds of ground-water and surface-water elevation measurement and sampling. Previously documented ground-water and soil analytical data and hydrogeologic information (well construction, hydraulic heads, hydraulic conductivity values) were compiled into a comprehensive relational database that also contains the newly-acquired data that complete the RI and fill the data gaps that remained following the first three phases of the RI. A similar database was also created to store and process soil data from the site. The comprehensive database was used to help characterize the site hydrogeology and distribution of VOCs discussed in this RI Report.

A TI Evaluation will be developed for ground water within:

- The potential NAPL zone;
- The zone where extensive matrix diffusion of VOCs has occurred into the geologic media; and
- The area between these zones and the downgradient extent of hydraulic capture achieved by the eventual, long-term ground-water containment system.

A TI Evaluation is appropriate for the SRSNE Site because of the presence of slowly dissolving NAPLs in the saturated zone, the heterogeneous nature and low permeability of the geologic media underlying the site, and the likely influence of matrix diffusion in bedrock. The demonstrated presence of NAPLs in the subsurface will substantially limit the site's restoration potential. The TI Evaluation will be prepared as a stand alone document, which will be included as an appendix to the FS Report. The FS will also include a containment and/or natural attenuation strategy to address the off-site VOC plume delineated during this RI. In support of the eventual TI Evaluation, this RI Report includes a TI Data Presentation, which describes: 1) the estimated three-dimensional volume of the overburden and bedrock NAPL zones; and 2) the estimated total VOC mass dissolved, sorbed, or present as NAPLs in the overburden and bedrock.

Bernard H. Kueper, Ph.D., P.Eng., an Associate Professor of Civil Engineering at Queens University in Kingston, Ontario, assisted in the preparation of this RI Report by providing supplemental data regarding overburden heterogeneity, and assistance with evaluating the nature and distribution of NAPL and VOC mass at the site. Appendix O to this document includes technical evaluations prepared by Dr. Kueper in support of this document. Dr. Kueper also helped formulate the data requirements for ground-water TI evaluation, including the information obtained during the RI to support a "front-end" TI decision for the site, in accordance with Section 4.2 of the TI guidance document (USEPA, September 1993). A front-end TI decision is made before implementing the overall site remedy and applies in certain cases when adequate, detailed site characterization has been performed. In accordance with the TI guidance document (USEPA, 1993), site characterization requires an assessment of the most critical limitations to ground-water restoration, including:

- the presence, quantity, distribution, and properties of NAPL;
- geologic formation heterogeneity and solute transport characteristics; and
- bedrock fracture characteristics

This RI Report describes the acquisition and evaluation of these and other types of field data acquired to support a front-end TI Evaluation.

1.2 RI Objectives

As stated in RI/FS SOW, the objectives of the RI were to:

- Complete the definition of the source(s), nature, extent, and distribution of chemical constituents released from the SRSNE Site; and
- Provide sufficient information to evaluate remedial alternatives, conceptually design the remedial action, select a remedy, and issue a record of decision (ROD) for the site.

The first three phases of the RI and other investigations completed at the site produced a substantial quantity of data regarding site geology, hydrogeology, and the distribution of chemical constituents. The goal in completing this RI, however, was to fill specific data gaps required to support the evaluations discussed below and to complete the FS for the site. As stated in the USEPA-approved RI Work Plan (BBL, November 1995), the actions required to meet the objectives required by the RI/FS SOW, were developed at a meeting between USEPA, CT DEP, and the SRSNE PRP Group on June 21, 1995 and included the following investigative actions:

- **Further characterize the NAPL zone and assess its restoration potential.** The difficulty of restoring ground-water quality in the vicinity of NAPL is well known and has been discussed in numerous technical papers and USEPA Guidance Documents [OSWER Directives 9234.2-25 (September 1993) and 9200.4-14 (January 1995)]. Based on the limitations to NAPL-zone restoration, the NAPL-zone evaluation during this RI focused on accumulating data that will be used to develop the TI Evaluation. In support of the TI Evaluation, this RI presents the estimated extent of the NAPL zone, describes NAPL chemical and physical characteristics, and discusses the overburden and bedrock characteristics (e.g., heterogeneity, hydraulic conductivity, fracture aperture and spacing, matrix porosity) that influence the effectiveness of potential ground-water restoration alternatives. Appendices A and B of the RI Work Plan (BBL, November 1995), which were prepared by Dr. Kueper, presented a detailed discussion of DNAPL behavior and a preliminary evaluation of NAPL-zone remedial technologies, respectively. Appendix V to this final RI Report presents the Development and Initial Screening of Alternatives, which evaluates potential remedial alternatives that are considered appropriate for the site, and initiates the FS. The FS will include a TI Evaluation, which will quantitatively evaluate the restoration potential for the NAPL zone and the zone where substantial VOCs have diffused into the geologic media. Given the well-documented difficulty in NAPL-zone restoration, and the detailed analysis that will be presented in the TI Evaluation, the majority of the FS Report will focus on remedial alternatives for: 1) the portions of the VOC plumes downgradient of the TI zone; and 2) on-site vadose-zone soil.

- **Delineate and define the nature and extent of the off-site regulatory VOC plume associated with the SRSNE Site.** A fundamental objective of the overall RI/FS process was to develop a strategy to address the off-site VOC plume associated with the SRSNE. This RI Report delineates the SRSNE-related VOC plumes in the overburden and bedrock formations, and distinguishes it from other plumes, some of which are associated with other documented and potential sources of VOCs similar to those at the associated SRSNE Site. The plumes delineated in this document are based on fundamental ground-water hydraulics and solute-transport principles, as well as exceedences of regulatory criteria such as Federal Maximum Contaminant Levels (MCLs) and State of Connecticut Class GA/GAA Ground-Water Protection Criteria. These factors provided multiple levels of screening to delineate the dissolved-phase VOC plume associated with the SRSNE Site based on technical or regulatory criteria.

- **Assess whether the off-site VOC plume impacts or could potentially impact private water-supply wells.** This evaluation was completed as part of the broader task of off-site plume delineation. Private residences in the areas immediately north, northwest, and west of the site rely on domestic wells (primarily drilled bedrock wells) for their water supply. Additional ground-water elevation data were obtained to develop a three-dimensional hydraulic analysis, which confirmed that the nearest private residences using ground water are upgradient from the site. Two private wells, however, appear to be situated near the upgradient edge of the VOC plume associated with the SRSNE Site. One of the two private wells in question has contained VOCs in excess of ground-water regulatory criteria, and the CT DEP supplies that property owner with bottled water. The other well in question has historically indicated low concentrations of VOCs below applicable ground-water regulatory criteria (HNUS, July 1994). The SRSNE PRP Group is taking action to connect these properties to the municipal water supply system by November 1997 and Spring 1998, respectively. Residences south and east of the site have been using municipal water for approximately 100 years.

- **Delineate recoverable LNAPL.** The USEPA requested that recoverable LNAPL, if any, be delineated as part of the RI. To assess the distribution of potentially recoverable LNAPL, the completion of the RI included NAPL thickness measurements at wells in the Operations Area and the former Cianci Property. This task is required as part of the overall NAPL-zone evaluation, and indicated a limited extent of measurable LNAPL near the center of the Operations Area (Figure 2).

- **Assess vadose-zone VOC contribution to the ground-water plume.** Prior to the development of the RI Work Plan, the USEPA expressed an interest in evaluating the benefit of vadose-zone remediation in the SRSNE Operations Area, as a potential means to reduce VOC loading to the ground water. During the completion of the RI, vadose-zone soil quality data were obtained. The new data and historical vadose-zone soil sampling results were compiled in a relational data base, and were used to develop a one-dimensional, vadose-zone solute-transport model (VLEACH, which was prepared on behalf of USEPA). The vadose-zone model was used to assess the relative contribution of VOCs from the vadose zone to site ground water.

1.3 Report Organization

This RI Report is organized into the following sections:

Section	Description
1 - Introduction	Explains the reasons for completing the RI and describes the scope of the RI Report and the overall objectives of the RI.
2 - Site Background and Physical Setting	Summarizes site conditions, operating history, geology, hydrogeology, and prior hydrogeologic investigations at and around the SRSNE Site, previous remedial actions, other VOC source areas unrelated to the SRSNE Site, and ground-water classification and use.
3 - Study Area Physical Characteristics	Presents a detailed discussion of regional and site-specific overburden and bedrock geology and hydrogeology, including a comprehensive hydrogeologic conceptual model describing ground-water flow and interaction with surface-water bodies in the vicinity of the site.
4 - Nature, Extent, and Fate of Contamination	Describes the distribution of SRSNE Site-related VOCs in various chemical phases within the geologic media, including the nature and extent of the dissolved VOC plume and NAPL zone, estimated solute-transport rates, and the migration and exposure conceptual model.
5 - Technical Impracticability Data Summary	Presents the specific data and calculations to support the TI Evaluation, including quantitative estimates of the VOC mass distribution and results of NAPL removal and ground-water restoration efforts to date.
6 - Interim Monitoring and Sampling	Provides and overview of the Interim Monitoring and Sampling Plan, which is presented as Appendix U.

Section	Description
7 - Treatability and Pilot Studies	Describes the SRSNE PRP Group's ongoing assessment of innovative remedial technologies, including phytoremediation and constructed wetlands for ground water treatment
8 - Summary and Conclusions	Summarizes the results of this RI.
9 - References	Lists the documents referred to in this RI Report.

To facilitate the overall flow of this RI Report, a detailed discussion of field activities completed as part of this investigation (dates of activities; sampling techniques; number, type, and locations of samples) is presented as Appendix A. Acquisition of data to complete the RI commenced during the installation of a constructed wetland in June 1996. The majority of the field data required to complete the RI were obtained between August 1996 and February 1997. A final data gap was filled through the installation, sampling, and hydraulic monitoring of a final monitoring well cluster (MW-710) between May and June 1997. The RI field investigation activities are summarized in Table 1 and on Figure 3. Attachment A-1 to Appendix A presents a complete, detailed sample log of the laboratory samples obtained during the completion of the RI, including: bedrock; soil; direct-push (Hydropunch™) and auger-grab ground-water samples; ground-water and DNAPL samples obtained from wells and piezometers; and surface-water samples.

While Appendix A presents a detailed description of the RI field activities, it should be noted that the completion of the RI included several types of specialized technical data acquisition and evaluation techniques:

- bedrock fracture aperture estimates;
- in-situ bedrock fracture spacing and orientation measurements using a digital Borehole Image Processing System (BIPS);
- demonstration of VOCs within the unfractured matrix of the New Haven Arkose bedrock by crushing core samples, immersing them in methanol, and submitting the samples for VOC analysis;
- detailed assessment of the thickness, continuity, dip, and hydraulic conductivity of overburden strata on a scale of one centimeter to several feet;
- an empirical demonstration that Raoult's Law is useful for assessing the effective solubility of NAPL components, based on chemical characterization of ground-water and NAPL samples in the same monitoring wells; and
- a comparison between traditional and low-flow ground-water sampling for VOCs.

Completing the RI required substantial field activities:

- excavation of two test pits;
- drilling of 30 soil borings (total of approximately 2200 lineal feet of overburden drilling);
- drilling of 15 bedrock boreholes (total of approximately 820 lineal feet of bedrock drilling);
- performance of 70 bedrock packer tests;
- installation of 28 monitoring wells (total of approximately 2960 lineal feet);
- acquisition of 130 new hydraulic conductivity estimates for the overburden and bedrock formations based on data obtained during pumping of wells and piezometers, including specific capacity test results;
- collection and analysis of 82 soil samples [not including associated quality assurance/quality control (QA/QC) samples] for physical and/or chemical characterization;

- collection and analysis of 19 bedrock core samples (not including associated QA/QC samples) for physical and/or chemical characterization;
- collection and analysis of 16 direct-push ground water samples or auger-grab samples (not including associated QA/QC samples) for chemical laboratory characterization;
- collection and analysis of three DNAPL samples for chemical and physical characterization;
- collection and analysis of 192 ground-water samples (not including associated QA/QC samples) for chemical characterization;
- collection and analysis of 18 surface-water samples (not including associated QA/QC samples) for chemical characterization; and
- measurement of ground-water elevation (considered synonymous with "potentiometric elevation" or "head") and surface-water elevation at up to 227 locations during each of two comprehensive measurement rounds.

These activities were performed in accordance with the USEPA-approved RI Work Plan and POP, and seven RI Work Plan addenda. In addition, several modifications were made to the scope of work to complete the RI, and were communicated to USEPA via meetings, telephone discussions, or letters. During the field investigations performed to complete the RI, biweekly conference calls were held between USEPA, CT DEP, and the SRSNE PRP group. A thorough description of the modifications to the scope of work and the field activities required to complete the RI is included in Appendix A.

The data acquired during BBL's field investigation between August 1996 and February 1997 were summarized in a Preliminary Data Evaluation, which was submitted to USEPA and CT DEP on February 28, 1997. A meeting between USEPA, CT DEP, and the SRSNE PRP Group was held at USEPA's offices in Boston on March 20, 1997, to discuss the Preliminary Data Evaluation. During the March 20, 1997 meeting, it was determined that a final monitoring well cluster (MW-710 series, along Queen Street) would be installed to fill a data gap in the ground-water monitoring network southeast of the site, and complete the RI. Following the installation and sampling of the MW-710 well cluster, and the completion of the second comprehensive round of ground-water elevation measurements, the new analytical results, water-levels, and ground-water elevation contour maps were transmitted to USEPA and CT DEP on July 14, 1997. These data were discussed In a telephone conference between USEPA, CT DEP and the SRSNE PRP Group on July 17, 1997. During the July 17, 1997 conference call, USEPA indicated that no additional subsurface work was required for the SRSNE PRP Group to prepare this RI Report.

1.4 Potential Applicable or Relevant and Appropriate Requirements (ARARs)

This subsection presents a discussion of potential Applicable or Relevant and Appropriate Requirements (ARARs) for consideration throughout the future identification, screening, and evaluation of remedial alternatives during the FS.

ARARs are promulgated, enforceable federal and state environmental or public health requirements, which fit into either of two categories: "applicable requirements;" and "relevant and appropriate requirements." Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not legally applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site or actions at the site.

The USEPA and the states have also identified certain guidance as "to be considered" criteria (TBCs). TBCs are non-promulgated advisories or guidance issued by federal or state government that are not legally binding and do not have the status of potential ARARS. Along with ARARS, TBCs may be used to develop the remedial action limits necessary to protect human health and the environment.

The USEPA categorizes ARARs and TBCs as being chemical-specific, location-specific, or action-specific. These ARAR categories are described below.

1.4.1 Potential Chemical-Specific ARARs and TBCs

Chemical-specific ARARs and TBCs are usually health- or risk-based values which may define acceptable exposure levels and, therefore, may be used in establishing remediation goals. In general, chemical-specific ARARs are set for a single chemical or a closely related group of chemicals. A preliminary listing of potential chemical-specific ARARs and TBCs is included in Table 2.

1.4.2 Potential Location-Specific ARARs and TBCs

Location-specific ARARs and TBCs are restrictions placed on the concentrations of hazardous substances or the conduct of activities solely because they are in specific areas. The general types of potential location-specific ARARs and TBCs that may be applied to the SRSNE Site are briefly described below.

Several potential federal and state ARARs regulate wetlands and floodplains. Because the study area includes wetlands and portions of the area are located in the 100-year floodplain of the Quinnipiac River, these regulations would be ARARs if the remedial alternatives to be evaluated during the FS would result in impacts to these resources. Section 404 of the Clean Water Act and State Inland Wetland and Water Courses Regulations restrict activities that adversely affect wetlands and waterways. RCRA Location Standards outline the requirements for the construction of a RCRA facility located in a 100-year floodplain. The Floodplains Executive Order, incorporated into 40 CFR Part 6, Appendix A, requires that floodplains be protected and preserved and that adverse impacts be minimized.

Additional potential location-specific ARARs include the Fish and Wildlife Coordination Act, which requires that any federal agency proposing to modify a body of water must consult with the U.S. Fish and Wildlife Service. Again, these requirements would be ARARs for the SRSNE Site if the remedial alternatives evaluated in the FS impact the Quinnipiac River.

A preliminary listing of potential location-specific ARARs and TBCs is included in Table 3.

1.4.3 Potential Action-Specific ARARs and TBCs

Action-specific ARARs and TBCs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements generally focus on actions taken to remediate, handle, treat, transport, or dispose of hazardous wastes. These action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate how a selected alternative must be achieved. The general types of potential action-specific ARARs that may be applied to the SRSNE Site are briefly described below.

The Clean Water Act (CWA) requires that any point source discharge to waters of the U.S. meets all applicable requirements under the National Pollutant Discharge Elimination System (NPDES) program. These requirements would apply if the remedial alternatives evaluated during the FS involve point source discharges to the Quinnipiac River. The CWA Pretreatment Regulations state that all discharges to a publicly owned treatment works (POTW) must be treated so as to prevent interference with operation of the POTW, pass-through of pollutants, and violations of local limits. These regulations would be ARARs if the remedial alternatives for the SRSNE Site include discharge to a POTW. The state regulates the discharge of process wastewater and does not permit the discharge of toxic pollutants for which "Health Advisories" are unavailable and for which there is insufficient data for the establishment of a Health Advisory. This discharge restriction is potentially applicable to several contaminants detected in the study area.

Various requirements under the Clean Air Act would also be potential ARARs, if the remedial alternatives to be evaluated as part of the FS involve air emissions. The National Ambient Air Quality Standards (NAAQS) set maximum primary and secondary 24-hour concentrations for six criteria pollutants in the ambient air. The Connecticut State Implementation Plan (SIP) contains specific requirements for particular sources designed to ensure the attainment and maintenance of the NAAQS and Connecticut Ambient Air Quality Standards. Two of the six criteria pollutants, particulate matter and ozone, may be released into the air during implementation of remedial activities. State regulations also establish limits for air emissions from treatment facilities. Disposal actions may also be regulated by the state hazardous waste regulations and state waterways regulations and the ground-water injection program. These regulations may also be potential ARARs.

The RCRA facility standards address the design, facility operations, manifesting and record keeping, treatment, disposal, ground-water monitoring, and closure for certain types of waste management facilities.

Ambient Water Quality Criteria (AWQC) have been developed under the CWA as guidelines for the protection of freshwater aquatic life and human health, based on ingestion of water and fish consumption. These standards would be used to develop effluent discharge limits for those alternatives that require discharges to the Quinnipiac River.

A preliminary listing of potential action-specific ARARs and TBCs is included in Table 4. These lists of ARARs and TBCs will be revised and refined throughout the development of the FS. The final ARARs and TBCs will be used in the detailed analysis of the effectiveness of remedial alternatives, and will be factored into the development of performance standards to be included in the Record of Decision (ROD) for the site.

1.4.4 ARAR Waivers

There are certain circumstances under which a remedial alternative may be selected which does not meet an ARAR, and for which a waiver of the necessity to comply with the ARAR may be granted. Of the six sets of circumstances described in Section 300.430(f)(1)(ii)(c) of the NCP for which waivers may be granted, one is considered applicable to the SRSNE Site:

> "Compliance with the requirements is technically impracticable from an engineering perspective."

All ARARs listed above will be evaluated with regard to the applicability of the waiver mechanisms in the NCP as part of the FS. The appropriateness of a *technical impracticability* waiver will be evaluated in consideration of the USEPA's "Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration."

Summary of Section 1

- The information presented in this document fills specific data gaps that remained following twenty previous subsurface investigations, removal actions, and/or investigatory reports regarding the RI Study Area, including three phases of RI performed by HNUS on behalf of the USEPA. This report completes the characterization of the SRSNE Site, and supports the Feasibility Study, which will develop and analyze appropriate remedial alternatives for the site.

- Data gaps that remained following the three previous RI phases led to the following five objectives, which were identified in the RI Work Plan (BBL, November 1995), and filled during the completion of the RI:

  1) Further characterize the non-aqueous-phase liquid (NAPL) zone associated with the SRSNE Site and assess its restoration potential.

  2) Delineate and define the nature and extent of the off-site volatile organic compound (VOC) plume associated with the SRSNE Site.

  3) Assess whether the off-site VOC plume impacts or could potentially impact private water-supply wells.

  4) Delineate recoverable light NAPL (LNAPL).

  5) Assess vadose zone VOC contribution to the ground-water plume.

- To meet the above-listed objectives, and provide sufficient data to support a Technical Impracticability (TI) Evaluation as part of the forthcoming FS, several types of specialized data acquisition and evaluation techniques, and substantial field investigation activities were performed between June 1996 and July 1997.

2. Site Background and Physical Setting

2.1 General

The SRSNE Superfund Site is located on approximately 14 acres of land along Lazy Lane in the Town of Southington, Connecticut. The SRSNE Site is located in Hartford County, approximately 15 miles southwest of the city of Hartford (see Site Location Map, Figure 1). The RI study area (Figure 2) includes the:

- SRSNE facility Operations Area;
- adjoining former Cianci Property, including the Containment Area where the NTCRA 1 Ground-Water Containment System was installed;
- Town of Southington Well Field Property; and
- adjacent areas to the north, south, east, and west.

In this document, the terms *SRSNE Site* and *the site* are synonymous, and refer to the SRSNE Operations Area and the Containment Area on the former Cianci Property. *Off-site* refers to areas within the study area that are hydraulically downgradient of the Containment Area, including the Town Well Field Property.

2.2 Study Area Description

The RI *study area* encompasses the three specific properties listed above in Section 2.1 and the adjacent areas to the north, south, east, and west (Figure 2). A comprehensive description of the study area background and physical setting for the three subject areas is included in the previously conducted RI, Sections 1 and 3 (HNUS, May 1994). This section presents an overview of the study area conditions and history based upon information provided in the previously conducted RI and other investigation documents.

The key elements of the RI study area are discussed in the sections below.

2.2.1 SRSNE Operations Area

The SRSNE Operations Area is located in the Quinnipiac River basin approximately 600 feet west of the Quinnipiac River channel (Figure 2). The Operations Area consists of approximately 2.5 acres of grounds and structures situated on a 3.7-acre lot. An access road extends to the north, connecting the Operations Area to Lazy Lane. The Operations Area is bordered on the east (downhill) by the Boston and Maine (B&M) railroad right-of-way and the former Cianci Property, to the north by Mickey's Garage automotive repair shop (Maiellaro Property), to the west (uphill) by the S. Yorski Property, and to the south by the Delahunty Property, the Connecticut Light and Power (CL&P) electrical transmission line easement, and the Town of Southington Well Field Property.

Much of the Operations Area currently is paved with asphalt and/or concrete and is completely enclosed with security fencing. Site features include an office trailer, operations building, former ground-water treatment system control building, multiple above ground storage tanks, and two concrete-surfaced drum storage areas. From approximately 1955 to 1991, daily operations in the Operations Area included drum and bulk storage solvent distillation and fuel blending. A number of spent solvents and chemicals, including chlorinated solvents, aromatic hydrocarbons, alcohols, and ketones, were handled, stored, and processed in the SRSNE Operations Area. The history of the Operations Area is discussed further in Section 2.3 below.

2.2.2 Former Cianci Property

The former Cianci Property is the 10-acre parcel situated immediately east of the Operations Area, across the B&M Railroad right-of-way. The Quinnipiac River borders the eastern edge of the former Cianci Property. Lazy Lane is located to the north, and the Town of Southington Well Field Property borders the former Cianci Property to the south.

The former Cianci Property lot was occupied by the Cianci Construction Company from approximately 1969 through 1988 and was used for the storage of construction equipment and as a truck washing station. The property was sold to SRSNE in June 1988.

Until the construction of the NTCRA 1 Ground-Water Containment and Treatment System, the former Cianci Property contained no permanent structures, but had been altered by past earthmoving and leveling activities. Some of the wetland areas that formerly occupied a portion of this property had been filled. The impact of the NTCRA 1 system on the remaining wetland areas along the floodplain of the Quinnipiac River was evaluated in accordance with a Conceptual Wetlands Mitigation Plan (BBL, April 1995). Subsequently, a Detailed Wetlands Mitigation Design (BBL, September 1995) was developed to mitigate potential impacts to small, isolated wetlands within and immediately adjacent to the Containment Area during implementation of NTCRA 1. The wetland mitigation activities included the construction and planting of new wetland in the shape of an oxbow in the northeast corner of the Cianci Property in June 1996 (Figure 4). No impacts were observed at the wetlands adjacent to the Quinnipiac River (BBL, September 1995). An unpaved access road traverses from north to south through the Cianci Property and into the Town of Southington Well Field Property.

2.2.3 Southington Well Field Property

The Town of Southington Well Field Property consists of 28.2 acres of undeveloped land situated south of the former Cianci Property and southeast of the Operations Area. The Southington Well Field Property is bounded to the east by the Quinnipiac River and to the south by the Quinnipiac River and Curtiss Street. The B&M railroad right-of-way and the Delahunty property border the western perimeter of the Southington Well Field Property. The CL&P easement runs northwest-southwest through the northern portion of the Southington Well Field Property.

Town Production Wells No. 4 and 6 are located approximately 2,000 and 1,400 feet south of the SRSNE property, respectively. The Quinnipiac River divides the area between Production Wells No. 4 and 6. Production Well No. 6 is accessible using dirt roads originating on Lazy Lane or Curtiss Street while Well No. 4 is only accessible from Curtiss Street. The following table summarizes the pumping history of Town Wells No. 4 and 6 during their period of use (Southington Water Department, June 1997).

Year	Production Well No. 4		Production Well No. 6	
	Gallons per Year	Yearly Avg. GPM	Gallons per Year	Yearly Avg. GPM
1965	0	0	0	0
1966	1.15E+08	219	0	0
1967	2.90E+08	552	0	0
1968	2.93E+08	557	0	0
1969	2.94E+08	559	0	0
1970	3.03E+08	576	0	0
1971	2.68E+08	510	0	0

Year	Production Well No. 4		Production Well No. 6	
	Gallons per Year	Yearly Avg. GPM	Gallons per Year	Yearly Avg. GPM
1972	2.47E+08	470	0	0
1973	1.89E+08	360	0	0
1974	1.45E+08	276	0	0
1975	1.27E+08	242	0	0
1976	7.13E+07	136	0	0
1977	8.87E+07	169	0	0
1978	0	0	1.03E+08	196
1979	0	0	5.40E+07	103
1980	0	0	2.30E+04	0.04
1981	0	0	0	0
Average Rate During Production Years		385 GPM	100 GPM	

Production Well No. 4 was installed in August 1965 and provided drinking water to the Town of Southington from July 1966 to December 1977 at an average rate of approximately 385 gallons per minute (gpm) during the twelve years it was in use. Production Well No. 6 was installed in April 1976 and was pumped from May - October 1978, May - July 1979, and March 1980, at an average rate of 100 gpm during the three years it was used. The actual usage rates of Wells No. 4 and 6 were considerably less than their sustainable rates of approximately 700 and 1,400 gpm, respectively, which were determined based on pumping tests (Geraghty & Miller, September 1965; Amory, November 1975). Except for the brief period of pumping at Well No. 6 in March 1980, Wells No. 4 and 6 have not been used for water supply since approximately 1979 due to the detection of VOCs in the discharge water from the wells (HNUS, May 1994).

2.3 SRSNE Site History

The SRSNE facility began operations in Southington in 1955. From approximately 1955 to the early 1980s, spent solvents were received from customers, the materials were distilled to remove impurities, and the recovered solvents were returned to the customer or others for reuse. Reports on the quantities of materials processed at the SRSNE Operations Area vary widely. Based on a partial record of materials processed at the SRSNE facility (excluding pre-1967 operations files, which were destroyed in a fire) SRSNE handled in excess of 41 million gallons of waste solvents, fuels, paints, etc. Assuming a similar rate of solvent processing before and after the 1967 fire, an estimated 60 million gallons of materials were processed at the site. According to ATSDR (1992), however, approximately 3 to 5 million gallons of liquid wastes and 100,000 pounds of solid wastes were processed annually at the SRSNE facility during the period of operations (ATSDR, July 1992), which lasted from 1955 to 1991. This rate of processing over the 36 year operating period would suggest a total of 108 to 180 million gallons of liquid materials were processed at the site.

The liquid wastes processed at the SRSNE facility included unrecoverable or spent solvent-based fuels, spent chlorinated solvents, and wastes generated from fuel-blending operations. The facility processed approximately 170,000 gallons of state-regulated waste annually, including spent lubricating and hydraulic oils and antifreeze. Wastes generated on site included still-bottom sludges and contact and non-contact steam from the distillation process, non-contact cooling water from the fuel-blending operations, overflow water generated from an on-site ground-water recovery system, boiler blow down generated from boiler steam condensate, and storm-water runoff

(ATSDR, July 1992). Contact and non-contact distillation stream generated during distillation were discharged into a subsurface drain pipe that discharged into a ditch along the west side of the B&M railroad tracks.

From 1957 to approximately 1967, the non-recoverable portion of distilled solvents, consisting of distillation or still-bottom sludge, was stored in two on-site unlined lagoons located in the Operations Area (Figures 4 and 5). The largest lagoon was approximately 90 feet long, 40 feet wide, and 10 feet deep (approximately 270,000-gallon capacity) (CT DEP, October 1978). The exact quantity of waste material placed in the on-site lagoons cannot be determined. Sludge was periodically removed from the lagoons; however, the lagoons sometimes were filled beyond their capacity with solvent sludge (CT DEP, October 1978). According a CT DEP (October 1978) memorandum, the lagoons were frequently full and sometimes overflowed into the drainage ditch adjacent to the railroad tracks east of the site. The ditch discharged under the tracks via a culvert to a stream that flowed across the former Cianci Property to the Quinnipiac River (see Figure 5). In 1967, sludge disposal in the lagoons was discontinued, and the lagoons were cleaned out and covered with fill.

After the closure of the lagoons in 1967, wastes, including still-bottom sludge and flammable liquid wastes, were incinerated in an open pit on site or disposed of off site. The open pit incinerator burned approximately 1,000 gallons of solvent sludge per day between 1966 and 1974, when it was decommissioned (ATSDR, July 1992). Ash from the open pit incinerator was used as fill material within the Operations Area. By about 1976, some of the spent solvents were incorporated into SRSNE's fuel blending program. The solvent burning and fuel blending operations involved handling, storage, and transfer activities that resulted in leaks and spills to bare ground within the Operations Area. Figure 6 shows site operations including drums, tanks, and tanker trucks in 1980. In 1989 and 1990, site paving and control measures were installed in accordance with a Resource Conservation and Recovery Act (RCRA) corrective measures plan.

On September 16, 1976, VOCs were detected at Town of Southington Production Well No. 4 (Amory, August 1978). Between 1977 and 1978, water-supply pumping in the Southington Well Field Property shifted from Well No. 4 to Well No. 6. In approximately 1979, however, Town of Southington Production Well No. 6 also ceased operation due to the presence of VOCs in the discharge from the well (HNUS, May 1994).

In 1983, USEPA and SRSNE reached a Consent Decree, which required the installation of an on-site ground-water interceptor system (OIS) along the downgradient property line of the Operations Area. The on-site interceptor system, which was installed in 1985 and started operation in 1986, ostensibly consisted of 25 combination overburden/bedrock ground-water extraction wells spaced every 24 feet along a generally north-south line, transverse to the east-southeastward hydraulic gradient at the site (Figure 4). The Consent Decree also required modifications to SRSNE's solvent handling practices and the performance of subsurface investigation activities to assess impacts associated with the site. Concurrent with the issuance of the Consent Decree, the USEPA placed the site on the National Priority List (NPL), making it eligible for federal assistance with site study and cleanup expenses. Between 1983 and the facility's closure in 1991, SRSNE made some improvements as required under the Consent Decree, including spill control measures, paving of the Operations Area, fire protection measures, and installation of a ground-water treatment system discussed below.

From 1986 through 1991, the on-site ground-water treatment system utilized a cooling tower, which was converted into an air stripper on the roof of the operations building, with discharge via a subsurface drain pipe to the ditch along the railroad tracks east of the site. In addition to ground water from the OIS wells, the converted air stripper also received wet steam containing high concentrations of solvent compounds from the solvent distillation process. Thus, during system operation, VOC concentrations in the tens of parts per million (ppm), potentially including NAPL, may have been discharged to the ditch along the railroad tracks.

A USEPA RCRA inspection in February 1989 documented 75 cases of solvent releases from drums, tank trucks, hoses, and other solvent containers and transfer equipment during 1988 (USEPA, February 1989). During the February 1989 USEPA RCRA inspection, the OIS was not operating as a continuous hydraulic barrier to downgradient ground-water flow (USEPA, February 1989). Subsequently, three extraction wells were removed and replaced in 1989. The three replacement wells, which were constructed of 4-inch diameter stainless steel screen and riser to improve the ground-water extraction rate of the OIS, were screened across the overburden/bedrock interface.

In 1988, the three batch stills were removed, and spent solvents received by SRSNE were transferred to other facilities for the remainder of SRSNE's operations period. Additional USEPA and CT DEP enforcement orders were subsequently issued to compel SRSNE to perform further site cleanup work at the facility. The facility ceased operation in March 1991 and was closed down in May 1991.

In 1992, CT DEP retained Metcalf and Eddy to identify a more effective treatment alternative to the converted cooling tower/air stripper. Based on an evaluation of other treatment options, a UV peroxidation system was installed. From July 1992 though 1994, the water pumped from the OIS wells was treated using the UV peroxidation system, which was operated by Metcalf and Eddy on behalf of CT DEP. SRSNE continued to operate the well pumps, which produced an average combined flow rate of approximately 3 gpm during this period of operation. SRSNE discontinued operation of the OIS wells and the UV peroxidation system was shut down concurrent with NTCRA 1 design activities in 1994.

2.4 Physical Setting of the Site

2.4.1 Topography and Ground Cover

The SRSNE Site is located in the Quinnipiac River Basin and is shown in the northeastern corner of the Southington 71/2-minute quadrangle map [United States Geological Survey (USGS) Map No. KU-146, dated 1992], as depicted on Figure 1. This area is characterized by relatively broad river valleys separated by low north-northeast trending bedrock ridges. The SRSNE Operations Area is situated near the base of the eastward sloping hill that forms the west margin of the Quinnipiac River Valley. The former Cianci Property and the Town of Southington Well Field Property are in the flat, central portion of the river valley. The Quinnipiac River flows generally south adjacent to the study area, then turns west in the Southington Well Field. The river valley floor ranges in elevation from 145 to 170 feet above mean sea level (MSL) (Figure 2). Topography within the valley includes small hills which extend approximately 10 to 15 feet in elevation above the surrounding valley floor with wetlands and floodplain areas abutting the river. Figures 4 and 7 show wetlands in the vicinity of the site.

The Operations Area is situated approximately 600 feet west of the Quinnipiac River. Ground-surface elevations range from 164 to 180 feet MSL, with a majority of the developed Operations Area located on a level area of the site (Figure 2). A steep hill is located on the western and southwestern portion of this property. The steep slopes associated with this hill have been stabilized with crushed stone. Historical photographs have shown that grading operations were used to create the level site area and, consequently, the steeply graded hillside.

The former Cianci Property is bordered on the eastern edge by the Quinnipiac River. Prior to NTCRA 1, this property did not contain any permanent structures, but had been graded to level in certain areas. A gravel access road and the NTCRA 1 Ground Water Containment and Treatment System were constructed within the Containment Area. The remainder of the former Cianci Property is characterized by open grassy fields, woodlands, and wetlands, some of which were filled prior to NTCRA 1 or have been dewatered due to NTCRA 1 ground-water extraction. Site elevations range from 150 to 160 feet MSL. Current wetlands exist along the entire eastern border of the property along the floodplain of the Quinnipiac River, and within a constructed wetland built in the northeastern corner of the property to mitigate wetland loss associated with NTCRA 1 activities (Figures 4 and 7).

The 28.2-acre Town of Southington Well Field Property, located south of the SRSNE Operations Area, is characterized by open grassy fields and gently rolling terrain. Some forested areas and shrubs are present along the boundary with the former Cianci Property. Wetlands are located along the Quinnipiac River (Figure 7). Ground elevations range from 145 feet to 160 feet MSL.

2.4.2 Geology

The SRSNE Site is located within the Connecticut Valley Lowland section of the New England physiographic province. The Connecticut Valley Lowland occupies a regional, structural rift basin, which is characterized by block-faulted and tilted bedrock strata (Figure 8). The geology of the region, in general, consists of glacially-derived unconsolidated deposits overlying the Upper Triassic New Haven Arkose bedrock (Rogers, 1985). Bedrock fractures in the region dip moderately eastward, parallel to the eastward-dipping bedding (Hubert *et al.*, 1978; Rogers, 1985; this document). Steeply dipping fractures, however, have also been observed in outcrops near the site, and in core samples and downhole fracture-logging results obtained within the study area. While normal faults have been mapped approximately 2.5 miles west and 2.0 miles east of the site (Rogers, 1985; also see Figure 8), no bedrock faults have been reported within the RI Study Area. The published bedrock geologic maps do not provide a sufficient basis to evaluate the presence or locations of faults, if any, beneath the thick sequence of unconsolidated materials within the Quinnipiac River Valley in the vicinity of the site (Rogers, pers. com. with M.J. Gefell, June 1997). The depth to bedrock varies throughout the study area, from approximately 15 to 40 feet below grade at the SRSNE Operations Area, to approximately 25 to 45 feet below grade, on the former Cianci Property, to approximately 80 to 100 feet below grade at the Town Well Field Property.

Wisconsin-age glaciation partly eroded and smoothed the bedrock hills and deposited the principal unconsolidated overburden units throughout the region (La Sala, 1961). The overburden geology beneath the Operations Area and former Cianci Property site consists of two main unconsolidated layers. The upper layer extends from ground surface to approximately 10 to 25 feet below grade at the site and consists of reddish-brown silty sand and gravel deposits, interbedded with discontinuous layers of silt and relatively well-sorted sand and gravel. The lower layer consists of glacial *till*, a generally unstratified unit consisting of reddish-brown clay, silt, sand, gravel, cobbles, and boulders, but also including isolated, discontinuous sandy seams. Fill materials are also present above the outwash in the Operations Area and former Cianci Property, where grading operations have reworked the upper few feet of soil and filled low areas. In the area south of the site (i.e., the Town Well Field Property), the entire overburden grades to a coarser overall grain size distribution, and resembles classic stratified drift (Mazzaferro *et al.*, 1979) throughout the overburden thickness. The deeper portion of the overburden south and southeast of the site generally lacks fines, and is described herein as "gravelly drift."

The bedrock and overburden geology of the SRSNE Site and vicinity are described in detail in Section 3.

2.4.3 Hydrogeology

Ground water within the study area flows through the overburden units and the bedrock, and converges toward the Quinnipiac River from the east and the west. The horizontal component of the hydraulic gradient at the site is generally southeastward toward the river. The regional hydrogeologic cross section presented on Figure 9 summarizes the regional ground-water flow pattern within the Quinnipiac River valley. The overburden and bedrock units are recharged primarily via precipitation, although ground-water underflow also occurs from the north within the saturated zone in the vicinity of the river (Mazzaferro *et al.*, 1979). Where the till layer is relatively thick, it may limit the rate of ground-water flow between the two aquifers. In areas where till is anomalously thin or absent ("till windows"), or lacks fine-grained material, more ground-water flow may occur between the overburden and bedrock aquifers. Based on the available hydraulic head data measured at wells, piezometers, and surface-water measurement points within the RI Study Area, essentially all overburden and bedrock ground water within the monitored geologic zones discharges to the Quinnipiac River.

Five ground-water zones are currently monitored in the RI study area, including the:

- *Shallow, middle and deep overburden*, which represent the upper, middle, and lower thirds of the saturated overburden deposits, respectively; and

- *Shallow and deep bedrock*, which represent approximately the upper 30 feet of bedrock and a zone between 60 and 90 feet below the top of bedrock, respectively.

These five zones were established based on geology (overburden versus bedrock) and on the desire to add vertical resolution to the presentation of data from the overburden. As the thickness of the saturated overburden ranges from approximately zero to 100 feet in the RI Study Area, the thickness and depth of the three overburden zones are variable. These five monitored zones are hydraulically connected and comprise a hydrogeologic continuum from the water table downward through the deepest monitored bedrock interval. Deeper sections of bedrock, below the deepest monitoring well in the study area, are also interpreted as part of the regional ground water flow system.

During the development of the RI Work Plan (BBL, November 1995), the existing site ground-water data management system was used to sort the overburden wells into three major categories to understand the three-dimensional distribution of overburden ground-water monitoring wells and evaluate gaps in the monitoring network. Overburden wells are designated as *shallow, middle, or deep overburden* depending on the vertical position of the well-screen midpoint with respect to the saturated overburden thickness, as shown on Figure 10. Because of the textural similarity between the outwash and the till on site, outwash and till are not differentiated, but are both included in the overburden thickness used in the screening process. The hydrogeologic database provided a useful tool to identify data gap locations in the overburden ground-water monitoring network, which were filled during the completion of the RI. This screening procedure also provides a means to differentiate between ground-water quality and hydraulic conditions in different vertical zones within the overburden, and was maintained during the evaluation of the new hydraulic head (i.e. ground-water elevation, or potentiometric elevation) and ground-water quality data presented in this document.

Bedrock monitoring wells have been installed over a wide area surrounding the SRSNE Site, as shown on Figure 11. Prior to the subsurface investigations performed to complete the RI, nearly all of the bedrock wells were screened in the shallow bedrock. The main enhancement to the bedrock ground-water monitoring network made during the completion of the RI was the installation of deep bedrock wells to depths of approximately 60 to 90 feet below the top of bedrock to further characterize the three-dimensional VOC distribution and ground-water flow directions. This deep bedrock depth interval is relatively arbitrary, but was selected to provide a deeper set of data points within the bedrock. Additional shallow bedrock monitoring wells were also installed to fill gaps in the shallow bedrock monitoring system. Consistent with the bedrock characterization approach used by HNUS (May 1994), BBL installed shallow or deep bedrock wells with screens within bedrock intervals that exhibited relatively high water flow during bedrock packer testing (see Appendix A).

The hydraulic properties of the overburden units vary considerably from location to location due to varying grain-size distribution and density of the soil deposits. On a regional scale, the overburden is viewed as heterogeneous and anisotropic. The saturated overburden units, including the outwash and underlying "coarse drift," are considerably thicker and more permeable south of the site in the Town of Southington Well Field Property, where Town Production Well Nos. 4 and 6 were installed for public water production. These two wells have 15- and 10-

foot long screened sections placed in the middle to deep overburden, respectively, and sustained yields of 700 and 1,400 gpm, respectively, during pumping tests (Geraghty & Miller, September 1965; Walter Amory, Consultant Engineers, November 1975).

The hydraulic properties of the fractured New Haven Arkose bedrock are interpreted as highly heterogeneous on a small scale due to the variable spacing and connectedness of bedrock fractures; however, on a regional scale, the bedrock is believed to be relatively homogeneous and anisotropic.

During the completion of the RI, the hydrogeologic and ground-water quality conditions at the site were characterized using an extensive network of monitoring wells, extraction wells, wetland drive points, and piezometers, many of which were installed by on behalf of the USEPA during the three previous phases of the RI. Ground-water elevation data were measured on two occasions at 209 wells, piezometers and drivepoints, and ground-water samples were obtained at 192 locations by BBL between November 1996 and July 1997. With the exception of two monitoring wells, the existing ground-water monitoring locations are considered suitable for ground-water elevation measurements and sampling. Well MW-207A, a shallow bedrock monitoring well situated along Curtiss Street, was found to be plugged or filled by sandy material that precluded water-level measurements and sampling. As discussed in Section 4.3.1 of this document, well MW-207A is outside of the shallow bedrock VOC plume attributable to the SRSNE Site. Also, shallow overburden monitoring well MW-8 in the northeast corner of the Town Well Field Property is partially plugged by a hard object, which precluded sampling by BBL. Well MW-8 was used for ground-water elevation monitoring in July 1997, but the top of the water column was frozen in January 1997. VOCs have been detected in the vicinity of well MW-8. Well MW-8 is not considered necessary or further monitoring, however, because shallow overburden ground water is known to discharge to the Quinnipiac River (see Sections 3.3, 3.4.3, and 3.4.4), and VOCs have not been detected in the Quinnipiac River in the vicinity of well MW-8 (see Section 4.3.2). Based on these findings, wells MW-207A and MW-8 are recommended for abandonment.

2.4.4 Climate and Air Classification

The Town of Southington, Connecticut is situated in a temperate climate characterized by wide variations in seasonal and daily temperature. As of 1994, the 30-year annual mean high and low temperatures measured at the Middletown meteorological station were 59.5 and 41.4 degrees Fahrenheit (°F). The 30-year mean daily high and low temperatures were 83 and 19.2 °F, and the 30-year normal mean annual temperature was 50.3 °F (HNUS, May 1994).

The total annual mean precipitation measured at the Hartford Airport is approximately 44 inches (NRCC, October 1995). Precipitation occurs throughout the year. For the years of 1954 to 1995, the mean monthly precipitation ranged from 3.39 inches for July to 4.11 inches for August (NRCC, October 1995). However, the monthly precipitation can vary substantially. For example, for the period of 1954 to 1995, the monthly precipitation ranged from 0.27 to >21.29 inches (NRCC, October 1995).

The Town of Southington is in the Hartford-New Haven-Springfield Interstate Air Quality Control Region as specified in 40 CFR 81.26. The area is in serious "non-attainment" for ozone. All other criteria pollutants are in attainment or are not classifiable (40 CFR 81.307).

2.5 Previous Investigations of SRSNE and Town Well Field Areas

As discussed and cited below, numerous investigations have been conducted by various consultants and contractors to determine the sources of VOC contamination at Town Production Wells No. 4 and 6 prior to the 1990 initiation of the RI by USEPA. These investigations focused on the study area hydrogeology, potential VOC migration pathways, and potential sources of the VOCs detected at the wells.

As described below, previous investigations have identified several potential sources of VOCs in the RI study area. A key focus of the RI completion, therefore, was to distinguish the off-site VOC plume associated with the SRSNE Site from VOC plumes associated with the other VOC sources in the study area.

Brief summaries of the investigations completed in the RI Study Area, presented below in chronological order, provided the necessary background for later discussions of the new information acquired to complete the RI.

<u>CT DEP (April 1978)</u>. CT DEP performed a limited investigation of the potential sources of solvent-related VOCs detected at Production Well No. 4 and issued an internal memorandum titled "Southington Well #4: Survey of Possible Sources of Organohalide Contamination." According to the memorandum, the investigation entailed a walkover of properties near Well No. 4, interviews with property owners, and searches for any existing wells that may be sampled to locate potential VOC sources. No wells were located in the area, and some formerly reported wells were found to have been filled in due to the availability of public water in the area for approximately 100 years.

One verified source of VOCs was discussed, including:

- Southington Form Construction Co. at 45 Curtiss Street.

During the investigation of the property at 45 Curtiss Street, which was used by Southington Form Construction Co., several drums were observed that had labels indicating two types of form-coating products that contain aliphatic hydrocarbons. The mode of facility operation and method of disposal of the residue observed in the drums, as practiced by Southington Form Construction Co., was not indicated in the memorandum.

Mr. Yorski of Lazy Lane alleged in an interview that sludge was placed along the east bank of the Quinnipiac River in the vicinity of a former diner and was placed only a few feet above the level of the River. The memorandum noted that presently, the ground surface is 25 to 30 feet above the river, indicating that much fill material had been placed above the sludge, hindering the verification of the alleged sludge (CT DEP, April 1978).

<u>CT DEP (October 19, 1978)</u>. CT DEP performed an additional investigation of the potential sources of solvent-related VOCs and hydrogeology in the area of Production Wells No. 4 and 6 and issued an internal memorandum titled "Hydrogeologic Conditions and Contaminant Levels in the Well Field of the Southington Water Department Wells #4 and #6." The memorandum estimated cones of depression and resultant ground-water flow directions induced by pumping of Production Wells No. 4 and 6, and potential ground-water travel times from the SRSNE Site during pumping (which was estimated as approximately 1 to 4 years) versus non-pumping (approximately 6 to 18 years) conditions, based on pumping tests performed by Walter Amory, Consultant Engineers. The memorandum also discussed and tabulated ground-water quality data based on sampling by Walter Amory. [It should be noted that the travel time estimates performed by Amory did not account for retardation of organic compounds due to partitioning to immobile solid particles, nor the transition to a much lower hydraulic conductivity at the SRSNE Site, both of which would increase the travel time for VOCs from the site to the Town Production Wells.]

The memorandum interpreted that, based on its hydrogeologic context and a survey of nearby industries, Well No. 4 was impacted by VOCs from "other pollutant source(s) and not Solvents Recovery." The two other "likely sources" of VOCs situated near west and southwest of Production Well No. 4 include:

- Supreme Lake Company, located west of Well No. 4 along the north side of Curtiss Street; and
- A chrome plating facility southwest of Well No. 4, south of Curtiss Street.

The memorandum suggested that pumping from Well No. 6, situated north of the Quinnipiac River, would reverse the natural southward gradient and induce flow from the river and from the other (south) side of the river via underflow. Thus, while the SRSNE Site was interpreted as one potential source of the VOCs detected at Well No. 6, the CT DEP memorandum stated that "the greatest threat to well #6 at this time is the contaminated area southwest of well #4 on the other side of the Quinnipiac." Indeed, VOC concentrations were reported as high as 3,700 micrograms per liter (ug/L) at well CW-10-78, which is located southwest of Production Well No. 4.

CT DEP (October 25, 1978). CT DEP issued an internal memorandum titled "An Assessment of the Extent and Probable Sources of Surface and Groundwater Contamination in and around Solvents Recovery Services [sic] of New England, Southington," summarizing some of the site history and environmental sampling results near the SRSNE Site. The memorandum indicated that lagoons had been created at the SRSNE Operations Area for the storage of waste liquids and sludges, composed of various paints, solvents, oils, and still-bottom solids. The largest lagoon was approximately 90 feet long, 40 feet wide, and 10 feet deep (approximately 270,000 gallon capacity). According to the memorandum, the lagoons were frequently full and sometimes overflowed into the drainage ditch adjacent to the railroad tracks east of the site. The ditch discharged under the tracks via a culvert to a stream that flowed across the former Cianci Property to the Quinnipiac River (see Figure 5).

Warzyn Engineering, Inc. (1980). Warzyn Engineering, Inc., a USEPA subcontractor to JRB Associates, performed field investigations to define contamination sources that may have contributed to the closure of three municipal wells (Well Nos. 4, 5, and 6) in two well fields in Southington, including the Curtiss Street Well Field south of SRSNE. The Warzyn investigation included sampling of surface water, ground water, and soils throughout the Quinnipiac River Valley (including the SRSNE Operations Area and other potential sources).

During the subsurface investigation, Warzyn (1980) installed 14 TW-series monitoring wells at the former Cianci Property, the Town Well Field Property, and several commercial properties south of the Curtis Street Well Field. These wells were installed by hollow-stem augers and/or rotary drilling equipment. Twelve of the TW-series wells were installed in the shallow overburden to monitor the water table. The remaining two new wells, TW-7B and TW-8B, were installed on the former Cianci Property. Wells TW-7B and TW-8B were installed approximately 15 to 20 feet deeper than the adjacent shallow wells, TW-7A and TW-8A, to provide vertical gradient data. While well TW-8B was screened entirely in the bedrock, well TW-7B was screened across the overburden/bedrock interface. Higher concentrations of VOCs were detected in the shallow well (TW-8A) than in the deep overburden well (TW-8B) at the TW-8 cluster along the western boundary of the former Cianci Property. In contrast, at the TW-7 cluster, higher VOC concentrations were detected at deep well TW-7B. Warzyn (1980) attributed these results to the slightly downward hydraulic gradient at the TW-7 cluster and/or relatively high density of the potential "undissolved portion or subparticles" of the VOC materials detected in the ground water at the former Cianci Property. During later investigations (HNUS, May 1994; ENSR, November 1994; ENSR, June 1995), high concentrations of VOCs, consistent with the interpreted presence of DNAPL, were detected in the shallow bedrock in the area immediately downgradient (east) of interface well TW-7B. These findings suggested that overburden/bedrock interface well TW-7B may have acted as a conduit for the downward migration of NAPL into the bedrock. Well TW-7B was abandoned in May 1995 during NTCRA 1 implementation.

Warzyn produced a report entitled "Hydrogeologic Investigation, Town of Southington, CT," which interpreted that the SRSNE facility was a primary source of VOC contamination to ground water and was partially responsible for closing Well Nos. 4 and 6. However, this document also identified four VOC sources unrelated to SRSNE that are nearer to Town Production Wells No. 4 and 6 (see Figure 2):

- The Caldwell property (Supreme Lake Manufacturing);
- Southington Form Construction Company;
- An abandoned chrome plating factory; and
- An unlocated source south of Southington Form Construction Company.

An additional, "isolated" VOC source was also identified on the former Cianci Property based on the detection of elevated concentrations of VOCs at the former Cianci production well, including trichloroethene (TCE) (60,000 ug/L), PCE (4,500 ug/L), methylene chloride (4,300 ug/L), and 1,1,1-trichloroethane (1,1,1-TCA) (3,400 ug/L). [During the completion of the RI, NAPL presence was inferred in the vicinity of the former Cianci well based on high VOC concentrations and/or alcohols detected at two bedrock monitoring wells installed in the 8-inch diameter, open-bedrock borehole. In addition, hydraulic tests were performed at the former Cianci well prior to the installation of the monitoring wells to assess the potential yield of the former Cianci Well. These tests indicated that the former Cianci Well was likely capable of sustaining a yield of up to 40 gpm, which would represent a substantial hydraulic stress in the fractured bedrock at the site. Given these results, and the inferred presence of NAPL near the former Cianci Well location, which is cross-gradient from the Operations Area, it appears that the former Cianci Well may have mobilized NAPL toward itself during pumping.]

Warzyn (1980) maps show the location of the former Cianci Production well in the north-central portion of the former Cianci Property, approximately 50 feet south of Lazy Lane. The former Cianci Production Well was identified and used to obtain additional hydrogeologic characterization data during the completion of the RI. These activities included: obtaining three grab samples of ground water from top, middle and bottom of the water column in the former Cianci Well; specific-capacity testing the well; performing downhole fracture logging within the open-bedrock well; and installing and sampling two new monitoring wells within the open bedrock interval of the well. The results of these activities are discussed below in Sections 3 and 4.

Ecology & Environment, Inc. (E&E) (1980). E&E, a USEPA contractor, conducted an investigation of the contamination of the Curtiss Street Well Field (Town Production Well Nos. 4 and 6). E&E attempted to identify potential sources that may have contributed to the contamination. Some historical information about the operations at the SRSNE facility was provided. No field sampling was performed as part of this effort.

Ecology & Environment, Inc. (E&E) (1982). E&E installed monitoring wells MW-1 through MW-8 and assessed the hydrogeology of the Town Well Field area under unstressed (natural) and stressed (pumping) conditions to assess horizontal and vertical ground-water flow. E&E performed ground-water sampling from overburden and bedrock wells adjacent to the Operations Area. E&E reviewed previous hydrogeologic and analytical data and concluded that the former lagoons at the Operations Area constituted a major source of ground-water contamination. E&E concluded that under pumping and non-pumping conditions, contaminated ground water under the SRSNE Operations Area could affect the Production Wells.

Wehran Engineering Corporation (1982). Based upon the water quality data contained in the Warzyn report and a limited amount of additional sampling and analysis, Wehran Engineering published a "Hydrogeologic Assessment and Recommendation for a Remedial Action Plan to Control Contaminant Migration and to Recover and Treat Ground Water" in January 1982 on behalf of SRSNE, Inc. This report further documented the off-site VOC sources and drew conclusions concerning the VOC contamination of the Town of Southington Well Field.

The Wehran report described six confirmed VOC source areas, which included the SRSNE Site, the Cianci Property, and four off-site locations shown on Figure 2 of this RI Report. A summary of the findings at the off-site locations is as follows:

- Caldwell Property. This site is located between the Quinnipiac River and Curtiss Street immediately east of the B&M railroad right-of-way and is located within 300 feet of both the Town of Southington Production Wells Nos. 4 and 6. VOC contaminants found on this site include but are not limited to TCA (up to 90 ug/L), TCE (up to 1 ug/L), and methylene chloride (up to 8.6 ug/L). The source of these organic contaminants is attributed to the disposal of waste solvents on the property, as documented in the Warzyn report. VOCs have been detected at shallow overburden monitoring well TW-5 on the Caldwell Property at higher concentrations than have been detected in overburden or bedrock in the area between Town Production Well Nos. 4 and 6 and the SRSNE Site. This property is the site of Supreme Lake Manufacturing, referred to by Warzyn (1980).

- Southington Form Construction Company. This site is located on the south side of Curtiss Street, approximately 200 feet from the Town of Southington Production Well No. 4. VOC contaminants found on this site include, but are not limited to, 1,1,1-TCA (up to 16 ug/L) and TCE (up to 0.2 ug/L). Wehran suggested that the source of VOC contamination found at this property may be attributable to an unnamed source located further to the south as described below.

- Chrome Plating Factory. This site is located to the south of Curtiss Street, immediately west of Southington Form Company. VOC contaminants found on this site include, but are not limited to, 1,1,1-TCA (up to 21 ug/L), TCE (up to 0.6 ug/L), and methylene chloride (up to 1.8 ug/L). The source of these organic contaminants is suspected to be attributed to the disposal of waste solvents on the property, as documented in the Warzyn report.

- Unnamed Site. The Wehran report documented a location somewhere to the south of the Southington Form Company site as a recognized source of VOC ground-water contamination. This conclusion was reached after analysis of an upgradient well (TW-2) on the Southington Form Company site showed concentrations of VOCs, which included 1,1,1-TCA (up to 3,300 ug/L), TCE (up to 23 ug/L), and methylene chloride (up to 120 ug/L). The Warzyn report first documented this situation by stating, "the contamination in Well TW-2 is probably up-gradient of the Southington Form Company property." [Information presented in this RI report suggests that the "unnamed site" is the former Ideal Forging Site.]

The following conclusions were indicated in the Executive Summary of the Wehran (1982) report:

- "The contaminant plume associated with the SRSNE Site becomes tenuous with distance from the site such that contaminant concentrations in Well No. 6 are either non-detectable or are obscured by the relatively higher concentration levels originating from the other identified contaminant sources in the Curtiss Street well field area;" and

- "The contaminant plume consisting of sources identified within the Curtiss Street well field area appear to pose the most significant continuous threat to the quality of ground water drawn from either Well Nos. 6 or 4."

York Wastewater Consultants, Inc. (YWC), 1983. YWC installed wells SRS-1 through SRS-4 and prepared a document titled "Engineering Report for Off-Site Groundwater Interceptor System, Hydraulic Performance Verification System, and Final Connecticut DEP Permit Application," in support of the installation of a well system to contain ground water in the off-site area downgradient of SRSNE. The document presented ground-water elevation contours showing a hydraulic gradient generally toward Town Production Well Nos. 4 and 6 from SRSNE. YWC calculated that a pumping rate of approximately 70 gpm may be sufficient to hydraulically control ground water within the outwash, till, and bedrock in the area approximately 300 feet south of the present NTCRA 1 Containment Area between the railroad tracks (on the west) and the Quinnipiac River (on the east).

The discharge permit application was not granted by CT DEP, and the containment system was constructed but was never finalized and brought into operation.

SRSNE, Inc. (1986 - 1992). To meet one condition of the 1983 Consent Decree, SRSNE installed and operated the OIS, which recovered contaminated ground water from the perimeter of the Operations Area. YWC and Loureiro Engineering Associates, Inc. (Loureiro) prepared an engineering report in 1983 regarding the conceptual design of the multi-point well system, the anticipated pumping rate from the system, the results of a treatability study for the pumped ground water, and a CT DEP discharge permit. Loureiro and YWC prepared the contract document titled "Final Design Plans and Specifications for Multi-Point Shallow Well Groundwater Recovery System, Solvents Recovery Service of New England, Inc., Southington, Connecticut," dated November 1984, which presented a site plan, drawings, and profile views of the proposed OIS multi-point ground-water extraction system design. The OIS was installed by S.B. Church Company in 1985, and operated by SRSNE from January 17, 1986 through 1994.

During operation of the OIS from its 1986 start up through 1991, ground water from the wells was pumped to a modified cooling tower within the Operations Area, where VOCs were air stripped from the aqueous phase and discharged to the ambient air. While the OIS system was reportedly designed to yield 7.5 gpm of ground water (Loureiro, October 1983), the total combined extraction rate of the system up until 1990 ranged from approximately 1 to 20 gpm (HNUS, April 1990).

In 1989, three of the 1.25-inch-diameter galvanized steel OIS wells were removed and replaced with 4-inch-diameter stainless steel wells, screened across the overburden/bedrock interface, in an attempt to improve the yield of the OIS. In July 1992, the CT DEP replaced the air stripper/cooling tower with an ultraviolet (UV)/peroxidation system, which treated contaminated ground water extracted by the OIS until the system was shut down in 1994. The average total combined pumping rate of the OIS from 1992 to 1994 was approximately 3 gpm.

Following the observation of DNAPL in the Containment Area during the NTCRA 1 construction activities, and based on the interpretation that the OIS wells, which were screened across the overburden/bedrock interface, could act as conduits and could transmit DNAPL downward into bedrock within the Operations Area, the OIS wells were overdrilled and grouted by BBL. This activity took place in June/July 1995, during NTCRA 1 construction and prior to the start-up of the NTCRA 1 extraction wells. DNAPL was encountered at six of the OIS wells during the OIS abandonment process, as discussed further below.

Ground-Water Associates (GWA), 1986. GWA installed wells TRW-3 through TRW-8, SRS-5, and SRS-6 in the same general area where YWC had installed wells SRS-1 through SRS-4, approximately 300 feet south of the present NTCRA 1 Containment Area between the railroad tracks (on the west) and the Quinnipiac River (on the east). Based on the relatively large diameter of the TRW-series wells (4 to 8 inches) and the fact that these wells underwent pumping evaluations by GWA, the TRW wells evidently were intended to be used as part of the Off-Site Interceptor System, which was described by YWC (1983). The results of step-drawdown and recovery tests at the TRW wells indicated that these wells could maintain pumping rates between 1 and 10 gpm each. The findings of the GWA investigation are presented in a document titled "Results of Pumping Test Analysis for Recovery Wells at Solvents Recovery Service of New England, Inc., Southington, Connecticut" (GWA, 1986).

EPA Technical Assistance Team (TAT) (1988). The USEPA TAT contractor, Roy F. Weston, Inc., collected soil samples in June 1988 from the Operations Area. The samples were analyzed by Contract Laboratory Program (CLP) laboratories for VOCs, semi-volatile organic compounds (SVOCs), pesticides/polychlorinated biphenyls

(PCBs), metals, and dioxins (Weston, 1988). The results were validated following USEPA protocols, and a number of organic and inorganic contaminants were identified.

The VOCs detected in the soil samples included 1,1,1-TCA, TCE, PCE, and ethylbenzene. Individual VOC concentrations ranged from 1 to 480,000 micrograms per kilogram (μg/kg). SVOCs detected include naphthalene, 2-methylnaphthalene, butyl benzylphthalate, and di-n-octylphthalate. The SVOCs ranged from 30 to 48,000 μg/kg. Pesticides detected included aldrin and heptachlor epoxide. One PCB, Aroclor 1254, was detected. Dioxins and furans, 0.336 milligrams per gram (mg/g) as 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) equivalents, were also identified in soil samples obtained in the area of the former secondary lagoon.

<u>USEPA RCRA Inspection (1989)</u>.The USEPA performed a RCRA inspection of the former SRSNE Operations Area on February 1 and 2, 1989. The USEPA inspection team observed existing site conditions, including: the drum staging, solvent processing, and drum storage areas; the tank farm; the operations building; the on-site ground-water recovery system; and operations records. The USEPA Inspection results were presented in Inspection Report (USEPA, February 1989), which reviewed the general observations and findings of the inspection. The report indicated numerous circumstances of practices that were found to be out of compliance. Based on operations records submitted by SRSNE, USEPA identified 75 circumstances of leaks during 1988. In addition, the Inspection Report indicated that the OIS did not appear to be operating as an effective hydraulic barrier that would prevent off-site ground-water flow.

<u>SRSNE Site Post Shutdown Cleanup (1991)</u>. SRSNE performed post-shutdown site cleanup activities between January 25 and March 26, 1991. As part of these cleanup activities, on-site tanks were emptied of all free liquids and sludges, and then scraped and pressure washed. In addition, all concrete containment dikes were steamed and pressure washed. The wash waters were collected using a vacuum truck and disposed off site. A total of 70,284 gallons of bulk liquid (including approximately 20,000 gallons of sludge), 178 55-gallon drums, two 25-gallon pails, and 1,735 gallons of cleaning residue were shipped off site during this cleanup activity.

<u>EPA Region I ESD and Technical Assistance Team (TAT) (1992)</u>. The USEPA ESD and the TAT contractor, Roy F. Weston, Inc., performed an evaluation to assess the extent of contaminated soils and sediments in the vicinity of the Operations Area. Samples of surface and subsurface soils and sediments were collected from the drainage ditch between the eastern perimeter of the Operations Area and former Cianci Property. These samples were field-screened for the presence of PCBs and VOCs. Two surface-water samples were also collected and analyzed. A soil gas survey was conducted to help identify the extent of VOCs in the subsurface. The field screening program was supported by the collection of several samples for laboratory analyses. The results of the investigation are presented in the report "Removal Program Supplemental Site Investigation" (Weston, June 1992).

Results of the laboratory analysis of soil and sediment samples indicated the presence of PCB Aroclors (1254 and 1260) in the range of 0.50 to 160 ppm and 0.30 to 210 ppm, respectively. The PCBs were identified in samples collected from the cooling tower/air stripper catch basin, in the drainage ditch, and in several outfalls. VOCs detected in the soil and sediment samples included 1,2-dichloroethylene (1,2-DCE), 1,1,1-TCA, toluene, ethylbenzene, xylenes (total), and methylene chloride. The VOC concentrations ranged from 19 to 7,600 parts per billion (ppb). The VOC data were generated using a field screening method; individual VOCs were tentatively identified and concentrations were estimated.

As a result of the TAT/ESD investigation, a removal action was implemented by USEPA ESD in September 1992 to mitigate potential health threats associated with PCB contamination in soils and sediments. The removal action included excavating contaminated sediments from the drainage ditch area, installing a french drain, and backfilling with clean materials.

USEPA (1994). USEPA conducted a Time-Critical Removal Action in January-February 1994, during which three 55-gallon drums, two 20-gallon pails, and six 5-gallon pails of lab-pack containers were filled with residual laboratory chemicals and disposed off site. In addition, 50 bags of asbestos-containing materials were removed from exterior processing equipment and disposed off site. In April 1994, a Nickel-63 radioactive source in a gas chromatogram was also shipped off site.

Halliburton NUS Environmental Corporation (May 1994). At the request of the USEPA, HNUS performed Phases I, II, and III of an RI at the site. This investigation was authorized by the USEPA Region I (Work Assignment No. 01-1L08, Contract No. 68-W8-0117). Results of the RI are presented in the "Final Remedial Investigation Report," May 1994. Phases 1 and 2 consisted of field investigations to determine the presence of contaminants in the study area. Phase 3 completed the additional field investigations and included the risk assessment, treatability studies, and feasibility studies. A summary of the data generated by HNUS is presented below.

Operations Area. VOCs at the Operations Area were detected in saturated and unsaturated soil samples collected from areas where past activities, such as spent solvent transfer, drum handling, and storage and fuel blending, occurred. Total VOC concentrations detected in soils collected from the former primary lagoon area range from 1,344,400 to 2,778,030 ug/kg. Soil samples collected from the foot of the hill where the tank farm is located indicated a total VOC concentration of 229,500 ug/kg. The highest VOC concentration (9,409,000 ug/kg) was detected in soils collected from location P-1A. For each sample location in the Operations Area, the highest value of SVOCs was bis(2-ethylhexyl)phthalate (BEHP). The highest concentration of total SVOCs in soil in the Operations Area were near the former primary lagoon area.

Dioxin/furan compounds were not detected in most soil samples analyzed from the Operations Area. The maximum concentration of 2,3,7,8-TCDD was 0.30 ug/kg and was collected at a location near the former open pit incinerator. The highest concentration of several inorganics (for all Phase 2 locations) were detected in soils collected from this same location, including arsenic (5.4 mg/kg), cadmium (389 mg/kg), lead (1,750 mg/kg) and zinc (171 mg/kg).

Four overburden wells were sampled during Phase 2 activities to evaluate the presence of contaminants in the overburden ground water beneath the Operations Area. The majority of the 17 VOCs detected in the overburden ground water in the Operations Area were chlorinated hydrocarbons. The highest concentration of total VOCs (451,100 ug/L) in the Operations Area was detected in well P-1B, adjacent to the both secondary lagoon and the OIS.

Sixteen SVOCs were detected in the overburden aquifer. The most frequently detected were the phenol compounds, 2-methylphenol and 4-methylphenol. Overall, elevated SVOC concentrations were detected primarily at P-1B.

A LNAPL, described as a 1.5-foot-thick floating layer of viscous, brown to black, oily liquid was observed in well P-1B, screened across the water table. The other locations did not exhibit any visible LNAPL. The presence of the LNAPL at well P-1B could be attributed to fuel product (from the tank farm) or the discharge of aromatic solvents. A DNAPL was also inferred to be potentially present at well P-1B based on a sheen observed in silt and fine sand at the bottom of the bailer, but this inference was complicated by the presence of a floating LNAPL layer in the well.

VOCs were also detected in the bedrock wells installed in the Operations Area. Results from locations P-1A and P-4A indicated concentrations in the tens to hundreds of ppm for several compounds, including predominantly 1,1,1-TCA in both wells and toluene and TCE in P-4A.

Only low levels of SVOCs were identified in the bedrock aquifer at the Operations Area. The extent of bedrock aquifer contamination in the Operations Area was noted in the area bounded approximately by P-2A, P-8A, and TW-10, with P-4A in the center.

Former Cianci Property. Elevated VOC concentrations were generally detected in soil samples obtained from the southern half of the former Cianci Property, which is directly downgradient of the Operations Area. The northern half of the property is generally free of VOC contamination.

A soil sample obtained at the 4-6 foot depth interval at location P-5 had the highest detected soil VOC concentrations for all Cianci Property locations. Total VOC concentrations at other Cianci Property locations were at least one order of magnitude lower. Only one SVOC, BEHP, was detected in the soil sample collected at location P-10 on the former Cianci Property. No SVOCs were detected at other sampled locations on the property.

A review of inorganic analyses for soils sampled at the former Cianci Property identified elevated concentrations of several metals at location P-11A, directly downgradient of the Operations Area. The arsenic concentration at P-11A was the highest arsenic concentration (5.5 mg/kg) of all soils sampled from all properties. Cadmium and zinc were detected at concentrations of 296 mg/kg and 158 mg/kg, respectively, in soils collected from P-11A. The other samples had inorganics concentrations comparable to, or lower than, those in the upgradient locations (site background).

Seven overburden wells within the former Cianci Property were sampled during Phase 2. The water table aquifer in the northern half of the property is relatively free of VOCs. The highest concentration of VOC contaminants in the water table aquifer outside the Operations Area appears to be confined to a narrow path running east from the facility to the river at locations P-1B, TW-8A, and P-3B. Total VOCs were detected at TW-8A at a concentration of 10,906 ug/L. The total VOC concentration for location P-3B was 1,540 ug/L, an order of magnitude lower than the upgradient well, TW-8A. The distribution of SVOCs within the Cianci Property overburden aquifer mirrors the distribution of VOCs. The highest VOC concentrations were detected within a narrow area leading from P-1B to P-3B.

Low levels of VOCs were detected in the bedrock aquifer in the northern portion of the former Cianci Property. The highest concentration of total VOCs in bedrock wells at the Cianci Property, 352,800 ug/L, was detected during Phase 3 sampling at well MW-125C, which is a shallow bedrock well located downgradient of the Operations Area. The predominant contaminants detected in the well include 1,2-DCE, TCE, toluene, and MIBK. Vinyl chloride was detected in the bedrock aquifer at P-3A at 7,300 ug/L.

Southington Well Field Property. Soil samples were obtained at five locations on the Town Well Field Property. VOCs were detected only at boring location B-3, which is situated in the northern portion of the property, near the property line between the Town Well Field and former Cianci Property. These VOCs consisted of chlorinated hydrocarbons and aromatics totaling 6,790 ug/kg. VOCs were not detected in soil samples collected from all other locations (all south of B-3) on this property. SVOCs were detected in soil samples collected at locations B-3 and MW-121C in the Town Well Field Property. At B-3, phenol (80 ug/kg) and benzoic acid (130 ug/kg) were identified. Only BEHP was detected at MW-121C. The other locations sampled were free of SVOCs. Most of the metals concentrations in Town Well Field Property soils were in the same range as those found in the upgradient locations (site background).

Three monitoring wells, P-13, MW-7, and MW-127B, were sampled during Phase 2 to evaluate the presence of organic compounds in the water table aquifer within the Town Well Field Property. In general, the concentrations of VOCs detected in the wells were substantially less than those detected at the Operations Area and the former Cianci Property. Elevated VOC levels in the Town Well Field Property water table aquifer are limited to the northernmost areas at the Town Well Field Property and the area adjacent to the OIS. Trace levels of SVOCs, mainly phenols and phthalates, were detected in the overburden of the Town Well Field Property. Both total and dissolved inorganics concentrations in the Town Well Field Property overburden ground water were comparable to the upgradient sample results (site background).

Human Health Risk. As a result of Phase 1 and 2 investigations described above, several contaminants of concern (COC) were identified in the study area ground water, shallow soil, surface water, and sediment. Phase 3 of the RI evaluated the possible adverse health effects to human receptors posed by these contaminants to determine the total cancer risks and total non-cancer risks present. Average total cancer risks and average total hazard indices (non-carcinogenic risk factors) posed by potential ingestion of the study area ground water exceeded acceptable USEPA target levels. The highest calculated ground-water ingestion risks were associated with the Operations Area and the former Cianci Property. VOCs comprised the primary constituents of concern (COCs) in ground water. The ground water in the area along the east side of the Quinnipiac River directly downgradient of the Operations Area and the former Cianci Property had the second highest calculated risk levels, which also exceeded acceptable USEPA target levels. No current ground-water receptors exist in the areas where the calculated ground-water ingestion risks exceeded target levels.

The average total cancer risks and total hazard indices calculated for accidental ingestion and dermal contact within the study area shallow soils do not exceed acceptable USEPA levels. The Operations Area and former Cianci Property had the only calculated maximum risks that exceeded USEPA acceptable levels, but these results were calculated using subsurface rather than surface soil data. Furthermore, most of the Operations Area is covered with asphalt. The total cancer risks calculated for accidental ingestion and dermal contact with study area surface waters and sediment do not exceed acceptable levels.

Ecological Risk. Several COCs in the study area pose potential adverse effects to ecological receptors. The ecological risk due to soil contaminants is associated exclusively within the Operations Area and the former Cianci Property. In surface water and sediment, potential ecological risks have been identified throughout the initial RI study area.

ENSR (June 1994). The SRSNE PRP Group undertook certain investigations with the NTCRA 1 SOW and AOC developed by the USEPA, and prepared a "Final Soil, Groundwater, and Additional Studies Work Plan for the SRSNE Superfund Site" (ENSR, June 1994). The work plan focused on collection of the ground-water data required to design and construct the overburden containment system and the treatment system for the extracted ground water and described the ground-water investigation activities, which included a containment area soil boring program, overburden pumping test, wetlands/floodplain assessment, effluent toxicity assessment, treated ground-water discharge option assessment, treatment plant siting option assessment, and the ground-water treatability assessment.

Soils investigations described in this work plan were developed to assess whether ground-water concentrations may be reduced by removing VOCs from the Operations Area soil, and included:

- a soil gas survey within the Operations Area to determine the distribution and nature of VOCs and DNAPL;
- a VOC concentration field survey to evaluate the possible presence of DNAPL;
- soil sampling and analyses to aid in the evaluation and/or pilot testing of remedial options;

- two-phase field pilot test to evaluate the feasibility of soil vapor extraction (SVE) and SVE coupled with air sparging;

- data collection to evaluate appropriate technologies for treatment of off-gas VOCs; and

- soil column studies to evaluate the feasibility of using methane and propane as primary substrate to induce cometabolic destruction of halogenated VOCs within the site soils.

This work plan also included a shallow bedrock pumping test and a DNAPL investigation.

Upon completion of the investigations as described above, ENSR completed a report entitled "Groundwater Technical Memorandum, Soils Study Report and Additional Studies Report for the SRSNE Superfund Site," which documented the results of the work plan activities.

The following summary was adapted from the Executive Summary of the ENSR report.

Geologic and hydrologic data. The geologic deposits in the area of the proposed containment system were identified, and a cross section showing the interpreted distribution of these deposits was prepared. This information was used for the conceptual NTCRA 1 Containment System design.

Aquifer tests to determine containment system requirements. Aquifer hydraulic properties in the area of the proposed containment system were measured. The overburden pumping well sustained a pumping rate of 1.6 gpm, with an approximately 60- to 90-foot-radius of influence. A line of overburden pumping wells was recommended for the NTCRA 1 Containment System.

Preliminary assessment of potential containment system effects on wetlands and floodplains. Water elevation measurements during the overburden pump test indicate no effects on the wetlands adjacent to the Quinnipiac River, and possibly minor effects on the drainage ditch on the east side of the B&M Railroad.

Bench-scale tests to optimize the design of an enhanced oxidation treatment system for ground water. Bench-scale tests were performed by two enhanced oxidation equipment vendors. Test results show that enhanced oxidation can achieve discharge goals for organics, but full-scale system effectiveness to be expected during NTCRA 1 were not known. Metals removal testing indicates that up to 97 percent of metals can be removed.

Aquatic toxicity tests to demonstrate that the enhanced oxidation treatment system will achieve effluent discharge limits. Effluent from enhanced oxidation treatment may require further treatment to achieve aquatic toxicity limits, based on the bench-scale tests and experience with the current full-scale system.

Assessment of discharge options for treated ground water. Discharge to the Quinnipiac River appears to be the most feasible option for treated ground water, provided that aquatic toxicity discharge limits can be met.

Evaluation of locations for siting the treatment system. An area in the northwest quadrant of the former Cianci Property is the preferred location for the treatment system.

Evaluation of other ground-water treatment technologies in comparison to enhanced oxidation. Bench-scale tests indicate that biodegradation can achieve similar results compared to enhanced oxidation treatment. Modeling results suggest that air stripping would also be an effective ground-water treatment method, when coupled with an air treatment system.

Subsurface air permeability testing. The vadose zone soil in the Operations Area appears to be highly anisotropic and heterogeneous based on the pilot test measurements, and in-situ air permeabilities could not be estimated. SVE would not be effective for soil treatment based on these findings and the shallow water table at the site.

Soil gas survey to delineate the distribution of VOCs within the Operations Area. Contaminant concentrations were measured in soil gas and soil samples at grid points throughout the Operations Area. Results are consistent with earlier estimates of the general extent of VOCs (HNUS, June 1992). Duplicate measurements at some locations indicate a high degree of variability in concentrations within the limits of the NTCRA 1 Containment Area.

Air sparging/extraction testing. Pilot test measurements indicate a high potential for preferential flow and lateral migration of contamination during air sparging (AS) in the Operations Area. The percentage of injected air that was captured during testing is unknown due to the lack of detection of SF_6 during the tracer gas study, the formation of anisotropy, probable lateral migration, and the low effectiveness of the SVE system.

Evaluation of catalytic oxidation or other technologies for treatment of vapor-phase VOCs. Air treatment requirements were not evaluated in detail because results of the soil vapor extraction (SVE)/AS test did not allow reliable estimates of air flow rate and concentrations of contaminants.

Bedrock investigations. Bedrock pumping test results indicate that hydraulic properties of the bedrock may be anisotropic and heterogeneous. The bedrock and overburden formations appear to be hydraulically connected based on the results of pumping tests of both aquifers.

DNAPL investigations. The potential presence of DNAPL was evaluated based on the site history and on measured concentrations of contaminants. DNAPL appears to be present in the Operations Area overburden and the overburden and upper portion of the bedrock beneath the Containment Area.

Geophysical surveys. Ground-penetrating radar (GPR) was not effective for mapping the till surface on the former Cianci Property. Electromagnetic anomalies were measured in the overburden and shallow bedrock, but did not appear correlative to the known distribution of contaminants.

Additional soil investigations. Physical, physicochemical, and biological properties of soil samples from the Operations Area were measured, and bench-scale bioventing tests were performed. Results of these tests indicate that in-situ biodegradation would not be effective for soil treatment in the vadose zone of the Operations Area.

ENSR (October 1994 to March 1995). ENSR performed comprehensive ground-water sampling and ground-water elevation measurement rounds, referred to as monitoring "snapshots," in October/November 1994 and March 1995. These monitoring rounds were performed to supplement the data obtained during the first three phases of the RI, which were obtained as separate, incomplete sampling rounds. In addition, monitoring wells MW-501A though MW-501C and MW-502 were installed and sampled in April and May 1995 to fill data gaps in the area east of the site.

These sampling rounds generally confirmed the hydrogeologic information presented in the May 1994 HNUS RI Report, including the apparent convergence of the hydraulic gradient along the Quinnipiac River in the overburden and bedrock. The snapshot sampling results indicated hundreds of ppm of total VOCs in the Operations Area overburden wells, consistent with previous results obtained by HNUS during the initial RI sampling. The snapshot results for Operations Area bedrock wells, however, indicated that bedrock ground-water concentrations had declined by approximately three orders of magnitude (from the tens or hundreds of ppm to the tens or hundreds of ppb) since the RI sampling by HNUS. The VOC concentrations at the former Cianci Property during the snapshot sampling events were generally consistent with the results obtained during the first three phases of the RI, with total VOC concentrations up to hundreds of ppm in the overburden and the bedrock.

The snapshot sampling results indicated anomalously high concentrations of VOCs in the deep overburden and bedrock across the river east of the site. The May 1995 snapshot sampling results of monitoring wells MW-501A though MW-501C, however, indicated relatively low VOC concentrations in ground water further to the east, showing that the eastern extent of the anomalously high concentrations in the deep overburden and bedrock ground water across the river east of the site have been reasonably well delineated. Anomalously high concentrations of VOCs were detected during snapshot sampling at wells installed in the deep overburden and bedrock near the corner of Lazy Lane and Queen Street, in the shallow overburden along Curtiss Street and in the Town Well Field area south of the site.

<u>Blasland, Bouck & Lee, Inc. (BBL) (September 1994 to September 1995) and Handex (December 1995 through present)</u>. BBL performed a NTCRA 1 pre-design investigation in September and October 1994 in the NTCRA 1 Containment Area to further characterize the overburden geology and hydrogeology in support of the design for the NTCRA 1 Ground-Water Containment and Treatment System (December 1994). The pre-design investigation included two geotechnical soil borings in the proposed area of the treatment system building. In addition, four initial NTCRA 1 overburden ground-water extraction wells (RW-1 through RW-4), four overburden piezometers (PZO-1 through PZO-4), and four bedrock piezometers (PZR-1 through PZR-4) were installed. Brief pumping evaluations were performed during the development of the extraction wells, and a 48-hour pumping test was completed at well RW-2. The results of the NTCRA 1 pre-design investigation and the previous investigations by HNUS and ENSR were used to develop a three-dimensional, numerical ground-water flow model in support of the design of the NTCRA 1 Ground-Water Containment System.

During the construction of the NTCRA 1 Ground-Water Containment and Treatment System between February and July 1995, BBL performed additional subsurface investigative activities associated with the installation of the NTCRA 1 ground-water extraction wells and compliance piezometer network. These installations provided additional geologic data in the vicinity of the NTCRA 1 Containment Area and confirmed that the till is relatively thin along the east side of the Containment Area, where HNUS had interpreted a potential "till window." During the drilling of these borings and the installation of the downgradient hydraulic barrier (sheet-pile wall), a layer of cobbles and/or boulders was encountered near the top of till.

During the installation of NTCRA 1 compliance piezometers near the north end of the Containment Area in May 1995, DNAPL was encountered near the base of the overburden within the till. At the location where DNAPL was encountered, a DNAPL collection well (MWD-601) was installed. Subsequent bailing and pumping of well MWD-601 yielded approximately one liter of DNAPL, which was submitted for chemical and physical characterization, as summarized in Table 5.

The MWD-601 DNAPL contained high concentrations of chlorinated and aromatic hydrocarbons, including TCE, PCE, toluene, and xylenes. Other VOCs were detected at lower concentrations. PCB 1260 was also detected in the MWD-601 DNAPL. A ground-water sample was also obtained from well MWD-601 for chemical characterization and contained high concentrations of chlorinated and aromatic hydrocarbons, including TCE, PCE, toluene, and xylenes. Other VOCs were detected, albeit at relatively minor concentrations. PCB 1260 was also detected in the MWD-601 ground water. Figure 12 shows the relationship between the ground-water concentrations detected at well MWD-601 (horizontal axis) versus the theoretical, chemical-specific, effective solubility limits (vertical axis) calculated based on Raoult's Law (Kueper, July 1995). The reasonably good correlation between the detected ground-water concentrations and theoretical solubility limits indicates that ground-water concentrations detected at well MWD-601 provide an empirical demonstration of the usefulness of Raoult's Law for calculating effective solubilities in ground water. This finding is consistent with the intent of DNAPL collection well MWD-601, which was installed with a short (5-foot long) well screen placed within the depth interval where DNAPL was encountered. Thus, the VOC concentrations detected in ground water at monitoring well MWD-601 provide an empirical basis for evaluating NAPL presence based on ground-water concentrations at other ground-water sampling locations.

The relationship between MWD-601 DNAPL density and temperature is depicted graphically on Figure 13, and the relationship between viscosity and temperature is shown on Figure 14 (Kueper, July 1995). These figures indicate that density and viscosity both increase with decreasing temperature. The MWD-601 DNAPL density and viscosity would be expected to be approximately 1.12 grams per cubic centimeter (g/cc) and 1.3 centistokes (cS), respectively, at a subsurface temperature [approximately 10° centigrade (C), or 50° Fahrenheit (F)]. The MWD-601 DNAPL interfacial tension measurement, 7.8 dynes/cm (Table 5), would not be expected to be significantly different at the ground-water temperature (Kueper, May 1995). These physical testing results suggest that the DNAPL collected at well MWD-601 is relatively easy to mobilize.

Prior to the start-up of the NTCRA 1 ground-water extraction system, BBL abandoned the 25 Interceptor Wells (IW series, shown on Figure 4), associated with the OIS on the SRSNE Operations Area, and monitoring wells TW-7B, DN-1, DN-2, MW-502, and WE-4 (BBL, October 1995). These wells were all thought to be screened across the overburden/bedrock interface and, therefore, could have presented pathways for DNAPL migration from overburden to bedrock. This interpretation is supported by the substantial increase in bedrock VOC concentrations immediately downgradient of the OIS and monitoring well TW-7B. Monitoring well MW-502 was subsequently replaced with a well screened only in the overburden. The overburden/bedrock interface wells in the vicinity of the NTCRA 1 extraction system were abandoned prior to system start-up to reduce the potential for downward NAPL mobilization under the modified hydraulic gradient conditions associated with NTCRA 1 pumping.

An initial screening was performed prior to abandonment drilling to measure and record well depths and presence/absence of DNAPL at the bottom of the wells. All abandoned were overdrilled using hollow-stem augers. Well casings and screens were removed to the extent practicable, and the boreholes were filled with neat cement grout via the tremie method.

During the well abandonment process, DNAPL presence was inferred or confirmed at several locations. DNAPL was identified in the soil at the bottom of OIS ground-water extraction wells IW-12, IW-15, and IW-16 (located near the center of the OIS), based on field screening of sediment at the bottom of the wells using hydrophobic dye (Sudan IV) (BBL, October 1995). The materials in the bottoms of these wells were removed prior to well abandonment. At extraction wells IW-13, IW-19, IW-20, and IW-21, sheens were also observed on the sediment from the base of the well and/or in the recirculation water during the flushing of the borehole prior to grouting (BBL, October 1995). During the grouting process at IW-23, NAPL was displaced out of the borehole and was collected for chemical analysis, as summarized in Table 5. While the material from IW-23 submitted for analysis was a mixture of NAPL and grout, the analytical results confirmed the presence of NAPL in that several VOC concentrations exceeded their pure-phase solubility limit, including TCE, PCE, xylenes, toluene, 1,1,1-TCA, and styrene.

These observations indicate that DNAPL was present in proximity to many of the OIS extraction wells, thus, several OIS wells could have provided a pathway for vertical migration of DNAPL within the overburden or between the overburden and bedrock. Extraction well IW-23, where free-phase DNAPL was encountered, is approximately 100 feet directly upgradient from wells MWD-601 and RW-5, where free-phase DNAPL was encountered near the base of the till during NTCRA 1 implementation. While the till (where present) is believed to be a capillary barrier to downward NAPL migration, boreholes drilled through the till, including the OIS wells, could have provided a vertical pathway for NAPL to migrate into the bedrock.

During the abandonment of monitoring well TW-7B, the base of the polyvinyl chloride (PVC) riser section removed from the borehole was found to be discolored, relatively thin, tapered, and folded, suggesting possible exposure to high concentrations of solvent compounds in the subsurface. Thus, well TW-7B could also have provided a pathway for DNAPL migration from overburden to bedrock. This interpretation is consistent with the anomalously high concentrations of VOCs historically observed at well TW-7B and at shallow bedrock monitoring well MW-125C, which is approximately 25 feet downgradient of the former TW-7B location.

Measurements of the well depths and lengths of well casings and screens during the abandonment of the OIS indicated incongruities with the pre-build design drawings (Loureiro, November 1984), as shown by the following observations:

- Several of the well depths, as measured prior to abandonment, were less than the depth to bedrock encountered during overdrilling. Whereas the design indicated that the OIS wells would be installed approximately three feet into bedrock, only 15 of the OIS wells appear to have been installed to or into the bedrock.

- In general, the OIS well screens were severely bent and/or crushed, suggesting that some of the screened well points may have been driven to refusal within the till layer or on the top of rock and were not drilled into the top of rock.

- Several of the rusty, corroded, galvanized screens were shorter than expected, based on the design drawings, or were missing.

- Rather than using a bushing/connection indicated on the design drawings, electrical tape was the only connecting material used between the well screen and the riser pipes.

Split-spoon samples that were taken following the removal of the well materials and careful evaluation of the return water during borehole reaming confirmed that the existing well materials had been removed from the borehole prior to tremie-grouting. The observations listed above, particularly those regarding missing, bent, crushed, rusty, and corroded well screens, are consistent with the observed ineffectiveness of the OIS (USEPA, February 1989).

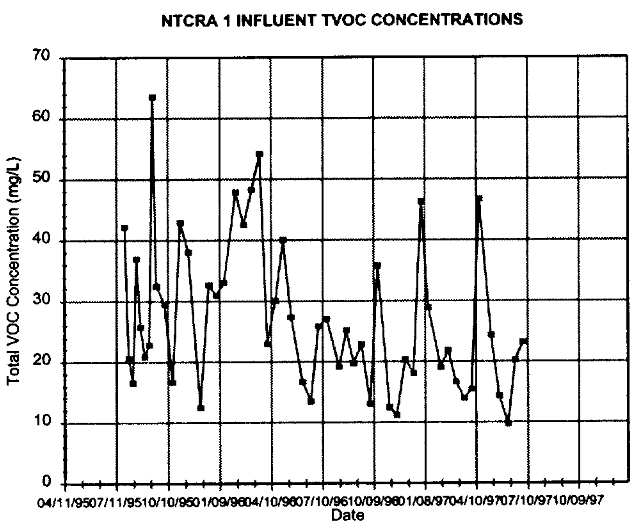
Shortly after the start-up of the NTCRA 1 Ground-Water Containment System, approximately 10 liters of DNAPL were observed in the sump of extraction well RW-5, approximately 20 feet east of NAPL collection well MWD-601. The RW-5 DNAPL was submitted for chemical and physical characterization, as summarized in Table 5. These results indicate that the RW-5 DNAPL is physically similar to that at well MWD-601 and would be relatively easy to mobilize in response to changes in the hydraulic gradient. The RW-5 DNAPL contained chlorinated and aromatic hydrocarbons similar to those detected in the MWD-601 DNAPL, including TCE, PCE, toluene, and xylenes. Other VOCs were detected at lower concentrations. PCB 1254 was also detected in the RW-5 DNAPL. A ground-water sample obtained from extraction well RW-5 was also submitted for chemical characterization and contained elevated concentrations of chlorinated and aromatic hydrocarbons, including 1,2-DCE, TCE, PCE, vinyl chloride, and xylenes. Other VOCs were also detected, albeit at relatively minor concentrations. After DNAPL was observed at extraction well RW-5, DNAPL accumulation at DNAPL collection well MWD-601 diminished to a negligible rate. In contrast, at extraction well RW-5, DNAPL continued to accumulate at up to 2 liters per week from August 1995 through October 1995.

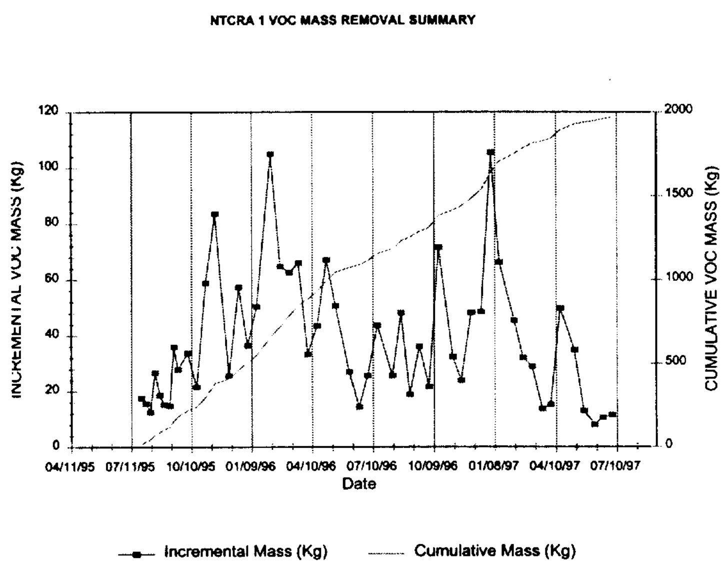
While both RW-5 and MWD-601 contained DNAPL when the ground-water samples were obtained, the dissolved VOC concentrations detected at extraction well RW-5 were substantially lower than those detected at well MWD-601 (Table 5). These results are consistent with the interpretation that substantial ground-water mixing affected the results from well RW-5, which extracts ground water from essentially the entire saturated overburden thickness, including the interval containing DNAPL and shallower, relatively "clean" strata.

NTCRA 1 ground-water extraction and treatment was initiated on July 19, 1995, and the results of routine monitoring of hydraulic heads and treatment system operation and maintenance are presented in monthly Demonstration of Compliance Reports to the USEPA (e.g., BBL, August 1995; BBL, October 1995; BBL, November 1995; Handex, December 1995 through July 1997). During the first two years of NTCRA 1 Containment System operation, the total two-week average pumping rate has ranged from approximately 13 to 34 gpm, with a long-term steady-state average of approximately 20 gpm (BBL, August 1995; BBL, October 1995; BBL, November 1995, Handex December 1995 through July 1997). The total volume pumped by the system during its first two years of operation was approximately 21 million gallons. Hydraulic responses have been observed in the overburden as well as the bedrock in the vicinity of the NTCRA 1 overburden ground-water extraction system, confirming a hydraulic connection between the two formations as suggested by the results of previous pumping evaluations (ENSR, June 1994; BBL, December 1994). These results indicate that the NTCRA 1 Overburden Ground-Water Containment system is also capturing some bedrock ground-water. Based on bedrock head measurements, the bedrock ground-water capture zone is interpreted as extending approximately 150 feet east of the NTCRA 1 Containment Area. With respect to overburden ground-water containment, the system has consistently achieved compliance with the Reversal of Gradient Test described in the Demonstration of Compliance Plan (BBL, June 1995). One deviation from the Demonstration of Compliance requirements occurred for a period of less than one day on December 15, 1996. Otherwise, the system has maintained continuous containment of overburden ground water since August 9, 1995 (BBL, August 1995).

With the exception of a hydrogen peroxide discharge exceedance on May 1, 1996, the treatment system effluent samples have met the discharge requirements. The effluent samples have passed the toxicity testing requirements established by CT DEP. Analytical results of combined influent from the 12 NTCRA 1 overburden ground-water extraction wells over the first two years of operation have contained approximately 9.75 to 63.8 ppm of total combined VOCs, including primarily 1,2-DCE, toluene, 1,1,1-TCA, ethylbenzene, xylenes, and vinyl chloride. The average total VOC concentration in the influent samples during the first two years of system operation was 27.2 mg/L. Alcohols and ketones have also been detected in the influent pumping from the NTCRA 1 extraction system. The temporal trend of VOCs in the influent from the ground-water extraction wells over the first two years of operation appears to be generally downward, as shown on the first graph below, although relatively high concentrations (above 40 ppm total VOCs) have been observed sporadically throughout the period of operation of the NTCRA 1 system. Declining concentration trends are commonly seen following the start-up of ground-water pump-and-treat systems even in persistent NAPL zones due to increased ground-water velocities and decreased contact time with NAPL (Gorelick *et al.*, 1993). The cumulative mass of dissolved VOCs removed by the NTCRA 1 Ground-Water Containment and Treatment System during the period from July 26, 1995 to July 2, 1997 was approximately 1970 kg, as shown on the second graph. The incremental dissolved VOC removal rate was sporadic throughout the first two years of operation (as shown on the second graph), with an average of approximately 39 kg every two weeks (2.7 kg/day). Over the same operating period, approximately 15 liters (approximately 16.5 kg) of NAPL have been removed from wells in the NTCRA 1 Containment Area, including extraction well RW-5 and DNAPL monitoring well MWD-601. NTCRA 1 mass removal will be evaluated further during the development of the TI Evaluation, which will be submitted as an appendix to the FS.

To assess the hydraulic influence of the NTCRA 1 Ground-Water Containment System at wetlands and private water-supply wells in the vicinity of the site, BBL prepared a Conceptual Wetlands Mitigation Plan (BBL, April 1995) and a Private Well Monitoring Plan (BBL, May 1995). In accordance with the Conceptual Wetlands Mitigation Plan, eight shallow overburden drivepoint piezometers (DP series) were installed in the wetland area along the Quinnipiac River, where the hydraulic impact due to NTCRA 1 was considered uncertain. Other wetlands situated within or adjacent to the NTCRA 1 Containment Area were expected to be dewatered due to the NTCRA 1 Ground-Water Containment System. Ground-water elevation data recorded at these drivepoints prior to and during NTCRA 1 ground-water extraction indicated slightly declining water-table elevations throughout the monitoring period, including the pre-pumping period. These results were expected due to the anomalously dry summer months during which the data were collected. The monitoring results, which were presented in a Detailed Wetlands Mitigation Design (BBL, September 1995), indicated little or no hydraulic impact due to NTCRA 1 pumping at the drivepoints installed along the Quinnipiac River. The Detailed Wetlands Mitigation Design was implemented in June 1996 through the installation of an approximately 0.4-acre constructed wetland in the shape of an oxbow along the west side of the Quinnipiac River immediately south of Lazy Lane, as shown on Figures 4 and 7.





In accordance with the Private Well Monitoring Plan (BBL, May 1995), three pairs of overburden and bedrock piezometers were installed in the areas west and northwest of the site, where the nearest residences using private water-supply wells are located. Ground-water elevation data were recorded at these three locations and at five pre-existing overburden and/or bedrock monitoring well locations prior to and during NTCRA 1 ground-water extraction. The data obtained at these monitoring locations indicated generally declining ground-water elevations throughout the monitoring period, including the pre-pumping period. These results were expected due to the anomalously dry summer months during which most of the data were collected. The ground-water elevations rose in September and early October 1995, apparently in response to precipitation events following the dry summer months. The monitoring results, which were presented in a Private Well Monitoring Report (BBL, October 1995), suggested little or no hydraulic impact due to NTCRA 1 pumping at the private wells around the site.

During NTCRA 1 design and construction, BBL also developed an interactive, relational ground-water database that summarized the available hydrogeologic and ground-water quality data generated at the site from before Phase

1 of the RI (performed by HNUS) up through ENSR's March 1995 "snapshot" well installation and ground-water sampling event.

2.6 Previous Remedial Actions

Seven previous remedial actions have been performed at the SRSNE Site, as summarized below.

Lagoon Closure - 1967

In 1967, SRSNE abandoned the two on-site lagoons formerly used to store solvent still bottom materials. The lagoons were drained, cleaned out to the extent practicable, backfilled with clean soil and compacted.

1983 Consent Decree Remedial Actions - 1983 through 1991

In 1983, USEPA and SRSNE reached a Consent Decree, which required modifications to SRSNE's solvent handling practices and the performance of subsurface investigation activities to assess impacts associated with the site. Concurrent with the issuance of the Consent Decree, the USEPA placed the site on the National Priority List (NPL), making it eligible for federal assistance with site study and cleanup expenses. Between 1983 and the facility's closure in 1991, SRSNE made some improvements as required under the Consent Decree, including spill control measures, paving of the Operations Area, fire protection measures, and installation of a ground-water treatment system discussed below.

On-Site Interceptor System Installation and Use - 1985 through 1992

To meet one condition of the 1983 Consent Decree, SRSNE installed the OIS, which recovered VOC-impacted ground water from twenty-five extraction wells installed at 24-foot spacings along the downgradient (east) property line of the Operations Area (Figure 4). The OIS was installed by S.B. Church Company in 1985, and was operated by SRSNE beginning on January 17, 1986. The system was designed to extract ground water at a rate of 7.5 gpm (Loureiro, October 1983). The actual total, combined ground water extraction rate by the interceptor wells ranged from approximately 1 to 20 gpm (HNUS, April 1990). From the start-up of the OIS until July 1992, ground water from the wells was pumped to a modified cooling tower within the Operations Area, where VOCs were air stripped from the aqueous phase and discharged to the ambient air. Treated water was discharged to a ditch along the railroad tracks east of the site, from which it flowed through pipe beneath the tracks, and through a culvert to the Quinnipiac River.

During a February 1989 USEPA RCRA inspection, the OIS was not operating as a continuous hydraulic barrier to downgradient ground-water flow (USEPA, February 1989). Subsequently, three extraction wells were removed and replaced in 1989. The three replacement wells, which were constructed of 4-inch diameter stainless steel screen and riser to improve the ground-water extraction rate of the OIS, were screened across the overburden/bedrock interface.

In 1992, CT DEP retained Metcalf and Eddy to identify a more effective treatment alternative to the converted cooling tower/air stripper. Based on an evaluation of other treatment options, a UV peroxidation system was installed. From 1992 though 1994, the water pumped from the OIS wells was treated using the UV peroxidation system, which was operated by Metcalf and Eddy on behalf of CT DEP. SRSNE continued to operate the well pumps, which produced an average combined flow rate of approximately 3 gpm. SRSNE discontinued operation of the OIS wells and the UV peroxidation system was shut down concurrent with NTCRA 1 design activities in 1994.

SRSNE Site Post Shutdown Cleanup - 1991

SRSNE performed post-shutdown site cleanup activities between January 25 and March 26, 1991. As part of these cleanup activities, on-site tanks were emptied of all free liquids and sludges, and then scraped and pressure washed. In addition, all concrete containment dikes were steamed and pressure washed. The wash waters were collected using a vacuum truck and disposed off site. A total of 70,284 gallons of bulk liquid (including approximately 20,000 gallons of sludge), 178 55-gallon drums, two 25-gallon pails, and 1,735 gallons of cleaning residue were shipped off site during this cleanup activity.

Ditch Sediment Excavation and Removal Action - 1992

The USEPA ESD and the TAT contractor, Roy F. Weston, Inc., performed an evaluation to assess the extent of contaminated soils and sediments in the vicinity of the Operations Area. As a result of the TAT/ESD investigation, USEPA ESD implemented a removal action in September 1992 to mitigate potential health threats associated with PCB contamination in soils and sediments. The removal action included excavating contaminated sediments from the drainage ditch area along the railroad tracks east of the Operations Area, installing a french drain, and backfilling with clean materials.

USEPA, Time-Critical Removal Action - 1994

USEPA conducted a Time-Critical Removal Action in January-February 1994, during which three 55-gallon drums, two 20-gallon pails, and six 5-gallon pails of lab-pack containers were filled with residual laboratory chemicals and disposed off site. In addition, 50 bags of asbestos-containing materials were removed from exterior processing equipment and disposed off site. In April 1994, a Nickel-63 radioactive source in a gas chromatogram was also shipped off site.

NTCRA 1 (1994 through present)

Between August 1994 and August 1995, BBL designed, installed, and started the operation of the NTCRA 1 Ground-Water Containment and Treatment System. The NTCRA 1 system has operated without interruption since its start-up on June 19, 1995 through the preparation of this RI Report. Further information regarding the NTCRA 1 design investigation, installation and first two years of operation is provided above in Section 2.5.

2.7 Other Source Areas

In addition to the extensive investigations that have been performed at the SRSNE Site and the Town Well Field Property summarized above in Section 2.5, several sites in the general vicinity of SRSNE have been or presently are under enforcement orders to perform environmental investigations and/or are on the CT DEP's inventory of hazardous waste sites in the state of Connecticut. As described in Sections 4.3.1.1 and 4.3.1.2 below, several other aqueous VOC plumes unrelated to the SRSNE Site are evident in the Quinnipiac River Valley, including two plumes that are closer to Town Wells No. 4 and 6 than the plumes associated with the SRSNE Site. All sources of VOCs in the RI Study Area that result in VOC plumes affect the overall regional ground-water quality evaluation, and would directly influence the future useability of the Town Production Wells for potable water supply.

As noted in the RI Work Plan (BBL, November 1995), any information that could be obtained from the investigations at these other nearby sites could help to substantiate the conclusions derived in this RI Report, particularly regarding:

- Interpretations that other VOC sources are present near in the region around the SRSNE Site, and could influence the delineation of the VOC plume attributed to the SRSNE Site;

- Hydrogeologic data, including formation thickness and hydraulic parameters in the region surrounding the SRSNE Site; and

- Hydraulic gradient data, which would further help to define hydraulic divides pertinent to delineating ground-water flow directions and potential plume migration pathways.

Pursuant to the Freedom of Information Act (FOIA), the SRSNE PRP Group requested that USEPA or CT DEP provide any available documents relating to investigations that have been performed at some of the sites in the vicinity of SRSNE. Mr. Bruce Thompson, de maximis, inc., visited Mr. Mark Lewis, CT DEP, to discuss the FOIA request. In their discussions with CT DEP personnel who had responsibility for various CT DEP sites under administrative orders, those personnel found no specific information regarding sites in the vicinity of SRSNE. CT DEP was aware of no investigations performed pursuant to the CT DEP orders listed in the table below. Therefore, there was no need to pursue additional information. Information was requested from USEPA and CT DEP regarding the following nearby sites, which were identified from a publicly accessible database search:

Site Name	Location	Pertinent Information
R.P. Olson & Son, Company	235 Queen Street, near cor. Lazy Lane (approx. 1600 ft. NE of the SRSNE Site, 300 ft from MW-202 wells)	USEPA Preliminary Assessment (PA) completed 7/29/88 and Site Investigation completed 7/12/93. Solvents and metals detected in drywell. Final SI Report received from USEPA.
Beaton & Corbin	329 North Main Street	Disposal lagoons on site; ground-water monitoring taking place; CT DEP Enforcement Order active as of 1987.
Southington Form Construction Company (Casmir Wygonowski)	45 Curtiss Street, approx. 200 feet from Production Well No. 4	Under CT DEP Enforcement Orders #2672 and #2673 (2/11/80); aliphatic hydrocarbons listed among constituents of drums observed on site in 1979.
Caldwell Property (Supreme Lake Company)	North of Curtiss Street next to Quinnipiac River, 300 feet from Production Wells No. 4 and 6	Higher concentrations of chlorinated hydrocarbons in ground water than the area separating Caldwell Property and the SRSNE Site since 1990 (concentr. gradient reversal); reported solvent disposal on site.
Former Ideal Forging Company Property	Corner of North Main and Darling Streets, approx. 800 feet south of Production Well No. 4	Under CTWRC Enforcement Order # 937 (1971) and CT DEP Enforcement Order #3045 to investigate and remediate "industrial contamination." Soil borings performed up to 104 feet depth; hydraulic gradient determined; higher concentrations of chlorinated hydrocarbons in monitoring wells than in the area separating Ideal Forging from SRSNE (concentration gradient reversal).
Marek Property*	Corner of North Main and Darling Streets	USEPA PA completed 4/13/93; reported as potential disposal site of some waste sludge materials from SRSNE. PA Report received from USEPA.
Vojtila Property*	Southeast of corner of North Main and Darling Streets	Under CT DEP Enforcement Order #3418 (1983) to investigate ground-water, surface-water, and soil contamination and prepare a remedial action plan.

* Marek and Vojtila Properties appear to be the same.

The current enforcement status of these sites is unknown to the SRSNE PRP Group. Some documents have been obtained from the USEPA regarding previous investigations at these sites.

Noteworthy data were obtained regarding subsurface investigations at the former Ideal Forging Property in 1981 (Welti, July 1981, October 1981). These data included subsurface drilling logs, monitoring well construction specifications, and soil and ground-water VOC concentrations. Common, solvent-related VOCs were detected in soil at concentrations up to 43 mg/kg PCE at the approximate depth of the water table. Based on solubility limits and fundamental soil-water partitioning assumptions, this result indicates the likely presence of a NAPL containing PCE in the vicinity of that soil sample interval (Feenstra *et al.*, 1991; Welti, July 1981). Based on these findings, Welti (October 1981) concluded that a "there appears to be a substantial concentration of both trichloroethylene and tetrachloroethylene in the unsaturated soil and possibly in the soil at water surface."

Similarly, high concentrations of solvent VOCs were detected in ground water samples obtained at the former Ideal Forging Property in 1981. High concentrations of VOCs were detected at monitoring well W-8, which was installed with an 80-foot long screen from 2.5 to 82.5 feet below grade. VOCs detected at monitoring well W-8 included 15.6 mg/L of PCE, 1.2 mg/L of 1,1,1-TCA, and 0.76 mg/L of TCE. These concentrations indicate the probable presence of DNAPL containing these compounds within the saturated zone. VOCs were also detected at several other wells within the shallow, middle, and deep overburden on the former Ideal Forging Property (Welti, October 1981). Hydraulic gradient data measured at the site on October 9, 1981, indicated a west-northwest directed horizontal flow component. Based on the distribution of VOCs in ground water, Welti (October 1981) indicated "the continued presence of tetrachloroethylene at Well #6 still indicates some probable off-site pollution." As discussed further in this report, a continuous, mappable plume of chlorinated VOCs exceeding ground-water regulatory criteria currently extends downgradient of the Ideal Forging Property and passes near the location of Town Production Well No. 4. These findings indicate that the Former Ideal Forging Property continues to influence ground-water quality in the immediate vicinity of the Town Production Wells. However, it should be noted that ground-water quality data gaps remain downgradient of the Former Ideal Forging Property in the middle and deep overburden, in which Production Wells No. 4 and 6 are screened, respectively.

In addition to the Ideal Forging Property, at least four other VOC sources unrelated to the SRSNE Site also are interpreted as present within the regional Quinnipiac River valley, and near or within the RI Study Area. Based on shallow overburden ground-water quality data obtained by Fuss & O'Neill (September 1996) on behalf of the State of Connecticut Department of Transportation, aromatic hydrocarbons including benzene, toluene, ethylbenzene, and xylenes (BTEX) were detected at concentrations of up to 3,170 ug/L approximately 200 feet south of the corner of Lazy Lane and Queen Street. These compounds were detected downgradient of an existing gasoline station. Based on consistent historical detections of chlorinated VOCs at the intersection of Queen Street (Connecticut Route 10) and Lazy Lane, and the southwestward prevailing hydraulic gradient at that location, one source of chlorinated VOCs is also interpreted in the area northeast of the intersection. Similarly, a VOC source is interpreted upgradient (east) of the MW-710 well cluster, which was installed along Queen Street southeast of the SRSNE Site. Finally, a separate VOC source is interpreted approximately 1000 feet south of the SRSNE Site, approximately 900 north of Curtiss Street in the area west of the B&M railroad tracks. This source is interpreted based on the detection of VOCs at monitoring wells at locations that are not downgradient of the SRSNE Site. These additional VOC sources are also discussed further in Sections 4.3.1.1 and 4.3.1.2.

Any additional documents that may have been prepared, and may be available through CT DEP or USEPA, regarding the hydrogeology, geology, hydraulic gradients, and distribution and types of constituents in ground water at the above-listed sites, and/or any other sites in the area, could enhance the understanding of the regional context presented in the SRSNE Site RI. In particular, these data could assist in distinguishing the off-site VOC plume associated with past operations at the SRSNE Site from other, unrelated plumes associated with other source areas. As noted in the RI Work Plan (Section 4.3.1), however, data gaps remain in the ground-water monitoring network in the area south of the Town Well Field Property, where many of the other above-listed potential source areas exist. These data gaps suggest that the ground-water quality impacts related to the other potential sources may not be adequately characterized at present.

2.8 Ground-Water Classification and Use

2.8.1 Ground-Water Classification

Ground water within the RI Study Area is currently classified by CT DEP as Class GA over the majority of the Study Area, including the SRSNE Site (Figure 15). Two current Class GA areas formerly were Class GB, and are currently described by CT DEP as "degraded." An isolated zone classified as GAA is also present in the study area, centered about Town of Southington Production Wells No. 4 and 6, although the southern portion of the Class GAA also does not currently meet Class GA/GAA Ground-Water Protection Criteria (CT DEP, April 1996, August 1997, October 1997).

Class GA

According to the CT DEP Water Quality Standards CT DEP, April 1996), Class GA ground water is defined as:

> "Ground water within the area of existing private water supply wells or in an area with the potential to provide water to public or private water supply wells. The Department presumes that ground water in [a Class GA] area is, at a minimum, suitable for drinking or other domestic uses without treatment."

The GA classification means that the State's goal is to maintain ground-water quality commensurate with drinking water standards. Ground waters with a classification of GA are designated for use as existing private and potential public water supplies (CT DEP, April 1996). The ground water within the two sub-areas within the present area designated as Class GA - "Degraded," were formerly classified as GB/GA, indicating that the water may not have been considered suitable for direct human consumption without treatment (CTDEP, August 1997).

These two areas are:

- The area bounded approximately by the CL&P Easement on the south, Lazy Lane on the North, the Quinnipiac River on the east and the 200-foot elevation contour on the west; and

- The area near the southern edge of the RI Study Area, bounded approximately by Curtiss Street or Queen Street at the north and the Quinnipiac River at the west.

In areas classified as Class GA - "Degraded," formerly Class GB/GA, the State's goal was to restore the ground water to drinking water quality (CT DEP, August 1997). However, under the revised Ground-Water Quality Standards which became effective on April 12, 1996, this dual classification (Class GA versus Class GB/GA) has been eliminated. All areas which were formerly designated as GB/GA are now classified as GA. The GA classification signifies that the ground water is presumed to be of natural quality and suitable for drinking without treatment (CTDEP, April 1996). A notation will be made in the State's ground-water quality maps indicating that this assumption is not currently true in former GB/GA areas (currently Class GA-"Degraded").

Water quality in the remainder of the current Class GA area has retained its GA classification (CTDEP, September 1997). Regardless of whether an area is referred to as "degraded", the State's goal of maintaining or restoring the ground water in GA areas to natural quality remains unchanged (CTDEP, April 1996).

Class GAA

An isolated area surrounding Town of Southington Production Wells No. 4 and 6 is currently classified as GAA. According to CT DEP Water Quality Standards, Class GAA ground water is defined as:

"Ground water used or which may be used for public supplies of water suitable for drinking without treatment; ground water within the area that contributes to a public drinking water supply well; and ground water in areas that have been designated as a future water supply in an individual water utility supply plan."

According to the CT DEP's Preliminary Ground-Water Use and Value Determination, the portion of the GAA area south of the Quinnipiac River, near the eastern end of Curtiss Street, does not currently meet Class GA/GAA Ground-Water Protection Criteria (CT DEP, October 1997). It should be noted that the plumes related to the SRSNE Site do not extend south of the Quinnipiac River, as discussed further in Section 4.3.

2.8.2 Ground-Water Use

The only known current use of ground water in the RI Study Area occurs via homes along Lazy Lane (HNUS, July 1994; Southington Water Department, January 1997). The private wells nearest the SRSNE Site are at the Maiellaro (Mickey's Garage) Property, which is situated approximately 400 feet north of the SRSNE facility (minus the access road), and the Onofrio Residence, which is located north of Lazy Lane opposite the location of the former Cianci water supply well (MW-709 well cluster, see Figure 4). Approximately 85 homes on Melcon Street, Curtiss Street, Juniper Road, Little Fawn Road, and Carrier Court on the hill west of the SRSNE Site also use domestic wells for their water supply, but these wells are located approximately 1000 to 2500 feet upgradient (west) of the western boundary of the RI Study Area (HNUS, July 1994; Southington Water Department, January 1997). Based on information compiled during the first round of private well sampling in the vicinity of the SRSNE Site in 1990 by the CT DEP, the majority of the private wells in the area of the site are drilled, open-bedrock wells ranging from 90 to more than 200 feet deep. The Town of Southington has an ordinance against the drilling of new water supply wells in the areas currently supplied by municipal water (Southington Water Department, August 1997).

The remainder of the study area is supplied with municipal water (Southington Water Department, January 1997; August 1997). The Town of Southington Water Department currently has nine municipal water supply wells in their inventory, of which seven are operating as of the preparation of this RI Report. An additional well field has been identified, but has not yet been developed for water supply. The Town obtains additional water supply via three surface-water reservoirs. None of the water-supply wells or reservoirs currently used by the Town of Southington are in the RI Study Area.

The currently operating production well closest to the SRSNE Site is Well No. 3, which is approximately 0.8 miles southeast of the SRSNE Site, 1000 feet south-southeast of the former Ideal Forging Site (Southington Water Department, August 1997). The next closest operating production well is Well No. 1A, is 1.1 miles south of the SRSNE Site. While the Town's Level B and preliminary Level A aquifer mapping program results suggested that Production Wells No. 3 and 1A could potentially be impacted by contaminants related to the SRSNE Site (CT DEP, October 1997), the regulatory VOC plume delineation results presented in Section 4.3 do not support this inference. The regulatory VOC plumes related to the SRSNE Site in overburden and bedrock ground water extend a maximum of 1200 feet (0.2 miles) downgradient of the site. Furthermore, while Production Wells No. 1A and 3 are currently in use, all of the available hydraulic gradient data from the area south of the Quinnipiac River have indicated northward ground-water flow in overburden and bedrock, presumably due to the hydraulic influence of the Quinnipiac River as a ground-water discharge location. Thus, under current pumping conditions (with Wells No. 1A and 3 active, but Wells No. 4 and 6 inactive), even if the plumes related to the SRSNE Site continued to migrate southward, they would likely be intercepted by the Quinnipiac River, rather than continue southward toward Production Wells No. 1A and 3.

As noted above, Town Production Wells No. 4 and 6, which are the production wells nearest to the SRSNE Site, have been dormant since approximately 1979. It appears unlikely that Production Wells No. 4 or 6 could be used for water supply in the foreseeable future without wellhead treatment to remove VOCs. As stated in the Town of Southington's 50-year water supply plan, Wells No. 4 and 6 are not expected to be needed until the year 2020 or later (Lenard, April 1996). While the CT DEP's Preliminary Ground Water Use and Value Determination states that "the aquifer in the area is threatened by site [i.e., SRSNE-related] contaminants" (CT DEP October 1997), the future use of these wells will depend on the potential to remediate all regional sources of VOCs in ground water, some of which are closer to the two dormant town production wells, and will be very difficult to remediate due to the likely presence of NAPLs. These topics are described in detail in Section 3 below.

2.9 Surface-Water Classification and Use

2.9.1 Surface-Water Classification

The primary use of surface water in the region around the RI Study Area occurs at the Quinnipiac River. Surface water along the Quinnipiac River within the RI Study Area is currently classified by CT DEP as Class C/B. (CT DEP, May 1992). This classification signifies that the goal for surface water quality is Class B, but the current surface-water quality is Class C. Thus, certain water quality criteria or one of more designated uses assigned to Class B are not currently met. Class B surface waters are designated for recreational use, fish and wildlife habitat, agricultural and industrial supply,.and other legitimate uses including navigation. Class C waters may be suitable for certain fish and wildlife habitat, certain recreational activities, industrial use, and other legitimate uses including navigation. Class C waters have a good aesthetic value. Surface-water quality conditions that result in a Class C designation are usually correctable, and commonly relate to combined sewer overflows, urban runoff, inadequate municipal or industrial waste-water treatment, and community-wide septic system failures (CT DEP May 1992).

2.9.2 Surface-Water Use

The Quinnipiac River is not used as a drinking water supply; however, nearby drinking water wells could be affected by the river. Urban runoff resulting from extensive paving of the river basin may be a major cause of the contaminant presence within the river (HNUS, May 1994).

The Quinnipiac River is used for recreation from Southington to its mouth in New Haven Harbor. The river is used for swimming, which is usually regulated by the Town or State Board of Health. Boating, mainly canoeing, and fishing are popular along the river. Two recreational areas within the Town of Southington provide public access to the river. Fishing is allowed along the river, and one area of particular interest is the Quinnipiac Gorge, where brown, brook, and rainbow trout are stocked annually. In 1990-1991, 60 trout 10 to 12 inches long were released. Bass, perch, sunfish, and bullheads are also caught (HNUS, May 1994).

<u>Summary of Section 2</u>

- The SRSNE Site RI Study Area is situated within the Quinnipiac River Valley, approximately 15 miles southwest of the city of Hartford, Connecticut.

- Subsurface investigations in the RI Study Area began with the development of the Town of Southington Well Field in the 1960s. Environmental investigations were initiated in the late 1970s due to the detection of VOCs at Production Wells No. 4 (which operated from 1966 to 1977) and No. 6 (which operated from 1978 through

1979). The subsequent evaluation of VOC sources in the vicinity of Production Wells No. 4 and 6 by the Connecticut Department of Environmental Protection (CT DEP, April 1978; October 1978) and a USEPA subcontractor (Warzyn, November 1980) identified five potential VOC sources, including the SRSNE Site. Ground-water sampling and hydraulic head measurements performed during this RI confirmed the presence of VOC plumes unrelated to the SRSNE Site in closer proximity to Town Wells No. 4 and 6. CT DEP enforcement orders have been issued to some of the property owners in the vicinity of Town Wells No. 4 and 6.

- For the purposes of this RI Report, the terms "SRSNE site" and "site" refer to the SRSNE Operations Area and the immediately downgradient Containment Area, which was established as part of Non-Time Critical Removal Action No. 1 (NTCRA 1).

- The key components of the RI Study Area include the SRSNE Operations Area, the adjoining former Cianci Property (including the NTCRA 1 Containment Area), the Town of Southington Well Field Property, and surrounding areas.

- Between 1955 and 1991, SRSNE processed in excess of 41 million gallons of waste solvents, fuels, paints, and similar liquid materials. A small fraction of these materials is believed to have entered the subsurface due to placement of distillation sludge in two unlined lagoons on site, occasional overflow of materials from these lagoons to ditches adjacent to the site, and incidental spills and leaks from drums, hoses, tanks, trucks, etc.

- The geology of the RI Study Area includes unconsolidated deposits composed of Pleistocene glacial outwash and till, with isolated deposits of fill and alluvium, overlying fractured, Triassic New Haven Arkose bedrock.

- The 216 monitoring wells, extraction wells, wetland drive points, and piezometers that comprise the ground-water monitoring network in the RI Study Area have been sorted into the following five hydrostratigraphic zones based on stratigraphy and for ease in data interpretation:

  - *Shallow, middle and deep overburden*, which represent the upper, middle, and lower thirds of the saturated overburden deposits, respectively; and

  - *Shallow and deep bedrock*, which represent approximately the upper 30 feet of bedrock and a zone between 60 and 90 feet below the top of bedrock, respectively.

- Seven previous remedial actions have been performed at the SRSNE Site.

  - Lagoon closure (1967);
  - 1983 Consent Decree remedial measures (installation of spill control and fire prevention measures, and surface pavement) (1983 to 1991);
  - On-site interceptor system installation and use for ground-water extraction and treatment (1985 through 1992);
  - SRSNE Site post shutdown cleanup of tanks and containment structures (1991);
  - Ditch sediment excavation and removal action (1992);
  - USEPA, Time Critical Removal Action, with removal and off-site disposal of laboratory chemicals, laboratory equipment, and processing equipment (1994); and
  - NTCRA 1, including the design, installation, and operation of a downgradient overburden ground-water containment and treatment system (1994 through present).

3. Study Area Physical Characteristics

This section discusses physical characteristics of the RI Study Area surrounding the SRSNE Site, including the geologic and hydrogeologic conditions that influence chemical migration in the subsurface. HNUS presented an extensive discussion of the geology and hydrogeology of the region around the SRSNE Site, and the RI Study Area in particular, in the previous RI Report (HNUS, May 1994). The intent of this section is to provide a thorough overview of the physical characteristics of the region and the site, and to supplement the information previously reported by HNUS with additional information and data obtained during the completion of the RI, with interpretations that are supported by previous and newly-obtained data. The regional geologic and hydrogeologic context of the site vicinity are first summarized in Sections 3.1 and 3.2, respectively. Detailed evaluations of the RI Study Area geology and hydrogeology are presented in Sections 3.3. and 3.4. Finally, Section 3.5 presents the Hydrogeologic Conceptual Model, which is one of the two fundamental components of the Site Conceptual Model required for the TI Evaluation to be performed in the FS.

3.1 Regional Geology

The SRSNE Site is located within the Connecticut Valley Lowland section of the New England physiographic province. The region around the site is characterized by relatively broad valleys separated by low, north-northeast trending ridges, and is distinguished from the crystalline bedrock Upland sections which form the western and eastern boundaries of the Lowland. The geology of the region consists of Pleistocene glacial deposits overlying the Upper Triassic New Haven Arkose bedrock. Wisconsin-age glaciation partly eroded and smoothed the bedrock hills and deposited the principal unconsolidated overburden units throughout the region (La Sala, 1961).

HNUS (May 1994) provided a detailed discussion of the regional geology, including the overburden and bedrock units in the region surrounding the RI study area. The sections that follow summarize the regional overburden and bedrock geology, and provide background information for the discussion presented in Section 3.2 regarding the geology within the RI Study Area.

3.1.1 Regional Overburden Geology

In general, the overburden deposits in the region surrounding the SRSNE Site were deposited by two continental ice sheets that sequentially covered New England during the Pleistocene epoch (La Sala, 1961). The only exceptions are areas underlain by modern fill due to anthropogenic activities or alluvium deposited by the modern Quinnipiac River. The advance of these ice sheets smoothed the bedrock hills and covered them with a thin mantle of ground moraine. The glaciers also scoured the intervening valleys and filled them with somewhat thicker sequences of ground moraine and stratified drift deposits (Melvin *et al.*, 1992a).

Ground-moraine deposits overlie bedrock and consist primarily of till, which was deposited by gradual accretion beneath the advancing ice sheet. Ground moraine also includes a few small lenses and discontinuous beds of stratified sand and gravel, which were probably deposited as subglacial streams as the ice sheet retreated (La Sala, 1961). Ablation till was also deposited in areas where stagnant portions of the glacier disintegrated in place, leaving behind the unsorted accumulation of the sediment carried by the glacier. Ground moraine deposits are widely heterogeneous in their grain-size distribution, and may include clay, silt, sand, gravel, and boulders, and generally range from 10 to 20 feet in thickness. Ground-moraine deposits are mapped as the surficial deposits on the hill immediately west of the Operations Area of the site, above a surface elevation of 170 feet (La Sala, 1961). Ground-moraine and ablation till deposits are collectively referred to as "till" for the remainder of this report.

The stratified drift deposits were deposited from glacial meltwaters during the retreat of the ice sheet and included: sediments from rapidly changing braided streams; deltaic sequences and lake bottom sediments deposited in pro-glacial lakes; and kame deposits, which were deposited in meltwater at the edge of the glacier.

Four main stratified drift units have been mapped as the surficial geologic deposits in the general region surrounding the SRSNE Site (La Sala, 1961; Hanshaw, 1962). Two units mapped in the central, low portion of the Quinnipiac River valley include:

- Flood-Plain Deposits, consisting of alluvial silt and sand containing organic matter, cover the present flood plain adjacent to the Quinnipiac River, below a surface elevation of 150 feet; and

- Valley Train Deposits, consisting of stratified sand and gravel, cover the remainder of the low, central portion of the Quinnipiac River Valley, between surface elevations of approximately 150 and 170 feet.

The remaining deposits were mapped above a surface elevation of 170 feet elevation, and include:

- Ice Channel Filling and Kame Terrace Deposits, consisting of sand and gravel, which are mapped west of the B&M Railroad south of the SRSNE Operations Area; and

- Kame Plain Deposits, which are flat-topped, steep-sided deposits of sand and gravel, mapped in the majority of the area east of Queen Street.

Consistent with the vernacular established by HNUS (May 1994), and maintained by ENSR (June 1994) and BBL (November 1995), these four stratified drift units are collectively referred to as "outwash" in the remainder of this report.

Artificial fill is mapped along the B&M Railroad easement and along portions of Lazy Lane near the Quinnipiac River (La Sala, 1961). In addition, based on the abrupt change in surface elevation contours, fill deposits are also believed to have been placed along the east bank of the Quinnipiac River in the area east-southeast of the SRSNE Operations Area (CT DEP, April 1978).

3.1.2 Regional Bedrock Geology

The bedrock in the RI Study Area is mapped as the Triassic New Haven Arkose "redbeds" (Rogers, 1985), which consist of red to reddish-brown to pink sedimentary rocks, including interbedded sandy to silty channel deposits and silty floodplain deposits that were laid down in a rift-basin setting known as the Hartford Basin (Fritts, 1963; Hubert *et al.*, 1978). In outcrops of the New Haven Arkose along Queen Street, northeast of the SRSNE Site, the silty strata (former overbank deposits) appear fissile, crumbly, and deeply weathered, and the interbedded sandy strata (former channel deposits) appear relatively competent and resistant. The New Haven Arkose is cemented by carbonate and is subject to weathering by partial dissolution. Localized, relict caliche deposits containing gypsum are also observed within the New Haven Arkose, and are interpreted to be the result of temporary deposition of soluble evaporite minerals in an arid paleoclimatic setting (Hubert *et al.*, 1978). The formation contains some relatively competent and resistant beds, however, which produce topographic ridges parallel to the north-northeast strike of bedding. Later in the Triassic and early Jurassic periods, the continued east-west crustal extension and rifting disrupted the New Haven Arkose along a series of north-striking, generally west-dipping normal faults. The resulting bedrock structure is characterized by gently eastward-dipping bedding (Hubert *et al.*, 1978). Within the New Haven Arkose are isolated sills and dikes consisting of diabase that were emplaced as igneous intrusions during the overall rifting process (Hubert *et al.*, 1978). Faults have been mapped approximately

2.5 miles west and 2.0 miles east of the site, but no faults have been reported within the RI Study Area (Rogers, 1985; see Figure 8).

3.2 Study Area Geology

HNUS presented a substantial volume of data regarding the overburden and bedrock geology within the RI study area in the previous RI Report (HNUS, May 1994). The discussion below summarizes the RI Study Area geology, and is generally consistent with previously reported data. The new data obtained during the completion of the RI are also presented and evaluated.

Figure 16 presents a geologic cross-section location map, and Figures 17 through 20 present four geologic cross sections through the RI Study Area. A detailed discussion of the RI field activities (dates of activities, sampling techniques, number, type, and locations of samples) associated with the completion of the RI is presented in Appendix A. Appendix B presents photos of test pit activities that were completed to provide a detailed understanding of the overburden stratigraphy and structure. Appendix C presents a log of the new soil and bedrock samples and the associated geotechnical and fraction of organic carbon (f_{oc}) data. Appendix D presents a summary of the complete hydrogeologic database for the site, including major stratigraphic contacts determined during this and previous investigations. Appendix E presents detailed subsurface logs summarizing the geologic materials encountered at each drilling location during the completion of the RI.

3.2.1 Study Area Overburden Geology

Thirty soil borings were installed by East Coast-Thomas between August 27, 1996 and June 10, 1997, as part of the current RI drilling and well installation activities. Three borings (SB-701, SB-702, and SB-703) were drilled and sampled in the Containment Area on the former Cianci Property to obtain a total of 13 samples of vadose and saturated soils (Figure 3). One soil boring was drilled and sampled during the installation of corehole RC-701 on the former Cianci Property, where bedrock core samples were obtained for matrix VOC and solute-transport characterization. Nine pilot borings were advanced through the overburden into the deep bedrock at nine monitoring well installation areas during the installation of an initial deep bedrock pilot hole and monitoring well (locations MW-701DR through MW-708DR and MW-710DR on Figure 3). In addition to the geologic data obtained during drilling operations, two test pits (TP-701 and TP-702) were installed on the former Cianci Property to obtain detailed information regarding overburden stratigraphy and permeability. A thorough discussion of soil boring and test pit sampling is presented in Appendix A. Soil samples filled specific data needs at each drilling location, as summarized in Table 1 of this RI Report. The soils at pilot holes RC-701, MW-701DR, MW-702DR, MW-705DR, MW-706DR, and MW-708DR were sampled primarily for field screening, geologic characterization, and field assessment of DNAPL presence or absence ("DNAPL Contingency" evaluation, as described in the FSP). Soil geotechnical data are summarized in Appendix C. Soils encountered at each boring location are described on the subsurface logs presented in Appendix E. The results of these investigations have further characterized the overburden geology in the study area, and provided detailed data needed for a solute-transport assessment of the on-site and off-site areas impacted by VOCs associated with the SRSNE Site.

The overburden geology beneath the Operations Area and former Cianci Property consists of two main unconsolidated layers. The shallow, upper layer, referred to as outwash, extends from ground surface to approximately 10 to 25 feet below grade at the site and consists of reddish-brown silty sand and gravel deposits, interbedded with discontinuous layers of silt and relatively well-sorted sand and gravel. The lower layer consists of glacial till, a generally unstratified unit consisting of reddish-brown clay, silt, sand, gravel, cobbles, and boulders, but also including isolated, discontinuous sandy seams. Fill materials are present above the outwash in portions of the Operations Area and former Cianci Property, where grading operations have reworked the upper few feet of soil and filled low areas. Fill materials are also observed along the B&M Railroad grade that separates the

Operations Area from the former Cianci Property, and appear to have been placed along the east bank of the Quinnipiac River in the area east-southeast of the SRSNE Operations Area (CT DEP, April 1978).

Outwash

The upper overburden unit appears to represent various glacial deposits described collectively as "stratified drift" in the literature (La Sala, 1961; Hanshaw, 1962). HNUS (May 1994) referred to the upper unit as outwash, and this term has been used in subsequent documents prepared by ENSR (June 1994) and BBL (December 1994). In earlier investigation reports, during the conceptual design of the off-site interceptor system, York Wastewater Consultants (YWC, June 1985) interpreted the shallow and deep overburden materials beneath the Operations Area and the Former Cianci Property both as till. This interpretation apparently was derived from the similar properties of the upper and lower overburden units on site. Based on its relatively fine-grain size; moderate density; variable, discontinuous stratification; and overall low-to-moderate hydraulic conductivity, the upper overburden unit beneath the Operations Area and Former Cianci Property could be construed as ablation till. However, the published mapping of the area shows the soil under the site as either "stratified drift" (i.e., outwash) or fill. To maintain consistency with the nomenclature used in the published literature and the previous RI Report, the term outwash was retained in the RI Work Plan (BBL, November 1995) and in this RI Report.

South of the former Cianci Property, the upper overburden unit grades laterally into a classic glacial outwash, with increasing grain size, degree of sorting, overall thickness, and hydraulic conductivity. At the Town Well Field Property, the upper overburden unit consists of 40 to 60 feet of highly permeable sand and gravel with relatively thin, interbedded, discontinuous silty lenses.

Till

Underlying the on-site and off-site upper soil unit immediately above the top of the New Haven Arkose is a relatively continuous layer of basal till. The till is typically 5 to 10 feet thick on site, but its thickness may be 30 feet or more in the areas east of the Quinnipiac River and at the Town Well Field Property. The top of the till in some areas is marked by a cobbly layer. The base of the till at the top of bedrock also exhibited a relatively coarse grain size. The presence of boulders within and near the base of the till required the use of special equipment to install two adjacent sections of sheet piling during the NTCRA 1 construction activities. As the boulders typically are red to red-brown and Arkosic in composition, boulders have complicated the identification of the top of bedrock in certain areas.

Within the Town Well Field Property, the deep overburden is generally referred to as "till" based on its relatively high density. It should be noted, however, that the coarse-grained deep overburden within the Southington Well Field Property exhibits a moderate to high permeability compared to the deep overburden on site. The deep overburden soil at the MW-704 well cluster, for example, consisted of dense, coarse sand and gravel with cobbles and boulders. The exact genesis of this unit is not certain. However, based on its coarse grain size, this unit is referred to as coarse drift or gravelly drift in this document (see Figures 18 and 19). Specific capacity tests were performed at several deep overburden wells around well MW-704D to help define the extent of the interpreted high-permeability zone encountered at deep overburden well MW-704D, as discussed in Section 3.4.2.

In the Operations Area and the former Cianci Property, the textural and grain-size similarity between the outwash and the till renders the contact between the units difficult to distinguish visually. As discussed above, the similarity between these units led previous workers to the interpretation that they comprise a single unit. Standard penetration blow counts are considered a useful indicator of the approximate depth of the contact, as blow counts typically increase from the range of 10 to 20 per 6 inches in the outwash to 20 to 60 per 6 inches in the till.

Because of this density contrast, the till may serve as an effective capillary barrier to downward DNAPL migration. The till permeability was measured to help evaluate this inference, as described in Section 3.4.2. Ground-water quality data from the Operations Area, have indicated VOC concentrations approximately three orders of magnitude higher in the overburden than in the bedrock ground water, indicating that the till may have limited downward VOC migration where intact. The bedrock VOC concentrations increase markedly along the east edge of the Operations Area where the till layer was breached by OIS wells. The top-of-till surface generally slopes down toward the east and southeast, away from the Operations Area, and the till layer is typically 5 to 10 feet thick. Immediately east of the Containment Area, however, the till is anomalously thin (typically 2 to 4 feet thick) and may be absent at certain locations ("till windows") (HNUS, May 1994).

New Gross-Scale Overburden Stratigraphic Information

New geologic data obtained by BBL during the completion of the RI between June 1996 and July 1997 included stratigraphic information obtained during drilling of new soil borings and monitoring wells where overburden geologic data formerly were lacking. Monitoring well clusters MW-703 and MW-707 were installed during the current RI activities in the southern portion of the Town of Southington Well Field (Figure 3). The overburden geologic data from these locations indicated that outwash consisted of stratified fine-to-medium sand, silty-clayey sand, or gravelly sand, with a noteworthy coarsening in the bottom 10 feet, near the top of till. Overburden monitoring wells were later installed in this coarse zone at these two well clusters. The outwash colors graded from generally brown at the top to more reddish with increasing depth. Outwash was encountered from ground surface to approximately 40 feet below grade at the MW-703 location, and 30 feet below grade at the MW-707 location. Occasional cobbles or boulders consisting of gray diabase or red arkose were encountered within the till at the MW-703 and MW-707 locations. Red till was encountered beneath the outwash at these locations, and generally consisted of dense fine to medium sand and silt, with trace gravel. A relatively soft zone, with little silt content was encountered from approximately 60 to 70 feet below grade at the MW-707 location, and a middle overburden monitoring well was later screened in this zone.

As described above, in the northern portion of the Southington Well Field Property at the MW-704 cluster (Figures 3, 18, and 19), a sequence of sand, gravel, and boulders was encountered in the deep overburden, from approximately 50 feet to the top of bedrock at 75 feet. This interval has been interpreted as coarse drift. A layer of relatively fine grained homogeneous material was encountered from approximately 40 to 50 feet below grade at the MW-704 well cluster, which stratigraphically separated the outwash (above) from the coarse drift (below).

At the MW-705 well cluster on the Former Cianci Property (Figure 3), the outwash was highly stratified, and consisted of 0.5- to 4-foot thick layers of fine-to-coarse sand and gravel, silt and sand, or silt and clay. Outwash was encountered from ground surface to a depth of approximately 28 feet below grade at the MW-705 location, and was underlain by till, consisting of sand and gravel with varying amounts of silt, from 28 feet to the depth of the top of rock at 40 feet.

East of Queen Street, in the Oak Hill Cemetery, the MW-708 well cluster encountered a thick sequence of stratified medium-to-coarse sand and gravel from ground surface to a depth of approximately 90 feet below grade (Figures 3 and 17). This zone, classified as outwash for the purpose of this RI, is qualitatively consistent with the kame plain description previously mapped at that location (Hanshaw, 1962). The remainder of the outwash, from 90 feet to 120 feet below grade, exhibited a higher silt content than the upper 90 feet of the overburden. Till was encountered from 120 feet to the top of rock at approximately 175 feet, and consisted of fine-to-medium sand with varying amounts of silt and gravel.

Southeast of the site along Queen Street, the MW-710 well cluster encountered outwash from ground surface to a depth of 55 feet below grade, consisting of gravelly medium-to-coarse sand (Figure 3). Till was encountered from 55 feet to the top of rock at 128 feet, and consisted of fine-to-coarse sand with some silt, and a minor component of gravel which decreased with depth in the till.

Small-Scale Overburden Stratigraphy

In contrast to the gross-scale stratigraphic data yielded by the new soil borings, the overburden stratigraphy and range of permeability values were evaluated in detail at two test pits, TP-701 and TP-702, installed on the former Cianci Property. The findings from these test pits are included in Appendix B. Test pit TP-701 was performed north of the NTCRA 1 Containment Area, in a zone where the shallow overburden ground water has historically shown very low, if any, concentrations of VOCs (Figure 3). Test pit TP-702 was installed in the northwest area of the former Cianci Property during the installation of the constructed wetland, which was installed in the shape of an oxbow connected to the Quinnipiac River as part of NTCRA 1 wetland mitigation activities. This excavation provided large exposures of soil for characterization and sampling.

At test pits TP-701 and TP-702, a BBL geologist quantified the overburden stratigraphic continuity, thickness, and orientation. Test pit TP-701 exposed two 16-foot long, vertical, perpendicular cuts, 3.5- to 4-feet deep each. Five general soil layers observed at TP-701 from the top down included:

- One to 1.5 feet of topsoil and red-brown, silty, sandy fill;
- A 0.3-foot thick relict soil horizon with a root mat;
- One to 1.5 feet of massive, tan, fine sand;
- One to 1.5 feet of massive, tan-gray silt; and
- Approximately 1.5 feet of finely stratified sands and silts.

Several different stratigraphic thicknesses, orientations, and scales of continuity were observed. A two-inch thick silt stratum within the lowest unit had an orientation of N22W, 7E. This two-inch thick silt layer was found to pinch out within a distance of 5 inches into the wall of test pit TP-701. Several fine, one-centimeter thick silt laminations exposed in the wall of the test pit had an orientation of N0E, 18E. Another sequence of finely cross-bedded sand and silt laminae had an orientation of N40E, 32E. In accordance with the RI Work Plan, BBL obtained five soil samples for laboratory hydraulic conductivity testing. These five samples were obtained by pushing a 6-inch long, 1-inch diameter, cylindrical brass split-spoon liner sleeve horizontally into the soil exposed in a vertical cut within the test pit. To provide an understanding of the scale dependence of hydraulic conductivity variation, Dr. Kueper also obtained 25 smaller scale soil samples for laboratory permeability testing. Dr. Kueper obtained these samples by carefully removing soil within the plane of bedding from layers that were approximately 1 cm thick. Dr. Kueper's samples were tested for permeability using a falling-head permeameter, with all samples repacked to the same porosity (approximately the same bulk density, assuming a uniform average grain density), as described by Freeze and Cherry (1979). The hydraulic conductivity results from BBL's samples indicated an eight-fold range in hydraulic conductivity (Figure 21; Appendix B). The results of Dr. Kueper's samples indicated that the hydraulic conductivity at a smaller scale of observation varied by a factor of 300 (i.e., range of more than two orders of magnitude) (Figure 21).

At the test pit TP-702 location, two vertical, perpendicular cuts approximately 7 feet high each were created. One cut was 25 feet long and the other was 45 feet long. The main strata, from the top down, included:

- 2.5 feet of light gray to dark brown, silty, sandy topsoil and fill;
- 1.5 to 2.0 feet of brown, fine-to-medium sand;
- 0.0 to 1.5 feet of white to light tan, coarse sand and gravel, which was observed to pinch out locally resulting in approximately 2- to 6-foot long, separated lenses, with basal apparent dips of 40W to horizontal to 35E in an east-west oriented cut; and

- 1.5 to 2.5 feet of red-brown, fine to medium sand and silt, with discontinuous, approximately 1- to 3-inch thick strata of red silt.

The overall orientation of the white to light tan, discontinuous stratum (third unit listed above) was approximately N70W, 2S. However, as noted above, the basal contact of the coarse sand and gravel lenses had widely variable dip directions. Similarly, fine-scale cross bedding (on the order of 1 to 5 millimeters thick) was observed within the lower fine-to-medium sand and silt unit (forth unit listed above). The results of the five permeability samples indicated that the permeability ranged by a factor of 25 at test pit TP-702 (Figure 21; Appendix B). The findings from the test pits all suggest that the overburden stratigraphy is relatively complex and heterogeneous.

Overburden Geotechnical and Geochemical Data

Geotechnical data and geochemical (f_{oc}) data were also obtained in the on-site area at soil borings SB-701 through SB-703, and in the off-site area within the Southington Well Field Property at the MW-703 and MW-704 locations. The data from SB-701 through SB-703 were obtained to supplement geotechnical information reported by ENSR (June 1994), and help support the evaluation of VOC solute-transport rates that influence potential remedial alternatives for the on-site area containing elevated VOC concentrations in the saturated overburden. Similarly, the data obtained from the MW-703 and MW-704 locations provide a means to assess VOC mobility within the off-site plume. These data are summarized below.

Summary of On-Site and Off-Site Overburden Geotechnical and VOC Transport Parameters

Statistic	On Site				Off Site			
	Porosity, %	Bulk Density, g/cm3	TOC, mg/kg	f_{oc}	Porosity, %	Bulk Density, g/cm3	TOC, mg/kg	f_{oc}
# Data	31	31	13	13	10	10	10	10
Mean	27.5	1.94	4044	0.00404	31.6	1.86	4260	0.00426
Std. Dev.	6.8	0.19	4244	0.00424	8.1	0.23	4460	0.00446
Min	17.3	1.40	<10	<.00001	17.7	1.61	514	0.000514
Max	47.2	2.25	13200	0.01320	40.4	2.24	16700	0.0167

Note: Soil porosity data reported as effective porosity by Core Laboratories, Inc., for BBL soil samples based on laboratory measurements using helium gas imbibation (API Method RP-40). These soil effective porosity data are slightly lower than the soil total porosity. On-site bulk density data presented above include BBL data and results formerly reported by ENSR (June 1994). On-site porosity data reported above include effective porosity data reported by Core Laboratories, Inc., for BBL samples (mean of 25.6 percent) and total porosity data reported by Daniel B. Stevens, Inc., for ENSR (1994) data (mean of 28.7 percent). These results indicate total and effective porosities on-site are similar, which is expected for many porous media (Cherry, February 1993). The porosity values presented above were used for overburden NAPL delineation, solute-transport, and VOC mass distribution evaluations in this RI Report.

The mean overburden porosity and bulk density results are typical of porous media. The mean f_{oc} data indicated similar values in the on-site and off-site areas, which suggest that organic-carbon based partitioning and VOC retardation are likely similar in these two overburden areas.

Four unsaturated soil samples obtained between ground surface and a depth of 4 feet at soil borings SB-701 through SB-703 had a mean f_{oc} value of 0.0077 (unitless), indicating a slightly higher organic carbon content in the shallowest portion of the overburden on site.

3.2.2 Study Area Bedrock Geology

Fifteen bedrock borings and coreholes were installed by East Coast-Thomas as part of the RI drilling and well installation activities. Nine deep bedrock pilot borings, MW-701DR through MW-708DR and MW-710DR, were installed at the nine main monitoring well installation areas (Figure 3). Each deep bedrock pilot hole was completed as a deep bedrock ground-water monitoring well. In addition, five bedrock borings were performed to install five shallow bedrock ground-water monitoring wells (MW-704R, MW-705R, MW-707R, MW-708R, and MW-710R). Also, one bedrock corehole (RC-701) was performed to obtain bedrock matrix samples for VOC characterization. Bedrock boreholes were installed using the rotary method with a roller bit or core barrel. Packer testing was performed at each deep bedrock pilot hole to identify bedrock flow zones and quantify bedrock hydraulic conductivity. In addition, down-hole fracture logging was performed by COLOG, Inc. of Golden, Colorado using a Borehole Image Processing System (BIPS) at two deep bedrock pilot holes (MW-702DR and MW-704DR) and at an existing open-bedrock well (the former Cianci Well) to measure in-situ bedrock fracture spacing and orientations. Bedrock sampling, packer testing, and downhole fracture logging are described in more detail in Appendix A. A complete sample log of bedrock samples, sample depth, date, time, and analysis is presented as Attachment A-1 to Appendix A. Bedrock geotechnical data and f_{oc} are summarized in Appendix C. Bedrock core descriptions are presented on the subsurface logs in Appendix E. Bedrock packer test and BIPS data are included in Appendices F and G, respectively. Table 6 summarizes bedrock packer test data and fracture characteristics.

The depth to bedrock varies throughout the study area, from approximately 15 to 40 feet below grade at the SRSNE Operations Area, to approximately 25 to 45 feet below grade on the former Cianci Property, and to approximately 80 to 100 feet below grade at the Southington Well Field. Top-of-bedrock elevation contours, shown on Figure 22, indicate that the bedrock surface dips toward the east in the vicinity of the site. These contours are consistent with top-of-bedrock elevation data published by the USGS (Mazzaferro, 1975). While generally smooth, the interpretation of the top of bedrock during drilling in some areas is complicated due the presence of boulders in the till, particularly near the base of the till. However, the drilling methods used during the RI, including the work previously performed by HNUS (May 1994) and the recent work by BBL, were appropriate to help distinguish between boulders and bedrock. HNUS (May 1994) used drive and wash drilling methods in the overburden, which are capable of penetrating boulders. BBL's subcontractor, East Coast-Thomas, used hollow-stem augers (or, as necessary, spun casing) to advance boreholes through the overburden, and used a core barrel to evaluate whether an obstruction was a boulder or the top of actual bedrock. Roller bitting was used, as necessary, to clear boulders and allow further augering until the top of bedrock was confirmed by coring, roller bitting, or persistent auger refusal.

Core samples and drilling observations at the SRSNE Site indicate that the upper 5 feet of bedrock (*weathered bedrock*) is severely weathered and partially decomposed. The deep weathering of the top of rock may be due to ground-water flow and the resultant partial dissolution of the carbonate cement within the arkose. The New Haven Arkose is cemented by carbonate and is subject to weathering by partial dissolution. Localized caliche deposits are also observed within the New Haven Arkose, indicating temporary deposition of soluble evaporite minerals in an arid paleoclimatic setting (Hubert *et al.*, 1978). Some of the fractures identified in core samples or downhole fracture logging indicated relatively open fractures at the borehole wall, which may represent washout of a caliche-like layer due to drilling. Split-spoon samplers can typically be driven into the top of the weathered rock during standard penetration testing, and hollow-stem augers can typically be advanced 5 feet or more into this weathered zone. The degree of weathering generally decreases with depth. The bedrock in the depth interval between 5 and 30 feet below the top of bedrock (*shallow bedrock*) is more competent than the weathered bedrock, but is still highly fractured and permeable. The fracture spacing generally increases with depth. At depths of 30 feet or more below the top of bedrock (*deep bedrock*), the rock is characterized by relatively few fractures and may exhibit a slightly lower hydraulic conductivity. The deep bedrock is capable of transmitting ground-water flow, however, and is the primary zone tapped by private water supply wells north and east of the site. Thus, local, transmissive, fractured zones are also likely to be present in the deep bedrock.

During the completion of the RI, bedrock core samples were obtained continuously from the top of weathered bedrock to the base of the deep bedrock borehole at the MW-702DR, MW-704DR, and MW-705DR pilot holes to further characterize the bedrock geology and to provide bedrock samples for laboratory analysis. The bedrock generally consisted of medium to coarse-grained, feldspathic sandstone; conglomerate; silty, fine sandstone; and siltstone. These lithologies reportedly reflect deposition as part of an alluvial fan sequence in an arid paleoclimate (Hubert *et al.*, 1978). In-situ, natural bedrock fractures were noted by the BBL field geologist, and were distinguished from mechanical breaks based on staining or infilling by silty material or mineral precipitates. Typical fracture spacings appeared to be approximately three feet, and fractures appeared to be predominantly parallel to the subhorizontal bedding of the arkose. At the MW-705DR pilot hole location, drilling was interrupted at a depth of 100 feet below grade, or 60 feet below the top of bedrock, due to the recognition of a sheen on the drilling water, indicating potential NAPL. Sandy material was also observed in the wash water at that depth, suggesting a zone of weakness, such as a fracture zone or caliche horizon.

At each of these drilling areas, one sample of weathered bedrock, two samples of shallow bedrock, and two samples of deep bedrock were obtained for analysis of f_{oc} and geotechnical parameters (matrix porosity, matrix permeability, and matrix bulk density), to support solute-transport analysis, including estimates of dissolved and sorbed VOC mass in the bedrock and an evaluation of VOC retardation based on matrix diffusion. The geotechnical and geochemical data that supported these evaluations are presented in Appendix C and summarized in the table that follows within this section of the document.

Bedrock fractures in the region generally dip moderately eastward, parallel to the eastward-dipping bedding. Steeply dipping fractures, however, have also been reported in cores and outcrops (HNUS, May 1994).

To provide a direct means to detect and document the in-situ spacing, orientation, and estimated aperture of in-situ bedrock fractures, downhole fracture logging was performed at deep bedrock pilot holes MW-702DR and MW-704DR, where continuous core samples were also obtained, and at the former Cianci Well (MW-709 location D) (Figure 3). In-situ bedrock fracture data obtained at these locations by COLOG, Inc., of Golden, Colorado, using digital, optical BIPS technology, are summarized as bedrock fracture tables, stereonet plots and rose diagrams of fracture orientations, statistics, and examples of BIPS digital images in Appendix G. The BIPS results indicated the following statistics for the 94 fractures observed at the three logged bedrock boreholes:

- Mean fracture dip direction (azimuth) after declination correction = 107.53 degrees (i.e., east-southeast);
- Standard deviation of dip direction = 2.26 percent;
- Mean fracture dip angle below the horizontal plane = 22.06 degrees; and
- Standard deviation of dip angle = 8.85 percent.

The fractures observed via BIPS and core samples generally appeared to be parallel to bedding, and the mean dip angle of 22.06 degrees is consistent with the gently-dipping stratigraphy observed in the outcrops throughout the Hartford Basin. A range of dip angles was observed, however, with relatively few dip angles as low as 0 degrees or as high as 50 degrees. Table 6 summarizes bedrock fracture spacing data obtained during this investigation, including BIPS and bedrock core sample data (at the MW-705 location, where BIPS was not performed), which indicate a mean fracture spacing of 142.3 cm (4.7 feet), with a standard deviation of 98.9 cm (3.2 feet).

Packer tests, also known as water pressure tests (Ziegler, 1976; USAR, 1977), were performed to develop a hydraulic conductivity profile for the bedrock stratigraphic column, to identify appropriate (permeable) zones for installing bedrock monitoring well screens, and to supplement the hydrogeologic database with additional bedrock hydraulic conductivity data. The packer test pumping rate, water pressure, and test section geometry provide a basis to estimate the average hydraulic conductivity within the tested section (Ziegler, 1976; USAR, 1977), as presented in Appendix F. Bedrock packer test results are summarized on Table 6, and discussed further in Section 3.3.2 in terms of hydraulic conductivity data. Bulk hydraulic conductivity data from the bedrock, however, including packer test results, provided a means to estimate the bedrock fracture aperture, or width, for a few bedrock intervals where fracture spacing was also quantified, as shown on Table 6.

The results of the key bedrock technical parameters quantified during the completion of the RI are summarized in the table below. The bedrock fracture porosity was estimated as the fracture aperture divided by the fracture spacing.

Summary of Bedrock Matrix and Fracture Parameters								
Statistic	Matrix Porosity, %	Matrix Permeability, cm/sec	Matrix Bulk Density, g/cm3	Matrix TOC, mg/kg	Matrix f_{oc}	Fracture Aperture, cm	Fracture Spacing, cm	Fracture Porosity, %
# Data	18	18	18	18	18	4	20	4
Mean	7.7	4.2E-07	2.52	4931	0.00493	9.6E-03	142	6.8E-03
Std. Dev.	3.0	8.7E-07	0.10	6780	0.00678	4.9E-03	99	7.4E-03
Min	4.4	4.3E-09	2.33	200	0.0002	5.0E-03	14	9.8E-03
Max	12.9	3.3E-06	2.64	28900	0.0289	7.7E-02	305	2.8E-02

Note: Matrix porosity reported as effective porosity by Core Laboratories, Inc., for BBL bedrock core samples based on laboratory measurements using helium gas imbibation (API Method RP-40). The bedrock matrix effective porosity will be less the matrix total porosity. For the purposes of this RI Report, the bedrock matrix effective porosity measurements by Core Laboratories, Inc.,are the matrix porosity measurements in this document. The mean matrix porosity value presented above was used for bedrock matrix diffusion and VOC mass distribution evaluations in this RI Report.

The mean matrix porosity is approximately 1,100 times larger than the mean fracture porosity, indicating that the matrix represents the predominant zone in which VOC mass would be stored in the saturated bedrock. However, the low permeability of the bedrock matrix suggests that VOC movement into or out of the bedrock matrix is generally controlled by molecular diffusion, or matrix diffusion, as described in Section 4.3.1.4.

The primary purpose for the geologic investigations described above was to provide a structural context to understand ground water and VOC migration in the region and, more specifically, within the RI Study Area. In light of the overburden and bedrock geology discussed above, Sections 3.3 and 3.4 describe the regional hydrogeology and study area hydrogeology, respectively.

3.3 Regional Hydrogeology

The SRSNE Site is situated within the Quinnipiac River Basin, which covers 363 square miles in south-central Connecticut, and is drained principally by the Quinnipiac River and six smaller rivers that discharge directly to Long Island Sound. The Quinnipiac River is the major surface-water drainage feature in the basin, and drains 166 square miles of the basin (Mazzaferro *et al.*, 1979). The Quinnipiac River Basin is 30 miles long from north to south. The SRSNE Site is near the headwaters of the basin, 5 miles from its northern limit. At the latitude of the site, the Quinnipiac River is near the center of the basin, 3 miles from the western limit of the basin, and 1.5 miles from the eastern margin of the basin.

Regional hydrogeology can be described in terms of a water budget, in which water enters the ground-water flow system in the form of infiltrated precipitation and ultimately is discharged back to the atmosphere via evapotranspiration from the water table (the top of the saturated zone), or enters surface water drainage features via ground-water discharge. Precipitation that does not evaporate or run off the land surface via overland flow enters the subsurface. A portion of the water that enters the ground is evapotranspired by vegetation. The remainder serves as *recharge* for the ground-water flow system. Water that recharges the ground-water flow system is stored temporarily in the subsurface, where it migrates in accordance with the laws of fluid flow through porous or fractured media until it discharges to surface water or is evapotranspired from the water table zone. Over a period of many years, an essentially steady state balance is achieved within a regional hydrology basin, where the recharge rate is roughly equal to the sum of ground-water discharge to surface water and ground-water underflow out of the downstream end of the basin through the saturated subsurface media, collectively termed *ground-water outflow*. Evapotranspiration also removes a fraction of the ground-water, though, such that the ground-water outflow provides a conservative (low) estimate of the natural recharge rate.

Within the northern portion of the Quinnipiac River Basin, from the northernmost headwaters southward to Southington inclusive, the ground-water outflow (units of L^3/T) divided by the area of that portion of the basin (units of L^2) equals approximately 14.9 inches per year (Mazzaferro *et al.*, 1979). Thus, the average annual ground-water recharge rate over the region surrounding the SRSNE Site can be conservatively estimated as 15 inches. The distribution of recharge is heterogeneous, however, due to differences in slope, vegetation, land use, and soil type. In general, flat, low-lying areas underlain by permeable, stratified drift receive more recharge than the surrounding hills, which are underlain by till at or near ground surface (Mazzaferro *et al.*, 1979). Thus, the long term average recharge rates in Connecticut range from approximately 7 to 20 inches per year depending on surface conditions (Melvin *et al.*, 1992b).

Water that enters the ground-water flow system flows downgradient (i.e., from higher to lower hydraulic potential). The hydraulic potential at ground surface can be quantified by measuring the elevation of surface-water bodies such as streams and ponds. Below ground surface, the hydraulic potential at a given depth interval can be quantified by measuring the elevation of the natural, equilibrium water level (ground-water elevation) in a well or piezometer installed within the saturated medium. As discussed in Section 3.4, a large number of surface-water and ground-water elevation measurements were used to characterize hydraulic gradients within the RI Study Area. The lowest hydraulic potential in a typical river basin is that of the river or other connected surface-water drainage features. With increasing distance from the river, the water table (the top boundary of the saturated zone) slopes upward in both directions following the topography in a subdued manner. In general, regional ground-water flow within the saturated zone approximates a circulation system that is lenticular in regional cross section, and is roughly symmetrical on either side of the central, surface-water discharge feature, such as a perennial stream (Freeze and Cherry, 1979). The movement of ground water within the regional ground-water circulation system over a period of many years is constant and gradual (approximately steady-state), with relatively consistent recharge throughout the basin and consistent discharge to the central surface-water feature. The overall depth of the ground-water flow path, however, differs depending on the original point of recharge. Ground water that enters the subsurface near the river follows a relatively shallow pathway to a discharge point at the river. In contrast, ground water that enters the saturated zone at a distance from the river, in the hills surrounding the river valley, migrates downward and follows a deep flow path to a point beneath the river, where it migrates upward into the base of the river (Freeze and Cherry, 1979). With reference to the Quinnipiac River Basin, this conceptual model is shown on an east-west oriented regional cross section through the site, as shown on Figure 9.

Figure 9 is consistent with the fundamental concept of regional ground-water flow. Ground water can be expected to converge toward the Quinnipiac River from both sides of the basin. According to the USGS, in Connecticut "most groundwater flow occurs within 300 feet of ground surface. Because of the shallow depth of the flow system and moderate topographic relief, the circulation of groundwater in most parts of Connecticut is confined to the drainage basin of each perennial stream" (Melvin *et al.*, 1992b). Consistent with this statement, the available hydrogeologic data from the SRSNE Site RI Study Area support the inference that essentially all overburden and bedrock ground water within the RI Study Area is discharging to the Quinnipiac River. The available hydraulic gradient data indicate that the ground water north and west of the Quinnipiac River within the Operations Area, former Cianci Property, and Southington Well Field Property migrates south-southeastward. In contrast, the ground water east of the Quinnipiac River migrates westward toward the river. Furthermore, the ground water south of the Quinnipiac River, in the vicinity of Curtiss Street, migrates northward toward the river. The convergence of flow toward the river from both sides is consistent with the interpretation of regional discharge of ground water into the river on a basin-wide scale. Preliminary modeling results from the NTCRA 2 MODFLOW model suggest that even deep bedrock ground water within the VOC plume associated with the SRSNE Site discharges into the Quinnipiac River north of the point where the river crosses Curtiss Street.

As ground water migrates downgradient, it preferentially follows pathways that offer the least hydraulic resistance (i.e., the most permeable geologic strata and lenses within the overburden or fracture networks within the bedrock). The ability of geologic media to transmit ground water is quantified in terms of the hydraulic conductivity. Representative values of hydraulic conductivity for the geologic units in a region can be estimated based on populations of measurements performed within a given unit. For example, based on 401 specific capacity tests performed by water well drillers at wells installed within the top 30 to 650 feet of the sedimentary bedrock units in Connecticut, the median hydraulic conductivity was calculated as approximately 0.31 feet per day (ft/day) (Melvin *et al.*, 1992b). This value is consistent with the geometric mean bedrock hydraulic conductivity of 0.35 ft/day based on available data from the RI Study Area, suggesting that the bedrock within RI Study Area is hydraulically typical of sedimentary bedrock in Connecticut (see Section 3.4.2). In contrast to the low conductivity of the bedrock, however, a representative hydraulic conductivity value of 170 feet per day has been estimated for the overlying coarse-grained stratified drift (sand and gravel outwash) based on aquifer tests and specific capacity tests (Melvin *et al.*, 1992b). These results demonstrate a considerable hydraulic conductivity contrast between the outwash and the bedrock and, in general, indicate that the overburden transmits considerably more ground-water flow than an equivalent thickness of bedrock. Representative till hydraulic conductivity values are typically reported between these two extremes, but can be as low as those for bedrock (Melvin *et al.*, 1992b). Within the RI Study Area, however, the till may be more permeable than the data reported for till in the literature, as discussed in Section 3.4.2.

Section 3.4 describes the ground-water hydraulics within the RI Study Area based on hydraulic conductivity and ground-water elevation data measured at the site during this and previous investigations.

3.4 Study Area Hydrogeology

Ground-water flow within the study area has been studied since the 1960s, beginning with the development of the Town of Southington Well Field. Data obtained during 15 subsurface investigations, including the completion of the RI, have generated a large quantity of data including hydraulic conductivity and ground-water elevation measurements at a continually expanding array of overburden and bedrock monitoring wells, currently numbering approximately 230. During the previous RI, HNUS (May 1994) compiled, presented, and interpreted an impressive volume of hydrogeologic data, and discussed in detail the hydrogeology in the RI Study Area, including the interpreted horizontal and vertical ground-water flow components and the interaction between ground water and the Quinnipiac River. This section evaluates the hydrogeology of the study area based on information compiled during previous investigations and new information obtained during the completion of the RI. Section 3.4 does not attempt to reevaluate all of the work completed by HNUS, but presents new information that help to complete the Hydrogeologic Conceptual Model presented in Section 3.5, which is a necessary component of the TI Evaluation that will be presented as an appendix to the FS. Previously reported data have been organized in the comprehensive relational database for the site, which has facilitated the evaluations presented below. Within the database, the geologic contacts, well construction, hydraulic conductivity value, and hydraulic head measurements from each well are stored, and the well is assigned to one of the five hydrostratigraphic zones currently monitored at the site, including the shallow, middle, and deep overburden, and the shallow and deep bedrock.

The key differences between the hydrogeologic information presented previously and the contents of this report are the new, supporting field data that were acquired by BBL between August 1996 and July 1997, during the completion of the RI, including:

- 115 hydraulic conductivity measurements obtained from 28 newly installed wells and numerous previously installed wells;
- Long-term hydrographs of hydraulic heads at three pairs of shallow and deep bedrock monitoring wells; and
- The two most complete ground-water and surface-water elevation measurement rounds ever obtained in the RI Study Area, which included all accessible (227) monitoring wells, piezometers, extraction wells, and surface-water measurement locations.

These data are discussed in the subsections that follow and are used to develop the understanding of study area hydrogeology needed to complete the Hydrogeologic Conceptual Model for the RI and proceed with the TI Evaluation and the FS. The study area hydrogeology can be summarized in terms of: the depth to ground water, hydraulic conductivity data, horizontal and vertical hydraulic gradients, and the location of surface-water drainage features, including the Quinnipiac River, its flood plains, and wetlands.

3.4.1 Depth to Ground Water

Based on data obtained at soil borings, monitoring wells, and piezometers throughout the RI Study Area, the depth to ground water is variable throughout the study area. As shown on east-west geologic cross sections A-A' and B-B', the water table is typically within approximately 4 to 5 feet of ground surface near the center of the Quinnipiac River Basin (Figures 17 and 18). In the vicinity of the NTCRA 1 Containment Area, which was installed to extract and treat overburden ground water, the depth to the water table is currently 2 to 4 feet. Prior to the start up of the NTCRA 1 extraction wells, the water table in the same area was similar, and occasionally was at ground surface. The depth to the water table increases with increasing distance on either side of the river. Near the western margin of the RI Study Area, at piezometer PZR-6, the water table is within the bedrock at a depth of approximately 15 feet below grade (Figure 17). The adjacent overburden piezometer (PZO-6) has been dry since its installation in the summer of 1995. Near the eastern margin of the RI Study Area, at well cluster MW-708, the water table is approximately 75 feet below grade (Figure 17). The slope of the water table east of the Quinnipiac River is more gentle than on the west, presumably due to the greater saturated thickness (H) and hydraulic conductivity (K) of the outwash east of the river, which render the transmissivity ($T = K \times H$) higher east of the river. In addition, as noted in Section 3.3, the Quinnipiac River is offset from the center of the basin, and is closer to the eastern edge of the regional river basin. The area available for ground-water recharge, and the resulting volumetric ground-water flux, are therefore expected to be less east of the river than west of the river. These considerations may explain why the water table is flatter east of the river than west of the river.

3.4.2 Hydraulic Conductivity Data

Hydraulic conductivity data have been obtained for the overburden and bedrock hydrogeologic units within the RI study area. These data have principally been obtained based on hydraulic field tests at wells and piezometers, including slug tests, specific capacity tests, and pumping tests. In addition, bedrock hydraulic conductivity data have been obtained from packer tests within open bedrock boreholes. These data are stored in the comprehensive relational database for the site, and provide a means to evaluate the statistics and spatial distribution of hydraulic conductivity values. Furthermore, during the completion of the RI, the small-scale hydraulic conductivity characteristics of the overburden were evaluated in detail based on the sampling and laboratory testing of soil samples from two test pits, and vertical permeability data were obtained from the till to assess its potential role as a capillary barrier to DNAPL. The following subsections summarize the hydraulic conductivity data for the overburden and bedrock units.

Overburden Hydraulic Conductivity

Small-Scale, Outwash Horizontal Hydraulic Conductivity

As described above in the discussion of overburden geology within the study area (Section 3.2.1), detailed stratigraphic and hydraulic conductivity data were obtained at test pits TP-701 and TP-702 to evaluate the degree of heterogeneity on site. The stratigraphy was found to contain several types of soil ranging from sand and gravel to silt, with bedding thicknesses ranging from a few millimeters to over one foot, and variable directions of stratigraphic dip and cross bedding (See Appendix B). Many strata were found to be discontinuous within a distance of a few feet. Furthermore, the horizontal hydraulic conductivity data obtained from these two test pits ranged from approximately $8x10^{-5}$ to $1x10^{-1}$ centimeters per second (cm/sec) or 0.2 to 300 feet per day (ft/day), indicating a total range of more than three orders of magnitude (Appendices B and C; Figure 21). The hydraulic conductivity data were more variable for the centimetric scale samples obtained by Dr. Kueper than the split-spoon liner samples obtained by BBL, indicating a greater degree of variability on a smaller scale of observation, and possible averaging in the split-spoon liner samples. These data show that the overburden is highly heterogeneous on site.

These results are consistent with previous information reported for the Operations Area soils (ENSR, June1994). ENSR (June 1994) reported that the vadose-zone soil in the Operations Area appears to be highly heterogeneous based on the pilot test measurements. The vadose-zone soil also exhibited different permeabilities depending on direction (anisotropy) which complicated the estimation of in-situ air permeabilities. ENSR concluded that, due to the observed heterogeneities in the Operations Area vadose-zone soil, SVE would not be effective for soil treatment at the site. Based on analogous logic, any in-situ ground-water remediation efforts involving flushing within the saturated zone would have a limited influence on ground-water quality, would leave many low-permeability soil zones untreated, and would not succeed in restoring on-site ground water to MCLs.

Glacial Till Vertical Hydraulic Conductivity

Three till samples were obtained from soil borings SB-701 through SB-703 within the NTCRA 1 Containment Area for laboratory testing of vertical permeability. These samples were obtained using brass, internal split-spoon liner sleeves to provide relatively undisturbed samples. The hydraulic conductivity data from these three samples ranged from approximately $4x10^{-7}$ to $1x10^{-6}$ cm/sec (0.0018 to 0.0034 ft/day) (see Appendix C), suggesting that the till, where present, may serve as an effective capillary barrier to vertical NAPL migration. This inference is supported by the relatively low concentrations of solvent-related VOCs in bedrock ground water beneath the Operations Area, whereas the overburden contains high VOC concentrations indicating the presence of NAPL. These data are being used as part of the NTCRA 2 design to evaluate the potential for downward NAPL mobilization from the overburden to the bedrock during future bedrock ground-water extraction.

Bulk Hydraulic Conductivity Data

While the test pits described above provided detailed hydraulic conductivity data on a relatively minute scale, the bulk hydraulic conductivity is normally measured using hydraulic tests at wells and piezometers. During the completion of the RI, single-well pumping tests (specific capacity tests) were performed at wells in the RI Study Area, as summarized on Table 7. Appendix H presents specific capacity test results and, for wells that did not yield sufficient flow, rising head test results. In addition, during the specific capacity tests, drawdown data were measured at other wells around the test well to provide a general understanding of the hydraulic responses in the surrounding formation (Table 7). Similarly, during well and piezometer purging prior to ground-water sampling, pumping rate and drawdown data were measured to estimate hydraulic conductivity data commensurate with specific capacity reduction (Walton, 1962), as summarized in Appendix I. A total of 115 new hydraulic conductivity data were produced in the process, most of which were overburden data. These data can be considered estimates of the average, or bulk, horizontal hydraulic conductivity for the stratigraphic section intersected by the 10- to 30-foot long screened interval of the tested wells. The hydrogeologic database was used to compile and sort data from the overburden wells into the categories of shallow, middle, and deep overburden. The hydraulic conductivity data sets for these three groups were contoured to help visualize the hydraulic conductivity distribution within these three zones.

- As shown on Figure 23, the bulk hydraulic conductivity of the **shallow overburden** over the horizontal scale of the study area ranges by more than three orders of magnitude (< 1 ft/day to >1,000 ft/day). Relatively low values, less than 1 ft/day, were measured in the NTCRA 1 Containment Area, and hydraulic conductivity values of approximately 1 ft/day to 10 ft/day were measured across the remainder of the former Cianci Property. In the northern portion of the Southington Well Field Property, the data are generally <1 ft/day in the shallow overburden. The hydraulic conductivities increase substantially in the southern portion of the Southington Well Field Property, however, to a high of approximately 1,000 ft/day.

- Town of Southington Production Well No. 4 is screened in the **middle overburden** where the hydraulic conductivity has been estimated as approximately 850 ft/day, as shown on the middle overburden hydraulic conductivity contour map (Figure 24). The middle overburden data indicate a slightly smaller range of conductivities, but still more than two orders of magnitude (<1 ft/day to >100 ft/day). The data near the site are higher than in the shallow overburden, generally on the order of 10 ft/day in the Operations Area and NTCRA 1 Containment Area. Immediately east of the NTCRA 1 Containment Area, however, a zone of less than 10 ft/day is mapped, which extends to near the Quinnipiac River (Figure 24). In the northern portion of the Southington Well Field Property, the hydraulic conductivity values in the middle overburden are generally between 1 and 10 ft/day, but increase to over 100 ft/day toward the south.

- Town of Southington Production Well No. 6 is installed in a **deep overburden** zone with a hydraulic conductivity of approximately 1,200 ft/day, as shown on the deep overburden contour map (Figure 25). The hydraulic conductivities in the deep overburden are greater than 100 ft/day throughout much of the Town Well Field Property. Of particular significance to the RI, a portion of the deep overburden with a hydraulic conductivity greater than 100 ft/day extends northward nearly to the former Cianci Property. This zone is considerably more conductive than the shallow or middle overburden in the same area. Furthermore, deep overburden conductivity data between 10 and 100 feet/day extend onto the former Cianci Property from the south. These data suggest that the deep overburden south of the site represents a path of relatively high conductivity for overburden ground-water migration, and should manifest itself as a preferential pathway for dissolved VOC migration. As discussed in Section 4.2.1, this inference is substantiated by the three-dimensional distribution of VOCs south of the site. Throughout the remainder of the SRSNE Site, the deep overburden hydraulic conductivity data are comparable to the shallow and middle overburden data in the same area. Deep overburden hydraulic conductivities between 1 and 10 ft/day are observed on the Operations Area and the northern portion of the former Cianci Property. Similar to the middle overburden pattern, the deep overburden conductivity values decrease considerably east of the NTCRA 1 Containment Area, and are generally less than 1 ft/day between the NTCRA 1 Containment Area and the river.

The overburden hydraulic conductivity maps provide a more detailed understanding of overburden conductivity distributions than was previously available, but are generally consistent with previous inferences. Relatively low overburden hydraulic conductivity values are observed within the shallow, middle, or deep overburden in the vicinity of the SRSNE Site Operations Area and the NTCRA 1 Containment Area. In general, the hydraulic conductivity values increase toward the south, in the direction of the Southington Well Field Property, but they also increase toward the north. East of the NTCRA 1 Containment Area, hydraulic conductivities are even lower than in the Containment Area itself (except in the shallow overburden). Generally low permeability data on site are consistent with the geologic inference discussed above in Section 3.2.1, that the area around the site may be underlain by a zone of ablation till.

Overburden Horizontal Anisotropy

While the bulk horizontal hydraulic conductivity data discussed above describe the magnitudes of the overburden horizontal hydraulic conductivity, single-well hydraulic test methods do not indicate whether the horizontal hydraulic conductivity has a directional dependence (horizonal anisotropy), or whether the representative horizontal conductivity is different from the vertical conductivity (indicating vertical anisotropy). Multi-well tests are required to measure the directional aspects of hydraulic conductivity. Single well hydraulic tests do provide an estimate for the geometric mean of the horizontal hydraulic conductivity in all directions around a given borehole (Kruseman and de Ridder, 1990). The horizontal conductivity in different directions may higher or lower than the mean. Theoretically, the highest and lowest horizontal hydraulic conductivities at a location are oriented along mutually perpendicular directions, and the relative magnitudes can be plotted as the axes of a hydraulic conductivity ellipse (Freeze and Cherry, 1978). The horizontal anisotropy can be evaluated using multi-well hydraulic test data.

To evaluate whether the overburden in the northern portion of the Southington Well Field Property near MW-704D may be anisotropic, BBL analyzed the specific capacity test data from well MW-704D in detail, as summarized graphically in Appendix H. The specific capacity test at well MW-704D was unique in that drawdown data were available from several nearby wells, including three other deep overburden observation wells (CW-2-75, MW-121B, and MW-204B) located in different directions surrounding well MW-704DR (Table 7). The observation well drawdowns after four hours were plotted on semilog paper to estimate the distance to a point of equal drawdown (0.2 feet) along the directional rays between the pumping well and each deep overburden observation well. The distances to the point of equal drawdown were plotted on a sketch map of the MW-704D area (Appendix H). Assuming an axisymmetrical drawdown distribution around the test well, symmetrical "data" points were plotted to help visualize the overall response around the test well. The points of equal drawdown describe an elliptical "cone of depression" around well MW-704D. The longer axis of the ellipse of equal drawdown, oriented approximately north-south, is twice as long as the east-west oriented axis. Based on this ratio, the horizontal hydraulic conductivity in the north-south direction is estimated as approximately four times that in the east-west direction (Kruseman and de Ridder, 1990). While horizontal anisotropy is seldom quantified, a 4:1 horizontal anisotropy value appears plausible considering the potential depositional setting for the tested material. The overburden in the Southington Well Field Property consists of relatively coarse-grained outwash, which presumably was deposited in braided, southward-flowing streams. This depositional setting could be expected to result in a higher permeability oriented parallel to the stream beds. However, as evidenced by the hydraulic responses observed during the well MW-704D specific capacity test, the overburden also exhibits hydraulic continuity in the east-west direction, parallel to the minor axis of the hydraulic conductivity ellipse.

BBL contacted ground-water flow modelers at the USGS office in Marlborough, Massachusetts and Hartford, Connecticut to discuss horizontal anisotropy characterization for stratified drift deposits in New England. The USGS was not aware of any efforts to measure horizontal anisotropy within stratified drift, but suggested multi-well pumping tests or numerical particle tracking would be appropriate approaches. During the calibration of the NTCRA 2 MODFLOW model, BBL found that horizontal anisotropy was necessary to account for the distribution of VOCs in the overburden south of the site (BBL, September 1997). A 4:1 anisotropy value was input to the overburden layers of the model, and substantially improved the visual match between the simulated ground-water particle tracks and the shape of the off-site, overburden VOC plume associated with the SRSNE Site. NTCRA 2 ground-water flow model development is discussed further in Appendix J. Without horizontal anisotropy in the overburden, it appears that ground-water flow beneath the SRSNE Site would not produce the observed plume shapes, which are presented in Section 4.3.1. The estimated horizontal anisotropy of 4:1 should be considered only an estimate, but it appears to be consistent with the available data, hydrogeologic setting, and observed VOC plumes.

Overburden Vertical Anisotropy

The bulk vertical anisotropy, or the ratio of the mean horizontal conductivity to vertical conductivity for the overburden deposits, was also estimated based on the drawdown responses at observation wells during pumping at individual specific capacity test wells. The individual test wells generally had short (10-foot long) screened intervals within a saturated overburden sequence up to 90 feet thick. To estimate the vertical anisotropy of the formation, the drawdown response measured at an observation well installed either above or below the pumping well screened interval is compared to the drawdown measured at another observation well screened within the same stratigraphic depth interval as the test well (or estimated using logarithmic distance drawdown interpolation) (Neuman-Witherspoon Method, described by Kruseman and de Ridder, 1990). Based on the evaluation of data sets obtained during the specific capacity tests at wells MW-703D and MW-704D, the ratio of the horizontal to vertical conductivity, or vertical anisotropy, was estimated as 1:1 to 520:1. This range of values is considered reasonable given the high degree of stratification observed in borings and test pits at the site, and reported for the stratified drift deposits (La Sala, 1961). Within this range, a value of 100:1 is estimated as representative, and was used in the calibrated NTCRA 2 MODFLOW model (BBL, September 1997). NTCRA 2 ground-water flow model development is discussed further in Appendix J.

The evaluations presented above show that glacial depositional processes resulted in a relatively systematic but highly heterogeneous and, evidently, anisotropic distribution of unconsolidated deposits. The bulk conductivities range by three to four orders of magnitude, but exhibit mappable areas of similar hydraulic conductivity. In addition, based on the evaluation of drawdown responses in plan view around deep overburden monitoring well MW-704D, it appears that horizontal flow in the north-south direction may be preferential to east-west flow within portions of the stratified outwash south of the site. These findings are consistent with the previous descriptions of the site, and provide a more detailed understanding of overburden ground-water hydraulics than that presented in previous investigations in the RI Study Area. In contrast to the systematic hydraulic conductivity of the overburden, however, the bedrock hydraulic conductivity is expected to be relatively random on a small scale, and uniform on a large scale.

Bedrock Hydraulic Conductivity

As described in Sections 3.1.2 and 3.2.2, the bedrock beneath the region and the RI Study Area consists of stratified, carbonate-cemented sandstone, siltstone, and conglomerate of the New Haven Arkose. Laboratory tests of intact core samples of the bedrock matrix indicated a mean matrix permeability of approximately 4.2×10^{-7} centimeters per second (cm/sec), or 0.00011 feet/day, which is considerably lower than the range of the overburden hydraulic conductivity data discussed above. It is clear that the bedrock matrix would not be capable of supplying a usable rate of ground water to a well, yet bedrock wells are used on the hill west of the site (where the overburden is dry) for domestic water supply. Similarly, hydraulic tests performed at the former Cianci water-supply well during the completion of the RI suggest that the well may have been capable of maintaining a pumping rate of up to 40 gpm. These considerations suggest that bedrock ground-water migration is dominated by the presence and interconnection of bedrock fractures rather than the unfractured matrix of the original bedrock strata. A brief discussion on bedrock fracture geometry and hydraulics is in order to help visualize ground-water flow within the rock.

Bedrock Fracture Geometry and Hydraulics

Downhole fracture logging and bedrock core sample inspection results, presented in Section 3.2.2, characterized the spacing, orientation, and aperture of bedrock fractures at the site. These data indicate that the spacing between fractures is highly variable, but averages approximately 4.7 feet. The bedrock is fractured predominantly parallel to the east-southeastward dipping bedding. The dip angles range from approximately 0 to 50 degrees, with a mean dip angle of approximately 22 degrees. The mean bedrock fracture aperture is approximately 9.6×10^{-3} cm. Using a parallel plate model to conceptualize flow through bedrock fractures (Ziegler, 1976), the mean bedrock fracture has a hydraulic conductivity of approximately 7.3×10^{-1} cm/sec, or 2100 ft/day (Table 6). Thus, the mean bedrock fracture has a hydraulic conductivity commensurate with the highest bulk overburden hydraulic conductivity measured at Town Production Well No. 6. This information indicates that, while ground water within the bedrock matrix is relatively stagnant, ground-water flow is very rapid within the fractures, albeit of a relatively small volumetric quantity.

To understand the relationship between highly conductive bedrock fractures and the relatively low conductivity reported for the bedrock at the site (HNUS, May 1994; ENSR, June 1994), recall that fractures occupy only a minute fraction of the overall bedrock volume. The mean bedrock fracture porosity was estimated as only 6.8×10^{-3} percent. The bulk hydraulic conductivity is a product of the spacing, interconnectedness, and apertures of individual bedrock fractures. To some extent, the overall, large-scale fracture network must reflect the mechanical properties of the rock, and may be expected to be grossly systematic. For example, most of the fractures are parallel to mechanical discontinuities separating beds of different rock composition. Thus, while fracture spacings, interconnectedness, and apertures appear to be randomly distributed, they are likely spacially correlated, and perhaps even cross-correlated. Defining the statistical parameters to describe the nature of the correlations is beyond the scope of this RI. However, the systematic orientation of fractures parallel to bedding suggests that the component of flow should be significantly higher parallel to bedding than orthogonal to bedding.

Bedrock Bulk Hydraulic Conductivity

To provide a practical understanding of bulk bedrock ground-water hydraulics, the bulk hydraulic conductivity is commonly measured using hydraulic tests at boreholes, wells or piezometers. Prior to the completion of the RI, bulk bedrock hydraulic conductivity data at the site were quantified based on packer tests performed at open-bedrock boreholes, slug tests at bedrock monitoring wells, or multi-well pumping tests. HNUS (May 1994) performed packer tests during bedrock drilling to identify relatively permeable zones within the bedrock to target bedrock monitoring well screens. Similarly, during the completion of the RI, BBL performed packer tests to identify preferential flow zones and to install bedrock monitoring wells. Thus, bedrock wells are generally screened in preferential flow zones within the bedrock. Packer testing and well installation activities performed by BBL are described in Appendix A. Packer test data reduction is presented in Appendix F. Packer test data are summarized on Table 6.

BBL also performed specific capacity tests at several wells and piezometers screened in the bedrock in the RI Study Area, as summarized in Appendix H. In addition, during bedrock specific capacity tests, drawdown data were measured at other bedrock wells around the test well to provide a general understanding of the hydraulic responses in the surrounding bedrock. Similarly, during well and piezometer purging prior to ground-water sampling, pumping rate and drawdown data were obtained to estimate hydraulic conductivity data commensurate with specific capacity data reduction (Walton, 1962), as summarized in Appendix I. These data can be considered estimates of the average, or bulk hydraulic conductivity for the stratigraphic section of bedrock intersected by the 10- to 30-foot long screened interval of the tested wells. As such, these data indicate the bulk hydraulic conductivity in the plane of bedding. Before installing monitoring wells MW-709R and MW-709DR in the former Cianci water-supply well, BBL also performed a specific capacity test at the former Cianci well to evaluate its yield and qualitatively assess its potential historical influence on bedrock ground-water flow and DNAPL migration. The results from the specific capacity test at the former Cianci well are discussed in Section 4.2.1.2.

The comprehensive, relational hydrogeologic database was used to compile and sort bedrock hydraulic conductivity data. Bedrock hydraulic conductivity data were then plotted as a histogram to depict the range and spread of the data. Also, the bedrock conductivities were plotted versus the depth of the center of the test interval below the top of bedrock to assess the variability of data versus depth. These evaluations are presented in Appendix K. As suggested by the histogram of hydraulic conductivity data, the bedrock hydraulic conductivity values cover a four order-of-magnitude range, from 0.0023 to 27 ft/day. Such a wide range is to be expected in a bedrock fracture network, where the fracture spacing, interconnectedness, and apertures are variable. As shown on the histogram in Appendix K, the data define a symmetrical distribution about the geometric mean value of 0.35 ft/day. This value is very similar to the median value of 0.31 ft/day reported based on 401 specific capacity tests performed by water well drillers at wells installed within the top 30 to 650 feet of the sedimentary bedrock units in Connecticut (Melvin *et al.*, 1992b). For the RI Study Area and surrounding region, the value of 0.35 ft/day is considered the representative bulk horizontal hydraulic conductivity value, and is appropriate to use in practical estimates of ground-water flow through the rock, such as the NTCRA 2 MODFLOW model (BBL, September 1997; also see Appendix J).

As shown on the profile graph of the vertical distribution of hydraulic conductivity versus depth below the top of rock (Appendix K), bedrock hydraulic conductivity data have been measured within the upper 96 feet of bedrock in the RI Study Area, but are largely clustered toward the top of bedrock. To help evaluate the overall relationship between depth below the top of bedrock and bulk hydraulic conductivity, geometric mean values were calculated and plotted for each 20-foot depth interval below the top of rock (except the interval of 80 to 100 feet below the top of rock, which had only one data point). The geometric mean values for the 20-foot intervals suggest that the bedrock conductivity is relatively consistent throughout the monitored section of rock.

Bedrock Anisotropy

The New Haven Arkose bedrock in the study area exhibits significant anisotropy due to the preferred orientation of bedrock fractures. As described earlier in this section, ground-water flow in the stratified, dipping New Haven Arkose bedrock is dominated by bedding-plane fractures that dip approximately 22 degrees toward the east-southeast (mean strike and dip of approximately N17E after declination correction, and 22E, respectively).

Bedrock flow is expected to be most efficient parallel to the bedding-plane fractures (i.e., within the plane of bedding, as discussed above), and least efficient perpendicular to the plane of bedding. Therefore, the principle axes of hydraulic conductivity are interpreted as being within the plane of bedding and perpendicular to the plane of bedding. The hydraulic conductivity within the plane of bedding was described above, and has a geometric mean value of 0.35 ft/day.

The bedrock hydraulic conductivity perpendicular to the plane of bedding was estimated based on the drawdown responses at observation wells during pumping at individual specific capacity test wells. The results of the Neuman-Witherspoon analysis (Kruseman and de Ridder,1990) are presented in Appendix H. Because bedrock fractures dip gently, the vertical hydraulic conductivity and the cross-bed hydraulic conductivity are considered approximately equal. Based on the data obtained during the specific capacity tests at well MW-702DR, the vertical anisotropy of the bedrock was estimated as 200:1. Similarly, an evaluation of data obtained during the specific capacity tests at well MW-705D suggested that the vertical anisotropy of the overburden/bedrock interface was as approximately 230:1 (Appendix H). These values are relatively consistent, and are considered reasonable given the high degree of stratification and consistent fracture orientations within the New Haven Arkose in the RI Study Area. [Based on these considerations, BBL incorporated bedrock anisotropy in the NTCRA 2 ground-water flow model (BBL, September 1997; see Appendix J)].

While the hydraulic conductivity data described herein present a thorough assessment of the hydraulic characteristics of the overburden and bedrock, ground-water flow directions within these media are also controlled by hydraulic gradients, which are discussed below.

3.4.3 Ground-Water and Surface-Water Elevation Data

Comprehensive Ground-Water and Surface-Water Elevation Measurement Rounds

Comprehensive rounds of ground-water and surface-water elevation (hydraulic head) measurements were obtained on January 21, 1997 and July 7, 1997, using all (up to 227) accessible monitoring wells, piezometers, extraction wells, and surface-water elevation measurement points in the RI Study Area. Each round of measurements was completed within one day to provide a "snapshot" of ground-water elevation and hydraulic gradient conditions. These two measurement events are the most complete rounds obtained in any investigation of the RI Study Area and provide the most complete basis to assess ground-water hydraulic head (synonymous with potentiometric elevation or ground-water elevation) conditions and hydraulic gradients. The January 21, 1997 and July 7, 1997 measurement events were temporally spaced approximately six months apart to allow an assessment of hydraulic gradient variability during different seasons. Ground-water and surface-water elevation data collection is described in Appendix A. The data are summarized on Table 8. Ground-water elevation measurements were used to develop plan-view and vertical profile flow nets depicting the three-dimensional ground-water flow regime within and between the overburden and bedrock formations. To prepare the plan-view head contour maps for the shallow, middle, and deep overburden zones, the data measured within the NTCRA 1 sheet-pile wall were contoured separately from the data outside of the sheet-pile wall. This approach was considered appropriate because the sheet-pile wall behaves as a hydraulic discontinuity. The NTCRA 1 extraction wells and overburden compliance piezometers are essentially fully penetrating within the saturated overburden, and were included in the head evaluation for all three overburden zones. Figures 26 through 30 present contours of the measured heads and the horizontal component of the hydraulic gradient within the five monitored hydrostratigraphic zones on January 21, 1997. Figures 31 through 35 present contours of the measured heads and the horizontal component of the hydraulic gradient within the five monitored hydrostratigraphic zones on July 7, 1997. Figures 36 through 38 summarize the head differences between hydrostratigraphic zones on January 21, 1997. Figures 39 through 41 summarize the head differences between hydrostratigraphic zones on July 7, 1997. Hydraulic heads measured on January 21, 1997 are also presented on geologic cross sections A-A', B-B', and C-C' (Figures 17 through 19).

The primary purpose for obtaining ground-water elevation data and plotting ground-water elevation contour maps and profiles was to identify hydraulic divides and zones of bedrock ground-water discharge to the overburden. Locating these key areas in the off-site plume area, in particular, helps to identify areas to which dissolved VOCs from the site could not migrate, and therefore provides a component of the rationale for VOC plume delineation.

Ground-water elevation data help to characterize the relationship, if any, between the SRSNE Site and private water supply wells in the residential area west of the site. Furthermore, when evaluated in conjunction with dissolved VOC data, the hydraulic head data help to delineate the potential NAPL zones within the overburden and bedrock.

The head measurement results are presented below for each comprehensive measurement performed during the completion of the RI.

Horizontal Component of Hydraulic Gradient on January 21, 1997

Shallow, middle, and deep overburden ground-water elevation data measured on January 21, 1997, indicated overburden ground-water flow converging toward the Quinnipiac River from both sides of the river throughout the overburden thickness.

Shallow overburden hydraulic heads measured on January 21, 1997, including ground-water and surface-water elevation measurements, are shown on Figure 26. In the vicinity of the Operations Area and the portion of the NTCRA 1 Containment Area within the sheet-pile wall, the horizontal component of the hydraulic gradient in the shallow overburden was generally toward the east, in the direction of the 12 fully-penetrating, overburden ground-water extraction wells. The heads are lower in the area immediately west of the sheet-pile wall than east of the sheet-pile wall, however, indicating a hydraulic gradient reversal across the sheet-pile wall. This result indicates effective containment of shallow overburden ground water flowing east from the Operations Area of the site by the NTCRA 1 system on January 21, 1997. With the exception of the aforementioned gradient reversal, the general direction of the horizontal gradient is toward the Quinnipiac River from both sides of the river. The lowest heads are along the axis of the river, and the lowest measurement in the entire data set is at the southern, downstream measurement point for the river (SW-704 at the Curtiss Street bridge). East of the river the gradient is westward, toward the river. In addition, the heads measured in the Curtiss Street Area indicate a northwestward gradient toward the Quinnipiac River. Therefore, the Quinnipiac River is the location of a hydraulic gradient reversal within the shallow overburden. The shallow overburden head contours have been interpreted as conforming to the shapes of surface-water features such as the Quinnipiac River, the constructed wetland in the northeast corner of the former Cianci Property, the intermittent stream in the Southington Well Field Property, and the tributary that enters the southeast corner of the Study Area. The distinct bend of the 150-foot shallow overburden hydraulic head contour near well P-13 in the northern portion of the Southington Well Field Property is attributed to shallow overburden ground-water drainage by the gravel-lined trench installed during the construction of the Off-Site Interceptor System (Loureiro, 1986). Prior to the installation of the NTCRA 1 Containment Area, similar deflections were observed based on heads measured at shallow overburden wells along the 30-inch, east-west-oriented buried culvert that crosses the former Cianci Property (ENSR, November 1994; June 1995), indicating that the 30-inch culvert may also be a drain to shallow ground-water flow. Culvert influent and effluent rates have indicated a higher effluent than influent rate during December 1996 and July 1997, suggesting that shallow overburden ground water discharges into the 30-inch culvert (Figure 42). The magnitude of the horizontal component of the hydraulic gradient (dimensionless) within the shallow overburden varies throughout the study area, as follows:

- Operations Area -- No shallow overburden data available, but expected to be eastward;
- Between the NTCRA 1 Containment Area and Quinnipiac River -- 0.020 toward the east;
- Between Queen Street and the Quinnipiac River -- 0.009 toward the west; and
- Northern Portion of Town Well Field Property -- 0.005 toward the south-southeast.

Middle and deep overburden heads measured on January 21, 1997 are shown on Figures 27 and 28, respectively. These ground-water elevation contours show the same pattern as the shallow overburden ground-water elevation contours in the vicinity of the Operations Area and the NTCRA 1 Containment Area, indicating effective containment of the overburden ground water flowing east from the Operations Area of the site. The horizontal component of the hydraulic gradient west of the Operations Area is toward the east. A hydraulic gradient reversal is evident across the NTCRA 1 sheet-pile wall. The middle overburden heads are interpreted as slightly conforming to the shapes of the surface-water features. East of the Operations Area, the lowest middle overburden heads are along the axis of the river, and ground-water flow is interpreted as converging toward the river from both sides. In addition, the heads measured in the Curtiss Street Area indicate a northwestward gradient toward the river. An anomalous, isolated area with a relatively high head was also observed next to the river, however, in the vicinity of deep overburden well MW-6. This effect is interpreted as the influence of the end of the gravel-filled trench associated with the off-site interceptor system, which ends (discharges) adjacent to well MW-6, and may surcharge overburden ground-water in that area (Loureiro, 1986). In general, however, given the available head data, and the fact that the Quinnipiac River represents the most significant ground-water discharge point within the Quinnipiac River Valley, the river is interpreted as producing a hydraulic gradient reversal within the middle overburden. Within the deep overburden, convergence toward the river from the east side cannot be directly demonstrated based on the available data, but is inferred due to the similarity between the patterns observed in the overlying, middle overburden and the underlying, shallow bedrock. The magnitude of the horizontal component of the hydraulic gradient within the middle and deep overburden varies throughout the study area, as follows:

- Operations Area -- 0.04 toward the east;
- Between the NTCRA 1 Containment Area and Quinnipiac River -- approximately 0.01 to 0.02, toward the southeast;
- Between Queen Street and the Quinnipiac River -- 0.003 toward the west in the middle overburden; no data available but expected to be similar in the deep overburden; and
- Northern Portion of Town Well Field Property -- 0.004 toward the southeast.

In general, the magnitudes of the horizontal component of the hydraulic gradient should be inversely related to the hydraulic conductivity of the geologic zones where the data are measured, and this inference appears to be reasonably valid at the site. The gradients are typically higher on site than east of the river or in the Southington Well Field Property, where higher conductivities have generally been measured. However, the inverse relationship between hydraulic conductivity and hydraulic gradient is not always valid, because the heads measured in one unit can be strongly influenced by the hydraulics of another subjacent unit. For example, in the northern portion of the Southington Well Field Property, the hydraulic gradients observed throughout the shallow, middle, and deep overburden all flatten considerably, suggesting that one may expect a much higher hydraulic conductivity there than on site in all three zones. However, only the deep overburden is markedly more conductive there than on site (Figure 25). The shallow and middle overburden hydraulic conductivities in the northern portion of the Southington Well Field Property are relatively similar to on site (Figures 23 and 24, respectively). Also, the gentler gradients in the northernmost portion of the Southington Well Field Property (north of well cluster MW-704) cannot be attributed to an increase in saturated overburden thickness (see Figure 18). These observations suggest that the relatively flat gradient in the northern portion of the Southington Well Field Property is dominated by the high permeability of the deep overburden, which can be interpreted as a preferential flow zone for overburden ground water, semi-confined between the less conductive middle overburden and the shallow bedrock.

Shallow bedrock heads measured on January 21, 1997 are depicted as contours on Figure 29. These ground-water elevation contours show the same general pattern as the shallower zones, but provide better resolution in the vicinity of the river than allowed by the middle and deep overburden data sets. The horizontal component of the hydraulic gradient west of and within the Operations Area is toward the east. A potentiometric depression is observed near the NTCRA 1 Containment System, indicating the hydraulic influence of the NTCRA 1 overburden ground-water extraction wells on flow conditions in the shallow bedrock. Close evaluation of the data reveals a hydraulic gradient reversal in the vicinity of compliance piezometer CPZ-6R, which is approximately 120 feet east of the NTCRA 1 Containment Area. West of CPZ-6R, shallow bedrock ground-water is flowing back toward the NTCRA 1 Containment Area. Based on the shapes of the shallow bedrock head contours, it appears that the NTCRA 1 Containment System hydraulically controls much of the shallow bedrock ground-water flow within the Operations Area and NTCRA 1 Containment Area. East of the Operations Area, the lowest heads are along the axis of the river, and ground-water flow is interpreted as converging toward the river from both sides. Also, in the southern portion of the Study Area, the hydraulic gradient is northward toward the Quinnipiac River. Therefore, the Quinnipiac River is interpreted as the general location of a hydraulic gradient reversal within the shallow bedrock. The magnitude of the horizontal component of the hydraulic gradient within the shallow bedrock varies throughout the study area, as follows:

- Operations Area -- 0.03 toward the east;
- Between the NTCRA 1 Containment Area and Quinnipiac River -- relatively flat gradient with apparent stagnation point (hydraulic divide) in the middle due to NTCRA 1 pumping system influence on shallow bedrock hydraulic heads;
- Between Queen Street and the Quinnipiac River -- 0.005 toward the west; and
- Northern Portion of Town Well Field Property -- 0.004 toward the southeast.

While the bedrock is interpreted as generally homogeneous on a large scale, these gradient values vary significantly from location to location, and closely resemble those observed in the overburden (particularly the deep overburden). For example, in the Southington Well Field Property, the shallow bedrock hydraulic gradient is relatively flat, even though the shallow bedrock hydraulic conductivity is expected to be the same there as on site, where the gradient is much steeper. Similar to the shallow and middle overburden, the horizontal component of the hydraulic gradient within the shallow bedrock in this area appears to be influenced by the hydraulic conductivity of the deep overburden.

Deep bedrock heads measured on January 21, 1997, are depicted as contours on Figure 30. These ground-water elevation contours show the same general pattern as the shallow bedrock, albeit with less resolution due to fewer data points in the deep bedrock, which were all installed during the completion of the RI. The horizontal component of the hydraulic gradient west of and within the Operations Area and at the former Cianci Property is toward the east. East of the Operations Area, the lowest head was measured adjacent to the Quinnipiac River at well MW-706R. East of the river, the hydraulic gradient is westward, toward the river. The Quinnipiac River is interpreted as the general location of a hydraulic gradient reversal within the deep bedrock. The magnitude of the horizontal component of the hydraulic gradient within the deep bedrock varies throughout the study area, as follows:

- Operations Area -- 0.04 toward the east;

- Between the NTCRA 1 Containment Area and Quinnipiac River -- Estimated as 0.03 toward east-southeast; however, a stagnation point (hydraulic divide) could also exist in the middle of this area due to NTCRA 1 pumping system influence on the bedrock heads;

- Between Queen Street and the Quinnipiac River -- 0.002 toward the west; and

- Northern Portion of Town Well Field Property -- Estimated as 0.02 toward east-southeast.

Horizontal Component of Hydraulic Gradient on July 7, 1997

The only significant difference between the monitoring locations in January 21, 1997 and July 7, 1997 data sets was the installation of the MW-710 well cluster along the east side of Queen Street, immediately south of the CL&P powerline easement in May and June 1997. The MW-710 cluster, with shallow overburden, shallow bedrock, and deep bedrock monitoring wells, was installed to fill data gaps in the delineation of the overburden and bedrock VOC plumes, and also provided ground-water elevation data.

Shallow, middle, and deep overburden ground-water elevation data measured on July 7, 1997 (Figures 31, 32, and 33, respectively), are generally consistent with those measured on January 21, 1997. Minor exceptions include slightly gentler horizontal gradients between the Quinnipiac River and Queen Street and in the north portion of the Southington Well Field Property in the shallow overburden. These differences in magnitude are to be expected seasonally, and may indicate a slightly reduced horizontal flux in the shallow overburden due to removal of some shallow overburden ground water via evapotranspiration. The directions of the horizontal component of the hydraulic gradient within the overburden units are generally consistent during the two monitoring events. However, unlike the January 1997 conditions, during the July 7, 1997 measurement round, the intermittent stream in the Southington Well Field Property was found to be dry. Its influence on ground-water flow in July 1997, therefore, was interpreted as negligible. The head measured at the newly installed shallow overburden well, MW-710S, was considerably higher than the river stage or the heads measured west of the river at wells CW-3-75 or MW-707S, indicating a strong westward hydraulic gradient in the shallow overburden at the MW-710 location. Otherwise, the July 7, 1997 overburden heads, and the interpretations derived from them, are essentially the same as those from the January 21, 1997 measurement round. The Quinnipiac River was interpreted as the location of a hydraulic gradient reversal throughout the saturated overburden.

Shallow and deep bedrock ground-water elevations measured on July 7, 1997, are summarized on Figures 34 and 35, respectively. The general contour patterns and horizontal components of the hydraulic gradient on July 7, 1997, were generally the same as those observed on January 21, 1997. Additional data were obtained in July 1997, however, at the newly installed MW-710 wells. Within the shallow bedrock, the hydraulic head measured at shallow bedrock monitoring well MW-710R was higher than those measured at all of the shallow bedrock wells in the southern portion of the Southington Well Field Property. These findings indicate that the horizontal gradient at well MW-710R is westward toward the river. The higher head at well MW-710R may indicate that the westward component continues from well MW-710R to a point west of the river (e.g., well MW-707R). Alternately, a convergence point may exist between these two wells, near the axis of the river. However, since well MW-707R has a lower head than MW-710R, the convergence point would likely be closer to well MW-707R than MW-710R. The same logic applies to the deep bedrock. Well MW-710DR has a higher head than wells MW-707DR and MW-703DR, which are west of the river, in the south portion of the Southington Well Field Property. A westward hydraulic gradient is evident at well MW-710DR, and may extend to well MW-703DR. Alternately, if deep bedrock ground-water converges somewhere between wells MW-710DR and MW-707DR, the point of convergence would likely be closer to the location with the lower head, namely MW-707DR.

Vertical Hydraulic Head Differences on January 21, 1997 and July 7, 1997

To evaluate the vertical component of the hydraulic gradient between various hydrostratigraphic zones, BBL overlaid the head contour maps for subjacent hydrostratigraphic intervals, and identified points of common head elevation. The points of common head elevation were visually connected to separate zones of either upward or downward head differentials. Figures 36 through 38 depict the differences between hydraulic heads measured within different hydrostratigraphic zones on January 21, 1997. Figures 39 through 41 show the same comparisons based on the July 7, 1997 measurement round. These figures indicate variable vertical components of the hydraulic gradient, including upward, downward, or neutral (less than or equal to 0.1 feet of head difference between units), depending on location. Head differentials near the Quinnipiac River were generally upward based on the January 21, 1997 data, with typical head differences on the order of 0.5 feet to over 3 feet between zones. Downward gradients, with head differences of up to 6 feet, were observed in some areas away from the river. An anomalous, isolated area with a downward component is also observed next to the river, however, between the deep overburden and shallow bedrock in the vicinity of well MW-6 and MW-5. This effect is interpreted as the influence of the end of the gravel-filled trench associated with the off-site interceptor system, which ends (discharges) adjacent to well MW-6, and may surcharge overburden ground water in that area. Within the Southington Well Field Property, vertical head differentials between the zones were close to neutral on January 21, 1997.

The magnitude of the vertical component of the hydraulic gradient measured between the monitored overburden and bedrock units on January 21, 1997 and July 7, 1997, vary throughout the study area, as follows:

- West of the Operations Area, MW-209A/B and MW-701DR -- 0.07 to 0.08 upward from deep bedrock to shallow bedrock; 0.4 downward from deep overburden to shallow bedrock.

- Operations Area, P-8A/B and MW-702DR -- 0.03 downward to 0.003 upward from deep bedrock to shallow bedrock; 0.003 to 0.006 upward from shallow bedrock to middle overburden.

- Adjacent to the Quinnipiac River, P-101A/B/C and MW-706DR -- Generally upward throughout the cluster from the deep bedrock to the shallow overburden, with an overall vertical gradient of 0.02 to 0.03. However, between the shallow bedrock and middle overburden, the vertical gradient component is approximately neutral.

- East of Queen Street, MW-708 cluster -- Consistently 0.02 downward from shallow to deep bedrock, 0.01 upward from shallow bedrock to shallow overburden.

- Northern Portion of Town Well Field Property, MW-704 cluster -- Generally upward from the deep bedrock to the shallow or middle overburden, with an overall vertical gradient of 0.005 to 0.008. However, within the middle and deep overburden, the vertical gradient component is approximately neutral, and a downward gradient was observed between the shallow and middle overburden in July 1997.

Vertical Flow-Nets on January 21, 1997

To further assess the vertical component of flow at the site, hydraulic heads were plotted and contoured on geologic cross sections A-A', B-B', and C-C' (Figures 17, 18, and 19, respectively). These data are posted on vertical sections that have a 10:1 vertical exaggeration. Given that the overburden and bedrock vertical anisotropies are estimated as approximately 100:1 and 200:1, the 10:1 vertical exaggeration allows for direct interpretation of ground-water flow directions, with flow vectors visualized as approximately perpendicular to the ground-water elevation contours.

As shown on east-west cross section A-A', the hydraulic gradient west of the site is upward and to the east, indicating that domestic water wells installed in the bedrock on the hill west of the site will not be impacted by VOCs in ground water associated with the SRSNE Site. In the east-west section, the hydraulic gradient converges toward the Quinnipiac River from both sides, and the river is the approximate point of convergence throughout the monitored stratigraphic section. In general, the vertical component of the hydraulic gradient is upward, and bedrock ground water is interpreted as discharging to the overburden throughout the majority of the section and, ultimately to the river or the NTCRA 1 Containment System. The anomalous downward hydraulic gradient between the shallow and deep bedrock at the MW-708 well cluster at the east end of cross section A-A' may indicate the preferential drainage of eastward dipping bedrock fractures that subcrop beneath the Quinnipiac River.

North-south cross section B-B' shows the convergence of ground water upward toward the Quinnipiac River along the axis of the river in the area east of the site and south of the site where the river bends toward the west. In general, upward hydraulic gradients are observed, and bedrock ground water is interpreted as discharging to the overburden throughout the majority of the section.

Northwest-southeast cross section C-C' shows upward hydraulic gradients, and bedrock ground water is interpreted as discharging to the overburden throughout the majority of the section.

In summary, two comprehensive ground-water elevation measurement events show gradients directed toward the Quinnipiac River from either side, throughout the entire monitored section of the overburden and bedrock. These data are consistent with the regional hydrogeologic discussion in Section 3.3, and support the interpretation that essentially all ground water within the monitored geologic zones within the RI Study Area discharges to the Quinnipiac River and its tributaries.

Continuous Ground-Water Elevation Data

In addition to comprehensive ground-water elevation measurement rounds, continuous ground-water elevation data were recorded at new shallow and deep bedrock monitoring wells MW-704R, MW-704DR, MW-707R, MW-707DR, MW-708R, and MW-708DR (Appendix L). Dedicated transducer and data logger units were installed at these locations to automatically record continuous water-level conditions for periods of approximately two to five months. The long-term, continuous hydrograph plots from each clustered pair of monitored wells were compared to assess the degree of hydraulic connection between the shallow and deep bedrock. As shown on the hydrographs from these clusters, which are plotted in Appendix L, the long-term responses measured at both wells are similar within all three pairs of monitored bedrock wells. These results support the interpretation that the shallow and deep bedrock zones are hydraulically connected. This finding is consistent with the results of observation well data obtained during bedrock specific capacity tests, which indicated hydraulic responses in bedrock zones above or below pumped bedrock monitoring wells.

3.4.4 Floodplains and Wetlands

Within the central portion of the Quinnipiac River valley, the Quinnipiac River is bordered by a floodplain. HNUS (May 1994) presented a map of the 100-year floodplain at the former Cianci Property and the northern portion of the Southington Well Field Property, which showed the 100-year flood plain at the approximate elevation of 156 feet (Figure 2). Based on information obtained from the Town of Southington Engineer during the development of the Detailed Wetland Mitigation Design (BBL, September 1995), the 100-year floodplain boundary corresponds closely with the 156-foot elevation contour within the RI Study Area.

Figures 4 and 7 show the locations of wetlands in the RI Study Area. In terms of hydrology, wetlands are defined as areas of permanent or periodic inundation of prolonged soil saturation sufficient to create anaerobic conditions in the soil (USFWS, 1989). In general, wetlands adjacent to rivers served as ground-water discharge zones, particularly during the growing season when evapotranspiration is at a maximum. During a wetland evaluation study for USEPA in 1992, HNUS identified six wetland areas (A through F) on the SRSNE Site and the adjacent Town of Southington Well Field Property (HNUS, December 1993). Figure 4 depicts the locations of five on-site wetland areas (A, C, D, E, and F), and Figure 7 shows the six wetland areas in RI Study Areas identified by HNUS. A seventh wetland area (G) was constructed on-site as part of NTCRA 1 activities to replace the smaller wetlands that were expected to be affected by NTCRA 1 implementation (Figures 4 and 7).

Wetland Area A is a riparian wetlands habitat located on the western floodplain of the Quinnipiac River. Most of this riparian wetlands habitat is canopied by a deciduous forest community interspersed with an understory of scrub-shrub and herbaceous communities. Wetlands Area A is the largest wetlands on the SRSNE Site (occupying approximately 1.9 acres on site) with an additional area to the south on the Town of Southington's well field property.

Wetland Area B is located along a drainage ditch between the Quinnipiac River and Curtiss Street on the Town's well field property. HNUS described this area as highly disturbed by past filling activity.

Wetland Areas C, D, and F are small, isolated depressional wetlands located near the property boundary between the SRSNE Site and the Town of Southington's well field property. These three wetlands systems cover approximately 0.15, 0.04, and 0.08 acres, respectively.

Wetland Area E consists of ditches along the railroad tracks that separate the SRSNE Operations Area on the west from the former Cianci Property on the east. During a 1992 USEPA removal action, the field delineation flags installed by HNUS were destroyed before the boundaries of Wetlands Area E were surveyed. After this area was altered substantially by USEPA during the 1992 removal action, Wetlands Area E was described by HNUS as scrub-shrub riparian habitat.

Wetland Area G is a constructed oxbow (BBL, September 1995), which was installed to expand the riparian wetlands habitat associated with the floodplain of the Quinnipiac River (Wetland Area A).

3.4.5 Ground-Water/Surface-Water Interaction

While Section 3.3 described the regional relationship between the Quinnipiac River and the ground-water flow, this section discusses the hydraulic aspects of ground-water/surface-water interaction in the RI Study Area in more detail based on research reported in the literature, site-specific stream-flow data, and the hydraulic head relationships discussed above.

The magnitude of ground-water discharge to a surface-water body is constantly changing, and in some circumstances the relative direction of flux may change. According to classic hydrology principles, during a storm event, the river level rises and the ground-water discharge rate, or baseflow, may decrease (Fetter, 1994). Based on data collected in Iowa, Wang and Squillace (1994) documented a temporary reversal of gradient along a perennial gaining streams due to a storm event. During the temporary reversal of gradient, river water was found to surcharge the stream banks creating an effect known as bank storage. However, a temporary reversal of gradient does not occur in all circumstances.

Contrary to the reversal of gradient response, hydrochemical, isotopic, and detailed soil piezometric studies of ground-water/surface-water interaction in a temperate climate have indicated that pre-event ground-water discharge continues and may even increase during a storm, and can contribute 40 to 50 percent of peak flow in some streams (Sklash and Farvolden, 1979; Abdul and Gilham, 1988). The interpreted cause for the observed increase in ground-water discharge during a storm is the close proximity of the capillary fringe to the ground surface on a flood plain adjacent to a stream, such as along the Quinnipiac River in the study area. A small amount of recharge to the initial, near-saturated capillary fringe creates a ridge of saturation consisting primarily of pre-event ground water adjacent to a stream. The ground-water ridge increases the ground-water discharge rate to the stream (Abdul and Gilham, 1988). Due to the increased ground-water discharge during a storm event, the surface-water chemistry does not change as much during a storm as would be anticipated under classic hydrologic assumptions. This principle suggests that the surface-water quality conditions in the Quinnipiac River may be relatively consistent regardless of precipitation and stream flow. Surface-water sampling events along the Quinnipiac River by HNUS (May 1994) and BBL have indicated similar surface-water quality results during various seasons with different river stages, and appear to support the model discussed by Abdul and Gilham (1988).

The flow of the Quinnipiac River has been evaluated based on data obtained from USGS Water Resources Division Regional Headquarters in Hartford and field measurements performed by HNUS. The annual mean flow of the Quinnipiac River at the USGS's Southington Station gaging, 0.5 miles south (downstream) of the RI Study Area, was 34.0 cubic feet per second (cfs), or 15,300 gpm, during the period from 1988 through 1996 (water years measured from October through September). The annual lowest flow rate of the Quinnipiac River at the Southington Station, based on the mean August flow rates over the same period is 7.3 cfs, and the lowest daily measurement was 3.9 cfs (1750 gpm).

In September 1992, HNUS measured the flow rate of the Quinnipiac River at Lazy Lane (1.37 cfs, or 614 gpm) and at the southern limit of the former Cianci Property (1.48 cfs, or 662 gpm). These streamflow measurements suggest that the river flow increases between these two measurement stations. Also, both of these measurements are less than the lowest daily measurement at the Southington Station from 1988 through 1996, indicating that the flow also increases in the direction downstream from the site. These data support the interpretation that the Quinnipiac River is a gaining stream in the region of the SRSNE Site, as is commonly observed in temperate climates in areas of relatively moderate to low relief (Fetter, 1994).

Relative to typical measurements of ground-water flow, which are evaluated in terms of pumping rates from wells, even the very low streamflow rates measured by HNUS in September 1992 equate to comparatively high flows (greater than 600 gpm) within the river. The flow rates measured by HNUS are similar to the highest annual flow rate pumped from Production Well No. 4 (576 gpm in 1970), which is screened in a highly-permeable middle overburden zone, approximately 200 feet from the Quinnipiac River.

The difference between the September 1992 flow rates measured by HNUS suggests that even during dry, low-flow conditions, ground water discharges to the Quinnipiac River at a rate of approximately 48 gpm between Lazy Lane and the southern limit of the former Cianci Property. This estimate is reasonably comparable to, but slightly higher than the simulated steady-state ground-water discharge rate of approximately 33 gpm estimated for the same reach within the regional NTCRA 2 ground-water flow model (BBL, September 1997; see Appendix J).

As stated by the USGS, "the circulation of groundwater in most parts of Connecticut is confined to the drainage basin of each perennial stream" (Melvin *et al.*, 1992b). The preponderance of the hydraulic gradient data measured within the five monitored hydrostratigraphic intervals in the RI Study Area show that ground-water is migrating toward the Quinnipiac River or its tributaries. Horizontal hydraulic gradient components converge toward the river from both sides throughout the monitored geologic interval from the deep bedrock to the shallow overburden. Vertical gradient components in the vicinity of the river are generally upward from deep bedrock through shallow overburden. Head differentials in the shallow overburden hydrogeologic zone adjacent to the river are higher than the river stage elevations. These findings all support the conclusion that essentially all monitored ground water within the RI Study Area is controlled by the Quinnipiac River and its tributaries.

3.5 Hydrogeologic Conceptual Model

This section presents a summary discussion of the Hydrogeologic Conceptual Model for the RI Study Area, which represents a key component of the Site Conceptual Model required for the TI Evaluation, which will be conducted during the FS. This Hydrogeologic Conceptual Model was prepared in accordance with USEPA TI Guidance (USEPA, September 1993).

Water supply wells in the vicinity of the SRSNE Site RI Study Area include:

- Several domestic wells along Lazy Lane at locations upgradient of the SRSNE Site;
- A private, drilled bedrock well situated at the Maiellaro (Mickey's Garage) Property which is immediately north of the SRSNE Site Operations Area;
- A private, drilled bedrock well at the Onofrio Residence situated north of Lazy Lane across from the former Cianci Property;
- Town of Southington Production Well No. 4 (which last operated in 1979); and
- Town of Southington Production Well No. 6 (which last operated in 1980).

Ground water within the RI Study Area is currently classified as Class GA over the majority of the Study Area, including the SRSNE Site. Two current Class GA areas, including the SRSNE Site proper, formerly were Class GB, and are currently described by CT DEP as "degraded." An isolated zone classified as GAA is also present in the study area, centered in the vicinity of Town of Southington Production Wells No. 4 and 6 (CT DEP, August 1997). However, the portion of the Class GAA area south of the Quinnipiac River currently does not meet CT DEP Ground-Water Protection Criteria (CT DEP, October 1997). The status of current wellhead protection areas in the region around the site is not currently known. A regional ground-water flow modeling study performed on behalf of the Town of Southington Water Department, however, reportedly interpreted the SRSNE Site and environs as being within the capture zone of Town of Southington Production Well No. 3. Well No. 3 is approximately 0.8 miles south-southeast of the SRSNE Site and 1,000 feet south-southeast of the former Ideal Forging Site, near the southern limit of the RI Study Area (Southington Water Department, August 1997).

The Town of Southington Water Department currently has nine municipal water-supply wells in their inventory, of which seven are operating as of the preparation of this RI Report. The Town obtains additional water supply via three surface-water reservoirs. None of the water-supply wells or reservoirs currently used by the town are in the RI Study Area. The closest currently operating production well is Well No. 3. The stratified drift aquifer at the Town Well Field Property within the RI Study Area was classified as having a high likelihood of future drinking water use by in CT DEP's Preliminary Ground-Water Use and Value Determination (CT DEP, October 1997) in spite of:

- The various water-supply resources available to the Town of Southington;
- The 17-year period that has elapsed since the last use of Production Wells No. 4 or 6; and
- The presence of several VOC sources in the RI Study Area.

Potential environmental receptors in the area around the site under current ground-water usage include the Maiellaro Well and the Onofrio Well. The Maiellaro Property is provided with bottled drinking water by the CT DEP. The Onofrio Well historically has indicated no VOC concentrations above drinking-water criteria (HNUS, July 1994). The Onofrio Residence is currently unoccupied. The SRSNE PRP Group is taking action to provide municipal water to the Maiellaro Property by November 1997, and the Onofrio Property by Spring 1998.

Recharge to the ground-water flow system occurs throughout the study area due to areal precipitation and infiltration, except in paved areas such as the Operations Area and the commercial sections along Queen Street. In the SRSNE Operations Area, the water table is approximately 7 to 10 feet below grade, and recharge and evapotranspiration are negligible due to the existing pavement. On the Cianci Property, the water table is extremely shallow (typically between 1 and 5 feet), and the evapotranspiration rate likely is high during the growing season. The residential upland area west of the SRSNE Site and the hill east of Queen Street are recharge zones for the regional ground-water flow system. In these areas, near the boundaries of the drainage basin, the vertical component of the hydraulic gradient is generally downward from the overburden to the shallow bedrock and would be expected to be downward between the shallow and deep bedrock. Conversely, the main regional hydrogeologic discharge zone in the region is the Quinnipiac River, which is a perennial gaining stream. Its tributaries are ephemeral, but they are also generally gaining streams when they are active. Ground water discharges from the shallow overburden directly to the river system and is also lost from the shallow water table to the atmosphere via evapotranspiration during the growing season within the adjacent thickly-vegetated floodplain and wetland areas.

Due to the discharge of shallow overburden ground water at and near the river, overburden ground water converges toward the river from both sides and from below the river, with an upward vertical hydraulic gradient throughout the saturated overburden. Deep overburden ground water is replenished by bedrock ground-water discharge to the overburden in the area along the Quinnipiac River. The hydraulic influence of the river is manifest as converging gradients in three dimensions around the river throughout the monitored geologic zone to a depth of approximately 90 feet below the top of bedrock. Horizontal gradients toward the river range from approximately 0.003 to 0.04. Upward vertical gradients adjacent to the Quinnipiac River range from 0.02 to 0.03. Further from the river, vertical gradients are variable upward or downward. Seasonal head changes on the order of 1 to >5 feet are observed at wells in the study area. However, the hydraulic gradient directions and magnitudes remain relatively consistent throughout the year.

Ground-water flow at the site occurs predominantly within the saturated overburden glacial deposits, and to a lesser degree, within the underlying, fractured New Haven Arkose bedrock. The geometric mean hydraulic conductivity value for the silty, fine-sand to gravelly overburden deposits in the Operations Area and the NTRCA 1 Containment Area is approximately 1.8 ft/day. This result contrasts with hydraulic conductivities typically in the hundreds of feet per day for the stratified sand and gravel at the Town of Southington Well Field Property. The mean on-site porosity and bulk density are approximately 27.5 percent (dimensionless) and 1.94 g/cm^3, respectively. The mean off-site porosity and bulk density are 31.6 percent (dimensionless) and 1.86 g/cm^3, respectively. The various glacial deposits comprising the overburden exhibit a high degree of heterogeneity vertically (between the various types of strata) and horizontally.

Hydraulic conductivity ranges of more than two orders of magnitude are observed vertically on a scale of individual strata, approximately one centimeter thick. Given the observed degree of heterogeneity, the on-site overburden is not amenable to remediation via any current flushing technologies, which would leave many lower permeability lenses untreated. In plan view, the hydraulic conductivity in the study area also ranges by at least three orders of magnitude. The anisotropy of the overburden is estimated as approximately 100:1 between the horizontal and the vertical value. However, the overburden may also be anisotropic in plan view. Pumping responses in the Southington Well Field Property, numerical particle tracking results, and VOC plume morphology suggest that the overburden may exhibit a horizontal anisotropy on the order of 4 (north-south) to 1 (east-west). This horizontal anisotropy value is considered an estimate only, but appears to be consistent with the available data.

A detailed evaluation of overburden stratigraphy in test pits on site indicated that strata are discontinuous on the scale of a few feet, and exhibit several dip directions of contacts between layers and internal cross bedding. Textural variations are considerable in the on-site glacial deposits, and range from gravel to silt. Gravel lenses may represent stream channels in the outwash deposits within the upper overburden unit. These gravelly zones present potential pathways for NAPL accumulation and migration, and are likely complex and discontinuous in their distribution. Thus, the distribution of mobilizable NAPL is likely sporadic, with many small pools scattered throughout the overburden NAPL zone, rather than a large, site-wide accumulation in any individual stratum. This interpretation is consistent with NAPL collection data from the site. Following the NTCRA 1 ground-water extraction system start-up, DNAPL accumulated in recovery well RW-5 for a few months but then stopped, indicating hydraulic mobilization and exhaustion of a relatively small DNAPL pool.

The New Haven Arkose bedrock consists of stratified siltstone, sandstone, and conglomerate, with bedding thicknesses ranging from less than one foot to a few feet. The bedding dips approximately 22 degrees toward the east-southeast (dip direction azimuth of 107.5 degrees). Bedrock fractures are primarily parallel to the bedding. Mean fracture aperture and spacings are 9.6×10^{-3} cm and 142 cm, respectively. The fractured bedrock at the site exhibits extreme heterogeneity between the hydraulic conductivity of the matrix (mean value of 4.2×10^{-7} cm/sec) and individual fractures (mean of 7.1×10^{-1} cm/sec). The mean matrix bulk density is 2.52 g/cm^3. The bedrock exhibits a relatively high matrix porosity (mean of 7.7 percent), which presents a significant storage capacity for dissolved VOCs that diffuse into the matrix and remain in the dissolved or sorbed phase. In contrast, the fracture porosity (mean value of 6.8×10^{-3} percent) presents very little storage capacity. The bedrock fracture network represents the likely DNAPL migration pathways within the bedrock. However, given the limited storage capacity of bedrock fractures, NAPL within the fractures may be reduced from mobile to residual due to the influence of matrix diffusion (Pankow and Cherry, 1996). The geometric mean bulk hydraulic conductivity for the bedrock is 0.35 ft/day. The vertical anisotropy is estimated as 200:1 horizontal to vertical. In plan view, the horizontal anisotropy is estimated as 20:1 (north-south versus east-west) based on published techniques for characterizing dipping bedrock strata, and numerical particle pathline tracking results. The estimated horizontal anisotropy is considered an estimate only, but appears to be consistent with the available data.

This Hydrogeologic Conceptual model indicates that, while overburden and bedrock ground-water flow are extremely complex on a small scale, ground-water flow within the RI Study Area is interpreted as relatively systematic. Consistent with regional hydrogeologic principles, the ground water within the RI Study Area is discharging to the Quinnipiac River, its tributaries, or the associated wetland areas.

This concludes the discussion of the Study Area Physical Characteristics. Section 4 presents a discussion of the nature, extent, and fate of chemical constituents associated with the SRSNE Site.

Summary of Section 3

- The ground water within the monitored geologic section in the RI Study Area (to a depth of approximately 270 feet below grade) discharges to the Quinnipiac River and its tributaries. This inference is based on the observed hydraulic gradients, surface-water elevations, surface-water flow rates in the Quinnipiac River, and fundamental hydrogeologic principles.

- Ground-water flow converges toward the Quinnipiac River from both sides of the river throughout the monitored geologic section. This finding is consistent with the historical data measured during the previous investigations in the RI Study Area. Overburden hydraulic gradients also demonstrate flow into the NTCRA 1 overburden ground-water containment system. A potentiometric depression in the shallow bedrock in the vicinity of the NTCRA 1 overburden ground-water containment system indicates partial containment of shallow bedrock ground-water due to the NTCRA 1 system.

- Vertical hydraulic gradients throughout the monitored section of overburden and bedrock in the study area are generally upward in the vicinity of the Quinnipiac River, downward within localized areas further from the river, and upward or neutral in the central portion of the Town of Southington Well Field Property. This finding is consistent with the historical data measured during the previous investigations in the RI Study Area.

- The overburden geologic formations include several glacially-derived soil units that range in texture from silty, fine sand to clean sand and gravel, with occasional cobbles and boulders. The horizontal hydraulic conductivity of the overburden is relatively low on site, but it increases by up to three orders of magnitude toward the south within the Town of Southington Well Field Property. This increase corresponds with a gradation from relatively silty outwash and till on site, to coarser outwash and gravelly drift in the Town Well Field Property. The overburden has been characterized as heterogenous and anisotropic in horizontal and vertical perspectives.

- Fractures within the New Haven Arkose bedrock were characterized in terms of dip angle, dip direction, aperture, and spacing. Bedrock fractures are primarily parallel to the gently east-southeastward dipping bedding.

- The hydraulic properties of the fractured New Haven Arkose bedrock are interpreted as highly heterogeneous on a small scale due to the variable spacing and connectedness of bedrock fractures; however, on a regional scale, the bedrock is believed to be relatively homogeneous and anisotropic. The bulk bedrock hydraulic conductivity in the plane of bedding is consistent with data reported in the literature.

4. Nature, Extent, and Fate of Chemical Constituents

This section describes the nature, extent, and fate of chemical constituents associated with SRSNE Site operations. This section focuses on the three areas that require delineation as specified in the USEPA TI Guidance document (USEPA, September 1993):

- NAPL entry location;
- NAPL zone; and
- Aqueous plume.

NAPL entry locations are evaluated on the basis of vadose-zone soil VOC data (Figure 43), aerial photographs (e.g., Figures 5 and 6), and observations regarding site conditions described in site history and site inspection reports (e.g., CT DEP, October 25, 1978; USEPA, February 1989), as discussed in Section 4.1. The NAPL zones in overburden and bedrock are evaluated in Section 4.2 based on site history and usage, direct observation, and soil and ground-water chemical concentrations. The aqueous plume related to the SRSNE Site is delineated in Section 4.3 using of current Federal Maximum Contaminant Levels (MCLs) or CT DEP Class GA/GAA Ground-Water Protection Criteria, whichever is lower (collectively referred to hereafter as ground-water regulatory criteria). Section 4.3 also summarizes the results of surface-water samples obtained along the Quinnipiac River and the upstream and downstream ends of the 30-inch culvert that crosses the former Cianci Property.

HNUS presented an extensive discussion of soil, sediment, and ground-water VOCs, SVOCs, pesticides/PCBs, and inorganics data obtained during Phases 1 through 3 of the (HNUS, May 1994). In addition, HNUS described in detail the contribution of site-related chemicals to air, land, water, and the food chain (HNUS, May 1994). As discussed in the USEPA-approved RI Work Plan (BBL, November 1995 and associated addenda), the key data gaps filled during the completion of the RI relate to VOC distribution, fate, and transport in the subsurface. The distribution of VOCs in vadose-zone soil, NAPL, ground water and surface water are discussed below.

4.1 Vadose-Zone Soil

The evaluation of VOC distribution in the vadose zone is primarily limited to the vicinity of the SRSNE Site Operations Area, where the primary NAPL entry points were likely located and relatively high concentrations of VOCs have been historically detected. The current pavement on the Operations Area limits infiltration and allows VOCs to remain within the vadose zone at higher concentrations than in the uncovered area downgradient of the Operations Area.

Downgradient of the Operations Area, on the former Cianci Property, the vadose zone is very thin (approximately 1 to 3 feet), vegetated, and open for recharge due to precipitation. Therefore, VOC concentrations in the vadose zone at the former Cianci Property are expected to be relatively low. This interpretation is supported by the results of vadose-zone soil samples obtained from borings SB-701 through SB-703 during the completion of the RI, which are summarized on Table 9. The highest total VOC concentration detected in vadose-zone soil samples from the former Cianci Property was 2.195 mg/kg, based on the average of the primary sample and its duplicate. The average total VOC concentration for the three vadose-zone soil sampling locations was 0.966 mg/kg. Given these relatively low concentrations, and limited potential for any substantial accumulation of VOCs within the vadose zone on the former Cianci Property, the remainder of Section 4.1 focuses on the Operations Area vadose-zone soils.

To identify vadose-zone soil sample locations, BBL used the relational soil database to sort the historical soil samples and compared the soil sample elevation to the highest historical water-table elevation, which was measured on March 20, 1995. Soil samples below the March 20, 1995 water table lie within the saturated zone during wet conditions and, therefore, are not considered representative of vadose (unsaturated) soil conditions. A summary map showing soil sampling locations and the elevation contours of the March 20, 1995 water table are presented in Appendix M. The soil samples identified as being within the vadose zone were primarily obtained at the Operations Area and the ditches between the Operations Area and the former Cianci Property (sediment samples). Appendix M also includes the database output list of total VOCs detected in vadose-zone soil samples.

4.1.1 VOC Distribution versus Operations Area Infrastructure

The distribution of VOCs in the Operations Area is summarized as contours of total VOC concentrations on Figure 43. Due to seasonal water-table fluctuation, the vadose-zone soil data distribution in the vicinity of the Operations Area stops along the ditches adjacent to the eastern boundary of the Operations Area. The samples obtained from the vadose zone (depths of zero to 2 feet and 2 to 4 feet) at soil borings SB-701 through SB-703 within the NTCRA 1 Containment Area actually were saturated on March 20, 1995, and were not used for contouring vadose-zone VOC concentrations. The vadose-zone VOC distribution is relatively widespread throughout the Operations Area. The highest total VOC concentrations (>1,000 mg/kg) were detected in the central portion of the Operations Area, and appear to correspond with certain components of the site infrastructure. The northern 1,000 mg/kg contour is located near the downgradient (east) end of the former leach field, the northern portion of the drum staging area, and the location where solvent transport trucks backed into the facility. The western 1,000 mg/kg contour is at the downgradient end of the former primary sludge storage lagoon. The eastern 1,000 mg/kg contour is situated near the former secondary sludge storage lagoon and the northern portion of the drum staging area. An isolated area with relatively high vadose-zone total VOC concentrations (>100 mg/kg) was also identified in the southern portion of the Operations Area, in the vicinity of the former open-pit incinerator.

The areas with elevated VOC detections in the vadose zone are interpreted as a residual chemical fingerprint at or near areas where NAPL entered the subsurface. While the exact locations of all NAPL entry points at the SRSNE Site can not be determined, the distribution of VOCs in the vadose zone covers much of the Operations Area (Figure 43), suggesting that solvent VOCs likely entered the subsurface in varying quantities at many locations within the Operations Area. For example, the USEPA's RCRA Inspection (1989) identified 75 circumstances of recorded solvent leaks in the Operations Area during 1988. Based on a 1970 aerial photograph, solvent drum and tank storage facilities on site did not include visible secondary containment structures, such that incidental leaks from these storage areas may have entered the subsurface over an area larger than the storage areas themselves (USEPA, May 1988). A 1980 aerial photograph indicated that the drum storage areas still did not have secondary containment structures. Unlike the 1980 aerial photograph, a 1982 aerial photograph showed that most of the Operations Area had been surfaced (paved). However, prior to paving, most of the Operations Area was open for infiltration or entry of solvent-related materials.

A 1975 aerial photograph reportedly shows a pool of liquid in the vicinity of the open-pit incinerator draining into the adjacent ditch along the railroad tracks. This general location correlates with the southern area with relatively high VOC concentrations in vadose-zone soils. The lagoon locations also correlate reasonably well with high vadose-zone VOC concentrations. Reportedly, the secondary lagoon on site was occasionally filled beyond capacity with liquids including still bottom sludge, and overflowed into the ditch along the railroad tracks (CT DEP, October 1978), suggesting that some of the entry points for NAPL may have been situated near the railroad tracks. In addition, prior to the installation of a 30-inch culvert from the railroad tracks to the Quinnipiac River between 1975 and 1980, the ditch discharged under the railroad tracks via a culvert to a stream that flowed across the former Cianci Property, as shown on the 1965 aerial photograph (Figure 5).

4.1.2 Vadose-Zone Solute Transport (VLEACH Modeling)

One of the objectives of completing the RI was to evaluate the potential VOC loading rate from the vadose zone to the saturated zone. During various occasions throughout the SRSNE Site project, USEPA has expressed an interest in evaluating the benefit of vadose-zone remediation in the SRSNE Operations Area as a potential means of reducing VOC loading to the ground water, in an effort to improve ground-water quality. The August 1996 through February 1997 RI field investigation generated soil data to support a one-dimensional solute-transport (VLEACH) model, which was used to assess the relative contribution of VOCs from the vadose zone to site ground water. The resulting vertical mass loading estimates were compared to the horizontal VOC mass flux currently observed in the Operations Area saturated overburden to assess the relative merits of vadose-zone restoration, as described below. The USEPA-published vadose-zone leaching model, VLEACH, was used to evaluate vadose zone solute-transport characteristics (Ravi and Johnson, 1996). The VLEACH model output file and summary table are presented in Appendix N.

VLEACH (Version 2.2a; Ravi and Johnson, 1996) is a one-dimensional, transient, vadose-zone leaching model used to estimate chemical mobility in the vadose zone. Based on user-specified soil characteristics and the total concentration of a chemical in soil, VLEACH partitions the chemical into three chemical phases: 1) dissolved in pore water; 2) vapor phase; and 3) sorbed to the solid phase. During each time-step, VLEACH computationally redistributes the chemical mass according to the mass transport parameters specified by the user. Each time step is solved successively until the final, user-specified simulation time is reached.

Vadose zone transport processes computed by VLEACH include:

- Advection from recharge (at upper boundary);
- Diffusion into atmosphere (at upper boundary);
- Advection into ground water (at lower boundary); and
- Diffusion to or from ground water (at lower boundary).

To provide an understanding of the relative VOC contribution from the vadose zone to the saturated zone in the Operations Area, BBL evaluated two representative VOCs, including TCE (a primary constituent in the DNAPL samples obtained from the site), and ethylbenzene (which was detected at the highest concentrations in overburden ground water in the Operations Area during the most recent sampling round). The VLEACH model of the Operations Area was performed by assigning representative values for soil parameters, including mean values for dry bulk density (1.94 g/cm^3) and porosity (0.27) from the data collected by ENSR (1994) and by BBL during the completion of the RI. Soil f_{oc} (0.00404) was determined from soil samples collected by BBL, and is considered representative of saturated and unsaturated soils at the site. Partitioning coefficients and Henry's Law constants were obtained from the VLEACH documentation. Values for the compound free air diffusivity were obtained from Cohen *et al.* (1993) and LaGrega *et al.* (1994).

The Operations Area vadose zone was represented in the model as 8-feet thick, discretized into 16 stacked cells, 0.5-feet thick each, which have the same initial VOC concentration. The initial TCE or ethylbenzene soil concentration assigned to each cell the mean vadose-zone soil concentrations measured in the Operations Area. The vadose-zone pore-water movement is steady-state downward. The recharge rate is constant and uniform. The concentration in the recharge water is constant. The rate and concentration determine the advective flux due to recharge. In the VLEACH simulations, the recharge was assumed to be clean water entering at a rate of one inch per year, which is considered representative of paved areas. The ground water at the water table has a constant concentration equal to the arithmetic mean of Operations Area overburden ground-water concentrations at wells P-1B, P-2B, P-4B, and P-16 during the 1996 ground-water sampling event performed by BBL. Diffusion across the lower and upper boundaries is unimpeded. The model does not account for degradation, resulting in conservative (high) concentration values for leaching fluxes and soil concentrations.

The VOC flux within the saturated overburden was calculated by multiplying the volumetric ground-water flow rate cross the eastern property line of the Operations Area (minus the access road) by the mean dissolved concentrations of TCE and ethylbenzene detected at overburden wells in the Operations Area in December 1996. Mean hydraulic conductivity, hydraulic gradient, and dissolved concentrations within the saturated zone were calculated using data from wells P-1B, P-2B, P-4B, and P-16.

The VLEACH model results for TCE and ethylbenzene leaching (from zero to two and one-half years, expressed in terms of kg/yr) are summarized in the table below.

Calculated VOC Fluxes (kg/yr)	TCE	Ethylbenzene
Vadose Zone		
1. Vapor Diffusion to Atmosphere	1.4	3.0
2. Vapor Diffusion to Ground Water	0.96	-4.0
3. Advection (Leaching) to Ground Water	5.0	2.4
4. Total Flux to Ground Water from Operations Area Vadose Zone (Sum of 2 and 3).	6.0	-1.6
Saturated Overburden (Ground Water)		
5. Total Horizontal Ground-Water Flux	81.	1,500
6. Operations Area Vadose-Zone Contribution to Total Overburden Ground-Water Horizontal Flux (unitless ratio of #4 and #5).	0.074	-0.0010

The total overburden ground-water flux of either TCE (81 kg/yr) or ethylbenzene (1,500 kg/yr) (Line No. 5 above) represents the flux of either TCE or ethylbenzene within the saturated overburden in the Operations Area, and provides a basis for comparison to the mass flux contributed from vadose-zone leaching. The Operations Area vadose-zone VOC flux to the saturated overburden was computed as 6.0 kg/yr for TCE, which represents 7.4 percent of the TCE flux within the saturated overburden. For ethylbenzene, the vadose-zone flux to the saturated zone was computed as -1.6 kg/yr, representing -0.1 percent of the ethylbenzene flux within the saturated zone.

For ethylbenzene, the computed diffusive mass flux between the vadose zone and the ground water was negative, indicating net diffusion out of the ground water and into the vadose zone (Line No. 2 above). The computed rate of ethylbenzene diffusion from ground water to the vadose zone exceeded the calculated leaching rate from the vadose zone (Line No. 3 above), such that the total ethylbenzene mass flux was from the ground water to the vadose zone, as indicated by the negative flux shown on Line No. 4 above.

For either TCE or ethylbenzene, the VLEACH modeling results suggest that VOC loading to the saturated zone from the Operations Area vadose-zone soil represents a negligible component of the observed VOC flux in the saturated zone. These findings indicate that an Operations Area vadose-zone soil remedy would not significantly reduce the ground-water quality or flux of VOCs in the saturated zone currently leaving the Operations Area.

4.1.3 Comparison of Vadose-Zone Soil Quality to CT DEP Remediation Standard Regulations

To compare the available vadose-zone soil quality data to CT DEP Remediation Standard Regulations (CT DEP, January 1996), BBL used the relational soil database. The vadose-zone soil data were compared to CT DEP Class GA/GAA and Class GB Pollutant Mobility Criteria, and the Residential and Industrial/Commercial Direct Exposure Criteria. Tables and figures summarizing the results of this evaluation are presented in Appendix M.

The vadose-zone soil sampling locations exceeding Class GA/GAA and Class GB Pollutant Mobility Criteria were similar, and in were primarily limited to the Operations Area and the ditch along the railroad tracks near the western end of the culvert that extends across the former Cianci Property. The exceedances in these areas included VOCs and SVOCs. In addition, one vadose-zone soil sample obtained at ground surface on the former Cianci property indicated an exceedance for two SVOCs. These locations are likely to be within the TI zone that will be delineated as part of the FS.

Vadose-zone soil sampling locations exceeding Residential Direct Exposure Criteria were similar to the distribution of Pollutant Mobility exceedances. Residential Direct Exposure Criteria exceedances were primarily limited to the Operations Area and the ditch along the railroad tracks near the western end of the culvert that extends across the former Cianci Property. The exceedances in these areas included VOCs, SVOCs, and PCBs. In addition, one vadose-zone soil sample obtained at ground surface on the former Cianci property indicated an exceedance for one PCB and one SVOC. The Industrial Direct Exposure Criteria were exceeded only in the Operations Area and along the ditch adjacent to the railroad tracks.

4.2 NAPLs

As described in the USEPA-approved RI Work Plan (BBL, November 1995), two of the key objectives of completing the RI were to:

- Further characterize the NAPL zone and assess its restoration potential; and

- Delineate recoverable LNAPL, if any.

The difficulty of restoring ground-water quality in the vicinity of NAPL is well known and has been discussed in numerous technical papers and USEPA Guidance Documents (OSWER Directives 9234.2-25, September 1993; and 9200.4-14, January 1995). Based on the limitations to NAPL-zone restoration, the NAPL-zone evaluation presented herein focuses on information that will be used to develop a TI Evaluation that will be submitted as part of the FS. In support of the TI Evaluation, this section describes NAPL characteristics and presents an estimate of the extent of the NAPL zone. Further discussion of TI data is presented in Section 5.0.

4.2.1 NAPL Characteristics and General Distribution

This section discusses the chemical characteristics and general distribution of LNAPL and DNAPL at the site. Prior to ground-water sampling during the completion of the RI, BBL monitored the top of the fluid column and the bottom of each well in the Operations Area and the former Cianci Property for the presence of LNAPL or DNAPL, respectively, using a bottom-loading bailer. NAPL was identified at the following wells:

Well	NAPL Observation
CPZ-7R	Sheen at top of water column and bottom of bedrock piezometer
CPZ-9R	0.01 feet LNAPL at top of water column, sheen at bottom of bedrock piezometer
MW-705DR	2.0 feet DNAPL in sump of bedrock well (approximately 100 feet below grade)
MWD-601	0.2 feet DNAPL in sump of overburden well, which have previously been bailed to remove all DNAPL from the well
P-1B	0.01 feet LNAPL at top of water column, possible sheen at bottom of overburden well
P-2B	Sheen at top of water column and bottom of overburden well
RW-5	Sheen at bottom of overburden extraction ground-water well

With the exception of MW-705DR, where several NAPL samples were obtained, these NAPL occurrences did not yield sufficient volume to sample NAPL for characterization. The MW-705DR DNAPL characteristics are described in Section 4.2.1.2. A more detailed delineation of NAPL in the overburden and bedrock is presented in Section 4.2.2.

4.2.1.1 LNAPL

Historical observations of LNAPL at the site are limited. During the previous RI, HNUS observed LNAPL at overburden monitoring well P-1B in the central portion of the Operations Area, immediately downgradient of the former secondary sludge storage lagoon (HNUS, May 1994). HNUS described the P-1B LNAPL as a 1.5-foot-thick, floating layer of viscous, brown to black, oily liquid. As a component of Phase 3 of the RI, HNUS installed 14 water-table monitoring wells (MWL-300 series) to delineate the distribution of LNAPL in the area downgradient of well P-1B. No locations besides well P-1B, however, exhibited any visible LNAPL.

As discussed above, BBL also performed NAPL monitoring to help evaluate the distribution of LNAPL at the site, but identified LNAPL in only three locations, including P-1B, CPZ-7R, and CPZ-9R. Because piezometers CPZ-7R and CPZ-9R are screened below the water table in the bedrock, the NAPL observed at the top of fluid column in these locations is interpreted as indicating the presence of a NAPL in the bedrock rather than at the water table. The LNAPL thickness at well P-1B, approximately 0.01 feet, is substantially less than observed by HNUS, and may indicate a change in conditions, such as a:

- Reduction in the LNAPL thickness due to NAPL volatilization and solubization;
- Seasonal variation associated with water-table fluctuation; or
- Reduced LNAPL thickness due to the entrapment of residual LNAPL in the vadose-zone due to the slight dewatering caused by the NTCRA 1 Containment System.

In any case, the distribution of recoverable LNAPL, if any, is interpreted as the area immediately around, and centered on the location of well P-1B. To help delineate the LNAPL layer identified at well P-1B, SVE pilot test wells MW-486, MW-487, and MW-489 were gauged using an oil-water interface probe and a bottom-loading bailer on February 4, 1998 (Figure 4). None of these wells indicated measurable, recoverable LNAPL using the oil-water interface probe or the bottom-loading bailer, indicating that the layer of potentially recoverable LNAPL historically observed at well P-1B has been delineated in the upgradient direction. These findings support the interpretation that the potentially recoverable LNAPL at well P-1B is limited to the immediate vicinity of the former secondary lagoon.

HNUS attributed the presence of the LNAPL at well P-1B to fuel product from the on-site tank farm or the discharge of aromatic solvents. Given its limited distribution in the area immediately downgradient of the center of the former secondary sludge holding lagoon, the LNAPL could also represent the lighter fraction of the solvent sludge mixtures that were placed in the lagoon. The chemical characteristics of the P-1B LNAPL are consistent with this interpretation, as the P-1B LNAPL exhibited a complex chemical mixture, including:

- 47 percent by weight VOCs (eight chlorinated hydrocarbons and five aromatics);
- 0.5 percent by weight semivolatiles (five compounds); and
- 0.1 percent by weight PCBs.

VOCs detected in the P-1B LNAPL were very similar to those detected in DNAPL at the site, suggesting that differences in NAPL density in general reflect different relative ratios of lighter and heavier solvent compounds, rather than different groups of compounds. No LNAPL samples from the site have been tested for physical characteristics.

4.2.1.2 DNAPL

Prior to the completion of the RI, BBL had obtained three DNAPL samples during NTCRA 1 activities in 1995, as summarized on Table 5. Table 5 also shows the results of supernatant ground-water samples obtained at two of three previous DNAPL sampling locations.

Similar to the P-1B LNAPL, the DNAPL sample obtained from well MWD-601 contained high concentrations of 9 chlorinated and 5 aromatic hydrocarbons, including TCE, PCE, toluene, and xylenes. Other VOCs were detected at lower concentrations. PCB Aroclor 1260 was also detected in the MWD-601 DNAPL.

During the RI completion, BBL obtained three DNAPL samples from well MW-705DR for analysis of physical parameters (January 29, 1997) and chemical constituents (December 27, 1996, and June 19, 1997). The DNAPL sample obtained from well MW-705DR on December 27, 1996, for chemical characterization, did not yield any detectible VOCs due to the high dilution factor and narrow calibration range used in the analysis for VOCs by CLP-RAS Method 10/92 Low Concentration Organics in Water. One DNAPL sample and one ground-water sample were obtained on June 19, 1997, for analysis of VOCs by modified SW-846 Method 8260; the analytical results from these samples are summarized on Table 5 and Figure 44 of this RI Report. As shown on Table 5, the sum of VOC concentrations detected in the DNAPL sample from well MW-705DR add up to 899,000 mg/L (89.9 percent by weight), indicating a better overall characterization of the DNAPL chemistry than previously obtained at wells MWD-601 and RW-5. All seven of the VOCs detected in the MW-705DR DNAPL were also detected at well MWD-601. Again, the compounds detected at the highest concentrations were TCE, PCE, toluene, and xylenes. The finding that the sum of the detected NAPL components added up to less than 100 percent is attributed to the high detection limits employed in laboratory analysis, which precludes detection of some of the NAPL components.

Wells MWD-601 and MW-705DR provided a unique opportunity to characterize the ground-water chemistry in the presence of known DNAPL, as summarized on Table 5. A ground-water sample was obtained from well MWD-601 during NTCRA 1 activities for chemical characterization, and contained high concentrations of chlorinated and aromatic hydrocarbons and ketones, including TCE, PCE, toluene, and xylene (Table 5). Other VOCs were detected at relatively minor concentrations. PCB Aroclor 1260 was also detected in the MWD-601 ground water. A ground-water sample was also obtained from well MW-705DR on June 19, 1997 for analysis of VOCs by modified SW-846 Method 8260 (Table 5), and contained high concentrations of chlorinated and aromatic hydrocarbons and ketones, including TCE, 4-methyl-2-pentanone (MIBK), 2-hexanone, toluene, 1,1-DCA and 2-butanone (MEK) (Table 5).

Figures 12 and 44 show the relationship between the ground-water concentrations detected at wells MWD-601 and MW-705DR (horizontal axis) versus the theoretical, chemical-specific, effective solubility limits (vertical axis) calculated based on Raoult's Law [Kueper, July 1995; July 1997 (see Appendix O)]. The correlation between the detected ground-water concentrations and theoretical solubility limits indicates that ground-water concentrations detected at wells MWD-601 and MW-705DR provide an empirical demonstration of the application and usefulness of Raoult's Law in calculating effective solubilities in ground water. This finding is consistent with the intent of NAPL collection wells MWD-601 and MW-705DR. MWD-601 was installed with a short (5-foot long) well screen placed within the depth interval where DNAPL was encountered. Similarly, well MW-705DR was installed with a 10-foot well screen placed at the location of a discrete bedrock fracture containing DNAPL. Thus, the VOC concentrations detected in ground water at wells MWD-601 and MW-705DR provide an empirical basis for evaluating NAPL presence based on ground-water concentrations at other ground-water sampling locations.

DNAPL physical properties were also quantified based on DNAPL samples obtained from wells MWD-601, RW-5, and MW-705DR (Table 5). The relationship between MWD-601 DNAPL density and temperature is depicted graphically on Figure 13, and the relationship between viscosity and temperature is shown on Figure 14 (Kueper, July 1995). The physical characteristics of the RW-5 DNAPL and the MW-705DR DNAPL, which were tested at the approximate ground-water temperature, are summarized on Table 5. Based on ground-water temperature data obtained during sampling activities, a representative ground-water temperature is approximately 10°C, or 50°F. At the ground-water temperature, the subsurface physical characteristics, and the total VOCs detected in each of these three DNAPL samples, can be summarized as follows:

Sampling Location	Density (g/cm3)	Viscosity (cS)	Interfacial Tension (dynes/cm)	Total VOCs (mg/L)
MWD-601	1.12	1.3	7.8	282,000
RW-5	1.11	1.23	3.1	99,800
MW-705DR	1.23	0.993	9.0	899,000

The physical testing results, particularly the relatively low viscosity and interfacial tension values, suggest that the DNAPL sampled at these locations is relatively easy to mobilize, where present in pools.

4.2.2 NAPL Delineation -- Probable and Potential NAPL Zones

The NAPL delineation completed during this RI includes an evaluation at two levels of relative NAPL likelihood, including the:

- *Probable* NAPL zone, which was delineated based on direct observations of NAPL, site history, anomalous VOC distributions, or accepted technical principles based on effective solubility limits of NAPL constituents; and

- *Potential* NAPL zone, which serves as a safety factor around the probable NAPL zone, but also is consistent with effective solubility principles recognized by USEPA as indicating the likely nearby presence of NAPL (USEPA, January 1992).

The conceptual basis for these zones was described by Kueper (October 1997, see Appendix O), and is discussed below.

Rationale

The need to define both a *probable* and a *potential* NAPL zone at the SRSNE Site stems from the fact that subsurface investigations generally yield data only at specific points in space, rather than continuous distributions of the parameters of interest. In other words, information such as contaminant concentrations in soil and groundwater are only known at specific locations, not at every point in the subsurface. Delineation of that region of the subsurface which contains NAPLs is therefore subject to uncertainty because the delineation procedure relies upon the magnitude and spatial distribution of soil and ground-water chemical concentrations. The use of both a *probable* and a *potential* NAPL zone reflects this uncertainty, and corresponds to a 'factor of safety' as used in other engineering design and analysis problems.

Definitions

The *probable NAPL zone* is defined as that region of the subsurface where NAPL is either confirmed to be present, or very likely to be present. The *potential NAPL zone* is defined as that region of the subsurface where NAPL may be present, but current site data do not yield conclusive evidence that it is present.

Implications

Decisions regarding certain site investigation and remediation activities should be made differently in the two NAPL zones. The *probable NAPL zone* is that region of the subsurface where drilling should be minimized to avoid vertical DNAPL mobilization, where the influence of ground-water pumping on NAPL pool mobilization should be considered, and where estimates of NAPL mass can be performed. The *potential NAPL zone* encompasses the *probable NAPL zone*, and provides a safety factor in NAPL delineation, given the unpredictable nature of NAPL migration and distribution in geologic media. However, it should be noted that the *potential NAPL zone* delineation process, described below, is consistent with USEPA guidance on DNAPL site evaluation (Publication 9355.4-07FS, 1992) and methods presented in other technical sources (WCGR, 1991; Cohen and Mercer, 1993; Pankow and Cherry, 1996). Some NAPL is likely to exist in the *potential NAPL zone* but outside of the *probable NAPL zone*. The dimensions of the *potential NAPL zone*, therefore, should also be considered in estimating the relative distribution of NAPL mass. The TI zone at a NAPL site should encompass the *potential NAPL zone*. It should not be surprising for future site investigation activities to locate NAPL within the *potential NAPL zone*.

Sections 4.2.2.1 and 4.2.2.2 discuss the delineation methods for the probable and potential NAPL zones at the SRSNE Site. The site-specific delineation of the NAPL zones in overburden and bedrock are discussed in Sections 4.2.2.4 and 4.2.2.5.

4.2.2.1 Probable NAPL Zone Delineation Process

The probable NAPL zones in overburden and bedrock (Figures 45 and 46) have been delineated based, in part, on methods presented in USEPA guidance on DNAPL site evaluation (Publication 9355.4-07FS, 1992) and other sources (WCGR, 1991; Cohen and Mercer, 1993; Pankow and Cherry, 1996). Ten independent screening approaches were used to identify locations where NAPL is known or is strongly suspected to be present, as described below.

Visual Observation

The first and most direct basis for delineating the probable NAPL zone is the distribution of locations where NAPL was directly observed in the field during the RI or previous investigations based on visual determinations, including: direct visual identification; sheens on soil samples, ground-water samples, or drilling recirculation water; and positive Sudan IV test results.

NAPL has been observed at several locations at the former Operations Area and the former Cianci Property, including : monitoring well P-1B; former OIS wells IW-12, IW-13, IW-15, IW-16, IW-19, IW-20, IW-21, and IW-23; NTCRA 1 extraction well RW-5; DNAPL collection well MWD-601; NTCRA 1 piezometers CPZ-7R and CPZ-9R; and monitoring well MW-705DR. These locations are all within the probable NAPL zone.

NAPL Confirmation by Laboratory Analysis

The second basis for delineation is the confirmation of interpreted NAPL by laboratory analysis, indicating chemicals at concentrations above aqueous solubility limits. As discussed above, NAPL samples have been obtained from several locations on site for chemical and/or physical characterization, which confirmed the interpreted visual observation of NAPL in the field. These locations, which are all within the probable NAPL zone, include: P-1B; MWD-601; IW-23; RW-5; and MW-705DR.

Aqueous VOC Concentrations

Mathematical and empirical methods were used to estimate the probable NAPL zone in overburden and bedrock using aqueous VOC data from the site. These methods rely on a comparison between detected VOC concentrations and effective solubility limits based on principles presented in USEPA guidance on DNAPL site evaluation (Publication 9355.4-07FS, 1992) and other sources (WCGR, 1991; Cohen and Mercer, 1993; Pankow and Cherry, 1996; Kueper, pers. com. with M.J. Gefell, 1997). NAPL presence is strongly suggested and can reasonably be expected to exist in immediate proximity to any monitoring well exhibiting VOC concentrations greater than one percent of the VOC effective solubility within and downstream of known or suspected NAPL release locations (WCGR, 1991; USEPA, 1992; Cohen and Mercer, 1993; Pankow and Cherry, 1996). To provide a higher degree of confidence in the identification of ground-water samples obtained in the immediate vicinity of NAPL, VOC detections at or above 10 percent of the effective solubility in ground water were used to help delineate the probable NAPL zone associated with the SRSNE Site. Other criteria were also used to delineate the probable NAPL zone, as discussed further below.

The criterion described above, 10 percent of effective solubility, likely provides a conservative measure (underestimate) of the probable NAPL distribution. Concentrations even below one percent of the effective solubility can exist in the vicinity of NAPL. For example, DNAPL was encountered at well MWD-601, which was installed within 50 feet of a well with no detectible VOCs. Dissolved concentrations of NAPL constituents in ground-water samples are typically below the constituent effective solubility limits due to several factors, including: 1) heterogeneous distribution of residual and pooled NAPL; 2) hydrodynamic dispersion within the geologic medium; 3) borehole dilution; and 4) rate-limited mass transfer at low NAPL saturations..

At the SRSNE Site, the effective solubility comparison was performed using mathematical and empirical methods, as discussed below. Note that these methods were also used for comparison with calculated aqueous concentrations in soil samples to estimate NAPL presence or absence. Locations where sampled ground-water concentrations exceed 10 percent (or calculated pore-water concentrations in soil samples exceed 100 percent) of a component's effective solubility, using the mathematical and/or empirical approach, were included in the *probable NAPL zone.* Appendix M summarizes the results of effective solubility screening.

Mathematical Method

The ground-water and soil quality databases were queried to identify each location where VOCs were detected during the most recent sampling event at the location. The analytical data included aqueous concentrations detected at wells and piezometers and total soil concentrations, which were used to calculate equilibrium aqueous concentrations. Where primary and duplicate samples were collected, the higher of the two values was used for each constituent. To assess NAPL presence, the measured concentration of each VOC detected in ground water (or calculated as present within soil based on equilibrium partitioning assumptions) (Cm_i) was compared to the effective solubility limits of the chemical (C_i). Any ground-water sampling location for which the ratio of Cm_i/C_i was greater than 0.10 was included within the probable NAPL zone. Similarly, any soil sampling location for which the ratio of Cm_i/C_i was greater than 1.0 was included within the probable NAPL zone.

The mathematical approach is complicated at the SRSNE Site by the presence of a highly complex mixture of NAPLs in the subsurface. Several simplifying assumptions were used to allow a mathematical assessment of the solubility ratio discussed above, including:

- The suite of VOCs detected (or calculated) in the aqueous phase at each location comprises the exact suite of VOCs in the source NAPL. This assumption allows effective solubilities to be evaluated based on the correct number of VOCs in a hypothetical NAPL mixture, rather than applying a common solubility reduction factor for all locations, which would require that the NAPL have the same properties everywhere. This approach, therefore, provides a useful means to account for the fact that NAPL composition may vary spatially at the site.

- The degree of sorption is the same for each compound. This assumption is justified by the likely, near saturation of available sorption sites due to the length of time that NAPL has been in the subsurface.

- The dispersion is the same for each compound. This assumption is justified by the fact that dispersion is a physical property of the geologic medium, and does not vary between different solutes.

- The degradation rates are the same for each compound. This assumption is considered reasonable given that samples obtained in the NAPL zone would be located near enough to NAPL that travel times available for degradation processes would be limited. While this is considered the weakest of the assumptions in the method, this weakness is counter-balanced by the fact that this approach accounts for every solute detected (or calculated) in the aqueous phase. Also, this is only one of several methods used to delineate the probable NAPL zone.

These assumptions lead to the result that each measured VOC concentration in ground water (or calculated as present within soil based on equilibrium partitioning assumptions) (Cm_i) is proportional to the chemical's effective solubility limit (C_i). This result is presumed to be valid at the interface between the water and the NAPL, where all compounds in the NAPL are at the effective solubility limits in the aqueous phase, in accordance with Raoult's Law. In terms of a proportionality constant ($\acute{\alpha}$), we assume that $Cm_i / C_i = \acute{\alpha}$, where $\acute{\alpha} = 1$ at the NAPL-water interface, and diminishes with increasing distance from the NAPL source zone because of dispersion, degradation, and borehole dilution (which are assumed equal for each NAPL constituent). Note that $\acute{\alpha}$ also equals the detected percent of the effective solubility for compound *i*. Using these assumptions, the derivation below describes the development of a relatively simple expression to compare measured concentrations to effective solubilities for any mixture of constituents.

According to Raoult's Law, which has been demonstrated as useful at the site (Figures 12 and 44), we know that:

$$C_i = M_i S_i, \text{ or } M_i = C_i / S_i ,$$

where: M_i = chemical mole fraction in the NAPL phase; and
S_i = chemical pure-phase solubility.

Since the sum of the NAPL-constituent mole fractions must add up to unity, it follows that:

$$(C_1 / S_1) + (C_2 / S_2) + (C_3 / S_3)....+(C_n / S_n) = 1,$$

where n is the number of components comprising the NAPL.

Based on the discussion above, we can replace C_i with $Cm_i / \acute{\alpha}$, which leads to:

$$\acute{\alpha} = [(Cm_1 / S_1) + (Cm_2 / S_2) + (Cm_3 / S_3)....+ (Cm_n / S_n)].$$

Given the relationship that $Cm_i / C_i = \acute{\alpha}$, we obtain the following equation relating any mixture of measured chemicals to their estimated effective solubility limits:

$$\frac{Cm_i}{C_i} = \sum_{i=1}^{n} \frac{Cm_i}{S_i}$$

BBL used the ground-water analytical database to solve the equation above using the ground-water VOC data from wells and piezometers in the overburden and bedrock hydrogeologic units, and the pure-phase (textbook) solubilities for each detected compound. Wells and piezometers that meet or exceed the 0.10 criterion (10 percent of effective solubility) were included within the *probable NAPL zones* indicated on Figures 45 and 46 for the overburden and bedrock, respectively. Similarly, saturated and unsaturated soil samples with calculated aqueous VOC concentrations that meet or exceed a 1.0 criterion (100 percent of effective solubility) were included within the overburden *probable NAPL zone* (Figure 45).

Empirical Method

The effective solubility of VOCs in the presence of NAPL were empirically demonstrated at wells MWD-601 and MW-705DR, where aqueous VOCs concentrations compared closely with the effective solubility limits estimated based on Raoult's Law (Figures 12 and 44). The VOC concentrations at wells MWD-601 and MW-705DR account for the reduction in aqueous solubility due to the multi-component nature of the DNAPL at those wells. To be conservative in subsequent calculations, the lower concentration from the two wells was used as the empirical effective solubility. Due to the complicated mixture of VOCs in the ground-water samples obtained at wells MWD-601 and MW-705DR, some of the compounds had extremely low effective solubility limits. Therefore, the empirical approach included an initial screening to ensure that a sufficient number of VOCs were detected to render such low effective solubilities appropriate.

The ground-water analytical database was queried to identify monitoring wells in the overburden and bedrock where:

- at least half the fifteen compounds detected in ground water at well MW-705DR and/or MWD-601, which are considered characteristic of dissolved VOCs in the presence of NAPL at the SRSNE Site, were detected; *and*

- at least half the detected compounds exceeded 10 percent (for ground-water samples) or 100 percent (for aqueous VOC concentrations calculated from soil samples) of the empirical effective solubility for that compound.

The distribution of wells and piezometers that meet both of these criteria were considered within the *probable NAPL zone* indicated on Figures 45 and 46 for the overburden and bedrock, respectively. During the database query process, the most recent set of results from each well sampled was used. Where primary and duplicate samples were collected, the higher of the two values was used. The empirical method was also applied to calculated equilibrium aqueous VOC concentrations in soil samples, as described below.

Note that this empirical solubility analysis is based on effective solubility limits measured at only two locations (wells MWD-601 and MW-705DR). Given the site history and variety of solvent materials handled at the site, NAPLs with chemical compositions different from the MW-601 and MW-705DR DNAPLs are likely present, and NAPLs with different constituent effective solubilities are likely also present at the site. In general, however, the empirical approach yielded results that were consistent with the other approaches to NAPL zone delineation.

Ground-Water Alcohols Concentrations

Alcohols including ethanol, isopropanol, methanol, and sec-butanol have been detected in ground-water samples obtained from several overburden and bedrock monitoring wells situated in the former Operations Area and the former Cianci Property where high concentrations of solvent-related VOCs have also been detected. Alcohols are interpreted as indicating nearby NAPL presence because they partition preferentially to NAPL. Also, dissolved alcohol degradation rates are usually relatively high in ground water (see Table 10), such that they would not be expected to be detected at locations distant from their source material (interpreted as NAPL).

Soil VOC Concentrations

The mathematical and empirical aqueous solubility assessments described above were applied to soil samples by calculating equilibrium pore-water concentrations based on the methods of Feenstra *et al.* (November 1991). Unlike ground-water samples from wells, soil samples are not subject borehole dilution effects. To help delineate the probable NAPL zone, therefore, the soil VOC data were evaluated with respect to 100 percent of the effective solubility limit, indicating that NAPL was present in the soil sample analyzed by the laboratory.

For comparison with effective solubility criteria, equilibrium pore-water concentrations within the soil samples were estimated using the following expression (based on Feenstra *et al.*, November 1991):

$$Cm_i = C_t \varrho_b / [(K_{oc})(f_{oc})(\varrho_b)+(n_W)+(H_C)(n_A)],$$

where: Cm_i = calculated chemical concentration in pore water (mg/L or ug/cm^3);
C_t = measured total soil concentration (ug/g or mg/kg, dry weight);
K_{oc} = organic carbon based partition coefficient (cm^3/g);
f_{oc} = fraction of organic carbon in soil (dimensionless);
ϱ_b = dry bulk density of soil sample (g/cm^3);
n_W = water-filled porosity (volume fraction);
H_C = Henry's Law constant (dimensionless); and
n_A = air-filled porosity (volume fraction, equal to zero in the saturated zone).

This equation was used to assess the NAPL distribution based on saturated and unsaturated (vadose) soil sampling results from the RI Study Area and site-specific soil-water partitioning parameters characterized during the completion of the RI. In the saturated and unsaturated zones, the calculated pore-water concentrations were compared to 100 percent of the effective solubility limits using the mathematical or empirical methods described above to help delineate the probable NAPL zone. The results of the soil screening are included in Appendix M.

Site History and Usage

In addition to the chemical data evaluations described above, which were performed using the soil and ground-water analytical databases, the estimated boundaries of the probable NAPL zone are also based on our knowledge of the site history and usage.

Given the solvent handling and processing locations and activities associated with the former SRSNE Operations Area, NAPL can be expected to be closely associated with any of a number of likely NAPL entry points. Based on the site history discussed in Section 2.3 and the vadose-zone soil data and aerial photographic information discussed in Section 4.1, the potential entry points of waste solvent materials to the subsurface likely relate to several former structures within and adjacent to the SRSNE Site Operations Area, including:

- Two unlined primary and secondary sludge storage lagoons;
- Two drum handling and storage areas;
- Open-pit incinerator;
- Several fuel and blend tank areas;
- Septic tank and associated leach field;
- Subsurface pipe and catch basin that discharged materials from the former air stripper tower to the ditch along the railroad tracks; and
- Ditch(es) along the railroad tracks.

Anomalous Plume Configuration

A final indication of NAPL is based on a comparison between ground-water flow directions and dissolved VOCs in ground water, to identify any location(s) where VOC detections would not be expected based solely on advective-dispersive transport. This observation would suggest the presence of NAPL in the area around or immediately upgradient from these wells.

Because NAPL is considered to be the original source material for the dissolved VOC plumes detected historically on site, any indications of dissolved VOCs in areas upgradient or cross gradient from the Operations Area are likely to be areas where NAPL has migrated. For example, VOCs have historically been detected at high concentrations indicating nearby NAPL at the former Cianci Well near the north end of the former Cianci Property. This location is generally upgradient of the former solvent handling and storage areas associated with the site, and would not be expected to be exhibit persistent, high concentrations of site-related VOCs based only on advective-dispersive transport. While pumping of the former Cianci Well could potentially have mobilized dissolved VOCs upgradient toward the former Cianci Well, the continued presence of high concentrations of VOCs in this generally upgradient area raises the question of whether NAPL was mobilized toward the former Cianci Well. BBL evaluated this question based on hydraulics and bedrock fracture orientations during the RI completion.

Before installing monitoring wells MW-709R and MW-709DR in the open-bedrock borehole of the former Cianci Well, BBL performed a specific capacity test at the former water-supply well to evaluate its yield and qualitatively assess its potential historical influence on bedrock ground-water flow and DNAPL migration. The former Cianci Well sustained a pumping rate of approximately 4.0 gpm for a period of 240 minutes with approximately 6.9 feet of drawdown. Assuming an approximately linear relationship between pumping rate and drawdown, the 134-foot deep former Cianci Well likely could have sustained a pumping rate up to 30 or 40 gpm during its period of use. Given the generally low-to-moderate hydraulic conductivity of the bedrock at the site, these pumping rates would produce a significant change in the hydraulic gradients within the bedrock over a large area around the former Cianci Well, which could result in NAPL mobilization toward the former Cianci Well within the bedrock. The well is believed to be the source of water used for truck washing by the former Cianci Construction Company.

During the specific capacity test at the former Cianci Well, drawdown data were measured at some of the nearby bedrock wells and piezometers, as summarized in Table 7. Drawdown measurements ranged from zero feet at well MW-705R and piezometer CPZ-10R, to 1.29 ft at well P-12A. Of particular note, a drawdown of 0.58 ft was measured at deep bedrock monitoring well MW-705DR, where DNAPL has been observed and confirmed by laboratory analysis. The drawdown observed at MW-705DR during pumping at the former Cianci Well is consistent with the average bedrock fracture geometry. A connection between these wells should be expected given the average dip of the bedrock fractures. The fracture containing DNAPL within the screened interval of well MW-705DR was intercepted at an elevation of approximately 59 feet above mean sea level (AMSL). Assuming this fracture had an average orientation (22.1 degrees dip angle, with a dip azimuth of 107.5), it would also have been intercepted at an elevation of approximately 103 feet AMSL at the open bedrock borehole of the former Cianci Well, which is within the current screened interval of monitoring well MW-709R.

We infer that DNAPL within the bedrock was mobilized toward the former Cianci Well due to changes in the hydraulic gradient caused during pumping at the former Cianci Well, based on the following observations:

- the historical and current high concentrations of VOCs at the location of the former Cianci Well;
- the observed hydraulic connection between the former Cianci Well and well MW-705DR, where DNAPL was encountered;
- the bedrock fracture geometry, which suggest that the same fracture containing DNAPL at the MW-705DR location was intercepted at the former Cianci Well open borehole;
- the physical properties of the DNAPL in the bedrock at the site (which indicate a relatively high potential for mobility due to changes in the hydraulic gradient); and
- the fact that even small increases in the hydraulic gradient are capable of mobilizing pooled DNAPL in bedrock fractures (Kueper, March 24, 1997).

4.2.2.2 Potential NAPL Zone Delineation Process

While the probable NAPL zone indicates where NAPL is either likely or confirmed in overburden or bedrock, NAPL migration on a small scale is expected to be highly irregular, erratic, and extremely difficult to predict accurately due to small-scale permeability variations in overburden and bedrock. Ambient hydraulic gradients, in the absence of pumping stresses, typically have little or no influence on DNAPL migration. The effects of geologic heterogeneity dominate the migration and distribution of NAPL in field situations (Pankow and Cherry, 1996). Even in relatively homogeneous sandy soils, DNAPL migration is controlled by extremely subtle differences in soil structure, permeability, and displacement pressure characteristics (Poulsen and Kueper, 1992). Stratigraphic features that are not visually discernable in the field can halt or redirect the downward migration of DNAPL (Pankow and Cherry, 1996). Because NAPL migration is dominated by the structure of subsurface media, laterally continuous low-permeability layers may serve as (partial) capillary barriers to downward DNAPL migration. The basal till beneath the SRSNE Operations Area, for example, appears to behave as a relatively effective capillary barrier based on the substantial contrast between VOC concentrations in overburden ground water (hundreds of ppm) versus those in the bedrock ground water (on the order of 0.4 ppm or less) (ENSR, June 1995). However, because NAPL migration is highly sensitive to subtle changes in geologic structure, permeability, and entry pressure characteristics, which are highly variable, NAPL migration is extremely erratic.

Detailed delineation and characterization of NAPL pools and zones containing residual NAPL are not possible with available investigative technologies (Pankow and Cherry, 1996; Cohen and Mercer, 1993). At best, the three-dimensional extent of NAPL in the subsurface can be inferred using indirect indicators of NAPL presence, in conjunction with the chance incidence of direct NAPL observation and sampling. A NAPL zone can be inferred based on NAPL constituent effective solubility analysis versus ground-water concentrations and calculated pore-water concentrations in soil based on partitioning principles (Feenstra *et al*, November 1991; Cohen and Mercer, 1993; Pankow and Cherry, 1996). However, even effective solubility evaluation can lead to errant estimation of the NAPL-zone extent, as demonstrated by the detection of DNAPL at well MWD-601, which was installed adjacent to well MWL-301, where VOCs had been shown to be non-detectible. Prior to encountering DNAPL at well MWD-601, this location would likely not have been included within the probable NAPL zone based on an effective solubility analysis.

NAPL can migrate further in subsurface media characterized by a relatively high degree of heterogeneity, such as the on-site soils and the fractured New Haven Arkose bedrock, because the NAPL penetrates primarily or exclusively the more permeable pathways, leaving the remainder of the formation essentially free of NAPL. Thus, NAPL tends to penetrate in narrow, elongated distributions, such that invasion by even small volumes of NAPL can result in extensive spreading (Pankow and Cherry, 1996). Regardless of the dimensions of the probable NAPL zone estimated in overburden and bedrock during the RI, NAPL can be reasonably assumed to have migrated beyond the probable NAPL zones within a number of isolated geologic laminae, strata, lenses, channels, or fractures near the periphery of the probable NAPL zone. While such incidences may represent a relatively minor fraction of the total NAPL volume at the site, NAPL within these zones would substantially impact the practicability of ground-water restoration within the surrounding formation. Based on these considerations, a second level of NAPL delineation is warranted due to the highly uncertain nature of NAPL distribution.

The potential NAPL zones were delineated using site data by identifying the following:

- Regions of the subsurface where aqueous VOC concentrations exceed one percent (detected in ground-water samples) or 10 percent (calculated based on saturated soil samples) of the component's effective solubility using either the mathematical or empirical approach discussed above;

- Regions of the subsurface where VOCs were detected in hydraulically anomalous locations, and the presence of the dissolved VOCs could be explained by the presence of NAPL. An example of this is the presence of VOCs in ground water on the other side of a perceived ground-water flow divide (e.g., the Quinnipiac River), where the exact location of that flow divide is not known; and

- Regions where an abrupt change in contaminant chemistry is observed, and the concentrations of interest exceed one percent a component's effective solubility.

The potential NAPL zone represents a safety factor with respect to NAPL-zone delineation. Within the potential NAPL zone, ground-water restoration can be presumed to be technically impracticable due to the immiscible nature of the NAPL, the relatively low hydraulic conductivity of the overburden and bedrock formations, the diffusion of constituent mass into relatively impermeable zones, the heterogeneity of the geologic media, and other factors.

4.2.2.3 Probable and Potential NAPL Zones in Overburden

Figure 45 summarizes the results of the NAPL screening process for the overburden. The overburden probable NAPL zone was delineated as the zone containing all the data points where NAPL is known or highly suspected based on the criteria listed in Section 4.4.4.3. The overburden probable NAPL zone covers an area of approximately 214,000 square feet (4.9 acres), and extends east from the Operations Area to the vicinity of the Quinnipiac River and southeast to the northern edge of the Southington Well Field Property. The overburden potential NAPL zone covers an area of approximately 540,000 square feet (12.4 acres). The TI zone will be conceptually delineated during the FS and will include, at a minimum, the entire overburden potential NAPL zone.

4.2.2.4 Probable and Potential NAPL Zones in Bedrock

Figure 46 summarizes the results of the NAPL screening process for the bedrock. The bedrock probable NAPL zone was delineated as the zone containing all the data points where NAPL is known or highly suspected based on the criteria listed in Section 4.4.4.3. The bedrock probable NAPL zone covers an area of approximately 260,000 square feet (6.0 acres), and extends from the Operations Area eastward to the vicinity of the Quinnipiac River, and north (upgradient based on non-pumping head data) to the location of the former Cianci Water Supply Well. The extension of the bedrock probable NAPL zone to the former Cianci Well is consistent with the information presented in Section 4.2.2.1, and supports the interpretation that NAPL was mobilized to the vicinity of the former Cianci Well during its use. The potential bedrock NAPL zone covers an area of approximately 618,000 square feet (14.2 acres). The TI zone will be conceptually delineated during the FS and will include, at a minimum, the entire potential bedrock NAPL zone.

The depth of the potential NAPL zone was not investigated directly during the RI and can not be determined safely due to the risk of mobilizing NAPL during drilling and contaminating the deeper bedrock, which may not contain any VOCs. Also the depth of the NAPL zone in the bedrock does not warrant detailed delineation given that the VOC plume associated with the bedrock NAPL zone is discharging upward to the overburden. The depth of the NAPL zone may be inferred indirectly, based on the three-dimensional distribution of dissolved VOCs and ground-water flow directions. Based on the interpreted depth of the VOC plume in bedrock and the hydraulic gradients shown on cross section B-B', it appears that the probable NAPL zone shown on Figure 46 could potentially extend to a depth on the order of 200 feet below grade.

The overburden and bedrock NAPL zones delineated in Section 4.2 provide an understanding of the distribution of the original VOC sources attributed to the SRSNE Site. However, due to the partial solubilization of the NAPLs, dissolved-phase plumes of VOCs have resulted in overburden and bedrock at concentrations exceeding ground-water quality ARARs. Section 4.3 discusses the ground-water quality conditions at the site, with particular attention to the delineation of the regulatory VOC plumes. Section 4.3 also addresses surface-water quality, and the interaction between the ground-water regulatory plumes and the Quinnipiac River.

4.3 Ground-Water and Surface-Water Quality

A fundamental objective of the overall RI/FS process was to develop a strategy to address the off-site VOC plume associated with the SRSNE Site that has migrated beyond the NTCRA 1 Ground-Water Containment System. Prior to this investigation, most of the ground-water and surface-water data were obtained sporadically, in subsets of the overall monitoring network that has developed through fourteen previous subsurface investigations. The completion of the RI, therefore, included a comprehensive ground-water and surface-water sampling round at essentially all accessible monitoring locations within the RI Study Area to delineate the SRSNE plumes in the five monitored hydrostratigraphic intervals of the overburden and bedrock. Also, the plumes related to the SRSNE Site were distinguished from the other previously-documented, and newly-interpreted VOC plumes within the regional

Quinnipiac River Valley. SRSNE plume delineation was performed based primarily on regulatory constraints such as federal and state ground-water cleanup criteria, but also on fundamental ground-water hydraulics and solute-transport principles. These factors provide multiple levels of screening to isolate the area beyond which further investigation is not warranted based on technical or regulatory criteria. Plume delineation also supports an evaluation of the potential impact of the SRSNE-related plumes at private water-supply wells. In addition to ground-water sampling, BBL performed two rounds of surface-water sampling to evaluate the surface-water quality in the Quinnipiac River. The ground-water and surface-water data obtained during the completion of the RI are tabulated in Appendix P.

To provide a comprehensive ground-water quality data set to characterize ground-water quality in the study area, BBL obtained approximately 192 ground-water samples (not including the associated QA/QC samples) from nearly all available wells and piezometers in the study area for analysis of VOCs by CLP-RAS Methods (10/92 Low Concentration Organics in Water, including ketones and tetrahydrofuran) and alcohols by SW-846 Method 8015. To help assess the extent of natural attenuation in mitigating the VOC plumes associated with the site, additional ground-water samples from wells P-1A, P-1B, P-6, P-8A, P-8B, MW-414, MW-415, MW-502 and each of the wells in the MW-703 and MW-704 clusters were analyzed for the following parameters: total and dissolved Fe and Mn, nitrate, ammonia, sulfate, sulfide, TOC, orthophosphate, chloride, phospholipid fatty acids, methane, ethane, and ethane. Additional ground-water field parameters, dissolved oxygen and oxidation reduction potential (ORP), were measured using a flow-through cell. Orthophosphate and dissolved metal samples were filtered by pumping ground-water from the well directly through a disposable, in-line, 0.45-micron filter. To allow a comparison between sample results obtained using traditional and low-flow purging and sampling techniques, six additional samples were also collected at wells P-4A, P-4B, P-5A, P-5B, MW-704S, and MW-704R following the USEPA Region 1 Draft Low-Flow Purging and Sampling Method (USEPA, August 1995), immediately prior to performing traditional purging and sampling at these wells. A detailed discussion of the ground-water sampling activities is presented in Appendix A. The analytical results from these samples are tabulated in Appendix P.

Upon inspection of analytical data received for the SRSNE Site ground-water and surface-water samples, a number of gas chromatograph/ mass spectrometer (GC/MS) volatile target compounds were observed in the rinse blanks and trip blanks associated with the 264 samples collected between November 19, 1996 and February 7, 1997. In response to the apparent blank contamination, a general review of the data quality was conducted to assess whether these factors impact the data usability and to determine if any data quality issues warrant full data validation. Along with rinse and trip blanks, method blanks, surrogate recoveries, matrix spike and matrix spike duplicate (MS/MSD) recoveries and matrix spike blank (MSB) recoveries were examined for deviations which might indicate systemic problems. The data evaluation procedure was consistent with the USEPA Contract Laboratory Program - National Functional Guidelines for Organic Data Review (2/94). An expected number of deviations were observed in the surrogates, MS/MSDs, and MSBs, with no indications of a systemic problem. Inspection of the method blanks revealed a pattern of contamination similar to that observed in the rinse and trip blanks. Based on the results of this data review, it was determined that complete data validation was not required, but the data should be corrected for blank contamination to screen out false positives in the reported data. BBL performed blank corrections for the ground-water and surface-water VOC data, consistent with the above-referenced document. The corrected analytical results, and a more thorough discussion of the blank correction procedure are presented in Appendix P.

BBL also performed full (comparable to Tier III) data validation for the analytical data from a limited number of wells where new VOC detections were inconsistent with historical results (no VOCs detected prior to the November 1996 - February 1997 sampling event). BBL queried the ground-water database to identify any monitoring wells that met the following three criteria: 1) contained detectible VOCs during the most recent sampling event (performed by BBL); 2) were sampled at least once prior to November 1996; and 3) contained no detectible VOCs during all previous sampling events. Methylene chloride and acetone were excluded from the database query, as these are both common laboratory contaminants. Nine wells were identified based on the database query, including: MW-129, MW-201B, MW-203A, MW-205B, MW-209B, MWL-302, P-8A, P-15, and WE-2. The analytical data obtained from these wells during the November 1996 - February 1997 sampling event were subject to full validation. The data validation report is included in Appendix P. The data presented in the text and figures of this RI report, and the summary table presented in Appendix P, are consistent with the data validation results.

The results of the low-flow and traditional ground-water samples are summarized on a log-log concentration graph in Figure 47. The low-flow versus traditional data conform closely to the line of equal concentration, with a correlation factor of 0.98. Approximately 75 percent of the detected VOCs, however, were identified at higher concentrations in the traditional sample. All of the VOCs detected below 50 micrograms per liter (ug/L) in the low-flow samples were detected at higher concentrations in the associated traditional samples. These results indicate no adverse degree of VOC loss during traditional ground-water purging and sampling, rather traditional sampling is interpreted as more conservative than low-flow sampling with respect to regulatory plume delineation.

The remainder of this Section 4.3 describes the ground-water and surface-water quality conditions in the RI Study Area.

4.3.1 Regulatory VOC Plume Characterization

This section describes the current conditions within the regulatory plumes associated with the SRSNE Site. The strategy for delineating the off-site VOC plume associated with the SRSNE Site, which is situated downgradient of the NTCRA 1 Containment Area, was driven by fundamental hydrogeologic and institutional constraints, including:

- Potential NAPL distribution and solubility (see Section 4.2);
- Ground-water flow directions (see Section 3.4.3);
- VOC solute-transport characteristics (discussed below in Section 4.3.1.5);
- Federal and State of Connecticut ground-water regulatory criteria; and
- Other potential VOC sources in the vicinity of the potential SRSNE plume.

As described in the RI Work Plan (BBL, November 1995), the approach used to define the nature and extent of the off-site VOC plume associated with the SRSNE Site included six logical steps, which are summarized as a flow chart on Figure 48 and further discussed below. The flow chart provides a framework for characterizing the VOC source associated with the SRSNE Site and, based on technical principles (e.g., ground-water hydraulics, solute-transport characteristics), provides maximum boundaries beyond which the SRSNE plume could not have migrated. The approach also constrains the plume within the area that exceeds regulatory cleanup standards and builds in an evaluation of other potential sources, as appropriate. While Figure 48 presents the key evaluations that may be necessary to characterize the off-site VOC plume, not all of the evaluation steps will necessarily be required.

Step 1 in the plume delineation process characterizes the extent of the probable and potential NAPL zones associated with the SRSNE Site, as discussed above in Section 4.2 (Figures 45 and 46). Any area where site-related NAPL is present, is a source of dissolved VOCs contributing to the ground-water regulatory plume associated with the site.

Step 2 in the off-site plume evaluation was to define the ground-water hydraulics that control the direction of VOC transport from the estimated NAPL zone. Section 3.4.3 describes the general ground-water flow directions and locations of hydraulic divides in the area of the potential off-site plume to identify hydraulic boundaries to the off-site plumes. Where hydraulic divides exist, boundaries can be drawn beyond which no further investigation is warranted. The available ground-water (potentiometric) elevation data indicate that hydraulic divides exist throughout the monitored section of the overburden and bedrock near the Quinnipiac River east and south of the site. Within the regional Quinnipiac River Valley, a hydraulic gradient reversal has been identified in the overburden and bedrock generally coincident with the river, which represents the regional ground-water discharge point. Vertical cross sections have been used to evaluate the vertical components of ground-water flow, indicating that ground-water flow is primarily upward in the area downgradient of the site, and that bedrock ground-water is discharging to the overburden. Also, by plotting ground-water flow nets and VOC concentration contours in vertical profile, ground-water flow lines may be traced backward to indirectly assess where and to what depth NAPL may have migrated into the bedrock.

Step 3 of the off-site plume characterization process constrains the potential extent of the SRSNE plume based on VOC solute-transport/mobility characteristics, which control the velocity of VOC plume advancement and limit the extent to which the plume could have migrated within the approximately 40-year period since SRSNE operations began. By calculating the potential extent to which various VOCs could have migrated from the SRSNE Site, additional boundaries can be delineated beyond which no further investigation is warranted. However, given the uncertainties regarding the exact timing of NAPL releases at the site and uncertainty in the solute-transport characteristics of complex geologic media, solute-transport considerations were found to be less important than the other steps in the plume delineation process. An evaluation of solute transport is presented in Section 4.3.1.5 below.

Step 4 in characterizing the off-site VOC plume, which for practical reasons was found to be the most efficient and direct step in the process, was to identify wells in the study area where VOCs have been detected in ground water at concentrations above Federal MCLs or CT DEP Class GA/GAA Ground-Water Protection Criteria. Given the wide range of solvent-related compounds and concentrations detected in ground-water samples and the wide range of ground-water regulatory criteria applicable to the various compounds, an innovative method was devised to efficiently define the regulatory plumes associated with the site. BBL screened the ground-water analytical data from the comprehensive ground-water sampling round, completed between November 1996 and July 1997, using the relational, ground-water analytical database to identify sampling locations where VOCs were detected above applicable ground-water regulatory criteria. To indicate the magnitude of each regulatory exceedance, BBL calculated an exceedance ratio, defined as the detected concentration divided by either the federal MCL or the CTDEP Class GA/GAA Ground-Water Protection Criterion for the analyte, whichever is lower. Thus, an exceedence ratio of 5.0 indicates that a compound was detected at 5.0 times the lower regulatory criterion at a given location. Based on the results of this screening and ranking process, BBL mapped out the distribution of ground-water regulatory exceedences in plan view and cross section, assessed the magnitudes of exceedences, and identified the key compounds causing regulatory exceedences in certain areas of the plume within each of the five monitored hydrostratigraphic zones.

Steps 5 and 6 in the plume delineation process comprise an evaluation of other potential sources of VOCs within the regional Quinnipiac River valley. Given the common occurrence and use of many of the solvent compounds associated with the SRSNE Site, other sources of similar constituents can be reasonably expected in the region of the site. Some of the other sources areas are well known, as described in detail in Section 2.7. On the basis of concentration reversals and ground-water hydraulics, at least four other sources of VOCs, in addition to the SRSNE Site, are interpreted as influencing ground-water quality in the RI Study Area.

These logical steps were used to delineate the regulatory VOC plumes associated with the SRSNE Site, as described below.

4.3.1.1 Regulatory VOC Plume Delineation

Figures 49 through 53 summarize the interpreted horizontal extent of the regulatory plumes associated with the SRSNE Site within the five monitored hydrostratigraphic intervals, including the shallow, middle, and deep overburden, and the shallow and deep bedrock. Figures 17 through 20 summarize the interpreted vertical extent of regulatory exceedences in ground water. Note that the data from the fully-penetrating NTCRA 1 extraction wells and overburden compliance piezometers are plotted on all three overburden plume maps (Figures 49 through 51).

The plume descriptions presented below focus on the locations where regulatory exceedences were identified, and describe the salient aspects of the regulatory exceedences. While this discussion does not present a detailed analysis of the concentrations of specific analytes or groups of analytes, a detailed listing of all VOCs and alcohols detected in ground water and surface water during the completion of the RI, and the compound-specific regulatory criteria for ground water, are presented in Appendix P. Also, Appendix M includes isoconcentration contour maps summarizing the total dissolved VOC concentrations in the five monitored hydrostratigraphic zones. The data tables within Appendix P and figures within Appendix M, therefore, provide a mechanism for the reader to assess the ground-water quality conditions in more detail. However, as described below, the primary objective was to identify the areas that exhibit exceedences of ground-water regulatory criteria, evaluate the relative magnitudes and the types of compounds exhibiting exceedences, and distinguish which regulatory exceedence areas are or are not related to the SRSNE Site.

Shallow Overburden Regulatory Plume

As shown on Figure 49, the distribution of VOCs exceeding regulatory criteria in the shallow overburden near the SRSNE Site is limited to the immediate vicinity of the overburden NAPL zone, and extends from the Operations Area to the vicinity of the Quinnipiac River. Within the Operations Area and NTCRA 1 Containment Area, the most significant detected exceedances included vinyl chloride (regulatory exceedence ratio up to 5,000), and 1,1-DCA (regulatory exceedence ratio up to 190). These high concentrations were detected in the NAPL zone, which will be included within the TI zone. The TI zone will be delineated conceptually in the TI Evaluation, which will be submitted with the FS.

The compound with the highest regulatory exceedence in the distal, eastern extent of the shallow overburden plume is benzene, which was detected at concentrations of 2.0 to 58 times the regulatory limit. The shallow overburden regulatory plume extends approximately 100 feet into the northwestern corner of the Southington Well Field Property, where low exceedences of vinyl chloride and TCE were detected. Other VOCs detected below regulatory criteria in the north portion of the Southington Well Field Property included: 2-butanone; 1,1-DCA; 1,1-dichloroethene (1,1-DCE); 1,2-DCE; methylene chloride; TCA; TCE; toluene; and xylenes.

South of the westward bend in the Quinnipiac River, a second, unrelated VOC plume is evident in the shallow overburden. Ground-water quality data obtained in November and December 1996 from shallow overburden wells TW-1 through TW-5 indicated a continuous trail of ground-water regulatory exceedences of up to 30 times the regulatory criterion for tetrachloroethene (PCE). These detections define a plume extending downgradient (northwest) from the former Ideal Forging Site, where high concentrations of solvent compounds including PCE, TCE, and 1,1,1-TCA were detected in soil at the depth of the water table in 1981. Moreover, the concentrations of these compounds detected in 1981 in an adjacent monitoring well installed with an 80-foot long screen were high enough to suspect the presence of NAPL in the saturated zone at the former Ideal Forging Property (Welti, July 1981; October 1981). These data, and the observed continuing source of VOCs suggest the continued presence of NAPL at the former Ideal Forging Site. The interpreted shallow overburden plume associated with the former Ideal Forging Site passes within 150 to 250 feet of Town Production Wells No. 4 and 6 under the current, non-pumping conditions.

The relatively high concentration of PCE detected at well TW-5, situated nearest the Quinnipiac River, may indicate that a deeper plume is discharging upward toward the river at that location, or could signify another VOC source area on that parcel. Well TW-5, which has historically contained among the highest VOC concentrations south of the river, is situated on the Caldwell (Supreme Lake Company) Property, where solvents reportedly have been disposed, as documented by Warzyn (1980).

The shallow overburden ground-water regulatory plume underlies buildings, tanks, and concrete pads within the Operations Area (Figure 49A). The shallow overburden ground-water regulatory plume is near, but does not underlie the NTCRA 1 Ground-Water Treatment System Building. The NTCRA 1 Ground-Water treatment building has an epoxy-coated concrete floor slab with no unsealed penetrations. Thus, the likelihood of VOC migration into the building from shallow ground water is minimal. The shallow overburden ground-water concentrations in the vicinity of the NTCRA 1 treatment building do not exceed CT DEP Residential or Industrial/Commercial Volatilization Criteria.

To compare the available shallow overburden ground-water quality data to CT DEP Remediation Standard Regulations regarding surface-water protection and volatilization (CT DEP, January 1996), BBL used the relational ground-water database. The shallow overburden ground-water data from the most recent ground-water sampling event (November 1996 through February 1997, and June 1997 at the MW-710 well cluster) were compared to CT DEP Residential and Industrial/Commercial Volatilization Criteria. Tables and figures summarizing the results of this evaluation are presented in Appendix M. In addition, shallow overburden ground-water quality data from wells adjacent to the Quinnipiac River were compared to the Surface-Water Protection Criteria, which indicated an exceedence only at well TW-5, which is situated in the southern portion of the RI Study Area, south of the Quinnipiac River (Figure 49A).

The shallow overburden ground-water sampling locations exceeding CT DEP Residential and Industrial/Commercial Volatilization Criteria for VOCs in ground water were identical, and in were primarily limited to the area extending from the Operations Area to within approximately 75 feet of the west bank of the Quinnipiac River. Exceedences were also observed at well TW-5, however, which is south of the Quinnipiac River (Figure 49A). No exceedences of volatilization criteria were observed adjacent to the NTCRA 1 Ground-Water Treatment System Building.

Middle Overburden Regulatory Plume

As shown on Figure 50, the distribution of VOCs exceeding regulatory criteria in the middle overburden is more extensive than the shallow overburden plume. Within the Operations Area and NTCRA 1 Containment Area, the most significant detected exceedances in the middle overburden included vinyl chloride (regulatory exceedence ratio up to 3,900), PCE (regulatory exceedence ratio up to 2,400), and 1,2-DCE (regulatory exceedence ratio up to 940). These high concentrations were detected in the NAPL zone, which will be included within the TI zone.

The middle overburden plume extends southward through the center of the Southington Well Field Property to a distance of approximately 1,200 feet south of the former Cianci Property. The compound with the highest regulatory exceedence in the distal, southern extent of the middle overburden plume in the Southington Well Field Property is benzene, which was detected at a concentration of 6.0 to 8.0 times the regulatory limit. Vinyl chloride and TCE were also detected slightly above regulatory criteria near the downgradient, leading edge of the middle overburden plume. Other VOCs detected in the Southington Well Field Property included: 2-

butanone; 1,2-DCE; ethylbenzene; methylene chloride; TCE; toluene; and xylenes. The middle overburden VOC data in the Southington Well Field Property generally define a north-to-south trail of benzene and other detections, which appear to be associated with the SRSNE Site NAPL zone.

The interpreted middle overburden plume extends from the Operations Area eastward past the Quinnipiac River to the MW-501 well cluster. However, VOCs have also been detected historically in the deep overburden and shallow bedrock near the corner of Lazy Lane and Queen Street and, given the prevailing southwestward hydraulic gradients in that area, the TCE detected at well MW-501B could also relate to a VOC source situated northeast of the RI Study Area.

South of the westward bend in the Quinnipiac River, a VOC plume is evident extending downgradient from the former Ideal Forging Property within the middle overburden. The interpreted shallow overburden plume associated with the former Ideal Forging Site passes within approximately 100 to 250 feet of Town Production Wells No. 4 and 6 under the current, non-pumping conditions.

Deep Overburden Regulatory Plume

As shown on Figure 51, the distribution of VOCs exceeding regulatory criteria in the deep overburden is similar but not as extensive as the middle overburden plume. Within the Operations Area and NTCRA 1 Containment Area, the most significant detected exceedances in the deep overburden included TCE (regulatory exceedence ratio up to 19,000), 2-butanone (regulatory exceedence ratio up to 1,200), and vinyl chloride (regulatory exceedence ratio up to 750). These high concentrations were detected in the NAPL zone, which will be included within the TI zone.

The deep overburden plume extends southward through the center of the Southington Well Field Property to a distance of approximately 800 feet south of the former Cianci Property. The compound with the highest regulatory exceedence near the southern extent of the deep overburden plume in the Southington Well Field Property is benzene, which was detected at a concentration of 46 times the regulatory limit. TCE was also detected slightly above regulatory criteria near the downgradient, leading edge of the deep overburden plume. Vinyl chloride was detected at up to 16 times the regulatory criterion in the northwest portion of the Southington Well Field Property. Several other VOCs were detected in the Southington Well Field Property including: 2-butanone; 1,1-DCA; 1,2-DCE; methylene chloride; PCE; TCE; toluene; and xylenes. The deep overburden VOC data in the Southington Well Field Property generally define a north-to-south trail of benzene and other detections, which appear to be associated with the SRSNE Site NAPL zone.

The interpreted deep overburden plume extends from the Operations Area eastward to the vicinity of the Quinnipiac River. While VOCs have been detected historically in the deep overburden at well MW-202B near the corner of Lazy Lane and Queen Street, no compounds were detected above regulatory criteria at this well in December 1996. Given the west-southwestward hydraulic gradient at the MW-202 location, VOCs detected there historically are attributed to an upgradient source to the east-northeast of the intersection. The R.P. Olson Site, for example, is situated approximately 300 feet hydraulically upgradient of the MW-202 location.

South of the westward bend in the Quinnipiac River, no data points currently exist within the deep overburden downgradient of the Ideal Forging Site, indicating a data gap in the regional ground-water monitoring network. However, a deep overburden plume is considered likely downgradient of the former Ideal Forging Site given the shallow and middle overburden VOC plumes discussed above and the results of deep overburden ground-water quality data obtained at the former Ideal Forging Site in 1981. Given the available hydraulic gradient data, the deep overburden plume, if any, would be expected to follow the same general path as the shallow and middle overburden plumes identified downgradient of the former Ideal Forging Company.

Another regulatory VOC plume, which is unrelated to the SRSNE Site, is interpreted in the southwestern portion of the Southington Well Field Property based on the detection of TCE at a concentration of 26 times the regulatory criterion for TCE at deep overburden well CW-2-78. This detection is interpreted as separate from the SRSNE plume because the hydraulic gradient direction at the CW-2-78 location is from the northwest rather than the north, and the TCE detection there signifies a concentration gradient reversal. That is, the available data points situated generally north of the CW-2-78 location in any of the five monitored hydrostratigraphic intervals did not indicate any detections of TCE (or its potential parent compound, PCE) at similar or higher concentrations to the detection at well CW-2-78. This interpreted plume extends southeastward to within approximately 200 feet of Town Production Well No. 6 under the current, non-pumping conditions.

Shallow Bedrock Regulatory Plume

As shown on Figure 52, the distribution of VOCs exceeding regulatory criteria in the shallow bedrock is similar but not as extensive as the middle overburden plume. Within the Operations Area and NTCRA 1 Containment Area, the most significant detected exceedances in the shallow bedrock included TCE (regulatory exceedance ratio up to 146,000) and vinyl chloride (regulatory exceedance ratio up to 11,000). These high concentrations were detected in the NAPL zone, which will be included within the TI zone.

The shallow bedrock plume extends southward through the center of the Southington Well Field Property to a distance of approximately 1,100 feet south of the former Cianci Property. The compound with the highest regulatory exceedance near the southern extent of the shallow bedrock plume in the Southington Well Field Property is 1,1-DCE, which was detected at a concentration of 1.3 times the regulatory limit. Compounds detected above regulatory criteria in the central and northern portions of the Southington Well Field Property in the shallow bedrock included: TCE (regulatory exceedance ratio up to 60), benzene (regulatory exceedance ratio up to 100), and others at relatively low exceedance ratios. The shallow bedrock VOC data in the Southington Well Field Property generally define north-to south trails of VOC detections. A line of 1,1-DCE detections extends southeastward through the Well Field from the southeastern corner of the Operations Area. A line of benzene (and sporadic TCE) detections extends from north to south through the eastern portion of the Well Field, just west of the Quinnipiac River. These continuous, traceable data trends appear to be associated with the SRSNE Site NAPL zone.

The interpreted shallow bedrock regulatory plume extends northward to the location of the MW-709 cluster, which was installed in the former Cianci water supply well. As described above in Section 4.2.2, the former Cianci Well is believed to have had a pumping capacity of 30 to 40 gpm, which would create a substantial hydraulic influence in the bedrock. While NAPL has not been identified in the former Cianci Well, the detections of alcohols and high concentrations of VOCs at the MW-709 cluster suggest the current or past presence of NAPL in the near vicinity of the former Cianci Well. Based on these data, the interpreted bedrock probable NAPL zone extends to the former Cianci Well location. Pumping at the former Cianci Well, therefore, may have mobilized NAPL to the vicinity of the former Cianci Well. However, during its use, the former Cianci Well may have created a capture zone that would preclude further northward migration of ground-water or NAPL from the NAPL zone associated with the SRSNE Site. Also, as demonstrated by the hydraulic gradient data obtained during the completion of the RI, when the former Cianci Well is not in use, the hydraulic gradients across the northern portion of the former Cianci Property follow the expected east-southeastward pattern (Figures 26 through 35). Thus VOC migration north of the former Cianci Well would not be expected under either pumping or non-pumping conditions at the former Cianci Well.

Water samples obtained historically from the open-bedrock, drilled, water-supply well at the Onofrio residence, north of Lazy Lane, have indicated low concentrations of VOCs below federal and state ground-water and drinking-water regulatory criteria. Any use of the Onofrio Well has likely occurred at a low average rate. Given an estimated average per capita water use of 70 gallons per day in Connecticut (Mazzeferro *et al.* 1979) the daily water use at the Onofrio residence would likely be 280 gallons per day or less, or a long term average of 0.2 gpm. This pumping rate from the approximately 100-foot deep Onofrio Well would likely result in negligible hydraulic influence within the bedrock, and a low potential to reverse the hydraulic gradient at the location of the former Cianci Well. Also, the homes along Lazy Lane do not have public sewer service, such that most of the water pumped from the bedrock water supply wells is likely recharged on the same premises via domestic septic systems. These considerations may explain the historically low VOC concentrations (below regulatory criteria) at the Onofrio Well, and support the inference that the shallow bedrock regulatory plume associated with the SRSNE Site extends no further north than Lazy Lane.

The interpreted shallow bedrock plume extends from the Operations Area eastward past the Quinnipiac River to the MW-501 well cluster. However, VOCs have also been detected historically in the shallow bedrock near the corner of Lazy Lane and Queen Street and in the area north of the site along the east side of the Quinnipiac River at the MW-201 well cluster. These detections, in areas that are regionally upgradient of the SRSNE Site, are considered indicative of one or more unrelated VOC sources situated north or northeast of the RI Study Area.

Another regulatory VOC plume is interpreted in the southeastern portion of the RI Study Area, east of Quinnipiac River. At the MW-710 cluster, a minor regulatory exceedence for TCE was detected in the shallow bedrock. This detection is interpreted as separate from the SRSNE plume because the hydraulic gradient direction at the MW-710 location is from the northeast rather than the northwest. The westward component of ground-water flow at the MW-710 location is illustrated based on a comparison of heads measured there, versus west of the river (Figure 34). All of the shallow bedrock hydraulic heads measured at the wells west of the Quinnipiac River in the southern portion of the Southington Well Field Property, which indicated lower concentrations of a different suite of VOCs, were approximately 1 to 1.5 feet lower than the head measured at well MW-710R on July 7, 1997. These data indicate that rather than crossing beneath the river and migrating toward the MW-710 cluster, shallow bedrock VOC migration from the SRSNE Site would more likely occur toward the south, in the direction of the wells with the lower heads, situated west of the river.

Moreover, even in the northern portion of the Southington Well Field Property, where relatively high concentrations of VOCs were detected at wells MW-704R and MW-204A, the heads measured at these two wells on July 7, 1997 were lower than those at well MW-710R. These data signify a hydraulic gradient reversal between the wells west of the river and well MW-710R, indicating that VOC migration from the site toward MW-710R is highly unlikely.

In contrast to the relative heads measured at monitoring wells located west of the river, the head measured closest to well MW-710R in the area east of the river, at well MW-203A, was more than 3.5 feet higher than the head at MW-710R. These data indicate a relatively strong southeastward hydraulic gradient in shallow bedrock at the MW-710R location, and render the southwestward migration of VOCs from the SRSNE Site highly unlikely. The detection at well MW-710R also can not be explained in terms of upward discharge from the deep bedrock to the shallow bedrock, because the vertical gradient component between these two zones is downward.

A VOC source situated east of Queen Street and northwest of the MW-710 cluster would provide a simpler and, by inference, more likely explanation of the VOCs detected at well MW-710R.

However, given that ground-water flow pathways in fractured bedrock are complex, and the number of ground-water elevation data used to infer ground-water flow directions east of the river is limited, the available data do not rule out the possibility that the low concentrations of VOCs detected at well MW-710R are related to the SRSNE Site. The compounds detected at well MW-710R (1,1,1-TCA, 1,2-DCE, and TCE) comprise a subset of the VOCs detected at shallow bedrock wells MW-501A (1,1,1-TCA, 1,1-DCA, 1,2-DCE, PCE, and TCE) and well P-102A (1,2-DCE, ethylbenzene, PCE, TCE, and vinyl chloride). Wells MW-501A and P-102A are potentially upgradient and are included within the delineated shallow bedrock regulatory plume east of the river.

Deep Bedrock Regulatory Plume

As shown on Figure 53 the distribution of VOCs exceeding regulatory criteria in the deep bedrock is similar but not as extensive as the shallow bedrock plume. The only deep bedrock well situated in the Operations Area, MW-702DR, exhibited no regulatory exceedences. High concentrations of VOCs including TCE, 4-methyl-2-pentanone, toluene, 1,1-DCA, 1,2-DCE, methylene chloride, and xylenes were detected at deep bedrock wells MW-705DR and MW-709DR, in the northern portion of the former Cianci Property. Free-phase, mobilizable NAPL has been directly encountered at well MW-705DR, and is suspected near MW-709DR based on high VOC concentrations. These high concentrations were detected in the NAPL zone, which will be included within the TI zone.

The deep bedrock plume extends southward through the northeastern portion of the Southington Well Field Property to a distance of approximately 800 feet south of the former Cianci Property. The compound with the highest regulatory exceedence near the southern extent of the deep bedrock plume in the Southington Well Field Property is TCE, which was detected at a concentration of 11 times the regulatory limit at well MW-704DR. Benzene was also detected slightly above the regulatory criterion in the same area.

Similar to the shallow bedrock plume, the interpreted deep bedrock regulatory plume extends northward to the location of the MW-709 cluster, which was installed in the former Cianci water-supply well.

The interpreted deep bedrock plume extends from the Operations Area eastward past the Quinnipiac River to a location between deep bedrock wells MW-706D, where TCE was detected at 1,400 times the regulatory criterion, and MW-708DR, where VOCs were not detected. Based on the available hydraulic gradient data, which have indicated upward hydraulic gradients in the vicinity of the river, the VOCs detected at well MW-706DR are likely migrating southward and upward into the shallow bedrock, and ultimately, the overburden. The interpreted upward discharge of the deep bedrock plume into shallower hydrostratigraphic units would help to explain the seemingly isolated detections of TCE in the shallow bedrock, deep overburden, and middle overburden in the northern portion of the Southington Well Field Property. This relationship is depicted on north-south cross-section B-B' (Figure 18).

Another deep bedrock regulatory VOC plume is interpreted in the southeastern portion of the RI Study Area, east of Quinnipiac River. At the MW-710 cluster, a minor regulatory exceedence for TCE was detected in the deep bedrock. This detection is interpreted as separate from the SRSNE regulatory VOC plume because the hydraulic gradient direction at the MW-710 location is from the northeast rather than the northwest. The westward component of ground-water flow at the MW-710 location is illustrated based on a comparison of heads measured there versus west of the river (Figure 35). All of the deep bedrock hydraulic heads measured at the wells west of the Quinnipiac River in the southern portion of the Southington Well Field Property, which indicated no detectible VOCs, were approximately 0.5 to 1 foot lower than the head measured at well MW-710R on July 7, 1997. These data indicate that rather than crossing beneath the river and migrating toward the MW-710 cluster, deep bedrock VOC migration from the SRSNE Site would more likely occur toward the south, in the direction of the monitoring wells with the lower heads, situated west of the river.

In contrast, a VOC source situated east of Queen Street and northwest of the MW-710 cluster would provide a simpler and, by inference, more likely explanation of the VOCs detected at well MW-710R.

However, given the complexity of ground-water flow pathways in fractured bedrock, and the limited number of ground-water elevation data used to infer ground-water flow directions in the deep bedrock, the available data do not rule out the possibility that the VOCs detected at well MW-710DR are related to the SRSNE Site. Some of the compounds detected at well MW-710DR (1,2-DCE, acetone, chloroform, methylene chloride and TCE) also were detected at deep bedrock well MW-706DR (1,1-DCE, 1,2-DCA, 1,2-DCE, 2-butanone, benzene, chloroform, xylenes, methylene chloride, styrene, toluene, TCE, and vinyl chloride). Well MW-706DR is potentially upgradient, and is included within the delineated deep bedrock regulatory plume east of the river.

4.3.1.2 Regional Ground-Water Quality Evaluation

The regulatory plume delineation process resulted in several interpreted plumes associated with VOC sources unrelated to the SRSNE Site within the Quinnipiac River Valley. Based on regional ground-water hydraulics, other potential VOC sources are interpreted in the areas north, northeast, east, southwest, and south of the interpreted SRSNE plume limits. These findings are consistent with the available information regarding VOC sources other than the SRSNE Site within the vicinity of the RI Study Area, as discussed in Section 2.3. Any of these sources that have resulted in a VOC plume could impact the regional ground-water quality evaluation. Moreover, two of the interpreted plumes are located closer to Town Production Wells than the plumes associated with the SRSNE Site. As no known efforts are currently underway to characterize and contain the other plumes, particularly that associated with the former Ideal Forging Company, these unrelated plumes will likely impact the useability of the production wells for the foreseeable future.

4.3.1.3 Relationship of Plumes to Private Water-Supply Wells

A key objective of the RI was to assess whether the off-site plume impacts, or could potentially impact, private water-supply wells. Private residences in the areas immediately north and west of the site rely on domestic wells, primarily drilled bedrock wells, for their water supply. While these areas appear to be upgradient from the SRSNE Site, additional ground-water elevation data have been obtained to develop a three-dimensional flow net, which confirmed their inferred upgradient position relative to the site. Residences south and east of the site have been using municipal water for approximately 100 years.

The only private water supply-wells that could potentially be impacted by the SRSNE plumes are interpreted as the Onofrio Well and the Maiellaro (Mickey's Garage) Well. As discussed above, historical sampling of the Onofrio Well indicated low levels of VOCs below regulatory criteria (HNUS, July 1994). Given its probable low average pumping rate, the Onofrio Well is considered unlikely to produce a reversal in the hydraulic gradient at the northern limits of the regulatory plumes in bedrock. However, as a precautionary measure, the SRSNE PRP Group is evaluating mechanisms to provide municipal water to the Onofrio Property by Spring 1998. Due to the previous detection of VOCs above regulatory criteria at the Maiellaro Well, CT DEP supplies the Maiellaro Property with bottled drinking water. To provide a long-term source of potable water, the SRSNE PRP Group is evaluating mechanisms to provide municipal water service to the Maiellaro Property and anticipates that a municipal water supply hookup will be provided by November 1997.

While discussion of the regulatory plume thus far has focused on its extent in the various monitored hydrostratigraphic zones, Sections 4.3.1.4 through 4.3.1.6 focus on the solute-transport characteristics of the regulatory plume, including matrix diffusion in bedrock, solute-transport velocities for key VOCs, and natural attenuation processes, respectively.

4.3.1.4 VOC Diffusion into Bedrock Matrix

To evaluate whether VOCs had diffused into the bedrock matrix in the vicinity of the site, BBL obtained four bedrock core samples and one duplicate for analysis of VOCs. Bedrock matrix core samples were obtained during drilling at the MW-705DR corehole, and at corehole RC-701 (Figure 3). USEPA does not have a protocol for sampling for VOCs within the bedrock matrix. Based on discussions with USEPA representatives at the Robert S. Kerr Laboratory in Ada, Oklahoma, however, BBL developed a method that included rapidly placing the rock core sample in a triple Ziploc™ bag, crushing the sample with a hammer, transferring the sample to a sample jar appropriate for soils, immersing the sample in reagent grade methanol, and tightly capping the jar. The mass of rock and methanol were weighed to the nearest 0.1 gram in the field using a triple beam balance. Methanol was used as part of the preservation to begin the VOC extraction from bedrock particles as early as possible. The bedrock VOC sampling process was considered the best available, practical means to qualitatively demonstrate whether VOCs exist within the bedrock matrix, but the analytical results should not be considered quantitative.

The bedrock matrix sample analytical results, presented on Table 11, indicated up to 1,165 micrograms per kilogram (ug/kg) of total VOCs detected in the bedrock matrix samples. While these results demonstrate that VOCs have diffused into the bedrock matrix, several aspects of the sampling process likely cause VOC loss from the in-situ bedrock matrix. For example, clean drilling water is circulated along the side of the bedrock core sample throughout the drilling process, which likely loses some VOC mass to the water. Also, even the most diligent efforts to rapidly bag and crush the sample and immerse it in methanol likely result in VOC loss to the atmosphere. Lastly, the methanol immersion method results in considerably elevated VOC detection levels by the analytical laboratory. Given these factors, the VOCs detected in the bedrock matrix are considered a reliable, qualitative demonstration that VOCs have diffused into the matrix, and are likely present at concentrations higher than those detected in the bedrock matrix samples.

Molecular diffusion into the unfractured bedrock matrix is important to plume migration and the evaluation of ground-water restoration practicability in bedrock. Appendix O presents a preliminary assessment prepared by Dr. Kueper to describe the influence of matrix diffusion on VOC plume migration and bedrock ground-water restoration potential (Kueper, November 1997a).

In the initial stages of plume advance, constituent concentrations are high in the fractures where ground-water advection predominates. Initially, little or no constituent mass exists within the unfractured rock matrix. However, due to the strong concentration gradient between the fractures and the matrix, constituents migrate from the fractures into the matrix via molecular diffusion or "matrix diffusion." The initial transfer of constituent mass into the rock is relatively rapid during plume advance because of the strong initial concentration gradient from the fractures into the blocks. Bedrock that has a relatively high matrix porosity and/or high fraction of organic carbon may have a substantial capacity to uptake constituents from the fractures, which transmit a limited volumetric ground-water flux. Thus, a considerable fraction of the constituent mass may diffuse into the rock matrix, effectively "retarding" the overall advance of the dissolved constituent plume in the bedrock. The steady-state retardation of a constituent plume due to matrix diffusion can be approximated by the ratio of the bedrock matrix porosity to the bedrock fracture porosity (Kueper, August 1995). Thus, given the New Haven Arkose mean matrix porosity of 7.7 percent and the bedrock fracture porosity of 6.8×10^{-5} (6.8×10^{-3} percent), the bedrock plume retardation due to matrix diffusion is estimated as approximately 1,100 (dimensionless). That is, the average VOC migration velocity is 1/1,100 of the average lineal ground-water velocity in the rock. This result is consistent with the calculations presented by Kueper (November 1997a, see Appendix O), who estimated a plume retardation factor of 900 due to matrix diffusion. The influence of retardation due to matrix diffusion in fractured porous media, therefore, can be considerably greater than in granular aquifers (Pankow and Cherry, 1996).

Diffusion into low-permeability zones (such as the New Haven Arkose bedrock matrix, which has a mean permeability of approximately 4.3x10-7 cm/sec) can also influence the fate of NAPL in the subsurface. Diffusion of NAPL constituents into low-permeability zones results in a concentration gradient away from NAPL bodies, allowing NAPL dissolution into the matrix as dissolved and sorbed constituent mass. This process continues until the matrix storage capacity has been reached, or the NAPL body has been completely dissolved away, whichever occurs first. NAPL dissolution and diffusion into the bedrock matrix can result in complete disappearance of TCE or PCE DNAPL in a fractured sandstone (Pankow and Cherry, 1996). Ground-water restoration in this case would be controlled by reverse diffusion and desorption from the low-permeability matrix between fractures rather than by dissolution and mobilization of DNAPL from fractures (Pankow and Cherry, 1996). Fractured porous media in which the matrix porosity is likely to have significant influence on NAPL behavior and ground-water restoration include sedimentary rocks which have appreciable matrix porosity (Pankow and Cherry, 1996). The New Haven Arkose has a relatively high mean matrix porosity of 7.7 percent, indicating a substantial storage capacity for VOCs that diffuse into the matrix.

During natural flushing or remediation of a plume in fractured rock, the concentration gradient eventually reverses direction and constituents begin to diffuse back out of the rock matrix into the fractures. The constituent mass flux out of the matrix due to diffusion, however, is significantly lower than the mass flux into the matrix during the initial advance of the plume (Pankow and Cherry, 1996). During natural or remediation-enhanced flushing of the bedrock, constituent concentrations remain relatively high in the fractures. Thus, the concentration gradient and the VOC mass flux from the matrix to the fractures remains limited (Gorelick *et al.*, 1993). Also, because of the potentially high ratio between the matrix porosity and the fracture porosity, the matrix may serve as a persistent reservoir from which VOCs slowly diffuse. Preliminary calculations performed by Dr. Kueper suggest that the duration for ground water within the bedrock fractures to achieve MCLs will be on the order of hundreds of years due to the reverse diffusion of chemicals from the matrix to the fractures during ground-water flushing (Kueper, November 1997a, see Appendix O). A similar effect is seen in heterogeneous porous media due to the slow diffusion of VOCs back out of low-permeability lenses and strata, resulting in high, persistent concentrations of dissolved VOCs (Gorelick *et al.*, 1993). Thus, during long-term pump-and-treat, the time required to reach MCLs will be significantly greater than would be predicted based on ideal behavior in the absence of diffusion (Pankow and Cherry, 1996). Even areas downgradient of the NAPL zone, where significant matrix diffusion has occurred, may not be practicably remediable. Thus, the effects of matrix diffusion will be carefully considered, particularly with respect to the bedrock, in the Detailed TI Evaluation as part of the FS.

4.3.1.5 Solute-Transport Within Off-Site VOC Plumes

Solute transport within the off-site VOC plumes was evaluated by means of solute-transport calculations and a time-series evaluation. The purpose for performing solute-transport calculations is to help evaluate whether the observed extent of the overburden and/or bedrock VOC plumes associated with the SRSNE Site are consistent with advection and retardation, assuming a 40-year travel time. If the plumes appear to be more limited than would be expected based on solute-transport calculations, the interpretation may be derived that natural attenuation processes (biodegradation, abiotic decay, and/or dispersion) have stunted the growth of the plume(s). If an observed plume is found to be significantly less extensive than would be expected based on advection and retardation, the interpretation could be made that the plume has reached a steady-state configuration.

The results of the calculations for the SRSNE Site, presented below, suggest that the overburden and bedrock plumes are reasonably consistent with solute-transport calculation results, and that the plumes may still be advancing in the downgradient direction. The possibility also exists that the plumes could have established an approximately steady-state condition due to natural attenuation processes. However, as the results presented below neither support nor preclude the influence of natural attenuation processes on the plumes, a time-series evaluation of VOC concentrations at key wells in the Southington Well Field Property was also performed. and are discussed further in this section.

Description of Solute-Transport Calculations

The soil and bedrock physical characteristics that affect advection and retardation, which were quantified during the August 1996 to February 1997 RI field investigation, are summarized in the notes of Table 10. Table 10 also presents key parameters for the ground-water constituents of concern at the site, and summarizes the results of the solute-transport calculations. The evaluation presented herein is focussed on the estimated travel times for benzene and TCE, the two most prevalent compounds detected above regulatory criteria at the southern, downgradient periphery of the plumes. Solute-transport processes used in these calculations included advection (migration of dissolved chemicals due to the movement of ground water) and retardation (reduction in average chemical velocity due to the partial sorption of chemicals onto immobile soil particles and organic matter). Other factors such as dispersion and decay, however, can also affect plume migration. Longitudinal dispersion can result in a somewhat more rapid advance of the leading edge of the dissolved chemical plume, albeit at very low concentrations. Transverse dispersion tends to widen or thicken the plume, but reduces the chemical concentration along the central axis of the plume. Decay due to biodegradation, hydrolysis, or other factors would also reduce the chemical concentrations within the plume. Detailed solute-transport modeling would be required to account for all these factors. For the purpose of this relatively simple assessment, advection and retardation are assumed the most significant factors affecting plume velocity and travel time.

Advection

The advection rate was estimated for the on-site and off-site overburden soil and bedrock using representative values for hydraulic conductivity based on the SRSNE Site comprehensive ground-water database.

The average linear ground-water velocity (advection rate) in the overburden and bedrock were estimated as (after Freeze & Cherry, 1979):

$$v = Ki/n,$$

where: v = ground-water velocity;
K = hydraulic conductivity;
i = hydraulic gradient; and
n = porosity.

Based on the interpretation that the overburden hydraulic conductivity (K) differs markedly between the on-site and off-site areas, overburden solute-transport calculations were solved separately for these two areas. The on-site overburden area, with a representative hydraulic conductivity of approximately 2 feet per day, was assumed to extend from the center of the former SRSNE Site Operations Area to the location of the inferred hydraulic conductivity change in the northern portion of the Town of Southington Well Field, near the SRS series of wells. The off-site overburden area, with a representative hydraulic conductivity of approximately 200 feet per day, was assumed to extend from the location of the hydraulic conductivity change to Town Production Well No. 6. The hydraulic conductivity of the bedrock was assumed to be relatively uniform on a site-wide scale, and was approximated as the geometric mean bedrock value within the existing database (0.35 feet per day).

Hydraulic gradient (i) values were estimated for static conditions, without pumping in the Southington Well Field Property, and before the start up of the NTCRA 1 Overburden Ground-water Containment System

(ENSR, October 1994; ENSR, March 1995). Non-pumping conditions were also assumed in the Southington Well Field Property to provide a conservative result to the calculations. If the plumes was observed to be more limited than predicted by solute-transport calculations assuming non-pumping conditions, then the observed plumes would be even more stunted relative to the extent that would be expected during off-site pumping. The calculations assumed no NTCRA 1 pumping because a substantial portion of the dissolved-phase plume had migrated beyond the location of the NTCRA 1 Containment System prior to its start up in July 1995. Thus, the hydraulic effect of the NTCRA 1 system was considered irrelevant with respect to historical plume migration.

The porosity values for the on-site and off-site overburden soils were determined based on laboratory results from samples obtained during the RI. The porosity value used to estimate advective transport in the bedrock is the bedrock fracture porosity, or the fraction of the bulk volume of bedrock occupied by open fractures (6.8×10^{-3} percent). The bedrock fracture porosity was estimated based on the calculated bedrock fracture aperture and fracture spacing data, as measured based on bedrock packer test, core samples, and BIPS results (Table 6). The bedrock fracture porosity was estimated as $n_f = e/s$, where e is the mean fracture aperture and s is the mean fracture spacing. In this analysis, the effect of matrix diffusion is expected to dominate the retardation in the bedrock.

<u>Retardation</u>

The chemical constituent velocities (v_c) in overburden and bedrock were estimated as $v_c = v/R$, where v is the average linear ground-water (advective) velocity; and R is the chemical-specific retardation factor.

Retardation factors for the on-site and off-site overburden (R_{ovb}) were calculated as follows (Fetter, 1993):

$$R_{ovb} = 1 + (K_{oc})(f_{oc})\varrho_b / n,$$

where:
- K_{oc} = organic carbon-based partition coefficient;
- f_{oc} = fraction of organic carbon in soil;
- ϱ_b = dry soil bulk density; and
- n = soil porosity.

The soil parameters in the on-site and off-site areas were quantified based on laboratory analysis of soil samples obtained during the August 1996 to February 1997 RI field investigation. The foc values for the on-site and off-site soils are less than one percent, indicating that the retardation of VOCs may not be dominated by organic-based partitioning; rather, mineral surfaces may substantially influence the sorption of VOCs (Fetter, 1993). The sorption of VOCs to mineral surfaces is a function of surface area, and is primarily influenced by the presence of clay particles in soil. Soil samples obtained in the off-site area during the RI, however, indicated that the clay content ranged from approximately zero to 10 percent of the bulk volume. These data suggest that mineral sorption of VOCs may be limited off site. As an simplifying approximation, we assume that organic carbon, albeit limited, is the primary substrate for sorption of VOCs on site and off site.

The retardation factor for bedrock (R_{rock}) was estimated as (Kueper, August 1995):

$$R_{rock} = n_m / n_f,$$

where:
- n_m = bedrock matrix porosity; and
- n_f = bedrock fracture porosity.

Given the New Haven Arkose mean bedrock matrix porosity of 7.7 percent and fracture porosity of 6.8×10^{-5} (6.8×10^{-3} percent), the bedrock plume retardation due to matrix diffusion is estimated as approximately 1,100 (dimensionless). This result is consistent with the calculations presented by Kueper (November 1997a, see Appendix O), who estimated a plume retardation factor of 900 due to matrix diffusion.

The travel time for VOCs within on-site and off-site overburden ground water, or bedrock ground water, were estimated as:

$$t = x/v_c,$$

where: t = ground-water travel time;
x = distance; and
v_c = chemical constituent velocity.

Solute-Transport Calculation Results

The results of the solute-transport calculations are summarized in Table 10.

Overburden

As shown on Figures 50 and 51, benzene is the primary constituent comprising the off-site regulatory VOC plumes in the middle and deep overburden. The solute-transport calculation results suggest that the on-site travel time for benzene from a hypothetical release location in the center of the Operations Area to the hydraulic conductivity change in the northern portion of the Southington Well Field Property is approximately 21 years. The off-site travel time for dissolved benzene from the hydraulic conductivity change to Production Well No. 6 is estimated as approximately three years. Thus, the total time for benzene to travel from the Operations Area to Production Well No. 6 is estimated as 24 years during non-pumping conditions at Production Wells No. 4 and 6.

Given the estimated solute-transport rates for benzene in the overburden, the current extent of the benzene plumes in the middle and deep overburden correspond to approximately 23-year and 22-year travel times from the Operations Area, respectively. Given an approximately 40-year travel time available since the beginning of operations at the SRSNE Site, a benzene plume associated with the site would be expected to extend beyond Production Well No. 6 to the discharge point interpreted as the Quinnipiac River. These results suggest that the observed benzene plumes may be stunted to some degree due to natural attenuation processes (including biodegradation and dispersion).

As shown on Figures 50 and 51, TCE is a secondary constituent within the off-site regulatory VOC plumes in the middle and deep overburden. The calculation results suggest that the on-site travel time for TCE from a hypothetical release location in the center of the Operations Area to the hydraulic conductivity change in the northern portion of the Southington Well Field Property is approximately 34 years. The off-site travel time for dissolved TCE from the hydraulic conductivity change to Production Well No. 6 is estimated as approximately four years. Thus, the total time for TCE to travel from the Operations Area to Production Well No. 6 is estimated as approximately 38 years during non-pumping conditions at Production Wells No. 4 and 6. The extent of the TCE plumes in the middle and deep overburden correspond reasonably well to the distances that would be expected in a 38-year travel time based on advection and retardation (Figures 50 and 51), suggesting that the TCE in the overburden is advancing at a predictable pace.

The solute-transport results for the overburden plumes suggest that benzene migration may be slightly limited by natural attenuation processes. The observed TCE extent is reasonably consistent with the results of these travel time calculations, suggesting natural attenuation processes may not currently maintain the middle and deep overburden TCE plumes at steady state. Natural attenuation processes may significantly reduce VOC mass within the off-site aqueous plume, however, as discussed in detail in Section 4.3.1.6.

Bedrock

As shown on Figures 52 and 53, the primary constituents comprising the off-site regulatory VOC plumes in the bedrock are benzene and TCE. The calculation results summarized in Table 10 suggest that the time for benzene or TCE to travel from the Operations Area to Production Well No. 6 in bedrock is approximately 81 years. By linear interpolation, the currently observed benzene and TCE plumes in the shallow and deep bedrock correspond to approximately 68-year and 55-year travel times from the Operations Area (Figures 52 and 53, respectively). Thus, the bedrock VOC plumes appear to extend further than would be expected within the maximum 40-year travel time available for transport of VOCs associated with the SRSNE Site.

While these results suggest that another mechanism (e.g., longitudinal dispersion) may be increasing plume mobility in the bedrock, given the relatively order-of-magnitude accuracy of the parameters used in these calculations, these results are considered reasonably consistent with an assumed 40-year maximum travel time. Also, with the exception of the furthest downgradient shallow bedrock well that indicates a minor regulatory exceedance (well MW-127C), the greater mass of the shallow bedrock VOC plume extends to the vicinity of wells MW-704R and MW-204A, which (by interpolation) corresponds closely to an estimated travel time of 40 years.

The solute-transport results for the bedrock plumes are generally consistent with the approximately 40-year travel time available for VOC solute-transport via advection and retardation. These calculations do not provide a sufficient basis to conclude that natural attenuation processes are maintaining the bedrock VOC plume(s) at steady state. However, as discussed in Section 4.3.1.6 below, biologic and geochemical data from the site indicate that a substantial degree of degradation is occurring in the overburden and bedrock, which has limited the magnitudes of the concentrations detected within the off-site plumes.

Summary of Observed Concentration Trends Versus Time

Appendix Q presents a database output list of key VOC detections at wells in the Southington Well Field Property where several sampling rounds have been performed, which provide a basis to assess temporal concentration trends. Wells with sufficient sampling results to evaluate a trend (arbitrarily, at least four samples) were selected for this evaluation. The database was screened for the VOCs that generally define the leading edge of the VOC regulatory plumes, including, but not limited to, benzene, TCE, and vinyl chloride. The results of this evaluation were used to identify locations where concentrations have increased, decreased, or remained the same. The available historical data from the Southington Well Field Property, and associated apparent trends, are summarized below.

Well	Location	Unit	Samples	Time Range	Temporal Concentration Trend
CW-1-78	SWF	M	4	1981-1996	Decrease since 1982. (Increase before 1982.)
CW-3-78	SWF	S	4	1980-1996	Steady, few detects of the selected VOCs.
CW-4-78	SWF	D	4	1980-1996	Decrease before 1982.
MW-127C	SWF	R	5	1991-1996	Slight possible increase (TCA only).
TW-2	SWF	S	5	1980-1996	Decrease until 1994, then increase.
TW-5	SWF	S	6	1980-1996	Decrease (TCE, benzene) or variable (PCE)

Well	Location	Unit	Samples	Time Range	Temporal Concentration Trend
MW-2	CWF	O/R	4	1990-1996	Increase before 1994, then decrease.
MW-204A	CWF	R	4	1992-1996	Increase (TCE and PCE) and decrease (vinyl chloride).
MW-204B	CWF	D	4	1992-1996	Steady.
MW-204B	CWF	D	4	1992-1996	Steady.
MW-1	NWF	O/R	11	1982-1996	Decrease until 1990, then steady or slight increase.
MW-5	NWF	R	10	1982-1996	General increase since 1982 (benzene only).
MW-6	NWF	D	7	1982-1996	General increase since 1982 (benzene only).
MW-7	NWF	M	13	1982-1996	General increase since 1982 (benzene only).
MW-121A	NWF	R	5	1991-1996	Steady.
MW-121B	NWF	D	4	1991-1996	Slight possible increase (TCA only).
MW-121C	NWF	R	5	1991-1996	Steady.
SRS-3	NWF	D	5	1983-1996	Decrease.
TW-11	NWF	S	11	1980-1994	Variable, possible decrease (TCA, DCA).

Notes: CWF = central Well Field; NWF= north Well Field; SWF= south Well Field.
S, M, D = shallow, middle and deep overburden; O/R = overburden/bedrock interface; R = shallow rock.

These results suggest that several wells in the central and southern portions of the Southington Well Field Property have generally exhibited steady or decreasing trends throughout their monitoring history. These results may indicate that the southern extent of the plumes have attenuated back after extending beyond their natural steady-state limit. The interpreted, prior overextension of the plumes may have occurred during the use of Production Wells No. 4 and 6 prior to 1980.

However, the data trends in the northern portion of the Southington Well Field Property indicate generally steady or increasing concentration trends. These results suggest that natural attenuation processes may not be maintaining steady-state plume conditions in the northern portion of the Well Field. Geochemical and biologic data was acquired during the RI, however, indicate active biodegradation processes are mitigating the concentrations of dissolved VOCs within the plumes, as discussed below in Section 4.3.1.6.

If the delineated VOC plumes were to expand further downgradient, their maximum extent would be limited by the Quinnipiac River, which creates the ground-water divide in the vicinity of Curtiss Street. No current ground-water receptors exist in the area between the delineated plumes and this regional ground-water discharge point. To monitor any changes in the extent of the delineated regulatory VOC plumes between the completion of the RI and the issuance of the ROD, additional ground-water sampling will be performed at specific wells near the edges of the plumes, as described in Section 6 of this document and detailed in the proposed Interim Monitoring and Sampling Plan (see Appendix U). The data to be obtained during interim monitoring and sampling will indicate whether the leading edge of the plume(s) retract, advance, or remain the same up until the issuance of the ROD.

4.3.1.6 Evaluation of Natural Attenuation Processes, Indicator Parameters, and Products

During the comprehensive ground-water sampling round performed as part of the RI completion, BBL obtained biologic and geochemical parameters at several wells located along the general ground-water flow path from upgradient of the Operations Area at the P-8 well cluster, eastward through the probable NAPL zones in the overburden and bedrock, and southward into the Town Well Field Property (Tables 12 and 13). These data were then evaluated in detail with respect to biodegradation processes, to interpret the relative importance of biodegradation at mitigating VOC concentrations within the off-site plumes. The remainder of this section describes the results of this analysis in detail.

A screening method developed by the US Air Force Center for Environmental Excellence (USAF) was used to evaluate the potential for natural attenuation of dissolved chlorinated volatile organic compounds (CVOCs) in ground water (Wiedemeier *et al.*, September 1996; November 1996) (Table 13). The USAF evaluation process is summarized in Appendix R. The USAF screening method is a scoring process where points are awarded for various ground-water analytical data, and is based on the fact that natural attenuation processes manifest themselves as changes in ground-water geochemistry. Using the USAF scoring interpretation guidelines, scores less than five suggest inadequate evidence for biodegradation of CVOCs; scores from six to 14 suggest limited evidence for biodegradation of CVOCs; scores from 15 to 20 indicate adequate evidence for biodegradation of CVOCs; and scores greater than 20 indicate strong evidence of biodegradation of CVOCs. Based on ground-water analytical data, this scoring process was applied to 16 monitoring wells (9 overburden and 7 bedrock) along the interpreted flow path downgradient of the SRSNE Site. The results of this evaluation are presented in Table 13 and depicted in plan view on Figures 49 through 53. In addition, all of the USAF scores are summarized on Cross Section D-D', which was constructed along the interpreted downgradient flow path (Figure 20). As shown on Table 13, the USAF scores observed ranged from -1 to 27, with the lower scores associated with monitoring wells upgradient of the probable NAPL zone, or beyond the estimated extent of the regulatory VOC plume, and higher scores associated with monitoring wells located near and downgradient of the probable NAPL zone. Within the central mass of the VOC plume on the Operations Area and former Cianci Property, USAF scores ranged from 21 to 26 in the overburden and from 14 to 27 in the bedrock. Scores in the off-site plume area at the MW-704 cluster ranged from 16 to 26 within the depth interval of the regulatory plume (Figure 20). These results indicate that natural attenuation processes are robust within the regulatory plume associated with the SRSNE Site. Outside of the regulatory plume, including upgradient of the site, the USAF scores ranged from -1 to 6. The low scores observed outside of the plume do not indicate a lack of potential to degrade VOCs, only a lack of current activity due to limited VOCs.

Ground-water analytical data obtained at the site (Table 12; Appendix S) indicate that dissolved VOCs are being degraded to carbon dioxide (CO_2) and methane (CH_4) due to the presence of naturally occurring, biologically mediated oxidation reduction reactions, and that dissolved CVOCs are being dechlorinated in-situ due to the anaerobic conditions resulting from biodegradation of the aromatic VOCs. The data show that dissolved solvent compounds, such as PCE, TCE, and TCA, are undergoing complete dechlorination with byproducts consisting of ethene, ethane, and chloride. It is likely that, in addition to dechlorination, the more highly chlorinated CVOCs are also being cometabolically degraded during biodegradation of the ketones, alcohols, SVOCs, and aromatic VOCs. For example, toluene degrading organisms are known to produce the toluene-dioxygenase enzyme that has been shown to cometabolically oxidize TCE (Wackett and Gibson, 1988). The tendency for toluene to assist TCE degradation is currently being researched as a potential means to remediate ground-water containing dissolved TCE. Recent, full-scale field demonstration results showed that, by injecting toluene and oxygen into treatment wells, cometabolism by toluene-using microorganisms caused TCE concentrations to decline by 95 to 98 percent, and the resulting toluene concentrations were far below ground-water regulatory criteria (McCarty, September 1997). Furthermore, lesser chlorinated CVOCs, such as DCE (combined 1,1-DCE and 1,2-DCE isomers) and vinyl chloride, are also likely being metabolically degraded as a carbon source. As discussed below, these conclusions are supported by the following observations:

- A consortium of ground-water microorganisms is present in the ground-water system that is capable of utilizing both natural and anthropogenic carbon sources and creating reducing ground-water environments that facilitate dechlorination of most dissolved CVOCs.

- A series of complete oxidation-reduction processes is present in-situ associated with the currently existing hydrogeologic, geochemical, and microbiologic conditions of the ground-water system.

- The presence of intermediate breakdown products detected in ground water cannot be accounted for by either the operational history of the site or naturally occurring geochemical processes. That is, based on the NAPL chemical characteristics obtained at the site, vinyl chloride (VC), chloroethane, ethene, and ethane were not components of the NAPL and, with the exception of minor amounts of ethene and ethane detected upgradient of the operations area, do not occur naturally at the site.

Ground-Water Microorganisms

The presence, type, and status of indigenous subsurface microorganisms at the SRSNE Site were evaluated by analyzing ground-water samples from 16 overburden and bedrock monitoring wells for phospholipid fatty acids (PLFA). Wells selected for PLFA analyses were situated along an apparent ground-water flow path originating within the Operations Area upgradient of the probable NAPL zone, and extending across the former Cianci Property and through the Southington Well Field Property. Six well clusters, including overburden and bedrock wells, were selected upgradient from, near the middle of, and downgradient of the bedrock probable NAPL zone. The laboratory analyses were performed by Microbial Insights, Inc. (Knoxville, TN) and the analytical report is provided as Appendix T. Phospholipids are part of intact cell membranes and, therefore, identification and quantification of PLFA in ground-water samples provides information related to the biomass, community structure, and metabolic status of indigenous microbial populations (Guckert and White, 1986; White, 1988; and Findlay and Dobbs, 1993).

As shown in Appendix T, biomass ranged from 0.04 picomoles PLFA per milliliter of ground water (pMol/mL) to 32.95 pMol/mL. The PLFA results for overburden and bedrock monitoring wells are depicted graphically on Figures S-1 and S-2 (Appendix S). The maximum biomass concentration was detected at overburden monitoring well cluster MW-415 which is situated within the NAPL zone discussed in Section 4.3. The maximum biomass concentrations in bedrock ground water were detected in samples collected within the bedrock NAPL zone at monitoring wells MW-414 and P-6, respectively. A spatial correlation exists between the location of maximum biomass and the maximum ground-water VOC concentrations that strongly suggests the population of ground-water microorganisms in overburden and bedrock have grown in response to inputs of anthropogenic organic carbon associated with operations at the SRSNE Site. This correlation is corroborated by the nature of the microbial community structure, availability of nutrients in ground water, and the presence of VOC and metabolic byproducts as described below.

In terms of community structure, ground-water samples from overburden and bedrock deposits at the SRSNE Site were found to contain relatively diverse microbial populations composed primarily of gram-negative bacteria (Appendix T). Generally, gram-negative bacteria grow rapidly, adapt quickly to a variety of environments, and may utilize many carbon sources for food. PLFA biomarkers were detected in overburden and bedrock ground-water samples indicating the presence of a variety of sulfate- and iron-reducing bacteria, particularly Desulfobulbus, Desulfovibrio, and Desulfobacter (Appendix T). The PLFA biomarker for the bacteria Actinomycete was also detected in overburden and bedrock ground-water samples. Furthermore, the data show that the relative proportion of the PLFA biomarker for gram-positive bacteria (associated with a class of sulfate reducing bacteria) increases in overburden and bedrock ground-water samples near and downgradient of the NAPL zone. Similarly, the data show that the relative proportion of the PLFA biomarker for obligate anaerobic bacteria (another class of sulfate- and iron-reducing bacteria including Desulfovibrio) increases in overburden and bedrock ground-water samples near and downgradient of the NAPL zone. These observations indicate that a consortium of naturally occurring iron- and sulfate-reducing bacteria has been stimulated in response to inputs of anthropogenic organic carbon (ketones, alcohols, SVOCs and aromatic VOCs) associated with operations at the SRSNE Site.

In terms of metabolic status, the bedrock ground-water samples were found to contain the fastest growing microbial populations and the overburden ground water-samples were found to contain the slowest growing microbial populations. All of the overburden ground-water sampling locations indicated gram-negative microbial populations in a stationary phase of growth (slow growth) except one ground-water sampling location (MW-704D) which had a gram-negative microbial population in a log phase of growth (fast growth) (Appendix T). Three of the bedrock ground-water sampling locations (P-8A, P-1A, and P-6S) indicated gram-negative microbial populations in a stationary phase of growth and four of the bedrock ground-water sampling locations (MW-414S, MW-704R, MW-704DR, and MW-703DR) indicated the gram-negative populations were in a log phase of growth (Appendix T). This finding is reasonable and expected because stable, mature microbial communities (slow growing) would be developed in the near portions of the VOC plume soon after a spill or release event occurred, and fast growing, newer microbial communities would be developing in the distal portions of the VOC plume long after a spill or release event occurred.

Oxidation/Reduction Reactions

Upgradient ground water in overburden and bedrock deposits contains relatively high concentrations of dissolved oxygen, an abundance of alternate electron acceptors, a minor amount of naturally occurring organic carbon, and sufficient nutrients and environmental conditions for a variety of oxidation/reduction (redox) reactions to occur in-situ. As shown in Table 12, ground-water analytical results obtained from well cluster P-8 indicate that naturally occurring (unimpacted) ground water, upgradient of the probable NAPL zones, had dissolved oxygen (DO) concentrations ranging from 8 to 9 mg/L; a maximum nitrate concentration of 1.8 mg/L; ferric iron concentrations ranging from 1 to 7 mg/L; sulfate concentrations ranging from 22 to 2,320 mg/L; a maximum total organic carbon concentration of 1 mg/L; a maximum chloride concentration of 9 mg/L; and a maximum orthophosphate concentration of 0.2 mg/L. Also based on the ground-water analytical results from monitoring well cluster P-8, ground-water pH was circumneutral and ground-water oxidation-reduction potential ranged from 158 to 198 millivolts (mV) indicating the potential for aerobic microbiologic reactions to occur. The elevated sulfate concentration of 2,320 mg/L suggests a naturally occurring source of sulfate, such as the mineral gypsum, which is known to be present in bedrock in the region (see Section 3.1.2). Based on the site data, it appears that an aerobic oxidation-reduction reaction (aerobic respiration) is the predominant, naturally occurring redox reaction in upgradient ground water, by which ground-water microorganisms utilize DO as the terminal electron acceptor and naturally occurring organic carbon as the electron donor (substrate).

Ground-water geochemistry at the site changes, however, within the NAPL zone and dissolved VOC plume, as shown by depleted DO concentrations (anoxic conditions), negative ORP readings, and the presence of dissolved methane, indicating anaerobic bacteria have been stimulated due to the introduction of VOCs into the ground-water system (Table 12). Specific redox reactions occurring in ground water at the site can be deduced based on the presence and distribution of electron acceptors and metabolic byproducts in ground water near and downgradient of the NAPL zone and within the dissolved VOC plume. For example, the electron acceptor nitrate, which is present in upgradient ground water, is depleted to non-detectable quantities within and downgradient of the NAPL zone and VOC plume, indicating the presence of denitrification processes. Furthermore, manganese and iron reduction are occurring in ground water at the site as shown by the distribution of total and dissolved forms of manganese and iron in ground-water samples. For these redox reactions (manganese and iron reduction), the oxidized forms of manganese and iron can serve as electron acceptors and are represented in the site data as the difference between total and dissolved analytical results.

Oxidized and reduced forms of manganese and iron in ground water along the interpreted ground-water flow paths in overburden and bedrock monitoring wells are graphically depicted on S-3 through S-6 (Appendix S). As shown on Figures S-3 and S-4, the reduced form of manganese (dissolved manganese) is nearly 100 percent of total manganese detected at both overburden and bedrock monitoring wells sampled near the NAPL zone, indicating manganese reduction. Similarly, as shown in Figures S-5 and S-6, the reduced form of iron (dissolved iron) is nearly 100 percent of total iron detected at overburden monitoring wells sampled near and downgradient of the NAPL zone, and at bedrock monitoring wells sampled downgradient of the NAPL zone, indicating iron reduction. Additionally, sulfate reduction is occurring in ground water at the site as shown by the distribution of sulfate in ground-water samples.

For sulfate reduction, the oxidized form of sulfur (sulfate) can serve as an electron acceptor. Oxidized and reduced forms of sulfur (sulfate and sulfide, respectively) along the interpreted ground-water flow paths in overburden and bedrock monitoring wells are graphically depicted on Figures S-7 and S-8 (Appendix S). As shown on Figures S-7 and S-8, sulfate concentrations are depleted (compared to upgradient concentrations) downgradient of the NAPL zone in overburden monitoring wells, and are depleted at and downgradient of the NAPL zone in bedrock monitoring wells. The low concentrations of sulfide may be due to the presence of geochemical reactions in which sulfide (byproduct) reacts with dissolved iron (another byproduct) to form pyrite. Alternatively, the sulfide may react with carbon to form carbon disulfide, which was not detected in association with NAPL at the site, but has been detected in ground-water samples (Appendix P).

Generally, a zone of depleted DO, nitrate, manganese oxide (Mn IV, which is the difference between total and dissolved Mn), depleted ferric iron (Fe III, which is the difference between total and dissolved iron), and sulfate is observed in ground water coincident with a zone of increased dissolved VOC concentrations near and downgradient of the probable NAPL zones in overburden and bedrock based on the data from wells P-1B, MW-415, and MW-502 (overburden ground-water flow path) and P-1A, MW-414, and P-6 (bedrock ground-water flow path) (Table 12). This zone is also characterized by increased concentrations of metabolic byproducts, including dissolved manganese (Mn II), dissolved (ferrous) iron (Fe II), methane, and CVOC degradation products (VC, ethane, and ethene).

The redox reactions found to be occurring in site ground water, as discussed above, are biologically mediated reactions that consume organic matter and result in the degradation of anthropogenic carbon sources (e.g., VOCs). For example, using xylene as the electron donor (substrate) and the various electron acceptors discussed above, these redox reactions may be represented by the following mass balance equations:

- Aerobic Respiration: $10.5O_2 + C_8H_{10} \dashrightarrow 8CO_2 + 5H_20$
- Denitrification: $8.4NO_3^- + 8.4H^+ + C_8H_{10} \dashrightarrow 8CO_2 + 9.2H_20 + 4.2N_2$
- Iron Reduction: $42Fe(OH)_3 + 84H^+ + C_8H_{10} \dashrightarrow 8CO_2 + 110H_20 + 42Fe^{2+}$
- Sulfate Reduction: $5.25SO_4^{2-} + 7.88H^+ + C_8H_{10} \dashrightarrow 8CO_2 + 5H_20 + 2.63H_2S + 2.63HS-$
- Methanogenesis: $5.5H_20 + C_8H_{10} \dashrightarrow 2.75CO_2 + 5.25CH_4$

The occurrence of these reactions is confirmed not only by the presence of reactants and byproducts in ground-water samples collected at the site, but also by the spatial distribution of reactants and byproducts at the site. These data are shown in Table 12 and plotted over distance along the interpreted ground-water flow paths as seen in the figures presented in Appendix S. For each of these redox reactions, the dissolved VOCs (BTEX) serve as the electron donor (oxidized) and naturally occurring inorganic compounds serve as the electron acceptors (reduced).

Vertical spatial trends in electron acceptor depletion and metabolic byproduct production in ground water also show a spatial zonation. Figure S-9 (Appendix S) presents a vertical profile of electron acceptor and metabolic byproduct concentrations over depth at monitoring well cluster MW-704. As shown on Figure S-9, electron acceptor concentrations decrease with depth, metabolic byproduct concentrations increase with depth, and VOC and CVOC concentrations increase with depth.

CVOC Breakdown Products

The source of the dissolved VOCs and CVOCs consists of NAPL containing primarily PCE, TCE, TCA, DCE, DCA, BTEX, PCB, chloroform, styrene, 4-methyl-2-pentanone, and methylene chloride (Table 5). This NAPL composition can be considered a boundary condition in terms of possible degradation pathways. Other organic compounds, such as VC, chloroethane (CA), ethene, and ethane, which were not detected in the NAPL samples, have been detected in ground-water samples collected hydraulically downgradient of the probable NAPL zones and are interpreted as breakdown products (byproducts) of the dissolved NAPL component compounds. Vogel *et al.* (1987) showed that PCE, TCA, and their intermediate daughter product can be dechlorinated under reducing conditions according to the following pathways:

PCE ==> TCE ==> DCE ==> VC ==> Ethene
TCA ==> DCA ==> CA ==> Ethane
(or) ==> DCE ==> VC ==> Ethene

Production of the byproducts VC, CA, ethene, and ethane in overburden and bedrock ground water at the SRSNE Site is seen in the figures presented in Appendix S, which graphically depict ground-water analytical data over distance along the interpreted ground-water flow paths through the site and away from the probable NAPL zone. As shown on Figure S-1, VC and CA production in overburden ground water are demonstrated approximately 500 feet downgradient from the center of the Operations Area, and ethene and ethane production are demonstrated from 500 feet to 1,000 feet downgradient from the center of the Operations Area. As shown on Figure S-2, CA production in bedrock ground water is observed approximately 500 to 1,000 feet downgradient from the center of the Operations Area, and ethene and ethane production are demonstrated from approximately 1,000 to 1,500 feet downgradient from the center of the Operations Area. These observations show a zonation affect where VC and CA plumes have been produced within approximately 500 to 1,000 feet downgradient of the center of the Operations Area and ethene and ethane plumes have been produced within approximately 1,000 to 1,500 feet downgradient of the center of the Operations Area. These trends are also seen in Figures S-10 through S-13 (Appendix S) which show ethene and ethane concentrations in overburden and bedrock ground-water samples. As shown on Figures S-10 and S-11, in-situ dechlorination of dissolved PCE, TCE, DCE, and VC in both overburden and bedrock ground-water flow paths ultimately results in the production of dissolved ethene at the distal portions of the VOC plume. Similarly, as shown on Figures S-12 and S-13 (Appendix S), in-situ dechlorination of dissolved TCA, DCA, and CA in both overburden and bedrock ground-water flow paths ultimately results in the production of dissolved ethane at the distal portions of the VOC plume.

Further evidence of the production of CVOC breakdown products is shown by the distribution of chloride, ethene, and ethane concentrations in ground water. Production of chloride, ethene, and ethane in ground water is clearly seen in the site analytical data by comparing background ground-water concentrations to downgradient ground-water concentrations. The background ground-water chloride concentrations were less than or equal to approximately 9 mg/L in both overburden and bedrock ground water (P-8B and P-8A, respectively) and downgradient ground-water chloride concentrations were 211 mg/L in overburden (monitoring well MW-502) and 118 to 303 mg/L and bedrock ground water (wells MW-704R and MW-704DR, respectively) (Table 12). This increase in ground-water chloride concentrations from background to downgradient locations spans approximately two orders of magnitude. The background ground-water ethene concentrations were less than 0.1 ug/L in both overburden and bedrock ground water. In contrast, downgradient ground-water ethene concentrations were 11 ug/L in overburden and 1 to 5 ug/L bedrock ground water, respectively (same wells as above) (Table 12). This increase in ground-water ethene concentrations from background to downgradient locations spans approximately two orders of magnitude. The background ground-water ethane concentrations were less than 0.5 ug/L in both overburden and bedrock ground water. Downgradient ethane concentrations, however, were 282 ug/L in the overburden and 630 to 84 ug/L in the bedrock (same wells as above) (Table 12). This increase in ground-water ethane concentrations from background to downgradient locations spans approximately three orders of magnitude. These results demonstrate that ethene, ethane, and chloride are being produced in ground water between upgradient and downgradient monitoring wells in both overburden and bedrock.

In summary, results of the USAF screening method indicate strong evidence for natural attenuation of CVOCs in ground water at the site due to in-situ biodegradation processes (Table 13). This conclusion is firmly supported by:

- Ground-water biologic characterization data, which demonstrate a robust population of microorganisms in ground water at the site capable of utilizing anthropogenic carbon as a food source;
- A variety of redox processes occurring in ground water at and downgradient of the site;
- Abundant, non-chlorinated end-products of CVOC dehalogenation in ground water, indicating complete dehalogenation without any significant accumulation of intermediate degradation products (e.g., VC) at the leading edge of the plume; and
- The substantial decrease in VOC concentrations in the plume downgradient from the site.

The mixture of chlorinated and non-chlorinated dissolved organic compounds in ground water at and downgradient of the site is fortuitous, in that it results in relatively rapid degradation of the constituents of concern. A plume characterization technique developed by the USAF was used to assess the biodegradation potential within the plume based on the CVOC concentrations, biologically-available organic carbon in ground water, distribution and type of electron acceptors in ground water at and downgradient of the site (Wiedemeier *et al.*, 1996). The USAF method defines three types CVOC plumes:

- Type I Plume - Naturally occurring ground water microorganisms utilize anthropogenic carbon (VOCs) as a primary food source resulting in reducing ground water conditions and reductive dechlorination of CVOCs;
- Type II Plume - Naturally occurring ground water microorganisms utilize native carbon sources (e.g., humic acids) as a primary food source resulting in reducing ground water conditions and reductive dechlorination of CVOCs; and
- Type III Plume - Growth of naturally occurring ground water microorganisms is limited by an inadequate supply of biologically available carbon as a food source and aerobic conditions prevail.

Based on this characterization scheme, it appears that a majority of the CVOC-containing ground water at the SRSNE site exhibits Type I plume behavior, indicating the highest potential for degradation. This is demonstrated by ground-water analytical data which show that for the majority of the ground-water samples collected along the estimated ground-water flow path, CVOCs were detected concurrently with anthropogenic BTEX and other VOCs, which serve as a primary food source. In general, the wells that exhibited detectible CVOCs along the interpreted, generalized ground-water flow path (Cross Section D-D' shown on Figure 20) also contained non-chlorinated VOCs. At those sampling locations where CVOCs and VOCs were detected concurrently, biological oxidation of the anthropogenic VOCs consumes the naturally abundant electron acceptors and causes reducing conditions which are favorable for dechlorination of the chlorinated CVOCs.

Type II plume behavior likely occurs near the upgradient edge of the probable NAPL zone (at wells P-8A and MW-702DR) and at the furthest downgradient margin of the regulatory VOC plumes (e.g., well MW-127C, shown on Figure 20). At these locations, CVOCs were detected in the absence of non-chlorinated hydrocarbons. However, organic carbon was detected at wells in these areas, suggesting that native carbon sources may be utilized as a primary food source.

4.3.2 Surface-Water Quality

Figure 42 summarizes the results of two rounds of surface-water samples obtained by BBL on December 30, 1996 and July 8, 1997. During each of these sampling rounds, no VOCs were detected in the Quinnipiac River downstream of the former Cianci Property. VOCs were detected at low concentrations adjacent to the former Cianci Property during both rounds. In December 1996, TCE and vinyl chloride (1.0 ug/L) were detected at surface-water sampling locations SW-E and SW-F. In July 1997, 1,1-DCA (2 to 6 ug/L), 1,2-DCE (2 to 5 ug/L), acetone (0 to 6 ug/L), and chloromethane (0 to 3 ug/L) were detected at surface-water sampling locations SW-E through SW-F. These detections were observed immediately downgradient of the 30-inch buried culvert that passes from west to east under the former Cianci Property. The flow rate out of the culvert was higher than the flow into the culvert during each sampling event. Thus, the culvert appears to collect some shallow overburden ground water, particularly during periods of high water table conditions. The VOCs detected in the river are interpreted as partially resulting from the culvert discharge to the flood plain of the Quinnipiac River. Regardless, the absence of detectible VOCs downgradient of the former Cianci Property indicates no impacts to surface water caused by the ground-water VOC plumes related to the SRSNE Site.

4.4 Migration and Exposure Conceptual Model

This section presents the Migration and Exposure Conceptual Model for the chemical constituents of concern related to the SRSNE Site. In combination with the Hydrogeologic Conceptual Model included in Section 3.5, this section completes the Site Conceptual Model required for use in the TI Evaluation to be conducted as part of the FS. This Migration and Exposure Conceptual Model was prepared in accordance with the TI guidance document (USEPA, September 1993). The Migration and Exposure Conceptual Model for the site includes several sub-components, which fit into either of two general categories, including: contaminant source and release information; and contaminant distribution, transport, and fate parameters. This section summarizes the sub-components of these two categories, which are treated in substantially more detail in previous sections of this RI Report.

Contaminant Source and Release Information

Based on the volumes of liquid wastes handled and stored during the 35-year SRSNE facility operating history described in Section 2.3, the nature of the NAPL previously releases at the site can be qualitatively characterized as a large-volume, long-duration, continual release. According to USEPA Guidance on TI (USEPA, 1993), these release characteristics would render NAPL-zone remediation highly difficult.

Vadose-zone soil data indicate that solvent-related VOCs are relatively widespread throughout the Operations Area of the Site, likely indicating numerous, incidental releases over the operating history of the site. The interpreted primary entry points of waste solvent materials to the subsurface relate to former structures within and adjacent to the SRSNE Site Operations Area, including:

- the two unlined primary and secondary solvent sludge storage lagoons, which were excavated into unstratified fill materials;
- two drum handling and storage areas;
- the open-pit incinerator;
- several fuel and blend tanks;
- the septic tank and associated leach field;
- a subsurface pipe and catch basin that discharged materials from the former air stripper tower to the ditch along the railroad tracks; and
- the ditch(es) along the railroad tracks.

All of the structures listed above could have been entry points for NAPL. The solvent sludge storage lagoons, however, likely represent the primary mechanism for NAPL entry into the subsurface because of their considerable size and reported mode of usage. The largest lagoon was approximately 90 feet long, 40 feet wide, and 10 feet deep (approximately 270,000-gallon capacity) (CT DEP, October 1978). The exact quantity of waste material placed in the on-site lagoons can not be determined. Sludge was periodically removed from the lagoons; however, the lagoons sometimes were filled beyond their capacity with solvent sludge (CT DEP, October 1978). In addition, operations records from the site indicate that numerous smaller NAPL leaks occurred. The solvent burning and fuel blending operations at the site involved handling, storage, and transfer activities that resulted in leaks and spills to bare ground within the Operations Area. A USEPA RCRA inspection in February 1989 documented 75 cases of solvent releases from drums, tank trucks, hoses, and other solvent containers and transfer equipment during 1988 (USEPA, February, 1989).

The materials released at these locations likely included complex mixtures of solvents, fuels, paints, and alcohols, that resulted in a complex distribution of multi-component NAPLs in the subsurface. This interpretation is supported by the following suite of analytes detected in a multi-component LNAPL sample obtained at Operations Area overburden monitoring well P-1B, as presented in the initial RI Report (HNUS, May 1994):

- eight chlorinated and five aromatic hydrocarbon compounds;
- five SVOCs; and
- two PCB aroclors.

Previous investigations inferred the presence of DNAPL in the Operations Area overburden and in the overburden and bedrock beneath the former Cianci Property based on soil and ground-water quality data. However, during NTCRA 1 implementation, NAPLs were visually identified by BBL at six different locations, including three locations where DNAPL presence was confirmed by laboratory analysis:

- in May 1995 at NAPL collection well MWD-601, which was installed near the north end of the Containment Area upon the recognition of NAPL during the installation of a NTCRA 1 compliance piezometer. DNAPL presence was confirmed by chemical and physical analysis of NAPL samples (Table 5);

- in July 1995 during the abandonment of the OIS along the downgradient property line of the Operations Area. NAPL presence was confirmed at IW-23 based on chemical analysis of a NAPL/grout mixture (Table 5); NAPL was also evident at IW-12, IW-15, and IW-16 based on field screening of sediment from the base of the wells using hydrophobic dye (Sudan IV); and

- in August 1995 at extraction well RW-5 near the north end of the Containment Area following the start-up of the NTCRA 1 system, approximately 20 feet east of MWD-601. DNAPL presence was confirmed by chemical and physical analysis of NAPL samples (Table 5).

The physical properties of the MWD-601 and RW-5 DNAPLs were determined by laboratory analysis as:

- density 1.11 to 1.12 g/cm^3
- viscosity 1.23 to 1.3 cS; and
- interfacial tension with water 3.1 to 7.8 dynes/cm

These properties indicate that the DNAPL encountered at these wells would be relatively easy to mobilize. Indeed, following the start-up of the NTCRA 1 system, approximately 10 liters of DNAPL collected in the sump of well RW-5, and DNAPL accumulation at adjacent DNAPL collection well MWD-601diminished to a negligible rate. These results indicate changing DNAPL distribution in response to pumping, but also suggest that the DNAPL pool in this area was relatively small.

The following groups of analytes were detected in multi-component DNAPL samples obtained at NAPL collection well MW-601, OIS well IW-23, and extraction well RW-5 during NTCRA 1 implementation:

- eight chlorinated and five aromatic hydrocarbons;
- no SVOCs; and
- one PCB aroclor.

The compound groups detected in the DNAPL samples obtained during NTCRA 1 activities are similar to those detected in LNAPL at well P-1B, as discussed above, indicating that multi-component NAPLs at the site may behave as light or dense liquids depending on the relative ratios of NAPL components. In addition, the collection of DNAPL in the sump of well MWD-601 provided a unique opportunity to sample the ground-water from the same well, and empirically characterize the effective solubility of the DNAPL constituents at that location. Deep overburden monitoring well MWD-601 is located adjacent to shallow overburden monitoring well MWL-301 that historically contained either very low concentrations or no detectible dissolved VOCs. Given that these two well screens are vertically separated by only 10 feet, this juxtaposition tangibly demonstrates the complexity and irregularity of the NAPL distribution at the site. NAPL migration at the site can be assume to be complex, given the substantial heterogeneity of the overburden and fractured units. The identification of DNAPL at MWD-601 suggests that the presence and extent of NAPL were underestimated during previous investigations. This finding also illustrates that DNAPL may be more widely distributed than would be inferred based on ground-water quality data alone. Based on all of the available ground-water quality data from the RI Study Area, and using 1 percent of the empirical solubilities observed at well MWD-601 as a guideline to interpret NAPL proximity, Dr. Kueper and BBL prepared maps showing the probable and potential NAPL zone boundaries in the overburden and bedrock during the development of the RI Work Plan (BBL, November 1995). The potential NAPL zone was used as a safety factor around the probable NAPL zone due to the inherent complexity and uncertainly regarding NAPL migration. This exercise showed that NAPL would have been interpreted as absent at the MWD-601 location prior to its installation. Also, while the NAPL zone delineation in the RI Work Plan was considered reasonably complete, subsequent data collected from the site have once again shown that NAPL can be encountered outside of a NAPL zone interpreted based on comparison to effective VOC solubility limits.

In spite of the effort to delineate the NAPL zone at the site in the RI Work Plan, BBL visually identified NAPL and confirmed its presence by laboratory analysis at a deep bedrock well (MW-705DR) situated outside of the potential bedrock NAPL zone interpreted in the RI Work Plan. This result tangibly demonstrates the difficulty of NAPL zone delineation, and justifies the use of a safety factor in delineating NAPL associated with the SRSNE Site, as discussed in detail below. The following groups of analytes were detected in multi-component DNAPL sample and a ground-water sample obtained at well MW-705DR (Table 5):

- seven chlorinated and five aromatic hydrocarbons; and

- three ketones.

The physical properties of the MW-705DR DNAPL were determined by laboratory analysis as:

- density 1.23 g/cm^3
- viscosity 0.993 cS; and
- interfacial tension with water 9.0 dynes/cm

During the completion of the RI, NAPL was also observed at shallow bedrock piezometers CPZ-7R and CPZ-9R.

<u>Probable and Potential NAPL-Zone Boundaries</u>

The technical challenges to remediating contaminated ground water include many complex factors related to site hydrogeology and chemistry. One of the most difficult of these challenges is the problem presented by DNAPLs. A recent EPA study indicates that DNAPLs may be present at up to 60 percent of NPL sites, are often very difficult to locate and remove from the subsurface environment, and may continue to contaminate ground water for many hundreds of years despite best efforts to remedies them. The prevalence and intractability of DNAPL contamination are among the principal reasons the TI guidance document was developed by USEPA (USEPA, September 1993).

Given the field observations and laboratory confirmation of DNAPL and LNAPL in the overburden in the Operations Area and the Containment Area during NTCRA 1, and the demonstrated presence of DNAPL within the deep bedrock under the former Cianci Property during the completion of the RI, ground-water restoration within the NAPL zone can be considered technically impracticable. To support the TI Evaluation, which will be performed during the FS, the distribution of NAPL in the subsurface has been better refined. The NAPL distribution has been evaluated at two levels of estimated NAPL likelihood: 1) the *probable NAPL zone*, which was delineated based on direct observations of NAPL, NAPL sampling and laboratory analysis, ground-water quality data indicating aqueous VOCs in excess of 10 percent of their effective solubility, soil quality data indicating aqueous VOCs in excess of 100 percent of their effective solubility, ground-water alcohols detections, site history and usage, and anomalous plume configuration; and 2) the *potential NAPL zone*, which was delineated based on ground-water quality data indicating aqueous VOCs in excess of one percent of their effective solubility, soil quality data indicating aqueous VOCs in excess of 10 percent of their effective solubility, and anomalous plume configuration.

While the *probable NAPL zone* indicates where NAPL is either likely or confirmed, NAPL migration on a small scale is expected to be highly irregular, erratic, and extremely difficult to predict accurately due to small-scale permeability variations in overburden and bedrock. Based on these considerations, Dr. Kueper and BBL estimated the *potential NAPL zone* in the overburden and bedrock to provide a second level of delineation for the NAPL zones in overburden and bedrock. The potential NAPL zone represents a safety factor with respect to NAPL-zone delineation. Within the potential NAPL zone, ground-water restoration can be presumed to be technically impracticable due to the immiscible nature of the NAPL, the relatively low hydraulic conductivity of the overburden and bedrock formations, the diffusion of constituent mass into relatively impermeable zones, the heterogeneity of the geologic media, and other factors discussed below.

The depth of the potential NAPL zone was not investigated directly during the RI due to the risk of mobilizing NAPL during drilling and contaminating the deep bedrock, which may not contain any VOCs. Also the depth of the NAPL zone in the bedrock does not warrant detailed delineation because the VOC plume associated with the bedrock NAPL zone is discharging upward into the overburden. Based on the three-dimensional distribution of dissolved VOCs the vertical ground-water flow directions, it appears that the NAPL zone may extend to a depth on the order of 200 feet below grade within the bedrock probable NAPL Zone

Contaminant Distribution, Transport and Fate Parameters

In general, the source of the dissolved-phase plume associated with the site is the NAPL zone. The VOC mass transport directions within the dissolved-phase plume are controlled mainly by ground-water flow directions. The NAPL source area may contain either DNAPL or LNAPL, depending on the ratios of specific compounds in the NAPL and their relative densities with respect to water. Chlorinated and aromatic hydrocarbons, ketones, furans, and alcohols have been detected at relatively high concentrations (tens to hundreds of ppm) within the NAPL zone, indicating partial dissolution of the NAPL.

The potential extent of the off-site dissolved-phase VOC associated with the SRSNE Site can be partly constrained by identifying the ground-water divides, where flow either converges or diverges, within the RI Study Area. Additional constraints can be placed on the potential extent of the off-site plume based on the interaction between the dissolved constituents and the geologic media, including the effects of dispersion, retardation, biogenic degradation/transformation, and diffusion into low-permeability zones. In particular, constituent retardation is controlled by the hydrophobicity of the constituent; the organic carbon content, porosity, and bulk density; and, in the bedrock, the molecular diffusion of constituents into the unfractured blocks of rock. These factors would be expected to limit the extent of the plume emanating from the NAPL zone and would limit the distance to which the detectible VOC plume could have migrated within the 40-year time frame since the SRSNE facility began operations. Solute transport calculations using site-derived physical parameters for the soil and bedrock, which are summarized on Table 10, indicate the literature-reported degradation half-lives and site-specific retardation factors for the ground-water constituents of concern, including the following key constituents detected within the downgradient regulatory plume:

- benzene retardation 2.65 to 2.83 in the overburden, and 1,100 in the bedrock; and
- TCE retardation 4.19 to 4.56 in the overburden, and 1,100 in the bedrock.

As implied by these retardation factors, molecular diffusion into the unfractured bedrock matrix is particularly important to plume migration and the evaluation of ground-water restoration practicability in bedrock. The steady-state retardation of a constituent plume due to matrix diffusion was approximated by the ratio of the bedrock matrix porosity to the bedrock fracture porosity, both of which were quantified during the completion of the RI (Kueper, August 1995). The influence of retardation due to matrix diffusion in fractured porous media can be even greater than in granular aquifers (Pankow and Cherry, 1996). Similarly, diffusion from the higher permeability zones to low-permeability lenses and strata also occurs in the overburden, contributing to the overall retardation of the plume (Gorelick *et al.*, 1993).

Diffusion into low-permeability zones (such as the bedrock matrix) can also influence the fate of NAPL in the subsurface. Diffusion of NAPL constituents into low-permeability zones results in a concentration gradient away from NAPL bodies, allowing NAPL dissolution into the matrix as dissolved and sorbed constituent mass. This process continues until the matrix storage capacity has been reached or the NAPL body has been completely dissolved away, whichever occurs first. NAPL dissolution and diffusion into the bedrock matrix can result in complete disappearance of TCE or PCE DNAPL within days to decades in a fractured sandstone (Pankow and Cherry, 1996).

Given the retardation factors presented above and the hydraulic conductivity, porosity, and hydraulic gradient data from the site, the constituent-of-concern solute velocities are calculated as shown on Table 10. For the key VOCs within the off-site plume, the solute velocities can be summarized as follows:

- Benzene velocity in the overburden 0.06 (on-site) to 1.09 (downgradient) feet/day;

- Benzene velocity in the bedrock 0.037 feet/day;

- TCE velocity in the overburden 0.04 (on-site) to 0.73 (downgradient) feet/day; and

- TCE velocity in the bedrock 0.037 feet/day.

The regulatory plumes in each of the five monitored hydrostratigraphic zones (shallow, middle and deep overburden; shallow and deep bedrock) have been delineated, as presented on Figures 49 through 53. An evaluation of the biologic and geochemical characteristics of the plume indicate that natural attenuation processes are highly active in transforming and/or reducing VOC mass at the site and within the downgradient VOC plume. Based on the USAF's method for assessing natural attenuation of dissolved chlorinated organics, the available data indicate "adequate" to "strong" evidence that these compounds area being naturally degraded. Furthermore, their degradation appears to be co-metabolically linked with the degradation of other non-chlorinated materials within the plume, such as aromatics, ketones, and alcohols. The degradation rates do not appear to be sufficient to preclude plume advance in the northern portion of the Town of Southington Well Field, however, as historical concentration trends in this area indicate either steady or increasing concentrations. In the south portion of the Well Field, north of the Quinnipiac River, concentrations are either steady or decreasing. However, the available data are not sufficient to reliably assess the temporal trends of plumes related to VOC sources other than the SRSNE Site.

The total subsurface mass of VOCs associated with the SRSNE Site, including NAPL, dissolved, sorbed, and vapor (in the vadose zone) phases, is estimated as between 0.385 and 4.13 million kg, with a mean estimate of 2.25 million kg (see Appendix M, and detailed discussion below in Section 5). Assuming a representative NAPL density of approximately 1.1 g/cm^3, the mean total combined VOC mass in all phases equates to a NAPL release of approximately 541,000 gallons (range of 92,100 to 991,000 gallons). While these numbers may appear relatively large, the total volume of solvent wastes processed at the site was in excess of 41 million gallons, and may have been as high as 180 million gallons (ATSDR, July 1992). The total estimated release of NAPL, therefore, represents approximately 1.3 percent (range of 0.2 to 2.4 percent) of the minimum estimated volume of waste liquids processed at the site.

Of the total estimated subsurface VOC mass, approximately 97.7 percent is still in the NAPL phase, and approximately 2.3 percent has solubilized and converted into the dissolved, sorbed, and vapor phases. Of the total estimated subsurface VOC mass, approximately 0.15 percent is in the vadose zone, 96.6 percent is in the saturated overburden, and 3.2 percent is in the bedrock.

<u>Exposure-Based Risk</u>

Baseline human health and ecological risk assessments were presented in the initial RI Report (HNUS, May 1994). Several COCs were identified with respect to Human Health Risk in the study area ground water, shallow soil, surface water, and sediment. Average total cancer risks and average total hazard indices (non-carcinogenic risk factors) posed by potential ingestion of the study area ground water were found to exceed USEPA target levels. The highest calculated ground-water ingestion risks relate to the Operations Area/former Cianci Property and the area immediately east of the Quinnipiac River downgradient of the Operations Area. As described by HNUS (May 1994), no current ground-water receptors exist in the areas downgradient and cross-gradient (immediately north) of the SRSNE Site, where the calculated ground-water ingestion risks exceeded target levels. Long-term risks relating to off-site ground-water quality will be managed through a final remedy for the portion of the regulatory VOC plume that extends beyond the TI zone.

The Baseline Risk Assessment evaluated potential soil exposure risks based on the following assumed exposure pathways: 1) incidental ingestion; 2) dermal contact; and/or 3) inhalation of fugitive dusts. The only calculated Human Health Risk that exceeded USEPA acceptable levels for dermal contact with soil was related to the Operations Area and former Cianci Property surface soils.

Given these considerations and the fact that the calculation in question only marginally exceeded USEPA target levels (2.5×10^{-4} rather than 1.0×10^{-4}), the surface soils at the Operations Area and Cianci Properties do not appear to pose an unacceptable risk under any exposure scenario evaluated in the Baseline Risk Assessment. However, institutional controls have been implemented to limit trespassers on the Operations Area and former Cianci Property, including the installation of fencing around the northern, western, and southern boundaries of the former Cianci Property and the repair of the fence surrounding the Operations Area during NTCRA 1 construction activities. In addition, the existing pavement within the Operations Area prevents direct exposure to soil. The SRSNE PRP Group will also cap the Operations Area to further limit exposure to surface soils at the site under NTCRA 2.

The total cancer risks calculated for accidental ingestion and dermal contact with study area surface waters and sediment as presented in the Baseline Risk Assessment (HNUS, May 1994) do not exceed acceptable levels.

According to HNUS, several COCs in the study area may pose adverse effects to ecological receptors. The ecological risk due to soil contaminants is associated exclusively within the Operations Area and the former Cianci Property.

The FS will identify Remedial Action Objectives using USEPA's Baseline Risk Assessment.

The Site Conceptual Model discussed above provides a general framework for understanding present site conditions, including several factors that render the SRSNE Site vicinity appropriate for TI consideration. Section 5 below presents in detail the TI data that will be used in the TI Evaluation during the FS, in particular the VOC mass distribution estimates summarized in the Migration and Exposure Conceptual Model presented above.

Summary of Section 4

- The VOC plumes associated with the SRSNE Site extend into the Town of Southington Well Field Property, but do not extend to the locations of Town Production Wells No. 4 or 6, which are inactive. Several other VOC sources (unrelated to the SRSNE Site) are evident in the RI Study Area, some of which are situated closer to dormant Production Wells No. 4 and 6. The ground-water VOC plume associated with the SRSNE Site has been delineated in the shallow, middle, and deep overburden, and the shallow and deep bedrock. To simplify the analysis of VOC plumes related to the site, which processed numerous types of organic liquid wastes, plumes have been delineated on the basis of applicable ground-water regulatory criteria (rather than concentration contours for specific compounds), the potential extent of NAPL sources, and fundamental ground-water hydraulics and solute-transport principles. The ground-water quality database was used to identify wells that exhibited one or more exceedences of ground-water regulatory criteria. The locations of these wells were used to define a "regulatory plume" in each of the five monitored zones.

- Two private water-supply wells are located immediately upgradient (north) of the site, near at the edge of the VOC plumes associated with the SRSNE Site. One of the two private wells in question has contained VOCs in excess of ground-water regulatory criteria, and the CT DEP supplies that property owner with bottled water. The other well in question has historically indicated low concentrations of VOCs below applicable ground-water regulatory criteria (HNUS, July 1994). However, as an additional precaution, the SRSNE PRP Group is taking action to provide municipal water to these two properties. All other water-supply wells in the area around the site, including Town of Southington Production Wells No. 4 and 6, are outside of the regulatory VOC plumes attributable to the SRSNE Site.

- The Baseline Risk Assessment completed by HNUS (May 1994) identified that the potential risks associated with the ingestion of the study area ground water exceed USEPA target levels. The highest calculated ground-water ingestion risks relate to the Operations Area/former Cianci Property and the area immediately east of the Quinnipiac River downgradient of the Operations Area. As described by HNUS (May 1994), no current ground-water receptors exist in the areas downgradient and cross-gradient (immediately north) of the SRSNE Site, where the calculated ground-water ingestion risks exceeded target levels. Long-term risks relating to off-site ground-water quality will be managed through a final remedy for the portion of the regulatory VOC plume that extends beyond the TI zone.

- The probable and potential NAPL zones have been delineated in the overburden and bedrock in consort with Bernard Kueper, Ph.D., P. Eng. The potential overburden and bedrock NAPL zones cover approximately 12.4 and 14.2 acres, respectively, and were delineated on the basis of VOC effective solubility calculations for soil and ground-water matrices, site history and usage, and the relationships between the configuration of the VOC plumes and hydraulic gradients at the site.

- NAPL thickness measurements at wells and piezometers indicated measurable LNAPL at only one overburden well, signifying a limited distribution of potentially recoverable LNAPL. Free-phase, dense NAPL (DNAPL) was observed at four overburden and three bedrock wells and piezometers in the Operations Area and the (downgradient) former Cianci Property. Approximately 20 liters of DNAPL were collected as part of the NTCRA 1 activities, but the current DNAPL collection rate by the NTCRA 1 system is negligible. The exact distribution of NAPLs in the heterogeneous overburden and the fractured bedrock is sporadic and unpredictable. The NAPL is present as both disconnected blobs and ganglia of organic liquid referred to as residual, and in larger (potentially mobile) accumulations referred to as pools.

- Vadose-zone solute transport (VLEACH modeling) results and VOC mass estimates indicate that vadose-zone soil remediation would not significantly reduce the dissolved VOC mass flux from the Operations Area. The overall contribution of VOCs to the saturated zone from the vadose zone in the Operations Area is negligible. The contribution of VOC leaching from the vadose zone accounts for approximately 7.4 percent of the total trichloroethene (TCE) mass flux within the saturated zone in the Operations Area. The net flux for ethylbenzene was from the saturated zone to the vadose zone due to diffusion from the water table. The remainder of the mass flux in the saturated zone in the Operations Area is attributed to NAPL solubilization and, potentially, VOC desorption from saturated soil. The total VOC mass in the vadose zone represents only 0.15 percent of the total combined subsurface VOC mass associated with the SRSNE Site.

- The distribution of VOCs in the vadose zone correlates closely with the Operations Area infrastructure where NAPL was stored and handled, including the primary and secondary solvent sludge storage lagoons, open-pit incinerator, leach field, and drum storage areas.

- The Baseline Risk Assessment (HNUS, May 1994) evaluated potential soil exposure risks based on the following assumed exposure pathways: 1) incidental ingestion; 2) dermal contact; and/or 3) inhalation of fugitive dusts. The only calculated Human Health Risk that exceeded USEPA acceptable levels for dermal contact with soil was related to the Operations Area and former Cianci Property surface soils. The existing pavement within the Operations Area prevents direct exposure to soil. The SRSNE PRP Group will also cap the Operations Area to further limit exposure to surface soils at the site under NTCRA 2.

- Natural attenuation of chlorinated organics in ground water was assessed based using the United States (US) Air Force method (Wiedemeier et al., September 1996; November 1996). The geochemical parameters indicate "adequate evidence" (rank between 15 and 20) to "strong evidence" (rank greater than 20) for biodegradation of chlorinated organics at the majority of the locations within the ground-water regulatory plume(s) where natural attenuation parameters were characterized. A detailed review of biologic and geochemical ground-water parameters and VOC degradation products confirms robust, active biodegradation within the probable NAPL zones and within the majority of the off-site, regulatory VOC plumes in overburden and bedrock. In general, VOC concentrations decline by approximately three orders of magnitude within a distance of 500 feet downgradient of the site. Nevertheless, temporal VOC concentration trends suggest concentrations may be increasing in the northern portion of the Town Well Field Property, immediately downgradient of the NAPL zones.

- The VOC plumes related to the SRSNE Site have resulted in little or no impact to surface-water quality in the Quinnipiac River. Surface-water analytical data indicate detectible VOCs at the inlet and outlet of the underground, 30-inch culvert that crosses beneath the former Cianci Property. Surface water samples from the Quinnipiac River indicated no detectible VOCs upstream of the culvert on December 30, 1997. Low concentrations of VOCs were detected upstream of the culvert on July 8, 1997. Immediately downstream of the culvert outlet, low concentrations of VOCs were detected in the river during both of these sampling events, with concentrations decreasing to non-detectible within approximately 500 feet downstream from the culvert.

- A graphical comparison between low-flow and traditional ground-water purging and sampling results for VOCs indicated similar results from both two methods. The majority of the data indicated slightly higher VOC concentrations detected in the traditional samples, and lower VOC concentrations detected in the low-flow samples, suggesting that traditional sampling is more conservative with respect to VOC plume delineation.

5. Technical Impracticability Data Summary

This section presents the results of calculations regarding the mass of VOCs and presents an overview of the appropriateness of a Technical Impracticability Waiver for the site. Dissolved mass calculations have been performed based on observed concentrations of VOCs in overburden and bedrock monitoring wells and piezometers. Sorbed mass estimates have been performed assuming equilibrium partitioning assumptions using geotechnical and geochemical parameters quantified during the completion of the RI. NAPL mass has been estimated using a range of bulk retention capacity for overburden NAPL zone, and an estimated bulk retention capacity for the bedrock NAPL zone. Appendix M presents the contour maps and database output tables of the VOC mass in the various phases and hydrostratigraphic zones, and a table summarizing the low-range, high-range, and mean estimates for the VOC mass distribution at the site.

Other aspects of site conditions considered directly relevant to future TI Evaluation have already been discussed in detail in previous sections, including:

- The presence of a large volume of NAPLs in the overburden and bedrock formations (Sections 4.2 and 5);
- The presence of NAPL at a depth of at least 100 feet below grade (60 feet into bedrock), and potentially as deep as 200 feet or more below grade (160 feet into bedrock) (Section 4.2);
- The relatively large extent of the overburden and bedrock potential NAPL zones, which cover approximately 12.4 and 14.2 acres, respectively (Section 4.2.2);
- The small-scale complexity and heterogeneity of the overburden deposits within the overburden NAPL zone, including silt, sand, and gravel strata with a variety of dip angles and hydraulic conductivity values ranging by several orders of magnitude, and pinch out within a few feet. These factors will significantly limit the effectiveness of in-situ flushing technologies (Sections 3.2.1 and 3.4.2);
- The low to moderate mean hydraulic conductivity of the soils within the overburden NAPL zone (Section 3.4.2);
- The bedrock fracture and matrix characteristics, which indicate that the bedrock hydraulic conductivity is extremely heterogeneous on a minute scale, and that the matrix has a significant storage capacity for VOCs, which will slowly diffuse back out of the matrix and will serve as a long-term VOC source to ground water (Sections 3.2.2 and 4.3.1.4); and
- The low mean hydraulic conductivity of the bedrock (Section 3.4.2).

These factors will be considered as part of the TI Evaluation, which will be submitted as part of the FS Report. The purpose of this section, however, is to estimate the relative magnitude of the VOC presence in the subsurface in the vicinity of the SRSNE Site in terms of the VOC mass and the equivalent volume of NAPL. The technical basis for the VOC mass estimates was described by Kueper (August 1997, see Appendix O), and is presented below.

<u>Technical Basis for VOC Mass Estimates</u>

<u>1) Mass of chemical component dissolved in ground water</u>

The mass of a given chemical component dissolved in ground water can be estimated using:

$$M_{A_i} = \int C_i \phi_{w_i} dV_i \qquad i=1,n$$

where M_{Ai} is the mass of the component dissolved in ground water within sub-area *i*, *n* is the total number of sub areas, C_i is the volume-averaged concentration of the component in ground water within sub-area *i*, ϕ_{wi} is the water-filled porosity of the medium within sub-area *i*, and V_i is the volume of the sub-area. This expression is valid for both porous and fractured media, under either saturated or unsaturated conditions.

2) Mass of chemical component sorbed to aquifer solids

The mass of a given chemical component sorbed to the soil or rock matrix can be estimated using:

$$M_{S_i} = \int C_i K_{d_i} \rho_{b_i} dV_i \qquad i=1,n$$

where M_{Si} is the mass of sorbed chemical component within sub-area *i*, *n* is the number of sub areas, C_i is the volume-averaged concentration of the component in ground water within sub-area *i*, K_d is the soil-water distribution coefficient within sub-area *i*, ρ_{bi} is the dry bulk density of the medium within sub-area *i*, and V_i is the volume of the sub-area. This expression assumes equilibrium partitioning between the aqueous and solid phases. The distribution coefficient, K_d, is often estimated using $K_d = K_{oc} f_{oc}$ where K_{oc} is the organic-carbon based partition coefficient, and f_{oc} is the fraction of organic carbon present in the porous medium (Pankow and Cherry, 1996).

3) Mass of chemical components present as vapors in the unsaturated zone

The mass of a given chemical component present as vapors in the unsaturated zone can be estimated using:

$$M_{V_i} = \int C_i H \phi_{a_i} dV_i \qquad i=1,n$$

where M_{Vi} is the mass of vapor-phase chemical component within sub-area *i*, *n* is the number of sub areas, C_i is the volume-averaged aqueous concentration of contaminant within sub-area *i*, *H* is the dimensionless Henry's constant for the component, ϕ_{ai} is the air-filled porosity, and V_i is the volume of sub-area *i*. The above expression assumes equilibrium partitioning between the aqueous and air phases.

4) NAPL Mass

The mass of NAPL in the subsurface can be estimated using:

$$M_{N_i} = R_i V_i \rho_n$$

where M_{Ni} is the mass of NAPL present within sub-area *i*, R_i is the bulk retention capacity of the medium within sub-area *i*, V_i is the total volume of medium containing NAPL, ρ_n is the chemical component mass density of the NAPL, within sub-area *i*. It is important to recognize that V_i includes lenses, laminations, and fractures void of NAPL as well as those containing NAPL within the overall volume of subsurface impacted by NAPL within the sub-area. For NAPL in overburden deposits, R_i typically ranges between 0.25 percent and 3 percent (Poulsen and Kueper 1992, WCGR 1996). For NAPL in fractured media, R_i depends on the fracture aperture and spacing characteristics, which have been quantified at the SRSNE Site during the completion of the RI. The estimated value of R_i in the New Haven Arkose is 4.1×10^{-3} percent (Kueper, pers. com. with M.J. Gefell, September 1997).

Application of VOC Mass Estimation Principles to SRSNE Site Data

To evaluate the subsurface distribution of VOCs related to the SRSNE Site, BBL used the ground-water and soil analytical database, standard soil-water (or rock-water) partitioning equations, and estimated NAPL bulk retention factors. The VOC mass distribution was evaluated for the aqueous, sorbed, vapor (in the vadose zone only) and NAPL phases. BBL developed a range of total VOC mass estimates for the vadose zone, saturated overburden (shallow, middle and deep), and saturated bedrock (shallow and deep) zones. The general process involved using the soil and ground-water analytical database to split the soil and ground-water VOC data into respective hydrostratigraphic zone, calculate equilibrium aqueous concentrations for the soil VOC concentrations, calculate the equilibrium VOC concentrations sorbed within the overburden or bedrock, and contour the data to depict the distribution of:

- total VOC concentrations in the vadose zone soil;
- total dissolved VOC concentrations in each overburden and bedrock ground-water zone; and
- total sorbed VOC concentrations in each saturated overburden and bedrock ground-water zone; sorbed VOC concentrations compound in the saturated overburden and bedrock were calculated and contoured based on measured aqueous concentrations.

The VOC mass distribution in the these zones was estimated by: 1) determining the area between adjacent total VOC concentration contours; 2) multiplying the area between contours by the estimated vertical thickness of the zone; 3) multiplying the resultant total volume by the bulk density (for sorbed concentrations) or the porosity (for aqueous concentrations); and 4) multiplying the resultant soil or bedrock mass or aqueous volume by the geometric mean sorbed (mg/kg), aqueous (mg/L), or (for vadose zone soil) combined (mg/kg)VOC concentration for the selected pair of adjacent contours. Within the highest concentration logarithmic contour, the representative concentration was assumed to be the geometric mean of the contour and the highest concentration data point inside the contour.

Because of the extensive distribution of soil and ground-water sampling data points and the availability of site-specific data for the overburden and bedrock partitioning parameters (e.g., porosity, bulk density f_{oc}), the calculations of dissolved and sorbed VOC mass are considered relatively reliable. Therefore, these parameters were not varied as part of the development of low- and high-range VOC mass estimates for the vadose-zone total VOC mass (all phases) or the saturated overburden dissolved and sorbed VOC mass. In the bedrock, however, this process provides a high-range estimate of the dissolved and sorbed VOC mass, based on the maximum storage capacity of the bedrock. The resulting high-range estimate for the bedrock assumes that the entire storage capacity of the bedrock (matrix porosity) is at chemical equilibrium with the ground-water samples obtained from monitoring wells and piezometers, which more likely characterize the ground-water within the bedrock fractures. The low-end estimate for the combined dissolved and sorbed bedrock VOC mass was calculated as the product of: 1) the mean concentration of the empirical total VOC concentrations from bedrock matrix samples (0.655 mg/kg) obtained at the site; 2) the total area of the bedrock VOC plume above 1 mg/L; 3) the total thickness of the shallow and deep bedrock (100 feet); and 4) the mean matrix porosity (0.077).

The NAPL volume in the saturated overburden and bedrock were evaluated based on the total estimated volume of the overburden and bedrock probable NAPL zones, and representative bulk retention capacity estimates. For the saturated overburden, the bulk retention capacity was assumed to range from approximately 0.25 percent (low-range) to 3.0 percent (high-range) of the total volume of the probable overburden NAPL zone (Kueper, pers. com. with M.J. Gefell, September 1997). This range is consistent with the range of bulk retention capacity values reported in the literature for a variety of NAPL compositions in porous media (Cohen and Mercer, 1993; Pankow and Cherry, 1996). Based on the mean bedrock fracture aperture and spacing characteristics, which were quantified at the site during the completion of the RI, the bulk retention capacity for the bedrock was estimated as $4.1x10^{-3}$ percent of the total volume of the bedrock probable NAPL zone (Kueper, pers. com. with M.J. Gefell, September 1997).

The vadose-zone total VOC concentrations in the Operations Area have been characterized by 36 vadose-zone soil samples. These vadose-zone total VOC concentrations include all chemical phases (dissolved, sorbed, vapor, and NAPL). Using the high-end value of 3.0 percent for the NAPL bulk retention capacity resulted in a NAPL VOC mass estimate (9,300 kg) that exceeds the total VOC mass in the vadose zone calculated from the extensive array of vadose-zone soil samples obtained in the Operations Area (3,500 kg), which includes all chemical phases. While the exact fraction of the total VOC mass in the vadose zone in the form of NAPL can not be determined, this result indicates that the NAPL bulk retention is less than 3.0 in the Operations Area vadose zone. (Note that the upper end of the range of bulk retention in the saturated zone can not be constrained in this manner, because saturated soil samples are relatively sparsely distributed over the probable overburden NAPL zone, and aqueous concentrations from wells indicate only the mass in the dissolved phase.) Assuming NAPL constitutes one-half of the total vadose-zone VOC mass in the Operations Area (1,700 kg) leads the estimated bulk retention of 0.56 percent, which is within the range of 0.25 to 3.0 reported in the literature, and is considered a reasonable high-end estimate for the Operations Area vadose zone. The low-end bulk retention value of 0.25 percent was used to estimate the low-end of the range of NAPL mass in the vadose zone.

In addition to the high-end and low-end of the VOC mass estimates, a mean value was calculated as the average of the high and low estimates to summarize the VOC mass calculation results. While the average of the high-end and low-end estimates provides a convenient mechanism to simplify the VOC mass estimates, the "mean" mass may not provide an exact measure of the actual VOC mass present in a given chemical phase or stratigraphic zone. The table below summarizes the mean results of this exercise.

<u>Estimated Mean VOC Mass Distribution (VOC Mass in kg, and Percent of Total Subsurface VOC Mass)</u>

<table>
<tr><th>Stratigraphic Zone</th><th>Dissolved Phase</th><th>Sorbed Phase</th><th>NAPL Phase</th><th>Total</th></tr>
<tr><td>Vadose-Zone Soil</td><td colspan="2">Undifferentiated, 2,210
(0.098 percent)</td><td>1,254
(0.056 percent)</td><td>3,464
(0.15 percent)</td></tr>
<tr><td>Shallow Overburden</td><td>208
(0.009 percent)</td><td>833
(0.04 percent)</td><td rowspan="3">2,166,622
(96.1 percent)</td><td rowspan="3">2,177,833
(96.6 percent)</td></tr>
<tr><td>Middle Overburden</td><td>1,081
(0.05 percent)</td><td>6,103
(0.27 percent)</td></tr>
<tr><td>Deep Overburden</td><td>625
(0.03 percent)</td><td>2,361
(0.10 percent)</td></tr>
<tr><td>Shallow Bedrock</td><td colspan="2" rowspan="2">Undifferentiated
39,259 (1.7 percent)</td><td rowspan="2">33,208
(1.5 percent)</td><td rowspan="2">72,467
(3.2 percent)</td></tr>
<tr><td>Deep Bedrock</td></tr>
<tr><td>Total Estimated VOC Mass (kg) by Phase</td><td colspan="2">52,680 (2.3 percent)</td><td>2,201,084
(97.7 percent)</td><td>2,253,764
(100.0 percent)</td></tr>
</table>

The mass distribution in each phase and major hydrostratigraphic zone is discussed below.

5.1 Vadose-Zone Soil VOC Mass

Vadose-zone samples were identified using the soil analytical database, including the sample depth interval and ground-surface elevation for the sampling location, and a digital file of the highest water table observed at the site, on March 20, 1995. The high water table was used because any soils below the highest water table are within the saturated zone some of the time. Vadose-zone samples, therefore, were identified as samples for which the entire sample interval was above the water table on March 20, 1995. Downgradient of the Operations Area, the water table on March 20, 1995 was at or near ground surface. Nearly all vadose-zone samples with VOCs detected, therefore, were identified within of the Operations Area.

Total VOC contours were prepared using the vadose-zone soil total VOC data obtained historically at the site. The total estimated mass of VOCs in the vadose zone, including all chemical phases, is 3,464 kg, or approximately 0.15 percent of the total estimated subsurface VOC mass. Approximately 776 to 1,731 kg of the vadose-zone VOC mass is believed to be in the NAPL phase. In comparison, NAPL in the saturated zone accounts for approximately 0.33 million to 4.0 million kg of VOCs.

Based on the VLEACH modeling results presented in Section 4.1, the contribution of VOCs from the vadose zone to ground water is negligible in comparison to the total VOC flux within the saturated zone, which includes VOCs dissolved from NAPL and desorbed from saturated soils. For example, the estimated mass flux of TCE (one of the primary NAPL constituents) from the vadose zone accounts for 7.4 percent of the total TCE flux leaving the Operations Area in the saturated overburden. Thus, even if the vadose zone were remediated, the TCE mass flux leaving the Operations Area in the saturated overburden would still be approximately 92.6 percent of the current flux, which likely would not be a measurable difference. Moreover, due to the presence of NAPL in the overburden downgradient of the Operations Area, vadose-zone remediation would not improve ground-water quality downgradient of the site. These considerations, and the lack of an existing exposure pathway associated with vadose-zone soils in the Operations Area, suggest that vadose-zone soil remediation would not significantly reduce health-based risk related to the site.

The VLEACH simulation results for ethylbenzene (which was detected at the highest concentration in the Operations Area ground water during the completion of the RI) indicate that the vadose zone leaching rate to the saturated zone is less than the diffusion *from* the water table *to* the vadose zone. This finding suggests that vadose zone restoration would provide no reduction in dissolved ethylbenzene concentrations in the Operations Area ground water.

In a NAPL zone, much of the constituent mass in ground water comes from dissolution of NAPL below the water table, not from leaching through the vadose zone (Pankow and Cherry, 1996). Thus, NAPL sites are distinct from non-NAPL sites in that remedial efforts in the vadose zone generally contribute little or no risk reduction resulting from ground-water quality impacts (Pankow and Cherry, 1996). This conceptual model is consistent with, and supported by, the VOC mass and vadose-zone leaching calculations completed as part of this investigation.

5.2 Ground Water

The dissolved and sorbed VOC mass distribution in the saturated zone were estimated using the ground-water VOCs concentrations measured at the wells and piezometers at the site, based on the most recent sampling results at each available sampling location.

5.2.1 Estimated Dissolved VOC Mass

The total dissolved VOC concentrations in each hydrostratigraphic zone were contoured to derive the total dissolved VOC mass estimate.

5.2.1.1 Overburden

The VOC data are well characterized in the overburden, given the extensive ground-water monitoring network throughout the RI Study Area. Thus, the overburden dissolved VOC estimates were considered better constrained than other VOC mass estimates (e.g., NAPL volumes and mass in the bedrock matrix), and were not subject to a range of estimation.

The total dissolved VOC mass in the overburden is estimated as 1,914 kg, or approximately 0.085 percent of the total subsurface VOC mass. The majority of the dissolved VOC mass in the overburden is in the middle overburden (1,081 kg) and the least is in the shallow overburden (208 kg).

5.2.1.2 Bedrock

Dissolved VOC Mass in Bedrock Fractures

The fraction of the bedrock occupied by the fracture system can be understood in terms of the mean fracture porosity, which was quantified as approximately $6.8x10^{-5}$ ($6.8x10^{-3}$ percent) during the completion of the RI. This minute fraction of the bedrock volume occupied by fractures is considered negligible in comparison to the much larger storage capacity of the bedrock matrix, which has a porosity of 7.7 percent (1100 times the fracture porosity). Thus, the dissolved VOC mass within the bedrock fractures was considered negligible, and was not quantified.

Estimated Dissolved VOC Mass in Bedrock Matrix

The VOC mass diffused into the bedrock matrix was evaluated as a range of estimates. The low-range estimates were made using the empirical matrix VOC data obtained during the completion of the RI (Table 11). The mean quantified total VOC concentration in the bedrock matrix samples was 0.655 mg/kg. This mean does not include the samples that had no detected VOCs, but could have had even higher total VOC results masked by the elevated detection levels that result from the methanol-immersion preservation method. Assuming an average, total VOC concentration of 0.655 mg/kg diffused into the bedrock matrix within the area bounded by the 1 mg/L total VOCs contour in the shallow and deep bedrock, we obtain a low-range mass estimate of approximately 2,195 kg of VOCs diffused into the bedrock matrix. This includes both dissolved and sorbed phases in the matrix.

The high-range estimate of the dissolved and sorbed VOC mass in the bedrock matrix was derived assuming that the entire bedrock matrix pore space (i.e., the entire storage capacity), was at chemical equilibrium with the ground-water concentrations detected at bedrock wells and piezometers. The total dissolved VOC data, therefore, were contoured and used to estimate the total dissolved mass of VOCs in the bedrock matrix pore space (7.7 percent of the total volume of the plume in the rock). The resulting high-range, total dissolved VOCs estimates were 1,331 kg for the shallow bedrock and 1,932 kg for the deep bedrock, or 3,263 for both zones combined. The high-range sorbed mass in the rock is considerably higher, however, as discussed below.

5.2.2 Estimated Sorbed VOC Mass in Saturated Zone

5.2.2.1 Overburden

The sorbed VOC mass in the saturated overburden was estimated in a manner analogous to the estimates for the dissolved phase. To estimate the sorbed VOC concentrations (and mass), however, each dissolved VOC detected during the most recent sampling event at each well and piezometer was converted to a commensurate sorbed concentration assuming equilibrium partitioning and a linear isotherm represented by the partition coefficient, as follows:

$$Cs = Cm\ K_{oc}\ f_{oc},$$

where: Cs is the chemical concentration sorbed to soil (mg/kg, dry weight), Cm is the measured chemical concentration in ground water (mg/L or ug/cm^3), K_{oc} is the chemical-specific organic carbon based partition coefficient (cm^3/g), and f_{oc} is the fraction of organic carbon in soil or rock (dimensionless). Given the extensive characterization of the overburden solute-transport parameters during the completion of the RI, the sorbed-phase mass estimates were considered relatively well-constrained, and were not subject to a range of estimates.

The total sorbed VOC mass in the overburden is estimated as 9,297 kg, or approximately 0.41 percent of the total combined subsurface VOC mass.

5.2.2.2 Bedrock

VOC Mass Sorbed in Bedrock Fractures

The fraction of the bedrock occupied by the fracture system, 6.8×10^{-3} percent, of the total volume was considered negligible. Thus, the sorbed VOC mass within the bedrock fractures was considered negligible, and was not quantified.

Estimated Sorbed VOC Mass in Bedrock Matrix

As discussed above, the low-range mass estimate for the total dissolved *and* sorbed VOC mass in the bedrock matrix is approximately 2,195 kg of VOCs.

The high-range estimate of the dissolved and sorbed VOC mass in the bedrock matrix was derived assuming that the entire bedrock matrix pore space (i.e., the entire storage capacity), was at chemical equilibrium with the ground-water concentrations detected at bedrock wells and piezometers. Similar to the sorbed VOC estimates for the overburden, the sorbed VOC mass in the matrix was also assumed to be at equilibrium with the dissolved VOC mass in the matrix. The total sorbed VOC concentrations were calculated, therefore, and were contoured for use in the total sorbed VOC mass estimates for the bedrock. The resulting high-range, total sorbed VOCs estimates were 35,167 kg for the shallow bedrock and 37,894 kg for the deep bedrock, or 73,061 for both zones combined. This estimated sorbed mass equates to approximately 3.2 percent of the entire subsurface VOC mass. Thus, the high-range sorbed VOC mass estimates are considerably higher than the high-range dissolved VOC mass estimates for the bedrock. This result relates to the relatively low, overall porosity of the bedrock (7.7 percent), which limits the amount in the dissolved phase, and the relatively high bulk density for the bedrock (2.52 g/cm^3).

5.3 NAPLs

Due to their relatively immiscible nature, NAPLs can persist for many years in the subsurface environment. The presence of NAPL contamination, and in particular DNAPL contamination, may have a significant impact on the ability to restore impacted portions of the subsurface to required cleanup levels. As proven technologies for the removal of NAPL do not exist yet, NAPL sites are more likely to require TI evaluations than sites with other types of contamination. Due to the nature of the SRSNE Site, which processed a minimum of 41 million gallons of waste solvents over an approximately 35-year period, it is reasonable to suspect that a relatively large volume of NAPL may have been inadvertently released via incidental leaks and spills. However, certain aspects of the site infrastructure, in particular the former unlined solvent sludge storage lagoons excavated into unsaturated fill materials, likely provided direct pathways for NAPLs to enter the subsurface with relatively little resistance. These factors suggest that a large volume of NAPL should be suspected in the subsurface beneath and downgradient of the site.

5.3.1 Estimated Range of NAPL Volume and VOC Mass

The volume and mass of NAPL in the saturated zone were estimated by multiplying the total saturated volume of the overburden or bedrock probable NAPL zone (see Figures 45 and 46) by the estimated bulk retention capacity for the overburden or bedrock.

5.3.1.1 Saturated Overburden

For the saturated overburden, a range of bulk retention capacity was used to estimate the range of NAPL volume within the overburden probable NAPL zone. The bulk retention capacity used in this analysis ranged from a low of 0.25 percent to a high of 3.0 percent. These numbers span the representative range of bulk retention observed based on studies of NAPL behavior in porous media (Kueper, pers. com. with M.J. Gefell, September 1997). Given this range of bulk retention capacity, the total NAPL quantity in the overburden is estimated as 80,059 to 960,710 gallons, or 0.33 to 4.0 million kg. While these numbers may appear relatively high, these represent no more than 0.2 to 2.3 percent of the total volume of waste liquids processed at the SRSNE Site. The estimated mean NAPL volume in the saturated overburden, 520,385 gallons (2.2 million kg), constitutes approximately 96.1 percent of all the subsurface VOC mass associated with the site.

5.3.1.2 Bedrock

Based on the bedrock fracture aperture and spacing characteristics, which were quantified during the completion of the RI, the bedrock bulk retention capacity was estimated as 4.1×10^{-5} (4.1×10^{-3} percent). Given this bulk retention capacity, the total NAPL quantity in the bedrock is estimated as 7,976 gallons, or 33,208 kg. Thus, the NAPL within the bedrock represents an estimated 1.5 percent of all the subsurface VOC mass associated with the site.

5.4 NAPL-Zone Restoration Potential

It is currently recognized that most saturated overburden and bedrock deposits contaminated by DNAPLs cannot be remediated to typical concentration-based clean-up goals (USEPA, September 1993). Achieving typical concentration-based clean-up goals for groundwater requires that virtually all of the NAPL be removed from a site (Kueper, pers. com., October 1997). Research and experience acquired during the past 10 years has shown that while partial NAPL removal may be possible at some sites, removing sufficient NAPL to achieve concentration-based clean-up goals is not technically practicable. The primary reason for this is an inability to hydraulically contact all residual and pooled DNAPL present in the subsurface. This inability stems from the fact that natural deposits are in general heterogeneous, resulting in preferential flow of injected fluids and incomplete contact with the target NAPL. In fractured porous media, the process of matrix diffusion serves to further impede the effectiveness of remedial technologies. At present, there have been no successful applications of in-situ groundwater clean-up technologies where it is known that moderate to large quantities of DNAPL are present below the water table and ground water was restored to MCLs (Kueper, pers. com. with M.J. Gefell, September 1997).

At the SRSNE Site, NAPL-zone restoration can be considered especially difficult due to the nature of the NAPL release. In qualitative terms, the release of NAPL at the SRSNE Site can be classified as a large-volume, long-duration, continual release to a heterogeneous, low- to moderate-permeability medium. According to the USEPA TI Guidance Document (USEPA, September 1993) and other sources (WCGR, 1991; Cohen and Mercer, 1993; Pankow and Cherry, 1996; Kueper, pers. com. with M.J. Gefell, 1997), these characteristics increase the difficulty of ground-water restoration.

Appendix O includes an identification and preliminary evaluation of remedial technologies within the Potential NAPL zone, which was prepared by Dr. Kueper (November 1997b). Dr. Kueper evaluated the following NAPL remediation technologies with respect to their applicability at the SRSNE Site:

- Hydraulic containment;
- Physical containment;
- Permeable treatment walls;
- Biodegradation;
- Alcohol flooding and cosolvent flushing;
- Surfactant flushing;
- Air sparging;
- Pump-and-treat;
- Waterflooding;
- Steam flooding;
- Oxidant flooding; and
- Natural attenuation.

A detailed discussion of the applicability of these technologies is presented in Appendix O (Kueper, November 1997b). A cursory review of the quantities of NAPL and dissolved VOCs extracted by the NTCRA 1 system, however, suggests that removal of the entire mass of VOCs by pump-and-treat would require hundreds to thousands of years, even if the mass-removal rate remains the same. In contrast to the estimated range of NAPL volume (approximately 88,000 to 970,000 gallons) remaining in the subsurface at and downgradient of the site, the total volume of NAPL removed during the operation of the NTCRA 1 Containment System is estimated as 4 gallons. Similarly, while the total subsurface mass of VOCs is estimated as 380,000 to 4.1 million kg, the NTCRA 1 Containment System has removed VOCs at an average rate of approximately 1000 kg per year during the first two years of operation.

Throughout the entire first two years of NTCRA 1 system operation, except for one period of less than one day, the Containment System has maintained hydraulic containment of overburden ground water. In addition, except for one exceedance of the discharge limit for hydrogen peroxide, the NTCRA 1 treatment system has met applicable discharge standards. These considerations suggest that the NTCRA 1 Containment and Treatment System design and operations history have been effective at containing and treating VOC-impacted ground water, and that the long time-frames required for aquifer restoration at the site relate to the immiscible nature of the source materials and the heterogeneity of the subsurface media.

A detailed discussion of the practicability of ground-water restoration within the TI zone, including the NAPL zones in overburden and bedrock, will be presented in the TI Evaluation (appendix to FS). Appendix V presents the Development and Initial Screening of Alternatives to address the NAPL zone, vadose zone soils, and the off-site aqueous ground-water plumes. The TI zone, and the specific ARARs for which a waiver will be requested will be defined in the TI Evaluation, which will be presented as appendix to the FS.

Summary of Section 5

- A TI Evaluation is appropriate for the SRSNE Site due to the presence of large quantities of NAPL in the subsurface, the highly heterogeneous nature of the geologic formations in the RI Study Area, and the influence of bedrock matrix diffusion.

- VOC mass calculations were performed by BBL in consort with Dr. Kueper. These calculations indicate that approximately 97.7 percent of the total subsurface VOC mass [2.20 million kilograms (kg), equivalent to 529,000 gallons of NAPL] associated with the SRSNE Site is in the form of NAPLs, and the remainder of the mass is in dissolved, sorbed, or vapor phase. Approximately 96.6 percent of the total subsurface VOC mass (2.18 million kg, equivalent to 520,000 gallons of NAPL) is in the saturated overburden, 3.2 percent (72,000 kg, equivalent to 17,000 gallons of NAPL) is in the bedrock, and 0.15 percent (3,500 kg, equivalent to 830 gallons of NAPL) is in the vadose zone. Given that more than 41 million gallons of waste liquids were processed at the SRSNE Site, the total estimated subsurface VOC mass associated with the site represents no more than 0.2 to 2.4 percent of the total materials processed by SRSNE.

- Detailed hydrogeologic characterization of the overburden and bedrock units, including their structure and hydraulic conductivity, indicate that these units are highly heterogeneous and complex at a small scale. Overburden strata observed in two test pits were discontinuous on a scale of a few feet, and exhibited cross-bedding, and varying dip directions along the contacts between layers. The overburden hydraulic conductivity was found to range by more than two orders of magnitude within a distance of a few feet based on soil samples collected at the test pits. The hydraulic conductivity of the bedrock matrix is approximately six orders of magnitude less than the hydraulic conductivity of the bedrock fractures.

- The bedrock matrix porosity represents a significant storage capacity for VOCs that diffuse into the matrix from the fractures, as confirmed by bedrock matrix VOC analysis. Matrix diffusion reduces the migration rate of the bedrock VOC plumes by a factor of 900 to 1,100. However, matrix diffusion will also significantly hinder efforts to restore bedrock ground-water quality. Preliminary matrix diffusion calculations performed by Dr. Kueper indicate that diffusion of VOCs back out of the bedrock matrix after the dissolution of NAPL will take hundreds of years.

- The TI zone, which will be delineated as part of the FS, will include

  - The potential NAPL zones in overburden and bedrock;

  - The zone where VOCs have diffused into the bedrock matrix to the degree that removal from the matrix can not be achieved within an acceptable time frame; and

- The portion of the VOC plume downgradient of the two above-listed zones and upgradient of the capture zone that will be achieved by a permanent ground-water remedy, which will be specified in the ROD to address the off-site regulatory VOC plume.

6. Interim Monitoring and Sampling

Appendix U presents the Interim Monitoring and Sampling Plan, in accordance with the requirements of the RI/FS SOW. The Interim Monitoring and Sampling Plan presents the proposed sampling process that will be used to evaluate the VOC plume conditions between the completion of the RI and the issuance of the ROD for the site. As described in Appendix U, the primary purpose for the Interim Monitoring and Sampling Plan is to periodically monitor the ground-water quality and distribution of VOC concentrations exceeding regulatory criteria near the edges of the regulatory VOC plumes presented in this RI (Figures 49 through 53). In addition, surface-water sampling is proposed along the Quinnipiac River to verify that VOCs associated with the site do not adversely impact surface-water quality in the river. Bi-annual sampling events will be performed to evaluate whether the conditions characterized in this RI Report remain through the completion of the FS and issuance of the ROD.

6.1 Overburden Ground Water

Overburden ground-water monitoring locations included in the Interim Monitoring and Sampling Plan are as follows:

- Shallow Overburden Monitoring Wells: No proposed sampling locations in the due to the relatively limited downgradient extent of detected VOCs;
- Middle Overburden Monitoring Wells: CW-B-7; MW-3; MW-127B; MW-205B; MW-501B; and MW-707M;
- Deep Overburden Monitoring Wells: CW-4-75; MW-4; MW-204B; MW-704D; and MW-707D;

6.2 Bedrock Ground Water

Bedrock ground-water monitoring locations included in the Interim Monitoring and Sampling Plan are as follows:

- Shallow Bedrock Monitoring Wells: MW-127C; MW-128; MW-204A; MW-205A; MW-501A; and MW-707R;
- Deep Bedrock Monitoring Wells: MW-703DR, MW-704DR; and MW-707DR.

6.3 Surface Water

Surface-water monitoring locations included in the Interim Monitoring and Sampling Plan are situated along the Quinnipiac River, and include: SW-C; SW-F; and SW-G.

Ground-water sampling procedures for the Interim Monitoring and Sampling events will be consistent with those specified in the RI Work Plan (BBL, November 1995) and Project Operations Plan (BBL, August 1996). Surface-water sampling will be performed as described in the RI Work Plan Addendum No. 6.

The data obtained from these sampling events will be qualitatively assessed to identify any changes in VOC concentrations or the interpreted boundaries of the regulatory VOC plumes associated with the SRSNE Site. Any proposed changes to the monitoring array will be made in consort with USEPA and CT DEP. Letter reports summarizing each sampling event will be submitted to USEPA and CT DEP.

7. Treatability and Pilot Studies

Based on the estimated extent of the NAPL zones in overburden and bedrock, and the calculated VOC mass within the NAPL zones, remediating the ground water within the NAPL zones is not considered practicable, as will be discussed in the TI Evaluation. Remedial technologies will not be evaluated in detail for the NAPL zones, which will be included within the TI zone. Remedial alternatives to address the vadose-zone soils on site and the off-site VOC plume associated with the SRSNE Site, however, are evaluated on a preliminary basis in Appendix V and will be addressed in detail through the FS process.

To help assess whether a given technology is feasible and effective for a certain application, treatability and pilot studies can be performed. Pilot studies are not considered necessary for routine remedial alternatives such as pump-and-treat design or treatment of dissolved VOCs by means of air stripping or UV-oxidation. Two potential uses for treatability and pilot studies within the RI Study Area, however, include:

- the evaluation of phytoremediation as a potential technology to naturally remove and treat VOC-impacted ground water; and

- the pilot-scale assessment of ground-water collection and treatment using a constructed wetland, which is among the remedial alternatives (Alternatives GW-3A and GW-3B) currently being considered to address the off-site VOC plume.

A treatability study will be performed to assess the potential use of phytoremediation to remove overburden ground water and treat dissolved VOCs. Phytoremediation is a general term used for the treatment of contaminated soil, sediment , and ground water using plants. With respect to ground-water treatment, phytoremediation involves characterizing a site and determining the proper planting strategy to maximize the interception and degradation of organic contaminants. Poplar trees, which use water at a relatively high rate during the growing season, have been shown to effectively treat chlorinated hydrocarbons. The SRSNE PRP Group is currently evaluating phytoremediation as a potential remedial technology that, if successful at full scale application within the NTCRA 1 Containment Area, may allow the NTCRA 1 ground-water extraction rate to be reduced during the growing season. On behalf of the SRSNE PRP Group, Phytokinetics, Inc., of North Logan, Utah will perform a phytotoxicity greenhouse study to assess whether poplar trees can grow using overburden ground water from the NTCRA 1 Containment Area. The results of the phytotoxicity study will be presented in the FS Report. If the phytotoxicity study results suggest that young poplar trees can grow in the overburden ground water within the Containment Area, the SRSNE PRP Group will implement a full-scale demonstration of phytoremediation within the Containment Area. The results of the full-scale demonstration, however, will not be available until after the scheduled completion of the FS.

A pilot study may be appropriate to evaluate whether a constructed wetland would effectively treat dissolved VOCs in ground water that would discharge into the wetland from the shallow overburden zone. The shallow overburden zone off site currently exhibits low dissolved VOC concentrations, with few exceedences of ground-water protection criteria and no exceedences of the CT DEP's surface-water protection criteria. In addition, in spite of the demonstrated flow of overburden and bedrock ground water toward the Quinnipiac River throughout the RI Study Area, the empirical surface-water data from the Quinnipiac River indicate little or no impact on surface-water quality. Because the VOC plumes related to the SRSNE Site extend to the area adjacent to and beneath the river, it appears that intrinsic factors (e.g., biodegradation in the zone below the river, dilution within the river, etc.) are mitigating the VOC concentrations sufficiently to protect surface water. The zone near and below surface-water bodies is expected to be an active zone for biodegradation because of the availability of naturally occurring organic carbon and the zonation of aerobic conditions over anaerobic conditions, which provide effective treatment conditions for a range of organic chemicals. Wetlands have been used effectively to treat municipal waste water and landfill leachate, and may represent a promising technology to cost-effectively collect and treat VOC-impacted ground water.

8. Summary and Conclusions

8.1 Summary

This RI Report describes the field investigations, data acquisition, and evaluations that were performed to complete the RI for the SRSNE Superfund Site in Southington, Connecticut (Figures 1 and 2). This document was prepared in accordance with the RI/FS SOW issued by the USEPA as part of the second AOC between USEPA and the SRSNE PRP Group. This RI Report, in conjunction with information produced during previous investigations, satisfies the requirements of an RI as specified by CERCLA.

Numerous subsurface investigations were completed in the RI Study Area (Figure 2) prior to this current RI, beginning with investigations in support of the Town of Southington Well Field development in the 1960s. USEPA conducted a three-phase RI between approximately May 1990 and December 1992 that characterized the geology, hydrogeology, and soil and ground-water quality, and risk assessment for the SRSNE Site and surrounding area. These data and a considerable quantity of background information and data evaluations were presented in the previous, four-volume RI Report (HNUS, May 1994).

Certain data gaps precluded the completion of an FS and selection of a remedy for the site. Thus, the SRSNE PRP Group performed the additional focused investigations described in the RI Work Plan (BBL, November 1995) to fill the data gaps, complete the RI, and support the remedy evaluation in the Feasibility Study (FS). The data gathered during the completion of the RI, which are discussed in detail in this RI Report, have achieved the following objectives described in the RI Work Plan (BBL, November 1995):

- Delineated the overburden and bedrock zones containing NAPLs in terms of a probable NAPL zone where NAPL presence is known or highly suspected, and a potential NAPL zone, which serves as a safety factor due to the complexity of NAPL delineation in heterogeneous and fractured geologic media;

- Characterized the nature and extent of the off-site VOC plume using pertinent ground-water regulatory criteria, the possible dimensions of the NAPL zone, regional ground-water hydraulics, solute-transport characteristics, and other potential VOC source areas. The VOC regulatory plumes associated with the SRSNE Site have been distinguished from several other, unrelated plumes associated with other VOC sources;

- Characterized the potential impact of the SRSNE-related plumes on private water-supply wells.

- Delineated the extent of LNAPLs in the overburden; and

- Characterized the potential VOC loading to site ground water from the vadose zone. Vadose zone mass loading rate to overburden ground water was estimated using a vadose zone leaching model (VLEACH). The model was applied to two representative VOCs, including TCE and ethylbenzene.

Several aspects of the site hydrogeology and the nature of the VOC distribution in the subsurface render the SRSNE Site appropriate for a TI Waiver with respect to ground-water restoration and other related ARARs. For example, VOC mass estimates indicate that approximately 97.7 percent of the subsurface VOC mass related to the SRSNE Site is in the form of NAPLs. NAPLs may be distributed over an area of approximately 12.4 acres in the overburden and 14.2 acres in the bedrock, to an undetermined depth that may approach 200 feet or more. These factors will be considered in the development of a TI Evaluation for the site as part of the FS.

8.2 Conclusions

This RI Report meets the objectives specified in the USEPA-approved RI Work Plan (BBL November 1995) and the RI/FS SOW, and provides the basis to proceed with the FS.

The overburden and fractured bedrock have been characterized in detail, and indicate that these formations are highly complex and heterogeneous within the RI Study Area. The hydraulic conductivity values of these formations were shown to range by several orders of magnitude on a small scale.

Based on the available ground-water (potentiometric) elevation data, and the surface-water elevation and flow measurements for the Quinnipiac River, the river is interpreted as the discharge location for all ground water within the monitored geologic section of the RI Study Area, which extends to a depth of approximately 270 feet below grade.

The NAPL zone delineation included ten different screening criteria to identify NAPL locations. The potential NAPL zones in overburden and bedrock cover approximately 12.4 and 14.2 acres, respectively. The NAPL zones estimated in this RI will be the focus of a TI evaluation with respect to ground-water restoration, based on USEPA TI Guidance (September 1993). The NAPL zone includes DNAPL and LNAPL. LNAPL was observed at one overburden monitoring well (0.01 foot thickness) near the center of the former SRSNE Site Operations Area, indicating a limited extent and quantity of potentially recoverable LNAPL.

The regulatory VOC plumes related to the SRSNE Site have been delineated in the shallow, middle and deep overburden and the shallow and deep bedrock. The plumes in the middle overburden and shallow bedrock extend the furthest downgradient of the site, and their extent appears to be relatively consistent with solute-transport principles. Several other plumes, which are unrelated to the SRSNE Site, are also evident based on historical and new ground-water quality data. The SRSNE plumes have negligible impact on surface-water quality in the adjacent Quinnipiac River.

Two private wells are situated near the upgradient edges of the VOC plumes associated with the SRSNE Site. Only one of these wells has historically indicated VOC concentrations above regulatory criteria, and this property is currently supplied with bottled drinking water by CT DEP. However, as an additional precaution, the SRSNE PRP Group will provide municipal water to these two properties.

Leaching calculations for TCE in the vadose zone indicate that the simulated vadose-zone TCE flux to ground water within the Operations Area represented 7.4 percent of the total flux leaving the Operations Area through overburden ground water. For ethylbenzene, the total flux to ground water from the vadose zone was negative due to rapid volatilization and diffusion from the ground water to the vadose zone.

Approximately 96 percent of the subsurface VOC mass associated with the SRSNE Site is in the form of NAPL in the saturated overburden, 3.2 percent is in the bedrock (approximately half of which is NAPL), and 0.15 percent is in the vadose zone. The total subsurface mass of VOCs is estimated as approximately 383,000 to 4.1 million kilograms. Converted to an equivalent volume of NAPL (assuming a mean NAPL density of 1.15 g/mL), this range of total VOC mass corresponds to a NAPL volume of 92,000 to 990,000 gallons, which represents no more than 0.2 to 2.4 percent of the waste materials processed at the site.

8.3 Remedial Action Objectives

Baseline human health and ecological risk assessment identified several COCs with respect to human health risk in the study area ground water, shallow soil, surface water and sediment (HNUS, May 1994). Average total cancer risks and average total hazard indices posed by potential ingestion of the study area ground water were found to exceed USEPA target levels. The highest calculated ground-water ingestion risks are related to the Operations Area/former Cianci Property (the area immediately west of the Quinnipiac River downgradient of the Operations Area). No current ground-water receptors exist in areas downgradient of the Operations Area (between the site and the Quinnipiac River, which is the point of discharge for the overburden and bedrock ground water). No current ground-water receptors exist in the limited areas upgradient or cross-gradient (immediately north) of the SRSNE Site where the calculated ground-water ingestion risks exceeded target levels (HNUS, May 1994).

The Baseline Risk Assessment evaluated potential soil exposure risks based on the following assumed exposure pathways: 1) incidental ingestion; 2) dermal contact; and/or 3) inhalation of fugitive dusts. The only calculated Human Health Risk that exceeded USEPA acceptable levels for dermal contact with soil was related to the Operations Area and former Cianci Property surface soils. The Baseline Risk Assessment used conservative assumptions regarding exposure which probably overestimated the actual risk. Using reasonable and realistic exposure scenarios, the surface soils at the Operations Areas and the former Cianci Property do not appear to pose an unacceptable risk under any exposure scenario evaluated in the Baseline Risk Assessment. For example, the Operations Area is currently capped by asphalt pavement, which precludes direct exposure to soil. In addition, institutional controls designed to further limit access to surface soils, including the installation of fencing around most of the Cianci Property and the repair of the fence around the Operations Area have been completed. Finally, in accordance with the NTCRA 2 Scope of Work, the SRSNE PRP Group is preparing to upgrade the existing pavement at the Operations Area to further limit exposure to surface soils.

The total cancer risks calculated as part of the Baseline Risk Assessment for incidental ingestion and dermal contact with study area surface waters and sediment do not exceed acceptable levels. According to HNUS (May 1994), several COCs in the study area may pose adverse effects to ecological receptors. The ecological risk due to soil contaminants is associated exclusively within the Operations Area and the former Cianci Property.

The restoration of the entire dissolved phase ground-water plume to MCLs is considered technically impracticable due to the presence of large quantities of un-recoverable NAPL in the overburden and bedrock and the influence of matrix diffusion in bedrock. NAPL will provide a continuing source of ground-water impacts in the saturated overburden and bedrock zones and, as recognized by the USEPA's TI Guidance (September 1993), the "inability to contain a sources, or other technical constraints, may render plume restoration technically impracticable." Because the source is expected to remain in place indefinitely, alternative remedial strategies designed to remediate the ground-water to the extent practicable, provide exposure control and/or provide hydraulic containment, will be evaluated for the dissolved phase ground-water plume.

The mass of VOCs in the vadose zone soils (approximately 0.15% of total VOC mass identified at the site), and the contribution of those VOCs to ground water impacts, is considered negligible in comparison of the VOC mass already dissolved, sorbed, diffused or present in the form of NAPL in the saturated zone. In a NAPL zone, much of the constituent mass in ground water comes from dissolution of NAPL below the water table, not from leaching through the vadose zone (Pankow and Cherry, 1996). Thus, NAPL sites are distinct from non-NAPL sites in that remedial efforts in the vadose zone generally contribute little or no risk reduction resulting from ground-water quality impacts (Pankow and Cherry, 1996).

At sites where the complete restoration of contaminated ground water is found to be technically impracticable, an alternative remedial strategy that is technically practicable, protective of human health and the environment and satisfies the statutory and regulatory requirements of CERCLA is appropriate. Alternative remedial strategies typically will address three types of problems at contaminated ground-water sites:

- Prevention of exposure to contaminated ground water;

- Containment of contamination sources; and
- Remediation of aqueous contaminant plumes.

The primary objective of any remedial strategy is overall protectiveness of human health and the environment. Thus, exposure prevention plays a significant role in an alternative remedial strategy. Source remediation is generally not appropriate in cases where the removal or treatment of the source is technically infeasible or will result in no significant risk reduction. In cases where contaminant sources can be effectively contained, however, the portion of the aqueous plume outside of the containment area should be restored to established cleanup levels.

The practicability of aquifer restoration will be assessed in a TI Evaluation which will be completed in conjunction with the FS. A TI Evaluation is appropriate for the SRSNE Site because of the presence of slowly dissolving NAPLs in the saturated zone, heterogeneous nature and low permeability of the geologic media underlying the site, and the likely influence of matrix diffusion into bedrock. Collectively, these factors are expected to render aquifer remediation technically impracticable. The TI zone will include

- The potential NAPL zones in overburden and bedrock;

- The zone where VOCs have diffused into the bedrock matrix to the degree that removal from the matrix can not be achieved within an acceptable time frame (to be specified by USEPA); and

- The portion of the VOC plume downgradient of the two above-listed zones and upgradient of the capture zone that will be achieved by the permanent ground-water remedy, which will be specified in the ROD to address the off-site regulatory VOC plume.

Based on the results of the TI Evaluation, it is expected that the USEPA will delineate a zone of impacted ground water which is technically impracticable to remediate. Remediation of the TI zone will not be evaluated as part of the FS.

While restoration of the TI zone will be technically impracticable, restoration of the regulatory VOC plume downgradient of the TI zone, and remediation of potential ground-water contaminant sources in soil, may be practicable and must be considered. Media to be considered for remediation during the FS, therefore, include the portion of the off-site VOC plume outside of the USEPA-defined TI zone and vadose-zone soils which may act as a source contributing to ground-water contamination.

The following RAOs have been developed for vadose-zone soil and ground water, in consideration of: the potential human health risks associated with exposure to surface soils at the Operations Area and Cianci Property; the human health risks associated with exposure to ground water; the technical impracticability of remediating the NAPL-zone (i.e., the contaminant source); and alternative remedial strategies.

Vadose-Zone Soil: Continue to limit potential human exposure to vadose-zone soils and mitigate the migration of constituents to ground water.

Dissolved Phase Ground Water: Limit potential future human exposure through ingestion, direct contact and inhalation, and restore ground-water beyond the TI zone to the extent practicable.

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TABLE 1

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

SUMMARY OF RI FIELD INVESTIGATION ACTIVITIES

Location	Depth to Rock	Wells Installed	Geologic Zone Screened	Screen (or Total) Depth (feet)	Date Completed	Drilling Methods: Overburden	Drilling Methods: Bedrock	Soil Sampling: Interval(s) *	Soil Sampling: Analyses ***	Bedrock Sampling: Interval(s) *	Bedrock Sampling: Analyses	Direct-Push, Hydropunch Ground-Water Sampling: Interval(s) *	Direct-Push, Hydropunch Ground-Water Sampling: Analyses	Hydraulic Conductivity Testing	Additional Investigative Activities/Comments
MW-701	20.5	MW-701DR	Deep Bedrock	93.3-107.8	9/13/96	Hollow-Stem Auger	Roller-Bit	Approximately Every 5 ft.	Geologic Description	None	None	None	None	Bedrock Packer Tests	None
MW-702	21.7	MW-702DR	Deep Bedrock	80.3-110.3	10/11/96	Hollow-Stem Auger	Core Barrel	Approximately Every 5 ft.	Geologic Description	Weath. Rock (1) Highly Fractured Rock (2) Competent Rock (2)	Geologic Description; toc; Matrix Porosity, Matrix Permeablity, Matrix Bulk Density	None	None	Bedrock Packer Tests	Borehole Image Processing for Fracture Spacing, Orientation, and Aperture Estimation
MW-703	84.0	MW-703S MW-703D MW-703DR	Shallow Overburden Deep Overburden Deep Bedrock	25.0-35.0 74.0-84.0 144.3-174.3	10/2/96 10/2/96 10/2/96	Hollow-Stem Auger and Roller-Bit	Roller-Bit	Approximately Every 5 ft. @ MW-703DR	Geologic Description; toc (5), Porosity (5), Bulk Density (5), VOCs (4) with 48-Hour Turnaround at Approx. 10 ft. Intervals	None	None	Overburden Hydropunches Approximately Every 10 ft. (4)	Lab Analysis for VOCs with 48-Hour Turnaround	Bedrock Packer Tests*, Overburden and Bedrock Specific Capacity or Rising Head Tests	None
MW-704	75.6	MW-704S MW-704M MW-704D MW-704R MW-704DR	Shallow Overburden Middle Overburden Deep Overburden Shallow Bedrock Deep Bedrock	4.0-19.0 37.0-47.0 53.0-63.0 79.0-89.0 102.5-132.5	10/14/96 10/28/96 10/28/97 10/28/96 10/28/96	Hollow-Stem Auger, Roller-Bit, Spun Casing	Core Barrel or Roller-Bit	Approximately Every 5 ft. @ MW-704DR	Geologic Description; toc (5), Porosity (5), Bulk Density (5), Grain Size (5)	Weath. Rock (1) Highly Fractured Rock (2) Competent Rock (2)	Geologic Description; toc; Matrix Porosity, Matrix Permeability, Matrix Bulk Density	Overburden Hydropunches (4) or Auger Grab Samples (2) Approximately Every 10 ft.	Lab Analysis for VOCs with 48-Hour Turnaround	Bedrock Packer Tests*, Overburden and Bedrock Specific Capacity or Rising Head Tests	Installed Data Loggers at Wells MW-704R and MW-704DR; Borehole Image Processing for Fracture Spacing, Orientation, and Aperture Estimation
MW-705	40.0	MW-705D MW-705R MW-705DR	Deep Overburden Shallow Bedrock Deep Bedrock	25.0-35.0 44.0-54.0 90.3-100.3	9/5/96 9/9/96 9/5/96	Hollow-Stem Auger	Core Barrel @ MW-705DR and MW-705R	Continuous	Geologic Description	Weath. Rock (1) Highly Fractured Rock (2) Competent Rock (2)	Geologic Description; toc; Matrix Porosity, Matrix Permeability, Matrix Bulk Density	None	None	Bedrock Packer Tests @ MW-705R	Screened Soils per DNAPL Contingency Plan
MW-706	60.0	MW-706DR	Deep Bedrock	116.5-126.5	9/24/96	Hollow-Stem Auger	Roller-Bit	Continuous	Geologic Description	None	None	None	None	Bedrock Packer Tests	Screened Soils per DNAPL Contingency Plan
MW-707	100.0	MW-707S MW-707M MW-707D MW-707R MW-707DR	Shallow Overburden Middle Overburden Deep Overburden Shallow Bedrock Deep Bedrock	20.0-30.0 58.0-68.0 84.9-94.9 115.0-125.0 162.9-192.9	10/9/96 10/10/96 10/11/96 10/18/96 12/18/96	Hollow-Stem Auger and Roller-Bit	Roller-Bit	Approximately Every 5 ft. @ MW-707DR	Geologic Description; VOCs (7) with 48-Hour Turnaround at Approx. 10 ft. Intervals	None	None	Overburden Hydropunches (2) at Approx. 10 ft. Intervals	Lab Analysis for VOCs with 48-Hour Turnaround	Bedrock Packer Tests*	Installed Data Loggers at Wells MW-707R and MW-707DR
MW-708	174.0	MW-708S MW-708M MW-708R MW-708DR	Shallow Overburden Middle Overburden Shallow Bedrock Deep Bedrock	83.0-93.0 116.0-126.0 179.4-189.4 236.1-266.1	2/4/97 1/24/97 2/3/97 1/20/97	Hollow-Stem Auger and Roller-Bit	Roller-Bit	Approximately Every 5 ft. @ MW-708DR	Geologic Description	None	None	None	None	Bedrock Packer Tests*	Installed Data Loggers at Wells MW-708R and MW-708DR
MW-709 (former Cianci Well)	31.0	MW-709R MW-709DR	Shallow Bedrock Deep Bedrock	50.0-70.0 120.0-134.0	11/13/96 11/13/96	NA NA	NA NA	None None	None None	None None	None None	None None	None None	Specific Capacity Tests of Former Cianci Well	Borehole Image Processing for Fracture Spacing, Orientation, and Aperture Estimation
MW-710	127.5	MW-710S MW-710R MW-710DR	Shallow Overburden Shallow Bedrock Deep Bedrock	32.2-42.2 133.5-143.5 186.5-205.5	6/10/97 6/9/97 6/3/97	Hollow-Stem Auger	Roller-Bit	Approximately Every 5 ft. @ MW-710DR	Geologic Description; VOCS (7) with 48-Hour Turnaround at Approx. 10 ft. Intervals	None None	None None	Overburden Hydropunches (4) at Approx. 10 ft. Intervals	Lab Analysis for VOCs with 48-Hour Turnaround	Bedrock Packer Tests*	None
SB-701 SB-702 SB-703	NA NA NA	None None None	NA NA NA	20 20 22	8/27/96 8/28/96 8/28/96	Hollow-Stem Auger	NA NA NA	Continuous	Geologic Description; (3) VOCs (Vadose Only); (13) toc, Porosity, and Bulk Density; (3) Till Permeability	None	None	None	None	None	Screened Soils per DNAPL Contingency Plan
RC-701 **	50.0	None	NA	70	9/12/96	Hollow-Stem Auger	Core Barrel	Continuous	Geologic Description	Weath. Rock (1) Highly Fractured Rock (2)	Geologic Description; toc; Matrix Porosity, Matrix Permeability, Matrix Bulk Density; Matrix VOC Content	None	None	None	Screened Soils per DNAPL Contingency Plan; Observed Recirculation Water During Coring for Presence of Sheen
TP-701 TP-702	NA NA	None None	NA NA	7 7	9/12/96 6/19/96	Backhoe	NA	Grab (Based on Qualitative Texture)	Geologic Description; Five (5) Lab Samples from Each Test Pit for Permeablity Tests	None	None	None	None	None	Observations of Continuity, Thickness, and Orientations of Overburden Strata; Video, Photographs

Notes:

RI Field Investigation Activities also included:

a) One comprehensive ground-water sampling round for VOCs, ketones, alcohols, and tetrahydrofuran at essentially all accessible monitoring wells, piezometers, and extraction wells in the study area.
In addition, temperature, pH, and specific conductance were measured in the field at these wells/piezometers at the time of sample collection.
Ground-water sampling from wells P-1A, P-1B, P-6, P-8A, P-8B, MW-414, MW-415, MW-502 and each of the MW-703 and MW-704 cluster wells for laboratory analysis of the following parameters:
nitrate; ammonia; sulfate; sulfide; methane; ethane; ethene; total Fe; dissolved Fe; total Mn; dissolved Mn; chloride; orthophosphate; and phospholipid fatty acids.
In addition, dissolved oxygen and redox (ORP) were measured in the field at these wells at the time of sample collection.
Collection of supplemental ground-water samples using the USEPA Region I low-flow purging and sampling procedure (August 1995), in addition to sampling using traditional sampling procedures described in FSP Appendix I, at the following wells: P-4A, P-4B, P-5A, P-5B, MW-704S, and MW-704R.

b) LNAPL and DNAPL thickness measurements at wells sampled in the potential NAPL zone.

c) Two comprehensive ground-water elevation measurement rounds on January 21, 1996 and July 7, 1997, including essentially all accessible monitoring wells, piezometers, extraction wells, and surface-water measuring points, in the study area

* -- Performed only at initial pilot boring locations (designated -DR).
** -- At the RC-701 location, the bedrock corehole was advanced and core samples were obtained with minimal recirculating of water.
*** -- Soil samples obtained from soil borings for porosity, bulk density, and permeability characterization were obtained using interval split-spoon liner sleeves.
All wells 2-inch in diameter with 0.010-inch slot screens, constructed of Sch. 40 PVC except for MW-705DR which is constructed with a Sch. 40 #304 stainless steel screen and sump.
NA - Not Applicable

TABLE 2

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

CHEMICAL-SPECIFIC ARARs AND TBCs

Regulatory Level	Requirement	Status	Requirement Synopsis	RI Work Plan Considerations
Federal	Clean Water Act (CWA) Water Quality Criteria for Protection of Human Health and Aquatic Life	Applicable	Contaminant levels regulated by water quality criteria are provided to protect human health for exposure from drinking water and from fish consumption.	The promulgated values will be compared to the maximum contaminant levels at the SRSNE Site during the evaluation of target cleanup levels.
	RCRA Maximum Concentration Levels (MCLs)	Applicable	Provides standards for protection of ground water. This regulation also provides the basis for application of alternate concentration limits on a site-specific basis.	The promulgated values are included in the SDWA MCLs (see SDWA below). The combined standards will be compared to the maximum contaminant levels at the SRSNE Site during the evaluation of target cleanup levels.
	Safe Drinking Water Act (SDWA) MCLs	Relevant and Appropriate	Provides contaminant concentration standards for public drinking water systems.	The SDWA MCLs, along with Connecticut standards and guidance values, will be used during the evaluation of target cleanup levels.
State of Connecticut	Remediation Standard Regulations	Applicable	Provides soil, surface water, and ground-water concentration standards for remedial activities in the state of Connecticut.	This ARAR would be considered during the development of target cleanup levels for soil and ground water at the Site.

TABLE 3

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

LOCATION-SPECIFIC ARARs AND TBCs

Regulatory Level	Requirement	Status	Requirement Synopsis	RI Work Plan Considerations
Federal	Fish and Wildlife Coordination Act (16 U.S.C. 661)	Relevant and Appropriate	This regulation requires that any federal agency that proposes to modify a body of water must consult with the U.S. Fish and Wildlife Service.	During the identification, screening, and evaluation of remedial alternatives in the FS, the effects of potential remedial actions on streams and wetlands will be evaluated. If an alternative modifies a body of water or potentially affects fish or wildlife, the U.S. Fish and Wildlife Service will be consulted.
	RCRA Location Standards (40 CFR 264.18)	Applicable	This regulation outlines the requirements for constructing a RCRA facility on a 100-year floodplain.	A facility located on a 100-year floodplain must be designed, constructed, operated, and maintained to prevent washout of any hazardous waste by a 100-year flood, unless waste may be safely removed before floodwater can reach the facility or no adverse effects on human health and the environment would result if washout occurred.
	Floodplains Executive Order (E.O. 11990)	Relevant and Appropriate	Federal agencies are required to reduce the risk of flood loss, and to restore and preserve the natural and beneficial values of floodplains.	The potential effects of any action must be evaluated to ensure that the planning and decision-making reflect consideration of flood hazards and floodplain management, including restoration and preservation of natural, undeveloped floodplains.

TABLE 4

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

ACTION SPECIFIC ARARs AND TBCs

Regulatory Level	Requirement	Status	Requirement Synopsis	RI Work Plan Considerations
Federal	Clean Air Act (CAA) - National Primary and Secondary Air Quality Standards for Particulate Matter (40 CFR 50.6)	Relevant and Appropriate	The primary and secondary 24-hour ambient air quality standard for particulate matter is 150 micrograms/cubic meter ($\mu g/m^3$) (24-hour average concentration). The primary and secondary annual ambient air quality standard for particulate matter annual standard is 50 $\mu g/m^3$ (annual arithmetic mean).	This potential ARAR would apply if remedial alternatives result in air emissions during demolition, grading, and paving.
	CAA - National Primary and Secondary Air Quality Standards for Carbon Monoxide (40 CFR 50.8)	Relevant and Appropriate	The primary and secondary ambient air quality standard for carbon monoxide, not to be exceeded more than once per year, is 10 milligrams/cubic meter (mg/m^3) for an 8-hour concentration, or 35 mg/m^3 for a 1-hour concentrations.	This potential ARAR would apply if air emissions from treatment (thermal/catalytic oxidation) of organics in the off-gas from a soil treatment system would be required.
	CAA - National Primary and Secondary Air Quality Standards for Nitrogen Dioxide (40 CFR 50.11)	Relevant and Appropriate	The primary and secondary ambient air quality standards for nitrogen oxide are 100 $\mu g/m^3$, annual arithmetic mean concentration.	This potential ARAR would apply if air emissions from treatment (thermal/catalytic oxidation) of organics in the off-gas from a soil treatment system would be required.
	CAA - National Emissions Standards for Hazardous Air Pollutants (NESHAPs) - Vinyl Chloride (40 CFR 61, Subpart F)	Relevant and Appropriate	The standard applies to plants that manufacture or use vinyl chloride in the production. The average concentration of vinyl chloride must not exceed 10 ppm in the exhaust gas stream for a 3-hour period. As off-gas treatment for vinyl chloride may be necessary for a soil treatment system, this ARAR is potentially relevant and appropriate.	This potential ARAR would apply if air emissions from treatment (thermal/catalytic oxidation) of organics in the off-gas from a soil treatment system would be required.
	CAA - NESHAPs for Equipment Leaks (Fugitive Emissions) (40 CFRR 61, Subpart V)	Relevant and Appropriate	These standards address fugitive emissions of volatile hazardous air pollutants from various equipment, including pumps, compressors, pressure relief valves, sampling connection systems, valves, flanges, connectors, and certain control devices and systems.	This potential ARAR would apply if air emissions from treatment (thermal/catalytic oxidation) of organics in the off-gas from a soil treatment system would be required.

TABLE 4
(CONT'D)

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

ACTION-SPECIFIC ARARs AND TBCs

Regulatory Level	Requirement	Status	Requirement Synopsis	RI Work Plan Considerations
Federal (cont'd)	CAA - NESHAPs for Benzene Waste Operations (40 CFR 61, Subpart FF)	Relevant and Appropriate	This regulation specifies use of a closed-vent system to route all organic vapors vented by an oil-water separator to a control device (40 CFR 61.347); and requirements for the design, installation, operation, and maintenance of closed-vent systems and control devices.	This potential ARAR would apply if air emissions from treatment (thermal/catalytic oxidation) of organics in the off-gas from a soil treatment system would be required.
	CWA - National Pollutant Discharge Elimination System (NPDES) (40 CFR 122, 125)	Applicable	Any point-source discharge must meet NPDES requirements, which include compliance with established discharge limitation, and completion of regular discharge monitoring records.	This potential ARAR applies to potential remedial alternatives that involve ground water and process water treatment and discharge to the Quinnipiac River.
	CWA Ambient Water Quality Criteria (AWQC)	Relevant and Appropriate	AWQC are health-based criteria that have been developed for 95 carcinogenic and non-carcinogenic compounds.	AWQC are used to develop discharge limitations for treated ground water.
	RCRA - General Facility Standards (40 CFR 264.10 - 264.18)	Relevant and Appropriate	General facility requirements outline general waste analysis, security measures, inspections, and training requirements.	Remedial alternatives requiring on-site treatment of soil or ground water would comply with this potential ARAR. The treatment facility will be constructed, fenced, posted, and operated in accordance with this requirement. All workers will be properly trained. Process wastes will be evaluated for the characteristics of hazardous wastes to assess further handling requirements.
	RCRA - Preparedness and Prevention (40 CFR 264.30 - 264.37)	Relevant and Appropriate	Outlines requirements for safety equipment and spill control.	This potential ARAR would apply to all remedial alternatives requiring on-site activities.
	RCRA - Contingency Plan and Emergency Procedures (40 CFR 264.50 - 264.56)	Relevant and Appropriate	Outlines requirements for emergency procedures to be used following explosions, fires, etc.	This potential ARAR would apply to all remedial alternatives requiring on-site activities.
	RCRA - Manifesting, Recordkeeping, and Reporting (40 CFR 264.70 - 264.77)	Relevant and Appropriate	Specifies the recordkeeping and reporting requirements for RCRA facilities.	All remedial alternatives requiring handling and disposal of hazardous waste would comply with this potential ARAR.

TABLE 4
(CONT'D)

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

ACTION-SPECIFIC ARARs AND TBCs

Regulatory Level	Requirement	Status	Requirement Synopsis	RI Work Plan Considerations
Federal (cont'd)	RCRA - Closure and Post-Closure (40 CFR 264.110 - 264.120)	Relevant and Appropriate	Details specific requirements for closure and post-closure of hazardous waste facilities.	This potential ARAR would apply to all remedial alternatives requiring on-site activities.
	RCRA - Use and Management of Containers (40 CFR 264 Subpart I)	Relevant and Appropriate	This regulation specifies conditions for hazardous waste storage in containers.	Remedial alternatives requiring the use of containers would comply with these requirements.
	RCRA - Tank Systems (40 CFR 264 Subpart J)	Relevant and Appropriate	This regulation applies to the use of tank systems to store or treat hazardous wastes. Specifies design, installation, containment, and operating criteria.	Remedial alternatives requiring the use of tanks would comply with these requirements.
	RCRA - Air Emission Standards for Process Vents (40 CFR 264 Subpart AA)	Relevant and Appropriate	Regulates air pollutant emissions for process vents, closed-vent systems, control devices for TSDFs, air/steam stripping operations when equipment treats identified or listed RCRA hazardous wastes.	Remedial alternatives requiring the use of air pollutant control equipment would require compliance with this potential ARAR.
	RCRA - Air Emission Standards for Equipment Leaks (40 CFR 264 Subpart BB)	Relevant and Appropriate	This requirement governs equipment that contains or contacts hazardous wastes with organic concentrations of at least 10 percent by weight. Specifies periodic monitoring for leaks that may cause air emissions and specifies repairs.	This potential ARAR would apply to remedial alternatives requiring on-site treatment of ground water or soil.
	RCRA - Thermal Treatment (40 CFR 265 Subpart P)	Relevant and Appropriate	This requirement regulates thermal treatment of hazardous wastes.	This potential ARAR would apply to alternatives requiring thermal and catalytic oxidation of VOCs from a soil treatment system.
State Regulatory Requirements	Control of Particulate Matter (RCSA §22a-174-18)	Applicable	This regulation governs visible emissions and fugitive dusts from stationary sources.	This potential ARAR would apply to remedial alternatives requiring on-site treatment of soil or ground water.
	Control of Organic Compound Emissions (RCSA §22a-174-20)	Relevant and Appropriate	This requirement regulates the storage of VOCs and specifies the air emission controls required if a storage tank of 250 gallons or greater is used, or the VOC has a vapor pressure of 1.5 psi or greater.	This potential ARAR would apply to remedial alternatives requiring on-site treatment of ground water.

TABLE 4
(CONT'D)

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

ACTION-SPECIFIC ARARs AND TBCs

Regulatory Level	Requirement	Status	Requirement Synopsis	RI Work Plan Considerations
State Regulatory Requirements (cont'd)	Control of Nitrogen Oxide Emission (RCSA §22a-174-22)	Relevant and Appropriate	This regulation specifies the emission limits of nitrogen oxide based on the type of fuel combusted.	This potential ARAR would apply to remedial alternatives requiring off gas treatment which use supplemental fuels to maintain oxidation of stripped VOCs.
	Primary Standards for Ambient Air (RCSA §22a-174-24)	Relevant and Appropriate	This regulation prohibits the operation of any source that substantially causes or contributes to a violation of the limits specified in this regulation.	This potential ARAR would apply if remedial alternatives result in air emissions.
	Hazardous Air Pollutants (RCSA §22a-174-29)	Applicable	These regulations limit emissions that interfere with maintenance of Connecticut Air Quality Standards for NAAQS. The regulations include ambient air quality standards (HLVs) and maximum allowable stack concentrations (MASCs) for hundreds of hazardous air pollutants.	Air emissions from ground-water treatment systems would be controlled and would comply with these air quality regulations.
	Connecticut Water Quality Standards (CGS 22a-426)	Relevant and Appropriate	These standards provide criteria for maintaining the quality of surface waters through limitations on point source discharges and implementation of reasonable controls or best management practices (BMP).	Ground water treated on-site and discharged to surface water would be required to comply with these standards.
	Connecticut Discharge Permit Regulations (22a-430-1 to 8)	Applicable	These requirements provide specific effluent limitations for a given discharge.	Ground water treated on-site and discharged to a surface water will need to comply with the substantive requirements of these regulations.
Criteria, Advisories, Guidance	OSWER Directive 9355.0-28, Air Stripper Control Guidance	To Be Considered	Guidance regarding use of air emission controls at CERCLA sites.	This guidance will be used to develop air emission controls if an alternative requiring air emissions is selected.

TABLE 5

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

DNAPL AND ASSOCIATED GROUND–WATER CHARACTERIZATION DATA

Characterization Parameter	Sample						
	MWD–601		RW–5		IW–23	MW–705DR	
VOCs, mg/L (Method 8240 or Modified 8260)	DNAPL	Water*	DNAPL	Water**	DNAPL/Grout	DNAPL	Water***
Vinyl Chloride	–	–	–	0.350	–	–	–
1,1–Dichloroethylene	187	1.120	126	–	418	–	2.6
Methylene Chloride	–	–	60	–	50	–	18
1,1–Dichloroethane	12.8	0.440	–	0.081	38	–	38
cis–1,2–Dichloroethylene	443.6	10.64	1321	0.932	1254	–	12
Chloroform	14	–	16	–	–	–	–
2–Butanone	–	–	–	–	–	–	32
1,1,1–Trichloroethane	4433	14.60	2313	0.103	1834	29000	33
Benzene	49.8	0.720	70	–	11	–	11
1,2–Dichloroethane	9	–	–	–	–	–	–
Trichloroethylene	163000	348.0	57371	0.660	19019	550000	780
4–Methyl–2–pentanone (MIBK)	–	1.440	75	–	–	–	50
2–Hexanone	Not Analyzed	Not Analyzed	Not Analyzed	Not Analyzed	Not Analyzed	–	50
Toluene	45104	48.40	15007	–	6636	81000	42
1,1,2–Trichloroethane	5.8	–	–	–	–	–	–
Tetrachloroethylene	46470	16.28	12866	0.286	15052	160000	31
Ethylbenzene	5239	8.640	3781	–	3891	21000	2.8
P/M Xylenes	12061	8.670	3629	–	5512	46000	5.1
O Xylene	4210	5.760	2569	0.084	2727	12000	1.6
Styrene	1056	0.430	643	–	784	–	–
TOTAL VOCs	282000	465	99800	2.50	57200	899000	1110
TCL SVOCs (Modified Methods 8270/8040)	ND	ND	ND	ND	ND	Not Analyzed	Not Analyzed
	MWD–601		RW–5		IW–23	MW–705DR	
PCBs/Pesticides, mg/L (Method 8080)	DNAPL	Water*	DNAPL	Water**	DNAPL/Grout	DNAPL	Water***
PCB–1254	–	–	300	–	0.730	Not Analyzed	Not Analyzed
PCB–1260	419	0.061	–	–	–	Not Analyzed	Not Analyzed
	MWD–601		RW–5		IW–23	MW–705DR	
Density, g/cm^3 (ASTM D–4052)	DNAPL	Water*	DNAPL	Water**	DNAPL/Grout	DNAPL	Water***
@ 10 degrees Celsius			1.1136			1.23	
@ 15.6 degrees Celsius	1.1093	Not		Not	Not		Not
@ 20.0 degrees Celsius	1.1005	Analyzed		Analyzed	Analyzed		Analyzed
@ 25.0 degrees Celsius	1.0963						
@ 38.0 degrees Celsius	1.0855						
	MWD–601		RW–5		IW–23	MW–705DR	
Viscosity, centistokes (ASTM D–445)	DNAPL	Water*	DNAPL	Water**	DNAPL/Grout	DNAPL	Water***
@ 8.5 degrees Celsius			1.23				
@ 10 degrees Celsius						0.993	
@ 20.0 degrees Celsius	1.120	Not		Not	Not		Not
@ 25.0 degrees Celsius	1.049	Analyzed		Analyzed	Analyzed		Analyzed
@ 38.0 degrees Celsius	0.901						
	MWD–601		RW–5		IW–23	MW–705DR	
Interfacial Tension, dynes/cm (ASTM D–971)	DNAPL	Water*	DNAPL	Water**	DNAPL/Grout	DNAPL	Water***
@ 20.0 degrees Celsius	7.8	Not Analyzed	3.1	Not Analyzed	Not Analyzed	9.0	Not Analyzed

Notes:
VOCs analyzed by Method 8240 except for samples from well MW–705DR, analyzed by modified Method 8260.
* Well MWD–601 installed with 5–foot long screen in 6.7–foot long sand pack.
** Well RW–5 installed with 10–foot long screen in 17–foot long saturated sand pack; ground–water sample obtained from RW–5 during NTCRA 1 system operation.
*** Well MW–705DR installed with 10–foot long screen in 12–foot long sand pack.
– Below detection level.
ND – Analyzed, but none detected.

TABLE 6

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

SUMMARY OF BEDROCK PACKER TEST DATA, BEDROCK FRACTURE SPACING, AND ESTIMATED FRACTURE APERTURE

Well I.D.	Top of Rock Depth (ft, bgs.)	Packer-Test Interval (ft, bgs.) *			Midpoint Depth Below Rock (ft)	Test Interval Bulk K (cm/sec)	Test Interval Length (cm)	Test Interval Bulk T (cm^2/s)	# of Fractures in Tested Interval *	Mean Fracture Spacing (cm)	Mean Fracture T (cm^2/s)	Mean Fracture Aperture (cm)	Mean Fracture K (cm/sec)
		Top	Bottom	Midpoint									
MW-701DR	20.5	33.1	43.4	38.3	17.8	< 2.7E-05	314	< 8.5E-03	NA	NA	NA	NA	NA
	20.5	43.1	53.4	48.3	27.8	7.5E-05	314	2.4E-02	NA	NA	NA	NA	NA
	20.5	53.1	63.4	58.3	37.8	5.1E-04	314	1.6E-01	NA	NA	NA	NA	NA
	20.5	63.1	73.4	68.3	47.8	2.7E-04	314	8.5E-02	NA	NA	NA	NA	NA
	20.5	73.1	83.4	78.3	57.8	7.6E-05	314	2.4E-02	NA	NA	NA	NA	NA
	20.5	83.1	93.4	88.3	67.8	< 1.9E-05	314	< 6.0E-03	NA	NA	NA	NA	NA
	20.5	93.1	103.4	98.3	77.8	9.7E-04	314	3.0E-01	NA	NA	NA	NA	NA
MW-702DR	21.7	22.0	27.5	24.8	3.1	< 8.9E-05	168	< 1.5E-02	7	24	< 2.1E-03	< 7.0E-03	< 3.1E-01
	21.7	31.0	41.0	36.0	14.3	< 3.5E-05	305	< 1.1E-02	6	51	< 1.8E-03	< 6.6E-03	< 2.7E-01
	21.7	35.5	45.5	40.5	18.8	< 3.1E-05	305	< 9.4E-03	5	61	< 1.9E-03	< 6.7E-03	< 2.8E-01
	21.7	45.5	55.5	50.5	28.8	< 5.2E-05	305	< 1.6E-02	4	76	< 4.0E-03	< 8.6E-03	< 4.6E-01
	21.7	55.5	65.5	60.5	38.8	< 2.2E-05	305	< 6.7E-03	2	152	< 3.4E-03	< 8.1E-03	< 4.1E-01
	21.7	65.5	75.5	70.5	48.8	< 2.6E-05	305	< 7.9E-03	2	152	< 4.0E-03	< 8.6E-03	< 4.6E-01
	21.7	75.5	85.5	80.5	58.8	< 1.7E-05	305	< 5.2E-03	3	102	< 1.7E-03	< 6.5E-03	< 2.7E-01
	21.7	85.5	95.5	90.5	68.8	< 1.5E-05	305	< 4.6E-03	1	305	< 4.6E-03	< 9.0E-03	< 5.1E-01
	21.7	95.5	105.5	100.5	78.8	< 1.4E-05	305	< 4.3E-03	1	305	< 4.3E-03	< 8.8E-03	< 4.8E-01
MW-703DR	84.0	90.5	100.5	95.5	11.5	1.4E-05	305	4.3E-03	NA	NA	NA	NA	NA
	84.0	100.5	110.5	105.5	21.5	< 1.3E-05	305	< 4.0E-03	NA	NA	NA	NA	NA
	84.0	110.5	120.5	115.5	31.5	< 1.4E-05	305	< 4.3E-03	NA	NA	NA	NA	NA
	84.0	120.5	130.5	125.5	41.5	< 1.6E-05	305	< 4.9E-03	NA	NA	NA	NA	NA
	84.0	130.5	140.5	135.5	51.5	< 2.4E-05	305	< 7.3E-03	NA	NA	NA	NA	NA
	84.0	140.5	150.5	145.5	61.5	< 1.5E-05	305	< 4.6E-03	NA	NA	NA	NA	NA
	84.0	150.5	160.5	155.5	71.5	< 1.7E-05	305	< 5.2E-03	NA	NA	NA	NA	NA
	84.0	160.5	170.5	165.5	81.5	< 2.0E-05	305	< 6.1E-03	NA	NA	NA	NA	NA
MW-704DR	75.0	76.0	81.5	78.8	3.8	< 6.8E-05	168	< 1.1E-02	1	168	< 1.1E-02	< 1.2E-02	< 9.3E-01
	75.0	79.0	89.0	84.0	9.0	2.9E-04	305	8.8E-02	2	152	4.4E-02	1.9E-02	2.3E+00
	75.0	82.0	92.0	87.0	12.0	< 1.7E-05	305	< 5.2E-03	1	305	< 5.2E-03	< 9.4E-03	< 5.5E-01
	75.0	92.0	102.0	97.0	22.0	< 1.5E-05	305	< 4.6E-03	2	152	< 2.3E-03	< 7.2E-03	< 3.2E-01
	75.0	102.0	112.0	107.0	32.0	< 1.4E-05	305	< 4.3E-03	2	152	< 2.1E-03	< 7.0E-03	< 3.1E-01
	75.0	112.0	122.0	117.0	42.0	1.5E-05	305	4.6E-03	6	51	7.6E-04	5.0E-03	1.5E-01
	75.0	122.0	132.0	127.0	52.0	< 1.6E-05	305	< 4.9E-03	0	> 305	NA	NA	NA
	75.0	132.0	142.0	137.0	62.0	< 1.2E-05	305	< 3.7E-03	0	> 305	NA	NA	NA
	75.0	142.0	152.0	147.0	72.0	< 1.3E-05	305	< 4.0E-03	0	> 305	NA	NA	NA
	75.0	152.0	162.0	157.0	82.0	< 1.2E-05	305	< 3.7E-03	1	305	< 3.7E-03	< 8.4E-03	< 4.4E-01
MW-705DR **	40.0	88.3	100.3	94.3	54.3	1.4E-04	366	5.2E-02	11	33	4.7E-03	9.1E-03	5.2E-01
MW-705R	40.0	42.0	47.0	44.5	4.5	< 1.4E-04	152	< 2.1E-02	11	14	< 1.9E-03	< 6.8E-03	< 2.9E-01
	40.0	45.5	50.5	48.0	8.0	< 7.5E-05	152	< 1.1E-02	3	51	< 3.8E-03	< 8.5E-03	< 4.5E-01
MW-706DR	60.0	72.0	82.0	77.0	17.0	2.8E-04	304.8	8.5E-02	NA	NA	NA	NA	NA
	60.0	76.5	86.5	81.5	21.5	< 4.4E-05	304.8	< 1.3E-02	NA	NA	NA	NA	NA
	60.0	86.5	96.5	91.5	31.5	< 1.6E-05	304.8	< 4.9E-03	NA	NA	NA	NA	NA
	60.0	96.5	106.5	101.5	41.5	< 2.0E-05	304.8	< 6.1E-03	NA	NA	NA	NA	NA
	60.0	106.5	116.5	111.5	51.5	< 1.9E-05	304.8	< 5.8E-03	NA	NA	NA	NA	NA
	60.0	116.5	126.5	121.5	61.5	8.4E-05	304.8	2.6E-02	NA	NA	NA	NA	NA
	60.0	126.5	136.5	131.5	71.5	< 1.8E-05	304.8	< 5.5E-03	NA	NA	NA	NA	NA
	60.0	136.5	146.5	141.5	81.5	< 2.6E-05	304.8	< 7.9E-03	NA	NA	NA	NA	NA
MW-707DR	100.0	112.5	122.5	117.5	17.5	1.8E-03	304.8	5.5E-01	NA	NA	NA	NA	NA
	100.0	116.7	126.7	121.7	21.7	1.7E-03	304.8	5.2E-01	NA	NA	NA	NA	NA
	100.0	126.7	136.7	131.7	31.7	< 2.5E-05	304.8	< 7.6E-03	NA	NA	NA	NA	NA
	100.0	136.7	146.7	141.7	41.7	< 1.4E-05	304.8	< 4.3E-03	NA	NA	NA	NA	NA
	100.0	146.7	156.7	151.7	51.7	< 1.4E-05	304.8	< 4.3E-03	NA	NA	NA	NA	NA
	100.0	156.7	166.7	161.7	61.7	< 1.2E-05	304.8	< 3.7E-03	NA	NA	NA	NA	NA
	100.0	166.7	176.7	171.7	71.7	< 2.0E-05	304.8	< 6.1E-03	NA	NA	NA	NA	NA
	100.0	176.7	186.7	181.7	81.7	< 1.5E-05	304.8	< 4.6E-03	NA	NA	NA	NA	NA
MW-708DR	175.0	178.0	188.0	183.0	8.0	4.2E-04	304.8	1.3E-01	NA	NA	NA	NA	NA
	175.0	183.0	193.0	188.0	13.0	1.9E-06	304.8	5.8E-04	NA	NA	NA	NA	NA
	175.0	193.0	203.0	198.0	23.0	< 7.6E-07	304.8	< 2.3E-04	NA	NA	NA	NA	NA
	175.0	203.0	213.0	208.0	33.0	1.4E-06	304.8	4.3E-04	NA	NA	NA	NA	NA
	175.0	213.0	223.0	218.0	43.0	7.6E-07	304.8	2.3E-04	NA	NA	NA	NA	NA
	175.0	223.0	233.0	228.0	53.0	4.1E-06	304.8	1.2E-03	NA	NA	NA	NA	NA
	175.0	233.0	243.0	238.0	63.0	9.7E-06	304.8	3.0E-03	NA	NA	NA	NA	NA
	175.0	243.0	253.0	248.0	73.0	< 6.6E-07	304.8	< 2.0E-04	NA	NA	NA	NA	NA
	175.0	253.0	263.0	258.0	83.0	2.0E-05	304.8	6.1E-03	NA	NA	NA	NA	NA

TABLE 6

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

SUMMARY OF BEDROCK PACKER TEST DATA, BEDROCK FRACTURE SPACING, AND ESTIMATED FRACTURE APERTURE

Well I.D.	Top of Rock Depth (ft, bgs.)	Packer-Test Interval (ft, bgs.) *			Midpoint Depth Below Rock (ft)	Test Interval Bulk K (cm/sec)	Test Interval Length (cm)	Test Interval Bulk T (cm^2/s)	# of Fractures in Tested Interval *	Mean Fracture Spacing (cm)	Mean Fracture T (cm^2/s)	Mean Fracture Aperture (cm)	Mean Fracture K (cm/sec)
		Top	Bottom	Midpoint									
MW-710DR	127.0	131.1	141.1	136.1	9.1	**1.4E-03**	304.8	**4.3E-01**	NA	NA	NA	NA	NA
	127.0	136.1	146.1	141.1	14.1	**1.4E-03**	304.8	**4.3E-01**	NA	NA	NA	NA	NA
	127.0	146.1	156.1	151.1	24.1	< 1.3E-06	304.8	< 4.0E-04	NA	NA	NA	NA	NA
	127.0	156.1	166.1	161.1	34.1	**2.6E-05**	304.8	**7.9E-03**	NA	NA	NA	NA	NA
	127.0	166.1	176.1	171.1	44.1	< 1.1E-06	304.8	< 3.4E-04	NA	NA	NA	NA	NA
	127.0	176.1	186.1	181.1	54.1	**6.7E-06**	304.8	**2.0E-03**	NA	NA	NA	NA	NA
	127.0	186.1	196.1	191.1	64.1	**4.9E-06**	304.8	**1.5E-03**	NA	NA	NA	NA	NA
	127.0	196.1	206.1	201.1	74.1	**3.9E-06**	304.8	**1.2E-03**	NA	NA	NA	NA	NA
Cianci Well **	30.0	30	130	80	50	**3.3E-04**	3048	**1.0E+00**	**13**	**234**	**7.7E-02**	**2.3E-02**	**3.3E+00**
Statistics for All Data, Including "<" and ">"	Geo. Mean					2.8E-05		8.1E-03			4.0E-03		4.7E-01
	Arith. Mean					1.5E-04		5.9E-02	3.7	163.5	9.5E-03	9.3E-03	6.6E-01
Statistics for Quantified Data Only	Geo. Mean					**6.9E-05**		**2.3E-02**			**4.2E-03**		**4.8E-01**
	Arith. Mean					**1.6E-04**		**6.0E-02**	**3.7**	**142.3**	**1.1E-02**	**9.6E-03**	**7.3E-01**
	Std. Dev.					**3.8E-04**		**1.6E-01**	**3.7**	**98.9**	**2.1E-02**	**4.9E-03**	**8.8E-01**

Notes: Fracture aperature estimates based on parallel plate fracture flow theory presented by Zeigler, T.W., 1976, Determination of Rock Mass Permeability, U.S. Army Engineers Waterways Experiment Station, Soils and Pavements Laboratory, Vicksburg, Mississippi.

Mean fracture aperature estimates based on the equation: T = p * (g * b^3) / 12 v;
where T is fracture transmissivity, p = water density (1.00 g/mL), g = gravitational constant,
b = fracture aperature, and v = kinematic viscosity of water at 10 degrees C (0.01306 cm^2/sec).

* -- Number of fractures for test interval based on core sample description or, where available, Borehole Image Processing results for fractures ranked 2 and above (COLOG, December 1996).

** Specific capacity tests were performed in lieu of packer tests at MW-705DR and the Cianci Well.

NA = Not Available.

Bold data are quantified (no "<" or ">").

TABLE 7

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

SPECIFIC CAPACITY TEST DATA SUMMARY

Well ID	Test Date	Q (gpm)	K (ft/day)	K (cm/sec)	Additional Drawdown Responses Measured (Feet) or Noteworthy Observations
CIANCI	11/7/96	4.0	0.94	3.3E-04	P-12A, 1.29; MW-705DR, 0.58; CPZ-9R, 0.01; MW-705R, 0.00; CPZ-10R, 0.00
MW-01	12/20/96	0.85	1.7	5.9E-04	
MW-02	12/5/96	2.0	34	1.2E-02	
MW-121B	12/13/96	2.0	397	1.4E-01	
MW-204B	12/5/96	2.2	164	5.8E-02	
MW-501B	12/6/96	2.0	5.4	1.9E-03	
MW-502	12/13/96	0.15	0.5	1.6E-04	
MW-703S	11/12/96	2.8	82	2.9E-02	MW-703D, 0.04; MW-127B, 0.06; CW-1-75, 0.06
MW-703D	11/13/96	3.0	3.4	1.2E-03	MW-703S, 0.05; MW-703DR, 1.88; MW-127B, 0.04; CW-1-78, 0.06
MW-704S	11/11/96	0.6	0.99	3.5E-04	MW-704M, 0.04; MW-704D, 0.05; MW-704DR, 0.01; MW-204B, 0.04; MW-121B, 0.10; MWL-314, 0.07; P-13, 0.06; USGS, 0.07, CW-2-75, 0.01
MW-704M	11/12/96	3.2	27	9.6E-03	MW-704M, 1.63; MW-704R, 0.18; MW-704D, 0.20; MW-204B, 0.16; USGS, 0.06; CW-2-75, 0.03; MW-121B, 0.12; P-13, 0.04; MWL-314, 0.04
MW-704D	11/13/96	3.0	52	1.8E-02	MW-704S, 0.05; MW-704M, 0.29; MW-204A, 0.11; MW-204B, 0.13; USGS, 0.05; CW-2-75, 0.04; MW-121B, 0.11; MW-121C, 0.13; P-13, 0.04; MWL-314, 0.03
MW-704DR	11/13/96	1.6	0.16	5.5E-05	Well dry after 63.5 minutes pumping
MW-707D	12/6/96	2.0	164	5.8E-02	
P-101B	12/19/96	0.74	28	1.0E-02	

TABLE 8

SRSNE SITE

SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

GROUND-WATER AND SURFACE-WATER ELEVATION MEASUREMENTS

Location	X (Easting)	Y (Northing)	Ground Surface Elev.	Meas. Point Elev.	Depth to Water 1/21/97	Water Elev. 1/21/97	Depth to Water 7/7/97	Water Elev. 7/7/97	(L)NAPL, (D)NAPL *	Well Formation **
CPZ-1	565212	286107	157.44	159.73	6.97	152.76	9.51	150.22	N	O
CPZ-2	565216	286045	156.44	158.64	4.11	154.53	6.90	151.74	N	O
CPZ-3	565290	286163	156.74	159.49	11.54	147.95	13.19	146.30	N	O
CPZ-4	565322	286092	155.21	158.80	7.60	151.20	9.94	148.86	N	O
CPZ-5	565376	286312	155.99	158.60	18.24	140.36	16.89	141.71	N	O
CPZ-6	565480	286325	152.31	154.47	3.67	150.80	4.39	150.08	N	O
CPZ-7	565343	286467	156.81	159.54	7.55	151.99	6.97	152.57	N	O
CPZ-8	565397	286529	157.29	160.35	5.92	154.43	6.38	153.97	N	O
CPZ-9	565229	286575	158.31	160.56	5.12	155.44	5.71	154.85	N	O
CPZ-10	565237	286643	158.51	160.97	3.45	157.52	4.42	156.55	N	O
CPZ-1R	565209	286103	157.44	161.32	3.14	158.18	4.55	156.77	N	R
CPZ-2R	565217	286039	156.74	160.79	-0.72	160.07	4.06	156.73	N	R
CPZ-3R	565286	286158	156.67	160.83	6.77	154.06	8.53	152.30	N	R
CPZ-4R	565322	286085	154.91	158.73	5.34	153.39	7.88	150.85	N	R
CPZ-5R	565374	286319	155.69	158.52	10.30	148.22	11.01	147.51	N	R
CPZ-6R	565480	286318	152.41	154.49	4.37	150.12	5.64	148.85	N	R
CPZ-7R	565338	286472	156.81	158.61	2.24	156.37	3.96	154.65	L, D	R
CPZ-8R	565395	286533	157.51	160.80	6.72	154.08	7.74	153.06	N	R
CPZ-9R	565244	286575	158.41	162.45	1.91	160.54	4.50	157.95	0.01' L, D	R
CPZ-10R	565233	286642	158.71	160.97	0.27	160.70	2.29	158.68	N	R
CPZ-2A	565219	286090	156.34	158.86	4.06	154.80	6.82	152.04	N	O
CPZ-4A	565300	286147	156.11	159.47	8.07	151.40	9.90	149.57	N	O
CPZ-6A	565396	286321	155.37	158.17	6.78	151.39	7.52	150.65	N	O
CW-10-78	565317	284256	149.90	151.35	4.97	146.38	5.58	145.77		O
CW-1-78	565213	285075	157.80	158.46	11.06	147.40	12.26	146.20		O
CW-2-75	565407	285677	152.60	153.69	5.29	148.40	6.71	146.98		O
CW-2-78	565073	285036	161.00	163.81	16.29	147.52	17.61	146.20		O

TABLE 8

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

GROUND-WATER AND SURFACE-WATER ELEVATION MEASUREMENTS

Location	X (Easting)	Y (Northing)	Ground Surface Elev.	Meas. Point Elev.	Depth to Water 1/21/97	Water Elev. 1/21/97	Depth to Water 7/7/97	Water Elev. 7/7/97	(L)NAPL, (D)NAPL *	Well Formation **
CW-3-75	565678	285115	152.00	153.04	6.30	146.74	7.28	145.76		O
CW-3-78	565162	284652	145.90	150.56	5.26	145.30	5.97	144.59		O
CW-4-75	565312	285355	150.60	151.42	3.21	148.21	4.54	146.88		O
CW-4-78	565155	284650	145.70	147.28	1.87	145.41	2.65	144.63		R
CW-5-75	565286	285030	152.80	153.12	6.29	146.83	7.64	145.48		O
CW-5-78	565251	284543	152.60	153.11	2.76	150.35	3.55	149.56		O
CW-6-75	565222	284832	150.10	151.31	5.72	145.59	6.48	144.83		O
CW-6-78	565396	284625	146.00	147.43	1.21	146.22	2.39	145.04		O
CW-7-75	565316	284843	150.80	151.10	5.33	145.77	6.19	144.91		O
CW-7-78	565366	284159	151.10	153.39	6.86	146.53	7.59	145.80		O
CW-7A	565314	284843	150.80	151.13	5.70	145.43	6.38	144.75		O
CW-8-78	565457	284171	150.90	153.06	5.97	147.09	6.67	146.39		O
CW-9-78	565527	284271	150.00	152.27	6.26	146.01	6.83	145.44		O
CW-B-77	565310	285711	150.52	151.72	3.43	148.29	4.91	146.81		O
DP-1	565620	286146	147.67	150.11	3.77	146.34	4.56	145.55	N	O
DP-2	565597	286323	147.81	149.33	2.28	147.05	3.10	146.23	N	O
DP-3	565578	286481	148.19	149.95	2.89	147.06	>2.85(dry)	<147.10	N	O
DP-4	565524	286655	149.06	150.87	2.11	148.76	2.60	148.27	N	O
DP-5	565602	287100	147.94	149.71	2.24	147.47	2.91	146.80	N	O
DP-6	565599	286886	147.91	150.04	2.71	147.33	3.56	146.48	N	O
MW-01	565281	285950	155.00	157.73	6.42	151.31	8.40	149.33		OR
MW-02	565307	285338	150.30	153.18	5.31	147.87	6.67	146.51		OR
MW-03	565509	285065	149.80	153.11	6.92	146.19	8.02	145.09		O
MW-04	565622	285470	148.80	151.62	3.07	148.55	4.25	147.37		OR
MW-05	565651	286030	147.40	150.67	1.31	149.36	2.58	148.09		R
MW-06	565660	286017	148.20	150.84	1.20	149.64	2.42	148.42		O
MW-07	565646	286028	147.30	150.36	1.33	149.03	2.64	147.72		O

TABLE 8

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

GROUND-WATER AND SURFACE-WATER ELEVATION MEASUREMENTS

Location	X (Easting)	Y (Northing)	Ground Surface Elev.	Meas. Point Elev.	Depth to Water 1/21/97	Water Elev. 1/21/97	Depth to Water 7/7/97	Water Elev. 7/7/97	(L)NAPL, (D)NAPL *	Well Formation **
MW-08	565654	286015	147.20	150.19	plugged	plugged	2.38	147.81		O
MW-121A	565539	285834	150.51	153.06	4.20	148.86	5.32	147.74		R
MW-121B	565532	285817	150.96	153.05	4.60	148.45	5.79	147.26		O
MW-121C	565535	285826	151.12	153.08	4.33	148.75	5.53	147.55		R
MW-123A	565280	286128	156.33	158.50	-2.57	161.07	2.10	156.40	N	R
MW-123C	565274	286126	156.72	158.55	5.43	153.12	7.43	151.12	N	O
MW-124C	565238	285852	155.98	158.51	3.18	155.33	6.47	152.04		R
MW-125A	565403	286393	155.83	158.10	3.49	154.61	3.72	154.38	N	R
MW-125C	565402	286382	155.97	158.18	6.38	151.80	6.72	151.46	N	R
MW-126B	565124	287008	162.79	162.46	2.35	160.11	3.25	159.21		O
MW-126C	565123	287011	162.78	162.62	0.87	161.75	2.74	159.88		R
MW-127B	565403	285087	147.86	149.84	2.46	147.38	3.64	146.20		O
MW-127C	565404	285081	147.58	150.05	2.65	147.40	3.87	146.18		R
MW-128	565211	285319	155.43	157.24	8.48	148.76	10.09	147.15		R
MW-129	563866	286975	227.54	226.62	0.74	225.88	2.95	223.67		R
MW-201A	565732	287690	154.29	156.97	7.92	149.05	8.85	148.12		R
MW-201B	565737	287694	154.48	156.82	8.25	148.57	9.05	147.77		O
MW-202A	566031	287225	156.25	155.90	5.61	150.29	6.98	148.92		R
MW-202B	566037	287225	156.28	156.10	6.42	149.68	7.60	148.50		O
MW-203A	566355	285360	188.78	188.39	35.77	152.62	37.27	151.12		R
MW-203B	566351	285359	188.47	188.23	35.37	152.86	36.87	151.36		O
MW-204A	565669	285566	148.83	150.87	2.21	148.66	3.43	147.44		R
MW-204B	565652	285569	148.74	150.63	2.22	148.41	3.43	147.20		O
MW-205A	565559	284997	150.29	152.70	5.78	146.92	6.77	145.93		R
MW-205B	565551	284992	149.96	152.18	5.32	146.86	6.31	145.87		O
MW-206A	565732	284158	153.13	152.71	5.75	146.96	6.48	146.23		R
MW-206B	565726	284159	153.20	152.90	5.96	146.94	6.71	146.19		O

TABLE 8

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

GROUND-WATER AND SURFACE-WATER ELEVATION MEASUREMENTS

Location	X (Easting)	Y (Northing)	Ground Surface Elev.	Meas. Point Elev.	Depth to Water 1/21/97	Water Elev. 1/21/97	Depth to Water 7/7/97	Water Elev. 7/7/97	(L)NAPL, (D)NAPL *	Well Formation **
MW-207A	565484	284175	150.70	152.98	plugged	plugged	plugged	plugged		R
MW-208A	565678	283622	156.82	156.55	8.41	148.14	9.17	147.38		R
MW-209A	564582	286263	196.13	198.25	21.76	176.49	22.33	175.92		R
MW-209B	564582	286258	195.81	198.31	15.85	182.46	16.29	182.02		O
MW-408	565318	286324	156.98	159.56	10.46	149.10	10.62	148.94	N	R
MW-409	565320	286332	157.14	159.60	4.88	154.72	5.70	153.90	N	O
MW-410	565305	286329	157.04	160.01	5.01	155.00	5.96	154.05	N	O
MW-411	565299	286341	157.22	160.29	8.88	151.41	9.60	150.69	N	R
MW-412	565302	286335	157.13	159.74	12.46	147.28	12.72	147.02	N	O
MW-413	565278	286350	158.00	160.66	5.56	155.10	6.51	154.15	N	O
MW-414	565273	286339	158.29	161.37	9.65	151.72	10.32	151.05	N	R
MW-415	565275	286346	158.15	160.86	5.64	155.22	6.58	154.28	N	O
MW-416	565264	286291	157.42	160.06	3.92	156.14	9.02	151.04	N	R
MW-501A	565838	286346	169.26	169.15	19.18	149.97	20.72	148.43		R
MW-501B	565837	286343	169.35	169.17	19.17	150.00	20.56	148.61		O
MW-501C	565838	286350	169.17	168.94	21.10	147.84	22.18	146.76		O
MW-502	565495	286270	153.07	155.62	5.49	150.13	7.47	148.15	N	O
MW-701DR	564579	286254	196.15	198.71	16.50	182.21	17.92	180.79		R
MW-702DR	564912	286075	179.13	181.30	14.95	166.35	20.38	160.92	N	R
MW-703D	565300	285097	153.02	155.42	8.01	147.41	9.45	145.97		O
MW-703DR	565299	285073	153.04	155.20	7.78	147.42	9.19	146.01		R
MW-703S	565299	285087	153.40	155.68	8.62	147.06	9.87	145.81		O
MW-704D	565540	285591	150.49	153.37	5.22	148.15	6.36	147.01		O
MW-704DR	565552	285565	150.55	153.06	4.48	148.58	5.50	147.56		R
MW-704M	565557	285574	150.58	152.55	4.39	148.16	5.52	147.03		O
MW-704R	565568	285583	150.52	152.00	3.71	148.29	4.83	147.17		R
MW-704S	565557	285583	150.53	152.69	4.62	148.07	5.03	147.66		O

TABLE 8

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

GROUND-WATER AND SURFACE-WATER ELEVATION MEASUREMENTS

Location	X (Easting)	Y (Northing)	Ground Surface Elev.	Meas. Point Elev.	Depth to Water 1/21/97	Water Elev. 1/21/97	Depth to Water 7/7/97	Water Elev. 7/7/97	(L)NAPL, (D)NAPL *	Well Formation **
MW-705D	565421	286754	159.39	161.58	4.30	157.28	4.88	156.70	N	O
MW-705DR	565429	286750	158.79	160.89	3.39	157.50	5.13	155.76	2.0' D	R
MW-705R	565422	286744	159.54	161.50	5.74	155.76	6.56	154.94	N	R
MW-706DR	565668	286216	147.82	149.91	-0.05	149.96	1.22	148.69	N	R
MW-707D	565599	285102	153.78	156.00	8.86	147.14	9.98	146.02		O
MW-707DR	565567	285124	154.72	156.72	8.92	147.80	10.26	146.46		R
MW-707M	565605	285109	153.41	155.12	7.92	147.20	9.03	146.09		O
MW-707R	565599	285115	153.91	155.85	8.11	147.74	9.28	146.57		R
MW-707S	565608	285116	153.16	154.94	7.87	147.07	8.98	145.96		O
MW-708S +	566241	286418	222.10	224.57	73.53+0.20	150.84	75.03	149.54		O
MW-708M +	566245	286405	223.30	226.08	74.49+0.25	151.34	76.10	149.98		O
MW-708R +	566254	286408	223.20	225.60	73.07+0.31	152.22	74.76	150.84		R
MW-708DR +	566251	286424	221.90	224.85	73.99+0.00	150.86	75.42	149.43		R
MW-709R	565403	287092	161.60	161.53	4.07	157.46	5.42	156.11		R
MW-709DR	565403	287092	161.60	161.53	2.27	159.26	4.28	157.25		R
MW-710S	566112	284847	165.00	164.93	Not	Installed	16.73	148.20		O
MW-710R	566110	284836	165.00	164.58	Not	Installed	17.13	147.45		R
MW-710DR	566113	284857	165.00	164.99	Not	Installed	18.02	146.97		R
MWD-601	565228	286572	158.31	160.45	5.22	155.23	5.63	154.82	0.2' D	O
MWL-301	565261	286598	158.82	160.57	3.51	157.06	4.14	156.43	N	O
MWL-302	565359	286603	159.15	161.72	6.38	155.34	6.59	155.13	N	O
MWL-303	565457	286604	156.96	158.81	8.12	150.69	9.04	149.77	N	O
MWL-304	565265	286466	157.96	160.22	4.52	155.70	5.22	155.00	N	O
MWL-305	565354	286450	157.55	159.30	5.24	154.06	5.22	154.08	N	O
MWL-306	565502	286450	153.80	155.48	5.68	149.80	7.18	148.30	N	O
MWL-307	565259	286297	157.71	159.29	4.16	155.13	5.29	154.00	N	O
MWL-308	565354	286304	155.88	157.88	3.63	154.25	4.30	153.58	N	O

TABLE 8

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

GROUND-WATER AND SURFACE-WATER ELEVATION MEASUREMENTS

Location	X (Easting)	Y (Northing)	Ground Surface Elev.	Meas. Point Elev.	Depth to Water 1/21/97	Water Elev. 1/21/97	Depth to Water 7/7/97	Water Elev. 7/7/97	(L)NAPL, (D)NAPL *	Well Formation **
MWL-309	565505	286302	152.78	154.77	4.27	150.50	4.68	150.09	N	O
MWL-310	565251	286147	157.34	159.74	6.68	153.06	8.77	150.97	N	O
MWL-311	565351	286149	155.46	157.47	5.99	151.48	8.28	149.19	N	O
MWL-312	565509	286154	153.75	155.83	5.91	149.92	7.42	148.41	N	O
MWL-313	565352	285992	154.52	156.61	6.25	150.36	9.25	147.36	N	O
MWL-314	565502	286001	153.68	155.53	6.27	149.26	8.14	147.39	N	O
P-10	565316	286803	160.84	162.84	4.32	158.52	5.14	157.70	N	O
P-101A	565674	286226	148.05	150.49	0.75	149.74	1.91	148.58	N	R
P-101B	565675	286232	148.19	150.62	0.85	149.77	2.04	148.58	N	O
P-101C	565676	286238	148.34	150.73	3.65	147.08	4.52	146.21	N	O
P-102A	565702	286458	148.77	151.01	1.47	149.54	2.25	148.76	N	R
P-102B	565702	286465	148.74	151.06	1.20	149.86	2.37	148.69	N	O
P-102C	565702	286472	148.71	151.20	3.51	147.69	4.36	146.84	N	O
P-11A	565583	286220	151.80	153.84	4.21	149.63	5.46	148.38	N	R
P-11B	565583	286220	152.22	155.25	5.78	149.47	6.88	148.37	N	O
P-12	565321	287115	161.27	164.56	6.03	158.53	6.98	157.58	N	O
P-12A	565321	287105	161.21	163.62	5.40	158.22	6.44	157.18	N	R
P-13	565242	285851	155.88	158.43	9.56	148.87	10.72	147.71	N	O
P-14	565582	286212	151.96	154.23	4.66	149.57	5.63	148.60	N	R
P-15	564917	285631	179.18	181.65	19.80	161.85	21.02	160.63		R
P-16	565129	286518	165.35	165.03	8.02	157.01	9.26	155.77	N	O
P-1A	565124	286367	166.20	165.71	4.81	160.90	7.88	157.83	N	R
P-1B	565125	286372	166.15	165.69	8.72	156.97	10.12	155.57	0.01' L, D	O
P-2A	565118	286221	166.41	165.94	3.72	162.22	7.62	158.32	N	R
P-2B	565116	286223	166.41	166.03	6.43	159.60	9.32	156.71	L, D	O
P-3A	565576	286459	148.20	150.22	-0.84	151.06	0.63	149.59	N	R
P-3B	565570	286457	148.13	150.09	0.66	149.43	1.64	148.45	N	O

TABLE 8

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

GROUND-WATER AND SURFACE-WATER ELEVATION MEASUREMENTS

Location	X (Easting)	Y (Northing)	Ground Surface Elev.	Meas. Point Elev.	Depth to Water 1/21/97	Water Elev. 1/21/97	Depth to Water 7/7/97	Water Elev. 7/7/97	(L)NAPL, (D)NAPL *	Well Formation **
P-4A	565008	286294	167.94	169.75	3.87	165.88	8.64	161.11	N	R
P-4B	565011	286294	167.60	169.78	6.27	163.51	8.82	160.96	N	O
P-5A	565394	286291	155.33	157.67	7.63	150.04	9.12	148.55	N	R
P-5B	565391	286283	155.24	158.28	5.85	152.43	5.91	152.37	N	O
P-6	565500	286294	152.74	153.93	3.62	150.31	4.70	149.23	N	R
P-7	565439	286805	158.06	160.31	2.88	157.43	3.77	156.54	N	O
P-8	564918	286064	179.72	181.25	14.23	167.02	20.54	160.71	N	O
P-8A	564921	286067	179.66	181.62	14.28	167.34	20.80	160.82	N	R
P-9	565412	286584	157.66	159.49	5.15	154.34	5.46	154.03	N	O
PW-406	565291	286337	157.71	160.40	9.88	150.52	10.33	150.07	N	R
PW-407	565291	286331	157.43	160.31	5.24	155.07	6.19	154.12	N	O
PZO-1	565335	286384	157.39	158.54	4.78	153.76	5.21	153.33	N	O
PZO-2	565351	286370	157.11	159.85	6.51	153.34	6.77	153.08	N	O
PZO-3	565313	286507	157.51	160.40	5.92	154.48	6.44	153.96	N	O
PZO-5	564621	287042	197.60	197.16	3.28	193.88	3.85	193.31	N	O
PZO-6	564176	285978	222.00	221.68	>9.25(dry)	<212.43	>9.25(dry)	<212.43	N	O
PZO-7	564951	286483	167.25	169.83	4.88	164.95	7.76	162.07	N	O
PZR-1	565331	286383	157.39	157.94	8.41	149.53	8.66	149.28	N	R
PZR-2	565349	286365	157.11	159.16	7.54	151.62	8.52	150.64	N	R
PZR-4	565355	286289	157.01	157.85	7.19	150.66	8.10	149.75	N	R
PZR-5	564616	287042	197.70	197.60	6.83	190.77	8.12	189.48	N	R
PZR-6	564177	285975	221.90	221.55	14.03	207.52	15.40	206.15	N	R
PZR-7	564948	286483	167.50	170.21	3.37	166.84	8.61	161.60	N	R
RW-1	565265	286133	157.14	157.56	19.90	137.66	24.70	132.86	N	O
RW-2	565377	286288	156.21	156.51	26.15	130.36	23.50	133.01	N	O
RW-3	565365	286384	156.79	157.24	19.10	138.14	23.25	133.99	N	O
RW-4	565314	286498	157.31	158.19	16.42	141.77	13.15	145.04	N	O

TABLE 8

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

GROUND-WATER AND SURFACE-WATER ELEVATION MEASUREMENTS

Location	X (Easting)	Y (Northing)	Ground Surface Elev.	Meas. Point Elev.	Depth to Water 1/21/97	Water Elev. 1/21/97	Depth to Water 7/7/97	Water Elev. 7/7/97	(L)NAPL, (D)NAPL *	Well Formation **
RW-5	565250	286570	158.51	159.90	14.41	145.49	18.36	141.54	D	O
RW-6	565225	286413	158.89	159.23	15.23	144.00	16.42	142.81	N	O
RW-7	565223	286113	157.04	157.16	15.65	141.51	14.72	142.44	N	O
RW-8	565304	286179	156.34	156.92	16.83	140.09	24.24	132.68	N	O
RW-9	565344	286238	156.64	156.68	26.03	130.65	27.60	129.08	N	O
RW-10	565370	286333	156.19	156.47	25.68	130.79	24.65	131.82	N	O
RW-11	565354	286446	156.91	157.82	21.57	136.25	21.80	136.02	N	O
RW-12	565281	286161	157.36	158.50	20.35	138.15	23.04	135.46	N	O
SG-701	565635	286250		148.89	2.42	146.47	3.60	145.29		
SG-702	565506	287057		148.89	1.41	147.48	1.75	147.14		
SRS-1	565194	285871	159.89	160.86	6.85	154.01	5.56	155.30		O
SRS-2	565200	285871	159.64	160.68	6.91	153.77	9.70	150.98		O
SRS-3	565394	285864	151.38	152.68	2.87	149.81	4.43	148.25		O
SRS-4	565392	285868	151.51	152.65	4.63	148.02	6.14	146.51		O
SRS-5	565530	285997	152.57	154.35	5.65	148.70	6.85	147.50		O
SRS-6	565578	286010	152.81	153.88	4.81	149.07	6.12	147.76		O
SW-A	565964	285255		148.75	3.52	145.23	4.00	144.75		
SW-B	565749	285688		150.32	4.11	146.21	4.65	145.67		
SW-C	565685	285974		150.59	4.25	146.34	4.79	145.80		
SW-D	565622	286151		150.54	4.33	146.21	4.96	145.58		
SW-E	565682	286278		150.37	3.88	146.49	4.74	145.63		
SW-F	565628	286472		150.41	3.81	146.60	4.52	145.89		
SW-G	565609	287092		149.79	3.12	146.67	3.83	145.96		
SW-701	565681	287171		155.33	8.12	147.21	8.55	146.78		
SW-702	565590	283894		153.52	5.30	148.22	5.37	148.15		
SW-703	565552	284184		153.73	8.30	145.43	8.34	145.39		
SW-704	564861	284208		154.53	9.73	144.80	10.59	143.94		

TABLE 8

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

GROUND-WATER AND SURFACE-WATER ELEVATION MEASUREMENTS

Location	X (Easting)	Y (Northing)	Ground Surface Elev.	Meas. Point Elev.	Depth to Water 1/21/97	Water Elev. 1/21/97	Depth to Water 7/7/97	Water Elev. 7/7/97	(L)NAPL, (D)NAPL *	Well Formation **
TW-01	565344	284065	150.50	152.21	5.62	146.59	6.28	145.93		O
TW-02	565355	283770	149.80	151.81	4.96	146.85	5.66	146.15		O
TW-03	565269	284027	150.10	150.92	4.21	146.71	4.88	146.04		O
TW-04	565245	283814	148.90	151.01	4.14	146.87	4.75	146.26		O
TW-05	565149	284350	151.10	152.72	6.63	146.09	7.32	145.40		O
TW-07A	565393	286384	156.20	158.72	5.98	152.74	6.38	152.34	N	O
TW-08A	565213	286406	157.90	160.55	4.69	155.86	5.65	154.90	N	O
TW-11	565282	285956	155.60	157.39	5.71	151.68	8.78	148.61		O
TW-12	565269	287366	175.00	177.15	18.96	158.19	20.58	156.57		O
WE-1	565220	286787	163.00	163.01	2.18	160.83	3.94	159.07		R
WE-2	565220	286808	162.10	162.29	3.29	159.00	4.09	158.20		O

Notes: **All measurements are in feet; elevations are referenced to the NGVD of 1929.**

+ Well cluster MW-708 not completed on January 21, 1997. Ground-water elevation at MW-708 wells measured on 2/11/97, and adjusted to estimated level on 1/21/97 based on average change between 1/21/97 and 2/11/97 at wells in same respective hydrostratigraphic intervals east of Quinnipiac River. Wells used for comparison between 1/21/97 and 2/11/97 included: Shallow Overburden (MW-201B, MW-501C, P-101C, and P-102C); Middle Overburden (MW-203B, MW-501B, P-101B and P-102B); Shallow Bedrock (MW-201A, MW-202A, MW-203A, P-101A, and P-102A); and Deep Bedrock (MW-706DR).

* L, D indicate LNAPL and/or DNAPL observed in well/piezometer before or after purging for sampling during the November 1996 - January 1997 ground-water sampling event and/or during comprehensive ground-water elevation measurement rounds based on clear bottom-loading bailer and/or interface probe measurement. Number indicates maximum observed thickness during these activities. Where no thickness indicated, NAPL present as sheen. N indicates no sheen or measureable NAPL observed during sampling or water level measurement activities.

** O = Overburden R = Bedrock Well

Piezometer PZO-6 was dry on January 21, 1997, and July 7, 1997. Elevation based on piezometer bottom elevation.

TABLE 9

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

SUMMARY OF VOCs DETECTED IN UNSATURATED SOILS

Location	SB-701	SB-702	SB-702	SB-703
Client I.D.	S001	S008	S009	S013
Matrix	Soil	Soil	Soil	Soil
Depth Interval	2-4'	2-4'	2-4' (dup)	2-4'
Chloroethane	11	<12	<11	<12
Methylene Chloride	6 J	5 J	5 J	4 J
Acetone	11	170	17	170
Carbon Disulfide	<11	7 J	<11	<12
1,1-Dichloroethane	4 J	6 J	<11	<12
cis-1,2-Dichloroethene	<11	11 J	6 J	<12
2-Butanone	<11	<12	<11	52
1,1-Trichloroethane	<11	4 J	<11	<12
Benzene	<11	3 J	<11	<12
Toluene	<11	130 D	34	<12
Chlorobenzene	<11	8 J	<11	3 J
Ethylbenzene	340 D	830 D	2900	7 J
Xylene (total)	32	99 D	110	37
Tetrahydrofuran	<11	45	<11	26
TOTAL VOCs	404	1318	3072	299

Notes:
Units are microgram per kilogram (ug/kg) equivalent to parts per billion (ppb).
Samples were analyzed using CLP-RAS methods.
Total VOCs does not include compounds detected in QA/QC blanks.
Only detected compounds are listed.
dup = duplicate sample

TABLE 10

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

SUMMARY OF SOLUTE TRANSPORT CHARACTERISTICS FOR CONSTITUENTS OF CONCERN

Compound	Solubility		Koc		Henry's Law Const.		Degradation Half Life (days)		GW Reg. Criteria		Overburden R, On-Site	Overburden R, Well Field	Bedrock Matrix Diffusion R	Solute Velocity (ft/day)			Travel Time to Prod. Well No. 6 (years)			
														Overburden			Overburden (3)			
	mg/L	Ref.	mL/g	Ref.	unitless	Ref.	Low	High	CT DEP 1/96	EPA MCLs 10/96				On-Site	Well Field	Bedrock	On-Site	Well Field	Total	Bedrock
methanol	miscible	f	0.11	f,c	5.50E-03	f	1	7			1.00	1.00	1100	0.17	2.30	0.037	7.52	1.31	8.8	81
acetone	miscible	f	0.36	f,c	8.57E-04	g	2	14	700		1.01	1.01	1100	0.17	2.29	0.037	7.58	1.32	8.9	81
2-propanol (IPA)	miscible	f	0.71	f,c	3.29E-04	f	2	14			1.02	1.02	1100	0.17	2.24	0.037	7.65	1.35	9.0	81
tetrahydrofuran	300000	a	1.8	a,c	4.47E-03	a	low	low			1.05	1.05	1100	0.16	2.23	0.037	7.88	1.35	9.2	81
2-butanol (isobutanol)	76270	f	3.6	f,c	1.63E-02	f	4	14			1.10	1.09	1100	0.15	2.17	0.037	8.27	1.39	9.7	81
2-butanone (MEK)	268000	a	4.5	a	1.11E-03	a	2	14	400		1.13	1.11	1100	0.15	2.14	0.037	8.45	1.41	10	81
vinyl chloride (chloroethylene)	1100	a	8.1	a	2.83E+01	a	56	2875	2	2	1.23	1.21	1100	0.14	2.02	0.037	9.21	1.49	11	81
methylene chloride	16700	b	11	b,c	1.04E-01	a	14	56	5	5	1.32	1.28	1100	0.13	1.93	0.037	9.87	1.56	11	81
1,2-dichloroethane	8690	a	14	a	4.47E-02	a	100	365	1	5	1.40	1.36	1100	0.12	1.86	0.037	10.48	1.62	12	81
MIBK (4-methyl-2-pentanone)	19000	a	24	a	6.30E-03	a	2	14	350		1.68	1.61	1100	0.10	1.63	0.037	12.58	1.85	14	81
1,1-dichloroethane	5500	a	30	a	2.32E-01	a	63	154	70		1.85	1.76	1100	0.09	1.52	0.037	13.89	1.98	16	81
cis-1,2-dichloroethylene	3500	a	32	a	3.05E-01	a	56	2875	70	70	1.90	1.81	1100	0.09	1.49	0.037	14.27	2.02	16	81
chloroform (trichloromethane)	8220	a	44	a	1.52E-01	a	56	1800	6	80	2.24	2.11	1100	0.08	1.31	0.037	16.81	2.29	19	81
1,1,2-trichloroethane	4500	a	56	a	4.76E-02	a	135	730	5	5	2.58	2.42	1100	0.07	1.18	0.037	19.35	2.56	22	81
trans-1,2-dichloroethylene	6300	a	59	a	2.68E-01	a	56	2875	100	100	2.66	2.49	1100	0.06	1.14	0.037	19.99	2.65	23	81
1,1-dichloroethylene	400	a	65	a	6.26E+00	a	56	132	7	7	2.83	2.65	1100	0.06	1.09	0.037	21.26	2.76	24	81
benzene	1780	a	65	a	2.21E-01	a	10	730.5	1	5	2.83	2.65	1100	0.06	1.09	0.037	21.26	2.76	24	81
trichloroethylene	1000	a	126	a	3.63E-01	a	321	1643.6	5	5	4.56	4.19	1100	0.04	0.73	0.037	34.17	4.12	38	81
1,1,1-trichloroethane	950	a	151	a	1.12E-01	a	140	546	200	200	5.26	4.82	1100	0.03	0.64	0.037	39.46	4.68	44	81
M-xylene	200	a	240	d,c	2.85E-01	a	14	365			7.77	7.07	1100	0.02	0.45	0.037	58.29	6.67	65	81
O-xylene	170	a	240	d,c	2.01E-01	a	14	365.25	530	10000	7.77	7.07	1100	0.02	0.45	0.037	58.29	6.67	65	81
P-xylene	198	a	240	d,c	2.85E-01	a	14	360	Total	Total	7.77	7.07	1100	0.02	0.45	0.037	58.29	6.67	65	81
toluene	515	a	257	a	2.69E-01	a	7	28	1000	1000	8.25	7.50	1100	0.02	0.43	0.037	61.89	7.05	69	81
carbon tetrachloride	800	a	338	b,c	8.13E-01	a	7	365.25	5	5	10.54	9.55	1100	0.02	0.34	0.037	79.03	8.86	88	81
tetrachloroethylene	150	a	364	e	9.23E-01	a	360	720	5	5	11.27	10.21	1100	0.01	0.32	0.037	84.54	9.44	94	81
ethylbenzene	152	a	676	a	3.21E-01	a	6	228	700	700	20.08	18.11	1100	0.01	0.18	0.037	150.57	16.40	167	81
styrene	300	a	911	a,c	9.27E-02	a	28	210	100	100	26.71	24.08	1100	0.01	0.14	0.037	200.30	21.65	222	81
naphthalene	31	a	1288	a	5.16E-02	a	1	258	280		37.35	33.60	1100	0.00	0.10	0.037	280.09	30.07	310	81
PCB, 1254	0.012	a	675000	a,c	1.14E-02	a	388	690	0.5	1	19048.27	17085.34	1100	0.00	0.00	0.037	142862	15073	157935	81
PCB, 1260	0.0027	a	8900000	a,c	1.38E-02	a	388	690	Total	Total	251142.82	225261.13	1100	0.00	0.00	0.037	1883571	198719	2082290	81

Notes:

1) References:
a = Ravi, V, and J.A. Johnson, 1994, VLEACH, A One-Dimensional Finite-Difference Vadose Zone Leaching Model, Version 2.1, developed for USEPA Robert S. Kerr Laboratory, Ada, Oklahoma.
b = USEPA, 1992, Handbook of RCRA Ground-Water Monitoring Constituents: Chemical and Physical Properties, 40CFR Part 264, Appendix IX.
c = Koc value estimated as Koc=0.63*Kow, from Karickhoff, Brown and Scott, 1979, as presented by Fetter, C.W., 1993, Contaminant Hydrogeology, McMillan Publishing Co., New York.
d = American Society for Testing and Materials (ASTM), 1995, Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites, Designation E1739-95, West Conshohocken, Penn.
e = Schwille, F., 1988, Dense Chlorinated Solvents in Porous and Fractured Media: Translated by J.F. Pankow, Lewis Publishers, Chelsea, Michigan.
f = Howard, P.H., 1990, Handbook of Environmental Fate and Exposure Data for Organic Chemicals: Vol. II-Solvents, Lewis Publishers, Chelsea, Michigan.
g = Korfiatis, G.P., and N.M. Kalmcioglu, IMPACT: A Model for Calculation of Soil Cleanup Goals: Remediation, Spring 1994, pp. 175-188.

2) Half-lives (assuming biodegradation and hydrolysis) from Howard, P. H., R. S. Boethling, W. F. Jarvis, W. M. Meylan, E. M. Michalenko, 1991, Handbook of Environmental Degradation Rates, Lewis Publishers, Chelsea, Michigan.
3) On-site overburden solute velocity and travel time (pre-NTCRA 1) measured from center of SRSNE Operations Area to estimated location of hydraulic conductivity change in north portion of Town Well Field, near SRS series wells. Well Field overburden solute velocity and travel time measured from hydraulic conductivity change in north portion of Well Field, near SRS series wells, to Town of Southington Production Well No. 6, with Well Field inactive.

Overburden Parameters	On-Site	Off-Site
Overbdn hydraulic cond. (cm/s) =	7.1E-04	7E-02
Overbdn bulk density (g/cm^3)=	1.94	1.86
Overburden porosity=	0.275	0.316
Overburden foc=	0.0040	0.0043

Estimated based on comprehensive hydrogeologic database for the SRSNE Site, including historical pumping tests, slug tests, and specific capacity tests.
On-site soil physical parameters and foc based on ENSR (June 1994) and RI soil sample physical characterization by Core Laboratories, Inc., and Galson Laboratories, Inc.
Off-site soil physical parameters and foc based on RI soil sample physical characterization by Core Laboratories, Inc., and Galson Laboratories, Inc.

Bedrock Parameters		
Bedrock hydraulic conductivity (cm/s) =	1.2E-04	Based on comprehensive hydrogeologic database for the SRSNE Site, including historical pumping tests, packer tests, slug tests, and specific capacity tests.
Bedrock fracture spacing (cm) =	142	Calculated based on bedrock fracture data obtained from RI core sampling or Borehole Image Processing System (COLOG, Inc).
Bedrock fracture aperture (cm) =	0.0096	Calculated based on RI bedrock packer-test results and fracture data obtained from core sampling or Borehole Image Processing System (COLOG, Inc).
Bedrock fracture porosity =	0.00007	Bedrock fracture porosity estimated as fracture aperture/fracture spacing.
Bedrock matrix porosity=	0.077	RI bedrock core sample physical characterization by Core Laboratories, Inc.
Bedrock bulk density (g/cm^3)=	2.52	RI bedrock core sample physical characterization by Core Laboratories, Inc.
Bedrock foc=	0.00493	RI bedrock core sample chemical characterization by Galson Laboratories, Inc.
Bedrock R (matrix porosity/fracture porosity) =	1100	Bedrock retardation factor based on matrix diffusion only, estimated as matrix porosity/fracture porosity. Does not include sorption to organic carbon within the matrix.

TABLE 11

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

BEDROCK MATRIX VOC ANALYTICAL RESULTS

Location Client I.D. Matrix Depth Interval	MW-705DR R005 Rock 101'	RC-701 R008 Rock 54'-55'	RC-701 R009 Rock 61'-62'	RC-701 R010 Rock 67'-68'	RC-701 R011 Rock 67'-68' (dup)
Acetone	<620	<420	<500	540	700
trans 1,2-Dichloroethene	<310	<210	<250	290	340
Methylene Chloride	780B	52JB	<250	110J	<210
Toluene	<310	<210	<250	<220	73 J
Trichloroethene	370	<210	<250	<220	<210
Vinyl Chloride	<620	<210	<500	<430	52J
TOTAL VOCs	370	ND	ND	940	1165

Notes:
Units are microgram per kilogram (ug/kg) equivalent to parts per billion (ppb).
Samples were analyzed using EPA Method 8240.
ND = None Detected.
Total VOCs does not include compounds detected in QA/QC blanks.
Only detected compounds are listed.
dup = duplicate sample

TABLE 12

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESIGATION

SUMMARY OF GEOCHEMICAL AND BIOLOGIC PARAMETERS IN GROUND WATER

OVERBURDEN WELLS

LAB CONTAINER NAME SAMPLING LOCATION DISTANCE ALONG FLOWPATH (FEET)		G115 P-8B -300	G177 P-1B 60	G111 MW-415 210	G179 MW-502 430	G175 MW-704D 1150	G099 MW-703D 1700	G171 MW-704S 1150 Traditional	G170 MW-704S 1150 Low Flow	G167 MW-704M 1150	G098 MW-703S 1700
Analytical Parameter	**Analytical Method**	**Wells In Interpreted Primary Flow Path of Overburden Plume**						**Other Data**			
Dissolved Oxygen, mg/L	Field Meter	9.54	0.85	0.02	0.91	0.32	8.20	2.87	0.14	0.23	6.29
Ammonia, mg/L	USEPA Method350.3	<0.63	<0.63	2.78	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63
Nitrate-nitrite, mg/L	USEPA Method353.3	<0.20	2.48	<0.20	<0.20	<0.20	1.34	<0.20	<0.20	0.23	0.25
Fe, Dissolved, mg/L	SW-846 Method 6010	0.03	20.90	30.00	20.10	1.20	0.15	0.06	0.05	0.05	0.03
Fe, Total, mg/L	SW-846 Method 6010	0.89	21.30	29.70	73.90	1.34	0.64	3.77	30.10	0.46	0.63
Mn, Dissolved, mg/L	SW-846 Method 6010	0.03	7.40	4.36	4.09	4.61	0.01	6.70	0.16	0.23	0.00
Mn, Total, mg/L	SW-846 Method 6010	0.05	7.19	4.12	5.50	4.27	0.03	0.20	1.35	0.21	0.02
Sulfate, mg/L	USEPA Method375.4	21.6	17.8	23.2	301	<7	45.3	23.7	94.4	12.4	18.4
Sulfide, mg/L	USEPA Method376.1	1.69	<0.68	1.38	1.76	1.12	3.15	0.93	1.44	1.50	2.93
Methane, mg/L	Microseeps, Inc. Method AM18	0.004	1.336	0.463	29.606	17.770	0.001	0.006	0.012	4.769	0.001
ORP, mV	Field Meter	198	-38	-37	-65	-100	38	62	71	96	133
TOC, mg/L	SW-846 Method 9060	<1.0	39.9	53.9	47.4	5.97	<1.0	1.13	1.7	1.41	<1.0
Orthophosphate, mg/L	USEPA Method 365.3/5	0.2	0.57	0.32	0.2	0.2	0.2	<0.20	<0.20	<0.20	<0.20
Chloride, mg/L	USEPA Method 325.3	< 9	61.50	63.50	211.00	68.30	20.60	<9.0	<9.0	20.40	18.40
Ethene, mg/L	Microseeps, Inc. Method AM18	8.50E-05	2.38E-01	5.95E-02	1.12E-02	3.75E-04	2.10E-05	2.50E-05	1.17E-04	2.98E-04	<.000005
Ethane, mg/L	Microseeps, Inc. Method AM18	3.73E-04	2.16E-02	2.18E-02	2.82E-01	1.02E+00	1.10E-04	2.20E-04	4.11E-04	2.85E-01	3.80E-05
Phospholipid Fatty Acids (picomoles per mL)	Kemp (1993) Ch.32	0.04	5.96	32.95	3.02	0.22	0.6	0.42	1.37	0	0.11
Total BTEX, mg/L	USEPA Method CLP-RAS	< 0.004	129.8	10.33	84	0.137	< 0.004	< 0.004	< 0.004	0.039	< 0.004
Vinyl Chloride, mg/L	USEPA Method CLP-RAS	< 0.001	2.4	0.74	<0.01	< 0.01	< 0.001	< 0.001	< 0.001	<0.002	< 0.001
Chloroethane, mg/L	USEPA Method CLP-RAS	< 0.001	2.2	0.54	<0.01	0.3	< 0.001	< 0.001	< 0.001	0.076	< 0.001

TABLE 12

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESIGATION

SUMMARY OF GEOCHEMICAL AND BIOLOGIC PARAMETERS IN GROUND WATER

BEDROCK WELLS

LAB CONTAINER NAME		G114	G176	G113	G116	G172	G100	G173	169
SAMPLING LOCATION		P-8A	P-1A	MW-414	P-6	MW-704R	MW-703DR	MW-704R	MW-704DR
DISTANCE ALONG FLOWPATH (FEET)		-300	60	210	430	1150 Traditional	1700	1150 Low Flow	1150
Analytical Parameter	Analytical Method	Wells in Interpreted Primary Flow Path of Bedrock Plume						Other Data	
Dissolved Oxygen, mg/L	Field Meter	8.24	2.13	8.62	0.27	0.19	2.46	0.88	0.29
Ammonia, mg/L	USEPA Method350.3	< 0.63	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63
Nitrate-nitrite, mg/L	USEPA Method353.3	1.8	0.53	<0.20	<0.20	<0.20	1.52	<0.20	<0.20
Fe, Dissolved, mg/L	SW-846 Method 6010	0.03	0.05	0.08	36.60	2.40	0.05	2.53	0.03
Fe, Total, mg/L	SW-846 Method 6010	6.99	0.67	2.10	45.20	2.65	2.28	4.74	0.19
Mn, Dissolved, mg/L	SW-846 Method 6010	0.01	0.57	0.07	15.60	2.48	0.11	2.64	0.11
Mn, Total, mg/L	SW-846 Method 6010	0.29	0.91	0.20	14.60	2.39	0.15	1.64	0.11
Sulfate, mg/L	USEPA Method375.4	2320	12.4	26.5	91.7	33.6	917	47.4	222
Sulfide, mg/L	USEPA Method376.1	2.11	2.40	1.82	1.63	<0.68	2.93	<0.68	<0.68
Methane, mg/L	Microseeps, Inc. Method AM18	0.075	11.805	0.675	> 7.04	15.533	0.004	20.270	3.293
ORP, mV	Field Meter	158	-28	6	-51	-59	143	-30	76
TOC, mg/L	SW-846 Method 9060	1.01	<1.0	13.3	24.2	7.23	<1.0	6	1.3
Orthophosphate, mg/L	USEPA Method 365.3/5	<0.20	<0.20	<0.20	<0.20	0.6	<0.20	<0.20	<0.20
Chloride, mg/L	USEPA Method 325.3	9.39	17.40	32.20	< 9	118.00	41.00	159.00	303.00
Ethene, mg/L	Microseeps, Inc. Method AM18	6.00E-05	2.04E-02	3.61E-02	3.72E+00	1.17E-03	3.90E-05	9.06E-04	5.22E-03
Ethane, mg/L	Microseeps, Inc. Method AM18	7.80E-05	1.18E-01	1.46E-01	9.65E-01	6.27E-01	3.67E-04	7.95E-01	8.36E-02
Phospholipid Fatty Acids (picomoles per mL)	Kemp (1993) Ch.32	4.2	2.57	23.98	9.88	2.79	3.48	2.61	2.14
Total BTEX, mg/L	USEPA Method CLP-RAS	< 0.004	0.295	0.157	23.97	0.174	< 0.004	0.249	0.102
Vinyl Chloride, mg/L	USEPA Method CLP-RAS	< 0.001	0.096	0.009	0.01	< 0.02	< 0.001	<0.020	<0.020
Chloroethane, mg/L	USEPA Method CLP-RAS	< 0.001	< 0.01	0.018	0.83	0.35	< 0.001	0.4	0.053

TABLE 13

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

USAF RANKING FOR NATURAL ATTENUATION OF CHLORINATED HYDROCARBONS
OVERBURDEN GROUND WATER

LAB CONTAINER NAME SAMPLING LOCATION DIST. ALONG FLOWPATH (feet	G115 P-8B -300		G177 P-1B 60		G111 MW-415 210		G179 MW-502 430		G175 MW-704D 1150		G099 MW-703D 1700		G171 MW-704S Traditional 1150		G170 MW-704S Lowflow 1150		G167 MW-704M 1150		G098 MW-703S 1700	
OVERBURDEN WELLS	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points
Dissolved Oxygen, mg/L	9.54	-3	0.85		0.02	3	0.91		0.32	3	8.20	-3	2.87	-3	0.14	3	0.23	3	6.29	-3
Nitrate-nitrite, mg/L	<0.20	2	2.48		<0.20	2	<0.20	2	<0.20	2	1.34		<0.20	2	<0.20	2	0.23	2	0.25	2
Fe (II), Dissolved, mg/L	0.0		20.9	3	30.0	3	20.1	3	1.2	3	0.1		0.1		0.0		0.0		0.0	
Sulfate, mg/L	21.6		17.8	2	23.2		301		<7	2	45.3		23.7		94.4		12.4	2	18.4	2
Sulfide, mg/L	1.69	3	<0.68		1.38	3	1.76	3	1.12	3	3.15	3	0.93		1.44	3	1.50	3	2.93	3
Methane, mg/L	0.004		1.336	3	0.463	2	29.606	3	17.770	3	0.001		0.006		0.012		4.769	3	0.001	
ORP, mV	198		-38	1	-37	1	-65	1	-100	1	38	1	62		71		96		133	
Chloride, mg/L	<9.0		61.50	2	63.50	2	211.00	2	68.30	2	20.60	2	<9.0		<9.0		20.40	2	18.40	2
Ethene, mg/L	8.50E-05		2.38E-01	3	5.95E-02	2	1.12E-02	2	3.75E-04		2.10E-05		2.50E-05		1.17E-04		2.98E-04		<.000005	
Ethane, mg/L	3.73E-04		2.16E-02	2	2.18E-02	2	2.82E-01	3	1.02E+00	3	1.10E-04		2.20E-04		4.11E-04		2.85E-01	3	3.80E-05	
Total BTEX, mg/L	<0.004		129.8	2	10.33	2	84	2	0.137	2	<0.004		<0.004		<0.004		0.039		<0.004	
Vinyl Chloride, mg/L	<0.001		2.4	2	0.74	2	<10		<0.010		<0.001		<0.001		<0.001		<0.002		<0.001	
Chloroethane, mg/L	<0.001		2.2	2	0.54	2	<10		0.300	2	<0.001		<0.001		<0.001		0.076	2	<0.001	
Total Points Awarded		**2**		**22**		**26**		**21**		**26**		**3**		**-1**		**8**		**20**		**6**

Notes:

1) Ranking system adopted from Wiedemeier, T.H., et al., 1996, "Overview of Technical Protocol for Natural Attenuation of Chlorinated Aliphatic Hydrocarbons in Ground Water Under Development for the U.S. Air Force Center for Environmental Excellence", Presented at Symposium on Natural Attenuation of Chlorinated Organics in Ground Water, Dallas, TX, September 11-13, 1996: USEPA Office of Research and Development, Publication EPA/540/R-96/509.

2) Based on Wiedemeier, T.H., et al., 1996, the points awarded for each well location may be interpreted as follows:
   - 0-5: Inadequate evidence for biodegradation of chlorinated organics.
   - 6-14: Limited evidence for biodegradation of chlorinated organics.
   - 15-20: Adequate evidence for biodegradation of chlorinated organics.
   - >20: Strong evidence for biodegradation of chlorinated organics.

TABLE 13

SRSNE SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

USAF RANKING FOR NATURAL ATTENUATION OF CHLORINATED HYDROCARBONS
BEDROCK GROUND WATER

LAB CONTAINER NAME SAMPLING LOCATION DIST. ALONG FLOWPATH (feet)	G114 P-8A -300		G176 P-1A 60		G113 MW-414 210		G116 P-6 430		G173 MW-704R Traditional 1150		G100 MW-703DR 1700		G172 MW-704R Low Flow 1150		G169 MW-704DR 1150	
BEDROCK WELLS	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points	Analytical Result	USAF Points
Dissolved Oxygen, mg/L	8.24	-3	2.13	-3	8.62	-3	0.27	3	0.19	3	2.46	-3	0.88		0.29	3
Nitrate-nitrite, mg/L	1.80		0.53	2	<0.20	2	<0.20	2	<0.20	2	1.52		<0.20	2	<0.20	2
Fe (II), Dissolved, mg/L	0.0		0.0		0.1		36.6	3	2.5	3	0.1		2.4	3	0.0	
Sulfate, mg/L	2320		12.4	2	26.5		91.7		47.4		917		33.6		222	
Sulfide, mg/L	2.11	3	2.40	3	1.82	3	1.63	3	<0.68		2.93	3	<0.68		<0.68	
Methane, mg/L	0.075		11.805	3	0.675	2	>7.041061	3	20.270	3	0.004		15.533	3	3.293	3
ORP, mV	158		-28	1	6	1	-51	1	-59	1	143		-30	1	76	
Chloride, mg/L	9.39		17.40		32.20	2	<9.0		159.00	2	41.00	2	118.00	2	303.00	2
Ethene, mg/L	6.00E-05		2.04E-02	2	3.61E-02	2	3.72E+00	3	9.06E-04		3.90E-05		1.17E-03		5.22E-03	
Ethane, mg/L	7.80E-05		1.18E-01	3	1.46E-01	3	9.65E-01	3	7.95E-01	3	3.67E-04		6.27E-01	3	8.36E-02	2
Total BTEX, mg/L	<0.004		0.295	2	0.157	2	23.97	2	0.249	2	<0.004		0.174	2	0.102	2
Vinyl Chloride, mg/L	<0.001		0.096	2	0.009		0.012	2	<0.020		<0.001		<0.020		<0.002	
Chloroethane, mg/L	<0.001		<0.010		0.018		0.83	2	0.400	2	<0.001		0.350	2	0.053	2
Total Points Awarded		**0**		**17**		**14**		**27**		**21**		**2**		**18**		**16**

Notes:

1) Ranking system adopted from Wiedemeier, T.H., et al., 1996, "Overview of Technical Protocol for Natural Attenuation of Chlorinated Aliphatic Hydrocarbons in Ground Water Under Development for the U.S. Air Force Center for Environmental Excellence", Presented at Symposium on Natural Attenuation of Chlorinated Organics in Ground Water, Dallas, TX, September 11-13, 1996: USEPA Office of Research and Development, Publication EPA/540/R-96/509.

2) Based on Wiedemeier, T.H., et al., 1996, the points awarded for each well location may be interpreted as follows:
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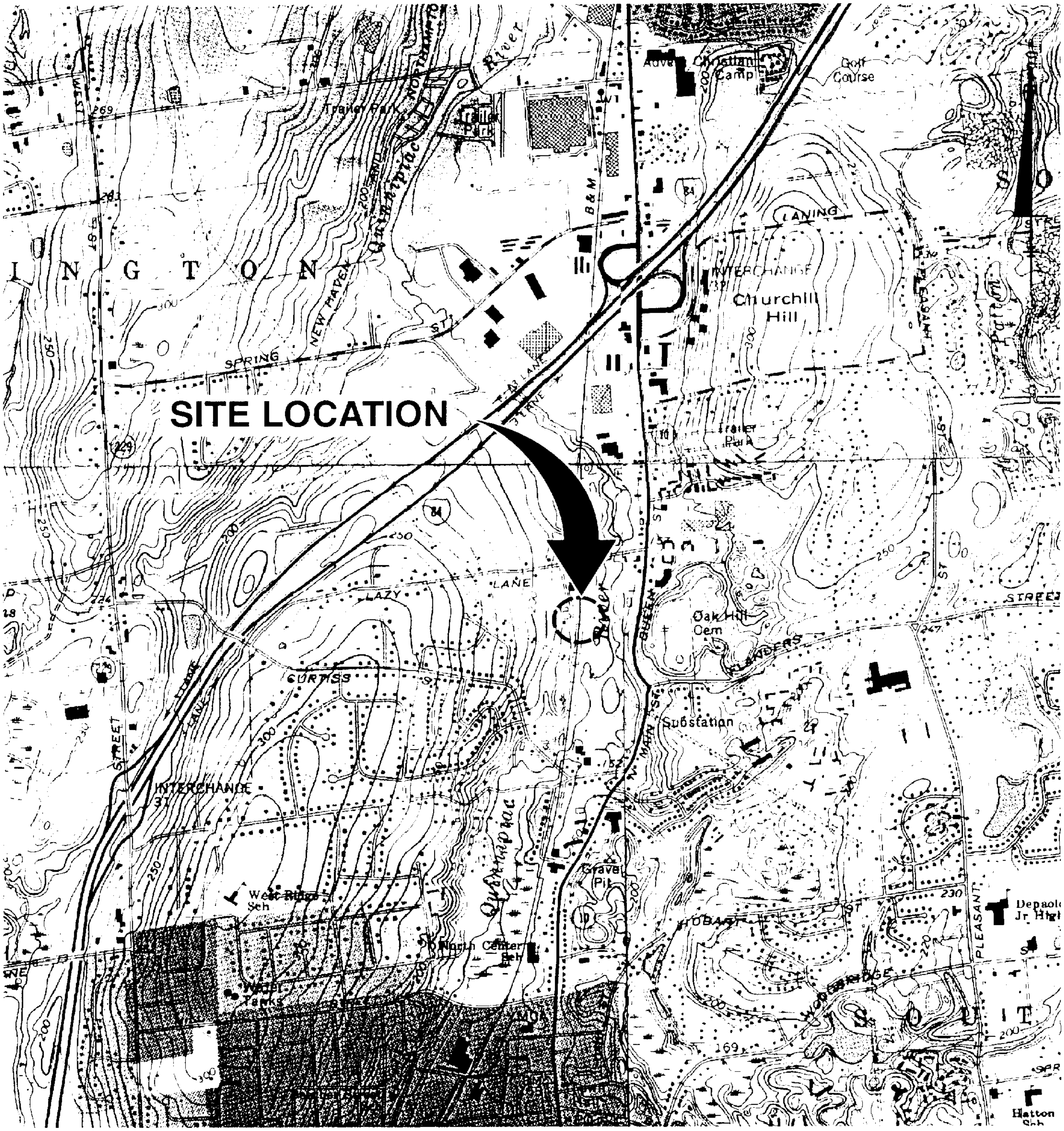
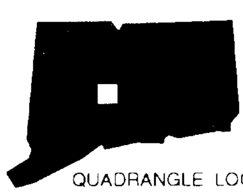
   6-14: Limited evidence for biodegradation of chlorinated organics.
   15-20: Adequate evidence for biodegradation of chlorinated organics.
   >20: Strong evidence for biodegradation of chlorinated organics.



REFERENCE: SOUTHINGTON, CONN. USGS QUAD. 1968 PR 1992, MERIIDAN, CONN. USGS QUAD. 1966 PR 1984, NEW BRITIAN, CONN. USGS QUAD. 1966 PR 1984, & BRISTOL, CONN. USGS QUAD 1967 PR 1984

2000' 0 2000'

APPROX. SCALE: 1" = 2000'



QUADRANGLE LOCATION

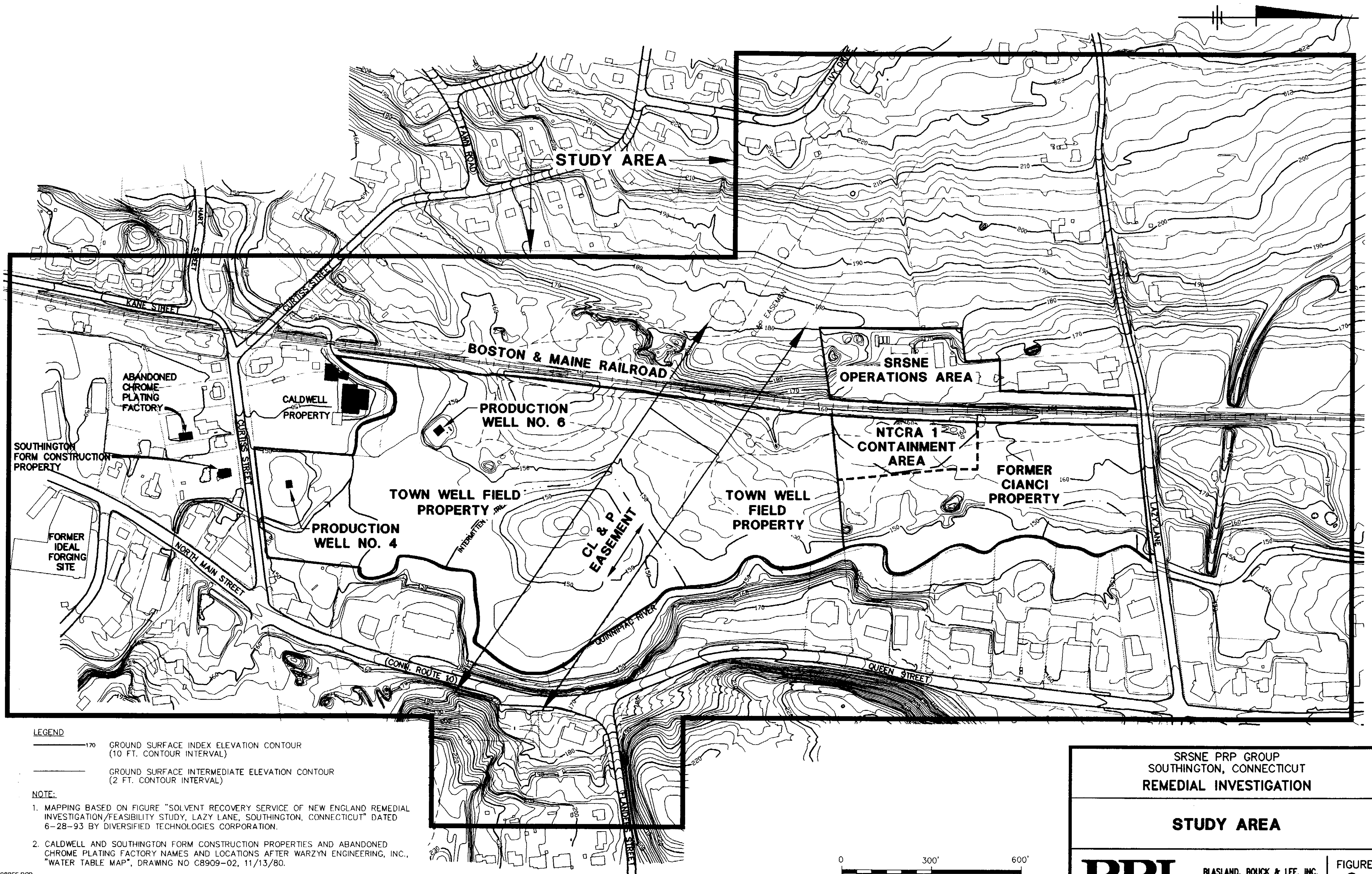
8/97 SYR D54-DJH
08331008/08331N01.cdr

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

SITE LOCATION MAP

BBL BLASLAND, BOUCK & LEE, INC.
engineers & scientists

FIGURE
1



LEGEND

170 GROUND SURFACE INDEX ELEVATION CONTOUR (10 FT. CONTOUR INTERVAL)

GROUND SURFACE INTERMEDIATE ELEVATION CONTOUR (2 FT. CONTOUR INTERVAL)

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.
2. CALDWELL AND SOUTHINGTON FORM CONSTRUCTION PROPERTIES AND ABANDONED CHROME PLATING FACTORY NAMES AND LOCATIONS AFTER WARZYN ENGINEERING, INC., "WATER TABLE MAP", DRAWING NO C8909-02, 11/13/80.

0 300' 600'

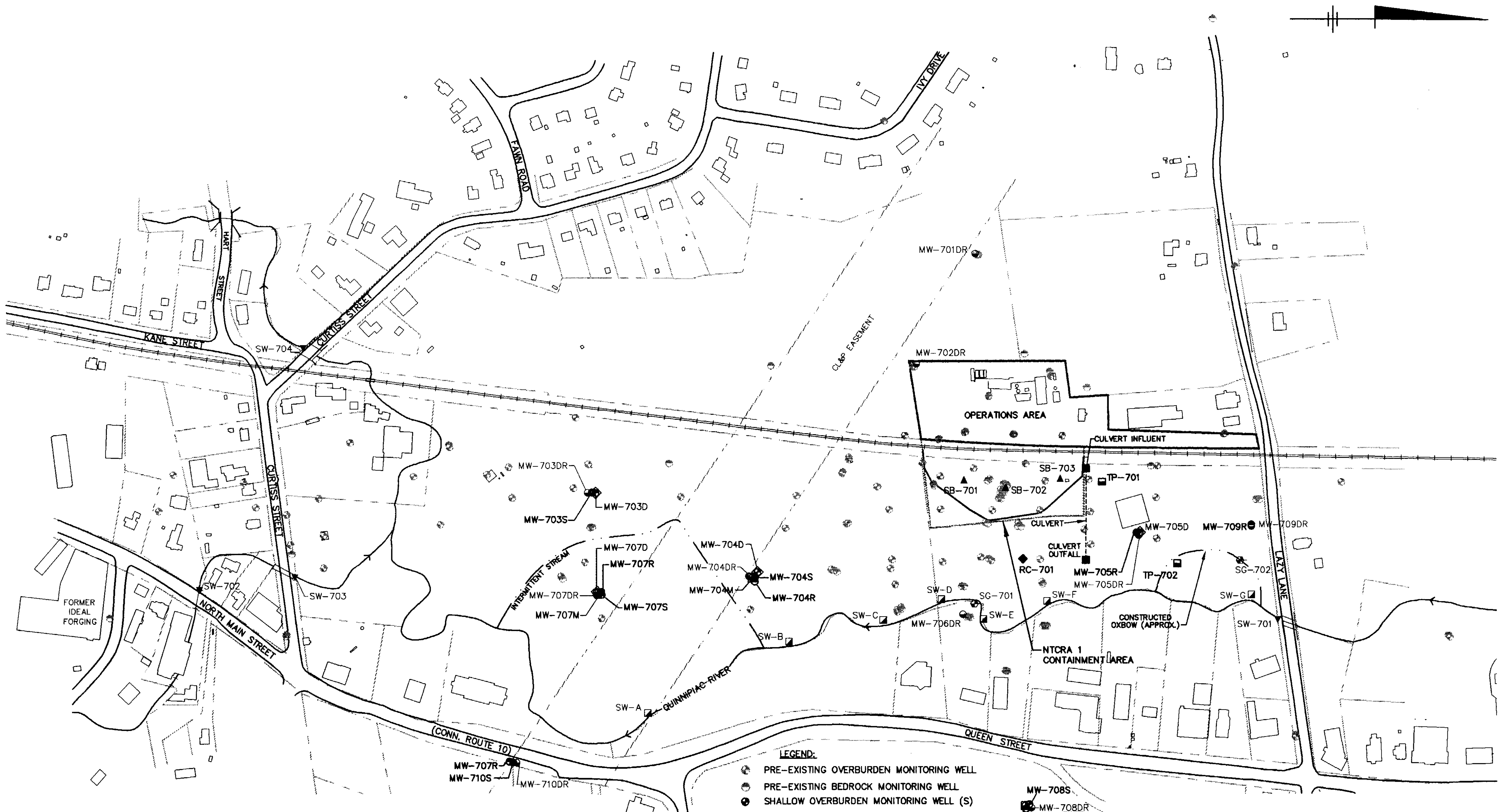
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

STUDY AREA

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 2

OJ808REF.PCP
X:08325X00,08325X01;L: OFF: REF*,(XREF X01:PIPES)
11/12/97 SYR-54-DMW, PGL
08331008/08331G01.DWG



LEGEND:

- PRE-EXISTING OVERBURDEN MONITORING WELL
- PRE-EXISTING BEDROCK MONITORING WELL
- SHALLOW OVERBURDEN MONITORING WELL (S)
- MIDDLE OVERBURDEN MONITORING WELL (M)
- DEEP OVERBURDEN MONITORING WELL (D)
- SHALLOW BEDROCK MONITORING WELL (R)
- DEEP BEDROCK MONITORING WELL (DR)
- SOIL BORING
- TEST PIT
- SHALLOW BEDROCK COREHOLE
- SURFACE WATER MEASUREMENT POINTS
- SURFACE WATER SAMPLING LOCATION
- CULVERT ENDPOINT
- STREAM GAUGE

0 300' 600'

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

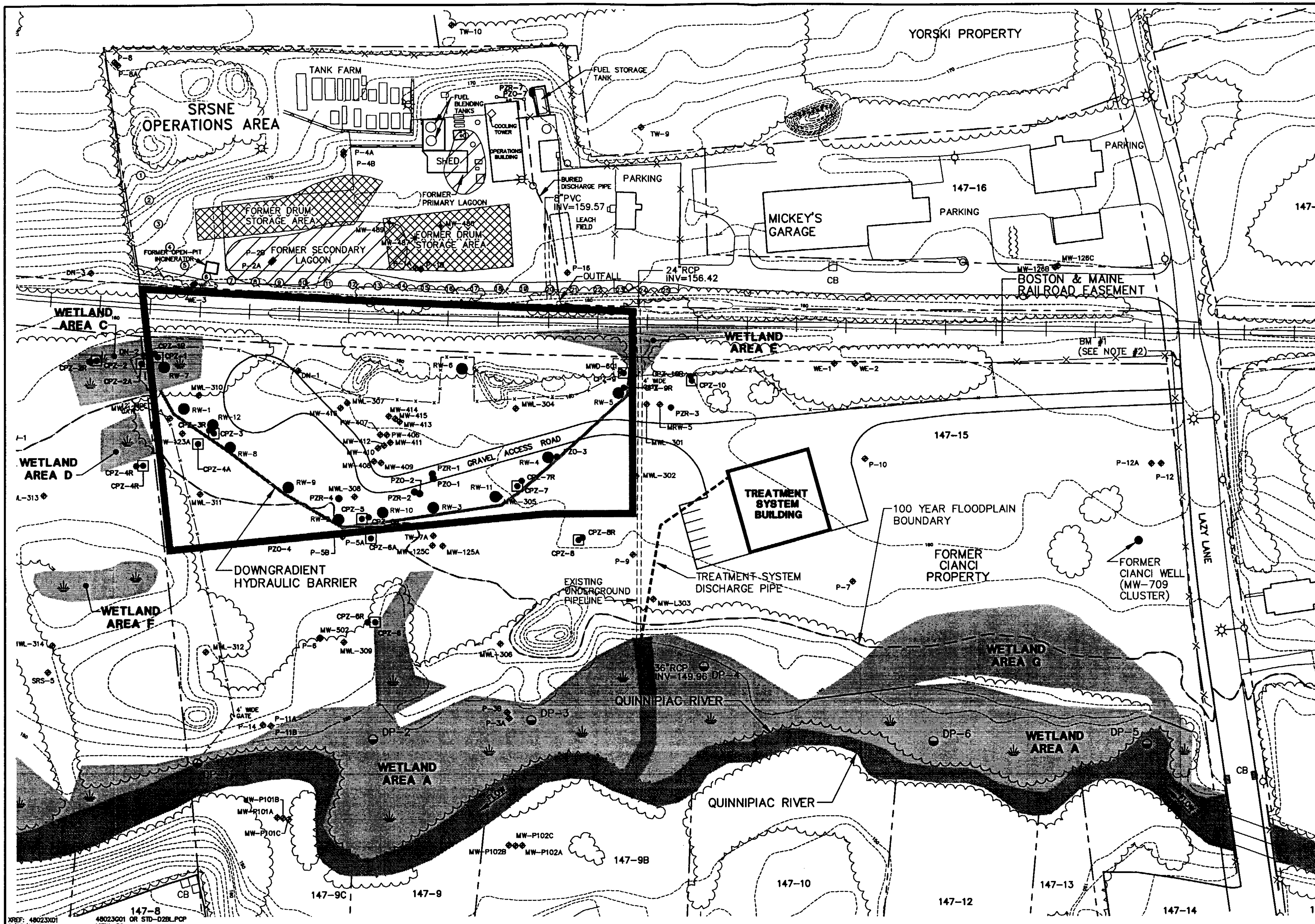
P:STD-DL.PCP ● E-SIZE OR DJB.PCP
XREF: 08325X00,08325XD1
8/11/97 SYR-54-RLP,DMW,PGL
08331900/08331B03.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

RI
FIELD INVESTIGATION
SUMMARY MAP

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 3



LEGEND

— — —	PROPERTY LINE
— — —	100-YEAR FLOOD LIMIT
	WATER
	RIVER
	WETLAND
	NTCRA 1 CONTAINMENT AREA
	EXISTING STRUCTURE
	VEGETATION
	EXISTING CONTOUR
—x—x—	FENCE
P-10	PREVIOUSLY INSTALLED MONITORING WELL
PZR-3	NTCRA 1 PIEZOMETER
CPZ-10	NTCRA 1 COMPLIANCE PIEZOMETER
RW-1	NTRCA 1 OVERBURDEN EXTRACTION WELL
DP-5	WETLAND DRIVE POINT
147-12	LOT NUMBER
□ ○	ABOVE-GROUND TANK
⑫	FORMER ON-SITE INTERCEPTOR SYSTEM EXTRACTION WELL
MW-489	SVE PILOT TEST WELL

NOTES

1. SITE PLAN TAKEN FROM DIVERSIFIED TECHNOLOGIES CORP., 556 WASHINGTON AVE., NORTH HAVEN, CT, DATED 6/93. TOPOGRAPHY REPORTED TO HAVE BEEN DIGITIZED FROM TOWN OF SOUTHINGTON TOPOGRAPH MAPS G-7, G-8, G-9; PHOTOGRAPHY DATED NOV. 1978, SCALE: 1"=100'. PROPERTY LINES REPORTED TO HAVE BEEN DIGITIZED AND LOT NUMBERS TAKEN FROM "PROPERTY MAP, TOWN OF SOUTHINGTON" MAPS 134 & 147, SCALE: 1"=100' BY DIVERSIFIED TECHNOLOGIES CORPORATION.
2. BENCHMARK #1 IS AT ELEVATION 164.03. PK NAIL; S'LY SIDE; POLE #9049.
3. THE 100-YEAR FLOOD LIMIT AND WETLAND AREAS WERE TAKEN FROM THE FINAL REMEDIAL INVESTIGATION REPORT (HNUS, MAY 1994). THE 100-YEAR FLOOD LIMIT WAS REVISED TO FOLLOW THE ELEVATION 156 CONTOUR BASED ON INFORMATION PROVIDED BY THE SOUTHINGTON TOWN ENGINEER.
4. THE LOCATIONS OF EXISTING DRIVE POINTS, WELLS AND PIEZOMETERS ARE APPROXIMATE ONLY.

XREF: 48023X01 48023C01 OR STD-D2BL.PCP
6/25/98 SYR-54-PGL RCB VIEW: 50
08331008/48023001.DWG LAYER: ON=*; OFF=1,REF

Graphic Scale 1" = 100' (50' 0 50' 100')

NO ALTERATIONS PERMITTED HEREON EXCEPT AS PROVIDED UNDER SECTION 7209 SUBDIVISION 2 OF THE NEW YORK STATE EDUCATION LAW

No.	Date	Revisions	Init

Project Mgr. ________
Designed by ________
Drawn by ________
Checked by ________
Prof. Eng. ________
PE License ________

BBL
BLASLAND, BOUCK & LEE, INC.
engineers & scientists

SRSNE PRP GROUP • SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

OPERATIONS AREA, NTCRA 1 CONTAINMENT AREA, AND FORMER CIANCI PROPERTY MAP

File Number 083.31.008
Date SEPTEMBER 1997
Blasland, Bouck & Lee, Inc. Corporate Headquarters 6723 Towpath Road Syracuse, NY 13214 315-446-9120

4

TARGET SHEET

THE MATERIAL DESCRIBED BELOW
NOT SCANNED BECAUSE:

(X) OVERSIZED

() NON-PAPER MEDIA

() OTHER

DESCRIPTION: DOCUMENT ID # 4932, FIGURE 5, AERIAL PHOTOGRAPH - 1965.

THE OMITTED MATERIAL IS AVAILABLE FOR REVIEW
AT THE EPA NEW ENGLAND SUPERFUND RECORDS CENTER,
BOSTON, MA

TARGET SHEET

THE MATERIAL DESCRIBED BELOW
NOT SCANNED BECAUSE:

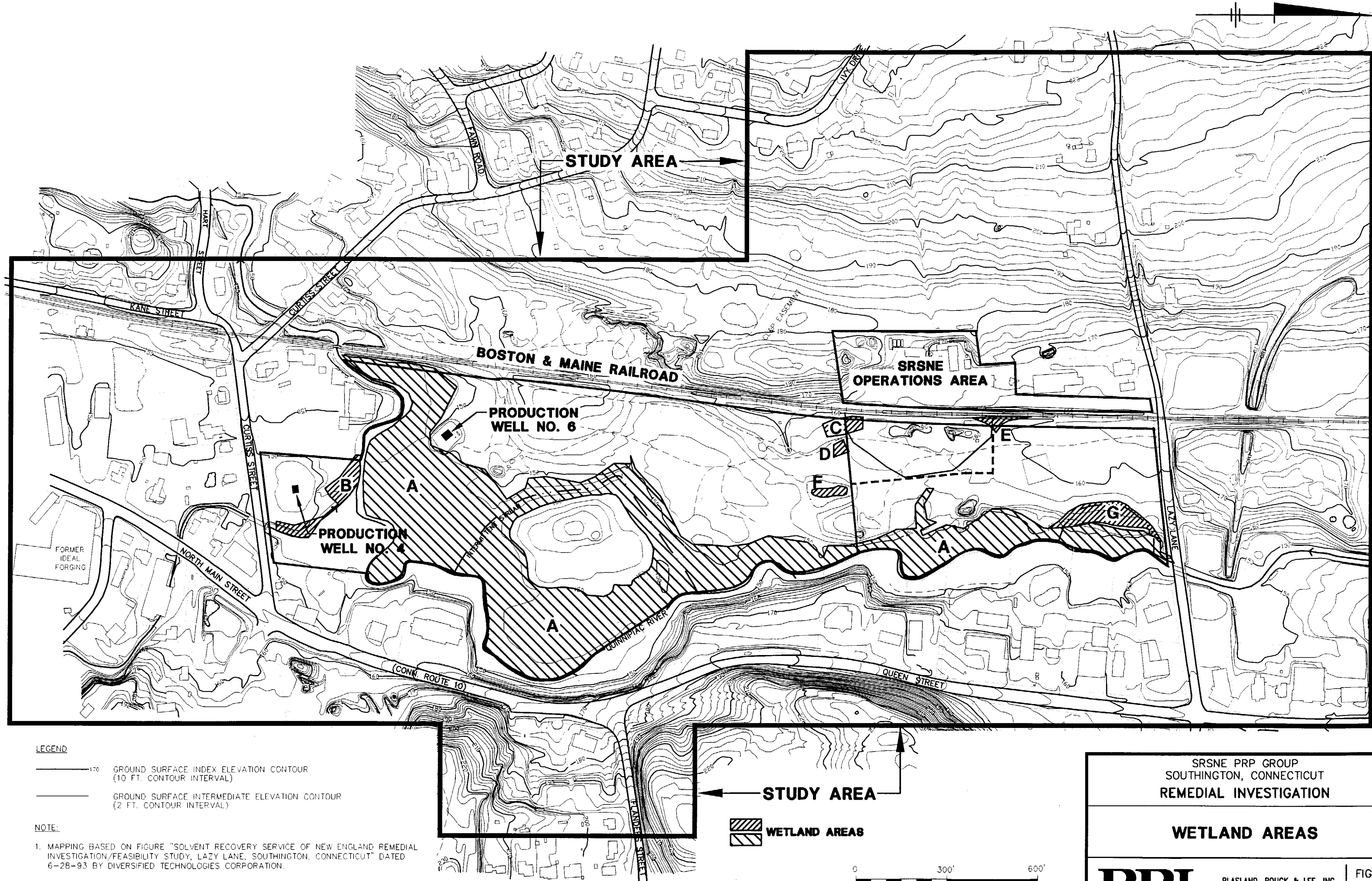
(X) OVERSIZED

() NON-PAPER MEDIA

() OTHER

DESCRIPTION: DOCUMENT ID # 4932, FIGURE 6, AERIAL PHOTOGRAPH - 1980.

THE OMITTED MATERIAL IS AVAILABLE FOR REVIEW
AT THE EPA NEW ENGLAND SUPERFUND RECORDS CENTER,
BOSTON, MA



LEGEND

170 GROUND SURFACE INDEX ELEVATION CONTOUR (10 FT. CONTOUR INTERVAL)

GROUND SURFACE INTERMEDIATE ELEVATION CONTOUR (2 FT. CONTOUR INTERVAL)

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

MVB.PCP
X: 08325X01;L: OFF: REF=(XREF X01:PIPES)
9/23/97 SYR-54-DMW, PGL
08331008/08331G03.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

WETLAND AREAS

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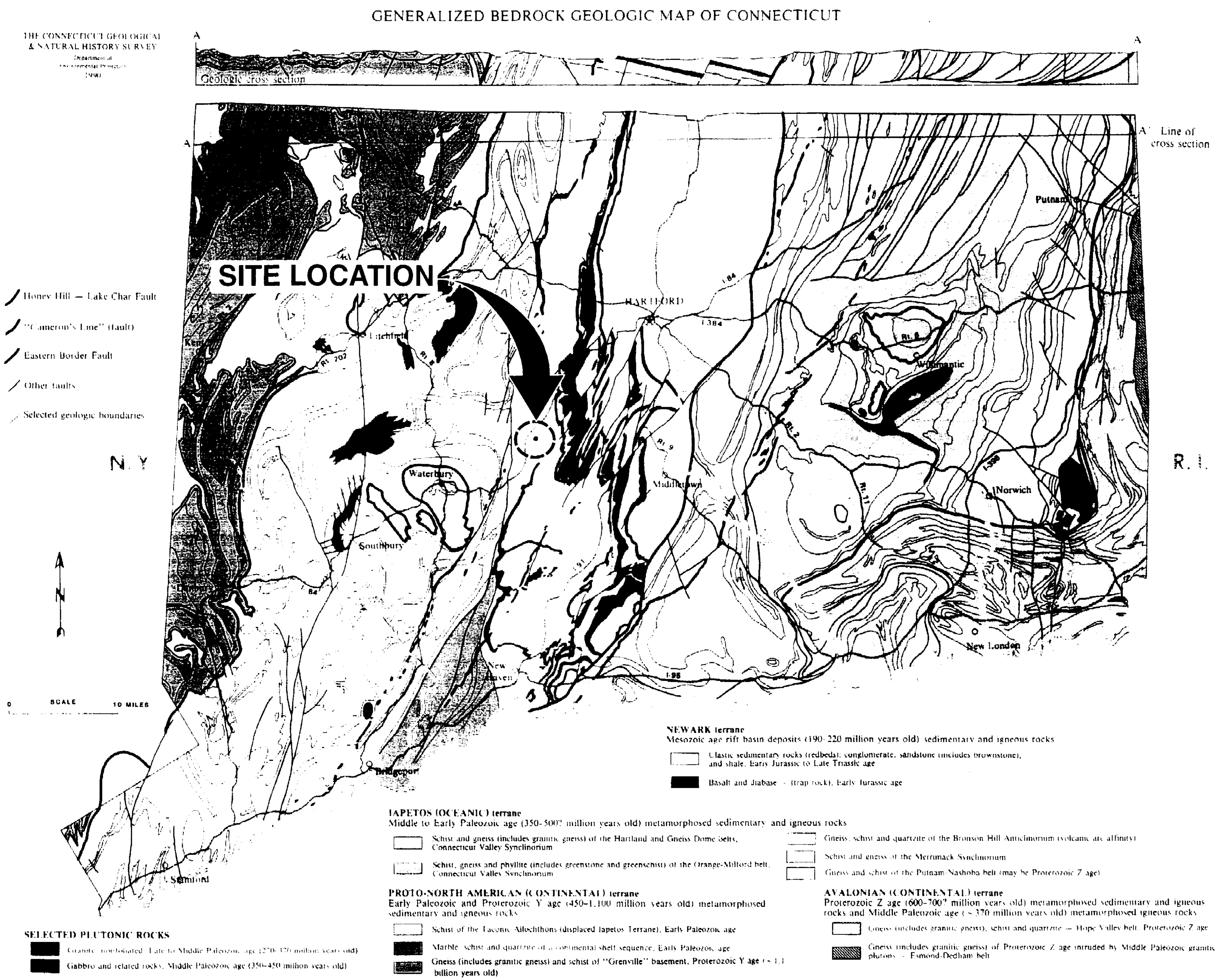
FIGURE 7



NOTE:
1. Base map published by CT DEP and by the Connecticut Geological & Natural History Survey (1990).

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

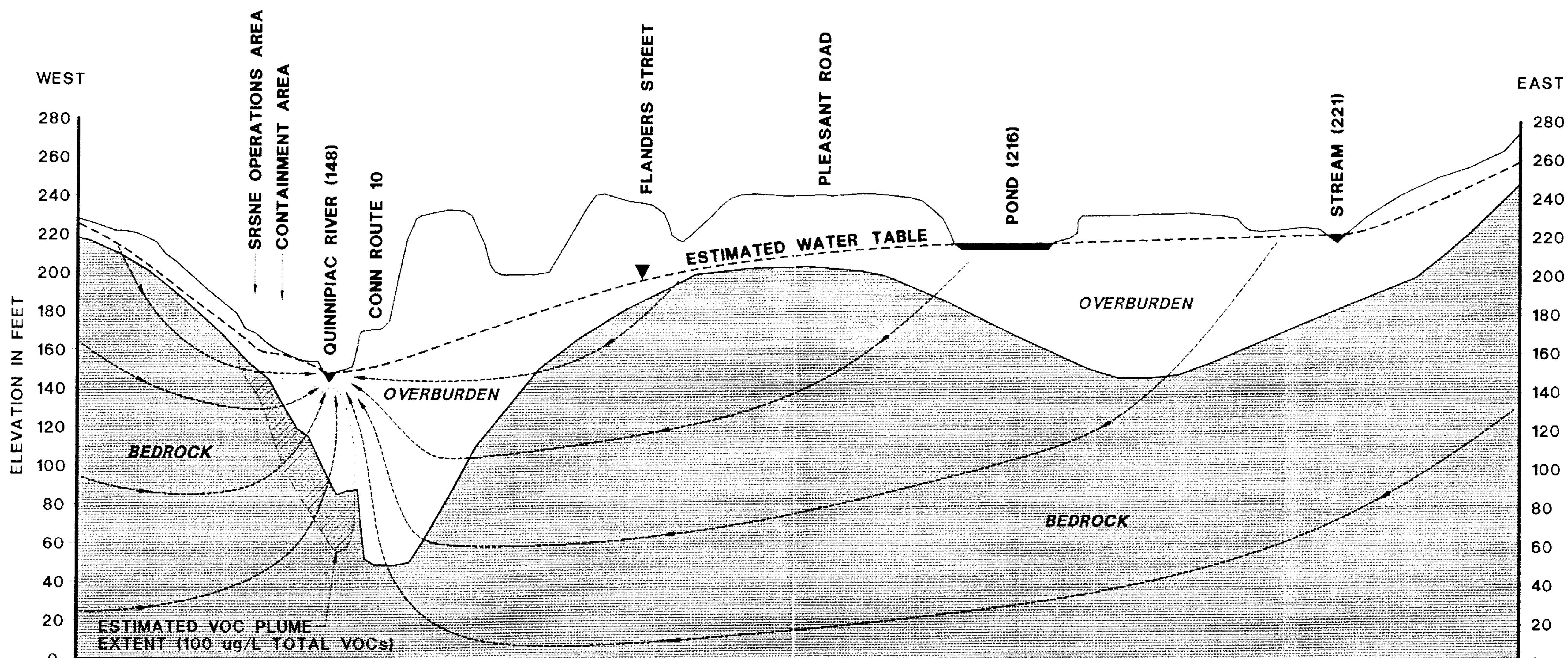
GENERALIZED BEDROCK GEOLOGIC MAP OF CONNECTICUT

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 8

8/97 SYR D54-DJH
08331008/08331g02.cdr

Original Includes Color Coding.
Available at the US EPA New England Superfund Records Center, Boston, MA



NOTES:

1. GROUND SURFACE AND WATER TABLE CONTINUE TO RISE TO THE EAST OF THIS CROSS SECTION.
2. APPROXIMATELY 17,000 FT TO THE EAST IS HATCHERY BROOK, WHICH IS AT THE SAME ELEVATION AS QUINNIPIAC RIVER.
3. WATER TABLE DIVIDE APPROXIMATELY 6,000 FT EAST OF THIS CROSS SECTION.
4. TOP OF BEDROCK AND GROUND SURFACE DATA FROM USGS MAPS MF-660A (1975) AND MF-661A (1976).

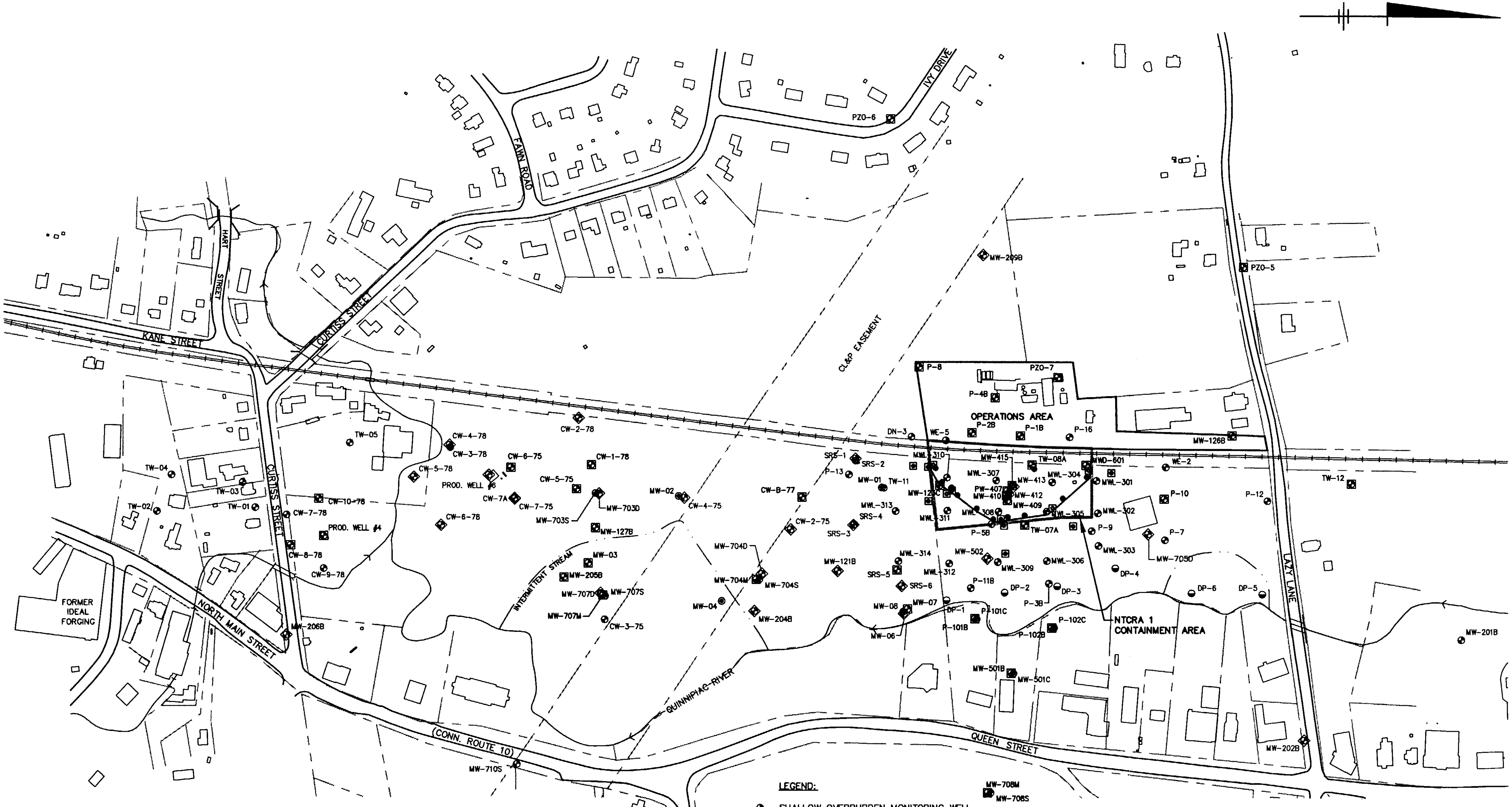
HORIZONTAL SCALE
1000' 0 1000'

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

GENERALIZED REGIONAL GEOLOGIC CROSS SECTION

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 9



LEGEND:

- SHALLOW OVERBURDEN MONITORING WELL
- MIDDLE OVERBURDEN MONITORING WELL
- DEEP OVERBURDEN MONITORING WELL
- OVERBURDEN/BEDROCK INTERFACE MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- NTCRA 1 WETLAND DRIVEPOINT

0 300' 600'

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

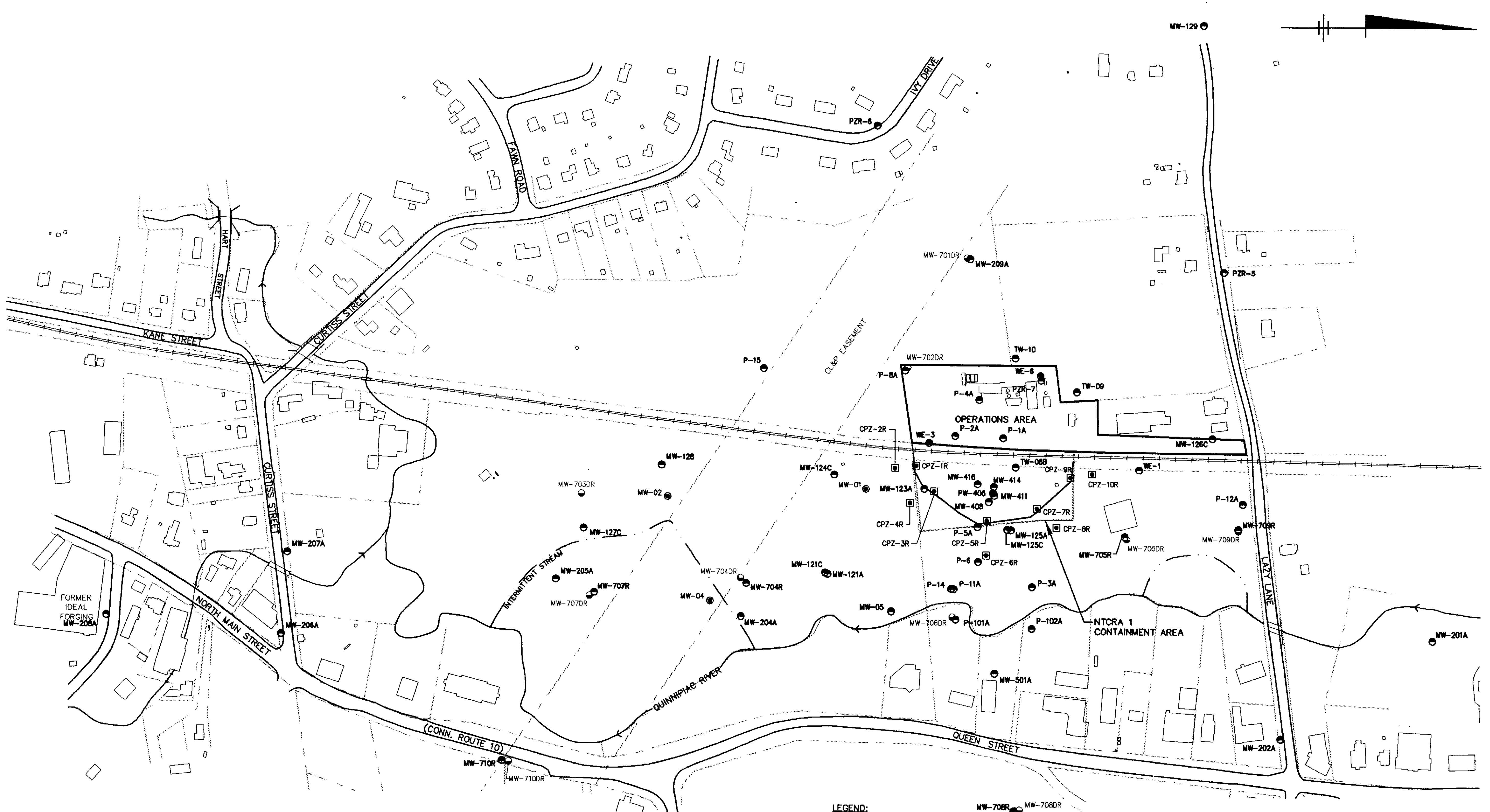
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

OVERBURDEN WELL, PIEZOMETER, AND DRIVEPOINT LOCATION MAP

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 10

P:STD-DL.PCP ● E-SIZE OR DJB.PCP
XREF: 08325X00,08325X01
6/25/98 SYR-54-RLP,DMW,RCB
08331900/08331B01.DWG



NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

LEGEND:

- OVERBURDEN/BEDROCK INTERFACE MONITORING WELL
- SHALLOW BEDROCK MONITORING WELL
- DEEP BEDROCK MONITORING WELL
- SHALLOW BEDROCK PIEZOMETER (NTCRA 1)

0 300' 600'

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

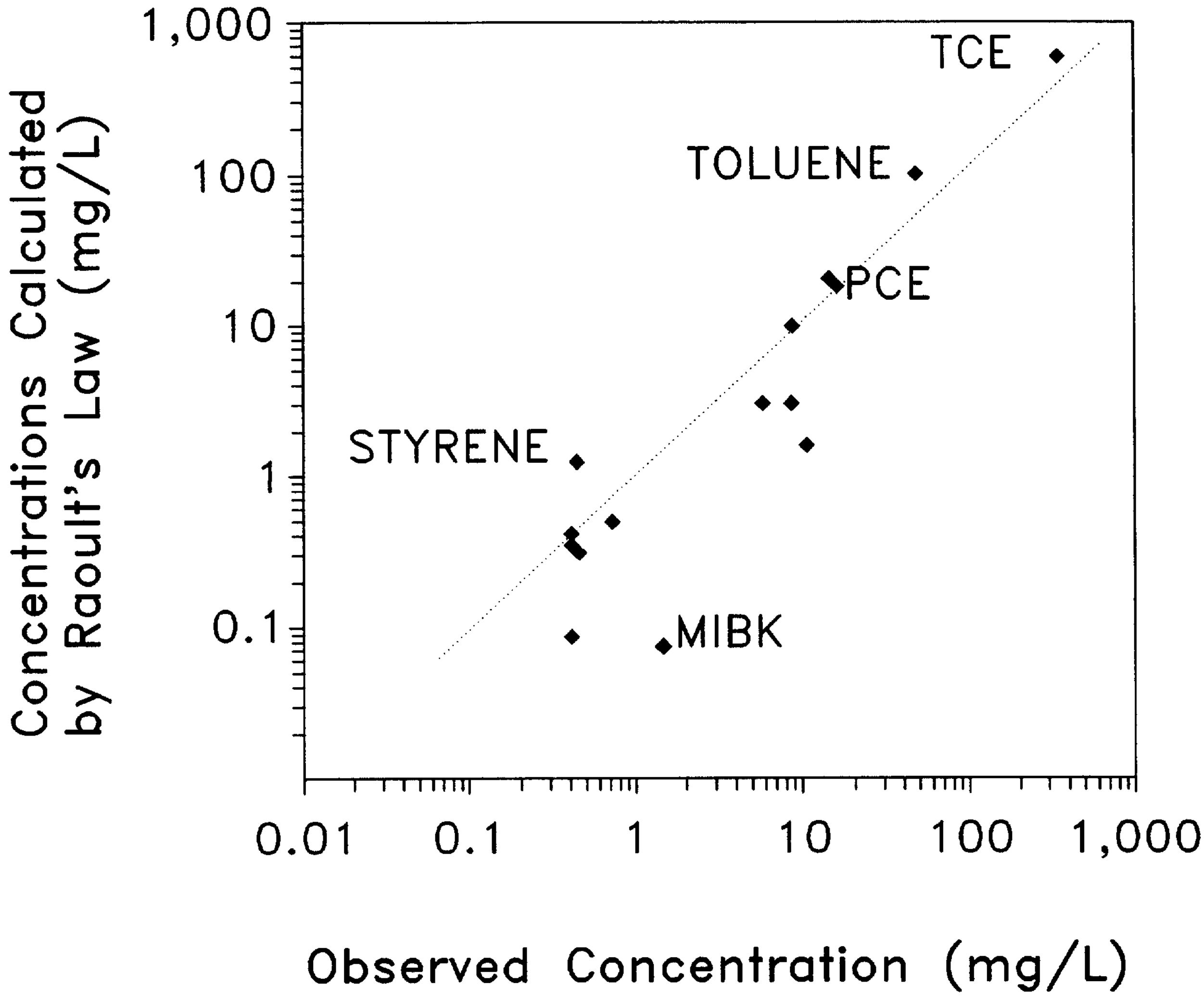
REMEDIAL INVESTIGATION

BEDROCK WELL AND PIEZOMETER LOCATION MAP

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 11

P: STD-DL.PCP ● E-SIZE OR DJB.PCP
XREF: 08325X00,08325X01
8/12/97 SYR-54-PGL DMW, PGL
08331008/08331B02.DWG



NOTES:

1. DATA BASED ON DNAPL AND GROUND-WATER CHEMICAL CHARACTERIZATION AT WELL MWD-601.
2. DATA EVALUATION BY DR. BERNARD KUEPER, QUEENS UNIVERSITY.

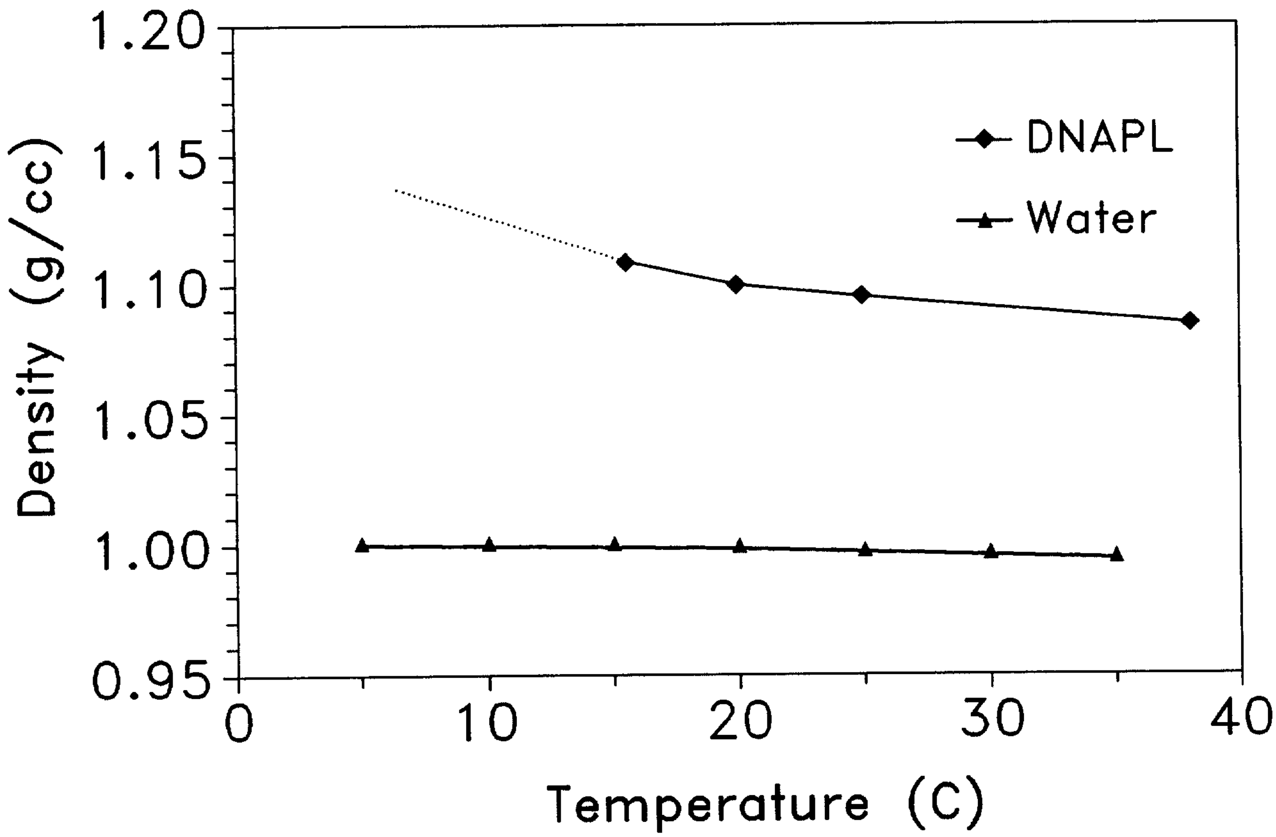
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

MWD-601
EFFECTIVE SOLUBILITY

BBL BLASLAND, BOUCK & LEE, INC. *engineers & scientists*

FIGURE **12**

P: STD-PCP/AP
8/12/97 SYR-54-PGL
08331008/08331N01.DWG



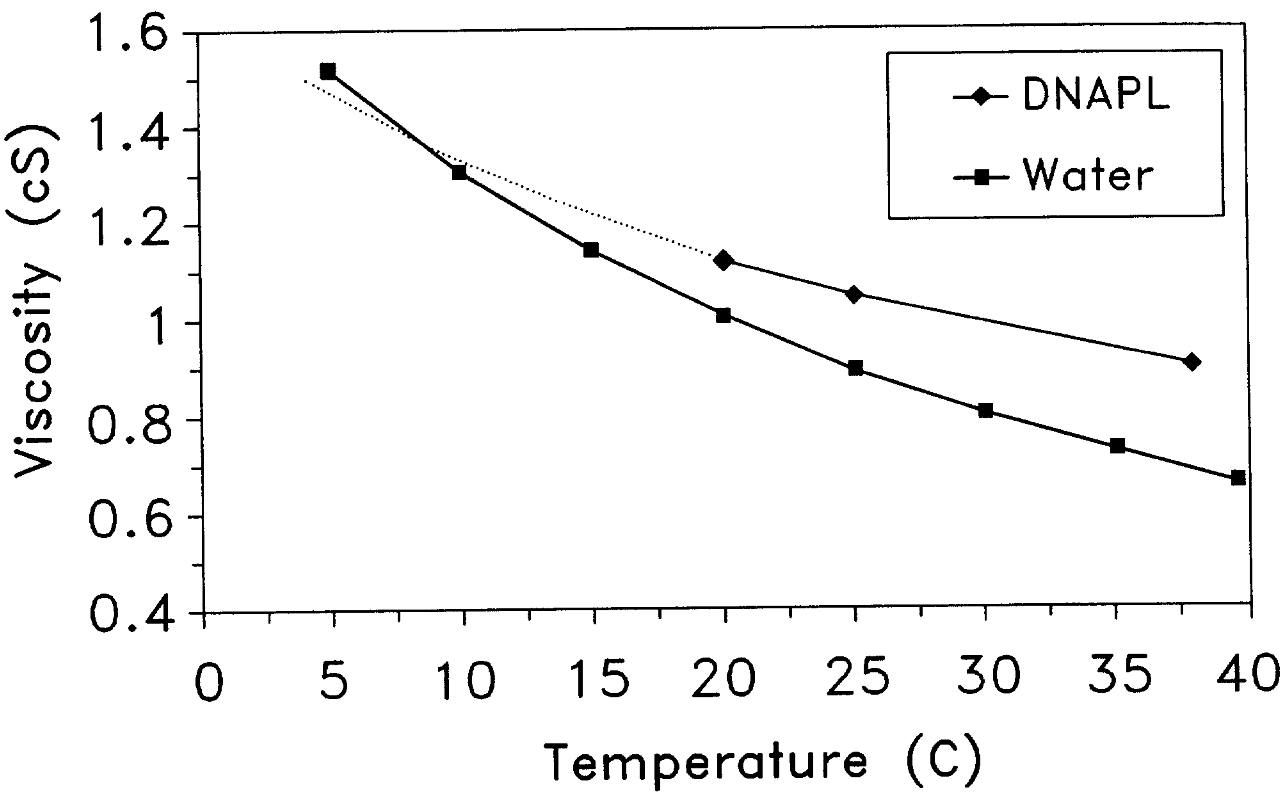
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

MWD-601
DNAPL DENSITY

BBL BLASLAND, BOUCK & LEE, INC.
engineers & scientists

FIGURE
13

P: STD-PCP/AP
8/13/97 SYR-54-PGL
08331008/08331N03.DWG



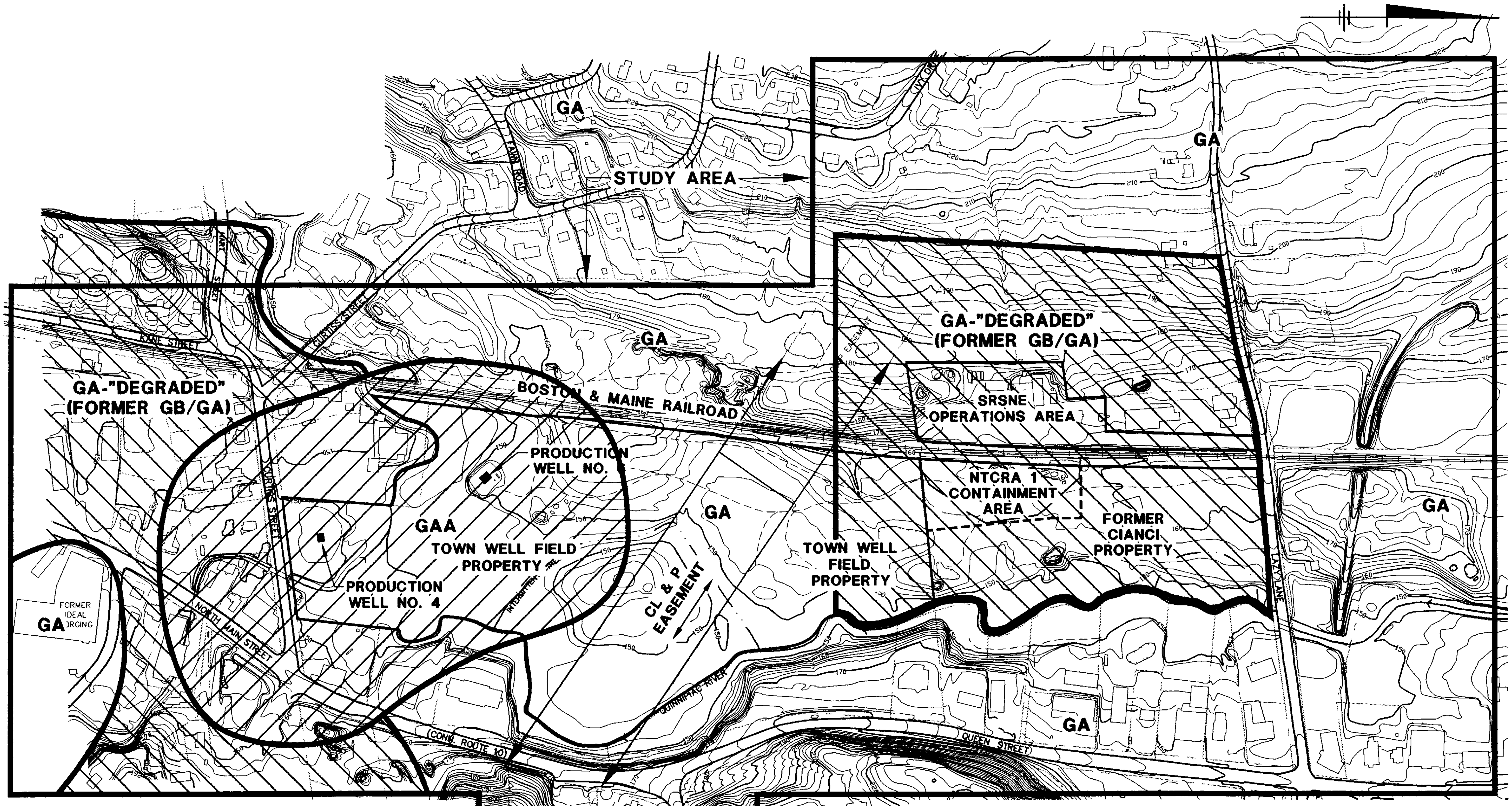
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

MWD-601
DNAPL VISCOSITY

BBL BLASLAND, BOUCK & LEE, INC. *engineers & scientists*

FIGURE
14

P: STD-PCP/AP
8/12/97 SYR-54-PGL
08331006/08331N02.DWG



LEGEND

170 GROUND SURFACE INDEX ELEVATION CONTOUR (10 FT. CONTOUR INTERVAL)

GROUND SURFACE INTERMEDIATE ELEVATION CONTOUR (2 FT. CONTOUR INTERVAL)

APPROXIMATE BOUNDARY BETWEEN GROUND-WATER CLASSIFICATION AREAS

GAA CT DEP GROUND-WATER CLASSIFICATION

0 300' 600'

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

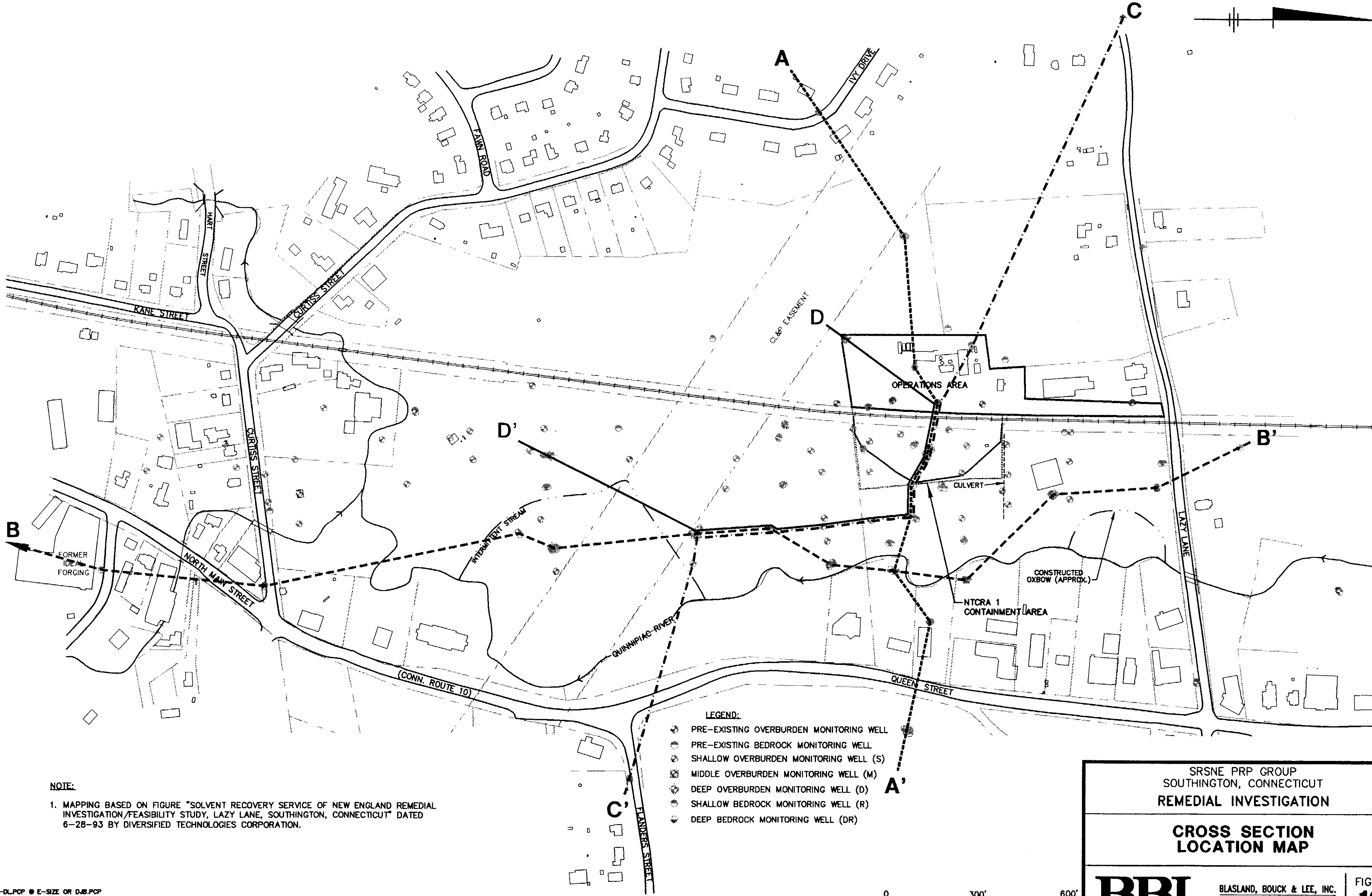
DJB08REF.PCP
X: 08325X00,08325X01;L: OFF: REF*.(XREF X01:PIPES)
10/20/97 SYR-54-DMW, PGL
08331008/08331G02.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

CT DEP GROUND-WATER CLASSIFICATION

BBL BLASLAND, BOUCK & LEE, INC. *engineers & scientists*

FIGURE 15



NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

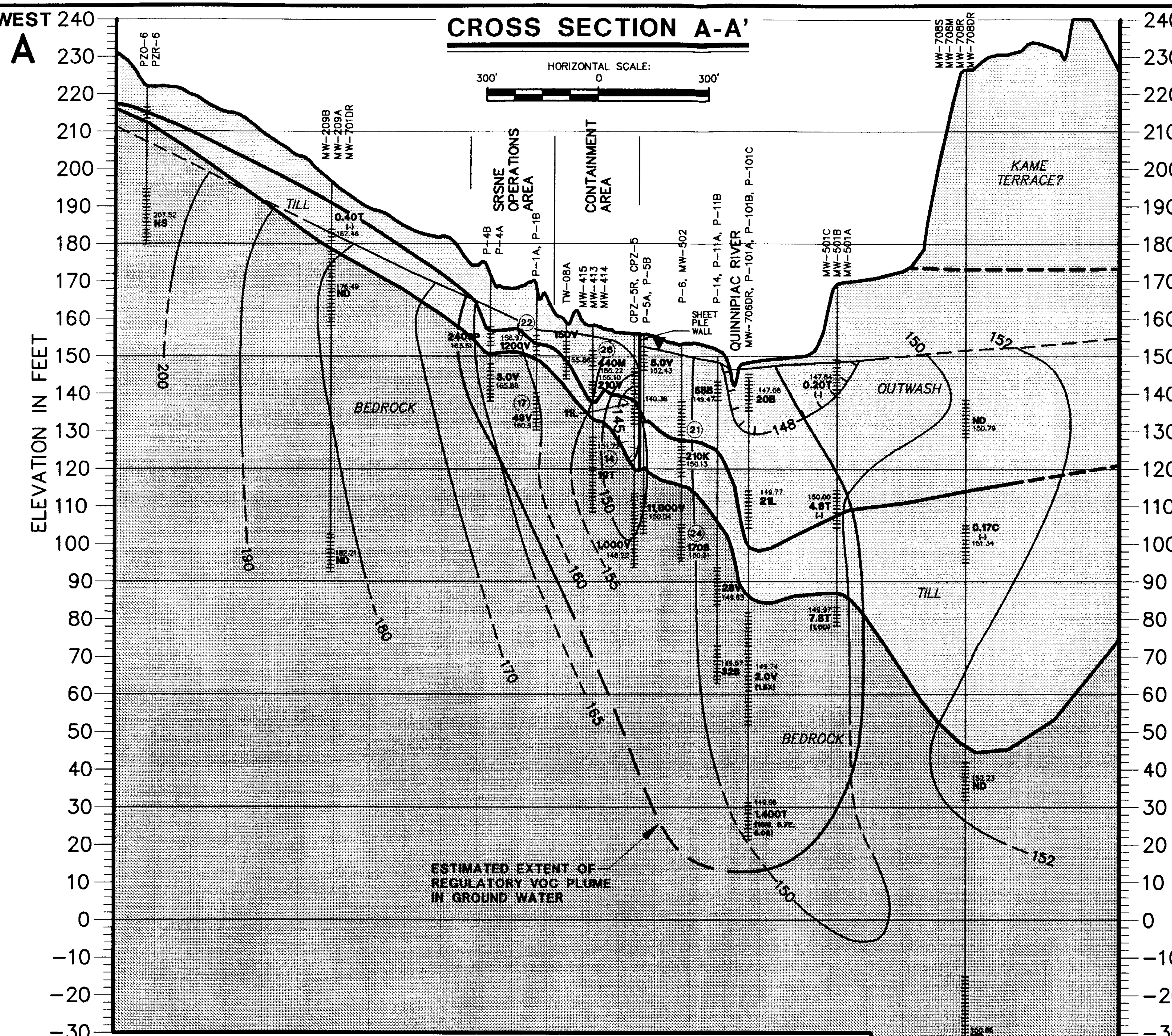
CROSS SECTION LOCATION MAP

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

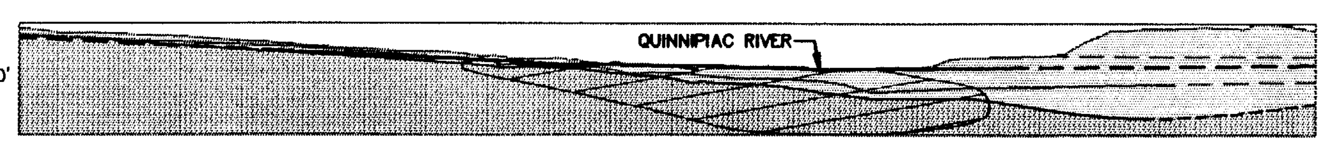
FIGURE 16

P:STD-DL.PCP ● E-SIZE OR DJ8.PCP
XREF: 08325X00,08325X01
2/17/97 SYR-54-RLP.DMW
08331900/08331B22.DWG

CROSS SECTION A-A'



CROSS SECTION A-A'
WITH NO VERTICAL EXAGGERATION
HORIZONTAL SCALE:
400' 0 400'



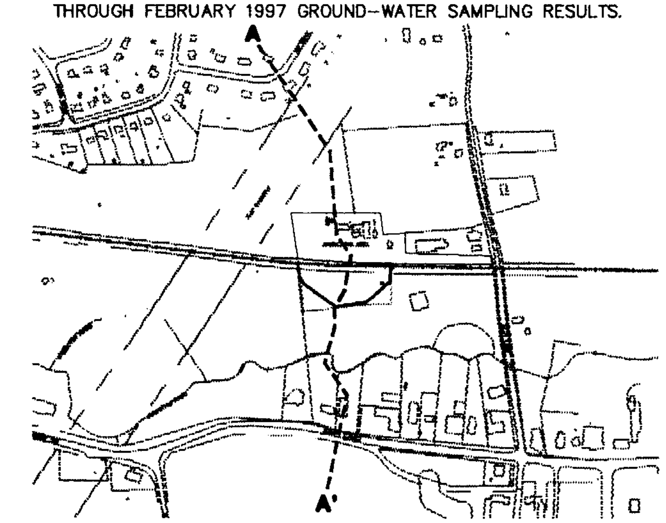
XREF: 08331X01,08331X02.DWG
P:CSA2.PCP OR CXE.PCP
10/16/97 SYR-54-DMW,AK,PGL
08331008/08331CA2.DWG

LEGEND:

- WELL NUMBER (MW-125A)
- MONITORING WELL
- WATER TABLE JANUARY 21, 1997, DASHED WHERE INFERRED
- GROUND-WATER ELEVATION (HEAD) CONTOUR, JANUARY 21, 1997, INTERVAL VARIABLE (152)
- GROUND-WATER ELEVATION MEASURED JANUARY 21, 1997 (152.86)
- SCREENED INTERVAL
- USAF NATURAL ATTENUATION RANK (20)
- BOTTOM OF BORING
- WELL WITH REGULATORY EXCEEDENCE RATIO. NUMBERS >1.0 INDICATE GROUND-WATER REGULATORY LIMIT EXCEEDED. NUMBERS <1.0 INDICATE EXCEEDENCE RATIO FOR COMPOUNDS DETECTED BELOW REGULATORY LIMIT. FIRST NUMBER INDICATES MAXIMUM MULTIPLE OF A DETECTED VOC OVER REGULATORY LIMIT. LETTER INDICATES COMPOUND WITH INDICATED EXCEEDENCE RATIO. NUMBERS IN PARENTHESIS INDICATE OTHER EXCEEDENCE RATIOS FOR SELECT COMPOUNDS AND WELLS. (-) = NO OTHER EXCEEDENCES. (46B (2.08))

B BENZENE
C CHLOROFORM
D 1,2-DICHLOROETHENE
E 1,1-DICHLOROETHENE
K 4-METHYL-2-PENTANONE (MIBK)
L TOLUENE
M METHYLENE CHLORIDE
P TETRACHLOROETHENE
R 1,1,1-TRICHLOROETHANE
T TRICHLOROETHENE
U 2-BUTANONE
V VINYL CHLORIDE
X XYLENES
ND NONE DETECTED
NS NOT SAMPLED

NOTE:
1. GROUND-WATER QUALITY DATA BASED ON NOVEMBER 1996 THROUGH FEBRUARY 1997 GROUND-WATER SAMPLING RESULTS.



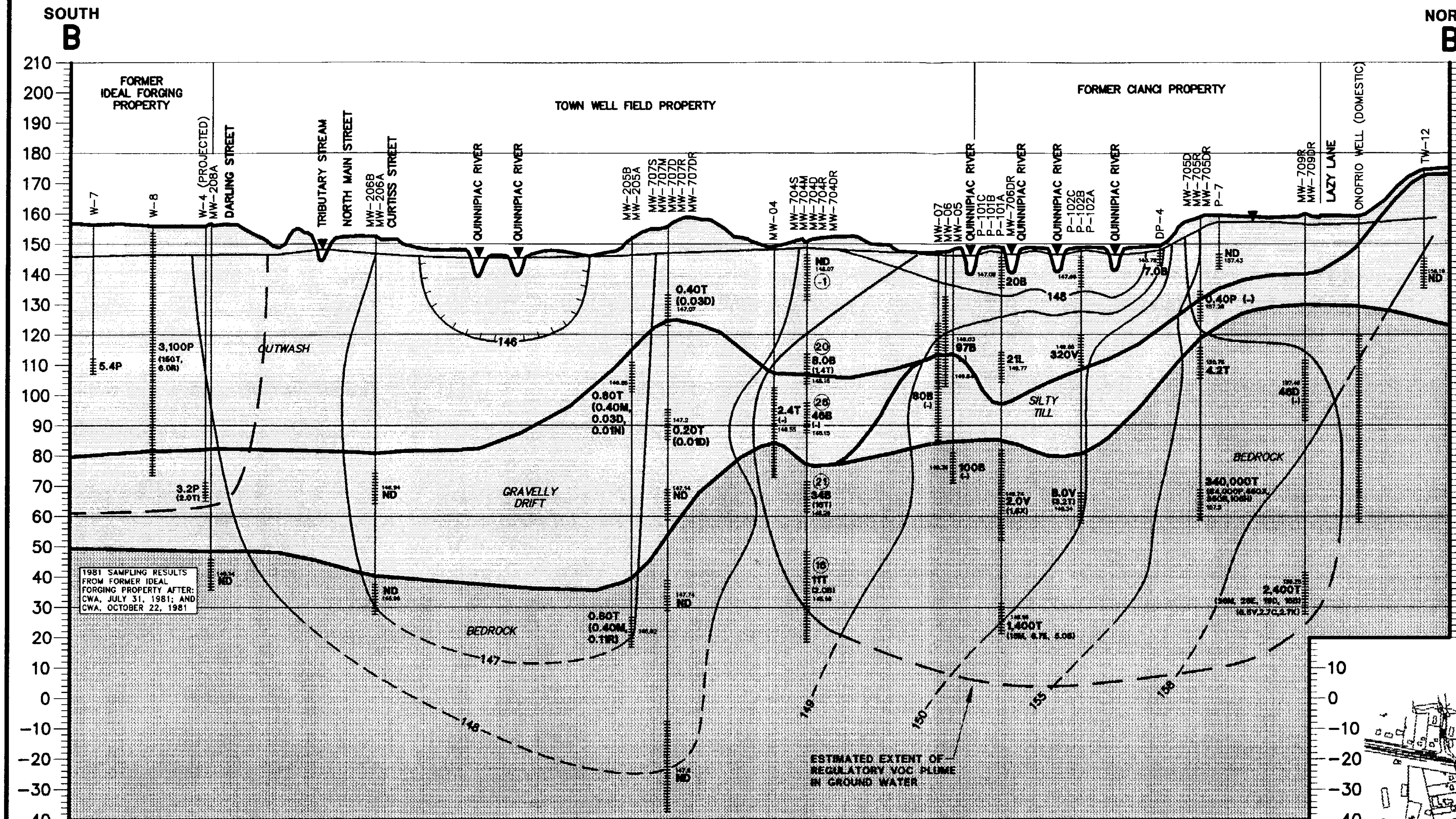
LOCATION MAP
1000' 0 1000'

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

GEOLOGIC CROSS SECTION A-A' WITH HEAD CONTOURS AND REGULATORY PLUME

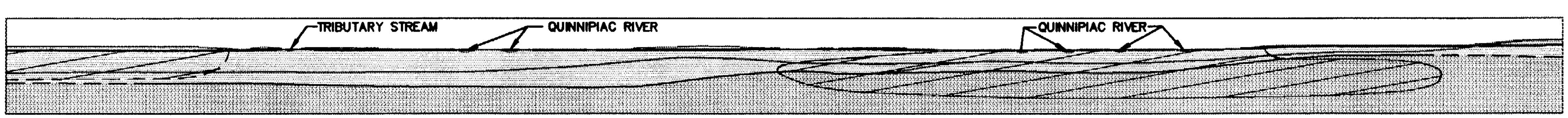
BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 17



CROSS SECTION B-B'

HORIZONTAL SCALE: 400' 0 400'



CROSS SECTION B-B' WITH NO VERTICAL EXAGGERATION

HORIZONTAL SCALE: 400' 0 400'

LEGEND

- MW-125A — WELL NUMBER
- MONITORING WELL
- WATER TABLE JANUARY 21, 1997, DASHED WHERE INFERRED
- 152 — GROUND-WATER ELEVATION (HEAD) CONTOUR, JANUARY 21, 1997, INTERVAL VARIABLE
- 152.86 — GROUND-WATER ELEVATION MEASURED JANUARY 21, 1997
- SCREENED INTERVAL
- (20) — USAF NATURAL ATTENUATION RANK
- BOTTOM OF BORING
- 46B (2.0B) — WELL WITH REGULATORY EXCEEDENCE RATIO. NUMBERS >1.0 INDICATE GROUND-WATER REGULATORY LIMIT EXCEEDED. NUMBERS <1.0 INDICATE EXCEEDENCE RATIO FOR COMPOUNDS DETECTED BELOW REGULATORY LIMIT. FIRST NUMBER INDICATES MAXIMUM MULTIPLE OF A DETECTED VOC OVER REGULATORY LIMIT (e.g., 2.0 INDICATES 2 x LIMIT). LETTER INDICATES COMPOUND WITH INDICATED EXCEEDENCE RATIO (e.g., B = BENZENE). NUMBERS IN PARENTHESIS INDICATE OTHER EXCEEDENCE RATIOS FOR SELECT COMPOUNDS AND WELLS. (-) = NO OTHER EXCEEDENCES.

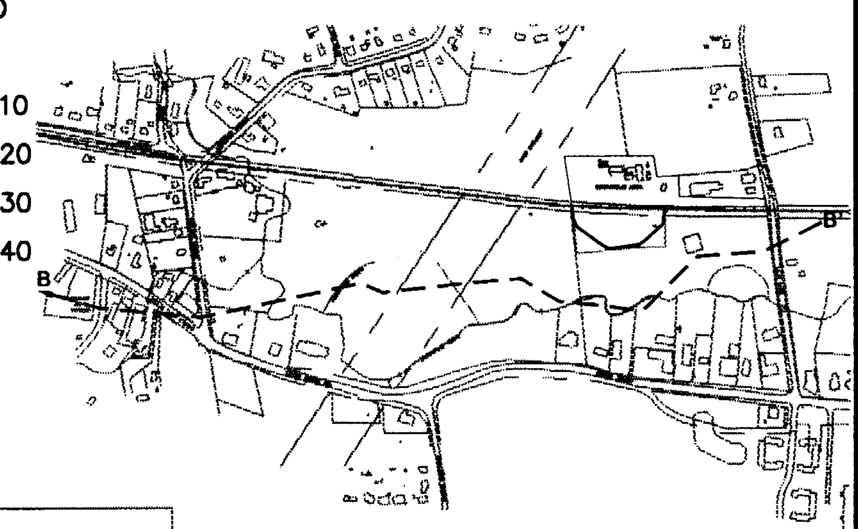
B	BENZENE
C	CHLOROFORM
D	1,2-DICHLOROETHENE
E	1,1-DICHLOROETHENE
K	4-METHYL-2-PENTANONE (MIBK)
L	TOLUENE
M	METHYLENE CHLORIDE
P	TETRACHLOROETHENE
R	1,1,1-TRICHLOROETHANE
T	TRICHLOROETHENE
U	2-BUTANONE
V	VINYL CHLORIDE
X	XYLENES
ND	NONE DETECTED

NOTE:

1. GROUND-WATER QUALITY DATA BASED ON NOVEMBER/DECEMBER 1996 GROUND-WATER SAMPLING RESULTS, EXCEPT FOR DATA FROM FORMER IDEAL FORGING PROPERTY.

LOCATION MAP

1000' 0 1000'



SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

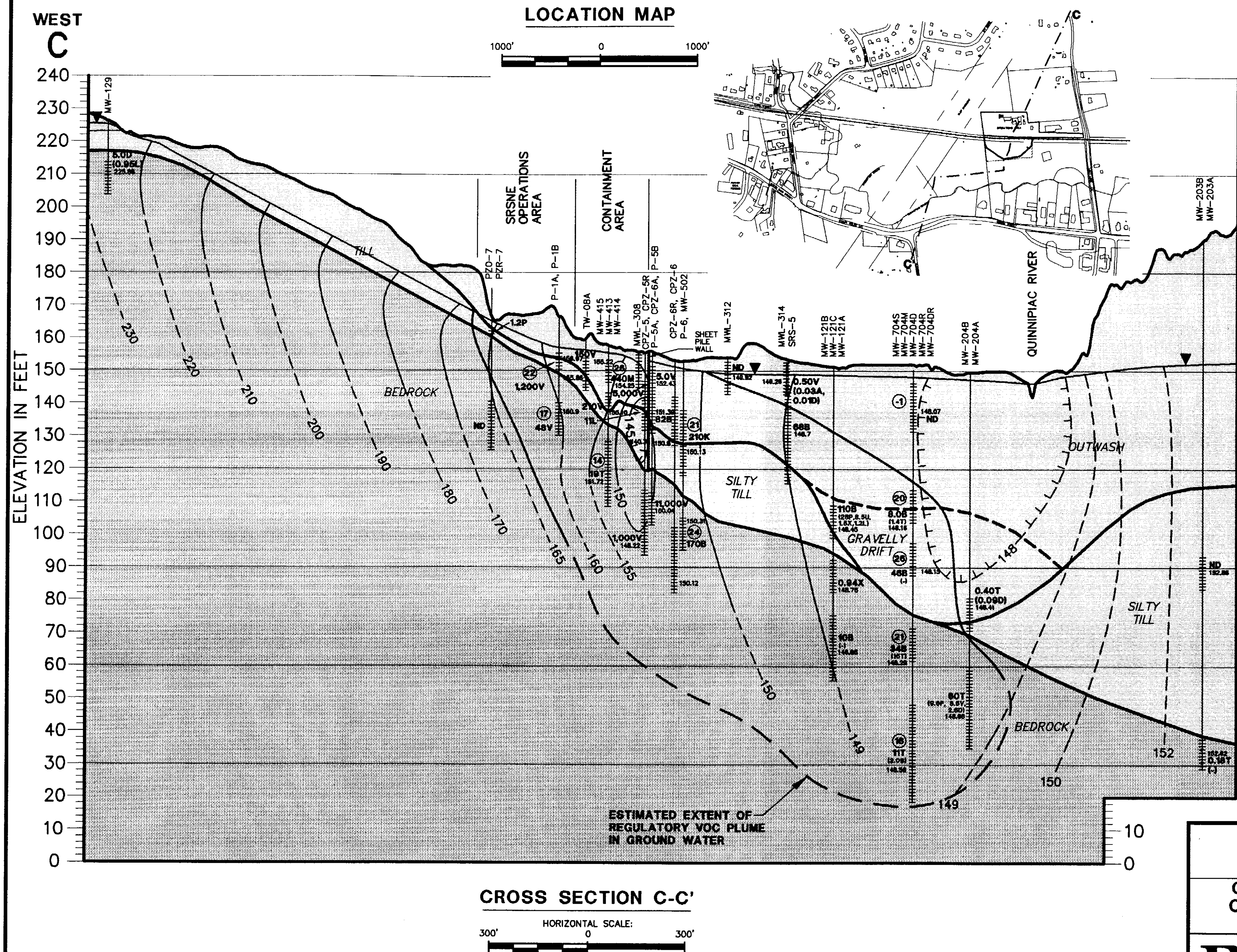
REMEDIAL INVESTIGATION

GEOLOGIC CROSS SECTION B-B' WITH HEAD CONTOURS AND REGULATORY PLUME

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 18

XREF: 08331X01, 08331X03.DWG
P:CSA2 OR CXE.PCP
10/17/97 SYR-54-DMW, AK, PGL
08331008/08331C82.DWG



LEGEND

- MW-125A — WELL NUMBER
- MONITORING WELL
- WATER TABLE JANUARY 21, 1997, DASHED WHERE INFERRED
- 152 — GROUND-WATER ELEVATION (HEAD) CONTOUR, JANUARY 21, 1997, INTERVAL VARIABLE
- 152.86 — GROUND-WATER ELEVATION MEASURED JANUARY 21, 1997
- SCREENED INTERVAL
- (20) — USAF NATURAL ATTENUATION RANK
- BOTTOM OF BORING
- 46B (2.0B) — WELL WITH REGULATORY EXCEEDENCE RATIO. NUMBERS >1.0 INDICATE GROUND-WATER REGULATORY LIMIT EXCEEDED. NUMBERS <1.0 INDICATE EXCEEDENCE RATIO FOR COMPOUNDS DETECTED BELOW REGULATORY LIMIT. FIRST NUMBER INDICATES MAXIMUM MULTIPLE OF A DETECTED VOC OVER REGULATORY LIMIT (e.g., 2.0 INDICATES 2 x LIMIT). LETTER INDICATES COMPOUND WITH INDICATED EXCEEDENCE RATIO (e.g., B = BENZENE). NUMBERS IN PARENTHESIS INDICATE OTHER EXCEEDENCE RATIOS FOR SELECT COMPOUNDS AND WELLS. (-) = NO OTHER EXCEEDENCES.

B	BENZENE
C	CHLOROFORM
D	1,2-DICHLOROETHENE
E	1,1-DICHLOROETHENE
K	4-METHYL-2-PENTANONE (MIBK)
L	TOLUENE
M	METHYLENE CHLORIDE
P	TETRACHLOROETHENE
R	1,1,1-TRICHLOROETHANE
T	TRICHLOROETHENE
U	2-BUTANONE
V	VINYL CHLORIDE
X	XYLENES
ND	NONE DETECTED

NOTE:

1. GROUND-WATER QUALITY DATA BASED ON NOVEMBER/DECEMBER 1996 GROUND-WATER SAMPLING RESULTS

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

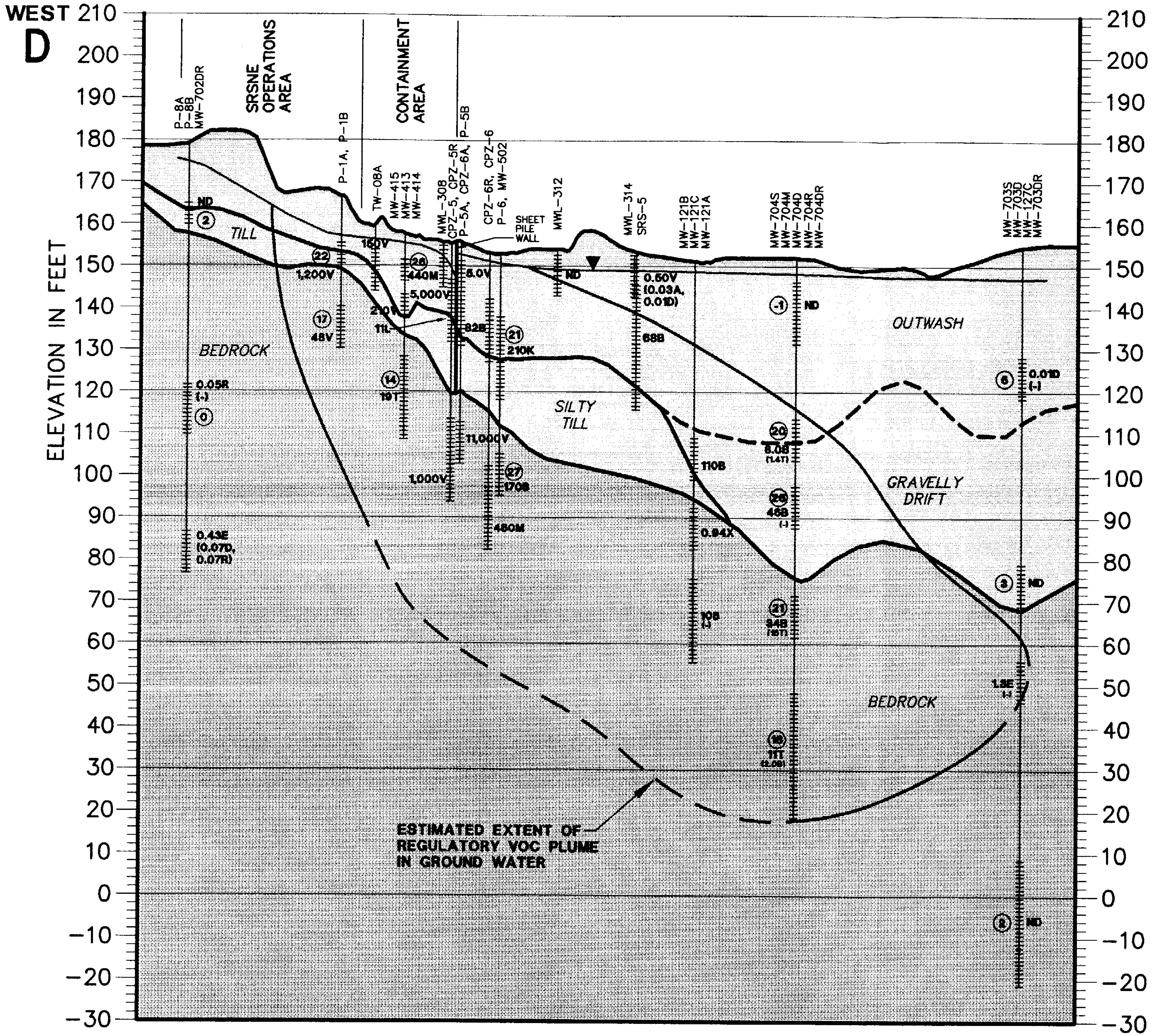
REMEDIAL INVESTIGATION

GEOLOGIC CROSS SECTION C-C' WITH HEAD CONTOURS AND REGULATORY PLUME

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

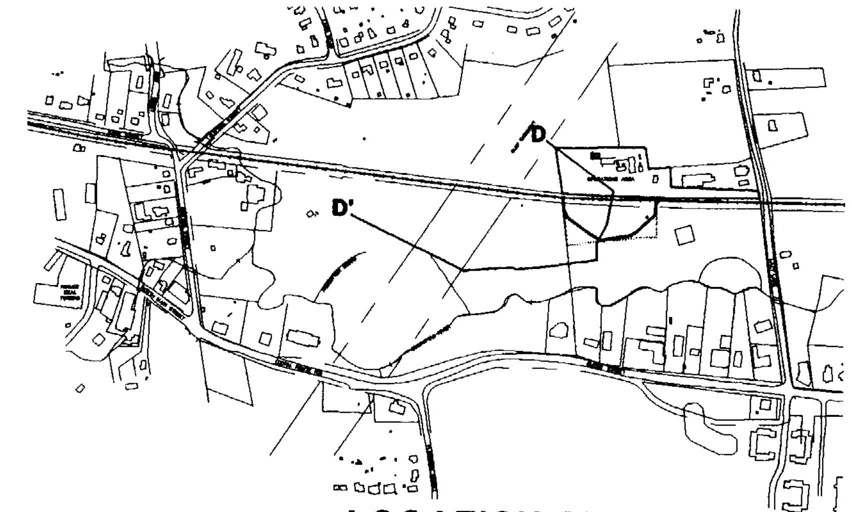
FIGURE 19

XREF: 08331X01, 08331X03.DWG
P:CXA2 OR CXE.PCP
10/20/97 SYR-54-DMW, PGL, JER
08331017/08331CC2.DWG



CROSS SECTION D-D'

HORIZONTAL SCALE: 300' 0 300'



LOCATION MAP

1000' 0 1000'

LEGEND

- MW-125A — WELL NUMBER
- MONITORING WELL
- WATER TABLE JANUARY 21, 1997, DASHED WHERE INFERRED
- SCREENED INTERVAL
- (20) USAF NATURAL ATTENUATION RANK
- BOTTOM OF BORING
- 46B (2.08) — WELL WITH REGULATORY EXCEEDENCE RATIO. NUMBERS >1.0 INDICATE GROUND-WATER REGULATORY LIMIT EXCEEDED. NUMBERS <1.0 INDICATE EXCEEDENCE RATIO FOR COMPOUNDS DETECTED BELOW REGULATORY LIMIT. FIRST NUMBER INDICATES MAXIMUM MULTIPLE OF A DETECTED VOC OVER REGULATORY LIMIT (e.g., 2.0 INDICATES 2 x LIMIT). LETTER INDICATES COMPOUND WITH INDICATED EXCEEDENCE RATIO (e.g., B = BENZENE). NUMBERS IN PARENTHESIS INDICATE OTHER EXCEEDENCE RATIOS FOR SELECT COMPOUNDS AND WELLS. (-) = NO OTHER EXCEEDENCES.

B	BENZENE
C	CHLOROFORM
D	1,2-DICHLOROETHENE
E	1,1-DICHLOROETHENE
M	METHYLENE CHLORIDE
P	TETRACHLOROETHENE
R	1,1,1-TRICHLOROETHANE
T	TRICHLOROETHENE
U	2-BUTANONE
V	VINYL CHLORIDE
X	XYLENES
ND	NONE DETECTED

NOTE:

1. GROUND-WATER QUALITY DATA BASED ON NOVEMBER/DECEMBER 1996 GROUND-WATER SAMPLING RESULTS

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

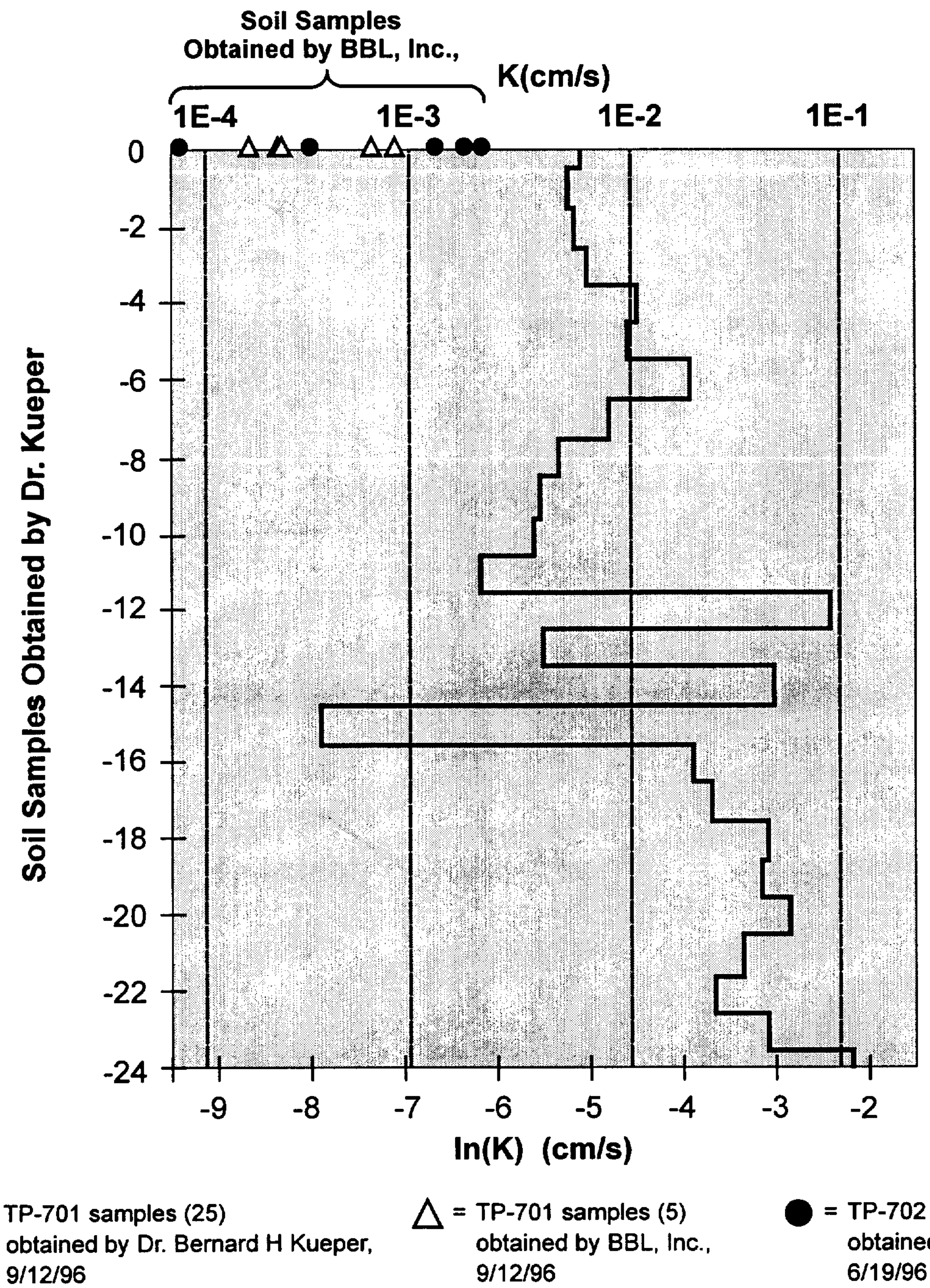
REMEDIAL INVESTIGATION

GEOLOGIC CROSS SECTION D-D' WITH REGULATORY PLUME

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 20

XREF: 08331X01, 08331X03.DWG
P:CXA2 OR CXE.PCP
10/20/97 SYR-54-DMW, PGL, JER
08331017/08331C02.DWG



NOTES:

1. Dr. Bernard H. Kueper obtained samples continously at TP-701 starting at a depth of approx. 4 ft. BGS; Samples obtained by scraping away soil in approx. 1 cm thick subhorizontal slabs in an area approx. 1.5' x 1.5' (see test pit photos appendix).

2. Kmax/Kmin is approx. 300 for Dr. Bernard H. Kueper's samples. Kmax/Kmin is approx. 25 for BBL's samples

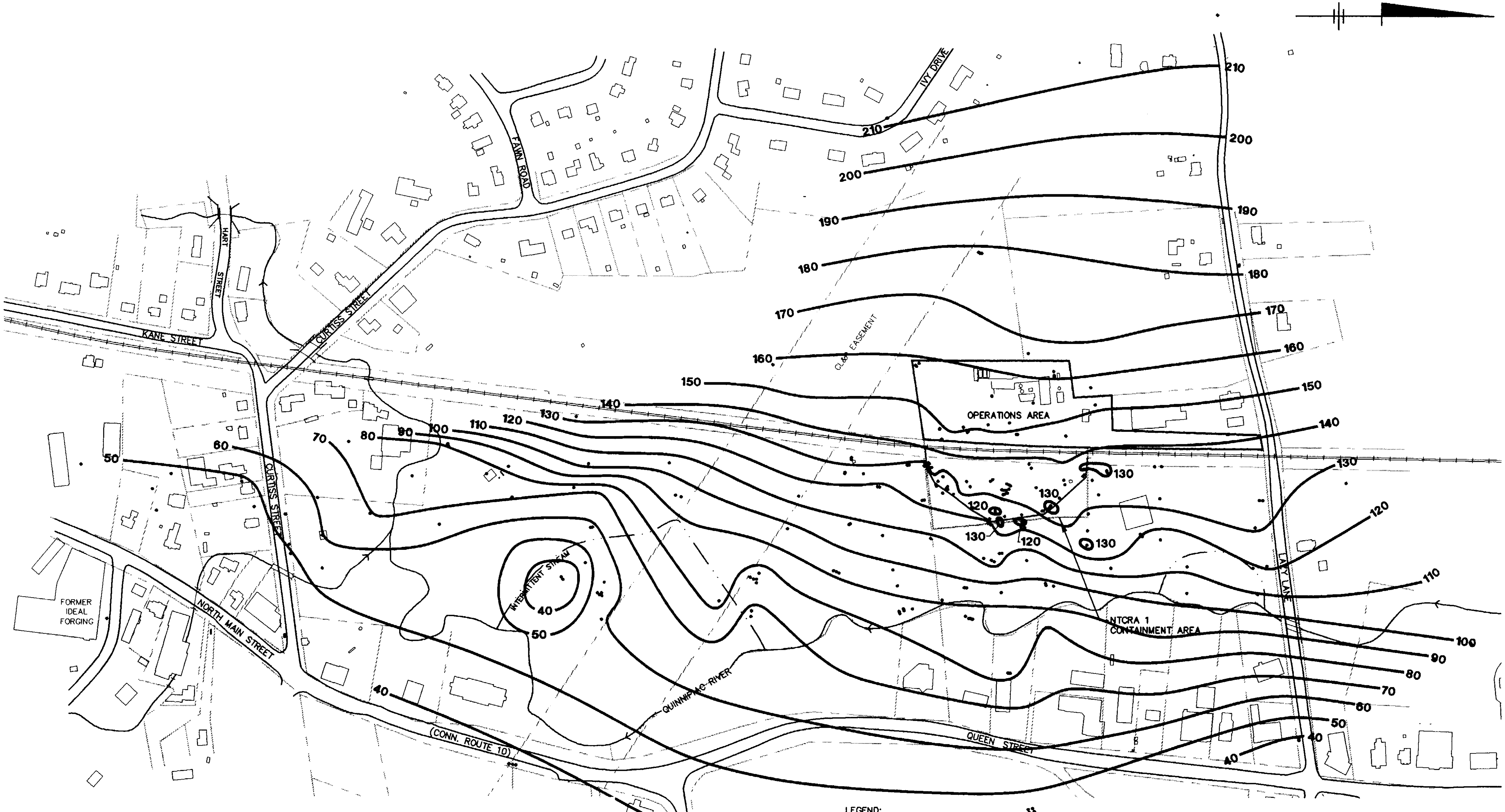
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

TEST PIT SOIL HYDRAULIC CONDUCTIVITY MEASUREMENTS SUMMARY

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 21

8/97 SYR D54-DJH
08331008/08331g01.cdr



LEGEND:

- • DATA POINT LOCATION
- 50 ——— TOP OF BEDROCK ELEVATION CONTOUR (FT AMSL)

0 300' 600'

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

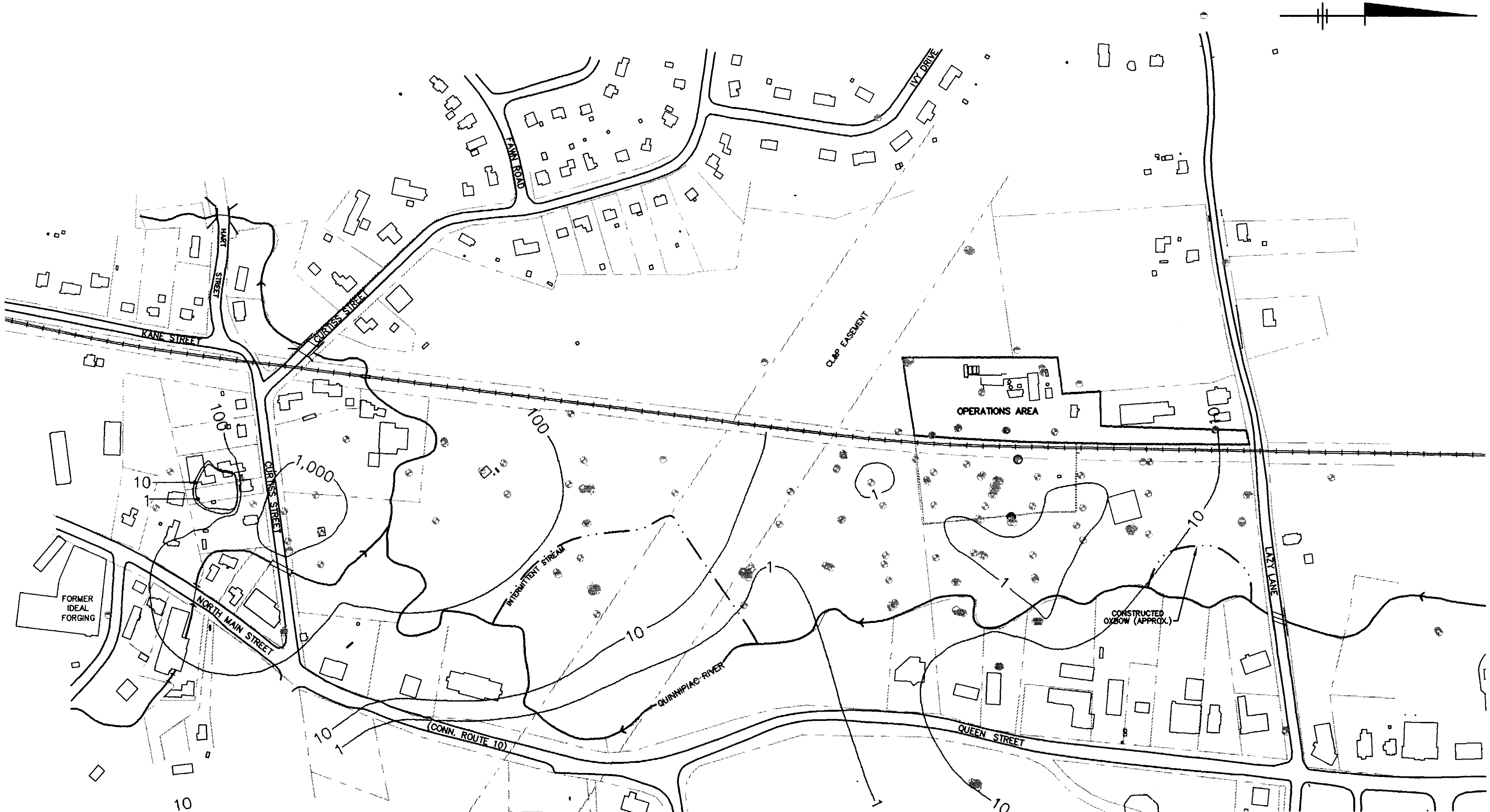
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

TOP OF BEDROCK ELEVATION CONTOUR MAP

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 22

P: STD-DL.PCP ● E-SIZE OR DJB.PCP
XREF: 08325X00,08325X01
10/20/97 SYR-54-PGL, DMW, PGL
08331900/08331B33.DWG



NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.
2. HYDRAULIC CONDUCTIVITY DATA BASED ON HNUS (MAY 1994), EWSR (JUNE 1994), AND SPECIFIC CAPACITY TESTS, PACKER TESTS, AND WELL PUMPING DATA OBTAINED DURING CURRENT RI BY BBL (AUGUST 1996 THROUGH JANUARY 1997).

LEGEND:

- 10 —— HYDRAULIC CONDUCTIVITY CONTOUR (FT/DAY)
- PRE-EXISTING OVERBURDEN MONITORING WELL
- PRE-EXISTING BEDROCK MONITORING WELL
- SHALLOW OVERBURDEN MONITORING WELL (S)
- MIDDLE OVERBURDEN MONITORING WELL (M)
- DEEP OVERBURDEN MONITORING WELL (D)
- SHALLOW BEDROCK MONITORING WELL (R)
- DEEP BEDROCK MONITORING WELL (DR)

0 300' 600'

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

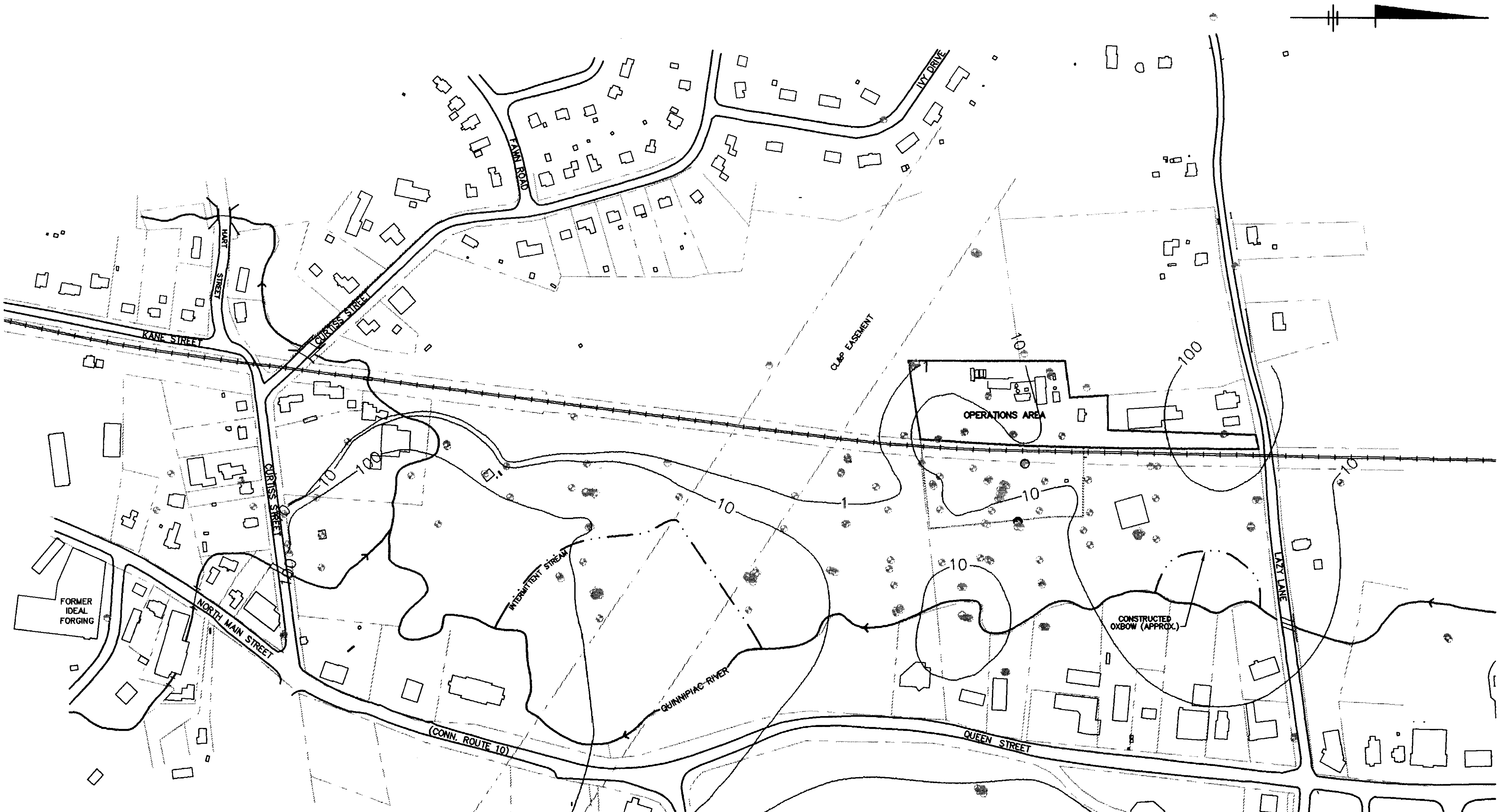
REMEDIAL INVESTIGATION

SHALLOW OVERBURDEN HYDRAULIC CONDUCTIVITY CONTOURS (FT/DAY)

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 23

L: ON=*, OFF=DOVB*,MOVB*,BEDSH,GRID,OV*,REF
P: STD-BL_PCP
XREF: 08325X00,08325X01 L: OFF= *CO*
10/20/97 SYR-54-RLP,PGL,JER
08331900/08331B04.DWG



LEGEND:

- 10 —— HYDRAULIC CONDUCTIVITY CONTOUR (FT/DAY)
- PRE-EXISTING OVERBURDEN MONITORING WELL
- PRE-EXISTING BEDROCK MONITORING WELL
- SHALLOW OVERBURDEN MONITORING WELL (S)
- MIDDLE OVERBURDEN MONITORING WELL (M)
- DEEP OVERBURDEN MONITORING WELL (D)
- SHALLOW BEDROCK MONITORING WELL (R)
- DEEP BEDROCK MONITORING WELL (DR)

0 300' 600'

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.
2. HYDRAULIC CONDUCTIVITY DATA BASED ON HNUS (MAY 1994), EWSR (JUNE 1994), AND SPECIFIC CAPACITY TESTS, PACKER TESTS, AND WELL PUMPING DATA OBTAINED DURING CURRENT RI BY BBL (AUGUST 1996 THROUGH JANUARY 1997).

L: ON=*, OFF=DOVB*,SOVB*,BEDSH,GRID,OV*,REF
P: STD-BL.PCP
XREF: 08325X00,08325X01 L: OFF= *CO*
10/20/97 SYR-54-RLP,PGL,JER
08331900/08331B04.DWG

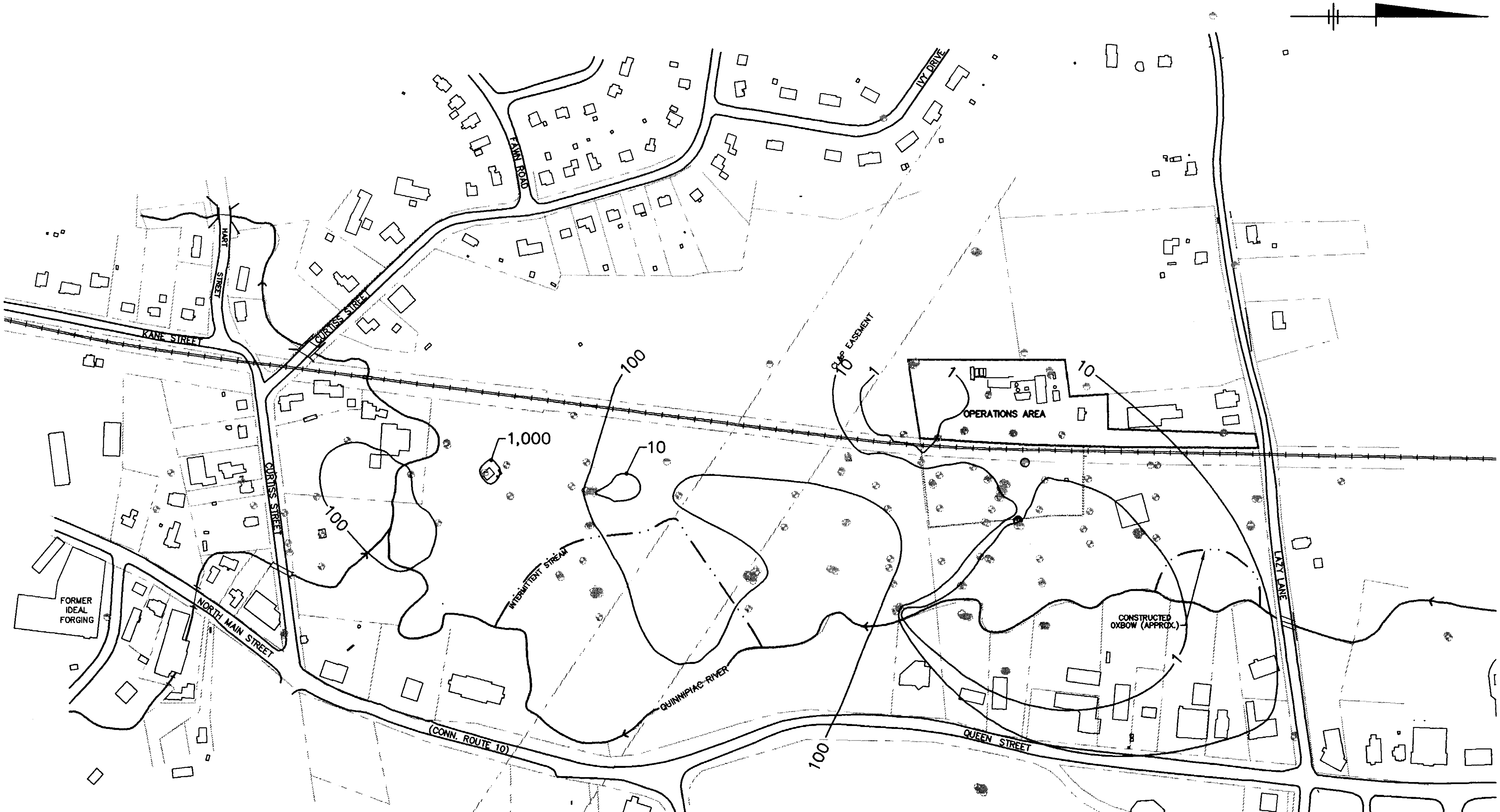
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

MIDDLE OVERBURDEN HYDRAULIC CONDUCTIVITY CONTOURS (FT/DAY)

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 24



LEGEND:

- 10 —— HYDRAULIC CONDUCTIVITY CONTOUR (FT/DAY)
- PRE-EXISTING OVERBURDEN MONITORING WELL
- PRE-EXISTING BEDROCK MONITORING WELL
- SHALLOW OVERBURDEN MONITORING WELL (S)
- MIDDLE OVERBURDEN MONITORING WELL (M)
- DEEP OVERBURDEN MONITORING WELL (D)
- SHALLOW BEDROCK MONITORING WELL (R)
- DEEP BEDROCK MONITORING WELL (DR)

0 300' 600'

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.
2. HYDRAULIC CONDUCTIVITY DATA BASED ON HNUS (MAY 1994), EWSR (JUNE 1994), AND SPECIFIC CAPACITY TESTS, PACKER TESTS, AND WELL PUMPING DATA OBTAINED DURING CURRENT RI BY BBL (AUGUST 1996 THROUGH JANUARY 1997).

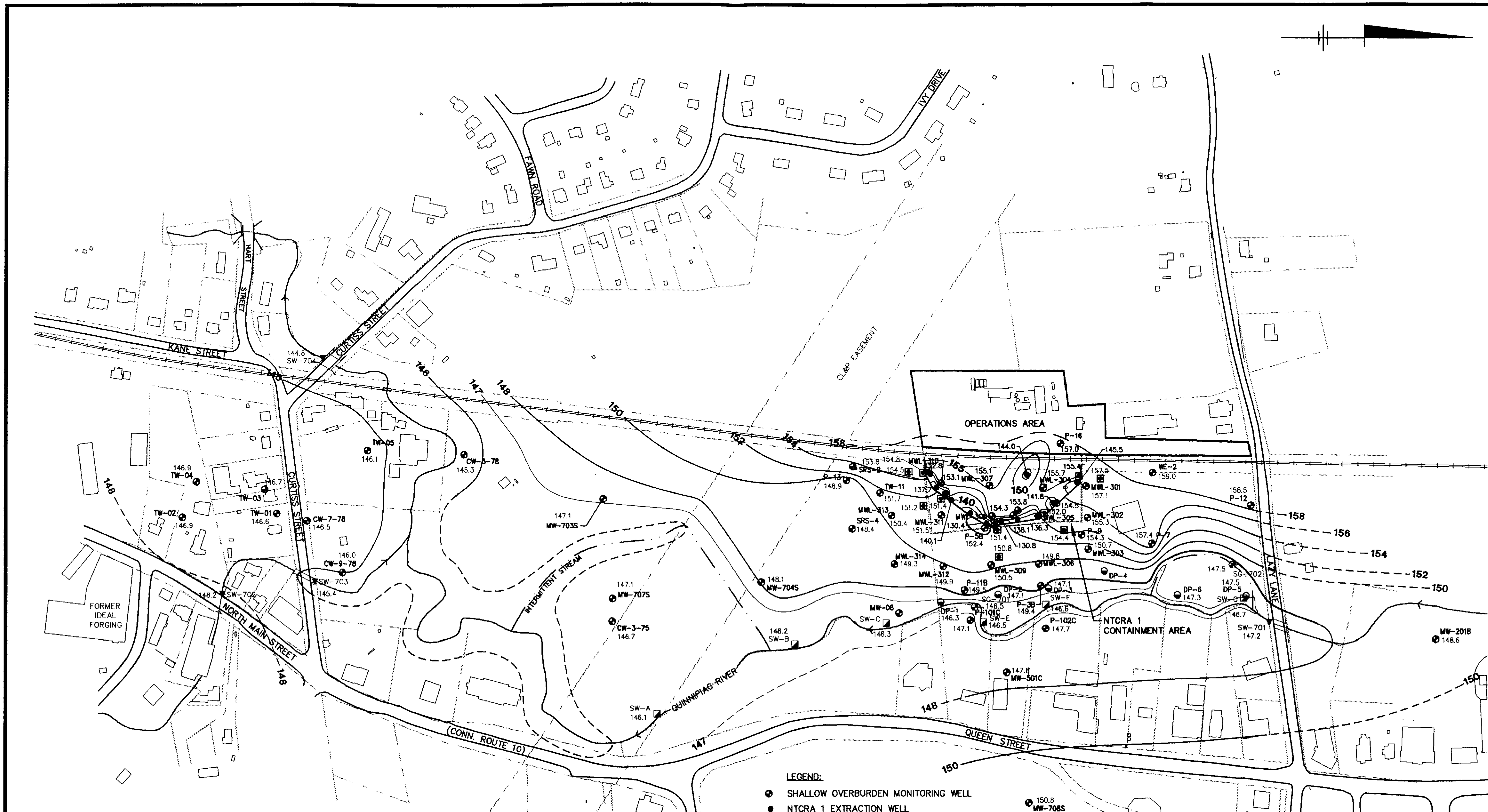
L: ON=*, OFF=MOVB*,SOVB*,BEDSH*,GRID,OV*,REF
P: STD-BL.PCP
XREF: 06325X00,06325X01 L: OFF= *CO*
10/20/97 SYR-54-RLP,PGL,JER
06331900/06331B04.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

DEEP OVERBURDEN HYDRAULIC CONDUCTIVITY CONTOURS (FT/DAY)

BBL BLASLAND, BOUCK & LEE, INC. *engineers & scientists*

FIGURE **25**



LEGEND:

- SHALLOW OVERBURDEN MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- NTCRA 1 WETLAND DRIVEPOINT
- ▼ SURFACE WATER MEASUREMENT POINTS
- SURFACE WATER SAMPLING LOCATION
- STREAM GAUGE
- 157.5 GROUND-WATER (POTENTIOMETRIC) ELEVATION (FT AMSL)
- 160 ——— GROUND-WATER (POTENTIOMETRIC) ELEVATION CONTOUR (FT AMSL), DASHED WHERE INFERRED, CONTOUR INTERVAL VARIES

0 300' 600'

NOTES:

1. WELL MW-708 CLUSTER NOT COMPLETED ON 1/21/97. GROUND-WATER ELEVATION AT WELL MW-708S MEASURED ON 2/11/97 AND ADJUSTED TO ESTIMATED LEVEL ON 1/21/97 BASED ON AVERAGE CHANGE BETWEEN 1/21/97 AND 2/11/97 AT WELLS MW-201B, MW-501C, P-101C, AND P-102C.
2. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

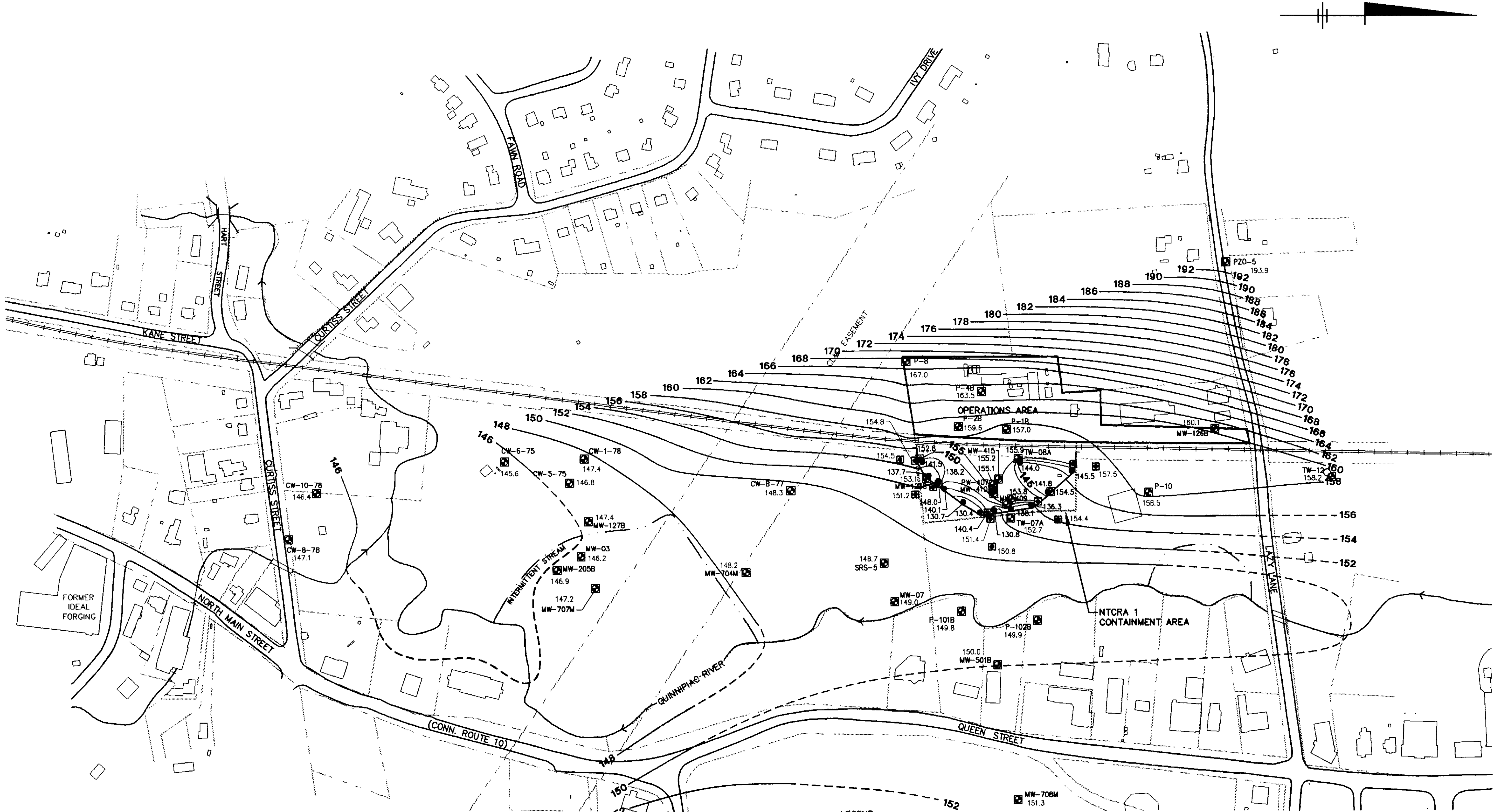
X: 08325X00,08325X01.DWG
P: STD-DL.PCP ● E-SIZE OR DJB.PCP
10/20/97 SYR-54-RLP,PGL,DMW,PGL
08331B00/08331B27.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

SHALLOW OVERBURDEN GROUND-WATER ELEVATION CONTOURS, 1/21/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 26



NOTES:

1. WELL MW-708 CLUSTER NOT COMPLETED ON 1/21/97. GROUND-WATER ELEVATION AT WELL MW-708M MEASURED ON 2/11/97 AND ADJUSTED TO ESTIMATED LEVEL ON 1/21/97 BASED ON AVERAGE CHANGE BETWEEN 1/21/97 AND 2/11/97 AT WELLS MW-203B, MW-501B, P-101B, AND P-102B.
2. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

X: 08325X00,08325X01.DWG
P: STD-DL.PCP ● E-SIZE OR DJB.PCP
10/20/97 SYR-54-PGL,DMW,PGL
08331B00/08331B05.DWG

LEGEND:

- MIDDLE OVERBURDEN MONITORING WELL
- ● NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- 157.5 GROUND-WATER (POTENTIOMETRIC) ELEVATION (FT AMSL)
- 160 ——— GROUND-WATER (POTENTIOMETRIC) ELEVATION CONTOUR (FT AMSL), DASHED WHERE INFERRED, CONTOUR INTERVAL VARIES

0 300' 600'

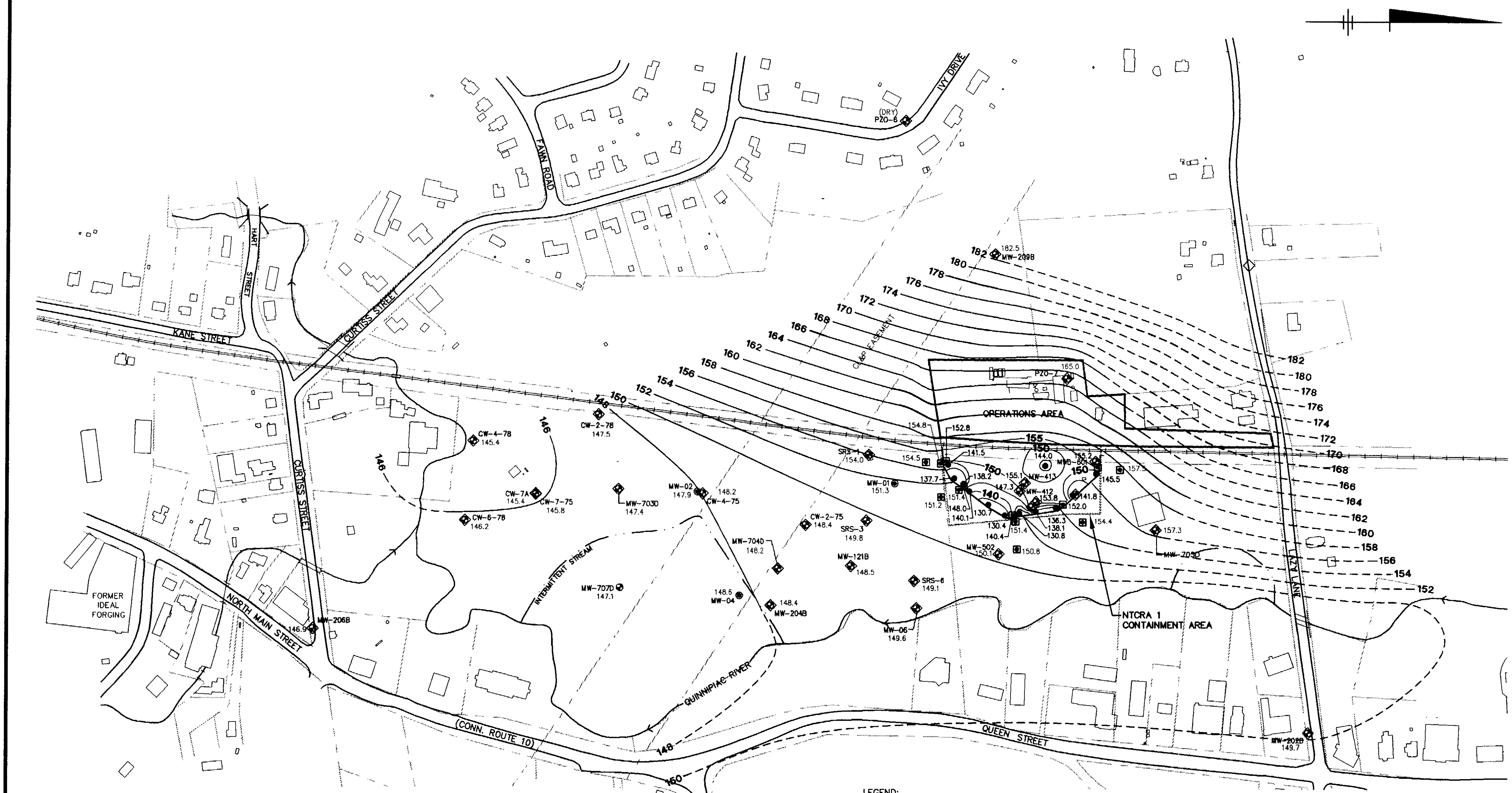
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

MIDDLE OVERBURDEN GROUND-WATER ELEVATION CONTOURS, 1/21/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 27



LEGEND:

- DEEP OVERBURDEN MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- OVERBURDEN/BEDROCK INTERFACE MONITORING WELL
- 157.5 GROUND-WATER (POTENTIOMETRIC) ELEVATION (FT AMSL)
- 160 —— GROUND-WATER (POTENTIOMETRIC) ELEVATION CONTOUR (FT AMSL), DASHED WHERE INFERRED, CONTOUR INTERVAL VARIES

0 300' 600'

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

X: 08325X00,08325X01.DWG
P: STD-DL.PCP ● E-SIZE OR DJB.PCP
10/20/97 SYR-54-PGL,DMW,PGL
08331900/08331B06.DWG

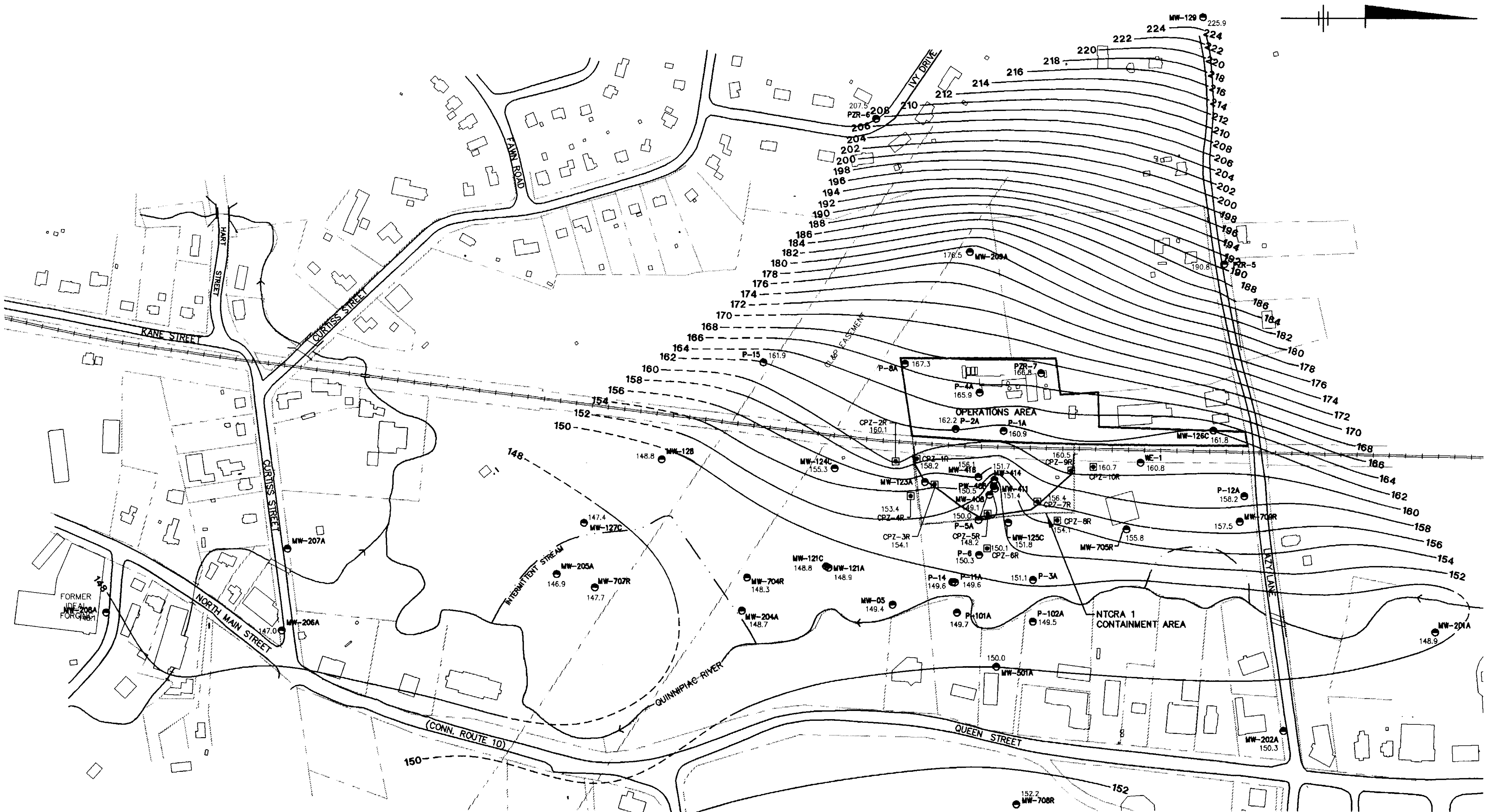
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

DEEP OVERBURDEN GROUND-WATER ELEVATION CONTOURS, 1/21/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 28



NOTES:

1. WELL MW-708 CLUSTER NOT COMPLETED ON 1/21/97. GROUND-WATER ELEVATION AT WELL MW-708R MEASURED ON 2/11/97 AND ADJUSTED TO ESTIMATED LEVEL ON 1/21/97 BASED ON AVERAGE CHANGE BETWEEN 1/21/97 AND 2/11/97 AT WELLS MW-201A, MW-202A, MW-203A, MW-501A, P-101A, AND P-102A.
2. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

LEGEND:

- SHALLOW BEDROCK MONITORING WELL
- SHALLOW BEDROCK PIEZOMETER (NTCRA 1)
- 157.5 GROUND-WATER (POTENTIOMETRIC) ELEVATION (FT AMSL)
- 160 ——— GROUND-WATER (POTENTIOMETRIC) ELEVATION CONTOUR (FT AMSL), DASHED WHERE INFERRED, CONTOUR INTERVAL VARIES

0 300' 600'

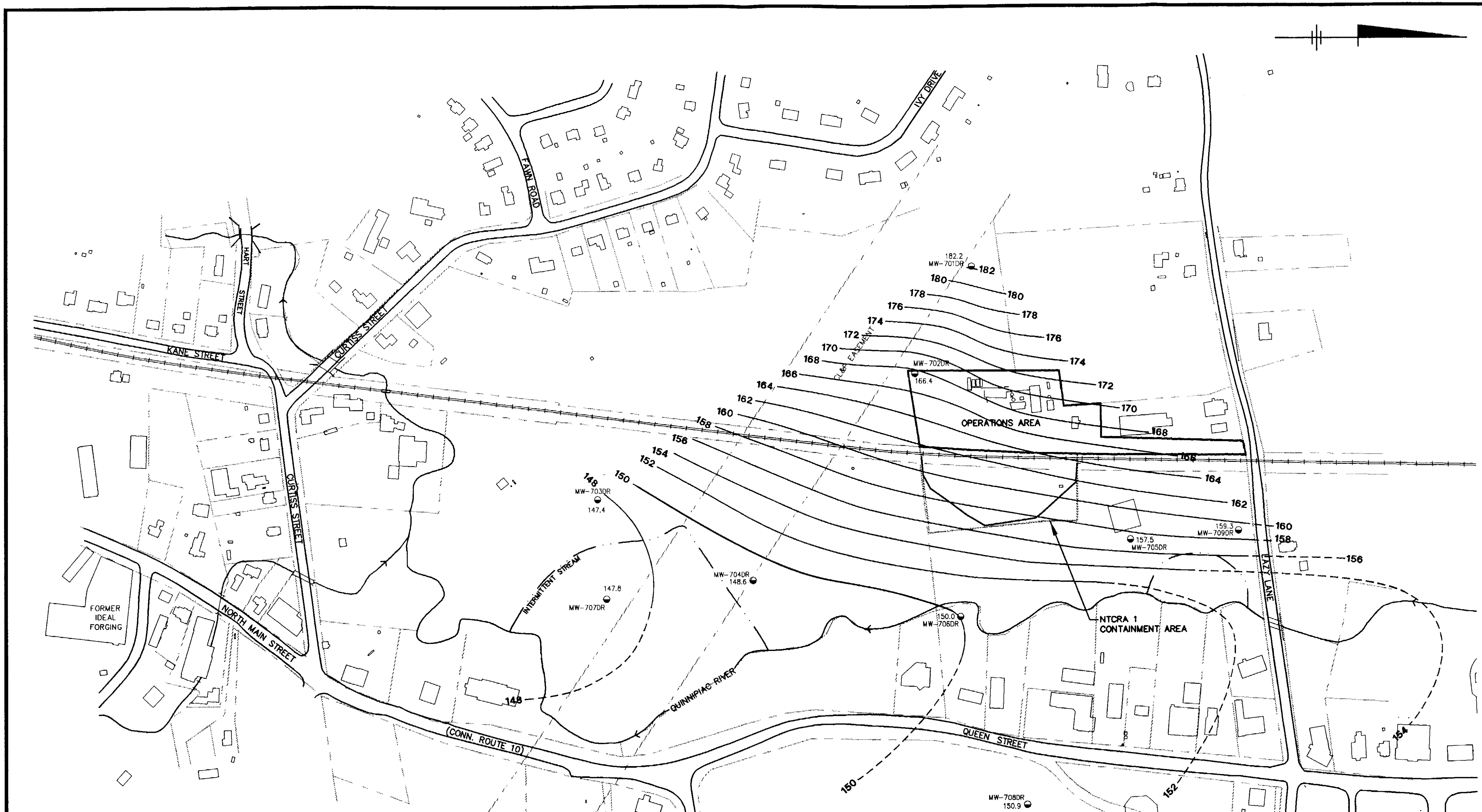
P:STD-DL.PCP ● E-SIZE OR DJB.PCP
XREF: 08325X00,08325X01
10/20/97 SYR-54-PGL, DMW, PGL
08331900/08331B07.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

SHALLOW BEDROCK GROUND-WATER ELEVATION CONTOURS, 1/21/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 29



NOTES:

1. WELL MW-708 CLUSTER NOT COMPLETED ON 1/21/97. GROUND-WATER ELEVATION AT WELL MW-708DR MEASURED ON 2/11/97 AND ADJUSTED TO ESTIMATED LEVEL ON 1/21/97 BASED ON CHANGE BETWEEN 1/21/97 AND 2/11/97 AT WELL MW-706DR.
2. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

LEGEND:

◒ DEEP BEDROCK MONITORING WELL

157.5 GROUND-WATER (POTENTIOMETRIC) ELEVATION (FT AMSL)

160 ——— GROUND-WATER (POTENTIOMETRIC) ELEVATION CONTOUR (FT AMSL), DASHED WHERE INFERRED, CONTOUR INTERVAL VARIES

0 300' 600'

X: 08325X00,08325X01.DWG
P: STD-DL.PCP ● E-SIZE OR DJB.PCP
10/20/97 SYR-54-PGL,DMW,PGL
08331900/08331B08.DWG

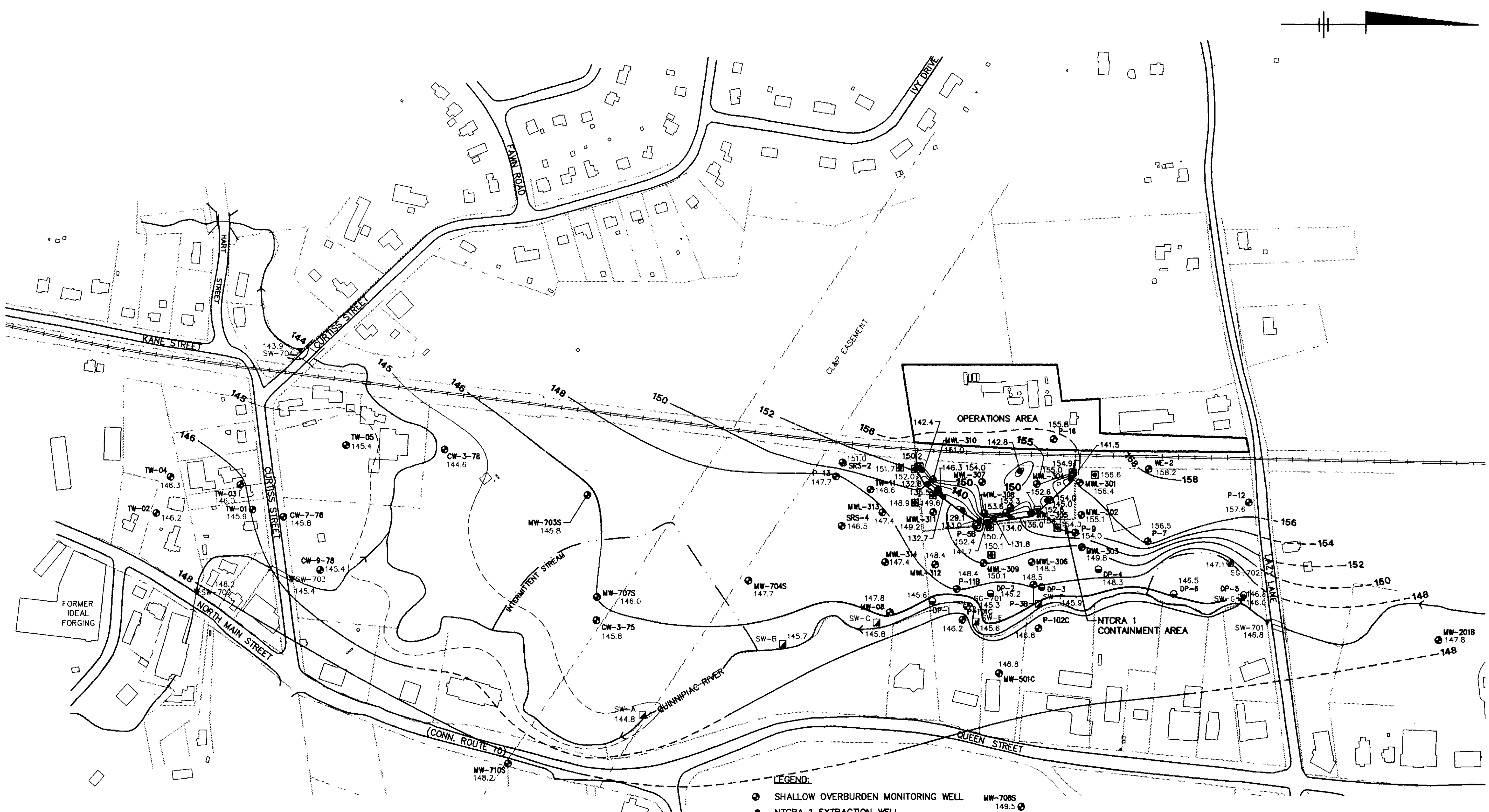
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

DEEP BEDROCK GROUND-WATER ELEVATION CONTOURS, 1/21/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 30



NOTES:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

LEGEND:

- SHALLOW OVERBURDEN MONITORING WELL (MW-708S 149.5)
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- NTCRA 1 WETLAND DRIVEPOINT
- SURFACE WATER MEASUREMENT POINTS
- SURFACE WATER SAMPLING LOCATION
- STREAM GAUGE
- 157.5 GROUND-WATER (POTENTIOMETRIC) ELEVATION (FT AMSL)
- 160 ——— GROUND-WATER (POTENTIOMETRIC) ELEVATION CONTOUR (FT AMSL), DASHED WHERE INFERRED, CONTOUR INTERVAL VARIES

0 300' 600'

X: 08325X00,08325X01.DWG
P: STD-DL.PCP ● E-SIZE OR DJB.PCP
10/20/97 SYR-54-RLP,PGL,DMW,PGL
08331900/08331B25.DWG

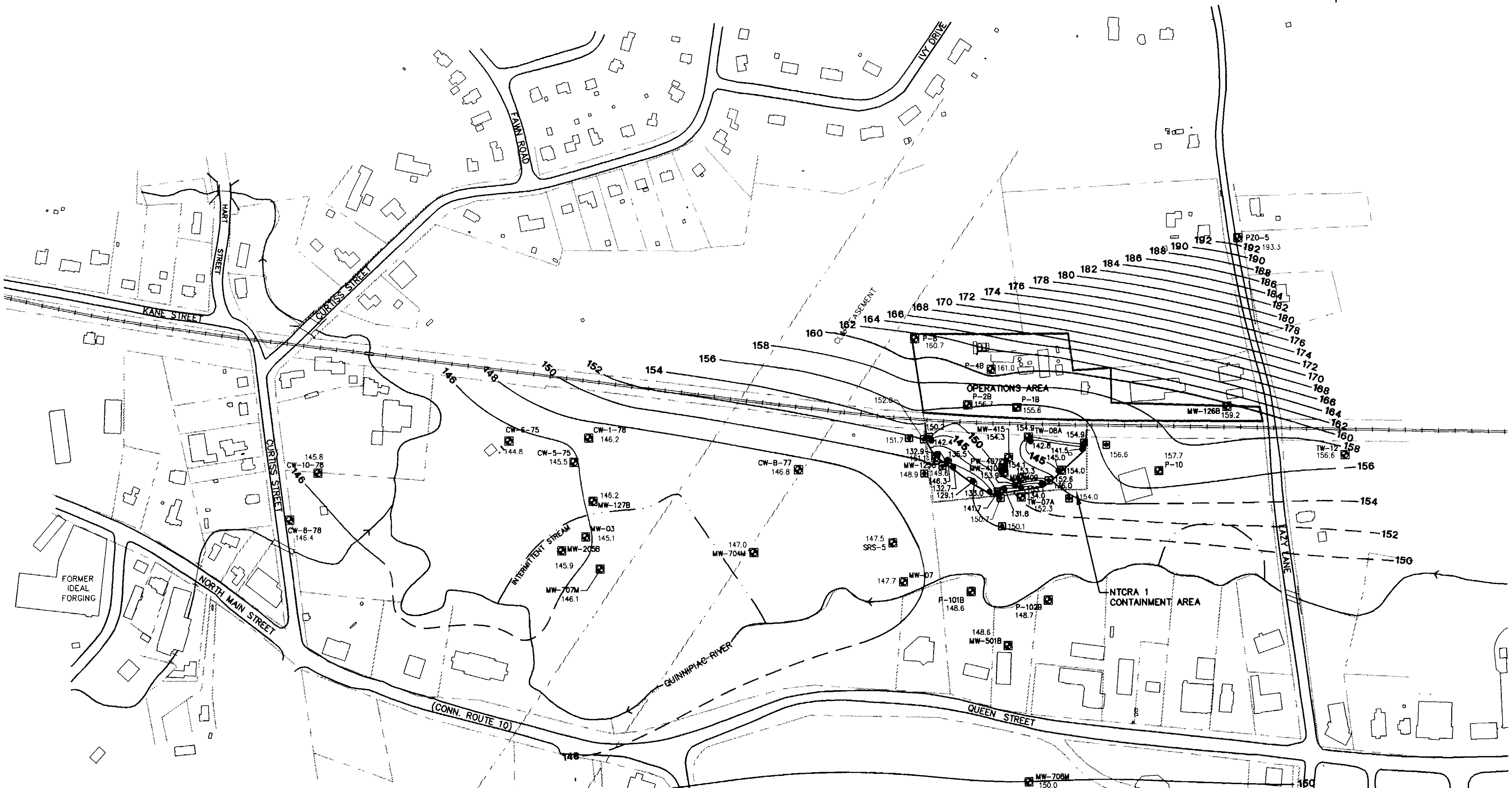
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

SHALLOW OVERBURDEN GROUND-WATER ELEVATION CONTOURS, 7/7/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 31



NOTES:

1. WELL MW-708 CLUSTER NOT COMPLETED ON 1/21/97. GROUND-WATER ELEVATION AT WELL MW-708M MEASURED ON 2/11/97 AND ADJUSTED TO ESTIMATED LEVEL ON 1/21/97 BASED ON AVERAGE CHANGE BETWEEN 1/21/97 AND 2/11/97 AT WELLS MW-203B, MW-501B, P-101B, AND P-102B.
2. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

LEGEND:

- MIDDLE OVERBURDEN MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- 151.4 GROUND-WATER (POTENTIOMETRIC) ELEVATION (FT AMSL)
- 148 —— GROUND-WATER (POTENTIOMETRIC) ELEVATION CONTOUR (FT AMSL), DASHED WHERE INFERRED, CONTOUR INTERVAL VARIES

0 300' 600'

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

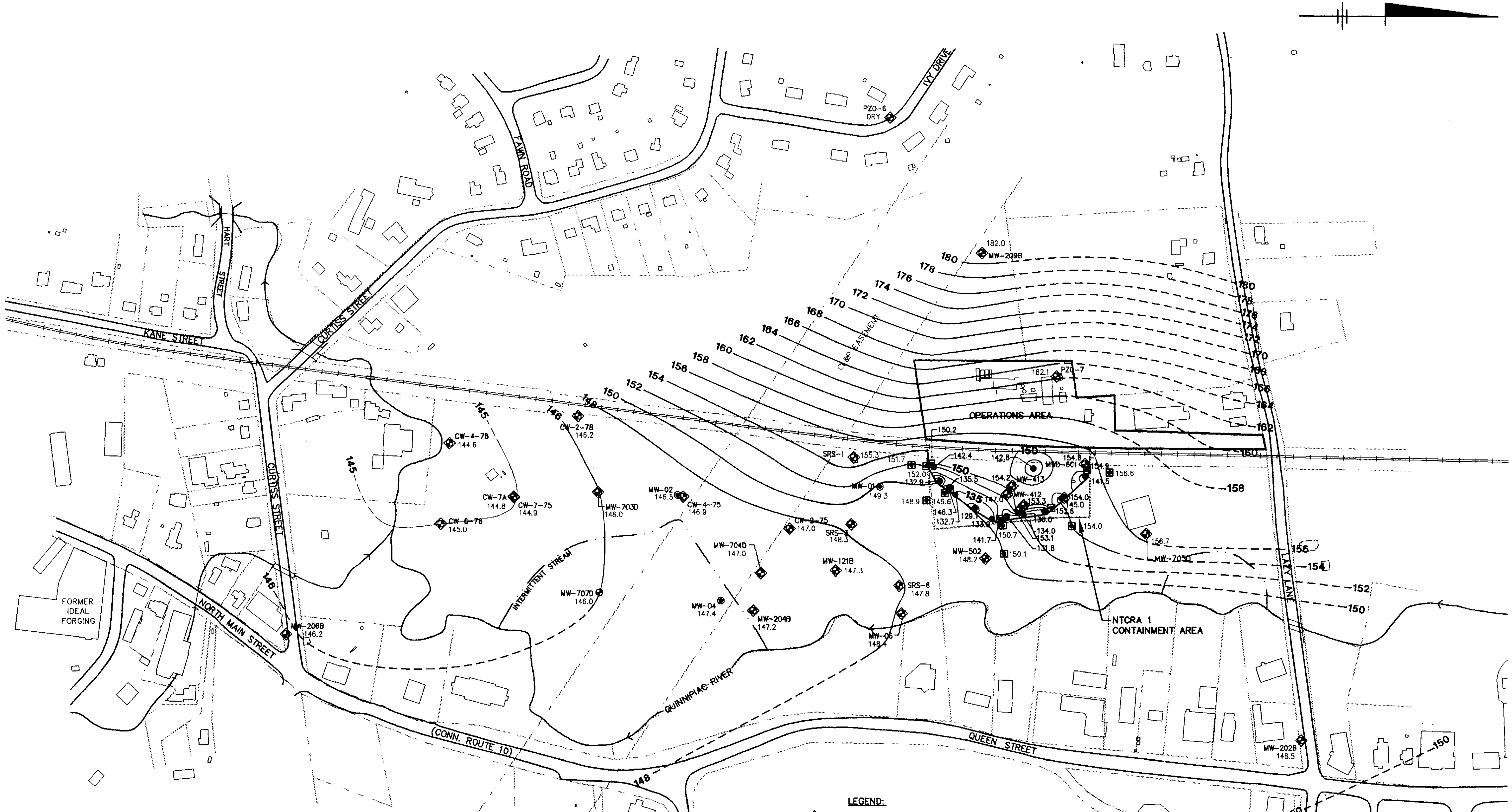
REMEDIAL INVESTIGATION

MIDDLE OVERBURDEN GROUND-WATER ELEVATION CONTOURS, 7/7/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 32

X: 08325X00,08325X01.DWG
P: STD-DLPCP ● E-SIZE OR DJB.PCP
10/20/97 SYR-54-PGL,DMW,PGL
08331900/08331B28.DWG



LEGEND:

- DEEP OVERBURDEN MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- OVERBURDEN/BEDROCK INTERFACE MONITORING WELL
- 147.8 GROUND-WATER (POTENTIOMETRIC) ELEVATION (FT AMSL)
- 148 —— GROUND-WATER (POTENTIOMETRIC) ELEVATION CONTOUR (FT AMSL), DASHED WHERE INFERRED, CONTOUR INTERVAL VARIES

0 300' 600'

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

X: 08325X00,08325X01.DWG
P: STD-DL.PCP ● E-SIZE OR DJB.PCP
10/20/97 SYR-54-PGL,DMW,PGL
08331900/08331B29.DWG

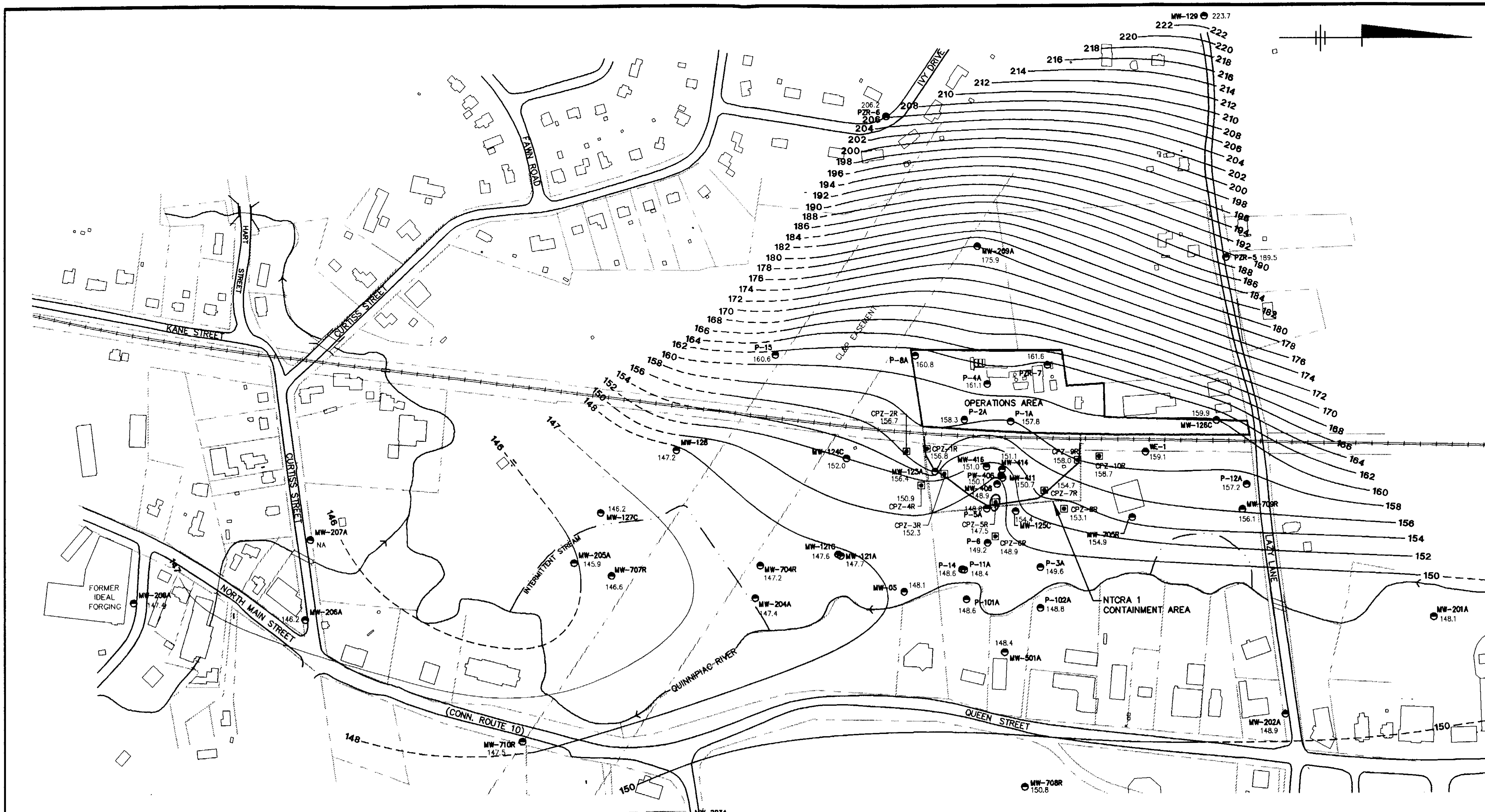
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

DEEP OVERBURDEN GROUND-WATER ELEVATION CONTOURS, 7/7/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 33



NOTES:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

LEGEND:

- SHALLOW BEDROCK MONITORING WELL
- SHALLOW BEDROCK PIEZOMETER (NTCRA 1)
- 157.5 GROUND-WATER (POTENTIOMETRIC) ELEVATION (FT AMSL)
- 160 —— GROUND-WATER (POTENTIOMETRIC) ELEVATION CONTOUR (FT AMSL), DASHED WHERE INFERRED, CONTOUR INTERVAL VARIES

0 300' 600'

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

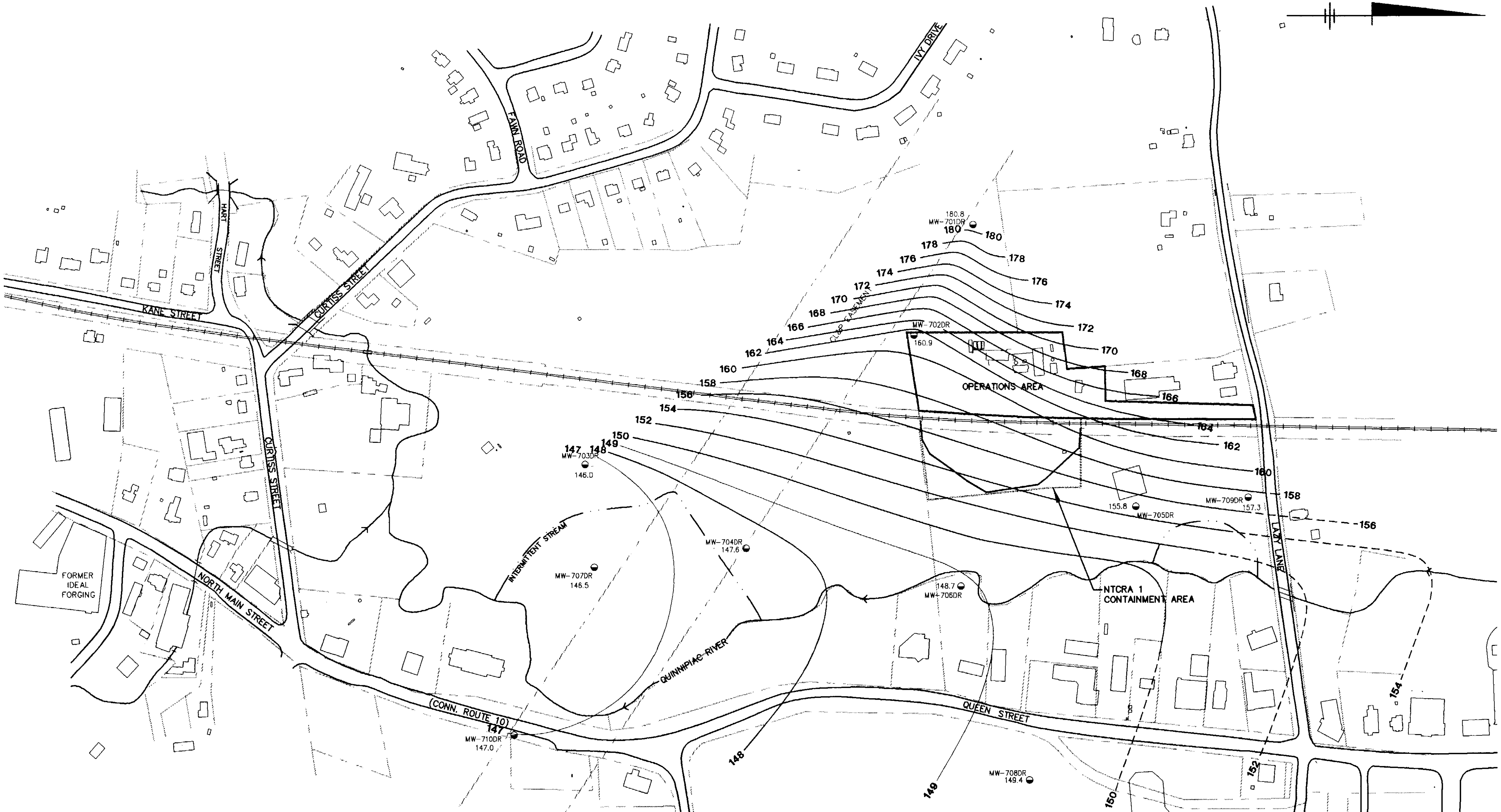
REMEDIAL INVESTIGATION

SHALLOW BEDROCK GROUND-WATER ELEVATION CONTOURS, 7/7/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 34

P:STD-DL.PCP ● E-SIZE OR DJB.PCP
XREF: 08325X00,08325X01
10/20/97 SYR-54-PGL,DMW,PGL
06331900/06331B26.DWG



NOTES:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

LEGEND:

◒ DEEP BEDROCK MONITORING WELL

157.5 GROUND-WATER (POTENTIOMETRIC) ELEVATION (FT AMSL)

160 ——— GROUND-WATER (POTENTIOMETRIC) ELEVATION CONTOUR (FT AMSL), DASHED WHERE INFERRED, CONTOUR INTERVAL VARIES

0 300' 600'

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

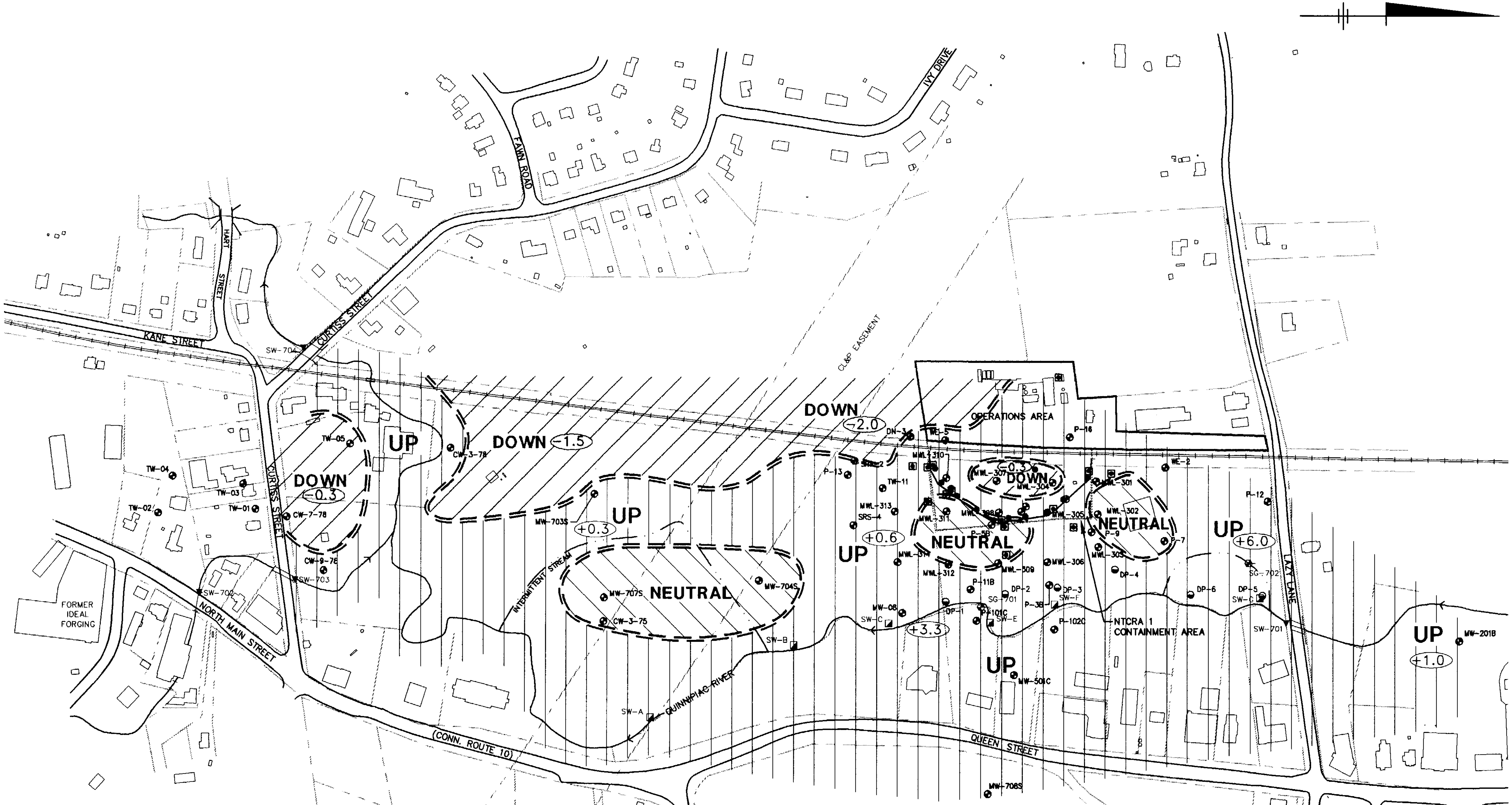
REMEDIAL INVESTIGATION

DEEP BEDROCK GROUND-WATER ELEVATION CONTOURS, 7/7/97

BBL BLASLAND, BOUCK & LEE, INC. *engineers & scientists*

FIGURE 35

X: 08325X00,08325X01.DWG
P: STD-DL.PCP ● E-SIZE OR DJB.PCP
10/20/97 SYR-54-PGL,DMW,PGL
08331900/08331B24.DWG



NOTES:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.
2. "UP" AND "DOWN" AREAS HAVE HEAD DIFFERENCES > 0.1 FT. BETWEEN THE TWO COMPARED ZONES.
3. "NEUTRAL" AREAS HAVE HEAD DIFFERENCES OF < 0.1 FT. BETWEEN THE TWO COMPARED ZONES.

0 300' 600'

LEGEND:

- SHALLOW OVERBURDEN MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- NTCRA 1 WETLAND DRIVEPOINT
- SURFACE WATER MEASUREMENT POINTS
- SURFACE WATER SAMPLING LOCATION
- STREAM GAUGE
- (+3.3) HEAD DIFFERENCES AT PAIRED WELLS IN DIFFERENT ZONES, OR ESTIMATED MAXIMUM ZONE DIFFERENCE BASED ON CONTOURS (+=UP, -=DOWN)

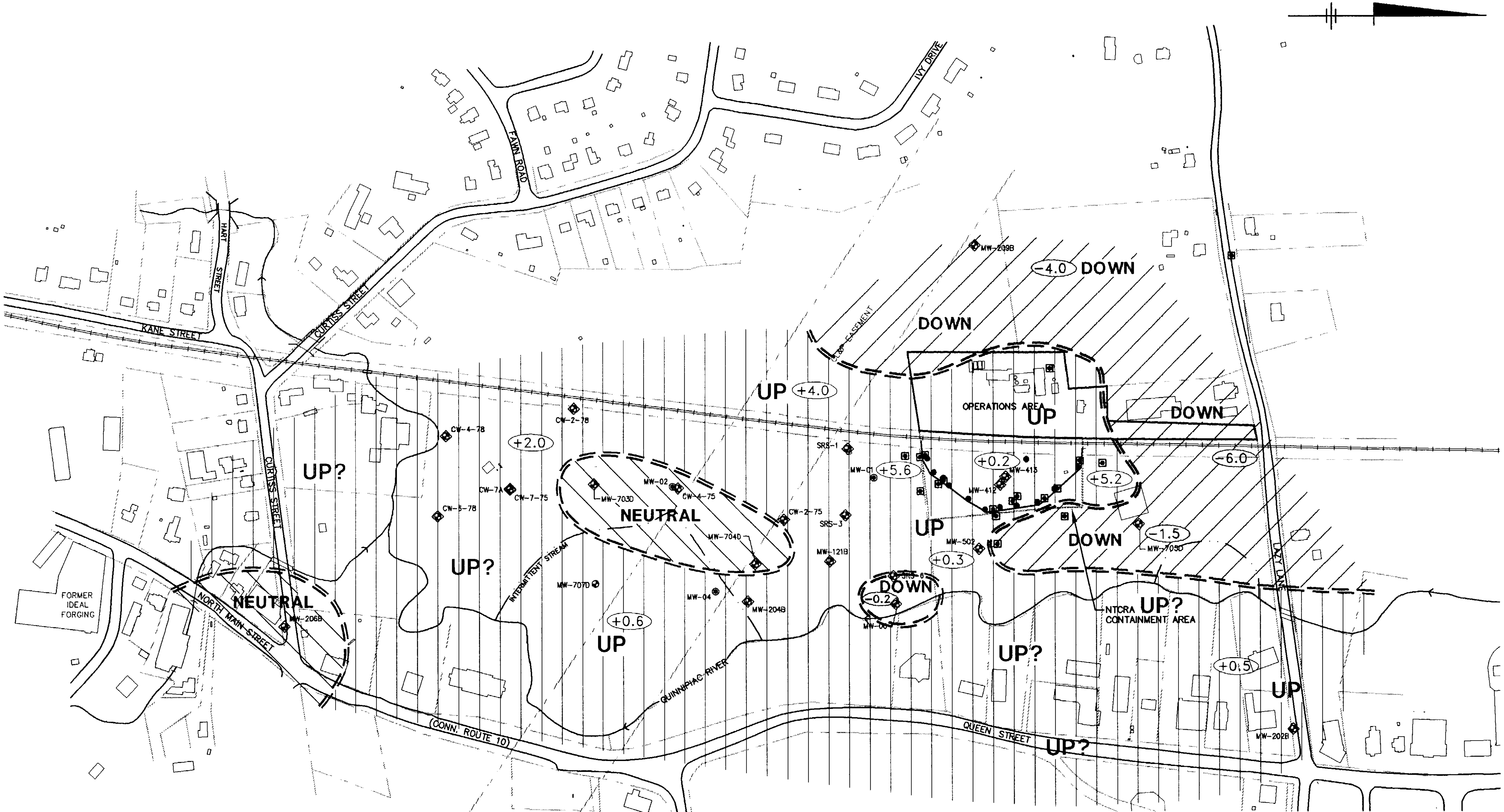
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

HEAD DIFFERENCES BETWEEN SHALLOW AND DEEP OVERBURDEN, 1/21/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 36

X: 08325X00,08325X01.DWG
P: STD-DL.PCP ● E-SIZE OR DJB.PCP
8/15/97 SYR-54-RLP,DMW,PGL
08331900/08331B10.DWG



NOTES:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.
2. "UP" AND "DOWN" AREAS HAVE HEAD DIFFERENCES > 0.1 FT. BETWEEN THE TWO COMPARED ZONES.
3. "NEUTRAL" AREAS HAVE HEAD DIFFERENCES OF ≤ 0.1 FT. BETWEEN THE TWO COMPARED ZONES.

0 300' 600'

LEGEND:

- DEEP OVERBURDEN MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- OVERBURDEN/BEDROCK INTERFACE MONITORING WELL
- (+0.5) HEAD DIFFERENCES AT PAIRED WELLS IN DIFFERENT ZONES, OR ESTIMATED MAXIMUM ZONE DIFFERENCE BASED ON CONTOURS (+=UP, −=DOWN)

XREF: 08325X00,08325X01.DWG
P:STD-DL.PCP ● E-SIZE OR DJB.PCP
2/28/97 SYR-54-RLP,PGL,DMW
08331900/08331B11.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

HEAD DIFFERENCES BETWEEN DEEP OVERBURDEN AND SHALLOW BEDROCK, 1/21/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 37

NOTES:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

2. "UP" AND "DOWN" AREAS HAVE HEAD DIFFERENCES > 0.1 FT. BETWEEN THE TWO COMPARED ZONES.

3. "NEUTRAL" AREAS HAVE HEAD DIFFERENCES OF ≤ 0.1 FT. BETWEEN THE TWO COMPARED ZONES.

0 300' 600'

LEGEND:

- ● SHALLOW BEDROCK MONITORING WELL
- ▣ SHALLOW BEDROCK PIEZOMETER (NTCRA 1)
- (+3.8) HEAD DIFFERENCES AT PAIRED WELLS IN DIFFERENT ZONES, OR ESTIMATED MAXIMUM ZONE DIFFERENCE BASED ON CONTOURS (+=UP, −=DOWN)

P:STD-DL.PCP ● E-SIZE OR DJB.PCP
XREF: 08325X00,08325X01
8/15/97 SYR-54-PGL
08331900/08331B09.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

HEAD DIFFERENCES BETWEEN SHALLOW AND DEEP BEDROCK, 1/21/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 38

NOTES:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.
2. "UP" AND "DOWN" AREAS HAVE HEAD DIFFERENCES > 0.1 FT. BETWEEN THE TWO COMPARED ZONES.
3. "NEUTRAL" AREAS HAVE HEAD DIFFERENCES OF ≤ 0.1 FT. BETWEEN THE TWO COMPARED ZONES.

0 300' 600'

LEGEND:

- SHALLOW OVERBURDEN MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- NTCRA 1 WETLAND DRIVEPOINT
- SURFACE WATER MEASUREMENT POINTS
- SURFACE WATER SAMPLING LOCATION
- STREAM GAUGE
- (+1.8) HEAD DIFFERENCES AT PAIRED WELLS IN DIFFERENT ZONES, OR ESTIMATED MAXIMUM ZONE DIFFERENCE BASED ON CONTOURS (+=UP, -=DOWN)

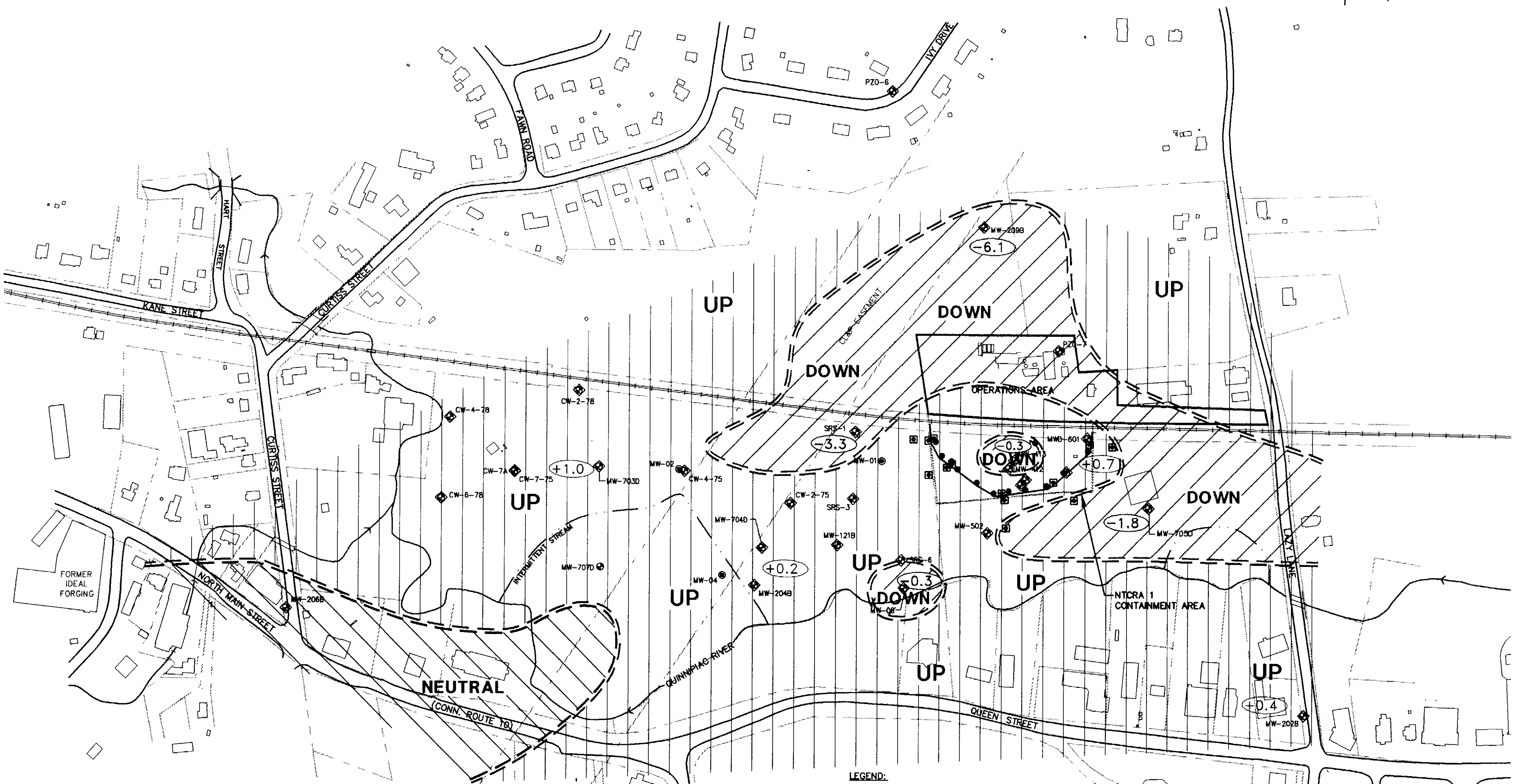
X: 08325X00,08325X01.DWG
P: STD-DL.PCP ● E-SIZE OR DJB.PCP
8/15/97 SYR-54-PGL,DMW,PGL
08331900/08331B31.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

HEAD DIFFERENCES BETWEEN SHALLOW AND DEEP OVERBURDEN, 7/7/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 39



NOTES:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.
2. "UP" AND "DOWN" AREAS HAVE HEAD DIFFERENCES > 0.1 FT. BETWEEN THE TWO COMPARED ZONES.
3. "NEUTRAL" AREAS HAVE HEAD DIFFERENCES OF ≤ 0.1 FT. BETWEEN THE TWO COMPARED ZONES.

LEGEND:

- DEEP OVERBURDEN MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- OVERBURDEN/BEDROCK INTERFACE MONITORING WELL
- (+0.4) HEAD DIFFERENCES AT PAIRED WELLS IN DIFFERENT ZONES, OR ESTIMATED MAXIMUM ZONE DIFFERENCE BASED ON CONTOURS (+=UP, -=DOWN)

0 300' 600'

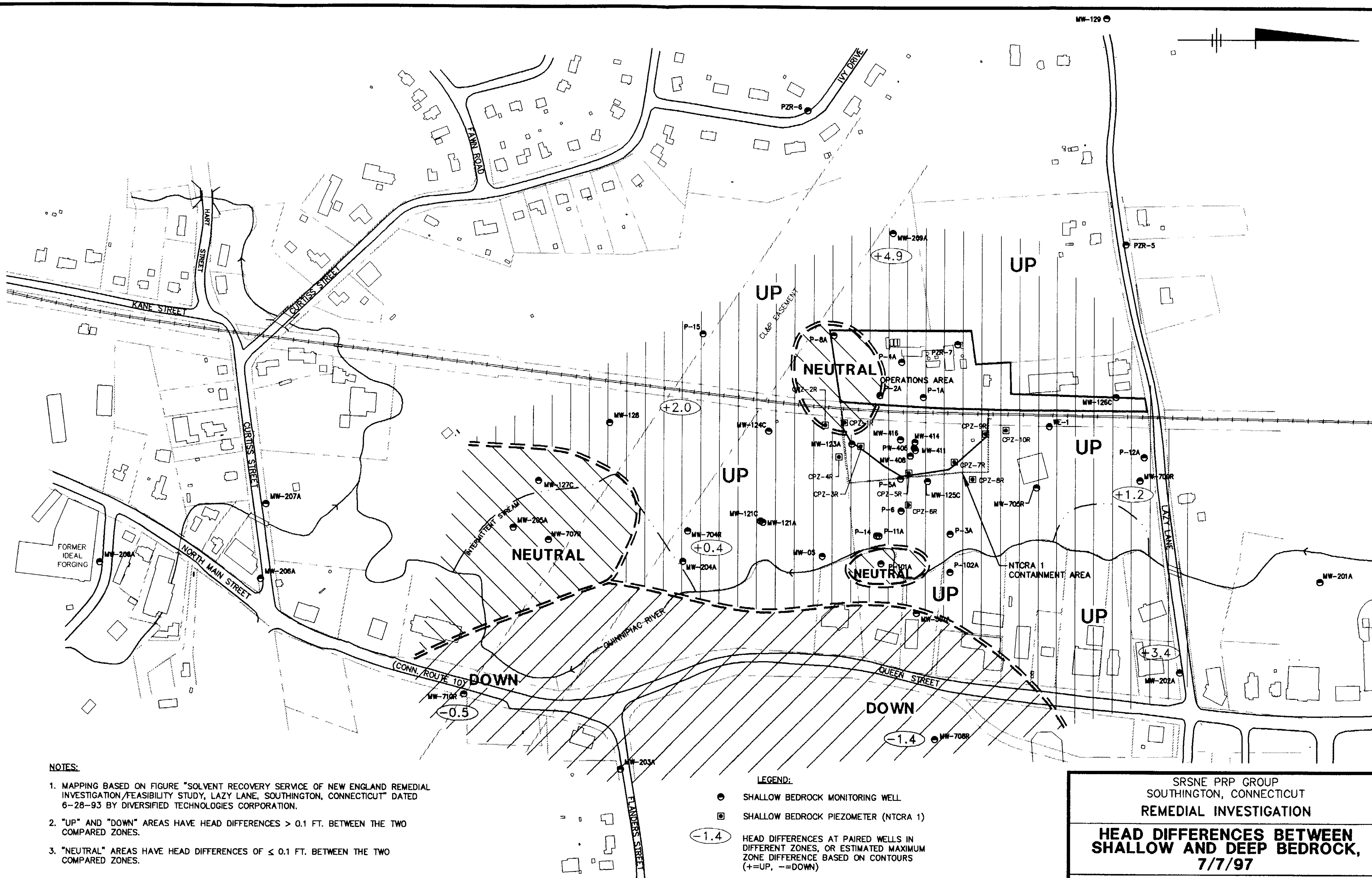
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

HEAD DIFFERENCES BETWEEN DEEP OVERBURDEN AND SHALLOW BEDROCK, 7/7/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 40

X: 08325X00,08325X01.DWG
P: STD-DL.PCP ● E-SIZE OR DJB.PCP
8/18/97 SYR-54-PGL,DMW,PGL
08331900/08331B32.DWG



NOTES:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.
2. "UP" AND "DOWN" AREAS HAVE HEAD DIFFERENCES > 0.1 FT. BETWEEN THE TWO COMPARED ZONES.
3. "NEUTRAL" AREAS HAVE HEAD DIFFERENCES OF ≤ 0.1 FT. BETWEEN THE TWO COMPARED ZONES.

LEGEND:

- ● SHALLOW BEDROCK MONITORING WELL
- ▣ SHALLOW BEDROCK PIEZOMETER (NTCRA 1)
- (-1.4) HEAD DIFFERENCES AT PAIRED WELLS IN DIFFERENT ZONES, OR ESTIMATED MAXIMUM ZONE DIFFERENCE BASED ON CONTOURS (+=UP, -=DOWN)

0 300' 600'

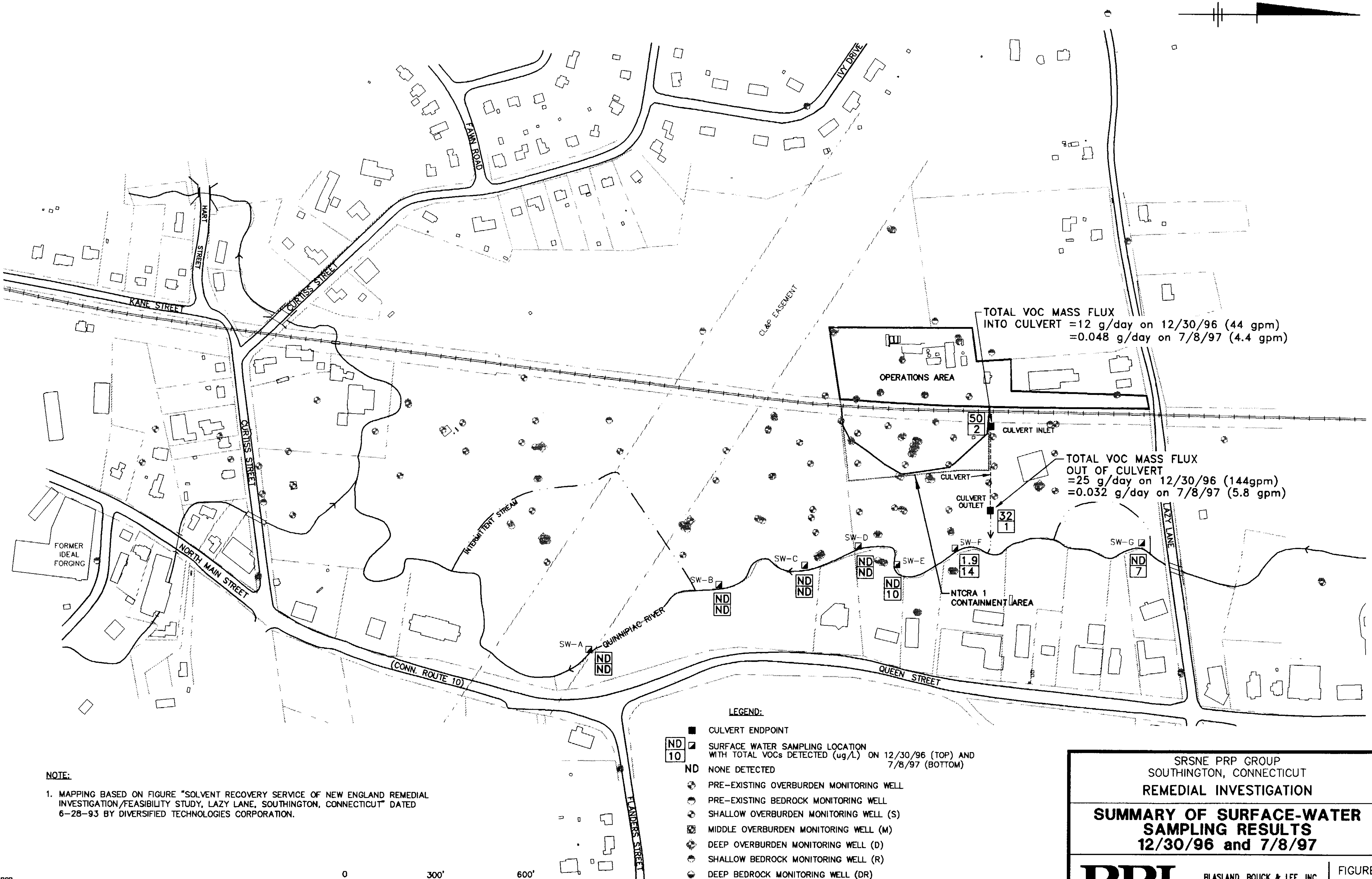
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

HEAD DIFFERENCES BETWEEN SHALLOW AND DEEP BEDROCK, 7/7/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 41

P: STD-DL.PCP ● E-SIZE OR DJB.PCP
XREF: 08325X00,08325X01
8/15/97 SYR-54-PGL, DMW, PGL
08331900/08331B30.DWG



LEGEND:

- CULVERT ENDPOINT
- SURFACE WATER SAMPLING LOCATION WITH TOTAL VOCs DETECTED (ug/L) ON 12/30/96 (TOP) AND 7/8/97 (BOTTOM)
- ND NONE DETECTED
- PRE-EXISTING OVERBURDEN MONITORING WELL
- PRE-EXISTING BEDROCK MONITORING WELL
- SHALLOW OVERBURDEN MONITORING WELL (S)
- MIDDLE OVERBURDEN MONITORING WELL (M)
- DEEP OVERBURDEN MONITORING WELL (D)
- SHALLOW BEDROCK MONITORING WELL (R)
- DEEP BEDROCK MONITORING WELL (DR)

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

P: DJB.PCP
XREF: 08325X01,08325X02
10/17/97 SYR-54-RLP,PGL
08331008/08331B44.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

SUMMARY OF SURFACE-WATER SAMPLING RESULTS 12/30/96 and 7/8/97

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 42

TARGET SHEET

THE MATERIAL DESCRIBED BELOW
NOT SCANNED BECAUSE:

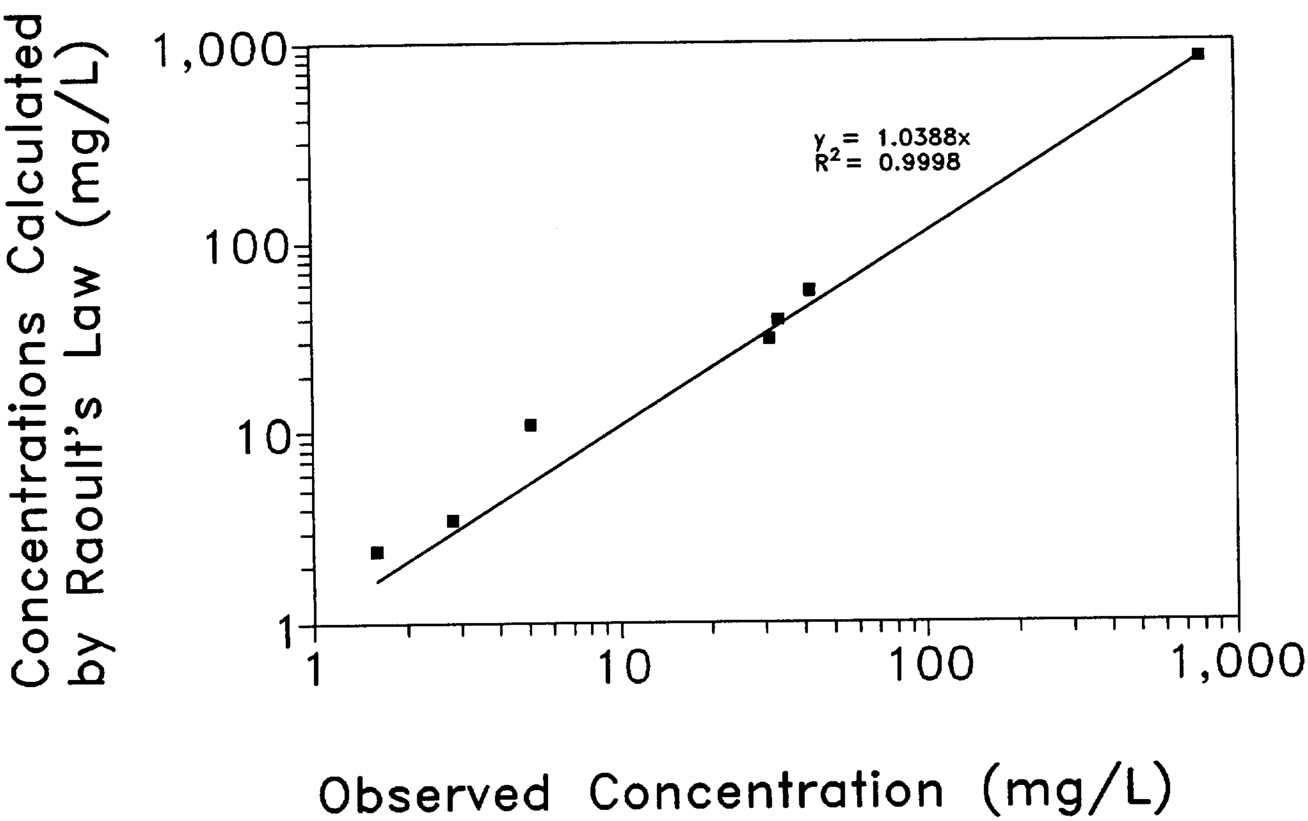
(X) OVERSIZED

( ) NON-PAPER MEDIA

( ) OTHER

DESCRIPTION: DOCUMENT ID # 4932, FIGURE # 43, 1965 AERIAL PHOTOGRAPH WITH VADOSE ZONE SOIL TOTAL VOC CONTOURS (mg/kg).

THE OMITTED MATERIAL IS AVAILABLE FOR REVIEW
AT THE EPA NEW ENGLAND SUPERFUND RECORDS CENTER,
BOSTON, MA



NOTES:

1. DATA BASED ON DNAPL AND GROUND-WATER CHEMICAL CHARACTERIZATION AT WELL MW-705DR.

2. DATA EVALUATION BY DR. BERNARD KUEPER, QUEENS UNIVERSITY.

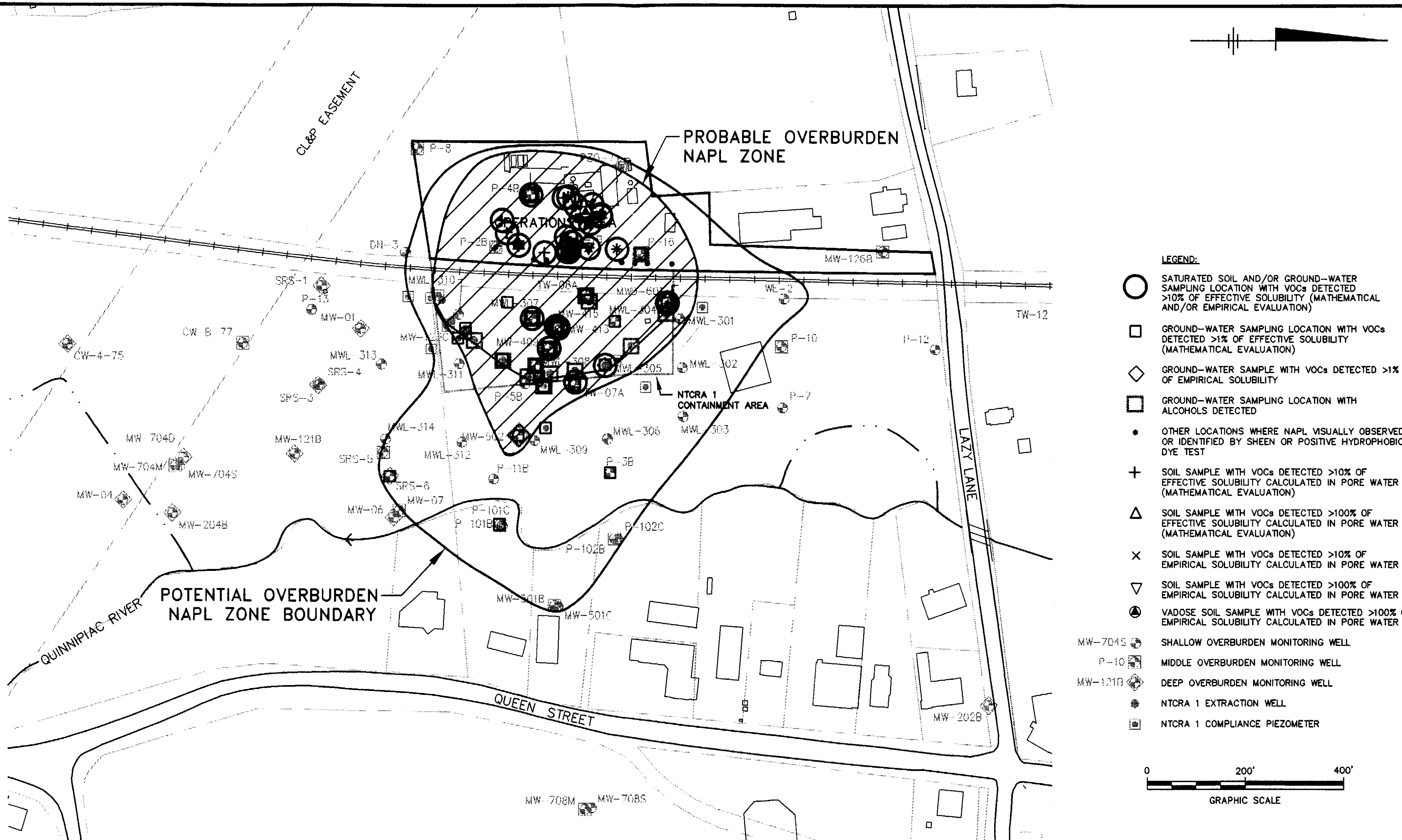
P: STD-PCP/AP
8/15/97 SYR-54-PGL
08331006/08331N04.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

MW-705DR
EFFECTIVE SOLUBILITY

BBL BLASLAND, BOUCK & LEE, INC. *engineers & scientists*

FIGURE **44**



NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

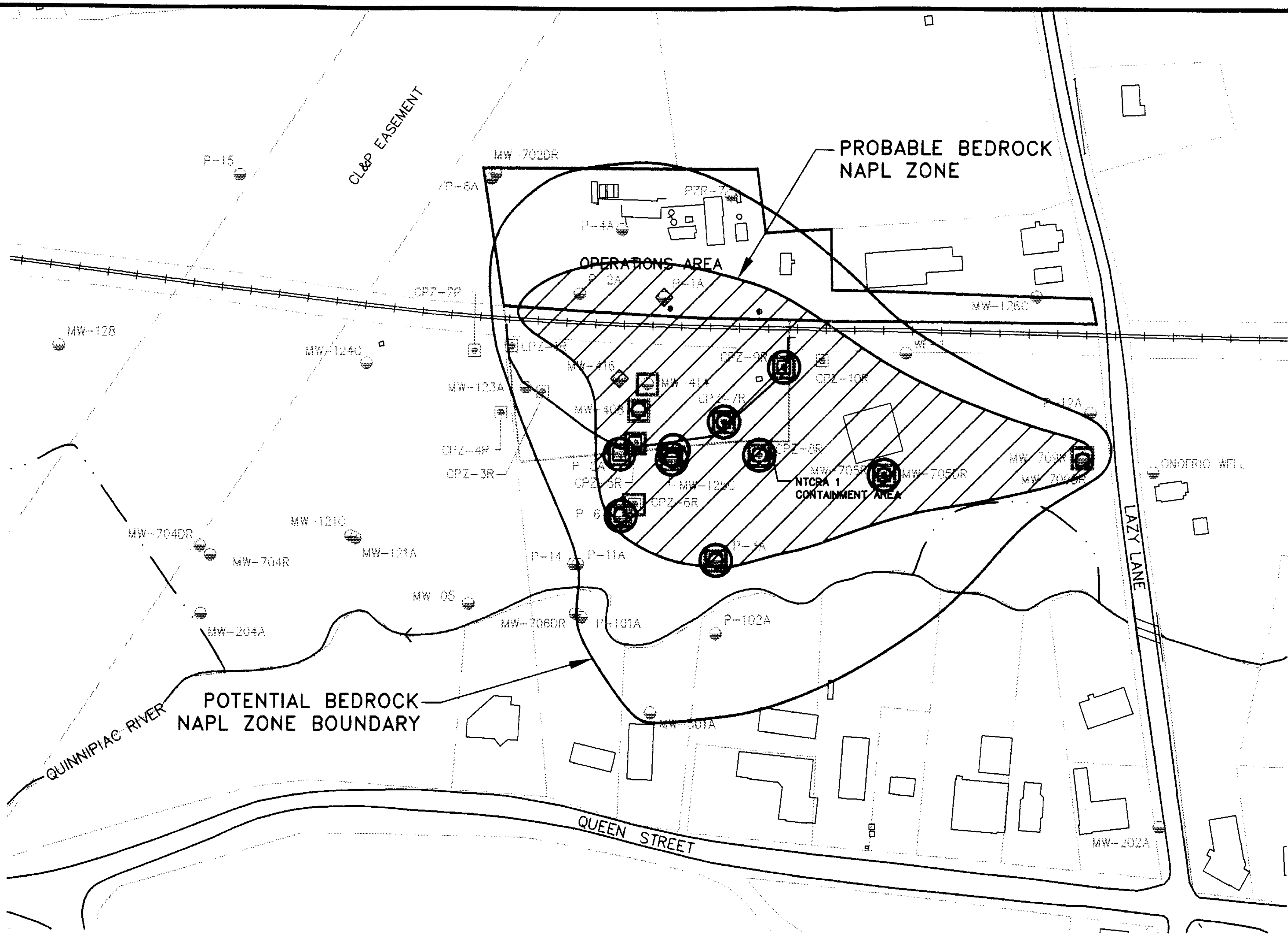
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

ESTIMATED NAPL-ZONE BOUNDARY IN OVERBURDEN

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE **45**

L: ON=*,(OVB*); OFF=BED*,REF
P: STD-B2DL.PCP ● E-SIZE OR STD-BL.PCP
XREF: 08325X00,08325X01: (XREF X01:L OFF=PIPES,TRAIL)
11/7/97 SYR-54-RLP.PGL
08331900/08331B41.DWG



LEGEND:

- GROUND-WATER SAMPLE WITH VOCs DETECTED >10% OF EFFECTIVE SOLUBILITY (MATHEMATICAL AND/OR EMPIRICAL EVALUATION)
- GROUND-WATER SAMPLING LOCATION WITH VOCs DETECTED >1% OF EFFECTIVE SOLUBILITY (MATHEMATICAL EVALUATION)
- GROUND-WATER SAMPLE WITH COMPOUNDS DETECTED >1% OF EMPIRICAL SOLUBILITY
- GROUND-WATER SAMPLING LOCATION WITH ALCOHOLS DETECTED
- OTHER LOCATIONS WHERE NAPL VISUALLY DETECTED BY SHEEN OR POSITIVE HYDROPHOBIC DYE TEST
- MW-709R BEDROCK MONITORING WELL
- CPZ-10R BEDROCK PIEZOMETER

0 200' 400'

GRAPHIC SCALE

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

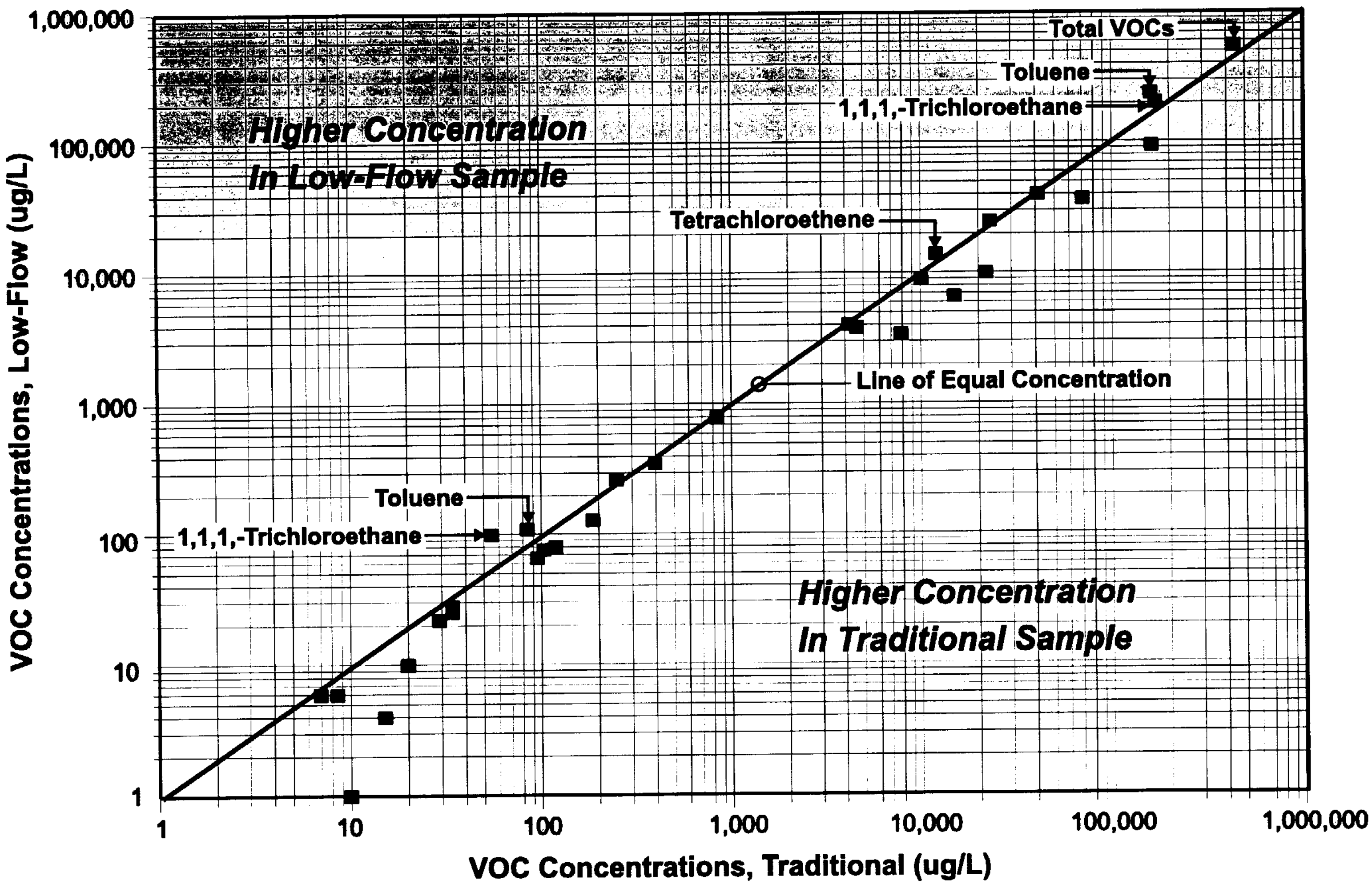
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

ESTIMATED NAPL-ZONE BOUNDARY IN BEDROCK

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 46

L: ON=*,(BED*); OFF=OVB*,REF
P: STD-B2DL.PCP ● E-SIZE OR STD-BL.PCP
XREF: 08325X00,08325X01: (XREF X01:L OFF=PIPES,TRAIL)
10/18/97 SYR-54-RLP,PGL
08331900/08331B40.DWG



SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

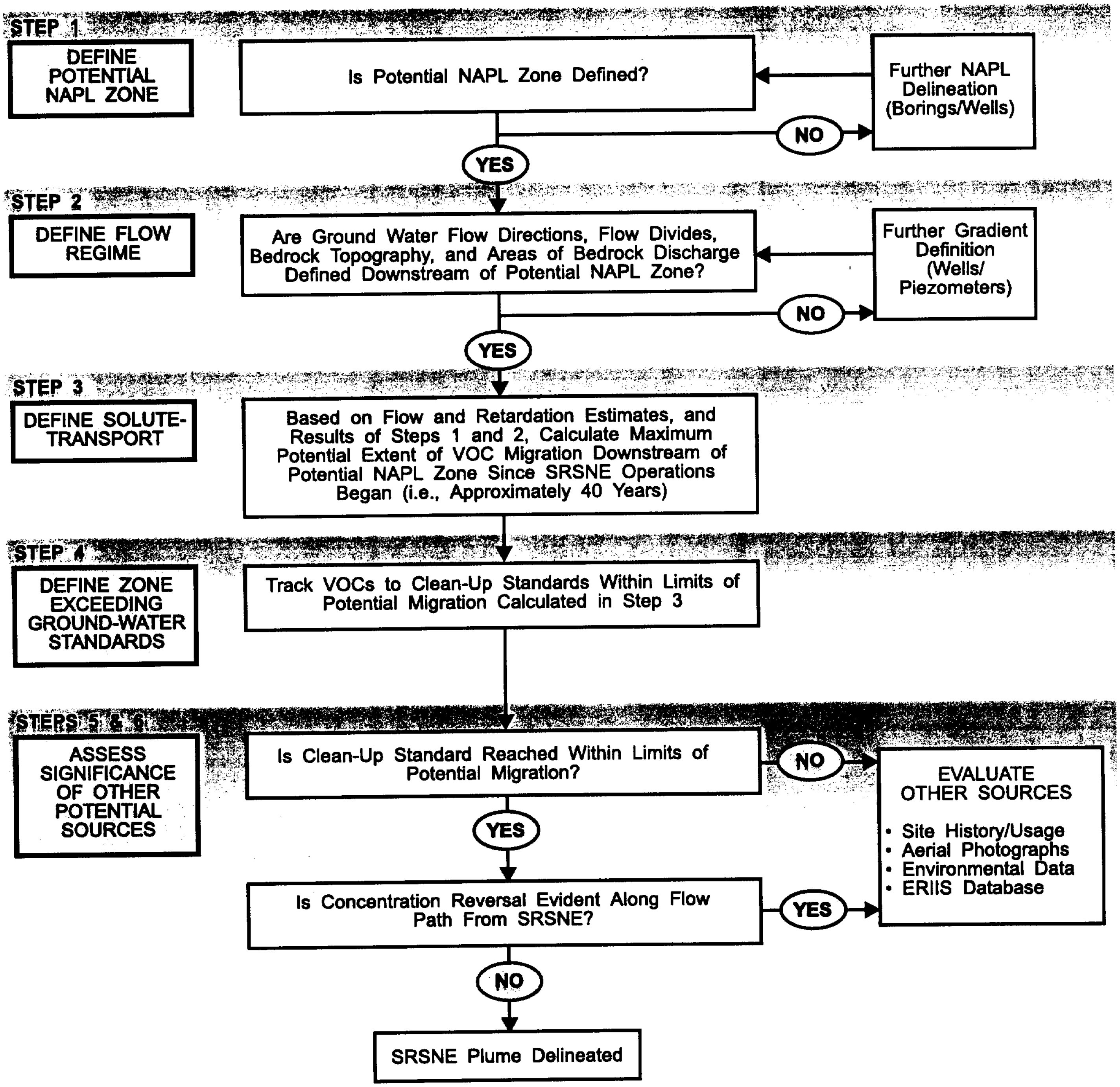
COMPARISON BETWEEN TRADITIONAL AND LOW-FLOW GROUND-WATER SAMPLING RESULTS

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 47

09/97 SYR-D54-DJH YCC
08331006/08331n03.cdr

STRATEGY FOR DEFINING NATURE AND EXTENT OF OFF-SITE VOC PLUME



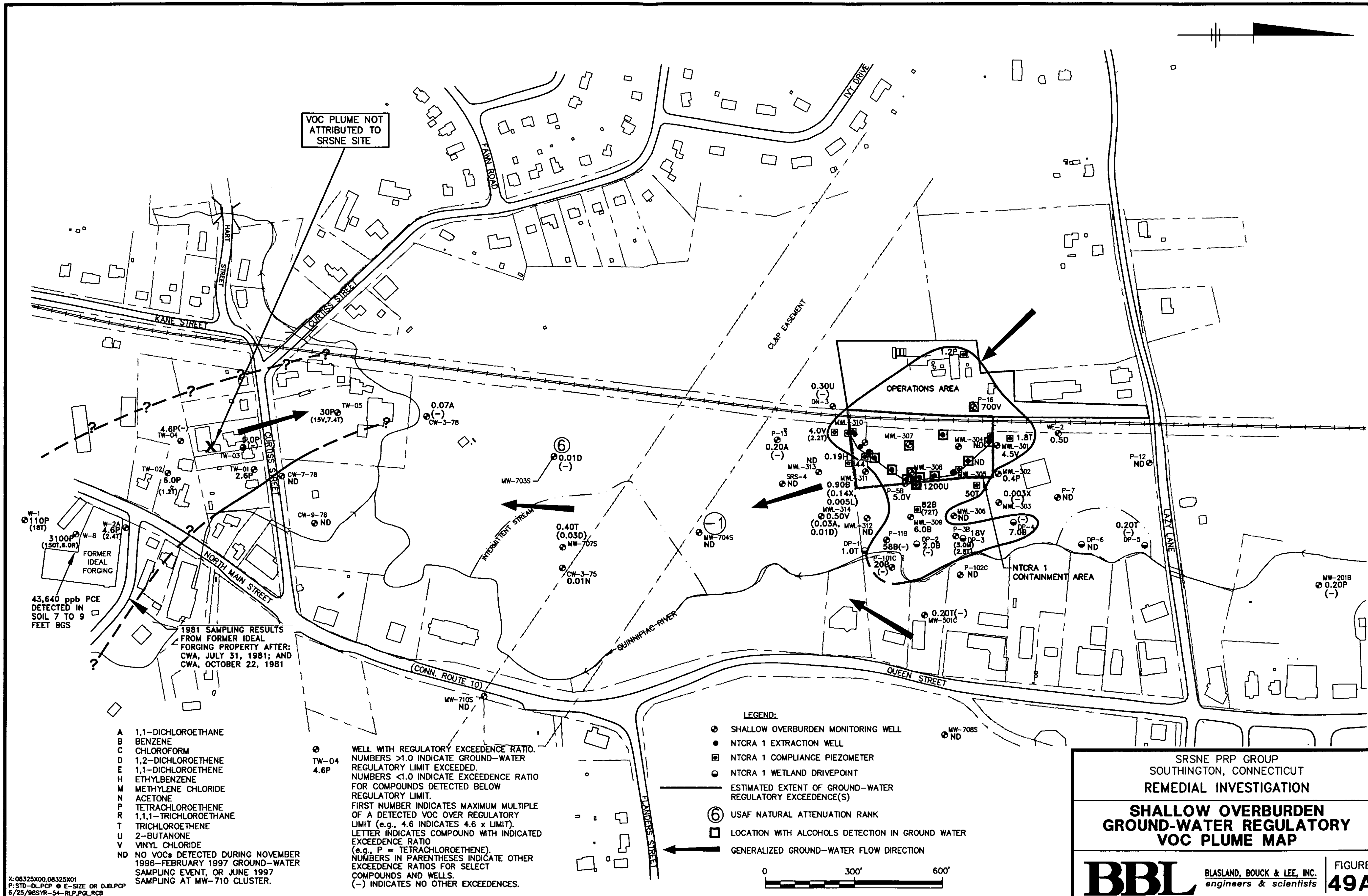
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

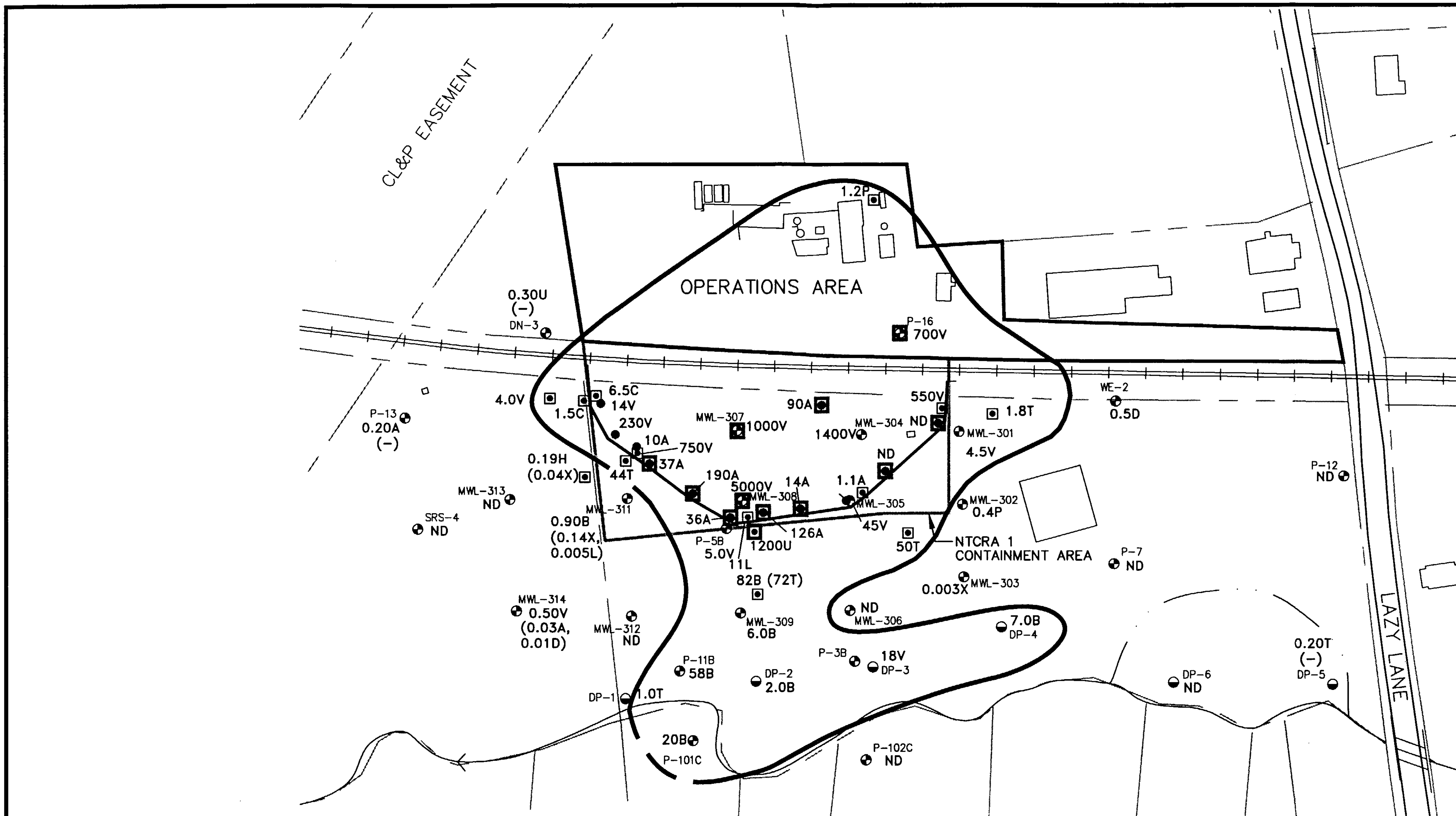
FLOW CHART

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 48

8/97 SYR D54-DJH
08331008/08331f01.cdr


SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION
SHALLOW OVERBURDEN GROUND-WATER REGULATORY VOC PLUME MAP
BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists
FIGURE 49A
LEGEND:
SHALLOW OVERBURDEN MONITORING WELL
NTCRA 1 EXTRACTION WELL
NTCRA 1 COMPLIANCE PIEZOMETER
NTCRA 1 WETLAND DRIVEPOINT
ESTIMATED EXTENT OF GROUND-WATER REGULATORY EXCEEDENCE(S)
USAF NATURAL ATTENUATION RANK
LOCATION WITH ALCOHOLS DETECTION IN GROUND WATER
GENERALIZED GROUND-WATER FLOW DIRECTION
0 300' 600'
A 1,1-DICHLOROETHANE
B BENZENE
C CHLOROFORM
D 1,2-DICHLOROETHENE
E 1,1-DICHLOROETHENE
H ETHYLBENZENE
M METHYLENE CHLORIDE
N ACETONE
P TETRACHLOROETHENE
R 1,1,1-TRICHLOROETHANE
T TRICHLOROETHENE
U 2-BUTANONE
V VINYL CHLORIDE
ND NO VOCs DETECTED DURING NOVEMBER 1996-FEBRUARY 1997 GROUND-WATER SAMPLING EVENT, OR JUNE 1997 SAMPLING AT MW-710 CLUSTER.
TW-04 4.6P
WELL WITH REGULATORY EXCEEDENCE RATIO. NUMBERS >1.0 INDICATE GROUND-WATER REGULATORY LIMIT EXCEEDED. NUMBERS <1.0 INDICATE EXCEEDENCE RATIO FOR COMPOUNDS DETECTED BELOW REGULATORY LIMIT. FIRST NUMBER INDICATES MAXIMUM MULTIPLE OF A DETECTED VOC OVER REGULATORY LIMIT (e.g., 4.6 INDICATES 4.6 x LIMIT). LETTER INDICATES COMPOUND WITH INDICATED EXCEEDENCE RATIO (e.g., P = TETRACHLOROETHENE). NUMBERS IN PARENTHESES INDICATE OTHER EXCEEDENCE RATIOS FOR SELECT COMPOUNDS AND WELLS. (-) INDICATES NO OTHER EXCEEDENCES.
VOC PLUME NOT ATTRIBUTED TO SRSNE SITE
1981 SAMPLING RESULTS FROM FORMER IDEAL FORGING PROPERTY AFTER: CWA, JULY 31, 1981; AND CWA, OCTOBER 22, 1981
43,640 ppb PCE DETECTED IN SOIL 7 TO 9 FEET BGS
FORMER IDEAL FORGING
OPERATIONS AREA
NTCRA 1 CONTAINMENT AREA
KANE STREET
HART STREET
CURTISS STREET
FAWN ROAD
IVY DRIVE
LAZY LANE
QUEEN STREET
NORTH MAIN STREET
FLANDERS STREET
(CONN. ROUTE 10)
CL&P EASEMENT
QUINNIPIAC RIVER
INTERMITTENT STREAM
X: 08325X00,08325X01
P: STD-DL.PCP @ E-SIZE OR DJB.PCP
6/25/98SYR-54-RLP,PGL,RCB
08331900/08331B12.DWG



LEGEND:

A 1,1-DICHLOROETHANE
B BENZENE
C CHLOROFORM
D 1,2-DICHLOROETHENE
E 1,1-DICHLOROETHENE
H ETHYLBENZENE
M METHYLENE CHLORIDE
P TETRACHLOROETHENE
T TRICHLOROETHENE
U 2-BUTANONE
V VINYL CHLORIDE
X XYLENES
ND NO VOCs DETECTED DURING NOVEMBER 1996–FEBRUARY 1997 GROUND-WATER SAMPLING EVENT

P-5B 5.0V — WELL WITH REGULATORY EXCEEDENCE RATIO. NUMBERS >1.0 INDICATE GROUND-WATER REGULATORY LIMIT EXCEEDED. NUMBERS <1.0 INDICATE EXCEEDENCE RATIO FOR COMPOUNDS DETECTED BELOW REGULATORY LIMIT. FIRST NUMBER INDICATES MAXIMUM MULTIPLE OF A DETECTED VOC OVER REGULATORY LIMIT (e.g., 5.0 INDICATES 5.0 x LIMIT). LETTER INDICATES COMPOUND WITH INDICATED EXCEEDENCE RATIO (e.g., V = VINYL CHLORIDE). NUMBERS IN PARENTHESES INDICATE OTHER EXCEEDENCE RATIOS FOR SELECT COMPOUNDS AND WELLS. (-) INDICATES NO OTHER EXCEEDENCES.

ESTIMATED EXTENT OF GROUND-WATER REGULATORY EXCEEDENCE(S)

SHALLOW OVERBURDEN MONITORING WELL
NTCRA 1 EXTRACTION WELL
NTCRA 1 COMPLIANCE PIEZOMETER
NTCRA 1 WETLAND DRIVEPOINT
LOCATION WITH ALCOHOLS DETECTION

0 150' 300'

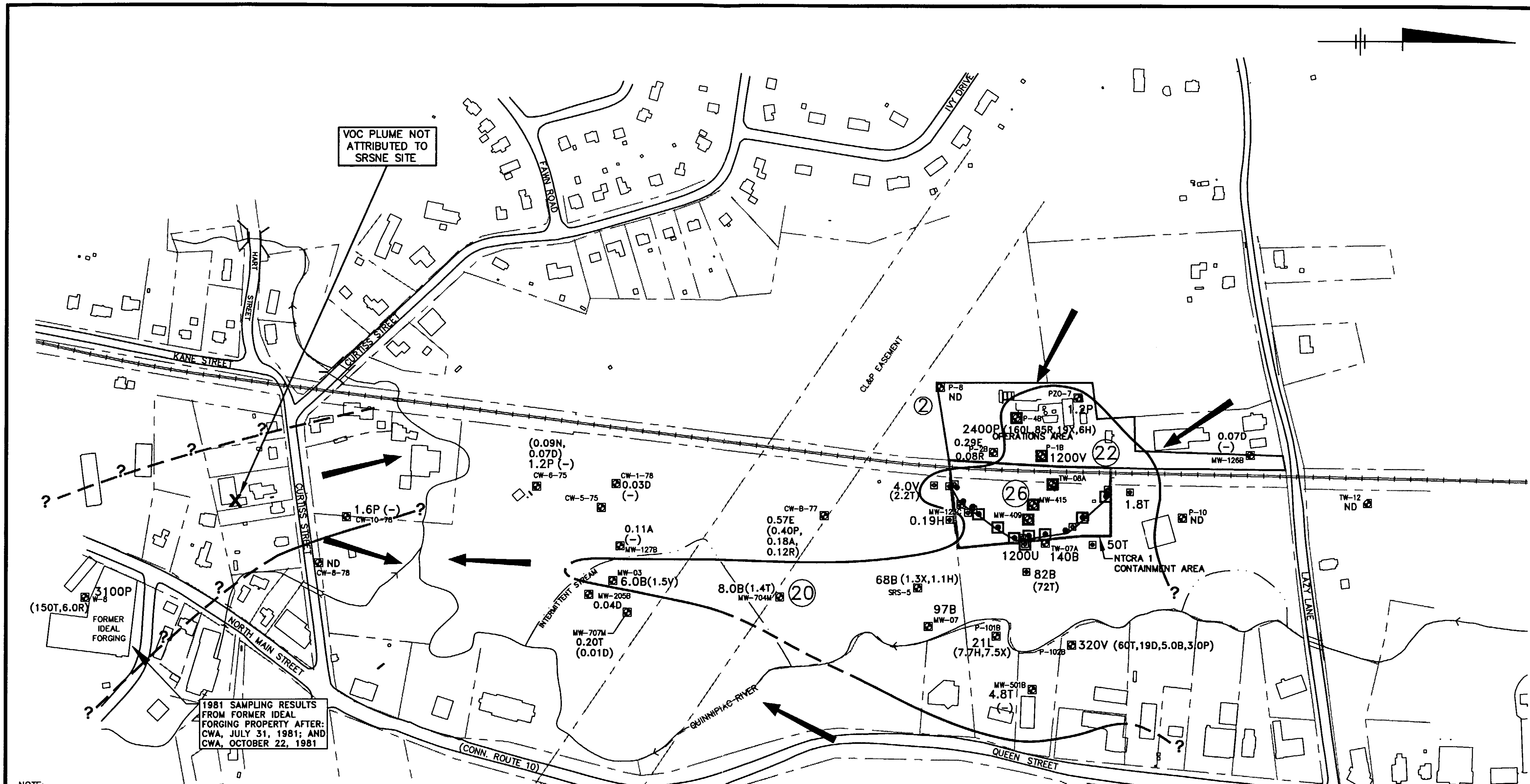
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

SHALLOW OVERBURDEN GROUND-WATER REGULATORY VOC PLUME MAP

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 49B

XREF: 08325X00,08325X01.DWG
P: STD-DL.PCP @ E-SIZE OR DJB.PCP
6/25/98SYR-54-RLP,DMW,PGL,RCB
08331900/08331B13.DWG



NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

A	1,1-DICHLOROETHANE
B	BENZENE
C	CHLOROFORM
D	1,2-DICHLOROETHENE
E	1,1-DICHLOROETHENE
H	ETHYLBENZENE
L	TOLUENE
M	METHYLENE CHLORIDE
N	ACETONE
P	TETRACHLOROETHENE
R	1,1,1-TRICHLOROETHANE
T	TRICHLOROETHENE
U	2-BUTANONE
V	VINYL CHLORIDE
X	XYLENES

MW-07 97B — WELL WITH REGULATORY EXCEEDENCE RATIO. NUMBERS >1.0 INDICATE GROUND-WATER REGULATORY LIMIT EXCEEDED. NUMBERS <1.0 INDICATE EXCEEDENCE RATIO FOR COMPOUNDS DETECTED BELOW REGULATORY LIMIT. FIRST NUMBER INDICATES MAXIMUM MULTIPLE OF A DETECTED VOC OVER REGULATORY LIMIT (e.g., 97 INDICATES 97 x LIMIT). LETTER INDICATES COMPOUND WITH INDICATED EXCEEDENCE RATIO (e.g., B = BENZENE). NUMBERS IN PARENTHESES INDICATE OTHER EXCEEDENCE RATIOS FOR SELECT COMPOUNDS AND WELLS. (-) INDICATES NO OTHER EXCEEDENCES.

LEGEND:

- MIDDLE OVERBURDEN MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- ESTIMATED EXTENT OF GROUND-WATER REGULATORY EXCEEDENCE(S)
- ② USAF NATURAL ATTENUATION RANK
- LOCATION WITH ALCOHOLS DETECTION IN GROUND WATER
- GENERALIZED GROUND-WATER FLOW DIRECTION
- ND NO VOCs DETECTED DURING NOVEMBER 1996-FEBRUARY 1997 GROUND-WATER SAMPLING EVENT

0 300' 600'

XREF: 08325X00,08325X01; L: ON: *, OFF:REF,(XREF X01: PIPES,TRAIL)
6/26/98 SYR-54-RLP,PGL,RCB
08331900/08331B43.DWG P: STD-DL.PCP ● E-SIZE OR DJB.PCP

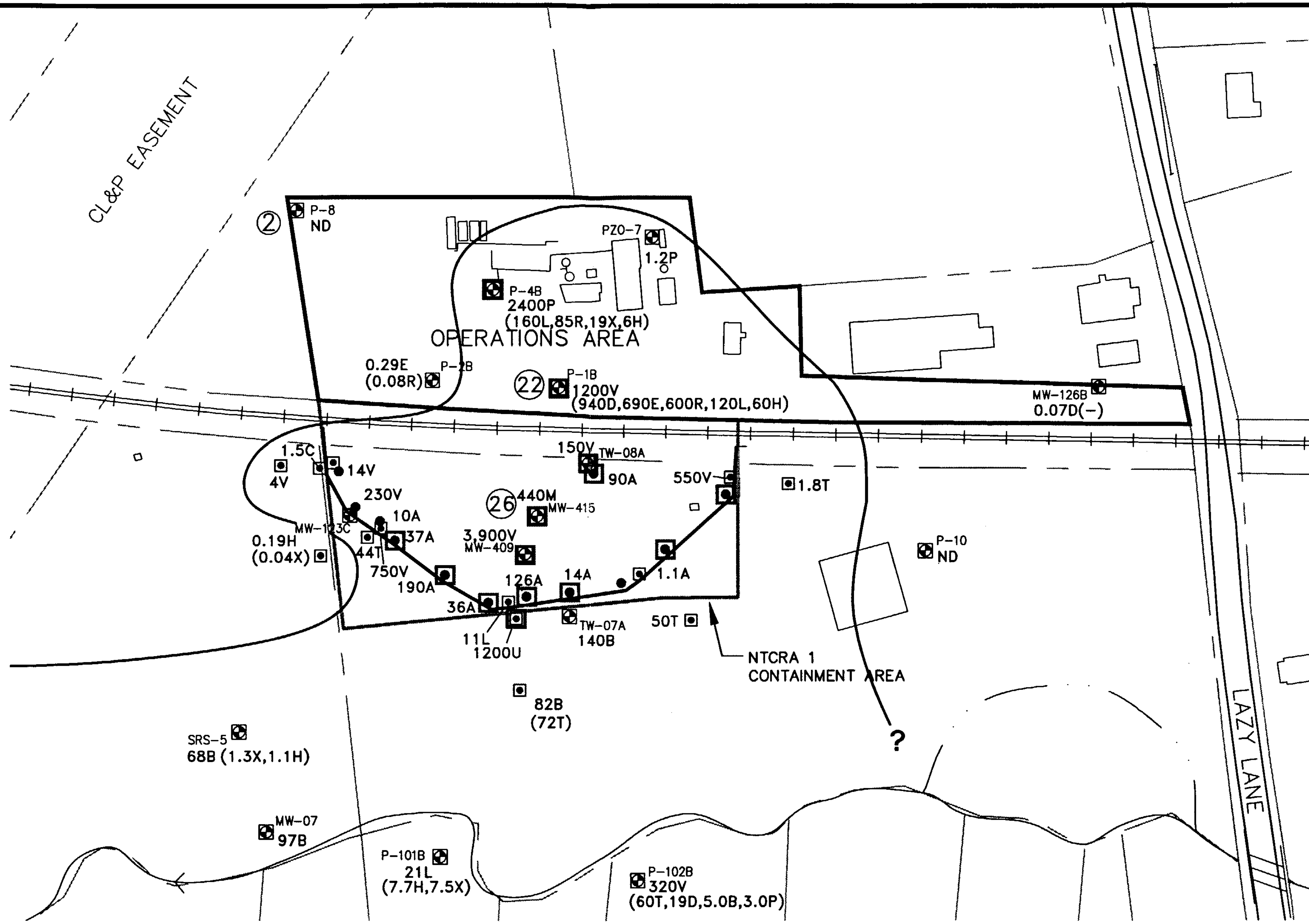
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

MIDDLE OVERBURDEN GROUND-WATER REGULATORY VOC PLUME MAP

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 50A



- A 1,1-DICHLOROETHANE
- B BENZENE
- C CHLOROFORM
- D 1,2-DICHLOROETHENE
- E 1,1-DICHLOROETHENE
- H ETHYLBENZENE
- L TOLUENE
- M METHYLENE CHLORIDE
- P TETRACHLOROETHENE
- R 1,1,1-TRICHLOROETHANE
- T TRICHLOROETHENE
- U 2-BUTANONE
- V VINYL CHLORIDE
- X XYLENES

P-10 — WELL WITH NO DETECTIONS EXCEEDING USEPA OR CTDEP REGULATORY CRITERIA

MW-07 97B — WELL WITH REGULATORY EXCEEDENCE, NUMBER INDICATES MAXIMUM MULTIPLE OF A DETECTED VOC OVER REGULATORY LIMIT (e.g., 97 INDICATES 97 x LIMIT). LETTER INDICATES COMPOUND WITH MAXIMUM EXCEEDENCE (e.g., B = BENZENE). NUMBERS IN PARENTHESIS INDICATE OTHER REGULATORY EXCEEDENCES FOR SELECT WELLS, (-) INDICATES NO OTHER EXCEEDENCES.

ND — NO VOCs DETECTED DURING NOVEMBER 1996–FEBRUARY 1997 GROUND-WATER SAMPLING EVENT.

LEGEND:

- MIDDLE OVERBURDEN MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- ESTIMATED EXTENT OF GROUND-WATER REGULATORY EXCEEDENCE(S)
- ② USAF NATURAL ATTENUATION RANK
- LOCATION WITH ALCOHOLS DETECTION

0 150' 300'

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

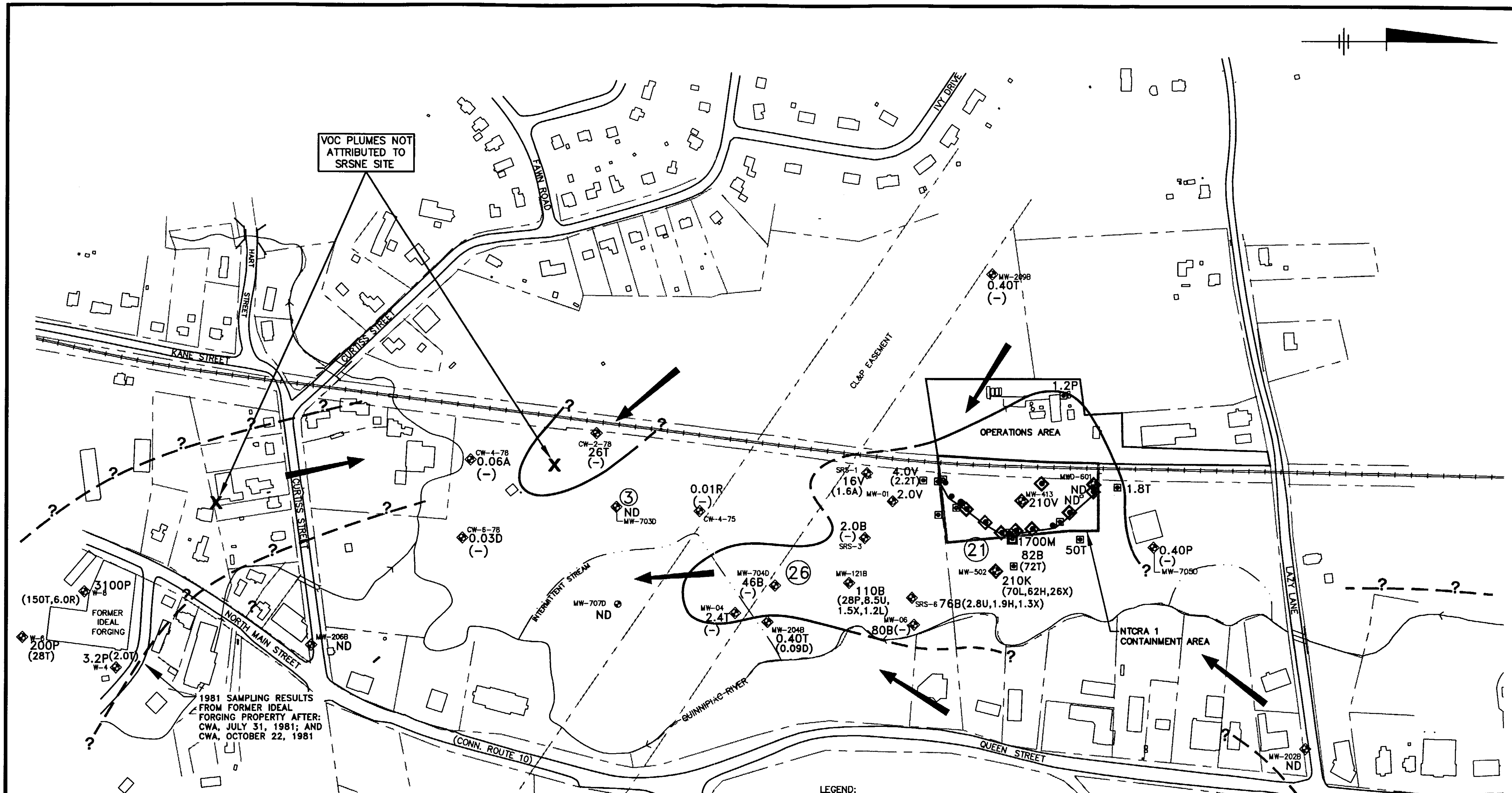
P:STD-DL.PCP @ E-SIZE OR DJB.PCP
XREF: 08325X00,08325X01; L: ON=*,OFF=REF,(XREF X01: PIPES,TRAIL)
6/26/98 SYR-54-RLP,PCL,RCB
08331900/08331B16.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

MIDDLE OVERBURDEN GROUND-WATER REGULATORY VOC PLUME MAP

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 50B



A 1,1-DICHLOROETHANE
B BENZENE
C CHLOROFORM
D 1,2-DICHLOROETHENE
E 1,1-DICHLOROETHENE
H ETHYLBENZENE
K 4-METHYL-2-PENTANONE (MIBK)
L TOLUENE
M METHYLENE CHLORIDE
P TETRACHLOROETHENE
R 1,1,1-TRICHLOROETHANE
T TRICHLOROETHENE
U 2-BUTANONE
V VINYL CHLORIDE
X XYLENES
ND NO VOCs DETECTED DURING NOVEMBER 1996-FEBRUARY 1997 GROUND-WATER SAMPLING EVENT

MW-502 3300C — WELL WITH REGULATORY EXCEEDENCE RATIO. NUMBERS >1.0 INDICATE GROUND-WATER REGULATORY LIMIT EXCEEDED. NUMBERS <1.0 INDICATE EXCEEDENCE RATIO FOR COMPOUNDS DETECTED BELOW REGULATORY LIMIT. FIRST NUMBER INDICATES MAXIMUM MULTIPLE OF A DETECTED VOC OVER REGULATORY LIMIT (e.g., 3300 INDICATES 3300 x LIMIT). LETTER INDICATES COMPOUND WITH INDICATED EXCEEDENCE RATIO (e.g., C = CHLOROFORM). NUMBERS IN PARENTHESES INDICATE OTHER EXCEEDENCE RATIOS FOR SELECT COMPOUNDS AND WELLS. (-) INDICATES NO OTHER EXCEEDENCES.

0 300' 600'

LEGEND:

- DEEP OVERBURDEN MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- ESTIMATED EXTENT OF GROUND-WATER REGULATORY EXCEEDENCE(S)
- (3) USAF NATURAL ATTENUATION RANK
- LOCATION WITH ALCOHOLS DETECTION
- GENERALIZED GROUND-WATER FLOW DIRECTION

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

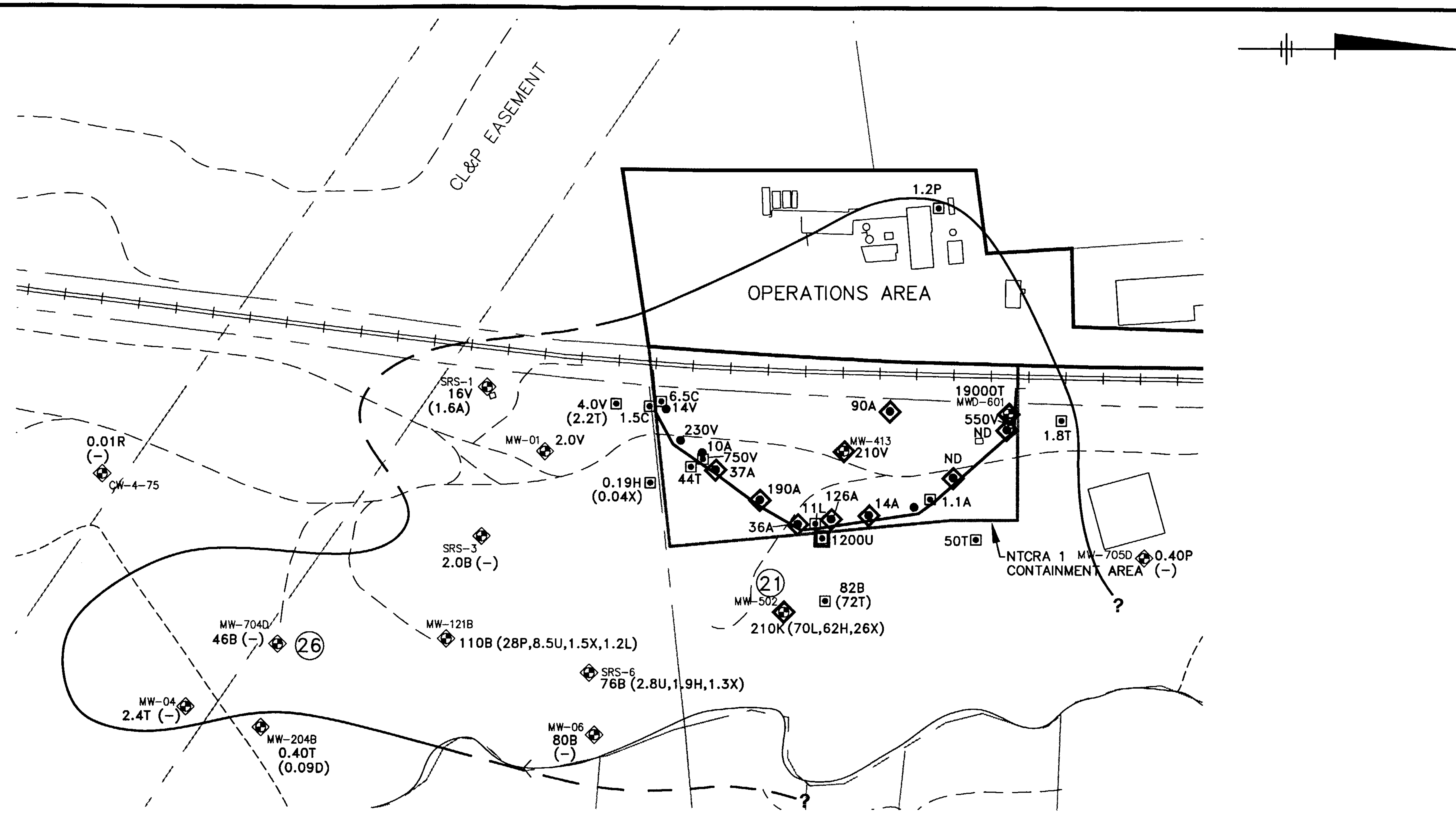
X: 08325X00,08325X01.DWG
P: STD-DL.PCP ● E-SIZE OR DJB.PCP
6/26/98SYR-54-RLP,PGL,RCB
08331900/08331B42.DWG

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

DEEP OVERBURDEN GROUND-WATER REGULATORY VOC PLUME MAP

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 51A



A 1,1-DICHLOROETHANE
B BENZENE
C CHLOROFORM
D 1,2-DICHLOROETHENE
E 1,1-DICHLOROETHENE
H ETHYLBENZENE
K 4-METHYL-2-PENTANONE (MIBK)
L TOLUENE
M METHYLENE CHLORIDE
P TETRACHLOROETHENE
R 1,1,1-TRICHLOROETHANE
T TRICHLOROETHENE
U 2-BUTANONE
V VINYL CHLORIDE
X XYLENES
ND NO VOCs DETECTED DURING NOVEMBER 1996-FEBRUARY 1997 GROUND-WATER SAMPLING EVENT

MW-502 3300C — WELL WITH REGULATORY EXCEEDENCE RATIO. NUMBERS >1.0 INDICATE GROUND-WATER REGULATORY LIMIT EXCEEDED. NUMBERS <1.0 INDICATE EXCEEDENCE RATIO FOR COMPOUNDS DETECTED BELOW REGULATORY LIMIT. FIRST NUMBER INDICATES MAXIMUM MULTIPLE OF A DETECTED VOC OVER REGULATORY LIMIT (e.g., 3300 INDICATES 3300 x LIMIT). LETTER INDICATES COMPOUND WITH INDICATED EXCEEDENCE RATIO (e.g., C = CHLOROFORM). NUMBERS IN PARENTHESES INDICATE OTHER EXCEEDENCE RATIOS FOR SELECT COMPOUNDS AND WELLS. (-) INDICATES NO OTHER EXCEEDENCES.

LEGEND:

- DEEP OVERBURDEN MONITORING WELL
- NTCRA 1 EXTRACTION WELL
- NTCRA 1 COMPLIANCE PIEZOMETER
- ESTIMATED EXTENT OF GROUND-WATER REGULATORY EXCEEDENCE(S)
- (26) USAF NATURAL ATTENUATION RANK
- LOCATION WITH ALCOHOLS DETECTION

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

0 150' 300'

X: 08325X00,08325X01.DWG
P: STD-DL.PCP ● E-SIZE OR DJB.PCP
6/26/98 SYR-54-RLP,PCL,RCB
08331900/08331B18.DWG

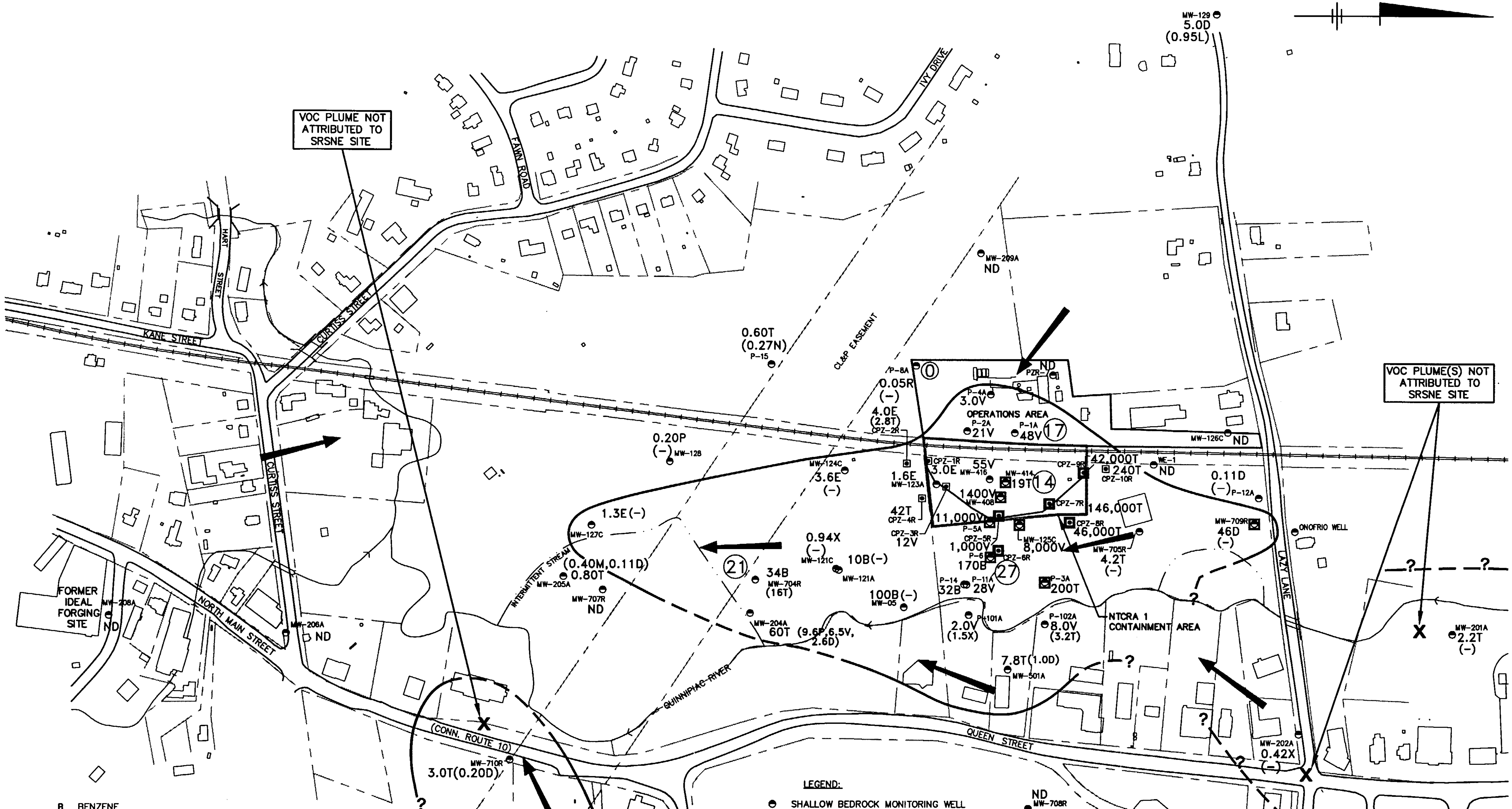
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

DEEP OVERBURDEN GROUND-WATER REGULATORY VOC PLUME MAP

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 51B



B BENZENE
C CHLOROFORM
D 1,2-DICHLOROETHENE
E 1,1-DICHLOROETHENE
M METHYLENE CHLORIDE
P TETRACHLOROETHENE
R 1,1,1-TRICHLOROETHANE
T TRICHLOROETHENE
U 2-BUTANONE
V VINYL CHLORIDE
X XYLENES
ND NO VOCs DETECTED DURING NOVEMBER 1996-FEBRUARY 1997 GROUND-WATER SAMPLING EVENT, OR JUNE 1997 SAMPLING AT MW-710 CLUSTER.

MW-707R 4.8T — WELL WITH REGULATORY EXCEEDENCE RATIO. NUMBERS >1.0 INDICATE GROUND-WATER REGULATORY LIMIT EXCEEDED. NUMBERS <1.0 INDICATE EXCEEDENCE RATIO FOR COMPOUNDS DETECTED BELOW REGULATORY LIMIT. FIRST NUMBER INDICATES MAXIMUM MULTIPLE OF A DETECTED VOC OVER REGULATORY LIMIT (e.g., 4.8 INDICATES 4.8 x LIMIT). LETTER INDICATES COMPOUND WITH INDICATED EXCEEDENCE RATIO (e.g., T = TRICHLOROETHENE). NUMBERS IN PARENTHESES INDICATE OTHER EXCEEDENCE RATIOS FOR SELECT COMPOUNDS AND WELLS. (-) INDICATES NO OTHER EXCEEDENCES.

0 300' 600'

LEGEND:

- SHALLOW BEDROCK MONITORING WELL
- SHALLOW BEDROCK PIEZOMETER
- ESTIMATED EXTENT OF GROUND-WATER REGULATORY EXCEEDENCE(S)
- (0) USAF NATURAL ATTENUATION RANK
- LOCATION WITH ALCOHOLS DETECTION
- GENERALIZED GROUND-WATER FLOW DIRECTION

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

P: STD-DL.PCP @ E-SIZE OR DJB.PCP
XREF: 08325X01,08325X02; L: ON=*, OFF: REF,(XREF X01: PIPES,TRAIL)
6/25/98 SYR-54-PGL,RCB
08331008/08331B19.DWG

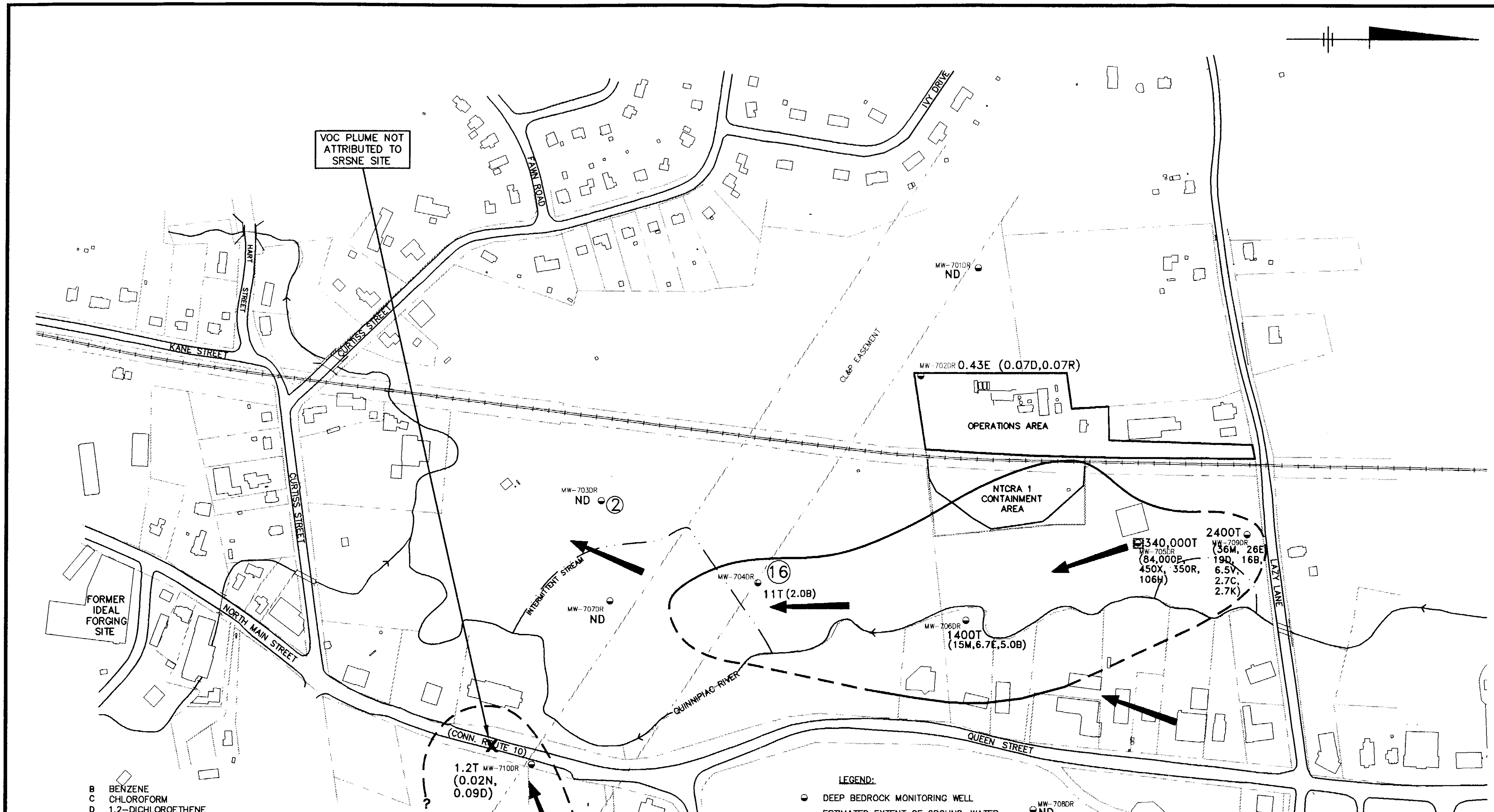
SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT

REMEDIAL INVESTIGATION

SHALLOW BEDROCK GROUND-WATER REGULATORY VOC PLUME MAP

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 52



B BENZENE
C CHLOROFORM
D 1,2-DICHLOROETHENE
E 1,1-DICHLOROETHENE
H ETHYLBENZENE
K 4-METHYL-2-PENTANONE (MIBK)
L TOLUENE
M METHYLENE CHLORIDE
N ACETONE
P TETRACHLOROETHENE
R 1,1,1-TRICHLOROETHANE
T TRICHLOROETHENE
U 2-BUTANONE
V VINYL CHLORIDE
X XYLENES
ND NO VOCs DETECTED DURING NOVEMBER 1996-FEBRUARY 1997 GROUND-WATER SAMPLING EVENT, OR JUNE 1997 SAMPLING AT MW-710 CLUSTER.

MW-704DR 11T — WELL WITH REGULATORY EXCEEDENCE RATIO. NUMBERS >1.0 INDICATE GROUND-WATER REGULATORY LIMIT EXCEEDED. NUMBERS <1.0 INDICATE EXCEEDENCE RATIO FOR COMPOUNDS DETECTED BELOW REGULATORY LIMIT. FIRST NUMBER INDICATES MAXIMUM MULTIPLE OF A DETECTED VOC OVER REGULATORY LIMIT (e.g., 11 INDICATES 11 x LIMIT). LETTER INDICATES COMPOUND WITH INDICATED EXCEEDENCE RATIO (e.g., T = TRICHLOROETHENE). NUMBERS IN PARENTHESES INDICATE OTHER EXCEEDENCE RATIOS FOR SELECT COMPOUNDS AND WELLS. (-) INDICATES NO OTHER EXCEEDENCES.

LEGEND:

- DEEP BEDROCK MONITORING WELL
- ESTIMATED EXTENT OF GROUND-WATER REGULATORY EXCEEDENCE(S)
- ② USAF NATURAL ATTENUATION RANK
- LOCATION WITH ALCOHOLS DETECTION
- GENERALIZED GROUND-WATER FLOW DIRECTION

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

0 300' 600'

SRSNE PRP GROUP
SOUTHINGTON, CONNECTICUT
REMEDIAL INVESTIGATION

DEEP BEDROCK GROUND-WATER REGULATORY VOC PLUME MAP

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

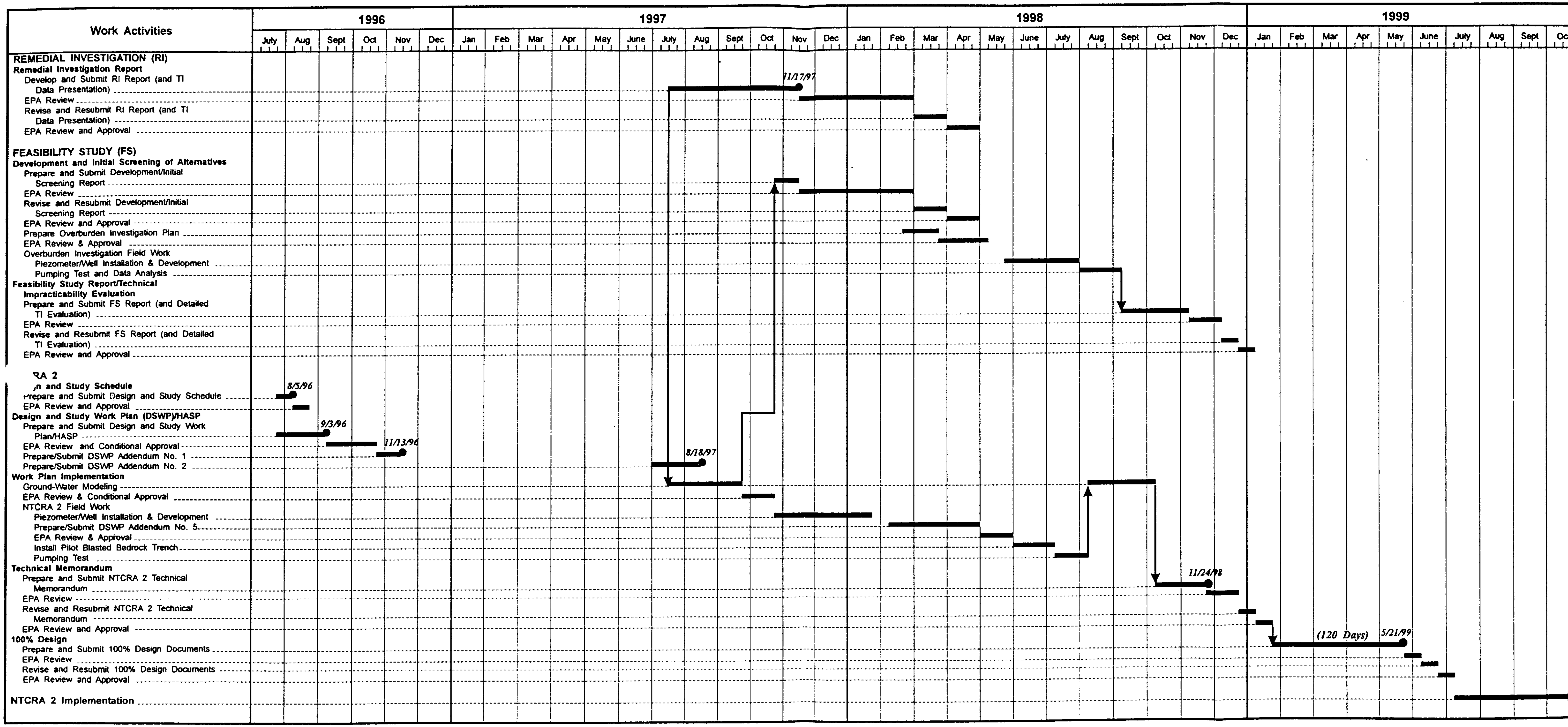
FIGURE 53

11/12/97 SYR-54-RLP,PGL 06331006/06331821.DWG X: 08325X01,08325X02.DWG P: STD-DL.PCP ● E-SIZE OR DJB.PCP

Project Schedule (Sixth Revision)

Figure 54

SRSNE Site - Southington, Connecticut



Critical Path

NOTES:
1) This schedule is based on Administrative Order on Consent effective date of July 20, 1996.
2) This schedule will be revised, if necessary, based on actual review and approval times required by EPA.

04/98 SYR-D54-DJH
08331017/08331j02 cdr

BBL
BLASLAND, BOUCK & LEE, INC.
engineers & scientists