6.0 CONCLUSIONS

The following section discusses the degree and extent of contamination existing in the Wells G & H study area. Contaminant pathways and mechanisms as well as a description of the groundwater plumes and areas of contamination are included. An identification of source areas is then presented, followed by a summary and recommendations.

6.1 Degree And Extent of Contamination

The following is a summary of the contamination of surface water and sediments, air, and groundwater detected at the site. Soil contamination will be addressed in Part II of the Remedial Investigation. The following section serves as a summary of analytical results and therefore does not reiterate all of the evidence to support the conclusions of the study.

- Surface Water and Sediment Contamination

The volatile organic compound 1,1,1-TCA was detected in both upstream and downstream surface water samples at concentrations ranging from not detected (ND) to 10 ppb in the April and May, 1985 NUS/FIT sampling rounds. During the May, 1985 sampling round, trans-1,2-DCE; TCE; and TETRA were also detected (3 to 26 ppb) at one surface water location in the center of site located on the western branch of the Aberjona River. In addition, trace levels of toluene (1 ppb) were detected at one downstream location during the April, 1985 sampling round. No volatile organic compounds were detected in surface water in the June, 1985 NUS/FIT CLP sampling round. Trace concentrations (<10 ppb) of TCE were detected by NUS/FIT analytical screening in one sediment sample collected upstream of the study area. No extractable organic compounds (acid and base/neutral extractables, pesticides and PCBs) were detected in surface water. The following inorganic elements were detected in surface water at varying concentrations: aluminum, barium, beryllium, cadmium, calcium, chromium, iron, magnesium, manganese, potassium, silver, sodium, and zinc.

During the investigation, levels of contamination in surface water varied from none detected (ND) to low levels (<26 ppb) of four different volatile organic compounds. The volatile organic compounds trans-1,2-DCE; TCE; and TETRA were only detected at one onsite location and, therefore, may indicate an onsite source. However, the most prevalent surface water contaminant, 1,1,1-TCA, was found at the same levels in both upstream and downstream samples.

- Air Contamination

The air route is not a major pathway of contaminant movement in the Wells G & H study area. Ambient air monitoring was conducted during all NUS/FIT field activities including installation of monitoring wells. No airborne volatile organic compounds were detected with the Foxboro Century Systems (OVA) Model 128 Organic Vapor Analyzer in any part of the study area. Surface water does not appear to be a significant pathway for volatile vapors as contaminant concentrations detected in surface water were relatively low.

Soil contamination could impact air quality by releases of volatile organic compounds, dispersion of dust or transport of soil by flooding of low lying areas. Soil contamination will be discussed in the contaminant source characterization and assessment document (Part II of the Remedial Investigation). However, no airborne volatile organic compounds were detected in areas of soil contamination unless those areas were physically disturbed (e.g., by test pit excavation).

- Groundwater Contamination

The most prevalent form of groundwater contamination present at the Wells G & H site was found to be volatile organic contamination. The most common volatile organic contaminants detected were: TCE; trans-1,2-DCE; 1,1,1-TCA; and TETRA. Volatile organic contaminants detected less frequently and generally in lower concentrations included: 1,1-dichloroethane; 1,1,2,2-tetrachloroethane; 1,2-dichloroethane; 1,1-dichloroethene; benzene; ethylbenzene; toluene; vinyl chloride; styrene; and xylene.

High levels of volatile organic compounds were detected primarily in the northeastern and southwestern portions of the study area. The most pervasive and highly concentrated volatile organic compounds in the northeastern portion of the study area are TCE and trans-1,2-DCE. TCE was also found in the southwestern portion of the site where this compound comprises the main contaminant constituent.

High levels (>1,000 ppb) of volatile organic contamination were also detected due north of Wells G & H at S71 and the northwest at S75. The contamination at well S71 was characterized by high concentrations of TETRA. Analytical samples drawn from S75 in the northwest portion of the site exhibited high concentrations of volatile organic compounds which are constituents of petroleum. These contaminants include benzene, ethylbenzene, toluene, and xylene.

The few extractable organic compounds detected were, for the most part, limited to the southwestern portion of the study area and well location S75 in the northeastern corner of the study area and were detected in much lower concentrations than the volatile organic compounds. The extractable organic compounds 1,2-dichlorobenzene; naphthalene; 2-methylnaphthalene; benzoic acid; and the pesticide chlordane were detected only in the southwestern portion of the study area. A number of extractable compounds, classed as polynuclear aromatic hydrocarbons (PAHs) such as fluoranthene and acenaphthene were detected at well location S75. These compounds are also constituents of petroleum products. All Hazardous Substance List (HSL) inorganic elements, with the exception of antimony and selenium, were detected in groundwater at varying concentrations. A pattern of distribution of elements throughout the study area was not demonstrated.

Based on the history of the Wells G & H study area and the analytical and hydrogeologic data presented in this report, the major pathway of concern for volatile organic contamination is groundwater. The following sections detail the distribution pattern of groundwater contamination in the study area and present the supporting evidence for identifying groundwater contamination source areas. Prior to the discussion of groundwater contamination distribution, an overview of key groundwater transport mechanisms is presented.

6.1.1 Groundwater/Contamination Transport Mechanisms

This section presents a generalized discussion of the mechanisms that influence organic chemical solute (contaminant) transport in saturated groundwater environments. It is meant to familiarize the reader with terms used in the following sections. The mechanisms include:

- Advection
- Dispersion
- Transformation
- Sorption

The dominant factor governing the migration of a dissolved contaminants through a sand and gravel aquifer is advection. In the advection process, contaminants are transported by the bulk motion of flowing groundwater.

Dissolved contaminants spread as a result of molecular diffusion and mechanical mixing as they migrate with the groundwater. This process is referred to as dispersion. Dispersion and spreading during transport result in the dilution of contamination. The maximum contaminant concentrations would therefore diminish with increased distance from the source (MacKay et al., 1985)

As the contaminants flow through the groundwater, they might become degraded, or transformed into other compounds. This effect is acccomplished through either chemical or biological processes. Hydrolysis and oxidation reactions are the principal causes of chemical degradation of contaminants. Most chemical reactions occurring in the groundwater are likely to be slow when compared with biological transformations resulting from the action of microorganisms (MacKay et al., 1985).

Certain contaminants can be biologically transformed by microorganisms attached to solid surfaces in the aquifer, for example, biotransformation of groundwater contaminants such as TETRA; TCE; or 1,1,1-TCA can result in the formation of vinyl chloride (MacKay et al., 1985).

Some dissolved contaminants may interact with aquifer solids encountered along the flow path through adsorption. The higher the fraction of contaminant sorbed, the more retarded the transport. The retardation factors for the primary contaminants found at the Wells G & H site (TETRA; TCE; 1,1,1-TCA) are expected to fall in the ranges from 1 to 10 (MacKay et al., 1985) and would therefore travel at 10 percent to 100 percent of the velocity of groundwater. Retardation of contaminant flow due to sorption in the overburden aquifer is likely minimal at the Wells G & H site due to the nature of the geologic deposits (excluding peat deposits).

6.1.2 Distribution Pattern of Groundwater Contamination

The evaluation of analytical data in conjunction with groundwater flow directions and contaminant flow mechanisms suggests the existence of two major plumes of groundwater contamination (the Northeastern Plume and the Northern Plume) and two other areas of major groundwater contamination (the Wildwood Conservation Corporation site and well location S75 in the northwest corner of the study area). A plume of contamination is defined as an area of groundwater contamination that can be described horizontally and vertically, and can be traced continuously over a distance. Discussed below is the evidence to support the delineation of these plumes and areas of groundwater contamination.

6.1.2.1 Northeast Volatile Organic Contaminant Plume

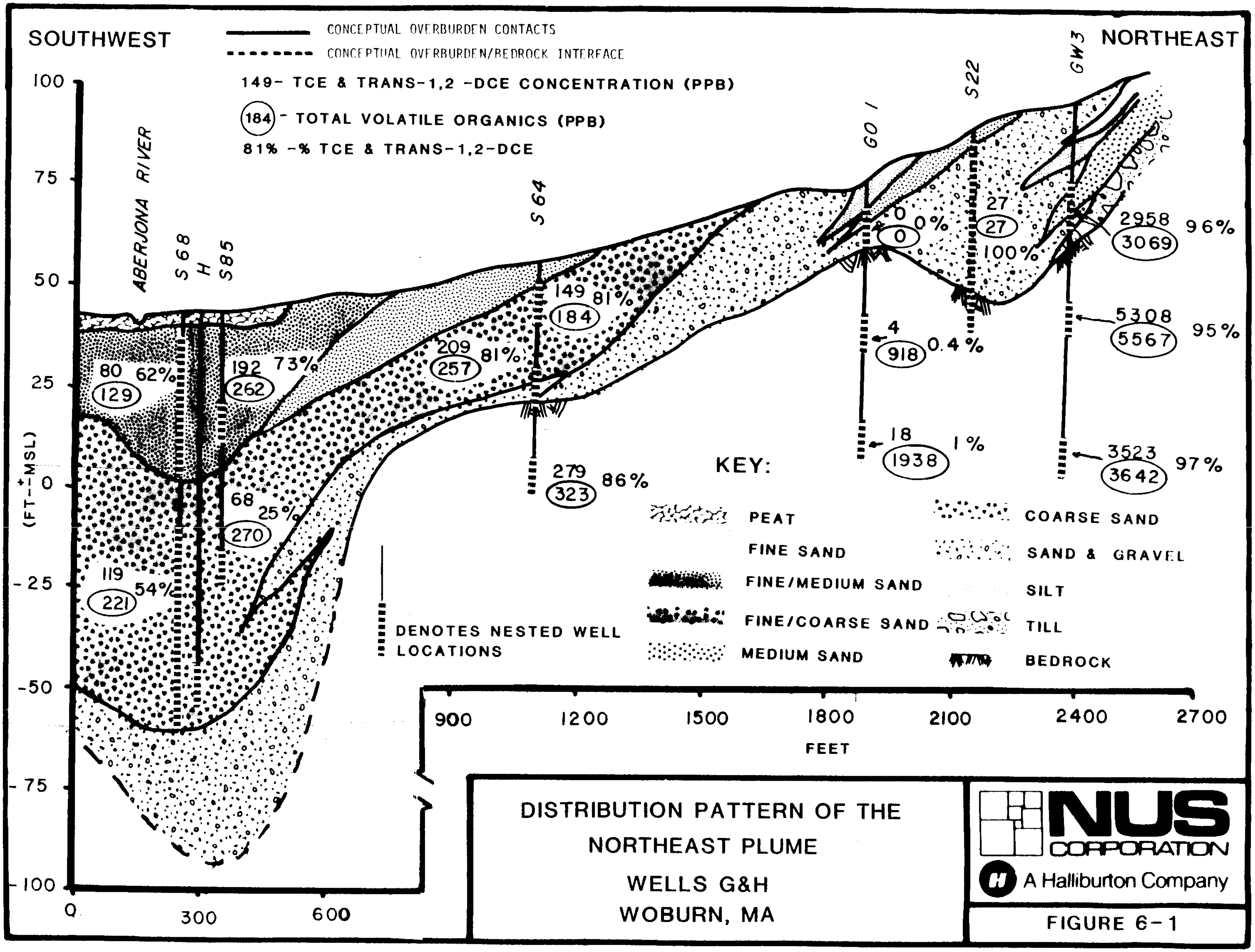
NUS/FIT has identified horizontal and vertical distribution of volatile organic contaminants that is indicative of a plume of overburden and bedrock groundwater contamination that extends from Wells G & H northeast to the W.R. Grace property.

This plume consists primarily of chlorinated solvents and is characterized by high percentages of TCE and trans-1,2-DCE with respect to the remaining constituents. Other constituents include: 1,1,1-TCA; TETRA; 1,1-dichloroethene and vinyl chloride. Table 6 (Appendix G) lists the mean concentrations of volatile organic compounds detected in the Wells G & H study area. The highest concentrations of TCE and trans-1,2-DCE in the northeastern portion of the study area were detected in samples from the W.R. Grace monitoring wells. Mean concentrations of TCE are as high as 1,003 ppb (GW3S) and 2,433 ppb (GW3D) in overburden and shallow bedrock, respectively. Mean concentrations of trans-1,2-DCE are as high as 1,955 ppb (GW3S) and 2,875 ppb (GW3D) in overburden and shallow bedrock, respectively.

Water level measurements from monitoring wells in the area indicate the predominant groundwater flow direction to be from the northeast to the southwest. The wells located northeast of well GW3 are considered to be upgradient and those wells to the southwest downgradient.

Samples collected from the upgradient wells (GW1 and GW8) did not contain TCE and trans-1,2-DCE contamination. Samples collected from downgradient wells S22, S21, S63 and S64 contained concentrations of TCE and trans-1,2-DCE ranging from 27 to 350 ppb (Appendix G: Table 6). Figure 6-1 depicts the vertical distribution of TCE and trans-1,2-DCE in overburden and shallow bedrock. The plume migrates to the southwest from the vicinity of well GW3 flowing beneath West Cummings Park to Wells G & H. The mean concentrations decrease downgradient. The same compounds are detected with the main constituents (TCE and trans-1,2-DCE) comprising 25 percent to 86 percent of the total volatile organic contaminant concentrations.

The volatile organic contamination detected in the two bedrock wells, located at the W.R. Grace monitoring well cluster GO1, does not reflect the same chemical pattern as the other wells in the northeastern portion of the study area. A lower percentage of TCE and trans-1,2-DCE is detected (0 to 1.0% of the total volatile



DISTRIBUTION PATTERN OF THE
NORTHEAST PLUME
WELLS G&H
WOBURN, MA

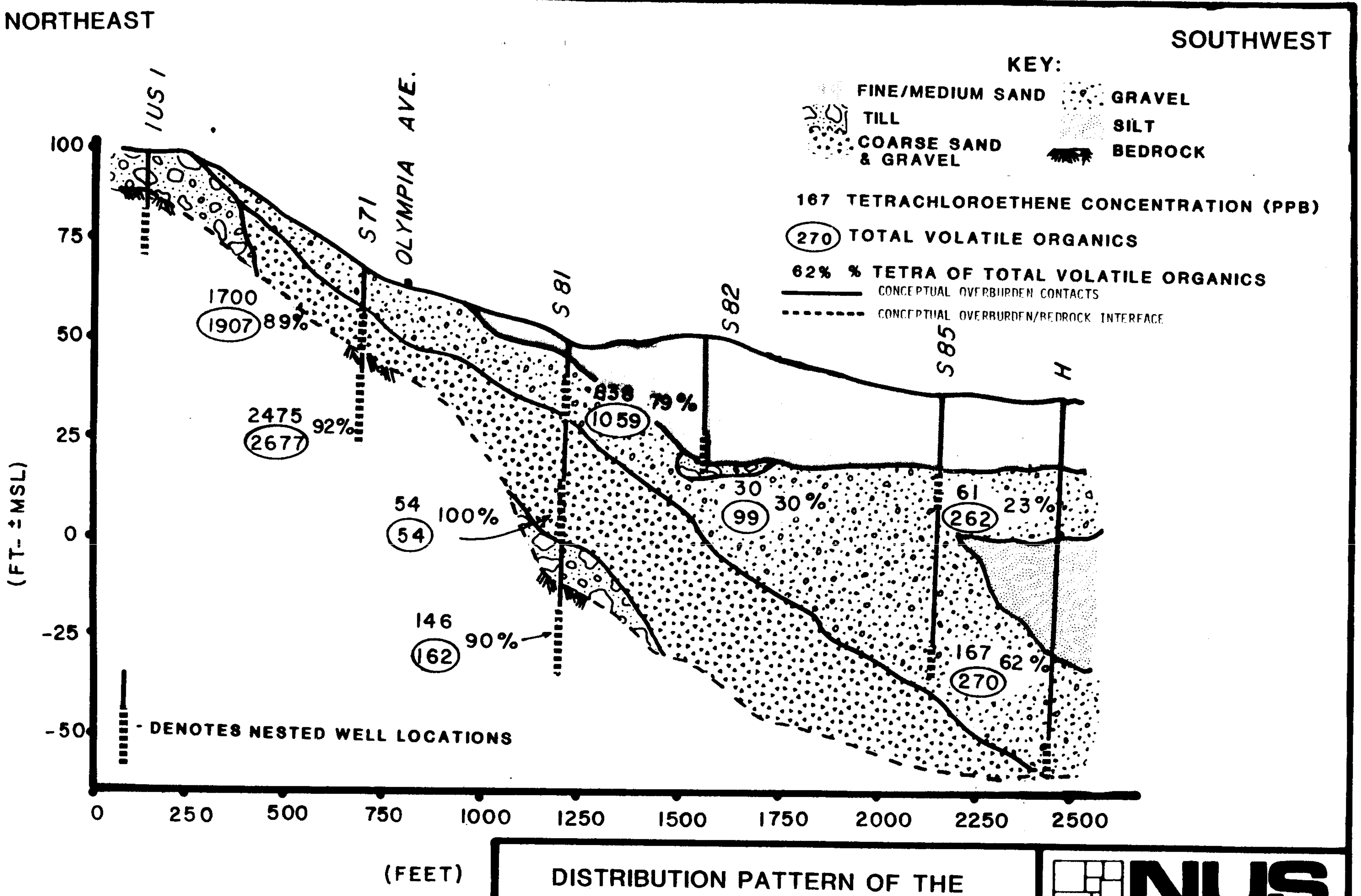
NUS CORPORATION
A Halliburton Company

FIGURE 6-1

organic contamination) and a higher percentage of TETRA is detected (92 to 98% of the total volatile organic contamination). This pattern is similar to that which characterizes the northern plume. A description of the northern plume and a discussion of the relationship of well location GO1 to this plume is included in the following section.

6.1.2.2 Northern Volatile Organic Contaminant Plume

A second plume was identified by NUS/FIT in the north/central portion of the site, based on the horizontal and vertical distribution of volatile organic contaminants. The plume exists between Wells G & H and the UniFirst Corporation property. The Northern Plume can be differentiated from the Northeastern Plume based on differences in the amounts of its chemical components. The Northern Plume is characterized by a predominance of tetrachloroethene (TETRA) which comprises as much as 100% (well S81M) of the total volatile organic contaminant concentrations. A secondary constituent is 1,1,1-trichloroethane (1,1,1-TCA), with minor percentages of trichloroethene (TCE) and trans-1,2-dichloroethene (trans-1,2-DCE). Mean TETRA concentrations of 1,700 ppb and 2,475 ppb were detected in groundwater drawn from overburden and bedrock at S71, respectively (Figure 6-2). Water level measurements collected from monitoring wells in the area indicate the predominant groundwater flow direction is from the east-northeast to west-southwest. Groundwater flow direction beneath the UniFirst Corporation property to the southwest becoming increasingly southerly as it migrates downgradient toward Wells G & H and the Aberjona River. Samples collected from monitoring wells IUS-1, IUS-2, IUS-3 upgradient and north from S71 contained no detectable volatile organic contamination. Vertical distribution of TETRA in overburden and bedrock is depicted in Figure 6-2. Mean concentrations of contaminants decrease downgradient from well location S71. The percentage of TETRA as compared to total volatile organic contaminant concentrations decreases from a range of 89 to 100% at well locations S71 and S81 to a range of 23 to 62% at well locations S82 and S85. The percentage of TCE and trans-1,2-DCE compared to total volatile organic contaminant concentrations increases from



DISTRIBUTION PATTERN OF THE
NORTHERN PLUME
WELLS G&H
WOBURN, MA

NUS CORPORATION
A Halliburton Company

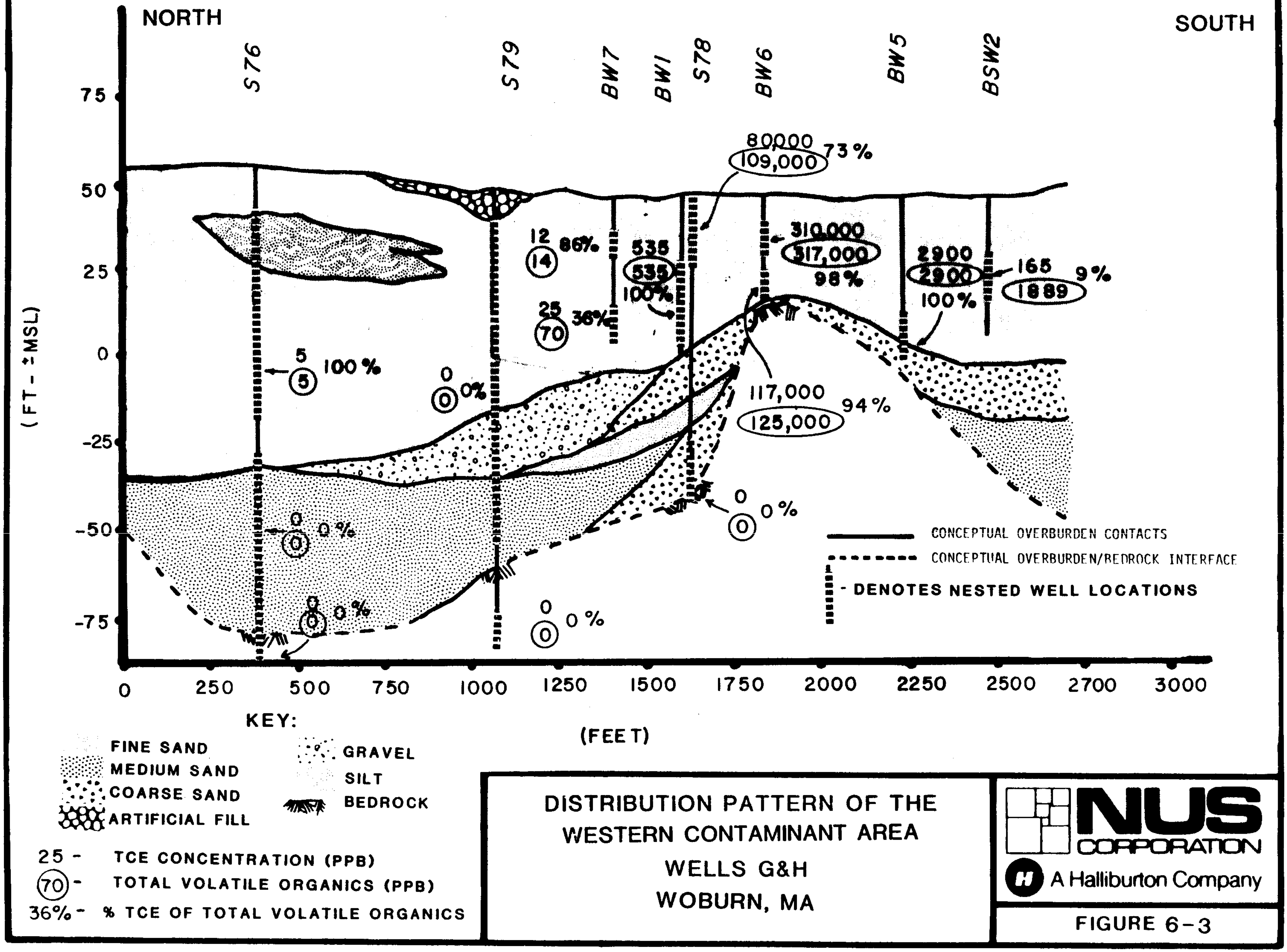
FIGURE 6-2

a range of 0 to 5% at well locations S71 and S81 to a range of 25 to 73% at well locations S82 and S85. This increase in TCE and trans-1,2-DCE percentage and decrease in TETRA percentage suggests that well locations S82 and S85 were installed within the zone of convergence of the Northern and Northeastern plumes.

It was noted in the previous section that the constituent percentages of contaminants characteristic of the Northern Plume were detected in samples drawn from bedrock wells GO1D and GO1DB. These wells are located approximately 600 feet south-southeast of well location S71 where the highest contaminant concentrations were detected. Well GO1 is located in the proximity of a destroyed bedrock production well previously used by Johnson Brothers, Inc., bedrock production well (Section 4.3) was reported to be capable of yielding 110 gallons per minute. This pumping rate indicates that the well drew from a substantial system of interconnected fractures in the bedrock. Fracture analysis conducted in the study area indicates a moderately preferred orientation of joints striking between N63°W and N90°W and dipping from 10° to 40° SW (E & E, 1982). This data suggests that well G01D and G01DB may intercept the Northern Plume moving downdip in the bedrock fracture plane.

6.1.2.3 Western Volatile Organic Contaminant Area

An area of volatile organic contamination of groundwater exists in the western and southwestern portion of the study area. The contamination consists primarily of high concentrations of the chlorinated solvent TCE detected at a number of wells, with high concentrations of 1,1,1-TCA; trans-1,2-DCE; and TETRA detected at only a few wells. The highest mean concentrations of TCE were detected at well S78S (80,000 ppb), well BSSW6 (310,000 ppb) and well BSW6 (117,000 ppb) (Figure 6-3). High levels of 1,1,1-TCA were also detected at well locations BSW6 (4,667 ppb). High levels of TETRA were only detected at well S78S (26,677 ppb) (Appendix G: Table 6). No volatile organic contaminants were detected in the NUS/FIT bedrock well S78D or the upgradient well S79. However, volatile organic compounds were detected in bedrock wells (BW8, 9, 10 and 13) by other consultants (Plate 5). This contamination consisted primarily of TCE ranging from 170 to 3,600 ppb (Appendix C: Table 4). The contaminated area is concentrated in the



DISTRIBUTION PATTERN OF THE WESTERN CONTAMINANT AREA
WELLS G&H
WOBURN, MA

FIGURE 6-3

shallow overburden as demonstrated by the high concentrations detected at S78S (109,000 ppb) and BSSW6 (317,000 ppb) (Figure 6-3). Extractable organic compounds were detected in lower concentrations and less frequently. The compounds 1,2-dichlorobenzene; naphthalene; 2-methylnaphthalene; and benzoic acid were detected at well locations BW5, BSSW6, and S78S. Trace amounts of the pesticide chlordane was also detected at well BSSW6 (Section 5.2.2).

The John J. Riley Tannery Production Well no. 2 (S46) is located within the area of groundwater contamination on the Wildwood Conservation Corporation property. This production well is capable of pumping 750 gallons per minute but is pumped according to work demand typically 14 hours per day. It is approximately 50 feet deep and is screened in sands and gravel. Pumping of this well would influence groundwater and contaminant transport through the overburden near the well. The area affected would correlate to the production well's area of diversion. The hydrologic relationship between this area of groundwater contamination, the Aberjona River, and Wells G & H is unknown. An aquifer test that involved pumping Wells G & H at historical pumping rates and the measurement of water levels at a large number of well locations in study area was conducted by USGS (Section 2.7). The results of this aquifer test should provide insight into the relationship between pumping Wells G & H, the Aberjona River, and groundwater west of the river.

6.1.2.4 Northwestern Contaminant Area

The volatile organic compounds benzene, toluene, ethylbenzene, and xylene were detected at well S75 located on the Weyerhauser property (in the northwestern portion of the study area) and at wells located on the Juniper Development Group property (in the north-northwestern portion of the study area). In addition, a number of polynuclear aromatic hydrocarbons (PAHs) including fluoranthene, acenaphthene, naphthalene, acenaphthylene, phenanthrene, and 2-methyl-naphthalene were also detected in groundwater samples from well S75. This combination of contaminants was not detected in groundwater or surface water elsewhere in the study area. These volatile organic and extractable organic (PAH) compounds are common constituents of gasoline. The highest concentrations of this contamination was detected in the shallow overburden well S75S (4,712 ppb). The concentrations decreased with depth to 230 ppb in the bedrock well S75D. Lower levels (170 to 750 ppb) were detected in wells located on the Juniper Development Group property. Gasoline is less dense than water and if spilled on the ground surface could migrate through the vadose zone to groundwater. The resultant plume of gasoline contamination would consist of an immiscible layer on top of the water and a dissolved portion in groundwater. Sparce data make description of the extent and characteristics of this plume difficult.

6.2 Sources of Contamination

NUS/FIT identified four areas of groundwater contamination within the study area. The following sections will present the evidence for identifying the source areas. The northeastern plume, characterized by a predominance of TCE and trans-1,2-DCE, emanates from the W.R. Grace property. The northern plume, characterized by a predominance of TETRA emanates from the UniFirst Corporation property. The western area of contamination, characterized by a predominance of trichloroethene and isolated part per million (ppm) concentrations of other volatile organic contaminants, emanates primarily from the Wildwood Conservation Corporation property. The source area of the gasoline contaminated groundwater detected at well S75 cannot be determined. Volatile organic groundwater contamination underlying the Juniper Development Group property may be due to prior site activities.

6.2.1 Northeastern Volatile Organic Contaminant Plume

NUS/FIT concludes that the northeastern plume emanates from the W.R. Grace property. The evidence supporting this conclusion is as follows:

- Onsite disposal of hazardous waste was demonstrated by the excavation and sampling of the contents of 55-gallon drums in the rear of the facility. A number of volatile organic and extractable organic compounds were detected in the contents of the drums as well as in soils in the excavated area (Section 2.3). Further excavation of contaminated soils has been conducted and will be discussed in Part II of the Remedial Investigation.

- Groundwater underlying W.R. Grace property is contaminated primarily by chlorinated solvents with a high percentage of TCE (40 to 60%) with respect to the remaining constituents trans-1,2-DCE; 1,1,1-TCA; TETRA; 1,1-dichloroethene; and vinyl chloride. TCE was not detected in these proportions elsewhere in the north and the northeastern portions of the study area.

- Volatile organic groundwater contamination was not detected upgradient of the W.R. Grace property at well locations GW-1, GW-2, and GW-8.

- NUS/FIT has detected a continuous plume of volatile organic groundwater contamination that extends from the W.R. Grace property downgradient to Wells G & H. The highest concentrations detected were on the W.R. Grace property with mean concentrations as high as 1,003 ppb and 2,433 ppb in the overburden and shallow bedrock, respectively. Concentrations decrease with distance away from the W.R. Grace property and towards Wells G & H. This plume configuration is consistent with local groundwater flow patterns.

6.2.2 Northern Volatile Organic Contaminant Plume

NUS/FIT concludes that the northern plume emanates from the UniFirst Corporation property. The evidence supporting this conclusion is as follows:

- UniFirst used TETRA as a dry cleaning agent in its uniform service operations. It stored the solvent onsite in a 5,000 gallon above ground tank from 1977 to 1982. A spill, contained and cleaned up by UniFirst, was reported by the firm in 1979.

- Contamination detected in groundwater underlying the UniFirst Corporation property consisted of 89 to 92% TETRA with respect to the remaining constituents (1,1,1-TCA; TCE; trans-1,2-DCE).

- Volatile organic groundwater contamination was not detected upgradient and north of the property at well locations IUS-1, IUS-2, and IUS-3.

- NUS/FIT has detected a continuous plume of volatile organic contamination emanating from the UniFirst property and extending downgradient to Wells G & H and the Aberjona River.

6.2.3 Western Volatile Organic Contaminant Area

NUS/FIT concludes that the western area of groundwater contamination emanates primarily from the Wildwood Conservation Corporation property with possible additional sources of volatile organic groundwater contamination located north and south of the property. The evidence supporting this conclusion follows:

- Surface disposal of 55-gallon drums (now rusted), miscellaneous debris, and pesticide caps on the Wildwood Conservation Corporation property has been documented. Interpretation of aerial photography suggests that the Wildwood Conservation Corporation property may have been used for disposal of drums and/or tanks.

- Soil boring analytical data collected by Woodward-Clyde Consultants in 1983 demonstrated shallow soil contamination on the Wildwood Conservation Corporation property.

- Groundwater contamination has been detected at the Wildwood Conservation Corporation property consisting primarily of the chlorinated solvent TCE with localized high concentrations of 1,1,1-TCA; trans-1,2-DCE; and TETRA.

- Volatile organic groundwater contamination was not detected north and northwest of the property at well locations S79, S80, and S74.

- NUS/FIT identified an area of volatile organic groundwater contamination concentrated in shallow overburden extending from well location BW-7 to well location BSW-2.

- Volatile organic contamination of groundwater was also demonstrated south and downgradient of the property at well locations S83 and S77.

6.2.4 Northwestern Contaminant Area

NUS/FIT concludes that an area of gasoline contamination of unknown dimensions exists in the vicinity of well location S75 and is likely the result of a spill(s) or leaking underground storage tank(s). This contamination is characterized by the presence of volatile organic (benzene, toluene, ethylbenzene, xylene) and extractable organic (polynuclear aromatic hydrocarbons) compounds detected in groundwater at this location. These compounds are common constituents of gasoline. Additional groundwater contamination by benzene, toluene, ethylbenzene, and xylene underlies the Juniper Development Group property. It is also likely the result of a gasoline spill(s) or leaking underground storage tank(s).

This pattern of contamination was not detected elsewhere in the study area. Based on groundwater flow, the source of contamination at well S75 is believed to be northwest of well S75. Contamination of groundwater underlying the Juniper Development Group property may be due to site activities occurring before the current ownership.

6.3 Summary

NUS/FIT conducted the Wells G & H Remedial Investigation to characterize the extent and degree of contamination at the site, identify potential source areas, and provide data for the Feasibility Study. Through the installation of groundwater monitoring wells and subsequent sampling and analysis, NUS/FIT has demonstrated that four areas of groundwater contamination exist in the Wells G & H aquifer area. Separate plumes of volatile organic groundwater contamination have been linked to the W.R. Grace property and the UniFirst Corporation property. An area of volatile organic groundwater contamination has been linked to the Wildwood Conservation Corporation property and a separate area of groundwater contamination has been identified in the northwest corner of the study area. On the basis of groundwater flow, the source of the latter area of contamination in the northwest corner of the study area is likely northwest of well location S75. However, the exact source area can not be identified due to the lack of data in that area. Contamination of groundwater underlying the Juniper Development Group property may be due to past site activities.