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Corrective Action Plan
122/124 Arrowwood Drive
Nautilus Park – Navy Family Housing
Groton, Connecticut

Contract No. N62472-92-D-1296
Contract Task Order No. 0103

Prepared for

Engineering Field Activity Northeast
Naval Facilities Engineering Command
10 Industrial Highway, Mail Stop 82
Lester, Pennsylvania 19113-2090

Prepared by

EA Engineering, Science, and Technology, Inc.
Southborough Technology Park
333 Turnpike Road, Route 9
Southborough, Massachusetts 01772

29601.03
FINAL
October 2003

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Alexander Easterday — 10 October 2003
Alexander C. Easterday, P.G. — Date
CTO Manager

Kenneth W. Kilmer — 10 October 2003
Kenneth W. Kilmer — Date
Program Manager

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FINAL
October 2003

QUALITY REVIEW STATEMENT

Contract No. N62472-92-D-1296
Contract Task Order No. 0103
Activity: Groton, Connecticut

EA Project No.: 29601.03.3004

Description of Report/Deliverable:

Final Corrective Action Plan, 122/124 Arrowwood Drive, Nautilus Park – Navy Family Housing, Groton, Connecticut

EA CTO Manager: Alexander C. Easterday, P.G.

In compliance with EA's Quality Procedures for review of deliverables outlined in the Quality Management Plan, this final deliverable has been reviewed for quality by the undersigned Senior Technical Reviewer(s). The information presented in this report/deliverable has been prepared in accordance with the approved Implementation Plan for the Contract Task Order (CTO) and reflects a proper presentation of the data and/or the conclusions drawn and/or the analyses or design completed during the conduct of the work. This statement is based upon the standards identified in the CTO and/or the standard of care existing at the time of preparation.

Senior Technical Reviewer

Peter A. Conde, P.G.
Senior Geologist

10/10/03
(Date)

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Mystic Air Quality Consultants, Inc.

1204 North Road (Rt. 117) Groton, Connecticut 06340

March 12, 2003

Subase Housing
Groton, Connecticut 06340
Attn: Ms. Amy Carzoo

Re: Expanded Volatile Organic Scan Sampling

Locations: 122 and 124 Arrowwood
132 and 135 Arrowwood

Date of Sampling: March 3, 2003

Encl: (1) Sample Results and Related Laboratory Documentation

Dear Ms. Carzoo:

As requested, on March 3, 2003, Mystic Air Quality Consultants, Inc. conducted ambient air sampling for volatile organic compounds in the apartments referenced above. The sampling was conducted to determine the presence of compounds related to fuel oil that maybe present in the ambient air of the apartments.

Sampling was conducted using thermal desorption media and samples were analyzed using gas chromatography/mass spectrum analysis, modified EPA TO1/TO2. Analysis was performed by a laboratory accredited by the American Industrial Hygiene Association. Sample BL 0176 was taken in the living room of 132 Arrowwood, BL 0193 was taken in the dining room of 124 Arrowwood, sample BL 0194 was taken in the living room of 135 Arrowwood and finally sample BL 0195 was taken in the living room of 122 Arrowwood. **At the time of the testing sample results were below detectable limits and do not indicate high levels of volatile organic chemicals present in the apartments**. Please refer to **Enclosure (1)** for all the specifics.

Occupants in 124 Arrowwood complain of dryness and bloody noses when the heating system is in operation. Relative humidity during the winter months in New England is quite low usually around 20% or less. If occupants of the home experience dryness of the mucous membranes it is recommended that they increase their water intake. Mystic Air Quality does not recommend humidification systems since they are a known source for microbial growth if not maintained correctly.

Communications (24 hours):

Office: (860) 449-8903 FAX: (860) 449-8860 Toll Free: 1 (800) 247-7746

Studies on low humidity have shown four main effects on the human body. They include the following:

- Can cause respiratory ailments as asthma, bronchitis, sinusitis, nosebleeds or general dehydration.
- Skin moisture evaporation can cause skin irritations and eye itching.
- Irritative effects such as static electricity that can cause mild shocks are common.
- The apparent temperature of the air is lower than what the thermometer indicates, and the body feels colder.

They also had concerns about the carbon dioxide monitor that is located in the dining room periodically beeping but reading zero. If the battery has not been replaced it should be conducted, after replacing the battery if the unit still periodically beeps then it is recommended that the unit be replaced.

If you have any questions or concerns please do not hesitate to contact me directly.

Sincerely,

Christopher Eident, CIH, CSP, RS
CEO

1. INTRODUCTION

Under Contract No. N6472-92-D-1296, Task Order No. 103, Engineering Field Activity Northeast, Naval Facilities Engineering Command issued a Record of Change Memorandum to EA Engineering, Science, and Technology to complete environmental site investigation activities and develop a Corrective Action Plan for a fuel oil release at a residential duplex housing unit located at 122/124 Arrowwood Drive, Nautilus Park, in Groton, Connecticut. The Nautilus Park housing development is a residential subdivision owned by Navy Submarine Base – New London (NSB-NLON) and operated by the Navy Housing Authority. Arrowwood Drive is located approximately 1 mi southeast of NSB-NLON, near the intersection of Connecticut Route 12 and Gungy Wamp Road, in Groton, Connecticut as shown on Figure 1.

The fuel oil release was discovered in March 2002 during removal of a former 550-gal No. 2 fuel oil underground storage tank (UST), previously located at the northern side of the 122/124 Arrowwood Drive duplex housing unit.

The purpose of this Corrective Action Plan is to provide a detailed environmental site evaluation for the fuel oil release at 122/124 Arrowwood Drive and develop recommended remedial actions to mitigate residual petroleum hydrocarbon contamination in site soil and groundwater. This Corrective Action Plan has been developed in accordance with regulatory requirements established by the Connecticut Department of Environmental Protection (CTDEP), as appropriate.

1.1 REPORT ORGANIZATION

This subsection includes a site description and summary of the UST removal operations completed by Phillips National Service Station Equipment, Inc. of Uncasville, Connecticut (SSE). The remaining sections in this report address the following topics:

- **Section 2 – Summary of Environmental Site Investigations**—Summary of environmental site investigation activities completed by SSE and RECON Engineers, P.C. of Guilford, Connecticut during March-June 2002, and additional environmental site investigation activities completed by EA during October 2002.
- **Section 3 – Environmental Site Evaluation**—Detailed environmental site evaluation providing an assessment of current site conditions based on soil and groundwater sampling results obtained during site investigations completed by SSE, RECON, and EA with additional site information taken from Nautilus Park construction plans provided by NSB-NLON.
- **Section 4 – Recommended Remedial Actions**—Recommended remedial actions to address data gaps and mitigate petroleum hydrocarbon contamination in site soil and groundwater based on the site evaluation provided in Section 3. This subsection also

provides recommendations for continued groundwater and surface water monitoring to ensure that dissolved-phase hydrocarbons are not migrating offsite.

- Appendix A provides soil boring logs; Appendix B provides monitoring well schematic construction diagrams; Appendix C provides field record of well development forms; Appendix D provides Field Record of Well Gauging, Purging, and Sampling forms; Appendix E provides laboratory chain-of-custody and Form I documents; Appendixes F and G include the tank pull reports for 132/134 and 121/125 Arrowwood Drive, respectively; Appendix H provides the indoor air sampling report for 122/124, 132, and 135 Arrowwood Drive; and Appendix I includes the CTDEP application for an emergency or temporary discharge authorization.

1.2 SITE DESCRIPTION

The 122/124 Arrowwood Drive fuel oil release site is located southeast of the intersection of Connecticut Route 12 and Gungy Wamp Road, in Groton, Connecticut. Figure 1 provides the location of the subject site, as taken from the Groton, Connecticut, U.S. Geological Survey 7.5-minute series topographic quadrangle map. Figure 2 provides a site map showing current conditions based on construction plans provided by NSB-NLON for the Nautilus Park residential development and a recent survey completed during 17 October 2002. The duplex housing unit located at 122/124 Arrowwood and several neighboring housing units located along Arrowwood Drive constitute the area discussed in this Corrective Action Plan.

The 122/124 Arrowwood fuel oil release site is located on the north side of Arrowwood Drive and is bordered on all sides by neighboring residential housing units in the Nautilus Park residential development. Connecticut Route 12 and Gungy Wamp Road are located approximately 800 ft west and 520 ft north of the site, respectively. The Beaverdam Brook wetlands are located across Arrowwood Drive, directly south of the site. Beaverdam Brook is a headwater to a drinking water reservoir and is centrally located within the wetland area, approximately 650 ft south of the fuel oil release site.

The topography of the site area is characterized as gently sloping to the southeast in the direction of the Beaverdam Brook wetlands. The topographical relief from a location 50 ft north of 122/124 Arrowwood Drive to the northern edge of the Beaverdam Brook wetlands is approximately 2-3 ft based on survey information provided in a construction drawing entitled *Existing Storm Sewer System, Nautilus Park, Groton, Connecticut* (Naval Facilities Drawing No. 2064352).

Several buried utilities are located in the vicinity of the subject site, including drinking water, sanitary sewer, and storm sewer lines. An 8-in. water main (invert elevation approximately 3-4 ft below ground surface [bgs]) extends along the north side of Arrowwood Drive and serves the duplex housing units and several fire hydrants located within 100 ft of the site. An 8-in. sewer main (invert elevation approximately 3 ft bgs) extends along the center of Arrowwood Drive and serves the duplex housing units. A stormwater collection line runs from a catch basin

located approximately 40 ft northwest of 122 Arrowwood Drive south to an outfall located behind the duplex housing unit located at 121/125 Arrowwood Drive. A second stormwater collection line runs from a catch basin located approximately 50 ft east of 144 Arrowwood south to an outfall located behind 143 and 149 Arrowwood Drive. Both of the storm sewer outfalls release stormwater to the Beaverdam Brook wetlands, located south of the site. Overhead electric and telephone services are located within the vicinity of the subject site. The approximate locations of known underground utility lines and storm sewer outfalls are shown on Figure 3.

The duplex housing units shown on Figure 2 consist of single story, wood-framed structures built on concrete foundation slabs measuring approximately 26 × 51 ft. Continuous 10-in. thick concrete footings extend along the perimeter of the foundations to a depth of 3.5 ft bgs. The concrete foundation slabs and footings were installed on virgin soil or fill material compacted to 95 percent of maximum density (Navy Bureau of Yards and Docks Drawing No. 961532).

1.3 SUMMARY OF UNDERGROUND STORAGE TANK REMOVAL OPERATIONS

A 550-gal No. 2 fuel oil UST was removed from the northern side of the 122/124 duplex housing unit by SSE on approximately 12 March 2002. The fuel oil UST was a single-walled steel tank, estimated to have been installed circa 1950. The tank was observed to be in poor condition, with significant pitting and holes.

Approximately 250 tons of petroleum-impacted soil were excavated and removed from the tank pit by SSE (RECON 2002a). Bedrock was partially encountered at the bottom of the tank pit during UST removal. Eight soil samples were collected from the sidewalls of the UST excavation and submitted to Earthwise Analytical Laboratory of New Haven, Connecticut for analysis by the CTDEP extractable total petroleum hydrocarbon (ETPH) Method. Laboratory analyses of post-excavation soil samples indicated that significantly contaminated soil remained along the eastern and southern sides of the excavation following tank removal. The specific locations and analytical results for the confirmatory soil samples are further discussed in Section 2.

Free-phase petroleum was encountered at the groundwater surface in the UST excavation. To the extent possible, the free-phase petroleum was removed using a vac-truck. On 13 March 2002, SSE installed a 10-in. perforated polyvinyl chlorinated (PVC) recovery well in the center of the excavation prior to backfilling with clean material. This recovery/monitoring well was designated MW-1. To enhance the recovery of free-phase petroleum at MW-1, approximately 2 ft of pea stone was placed at the bottom of the excavation prior to backfilling. Additional free-phase petroleum removal was performed at MW-1 by SSE on 19 March 2002. No information was available regarding the volume of free-phase petroleum recovered during UST removal in early March 2002. Approximately 3,200 gal of petroleum-impacted groundwater was recovered from MW-1 on 19 March 2002. There was no specific information available to assess the volume of free-phase petroleum recovered on 19 March 2002.

Following UST and petroleum-impacted soil removal operations, SSE installed two 4-in. PVC monitoring wells (identified as MW-2 and MW-3) in the inferred downgradient location to the former fuel oil UST. Monitoring wells MW-2 and MW-3 were installed using a backhoe. Monitoring well MW-2 was installed to the south of 122 Arrowwood Drive, north of the sidewalk. Monitoring well MW-3 was installed approximately 23 ft east of 124 Arrowwood Drive. No information was available regarding the well screen size, screened interval, or well development procedures.

Subsequent to the UST removal and backfilling activity, additional environmental investigation activities, including installation of 5 additional monitoring wells and collection of groundwater and soil samples, were performed by SSE and by RECON under subcontract to SSE. The results of these environmental site investigation activities, which were completed during March-June 2002, were provided in three separate reports submitted by RECON on 23 April 2002 (RECON 2002a), 14 June 2002 (RECON 2002b), and 17 July 2002 (RECON 2002c).

Following submission of the environmental investigation reports prepared by RECON, the Navy directed EA to complete additional site investigation tasks (including collection of direct-push soil and groundwater samples and installation of sentinel monitoring wells) as necessary to delineate the extent of hydrocarbon contamination resulting from the previous fuel oil release at 122/124 Arrowwood Drive. These additional environmental investigation activities were completed during October 2002.

A complete summary of environmental investigation activities conducted in the vicinity of the fuel oil release associated with the former 550-gal UST at 122/124 Arrowwood, including those conducted by SSE and RECON (March-June 2002) and EA (October 2002), is discussed in Section 2.

2. SUMMARY OF ENVIRONMENTAL SITE INVESTIGATIONS

This section provides a summary of environmental site investigation activities completed in the vicinity of 122/124 Arrowwood following discovery of petroleum contamination during removal of the former 550-gal No. 2 fuel oil UST during early March 2002. The fuel oil tank was previously located adjacent to the northern foundation wall of the duplex housing unit located at 122/124 Arrowwood Drive.

Preliminary environmental investigations were completed by SSE (including installation and sampling of 3 monitoring wells (MW-1, MW-2, and MW-3) during March 2002 and by RECON under subcontract to SSE during April-June 2002. Site investigation activities completed by RECON included installation and sampling of 5 additional monitoring wells (MW-4 through MW-8) and completion of 29 direct-push soil borings (B-1 through B-28 and B-14A).

To further delineate the extent of the petroleum-impacted area and to assess the potential for offsite migration of dissolved-phase petroleum hydrocarbons, EA completed additional site investigation activities during October 2002, including 7 direct-push borings locations (DP-1 through DP-7) and 1 conventional boring (SB-1); installation of 2 new sentinel wells (MW-9 and MW-10); and replacement/repair of several existing monitoring wells. Direct-push borings and drilling operations, including monitoring well installation and development, were completed during 7-10 October 2002. During 15-16 October 2002, EA collected a complete set of well gauging measurements and groundwater samples from the 10 site monitoring wells.

Monitoring well and soil boring locations are depicted on Figure 4. The locations of existing monitoring wells MW-1R through MW-10 and soil borings SB-1 and DP-1 through DP-7 have been confirmed by a site survey completed on 17 October 2002. The locations of soil borings B-1 through B-28 and B-14A have been approximately located based on field observations reported by RECON.

Analytical results have been compared to applicable CTDEP remedial standards, including Class GA/GAA pollutant mobility criteria for soils, surface water protection criteria, and residential volatilization criteria, where appropriate. The CTDEP Class GA/GAA groundwater protection criteria have also been provided as a comparative reference for groundwater analytical results; however, the GA/GAA groundwater protection criteria are not applicable, as the site is classified as a Class GAA aquifer that is located within a protected watershed for public drinking water supply reservoir, as per the City of Groton Water Commission. As such, the applicable remedial standards over time for groundwater at 122/124 Arrowwood Drive consist of background concentrations (i.e., non-detect) for the applicable contaminants of concern (total petroleum hydrocarbons [TPHs]; benzene, toluene, ethylbenzene, and total xylene [BTEX]; and methyl tertiary-butyl ether [MTBE]).

2.1 SITE INVESTIGATIONS BY SSE AND RECON (MARCH-JUNE 2002)

SSE completed water level gauging and groundwater sampling at monitoring wells MW-1, MW-2, and MW-3 on 19 March 2002. The depth to water ranged from 5.11 to 6.49 ft bgs. There were no data available regarding the presence or absence of light, non-aqueous phase liquid (LNAPL) at the groundwater interface. Groundwater samples collected from MW-1 through MW-3 were submitted to Spectrum Analytical, Inc. of Agawam, Massachusetts for analysis by the CTDEP ETPH Method. No information was available regarding the specific well purging and groundwater sampling method. The reported concentrations of TPHs in the 19 March 2002 groundwater samples ranged from non-detect (<0.1 mg/L) at MW-2 and MW-3 to 4.1 mg/L at monitoring well MW-1. The dissolved-phase TPH concentration reported at MW-1 exceeded the CTDEP Class GA/GAA144 groundwater protection criteria for TPHs (0.5 mg/L).

Under subcontract to SSE, RECON completed additional site investigation activities during April-June 2002. RECON completed 16 direct-push soil borings (B-1 through B-16) on 5 April 2002, 12 direct-push soil borings (B-14A and B-17 through B-27) on 28 May 2002, and a single conventional soil boring (B-28) on 13 June 2002. With the exception of B-28, all borings were completed with a Geoprobe® direct-push rig and advanced until bedrock or other refusal was encountered (generally 6-8 ft bgs). RECON Environmental Studies I and II provide boring logs for these direct-push locations.

RECON reported that there was no indication of fuel oil contamination above the water table. At soil boring locations which exhibited evidence of fuel oil contamination (i.e., visual and/or olfactory observations), saturated zone soil samples were collected at a depth equal to or below the interpreted groundwater interface. Soil samples were submitted to Spectrum Analytical, Inc. for TPH analysis by U.S. Environmental Protection Agency (EPA) Method 418.1. Soil samples were not collected at borings B-11 and B-13, since petroleum contamination was not indicated at these locations. Groundwater samples were not collected at the soil boring locations. The soil boring locations and corresponding sorbed-phase TPH concentrations (mg/kg) are provided on Figure 4.

On 5 April 2002, SSE and/or RECON (specific information not available) installed monitoring well MW-4 approximately 15 ft south of 124 Arrowwood Drive, between the front of the duplex housing unit and the sidewalk along the north side of the road. Monitoring well MW-4 was installed by placing a 2-in. PVC well screen and riser assembly into a narrow excavation using a backhoe, similar to the installation method used for monitoring wells MW-2 and MW-3. No information was available regarding the well screen size, screened interval, or well development procedures for monitoring wells MW-2, MW-3, and MW-4.

An 8-in. water main located below the sidewalk was broken during installation of MW-4 and was reportedly repaired in less than 1 hour. Based on discussions with Navy Housing Authority personnel, water released from the broken main appeared to have been discharged to the northeast below Arrowwood Drive. A petroleum sheen was observed at the surface of the mounded water. The water main break may have contributed to the east-southeast extension of

the interpreted petroleum-impacted area depicted on Figure 4. It should also be noted that the water main break may have deposited petroleum hydrocarbons above the static groundwater interface due to localized groundwater mounding.

On 13 June 2002, RECON installed 4 additional wells (MW-5 through MW-8) using a truck-mounted drill rig. Monitoring wells MW-5 through MW-8 were installed to the top of bedrock (ranging from 7 to 9 ft bgs) and were constructed with 2-in. diameter PVC well screen and riser assemblies. Each well was screened from the top of bedrock to approximately 1-2 ft bgs, so that the well screens crossed the groundwater interface. RECON developed the new monitoring wells shortly after installation using disposable polyethylene bailers.

RECON gauged monitoring wells MW-1, MW-2, and MW-4 through MW-8 with an interface probe on 19 June 2002. Monitoring well MW-3 could not be found. The depth to water ranged from 2.71 to 5.84 ft bgs. LNAPL was observed at the groundwater interface at monitoring wells MW-2, MW-7, and MW-8. LNAPL thickness was reported at 0.02 in. at MW-2 and 0.01 in. at MW-7 and MW-8. Groundwater samples were collected from each well following gauging. Prior to groundwater sample collection, approximately 4-5 gal of groundwater were purged from each well. Groundwater samples were collected using disposable polyethylene bailers and submitted to Spectrum Analytical, Inc. for volatile organic compound (VOC) analysis by EPA Method 8260B and TPHs by the CTDEP ETPH Method.

Total BTEX and TPH concentrations reported in the RECON groundwater samples collected on 19 June 2002 are provided on Figure 5. Specific BTEX and VOC constituent concentrations are provided under separate cover in RECON Environmental Study III. Exceedances of the CTDEP Class GA/GAA groundwater protection criteria for TPHs (0.5 mg/L) were reported at monitoring wells MW-2, MW-4, MW-5, MW-7, and MW-8. VOCs that were reported at concentrations above the corresponding CTDEP Class GA/GAA groundwater protection criteria included benzene at monitoring wells MW-4 and MW-7, and both naphthalene and 1,2,4-trimethylbenzene at monitoring well MW-8.

2.1.1 Underground Storage Tank Removal at 121/125 Arrowwood Drive (SSE, September-October 2002)

The 550-gal fuel oil UST previously located to the west/southwest of the utility shed behind 121/125 Arrowwood Drive was removed by SSE on 3 September 2002. SSE reported that the UST was in poor condition, with at least one visible hole. Petroleum-impacted soil was observed within the UST excavation from approximately 6 to 10 ft bgs. During the UST removal process, SSE completed remedial excavation at the former UST location over an area approximately 10 × 12 ft from ground surface to approximately 6-10 ft bgs. SSE reported that approximately 16 tons of petroleum-impacted soil was excavated and removed from the site during UST removal operations.

Based on a confirmatory soil sample collected from the east/northeast wall of the tank pit that reported TPH at 12,057 mg/kg, this side of the tank pit was re-excavated on 1 October 2002. During this second remedial excavation period, SSE reported that approximately 19.5 tons of

soil were removed from the site. It should be noted that a significant amount of this soil volume may have consisted of clean fill material previously used as backfill following the first remedial excavation. The excavation was completed in the direction of the utility shed from ground surface to the top of a bedrock ledge located at approximately 6-8 ft bgs. SSE reported that a layer of petroleum-impacted soil, which appeared to be saturated with fuel oil, was located on the bedrock ledge in a layer approximately 1-ft thick. To the extent possible, this impacted soil was removed during the second excavation period. However, the extent of the excavation was limited by the presence of the utility shed, since further soil removal would have undermined the concrete slab supporting the shed.

SSE terminated the excavation process west/southwest of the utility shed upon reaching limits that would potentially undermine the shed foundation. SSE reported that a layer of petroleum-saturated soil approximately 1-ft thick remained on top of the bedrock ledge below the utility shed foundation. Soil samples collected from this interval at 6 and 7 ft bgs reported TPH at 6,181 mg/kg and 28,782 mg/kg, respectively.

2.2 SITE INVESTIGATIONS COMPLETED BY EA (OCTOBER 2002)

To further delineate the extent of petroleum-impacted soil and groundwater resulting from historic fuel oil releases at 122/124 Arrowwood Drive, EA completed additional environmental investigations during October 2002, as detailed in the following sections.

2.2.1 Direct-Push Soil and Groundwater Sampling

On 7 October 2002, EA completed direct-push borings DP-1 through DP-7 at the locations indicated on Figure 4. Each direct-push boring was installed by a Geoprobe® contractor (Aquifer Drilling and Testing, Inc. of Troy, New York) under direct subcontract to EA. The soil borings started at ground surface and were advanced to approximately 12-15 ft bgs or until bedrock or large bolder refusal was encountered, generally from 8 to 15 ft bgs. The subsurface soil characteristics were recorded and screened using a photoionization (PID), as well as visual and olfactory indication. Saturated zone soil samples were collected from 6 to 8 ft bgs since this depth interval was consistent with the "smear zone" and field screening measurements indicated no discernable petroleum contamination. Direct-push soil boring logs for DP-1 through DP-7 are provided in Appendix A. Saturated zone soil samples were collected from the direct-push acetate liners using disposable, pre-cleaned sampling equipment. Groundwater samples were collected at each direct-push soil boring location using a peristaltic pump with dedicated, disposable polyethylene tubing.

Duplicate soil and groundwater samples were collected at direct-push boring DP-5. To assess the potential for contamination during sample transport, a trip blank sample was analyzed with the groundwater sample delivery group. The soil, groundwater, and trip blank samples were shipped by overnight courier to Chemtech of Mountainside, New Jersey, a Navy and CTDEP-approved laboratory (Environmental Laboratory Analytical Program No. 11376). The soil and groundwater samples were each analyzed for VOCs and MTBE by EPA Method 8260B and for TPHs by the CTDEP ETPH Method. The trip blank sample was analyzed for VOCs and MTBE

by EPA Method 8260B. Analytical data reported for the direct-push soil and groundwater samples are summarized in Tables 1 and 2, respectively. The laboratory chain-of-custody and Form I documents are provided in Appendix E.

The direct-push soil borings were installed at downgradient locations to the interpreted extent of fuel oil contamination resulting from previous releases at 122/124 Arrowwood Drive. Direct-push soil boring DP-1 was also installed to assess potential migration of dissolved-phase petroleum hydrocarbons from the former fuel oil UST located behind 131/135 Arrowwood Drive. Similarly, direct-push borings DP-3 and DP-4 served to assess potential impacts to the subsurface from the former UST located behind 141/143 Arrowwood Drive, and direct-push boring DP-7 was installed to assess conditions downgradient from the former UST behind 121/125 Arrowwood Drive.

Based on field observations and PID screening, there were no significant indications of fuel oil contamination reported at any of the direct-push soil boring locations. This was confirmed by the analytical data for both saturated zone soil and groundwater samples. There were no exceedances of the CTDEP Class GA/GAA pollutant mobility or residential direct exposure criteria for TPHs (both 500 mg/kg) in direct-push soil samples collected at DP-1 through DP-7, which reported only trace concentrations of TPHs at a range of 5.9-9.6 mg/kg. There were no detectable concentrations of VOCs or MTBE in the direct-push soil samples.

There were only trace concentrations of petroleum hydrocarbons reported for direct-push groundwater samples collected at DP-1 through DP-7. Benzene was detected at concentrations slightly above the CTDEP Class GA/GAA groundwater protection criteria at direct-push borings DP-1 and DP-6. There were no other exceedances of the CTDEP Class GA/GAA groundwater protection criteria reported in the groundwater samples. Dissolved-phase TPHs were detected only at direct-push boring DP-1 (280 mg/L), below the corresponding CTDEP Class GA/GAA groundwater protection criteria. There were no exceedances of the CTDEP surface water protection or residential volatilization criteria.

2.2.2 Supplemental Soil Boring SB-1

SSE has provided preliminary analytical data (CTDEP ETPH, mg/kg) for excavation sidewall and tank pit bottom soil samples collected following removal of fuel oil USTs previously located behind 122/124, 121/125, 131/135, and 141/143 Arrowwood Drive. These data are provided on Figure 4 together with the approximate extents of the UST excavations. With the exception of the fuel oil UST excavation at 122/124 Arrowwood Drive, the only confirmatory soil sample location at which TPHs were reported above the CTDEP Class GA/GAA pollutant mobility or residential direct exposure criteria (both 500 mg/kg) was the west/northwest sidewall of the UST excavation located behind 121/125 Arrowwood Drive. The reported concentration of TPH at this sampling location ranged from 6,181 to 28,782 mg/kg, which is indicative of soil potentially saturated with fuel oil.

As discussed above, soil and groundwater samples collected at direct-push boring DP-7 on 7 October 2002 seemed to indicate that petroleum hydrocarbons had not migrated from the UST previously located behind 121/125 Arrowwood Drive. To further assess potential subsurface impacts directly downgradient from this former UST, EA completed a conventional soil boring (identified as SB-1) on 9 October 2002 using a track-mounted drill rig operated by Aquifer Testing and Drilling, Inc. of Troy, New York. Soil boring SB-1 was advanced to 9 ft bgs and was continuously logged and screened with a PID by the EA field geologist. Field observations and PID readings exhibited no indications of fuel oil contamination. A saturated zone soil sample was collected from a depth interval of 6-8 ft bgs.

The soil sample collected at SB-1 was shipped by overnight courier to Chemtech of Mountainside, New Jersey for analysis. The soil sample was analyzed for VOCs and MTBE by EPA Method 8260B and TPHs by the CTDEP ETPH Method. Analytical data reported for the soil sample are provided in Table 3. The laboratory chain-of-custody and Form I documents are provided in Appendix E.

There were no reported concentrations of VOCs or MTBE in the soil sample collected at SB-1. The reported concentration of TPH was 61 mg/kg, significantly below the CTDEP Class GA/GAA pollutant mobility or residential direct exposure criteria for TPHs (both 500 mg/kg).

2.2.3 Monitoring Well Installation and Repair

During 8-10 October 2002, EA installed two sentinel monitoring wells (identified as MW-9 and MW-10) downgradient to the inferred direction of groundwater flow from the fuel oil source area located along Arrowwood Drive. During this period, EA also replaced monitoring well MW-3 with a new 2-in. monitoring well identified as MW-3R and installed a new 2-in. screen and riser (identified as MW-1R) within the existing 10-in. well riser previously designated as MW-1.

Monitoring wells were installed and constructed in accordance EPA guidelines (U.S. EPA 1991). The monitoring wells were installed using a track-mounted drill rig and drive-and-wash methods (with 4-in. inner diameter casing) through the overburden to completion depth or until encountering bedrock or other refusal.

EA also completed repairs to the surface casings of existing flush-mount monitoring wells MW-2 and MW-4, as described below.

2.2.3.1 Soil Sampling

During installation of monitoring wells MW-3R, MW-9, and MW-10, split-barrel sampling was conducted over 2-ft intervals for soil characterization purposes and analytical sample collection. Soil descriptions were recorded in the designated field notebook and on Log of Soil Boring forms (Appendix A). The soil borings were described in accordance with American Society for Testing and Materials Method D 2488-93. Soil samples were screened in the field utilizing closed-container headspace analysis with a PID.

Saturated zone soil samples were collected from the depth interval at which the most significant indication of petroleum hydrocarbon contamination was observed (7-9 ft bgs at MW-3R) or from just below the groundwater interface (i.e., center of the "smear zone") if there was no discernable petroleum impact (6-8 ft bgs at MW-9 and MW-10).

The soil samples collected at MW-3R, MW-9, and MW-10 were shipped by overnight courier to Chemtech of Mountainside, New Jersey for analysis. The soil samples were each analyzed for VOCs and MTBE by EPA Method 8260B and for TPHs by the CTDEP ETPH Method. Analytical data reported for the soil samples are provided in Table 3. The laboratory chain-of-custody and Form I documents are provided in Appendix E.

There were no reported concentrations of VOCs or MTBE in the soil samples collected at MW-3R, MW-9, or MW-10. The reported concentrations of TPHs ranged from 64 to 67 mg/kg, significantly below the CTDEP Class GA/GAA pollutant mobility or residential direct exposure criteria for TPHs (both 500 mg/kg).

2.2.3.2 Monitoring Well Installation

Monitoring wells were installed using new PVC riser casing and well screens. Material was delivered directly to the field in packaging from the manufacturer. After the borehole was drilled to completion depth, a 2-in. inner diameter Schedule 40, threaded, flush-jointed PVC riser casing and attached screen were set through the 4-in. inner diameter casing into the borehole. The monitoring wells were completed with well screen intervals between 5 and 10 ft in length. Specific screen lengths and intervals are shown on Monitoring Well Schematic Construction Diagrams (Appendix B). Monitoring wells were completed with 0.010-in. slot screens and No. 0 sand filter media.

Each newly installed monitoring well was completed at the surface with a flush-mounted, traffic bearing, 8-in. diameter (12-in. diameter in the case of monitoring well MW-1R) protective steel casing that was grouted in place with a cement collar and bolted cap. Care was taken to ensure that the protective casing did not extend into the bentonite chip seal and compromise the integrity of the monitoring well. At the ground surface, the cement formed a 2 ft × 2 ft, 4-in.-thick concrete pad sloping outward around the well. An internal grout collar was placed in the annular space between the inner casing and the outer protective steel casing from below the frost line to the ground surface. The wells were provided with expandable well caps and brass locks (keyed alike).

Soil cuttings and drilling fluids (including decontamination, development, and well purging fluids) were containerized in U.S. Department of Transportation-approved 55-gal drums and staged at the offsite designated staging area (Serviceberry Road Depot) at the end of each day. The drums were labeled and staged in accordance with applicable state and federal regulations. The drums were removed for disposal on 26 November 2002 by R.M. Jones and Company Inc., a licensed waste disposal contractor. Steam cleaning of the drill rig, drilling augers, rods, split-

barrel samplers, and other downhole equipment was performed prior to use at each boring and after the completion of the final boring at the offsite decontamination pad, located at the Serviceberry Road Depot staging area.

2.2.3.3 Monitoring Well Repairs

Repairs to the surface casings of monitoring wells MW-2 and MW-4 were performed on 9 October 2002. An 8-in. diameter protective outer casing (flush-mounted) and 2 ft × 2 ft, 4-in.-thick concrete pad sloping outward around the well were installed similar to the newly installed monitoring wells at the site. An internal grout collar was placed in the annular space between the inner casing and the outer protective steel casing from below the frost line to the ground surface. Additionally, monitoring wells MW-2 and MW-4 were each fitted with an expandable well cap and brass locks (keyed alike).

2.2.3.4 Monitoring Well Development

The newly installed monitoring wells were developed between 10 and 15 October 2002 to remove silt from the well screens and to ensure that representative groundwater samples could be collected. Monitoring wells were developed for a maximum of 2 hours, and water quality indicator parameters were monitored during well development activities.

Each monitoring well was alternately mechanically surged with a surge block and pumped clear of sediment with a peristaltic pump. Care was taken during surging to ensure that low pressures within the well casing and screened interval did not cause implosion of the well screen. Surging continued until little or no sediment entered the well. Following surging, the monitoring wells were continuously pumped using a Geo-Tech® variable speed peristaltic pump and dedicated polyethylene tubing. Temperature, pH, specific conductivity, turbidity, dissolved oxygen, and Eh were monitored during pumping at a rate of one reading per well casing volume removed. Water quality data were recorded on Field Record of Well Development forms (Appendix C). Turbidity was measured when the sample was brought to the surface. Pumping continued until parameters had stabilized (±10 percent change between three consecutive readings) and the turbidity did not exceed 10 nephelometric turbidity units, or for a maximum of 2 hours. Monitoring well development fluids were containerized in U.S. Department of Transportation-approved 55-gal drums that were staged at the offsite designated staging area (Serviceberry Road Depot), prior to disposal on 26 November 2002, as discussed above.

2.2.3.5 Surveying

The newly installed monitoring wells, the existing monitoring wells, soil boring SB-1, and direct-push borings DP-1 through DP-7 were surveyed on 17 October 2002 by the Bongiovanni Group, Incorporated of Newington, Connecticut, a State of Connecticut licensed land surveyor. Horizontal positions were measured to ±0.1 ft. Elevations were measured to ±0.01 ft. Horizontal controls were reported based on the Connecticut Plane Coordinate System. Vertical control was established in accordance with National Geodetic Vertical Datum.

2.2.4 Monitoring Well Sampling

During 15 and 16 October 2002, EA collected groundwater samples from 9 of 10 site monitoring wells, including MW-1R, MW-2, MW-3R, and MW-5 through MW-10. Monitoring well MW-4 was dry and could not be sampled. Prior to sampling, each monitoring well was gauged to determine the absence/presence of LNAPL, depth to groundwater, and depth to well bottom using an oil/water interface probe capable of distinguishing between water and LNAPL to 0.01 in. The wells were then purged until a minimum of three well volumes were removed or until the well became dry, whichever occurred first.

Groundwater sampling was accomplished using low-flow purging and sampling techniques to minimize turbidity. Temperature, pH, specific conductivity, turbidity, dissolved oxygen, and Eh were monitored during the purging process to document the stabilization of water quality prior to sampling. Turbidity was measured when the sample was brought to the surface. These parameters were measured and recorded on Field Record of Well Gauging, Purging, and Sampling forms (Appendix D). A summary of the stabilized water quality parameter values, including pH, temperature, conductivity, dissolved oxygen, turbidity, and Eh is provided in Table 4.

A duplicate groundwater sample was collected at monitoring well MW-2. To assess the potential for contamination during sample transport, a trip blank sample was analyzed with the groundwater sample delivery group. The groundwater and trip blank samples were shipped by overnight courier to Chemtech of Mountainside, New Jersey for analysis. The groundwater samples were each analyzed for VOCs and MTBE by EPA Method 8260B and for TPHs by the CTDEP ETPH Method. The trip blank sample was analyzed for VOCs and MTBE by EPA Method 8260B. Analytical data reported for the groundwater samples collected during 15-16 October 2002 are summarized in Table 5. The laboratory chain-of-custody and Form I documents are provided in Appendix E.

As indicated in Table 5, total BTEX was detected at only 2 of 10 monitoring well locations, including monitoring wells MW-7 (536 µg/L) and MW-8 (1.13 µg/L). Similarly, monitoring wells MW-7 and MW-8 were the only locations at which dissolved-phase TPHs were detected. Benzene (26 µg/L) and TPHs (2,600 µg/L) were reported at concentrations above the CTDEP Class GA/GAA groundwater protection criteria at monitoring well MW-7. There were no other exceedances of the CTDEP Class GA/GAA groundwater protection criteria reported in the groundwater samples collected during 15-16 October 2002. There were no exceedances of the CTDEP surface water protection or residential volatilization criteria.

Trace concentrations of non-BTEX VOCs (i.e., < 10 µg/L total VOCs) were reported at several monitoring well locations. However, non-BTEX VOCs were also reported in the trip blank sample at 1.1 µg/L, indicating that these compounds could have been introduced during holding and transport of the samples, and may not be representative of site conditions.

Trace concentrations of MTBE were reported at several monitoring well locations, including MW-5, MW-6, MW-9, and MW-10. Reported concentrations of dissolved-phase MTBE ranged from 0.64 to 0.79 µg/L. MTBE was not detected in the trip blank sample. The reported concentrations of MTBE were several orders of magnitude below the corresponding CTDEP Class GA/GAA groundwater protection criteria (100 µg/L). Based on a review of CTDEP files pertaining to fuel oil releases from the late 1980s to the present, it has been demonstrated that MTBE is commonly present in fuel oil as a result of cross-contamination from gasoline products during petroleum bulk storage and distribution operations (Robbins et al. 1999). However, it should be noted that the trace concentrations of MTBE detected in groundwater in the vicinity of 122/124 Arrowwood Drive may also have resulted from other sources, such as minor gasoline releases from vehicles or maintenance equipment.

The dissolved-phase total BTEX and TPH concentrations reported for groundwater samples collected during 15-16 October 2002 are provided on Figure 5.

During monitoring well gauging on 15 October 2002, LNAPL sheens were reported at monitoring wells MW-2, MW-7, and MW-8. At each location, the LNAPL thickness was less than 0.01 in. Monitoring well MW-4 was dry. The depth to water at the remaining monitoring well locations ranged from 3.30 ft bgs (MW-6) to 6.35 ft bgs (MW-2). The results of the 15 October 2002 gauging event are summarized in Table 6. The interpreted groundwater contour map based on the well gauging data is provided on Figure 6. As indicated by the groundwater contour map, the direction of groundwater flow is generally to the southeast in the vicinity of 122/124 Arrowwood Drive and appears to flow in a more southerly direction to the east of this location. As expected, the overall direction of groundwater flow is south-southeast, toward the Beaverdam Brook wetlands.

A summary of monitoring well gauging data collected by SSE (19 March 2002), RECON (19 June 2002), and EA (15 October 2002) is provided in Table 7. LNAPL has been reported at monitoring wells MW-2, MW-7, and MW-8. LNAPL was also observed and removed from monitoring well MW-1/MW-1R prior to 19 March 2002. There have been no further indications of LNAPL at this location. It should be noted that the groundwater table in the vicinity of 122/124 Arrowwood Drive decreased by approximately 0.5 to 1 ft between 19 June and 15 October 2002.

3. ENVIRONMENTAL SITE EVALUATION

This section provides a detailed evaluation of the nature and extent of soil and groundwater impacts in the vicinity of 122/124 Arrowwood Drive as a result of petroleum previously released to the subsurface from the former 550-gal fuel oil UST at this address. This section also includes a preliminary evaluation of fuel oil UST removals completed at several neighboring residences located south of the subject site, including 121/125, 131/135, 132/134, and 141/143 Arrowwood Drive.

3.1 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

A general site description has been provided in Section 1, including surface features and the locations of known underground utilities. This subsection provides a discussion of the local subsurface physical characteristics in the vicinity of 122/124 Arrowwood Drive. Descriptions of subsurface physical features, including geology and hydrogeology, are based primarily on the findings of monitoring well installation and soil borings completed by RECON during April-June 2002 and EA during October 2002. Additional information from regional geology sources has been referenced, as appropriate.

The site is located within the Southeast Coast Major Basin, in the Southeast Eastern Regional Complex, within the watershed of the Poquonock River. Several drinking water reservoirs are located within this watershed. Groundwater in the vicinity of the site is classified as GAA by CTDEP. The GAA classification indicates groundwater that is a tributary to a public drinking water supply reservoir. As discussed previously, Beaverdam Brook is located approximately 650 ft south of the fuel oil release site. The Beaverdam Brook is a headwater to a drinking water reservoir and is centrally located within the Beaverdam Brook wetlands.

Groundwater flow in the vicinity of 122/124 Arrowwood Drive is generally to the south-southeast, in the direction of the Beaverdam Brook wetlands, as depicted on Figure 6.

3.1.1 Overburden Geology

Site geology is comprised of 6-15 ft of overburden overlying bedrock. Soil boring and monitoring well logs from the site indicate that the area is underlain by three overburden units. In descending order from ground surface, the overburden units include fill material, sand, and glacial till:

- **Fill Material**—The fill material is composed of silt and sand and often contains a root zone. This unit is likely to have been deposited during the grading activities completed when the subdivision was constructed. Fill material is approximately 2- to 5-ft thick.
- **Sand Unit**—The majority of the overburden underlying the site is fine to coarse sand. Smaller amounts of silt, gravel, and rock fragments may be present. The sand unit ranges in thickness up to approximately 15 ft and appears to directly overlie bedrock in most

areas of the site. One soil boring log (B-9) noted a separate layer of silt within the sand unit, although significant silt units do not appear to be common. The sand unit has been interpreted to be glacial outwash deposited by glacial melt water streams (RECON 2002c). The water table is present within the sand unit, and appears to be the primary water-bearing unit at the site.

- **Till**—A glacial till unit has been reported to be present below the sand unit (RECON 2002c). This till unit is composed of sand with additional amounts of fine material, including silt and clay. This unit has been reported in two soil borings (B-2 and B-27) and does not appear to be a significant overburden unit that is present across the site.

3.1.2 Bedrock Geology

The bedrock underlying the site has been reported to be the Potter Hill granitic gneiss (RECON 2002c). Bedrock has not been penetrated by site monitoring wells, and no site-specific data have been collected related to the properties of this formation.

Data are available for bedrock from NSB-NLON, located approximately 1 mi north of the site. A description of bedrock geology indicates that bedrock in the NSB-NLON area is comprised of medium-grained granitic gneiss (Brown and Root 1997). Regionally, bedrock topography can range in elevation by approximately 50 ft. Hills and valleys in the bedrock surface are common.

3.1.3 Hydrogeology

The depth to groundwater at the site ranges from approximately 3 to 6 ft bgs. The water table is present within the sand unit of overburden. Several rounds of water elevation data are available for the site, summarized in Table 7. Based on these measurements, groundwater flow at the site is toward the south-southeast. Groundwater flow appears to be similar to site surface topography which slopes toward the southeast. The groundwater flow direction is toward the Beaverdam Brook wetlands located southeast of the site area.

The sand overburden unit contains the majority of soil and groundwater impacts at the site. No site-specific hydraulic testing of this unit has been completed. Literature values of hydraulic conductivity for silty sand or fine sand range from 0.028 ft/day to 2.835 ft/day (Fetter 1994). The till unit which underlies the sand unit is likely to have a hydraulic conductivity that ranges from 1 to 2 orders of magnitude below the hydraulic conductivity of the sand unit.

3.1.4 Geologic Cross-Section

Based on the subsurface investigation data collected at the site, an interpreted geologic cross-section has been developed, as shown on Figure 7. The cross-section extends from the former location of the 550-gal fuel oil UST (previously located to the north of 122/124 Arrowwood Drive) in a southeasterly direction through the central axis of the petroleum-impacted area and terminates to the south of the duplex housing unit located at 141/143 Arrowwood Drive.

3.2 NATURE AND EXTENT OF CONTAMINATION

This subsection provides media-specific evaluations of fuel oil contamination in the vicinity of 122/124 Arrowwood Drive, including sorbed-phase, dissolved-phase, and potentially free-phase petroleum hydrocarbons.

3.2.1 Sorbed-Phase Contamination

For the purposes of this site evaluation, sorbed-phase contamination is understood to include residual fuel oil compounds reported in soil samples collected from below the high groundwater table, shown as a dashed blue line in the geologic cross-section provided on Figure 7. Groundwater elevation data available for the site include a limited set of well gauging measurements recorded in March, June, and October 2002. The high groundwater table depicted on Figure 7 is based on monitoring well gauging data collected by RECON on 19 June 2002. It should be noted that sorbed-phase petroleum hydrocarbons may be present slightly above the high groundwater table elevation shown on Figure 7 as a result of contamination from impacted groundwater and/or LNAPL during historic periods of shallow groundwater. As discussed previously, localized groundwater mounding in the vicinity of MW-4, as a result of the 5 April 2002 water main break, may also have deposited hydrocarbons above the high groundwater table shown on Figure 7.

The geologic stratigraphy provided on Figure 7 indicates that sorbed-phase contaminants are primarily associated with the fine to coarse sand unit. Post-excavation soil samples collected from the southeast corner of the tank pit sidewalls behind 122/124 Arrowwood Drive reported sorbed-phase TPHs up to 37,194 mg/kg. Downgradient to this location, sorbed-phase TPHs have been reported at concentrations up to 13,400 mg/kg within the petroleum-impacted area. Based on these data, it is believed that the fuel oil saturation limit in the fine to coarse sand unit is generally >10,000-20,000 mg/kg.

The interpreted extent of sorbed-phase TPH contamination resulting from fuel oil released from the UST formerly located behind 122/124 Arrowwood is depicted on Figure 4. The residual extent of sorbed-phase contamination includes an isolated area (approximately 325 ft^2) centered around soil borings B-7 and B-8, located north of the former UST excavation. The sorbed-phase TPH concentration reported at each of these soil borings was 7,700 mg/kg. The soil boring logs for B-7 and B-8 and groundwater elevation data in the vicinity of this area indicate that sorbed-phase petroleum is present from approximately 5 to 7.5 ft bgs, consistent with the 2.5 ft saturated zone interval above shallow bedrock.

The source for the separate, upgradient area of impacted soil centered around soil borings B-7 and B-8 is assumed to be related to fuel oil released from the UST formerly located behind 122/124 Arrowwood Drive, particularly since several upgradient soil borings (including B-9, B-10, and B-11) did not exhibit evidence of petroleum contamination. It is not clear, however, why there is a discontinuity between this impacted area and the larger impacted area extending

from the former UST location south to Arrowwood Drive. The complete extent of the impacted area centered around soil borings B-7 and B-8 will be further delineated as part of the remedial program.

The remainder of the residual sorbed-phase fuel oil contamination appears to consist of two areas of elevated TPH concentrations, meeting at soil borings B-19 and B-24, in the center of Arrowwood Drive. The first of these impacted areas includes sorbed-phase contamination below the foundation and front yard of 122/124 Arrowwood Drive, extending toward the southeast to soil borings B-19 and B-24. This impacted area has a total surface footprint of approximately 4,200 ft^2. The depth to bedrock ranges from approximately 6 ft bgs in the vicinity of the former UST located behind 122/124 Arrowwood Drive to 8 ft bgs at soil boring B-24. The interpreted extent of sorbed-phase hydrocarbon contamination includes soil from the high groundwater table to the bedrock surface, or approximately 4-7 ft bgs. Sorbed-phase hydrocarbon contamination may also be present at 3-4 ft bgs in the vicinity of MW-4 due to mounding effects associated with the 5 April 2002 water main break. The reported TPH concentrations in sorbed-phase soil samples collected from this impacted area range from 1,600 mg/kg (soil boring B-24) to 37,194 mg/kg (southeast UST sidewall sample), with the most elevated hydrocarbon concentrations indicated to be present below the foundation and driveway of 124 Arrowwood Drive.

There appears to be a separate area of sorbed-phase fuel oil contamination located immediately east of the area discussed above, extending from soil boring B-19 to the northeast corner of 135 Arrowwood Drive. This impacted area has a total surface footprint of approximately 3,650 ft^2. The depth to bedrock ranges from approximately 7.5 ft bgs in the vicinity of soil boring B-19 to 10 ft bgs to the southeast of monitoring well MW-8. The interpreted extent of sorbed-phase hydrocarbon contamination in this area includes soil from the high groundwater table to the bedrock surface, or approximately 3-9 ft bgs. The reported TPH concentrations in sorbed-phase soil samples collected from this impacted area range from 1,600 mg/kg (soil boring B-24) to 10,000 mg/kg (soil boring B-27), although previous observations of LNAPL at monitoring wells MW-7 and MW-8 indicate that sorbed-phase TPHs may be closer to the saturation limit at some locations.

The mass of sorbed-phase petroleum hydrocarbons within the three contaminated areas discussed above has been estimated to be approximately 7,900 kg or 17,400 lb, based on the volume of soil within the sorbed-phase contamination areas, the corresponding average TPH concentrations, a porosity of 0.35, and an average soil bulk density of 107 lb/ft^3. Detailed contaminant mass estimate calculations and soil property sources are provided in Table 8 and Figure 8. Assuming a fuel oil specific gravity of 0.87 (from the material safety data sheet for No. 2 fuel oil, Amerada Hess Corporation No. 0088, January 1998), the estimated mass of sorbed-phase TPHs in the contaminated areas discussed above is equivalent to approximately 2,400 gal of fuel oil.

3.2.1.1 Sorbed-Phase Contaminant Exposure Pathways

A review of applicable CTDEP regulatory criteria indicates that the several potential contaminant exposure pathways must be considered for the sorbed-phase petroleum hydrocarbons discussed above. These pathways include:

- **Pollutant Mobility Criteria (Class GA/GAA)**—The pollutant mobility criteria apply to sorbed-phase petroleum hydrocarbons which have the potential to impact groundwater. Since Arrowwood Drive is located within a CTDEP Class GAA groundwater area, the applicable pollutant mobility criteria for Class GA/GAA groundwater apply (Appendix B of Sections 22a-133k-1 through 22a-133k-3 of the Regulations of Connecticut State Agencies), even though the CTDEP Class GA/GAA groundwater protection criteria do not apply, as previously noted in Section 2, and later detailed in Section 4. Specific pollutant mobility criteria for sorbed-phase soil contaminants are provided for BTEX constituents, MTBE, and TPHs in Tables 1 and 3.

  There were no reported exceedances of the CTDEP Class GA/GAA pollutant mobility criteria in soil samples collected by EA during October 2002 (including direct-push borings DP-1 through DP-7; soil boring SB-1; and samples collected during installation of monitoring wells MW-3R, MW-9, and MW-10). However, these soil samples were collected from locations either upgradient (in the case of MW-3R) or downgradient to the interpreted sorbed-phase contaminant areas discussed in Subsection 3.2.1.1. With a single exception (soil boring B-1), each of the direct-push soil samples collected from within the sorbed-phase contaminant areas exceeded the CTDEP Class GA/GAA pollutant mobility criteria for TPHs (500 mg/kg).

  Soil samples which reported TPHs above 500 mg/kg included 10 direct-push borings completed by RECON during April-May 2002 and 4 excavation sidewall samples collected along the eastern and southern walls of the former UST tank pit by SSE during March 2002. These samples were analyzed for TPHs only, no information is available regarding potential exceedances of CTDEP Class GA/GAA pollutant mobility criteria for BTEX constituents or for MTBE (a possible fuel oil cross-contaminant). Based on a downgradient concentration of benzene (2 µg/L) reported at direct-push boring DP-6, the potential exists for localized exceedances of the CTDEP Class GA/GAA pollutant mobility criteria for benzene within source area soils.

- **Residential Direct Exposure Criteria**

  The residential direct exposure criteria apply to petroleum hydrocarbons in soil located within <4 ft of the ground surface, since these soils are considered to represent a potential exposure route to site residents (Appendix A of Sections 22a-133k-1 through 22a-133k-3 of the Regulations of Connecticut State Agencies). The residential direct exposure criteria do not apply to soils located below asphalt or concrete surfaces. Specific residential direct exposure criteria for sorbed-phase soil contaminants are provided for BTEX constituents, MTBE, and TPHs in Tables 1 and 3.

  There were no reported exceedances of the CTDEP residential direct exposure criteria in soil samples collected by EA during October 2002 (including direct-push borings DP-1 through DP-7; soil boring SB-1; and samples collected during installation of monitoring wells MW-3R, MW-9, and MW-10). However, these soil samples were collected from

locations either upgradient (in the case of MW-3R) or downgradient to the interpreted sorbed-phase contaminant areas discussed in Subsection 3.2.1.1.

As indicated by the interpreted sorbed-phase concentration isopleths provided on Figure 4 and the geologic cross-section provided on Figure 7, there are several non-paved areas below which sorbed-phase contamination has been indicated at <4 ft bgs. These areas include the front yards of 122/124 and 135 Arrowwood Drive and the grassed area in the vicinity of soil boring B-15. The tank pull report for 132/134 Arrowwood Drive indicates that a leak did not occur at the UST located behind this duplex, and that sorbed-phase contamination is likely not a concern in the front yard as a potential source for residential direct exposure. Additional soil samples will be collected in the front yard as part of the remedial activities detailed in Section 4 to confirm these results. The results associated with the tank pull at 132/134 Arrowwood Drive are provided as Appendix F. It should be noted that there have been no soil samples collected from <4 ft bgs. The potential for exceedances of the CTDEP residential direct exposure criteria for TPHs is inferred based on samples collected from approximately 5 to 8 ft bgs, and the assumption that similar concentrations would be reported if "smear zone" samples were collected from 3 to 4 ft bgs at areas that have exhibited shallow groundwater.

- **Residential Volatilization Criteria for Soil Vapor**

The CTDEP residential volatilization criteria for soil vapor apply to VOCs located below or adjacent to residential building foundations. Soil vapor samples have not been collected in the vicinity of 122/124 Arrowwood Drive. As discussed below, there have been no reported exceedances of the CTDEP residential volatilization criteria in groundwater samples collected at the site. However, based on the elevated concentrations of sorbed-phase petroleum hydrocarbons reported in soil samples collected between the high and low groundwater tables shown on Figure 7 and previous observations of LNAPL in the vicinity of duplex housing foundations, the potential exists for soil vapor concentrations to exceed the corresponding CTDEP residential volatilization criteria. Soil vapor concentrations would likely be most elevated during periods of low groundwater, when voided soil pore spaces would be exposed to sorbed-phase hydrocarbons remaining in the "smear zone."

3.2.2 Dissolved-Phase Contamination

Dissolved-phase TPH and total BTEX concentrations reported in groundwater samples collected in the vicinity of 122/124 Arrowwood Drive by SSE, RECON, and EA are provided in tag map format on Figure 5. Specific BTEX constituent, MTBE, and total VOC concentrations reported in groundwater samples collected by EA at direct-push borings DP-1 through DP-7 on 7 October 2002 and at site monitoring wells during 15-16 October 2002 are provided in Tables 2 and 5, respectively.

The dissolved-phase analytical data reported at monitoring well and direct-push sampling locations are consistent with the interpreted sorbed-phase contaminant source areas discussed in Subsection 3.2.1.1. With the exception of trace concentrations of VOCs and TPHs, there were no indications of dissolved-phase petroleum contamination reported at monitoring wells MW-3/MW-3R and MW-6. In contrast to these upgradient monitoring wells, monitoring wells located within areas determined to contain sorbed-phase TPH concentrations >500 mg/kg each have reported dissolved-phase TPHs and/or benzene concentrations above the corresponding CTDEP Class GA/GAA groundwater protection criteria comparative reference.

Groundwater samples collected at monitoring wells MW-9 and MW-10 on 15 October 2002 reported non-detect concentrations of TPHs and BTEX, although trace concentrations (i.e., <1 µg/L) of MTBE were reported at each location. Monitoring wells MW-9 and MW-10 were installed as sentinel wells in the inferred downgradient direction to the sorbed-phase contaminant source area, based on the delineation of the sorbed-phase area and groundwater table elevation data collected prior to the 15 October 2002 gauging event. It has since been determined that groundwater in the eastern extent of the sorbed-phase contaminant source area appears to flow directly south, possibly south-southwest, as opposed to southeast in the direction of monitoring wells MW-9 and MW-10. Therefore, although these monitoring wells serve to bound the southeastern extent of the fuel oil plume, the well locations are not entirely adequate for monitoring potential offsite migration of dissolved-phase hydrocarbons. These flow patterns are based on limited gauging data (i.e., one data round) and additional data may slightly alter the interpreted site groundwater flow patterns.

Given that groundwater flows as depicted on Figure 6, the groundwater samples collected at direct-push borings DP-1, DP-6, and DP-7 are the only available data to assess potential migration of fuel oil compounds from the sorbed-phase contaminant source area. The groundwater samples collected at these sentinel borings reported dissolved-phase TPHs only at DP-1 (280 µg/L). Dissolved-phase BTEX constituents were also detected at DP-1, including benzene at 11 µg/L, above the corresponding CTDEP Class GA/GAA groundwater protection criteria comparative reference of 1 µg/L. It should be noted that the reported TPH and BTEX concentrations at DP-1 may be due, in part or whole, to petroleum released from the fuel oil UST formerly located behind 131/135 Arrowwood Drive. However, since the maximum concentration of TPHs reported in the confirmatory excavation samples collected following removal of the UST was <32 mg/kg (significantly below the overburden fuel oil saturation limit), it is also possible that the dissolved-phase concentrations reported at DP-1 were the result of migration from the sorbed-phase contaminant source area north of 131/135 Arrowwood Drive.

Dissolved-phase TPHs were not detected at direct-push boring DP-6, although several BTEX constituents (including benzene at 2 µg/L) were reported. There were no reported concentrations of TPHs or BTEX in the groundwater sample collected from sentinel boring DP-7.

Although the dissolved-phase benzene concentrations reported at DP-1 and DP-6 were slightly above the corresponding CTDEP Class GA/GAA groundwater protection criteria comparative reference, it should be noted there has been no indication that significant migration of dissolved-

phase fuel oil constituents has occurred. Although RECON did not collected groundwater samples at downgradient soil boring locations B-18, B-20, B-21, B-22, and B-26 (each located immediately downgradient from the sorbed-phase contaminant source area), the reported concentrations of sorbed-phase TPHs at these locations were mostly below the method detection limit.

The mass of dissolved-phase petroleum hydrocarbons within the contaminated source area, which encompasses monitoring well locations MW-1R, MW-2, MW-4, MW-5, MW-7, and MW-8, has been estimated to be approximately 6 kg or 13 lb. This estimate was based on the volume of groundwater within the contaminated source area (assuming a porosity of 0.35 and depth to water based on the 15 October 2002 gauging data) and the corresponding maximum dissolved-phase TPH concentrations reported in groundwater samples. Detailed contaminant mass estimate calculations are provided in Table 8 and Figure 8. Assuming a fuel oil-specific gravity of 0.87 (from the material safety data sheet for No. 2 fuel oil, Amerada Hess Corporation No. 0088, January 1998), the estimated mass of dissolved-phase TPHs in the contaminated area discussed above is equivalent to 1.8 gal of fuel oil.

3.2.2.1 Dissolved-Phase Contaminant Exposure Pathways

A review of applicable CTDEP regulatory criteria indicates that the several potential contaminant exposure pathways must be considered for the dissolved-phase petroleum hydrocarbons discussed above. These pathways include:

- **Groundwater Protection Criteria**

  The CTDEP Class GA/GAA groundwater protection criteria are provided as a comparative reference for groundwater analytical results; however, the GA/GAA groundwater protection criteria are not applicable, as the site is classified as a Class GAA aquifer that is located within a protected watershed for public drinking water supply reservoir, as per the City of Groton Water Commission. The applicable remedial standards over time for groundwater at 122/124 Arrowwood Drive consist of background concentrations (i.e., non-detect) for the applicable contaminants of concern (TPH, BTEX, and MTBE). Specific groundwater protection criteria comparative references for dissolved-phase contaminants are provided for BTEX constituents, MTBE, and TPHs in Tables 2 and 5.

  Generally, exceedances of the CTDEP Class GA/GAA groundwater protection criteria comparative references have been limited to samples collected from within the sorbed-phase contaminant source area, including monitoring wells MW-1, MW-2, MW-4, MW-5, MW-7, and MW-8. Dissolved-phase TPH and/or benzene concentrations have exceeded the corresponding CTDEP Class GA/GAA groundwater protection criteria at these locations. During the most recent groundwater sampling event (15-16 October 2002), exceedances of the CTDEP Class GA/GAA groundwater protection criteria within the sorbed-phase contaminant source area have been limited to monitoring well MW-7, although sheens were observed at monitoring wells MW-2 and MW-8.

As discussed previously, there have been two downgradient locations at which the CTDEP Class GA/GAA groundwater protection criteria comparative references have been exceeded, including direct-push groundwater samples collected at DP-1 and DP-6 (7 October 2002). Benzene was reported at concentrations slightly above the CTDEP Class GA/GAA groundwater protection criteria at each of these locations.

- **Surface Water Protection Criteria**

  The surface water protection criteria apply to dissolved-phase petroleum hydrocarbons that have the potential to discharge to surface waterbodies (Appendix D of Sections 22a-133k-1 through 22a-133k-3 of the Regulations of Connecticut State Agencies). Groundwater flowing from the fuel oil release area at 122/124 Arrowwood Drive ultimately discharges to the Beaverdam Brook, located approximately 650 ft south of the site. The Beaverdam Brook is a headwater to a drinking water reservoir and is centrally located within the Beaverdam Brook wetlands. Specific surface water protection criteria for dissolved-phase contaminants are provided for BTEX constituents, MTBE, and TPHs in Tables 2 and 5.

  None of the groundwater samples collected in the vicinity of 122/124 Arrowwood Drive have exceeded the corresponding CTDEP surface water protection criteria.

- **Residential Volatilization Criteria**

  The residential volatilization criteria apply to dissolved-phase petroleum hydrocarbons that have the potential to impact indoor air quality in a residential building (Appendix E of Sections 22a-133k-1 through 22a-133k-3 of the Regulations of Connecticut State Agencies). The depth to groundwater and relative location to residential housing foundations along Arrowwood Drive require that the residential volatilization criteria be evaluated. Specific residential volatilization criteria for dissolved-phase contaminants are provided for BTEX constituents, MTBE, and TPHs in Tables 2 and 5.

  None of the groundwater samples collected in the vicinity of 122/124 Arrowwood Drive have exceeded the corresponding CTDEP residential volatilization criteria.

3.2.2.2 Assessment of Contaminant Migration Potential

As discussed previously, soil borings installed downgradient to the sorbed-phase contaminant source area indicate that significant migration of dissolved-phase fuel oil compounds has not occurred at the site, although there were several slight exceedances of the CTDEP Class GA/GAA groundwater protection criteria comparative reference for benzene reported at soil borings DP-1 and DP-6. The dissolved-phase concentrations reported at soil boring DP-1 may be associated with fuel oil releases from the UST formerly located behind 131/135 Arrowwood. However, dissolved-phase benzene and total xylene concentrations reported at DP-6 are most likely associated with trace level migration from the sorbed-phase contaminant source area located along Arrowwood Drive.

The current extent of the sorbed-phase contamination appears to be at steady state, since TPH concentrations in saturated zone soil samples collected downgradient to the UST release area are significantly below the apparent saturation limit for the fine to coarse sand in the water-bearing unit. Additionally, based on the residual contaminant mass, and corresponding fuel oil volume release (estimated at approximately 2,400 gal), it can be inferred that fuel oil has been released at this location for at least several seasons. A loss of 2,400 gal of fuel oil would certainly have been noticed had it occurred over an interval less than several years. Although the specific age of the fuel oil releases period and the site-specific hydraulic conductivity are not known, based on the concentrations of sorbed-phase TPHs relative to the apparent soil saturation limit, it appears that the sorbed-phase contaminant area has reached steady state.

3.2.2.3 Preliminary Assessment of Dissolved-Phase Analytical Trends

The dissolved-phase analytical data provided on Figure 5 summarize the available groundwater sampling results for the site. These include sampling events completed on 19 March, 19 June, and 10-15 October 2002. At locations where dissolved-phase fuel oil compounds have been detected, there has been a consistent concentration decrease observed between the June and October 2002 sampling events. During this period, the water table elevation decreased between 0.5 and 1 ft. Although only a limited data set is available, it is believed that the apparent reduction in dissolved-phase hydrocarbon concentrations is associated with the reduced water table elevation. Since a significant mass of sorbed-phase hydrocarbons was no longer in contact with the groundwater during the October 2002 sampling event, it is believed that the corresponding dissolved-phase concentration measurements were reduced relative to the samples collected during June 2002, when the "smear zone" was submerged.

It should be noted that the apparent reduction in dissolved-phase hydrocarbons between June and October 2002 may also be associated with groundwater sampling methods and/or natural attenuation.

3.2.3 Light, Non-Aqueous Phase Liquid

As discussed in Section 1, SSE observed LNAPL at the groundwater interface during removal of the 550-gal fuel oil UST formerly located behind 122/124 Arrowwood Drive. LNAPL includes free-phase petroleum product occurring as a sheen or thicker layer. To the extent possible, this LNAPL was removed. There have been no further observations of LNAPL at this location. During the monitoring well gauging event completed on 19 June 2002, LNAPL was reported at monitoring wells MW-2 (0.02-ft thickness) and monitoring wells MW-7 and MW-8 (both 0.01-ft thickness). Each of these monitoring wells is located within the interpreted sorbed-phase contaminant source area. The LNAPL thickness was reduced to a sheen (i.e., <0.01 ft thickness) at each of these locations based on monitoring well gauging completed on 15 October 2002. LNAPL has not been observed at any other location in the vicinity of 122/124 Arrowwood Drive.

Although there has been an apparent reduction in the thickness of LNAPL observations, it should be noted that LNAPL may have been present above the water table during the 15 October 2002 well gauging event. During periods of elevated groundwater, it is possible that LNAPL may be observed at increased thickness levels.

3.3 CONCLUSIONS

Based on the review of recently collected environmental data and previous investigations, the following conclusions can be made regarding environmental impacts at the site:

- Fuel oil released from the UST formerly located behind 122/124 Arrowwood Drive has resulted in a residual petroleum-impacted area, as depicted on Figure 4. Based on interpretations of available data, the estimated residual contaminant mass in soil and groundwater includes approximately 17,400 lb of sorbed-phase petroleum hydrocarbons and 13 lb of dissolved-phase petroleum hydrocarbons. The total estimated mass of hydrocarbons remaining in soil and groundwater indicates that the historic release volume may have totaled approximately 2,400 gal of fuel oil.
- The sorbed-phase contaminated area (depicted on Figure 4) appears to have reached steady state, based on the apparent saturation limit of the overburden.
- Confirmatory soil samples and downgradient soil and groundwater data indicate that the USTs formerly located behind 121/125, 131/135, and 141/143 Arrowwood Drive may have leaked, but not to the extent of the UST formerly located behind 122/124 Arrowwood. None of the excavation sidewall or bottom samples collected at 131/135 and 141/143 exceeded the CTDEP pollutant mobility or residential direct exposure criteria for TPHs. Two excavation sidewall samples collected from the west/northwest side of the former UST located behind 121/125 Arrowwood Drive were reported at TPH concentrations up to 28,782 mg/kg. The remaining sidewall and bottom samples collected at this location were below the CTDEP pollutant mobility or residential direct exposure criteria for TPHs.
- Exceedances of the applicable regulatory cleanup goals for fuel oil include detections of dissolved-phase contaminants and the CTDEP Class GA/GAA pollutant mobility criteria for sorbed-phase contaminants. Although soil samples have not been collected from <4 ft bgs, the available data indicate that sorbed-phase concentrations are likely above the corresponding CTDEP residential direct exposure criteria at some locations. Similarly, although soil vapor samples have not been collected, the available data indicate that the CTDEP residential soil vapor criteria may be exceeded below or adjacent to the foundations of several duplex housing units.

Section 4 provides recommended remedial actions to address the exceedances of the applicable protection criteria as well as potential residential exposure pathways for residual fuel oil contaminants.

4. RECOMMENDED REMEDIAL ACTIONS

This section provides EA's recommended actions to mitigate residual petroleum hydrocarbon contamination identified in the vicinity of 122/124 Arrowwood Drive.

Recommended actions presented in this section are focused toward achievement of two separate goals:

1. Collection of data required to fill the following data gaps:
   - Address the current status of the fuel oil UST located behind 132/134 Arrowwood Drive.
   - Address the current status of the fuel oil UST removal behind 121/125 Arrowwood Drive.
   - Install and sample sentinel groundwater monitoring wells to confirm that dissolved-phase petroleum hydrocarbons are not migrating to the Beaverdam Brook wetlands.
   - Address the status of the indoor air sampling performed at 122, 124, 132, and 135 Arrowwood Drive to confirm that the CTDEP residential target indoor air concentrations have not been exceeded in residences located above and/or adjacent to petroleum-impacted soil.
2. Remedial actions for soil and groundwater to address the residual hydrocarbon contamination associated with fuel oil released from the 550-gal UST formerly located behind 122/124 Arrowwood Drive.

Recommended actions discussed in the following subsections are consistent with the Navy Housing Authority's overall goal of achieving site closure at former fuel oil UST locations in the Nautilus Park – Navy Family Housing neighborhood. The recommended actions have been developed in accordance with regulatory requirements established by CTDEP.

4.1 DATA GAPS

This subsection provides recommended site investigation activities to address the data gaps outlined above.

4.1.1 Fuel Oil Underground Storage Tank Located Behind 132/134 Arrowwood Drive

As shown by the interpreted sorbed-phase TPH isopleths on Figure 4, the existing analytical data indicated that the fuel oil UST currently located behind 132/134 Arrowwood Drive could potentially have been a source for subsurface contamination. The Navy Housing Authority

removed the tank behind 132/134 Arrowwood Drive on [redacted] 2003. The associated tank pull report is provided as Appendix F. The results of the tank pull indicate that a release did not occur at the UST located behind this duplex, and that this location is likely not an additional source of sorbed-phase contamination at the site.

It is recommended that two direct-push soil borings be completed in the front yard of 132 Arrowwood Drive, at the locations shown on Figure 8. Soil and groundwater samples collected from this location should be analyzed for TPHs by the CTDEP ETPH Method and for BTEX and MTBE by EPA Method 8260B. Analytical data from these soil borings will serve to document that a release did not occur at the UST behind 132/134 Arrowwood Drive by confirming that a residual sorbed-phase contaminant source is not present in the front yard of the duplex, and to further delineate the extent of the eastern component of the sorbed-phase contaminant source area (identified as Zone 3) on Figure 8.

4.1.2 Fuel Oil Underground Storage Tank Formerly Located Behind 121/125 Arrowwood Drive

SSE has provided analytical data (CTDEP ETPH, mg/kg) for excavation sidewall and tank pit bottom soil samples collected following removal of the fuel oil UST formerly located behind 121/125 Arrowwood Drive. These data are provided on Figure 4 together with the approximate extents of the UST excavation. The reported concentration of TPH in the two excavation sidewall samples collected from a layer of residual petroleum-impacted soil remaining on top of a bedrock ledge below the utility shed foundation at 121/125 Arrowwood Drive ranged from 6,181 to 28,782 mg/kg, which is indicative of soil potentially saturated with fuel oil. These elevated concentrations reported in the west/northwest sidewall samples indicate that petroleum-impacted soil located below the utility shed foundation could not be entirely removed due to physical limitations to excavation.

As discussed in Section 2, EA has completed two soil borings downgradient from this former UST location (SB-1 and DP-7). Analytical samples collected at these borings exhibited no indication that fuel oil has migrated from the former tank location. However, the elevated TPH concentrations collected along the west/northwest excavation sidewall exceed the CTDEP pollutant mobility criteria (500 mg/kg) and indicate the potential that the CTDEP residential direct exposure and/or residential soil vapor criteria may be exceeded in the vicinity of the utility shed.

The UST removal report for the tank located behind 121/125 Arrowwood Drive has been reviewed, and is provided as Appendix G. The tank was removed on 3 September 2002, along with approximately 35 tons of impacted soil (to the extent practicable) in the month following the removal action. Impacts to groundwater were not observed at the time of the tank removal, or removal of the associated impacted soil. Residual contamination may remain on top of bedrock underneath the shed and concrete slab located to the north of the excavation in minor quantities. A sentinel monitoring well (MW-13) will be installed downgradient of this location to monitor for potential migration of contaminants and any impacts to groundwater, as detailed in Subsection 4.1.3.

4.1.3 Installation and Sampling of Sentinel Groundwater Monitoring Wells

As discussed in Section 3, monitoring wells MW-9 and MW-10 were installed in the inferred downgradient direction to the residual hydrocarbon source area. It has since been established that additional downgradient monitoring wells are required to serve as an effective sentinel well network along the southern side of the sorbed-phase contaminant source area. The additional sentinel wells are necessary to confirm that dissolved-phase petroleum hydrocarbons do not migrate from the residual source area to the Beaverdam Brook wetlands. These wells will also be required to monitor and control the active remedial program discussed in Subsection 4.2.

Recommended locations for four additional sentinel wells are provided on Figure 8. The wells should be 2-in. diameter PVC, finished with flush-mount casings installed in a similar manner as monitoring wells MW-9 and MW-10. A track-mounted drill rig may be required to install the sentinel wells located adjacent to the wetland.

Previously collected soil samples have demonstrated that sorbed-phase hydrocarbons do not exceed the CTDEP cleanup criteria in the vicinity of the recommended sentinel wells. Therefore, it is not necessary to collect soil samples during sentinel monitoring well installation. Recommended groundwater sampling procedures for the sentinel well network are discussed in Subsection 4.2.

4.1.4 Indoor Air Sampling

As discussed in Section 3, the available analytical data indicate that the CTDEP residential volatilization criteria for soil vapor may be exceeded below and adjacent to several duplex housing unit foundations located in areas impacted with fuel oil. These housing units included 122/124, 132, and 135 Arrowwood Drive, based on the interpreted sorbed-phase contaminant source areas shown on Figure 4.

The CTDEP residential volatilization criteria for soil vapor (Appendix F to Sections 22a-133k-1 through 22a-133k-3 of the Regulations of Connecticut State Agencies) have been developed based on exposure risk calculations such that residential target indoor air concentrations will not be exceeded if soil vapor concentrations are maintained below the cleanup criteria.

Indoor air sampling was conducted to provide a direct assessment of the actual concentrations of volatile hydrocarbons (if any) in the duplex housing units identified above. These data alleviate the requirement for collecting soil vapor samples below or adjacent to the building foundations and also eliminate the ambiguity associated with inferred indoor air concentrations based on subsurface soil vapor measurements.

Time-weighted samples were collected on 3 March 2003 at each housing unit and analyzed for VOCs by EPA Method TO1/TO2. VOCs were not detected in any of the samples collected for analysis. Details specific to the sampling event and associated analytical results are provided as Appendix H.

4.2 REMEDIAL PROGRAM

This subsection provides recommended remedial actions to mitigate the sorbed-phase and dissolved-phase contamination associated with the fuel oil release at 122/124 Arrowwood Drive.

4.2.1 Remedial Goals

As detailed in Section 3, the available analytical data indicate that residual petroleum hydrocarbon concentrations in soil and groundwater exceed several of the corresponding CTDEP cleanup criteria:

- CTDEP Class GA/GAA pollutant mobility criteria (soil)
- Background concentrations for all dissolved-phase contaminants of concern (groundwater).

With the exception of two excavation sidewall samples collected in the vicinity of the utility shed behind 121/125 Arrowwood Drive, soil samples which have reported hydrocarbon concentrations above the CTDEP Class GA/GAA pollutant mobility criteria are limited to the sorbed-phase contaminant source areas identified on Figure 4. Detections of the primary contaminants of concern (TPH, BTEX, and MTBE) for groundwater samples have been reported for samples collected from monitoring wells and direct-push sampling locations within or immediately downgradient of the sorbed-phase contaminant source area (Figure 4).

Although there have been no soil samples collected from <4 ft bgs, the available data suggest that sorbed-phase hydrocarbon concentrations may exceed the CTDEP residential direct exposure criteria. Similarly, although there have been no soil vapor samples collected, the available data suggest that the CTDEP residential soil vapor criteria may be exceeded. Potential exceedances of either of the above criteria are limited to the sorbed-phase contaminant source areas identified on Figure 4.

Based on the CTDEP criteria discussed above, the recommended remedial goals for residual fuel oil contamination in the vicinity of 122/124 Arrowwood Drive are as follows:

- Reduction of sorbed-phase TPH and BTEX concentrations to the corresponding CTDEP Class GA/GAA pollutant mobility criteria (Table 1).
- Periodic groundwater monitoring to document dissolved-phase contaminant concentrations during treatment with respect to achieving the remedial cleanup objectives for the site (i.e., background concentrations).
- Following active remediation, quarterly groundwater sampling at site monitoring wells to confirm and document that the remedial cleanup objectives for the site are achieved.

Reduction of the sorbed-phase TPH and BTEX concentrations to the CTDEP Class GA/GAA pollutant mobility criteria will also satisfy the CTDEP residential direct exposure criteria, which may currently be exceeded at some locations. Additionally, this remedial action will reduce the source for soil vapor concentrations such that potential exceedances of the CTDEP residential soil vapor criteria will be eliminated.

Reduction and/or elimination of residual sorbed-phase petroleum hydrocarbons within the remedial target areas identified on Figure 9 should remove the source for dissolved-phase contaminants, which have been detected in groundwater samples collected from locations within and immediately downgradient of the sorbed-phase contaminant mass shown on Figure 9.

The following subsection outlines the recommended remedial action for reducing sorbed-phase TPH and BTEX concentrations to the CTDEP Class GA/GAA pollutant mobility criteria.

4.2.2 Denitrification-Based Bioremediation of Sorbed-Phase Contaminants

Following an evaluation of available technologies for achievement of the remedial goals presented in Subsection 4.2.1, denitrification-based bioremediation (DBB) has been selected as the most feasible for mitigating residual fuel oil contaminants in the vicinity of 122/124 Arrowwood Drive.

4.2.2.1 Technology Selection

Other technologies that were included for consideration but ultimately rejected included excavation of petroleum-impacted soil, *in situ* chemical oxidation (ISCO), soil vapor extraction/air sparging (SVE/AS), and aerobic bioremediation using oxygen release compound (ORC®) or similar products.

Remedial excavation was not selected since this technology would not be able to address contaminated soil located below or immediately adjacent to duplex housing foundations and subsurface utilities, including locations within the most impacted region of the sorbed-phase contaminant source area. Additionally, this technology would be cost prohibitive due to the requirement for dewatering during excavation and extensive road, sidewalk, and curb repairs following excavation (soil disposal and replacement costs notwithstanding). Remedial excavation would also create a significant disturbance and potential safety hazard in the suburban residential setting.

ISCO was not selected due to the large mass of sorbed-phase contamination (approximately 17,400 lb) which would require prohibitive chemical injection volumes to achieve the remedial target goals throughout the residual source area. In addition to being technically infeasible and cost prohibitive, ISCO would present a serious safety and health risk to site residents due to the exothermic reactions in the shallow aquifer and associated release of pressurized gases below duplex housing foundations. ISCO would also likely result in mobilization of sorbed-phase contaminants, which would potentially migrate to the Beaverdam Brook wetlands.

SVE/AS was not selected since this technology would not be effective for mitigating sorbed-phase contaminants and since operation of an active SVE/AS system would create a significant disturbance to the residential neighborhood. As discussed in the site evaluation, the majority of residual fuel oil contamination is understood to be present as sorbed-phase contamination below the water table and (seasonally) within the phreatic zone. Except during periods of low groundwater elevation, SVE would not be able to capture these hydrocarbons. Based on application of SVE/AS systems at similar sites, it is not believed that air sparging would effectively promote transfer of sorbed-phase hydrocarbons to the shallow vadose zone, where volatilized compounds would be captured by an SVE system. Also, operation of the SVE/AS system during periods of shallow groundwater would likely be restricted due to the potential for groundwater infiltration.

Aerobic bioremediation using ORC®, hydrogen peroxide solutions, or similar products was considered but ultimately rejected following an analysis of the stoichiometric demand for ORC® to achieve the site remedial goal of reducing sorbed-phase TPH and BTEX concentrations to the corresponding CTDEP Class GA/GAA pollutant mobility criteria throughout the residual source area. Due to oxygen solubility limitations, it is believed that ORC® would not be effective for mitigating the large mass of sorbed-phase hydrocarbons in the vicinity of 122/124 Arrowwood Drive. The advantages of DBB over ORC® or similar aerobic bioremediation technologies are discussed in the following subsection.

4.2.2.2 Technology Description

DBB involves subsurface injection of nitrate-based electron acceptors and nutrients to promote anaerobic degradation of petroleum hydrocarbons in soil and groundwater through denitrification. Denitrification is an anaerobic biodegradation pathway in which nitrate is used as an electron acceptor for metabolism of hydrocarbons. The products of denitrification are carbon dioxide, water, and inert nitrogen gas. DBB is a cost effective technology which is particularly suited for treatment of sorbed-phase contamination below building foundations and at other logistically complicated sites, including sites where subsurface utilities restrict application of more invasive remedial technologies.

In comparison to aerobic bioremediation technologies, DBB is significantly more likely to mitigate large residual hydrocarbon masses due to the solubility of nitrate (>600,000 mg/L) versus oxygen (6-9 mg/L), which allows for application of significant concentrations of nitrate as an electron acceptor to meet the stoichiometric demand for metabolizing the target hydrocarbons. In addition, the solubility of nitrate allows for the establishment of a subsurface diffusive flux sufficient to transfer the nitrate-based electron acceptor solution to otherwise inaccessible areas, such as contamination located below building foundations or subsurface utilities. Diffusion of nitrate-based electron acceptor solutions have even been found to exceed advective forces in certain instances.

Table 9 provides a comparative summary of microbial degradation processes, including aerobic respiration and several forms of anaerobic metabolism, including denitrification, manganese, iron, and sulfate reduction, and methanogenesis. During biodegradation of petroleum hydrocarbons, any or all of these metabolic pathways may contribute to the overall mineralization of contaminants. Facultative bacteria (i.e., organisms able to metabolize hydrocarbons in both aerobic and anaerobic environments) typically utilize available electron acceptors preferentially according to energy available per mole, beginning with oxygen (aerobic respiration) and proceeding in order through nitrate reduction, iron reduction, and sulfate reduction (NFESC 1996). In oxygen-depleted environments, methanogenic bacteria may utilize carbon dioxide as an electron acceptor, resulting in the production of methane gas.

As demonstrated by the data provided in Table 9, the available energy associated with aerobic respiration and denitrification is very similar, both significantly more preferable than the other biodegradation processes from a metabolic standpoint. This indicates that both oxygen and nitrate can serve as excellent electron acceptors for biodegradation. However, as discussed above, the solubility limitations associated with dissolved oxygen (6-9 mg/L) relative to nitrate (>600,000 mg/L) may restrict the capacity for aerobic degradation at sites which contain significant residual hydrocarbon concentrations, particularly when remedial target locations are not readily accessible, such as areas below building foundations.

At sites with elevated sorbed-phase or dissolved-phase petroleum hydrocarbons, the available oxygen concentration may rapidly be depleted due to the large stoichiometric demand for electron acceptors. This is not the case with nitrate, which can be introduced and maintained at a much higher concentration than oxygen. For the same reason, nitrate can be introduced at such high concentrations that a strong diffusive flux can be established, which promotes lateral movement of nitrate-based electron acceptor solutions from high concentration areas at the injection point(s) to lower concentration locations within the remedial target area. The areas benefiting from the diffusive flux of nitrate may be located below building foundations and/or adjacent to utility lines, where subsurface injection is not possible.

Due to the available metabolic energy associated with denitrification relative to other anaerobic metabolic processes, facultative bacteria preferentially utilize nitrate as an electron acceptor in the absence of oxygen or when insufficient oxygen is available for substrate (i.e., petroleum hydrocarbon) degradation. As indicated by the stabilized water quality parameters provided in Table 4, the sorbed-phase contaminant source area and immediate downgradient locations in the vicinity of 122/124 Arrowwood Drive exhibit reduced oxygen concentrations relative to upgradient sampling locations (i.e., monitoring wells MW-5 and MW-6). Within and downgradient to the sorbed-phase contaminant source area, the dissolved-oxygen concentrations are less than or slightly above 1 mg/L. These measurements are typical for anaerobic sites, where the oxygen demand posed by the residual petroleum contamination has nearly depleted the available dissolved oxygen. Based on water quality parameters measured at upgradient monitoring wells MW-5 and MW-6, the background dissolved oxygen concentration in the vicinity of 122/124 Arrowwood Drive is estimated to be >5-6 mg/L.

Since dissolved oxygen has been essentially depleted with the remedial target area, nitrate would be established as the preferred metabolic pathway by existing facultative bacteria (McQuillan and Faris 1999). Currently, the available water quality parameter data suggest that facultative bacteria are active at the site. Redox and pH measurements collected during well purging on 15 October 2002 are indicate of anaerobic conditions under which iron reduction is occurring. This assessment is based on the redox potential measurements, which ranged from approximately 50 to 150 mV and the observation of reduced pH conditions, which are likely associated with iron reduction.

The depleted oxygen conditions and presence of an established facultative microbial population indicate that conditions are favorable for DBB in the vicinity of 122/124 Arrowwood Drive.

4.2.2.3 Denitrification-Based Bioremediation Treatment

As discussed above, DBB is the recommended remedial technology for mitigation of sorbed-phase petroleum hydrocarbons in the vicinity of 122/124 Arrowwood Drive. The remedial goal is to reduce sorbed-phase TPH concentrations within the contaminated area identified in Figure 4 to 500 mg/kg or less and to similarly reduce sorbed-phase BTEX compounds to the CTDEP Class GA/GAA pollutant mobility criteria. This will immediately satisfy the CTDEP Class GA/GAA pollutant mobility criteria, as well as any potential exceedances of the CTDEP residential direct exposure and/or soil vapor criteria. Since the sorbed-phase petroleum hydrocarbon mass is the source for detections in groundwater reported in dissolved-phase samples, it is believed that reduction of the source area sorbed-phase concentrations will reduce or eliminate these detections over time.

Although DBB remediation has been successfully utilized in Massachusetts, New York, New Jersey, and several other states and countries, the technology has not yet been applied at contaminated sites in Connecticut. Since CTDEP regulates nitrate concentrations in groundwater, it will be necessary to obtain approval from CTDEP prior to injection of nitrate-based DBB solution at the 122/124 Arrowwood Drive remedial target area. A temporary injection and discharge permit will be filed in accordance with CTDEP guidance to document the injection treatment and to detail monitoring procedures associated with the DBB treatment. A completed CTDEP Application for an Emergency or Temporary Discharge Authorization for the 122/124 Arrowwood Drive site is included as Appendix I. As the remedial target area is located in a Class GAA aquifer and upgradient to the Beaverdam Brook, the DBB remedial approach will require extensive downgradient monitoring to ensure that nitrate solution injected into the sorbed-phase contaminant source area is entirely metabolized during hydrocarbon bioremediation, as detailed in the aforementioned discharge permit and later in this section.

At the 122/124 Arrowwood Drive site, the proposed DBB remedial program would include approximately 11 injection events conducted over a 6- to 9-month period, using 20 fixed injection point and 20 temporary shallow injection point locations. The fixed injection points would each consist of 2-in. PVC flush-mount wells, installed prior to the first injection event. The injection points would be re-usable, so that repetitive drilling and well installation would not be necessary. Temporary shallow injection points would also be used to target the capillary/smear zone at

approximately 1 ft above the seasonally high groundwater elevation, and would be coupled with the fixed injection points to provide active treatment in the saturated and vadose zones at each location. The proposed location of each treatment point is shown on Figure 9, and may be modified as per the results of the baseline sampling event discussed later in this section to target identified "hot zones" and to improve the overall efficiency of the treatment program. During each of the injection events, approximately 300 gal of Geovation's N-Blend™ nitrate-based electron acceptor and nutrient solution would be injected into each of the injection points. The N-Blend™ solution is a low viscosity liquid that contains approximately 300,000 mg/L of nitrate and trace concentrations of proprietary microbial nutrients. The N-Blend™ solution would be prepared at an offsite staging area and delivered to the site in a truck-mounted mixing tank.

Injections would be completed by gravity flow only; there is no requirement for pressurized subsurface injection since product delivery is accomplished gradually by establishment of a diffusive gradient. Other than the temporary presence of a pickup truck containing the N-Blend™ solution mixing tank and injection crew, there would be no disturbance to area residents. The injection events create endothermic reactions in the subsurface, with minimal generation of carbon dioxide and nitrogen gas, not expected to be observable from the surface.

The DBB remedial injection plan initially includes treatment of remedial target Zones 1 and 2 as shown on Figure 9, including the sorbed-phase contaminant area immediately downgradient from the former fuel oil UST at this location. Treatment of Zones 1 and 2 will provide preliminary treatment of sorbed-phase contaminants in Zone 3, as residual treatment chemicals will migrate downgradient into Zone 3 prior to treatment of this target area. The proposed treatment zones are shown on Figure 9.

To protect against generation of residual nitrate concentrations, which may migrate from the remedial target area, the injection points will be located in the upgradient section of each remedial target area. The site-specific volume and concentration of nitrate solution will be selected based on conservative stoichiometric analysis so that initial injections are a small percentage of the required dosage for biodegradation of the entire TPH mass. In this manner, several injection periods will be required to achieve the remedial target goals as previously discussed, however, this approach will ensure that excess N-Blend™ solution is not injected such that nitrate is entirely consumed within the remedial target area. The location of the injection points in the upgradient region of the remedial target area will allow any residual nitrate to be metabolized in downgradient contaminated areas so that offsite migration does not occur.

The anticipated radius of influence at each injection point is approximately 15 ft, although advective forces will likely result in increased downgradient treatment. As indicated by the estimated radii of influence shown on Figure 9, the central area below the building foundation at 122/124 Arrowwood Drive appears to be located beyond the effective treatment zone. To complete remediation of sorbed-phase petroleum hydrocarbons located below the center of the foundation, additional volumes of N-Blend™ solution will be injected upgradient to the foundation so that advection and increased diffusion will deliver nitrate to this area during treatment of Zones 1 and 2.

Prior to treatment, baseline groundwater and soil samples will be collected from existing monitoring wells and up to 15 sampling locations within Zones 1, 2, and 3 to collect pre-design information necessary to establish site-specific nitrate solution injection volumes and concentrations, as well as to assess the baseline microbial population, electron acceptor conditions, and confirm pre-treatment contaminant concentrations.

During the 6- to 9-month DBB treatment program, two periodic groundwater monitoring will be conducted at selected monitoring well locations to confirm the establishment of an active anaerobic microbial population which primarily utilizes nitrate as its electron acceptor, and to ensure that downgradient migration of nitrates, BTEX, and MTBE does not occur. Additionally, surface water samples will be collected at the time of each periodic groundwater sampling event to ensure that metals (which could be displaced and mobilized during treatment events), nitrates, TPHs, BTEX, and MTBE do not migrate downgradient into the wetlands within the protected watershed meant for public drinking water supply reservoir, as per the City of Groton Water Commission.

The groundwater monitoring program will include analysis of water quality parameters, electron acceptor concentrations (i.e., nitrate, iron, manganese, and sulfate), and microbial enumeration samples. At sentinel monitoring well locations, the groundwater monitoring program will focus on dissolved-phase nitrate, nitrite, and ammonia concentrations (all of which should not be detected) and dissolved-phase hydrocarbons, including TPHs, BTEX, and MTBE. The groundwater monitoring program conducted during the DBB treatment will be used to ensure that offsite migration of nitrate and other components of the N-Blend™ solution do not migrate from the remedial target areas.

At pre-established intervals during the DBB treatment and following completion of the treatment program, groundwater and saturated zone soil samples will be collected to assess the performance of the remedial program. These samples will collected using a direct-push rig and will be analyzed for TPHs by the CTDEP ETPH Method and for BTEX and MTBE by EPA Method 8260B.

A summary of the previously detailed DBB treatment program components and proposed schedule are provided as Table 10.

4.2.3 Confirmatory Sampling Program

Following active remediation of the sorbed-phase contaminant source areas using DBB, only low concentration residual sorbed-phase and dissolved-phase petroleum hydrocarbons should remain at the site. If successful, the DBB remedial program should significantly reduce these concentrations so that the CTDEP cleanup criteria are achieved. As required by CTDEP, a confirmatory groundwater sampling program will be conducted to assess residual dissolved-phase concentrations and to document the overall efficacy of the treatment program over time following treatment. It is recommended that the Navy Housing Authority work with CTDEP to agree on specific requirements of the confirmatory groundwater sampling program (i.e.,

frequency, analytical requirements, etc.) following completion of active site remediation. It is assumed that a minimum of 3 years of quarterly sampling will be required to document the efficacy of the treatment program in support of site closure, as per CTDEP guidance. It is also recommended that the Navy Housing Authority periodically review and discuss the results with CTDEP to re-evaluate sampling requirements and remedial goals for the site.

ENVIRONMENTAL HEALTH LABORATORY ANALYSIS REPORT

100 Sebetha Drive, Suite A-5
Cromwell, Connecticut 06416
(800)243-4903/(860)635-6475

Analysis: Expanded Scan

Analytical Method: GC/MS Thermal Desorption; Modified EPA TO1/TO2 **Report Number *C0313092***

Sample Number	BL0176	BL0176	BL0193	BL0193	BL0194	
Air Volume Liters	4.5	4.5	4.5	4.5	4.5	
Compounds	ug/m3	ppb	ug/m3	ppb	ug/m3	CAS #
Dichlorodifluoromethane	<1.1	<0.27	<1.1	<0.27	<1.1	75-71-8
Chloromethane	<1.1	<0.54	<1.1	<0.54	<1.1	74-87-3
Chloroethene	<1.1	<0.43	<1.1	<0.43	<1.1	75-01-4
Bromomethane	<1.1	<0.29	<1.1	<0.29	<1.1	74-83-9
Chloroethane	<1.1	<0.42	<1.1	<0.42	<1.1	75-00-3
Trichlorofluoromethane	<1.1	<0.20	<1.1	<0.20	<1.1	75-69-4
1,1-Dichloroethene	<1.1	<0.28	<1.1	<0.28	<1.1	75-35-4
Methylene Chloride	<1.1	<0.32	<1.1	<0.32	<1.1	75-09-2
trans-1,2-Dichloroethene	<1.1	<0.28	<1.1	<0.28	<1.1	156-60-5
1,1-Dichloroethane	<1.1	<0.27	<1.1	<0.27	<1.1	75-34-3
cis-1,2-Dichloroethene	<1.1	<0.28	<1.1	<0.28	<1.1	156-59-2
Bromochloromethane	<1.1	<0.21	<1.1	<0.21	<1.1	74-97-5
Chloroform	<1.1	<0.27	<1.1	<0.27	<1.1	67-66-3
2,2-Dichloropropane	<1.1	<0.24	<1.1	<0.24	<1.1	594-20-7
1,2-Dichloroethane	<1.1	<0.27	<1.1	<0.27	<1.1	107-06-2
1,1,1-Trichloroethane	<1.1	<0.20	<1.1	<0.20	<1.1	71-55-6
1,1-Dichloropropene	<1.1	<0.24	<1.1	<0.24	<1.1	563-58-6
Carbon Tetrachloride	<1.1	<0.18	<1.1	<0.18	<1.1	56-23-5
Benzene	<1.1	<0.35	<1.1	<0.35	<1.1	71-43-2
Dibromomethane	<1.1	<0.16	<1.1	<0.16	<1.1	74-95-3
1,2-Dichloropropane	<1.1	<0.24	<1.1	<0.24	<1.1	78-87-5
Trichloroethene	<1.1	<0.21	<1.1	<0.21	<1.1	79-01-6
Bromodichloromethane	<1.1	<0.17	<1.1	<0.17	<1.1	75-27-4
cis-1,3-Dichloropropene	<1.1	<0.24	<1.1	<0.24	<1.1	10061-01-5
trans-1,3-Dichloropropene	<1.1	<0.24	<1.1	<0.24	<1.1	10061-02-6
1,1,2-Trichloroethane	<1.1	<0.20	<1.1	<0.20	<1.1	79-00-5
Toluene	<1.1	<0.29	<1.1	<0.29	<1.1	108-88-3
1,3-Dichloropropane	<1.1	<0.24	<1.1	<0.24	<1.1	142-28-9
Dibromochloromethane	<1.1	<0.13	<1.1	<0.13	<1.1	124-48-1
1,2-Dibromoethane	<1.1	<0.14	<1.1	<0.14	<1.1	106-93-4
Tetrachloroethene	<1.1	<0.16	<1.1	<0.16	<1.1	127-18-4
1,1,1,2-Tetrachloroethane	<1.1	<0.16	<1.1	<0.16	<1.1	630-20-6
Chlorobenzene	<1.1	<0.24	<1.1	<0.24	<1.1	108-90-7

ENVIRONMENTAL HEALTH LABORATORY ANALYSIS REPORT

100 Sebethe Drive, Suite A-5
Cromwell, Connecticut 06416
(800)243-4803/(860)635-8475

Report Number C0313092

Sample Number	BL0176	BL0176	BL0193	BL0193	BL0194	
Air Volume Liters	4.5	4.5	4.5	4.5	4.5	
Compounds (cont.)	ug/m3	ppb	ug/m3	ppb	ug/m3	CAS #
Ethylbenzene	<1.1	<0.26	<1.1	<0.26	<1.1	100-41-4
m,p-Xylene	<2.2	<0.51	<2.2	<0.51	<2.2	1330-20-7
Bromoform	<1.1	<0.11	<1.1	<0.11	<1.1	75-25-2
Styrene	<1.1	<0.26	<1.1	<0.26	<1.1	100-42-5
1,1,2,2-Tetrachloroethane	<1.1	<0.16	<1.1	<0.16	<1.1	79-34-5
o-Xylene	<1.1	<0.26	<1.1	<0.26	<1.1	95-47-6
1,2,3-Trichloropropane	<1.1	<0.18	<1.1	<0.18	<1.1	96-18-4
Isopropylbenzene	<1.1	<0.23	<1.1	<0.23	<1.1	98-82-8
Bromobenzene	<1.1	<0.17	<1.1	<0.17	<1.1	108-86-1
Propylbenzene	<1.1	<0.23	<1.1	<0.23	<1.1	103-65-1
2-Chlorotoluene	<1.1	<0.21	<1.1	<0.21	<1.1	95-49-8
4-Chlorotoluene	<1.1	<0.21	<1.1	<0.21	<1.1	106-43-4
1,3,5-Trimethylbenzene	<1.1	<0.23	<1.1	<0.23	<1.1	108-67-8
tert-Butylbenzene	<1.1	<0.20	<1.1	<0.20	<1.1	98-06-6
1,2,4-Trimethylbenzene	<1.1	<0.23	<1.1	<0.23	<1.1	95-63-6
sec-Butylbenzene	<1.1	<0.20	<1.1	<0.20	<1.1	135-98-8
1,3-Dichlorobenzene	<1.1	<0.18	<1.1	<0.18	<1.1	541-73-1
1,4-Dichlorobenzene	<1.1	<0.18	<1.1	<0.18	<1.1	106-46-7
p-Isopropyltoluene	<1.1	<0.20	<1.1	<0.20	<1.1	99-87-6
1,2-Dichlorobenzene	<1.1	<0.18	<1.1	<0.18	<1.1	95-50-1
Butylbenzene	<1.1	<0.20	<1.1	<0.20	<1.1	104-51-8
1,2-Dibromo-3-chloropropane	<1.1	<0.11	<1.1	<0.11	<1.1	96-12-8
1,2,4-Trichlorobenzene	<1.1	<0.15	<1.1	<0.15	<1.1	120-82-1
Naphthalene	<1.1	<0.21	<1.1	<0.21	<1.1	91-20-3
Hexachlorobutadiene	<1.1	<0.10	<1.1	<0.10	<1.1	87-68-3
1,2,3-Trichlorobenzene	<1.1	<0.15	<1.1	<0.15	<1.1	87-61-6
	ug/m3		ug/m3		ug/m3	
**Total Hydrocarbons	<11		20		<11	

A blank was not provided for the analysis. We recommend that a blank control be submitted with each sample set so that the sampling media can be checked for possible contamination.

Thermal desorption requires the entire sample to be analyzed at one time. Sample breakthrough cannot be detected.

Concentrations reported are based on air volumes provided.

**This value is a summation of all peak areas present in the sample (quantitated as toluene).

ENVIRONMENTAL HEALTH LABORATORY ANALYSIS REPORT

100 Sebetha Drive, Suite A-5
Cromwell, Connecticut 06416
(800)243-4903/(860)635-6475

Analysis: Expanded Scan

Analytical Method: GC/MS Thermal Desorption; Modified EPA TO1/TO2 **Report Number C0313092**

Sample Number	BL0194	BL0195	BL0195			
Air Volume Liters	4.5	4.5	4.5			
Compounds	ppb	ug/m3	ppb			CAS #
Dichlorodifluoromethane	<0.27	<1.1	<0.27			75-71-8
Chloromethane	<0.54	<1.1	<0.54			74-87-3
Chloroethene	<0.43	<1.1	<0.43			75-01-4
Bromomethane	<0.29	<1.1	<0.29			74-83-9
Chloroethane	<0.42	<1.1	<0.42			75-00-3
Trichlorofluoromethane	<0.20	<1.1	<0.20			75-69-4
1,1-Dichloroethene	<0.28	<1.1	<0.28			75-35-4
Methylene Chloride	<0.32	<1.1	<0.32			75-09-2
trans-1,2-Dichloroethene	<0.28	<1.1	<0.28			156-60-5
1,1-Dichloroethane	<0.27	<1.1	<0.27			75-34-3
cis-1,2-Dichloroethene	<0.28	<1.1	<0.28			156-59-2
Bromochloromethane	<0.21	<1.1	<0.21			74-97-5
Chloroform	<0.27	<1.1	<0.27			67-66-3
2,2-Dichloropropane	<0.24	<1.1	<0.24			594-20-7
1,2-Dichloroethane	<0.27	<1.1	<0.27			107-06-2
1,1,1-Trichloroethane	<0.20	<1.1	<0.20			71-55-6
1,1-Dichloropropene	<0.24	<1.1	<0.24			563-58-6
Carbon Tetrachloride	<0.18	<1.1	<0.18			56-23-5
Benzene	<0.35	<1.1	<0.35			71-43-2
Dibromomethane	<0.16	<1.1	<0.16			74-95-3
1,2-Dichloropropane	<0.24	<1.1	<0.24			78-87-5
Trichloroethene	<0.21	<1.1	<0.21			79-01-6
Bromodichloromethane	<0.17	<1.1	<0.17			75-27-4
cis-1,3-Dichloropropene	<0.24	<1.1	<0.24			10061-01-5
trans-1,3-Dichloropropene	<0.24	<1.1	<0.24			10061-02-6
1,1,2-Trichloroethane	<0.20	<1.1	<0.20			79-00-5
Toluene	<0.29	<1.1	<0.29			108-88-3
1,3-Dichloropropane	<0.24	<1.1	<0.24			142-28-9
Dibromochloromethane	<0.13	<1.1	<0.13			124-48-1
1,2-Dibromoethane	<0.14	<1.1	<0.14			106-93-4
Tetrachloroethene	<0.16	<1.1	<0.16			127-18-4
1,1,1,2-Tetrachloroethane	<0.16	<1.1	<0.16			630-20-6
Chlorobenzene	<0.24	<1.1	<0.24			108-90-7

ENVIRONMENTAL HEALTH LABORATORY ANALYSIS REPORT

100 Sebetis Drive, Suite A-5
Cromwell, Connecticut 06416
(800)243-4903/(860)635-6475

Report Number C0313092

Sample Number	BL0194	BL0195	BL0195			
Air Volume Liters	4.5	4.5	4.5			
Compounds (cont.)	ppb	ug/m3	ppb			CAS #
Ethylbenzene	<0.26	<1.1	<0.26			100-41-4
m,p-Xylene	<0.51	<2.2	<0.51			1330-20-7
Bromoform	<0.11	<1.1	<0.11			75-25-2
Styrene	<0.26	<1.1	<0.26			100-42-5
1,1,2,2-Tetrachloroethane	<0.16	<1.1	<0.16			79-34-5
o-Xylene	<0.26	<1.1	<0.26			95-47-6
1,2,3-Trichloropropane	<0.18	<1.1	<0.18			96-18-4
Isopropylbenzene	<0.23	<1.1	<0.23			98-82-8
Bromobenzene	<0.17	<1.1	<0.17			108-86-1
Propylbenzene	<0.23	<1.1	<0.23			103-65-1
2-Chlorotoluene	<0.21	<1.1	<0.21			95-49-8
4-Chlorotoluene	<0.21	<1.1	<0.21			106-43-4
1,3,5-Trimethylbenzene	<0.23	<1.1	<0.23			108-67-8
tert-Butylbenzene	<0.20	<1.1	<0.20			98-06-6
1,2,4-Trimethylbenzene	<0.23	<1.1	<0.23			95-63-6
sec-Butylbenzene	<0.20	<1.1	<0.20			135-98-8
1,3-Dichlorobenzene	<0.18	<1.1	<0.18			541-73-1
1,4-Dichlorobenzene	<0.18	<1.1	<0.18			106-46-7
p-Isopropyltoluene	<0.20	<1.1	<0.20			99-87-6
1,2-Dichlorobenzene	<0.18	<1.1	<0.18			95-50-1
Butylbenzene	<0.20	<1.1	<0.20			104-51-8
1,2-Dibromo-3-chloropropane	<0.11	<1.1	<0.11			96-12-8
1,2,4-Trichlorobenzene	<0.15	<1.1	<0.15			120-82-1
Naphthalene	<0.21	<1.1	<0.21			91-20-3
Hexachlorobutadiene	<0.10	<1.1	<0.10			87-68-3
1,2,3-Trichlorobenzene	<0.15	<1.1	<0.15			87-61-6
		ug/m3				
**Total Hydrocarbons		<11				

A blank was not provided for the analysis. We recommend that a blank control be submitted with each sample set so that the sampling media can be checked for possible contamination.

Thermal desorption requires the entire sample to be analyzed at one time. Sample breakthrough cannot be detected.

Concentrations reported are based on air volumes provided.

**This value is a summation of all peak areas present in the sample (quantitated as toluene).

GC/MS Spectral Library Match Summation Report
Sorted by Top 5 Peak Area Amounts

Sample Name : BL0176, C0313092; BL0176, EHL tu
Misc Info : Rtx-200; 60m x 0.32mm
Vial Number : 6
Data File : D:\HPCHEM\1\!TD\BSB\13092176.D
Operator : JAL
Date Acquired : 4 Mar 2003 13:32
Method File : TD_200

Peak #	R.T.	Area %	Library/ID	Ref #	CAS #	Qual

NO RESULTS GENERATED !

ALL PEAKS ARE BELOW QUANTITATION LIMIT !

GC/MS Spectral Library Match Summation Report
Sorted by Top 5 Peak Area Amounts

Sample Name : BL0193, C0313092; BL0193, EHL tu
Misc Info : Rtx-200; 60m x 0.32mm
Vial Number : 7
Data File : D:\HPCHEM\1\!TD\BSB\13092193.D
Operator : JAL
Date Acquired : 4 Mar 2003 14:28
Method File : TD_200

Peak #	R.T.	Area %	Library/ID	Ref #	CAS #	Qual
1	4.11	78.88	c:\database\nist98.L			
			Isobutane	109242	000075-28-5	80
			Propene	108457	000115-07-1	5
			Propane, 1-chloro-2-methyl-	109244	000513-36-0	2
2	4.3	6.53	c:\database\nist98.L			
			1-Propene, 2-methyl-	108463	000115-11-7	82
			1-Butene	108673	000106-98-9	43
			2-Butene	2188	000107-01-7	40
3	15.48	14.59	c:\database\nist98.L			
			Cyclopentasiloxane, decamethyl-	128838	000541-02-6	91
			Benzeneethanamine, N-[(pentafluoro	103444	055429-13-5	38
			Silane, [[4-[1,2-bis[(trimethylsil	103450	056114-62-6	38

** LESS THAN 5 TOTAL PEAKS OVER DETECTION LIMIT **

GC/MS Spectral Library Match Summation Report
Sorted by Top 5 Peak Area Amounts

Sample Name : BL0194, C0313092; BL0194, EHL tu
Misc Info : Rtx-200; 60m x 0.32mm
Vial Number : 8
Data File : D:\HPCHEM\1\TD\BSB\13092194.D
Operator : JAL
Date Acquired : 4 Mar 2003 15:24
Method File : TD_200

Peak #	R.T.	Area %	Library/ID	Ref #	CAS #	Qual

NO RESULTS GENERATED !

ALL PEAKS ARE BELOW QUANTITATION LIMIT !

GC/MS Spectral Library Match Summation Report
Sorted by Top 5 Peak Area Amounts

Sample Name : BL0195, C0313092; BL0195, EHL tu
Misc Info : Rtx-200; 60m x 0.32mm
Vial Number : 9
Data File : D:\HPCHEM\1\!TD\BSB\13092195.D
Operator : JAL
Date Acquired : 4 Mar 2003 16:19
Method File : TD_200

Peak #	R.T.	Area %	Library/ID	Ref #	CAS #	Qual
1	13.21	21.00	c:\database\nist98.L			
			Cyclopentane, 1,1-dimethyl-	111918	001638-26-2	73
			6-Oxabicyclo[3.1.0]hexane	12953	000285-67-6	59
			1H-1,2,4-Triazole-3-carboxaldehyde	15378	056804-98-9	45
2	14.29	19.15	c:\database\nist98.L			
			Limonene	114006	000138-86-3	93
			D-Limonene	114020	005989-27-5	81
			Cyclohexene, 1-methyl-4-(1-methyle	21971	007705-14-8	74
3	14.8	29.11	c:\database\nist98.L			
			Undecane	16533	001120-21-4	87
			Dodecane	109555	000112-40-3	64
			Heptadecane, 2,6,10,15-tetramethyl	17067	054833-48-6	64
4	15.48	30.74	c:\database\nist98.L			
			Cyclopentasiloxane, decamethyl-	103462	000541-02-6	90
			Phenethylamine, N-methyl-.beta.,3,	128839	010538-85-9	47
			Benzoic acid, 2,5-bis(trimethylsil	115317	003618-20-0	47

** LESS THAN 5 TOTAL PEAKS OVER DETECTION LIMIT **

Environmental Health Laboratory
EHS Risk Control Services
One of the ACS Group of Companies

100 Sebethe Drive Suite A-5
Cromwell, CT 06416
(860) 635-6475; (800) 243-4903 FAX (860) 635-6750

REQUEST FOR ANALYTICAL SERVICES

(Please fill all blanks to help us better serve you)

☒ Standard TAT
☐ RUSH
Please call ahead for RUSH analysis. Additional charges apply.

3/4/03

For Lab Use Only
Lab Report No. C0313092
☐ Und. ☐ SRF ☐ AR
☐ ESIS ☐ Z ☐ Claims
Pol. Or Cont. No.

BILL INVOICE TO (REQUIRED)		SEND RESULTS TO (REQUIRED)	
Name: Linda Castella		Name: David Wiseman	
Company: Mystic Air Quality		Company:	
Mailing Address: 201 North Rd		Mailing Address: Same	
City, State, Zip: Groton, CT 06340		City, State, Zip:	
PO#, Ref # (If Required):		Phone No:	☐ Phone Results
Accts. Payable Phone No: 860-449-8903		Fax No:	☒ Fax Results
Accts. Payable Fax No: 860-449-8860		Email:	☐ Email Results
Sampling Location: Nautilus Park		Sampling Media: Thermal Desorption Tubes	
Product Manufactured/Service Rendered:		Sampling Method: Gas Tight Pump	

CHAIN OF CUSTODY

Collected by (print): David Wiseman		Collector's Signature:	
Relinquished by:	Date/Time 3/3/03	Received by:	Date/Time
Relinquished by:	Date/Time	Received by:	Date/Time
Method of Shipment: Fed Ex		Received at Lab by: Shawn Neves	Date/Time 3/4/03

Authorized: (signature required) Date: 3/2/03

Sample Condition Upon Receipt: ☒ Acceptable ☐ Unacceptable

Lab Sample No. (Lab Use Only)	Client Sample No. (Lab Use Only)	Matrix	Analysis Required (Analysis must be specified for each sample)	Notes (Please indicate sampling date, location, instructions, etc.)	Sampling Date	Sampling Time Start	Sampling Time End	Total Time (Minutes)	Sample Volume (Liters)
✓	8C0176	TOS	Acid Oil Steam GC/MS	132 Arrowood Lunge Rd	0.05	0828	0958	90	4.5
✓	8C0193	"	"	134 Arrowood Lunge Rd	0.05	0837	1007	90	4.5
✓	8C0194	"	"	135 Arrowood Lunge Rd	0.05	0904	1034	90	4.5
✓	8C0195	"	"	132 Arrowood Lunge Rd	0.05	0906	1036	90	4.5
			Normal Turnaround						

FOR LAB NOTES ONLY:

DISTRIBUTION: WHITE - LAB COPY CANARY - LAB FILE COPY PINK - CUSTOMER COPY

Appendix I

Connecticut Department of Environmental Protection Application for an Emergency or Temporary Discharge Authorization (To Be Provided Upon Receipt)